Phase II Report: Project Definition Options

Water management and reservoir operations
STRUCTURE OF THE PRESENTATION

- Inflows
- Regional water allocation context
- Reservoir filling
- Generation during filling period
- Cascade operation
- Sedimentation
- Climate change impact
INFLOWS

- Monthly discharges at ROGUN site from April 1932 to March 2008
- 76 complete hydrological years available constituting consistent and reliable basic data for the studies
REGIONAL WATER ALLOCATION CONTEXT

• The regional water allocation practices are ruled by the ICWC and based on Protocol n° 566 and Nukuss declaration

• The present situation is accepted by all parties:
  – Nurek reservoir is transferring 4.2 km$^3$ per year from summer to winter
  – Water withdrawal allocations are adapted each year by the ICWC depending on the hydrology forecast,
    Average allocated volumes over the period 1992-2010 are as follows:

<table>
<thead>
<tr>
<th>Allocation by BVO Amu Darya</th>
<th>Tajikistan</th>
<th>Kirgizstan</th>
<th>Uzbekistan</th>
<th>Turkmenistan</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average allocated</td>
<td>8.845 km$^3$</td>
<td>0.216 km$^3$</td>
<td>21.378 km$^3$</td>
<td>20.960 km$^3$</td>
<td>51.400 km$^3$</td>
</tr>
<tr>
<td>17.3%</td>
<td>0.4%</td>
<td>41.5%</td>
<td>40.8%</td>
<td>100%</td>
<td></td>
</tr>
</tbody>
</table>
REGIONAL WATER ALLOCATION CONTEXT

- Actual percentage use of allocated water (1992-2010)

<table>
<thead>
<tr>
<th></th>
<th>Tajikistan</th>
<th>Kyrgyzstan</th>
<th>Uzbekistan</th>
<th>Turkmenistan</th>
<th>Aral Sea release</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum</td>
<td>67.6%</td>
<td>1.8%</td>
<td>68.3%</td>
<td>74.8%</td>
<td>13.1%</td>
</tr>
<tr>
<td>Average</td>
<td>82.8%</td>
<td>51.9%</td>
<td>94.7%</td>
<td>92.9%</td>
<td>140.2%</td>
</tr>
<tr>
<td>Maximum</td>
<td>91.4%</td>
<td>100.0%</td>
<td>105.8%</td>
<td>101.4%</td>
<td>488.2%</td>
</tr>
</tbody>
</table>

- Tajikistan is not using its full water share allocation
- As an average, each year 1.57 km$^3$ of allocated water to Tajikistan is not used
RESERVOIR FILLING

- Rogun reservoir is filled using only up to 1.2 km$^3$ of water per year
- 1.2 km$^3$ is the Vakhsh part of unused Tajik water allocation

<table>
<thead>
<tr>
<th>Alternative</th>
<th>1290 masl</th>
<th>1255 masl</th>
<th>1220 masl</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time to fill Rogun reservoir and reach normal operation level, using a volume of water up to 1.2 km$^3$/year</td>
<td>16 years</td>
<td>13 years</td>
<td>9 years</td>
</tr>
</tbody>
</table>
RESERVOIR FILLING

- First years, reservoir filling is limited by the dam construction ⇒ Less than 1.2 km³ is used
- Then, the dam is rising faster than the reservoir level
- Compared to « No Rogun » case, and assuming that Tajikistan will use its full water allocation, the Rogun filling has no impact on the downstream Amu Darya discharge.
**GENERATION DURING FILLING PERIOD**

- During the reservoir filling period, early generation is realized, first with units 5 and 6 and then with all units.
- The additional energy produced by the Vakhsh cascade during the filling period is evaluated in comparison with the No Rogun case:

<table>
<thead>
<tr>
<th>FSL</th>
<th>Start of early generation (from TEAS validation and GoT decision to proceed with the project)</th>
<th>Additional energy produced over filling period (TWh)</th>
<th>Equiv. years of normal Rogun operation / Filling period (yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1290</td>
<td>6 years 3 months</td>
<td>111</td>
<td>7.7 / 16</td>
</tr>
<tr>
<td>1255</td>
<td>6 years 3 months</td>
<td>69</td>
<td>5.5 / 13</td>
</tr>
<tr>
<td>1220</td>
<td>7 years</td>
<td>37</td>
<td>3.7 / 9</td>
</tr>
</tbody>
</table>
RESERVOIR OPERATION

• **Objectives:**
  – Evaluate the impact of Rogun on the Vakhsh River
  – Evaluate the energy that can be produced by Rogun and the Vakhsh cascade

• **Basic assumption: the present situation is accepted by all parties**
  – Proposal: « unchanged flow pattern »
  – Vakhsh modelization to be calibrated on historical operation
RESERVOIR OPERATION

• **Simulate the Vakhsh river**
  - 5 HPPs, 2 regulating reservoirs, irrigation withdrawals
  - Present situation: Nurek is driving the Vakhsh cascade operation

• **Methodology:**
  - Understand present Nurek operation
  - Model the present situation in terms of downstream discharge, energy and Nurek reservoir level
  - Add Rogun and optimize Rogun/Nurek operation within the limits found in the previous step
The best calibration of the Vakhsh operation model is found when imposing the Nurek reservoir level. Water volume transferred from summer to winter = 4.2 km$^3$. 

=> Water volume transferred from summer to winter = 4.2 km$^3$. 

[Graph showing reservoir level changes over months, with labels for simulated and historical data.]
RESERVOIR OPERATION

- Rogun / Nurek Coupled operation
  - Calibrated operation rule = regulation volume (Volume of water transferred from summer to winter = 4.2 km$^3$)
  - This regulation volume is imposed at Rogun, Nurek becomes a run-off-the-river

- Rogun reservoir level is lowered during winter, and filled up in spring/summer (4.2 km$^3$; 30 m level variation for the 1290 m alternative)
RESERVOIR OPERATION

• Two scenarios of water withdrawals from the Vakhsh:
  – (a) The withdrawals are considered at their current level. The Tajik water share is not entirely used.
  – (b) The withdrawals have increased up to the point when the total Tajik water share is used.

• Several configurations: without Rogun, with Rogun 1290, with Rogun 1255, with Rogun 1220
RESERVOIR OPERATION

• Results

  – Average energy / firm energy (the one that is sure to be produced, at the statistical level of 95%)

  – Comparison of downstream discharge of the Vakhsh
## RESERVOIR OPERATION

- **Energy Results (Vakhsh Cascade)**

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Average energy (TWh)</th>
<th>Firm energy (TWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Without Rogun (a)</td>
<td>19.9</td>
<td>13.0</td>
</tr>
<tr>
<td>Without Rogun (b)</td>
<td>19.1</td>
<td>12.5</td>
</tr>
<tr>
<td>With Rogun 1290 (a)</td>
<td>35.3</td>
<td>22.8</td>
</tr>
<tr>
<td>With Rogun 1290 (b)</td>
<td>34.4</td>
<td>22.4</td>
</tr>
<tr>
<td>With Rogun 1255 (a)</td>
<td>33.3</td>
<td>21.7</td>
</tr>
<tr>
<td>With Rogun 1255 (b)</td>
<td>32.5</td>
<td>21.2</td>
</tr>
<tr>
<td>With Rogun 1220 (a)</td>
<td>31.0</td>
<td>20.1</td>
</tr>
<tr>
<td>With Rogun 1220 (b)</td>
<td>30.2</td>
<td>19.6</td>
</tr>
</tbody>
</table>
RESERVOIR OPERATION

• Conclusion

The entire study has been performed assuming that:
- the additional Rogun reservoir capacity is not used; only the present Nurek regulation volume is used;
- Tajikistan fully utilizes the water allocated to it;
- the seasonal flow pattern downstream of Nurek is kept unchanged.
SEDIMENTATION

• Important sediment transport in the Vakhsh river

• Potential impacts
  – Sediment deposit in reservoir
    ⇒ loss of storage
    ⇒ plugging of tunnels entrance (intakes, tunnels spillway,..)
  – Transport in tunnels and equipment
    ⇒ erosion

17/07/2014
SEDIMENTATION

• Sediment transport estimation:
  – 87-140 Mt per year
  – 62-100 hm³ per year

• 100 hm³ taken as main assumption for the study

• No feasible solution to significantly reduce this amount
SEDIMENTATION

- Impact on reservoir:

  FSL = 1290 m asl
  Vs   = 100 hm$^3$/yr

  FSL = 1255 m asl
  Vs   = 100 hm$^3$/yr

  FSL = 1220 m asl
  Vs   = 100 hm$^3$/yr
SEDIMENTATION

• Adaptive Rogun operation

  – Phase 1: active storage is decreasing with time, and sediment level at the dam is rising => yearly drawdown of Rogun is increased to compensate the active storage losses

  – Phase 2: regulation is done partly in Rogun partly in Nurek, because the loss of Rogun active storage is too important.
SEDIMENTATION

• Multi-level Intake

  – Inclined concrete culvert, resting on the bank slope in correspondence with the power waterways inlets, provided with openings at various levels up to the dam crest elevation

  ⇒ Allow for a sediment deposition level higher than the headrace tunnel elevation thus extending the lifetime of the powerhouse
SEDIMENTATION

- Rogun reservoir and powerhouse life span

<table>
<thead>
<tr>
<th>FSL = 1290 masl</th>
<th>Total volume (hm³)</th>
<th>100 Mm³/year</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>13 300</td>
<td>115 years</td>
</tr>
<tr>
<td>FSL = 1255 masl</td>
<td>8 600</td>
<td>75 years</td>
</tr>
<tr>
<td>FSL = 1220 masl</td>
<td>5 200</td>
<td>45 years</td>
</tr>
</tbody>
</table>

- Long term safety: surface spillway because tunnel spillways cannot be used anymore
- Ultimate end of life: powerhouse is out of service, river is passing through the surface spillway
CLIMATE CHANGE IMPACT

• Analysis of available data:
  – Trend analysis on 1930-2010 period indicate:
    • Increase in precipitations and discharges
    • Increase of 0.5°C per 100 years for the Fedchenko glacier
  – Specific studies show a clear recession of glaciers

• Potential impacts:
  – Decrease in flood peak volumes due to earlier and longer glaciers melt season
  – Temporary increase in average annual discharge

• Possible mitigations:
  – Higher storage allow for flexibility to handle hydrology variability
THANK YOU FOR YOUR ATTENTION