Ganges Strategic Basin Assessment

Techno-Economic Perspectives on the Water, Food and Energy Nexus

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- **Objective:** facilitate cooperation in the sustainable use & mgmt of the water resources of the Himalayan Rivers in addressing development challenges and the impacts from climate change

A partnership of Australia, Norway, the U.K. and the World Bank supporting efforts in the countries sharing the rivers that rise in the Greater Himalayas:

- Afghanistan
- Bangladesh
- Bhutan
- China
- India
- Nepal
- Pakistan
# Ganges Strategic Basin Assessment

A Techno-Economic Analysis of Transboundary Opportunities and Risks in the Ganges

## Context
- No comprehensive model of the world’s most populous basin
- Identified gap in knowledge
- World Bank regional research (OP 7.50)

## Objective
- Understand risks/opportunities in the Basin & possible futures
- Create a tool for information-based dialogue within & between countries

## Components
- Nested suite of models
- Water systems simulation models
- Economic optimization model
- Social analysis
The Ganges Basin

- The most populous in the world (~650m)
- A massive, moving, varied river system
  - High mountains & glaciers
  - Vast plains, dominated by large irrigation systems
  - The largest mangrove ecosystem in the world in the delta
- Driven by the South Asia monsoon
## Methodology

**Multiple models**

**Across disciplines**

**Public data**

**Converging picture of basin dynamics**

<table>
<thead>
<tr>
<th>Disciplines</th>
<th>Model</th>
<th>Objective</th>
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</thead>
<tbody>
<tr>
<td><strong>Water Systems</strong></td>
<td>MikeBasin (6-Mike1) Model</td>
<td>To model the surface water system in the Ganges</td>
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<tr>
<td></td>
<td>Groundwater, SWAT water balance &amp; water quality, flood modeling</td>
<td>To understand the dynamics of groundwater, water balance, water quality &amp; floods</td>
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<tr>
<td><strong>Economics</strong></td>
<td>GAMS/economic optimization Model</td>
<td>To explore economic trade-offs &amp; the distribution of benefits from new storage projects in the basin</td>
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<td></td>
<td>Commissioned research</td>
<td>Flood damages, ecosystem service values</td>
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<tr>
<td><strong>Social</strong></td>
<td>Literature review, focus group discussions, survey</td>
<td>To understand the social impacts of &amp; responses to water variability</td>
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</table>
Key questions from a basin-wide perspective

Or

techno-economic tradeoffs at the nexus
Is there substantial upstream reservoir storage in the basin?

Yes. Large multi-purpose dams could regulate the extreme flows of the Ganges River.

Not really. The largest 23 dams would only hold an additional 18% of the annual flow.
<table>
<thead>
<tr>
<th>Question</th>
<th>Commonly held perception</th>
<th>New Insights</th>
</tr>
</thead>
<tbody>
<tr>
<td>Can upstream water storage help <strong>control basinwide flooding?</strong></td>
<td><strong>Yes.</strong> Himalayan storage reservoirs are commonly seen as the answer to Ganges floods in the plains and delta.</td>
<td><strong>Basinwide? No.</strong> Too little to regulate the main stem. <strong>In sub-basins? Unlikely.</strong> Reduces peak flows, but doesn’t necessarily reduce floods.</td>
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**Little impact on mainstream**

**Modest impact in tributaries, but**
- most rivers are fully embanked
- local rainfall & embankment failures cause most flooding
### Question

Can **low-flows** be **augmented** by upstream water storage?

### Commonly held perception

**Yes.** Monsoon waters can be held upstream and released in the dry season

### New Insights

**Yes, but.** A small portion of the flood, makes a big difference to low flows

But the best use and economic value of this water is unclear

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**Max. increase of 20-45 BCM**

<table>
<thead>
<tr>
<th>Month</th>
<th>Low-flow at Ganges in Bangladesh (Hardinge Bridge)</th>
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</thead>
<tbody>
<tr>
<td>Nov</td>
<td><img src="image" alt="Graph showing low-flow variations" /></td>
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<tr>
<td>Dec</td>
<td><img src="image" alt="Graph showing low-flow variations" /></td>
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<td>Jan</td>
<td><img src="image" alt="Graph showing low-flow variations" /></td>
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<tr>
<td>Feb</td>
<td><img src="image" alt="Graph showing low-flow variations" /></td>
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<td>Mar</td>
<td><img src="image" alt="Graph showing low-flow variations" /></td>
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<tr>
<td>Apr</td>
<td><img src="image" alt="Graph showing low-flow variations" /></td>
</tr>
<tr>
<td>May</td>
<td><img src="image" alt="Graph showing low-flow variations" /></td>
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</table>

**Best use & value** of these increased flows is unclear

- Water does not appear to be the key factor limiting productivity
- In waterlogged areas additional low season water could harm
- Other values, i.e., ecosystems, navigation, municipal could be high but need study

Volumes are still small relative to peak flows, so the integrity of the hydrological system is unlikely to be threatened
**Question**

Are there good alternatives or complements to reservoir storage?

**Commonly held perception**

No. Large man-made storage is the only option adequate for the scale of the challenge.

**New Insights**

Yes. Natural underground water storage, strategically & sustainably managed, could be used in the basin on a scale comparable to the full suite of dams considered in our models.

Additional, sustainable groundwater resources available in the Ganges plains

In contrast to elsewhere in India

In the Ghaghra-Gomti Basin **2.5m new tubewells could be sustainably utilized** providing groundwater storage of over **20 BCM**

**Nexus: requires energy**

BGR & UNESCO, Map "Groundwater Resources of the World"
**Question**
Is there substantial **untapped hydropower**?

**Commonly held perception**
Yes. A lot. Enough for domestic energy as well as significant exports

**New Insights**
Yes. The 23 largest dams have an installed capacity of ~25,000MW (65-70 TWh) & a value of some $5bn/yr

### Annual Hydropower Benefits

#### 3 largest dams
- 19,000 MW installed capacity
- 35-45 TW-hr/yr power generated

#### 11 smaller dams
- 4,600 MW installed capacity
- 18 TW-hr/yr power generated
  (26-30 TWh/yr with 20 smaller dams)
Question: What is the magnitude of benefits, and what are the tradeoffs between uses?

Commonly held perception:

Big Gains & Tradeoffs.
There are great gains to be had, and big tradeoffs to be negotiated.

New Insights:

Big Gains, Little Tradeoffs.
The dams in this study could generate $3-8bn/yr, with little tradeoff between uses.

Little difference in optimal water releases for power & downstream supply uses

Little that can be done to achieve flood control
Question
What are the **cost & benefit sharing dynamics**; do downstream benefits justify compensation to upstream countries?

Commonly held perception
Big benefits upstream & downstream. Views vary widely about the upstream/downstream distribution of benefits

New Insights
Big benefits, mostly in hydropower. Hydropower (upstream) would provide the overwhelming share of benefits from dams today

- Hydropower benefits are greatest
- Current agricultural productivity is low
- In the future if agricultural productivity rises dramatically then the distribution of benefits will change
- Ecosystem values of enhanced low flows are uncertain, could be significant

**Low value in irrigation** ($0.01)
Low ecosystem values

$7.84bn
$0.38bn
$7.461

**High value in irrigation** ($0.1)
Low ecosystem values

$7.84bn
$3.8bn
$7.833

**High value in ecosystems** ($0.1)
Low value in irrigation ($0.01)

$7.41bn
$3.6bn
$5.646

$7.409
Take Away Messages from the Ganges Assessment

1. **Hydropower development: small tradeoffs, positive co-benefits**
   Significant potential to deliver clean peaking power & improve trade imbalances, and the benefit sharing calculus may be simpler if flood & agricultural water benefits are smaller

2. **For regional floods:**
   **focus on information & institutions, not just infrastructure**
   Upstream storage infrastructure cannot control flooding in the basin – real, immediate benefits can, however, come from cooperative regional monitoring & warning systems, coupled with localized flood responses

3. **For water storage to enhance low flows:**
   **look underground, not just upstream**
   Upstream storage can provide significant additional low season flows. Groundwater storage (i.e., in UP) can provide similar benefits, possibly more immediately & at lower costs
Thank you