Climate Change Adaptation in Water Sector

(Application of Modelling in Water Sector)

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Climate Change

Why it happens?

Is it a new problem?

How it affects Water System?

What to consider in Modelling of WRS?

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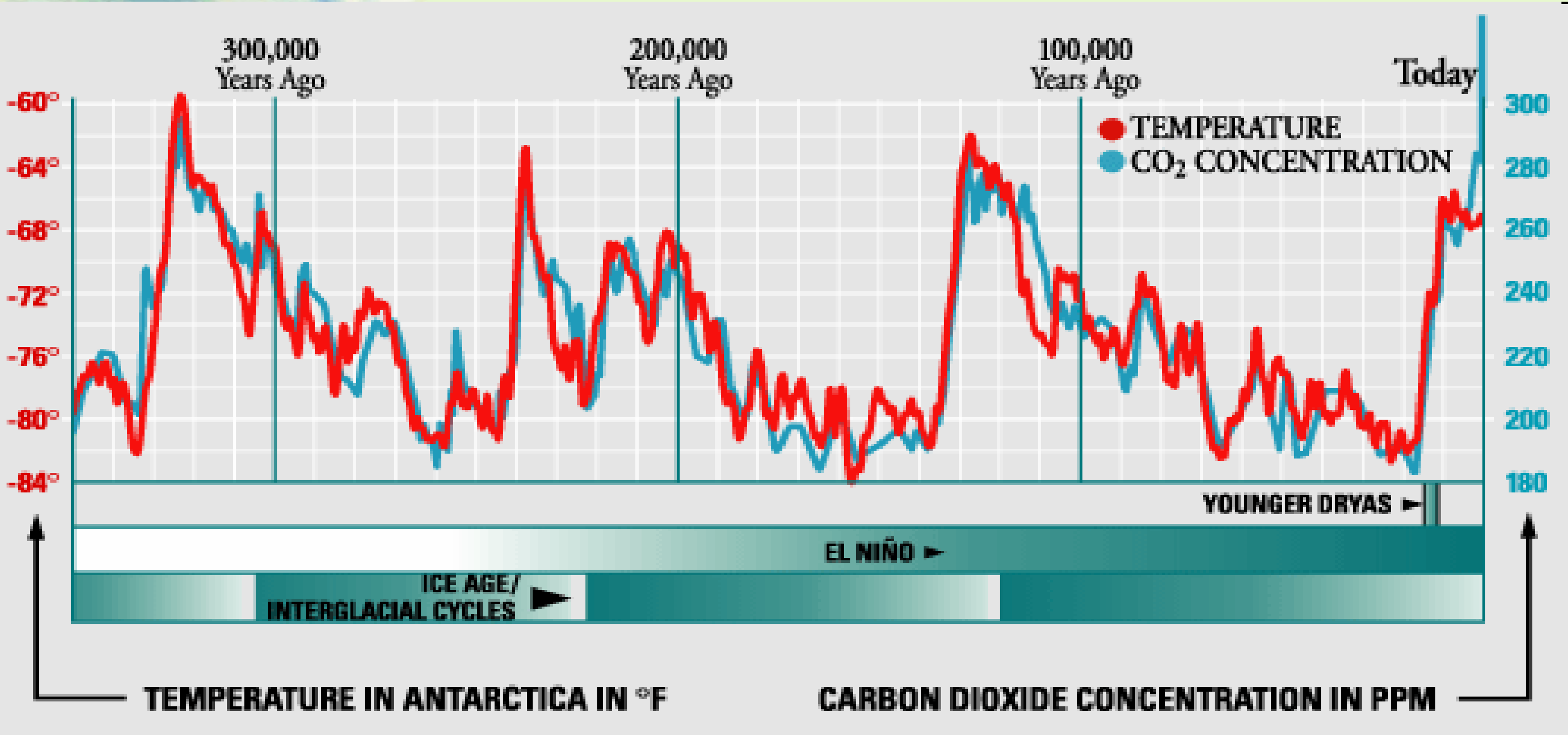
Why it happens?

Climate change may result from both natural and human causes.

– CO_2 and Other Greenhouse Gas Variations
– Ocean Circulation
– Volcanic Eruptions
– Solar Variations
– Orbital Variations
– Land Use Changes
– Human Activity and Greenhouse Gas

Climate Change Cycle



Based on ice cores drilled in Vostok, Antarctica. It shows temperature changes near the South Pole

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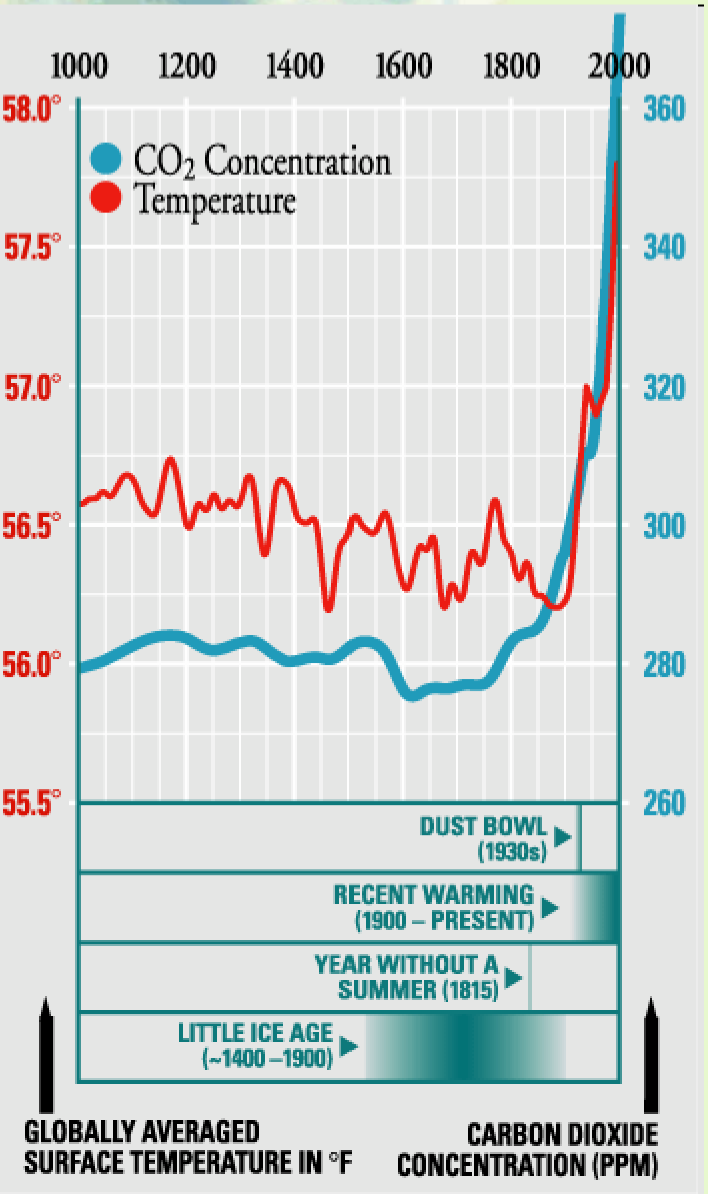
Recent Event



•Since the 1900s global average temperature and atmospheric CO2 concentration have increased dramatically, particularly compared to their levels in the 900 preceeding years.

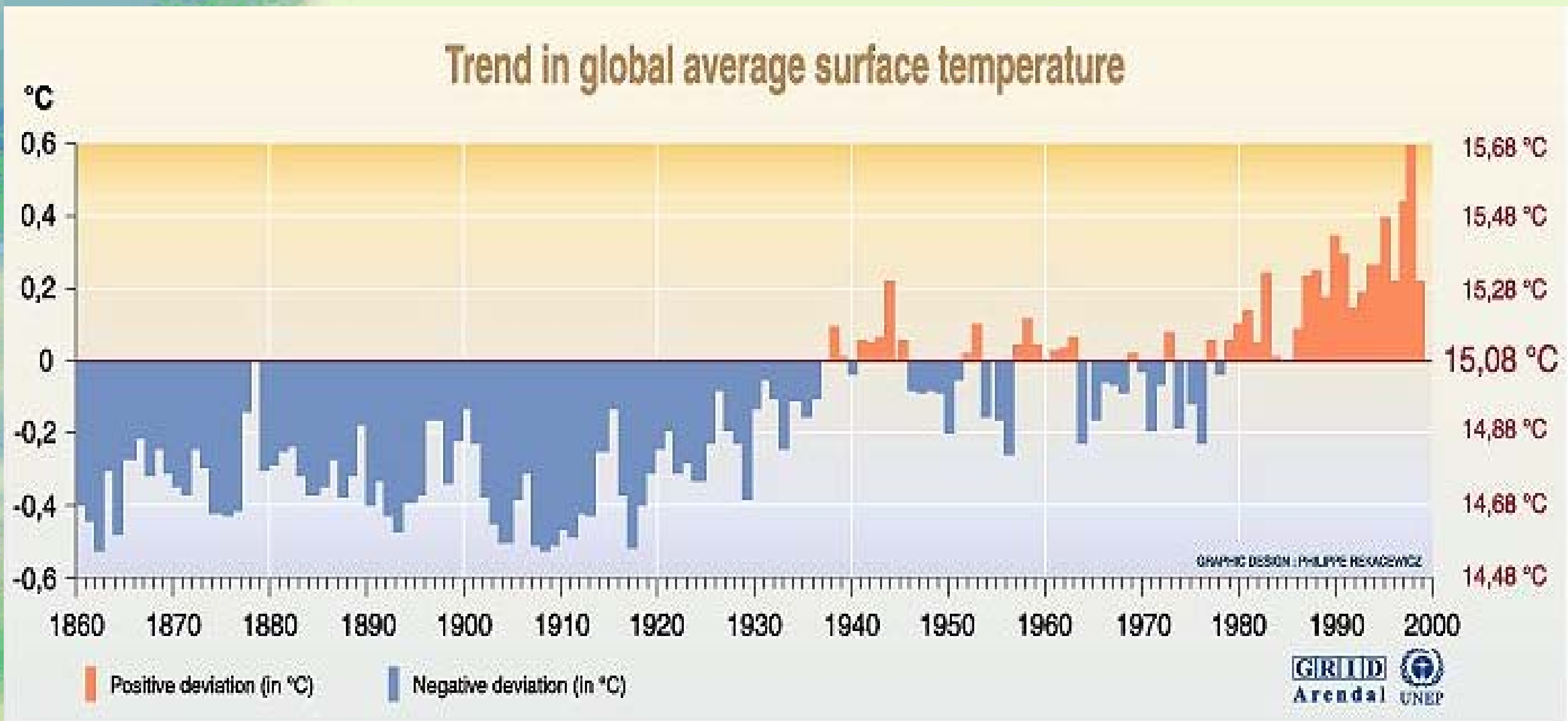
•The rapid rise in both surface temperature and CO2 is one of the indications that humans are responsible for some of this unusual warmth.

•This graph is based on data from tree rings, coral and ice cores, and historical records. It represents only the Northern Hemisphere.

• the modern temperatures are generally greater than during the past several hundred years.

Effects of Climate Change

Primary Effects: Global Warming which causes
-changes in Temperature and Precipitation



Source: School of environmental sciences, climatic research unit, university of East Anglia, Norwich, United Kingdom, 1999.

Secondary Impact – Sea Level Rise, Coastal Inundation and Salinity Intrusion

Relative vulnerability of coastal deltas as shown by the indicative population potentially displaced by current sea-level trends to 2050

Extreme = >1 million

High = 1 million to 50,000

Medium = 50,000 to 5,000

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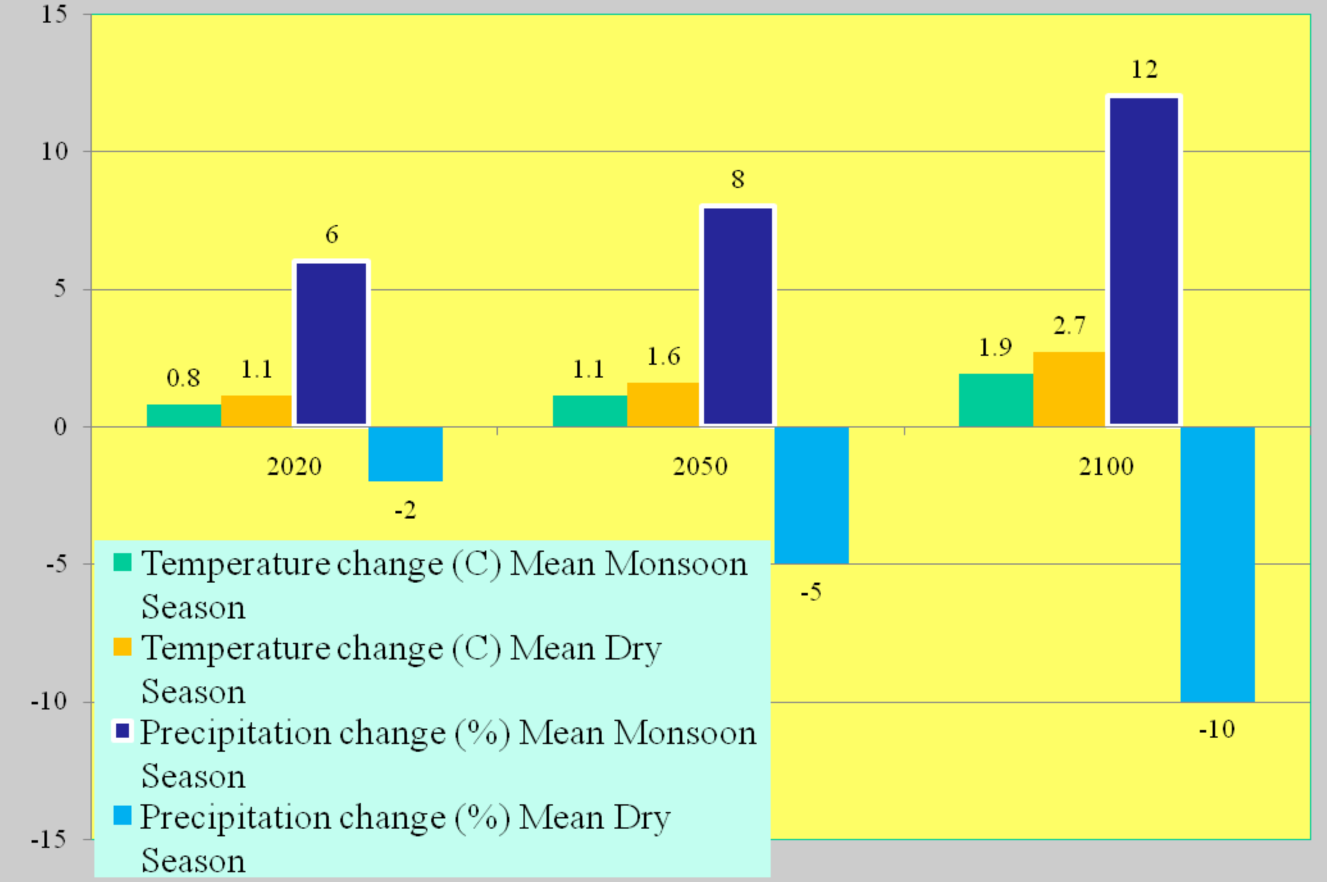
Source: IPCC 4th Assessment Report, 2007



Primary Impacts

Bangladesh:
Change in Temperature and Rainfall

National Adaptation Plan for Action (NAPA)

- ➢ Wet season will be more wet (2 floods in 2007)
- ➢ Hot season will be more hot
- ➢ Dry season will be more dry

Year	Temperature change (^{0}C) Mean		Precipitation change (%) Mean	
	Monsoon Season	Dry Season	Monsoon Season	Dry Season
2020	0.8	1.1	+6.0	-2.0
2050	1.1	1.6	+8.0	-5.0
2100	1.9	2.7	+12.0	-10.0

Secondary Impacts

- Flooding
- Drainage congestion
- Droughts
- Sea Level Rise

Changes in all above are happening in Bangladesh

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How it affects Water System?

- Increase in number and extent of floods and erosion
- Longer period of floods due to increased precipitation in monsoon and rising sea level
- Increase in period of drought due to reduced rainfall in winter
- Increase in number and intensity of cyclones, tropical storms
- Sea Level Rise

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What is Modelling of Water System?

Representation of the behavior of water system under certain conditions

-Physically
-Mathematically

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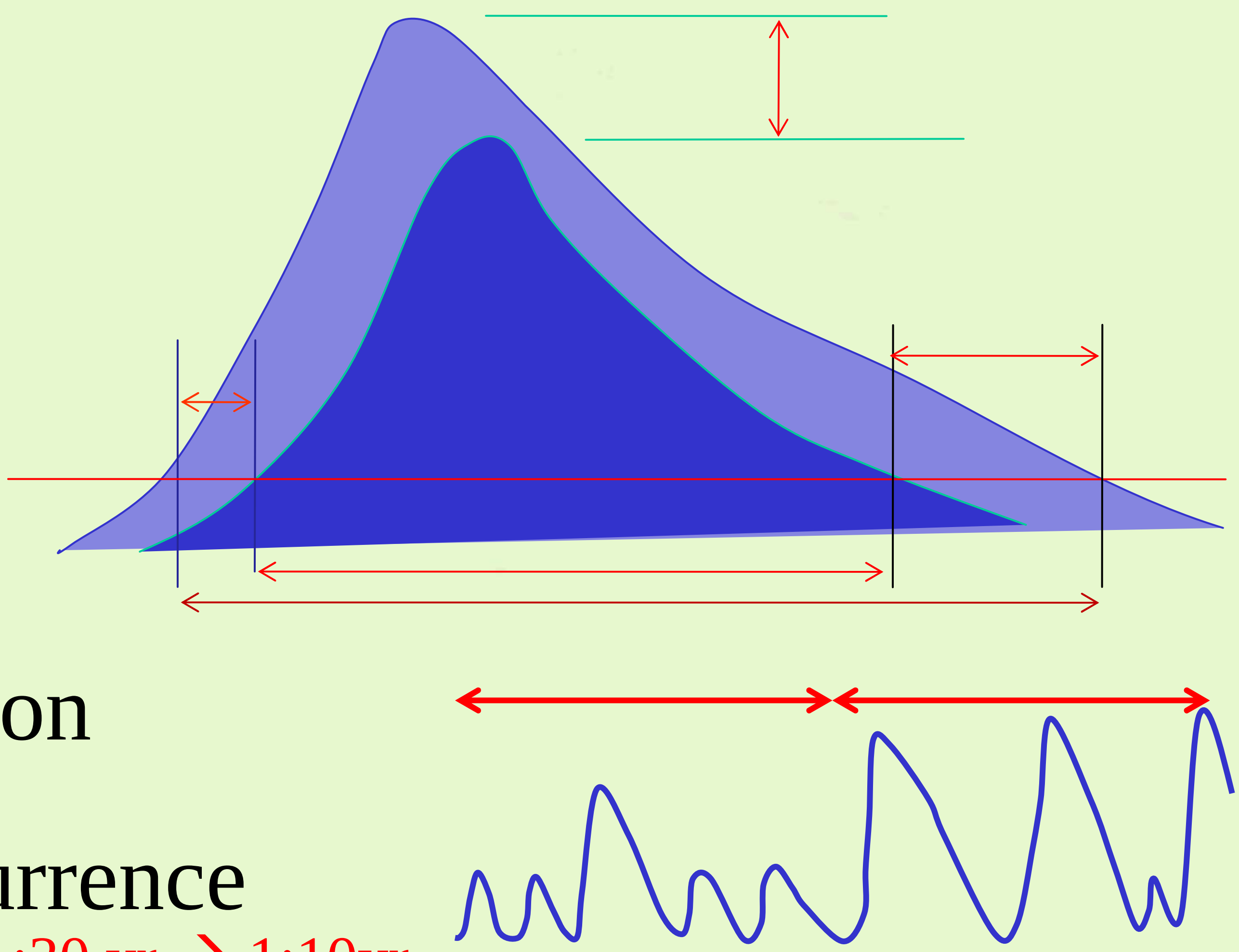
Climate Change Effect on FLOOD

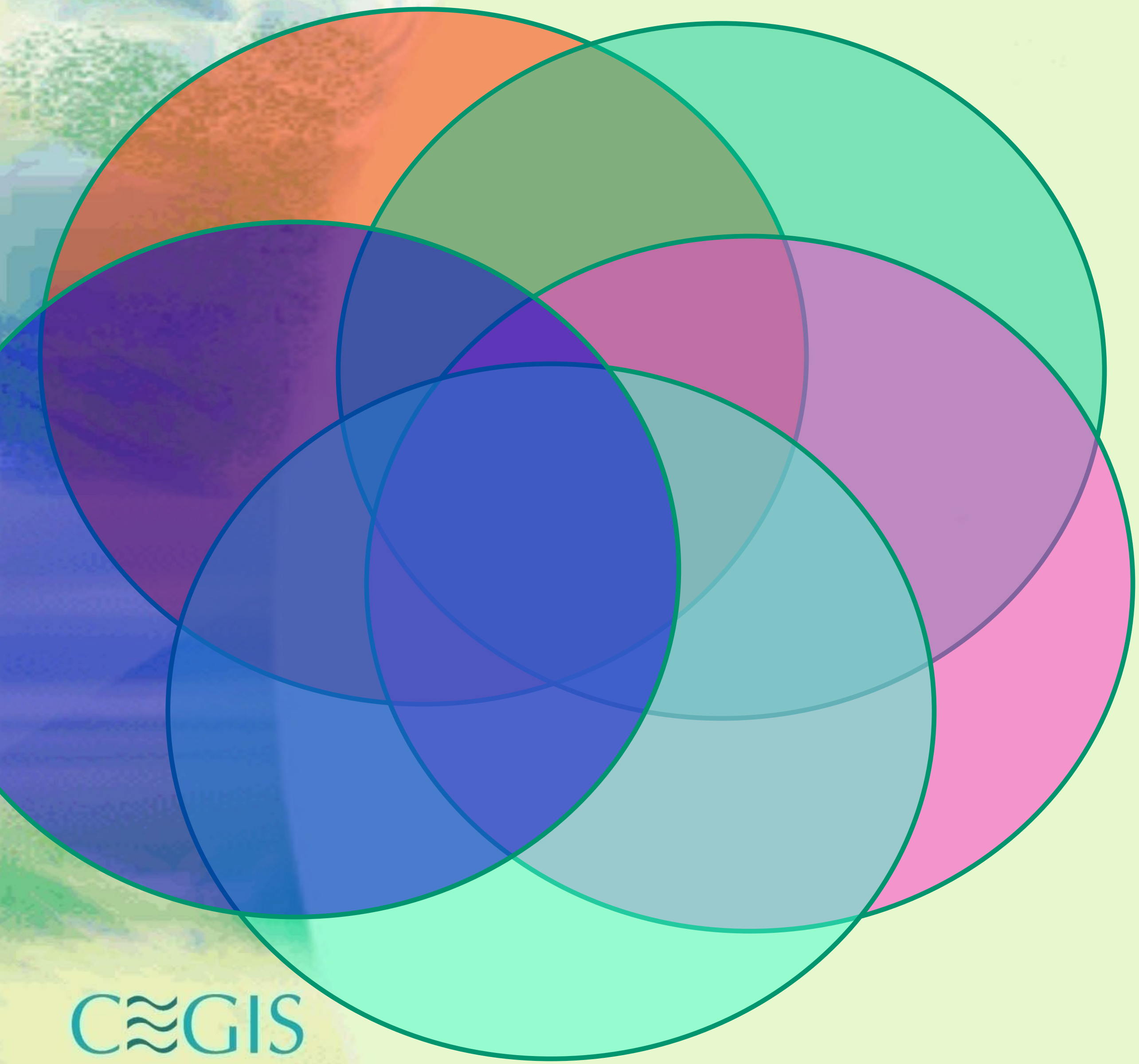
- Onset
- Peak
- Duration
- Recession
- Recurrence



High peak, long duration flood is coming more frequently

- huge impacts on lives, livelihoods, development, economy

Flood Complication due to CC



- High peak
- Longer duratio
- Early/delayed onset
- Slow recession
- More frequent

More Complication

Flood + Drainage + Rainfall + Drought + Temp + Cyclone + SLR + Erosion +

\+

CROP Calendar

Development Interventions

Policy/Politics…

Secondary Impact – Floods

Bangladesh

- The onset and withdrawal of the peak flows are shifting.
- Flow records over past 50 years for the station Bahadurabad (Brahmaputra/Jamuna rivers) shows: peak discharge is increasing and is peaking earlier.

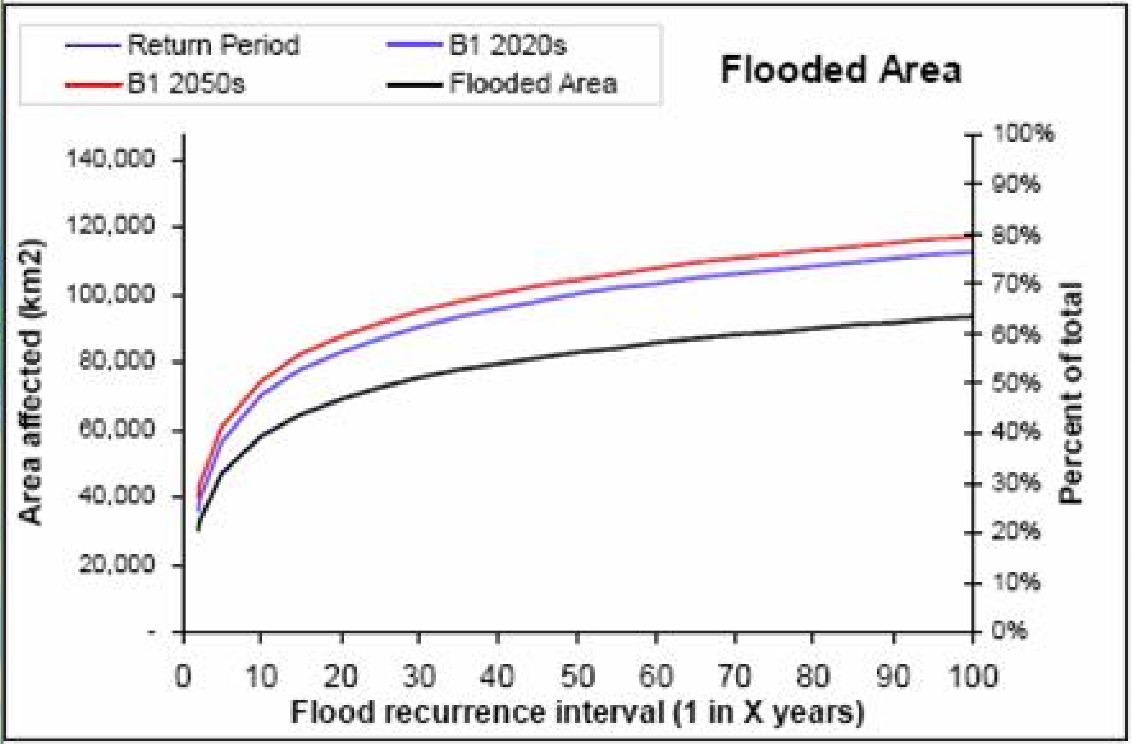
The estimated change in inundation categories under mean value of IPCC SRES scenarios in the year 2050s:

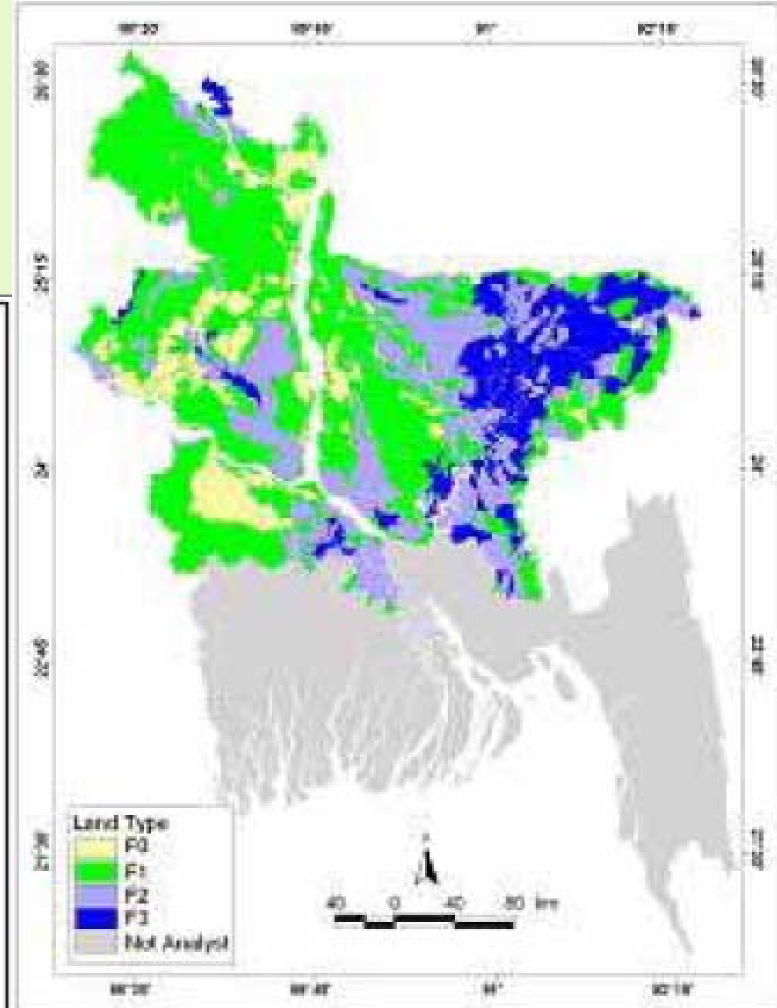
SRES scenario	Flood free area	Moderate flooded area
A2	57% decrease	about 51% increase
B1	63% decrease	about 82% increase

Source: ORCHID, 2007

Secondary Impact:
Floods

Bangladesh





(d) SRES B1 (2050)

Flooded Area in Bangladesh: Present & Future Scenario

Spatial Distribution of Flood extent and depth for mean IPCC SRES A2 and B1 Scenarios for the year 2020s and 2050s excluding the coastal area of Bangladesh.

Source: ORCHID, 2007

Secondary Impact – Sea Level Rise, Coastal Inundation and Salinity Intrusion

Bangladesh

Effects of Sea level rise

- **Increase in inundated areas of up to 3% (2030s) and 6% (2050s): Primarily in coastal low lying areas (ORCHID, 2007)**
- **Salinity intrusions along much of the coastline: Rates of intrusion vary with local conditions and are strongly influenced by dry season river flows and the rate of SLR.**

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Secondary Impact – Sea Level Rise, Coastal Inundation and Salinity Intrusion

Bangladesh

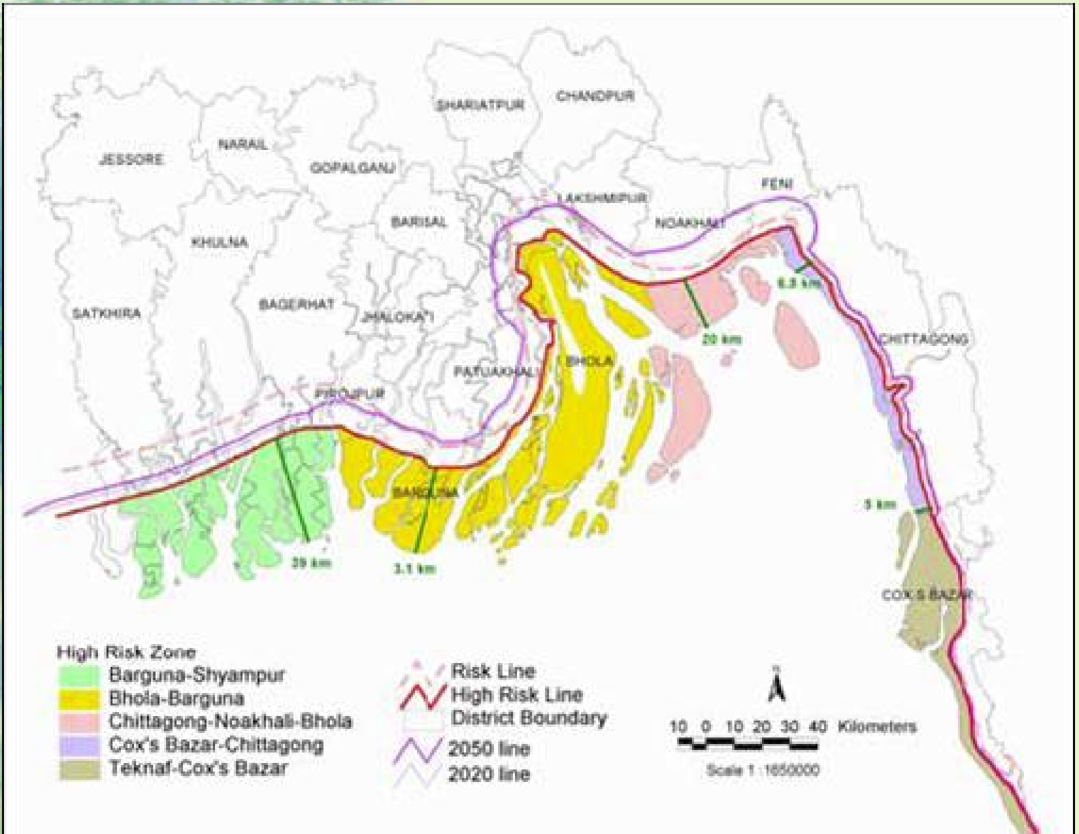
Inundation Due to Sea level Rise in coastal areas of Bangladesh

	Monsoon Season		Dry Season	
Scenarios	Inundated area, [ha]	Increase in inundation area	Inundated area, [ha]	Increase in inundation area
Base	1,720,200 [50%]		404,500 (12%)	-
B1, Yr 2080 (SLR 15cm)	1,863,600 [54%]	4%	Insignificant change	-
A2, Yr 2050 (SLR 27cm)	1,972,200 [57%]	7%	559,100 (16%)	4%
A2, Yr 2080 (SLR 62cm)	2,189,200 [63%]	13%	768,600 (22%)	10%
A2, Yr 2080 (SLR 62cm+10% rainfall)	2,271,700 [66%]	16%	Not Applicable	

Source: CEGIS & IWM, 2006

Secondary Impact – Cyclone and Storm Surge

Bangladesh



Source: NAPA, 2005

Changes in cyclone High Risk Areas for current conditions, the 2020s and the 2050s. Only worst case examples included – highest warming

- **Bangladesh is hit by about 0.93% of the world's total tropical storms**
- **About 53% of the total world deaths due to tropical cyclones occurred in Bangladesh (Ali, 1999)**

✓ **The cyclone High Risk Areas (HRAs) of 8900 sq km will increase by**
- ✓ **35% in the 2020s**
- ✓ **40% in the 2050s**

✓ **Population in cyclone HRAs**
- ✓ **Current - about 8.3 million**
- ✓ **in the 2020s - 14.6 million**
- ✓ **in the 2050s 20.3 million**

Source: ORCHID, 2007

An Example

- SEMP-UNDP conducted a study named "Impacts of Sea Level Rise on Land use Suitability and Adaptation Options" to develop land use zoning strategies to cope with different sea level rise scenarios for sustainable and equitable development in the SW region of Bangladesh

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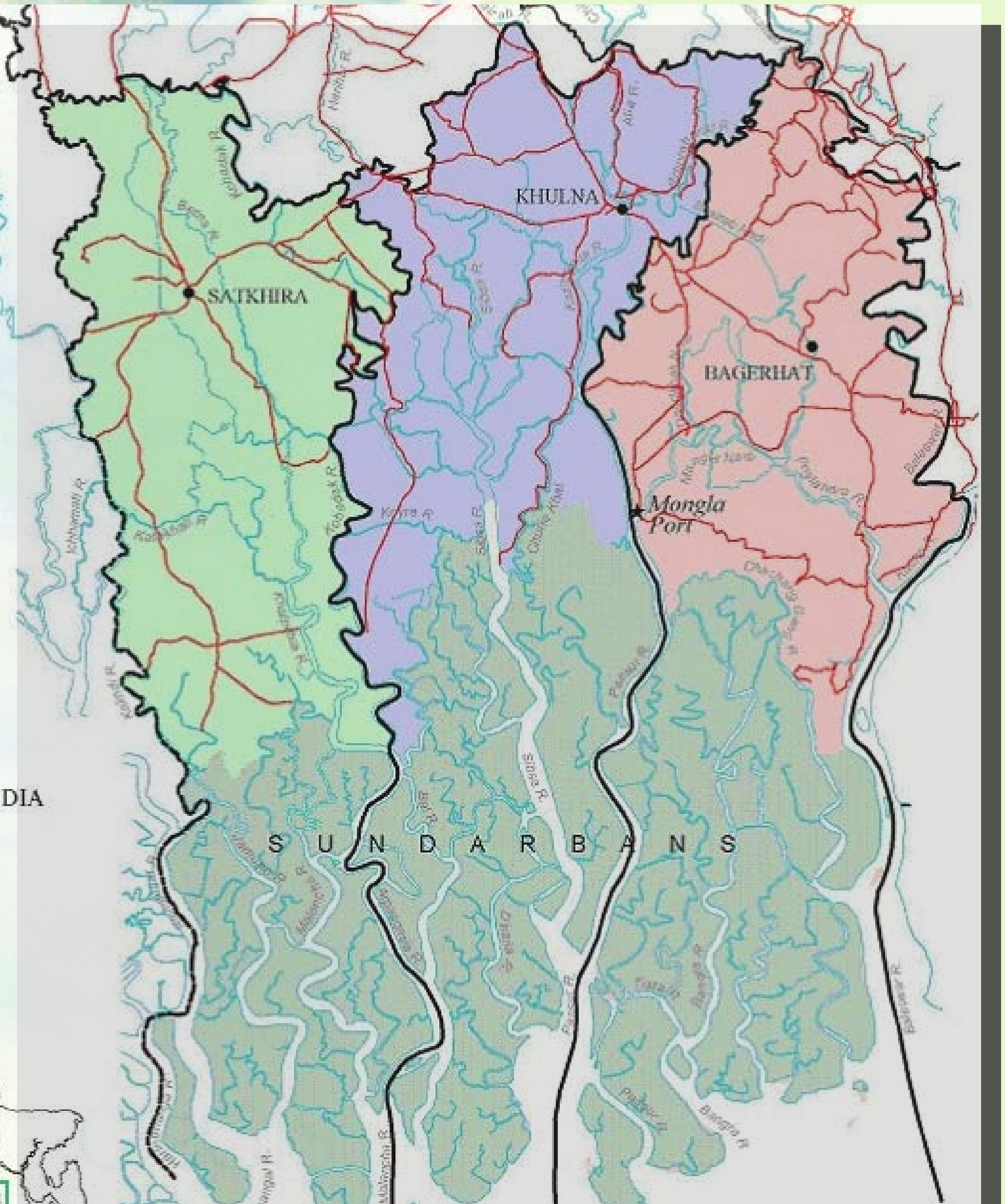
Study Area



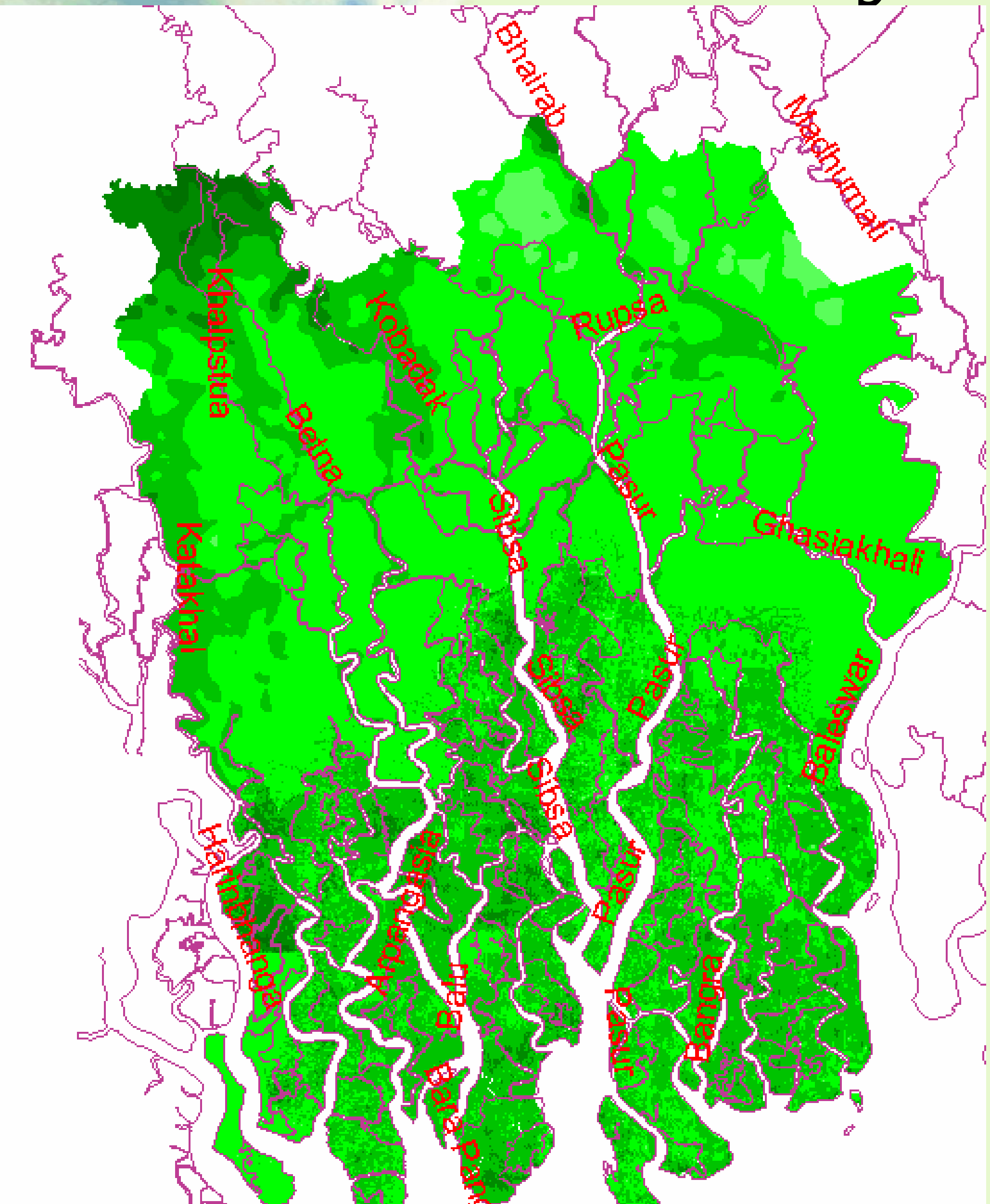
Total Study Area = 10,150 km2

Bagerhat = 3,426 km2

Khulna   = 3,412 km2

Satkhira = 3,317 km2

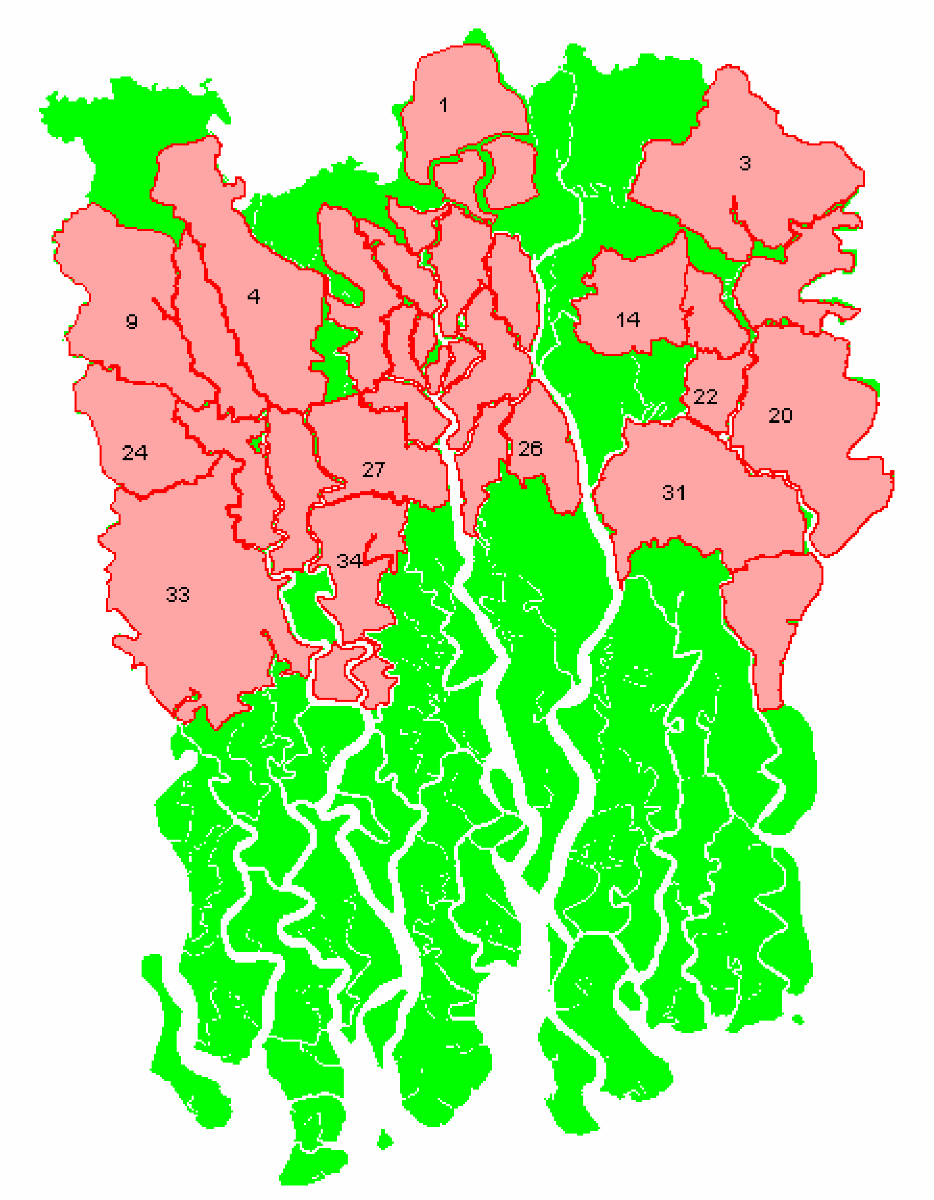
River System



1. Gorai- Pasur- Rupsha System
2. Modhumoti- Baleshor System
3. Betna- Kobadakha- Arpangashia-Kholpatura System
4. Sibsha System
5. Ichamoti-Raimongal System
6. Kobadakha Subsystm
7. Rupsha-Sibsha Link
8. Shala-Gang System
9. Bhairab Sub-System
10. Chitra Subsystem

Polders

- Polders
  - 35 Nos
  - 4,760 km2 (47%)
- Length of embankment: 2,060 km
- Hundreds of Sluices



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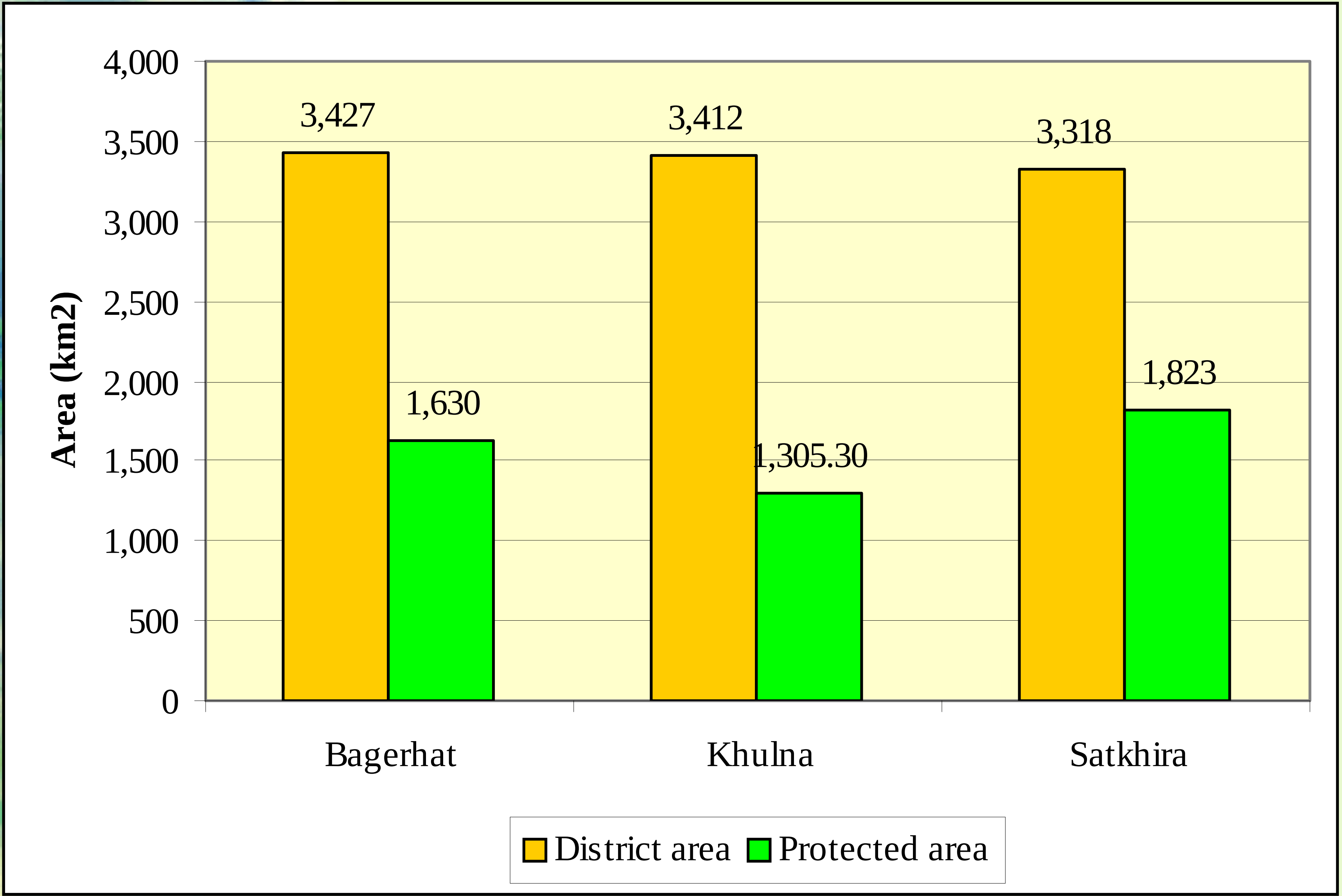
Area inside/outside polders



Base condition

- Flood season
  – Average year flow at Gorai: Yr 2000

- Dry season
  – Dry season flow at Gorai: Yr 1997

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Scenario for Hydrodynamic computation

- According to NAPA the Sea Level Rise is
  - 32cm in 2050
  - 88cm in 2100

Model run was planned for:

- Base condition Yr 2000 flow situation
  Yr 1997 flow situation
- Scenarios: Yr 2000 + 32 cm SLR
  Yr 2000 + 88 cm SLR
  Yr 1997 + 32 cm SLR
  Yr 1997 + 88 cm SLR

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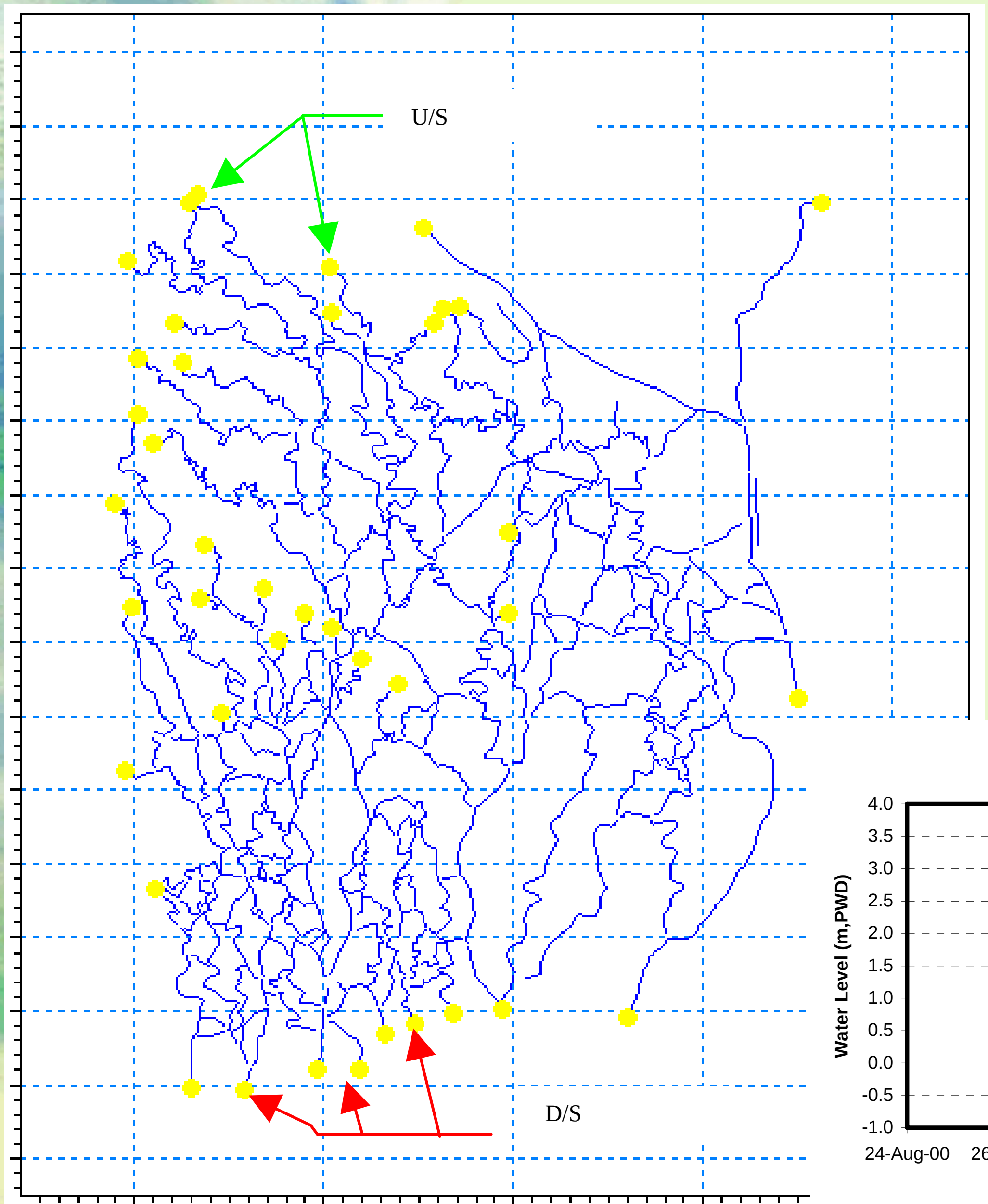
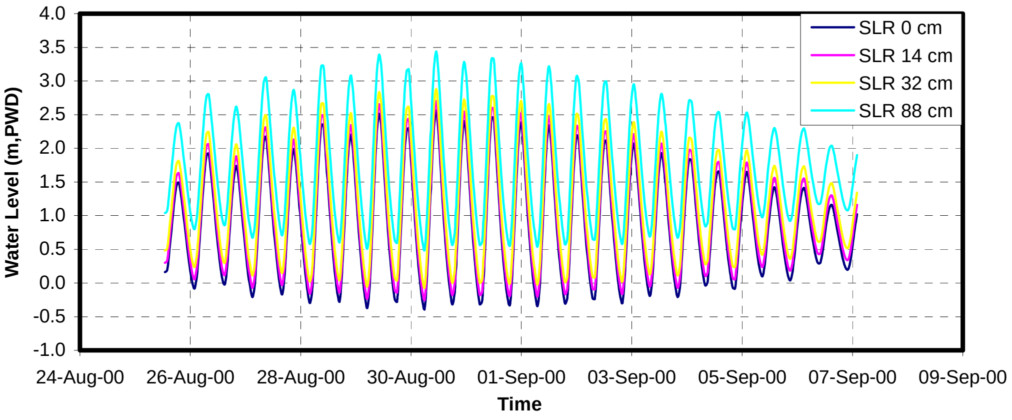
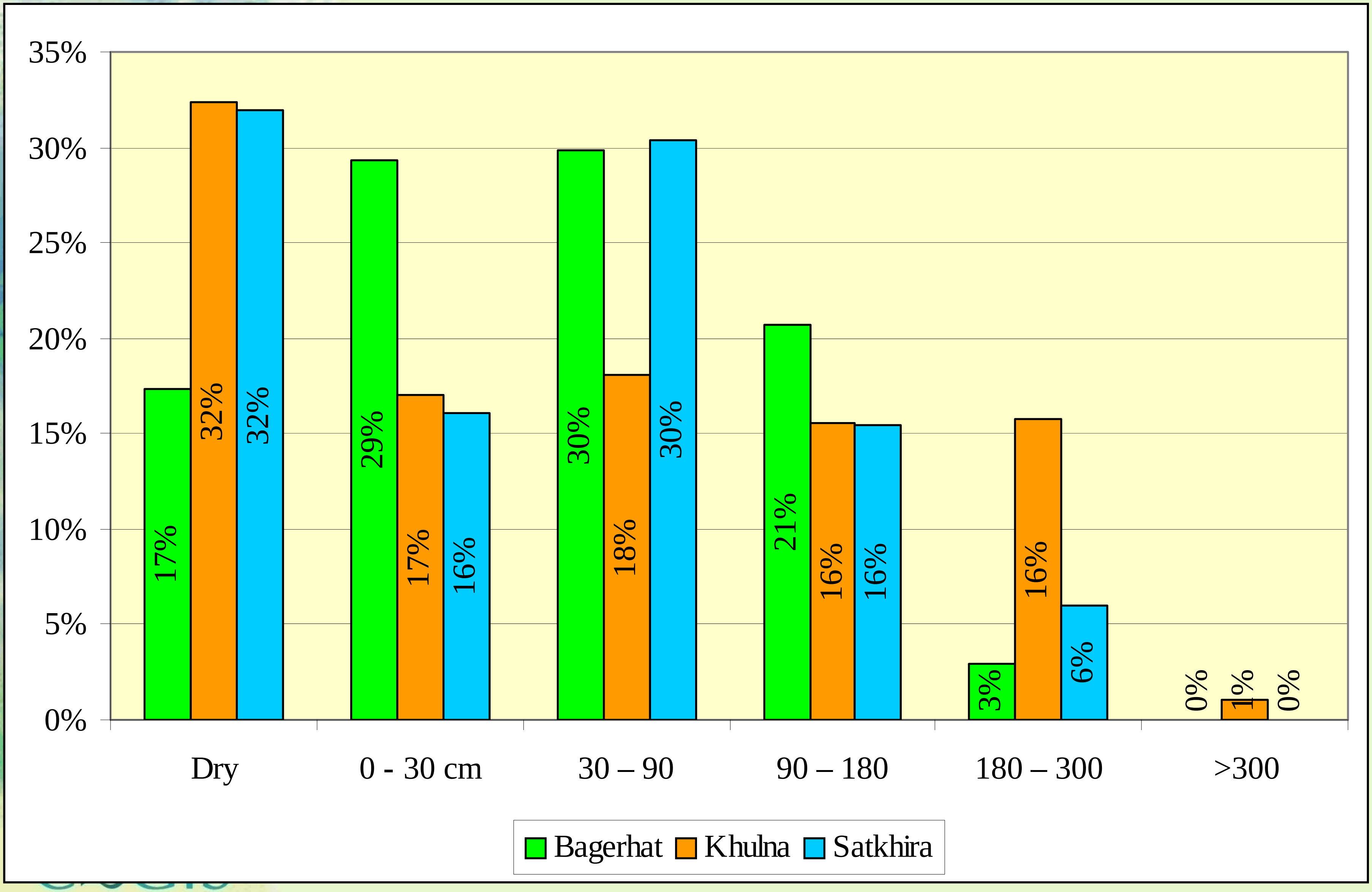
Model River Network



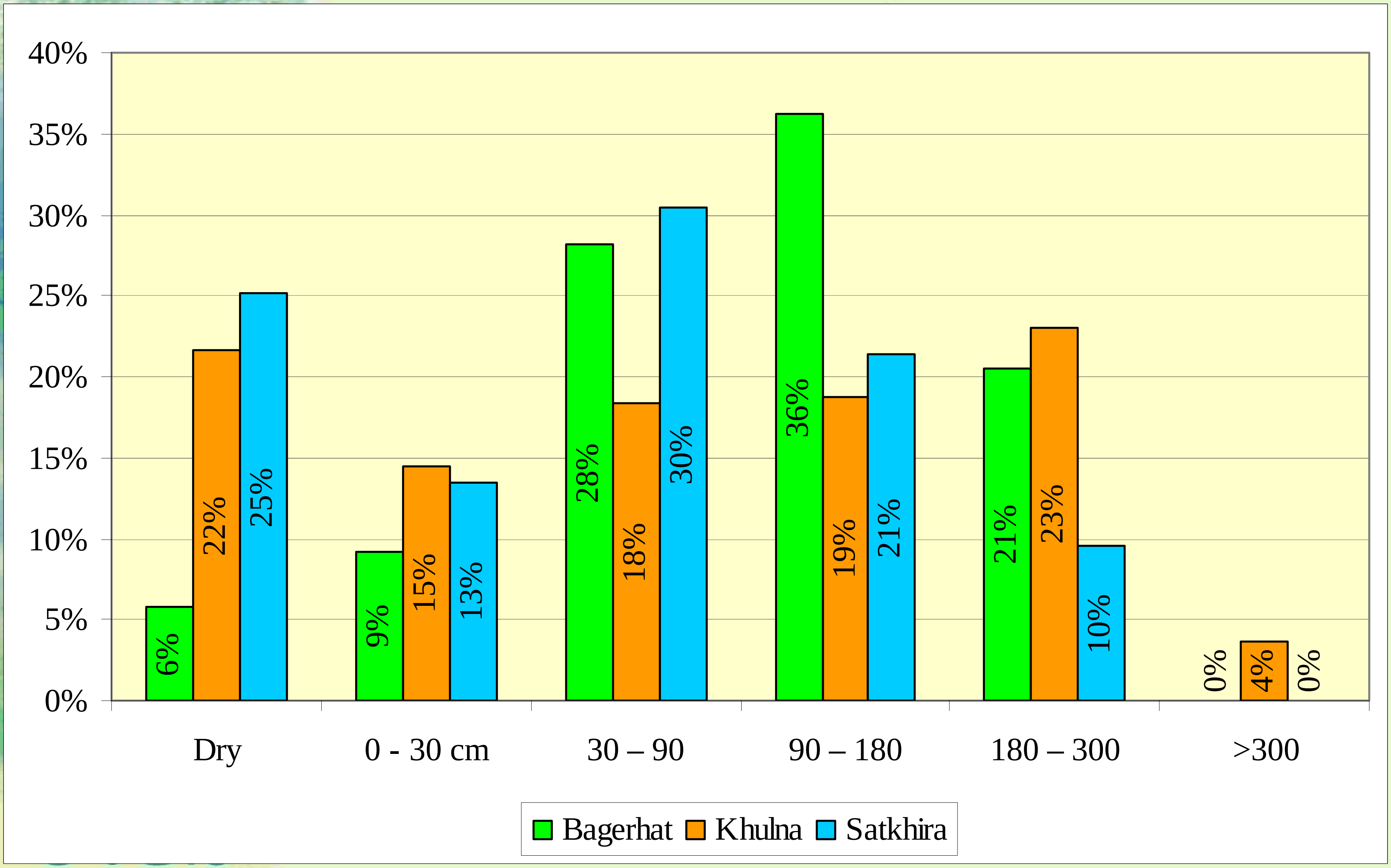
Source: IWM



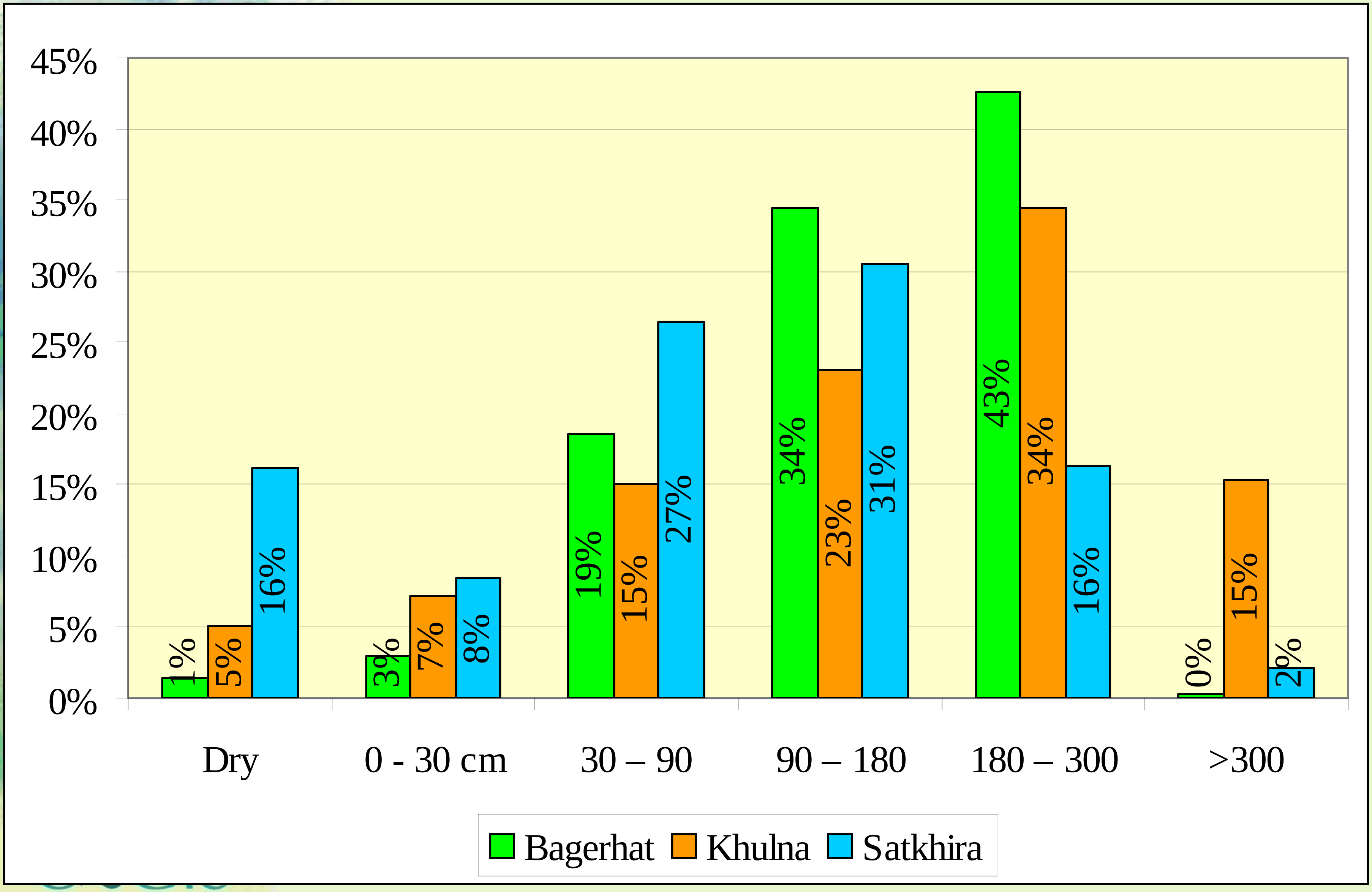
Flooding in Base Condition (Y2000)

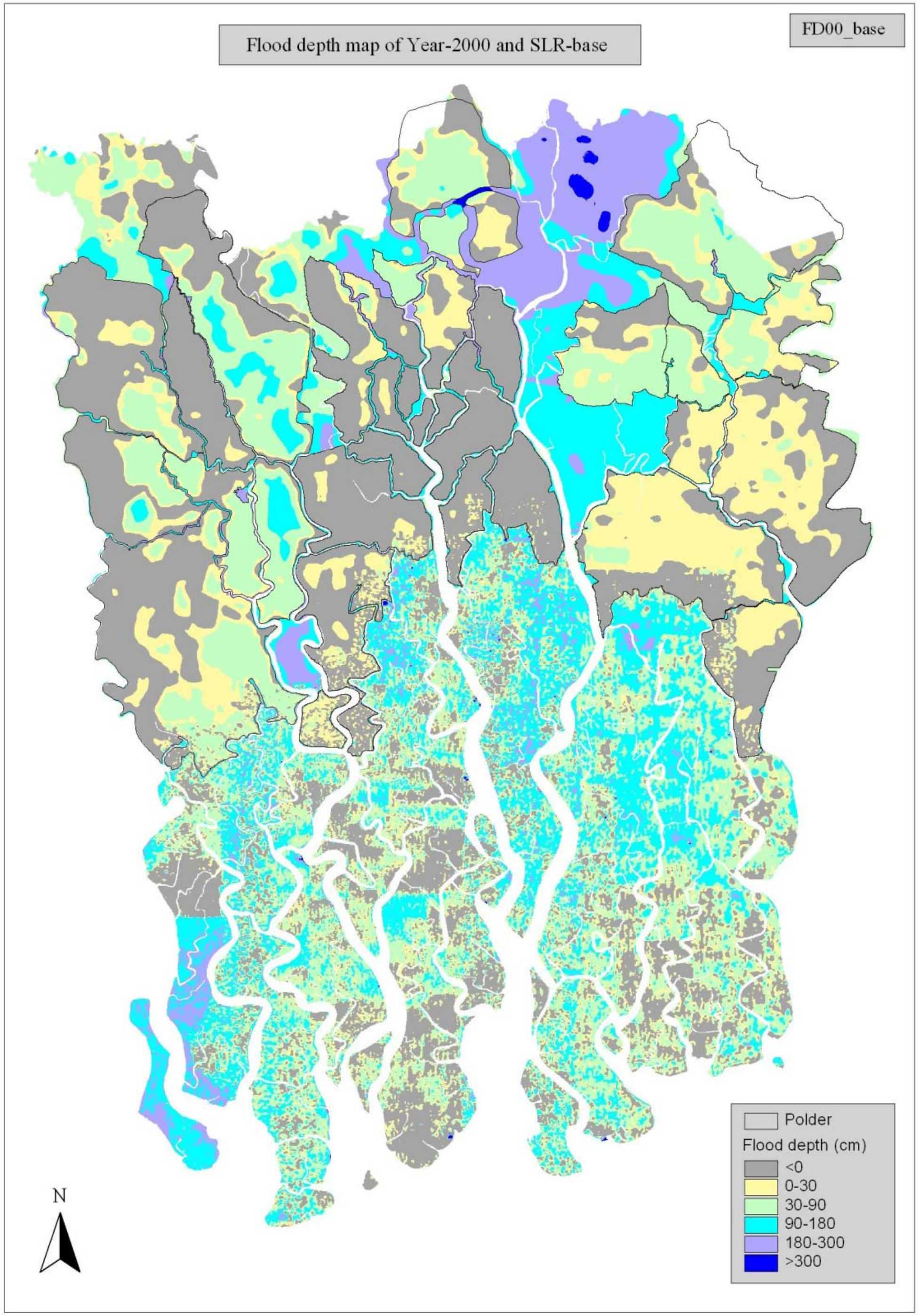


Flooding in (Y2000 + 32 cm SLR)



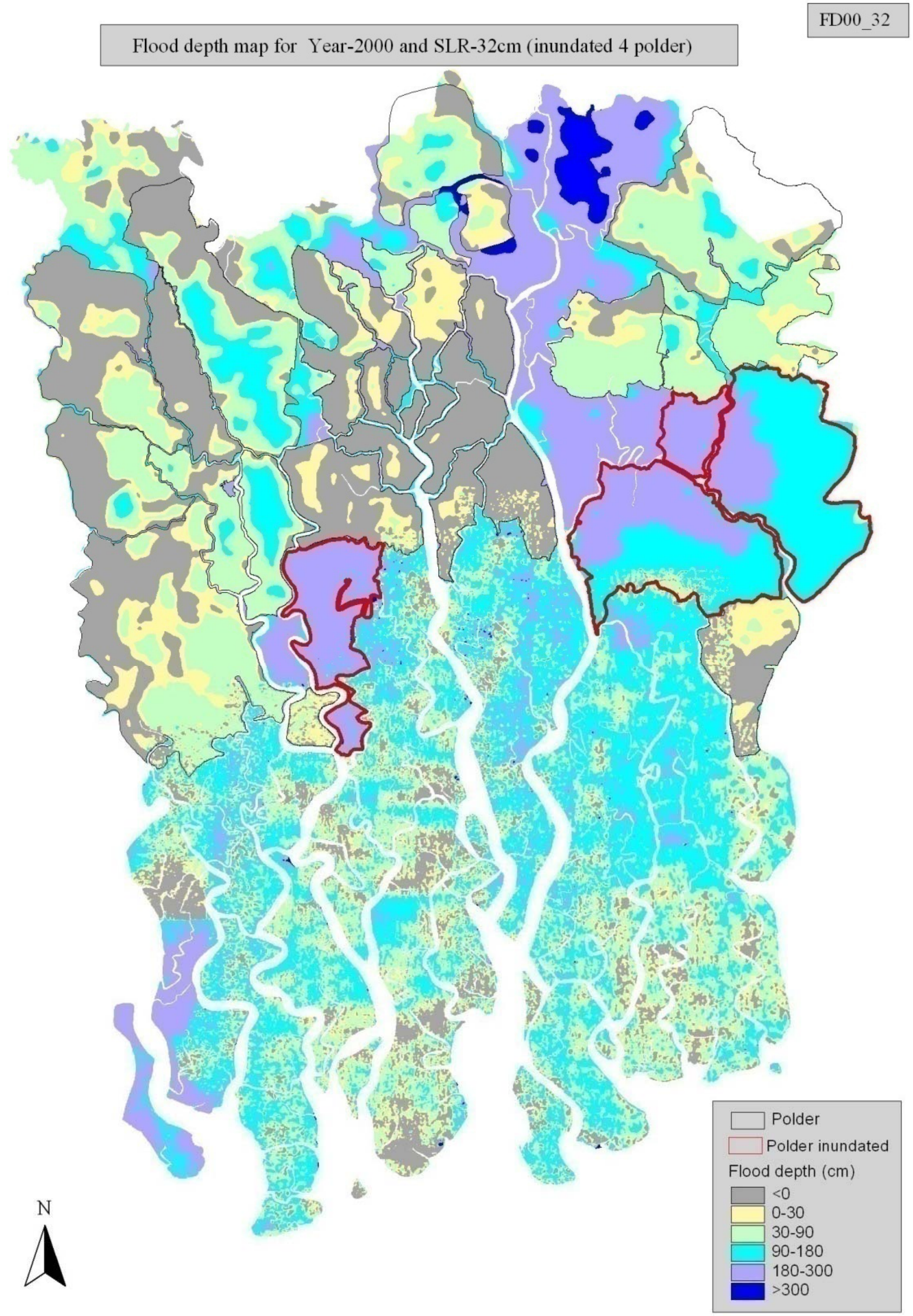
Flooding in (Y2000 + 88 cm SLR)





Flood depth in Yr 2000

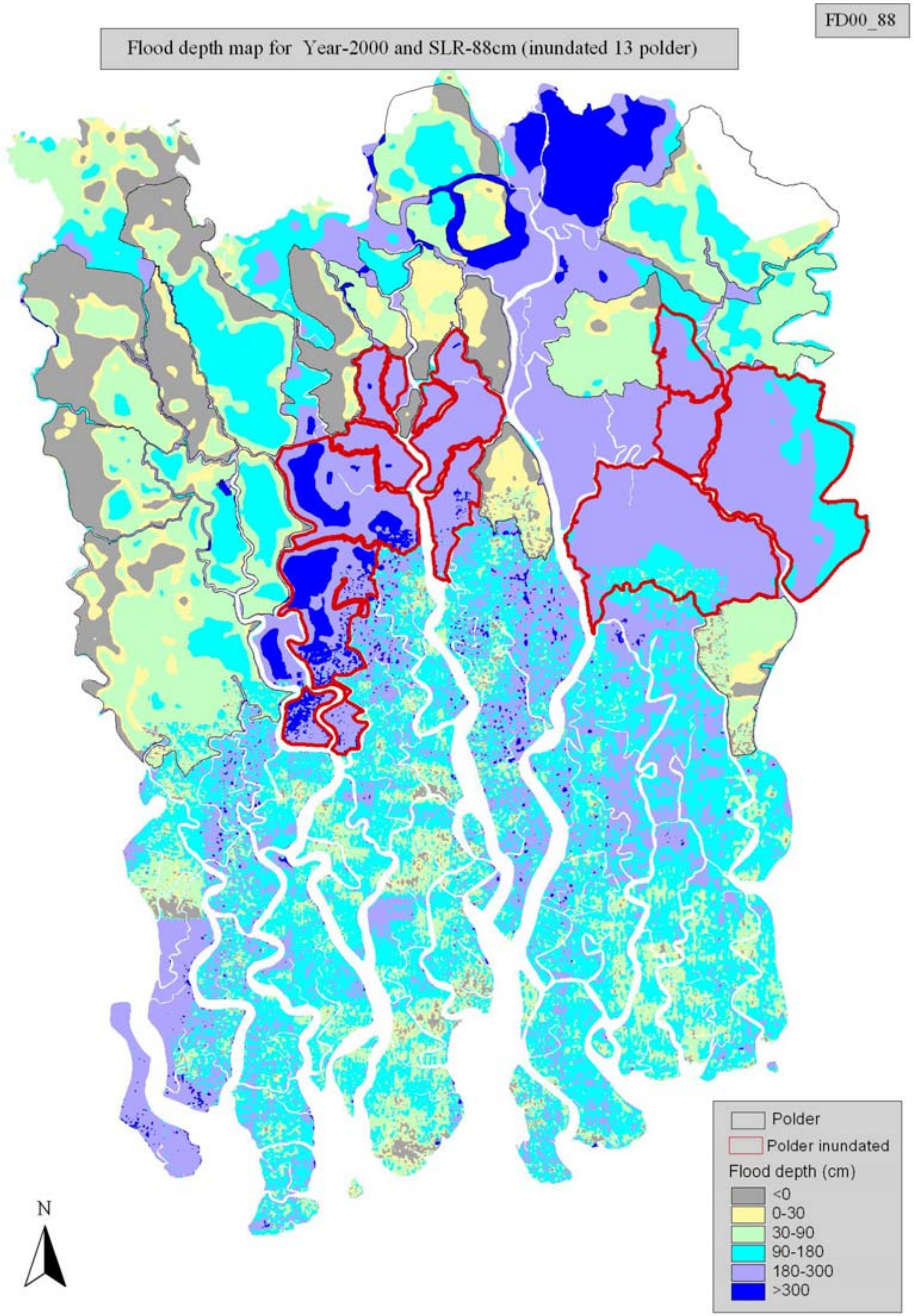
Flooding	Total	%
Dry	2,757	27%
0 - 30 cm	2,119	21%
30 - 90	2,648	26%
90 – 180	1,755	17%
180 – 300	837	8%
>300	39	0.4%



Flood depth in Yr 2050

4 polder inundated

Inundation	Area (km2)	%
Dry	1,775	17%
0 - 30 cm	1,252	12%
30 – 90	2,604	26%
90 – 180	2,593	26%
180 – 300	1,804	18%
>300	128	1.3%

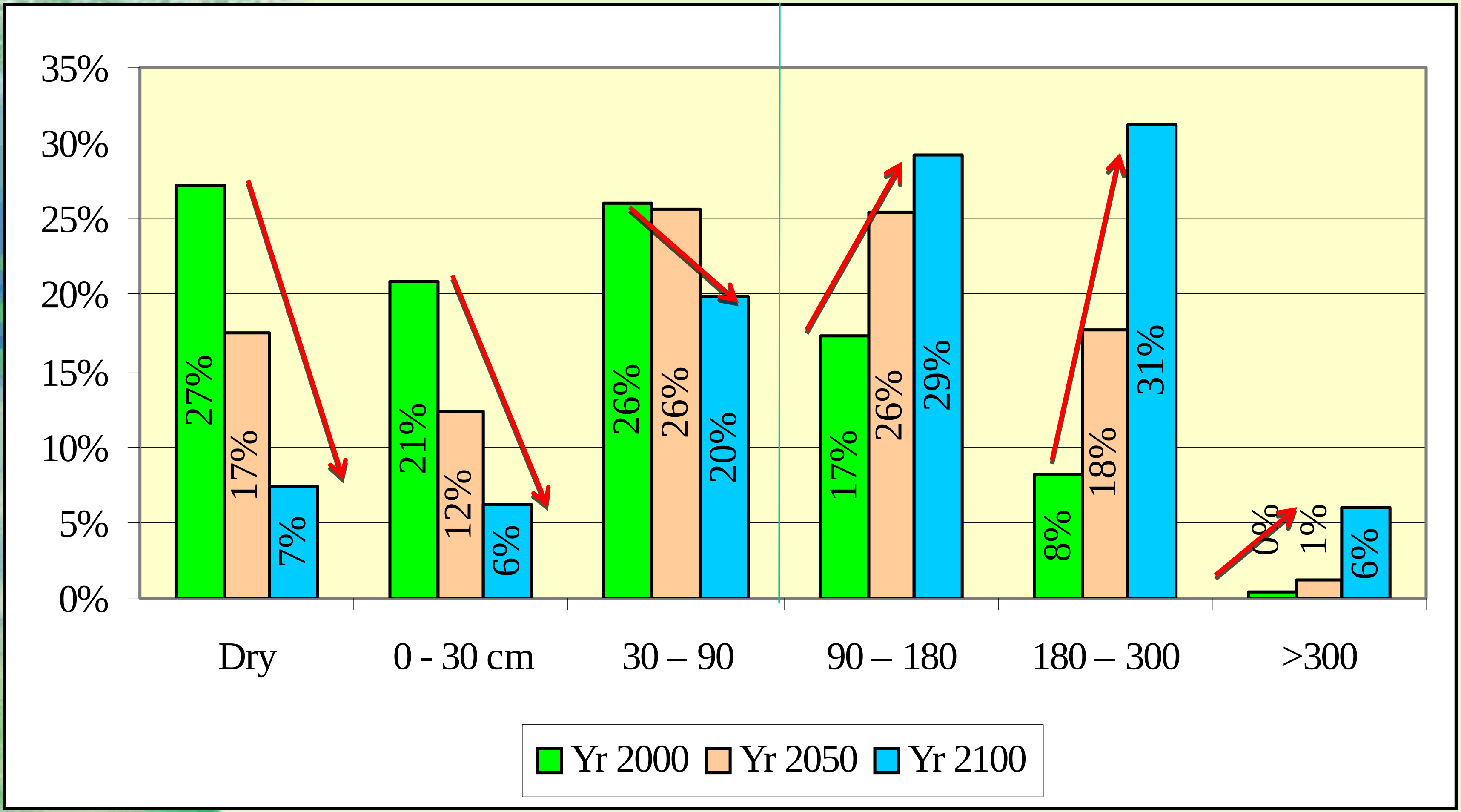


Flood depth in Yr 2100

13 polder inundated

Inundation	Area (km2)	%
Dry	756	7%
0 - 30 cm	625	6%
30 – 90	2,021	20%
90 – 180	2,978	29%
180 – 300	3,172	31%
>300	604	5.9%

Comparison of inundated area



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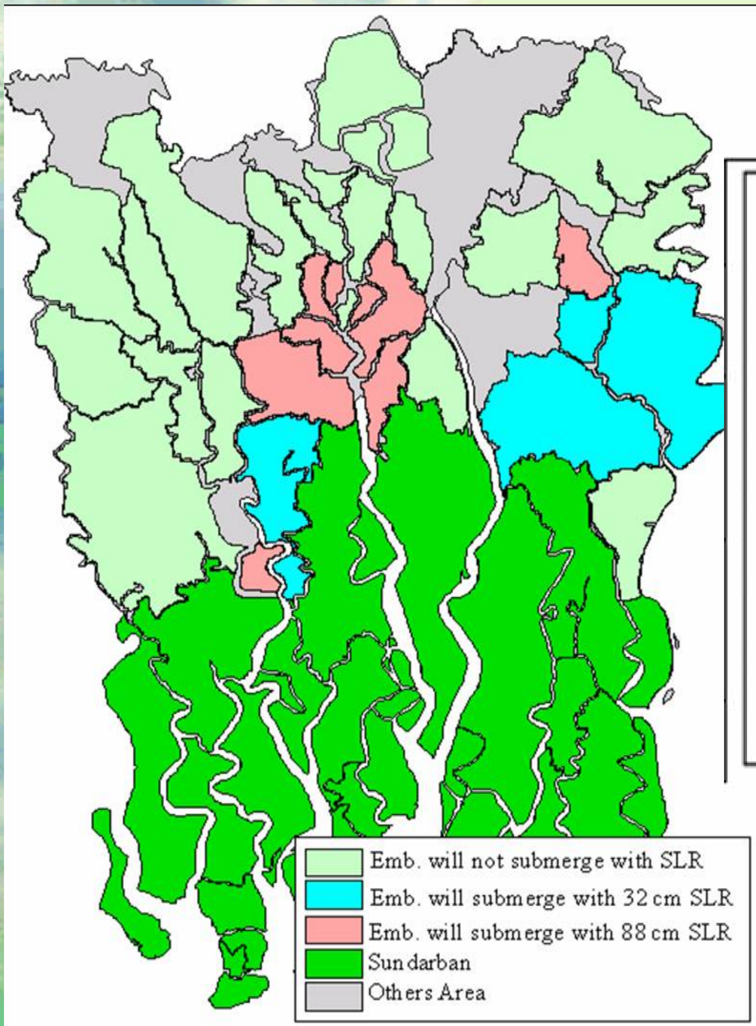
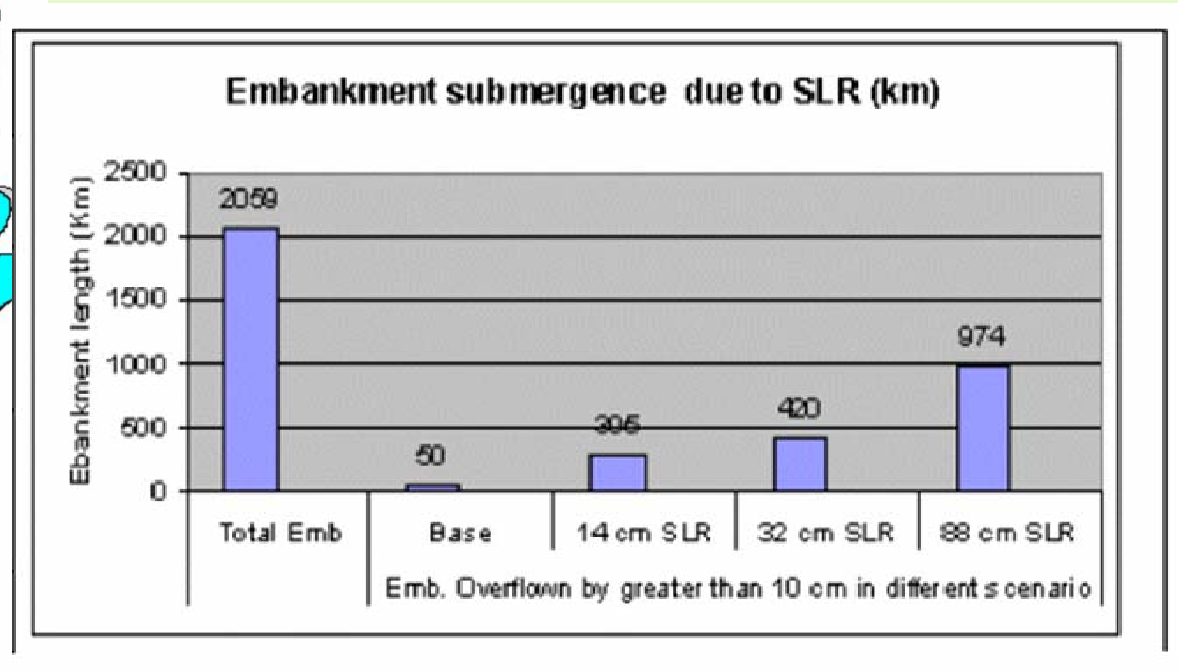
Submergence of Embankments





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Adaptation Options

Options:

- Long term measures – Ganges barrage (OGDA option 8)
- Mid term measure – Augmentation of Gorai flow (OGDA option 7)
- Construction of closures on main river systems (Pussur, Shibsha and Kobadak rivers)
- Raising embankments to prevent overtopping
- Rehabilitation of drainage systems

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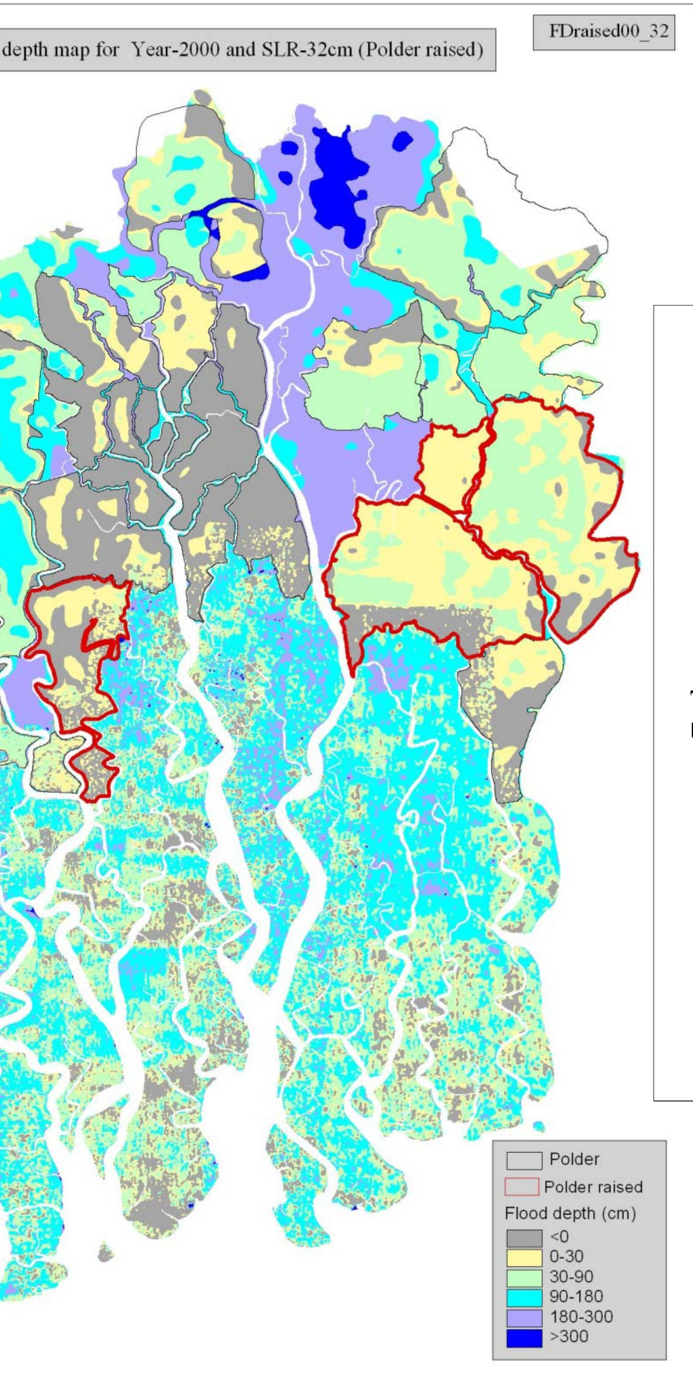
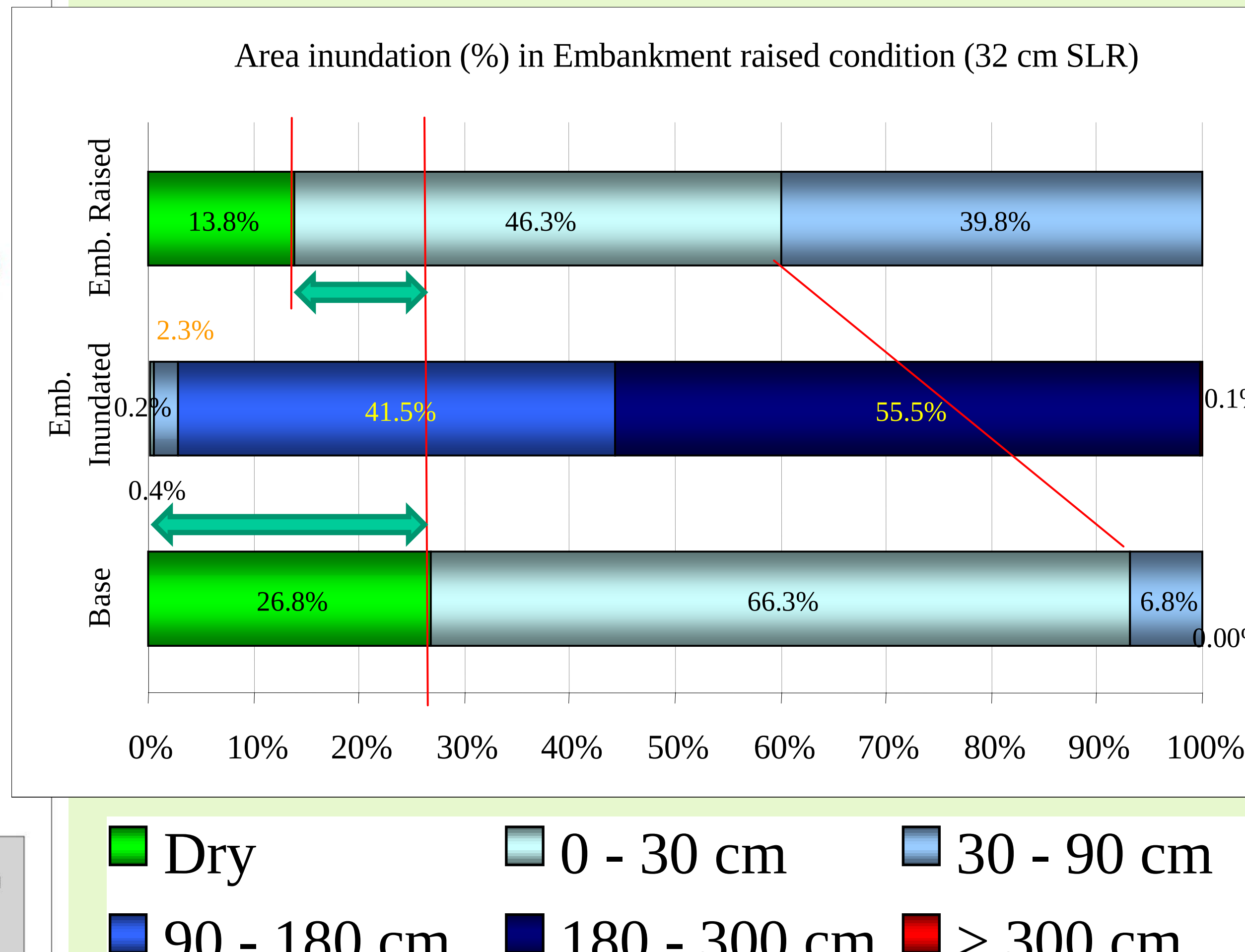
4 polder raised

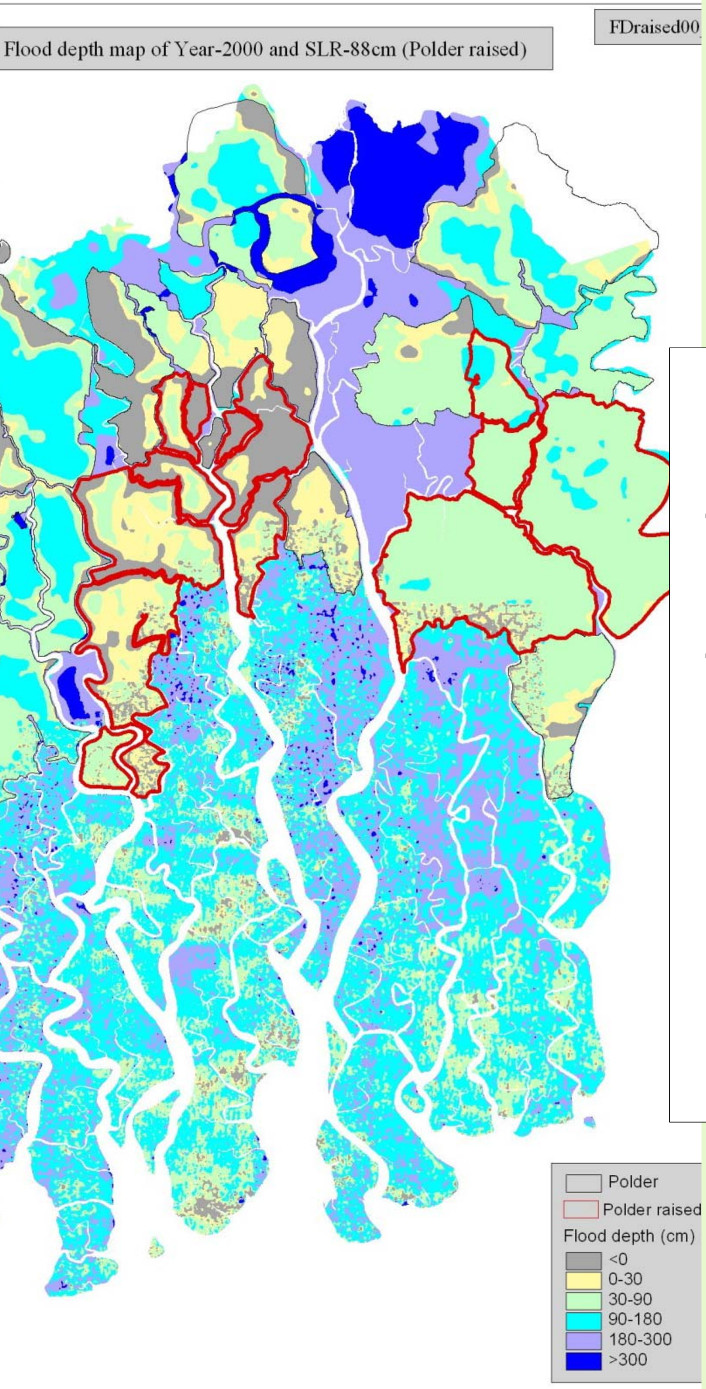


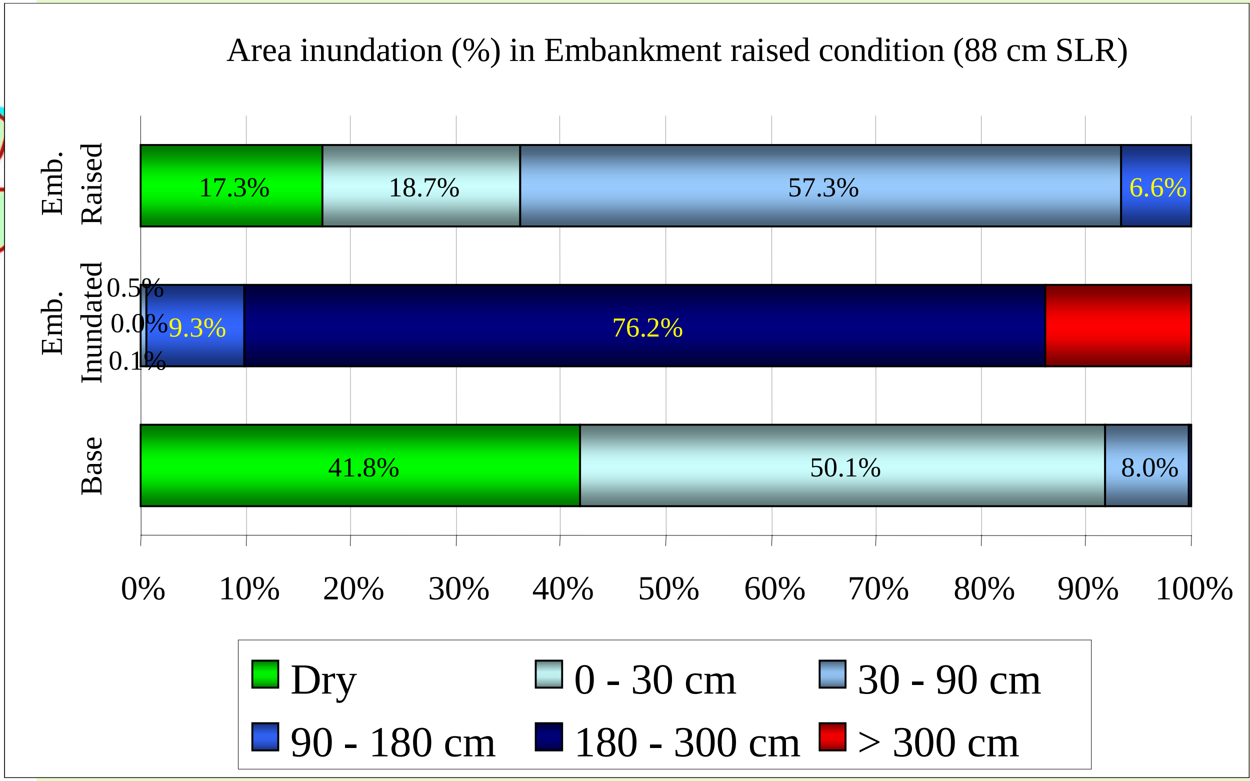
Flood depth in Yr 2050



13 polder raised

Flood depth in Yr 2100





Emb. Raised: Comparison Land Class

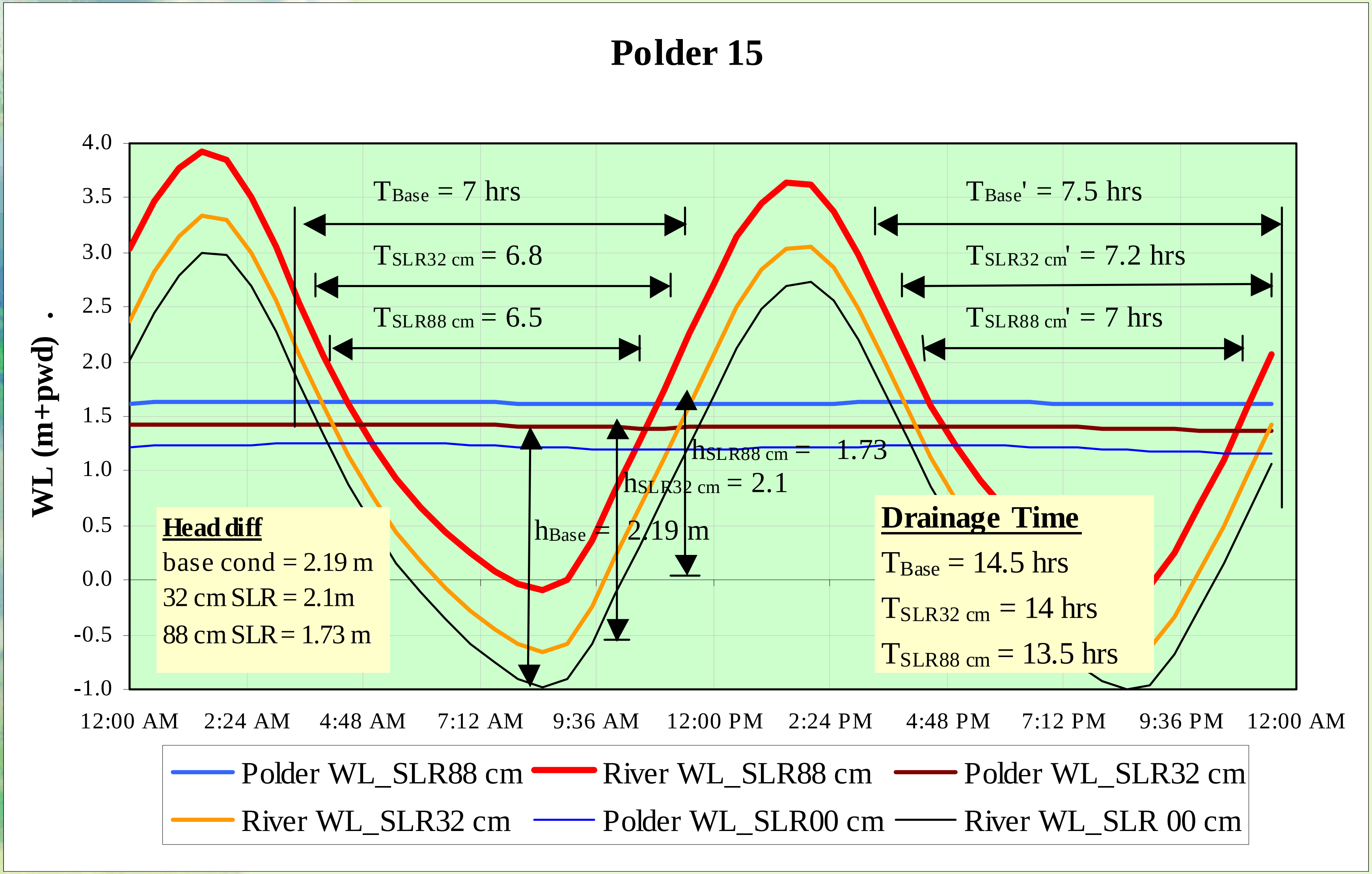
32 cm SLR: Embankment raised in 4 polder

Land class (depth, cm)	Base		Emb. inundated		Emb. Raised	
	Area	%	Area	%	Area	%
Dry	259	26.8%	2.31	0.2%	133.34	13.8%
0 – 30 cm	639	66.3%	3.59	0.4%	446.47	46.3%
30 - 90 cm	66	6.8%	22.27	2.3%	383.68	39.8%
90 - 180 cm	0.55	0.1%	399.75	41.5%	0.70	0.1%
180 - 300 cm	0.06	0.0%	535.12	55.5%	0.06	0.0%
> 300 cm	0.01	0.0%	1.22	0.1%	0.01	0.0%
Total	964		964	1.00	964	964

88 cm SLR : Embankment raised in 13 polder

Land class (depth, cm)	Base		Emb. inundated		Emb. Raised	
	Area	%	Area	%	Area	%
Dry	625	41.8%	0.43	0.0%	259	17.3%
0 - 30 cm	748	50.1%	0.85	0.1%	280	18.7%
30 - 90 cm	119	8.0%	7.00	0.5%	857	57.3%
90 - 180 cm	2	0.1%	139	9.3%	99	6.6%
180 – 300 cm	0.08	0.0%	1,139	76.2%	0.12	0.0%
> 300 cm	0.01	0.0%	208	13.9%	0.01	0.0%
Total	1,495		1,495	1.55	1,495	1,495

Example of SLR impact on drainage



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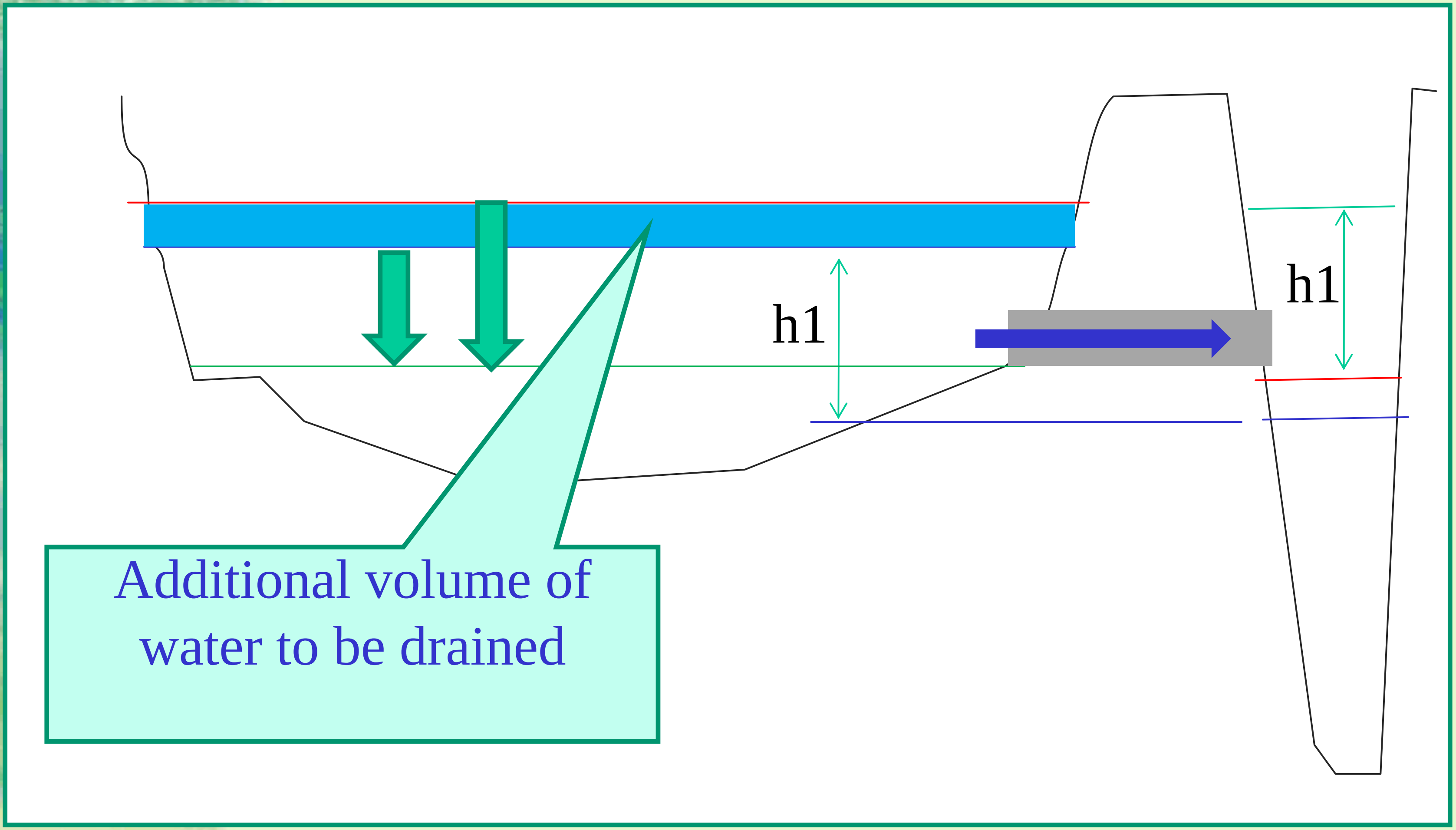
Drainage under SLR

What will happen with Increased Rainfall due to global worming??



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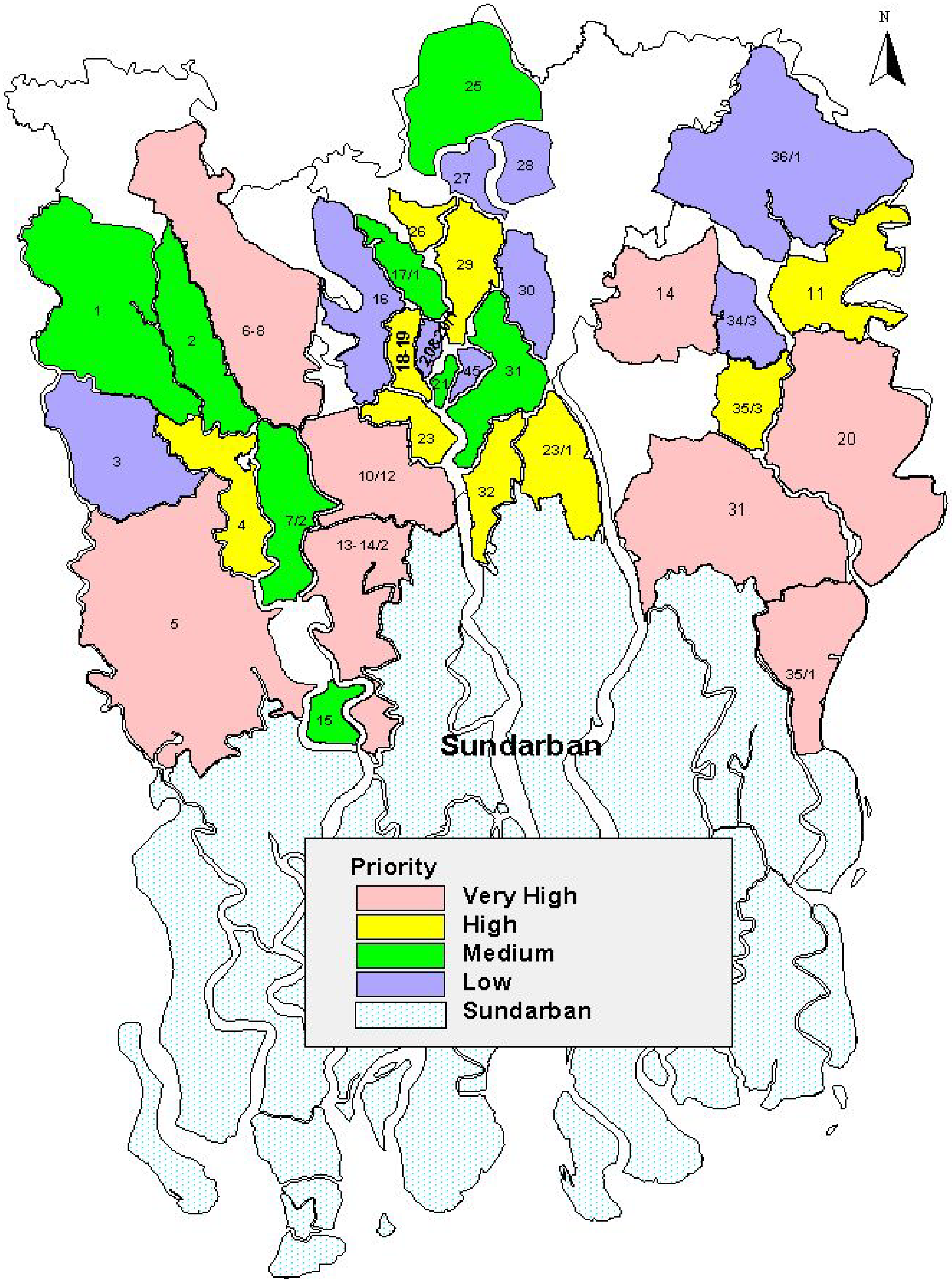
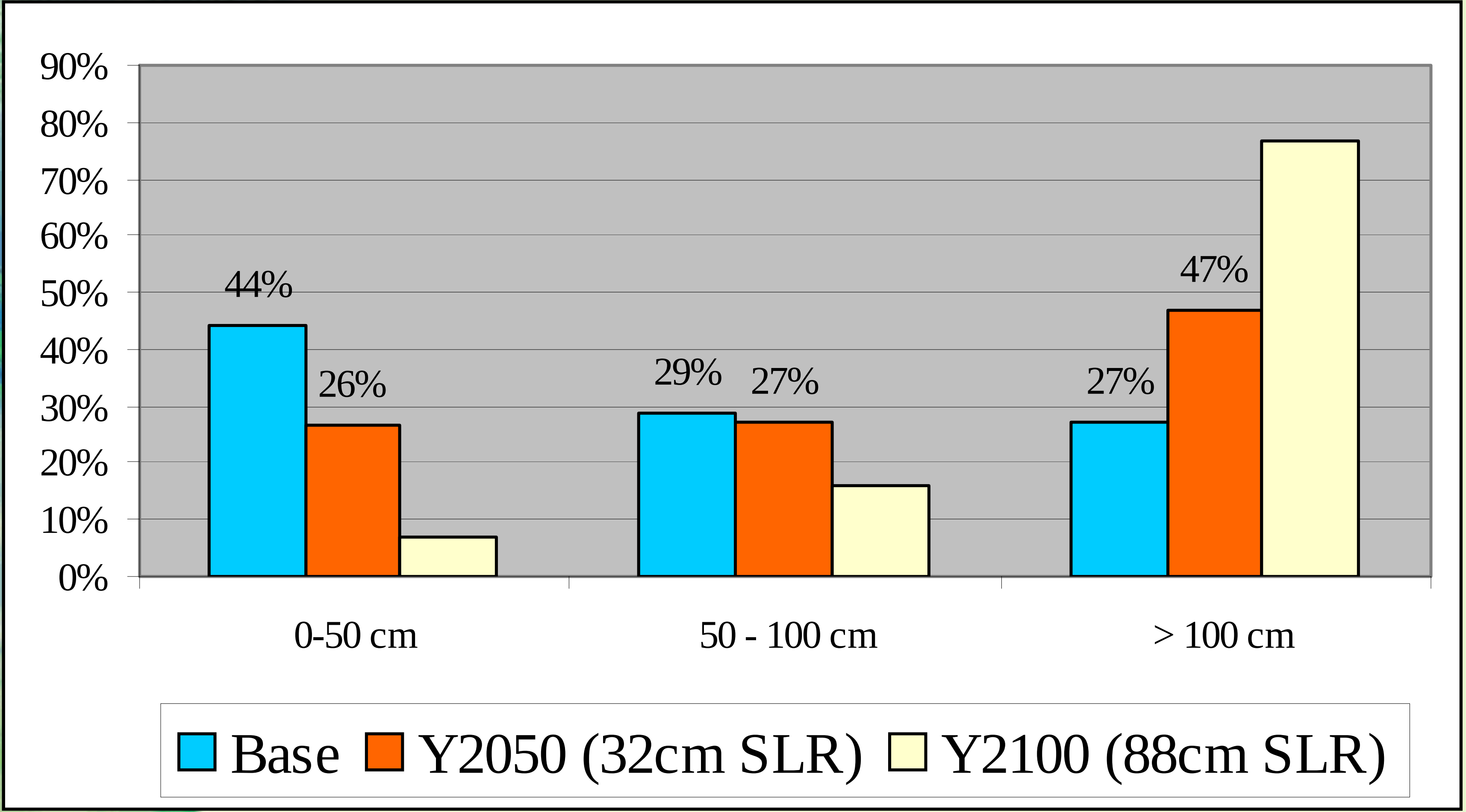
Polder drainage improvement priority



Inundation in Sundarbans



Sundarban area = 4,080 km2

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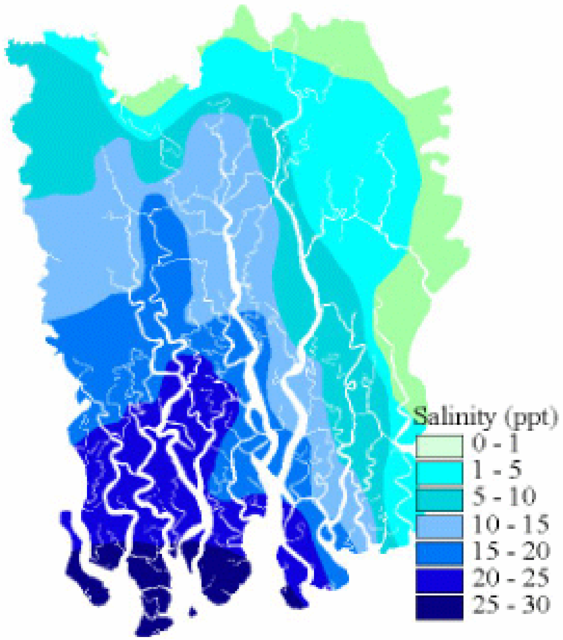
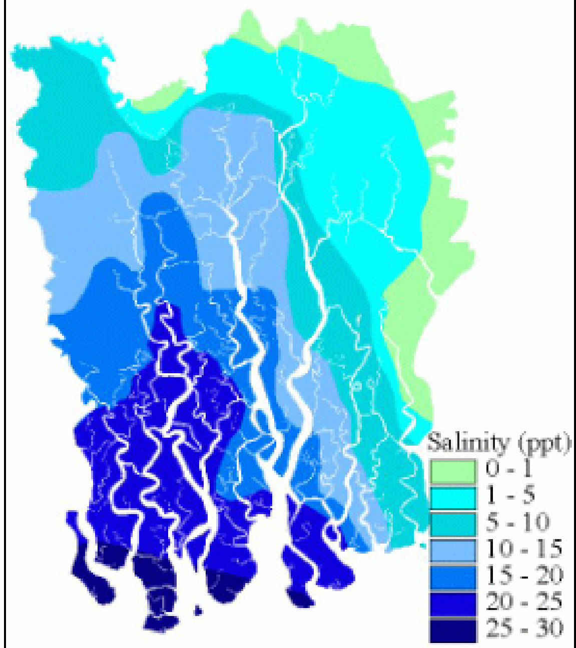
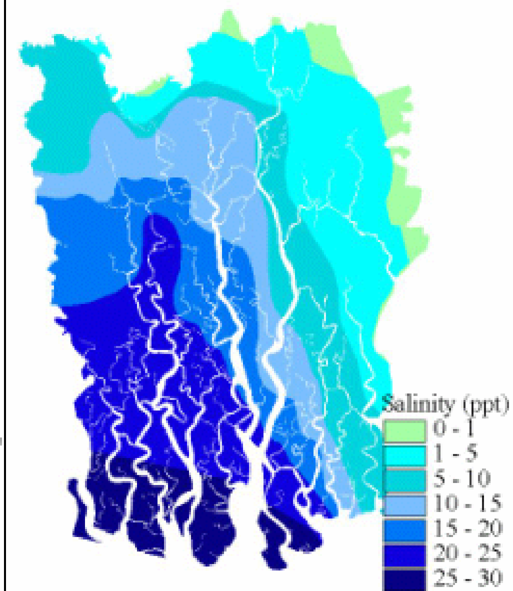
Salinity



Salinity distribution in base condition



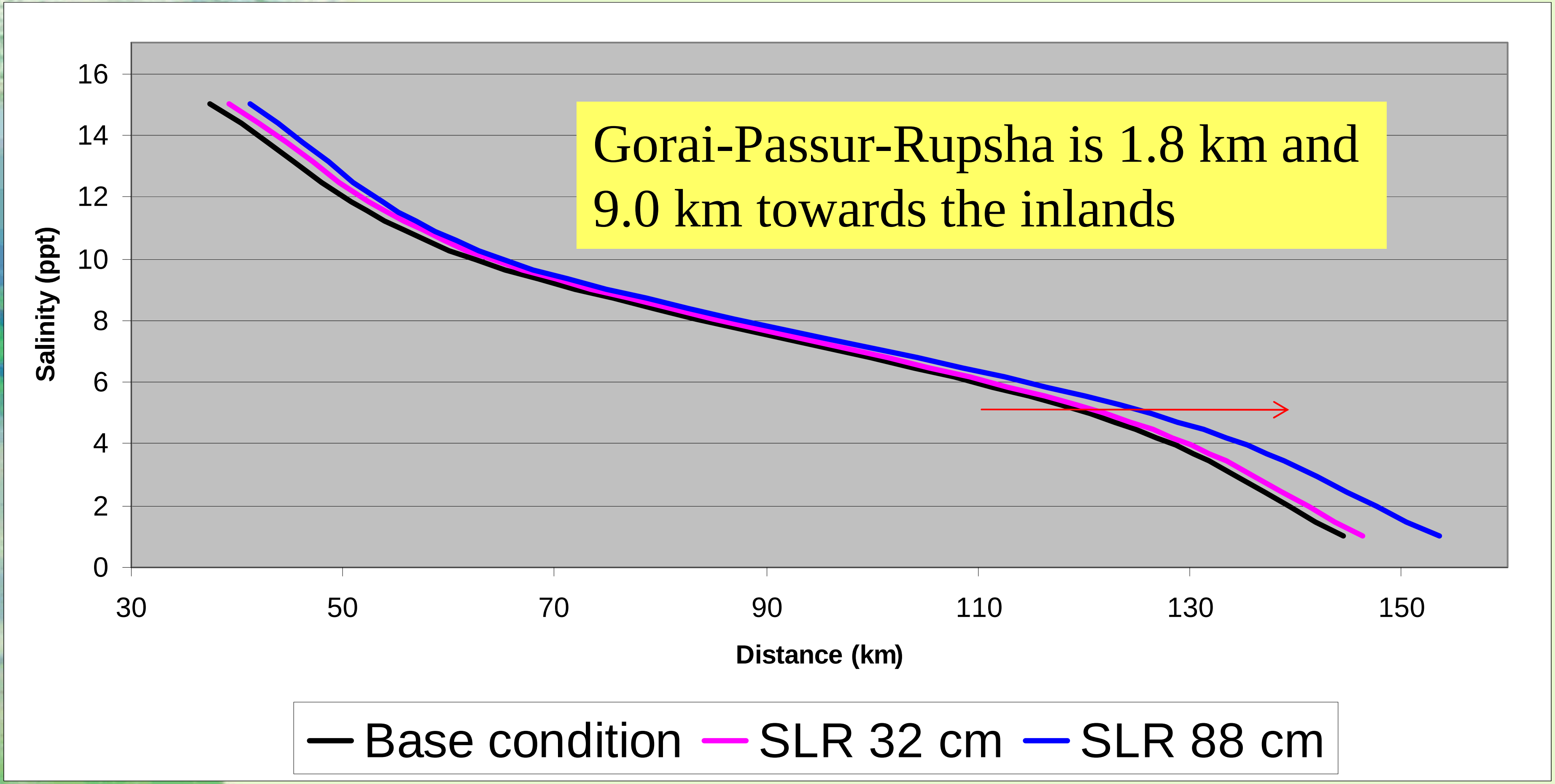
Salinity distribution with SLR 32 cm



Salinity distribution with SLR 88 cm

Condition	Salinity (ppt)						
	0-1 ppt	1-5 ppt	5-10 ppt	10-15 ppt	15-20 ppt	20-25 ppt	> 25 ppt
Base condition	10.8%	16.2%	19.1%	20.9%	15.9%	12.6%	4.5%
SLR 32 cm	9.2%	17.8%	18.0%	18.6%	15.6%	15.7%	5.0%
SLR 88 cm	4.0%	21.0%	17.8%	15.6%	14.9%	17.9%	8.8%

Salinity Propagation



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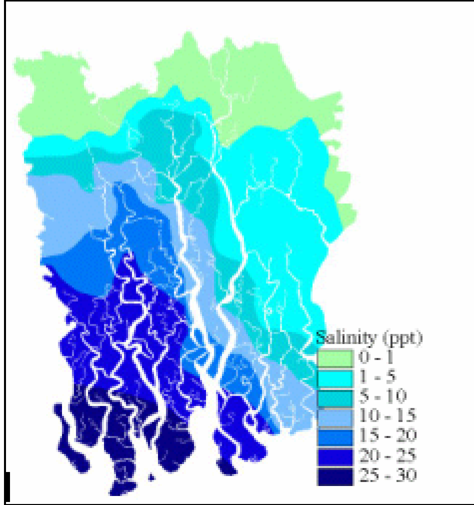
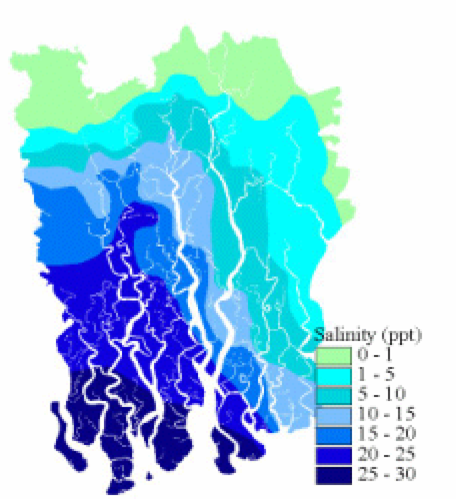
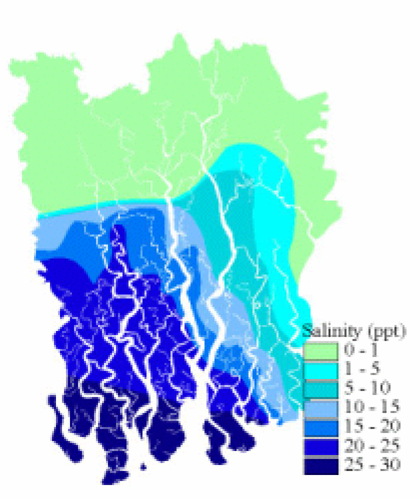
Salinity condition with adaptation



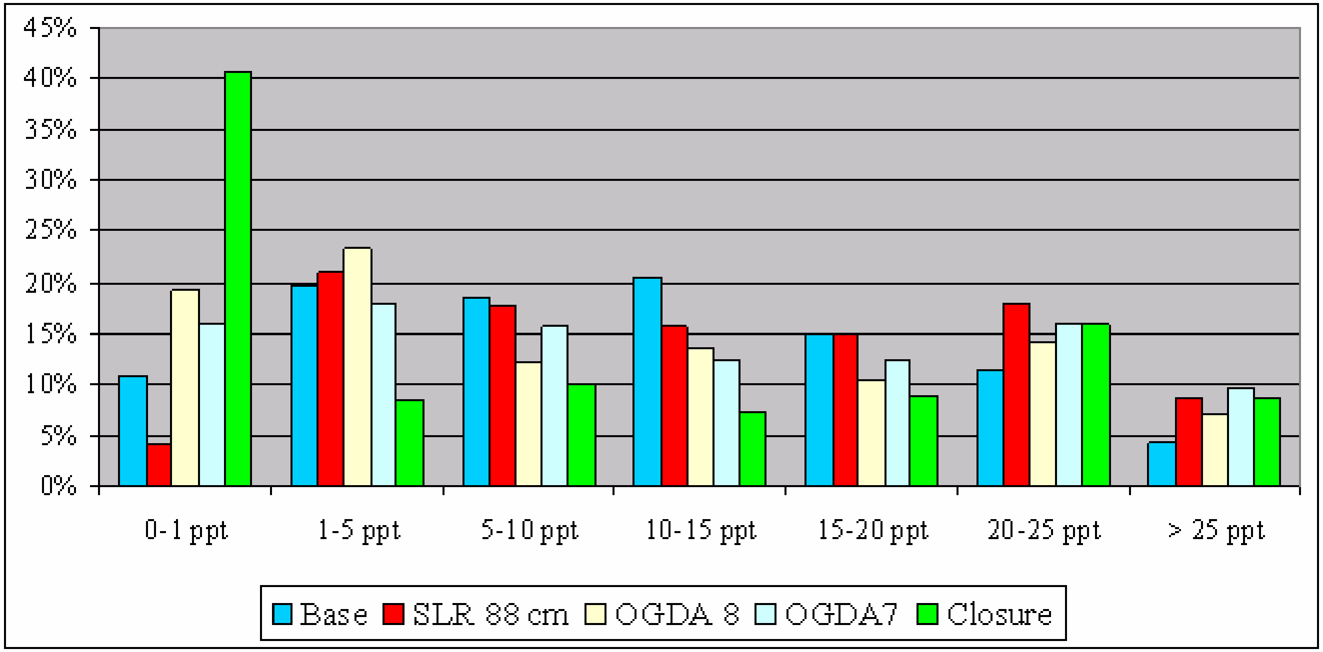
Salinity distribution with OGDA Option 8



Salinity distribution with OGDA Option 7



Salinity distribution with three Colsure



Conclusions of the study

- SLR will cause inundation of Polders
- Drainage will be slower resulting longer drainage period
- SLR should be included as a design parameter
- Estimation of openings (Sluices) should consider elongated drainage period

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Adaptation options in modelling of WRM

- Increase Emb. Height – considering SLR
- Increase Drainage opening – considering longer drainage period due to wetter wet season and higher d/s water level
- Estimate Frequency considering trend due CC
- Estimate Salinity propagation considering SLR and lower upstream flow due dryer dry season

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Thank You

Major impacts of climate change on water resources

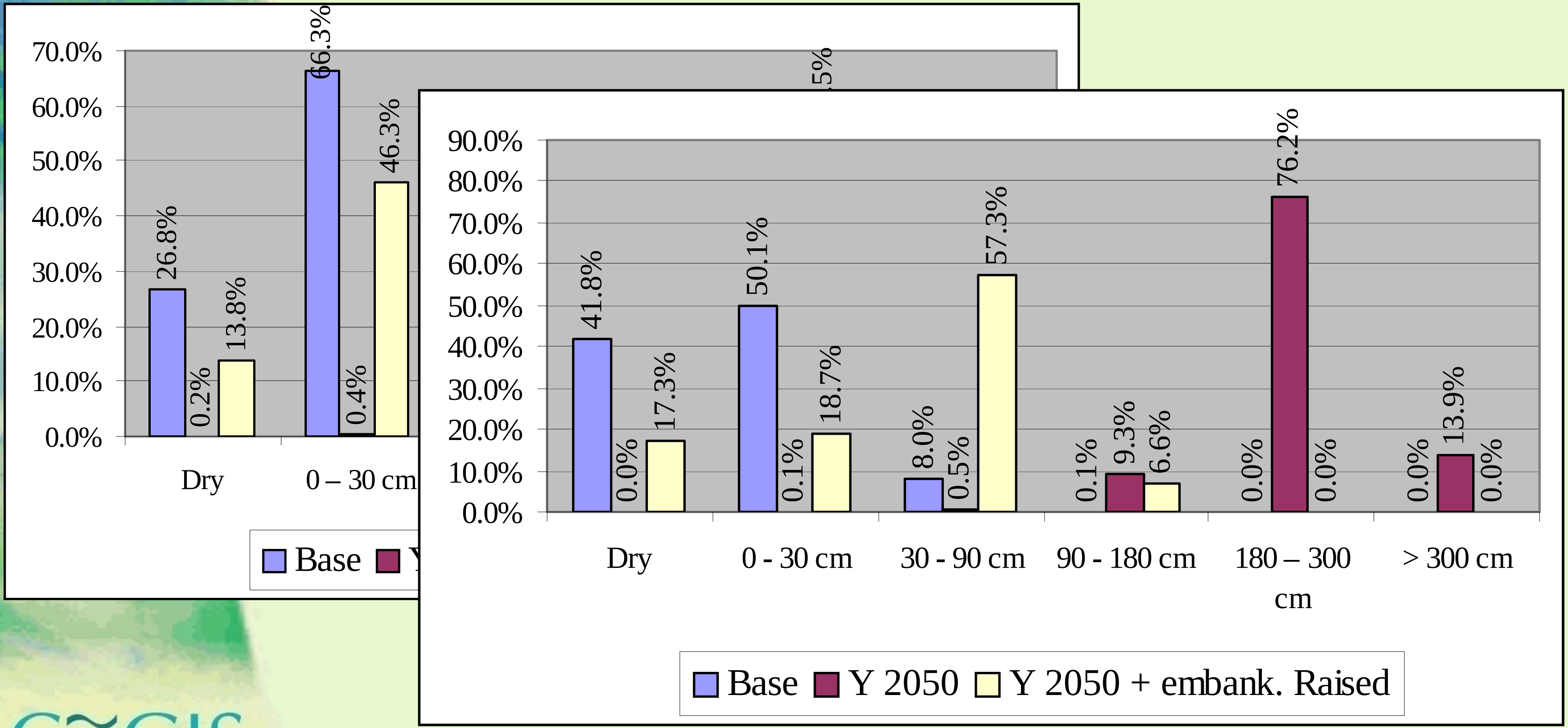
- Intensification of the hydrological cycle
- Dryer dry seasons and wetter rainy seasons
- Heightened risks of more extreme and frequent floods and drought
- Reduced availability of water
- Deterioration of the quality and quantity of available and accessible water
- Melting of glaciers which will increase flood risk during the rainy season, and strongly reduce dry-season water supplies to one-sixth of the World's population
- Melting of ice in mountains and Polar Regions resulting

Changes in Temperature and Precipitation

Bangladesh

- **According to ORCHID, 2007 report,**
  - **Rise in temperature By the 2020s:**
    - 0.9 (A2) and 1.0°C (B1)
    - 2.0°C (A2) and 1.6°C (B1)
  - **Changes in annual rainfall by the 2020s is 0% (A2)and -1% (B1)**
  - **Seasonal changes by the 2020s:**
    - slightly wetter winters (+3% A2, 0% B1)
    - slightly wetter monsoon summers (+1% A2, +4% B1).
  - **By the 2050s average changes are slightly larger, with**
    - winter drying (-3% A2, -4% B1)
    - summer wetting (+2% A2, +7% B1).

SRES: Special Report on Emissions Scenarios


70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
26.8%
0.2%
13.8%
66.3%
0.4%
46.3%
Dry
0 – 30 cm
Base
90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
41.8%
0.0%
17.3%
50.1%
0.1%
18.7%
8.0%
0.5%
57.3%
0.1%
9.3%
6.6%
0.0%
76.2%
0.0%
0.0%
13.9%
0.0%
Dry
0 - 30 cm
30 - 90 cm
90 - 180 cm
180 – 300 cm
> 300 cm
Base
Y 2050
Y 2050 + embank. Raised