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Basin Flood Management Plan Brahmani-Baitarani, Odisha

Final

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Deltares in association with RMSI and JPS

Cover photo:

Jokadia Barrage, Dianchhak on Kharsuan River, a tributary of Baitarani

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Abbreviations

ADB	Asian Development Bank
BB	Brahmani-Baitarani river basins in Odisha
CCA	Cultivable Command Area
CE	Chief Engineer
CWC	Central Water Commission
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
GoI	Government of India
IFM	Integrated Flood Management
IMD	India Meteorological Department
INR	Indian Rupees
IWRM	Integrated Water resources Management
MoEF&CC	Ministry of Environment, Forestry and Climate Change
MoWR,RD&GR	Ministry of Water Resources, River Development and Ganga Rejuvenation
NDMA	National Disaster Management Authority
NGO	Non- Government Organisation
NRSC	National Remote Sensing Centre
RCM	Regional climate Model
SDMA	State Disaster Management Authority
SDRF	State Disaster Response Force
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
Ham	Hectare meter (= 10,000 m^3) – unit of Area

Disclaimer

Chapter 1 Introduction

This report describes the Brahmani-Baitarani river basins and their flood risks. It proposes plans for reducing flood risks using a mixture of structural and non-structural measures. Chapter 2 describes the geophysical and hydrological characteristics as well as recent flood history. Importantly, it does so from a macro-perspective as well as from the perspective of communities living in the flood prone areas.

In chapter 3, a flood risk assessment is given of the current situation as well as under potential climate change conditions for the years 2040 and 2080. Chapter 4 elaborates the entire gamut of existing and possible future flood mitigation measures. Next to embankments, dams and river offtakes also non-structural elements such as flood forecasting, land use management, community level measures, agricultural adaptations and reservoir optimization techniques are discussed. Also the urban environment is taken into consideration, for which drainage designs and costings are described. Last but not least the economic and environmental considerations of all these interventions are presented.

Chapter 5 spells out the necessities of improvements in institutional and community activities in order to create a better enabling environment for flood management.

It is our sincere wish that this integrated approach will help mitigate the recurrent flood problems in the Brahmani-Baitarani basins, for the benefit of millions of people living in these fertile but yet hazardous environments. This report will give no decisions, but choices and options. Options which work best when implemented in harmony. Not all options may be economically or socially feasible. This requires further study and discussions between stakeholders. We hope this report may assist in these discussions.

Chapter 2 The flood hazard and vulnerability in Brahmani-Baitarani basin

2.1 River characteristics

2.1.1 General description

Brahmani river

Brahmani river basin is an inter-state river basin and it is spread across the states of Chhattisgarh, Jharkhand and Odisha (Figure 2). The Brahmani is the second largest river in Odisha. It originates as two major rivers: the Sankh and the Koel from the Chhotanagpur Plateau and join at Vedavyasa near Rourkela in Sundargarh district of Odisha forming the major river Brahmani (Figure 1). It flows through Sundargarh, Keonjhar, Dhenkanal and the coastal plains of Kendrapara and Jajpur districts before discharging into the Bay of Bengal at Dhamra. The Brahmani is 799 km in length and its catchment area spreads over 39,033 square km in Odhisha (GoO, 2011).

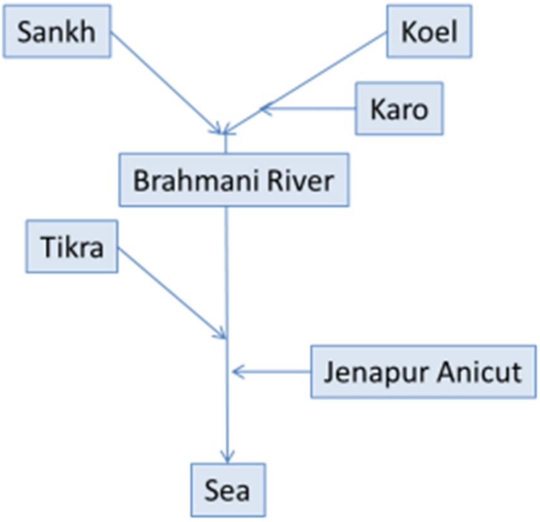

Figure 1 Schematized overview of Brahmani river

As can be seen from Figure 3 and Figure 4, a large part of the catchment (almost 80%) lies above 100 m. The upper parts of the basin virtually consist of series of plateaus at different levels of elevation. The elevation of whole north-eastern cap of the basin is generally between 600 - 700 m. This western part of central Ranchi plateau is also commonly known as Pats and also has few high level hills reaching higher than 750 m. The topography of this region is characterized by undulations and highly dissected. It slopes down towards south-east.

Figure 2 Base map of the Brahmani-Baitarani basin Source: (Deltares & RMSI)

The highlands of middle lower reaches of the basin presents a highly complicated physical set up as it contains several ranges rising above the coastal plains. The central tableland occupying lower Paschimi Singhbhum and whole Kendujhar has general elevation of 500 -750 m which may rise as high as 1000 m in western hills of Kendujhar. The elevation decreases in almost all direction from these highlands. The part of the basin covering Odisha state are a complex of denuded hills, plateaus, sharp ridges and mature valleys. It is mainly drained by the Brahmani and Baitarni river systems which cut wide valleys across the highlands. The elevation decreases to 10 m towards the coastal edge of the basin.

The deltaic region starts at Jenapur where the Kharasuan River branches off. Here the river branches into numerous spill channels, criss-crossing with the spill channels of the adjacent Baitarani River and finally discharges into the Bay of Bengal.

The Karasuan receives runoff from the Baitarani through the Burha branch. Near Rajnagar the Kharasuan joins Brahmani again. Downstream of Jenapur near Dharmasala the Relua river bifurcates from Brahmani. Relua is joined by the Mahanadi branch Birupa before it debouches again in Brahmani at Indupur. Shortly after Brahmani's confluence with Kharasuan the Maipura (Pathasala) branches off, which drains to the Bay of Bengal. The remainder of Brahmani is then joined by the Baitarani river to debouch into the Bay of Bengal as Dhamra river.

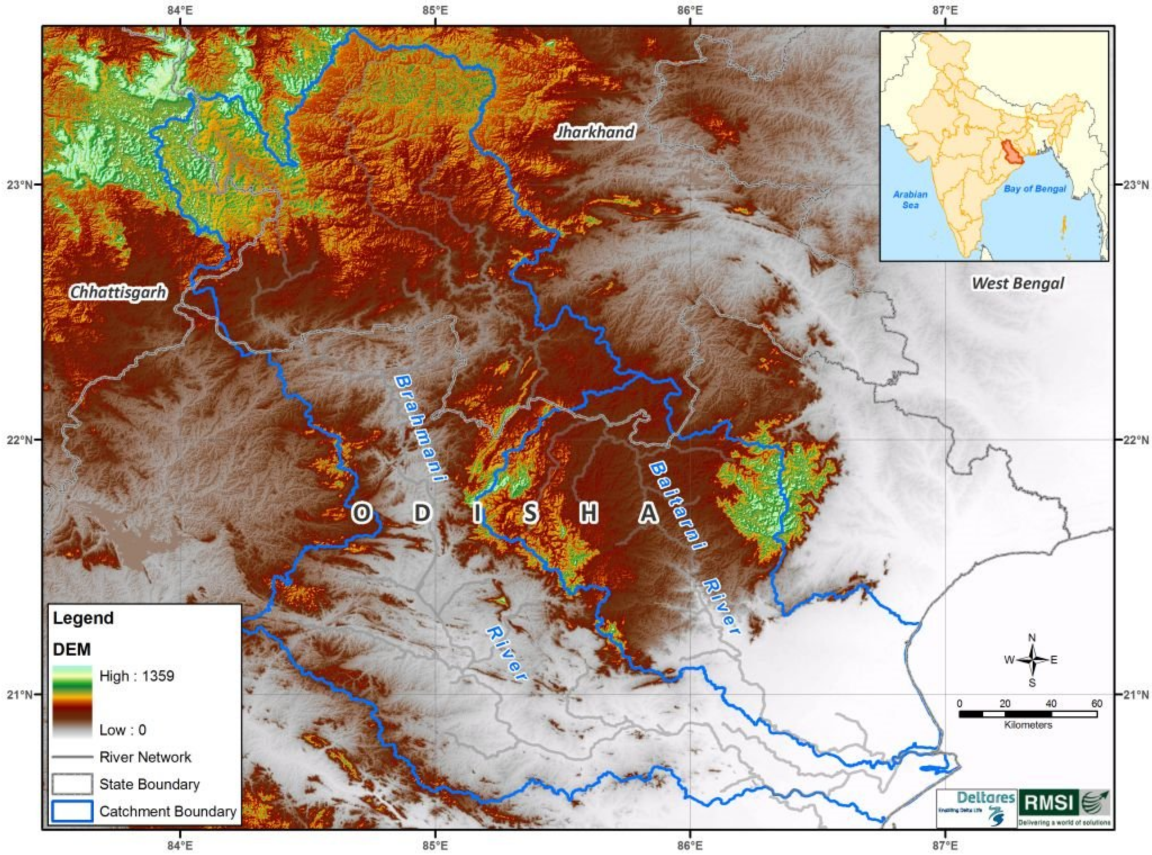

Figure 3 Elevation map for the Brahmani-Baitarani Basin

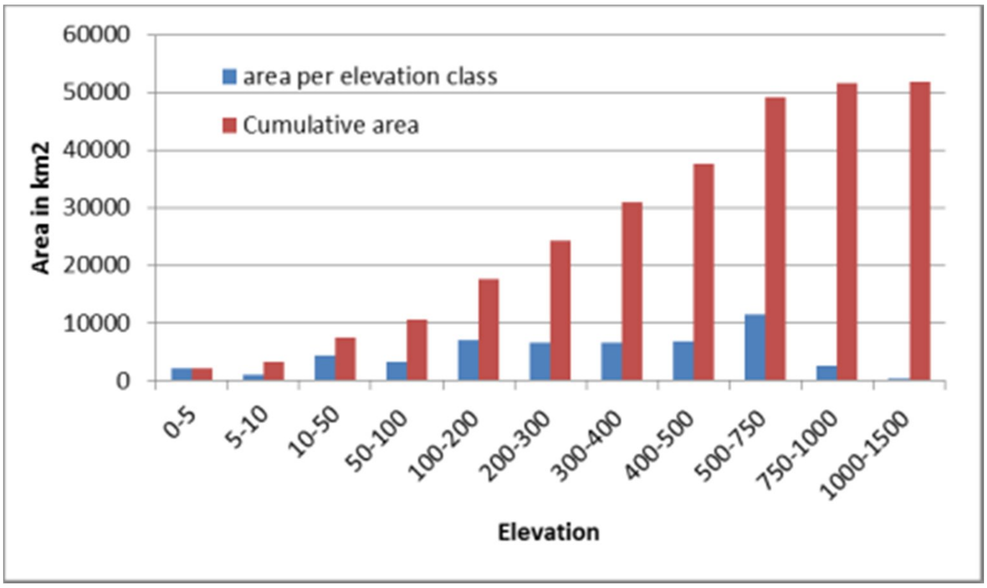

Figure 4 Area wise distribution of Brahmani catchment

Brahmani river bifurcates into Brahmani (kimiria) and Kharsuan below Jenapur. An anicut was built at Jokadia on Kharsuan (1890). On the left of the Kharsuan, a High Level Canal takes off for irrigation and navigation finally discharging into Baitarani. This canal has since become defunct. Brahmani below Jenapur branches out to Kimiria (the right arm), which joins Birupa, a branch of Mahanadi (Figure 5).

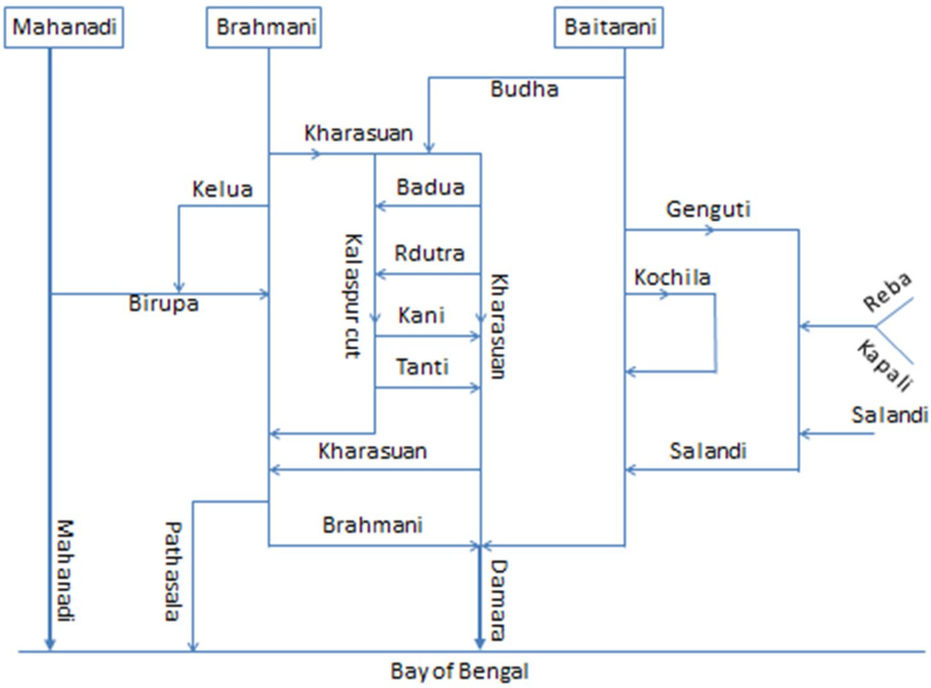

Figure 5 Schematized Delta Channel network (source: WRD, Odisha)

Baitarani River

The Baitarani River originates from Guptaganga hills near Gonasika village in Keonjhar district of Odisha. A major portion of the river basin lies in the state of Odisha, while a smaller part of the upper reach lies in Jharkhand state. Initially the river flows in a northern direction for about 80 km and then takes an abrupt right turn near Champua and flows in a south easterly direction and finally discharges into Bay of Bengal through the deltaic area of river Brahmani. The river travels a total distance of 360 km and drains an area of over 14,000 km^2. The major part of basin is covered with agricultural land accounting to 52% of the total area and 3% of the basin is covered by water bodies. The Baitarani sub basin covers major part of Kendujhar, Bhadrak, Mayurbhanj and Baleshwar districts. These parts of the basin are mainly drained by the Salandi, the Ramiala and the Matai.

2.1.2 Hydrology

Rainfall distribution

Both river basins fall within the sub-tropical monsoon climate zone (Mitra and Mishra, 2014). About 80% of the annual normal rainfall occurs during the 4 months of south-west monsoon season (June to September). The annual normal rainfall varies from 1250 mm to 1750 mm over the Brahmani basin and from 1250 mm to 1500 mm over the Baitarani basin. The coefficient of variation of annual rainfall is only about 20%, which shows that the rainfall in the region is fairly dependable (HP, 1998).

2.2 Flood characteristics

During flood the river Brahmani turns into a large turbulent channel posing potential threat to life and property of the population residing in the basin. The maximum flood observed in the river has been recorded as 24,246m^3/s on 20 August, 1975 at Expressway Bridge site, Pankapal gauging site. The gauge level at the gauging site was recorded to be 24.78 meters, against the danger level of 23 meters. Since then Rengali Multipurpose Project has come up (see section 4.2.2) and this is capable of moderating the flood in the lower reach covering an area of about 14,000 km^2. Of this the deltaic stretch of 4000 km^2 is the most vulnerable. At some locations, raising and strengthening, of flood embankments have also been taken up.

Flooding in the deltaic plains involves a complex combination of different flood types. River flows that transport water from the North-west to the South-east are at times obstructed by high sea levels. Such high sea levels correspond with depressions over the Bay of Bengal and cyclones, adding intense rainfall moving from the East to West as a third component. The impact of the 2011 super-cyclone, leading to extreme river levels and devastations are well remembered in the state as well as in the whole country.

Flood stages in the Brahmani delta are governed by inflow from:

- Brahmani river, observed at Jenapur; total drainage area at Jenapur is 35,700 km^2, of which 25,100 km^2 is controlled by Rengali dam, leaving 10,600 km^2 fully uncontrolled;
- Baitarani river, draining a catchment of 14,200 km^2 through Burha branch, observed at Akhuapada, and through the main branch draining to Dhamra river;
- Mahanadi river through Birupa branch, which inflow is nil during floods as its flow can be fully controlled at the upstream end;
- rainfall in the delta (catchment area about 2,000 km^2);
- water level in the river mouths at the Bay of Bengal.

From this it is observed that runoff from over 50,000 km^2 of land enters the delta out of which about 50% is fully uncontrolled. The other 50% is in full or in part controllable through Rengali dam. There are embankments on both sides of Brahmani river in the delta to protect the population against flooding. Given the carrying capacities of the river branches it has been estimated that in the delta flood damage will be small if the total discharge to the delta does not exceed 8,000 m^3/s. This figure will of course be dependent on the conditions at the river mouth. (HP, 1998).

Some of the major causes of flooding can be summarized as follows:

- The drainage pattern of Baitarani river basin (central plateau) is dendritic and flash flood is a natural character of such type of drainage pattern. Again since the upper catchment of Baitarani is full of hillocks and occurrence of a large number of drainage lines allow the run off generating over there to gush into the main river with greater force in a very short span of time. The lower part of Baitarani is a part of the greater Mahanadi & Brahmani delta.
- Baitarani is a highly meandering river. In meandering channels the flow is highly turbulent and forms eddy currents, which very often leads to sudden overflow of the embankments causing inundation of surrounding areas.
- Due to heavy mining activities and practices of shifting cultivation in the upper catchment a large quantity of sediments is added to the river during monsoon seasons. This lowers the carrying capacity of the river and thus even a medium size rainfall can cause high flood in Baitarani.

- The shallow aquifer conditions (water table near to the ground level), spread of water logging areas, swamps, and estuarine etc. do not allow precipitation to infiltrate and thus compound the impact of flood and resulting inundation.
- There is no major diversion channel to control flood in Baitarani river Basin
- The upper catchment i.e. the central plateau is controlled by severe fault and shear zones, which contributes more sediment into the basin.
- Encroachment of flood plains due to growth of population also causes heavy damage even when the flood is not very severe. Sufficient area should be left in order to allow the floodwater flow into the sea safely. This particular cause is an important human factor. Thus, there is no flood zone planning for the coastal area of eastern ghat region.
- The flow of Brahmani River also adds to the flood in Baitarani River in the downstream.

The most flood affected blocks in Baitarani system are Anandapur, Dasarathpur, Korei, Bari , Jajpur, Binjharpur , Rajkanika.

2.3 Recent floods and their economic impact

The Delta of the Mahanadi/Brahmani/Baitarani experienced serious floods in 1999, 2001, 2003, 2006, 2008 and also 2011. The super cyclone of 1999 brought massive rainfall of 500 to 900 mm causing flooding and damages to properties and irrigation infrastructure such as head works and canal systems. No less than 422 minor irrigation projects were seriously affected. Due to this intense rainfall between 29th Oct. to 1st Nov. the peak flood discharge is assessed as 498,000 cusecs (14,102 m^3/s) at Akhupada against safe carrying capacity of 10,000 cusecs (283 m^3/s) in the main channel and 50,000 cusecs (1416 m^3/s) in Budha (Figure 6).

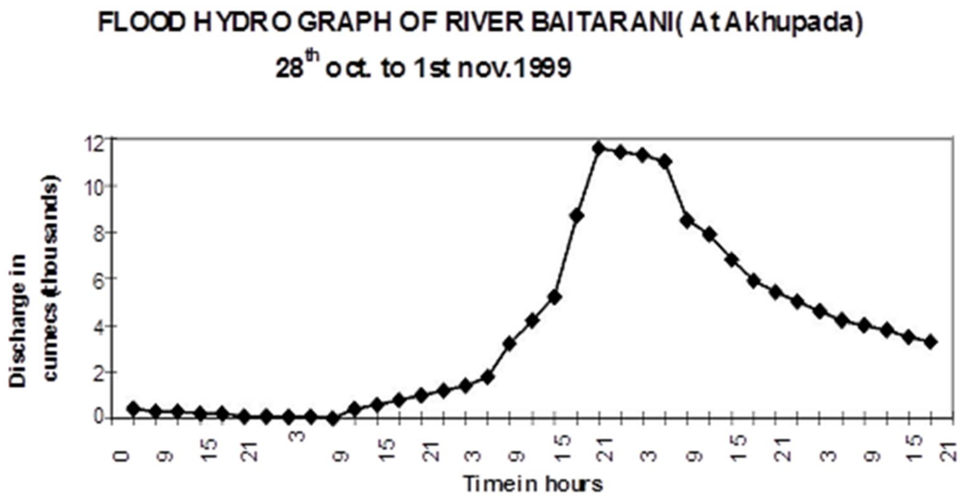

Figure 6 Flood hydrograph of Baitarani at Akhupada in 1999

During September 2011 heavy rainfall in the catchment of the Mahanadi, together with high sea water levels (it was full moon on 12 September) and heavy local rainfall, led to the flooding of large parts of the delta (Figure 7). It affected about 0.34 crores people of which 45 lost their life (GoO, 2011).

In 2013 cyclone Phailin created havoc along the coastal districts of Odisha. The damages caused by the cyclone were mainly due to gusts of wind with unprecedented velocity of up to 220 km/h and torrential rainfall from 11th to 13th October 2013. Due to storm surge up to 3.5m, large areas were inundated in Ganjam, Puri, Jagatsinghpur, Bhadrak, Kendrapada, Khurdha and Balasore districts. The Baitarani river, along with other rivers, experienced floods as a result of torrential downpour during 11 to 14 October. No less than 1.3 crores people were affected of which 44 lost their life. 430 pucca houses and 121,246 kutcha houses have been fully damaged due to the cyclone and the flood thereafter (GoO, 2013).

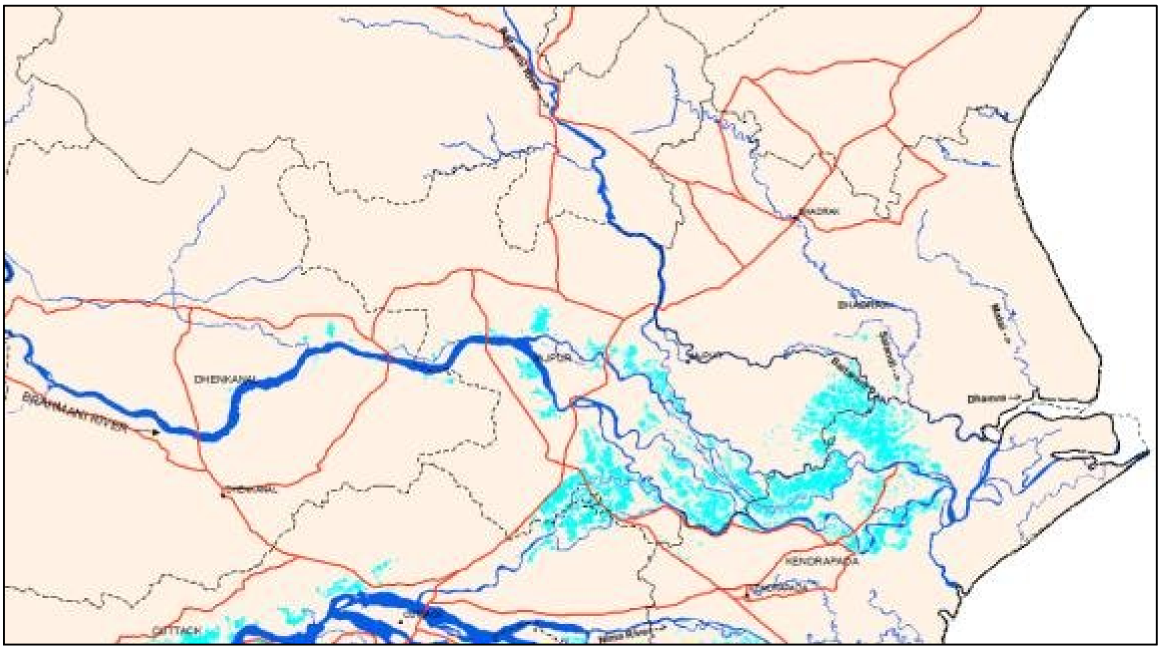

Figure 7 Flood extent in September 2011

Flood damages have particularly risen over the last decade, at a rate of 7% per annum over the period 2003 to 2011 in constant prices. Compared to the period 1980-93 the average annual damages nearly doubled for the period 1997-2012 (Phase 1 report)(Figure 8). An average of INR 784 crores would imply 1.7 % of GDP in 2001 (INR 46.752 crores). However, compared to the most recent GDP of INR 288,414 the damages would count for only 0.3 %. At least partially the rise in annual damages can be explained by an increase in the values of exposed assets (which correlate with the growth in GDP). Fortunately, from a macro-economic viewpoint the growth in GDP has been much faster than the growth in annual damages.

Nevertheless, natural events can at least temporarily result in a significant effect on GDP. In 2013-14, the GDP growth rate dropped to 2.21%. This slowdown was attributed to the Phailin cyclone, which caused a negative growth of 9.78% in the agriculture sector and also affected several other sectors[1] .

An overview of recent floods and their affected districts is given in Table 1.

[1] Odisha GSDP to grow 8.78% in 2014-15: Economic Survey". Business Standard. 16 February 2015. Retrieved 15 July 2015.

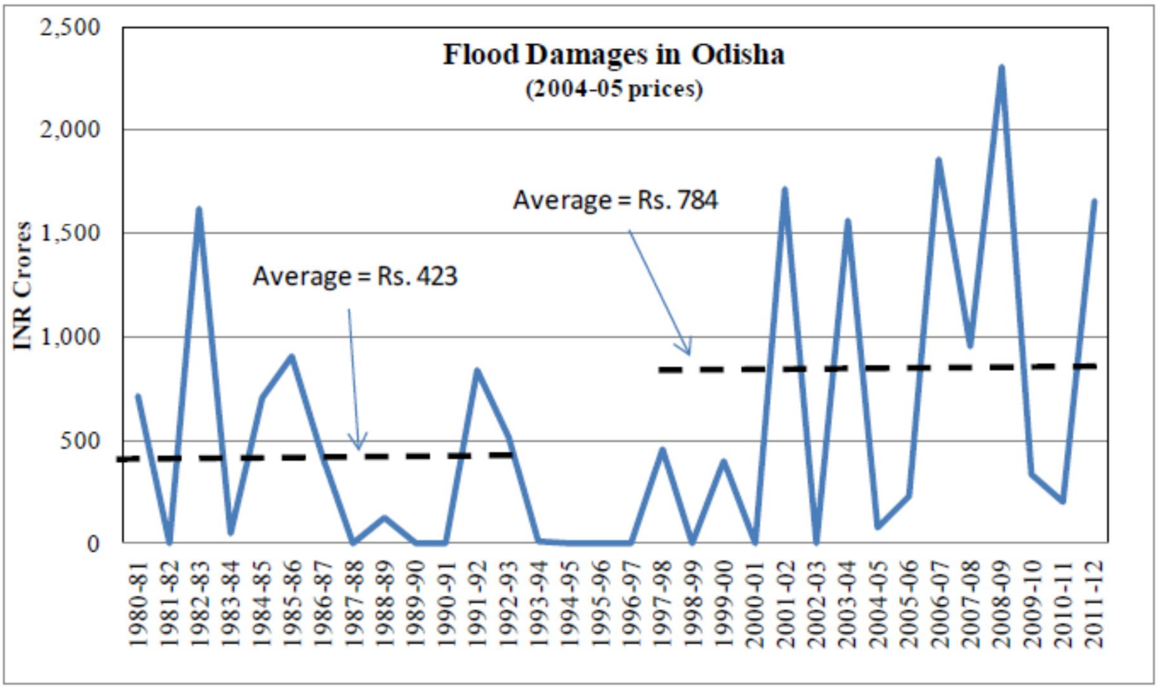

Figure 8 Recorded flood damages since 1980 (Source: OSDMA, Odisha)

Table 1 Flood affected districts in Brahmani-Baitarani rivers

Sl. No	*Year*	*Moth of Occurrence*	*Affected District/Area*
1	1960	August	Dhenkanal, Mayurbhanj & Keonjhar districts.
2	1961	July-August	Dhenkanal, Mayurbhanj,Keonjhar districts
3	1964	July-August	Dhenkanal, Keonjhar districts.
4	1971	July-October	Mayurbhanj, Sundergarh,Keonjhar districts.
5	1974	August	Dhenkanal, Keonjhar districts.
6	1980	September	Dhenkanal district.
7	1982	August-sept	Dhenkanal district.
8	1984	June-Sept	Dhenkanal, Keonjhar districts.
9	1985	August-sept	Keonjhar district.
10	1991	July-August	Dhenkanal, Keonjhar districts.
11	1992	July-August	Dhenkanal, Sundergarh districts
12	1994	July-Sept	Bhadrak,Jagatsinghpur,Jajpur, Kendarapada, Sundergarh districts.
13	1995	May-Novemeber	Anugul,Bhadrak, Dhenkanal, Jagatsinghpur,Jajpur, Keonjhar Kendarapada districts.

14	1997	June-August	Bhadrak, Jagatsinghpur,Jajpur, Kendarapada, Keonjhar, Sundergarh, Mayurbhanj districts.
15	1999	July-August	Jagatsinghpur, Kendarapada ,Jajpur, Bhadrak,Mayurbhanj districts.
16	2001	July-August	Anugul,Bhadrak, Jagatsinghpur,Jajpur, Kendarapada, Sundergarh districts.
17	2003	July-October	Anugul,Bhadrak, Jagatsinghpur,Jajpur ,Keonjhar, Kendarapada districts.
18	2006	July-August	Anugul,Bhadrak,Dhenkanal, Jagatsinghpur,Jajpur, Kendarapada,Keonjhar, Mayurbhanj districts.
19	2008	July-Sept	Anugul,Bhadrak, Jagatsinghpur,Jajpur, Kendarapada, Keonjhar, Mayurbhanj districts.
20	2011	September	Bhadrak, Jagatsinghpur,Jajpur, Kendarapada, Keonjhar, Mayurbhanj,Dhenkanal, Anugul districts.

2.4 Community perspective

Floods occur almost every year in the basin and cause heavy loss to livelihood and assets such as human life and loss of livestock. The flood is more devastating downstream compared to midstream of the basin. In several villages in the downstream, flood occurs more than once a year.

The downstream community, who are frequently affected by flood, prepare themselves every year. Traditionally community stocks processed dry foods mainly for rainy season, which are be eaten without cooking. They also stock fodder for the livestock and firewood for the kitchen. Some of the traditional food the community stocks includes *Chuda* (beaten rice), and *Mudhi* (puffed rice).

Even though the state has prepared village level disaster management plan with the support of UNDP and formulated DM committees at village level, these are not functional in most of the villages. Communities are well aware of the flood risk, though most of the people take a chance and carry on practicing agriculture.

The community perceives minor floods at the start of the Rabi season as a good sign since it not only brings silt to improve the fertility of the soil but also helps improve the availability of water for the Rabi crops as many parts of the basin face water shortage after the rainy season. But long standing floods destroy crops, reduce yields, and affect livestock.

Communities prefer to have flood protection structures (construction of dikes) and expect the government to support in flood proofing of houses. Awareness on agriculture insurance is poor and only 14% suggested that there should be agriculture insurance to protect their crops from flood.

Based on the community survey and consultations, the following key issues and needs were identified in the BB basin.

Flood warning information dissemination
Flood early warning system exists in the basin and community has access to this information. However, the efficiency of warning dissemination needs to be improved. The community accesses these information through radio, TV, and local newspapers. Warning dissemination through electronic media is not reliable during heavy rains due to power failures. The lead time of flood warning is very low for people to respond adequately. There is a lack of climate advisory support, which can help farmers to plan their agricultural activities.

Flood affecting assets

The basin in general is characterised by flash floods. In the delta region, several villages of Kendrapada and Bhadrak districts are situated between the distributaries of the Brahmani and Baitarani Rivers and flood waters come from both the rivers. The flow of Brahmani is regulated through the Rangali Dam, while Baitarani flow is not regulated. These floods cause extensive losses of human lives and livestock, and damage crops (particularly of rice) and kutcha houses. In addition to this, floods also impact public utilities and disrupt businesses.

Houses are mostly constructed in elevated parts of the village and flood depth in houses during heavy floods is 1-2m. However, in general, the flood depth in housing areas are mostly <0.5 m. Irrespective of the location (river bed, flood plain, or landward side of embankment) majority of the houses have ground level plinth heights while some are constructed below ground level.

The nature of incidence of flood hazard and its impacts derived from the survey results shows that vulnerability of the community is more specific to the location where they live, rather than income or social group. People living downstream are more vulnerable compared to those living in the midstream. The population density is very high in the downstream of the basin, which is highly vulnerable to flood.

Loss of livelihood

Floods mostly occur during the Kharif season (July-Sept) due to monsoon rain. Cyclonic depressions causing heavy rains and floods cause damages mostly in the Rabi season (start of Rabi season – between Sept – Nov), which are less frequent. Agriculture is the main livelihood in the basin. Community keeps livestock (cattle, goats, poultry, pig) in small numbers at home in most of the houses, which are considered as assets. The floods affect both agriculture and livestock.

Floods during July-Sept period are more devastating causing heavy loss particularly on rice crops as Kharif rice is the main crop in the basin. Flood water normally stays on agricultural fields for 10-12 days with average flood depth of 1-2 m which is damaging. Floods during Rabi season mostly affect pulses and vegetables and even short duration flood damage these crops. However, farmers in general consider minor floods during the Rabi season beneficial as they bring silt to the agricultural fields.

Sand casting and saline intrusion mainly in the downstream parts cause long term problems and reduce the farmers chances of growing crops in the subsequent year.

Livestock also gets affected due to lack of fodder, particularly in the downstream of the basin as the area gets affected due to water logging. Livestock diseases are also common during the long rainy season.

Post flood issues

Even though the state's administrative machinery is very effective in post flood relief efforts, the state has witnessed a high incidence of water borne and vector borne diseases after floods. There have been several instances of disease outbreaks – jaundice, malaria, diarrhoea, etc. in the state and the districts in the basin.

The state has constructed multipurpose cyclone shelters in many locations, which are mostly within 10 km from the coastline. Shelter facilities are inadequate in the midstream of the basin and the community resorts to schools, community halls, terraces of pucca houses, and even roads and embankments for shelter.

Availability of fodder for livestock and firewood are also key problems, which persist after floods.

Poor water retention of the soil

Both abundance and scarcity of water are problems in the basin according to the community. During floods there is excess water and during non-rainy season there is acute scarcity of water for agricultural use. By and large, the soil in the basin has poor water retention capacity, which makes it difficult for farmers to raise crops in summer months. The construction of embankments makes it difficult to uptake water for irrigation from the river, even though it protects the agricultural land during floods. WRD has tried to install pumping systems to take in water from the river to irrigate agricultural land during the summer months; though these are not sufficient to address their requirements, according to the community. According to the communities, the embankments also caused siltation of the river bed causing waterlogging in the agricultural fields.

Saline intrusion and sand overcast

Balasore and Bhadrak districts have report saline intrusion problems during flooding. The districts in downstream of the basin in general experience heavy silt deposition during heavy floods. Both these have a long lasting impact on community livelihoods that depend on agriculture. The state has developed flood, drought, and salt tolerant rice varieties, though it is not very popular among the cultivators in the basin. Due to various reasons including low yield compared to hybrid variety, and low awareness among the farmers these varieties are not cultivated widely.

Health

The rural part of Odisha has poor access to health facilities. As per the district statistics there is one hospital/health facility per 2,593 people while considering the population and health facilities in the basin. There are more health facilities in the downstream of the basin, which is densely populated.

Due to poor road access during floods, most of the villages in the basin have poor access to even primary health facilities. The community faces problems of safe drinking water and sanitation during floods leading to disease outbreaks. Floods also cause diseases among livestock thus causing casualties.

Another key problem in the basin is the poor transport network connecting the villages, which makes the response and relief activities difficult to carry out in post flood situations.

Water and sanitation

Drinking water and sanitation problem is common to all villages affected by flood. Lack of toilet facilities lead to open defecation. In many village schools toilets are constructed but don’t have water facility. The water and sanitation issues often cause high incidence of water borne diseases in the villages.

Education

During disaster situations, schools are used as shelters, which also cause disruption in studies. The community uses schools as shelters till the water recedes completely, which sometimes takes almost a month.

Chapter 3 Flood risk assessment

3.1 Current flood risks

Based on the model results it can be clearly seen that almost every other year there is a significant flooding (Table 2). Most of the flood extent is concentrated in the lower delta area (Figure 9 to Figure 13). Total damages on housing and crops is around INR 1800 crores (which corresponds rather well with the damages registered, see Figure 8).

For the 1:25 year flood the flood area more than doubles. During such flood also many areas upstream are being flooded. Furthermore, the average inundation depth also drastically increases, with many areas flooded for more than 3 m deep water (see also Figure 14). Total estimated damages rises to INR 4766 crores. Interestingly, larger floods with longer return periods do give more damages, but a six times lower frequency flood (1:150 yrs) increases the damages with only 20%, which corresponds with an increase of flood extent with also 20%.

Table 2 Flood characteristics under present conditions for different return periods

Item	unit	2 years	25 years	75 years	100 years	150 years
Max. flooding extent	Km2	1383.0	3151	3822.25	3937	4089.5
Max. flood volume	Mm3	2344.5	9306.3	12807.0	13250.5	13889.3
Maximum outflow Rengali	m3/s	2255.1	8563.9	12544.9	12038.5	13008.4
Max. water level Talcher	m	58.0	61.5	64.3	65.2	66.6
Max. water level Jenapur	m	21.4	25.1	25.7	25.8	26.0

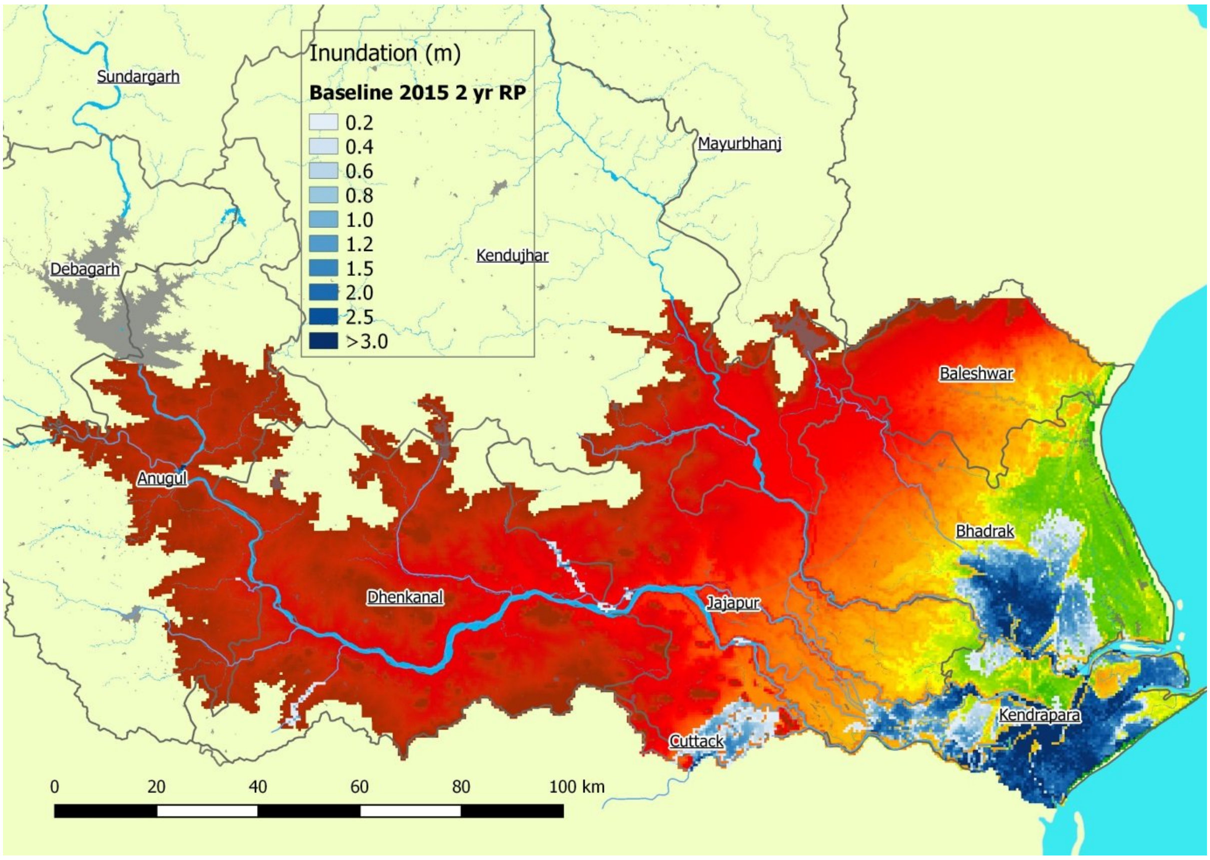

Figure 9 Flood inundation map for Brahmani-Baitarani for 1:2 year flood (SOBEK model result)

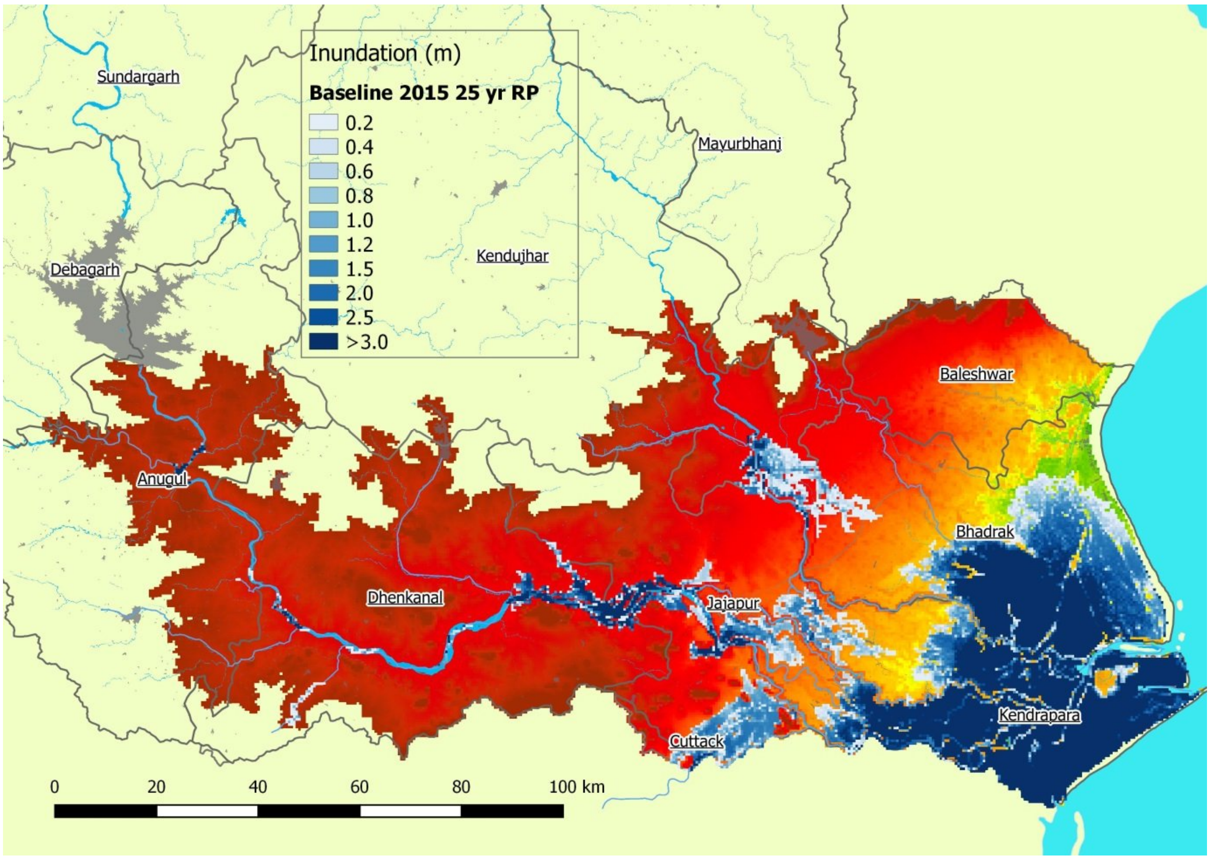

Figure 10 Flood inundation map for Brahmani-Baitarani for 1:25 year flood (SOBEK model result)

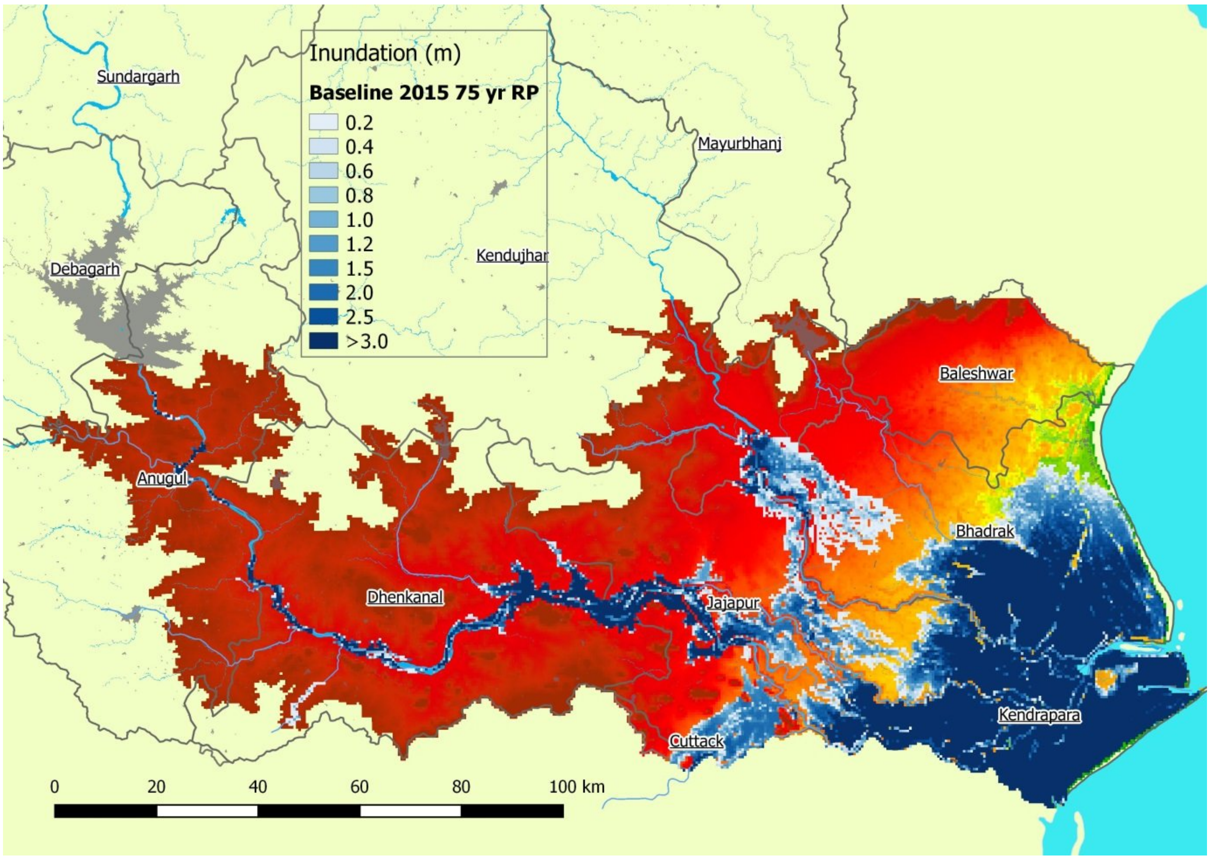

Figure 11 Flood inundation map for Brahmani-Baitarani for 1:75 year flood (SOBEK model result)

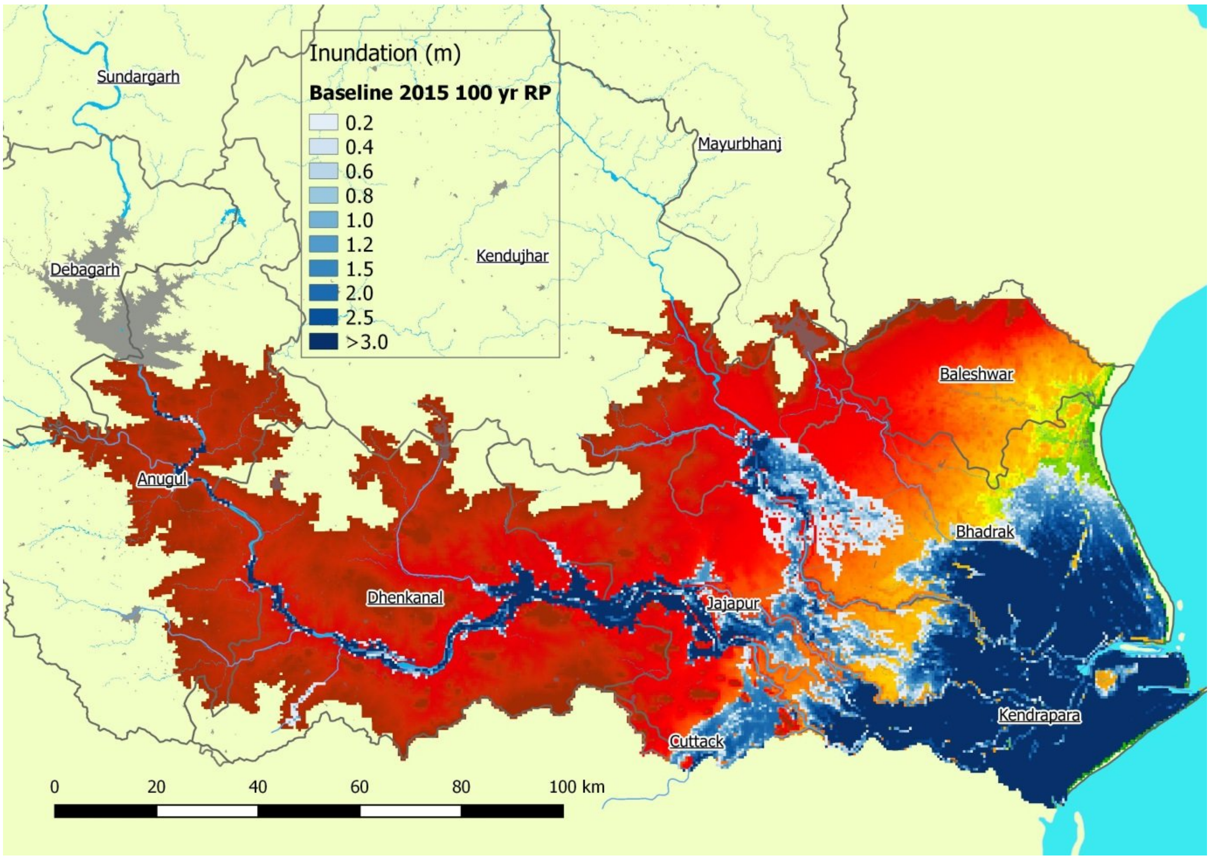

Figure 12 Flood inundation map for Brahmani-Baitarani for 1:100 year flood (SOBEK model result)

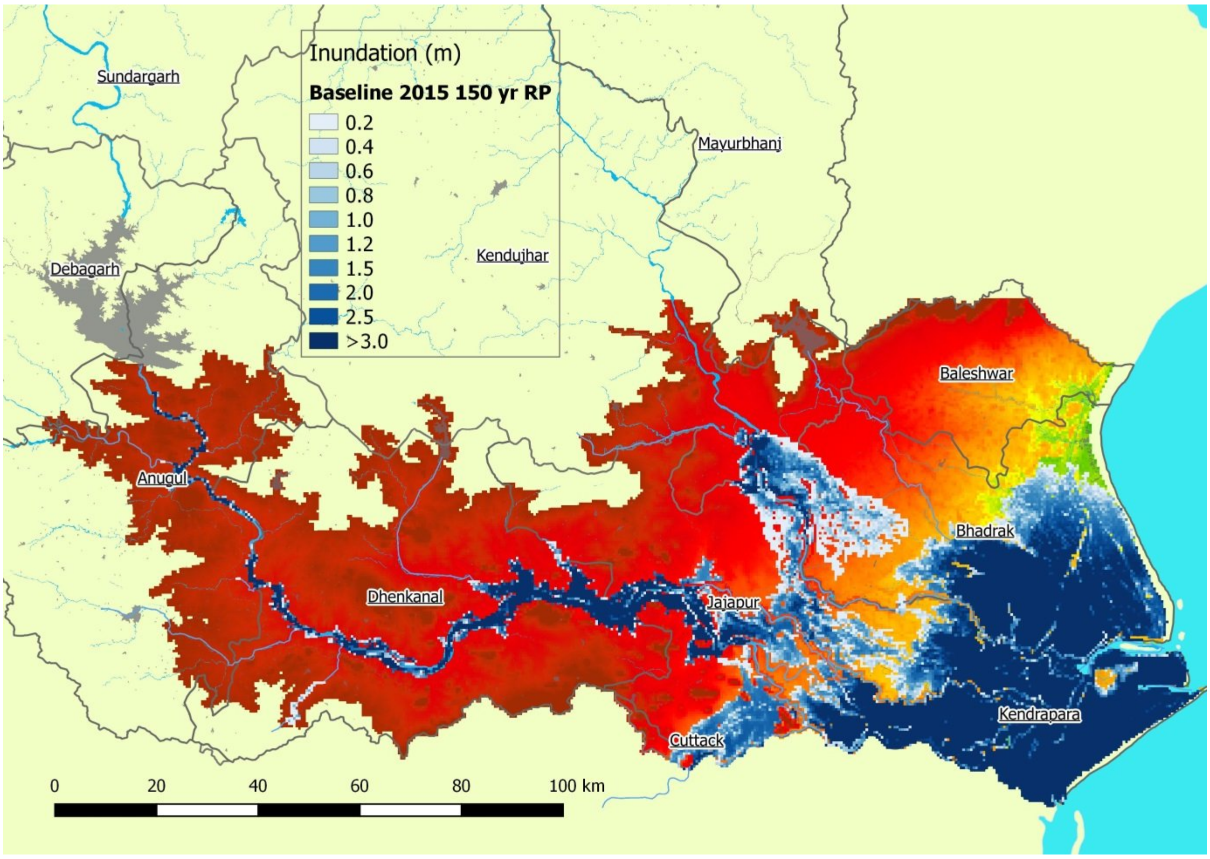

Figure 13 Flood inundation map for Brahmani-Baitarni for 1:150 year flood (SOBEK model result)

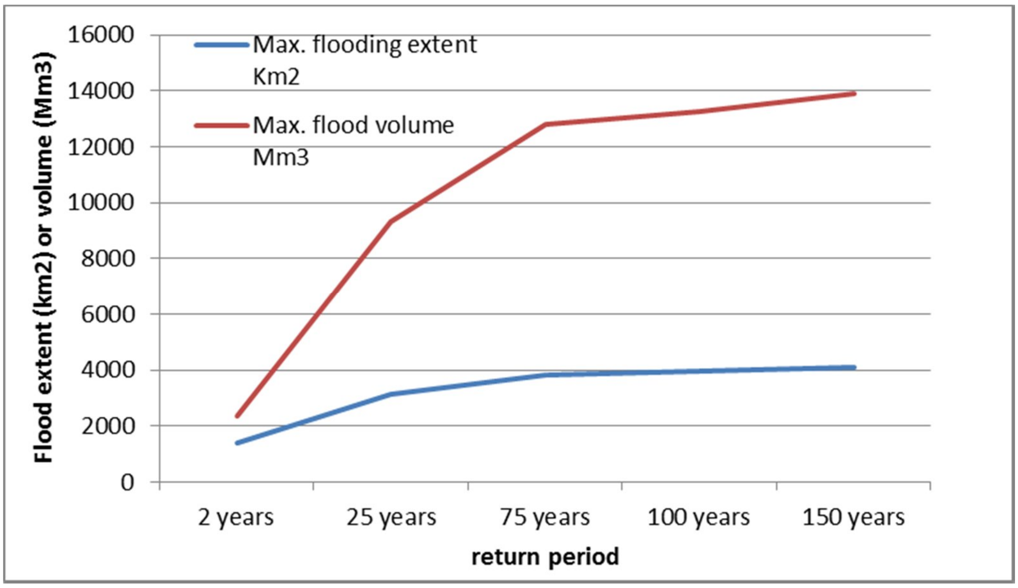

Figure 14 Flood extent (in km^2) and flood volume (in Mm^3) for different return periods

Table 3 Damages for different return periods in INR Lakh

Item	Unit value (INR)	2 years (Lakh INR)	25 years (Lakh INR)	75 years (Lakh INR)	100 years (Lakh INR)	150 years (Lakh INR)
Huts	25000	1,417	4,671	6,056	6,320	6,698
Kacha_HS	100000	37,439	114,406	150,154	155,160	160,887
Pucca_HS	350000	65,947	188,916	236,604	245,865	256,202
Pulses	42187 INR/t	5172	7517	7692	7693	7693
Rice	28191 INR/t	92071	183392	199202	201418	203651
TOTAL		*202,047*	*493,935*	*599,708*	*616,456*	*635,131*

3.2 Climate change scenarios for flood modelling

3.2.1 Introduction

Given that weather extremes (e.g., drought and flood) are directly affected by climate change, it is important to understand the degree to which the adverse impacts of these on flooding intensity and frequency in major river basins could be exacerbated in the future. Varying spatially and temporally, these impacts are likely to have considerable implications for water resource planning, as well as adding to the risks to water infrastructure systems. Attention is increasingly being paid to flood hazard adaptation strategies at the regional and basin levels. However, no assessment of the likely changes in rainfall over the flood prone river basins have yet been undertaken in India which could be effectively deployed to evaluate the potential risk to hydrological systems at this scale and thus facilitate in the development of an effective water resources planning and investment strategy. Against this background and with the objective of assessing the possible impacts of climate variability and climate change on the flood hazards in the Brahmani-Baitarani basin of Odisha, investigations have been attempted to: (i) validate the new CMIP5-based climate projections (temperature and rainfall) for the two States by comparing the CMIP5-based model simulated climate (Knutti, R. & J. Sedláček, 2013) for the baseline period (1961–1990) with that of APHRODITE-based observed climatology (Asian Precipitation Highly Resolved Observational Data Integration Towards Evaluation of Water Resources, Japan) over the same period; (ii) assess CMIP5-based short (2040s representing climatology over 2030–2059) and long-term (2080s representing climatology over 2060–2099) climate change projections (temperature and precipitation) for the Odisha state; and (iii) assess the projected change in frequency of extreme rainfall events in the Brahmani-Baitarani basin of Odisha based on CMIP5 projected climate change.

3.2.2 Selection of CMIP5 climate models, emission scenarios, and time slices

The climate models that could be considered for downscaling the climate scenarios at local scale must skillfully replicate the statistics of the current climate at local scales. Many of the global climate models used in Fifth Coupled Model Inter-comparison Project (CMIP5), the findings of which are detailed in IPCC AR5 (now called as Earth System Models or ESMs) with their current horizontal resolutions are not tuned to provide realistic climate simulations at sub-grid scales particularly in regions characterized by non-uniform topography and near the coastal locations. The main source of skill in new ESM simulated temperature and rainfall is the seasonal and annual cycle in rainfall and the warming trend with time, which is primarily forced by greenhouse gases and aerosols.

We have identified three better performing climate models and downscaled the model-simulated near surface air temperatures and rainfall for selected Brahmani-Baitarani river basin in Odisha State and compared these with the actual average monthly observations for the baseline period of 1961-1990 (Table 4). The findings of this validation exercise suggest that there still are problems in simulating the local climate with respect to current model statistics in most of the models. The standard deviation of model simulated surface air temperature and rainfall over India (averaged over land points only) as compared with CRU-based rainfall and temperature climatology (Climate Research Unit, Norwich-UK) for the period 1971-2000 suggests a fairly reasonable performance of almost all the models in simulating the annual cycle of surface air temperature. However, MIROC5 is one of the individual models that is closer to the observations in terms of simulation of surface temperature over the Indian sub-continent. For precipitation variable, the model simulations, invariably, deviate significantly from observations. The RMS errors are large and the correlation is weak, it ranges from 0.30 to 0.75 among the models analyzed here. GFDL-CM3 is the best-performing individual model for simulation of precipitation, followed closely by others over India. A further analysis of daily data generated by these two model simulations demonstrated a high skill in simulated surface air temperature and its annual cycle in the State of Odisha as when compared with Indian climatological data base (least bias) and a closer resemblance with the climatologically observed behavior of rainfall associated with monsoon onset, progression with time across India and its withdrawal with the end of monsoon season. It is therefore crucial that we apply systematic bias corrections to the model simulated surface air temperatures and rainfall considered in this study for obtaining meaningful future projections over Odisha. The said corrections are least in the identified three ESMs (<2.0^{o}C on point scale). The three state-of-the-art Global Climate Models used for CMIP5 experiments, namely, HadGEM2-ES Model (UK), GFDL-CM3 Model (USA), and MIROC-ES Model (Japan) reproduce current mean annual and seasonal monsoon rainfall over the land grid points of Indian sub-continent in the acceptable uncertainty band over India as compared to a total of 18 ESMs used in validation exercise (Ramesh Kumar & P. Goswami, 2014). The simulations of daily intensity of rainfall in some of the ESM are also in significant error in that the model does not realistically simulate the high daily rainfall episodes. Some models produce precipitation approximately twice as often as that observed and make rainfall far too lightly. Therefore we consider the choice of three ESMs adopted in this study as most appropriate for obtaining climate variability and climate change scenarios at a time scale of a century or shorter.

Of the many CMIP5 GCMs with daily fields available, three ESMs simulate the key regional aspects of climate over the Indian sub-continent sufficiently fairly well (and hence narrow the range of uncertainty) in that we consider the projections from those models ‘plausible’ (GFDL-CM3, HadGEM2, and *MIROC-ESM*). The data generated by simulations from these three models have been deployed for generating downscaled climate change information for a consistent multi-regional/local assessment of hydrological impacts to climate change in this study. It is also noteworthy here that, even though a majority of climate change impact assessment studies have been performed in India and some selected States using the future projections from previous version of the Hadley Centre Global Climate Model and the regional climate models including PRECIS, the latest version of MIROC and GFDL Earth System Models have performed better in terms of monsoon rainfall simulation irrespective of relatively coarser horizontal resolution. Whilst each of the three models capture the July–August peak in rainfall over the region of interest, HadGEM2 model has a tendency to over/under estimate the magnitude in June and/or September). We have also examined the rate of total precipitation explained by convective and stratiform precipitations in observations and in these three CMIP5 models. It is found that the models produce too much (little) convective (stratiform) precipitation compared to observations. In addition, we also find stronger precipitable water—precipitation relationship in the models as compared to observations. Hence, the atmospheric moisture content produced by the model perhaps immediately gets converted to precipitation even though the large-scale thermodynamics in models weaken. Therefore, under global warming scenarios, due to increased temperature and resultant increased atmospheric moisture supply, these models may tend to produce unrealistic local convective precipitation often not in tune with other large-scale variables. This may question the reliability of the Indian summer monsoon rainfall projections in climate models and highlight the need to improve the convective parameterization schemes in coupled models for the robust future projections.

Table 4: The validation statistics of climate models used in this study

Technical specifications	Observed Climatology	HadGEM2-ES Model (UK)	GFDL-CM3 Model (USA)	MIROC-ESM Model (Japan)
Horizontal Resolution	-	Longitude: 1.87°; Latitude: 1.25°	Longitude: 2.50°; Latitude: 2.00°	Longitude: 2.81°; Latitude: 2.79°
Number of model layers in vertical	-	Atmospheric component: 38; Oceanic component: 40	Atmospheric component: 48; Oceanic component: 50	Atmospheric component: 80; Oceanic component: 44
No of Grid points within Brahmani-Baitarani Basin	6	6	3	2
Annual mean surface air temperature in Odisha State (°C)	26.2	-*	25.49	-*
Annual Rainfall (mm) within Brahmani-Baitarani Basin (percent deviation from observed)	1204 mm	853 (-29.2%)	1540 (27.9%)	1421 (18.1%)
Monsoon season Rainfall (mm) within Brahmani-Baitarani Basin (percent deviation from observed)	964	630 (-34.7%)	1242 (28.8%)	1039 (7.7%)
* *Data not available*				

The GHG scenarios followed through Representative Concentration Pathways (RCP) in ESMs are a step evolving away from the non-mitigation SRES scenarios considered previously in IPCC AR4. They are compatible with the full range of stabilization, mitigation and baseline emission scenarios, represent consistent sets of projections of only the components of radiative forcing that serve as input for climate modeling, pattern scaling, and atmospheric chemistry modeling and span a full range of socio-economic driving forces. RCPs allow climate modelers to test different social, legislative and other policy initiatives, and see the economic effects as well as environmental; mitigation results as well as adaptation. In the current scenario of uncertainty in global agreement on mitigative actions for restricting the greenhouse gas emissions, the RCP 6.0 represents the most plausible concentration pathway for the future. As policy makers and decision makers at country level and at municipal level in a developing country are not so much interested in a range of possibilities as regards the absolute local climate change but in the scale of vulnerability due to nature of future extremes and adaptive actions to be mainstreamed in their future development plan, we have opted for considering the best choice of RCP6.0 in our vulnerability assessment. Hence, in this study, RCP 6.0 representative concentration pathway was considered for the generation of the climate change projections as it follows a stabilizing CO_2 concentration close to the median range of all the four policy pathways. The climate change data analysis for inferring projections of future climate change in this study has been done on three time scales, namely, baseline (1961-1990), near term (2040s i.e., 2030 to 2059), and long term (2080s i.e., 2070 to 2099). Figure 15 to Figure 17 depict the location of grid points in the data sets obtained from three climate models over the selected Brahmani-Baitarani river basin in Odisha.

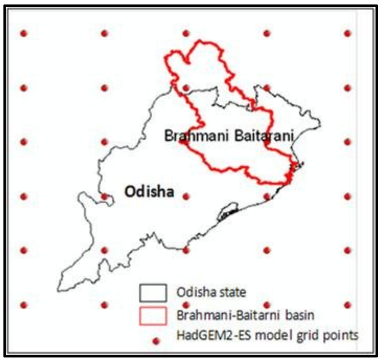

Figure 15: Location of HadGEM2-ES climate model grid points over the Brahmani-Baitarani basin

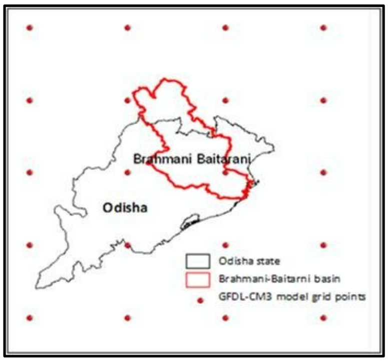

Figure 16: Location of GFDL-CM3 climate model grid points over the Brahmani-Baitarani basin

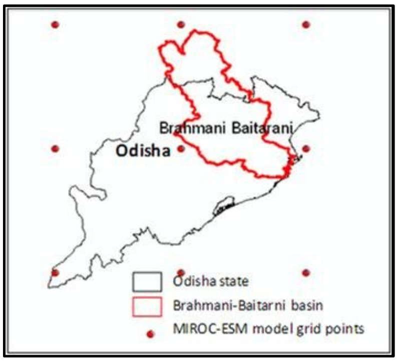

Figure 17: Location of MIROC-ESM climate model grid points over the Brahmani-Baitarani basin

3.2.3 Bias correction in rainfall data

The focuses of the great majority of climate change impact studies undertaken thus far are based on changes in mean climate. This is primarily due to the fact that these changes are more robust than changes in climate variability In terms of the ability of the climate models. However, by concentrating on changes in climate means in impact assessment studies available in literatures, the full impacts of climate change on hydro-meteorological systems are probably being seriously underestimated. Climate change is inevitably resulting in changes in climate variability and in the frequency, intensity, spatial extent, duration, and timing of extreme weather and climate events. Changes in the frequency and severity of extreme climate events and in the variability of weather patterns will have significant consequences for integrated flood management in a river basin among other human and natural systems. The possible impacts of changes in climate variability on hydrological systems in the tropical countries such as South Asia could be significant with human populations rising unabated throughout the present century, where the deleterious impacts of anthropogenic climate change are generally projected to be greatest.

Unfortunately GCMs are of rather coarse resolution to directly infer climatology of high-impact weather at local scales and it is common to downscale over regions of interest using statistical techniques or nested regional climate models (RCMs). Significant biases or systematic errors in the model are common due essentially to nonlinear nature of climate when compared to observed climatology at smaller spatial scales. These biases can be problematic for these downscaling applications to regional and extreme weather climate scales. In practice, statistical bias correction is applied independently across time and space, without taking into account feedback mechanisms between atmospheric processes. It is important to remember that the GCM data were generated at a coarse resolution, where local processes and terrain heterogeneity were not taken into account. It also is possible that statistical downscaling methods developed on past climate might not hold true under climate change conditions. An alternative, widely-used approach is to nest a RCM within GCM boundary conditions. RCMs can operate at higher resolution than GCMs to enable simulation of much finer scale features, which are required for assessment of many extreme weather phenomena. One shortcoming of this approach is the transmission of GCM biases through the RCM lateral and lower boundaries, which may have a severe impact on the interior climate. This approach suffers from the same limitations as the aforementioned statistical bias correction of GCMs and has the additional complication that GCM biases may irretrievably change—or even destroy—the high-impact weather signal of interest. An alternative bias-correction approach is to construct boundary conditions from a current climate reanalysis plus a climate change perturbation, a technique known as pseudo-global-warming. This approach is simple to apply and takes advantage of the improved ability of GCMs to simulate trends compared to absolute climates. However, there are substantial disadvantages arising from the inherent assumption of no change in synoptic and climate variability. Biases from current GCM simulations also may change into the future (arising from a possible non-stationarity of the bias) and alias into the imposed climate change perturbation.

In view of the limitations of obtaining precise climate change scenarios of future changes in rainfall at the scale of Brahmani-Baitarani river basin as desired in this study, bias correction will need to be applied to model simulated future projections of daily rainfall data. For this, first the model simulated baseline period daily rainfall data has been validated against high resolution global gridded rainfall climatology for the 1961-1990 period developed at MRI, Japan. Subsequently, the 30 year mean bias correction factor (multiplication factor) for each month is obtained and this has been applied to projected 30 year daily rainfall data series centered around 2040s and 2080s. The bias-corrected daily rainfall data series for the future time slices has subsequently been used for inferring a number of rainfall indices to understand the nature of future changes in rainfall variability and extremes over the identified river basin in Odisha at two future time scales (such as events of light rain, moderate rain, heavy rain, maximum rainfall intensity). These inferred changes in indices are applied in the hydrological modeling exercise to assess the future flood intensity potentials in Brahmani-Baitarani river basin of Odisha State during different time horizons.

3.2.4 Future climate change data analysis

Spatial distribution patterns in maximum and minimum surface air temperatures and rainfall over Brahmani-Baitarani basin of Odisha State were developed using above-mentioned climate simulation models data in GIS platform (ArcGIS 9.3). These analyses provide the likely shifts in spatial changes of temperature, and rainfall during 2040s (2030-2059) and 2080s (2070-2099) with respect to baseline time period (1961-1990). The key findings from these should be used to assess the implications of projected climate change on various meteorological and hydro-meteorological hazards (e.g., drought, flood, and heat wave etc.) over the Brahmani-Baitarani river basin in State of Odisha.

The possible impacts of changes in climate variability and the frequency of extreme events on droughts / floods in a river basin, requires analysis that tentatively links increases in climate variability with increasing flood severity in the future. The bias-corrected daily rainfall data series for the future time slices are used for inferring a number of rainfall indices to understand the nature of future changes in rainfall variability and extremes at various temporal scales. The rainfall indices are helpful in a better understanding of the nature of likely changes in rainfall and in assessment of the future flood scenarios in the selected river basin and subsequently in the development of integrated flood management options. These inferred changes in indices were also applied in the hydrological modeling exercise to assess the future flood intensity potentials during different time horizons. Our target in this analysis was aimed at the disaster management authorities who need to deal with climate variability and extremes and develop appropriate responses with actionable answers as to how they may adapt to prevent or minimize losses in the future. Given that the key knowledge on the full range of impacts of climate change on hydrological systems remains a critical gap on being able to address effectively the effects of climate variability and extreme events on human vulnerability, particularly in agriculturally based developing countries facing the challenge of having to feed rapidly growing populations in the coming decades. Our approach on developing the hydro-meteorological indices is an attempt to address this gap for the integrated flood management in the identified river basins in India.

3.2.5 Future climate change scenarios for Odisha

The projected rise in maximum (day-time) and minimum (night-time) surface air temperatures over Brahmani-Baitarani basin of Odisha State at two time slices namely, 2040s and 2080s are illustrated in Figure 18 and Figure 19, respectively. The plausible changes in annual mean and monsoon season rainfall over the Brahmani-Baitarani river basin of Odisha for two time slices namely, 2040s and 2080s are depicted in Figure 20 and Figure 21 respectively. The results shown here for the purpose is for GFDL-CM3 model only as a representative one.

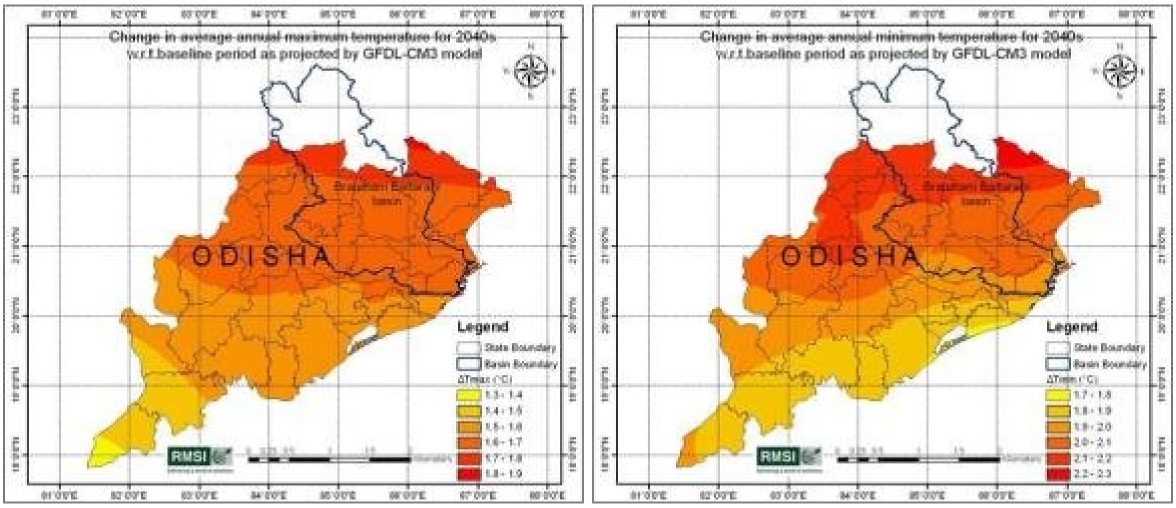

Figure 18: Projected rise in annual mean maximum and minimum surface air temperatures during for 2040s in Odisha (Brahmani-Baitarani basin is marked with blue colour boundary)

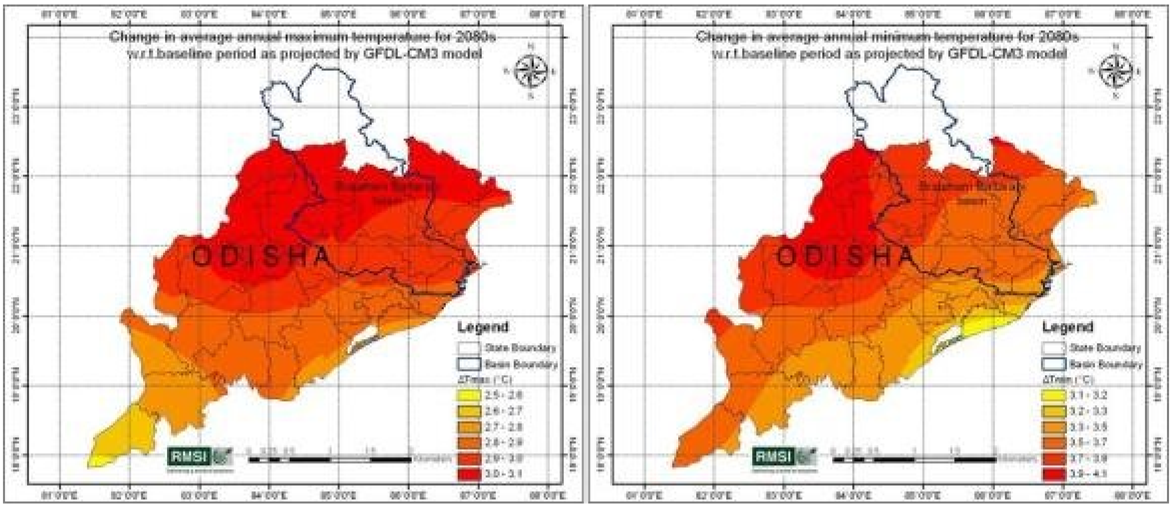

Figure 19: Projected rise in annual mean maximum and minimum surface air temperatures during for 2080s in Odisha (Brahmani-Baitarani basin is marked with blue colour boundary)

It is evident from Figure 18 that the mean maximum annual day-time surface air temperatures in Brahmani-Baitarani basin of Odisha State is likely to rise on an average by about 1.7°C around the middle of this century while the rise in mean annual night-time minimum surface air temperature could exceed 2.1°C by the middle of this century. The diurnal temperature range would become lesser in future in the Brahmani-Baitarani basin of Odisha State. During 2080s, annual maximum day-time and minimum night-time surface air temperatures in Brahmani-Baitarani basin are expected to rise by 3.0°C and 3.7°C respectively (Figure 19). These projections of rise in surface air temperatures in future suggest that the intensity of heat waves in Brahmani-Baitarani basin and, by and large, over Odisha State should become stronger with time during peak summer months and record high temperatures could be experienced here more often in future.

The spatial change in annual mean and monsoon season rainfall patterns (simulated by GFDL CM3 model) over the Odisha State by the middle of this century is depicted in Figure 20. Figure 21 depicts the annual mean and monsoon season rainfall over the Odisha State by the end of this century. More detailed examination of the rainfall change over the Brahmani-Baitarani river basin as inferred from an ensemble of three models considered here suggests (Figure 22) that the total rainfall increase during monsoon by the end of this century over the Brahmani-Baitarani basin would be about 230 mm (by about 400 mm in HadGEM2 model). On an average, the Brahmani-Baitarani basin is likely to experience an increase in rainfall by the mid 21st century and beyond. On annual basis, the rainfall could increase over the Brahmani-Baitarani basin by about 40% by the end of this century. It is interesting to note that, broadly speaking, both the monsoon as well as annual rainfall change projected by multi-model ensemble is marginally lower than those inferred by HadGEM2 model (Table 5).

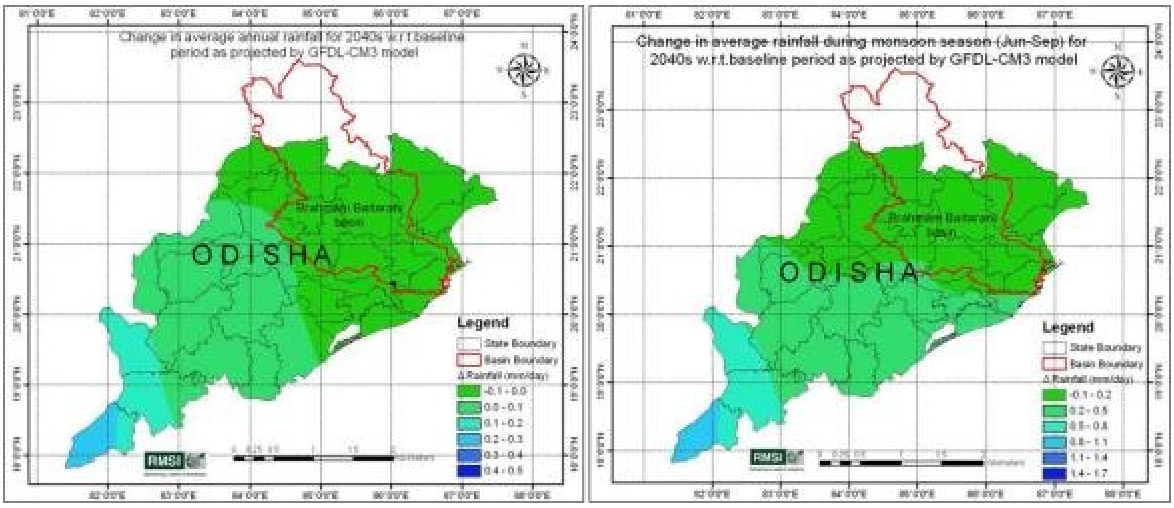

Figure 20: Projected change in annual and monsoon season rainfall (mm/day) for 2040s in Odisha (Brahmani-Baitarani is marked with red colour boundary)

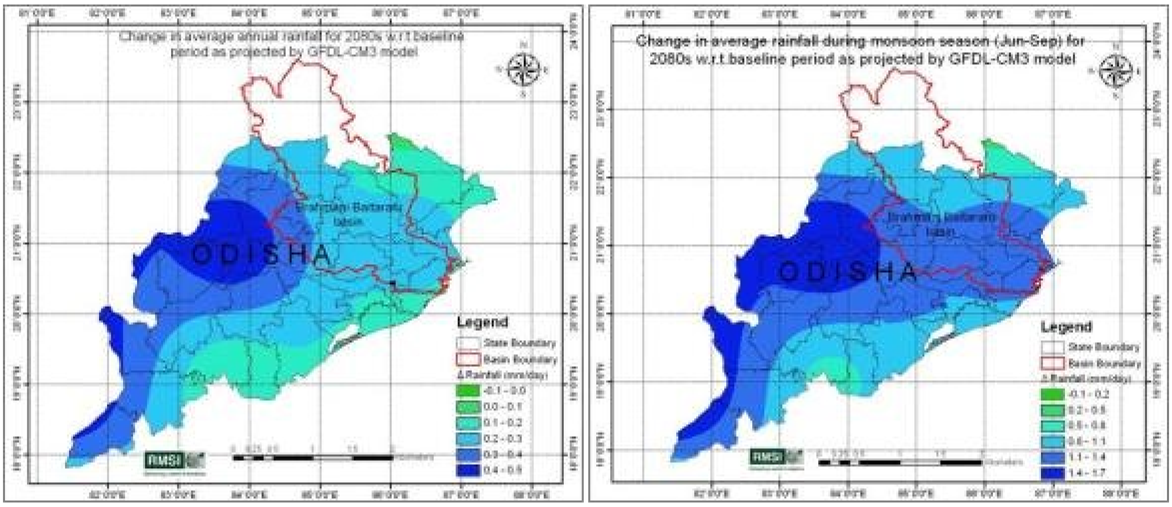

Figure 21: Projected change in annual and monsoon season rainfall (mm/day) for 2080s in Odisha (Brahmani-Baitarani basin is marked with red colour boundary)

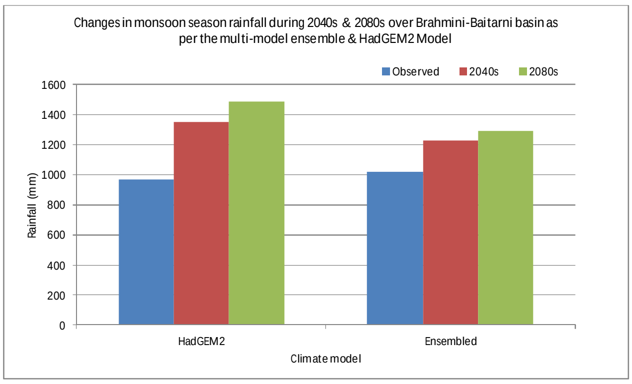

Figure 22: Changes in monsoon season rainfall during 2040s & 2080s w.r.t. baseline period (1961-90) over Brahmani-Baitarani basin as per the multi-model ensemble (HadGEM2, GFDL, & MIROC) & HadGEM2 Model

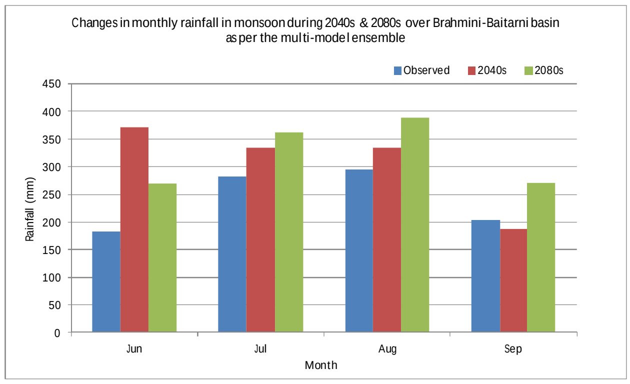

Figure 23: Changes in monthly rainfall in monsoon season during 2040s & 2080s w.r.t. baseline period (1961-90) over Brahmani-Baitarani basin as per the multi-model ensemble (HadGEM2, GFDL, & MIROC models)

Table 5: Percent deviation of projected monthly rainfall during 2040s & 2080s w.r.t. baseline (1961-90) over Brahmani-Baitarani basin as simulated by HadGEM2 Model and in the multi-model ensemble

Month	Observed rainfall (mm)	% deviation of RF during 2040s & 2080s w.r.t. BL period (1961-90) projected by HadGEM2 model		% deviation of RF during 2040s & 2080s w.r.t. BL period (1961-90) as per the multi-model ensemble	
		2040s	2080s	2040s	2080s
Jan	10.8	4.01	-21.10	12.54	-19.03
Feb	21.7	40.28	8.80	55.58	57.57
Mar	22.0	15.36	5.08	-20.62	24.34
Apr	27.0	-10.13	9.03	-31.64	-11.72
May	46.7	-5.98	31.84	44.26	9.39
Jun	183.4	120.87	53.22	102.60	46.78
Jul	282.2	32.35	53.22	18.57	28.37
Aug	294.4	12.47	33.08	13.75	32.12
Sep	204.5	17.27	86.29	-8.49	32.49
Oct	85.3	56.74	58.56	15.06	33.20
Nov	20.7	-60.95	-18.89	-28.51	13.87
Dec	5.1	-39.94	-53.17	-30.70	-46.30
Annual RF (mm)	1203.7	35.37	48.43	24.10	30.96
Monsoon season RF (mm)	964.5	39.92	54.09	27.34	33.89

We have also analyzed the intra-seasonal behavior of monsoon rainfall during the four months from June to September each year. Our findings on likely behavior of monthly rainfall in each of these four months as illustrated in Figure 23 and Figure 24 for multi-model ensemble and for HadGEM2 model respectively suggest that over Brahmani-Baitarani basin in Odisha the nature of rainfall change in June (onset of monsoon) and in September (withdrawal phase of the monsoon) has contrasting trends in the two illustrations (also evident in Table 5). This highlights the complexity in non-uniform behavior of the GCMs in simulating the rainfall and its change at the time of onset and withdrawal of monsoon over India.

From the point of view of riverine flood in Odisha, the likely changes in the nature intensity of rainfall over the entire catchment area is equally important as this modulates the stream flow downstream of the river and more so in Deltaic plains near the coast where the back water also plays a role in flood severity. Our analysis on the nature of rainfall intensity over the Brahmani-Baitarani basin suggests that each of the climate models simulate a decline in the frequency of light rain days and an increase in moderate and heavy rainfall episodes in future decades (Figure 25).

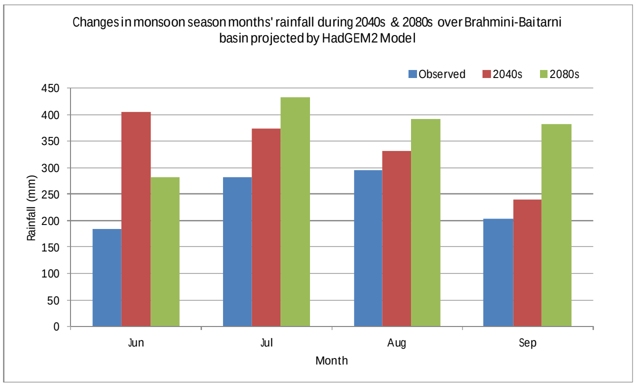

Figure 24: Changes in monthly rainfall in monsoon season during 2040s & 2080s w.r.t. baseline period (1961-90) over Brahmani-Baitarani basin projected by HadGEM2 Model

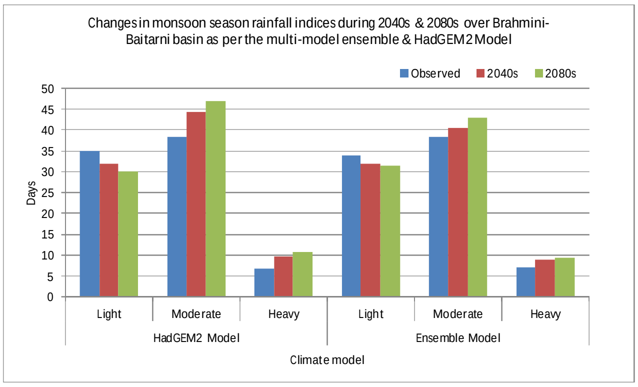

Figure 25: Changes in rainfall indices during monsoon season of 2040s & 2080s w.r.t. baseline period (1961-90) over Brahmani-Baitarani basin as per the multi-model ensemble (HadGEM2, GFDL, & MIROC) & HadGEM2 Model

Maximum daily rainfall intensity during baseline period, 2040s, and 2080s over Brahmani-Baitarani basin as inferred from observed data, HadGEM2 model, and the multi-model ensemble are given in Table 6. No consistent behavior in the projected change in daily rainfall intensity is observed over the Brahmani-Baitarani river basin as a whole in each of the months during monsoon season in the future. However, during the later part of the monsoon season (August and September) the findings suggest an increase in the daily maximum intensity of rainfall over Brahmani-Baitarani basin. Interestingly, the projected increase in the daily maximum intensity of rainfall over Brahmani-Baitarani basin is also projected in October which is indicative of the likely occurrences of more flash floods in and around the basin during September-October months in later part of the century.

Table 6: Maximum daily rainfall intensity during baseline period, 2040s, and 2080s over Brahmani-Baitarani basin as inferred from observed data, HadGEM2 model, and as per the multi-model ensemble

Month	Maximum daily rainfall intensity (mm)				
	Observed	2040s projected by HadGEM2	2080s projected by HadGEM2	2040s as per the multi-model ensemble	2080s as per the multi-model ensemble
Jan	46.0	51.4	31.6	73.1	36.9
Feb	35.4	53.7	46.1	53.7	77.4
Mar	36.8	51.4	47.0	51.4	57.0
Apr	26.9	23.9	27.5	23.9	27.5
May	90.0	83.9	106.9	279.6	106.9
Jun	172.9	301.2	201.9	1000.7*	535.6
Jul	130.0	183.1	229.0	183.1	229.0
Aug	157.6	191.4	220.9	191.5	229.0
Sep	138.3	169.2	217.9	169.2	217.9
Oct	114.4	195.7	162.0	195.7	166.0
Nov	88.8	31.2	67.9	66.3	89.3
Dec	40.4	26.4	16.0	34.2	29.4

** Believed to be a spurious daily rainfall point value and not reliable*

It is thus evident that as the total seasonal rainfall as well as the episodes of heavy rainfall incidences is projected to increase over the Brahmani-Baitarani basin of Odisha State, the river catchment is likely to face more widespread flooding by the middle of 21st century and beyond. The projected rise in maximum surface air temperature over the Brahmani-Baitarani basin and the Odisha State during future further suggests that warmer air would have higher water vapor holding capacity and stronger convective activity in May - June can lead to more intense spells of rainfall associated with thunderstorm activity which may contribute to faster stream flow and result in flash floods in parts of the catchment area.

Sea level rise

In Odisha State, large potential risks are also posed by sea level rise resulting from thermal expansion of the oceans and melting of land-based ice as the climate warms up. During the 20th century, while the global average sea level rose at an average rate of 1.8 mm/year over 1961–2003, the average mean relative sea level around the tropical oceans increased at the rate of 0.81 mm/year, although the rate of rise had been variable across locations due to local meteorological factors and vertical land movement (IPCC, 2007). Extreme sea-level events occur in the form of storm surges, driven by tropical or extra tropical cyclones and in the form of tsunamis. In the Bay of

Bengal, sea levels have reportedly risen by an average of 12.7 mm a decade, with the highest rate of increase observed during ENSO events. By the end of 21st century, sea level rise is projected to more than double and many GCMs project estimates of close to a meter for most parts of the north Indian Ocean including the Bay of Bengal. The projected rise in sea level along the coastline of Odisha as simulated by an ensemble of two Global Climate Models (out of the three considered in this study for which SLR projections were available) for 2040s and 2080s is illustrated in Figure 26 and Figure 27, respectively.

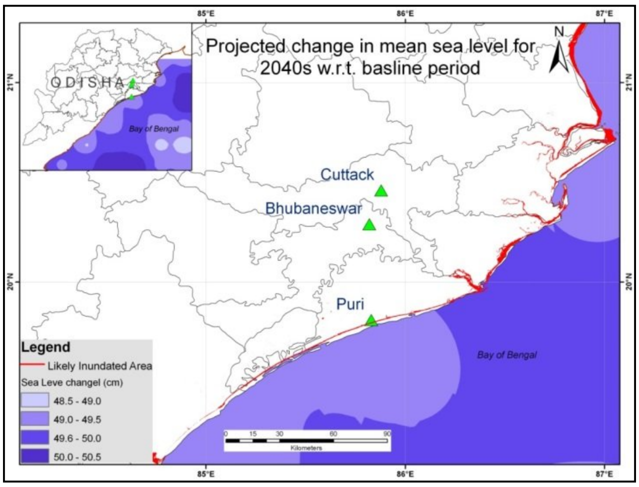

Figure 26: Projected rise in sea level along the coastline of Odisha by 2040s as simulated by an ensemble of two Global Climate Models

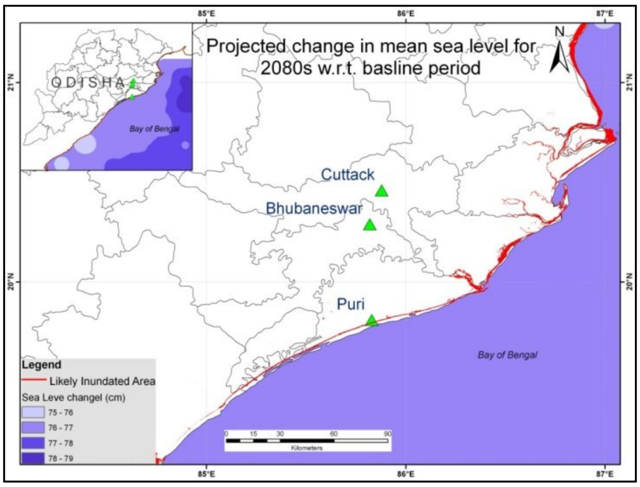

Figure 27: Projected rise in sea level along the coastline of Odisha by 2080s as simulated by an ensemble of two Global Climate Models

The most important effect of sea level rise would be to increase the inundation of deltaic areas adding to the miseries of local communities suffering from recurrent floods. However, most coastal hazards are intrinsically local in nature as the regular and repetitive local processes of wind, waves, tides and sediment supply that fashion the location and shape of the shorelines, other than the periodic storms. Therefore, coastal hazards along coastal Odisha shall need to be managed in the context of local knowledge, using data gathered by site-specific tide-gauges and other relevant technologies. Shorelines naturally move around over time in response to changing environmental conditions. Many planning regulations already recognize this, for example by applying minimum building setback distances or heights from the tide mark. In addition, engineering solutions are often used in attempts to stabilize a shoreline. To the degree that they are both effective and environmentally acceptable, such solutions should be encouraged. Nevertheless, occasional damage will continue to be imposed from time to time by severe tropical storms or other unusual natural events. This will happen no matter how excellent the pre-existing coastal engineering and planning controls may be. In these circumstances, the appropriate policy should be one of careful preparation for, and adaptation to, hazardous events. Broadly speaking, local sea level rise could lead to a decline in the availability of fresh water supply, increase in coastal erosion and salt water intrusion, and contribute to the loss of productive deltas. This also has attendant implications to agriculture, and coastal and marine resources. For populations living in coastal areas, inundation would also likely cause large costs for infrastructure relocation.

3.3 Impact of climate change on flood hazards

The projections on change in rainfall within the 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 7. It shows that for Brahmani-Baitarani rivers and increase of 21% in flooding extent could be expected in 2040 and even and 25% in 2080 for a 1:25 year flood event. 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 7 Impact of climate change on flood extent for Brhmani-Baitarani

1:25 year return period	Baseline (current) Maximum flooding extent (km^2)	2040 Maximum flooding extent (km^2)	2080 Maximum flooding extent (km^2)
Brahmani-Baitarani	3251	3933	4070

Chapter 4 Evaluation of flood risks

4.1 Benefits (avoided damage) for different return periods

The model results (section 3.1) have calculated the potential damages for different return periods. For the evaluation of the desired safety level it is important to calculate Average Annual Damages (AAD). To better understand this concept, take for instance a damage for a specific event, say one in 75 years. This damage does not occur every year, but has a chance of 1/75 to occur. So to derive the AAD we have to divide the damage of the event with the probability. This would give a potential damage for that specific event of 0.01333 x 599,708 = INR 7996 Lakh. In order to include all possible events we have to integrate the area under the damage curve. In our case we have 5 different points on this curve. The AAD can then be approximated by using the following formula:

$$AAD = \int_0^1 D_F\,dp \approx \sum_{i=1}^{N} (D_{i+1} + D_i) \times (p_{i+1} - p_i) / 2$$

Where

D_F = Flood Damage

D_i = Damage of a flood event i

P_i = probability of a flood event i

For the four intervals we can calculate the annual interval damage. This has been done in the next table. The total flood risk for the Brahmani-Baitarani river floodplains can now be estimated by adding up all annual interval damages, resulting in an AAD of INR 1787.7 crores. With this table or formula it is also possible to evaluate the benefits of safety levels. For instance, providing a safety level of 1:25 years would mean that the damage for the 1:2 and 1:25 year flood will be zero. The AAD then is reduced to INR 121.09 crores. It shows that providing a safety of 1:25 years reduces the risk with 93%. Of course it is assumed that this flood protection is ideal and without failures.

Table 8 Calculation of Average Annual Damages using different return periods

Return period (per year)	Probability	Damage (Lakh INR)	P interval	mean damage (Lakh INR)	Annual interval damage (Lakh INR)
150	0.006667	635,131			
			0.003333	625,793	2,086
100	0.01	616,456			
			0.003333	608,082	2,027
75	0.013333	599,708			
			0.026667	546,821	14,582
25	0.04	493,935			
			0.46	347,991	160,076
2	0.5	202,047			
AAD					178,771

Table 9 Calculating the remaining AAD with a flood protection of 1:25 years.

Return period (per year)	Probability	Damage (Lakh INR)	P interval	mean damage (Lakh INR)	Annual interval damage (Lakh INR)
150	0.006667	635,131			
			0.003333	625,793	2,086
100	0.01	616,456			
			0.003333	608,082	2,027
75	0.013333	599,708			
			0.026667	299,854	7,996
25	0.04	0			
			0.46	0	0
2	0.5	0			
AAD					12,109

4.2 Evaluation

The question whether the flood risk of INR 1787 crores per year as calculated in the previous section is acceptable or not requires further evaluation. From an economic perspective this risk should be compared with the costs of flood protection measures. For instance a cost-benefit analysis can be made by comparing the avoided damage of 1787-121 crores = INR 1666 crores with the cost of strengthening and completing the embankments up to the 1:25 year standard for the entire Brahmani-Baitarani river systems. Such requires a detailed estimation of these costs which is currently beyond the scope of the study. However, we have prepared a pilot study for the area near Jenapur.

4.3 Jenapur dike ring pilot

For estimating the optimal safety level we have chosen the floodplain just downstream of the bifurcation at Jenapur, where the river splits into the Brahmani and Kharsuan. This is an ideal area where a dike ring can be constructed (see Figure 28). The area is currently inundated even during 1:2 year flood events, because the embankments have gaps (around 42.5 km, see Table 10). The damages occurring during different flood events are calculated using the flood model (Table 11). Based on these damage calculations the AAD for different safety levels are calculated, as well as the benefits (Table 12). This shows that for instance if we can reach a safety level of 1:25 years, the average annual benefits would be INR 143.6 crores.

These benefits occur every year in perpetuity. The present value (PV) of an annual benefit (perpetuity) can be calculated as PV = AAD/r with r being the discount rate for government infrastructure investments. The PV in this case, assuming 12% discount rate, would be INR 1196.7 crores.

In order to obtain such safety, new dykes have to be constructed for 42.5 km. The costs of such investment would be INR 112.5 crores (assuming a 5.3 m high dike and using an unit cost of INR 2.65 crores per km). This would imply that in one year the investment costs have been recovered by the avoided damage already. Even if annual maintenance costs would be included (assume 10%) of the investment costs), the present value of the costs would be 1125+((1125*0.1)/12%)=INR 206.3 crores, which is far lower than the present value of the benefits. This would result in a BC ratio of 5.8 (Figure 29). Hence, from a macro-economic viewpoint, and looking at avoided damage and levee costs only, this would be a rational investment.

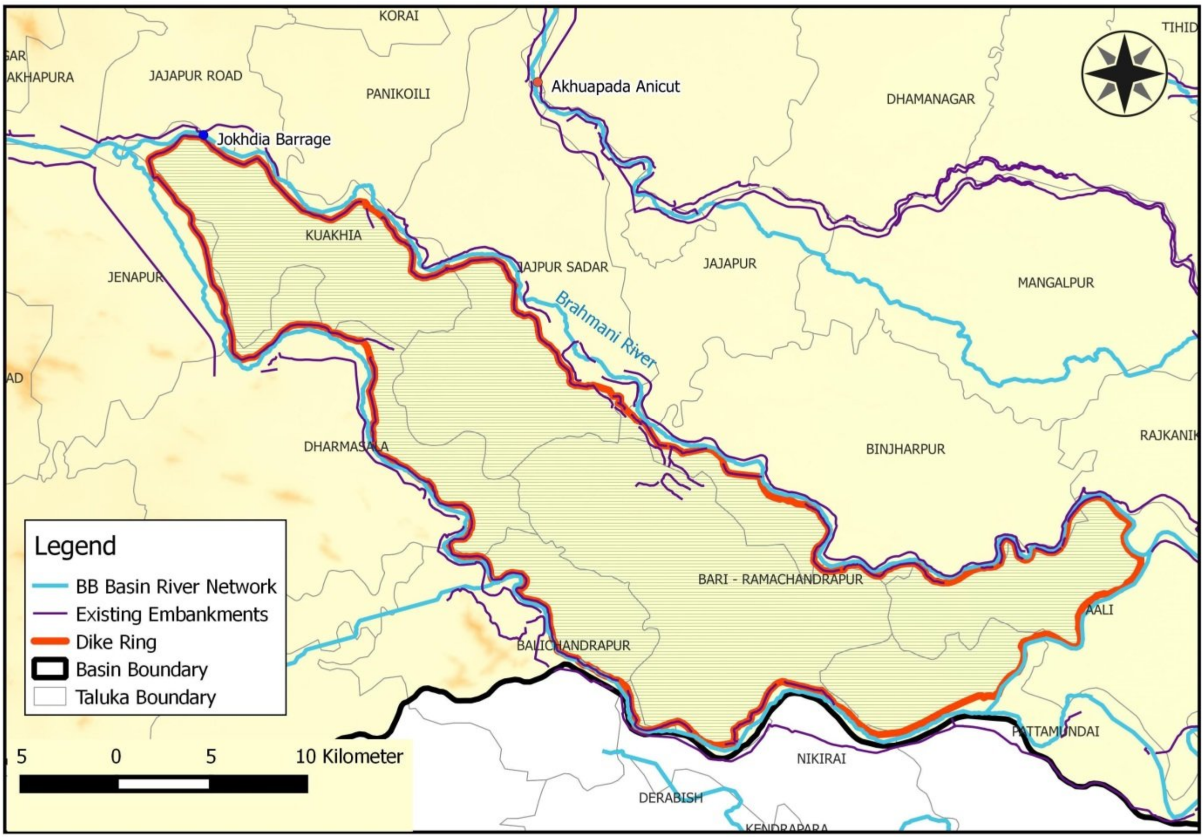

Figure 28 Proposed dike ring in the Jenapur bifurcation area.

Table 10. Dike-ring requirement

Item	Length (surface)
Present length of embankment at the area of interest (AOI)	122.30 km
Total proposed embankment/ dike-ring length	164.77 km
Length of new dike-ring construction	42.47 km
Total Embanked AOI	503.30 sq km

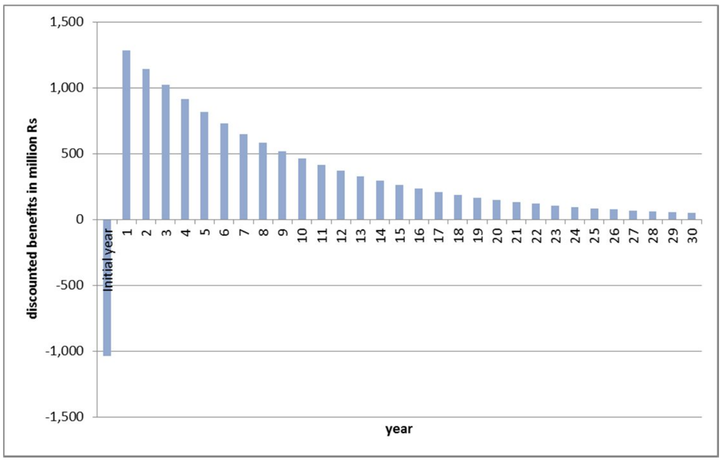

Figure 29 Graph showing discounted net annual benefits of embankment of area of interest

Of course this is a crude calculation and one should bear in mind that:

- The damage calculations have been based on a limited set of assets (houses and crops only) and therefore are a conservative estimate;
- The embankment condition needs to be checked in the field in order to improve the cost estimates;
- The exact delineation of the embankment on the downstream side requires detailed geographic study as well as community consultation;
- Other options for reducing the flood damage in the area, such as increasing Rengali dam flood cushion (see section 5.2.2) have not been taken into account and should also be evaluated through a similar cost-benefit analysis;
- The calculations assume that there will be no changes in the area in the future. For instance, including economic development would increase the benefits;
- The calculations do not take into account any disbenefits (costs) of building levees, of which there can be many, such as reduced drainage and hence an increase in pluvial flooding impacts; building flood protection in an area may reduce people's preparedness for larger floods and hence cause larger damage when they occur (the difference between baseline AAD and increased AAD due to reduced preparedness is a disbenefit); the land on which levees are being build has benefits for other uses (opportunity costs of building levees), the benefits of small floods in terms of fertilising agricultural land and recharging aquifers may be lost, etc. A detailed cost benefit analysis would need to take all these factors into account;
- Distribution of costs and benefits among different stakeholders is not taken into account (hence, the "macro-economic" viewpoint).

Nevertheless this pilot shows two important messages: first, it introduces the dike-ring concept which would improve flood management at the local level. Second, it shows that from a macro-economic viewpoint the upgrade of current embankment conditions up to 1:25 years safety could be a rational decision.

Table 11 Damages of the area of interest (talukas within the dike ring area) for different return periods

		Damages dike ring area (Lakh INR)				
Taluka	Dike Protected Area (% to total taluka area)	Case1 (1:2)	Case2 (1:25)	Case3 (1:75)	Case4 (1:100)	Case5 (1:150)
Bari - Ramachandrapur	96.52	8,877	14,461	16,076	16,438	17,004
Kuakhia	85.20	-	7,318	8,183	8,250	8,496
Jajpur Sadar	36.74	-	2,741	3,612	3,744	3,887
Aali	26.73	3,803	5,990	8,195	8,240	8,307
Balichandrapur	25.74	588	1,894	2,281	2,386	2,520
Dharmasala	20.76	1,253	3,038	3,360	3,374	3,310
Pattamundai	12.47	2,487	3,792	4,259	4,306	4,366
Binjharpur	12.21	1,646	1,695	1,930	1,952	1,975
Nikirai	2.67	114	179	201	195	199
Jenapur	2.02	-	158	210	223	233
Jajapur Road	0.11	-	4	7	7	7
TOTAL Dike-ring		*18,767*	*41,269*	*48,313*	*49,116*	*50,305*

Table 12 Average Annual Damage and benefits for different safety levels

Safety level	AAD (Lakh INR)	Benefit (avoided damage) (Lakh INR)
None	15331	0
1:2	11014	4317
1:25	972	14359
1:75	248	15083
1:100	84	15247
1:150	0	15331

Chapter 5 Flood mitigation measures and strategies

5.1 Flood mitigation measures

5.1.1 Flood embankments

Initially Brahmani - Kharsuan doab was open except at densely populated villages which were protected by short embankments. Gradually with Kharsuan developing in width and depth, it conveyed 60 to 70% of the discharge in high floods. Embankments both on left and right were built on Kharsuan and three escapes Tantighai, Palasahi and Routra were provided on the right bank of Kharsuan to spill into the central low land. Another spill channel Kani takes off from Kharsuan on its right, 45 km below Jokadia which joins Karsuan after travelling 30 km.

The entire flood spill of the major rivers Brahmani – Kharsuan continues to the sea over a 10 to 20 km wide and 70 km long flat flood plain. The entire delta of Brahmani Kharsuan of 3500 km^2 is significantly flood prone. But to protect, the very densely populated area near Kharsuan, Kani and Brahmani a 70 km long ring bund was constructed blocking a part of the flood plain and protecting 25,000 ha of agriculture land and a population of 150,000. The construction of embankments on the left of Kharsuan protecting the area between Kharsuan Baitarani is substantially completed. Similarly the area between Birupa and Brahmani is also totally protected. This area receives irrigation through the Mahanadi delta system.

The floodplains of 1500 km^2 in area between Kharsuan and Brahmani are substantially unprotected and experiences flooding of up to 1 to 2 m depth. When the river was not embanked, a discharge of 2,00,000 Cusec (5667.3 m^3/s) at Jenapur would be conveyed without any major problem, and the flood wave passed in 2 to 3 days. But after construction of embankments to protect at least 250 villages (600,000 people) the submersion due to flooding become longer, up to 30 days in the monsoon season. The vulnerable locations during floods are shown below in Table 13. The criteria used for identifying weak and vulnerable points are:

- Embankment at specified reach/point having less free board i.e. less than 1.20 mtr. with respect to known highest flood peak.
- Locations where the embankment section is below the standard section approved for the state i.e. crest width (Top Width) 3.66 mtr. and side slope 1:2.
- In a bend portion of the river, where the flow of water directly hits the embankments.
- Locations where the embankment is susceptible to wave action of tides and the embankment is heavily cut by gullies made by torrential rain.
- Locations where the river side berm is narrow i.e. less than 4.5m.
- Locations where the houses are built on the embankment. They are vulnerable to breaking due to possible existence of rat holes, which lead to piping.
- Breach closing section not visited by at least one flood.
- New embankment portion.
- Locations where big trees have grown on slope of the embankment as these are vulnerable to seepage due to presence of roots and rodent holes which lead to piping.

A summary of embankments in the Brahmani and Baitarani rivers is given in Table 14.

Table 13 Vulnerable locations for flooding

Sl.No.	Location	Irrigation Division	Name of the River
1	Gauligaon	Aul Embankment Division	Baitarani right near Gualigaon
2	maharakul	Aul Embankment Division	Gobindpur,Hadua,Madhuban TRE on Kharasuan right
3	Jharamal	Aul Embankment Division	Garadpur Iswarpur OAE on 'Brahmani Left'
4	Bhatapada	Aul Embankment Division	Keradagada Alatanga S/E on Hansua right
5	Gopalpur	Aul Embankment Division	Keradagada Alatanga S/E on Hansua right
6	Jagannathpur	Aul Embankment Division	Keradagada Alatanga S/E on Hansua right
7	Barkot	Aul Embankment Division	Keradagada Alatanga S/E on Hansua right
8	Koilipur	Aul Embankment Division	Keradagada Alatanga S/E on Hansua right
9	Pentha	Aul Embankment Division	Rajnagar Gopalpur S/E on Sea facing
10	Banaghat	Mahanadi North Division	Birupa left
11	Ganeshghat	Mahanadi North Division	Birupa left
12	Mula Basanta	Mahanadi North Division	Birupa left
13	Balipadia	Mahanadi North Division	Birupa left
14	Sherapur	Jaraka Irr. Division	Brahmani left (Sherapur OAE)
15	Saranga Sahi	Jaraka Irr. Division	Tantighai right (Bhanra TRE)
16	Radhadharpur	Jaraka Irr. Division	Kelua (Rahapada Mohanpur TRE)
17	Kochila Mouth near Daspur	Jajpur Irr. Division	Kochila mouth on Baitarani left embankment
18	Mohammadpur	Jajpur Irr. Division	Kharsuan right
19	Tala Astar	Jajpur Irr. Division	Baitarani left
20	Balarampur	Jajpur Irr. Division	Baitarani right
21	Dasandhikula	Jajpur Irr. Division	Baitarani left
22	Mugupur	Baitarani Division	Baitarani left embankment
23	Govindpur	Baitarani Division	Baitarani left embankment
24	At RD 2.85 to 2.93Km near village Kuli	Baitarani Division	Subarnarekha right

Table 14 Summary of river embankments (in km)

Name of the river system	Capital Embankment (C.E.)	Other Agricultural Embankment (O.A.E.)	Test Relief Embankment (T.R.E.)	Saline Embankment	Total
Brahmani	144.21	218.67	258.35	323.20	944.43
Baitarani	127.87	122.13	184.54	161.80	596.34

With respect to the issue of raising and strengthening river embankments, reference is made to Section 4.4.6.2 “Suggestions for improved design of embankments” of the Main Report. These suggestions could be followed depending on the site specific needs. The parameters on the degree of protection to be provided, spacing of the embankments, side slopes and free board are to be reviewed as per the suggestions provided in the above mentioned Section.

5.1.2 Outlined IFM plans for new structural measures

Already, many project interventions have been identified in Brahmani-Baitarani basins either by the State Water Resources Departments or by the NWDA (National Water Development Agency) under the Ministry of Water Resources, Govt. of India (Figure 30). As such, there seems to be no scope for the present study to explore more structural interventions, as all the possible sites/locations for such interventions have been identified by the State governments as well as by the NWDA. The identified projects have multi-objectives like irrigation, hydro-power and flood control.

Figure 30 Major existing and planned projects in Brahmani-Baitarani

The Water Resources Department, Government of Odisha, have been very active to create new projects with specific purposes of irrigation, flood control to possible extent and hydro-power generation (in collaboration with Odisha Hydro-power corporation). As such many projects have been identified or studied and some are under implementation. In the Brahmni-Baitarni basin also, they have been very active to harness the water resources for beneficial uses and to check/control floods wherever possible at whatever degree viable. We will analyse the following projects:

1. Kanupur Irrigation Project (nearing its commissioning)
2. Samakoi Irrigation Project in Brahmni basin(proposed)
3. Anandpur Barrage Project complex development (proposed)
4. Balijhori Hydropower Project across Baitarni (proposed)

The available records/reports for these projects are discussed below, with the background focus to explore their possible interventions with the present study, to develop an ideal Integrated Flood Management agenda.

Table 15 Details of the proposed projects in Brahmani-Baitarani basins

		Kanupur Irrigation Project	Samakoi Irrigation Project	Anandpur Barrage	Balijhori Hydropower project
1	Dam Site Location	Near Village Basudevpur of Champu Sub-Division of Keonjhar District, Odisha state	Near village Biralamunda, sub-division Pallahara, Angul District, Odisha state	Near village Anandapur in Anandapur Sub-divn. of Keonjhar District of Orissa	
2	Latitude	22^0 02' 03'' North	21^0 17' 50"North	21^0-13' North	21^0 29' 11'' North
3	Longitude	85^0 30'47'' East	85^0 21' 20"East	86^0-08' East	86^0 01' 53'' East
4	River	Baitarni River	Samakoi	Baitarani	Baitarani
5	Catchment area	1,525 Km^2	787 Km^2	8,570 km^2	7,042km^2
6	Mean Monsoon Rainfall	1343 mm	1696 mm		1500 mm
7	Maximum Monsoon Rainfall	2132	2260 mm		
8	Annual 75% dependable rainfall	1087mm			
9	Annual 75% yield	449.92 Mcum	75% dependable yield : 45,950Ham 75% dependable yield after keeping 10% reserve for upstream use. : 41355 Ham. 50% dependable yield : 65180 Ham.	88797 Ham	
10	Design Flood Discharge	14,450 m^3/sec	2267cumecs	12172 Cumec (100 years) 15520 Cumec (500 years)	
11	Gross Storage capacity at FRL	331.02 Mcum			265 Mcum
12	Dead Storage Capacity	62.05 Mcum			
13	Live Storage Capacity	268.97 Mcum			
14	Full Reservoir Level	RL 440.00 m	Pond Level : 118.00m. Crest Level : 112.00 Minimum B.L of River : 104.00	Pond Level R.L. 44.00 M. Crest Level R.L. 34.00 M. Deepest Bed Level R.L. 33.00 M. Top level of Aflux Bundh R.L. 47.50 M.	
15	Maximum Water Level	RL 440.00 m	M.W.L : 120.70m		
16	Dead Storage Level	RL 425.00 m			
17	Submerged area at FRL	2600.00 ha			
18	Free Board	3.50 m			
19	Top Bank Level	RL 443.50 m	T.B.L : 122.00 m		
20	Deepest Bed Level	404.00 m			
21	Forest land submerged	171.404 ha			

22	Cultivated Area Submerged	1849.037 ha			
23	Population to be affected	3557 nos			
24	No of villages affected	16 villages (09 villages fully 07 villages partially)			
25	Road Communication Submerged	11.50 Km			
26	Main Dam Type	Homogeneous rock-filled earth dam with gate controlled spillway			composite concrete gravity cum earth dam
27	Length of dam	3247 m	78.00M	491.60 M.	130
28	Maximum height of the dam	39.50 m			
29	Top Width of the dam	7.50 m			
30	Total Length of dam including spillway	3460.00 m			
31	Spillway location	Central portion of the dam			
32	Type of Spillway	Ogee type	Both Ogee & Broadcrested		
33	Length of spillway	213 m			
34	Crest Level of spillway	RL 428.00 m			
35	Design Flood Discharge	14,450 m3/sec			
36	No of Bays	12	8	25 Under Sluices - 8	
37	Size of gates	15.0 x 12.0 m	6.00 x 8.00m	River Bays – (12M x 9M) Under Sluices – (12Mx10M)	
38	Type of gates	Radial	Vertical	Vertical Lift Gate	
39	Gross Command Area	39,437 ha	14,270 ha	67,500 ha	
40	Culturable Command Area	29,578 ha	9,990 ha		
41	Area Irrigated during Kharif	24,555 ha	9,636 ha (96%)		
42	Area Irrigated during Rabi	17,154 ha	1,250 ha(12.5%)		
43	Area irrigated during summer	6,000 ha			
44	Annual Irrigation Intensity	161.28%			
	Left main canal discharge		12.07Cumecs		
	Right main canal discharge		10.00Cumecs		
45	Total cost of the project	INR 1,067.5 crores	INR 4,385 Lakhs	INR 6,174.8 crores	
46	Benefit Cost Ratio at 10% interest	2.4	1.60		
47	Internal Rate of Return	17.48 %	18.69%		

5.1.2.1 Kanupur Irrigation Project

This major Irrigation Project across the Baitarni, has reached its final stage of implementation and about to be commissioned, after the full development of the Irrigation Command area. The dam is located near Basudevpur in the Keonjhar district at North Latitude 22^0 02' 03'' and at East Longitude 85^0 30'47''. The catchment area of the Baitarni River at the dam site is 1525 Km^2 with a mean annual rainfall of 1343 mm, though in some years, even the monsoon rainfall itself stands at 2132 mm.

The dam is 3440 m long and 39.50 m high. The non-overflow section is an earthen dam. The Ogee type spillway is centrally located with a length of 213 m and is a concrete structure with gates over the crest. Its design capacity is 14,450 m^3/s under full opening of all the gates, perhaps at PMF (Probable Maximum Flood condition). The dam will provide irrigation on its right side, through the right main canal of 77.7 km length. The head discharge of the canal is 44.95 m^3/s, which is diverted away from the Baitarni River and thus reduces flooding downstream.

The Project was approved by the Planning Commission in 2002, with an estimated cost of INR 428.3 crores (1998 price level) and envisaged irrigation over a cultivable command area of 27,578 ha, with the annual irrigation of 47,709 ha with high intensity of irrigation. Initial project formulation started in 1991-92, whereas the latest revised cost estimate of the project is INR 1,067.5 crores (2008 price level), for which investment clearance has been received from the Planning Commission.

A reservoir operation with 15 to 20% flood cushion could bring about a very good degree of flood control, but at present we cannot assume such reservoir benefit. Therefore, in the absence of reservoir operation rules, we have fed the discharge reduction by 44.95 m3/s into the model only. This is indicative only and it is recommended that State and Central Governments provide necessary resources to the Water Resources Department to take up a reservoir operation study to optimise the Irrigation as well as Flood Control benefits. The developed SOBEK model can be also used for this study.

The location of the dam reservoir is shown in Figure 30 and the salient features are given in Table 15.

5.1.2.2 Samakoi Irrigation Project

The proposed Samakoi Irrigation Project is located near Chakdhar in village Birlamunda in Pallahara sub-division of Angul district, Odisha. (see Figure 30), at Lat. 21^0-17'-50"N, Lon. 85^0-21'-20"E. It envisages construction of a barrage across river Samakoi in Brahmni basin. The canal system consists of a main canal of 4.9 Km long and two distributaries, known as left and right. The project envisages irrigation over an extent of 9990 ha in Angul district, with irrigation intensity of 109 % (Kharif 96% and Rabi 13%), thus providing annual irrigation of 10,886 ha. Provision of 0.36 Mcum of drinking water per annum has been kept in the project planning for the population living in the command area.

The catchment area of the river Samakoi at the barrage site is 787 Km^2 and lies entirely in Odisha state. The annual rainfall over the catchment is of the order of 1996 mm.

A broad crested and Ogee type barrage of 78 m length with 8 numbers of bays, having provision of vertical lift gates of size 6mx8m. The crest level of the barrage is 112 m and the pond level is 118 m. The Maximum Water Level and the Top of the barrage level are 120.70 m and 122.00 m respectively. The barrage is designed for a flood discharge of 2298 m3/s.

The main canal of length 4.90 Km is designed to carry a discharge of 12.07 m3/s. The left distributary will be 10.40 Km long and the right distributary 18.00 Km long. Design discharge capacity of right distributary is 10 m^3/s and that of the left distributary is 1.7632 m^3/s. The CCA (Cultivable Command area) under right distributary and left distributary are 354 ha and 8190 ha, respectively (as per source "*Samakoi Irrigation Project Report –Application for TOR and PFR*" May 2008). The salient features are given in Table 15.

The Samakoi barrage does not have much storage element to alter the flood hazard. Since it continuously diverts 12.07 m^3/s for Kharif irrigation, the flows in the SOBEK Model run are reduced by the above rate at this location. Perhaps in future, if there is an expansion of CCA for Kharif irrigation, a further reduction in the flood flow downstream could be possible, especially when water intense crops (such as sugarcane) are planned with the help of the agriculture extension services.

5.1.2.3 Anandpur Barrage Complex Development

The complex development consists of the following components:

I. The Existing Salandi dam across the River Salandi and its water distribution barrage below, called Bidhyadharpur barrage also across Salandi River; the Salandi is a tributary of Baitarni River from its left side. This component has already been completed and is in operation.
II. The next component is an improvement for the Salandi dam by increasing its height and spillway discharging capacity to cater to additional irrigational requirements in the above system. This component is also already constructed and functioning.
III. The above components have a vast area below the Bidhyadharpur barrage, starving for water for irrigation development during Kharif in addition to scarcity of water even in the irrigated area covered by the above two components. The Government of Odisha has planned a barrage across the main stream of Baitarani with a Link canal that will divert water from Baitarni to the Bidhyadharpur barrage of the above two components. This diverts water during Kharif (entire monsoon) and thereby reduces the flood peaks in Baitarani river while taking water to large extent of land suitable for irrigation.

With respect to the present study the above component (III) is relevant with respect to flood reduction in Baitarni River. The components location is shown in Figure 31.

Component (I)- The Salandi Dam

A dam has been constructed across river Salandi forming the reservoir, near Hadagarh, at Latitude 21° 17' 18' North and at Longitude 86° 18' 00'' East. The Salandi Dam has a reservoir with a live storage capacity of 556.50 Mcum and has a catchment area of 673 Km^2. The dam is built over river Salandi, a tributary of river Baitarani with an annual average yield of 493 Mcum. The total planned CCA of both Left and Right Canal system is 85, 908 ha, providing Khariff irrigation to 85, 908 ha and Rabi irrigation of 12, 746 ha.

The river Salandi originates from Meghasini hills of Mayurbhanj district (Orissa) at an altitude of 1036 m and the stream attains an elevation of about 610m within a very short distance of about 10 km which then passes through a narrow gorge for a distance of about 2.5 km before joining its tributary Deodar and turns to East. After flowing about 160 km it joins river Baitarani.

The Salandi dam is a composite one, constructed with 640m long earth dam and 114.6m long masonry dam having 8 spans of 12.2m each as spillway. Water from the reservoir is let out through 3 sluices (1.52x2.27m) and picked up at Bidyadharpur barrage for irrigation (vide Figure 31). The latitude and longitudes are respectively 21^0 14' 16'' North and 86^0 18' 58'' East. As per the original project proposal one left canal known as Salandi main canal was constructed. Subsequently, the right side canal, known as Anandpur canal was also constructed. This component of Salandi Dam and Bidhyadharpur barrage are functioning since last 35 to 40 years.

The Left canal system includes 45 km long main and branch canals having designed irrigated area of 44,635ha and design discharge of 42.45 m^3/s and the right canal system has an irrigated area of 40,178ha with design discharge of 46.53 m^3/s. However, due to the limited storage capacity of the Salandi Dam, there is water shortage for the vast irrigated area.

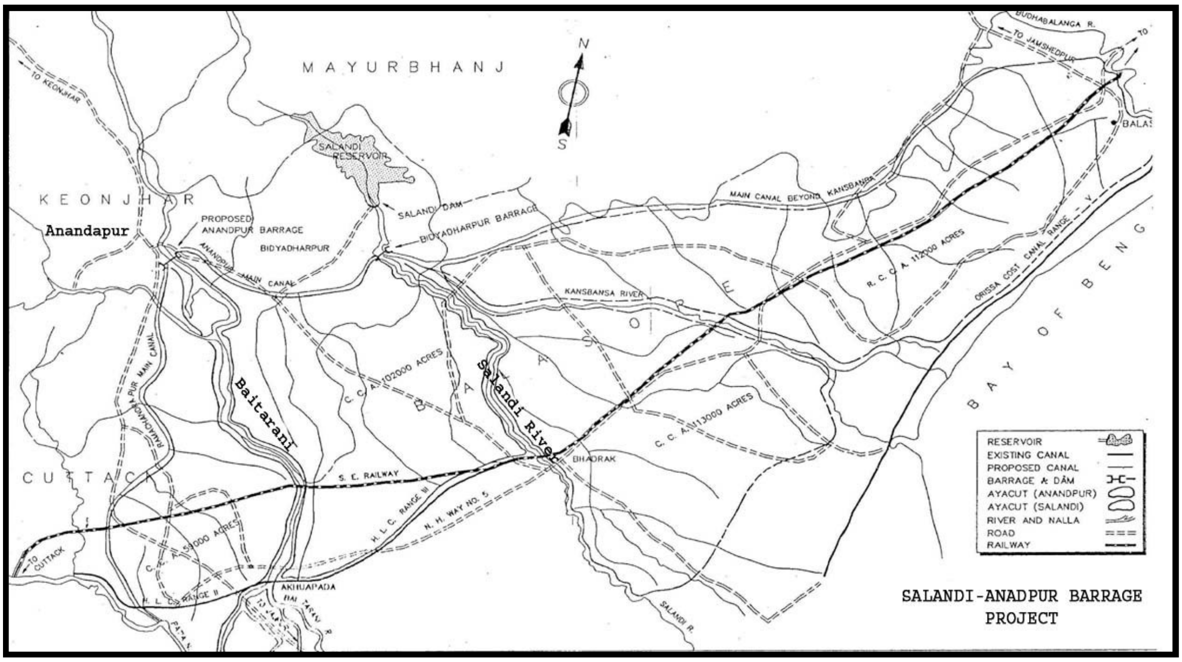

Figure 31 Anandapur barrage project
Source: WRD, Odisha

Component (II)- The Salandi Dam improvements

Subsequently the Full Reservoir Level of the Salandi reservoir was raised by 6.1m, by installing 8 numbers of radial gates which facilitated irrigation extension in both the canals of Bidhyadharpur barrage. The additional CCA was identified as 5,045 ha on the right side of Anandpur canal and a CCA of 832 ha on the left side Salandi canal. In addition, a total extent of 18, 335 ha was identified for stabilization of irrigation under both the canal commands. This improved component is functioning since late 1990s. However, even after these improvements, the irrigated area could not be fully developed because of water resources constraints.

Component (III)- The Anandpur Barrage across Baitarni to divert water to Salandi-Bidhyadharpur area (in the Monsoon season for Kharif Irrigation).

The present modified Anandpur Barrage project has been planned to become integrated with the Salandi Irrigation Project. It is proposed to construct a 566m long barrage across river Baitarani at Anadapur. The latitude and longitude of the barrage location are 21^0 13' 00'' North and 86^0 08' 00''

East, respectively. This location is in the Anandpur sub-division of Keonjhar district. The left main canal (Link Canal) with head discharge of 165 m^3/s would off-take from the Anandapur barrage and spill it in the Salandi River upstream of Bidyadharpur barrage. The Salandi main canal would be extended up to the river Kansabans after renovating and lining the existing canal for irrigating CCA of 45,730ha between Salandi and Kansabans river. It is proposed that irrigation would be provided for the entire integrated command from Baitarani River in Kharif season and from Salandi reservoir in Rabi season. The total cultivable command area for irrigation to be covered by the diverted water from Baitarani is 65,877 ha mostly in Kharif and as such a small portion of the monsoon flood waters of Baitarani (165 m^3/s) could be diverted for useful purposes. The latest estimated cost of the integrated project is INR 6,174.8 crores. The project is just commissioned.

The salient features of the Anandpur barrage are shown in Table 15. A line diagram of the Anandpur barrage-Salandi complex is shown in Figure 32.

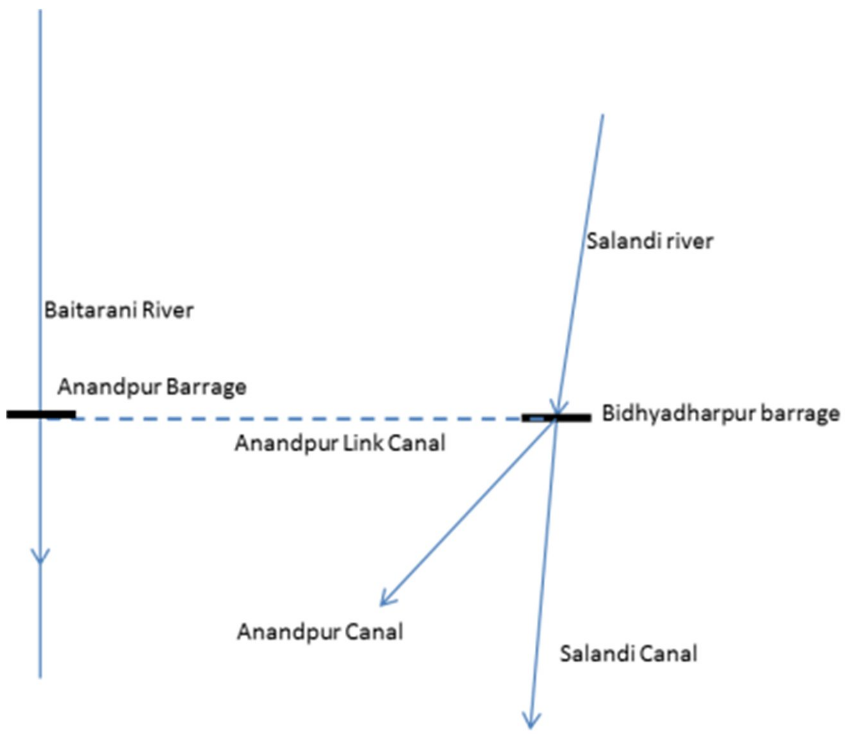

Figure 32. Line diagram of Salandi Anandpur barrage complex

The Anandpur barrage across main Baitarni River will reduce the monsoon discharges to the downstream by a rate of 165 m^3/s by diverting the water for Kharif irrigation. This reduction has been considered in the indicative SOBEK Model run.

5.1.2.4 Balijhori Hydropower project

A preliminary Feasibility Study has been carried out by the Water and Power Consultancy Services (WAPCOS) for the development of a storage dam across the river Baitarni to utilize a gross head of 173 m for hydro-power generation. The dam site has a catchment area of 7042 Km^2. The location is at 21^o 29' 11'' North and 86^o 01' 53'' East. A 130 m long composite concrete gravity-cum-earth dam enabling a reservoir with a gross storage of 265 Mcum has been identified. The project with the proposed installation capacity of 178 MW is estimated to yield an annual energy of 479.8 GWh even in a 90 % dependable year (below average nearly low flow year). The dam-site is approachable from Deonkikot (on National Highway No 215). The tailrace water will be discharged into Baitarni river downstream of the power house. The location is shown in Figure 30.

In an alternative proposition, the State Government of Odisha drafted a proposal in a slightly different way. They propose a dam upstream of the above WAPCOS dam location named Bimkund dam. Just below the location of this dam the Katmuli river, a small tributary, joins the Baitarni on its left bank. The state Government proposal includes the construction of a small dam across Katmuli river. After the joining of Katmuli with Baitarni, the proposal envisages a barrage near the village of Baigundi. At this barrage the regulated waters of Bhimkund and Katmuli are realised and utilised for power generation below the barrage with the gross head of about 170.00 meter. The tailrace waters of the power house in the Rabi season are proposed for irrigation development in the Ananthpur barrage system and downstream Akhupada barrage High level canal, which starve for water in Rabi, though they get good supply in Kharif (Monsoon) season (Figure 33).

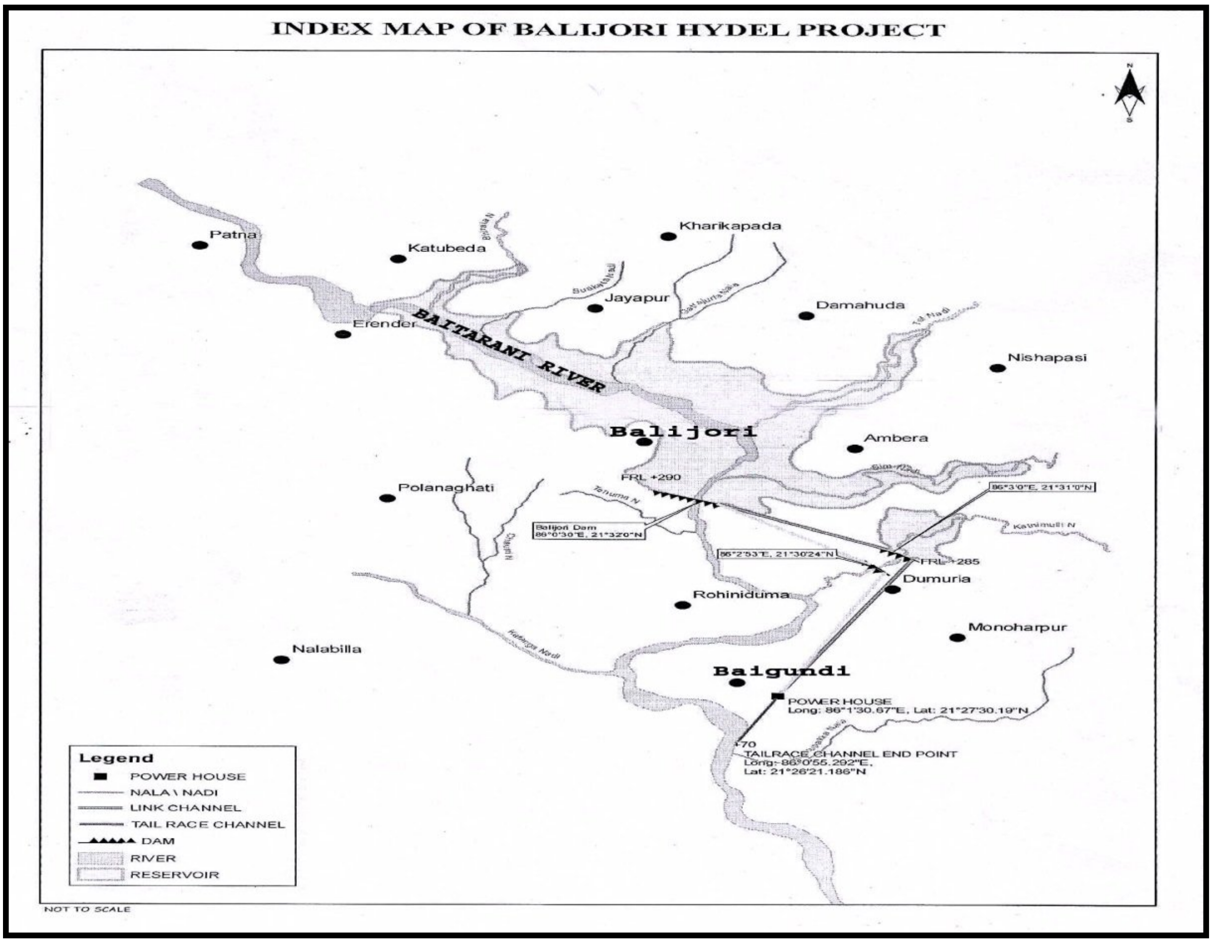

Figure 33 Map of Balijori project
Source: WRD ,Odisha

Some of the properties were not available for model implementation, so some assumptions have been made (see Vol. 5 Modelling Report). The Balijhori project is mainly for hydro-power generation and as such there is no effective diversion of water from Baitarani river. So at this stage in the indicative SOBEK Model run, no reduction of discharge is taken in to account. However there could be considerable flood control benefit if for instance about 15 to 20 % of the live storage could be used as flood cushion. A detailed study on the reservoir operation to be executed by the Government of Odisha with assistance from CWC is recommended. Similarly, the major reservoir at Rengali dam is to be scientifically studied for its operation during Monsoon with future Flood Forecasting back up. On doing so, the reservoir might bring out good amount of flood reduction in addition to Hydropower generation and Irrigation benefits.

In addition to the above identified proposals, the Consultants during their extensive field visits identified a location for a beneficial barrage across the river Brahmani, just upstream of the bifurcation of the Kursuan River from Brahmani, near the start of the floodplain. It could contribute to the regulation of the floods. In addition, during the site visits it was also learnt that there are many sites suitable for small to medium reservoirs in the Baitarani sub basin, which need to be explored by the State Government.

5.1.3 Non-structural measures

5.1.3.1 Watershed management

Watershed management involves management of soil and water, agriculture and forestry and consists of a wide range of measures to be implemented in a participatory manner with the local population. Examples of such measures include: re-vegetation/afforestation, slope protection and drainage structures, contour terracing, and check-dams.

Conservation practices can be divided into two main categories: 1) in-situ and 2) ex-situ management. Land and water conservation practices within agricultural fields, such as contour bunds, graded bunds, field bunds, terraces building, broad bed and furrow practice and other soil-moisture conservation practices, are known as in-situ management. These practices protect land degradation, improve soil health and increase soil-moisture availability and groundwater recharge. Construction of check dams, farm ponds, gully control structures, pits excavation across the stream channel is known as ex-situ management. Ex-situ watershed management practices reduce peak discharge in order to reclaim gully formation and harvest substantial amount of runoff, which increases groundwater recharge and irrigation potential in watersheds (Wani & Garg, n.d.).

It must be stated that these technical remedies will only succeed if they can function within and address local socio-economic constraints (FAO 1999). Farmers rarely adopt recommended technologies by the experts (Vishnudas et al., 2005). This has been recognised also in the Indian experience. In 2005 the Neeranchal Committee evaluated the entire government-sponsored, NGO and donor implemented watershed development programs in India and suggested a shift in focus “away from a purely engineering and structural focus to a deeper concern with livelihood issues” (Raju et al. 2008).

By considering the traditional practices and experiences of the farmers, experts and scientists could co-develop appropriate technology jointly with the people. For instance, instead of providing engineering structures, semi-permeable vegetative barriers using local materials and local labour can be used. These barriers will filter out sediments, reduce the velocity of runoff and also retain runoff water. This will be less costly compared with constructing engineering structures. Soil conservation measures that produce the most rapid return on investment are the most favoured. These include bunds that require relatively small initial investment, provide fodder or fuel, and conserve soil moisture (Vishnudas et al., 2005).

The watersheds of both Brahmani and Baitarani rivers are partly located in Chhattisgarh and Jharkhand, respectively. Both states have relatively good forest coverage (41 and 32% of geographic area is under some kind of forest). Also Odhisha has a relatively good forest cover of 34% (Chandrasekharan, 2010). Although rates of deforestation are hard to find, a recent study into the deforestation of the Eastern Ghats (extending into Odisha) over the period 1930 to 2013 showed a decline from 0.64 % per year (from 1930 to 1975) to 0.06% per year (1995-2005). The annual deforestation rate was very low (0.02) during the recent period (2005-2013) indicating the management intervention in protection of forests. However, forest degradation and small-scale deforestation still continue for meeting the needs of fuel wood, fodder and timber products and due to shifting cultivation in parts of Eastern Ghats (Reddy et al., 2014) as well as due to mining.

Because of the rich mineral resources in Odisha, mining is an important contributing factor for deforestation and soil erosion. The principal minerals in the Brahmani basin are Iron Ore, Copper, Chromites, Coal, Manganese, Lime Stone, Dolomite, Lead, Fire-Clay, Bauxite and China-Clay, whereas in the Baitarani sub-basin these are Iron ore, Copper, Chromites, Asbestos, Manganese, Atomic Minerals, China Clay and Soap Stone. Mining impacts the river basin in many ways. Excess soil is dumped into valleys filling rivers and streams. Much of the mining is done through open cast mines and causes deforestation. Also the infrastructure such as roads that are needed for these mines creates environmental degradation and runoff intensity.

Keonjhar district in Baitarani basin is the centre of iron ore production and has the heaviest mining activities. Especially mining in the Jhoda region of Keonjhar district is said to cause deforestation, river pollution and increase in sediment flow. Although Keonjhar holds one of the major forest resources of Odisha, due to deforestation the forest cover has reduced from 65% in 1975 to 45% nowadays. The major factor in reduction of forest cover is said to be increased mining activity.

Increased soil erosion and river sediment concentrations also lead to faster reservoir sedimentation, thereby reducing its live storage capacity. The Rengali reservoir, which was constructed in the year 1983, has lost about 5.7 % of its live storage capacity due to sedimentation. The annual rate of loss in live storage is estimated to be in the order of 0.32%.

It is important to mention that the Odisha Watershed Development Mission is involved in activities such as management of natural resources like soil and water along with various agronomical interventions with a focus on livelihoods improvement where communities are involved in participatory planning and implementation of watershed programmes. Since 2000-01, the Mission is giving emphasis on using participatory rural appraisal tools and techniques to promote community participation in planning and implementation of watershed programmes. As a part of the programme, 17024 Self Help Groups have so far been promoted in various watershed areas enrolling about 209742 members (website: http://www.orissawatershed.org/owdm.php). It is recommended to extend this programme to the watersheds of the Brahmani and Baitarani rivers.

5.1.3.2 Flood forecasting and warning

There are three flood forecasting stations located in the basin: one at Anandpur barrage on the Baitarani river, second near Jenapur on the Brahmani and third on same river at Indupur. All the stations are for level forecasting. Furthermore, there are 3 main organizations in the country which record meteorological parameters, viz. Indian Meteorological Department (IMD), Central Water Commission (CWC) and ISRO (Automatic Weather Stations). Thirteen meteorological stations of CWC are located in the basin. These stations are established to understand the relationship between meteorological parameter and river dynamics. The stations carry out observations pertaining to meteorological parameters viz. Rainfall, Temperature, Pan Evaporation, Relative Humidity, Wind Speed and Sunshine hours. Forty-four IMD stations and 27 ISRO AWS stations are also functional in the basin.

Flood warnings are constrained to a maximum lead time of 24 hrs. This is because the flooding in the delta is compounded by a number of interacting factors, such as local rainfall, high tides, and complicated river network. Information dissemination up to the communities in the basin is not very effective but several initiatives have been taken to make use of cellular phones for voice and text messages (see section 4.1.4).

Rengali dam has moderated the high floods significantly and provided much relief against floods. Flooding can be reduced by temporary storage of water behind Rengali dam on Brahmani river, which controls roughly some 50% of the total catchment area draining to the delta. To use the dam for flood mitigation, floods are being forecasted based on real-time information of rainfall and discharge in the two basins.

The existing set up is not up to the mark both with respect to the number of stations and their aerial coverage and quality of forecast. The WMO norms stipulate that 1 rain-gauge station is required for a catchment range of 600-900 km^2 for more or less flat regions of temperate, Mediterranean and tropical zones. For the Brahmani-Baitarni basin, having a catchment size of 53,033 km^2, the number of rain-gauge stations required is 70 (by considering the mean of the recommended range of catchments as 750 km^2). As indicated above, there are 71 rain-gauge stations in the basin. Therefore the existing rain-gauge network is adequate as per WMO norms. However it is recommended that, progressively, at least 10 stations in the network needs to be installed with automatic (self-recording) rain-gauges for accurate recording of hourly rainfall during storms, which will produce very useful meteorological data for hydro-meteorological/hydrological analyses.

With respect to the river gauging stations, the above WMO standards recommend one station for the catchment range of 1000-3000 km^2. This means that as a minimum the network should consist of 17 to 18 stations. Presently the network consists of only 15 stations in the basin (Hydrology Project II). Hence as an immediate measure 3 more stations (additional to the existing 15 stations) need to be established. All 3 stations are to be positioned in the upper catchments and are to be flood forecasting stations to give good forecasts for Rengali reservoir's advantageous operation with sufficient lead time.

Furthermore, the forecasting is issued on gauge to gauge correlation basis. This practice can be greatly improved by using modern mathematical models. It is understood that the Central Water Commission has these models in stock, but have not been put in to operation. These actions need to be taken up forthwith.

Optimal flood control for the Rengali reservoir is at present hampered by limited forecasting lead-times as only the contributions of the basins in Odisha are covered by the forecasting system. This includes the entire Baitarani basin and Brahmani river below Panposh. Upstream of Panposh, the Koel and Sankh rivers drain, which constitute over 75% of the catchment area controlled by the Rengali dam. By expanding the flood forecasting system to the upper reaches of the Brahmani basin lead-times can be extended and knowledge about the flood volumes to be temporarily stored at Rengali can be improved considerably. A specific study for optimising the Rengali reservoir for taking maximum advantage of flood control from the dam without sacrificing too much irrigation and hydro-power benefits is also recommended.

The Bhubaneshwar office of CWC, which is responsible for Mahanadi and eastern River Basins, is responsible for flood forecasting work in Brahmani basin. There are 15 hydrological observation stations maintained by CWC in Brahmani basin (CWC, 2014). The office works closely with Odisha State Water Resources Department, which prepares the flood bulletin using the flood forecast data provided by CWC, meteorological data (rainfall) provided by IMD and its own gauge, reservoir inflows and outflow data.

The office of the Chief Engineer also has one Superintending Engineer (Coordination). There are two Circle Offices under the office of the Chief Engineer, both based in Bhubaneshwar. One is the Hydrological Observation Circle and the other is Monitoring and Appraisal Directorate, both headed by one Superintending Engineer. The hydrological observation directorate, which is concerned with collection of hydrological data from the eastern rivers and Mahanadi River, has two divisions, viz., Eastern Rivers Division and the Mahanadi Division based in Bhubaneshwar and the Mahanadi Division based in Burla. Each division is headed by one Executive Engineer.

The sub-division, which looks after the hydrological observations in Baitarani River, is one of the four sub-divisions of the eastern rivers division, and this again is based in Bhubaneshwar. The other sub-divisions are Subarnarekha sub-division, Balasore; Brahmani sub-division, Rourkela; and Vamsadhara Sub-Division-Berhampur. Each sub-division is headed by one Asst Engineer. The Mahanadi division also has four sub-divisions, each one looking after one part of the basin. There are two sub-divisions for middle part of Mahanadi basin, one for lower Mahanadi and one for upper Mahanadi.

The flood forecasting is done using both Mike 1.1 and gauge to gauge forecasting. The accuracy of water level and inflow forecasting is reported to be high. During the year 2013, the accuracy was 92%, whereas it was 100% during the previous year. Since 2004, a total of 1859 forecasts were made by CWC for the region (1736 level forecasts and 123 inflow forecasts), and from these, 91.7% (1706) were accurate. As is evident from the flood forecast performance for Hirakud reservoir in Mahanadi, the performance had improved since its inception in 1985, when the accuracy was only 71%. In 2013, the accuracy was 98.7%.

The CWC communicates the flood forecast messages and warning based on field data from hydro meteorological stations and IMD weather forecasts to different departments including Water Resources Department.

The senior staff of the regional office had also attended National Remote Sensing Agency's training on basin-wide water resources assessment using remote sensing data (land use and land cover) and hydrological observation data (stream flows), IMD data on temperature using GIS tools and mathematical models for estimation of evapotranspiration.

The office had several vacant positions, though. Out of the total of 103 sanctioned positions, only 57 are filled and 46 are lying vacant as on today. Within these, the vacancies are the highest for the lower level cadre, i.e., for the Non-Gazetted posts, including Junior Engineers. Out of the total of 73 sanctioned positions, there are a total of 43 vacancies, mostly for Junior Engineer (C & M); Technical Assistant (Comm); Scientific Assistant and, Senior Research Assistant.

5.1.3.3 Land use Management

In the project region, the livelihoods of the community are dependent on the region's rich bio-diversity and as such, it is necessary to appreciate the linkages between the eco-systems and the community, so that approaches could be identified to reduce vulnerability and enhance resilience. One of the approaches is effective land use management. In this region, Mangroves forests play a critical role in storm protection. The Bhitarkanika national park and the Bhitarkania Wild Life Sanctuary are famous for mangrove ecosystems. These mangroves are situated at the terminal estuary of Brahmani River near the Bay of Bengal. Recent Studies are set to have proposed that Mangroves conservation could be considered for adoption strategy for coastal communities; these Mangrove Forests act as a natural barrier and further provide wide range of goods and employment opportunities to the community. They protect coastal zones against erosion and extreme weather. They provide key nursery areas for fish and homes to other animal species, including water birds and an abundance of sea life. They also provide the source of livelihood for the community living along the coastal areas. The conservation and restoration of Mangroves forests can provide a sustainable adoption option in the context of acting as a barrier to cyclonic storms and for enhancing resilience capacity of the community. As such for the Brahmani-Baitarni basin in Odisha, this could be one of the apt Non-structural measure.

In view of the above, the Environment and Forest Ministry, Government of Odisha are focusing attention and taking up required actions for the protection and expansion of Mangroves forests in the region.

5.1.3.4 Pilot projects at community level

After the super cyclone of 1999, there are several initiatives in the state with the support of several multilateral agencies and international NGOs which have implemented many community-based disaster risk reduction projects. These projects have improved the community resilience to natural disasters. However, many of these initiatives have failed to sustain thus reducing the effectiveness of these project objectives. The following are some of the key community-based initiatives towards disaster risk management in the state:

1. UNDP implemented Community Based Disaster Management Project (CBDMP) in collaboration with OSDMA in the year 2000 as a pilot in 10 blocks of the coastal districts of the state
2. In 2004, UNDP has scaled up this Disaster Risk Management (DRM) program at state level covering all the villages of the state focusing mainly on cyclone and flood hazards. As part of this project, village level DM plans were prepared along with formation of various community level task forces at village level. UNDP exited in 2007 and OSDMA continued the project activities till 2009.
3. UNDP, under the DRR program (2009-12) in three districts - Bolangir, Kendrapada & Ganjam, also supported the state with DRM capacity building, awareness, and technical studies.
4. Several international organisations are also involved in community-based DRM activities in the state. These include RED CROSS, OXFAM, Catholic Relief Services (CRS), CONCERN, CARE, etc. The activities include construction of multipurpose cyclone shelters and handing over these to the community to maintain, providing training for youth in the villages in rescue and response activities and general awareness activities.

Most of these programs ended with the exit of the donor organizations. The key aspects noticed in these programs are: they need sustained efforts to ensure that these initiatives stay active in the field so that they achieve the project objectives.

While identifying the pilot projects for the BB basin, we have considered key problems and needs of the community, and interventions that are feasible and being implemented in some form or other in the basin. Two potential pilot projects were identified, which are presently implemented in small scale in the basin and have the potential to scale up for wider benefits.

1. Preparedness: As flood is a recurring phenomenon in the basin, preparedness is a key step required to reduce casualties and damage. This was demonstrated by VAARAT, a local NGO in the state who is carrying out CBDRM activities in a few villages in Kendrapada districts. It facilitates villages to revive the DM committees, task forces, and trains them in various lifesaving skills. VAARAT also reorganised the Self Help Groups (SHG) and provides training and awareness on DRM to the community. VAARAT is now motivating the farmers for cultivating fast growing high yield crops as the farmers face loss of crop almost every year and are unwilling to continue farming.
2. Early warning information dissemination: The flood early warning information dissemination in the basin is not very effective as the community does not get a lead time to respond. The Reliance Foundation Information Services (RFIS) is working on poverty reduction activities in selected districts (Balasore, Bhadrak, Kendrapara, Jagatsinghpur, Puri, Ganjam, Jajpur, Bargarh, Nayagarh, Balangir and Kalahandi) in the state. The program supports farmers and coastal communities in various DRM and livelihood aspects. RFIS has signed an MoU with IMD and INCOIS and receive disaster warning information from these organizations and in turn disseminate to community and community extension workers through free of cost voice and text SMS. It also provides farm advisory support including use of saline and flood resistant rice varieties for the farmers.

Both these intervention projects have potential to be scaled up across the basin, which will improve the resilience of the communities. It is important to note that these intervention projects are successful and effective through continuous presence and field based activities of grass root organization or field volunteers.

5.1.3.5 Detailed agricultural systems review

Agricultural sectors play a key role in the overall Odisha economic and social well-being. Contribution of agriculture to GDP (Gross Domestic Product) is 21.05% in Odisha (UNDP, 2012). However, the share of agriculture in both the employment sector and the GDP has declined over time in India as well as in Odisha. The share of agriculture in GDP is observed to decline from 39% in 1980-81 to 17% in 2009–10 while at the same time the corresponding decline in the employment sector was observed to fall from 63 to 60% at the national level. One of the primary factors for such decline in food production in recent years is the enhanced severity of climatic hazards such as drought, flood, heat wave, and pest & diseases. This is attributed to the fact that climatic hazard affects the two most important direct agricultural production inputs, precipitation and temperature. Climatic hazard also indirectly affects agriculture by influencing emergence and distribution of crop pests and diseases, exacerbating the frequency and distribution of adverse weather conditions, reducing water supplies and irrigation, and enhancing severity of soil erosion. The potential impacts of extreme weather events such as drought and flood are varied and can affect a wide range of economic, environmental and social activities. Drought causes direct and indirect impacts. Those include acute water shortage and over exploitation of groundwater, soil degradation, loss of crop, spread of pest and disease, migration of people, increased unemployment, strain on financial institutions, malnutrition of human beings, etc. On the contrary, flood causes huge surplus of water in a very short span leading to infrastructural damage, agricultural and livelihood losses. For this study our focus only will be on the flood hazard and associated impacts on the cropping systems.

Review of agricultural systems in Brahmani-Baitarani basin

Historical agricultural data (from 2000 to 2010) has been collected for 12 districts of Odisha (Angul, Balasore, Bhadrak, Cuttack, Debagarh, Dhenkanal, Jajpur, Kendrapara, Kendujhar, Mayurbhanj, Sambalpur, and Sundargarh) which fall in the Brahmani-Baitarani basin. These data has been collected from the Department of Agriculture & Cooperation, Ministry of Agriculture, Government of India (http://apy.dacnet.nic.in/crop_fryr_toyr.aspx). Based on the analysis of available crop data, cultivable area, major crops cultivated, acreage, yield in each district falling in the Burhi-Ghandak basin were identified (Table 16).

Table 16 Agricultural profile in the districts of Odisha falls in Brahmani-Baitarni basin

District and cultivable area ('000 ha)	Major crops during Kharif season	Kharif season Cropped area (%)*	Crop yield (t/ha) *	Major crops during Rabi season	Rabi season cropped area (%)*	Crop yield (t/ha) *
Angul 191	Rice	74.57	1.26	Oil seed (rapeseed, mustard, castor seed, niger seed, sunflower, safflower)	48.21	0.48
	Pulses (pigeonpea, horse gram, black gram, green gram)	14.67	0.32	Chickpea	34.04	0.6
	Sesame	3.82	0.17	Wheat	2.32	1.37
Balasore 234	Rice	96.93	1.56	Oil seed (rapeseed, castor seed, mustard, sunflower, safflower)	59.6	0.45
	Pulses (green gram, pigeonpea, horse gram)	1.09	0.47	Other rabi pulses	24.94	0.85
	Groundnut	0.82	1.14	Chickpea	7.5	0.63
Bhadrak 175	Rice	97.07	1.71	Oil seed (rapeseed, mustard, sunflower, castor seed)	53.2	0.46
	Pulses (green gram, black gram, pigeonpea, horse	2.63	0.42	Wheat	17.8	0.94

	gram)					
Cuttack 157	Rice	74.93	1.47	Oil seed (rapeseed, mustard, castor seed, linseed, sunflower, safflower)	23.99	0.59
	Pulses (green gram, black gram, pigeonpea, horse gram)	21.94	0.48	Chickpea	22.22	0.52
Debagarh 57	Rice	84.45	1.08	Oil seed (rapeseed, mustard, castor seed, niger seed, sunflower, safflower)	46.68	0.38
	Pulses (green gram, black gram, pigeonpea, horse gram)	7.69	0.33	Chickpea	21.23	0.46
	Sesame	4.37	0.25	Wheat	6.73	1.22
Dhenkanal 186	Rice	83.5	1.39	Oil seed (rapeseed, mustard, castor seed, sunflower, safflower)	53.65	0.49
	Pulses (pigeonpea, black gram, green gram, horse gram)	9.6	0.37	Chickpea	19	0.39
	Groundnut	4.01	1.04	Wheat	2.41	1.3
Jajpur 145	Rice	79.81	1.25	Oil seed (rapeseed, mustard, castor seed, linseed, sunflower, safflower)	59.71	0.38
	Pulses (green gram, black gram, pigeonpea, horse gram)	11.73	0.3	Chickpea	11.61	0.4
	Groundnut	6.96	1.3	Wheat	4.38	1.08
Kendrapara 166	Rice	84.04	1.28	Other rabi pulses	69.51	1
	Pulses (green gram, black gram, pigeonpea, horse gram)	13.24	0.47	Chickpea	5	0.8
Kendujhar	Rice	80.97	1.25	Pigeonpea		

298	Niger seed	8.57	0.21	Oil seed (rapeseed, mustard, niger seed, castor seed, linseed, sunflower, safflower)	61.23	0.57
	Pulses (pigeonpea, horse gram, black gram, green gram)	4.81	0.32	Chickpea	5	
Mayurbhanj 389	Rice	91.17	1.41	Oil seed (rapeseed, mustard, castor seed, linseed, sunflower, safflower)	37.46	0.65
	Pulses (pigeonpea, black gram, horse gram, green gram)	3.33	0.37	Other rabi pulses	5.78	0.65
Sambalpur 194	Rice	93	1.68	Other rabi pulses	28.01	0.79
	Pulses (pigeonpea, black gram, horse gram, green gram)	2.97	0.39	Chickpea	9.2	0.47
Sundargarh 292	Rice	89.05	0.94	Oil seed (rapeseed, mustard, castor seed, linseed, niger seed, sunflower, safflower)	47.62	0.37
	Pulses (pigeonpea, black gram, horse gram, green gram)	5.35	0.3	Lentil	3.63	0.36

During Kharif season in the Brahmani-Baitarni basin, rice is the staple cereal crop and occupies about 90% of total cropped area. Pulses, which serve as staple as well as cash crop in this basin, occupies almost 8% of cropped area and stands second in terms of acreage. It has been observed from the field survey that during Kharif season rice is the only crop cultivated in some parts of the study area due to water logging problem as pulses, which fall in the leguminous family, cannot survive in the submergence condition even for couple of days (Tobisa et al., 2014).

During Rabi season, only about 50% of cultivable land is used for the cultivation in Brahmani-Baitarni basin. In this season, oilseed, which is grown mostly as a cash crop in this basin, occupies about 55% of total cropped area. Pulses including chickpea, which is cultivated as a staple as well as a cash crop in this basin, stand second (about 35%) in terms of cropped area. Wheat is also grown in this basin but its acreage is only about 8%. Based on the field survey, wheat is primarily grown by the prosperous farmers only. It has also been observed from the field survey that recently farmers have started growing sugarcane as well after coming up some sugar mill in these districts.

Some more key facts about the flood hazard, acquired from the field survey observations, in Brahmani-Baitarni basin have been summarized in Box 1.

Box 1: Summary of some key facts about the flood hazard acquired from the field survey in Brahmani-Baitarni basin

- There has been crop damage due to two ways one due to physical damage to the crops and another crop yield reduction due to crop physiological stress.
- There has been damage to the soil as well due to siltation.
- There has been damage to farm machinery such as crop thrasher, harvester, irrigation equipment, power tiller, etc.
- There has been damage to stored materials (inputs, feed, and fodder).
- There has been damage huge damage to infrastructure (e.g. roads) resulting increase in travel time to the cities.
- Almost every year there has been some level of flood which causes damage to the crops (about 30% every year).
- Every year flood causes some damage to the crops during Kharif season.
- Over the last couple of years onset date of monsoon rainfall has been shifted from mid-June to first week of July (i.e., by about 20 days).
- Rainfall distribution pattern has been changed over the last decade. Sometimes it rains so heavily causing severe damage to crops and houses and sometimes there is complete dry spell causing drought like situation.
- 1999, 2008, 2011, and 2013 were the severe flood year in this area which caused complete damage to the crops. Besides, these floods also caused severe damage to the road and houses.
- 2003, 2005, and 2007 were the moderate flood year which caused damage to crops only.
- In the event of flood, normally water stays for about 7-10 days.
- In some study area water level goes up to 7-8 feet above the road during the flood.
- Farmers do not get any benefit from the crop insurance scheme due to manipulation of the crop yield in favour of insurer.
- Communities in this area do not get any flood warning or advisory from the government authority or from NGO to protect their assets and lives.
- In some area during sever flood, about 60% acreage gets damaged.
- In the event of flood, farmers use Swarnasub1 rice variety as this variety can withstand waterlogging up to 15 days.
- About 45% area is under irrigation during Kharif season and 27% area is under irrigation during Rabi season.
- In some study areas during Kharif season, paddy is the only crop cultivated due to waterlogging problem.
- Earlier farmers used to do the mixed cropping (paddy + blackgram) during Kharif season but now a days they stopped mixed cropping due to waterlogging problem in the crop land which damages blackgram crop.
- Sometime cyclone also causes damage to the crops (e.g., 1999 super cyclone caused severe damage to the crops).
- Overall according to the field survey, it has been observed that large numbers of farmers in the study area are engaged in subsistence farming only due to very small operational land holding size at their disposal. Furthermore, small holdings also face new challenges on integration of value chains, liberalization and globalization effects, market volatility and other risks and vulnerability, adaptation of climate change etc. (Thapa and Gaiha, 2011).

Figure 34 shows the cropping pattern over the years in the Brahmani-Baitarni basin. This figure shows that there has been increasing trend in high value crop acreage (e.g., green gram) in this basin. Whereas, there has not been any significant changes in the acreage of principle crops such as rice and maize in this basin.

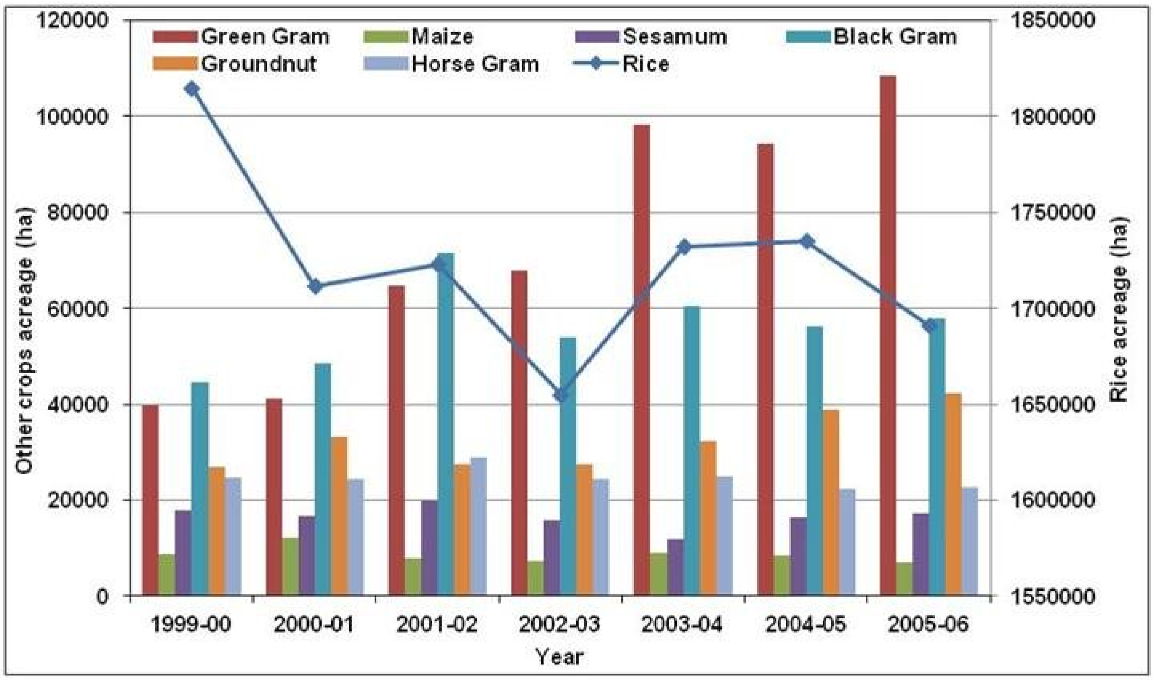

Figure 34: Kharif season crop acreage trend analysis over the years in the Brahmani-Baitarni basin

Assessment of flood induced impact on agriculture in Brahmani-Baitarani basin

Districts prone to the various hazards in the Brahmani-Baitarni basin have been summarized in Table 17. This table shows that except Sundargarh all districts in the Brahmani-Baitarni basin are prone to the flood hazard and it is causing huge damage to the crops in these districts leading to a reduction in the crop productivity. The severity of damage on the crop production depends on the flood intensity (flow/depth) and season. Aerobic crops (e.g., maize, pulses, and groundnut) cannot survive under standing water and submergence. Anaerobic crop (e.g., rice) can resist standing water due to supply of oxygen to root through aerial parts but cannot tolerate submergence for continuous 7 days. Deep water rice can resist flood up to 15 days when at rapid growth stages. But at early stage of crop growth, sudden rise of water level, speed and muddiness of water are the factors which make most of the varieties vulnerable. Since rice is the main crop in rainy season in Brahmani-Baitarani basin, the extent of damage varies according to days of submergence. The flood can be classified as Early Cropping Season Flood, Mid Cropping Season Flood, and Late Cropping Season Flood details of which have been described in the following paragraphs.

Early cropping season flood (June-July): For all major crops, June is the beginning of planting season in Brahmani-Baitarani basin. Normally before the onset of monsoon, farmers sow the lowland and some medium land rice which germinates after onset of Monsoon and grows to a certain height to resist standing water during the month of July and August. After onset of Monsoon, pulses, oilseeds, and upland rice are sown along with raising nursery for transplanted rice for medium land. Normally early season flood causes following damages:

- Damage of rice in nursery, standing crop of vegetables, pulses, and oilseeds.
- Early-transplanted and standing direct sown rice are also affected by flood.

Table 17 Districts prone to the various hazards in the Brahmani-Baitarni basin

	Hazards							
	Drought	**Flood**	**Cyclone**	**Hail storm**	**Heat wave**	**Cold wave**	**Sea water intrusion**	**Pests & disease outbreak**
Angul	√	√	√		√	√		√
Balasore	√	√	√	√	√	√	√	√
Bhadrak	√	√	√	√	√	√	√	√
Cuttack	√	√	√	√	√			√
Debagarh	√	√			√			
Dhenkanal	√	√	√		√	√		√
Jajpur	√	√	√	√	√			√
Kendrapara	√	√						√
Kendujhar	√	√			√			√
Mayurbhanj	√	√	√		√			√
Sambalpur	√	√		√	√			√
Sundargarh	√				√			√

(Source: District Agriculture Contingency Plan, Ministry of Agriculture, Government of India)

Mid cropping season flood (August-September): When flood comes during this period the extent of loss in most of the times is severe and irreparable as the crops are in active growth stage and the farmers have already spent enough money on management of crops. Besides, farmers loose the season of cultivation and the land cannot be used to cultivate immediately. Normally mid season flood causes following damages:

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

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

- Lodging and germination of grains in the field.
- Incidence of disease and pest in crops that escaped or resisted water logging.
- High value vegetables are also affected.

Table 18 shows the extent of crop land affected area due to flood in the districts of Odisha falling in Brahmani-Baitarni basin.

Table 18 District wise maximum crop land area affected during 2001 to 2008 (source: Disaster Management Plan for Odisha, 2014)

District	Maximum Area affected by flood (in '000 ha) (from 2001-2008)		
	Rice crop	Non-rice crop	Total
Angul	11.1 (2001)	10.47 (2001)	21.57
Balasore	71.35 (2007)	6.81 (2007)	78.16
Bhadrak	60.62 (2003)	3.13 (2005)	63.75
Cuttack	80.59 (2001)	13.87 (2008)	94.46
Deogarh	1.92 (2001)	0.76 (2001)	2.68
Dhenkanal	4.69 (2001)	1.85 (2001)	6.54
Jajpur	56.18 (2001)	7.44 (2003)	63.62
Kendrapara	58.39 (2001)	11.84 (2006)	70.23
Keonjhar	2.09 (2003)	0.98 (2003)	3.07
Mayurbhanj	9.74 (2007)	2.58 (2007)	12.32
Sambalpur	3.19 (2001)	0.58 (2001)	3.77
Sundargarh	0.8 (2001)	0.39 (2003)	1.19

Suggested flood mitigation measures and strategies to protect the crops in Brahmani-Baitarni basin

Damage to crops and livelihood is highly significant in terms of cost to the government as well as the farmers themselves. Although the floodplain is ideal for agriculture, measures should be taken to prevent losses. These can include a shift in timing for the planting and harvesting of crops, change in the cropping system, etc. This can be adopted to avoid seasonal floods and subsequent crop losses. Feasible remedial measures, which can be taken to minimize the flood induced risks during Vegetative, Flowering, Crop maturity, and at Harvest have been given in Table 19.

Table 19: Suggested mitigation measures and strategies to protect the crops in Brahmani-Baitarni basin

Crop	Vegetative stage	Flowering stage	Crop maturity stage	At harvest
Rice	Maintaining nursery of over aged rice seedlings of 45 days to 60 days duration Provide drainage Gap filling for damaged seedling with varieties such as Swarna sub-1 Management of Blast (0.2% Edifenphos), leaf blight (0.01% Streptocycline) & Stemborer (0.2% Trizaphos) If damage is more than 50% retransplant or put	Growing waterlogging resistant varieties like Swarnasub1, Durga, Sarala, Varshadhan and Hanseswari Intermittent drainage Management of Blast (0.2% Edifenphos), leaf blight (0.01% Streptocycline) & Stemborer (0.2% Trizaphos) Rinsing the top leaves and floral parts If revival is not possible go for sowing	Removal of stand from the field in case of stand deposition and planning for alternate crops like sweet potato under zero tillage Provide drainage Apply potash fertilizer Harvest at physiological maturity Protection against pest like , Green leaf hopper & BPH (Imidacloprid 0.025%) Blast, preventing crop from lodging, harvesting	Wet seeding of short duration rice varieties, pulses, vegetables during forthcoming rabi season. Drying Safe storage Early disposal Utilization of residual soil moisture and use of recharged soil profile for growing pulses Growing of vegetables after receding flood water and adoption of

	pregerminated sprouted seeds on puddle soil with higher seed rate and closer spacing Use short duration variety like Lalata, Khandagiri, Konark, Surendra, Jogesh Sidhhant Transplant 40 – 60 days old seedling after flood water recedes with close spacing and 4-5 seedlings per hill	blackgram/greengram Harvest at physiological maturity Paira cropping blackgram	in physiological maturity stage.	integrated farming system to obtain more income and to compensate the loss during kharif Preventing premature germination by hormonal spray Plan for rabi crop such as blackgram, greengram or groundnut Safe storage Threshing by power thresher and drying of the produce
Maize	-	Drain out excess water, spray the crop with Imidacloprid @ 3ml/10litre to check stemborer.	Drain out excess water, spray the crop with Imidacloprid @ 3ml/10litre to check stemborer.	Wet seeding of short duration rice varieties, pulses, vegetables during forthcoming rabi season.
Black gram	Provide drainage Higher seed rate Pest & disease management	Intermittent drainage Pest & disease management	Provide drainage Apply potash fertilizer Harvest at physiological maturity Protection against pest & diseases	Drying Safe storage Early disposal
Green gram	Provide drainage Higher seed rate Pest & disease management	Intermittent drainage Pest & disease (powdery mildew with 0.2% sulphur) management	Provide drainage Apply potash fertilizer Harvest at physiological maturity Drainage, Protection against pest (pod borer with 0.2% triazophos)	Drying Safe storage Early disposal
Groundnut	Termite & Tikka disease management, need based intercultural operation Provide drainage Higher seed rate	Intermittent drainage Pest & disease management(Manage leaf miner in Groundnut by spraying Monocrotophos or Triazophos 40 EC @ 1 litre/ha at fortnightly intervals)	Provide drainage Apply potash fertilizer Harvest at physiological maturity Pest & disease management(Manage leaf miner in Groundnut by spraying Monocrotophos or Triazophos 40 EC @ 1 litre/ha at fortnightly intervals)	Drying Safe storage Early disposal

There is acute shortage of seed for re-sowing and replanting operation in early season flood. Availability of seeds (both rice and non-rice crops) should be ensured by intervention of Government and NGOs. Further while recommending the crop management options under recurrent and/or severe flood conditions, possible shifts in the cropping calendar or cropping system, or uptake of new crop can be considered so that farmers can sustain their livelihood under the extreme weather conditions. For example, if flood has become a recurrent phenomenon then farming communities can switch from less water intensive crop (e.g., green gram) to more water intensive crop such as rice and sugarcane. However, before switching over from the conventional crop to the new crop, market analysis would be required so that the new crop can be sold in the market.

Furthermore, overall flood mitigation measures and strategies to protect the crops can be divided into two types of initiatives (short and long term initiatives) to adjust agriculture in the flood prone areas details of which has been elaborated in the following sub-sections.

Short term initiatives

Under this initiative, before the floods, farmers should make high soil beds in the flood free areas to sow seeds of rice, vegetables, and other crops. Furthermore, farmers should use following strategies to reduce damages of crops from floods:

Precaution before floods: Farmers should make seedlings of flood prone crops at flood-free highlands, while cultivate short duration water loving crops in lowlands of severe flood vulnerable areas. In this regard, farmers should wipe out weeds, grasses, and use medicine to control pest. Sometimes, they should cultivate sapling of long stem paddy and hard straw paddy in flash flood areas to resist the power of flood waters.

Action during floods: Farmers should harvest 60 to 80% of mature crops before submerging floodwater. At this time, they should prepare seedlings in flood-free highland and floating seedlings in raft or fence covered with soil in flood-free land. After recession of floodwater, farmers should transplant sapling onto lands.

Initiatives after flood: Farmers should prepare lands as soon as water drains away and sow seeds, such as molasses, lentils, coriander, maize, mustard, and khesari without cultivating lands after the recession of floodwater. In addition to recovering plants, farmers should make a systematic drainage system in lands to remove water that are still stagnant in the root of plants. In this regard, farmers should take special care of medicinal plants and fruit trees. However, they should pile fresh soil around roots of plants, and steady saplings and trees with bamboo sticks.

Migration to safer place: Farmers should migrate to safer place and select high land to cultivate some crops.

Long term initiatives

Under this initiative, farmers should use the following strategies for long-term initiatives to adjust the agricultural activities:

Diversity of crops: Based on flood intensity, farmers should change the cropping system.

Land levels: It normally consists 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.

Selection of appropriate crops types: Farmers should grow short duration crops with high yield varieties (HYV) to reduce the crop damage due to flood. The length of the growing period is very important towards the adjustment of agriculture in flood-prone areas.

Crops diversification: Farmers should cultivate various types of crops based on the climatic conditions and trends of flood.

Use of flood tolerant crop variety: Government would provide flood tolerant varieties to the farmers so that in the event of flood farmers can use this variety to get better yield.

Introduction of Early Warning System (EWS): Government would introduce EWS to inform farmers well ahead of time about the chances of flood so that farmers can protect their crops accordingly.

Construction of embankments to control flood: Government would construct embankment to control the floods.

5.2 Analysis of promising measures

5.2.1 Existing and new reservoirs

In the Brahmani-Baitarani basins the flood reduction effect are especially significant for with respect to storage reservoirs. 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 35) that this has no effect on most of the delta to the east.

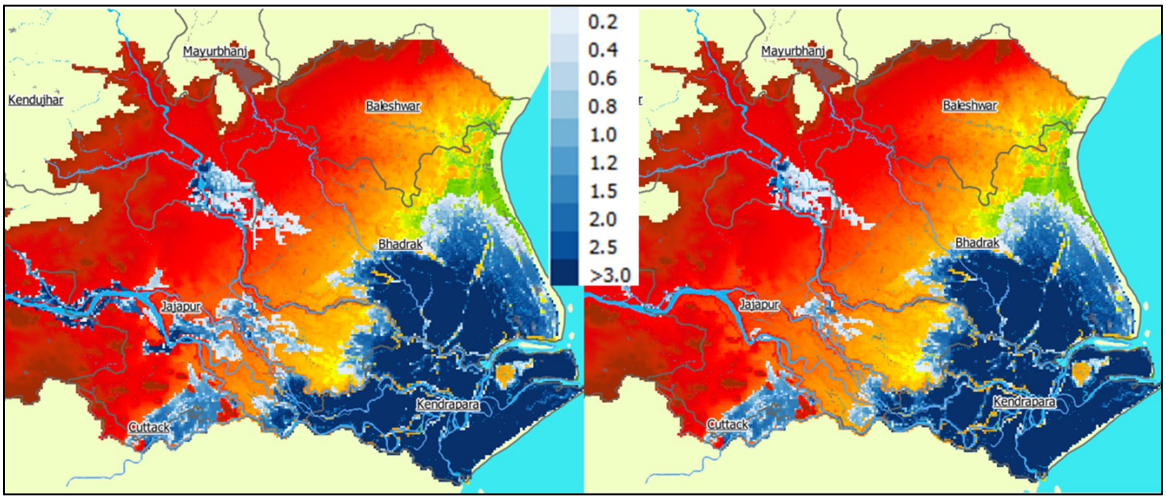

Figure 35 1:25 year flood extent (left) and impact of Rengali flood cushion increase and Kanupur project (right)

Table 20 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 (%)
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%

5.2.2 Rengali Dam operation

One of the key factors controlling floods in the Brahmani Basin is the Rengali reservoir. The Rengali dam on Brahmani river is a multipurpose dam to store water for irrigation (see Figure 36) and for the production of hydro-electric energy and to mitigate floods. Rengali dam is a gravity masonry type of dam with a length of 1,040 m. It has a 464 m long overflow section with an Ogee type spillway consisting of 24 gates. The spillway capacity is nearly 47,000 m^3/s at a maximum reservoir level of 125.4 m. The installed hydropower capacity is 5x50 MW. The dam controls a catchment area of over 25,000 km^2.

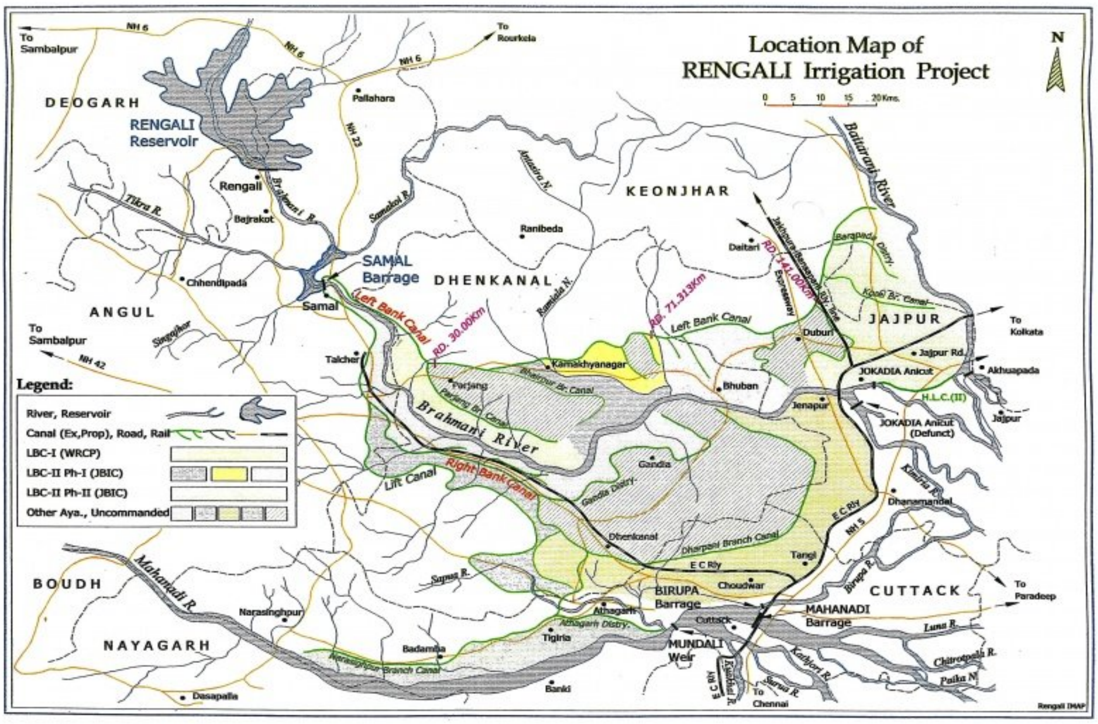

Figure 36 Rengali Reservoir and Irrigation system

The storage capacity of the reservoir is well described by the following equation:

$$S = 652{,}600 \times (H_{res}(m) - 92.423)^{2.566} \qquad 109.7 \leq H_{res} \leq 125.4$$

Where: S = storage capacity (m^3)

H_{res} = reservoir level (m+MSL)

For the operation of the reservoir a rule curve as shown in Table 21 is used. The storage capacity of the reservoir expressed as an effective precipitation amount over the catchment controlled by the dam is presented in Figure 12. The storage capacity is given between the actual initial reservoir level and FRL (=123.5 m, i.e. the full reservoir level) and MRL (= 125.4 m, i.e. the maximum reservoir level).

Table 21 Rule curve Rengali Dam

Date	Maximum Reservoir Level (m+MSL)
1 July	109.72
1 August	116.00
1 September	122.00
9 September	122.30
22 September	123.00
1 October	123.50
1 November	123.50

The figure shows that, during the first months of the monsoon, the flood mitigating capacity is considerable, and even severe storms can almost fully be stored. The capacity rapidly decreases during August and September and releases from the reservoir during and if possible prior to the arrival of a severe flood will be required to reduce the peak. To get an idea of the order of magnitude, note that a reservoir outflow of 3,000 m^3/s during one day is equivalent to the discharge of an effective rainfall depth over the upper basin of 10 mm. Releases prior to and during the occurrence of a flood requires proper forecasts of the flood volumes and peak discharges upstream and downstream of the dam.

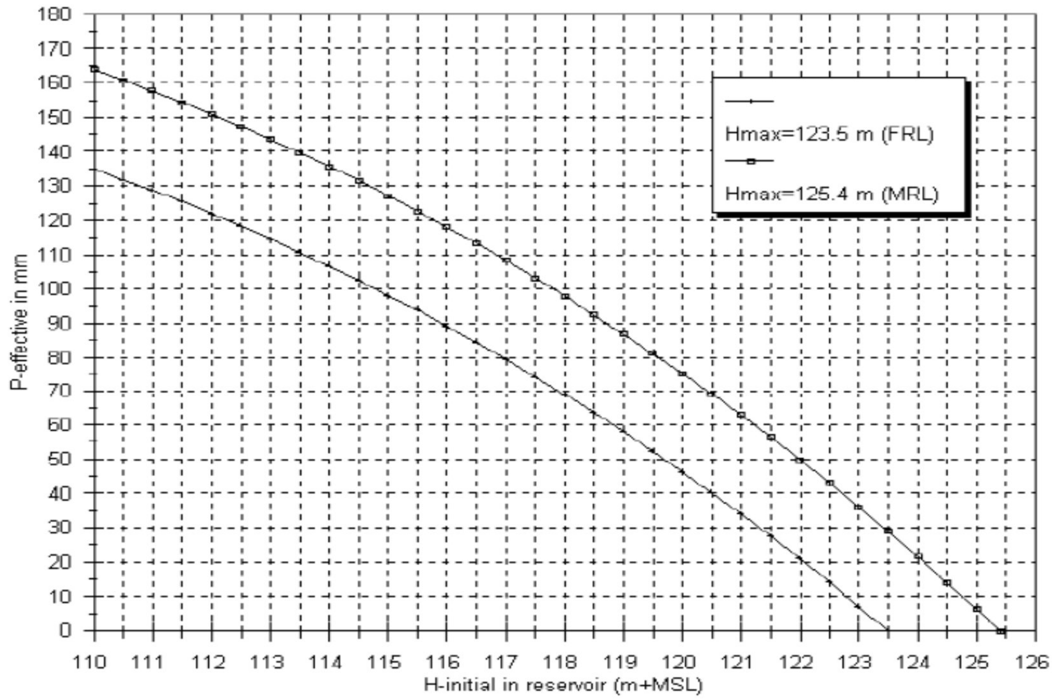

Figure 37 Storage capacity of Rengali reservoir expressed in mm rainfall in the controlled basin area (Source: HP 1998)

Reservoir operation

At present the operation of Rengali reservoir is guided by the following two considerations

- Dam safe condition: in no case the safety of the dam should be allowed to be threatened. There should always be ample space in the reservoir for moderation of the incoming flood. Releases from the reservoir should be designed accurately.
- Safe flood condition: an attempt should be made to restrict the release to safe flood conditions in the downstream area (i.e. a total inflow to the delta of a discharge less than 8,000 m^3/s); this should be done only if the dam safe condition so permits.

The first condition requires a reliable forecast of the maximum inflow volume to the reservoir, so that under all conditions the reservoir level can be kept below an MRL of 125.4 m. Both conditions benefit most from a low initial reservoir level. This conflicts however with the other two objectives of the multipurpose dam: storage of water for irrigation and hydropower.

Therefore, pre-releases from the reservoir to create extra storage capacity for flood mitigation will only be acceptable if the rule curve levels will at least be attained again after the passage of the flood. This requires thus a reliable forecast of a guaranteed minimum inflow volume to the reservoir.

The safe flood condition requires also a reliable forecast of the total inflow from the uncontrolled catchments, i.e. the releases of the Brahmani downstream of Rengali and that of the entire Baitarani. It is noted that effective manipulation of the gates at Rengali require proper information about the flow conditions well in advance. The travel time of Rengali releases to the delta is about 20 hours. This is almost equal to the basin lag (= time between centroid of net rainfall and runoff) of the Brahmani basin draining downstream of Rengali (about 24 hours) and only slightly less than the basin lag of Baitarani (approximately 30 hours).

Flood of 20 July 1994

The Rengali reservoir inflow, outflow and levels and the river stages along Brahmani and Baitarani rivers for the period 19 – 22 July 1994 are shown below (Figure 38). It is observed that by reservoir operation the flood peaks from Upper Brahmani were reduced from 11,000 to about 5,000 m3/s, which certainly has reduced the flood damage to a large extent. However, the outflow could have been further reduced if the flood volume would have been known well in time.

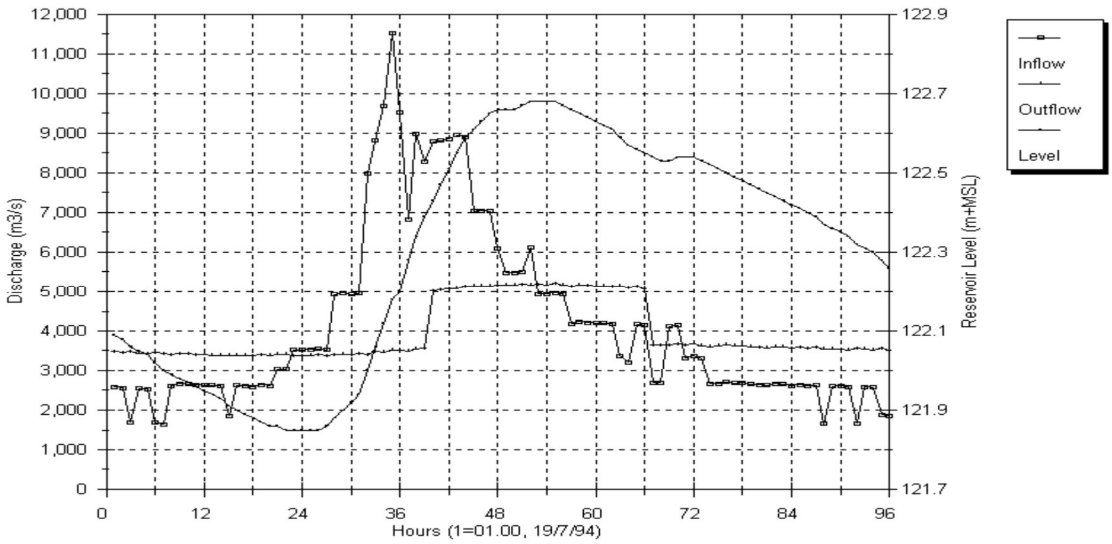

Figure 38 Rengali reservoir operation flood 19-22 July, 1994 (Source: HP 1998)

Flood of 4 August, 1994

The Rengali reservoir inflow, outflow and levels and the river stages along Brahmani and Baitarani rivers for the period 30 July – 6 August, 1994 are shown in Figure 39. It is observed that by reservoir operation the flood peaks from Upper Brahmani were reduced from 10,000 to about 6,000 m^3/s. It is noted that the initial reservoir level was about 6 m above the rule curve level. This implies that storage for about a net amount of 70 mm of rain was lost. Hence a much larger reduction could have been obtained. The reason why the level was kept 6 m above normal is not known. But even with an initial high reservoir level a larger reduction could have been achieved if more information about the time history of the flood waves would have been available.

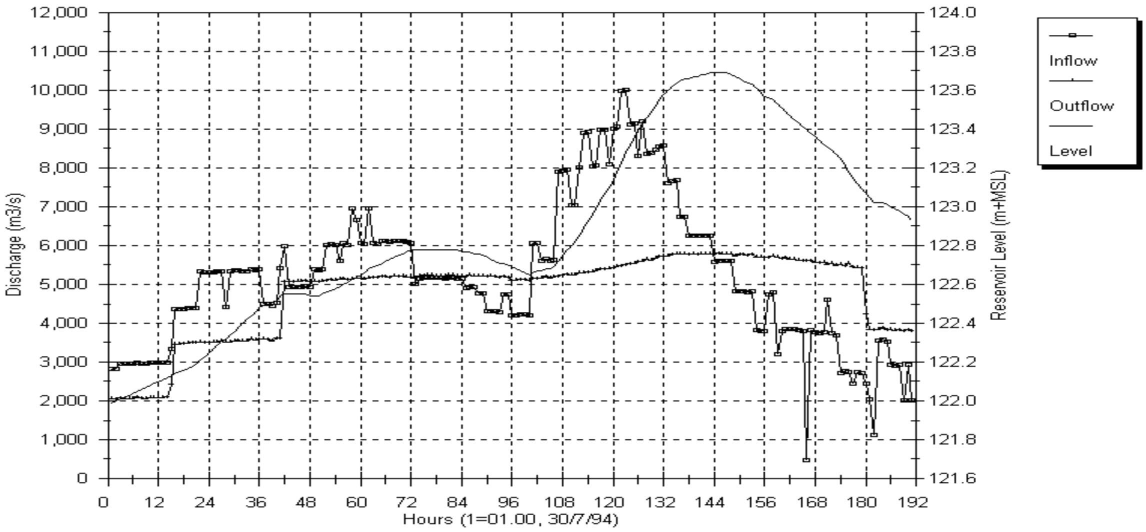

Figure 39 Rengali reservoir operation flood 30 July – 6 August, 1994 (Source: HP 1998)

Flood of July, 2014

The Rengali Reservoir operation during the flood in the last part of July 2014 is shown below along with the graphical presentation (Table 22 and Figure 40).

Table 22 In- and outflow of Rengali Reservoir during last part of July 2014

Date	Reservoir Level (m)	Inflow (Cumecs)	Outflow (Cumecs)
20-07-2014	110.28	794.5	0
21-07-2014	112.12	4702.6	480.45
22-07-2014	115.31	9556.32	0
23-07-2014	116.65	3833.64	0
24-07-2014	117.04	566.09	710.54
25-07-2014	117.04	-	694.57
26-07-2014	116.95	366.09	685.98
27-07-2014	116.86	369.45	688.98
28-07-2014	116.76	376.46	695.95

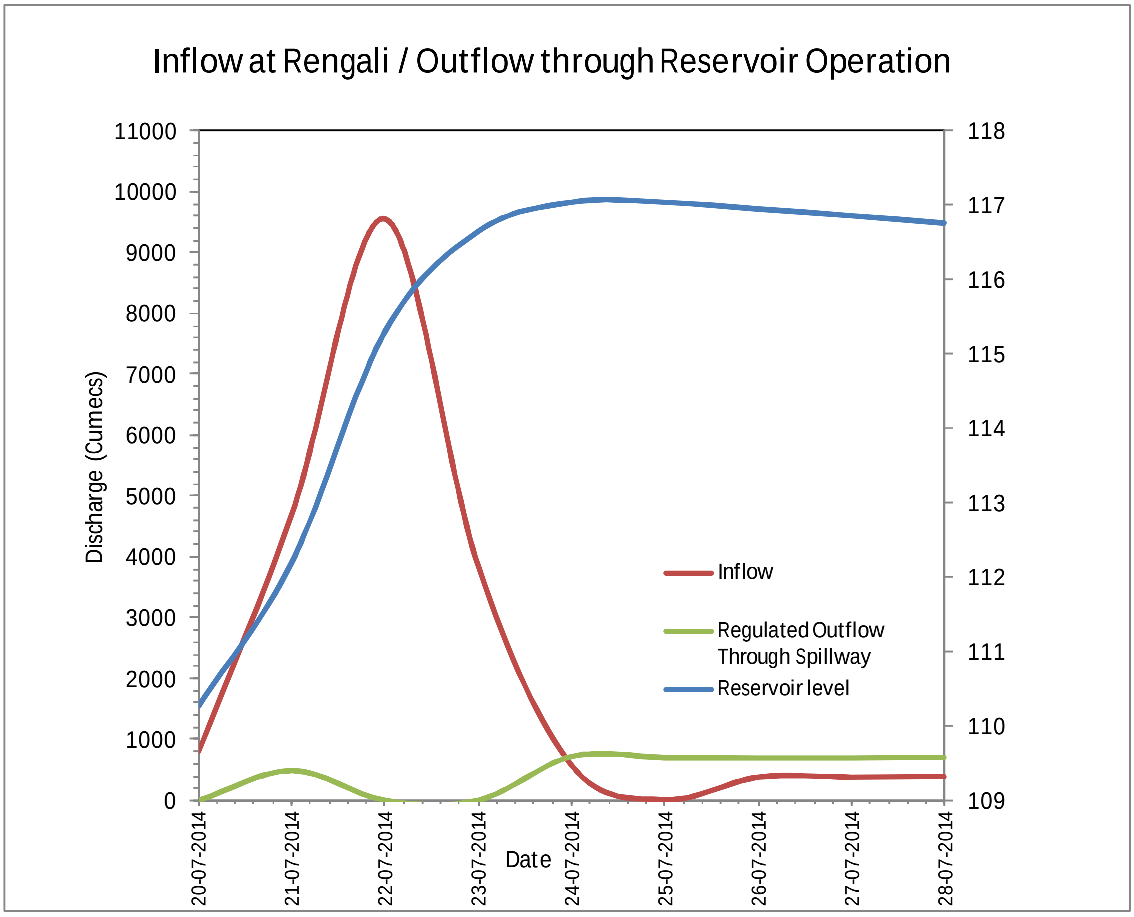

Figure 40 Inflow at Rengali reservoir, outflow through reservoir operation (July 2014)

5.2.3 Embankment improvements

The details of the existing embankments, their developments and the vulnerable reaches have been discussed in the section 4.1.1. This section makes an analysis of the effectiveness of these embankments in giving flood protection. As a first step, it becomes necessary to examine whether the planning and designs are as per recommended criteria and the construction has been made as per recommendations of the state as well as Central Water Commission. This is to examine whether frequent past failures are due to improper/inadequate criteria adopted for planning, design, implementation and maintenance.

In case, even if the criteria have been followed there could be failures of embankments in the event of occurrence of a higher Return Period flood (with lesser probability of exceedence).

The total lengths of the embankments in the Brahmni River is 944.43 km and that of Baitarni River is 896.34 Km; these embankments are grouped in to 4 categories: the Capital Embankments, other Agricultural Embankments, Test relief embankments and Saline embankments.

5.2.3.1 Criteria stipulations by Central Water Commission.

Various criteria stipulated by the Central Water Commission (Hand book of Flood control, Anti-erosion and River Training Works) are as below:

Degree of Protection

BIS Code 12094:2000 stipulates that the height of embankments and the corresponding cost and 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. However, for such time as the details of all the relevant parameters are available, following criteria may be adopted for fixing the degree of protection.

- The design flood for predominantly agricultural areas is kept 25-year return period flood for fixing the degree of protection.
- The embankments for townships or for areas having industrial installations need to be designed for 100-year return period flood.
- In special cases the observed maximum flood level can be used as design HFL (High Flood Level). Also, in cases where there is no gauge-discharge data, the design discharge could be estimated by using applicable empirical formula, connecting catchment area, catchment characteristics and rainfall intensity. If the catchments are not large the method prescribed by Central Water Commission for small catchments can be used to estimate the design flood discharge.

It has been known that for most if not all embankments in the BB basins the observed maximum flood level is used. However, since sufficient discharge data are currently available (annual maximum instantaneous discharge time series) a flood frequency analysis should now be adopted.

Alignment

The embankments should be aligned on the natural bank of the river where land is high and soil is available for the construction of the embankments.

Spacing

The spacing of the embankments and their alignment need careful consideration with respect to their vulnerability due to the river and the rise of high flood levels on account of reduction in flood plain storage by the construction of the embankments. The spacing of the embankments in the jacketed reach of the river should not be less than 3 times the Lacey's wetted perimeter while carrying the design flood discharge. The minimum distance of the embankments from the River bank and the mid-stream should be not less than 1 time Lacey's wetted perimeter and 1.50 times Lacey's wetted perimeter respectively.

Free Board

The top of the embankment should be so fixed that there is no danger of overtopping, even with intense wave actions or any other unexpected rise in water level due to sudden change in River course or aggradations of River bed or settlement of embankment.

The Free board in the absence of wave data should be taken as 1.50 M for discharges less than 3,000 m^3/sec and 1.80 M for discharges more than 3,000 m^3/sec

Top Width

The top width of the embankment should be sufficient to accommodate vehicular traffic. The top width of the embankment may be kept at 5.0 m. Turning platforms of 15 to 30 m length and 3 m width at cross section side slope at an interval of 1 Km or more may be provided.

River Side Slope

For embankments up to a height of 4.50 M, the river side slope should be not less than 2H:1V (2 horizontal length for 1 vertical length). In case of higher embankments the river side slope should be not less than 3H:1 V.

Country Side Slope

For embankments up to a height of 4.5m, the country side slope should be 2H:1V. For embankments with height between 4.5m and 6m, the country side slope should be 3H:1V, For still higher embankments, detailed designs should be taken up to decide the slope in the country side.

Other Parameters

In addition, detailed guide-lines are available in the Hand Book of the Central Water Commission, on various aspects, like the types of embankments, conversion of discharges into levels using the Rating Curves, hydraulic gradient, drainage, safety measures, sluices and other components.

5.2.3.2 Analysis

For the most important criterion, on the degree of protection the maximum observed level is taken as design high flood for embankment height. Now, sufficient discharge data is available to conduct Flood Frequency Analysis. This observed Maximum Flood Level being adopted as design HFL is well reflected in the following two tables.

Table 23 Warning and danger levels and observed HFL for Jenapur station on Brahmani river

Year	Warning Level	Danger Level	HFL Observed	Date
2000	22.00m	23.00m	21.420	29.07.2000
2001	22.00m	23.00m	23.360	25.07.2001
2002	22.00m	23.00m	20.320	09.09.2002
2003	22.00m	23.00m	22.320	10.11.2003
2004	22.00m	23.00m	21.600	23.08.2004
2005	22.00m	23.00m	23.100	31.07.2005
2006	22.00m	23.00m	23.200	24.08.2006
2007	22.00m	23.00m	22.600	28.07.2007
2008	22.00m	23.00m	22.580	18.09.2008
2009	22.00m	23.00m	22.380	22.07.2009
2010	22.00m	23.00m	19.692	08.07.2010
2011	22.00m	23.00m	23.765	26.09.2011
2012	22.00m	23.00m	21.040	20.08.2012
2013	22.00m	23.00m	20.820	31.07.2013

Table 24 Warning and danger levels and observed HFL for Anandpur station on Baitarani river

Year	Warning Level	Danger Level	HFL Observed	Date
2000	37.45	38.36	38.300	15.09.2000
2001	37.45	38.36	39.300	12.07.2001
2002	37.45	38.36	36.780	11.09.2002
2003	37.45	38.36	38.400	10.08.2003
2004	37.45	38.36	38.650	21.08.2004
2005	37.45	38.36	39.380	29.06.2005
2006	37.45	38.36	38.950	22.08.2006
2007	37.45	38.36	39.940	14.08.2007
2008	37.45	38.36	40.180	18.06.2008
2009	37.45	38.36	37.670	21.07.2009
2010	37.45	38.36	35.530	20.09.2010
2011	37.45	38.36	41.350	23.09.2011
2012	37.45	38.36	36.900	12.08.2012
2013	37.45	38.36	40.740	14.10.2013
2014	37.45	38.36		

Flood frequency analysis was calculated for Jenapur and Anandpur, both CWC Gauge-discharge Stations. For Jenapur the total Length of HFL Data analysed was 35 years, from 1979 to 2013. Both Gumbel's Extreme Value Type 1 distribution and Log Pearson Type III distribution have been adopted for analysis. The results are given in Table 25.

Table 25 Flood frequency analysis for Jenapur and Anandpur water levels

	Jenapur		Anandpur	
Return Period in Years	HFL by Gumbel's Extreme value Type 1 (m)	HFL by Log P 3 (m)	HFL by Gumbel's Extreme value Type 1 (m)	HFL by Log P 3 (m)
2	21.922	22.080	38.32	38.54
5	22.744	22.850	39.59	39.91
10	23.258	23.160	40.44	40.27
15	23.600	23.220	40.91	40.55
20	23.811	23.440	41.24	40.73
25	23.976	23.560	41.50	40.93
50	24.486	24.040	42.28	41.36
75	24.783	24.320	42.74	41.39
100	24.993	24.380	43.07	41.50
125	25.16	24.430	43.32	41.60
150	25.280	24.500	43.52	41.98

The present HFL adopted at Jenapur is 23.765 m. This corresponds to only 18.50 year Return Period as per Gumbel analysis. But in Log P3, this HFL corresponds to about 35 years Return Period. Similarly, present HFL used for designing embankments at Anandpur is 41.35 m, which corresponds to 22.50 year Return Period as per Gumbel analysis, which is slightly less than the safety criterion of 25-year return period. But in Log P3, this HFL corresponds to about 49 years Return Period, which is much higher than 25 years.

Gumbel analysis is most often used in India and performs well when there is only a small value of coefficient of variation. Because the analysis is performed on water levels such variation is indeed small.

The free board adopted is said to be 1.2 m, which is again less than the criteria. Even for a discharge up to 3,000 m^3/s, a free board of 1.5 m needs to be adopted. The discharges for the lower parts of these rivers is more than 3,000 m^3/s for which a free board of 1.8m should have been provided according to the criteria.

Breaches and overtopping (especially in Baitarani) have become a routine phenomenon during even normal floods. This has led to the damages to the shapes, slopes and the strength of the embankments, needing frequent repair and maintenance activities. Although the used HFL more or less equals the 1:25 return period (in rural areas), several other aspects, such as too little freeboard, less than appropriate maintenance and closure of gaps in embankment should be addressed properly.

Besides the immediate improvements as said above, in the long-term perspective for scenarios of years 2040 and 2080, there could be further needs for the embankment raisings because of the climate change effect on the intensity of flood producing rainfall.

5.2.4 Urban and rural drainage

5.2.4.1 Drainage Improvement Programme

The Government of Odisha runs a Drainage Improvement Programme (DIP) to rehabilitate the irrigable and non-irrigable command areas affected by waterlogging in the 17 doabs in coastal Odisha, to moderate the flooding and inundation period by way of increasing carrying capacity of drains and rivers, for river mouth clearance, improved natural drainage in areas around wetlands through gravity and pumping and renovation of urban water bodies. Main objective is to improve 179,000 ha of cultivable area and to increase crop productivity by an average of 10%.

The plan is to excavate about 5300 km of various drains, improve /renovate about 2000 km of drains, removal of shoals and islands and clearance of river mouth in selected rivers. Also some 450 cross drainage works, bridges and control structures are to be constructed and 125 structures to be rehabilitated. Furthermore about 100 km of embankment is to be constructed and 20 urban water bodies to be renovated.

5.2.4.2 Pre-feasibility designs and costings for urban and rural drainage

Conventional drainage systems are designed to achieve a single objective — flood control during large and infrequent storms. This objective is met by conveying and/or detaining peak runoff from large and infrequent storms. There are several forms of drainage, such as natural drainage systems, deep open drains, pipe drains etc. Simply put, when the drainage is sufficient, water will be removed quickly. If drainage capacity is less than the inflowing or precipitating water, flooding will occur. Today's drainage systems must cost-effectively manage flooding, control stream bank erosion, and protect water quality.

There is a need to develop effective drainage systems that balance the objectives of maximizing drainage efficiency and minimizing adverse environmental impacts. The development of agriculture and transportation networks has resulted in modifications to the natural drainage system. These modifications to land use and drainage patterns can be the source of drainage problems in rural systems.

Urban and Rural Drainage

Rural and urban drainage are interrelated since both may contribute to the overall hydrology of a watershed. The objectives of an urban water drainage design are to provide a drainage system that will collect and convey storm water from a catchment to its receiving waters with minimal nuisance, danger or damage at a financial and environmental cost that is acceptable to the community as a whole to provide limited flooding of public and private property. This system will provide convenience and safety for pedestrians and traffic in frequent storm water flows by controlling those flows within prescribed velocity/depth limits.

Further, because of the impermeable surfaces in urban areas, flooding occurs very often as a human-made event. Runoff from such surfaces has a high velocity, which adds to stormwater drainage systems. This increases peak flow and overland flow volume and decreases natural groundwater flow (as no is percolation possible) and evapotranspiration. Furthermore, urban runoff has an increased pollution load, which leads to water pollution.

In rural areas, the cumulative impact of countryside living subdivisions, roads and buildings causes an increase in peak flow rates, and the volume of water that is discharged after storm events. This leads to two key effects: flooding and stream erosion. The main problem in rural areas is impermeable surfaces (e.g. caused by roads and buildings) and overstrained sewer systems. In rural areas and agricultural land it can lead to erosion.

Basic design principles of drainage

An open channel or drain system generally consists of a secondary drainage system, with a network of small drains attached (micro-drainage). Each serves a small catchment area that ranges from a single property to several blocks of houses. These small drains bring the water to a primary drainage system, composed of main drains (also called interceptor drains), which serve large areas of the city. Thereafter these drains are generally connected with natural drainage channels such as rivers or streams. Not all water precipitating as rain needs to be removed by the drainage system. Some will be directly absorbed by naturally infiltrating into the ground, while some may stand in puddles and other depressions and will eventually evaporate.

The part that drains off the ground surface (runoff) into the drainage system is known as the runoff coefficient. There is little chance for evaporation during a rainstorm, so that the runoff coefficient used to calculate the size of the drains required should be based on the infiltration capacity of the ground. The latter mainly depends on soil condition (if the drainage system is not lined, as is often the case in rural areas, chances of percolation are high); the slope of the terrain (steep slope or flat area); land use in the catchment area (roofs and pavement prevent infiltration) and the intensity of rainfall (e.g. design for a 5-year storm return period).

In flat low-lying areas subject to flooding, a major problem often results from the relatively high level of the receiving water body. Because of the limited slope to which drains can be laid when water flows along them it is quite slow and inefficient. Together with the difficulty of digging deep drainage channels especially where the groundwater level is high, results in drains having to be proportionally wider in order to have sufficient water passage. There is also a risk of puddle building in which pests such as mosquitoes can breed. Building a drainage channel with sloping sides and a narrow bottom helps to maintain a steady flow speed whatever the water level in the channel. A refinement of this principle is to build a channel with a composite section.

Box 2. Indian standards for drainage

Drainage in India is based on gravity flow. Drainage systems comprise of three components:

- Main drains along main roads and nalas
- Area where drainage problems have been identified
- Branches and lateral drains

Even in areas where the slope is flat, pumping is avoided. Drainage by pumping is an expensive proposal to construct and is equally expensive to operate and maintain.

The design of drainage system should generally follow the guidelines recommended in Central Public Health & Environmental Engineering Organisation (CPHEEO), Ministry of Urban Development, Government of India, Manual on Sewerage and Sewage Treatment or other relevant codes with proper justification for deviation or modification. The design of the drainage system requires the following:

- Calculating the total discharge that the system require to drain off
- Fixing the slope & dimensions of the drain to have adequate capacity to carry the discharge and afford proper maintenance

The discharge is dependent upon intensity and duration of precipitation, characteristics of the area and time required for such flow to reach the drain. The storm water flow for the purpose may be determined by using the rational method, hydrograph method, rainfall runoff correlation studies and empirical formulae. The rational method is most commonly used and serves the purpose for design of drain satisfactorily.

A fraction of the storm water would flow to the Storm Water Drainage (SWD), which depends on the imperviousness, topography, shape of the drainage basin and duration of the storm. This imperviousness is quantified by a coefficient of runoff, which needs to be determined for each sub-catchment of the drain. The peak runoff at any given point is calculated using the following rational formula:

$Qp = Cs\ CIA/360$

In which:

Qp = peak flow in m^3 /sec
C = Runoff coefficient
I = design rainfall intensity mm/hr
A = Contributory area in hectares
Cs = storage coefficient

Pilot Study for City of Jajpur

Jajpur is located in Bhubaneshwar and falls in the Baitarani- Brahmani River Basin. Jajpur district covers an area of 1115 square miles. Six Tehsils fall under the jurisdiction of Jajpur District. These are Jajpur, Sukinda, Binjharpur, Bari, Dharmasala and Darpan. The district is surrounded by Cuttack in South West, Dhenkanalin West, Bhadrak in North East, Keonjhar in North and Kendrapara in South East.

The natural topographical factor, i.e., a flat terrain is the main cause of drainage congestion in the Jajpur City. Disposal of runoff resulting from rainfall takes considerable time to drain out. Further, the problem gets aggravated due to the existing drains remaining choked due to solid waste dumped into the drains. Hence, it was decided that Jajpur be studied as pilot study for urban drainage. The city experiences inundation depths of 0.5m or more and the duration of water stagnation is more than five days.

Encroachments are also a major problem in Jajpur. Habitations started growing into cities alongside rivers and watercourses. As a result of this, the flow of water has increased in proportion to the urbanization of the watersheds. Ideally, the natural drains should have been widened (similar to road widening for increased traffic) to accommodate the higher flows of stormwater. But on the contrary, there have been large scale encroachments on the natural drains and the river flood plains. Consequently the capacity of the natural drains has decreased, resulting in flooding.

The study involved a visit to Jajpur city to meet Municipality and WRD officers. A detailed walk through survey of the water logged spots was conducted. The following paragraphs explain observations found at site.

Observations during a field visit to Jajpur revealed that the existing situation at Jajpur is of open drains situated along roads. The total length of drain is 9015 m within the city and all the drains are unlined. That is they are not bound by brick, mortar or concrete. Only 10% of effective capacity of the drainage system is in use and moreover, sewage is dumped into drains as no appropriate disposal of solid waste occurs. The main concern at Jajpur is flooding after rainfall. The following were outcomes of discussions with the officials:

- Detailed Project Report for Master Storm Water Plan has been proposed and is under approval from GoO. This plan addresses potential flooding of the existing system and details the proposed stormwater management system to meet increasing demands for additional stormwater capacity in Jajpur.
- Final Master Plan of Jajpur was shared and discussed regarding urban drainage perspective.
- Old drainage system has never been improved since installation.
- Clogging of drains with sewage, which do not allow for free flow of water through storm water drain pipe, exuberates the situation.
- Encroachment of drains by residential homes and commercial property obstructs rain water drainage, thereby reducing efficiency of drains.
- Lack of available land to support solid waste management increases likelihood of improper dumping of waste into drains.
- Present drainage system works at 10% of total capacity which is a major hindrance to efficient storm water drainage.
- Drains are unlined and not maintained properly.
- Heavy siltation reduces carrying capacity of existing drainage network.

Jajpur Municipality has made a Detailed Project Report (DPR) for the Storm Water Drainage of Jajpur. The DRP is presently not available for public reference and is with State Government of Odisha for necessary approval. However the Municipality has identified a detailed plan for assuring successful urban drainage, based on the present grievances. The Stormwater Drainage Master Plan addresses potential flooding and nonpoint source pollution impacts of the existing and also of the proposed stormwater management system to meet increasing demands for additional stormwater capacity in Jajpur.

Cognizance has been taken care of to achieve the following in the proposed Storm Water Drainage plan:

- Minimize the threat of flooding
- Protect receiving water bodies
- Promote multi-functional use of stormwater management systems
- Develop sustainable stormwater systems

Further recommendations for urban drainage in Jajpur and a detailed costing are provided in Appendix A.

5.3 Economic and environmental considerations

5.3.1 Review of cost-effectiveness and CBA of flood management approaches

General

An economic analysis of flood management approaches is used for assessing if a project or measure has an added value for society. There are several methods to do so. Cost-effectiveness and Cost-Benefit Analysis (CBA) are two of the methods often used. A cost-effectiveness analysis can show whether a measure provides the maximum value in terms of goods or services for the money spent. We can use this for instance to compare two flood control strategies which both provide the same level of safety. The one which is cheapest has the highest cost-effectiveness. It is distinct from a CBA which assigns a monetary value to the effect itself and then compares it with the cost of the measure. The CWC stipulates in its 'Guidelines for preparation of detailed project reports of irrigation and multi-purpose projects' the use of CBA as part of the Detailed Project Report (DPR). Evidently, for a CBA more data is needed than for a cost-effectiveness approach.

For a cost-effectiveness analysis it is required to define the perceived goal or impact for a measure. In the case of flood management this could for instance be the safety level for embankment design of 1:25 years for agricultural areas and 1:100 years for urban and industrial areas as stipulated in the Guidelines for Planning and Design of River Embankments (levees) (BIS, 2000). With a flood model several ways to reach this safety level (e.g. through reservoir dams) can be analysed after which a comparison can be made with respect to the differences in cost. But even a project with the best cost-effectiveness can have a low benefit/cost ratio so that is why CWC stipulates to use CBA.

Suggested Benefit Cost Analysis method for flood mitigation projects

1. Benefit categories

The main benefits of a flood mitigation project are the avoided damages and losses. These include:

- Damages to private properties and assets, such as houses and household assets
- Damages to crops, livestock and culture fisheries
- Damages to income generating assets, such as tractors and waterpumps

- Damages to public infrastructure and buildings
- Loss of industrial and service sector incomes in urban and tourism areas
- Loss of wages due to unemployment during flooding, increased time and cost of commuting as transportation routes get disrupted and damaged
- Relief expenditures

2. Calculating annual average damage

Instead of using average damages over the last ten years or so it is recommended to use a risk approach. This entails the estimation of the expected damage for a given flood event, by combining data on the characteristics of the event (hazard) with information on the assets that would be affected by it (exposure) and information about the susceptibility of those exposed assets to the particular hazard (vulnerability). This involves the use of a mathematical flood model, such as used in this study for determining the probability of various flood events. For the vulnerability so called damage curves are used, relating the percentage of damage to an asset with the flood depth.

The Average Annual Damage (AAD) is then found by integrating the damages with each probability (see Figure 41) using the formula:

$$AAD = \int_0^1 D_F \, dp \approx \sum_{i=1}^{N} (D_{i+1} + D_i) \times (p_{i+1} - p_i) / 2$$

where D_F = flood damage, D_i = damage of a flood event I, and P_i = probability of a flood event i. Based on these damage calculations the AAD for different safety levels are calculated, as well as the benefits. These benefits occur every year in perpetuity. The present value (PV) of an annual benefit (perpetuity) can be calculated using the formula:

$$PV = AAD \times (1 / ((1+r)^n)$$

with r being the discount rate for government infrastructure investments. The AAD is an annuity; formula (3) can be simplified to:

$$PV = AAD / r$$

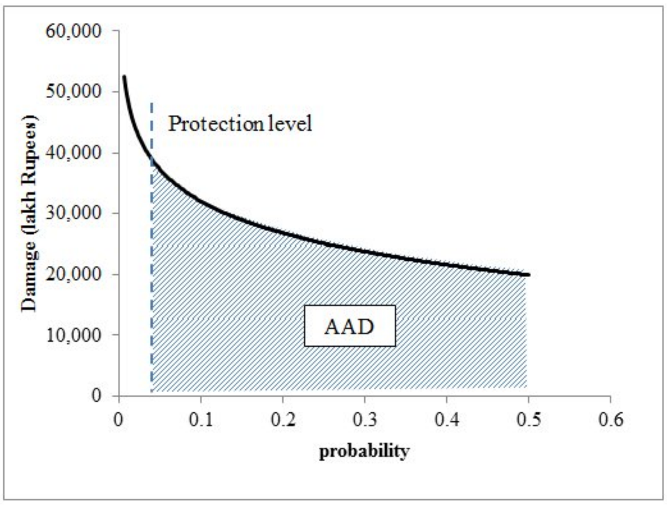

Figure 41 Damage probability curve

3. Adjustments to benefit calculations

- Because it is very difficult to estimate losses as a function of flood depth, a percentage of the asset damage can be used (e.g. 10%).
- Improvements of the present conditions of flooding could tap an additional production potential. Such improved productivity could occur from the much less frequent incidence of natural hazards and the perception of farmers that it would be safe enough to deploy better agricultural practices. A more stable physical environment would encourage farmers to accelerate productivity or to diversify into high-yield varieties or more profitable crops. Therefore the benefits could be hiked with a certain percentage per year.
- Increased flood safety will attract more people in the protected area and lead to more economic prosperity. This will generally result in more assets (houses, cars, small and medium enterprises) and higher asset values. A certain percentage could be used, or a number of scenarios could be developed.

4. Costs

In estimating the economic costs, conversion factors to be applied to the financial cost estimates of the IFM. For investment costs, conversion factors for different types of civil works (comprising embankments, sluice gates) are to be estimated based on their composition of key expenditure items and applying the relevant conversion factors to them. For other cost items (project management, and consultants), a standard conversion factor of 0.90 to be applied for local cost items. Following the project design, physical contingencies accounting for 12.5% of the base costs for civil works and 10.0% for other expenditures should also be included in the analysis.

Regarding the recurrent costs, the analysis includes the annual maintenance costs of the project (such as head works and embankments), estimated at 1.0% and 2.0% of the capital investment costs for the first 15 years, and twice as much amount beyond the year 15. For nonstructural components, project wise personnel and operational costs should be included as annual recurrent costs for individual subprojects.

For adaptation of reservoir operation (flood cushioning) an analysis needs to be made for the impacts on other reservoir functions in case of a multi-purpose reservoir (e.g. losses in energy production or irrigation potential).

The costs should also take into account cost for land acquisition, resettlement cost of people (if any), opportunity costs, sluices for drainage, reduced preparedness of the people for larger floods, the loss in soil fertility and aquifer recharge, etc.

5. Benefits and cost ratio

Based on the above estimation of the present value of costs and benefits of the project a ratio can be prepared. The assessment should assume that the project benefits associated with the avoidance of loss would be fully achieved after a certain period (e.g. by the end of the year 3). The analysis should be undertaken over a 50 year time period to reflect the economic life of the project assets/infrastructure. Furthermore, an assumption should be made that the residual value of the civil works amounts to 50% of the initial capital investments. The discount rate used for the calculation of present values is usually set by government rules.

6. Sensitivity analysis

A sensitivity analysis should be performed to test the economic viability of the proposed project works to various changes in the cost and benefit streams. At least the following items should be tested: i) a rise in investment costs; ii) a rise in O&M costs, iii) a delay in implementation, iv) lower crop prices.

Economic evaluation of BB projects

Because of the limited time, budget and data available we cannot perform a full-fledged CBA. Instead we have used our flood model results to estimate the potential benefits from protection measures. This should be considered as *indicative* and does not take into account steps 3 and 6 as described above.

As described in Section 5.1.2 the following projects are considered as most effective for the flood risk reduction in the river basin:

1. Kanupur Irrigation Project (nearing its commissioning)
2. Samakoi Irrigation Project in Brahmni basin (proposed)
3. Anandpur Barrage Project complex development (proposed)
4. Balijhori Hydropower Project across Baitarni (proposed)
5. Improvements of existing embankments system

For Kanupur and Samakoi Irrigation projects some details on costs and benefits have been given, whereas for the other three projects no detailed data is available because the projects are still in prefeasibility stage. However, for Anandpur and Balijhori projects we can use our model results to estimate the contribution of the flood mitigation of these projects (in terms of avoided damage) and compare it to the costs. It must be noted that these are very preliminary calculations due to the very limited data available.

Kanupur Irrigation Project

The latest cost estimate for this project is from 2008 and was INR 1,067 crores. combined with the estimated benefits from irrigation (27,578 ha) this would bring the Benefit Cost (BC) ratio to 2.4. The *added* benefit from flood mitigation is difficult to estimate because there is no information on the proposed operation rules of the barrage. However, from the SOBEK model results using only the diversion of water (discharge reduction of 44.95 m^3/s) this would give a reduction in flooded area of 3.2% (for 1:25 year flood). This could imply an avoided damage of INR 100 crores once in 25 years, i.e. an annual avoided damage of INR 4 crores per year. The net present value of this benefit would be INR 33 crore, assuming 12% discount rate. With this amount the BC ratio would increase from 2.4 to 2.43.

Samakoi Irrigation project

The total cost estimate for this project is INR 43.85 crores and has a BC ratio of 1.6. The barrage has no significant storage capacity, so the flood reduction has been estimated only on the diversion of 12.07 m^3/s for irrigation. This would give a reduction in flooded area of 0.7% for a 1:25 yr. flood equalling INR 53 crores avoided damage, which is an annual avoided damage of INR 2.12 crores per year. The net present value of this would be INR 17.6 crores. With this amount the BC ratio would increase from 1.6 to 2.0.

Anandpur Barrage Project

The total cost estimate for this project is INR 617 crores. The flood reduction has been estimated through the SOBEK model on the diversion of 165 m^3/s in the monsoon season. This would give a reduction in damage for a 1:25 year flood of INR 178 crores, which equals an annual avoided damage of INR 7.12 crores per year. The net present value of this would be INR 59 crores. With this amount the BC ratio would be 0.1 for *flood mitigation alone*. But of course the major benefit is agricultural and is not included in this calculation because of lack of data. It shows that the flood mitigation benefit would have a quite small contribution to the over-all BC ratio.

Balijhori Hydropower Project

The total cost estimate for this project is INR 1,779 crores. The flood reduction has been very preliminary estimated through the SOBEK model by assuming maximum flood cushioning effect of the Reservoir. This could give a reduction in damage for a 1:25 year flood of INR 607 crores, which equals an annual avoided damage of INR 24.28 crores per year. The net present value of this would be INR 202 crores. With this amount the BC ratio would be 0.1 *for flood mitigation alone*. But of course the major benefit is from power generation. In fact there is a trade-off between the two benefits because power generation requires full reservoir but flood control a reservoir as empty as possible in beginning of monsoon, so the real BC ratio can only be calculated by detailed study of the reservoir operation.

Improvements of existing embankments system

Improvement of the embankment system may include heightening of levees, strengthening and/or closing gaps. An example of the costs and benefits of embankment improvements has been given in Section 4.3 Jenapur Pilot.

Financing IFM project interventions

Government spending on IFM may be considered on two grounds: (a) humanitarian considerations helps save human life and resources which may not be economically viable in short term (b) economic considerations help grow GDP leading to enhanced or better livelihood of flood affected communities. The economic considerations of investments should be guided by positive cost benefit ratio, a positive NPV and EIRR.

There are also other contributors in growth of GDP besides IFM interventions. However, it will be interesting 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.

Flood management works are funded from different sources either from State Government or from the Government of India. Although the State Governments are primarily responsible for the execution of projects, their financial resources may not always be adequate for undertaking major flood control works. Therefore the Central Government provides both technical and financial assistance. But floods have never been considered as a priority sector in the planning process or in the process of funding in either the State Plan or Central Plan. Current levels of provisions under Five Year Plans and Finance Commission do not match desired capital investment in the IFM. This has resulted in projects getting stalled for quite a long time (even up to 30 or 40 years).

Thus we recommend that also alternative resources for IFM may be tapped from several programs and schemes. For instance from the Mahatma Gandhi National Employment Guarantee Program, which allows ‘Flood control and protection works including drainage in water logged area’ to be funded under the program. The resources under MGNREGA are useful for both capital investments in the above works and also to meet recurring / maintenance costs using community driven approach for caring O&M of flood control infrastructure.

Similarly there are several other programs meant for soil and water conservation on a watershed basis in the catchment area under the Ministry of Rural Development and implemented through District Rural Development Agency, and many other schemes and programs.

At present there is no arrangement to share the costs between different ministries when drainage congestion and flooding occurs due to the construction of railways and highways. Therefore it is recommended to arrange cost sharing between the Ministry of Surface Transport, Ministry of Railways and Ministry of Water Resources.

5.3.2 Review of environmental impacts of flood management strategies

Waterlogging

It was observed at Jajpur that Baitarani River has changed course in the near past due to severe sedimentation in the river bed which has resulted due to the embankment induced change in the hydrology of the river. At places in order to protect the embankment from the river which has changed course pitching have been done on the embankment.

Jajpur city also suffers from storm water drainage and sewage disposal problem, as the city is located in a comparatively flat watershed and discharge of storm water is a problem as the flow is cut off by the right embankment and canal along the city periphery. Hence, there is a negative impact of waterlogging in the city. It is recommended that proper storm water drainage system should be designed as per the recommendations made in the current study to mitigate this impact.

Water logging is a major problem outside of the embankment in Jajpur area. Due to the non-functional drainage sluices and gates, water is stagnant on the outside of the embankments. Further the problem is worsened by the fact that the terrain is flat and sewage and rainwater need to be pumped into the river from outside the embankments.

Kanupur Irrigation Project

It was observed during the site visit that the Kanupur Irrigation Project is located on confluence of two rivers Sona Nadi and Baitarni with small catchment areas. Watershed management is critical in this area as there are many mining projects and other industrial activities resulting into induced soil erosion and denudation. As mitigation of this impact Catchment Area Treatment Plans (CATP) are prepared for irrigation projects where water is ponded. Kanupur Irrigation Project has the CATP prepared as it was made mandatory to undertake this exercise vide the EC awarded to the project (EC, 1985). This study has addressed the following:

1. Identification of potential micro watersheds within the catchment with substantial influence on the flow of river Baitarani and its tributaries feeding and dam basin of Kanupur Irrigation Project,
2. Study of the land use pattern within each of the micro watershed identified above and assessment of the potential threats to the flow of river and nallahs from these areas,
3. Plan suitable mitigative (conservation) measures including changes in cropping pattern to address these threats within each of the micro watersheds,

4. Estimation of the cost for each type of intervention with suitable plans for direct execution in the field.
5. Identification and quantification of the threats relevant to the life of dam from mining operations upstream along Baitarani river system in the catchment area of this project and suitable mitigative measures to be adopted by mining firms.
6. Preparation of annual plan of action with all justification and miscellaneous regulations as applicable in the field.

Kanupur Irrigation Project is located in Kehonjar District. Kanupur has already acquired the forest land and compensatory afforestation has been done. Total forestland acquired for Kanupur project is 235.269 ha of which 38.35 ha is for the dam site, 133.05 ha is for reservoir and 63.869 ha is for distribution system. In order to mitigate the adverse impact due to the dam, similar extent of area has been handed over to the Forest area for compensatory afforestation along with funds for the same. 2600 ha land of sixteen villages has gone under submergence and the villages have been rehabilitated and resettled (EC, 1985).

In Kanupur Irrigation Project, 2600 ha of village land has been submerged of which nine villages are completely submerged and seven partly. Villages that have been established as a part of the R&R activity were visited in the field and it was observed that since the villages being more than five years old and have emerged as a successful settlement plan of R&R.

Samakoi Irrigation Project

Samakoi Irrigation Project will have impact on command area where currently rain fed agricultural practice is being followed. Once irrigated facilities will reach the farmers on completion of the barrage, command area development programmes like on farm development, land levelling, construction of field channels etc. will have to be initiated (GoO, 2014).

Samakoi Irrigation Project will give benefit of irrigation to 9990 ha of land through its canal network. This will lead to increase in cropped area and hence increase in chemical fertilizer use leading to fertilizer pollution in the runoff water. As a mitigation of this impact the Department has proposed to train the farmers to use compost, green manure and bio fertilizers along with chemical fertilizers and integrated pest management (GoO, 2014)

There will be some tree cutting while construction of the canals in Samakoi Irrigation Project. As mitigation of this adverse impact it has been recommended that tree plantation along the canal alignment should be done. Total recommended length of plantation alongside the canal is 30 km. Avenue plantation has been recommended along the periphery road of the pond submergence. Length of this road is 72 km. The impact of growth of aquatic weeds in the canal has been envisaged in the EIA Report. In order to mitigate this adverse impact it has been recommended that canal weeds should be cleared on regular intervals by mechanical, chemical and biological methods. (GoO, 2014).

It has been envisaged that there will be negative impact of waterlogging and soil salinity due to the construction of the Samakoi Irrigation Project. The remedial measures recommended to overcome this adverse impact are as follows:

- Adequate field drains in water logged areas,
- Introduction of farmers training programme activity to overcome the problem of waterlogging,

- Conjunctive use of groundwater.
- Selective cropping with crops having high tolerance to salinity and / or water intense crops.

Anandpur Barrage project

There is no inundation of farm or forest lands in the Anandpur Barrage project. Samakoi barrage at Village Chakadhar results into submergence of 369.96 ha of forestland and small part of two villages where there is no habitation. There will be an additional requirement of 1064.43 ha land for canal network (GoO, 2014). During the site visit it was observed that Barrage under construction does not cause any major impact to the adjacent environment.

In order to mitigate the adverse health impact due to malaria, it has been mentioned in the Environmental Clearance letter of Anandpur Barrage Project that a committee should be constituted with a health expert as member who has experience in anti-malaria measures. It is also stated that flow rate in the canal system should not be less than 0.6 m/s to avoid incidences of malaria epidemic. Suitable species of fish should be introduced to control malaria vector mosquitoes.

In order to mitigate the impact of barrage to the migratory species Anandpur Barrage has in its design a fish ladder along the left abatement of the barrage. Partially built ladder was observed during the site visit to Anandpur Barrage. This ladder will facilitate the migration of fish from downstream to upstream of the river in spite of the barrier created by the barrage.

EC letter of Anandpur Barrage Project states that there should be a project level monitoring committee constituted to keep a watch on the incidences of water logging in the command area and to initiate suitable remedies including restoring to conjunctive use of ground water. (EC Letter, 2003)

Baljori Hydropower project

In Baljori Hydropower project, the submergence area of the project is 1240 ha comprising forest and private land. The total land requirement for the construction of various components is about 500 ha. Most of the land falls under the category of forest land. Based on assessment of environmental impacts, management plans should be formulated for Catchment Area Treatment, compensatory afforestation and other environmental issues like rehabilitation & resettlement to mitigate the adverse impacts.

In the reservoir of Baljori H E Project, it is anticipated that the flooding of forest and agricultural land in the submergence area will increase the availability of nutrients resulting from decomposition of vegetative matter. Enrichment of impounded water with organic and inorganic nutrients at times become a major water quality problem immediately on commencement of the operation and is likely to continue in the initial years of operation. In order to understand impact on the dissolved oxygen levels dynamics in the catchment due to significant quantity of forest area and private land including agriculture land being submerged, it is recommended that a detailed modelling study be conducted to estimate the dissolved oxygen level in the reservoir during its initial years of operation. The fertilizer use in the catchment area intercepted at the dam site is negligible and is unlikely to change even during project operation phase. Since, the present proposal envisages only hydropower generation and does not entail any command area development, problems of eutrophication, which are primarily caused by enrichment of nutrients in water are not anticipated. (WAPCOS)

Brahmani and Baitarani river basins have a very good forest cover which is inhabited by Asiatic Elephants. They are a schedule and an endangered species. Apart from Asiatic Elephants there are many endangered species that have been recorded in these forests. Hence, in depth ecological studies are recommended prior to recommending any structural interventions.

Baljori H E Project has river Baitarani as the major water body in the project area is, which a perennial river is. River is flowing in gorge surrounded by thickly vegetated hillocks and does not have the easy access for the fishermen. During the discussions with the fisheries department and local villagers near the site it was indicated that river Baitarani does not have good fish potential in the study area. Another river observed in the area is Tel River. The fisheries potential especially in the stretch within in this river too are not very well developed. Based on the review of existing literature and secondary data, and interaction with Fisheries Department, major fish species reported in river Baitarani in the project area include major carps i.e. Rohu, Catla, Mrigal, etc.

Pond and tank fishery is also practiced in this area. Four fishing blocks namely Ghatgaon, Patna, Thakurumundu and Anandpur fall within the study area. There are about 3200 ponds and tanks available for fish culture in the above referred four fishing blocks. Major species cultured in the ponds and tanks are Rohu, Catla, Mrigal. Likewise, silver carps and grass carps are also being cultured in few of the fishing ponds and tanks. The presence of Golden Mahaseer, which is a migratory species, too has been reported in the project area. (WAPCOS)

Amongst the aquatic animals, it is the fish life which would be most affected by the construction of the Baljori Project. The diversion of water for hydropower generation could lead to adverse impacts on riverine fisheries. The dam could act as a barrier for Golden Mahaseer, a migratory fish species, reported in the area. If there are adverse impacts suitable management measures, should be formulated.

With the construction of dam, and creation of reservoir area of 1,240 ha there will be an increased potential of reservoir fisheries. The total fish production from reservoir could be of the order of 400 tonnes/annum. The reservoir may stocked Fisheries Department. The various fish species which can be cultured include Catla, Rohu, Mrigal, etc. For development of fisheries it would be desirable to encourage this activities through cooperative societies. Some of the Project Affected People could be rehabilitated as fishermen, and can be given fishing rights for catching fish from the reservoir (WAPCOS).

Chapter 6 Enabling institutional environment

6.1 Current institutional arrangements

The water policy of Odisha was approved in 2007. The State water policy has 16 sections, and Section 10 is devoted to flood control and management. The other sections are State water plan, Institutional mechanism, Drinking water, Development of water resources for irrigation and drainage, Hydro-power, Industrial water supply, Ecology and water quality, Resettlement and rehabilitation, Groundwater development, Management of saline ingress, Participatory irrigation management, Financial sustainability, Catchment treatment, Safety of dams, and Role of NGOs.

The Odisha Water Planning Organization within the Water Resources Department is mandated to develop basin plans, following basin studies to be conducted in four phases, of which three phases have already been completed. An IWRM plan for Baitarani basin has been completed by the department. A River Basin Organization for Baitarani basin was constituted but is currently dormant.

There is not much attention being paid to the strategies for reducing the vulnerability of coastal plains to floods and to reduce the flood risk. While mangroves can play an important role in reducing the vulnerability of the coastal areas to erosion caused by floods, not much attention is given to such measures. The entire focus is on construction of flood embankments.

Central Water Commission, Bhubaneswar

The Bhubaneswar office of CWC is responsible for flood forecasting work in Brahmani basin. There are 15 hydrological observation stations maintained by CWC in Brahmani basin (CWC, 2014). The office works closely with Odisha State Water Resources Department, which prepares the flood bulletin using the flood forecast data provided by CWC, meteorological data (rainfall) provided by IMD and its own gauge, reservoir inflows and outflow data.

The office of the Chief Engineer also has one Superintending Engineer (Coordination). There are two Circle Offices under the office of the Chief Engineer, both based in Bhubaneshwar. One is the Hydrological Observation Circle and the other is Monitoring and Appraisal Directorate, both headed by one Superintending Engineer. The hydrological observation directorate, which is concerned with collection of hydrological data from the eastern rivers and Mahanadi River, has two divisions, viz., Eastern Rivers Division and the Mahanadi Division based in Bhubaneshwar and the Mahanadi Division based in Burla. Each division is headed by one Executive Engineer.

The sub-division, which looks after the hydrological observations in Baitarani River, is one of the four sub-divisions of the eastern rivers division, and this again is based in Bhubaneshwar. The other sub-divisions are Subarnarekha sub-division, Balasore; Brahmani sub-division, Rourkela; and Vamsadhara Sub-Division-Berhampur. Each sub-division is headed by one Asst Engineer. The Mahanadi division also has four sub-divisions, each one looking after one part of the basin. There are two sub-divisions for middle part of Mahanadi basin, one for lower Mahanadi and one for upper Mahanadi.

The department has developed modelling skills, particularly in the use of Mike 1.1. The flood forecasting is done using both Mike 1.1 and gauge to gauge forecasting. The accuracy of water level and inflow forecasting is reported to be high. During the year 2013, the accuracy was 92%, whereas it was 100% during the previous year. Since 2004, a total of 1859 forecasts were made by CWC for the region (1736 level forecasts and 123 inflow forecasts), and from these, 91.7% (1706) were accurate. As is evident from the flood forecast performance for Hirakud reservoir in Mahanadi, the performance had improved since its inception in 1985, when the accuracy was only 71%. In 2013, the accuracy was 98.7%.

The CWC communicates the flood forecast messages and warning based on field data from hydro meteorological stations and IMD weather forecasts to different departments including Water Resources Department.

The senior staff of the regional office had also attended National Remote Sensing Agency's training on basin-wide water resources assessment using remote sensing data (land use and land cover) and hydrological observation data (stream flows), MID data on temperature using GIS tools and mathematical models for estimation of ET.

The office had several vacant positions, though. Out of the total of 103 sanctioned positions, only 57 are filled and 46 are lying vacant as on today. Within these, the vacancies are the highest for the lower level cadre, i.e., for the Non-Gazetted posts, including Junior Engineers. Out of the total of 73 sanctioned positions, there are a total of 43 vacancies, mostly for Junior Engineer (C & M); Technical Assistant (Comm); Scientific Assistant and, Senior Research Assistant.

Department of Water Resources, Govt. of Orissa

The Department of Water Resources formulates Water Policies & Water Plans and undertakes execution, operation and maintenance of irrigation projects, exploration and regulation of ground water, flood control and drainage development, industrial water supply and command area development activities. The institutional set of WRD in Odisha is hierarchical, headed by the Principal Secretary supported by five Additional Secretaries, each with specific functions. Flood Control and Drainage is under one Additional Secretary, who also handles several other functions. One major constraint faced by the WRD is shortage of staff, especially in flood management and research.

The functions of the Department are carried out through following organizations/wings and public sector undertakings: Major& Medium schemes; Minor (flow irrigation) schemes; Ground Water Survey & Investigation (GWSI); Command Area Development (CAD); Orissa Lift Irrigation Corporation Ltd. (OLICL); Water & Land Management Institute (WALMI); and, Orissa Construction Corporation Ltd. (OCCL) (GoO, 2012). Administratively, the department is headed by a Principal Secretary, who reports to the Minister. The Engineer-in-Chief is the technical head of the department, under whom several Chief Engineers work.

There are at present three Engineer-in-Chiefs and 21 Chief Engineers. The irrigation administration in the State of Odisha is organized around river basins, and command areas of schemes falling under these basins. For large basins, there could be more than one Chief Engineer, responsible for irrigation/flood control administration, like in the case of Mahanadi basin. In addition to having Chief Engineers looking after irrigation administration, there are Chief Engineers who look after GWSI; CAD; WALMI; OLICL; and, OCCL.

Under each Chief Engineer, there are three Superintending Engineers, each looking after one Circle office. Hence, there are 63 Superintending Engineers in the OSWRD. Under each Superintending Engineer, there are 3-4 Executive Engineers, each looking after one Division. Under each Executive Engineer, there are 4-5 Asst Engineers, each looking after one Sub-division. The jurisdiction of Circle, Division and Sub-divisional offices is based on the maximum area each can command as per norms in terms of design command of irrigation schemes.

The flood control wing of the department works during June to October, every year when the rivers are likely to experience floods. There are 13 circle offices of the WRD in Orissa, which look after flood control issues, as these Circles fall in flood prone areas of the State. During the monsoon season, for all flood control related issues, these Circle offices report to the Chief Engineer responsible for flood control, based at the headquarters, which is an additional duty. Additionally, there are 33 Ex. Engineers, 96 AEEs, and 100 J Engineers/Asst Engineers. Number of field supervisors to work under the AE is decided as per the work requirements in the field, identified by the Ex. Engineer in Charge of flood control works. The organogram of Odisha State Water Resources Department is given in Figure 42.

The water resource projects in Odisha are generally planned as multiple purpose projects, and there are no dedicated flood control projects in the State. The priority is on drinking water, followed by irrigation. Flood control becomes only 3rd or fourth priority. There are a total of 7600km of flood proofing/control embankments in the state. There are four types of embankments, viz., capital embankment (flood control); agricultural embankments (test relief embankments; ring bunds (around 3-4 villages); and salinity control embankments.

The size of population impacted by floods is on the rise in Orissa, and as such flood damages and relief costs are on the rise. The flooded area correlates with flood damages and population affected. Over the ten years ending 2010-11, the relief expenditure has sharply increased, at the aggregate level and also in per capita terms. While the average flood damage cost stood at INR 784 crores (for the period 1997-98 to 2010-11), the average expenditure on relief work was INR 400 crores for the same period (MoWR, 2014).

Flood control and drainage projects are implemented by the WRD with central assistance, under RIDF (Rural Infrastructure Development Fund) and Flood Management Programme (FMP) of Government of India. Under RIDF, loan is advanced by NABARD (National Bank for Agriculture and Rural Development) to the State government, and for the FMP, central assistance is available to Orissa state in the proportion of 75: 25, with the state contributing 25% (GoO, 2012)[2] . In addition, there are funds from JBIC and state budgetary allocation. The fund allocation for flood control work has increased over time.

Expenditure for relief and recovery are complemented by expenditure for flood prevention measures, largely the construction and raising and strengthening (R/S) of embankments through the WRD. The overall WRD budget also shows a sharp increase over the last ten years. Substantial funds are allocated to flood management infrastructure. The capital expenditure on flood prevention and control went up from nearly INR 40 crores in 1998-99 to 140 crores in 2010-11. Against this, the annual revenue expenditure went up from INR 20 crores to 60 crores during the same period.

[2] A total of 67 flood control and 16 road projects with an estimated cost of INR 355.03 crores has been taken up under this programme. By end of December 2010, 19 flood control projects and 5 road projects have been completed an amount of INR 110.74 crores had been spent. Besides this, 33 new projects amounting to INR 193.61 crore were approved for inclusion under RIDF-XVI. An outlay of INR 77.39 crore was proposed in the budget for 2011-12 for execution of on-going and new projects. A total of 29 flood control projects with estimated cost of INR 135.75 crore have been taken up under FMP. By end of March 2010, 25 projects were completed. It was also programmed to complete 3 projects in 2010-11 and 1 project in 2011-12. An outlay of INR 33.50 crore had been proposed in the budget of 2011-12 for these works.

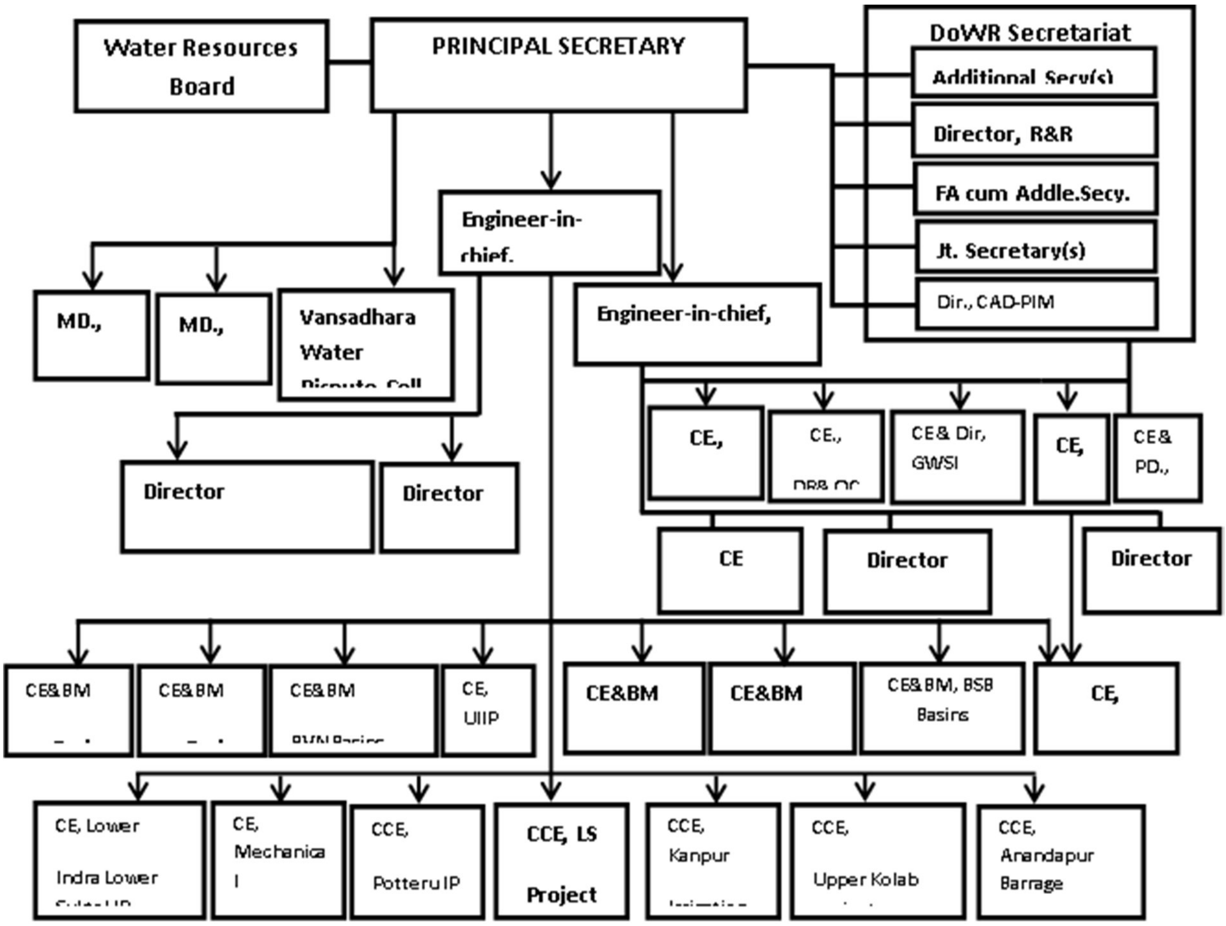

Figure 42 Organogram of the Department of Water Resources, Odisha

Flood forecasting and flood control: There is a Flood Management Information Systems Cell within the Department of Water Resources located within the HQ of WRD, headed by Director in the rank of Superintending Engineer. The Cell carries out flood forecasting work, including inflow and level forecasts using gauge to gauge forecasting based on stage relation curves of different water level gauging sites for selected basins. The limitation of gauge to gauge forecasting in situations for carrying flood discharges is quite well recognized by the department. But, the gauge forecast sites are maintained by CWC, and WRD of the state only supplement their data, and do cross checking of the data.

The department receives data through SMS from different reservoirs on inflow, outflow and probably gauges. Within the Brahmani basin, there are a total of 16 gauging stations, including one discharge gauging station maintained by the Odisha State Water Resources Department. Both inflow forecasting and gauge forecasting are done for Brahmani-Baitarani basins. The Brahmani-Baitarani basin has a large estuarine area, where the river meets the Bay of Bengal. Inflow forecasting is done for Rengali reservoir. The reservoir has a flood cushion of 2 metres, which amounts to total of 730 MCM of water.

Flood warning: Based on rainfall forecasts received from IMD, WRD estimates flow discharge, and flood warning are issued to 74 agencies, dept. or individuals, through bulletins issued every day during the monsoon for important basins. The bulletin contains among others the data on rainfall of the previous 24 hours, the inflows and outflows in the reservoirs and the water level forecasts for the next 24 hours. However, the cell uses the flood forecast information generated by the CWC for the flood bulletin, which is circulated among 74 key government officials and departments, including the Chief Minister and Minister for Water Resources. The Flood Management Information Systems Cell has professionals trained in Mike 1.1 model. There are four PhD's in the department of whom four are trained in the use of flood inundation models.

Flood preparedness: After 2001 floods, embankment strengthening is being done, raising their heights. A total of nine criteria are used for identifying weak and vulnerable embankments and short and long term measures are taken for flood proofing (GoO, 2008). There is regular maintenance of dams and embankments. There is special Chief Engineer, based at the HQ who looks after dam safety[3] . During the month of May every year, The Chief Engineer and basin manager, Lower Mahanadi basin reviews the position with regard to vulnerable locations using the nine criteria. During June 1 to June 30, report is given to the WRD's headquarters about the conditions of the dams and embankments, pertaining to safety aspects.

During natural calamities, the Chief Secretary of the State calls emergency meeting of various concerned departments, viz., WRD, revenue department, energy dept., disaster management dept., agriculture dept. and livestock dept. twice a day to take stock of the emergency situation. Information is passed on to Special Relief Commissioner, who coordinates the work of Odisha State Disaster Management Authority (OSDMA). During the period of emergency, there is a high level coordination established with CWC, OSDMA and IMD.

It is the responsibility of the Water Resources Department of Odisha to collect flood fighting materials such as sang bags, bamboo bullahs, bamboo coir mat etc., and stacks them at strategic locations for use in the event of breach or damage to the embankment. Additional materials should be ensured in consultation with private suppliers (GoO, 2008).

As regards training and capacity building, there are no community awareness programmes being undertaken by the department when it comes to flood proofing and flood preparedness. The awareness programme is within the domain of the Water Users Association, whose work nevertheless is not limited to flood related matters alone. The department occasionally send its staff to National Water Academy for trainings. The decision to depute staff however, is taken on the basis of the training calendar of NWA.

Odisha State Disaster Management Authority (OSDMA)

The Odisha State Disaster Management Authority came into being after the super cyclone of 1999, which hit Odisha coast, and much before many states had set up their own disaster management authorities, following the passing of National Disaster Management Act of 2005. The Odisha State Disaster Management Authority is a society registered under the Societies Act.

The OSDMA is an organization created for 'disaster preparedness' and 'response'. The disaster preparedness is achieved through capacity building programmes and implementation of structural interventions such as flood and cyclone shelters. The capacity building programmes also include 'flood preparedness' and 'mitigation of flood impacts. The authority has a Disaster Response Force, which is involved in field level rescue operations along with training and capacity building of various

[3] The State WRD takes care of a total of 10 major dams, 45 medium dams and 144 minor dams.

line agencies involved in emergency relief works such as fire department, paramedical services, and the home department.

The governing body of OSDMA is chaired by the Chief Secretary of the State government of Odisha. The Secretary of the governing board is the Managing Director of OSDMA, under whom three senior officials, viz., Ex. Director-Administration; Ex. Director-Finance; and Ex. Director-Projects work. Under each Ex. Director, there is one Chief General Managers, General Managers, DGMs, Managers and Consultants (service providers). The agency has a total of 74 managerial staff.

The OSDMA has large annual budgets, totalling roughly INR 2200 crores at present. It works on project basis and has funding from the World Bank, Chief Minister's relief fund, etc. A large chunk of the funds get utilized for structural interventions such as flood/cyclone shelters, embankments, equipment for ODRAF and housing.

The Odisha State Disaster Response Action Force (ODRAF) is constituted by police personnel, who report to a Deputy Director General of Police (Law and Order), who acts as the nodal officer for rescue and relief operations to be undertaken by ODRAF. The ODRAD has 10 units, each having strength of 40-50 police personnel. The Chief General Manage-Projects of OSDMA looks after the ODRAF. The ODRAF works in coordination with the Special Relief Commissioner, govt. of Odisha and the Managing Director of the OSDMA.

The response is categorized into five groups, viz., water related; structural collapse; medical first response; relief line clearance; and miscellaneous. The various special equipment, available with ODRAF, are: inflatable rubber boats; inflatable tower light; chain saw; concrete cutters; chipping hammers; submersible pumps; 150 KVA generators; 100 scuba divers; and, medical first response kit. More than 500 people are trained in the response action force and fire force every year by the OSDMA. A total of 24 line departments of the State government are involved in disaster management work, and OSDMA can leverage their strengths and mobilize their human resources and equipment through the Special Relief Commissioner. The OSDMA takes decisions on matters concerning the equipment for disaster rescue and relief.

OSDMA is working very closely with the regional office of UNDP in Bhubaneswar, which is providing technical support to the agency in activities related to disaster preparedness. UNDP has undertaken flood inundation mapping studies for the coastal areas, covering an area of 2644 sq. km from Kendrapada district, which is the vulnerable district in Odisha so far as floods are concerned. The study is being supported by National Remote Sensing Centre (NRSC). Currently, NRSC is able to provide remote sensing data at a periodicity of 4-5 hours, which can be used for preparing flood inundation maps and rescue operations.

Odisha State Disaster Management Department

Overseeing of relief operations during disasters including floods is the responsibility of the Disaster Management Department and the Revenue Dept. At the district level, the Collector monitors and coordinates the Disaster Management Activities. These departments coordinate with line departments such as Dept. of Water Resources, Health Department, Rural Development Department, Energy Dept., Panchayat Raj Department, Housing and Urban Development Dept., Information and Public Relations Dept., and Home department. The assistance of Central government

6.2 Community needs to support IFM plan/Proposals to mainstream community needs into IFM

The institutional arrangements for DM activities at state level and its coordination with districts in Odisha is reasonably well structured with well-defined Standard Operating Procedures (SOPs). This is institutionalized through the national DM Act and policies developed since 2005. However, even though there are efforts taken to institutionalize DM activities at sub district level, it needs further strengthening. It is important to strengthen the last mile connectivity to ensure that communities benefited as per the project envisaged objectives.

Based on the community issues and needs identified and explained in section 2.3.1, following are the proposals for mainstreaming community needs into IFM. A framework for strategy matrix for community involvement in IFM is provided in the volume 6 - Community report.

1. Consultation during flood management planning: Even though designing and implementing structural mitigation projects is more a mandate of the department and community can provide 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 considered 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. It needs training and capacity building of local body administration to steer GramSabha meeting to integrate DM into development planning.
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 emphasize 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.
6. Knowledge dissemination of adaptation and mitigation measures: There are efforts at the community level as well as private sector support for developing adaptation and mitigation strategies to protect community livelihoods. These include promoting flood, drought, and saline tolerant crop varieties to ensure returns from agriculture even when there are disasters. Short duration crops need to be promoted and need to be cultivated monitoring the flood season .
7. Demonstrating pilot plots to encourage community to adopt adaptation strategies: Agriculture department should demonstrate (farm-based demonstration) introduction of crops suitable for adopting in water logged and saline soil conditions.
8. Farm advisories: The state lacks farm advisories, which can provide farmers to plan for the whole season. There should be farm advisories, which are accessible to rural farm communities. This should be reliable and should forecast rainfall and other critical weather parameters in advance so that farmers can plan their agriculture calendar.

Chapter 7 Conclusions

7.1 Structural measures

We saw in Section 4.1 that that providing a safety of 1:25 years reduces the risk with 86%. This underpins the current recommended safety level according to the Guidelines of the National Flood Commission of 1980. The question that remains is how to effectively reach this safety standard.

Considering the various measures discussed in this report, a River Basin Flood Management Plan should constitute a mix of these. Because the structural measures are most capital intensive, a thorough evaluation of their costs and benefits is required before a decision can be made. In the table below the key figures of current and future flood risk is provided for a 1:25 year rainfall event. It shows that the combination of structural measures would reduce maximum flood area with 35% and would reduce the subsequent damage with 28%. The Annual Average Damage (for this return period) would go down from INR 190.6 crores to 137.4 crores. This is the yearly benefit of these projects for flood mitigation alone. Using these data a cost-benefit analysis can be made for such projects.

Table 26 Overview of flood risks and impact of structural measures in Brahmani-Baitarani as computed

1:25 yr flood	Current	CC 2040	CC2080	Reservoirs Rengali + Kanupur	Embankment improvement	Combined
Max. flood area (km2)	3151	3933	4070	2656	2617	2057 (-35%)
People affected (Lakh)	45.0	51.1	52.4	41.0	44.0	33.8 (-25%)
Damage (INR Crores)	4766	5795	6085	4094	4624	3436 (-28%)
AAD (INR Crores/yr)	190.6	231.8	243.4	163.8	184.9	137.4 (-28%)

For instance, we could calculate the benefit in terms of avoided annual damage for improving flood control with the two reservoirs (Rengali and Kanupur), as being 190.6 – 163.8 = 26.8 crores per year. This would justify an investment of around 300 crores (calculated net present value with 8% discount rate over 30 years).

7.2 Towards a River Basin Flood Management Plan

The analysis in the previous chapter discussed the features and feasibility of the structural and non-structural measures separately. Because a River Basin Flood Management Plan should consist of a well balanced mix of all of these measures, the next step in preparing such Plan consist of a comparison between measures using a set of criteria. These criteria should be selected during the planning process by the responsible agencies (for instance a River Basin Organisation) in due consultation with all stakeholders. To illustrate how this evaluation can look like, 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 27 Multi-criteria analysis for flood risk mitigation measures

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 reaches 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 nonstructural 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.

Based on this preliminary multi-criteria analysis it is advisable to start flood warning and community DM activities as soon as possible as they can be considered as no regret measures (low investment and high results). Most of the other measures that require substantial (government) investments need to be prioritized further based on more detailed cost-benefit analysis and a collectively agreed set of evaluation criteria.

Because of the operational research character of this study, the above evaluation is indicative only but can be used as input to a formal planning process for the basin. Such planning process can use the information from this report, together with the available flood model, to create a sound knowledge base for all stakeholders. This knowledge base can then be enriched with more specific local knowledge through a joint fact finding phase. During this phase also the evaluation criteria need to be agreed upon by all stakeholders.

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Appendix A Prefeasibility design with costing for urban drainage system

Based on the site visit made to Jajpur a prefeasibility design is proposed along with costing. Tables A-1 and A-1a to f display the costing and detailed breakup for each component. Further recommendations, which depend on available funding with State officials are mentioned in the following sections. They are important elements regarding efficient urban drainage and are included in this report considering their usefulness to abate the existing situation.

Control of Garbage

There is a significant amount of garbage accumulation in the drains of the study area. These accumulations are not only unsightly, but also restrict the hydraulic capacity of the drains and aggravate flooding. This menace cannot be avoided totally even if there is an organised system of solid waste management. However to restrict direct access to the main drains, they can be protected by a fence of MS BRC (IRC) fabric. The structural design will include the following:

- MS welded rectangular fabric mesh of 75mm X 25 mm.
- On two sides of drain the mesh will be placed vertically for a height of 2.5 m and then inclined outside for 0.75 m.
- This mesh will be stiffened by MS angles and flats.
- The span of each mesh panel will be 3 m c/c.
- On two sides the panel will be supported by 200 X 200 RCC posts which will be supported on drain top wall.
- The reinforcements will comprise of 4 nos-12mm Tor to be braced with 10 Tor transverse reinforcements @ 150 mm c/c
- The posts will be constructed monolithically from the drain wall.

Pump Station

Drainage pumping stations are necessary for the removal of storm water where gravity drainage is not possible or impractical. Therefore, the use of drainage pumping stations is recommended only where no other practicable alternative is available by gravity. The primary function of the pumping stations is to pump water out of the drains when gravity flow is not possible during the monsoon season when the rivers are high and the sluice gates are closed.

Inlet channel with sluice gate and trash rack

Since the pumping stations will be located off the main drains an inlet arrangement will be necessary. Such an arrangement will include a channel from the main drain to the wet well with a sluice gate at the transition from the main drain to the inlet channel and a trash rack at the entrance to the wet well.

The sluices gate will be automatically operated with a motor actuator and will normally be in the closed position. The gate will be opened when the water elevation in the main drain reaches a prescribed level. The sluice gate can also be used to isolate the pumping station for maintenance or repair purposes.

The inlet channel will be of reinforced cement concrete (RCC) construction and sized to carry the peak design flow at velocities less than 1.5 meters per second (m/s). Generally, the invert elevation of the entrance of the inlet channel will be 0.5 meters above from the bottom of the drain.

At the end of the inlet channel a trash rack will be located to catch debris and protect the pumps. The trash rack will be inclined at 15 degrees from the vertical and have 20 mm flat steel bars spaced 25 mm on center. It will be manually cleaned.

Wet Wells

The wet wells for the drainage pumping stations need to be large enough to provide the necessary flow to the pumps so they do not start and stop too frequently and so there is adequate room for the pumps to operate and not create turbulent flow with cavitation. There will be adequate flow to the pumps since they will only operate when the main drain system is filled to a predetermined level.

Under these conditions the entire drainage system will act as an extended wet well and the pumps will function to prevent the water from rising to flood level. The wet well will have a common flow distribution chamber that will distribute the flow from the inlet channel to the individual pumps. Each pump will be in a separate chamber open to the distribution chamber and separated by baffle walls which will dampen turbulence in the suction zone when one or more pumps is running.

The following criteria apple to the Wet Wells:

- The distribution chamber will have velocities of less than 0.9 m/s at peak design flow
- The minimum wet well size will be the volume discharged at peak flow for 30 sec.
- The minimum horizontal clearance around the suction end of the pumps will be 1.2 m
- The minimum clearance below the suction end of the pumps will be 0.5 m
- The minimum water depth (head) above the suction point will be of 1.5 m

Pumps

Vertical axial flow propeller or vertical mixed flow impeller type pumps are suitable for flood control pumping stations. These pumps are high volume - low head types well suited for flood level control applications. These types of pumps can be equipped with diesel engines, electric motors or a combination of both for each pump. The engine or motor is mounted above the high water level with the pump installed in a wet well. The axial flow pump specifies a pitch or angle of the propeller blades while the mixed flow pump specifies an impeller diameter trimmed to match the design point.

Prime Mover

Electric-driven pumps are often installed with a single main electric service and stand-by generator(s) for back-up power. In the study area, the reliability of power during flood condition is uncertain. In addition, the service provider connection fees for the electrical service will be cost prohibitive for large capacity pumping stations that will only operate periodically during the monsoon season. For these reasons the more reliable diesel driven pumps are recommended for the drainage pumping stations.

Diesel fueled internal combustion engines will be used for the pump drives. Engine drives offer the advantage of variable speed as the engine can be throttled, which is a further benefit when compared with electric motors that operate at a constant speed unless variable frequency drives are included.

Discharge System

The discharge line from each pump will enter a manifold which will combine the flow into one pipe. This pipe will be discharged through an energy dissipater to the rivers or canal at an elevation 1 m above high water. Gate valves and air valve will be located on each individual discharge line and connected to the one discharge line from the manifold. The discharge line will be Ductile Iron (DI) material and energy dissipaters will be of RCC construction.

Table A-1: General abstract of cost for storm water urban drainage for Jajpur

Description	Amount in lakhs of Indian Rupees
RCC Outfall drains	1,388.53
Trapezoidal drains and appurtenant works	2,309.49
Culverts	517.95
Covering of outfall drains with RCC slabs	1,395.94
Proposed internal drains	3,751
Renovation of existing internal drains	1,463.4
Hiring of godown	2.4
Land acquisition	200
Sub total	11,028.71

Table A-1a: Abstract of cost of proposed RCC outfall drains

Description	Unit	Rate in rupees
Excavation of earth including ramming of excavated earth into trenches		
0 to 1.50 mbgl	M^3	157
1.50 to 3 mbgl	M^3	178
Providing and laying cement concrete 1:4:8	M^3	2,144
RCC work with cement approved coarse sand and 2cm gauge. Including fixing and binding with wire.	M^3	5,181
RCC work in walls up to floor five level.	M^3	5,328
MS or iron in plane work	Quintal	6,760
Disposal of earth	M^3	135

Cost of cutting trees	Lumpsum	75,000
Traffic diversion and signage	Lumpsum	1,50,000
Cutting road and making good the same		
Bituminous road	M^3	1,081
Cement concrete road	M^3	4,706

Table A-1b: Abstract of cost of cost of outfall drains- (trapezoidal sections) and appurtenant works

Description	Unit	Rate in rupees
Excavation of earth including ramming of excavated earth into trenches		
0 to 1.50 mbgl	M^3	157
1.50 to 3 mbgl	M^3	178
Providing and laying cement concrete 1:4:8	M^3	2,144
1st class half brick masonry with 1:4 cement mortar	M^2	319
Providing and laying cement concrete 1:2:4 in bed of drain	M^3	3,409
Brick work of class 75 inches foundation and plinth with cement mortar 1:6	M^3	2,516
12 mm cement plaster mix 1:4 on side and exposed surfaces including labour	M^3	83.3
Disposal of earth	M^3	135
Dismantling of existing culverts etc	Lumpsum	300000
Traffic diversion and signage	Lumpsum	300,000
Shifting of telephone and poles falling in the alignment of proposed drains	Lumpsum	300,000
Providing protection works like toe walls at various disposal points of drain to Jokai Nala	Nos	75000
Diversion of existing drains during construction at various intercepting points	M	750
Cutting road and making good the same		
Bituminous road	M^3	1,081
Cement concrete road	M^3	4,706
Filling dry brick ballast in existing drain bed		
3000mx2mx0.5m	M^3	869
Intercepting internal street drains and joining the main external storm water drain with necessary brick work and plaster. Including labour	Nos	4,000
Desilting Furdooh Nala of 11km length approx.		

Making temporary earthen bundha for pumping out water	Lumpsum	300000
Desilting of drain	M^3	178
Strengthening of side slopes	Lumpsum	1,650,000
Cross drainage works under existing railway track	Lumpsum	2,250,000
Cross drainage work under existing state/ national highway	Lumpsum	2,250,000
Special repairs of anti flood at existing sluice gates at various points of stormwater disposal in Baitarani river	Nos	1,50,000
Construction of pumping houses including supply of pumps. Boundary walls and generators for 100% power. Including labour	Nos	18,750,000

Table A-1c: Estimate of proposed internal drains

Description	Unit	Rate in INR
Construction of internal drains including material and labour	Km	3,00,000
Shifting electrical/telephone lines	lumpsum	1,00,000

Table A-1d: estimate of the renovation of existing internal drains

Description	Unit	Rate in INR
Cleaning works of the existing internal drains filled with plastic bags. Desilting solid/semisolid garbage and disposal of the same.	Km	40,000
Renovation works of existing drains to ensure proper flow of stormwater. Including labour and materials	Km	1,50,000

Table A-1e: estimate of hiring godown

Description	Unit	Rate in INR
Hiring of godown for storing cement, steel and other items necessary for the period of execution of works	Month	10,000

Table A-1f: estimate for land acquisition

Description	Unit	Rate in INR
Land for the construction of pumping station with appurtenant works at outfall locations	M^2	5,000