COYNE ET BELLIER Ingénieurs Conseils | ELC ELECTROCONSULT | IPA Energy + Water Economics

**TECHNO-ECONOMIC ASSESSMENT STUDY**
**FOR ROGUN HYDROELECTRIC CONSTRUCTION PROJECT**

OSHPC BARKI TOJIK

# Phase II Report: Project Definition Options

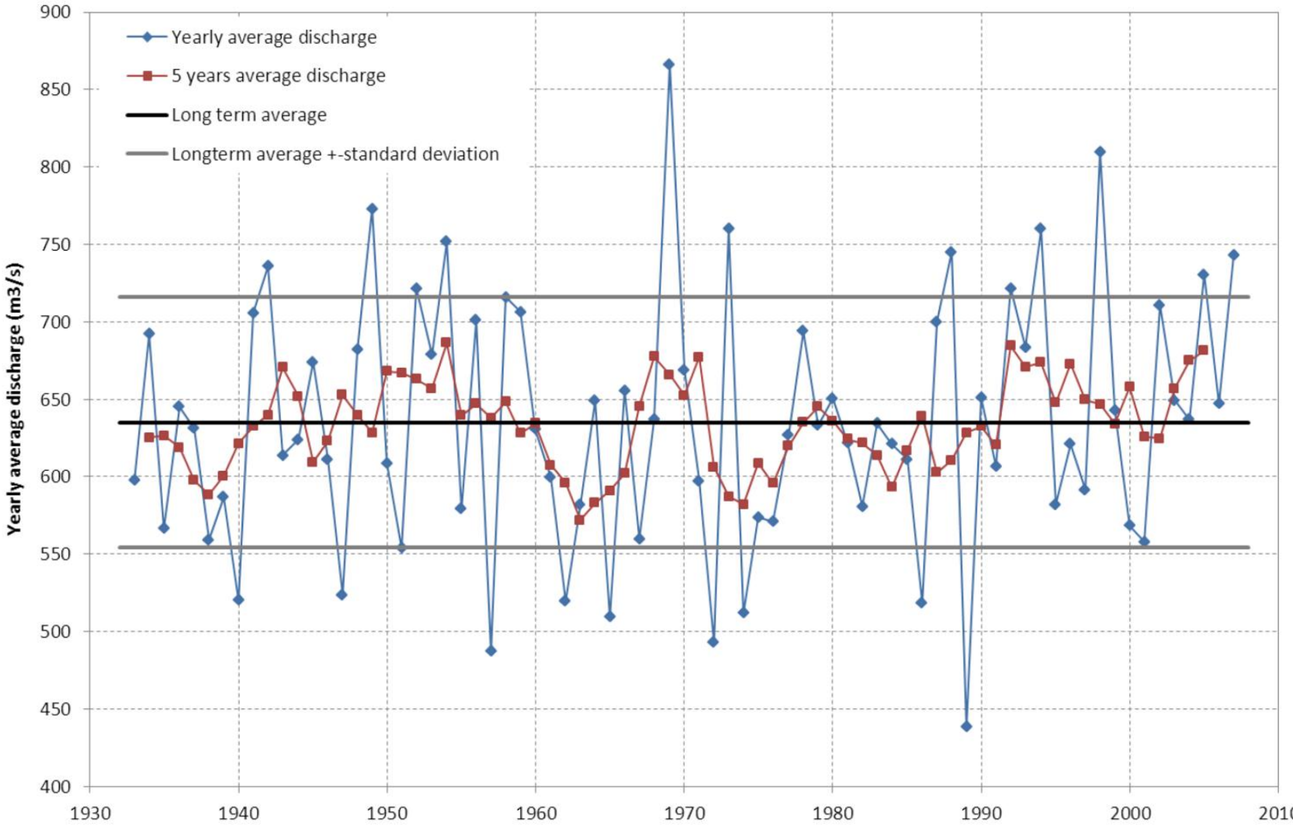
## Water management and reservoir operations

# 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:

| Allocation by BVO Amu Darya | Tajikistan | Kirgizstan | Uzbekistan | Turkmenistan | Total |
|---|---|---|---|---|---|
| Average allocated | 8.845 $km^3$<br>17.3% | 0.216 $km^3$<br>0.4% | 21.378 $km^3$<br>41.5% | 20.960 $km^3$<br>40.8% | 51.400 $km^3$<br>100% |

# REGIONAL WATER ALLOCATION CONTEXT

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

| | Tajikistan | Kyrgyzstan | Uzbekistan | Turkmenistan | Aral Sea release |
|---|---|---|---|---|---|
| Minimum | 67.6% | 1.8% | 68.3% | 74.8% | 13.1% |
| Average | 82.8% | 51.9% | 94.7% | 92.9% | 140.2% |
| Maximum | 91.4% | 100.0% | 105.8% | 101.4% | 488.2% |

- 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

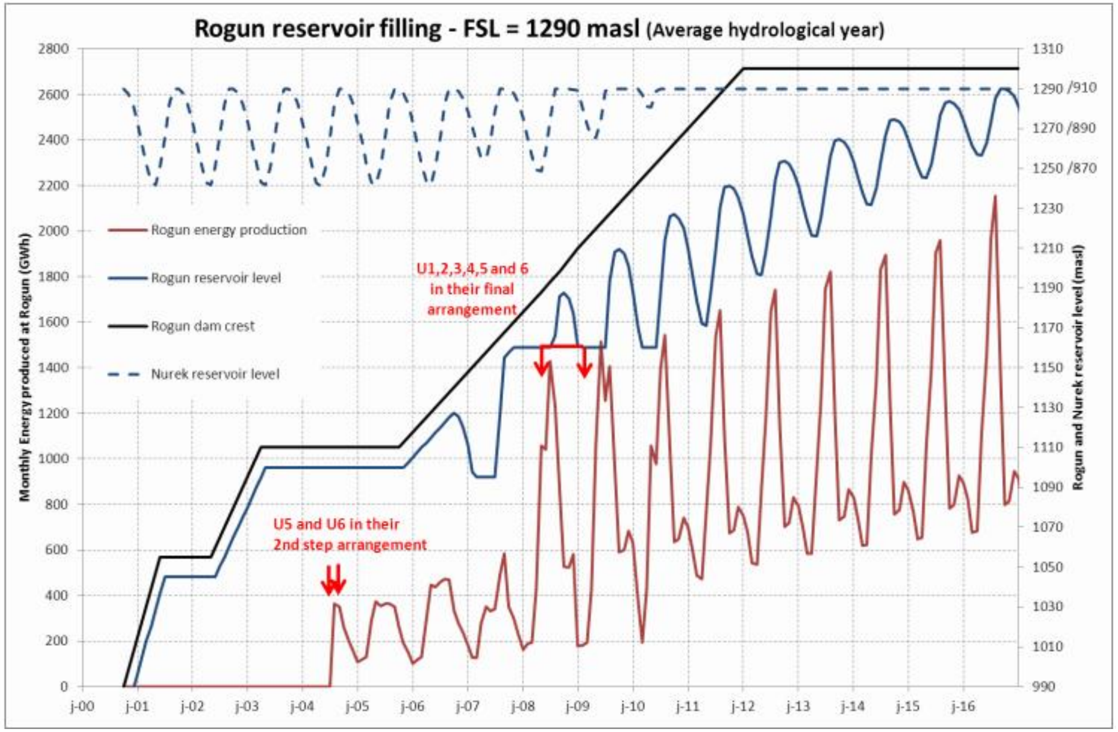
# RESERVOIR FILLING

- 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

| Alternative | 1290 masl | 1255 masl | 1220 masl |
|---|---|---|---|
| Time to fill Rogun reservoir and reach normal operation level, using a volume of water up to 1.2 $km^3$/year | 16 years | 13 years | 9 years |

# RESERVOIR FILLING

- First years, reservoir filling is limited by the dam construction
  ⇒Less than 1.2 $km^3$ 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:

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

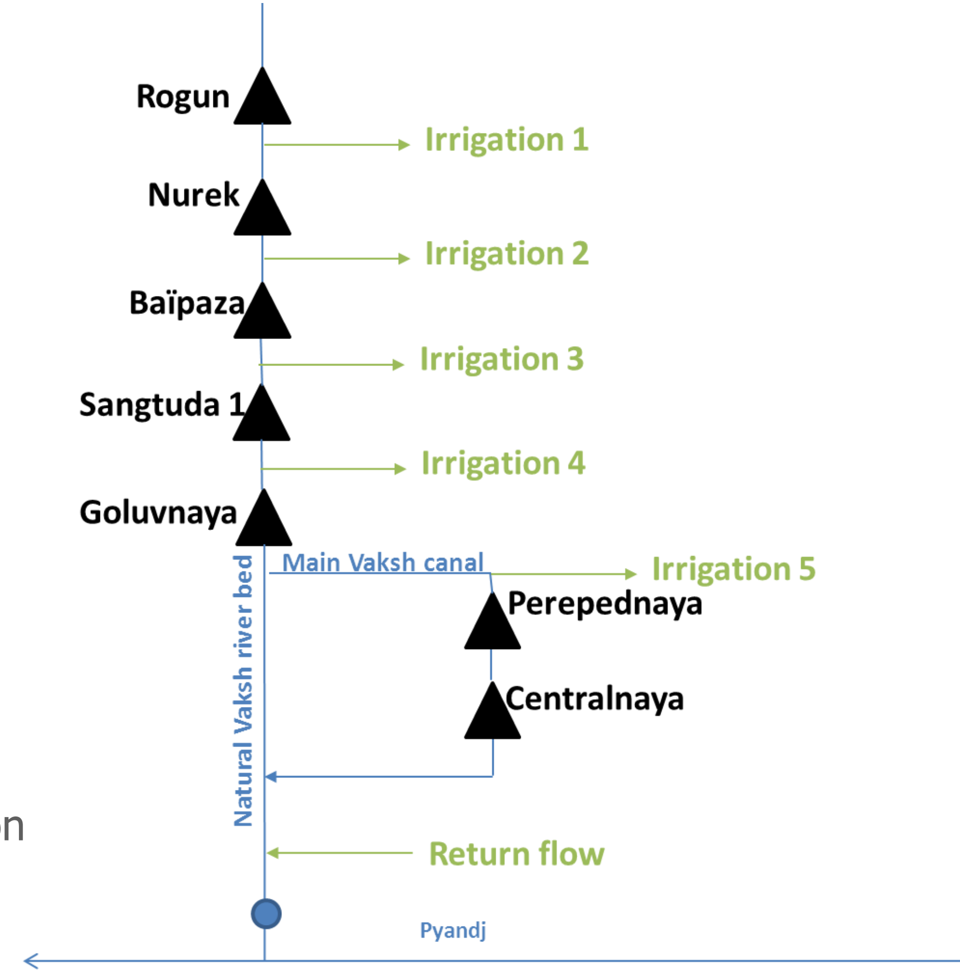
# RESERVOIR OPERATION

- 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

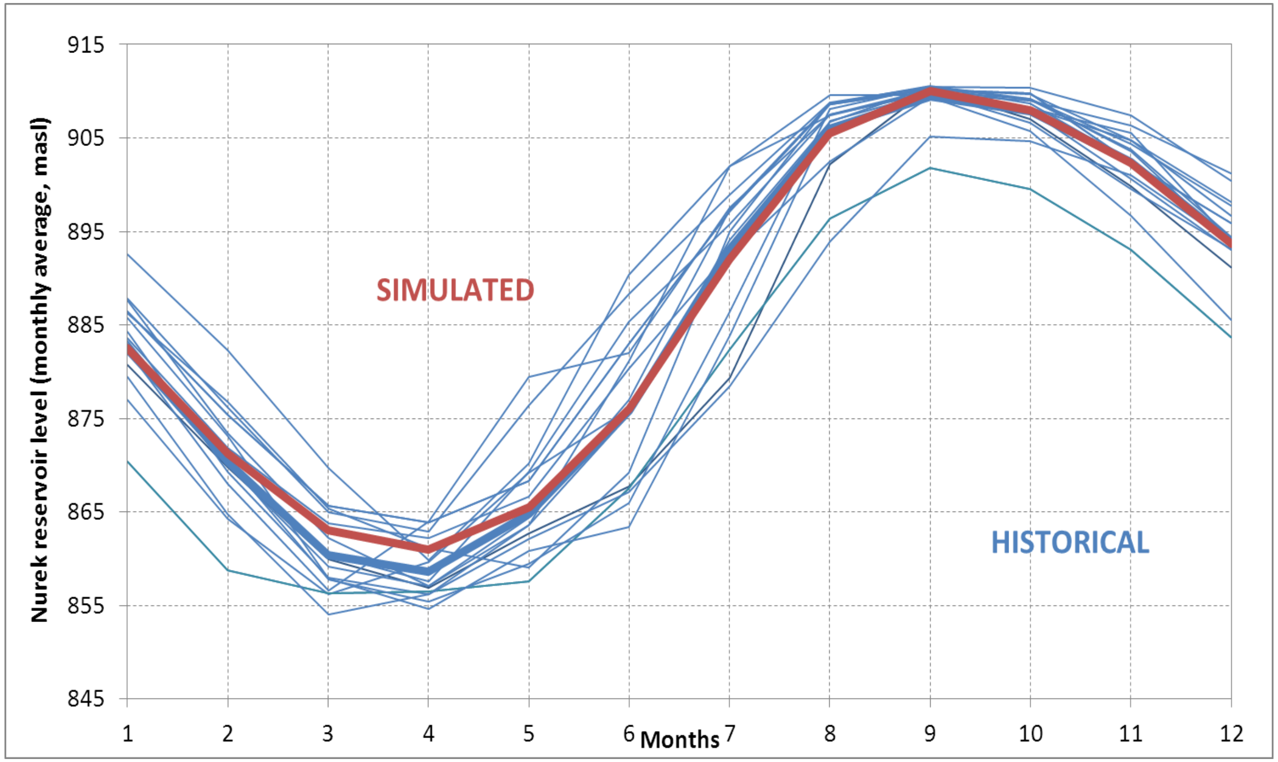
# RESERVOIR OPERATION

- 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



# RESERVOIR OPERATION

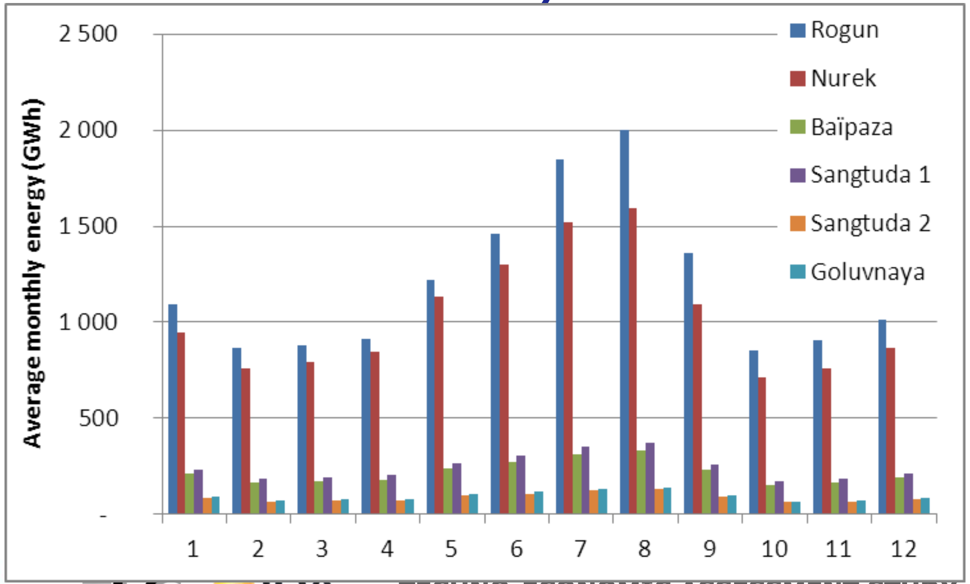
- The best calibration of the Vakhsh operation model is found when imposing the Nurek reservoir level

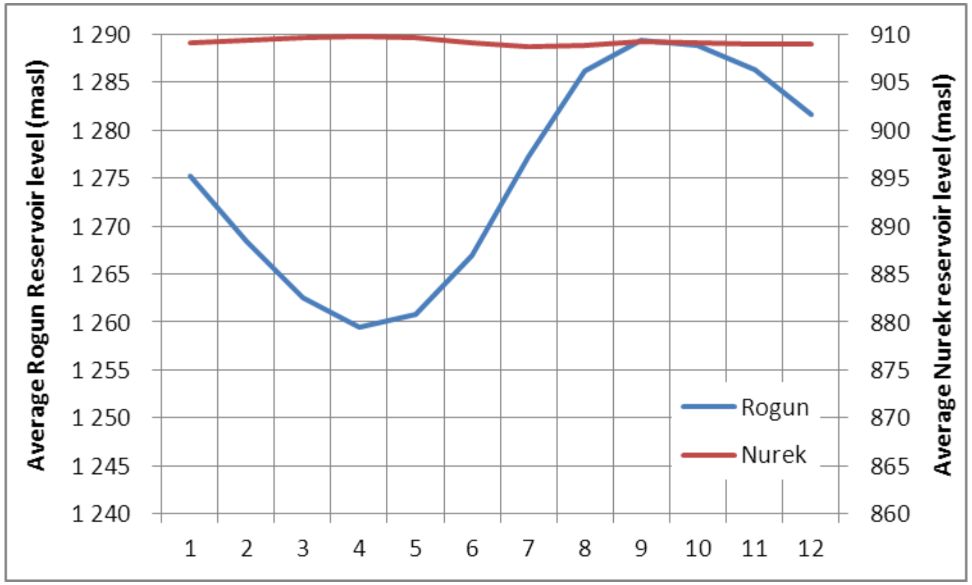



=> Water volume transferred from summer to winter = 4.2 $km^3$

# 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)



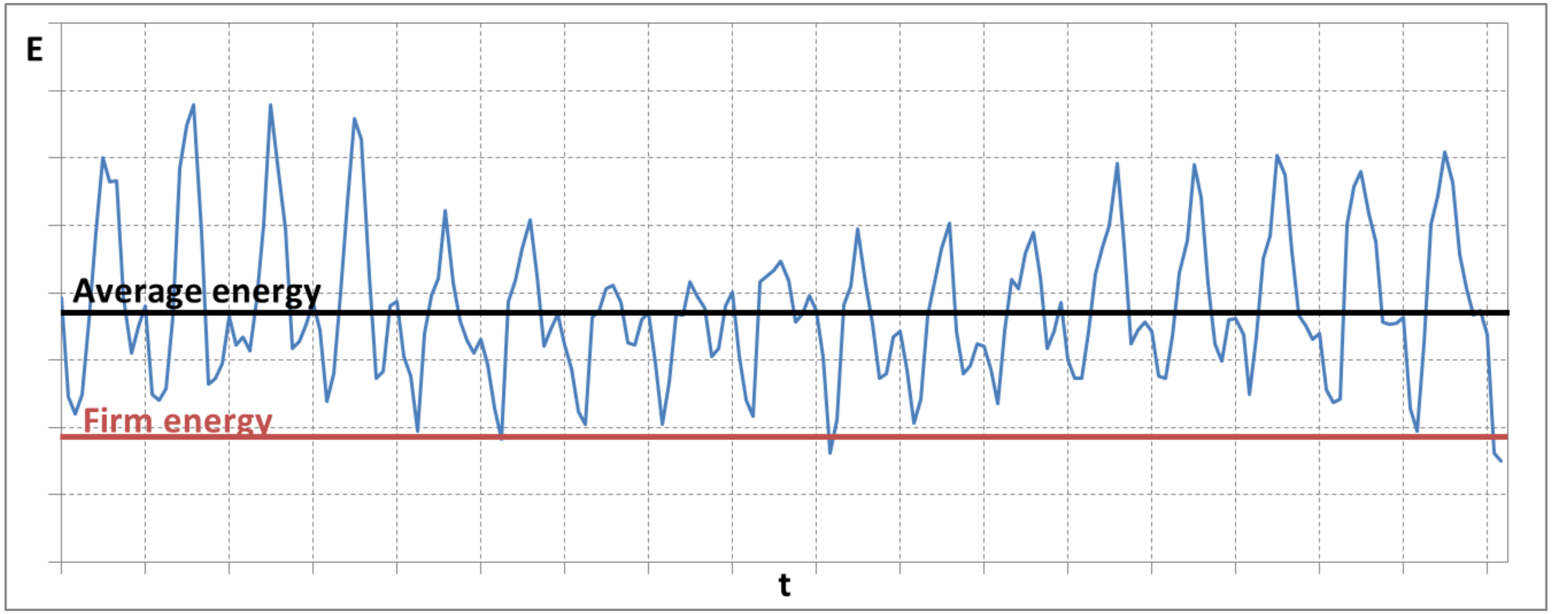
# RESERVOIR OPERATION

- 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%)

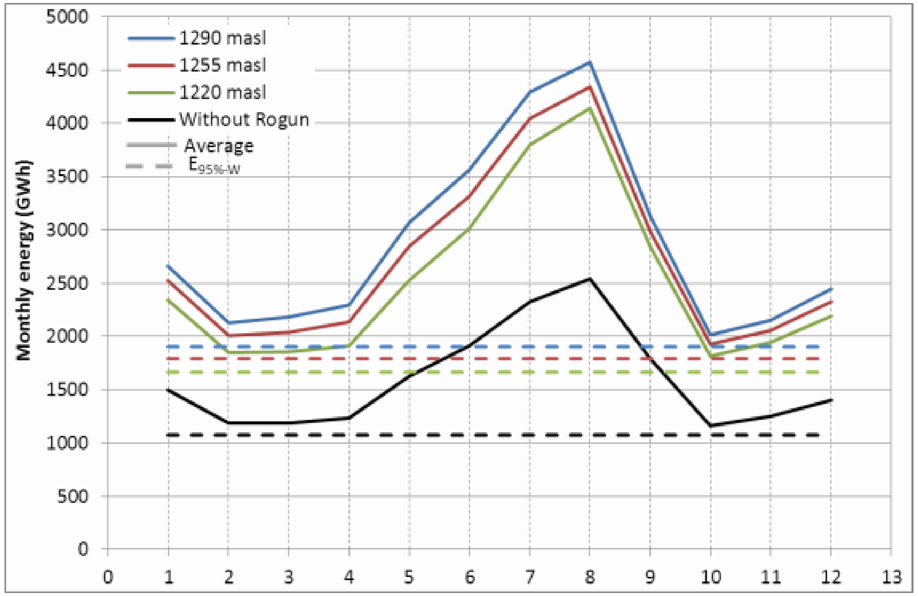



  - Comparison of downstream discharge of the Vakhsh

# RESERVOIR OPERATION

- Energy Results (Vakhsh Cascade)

| Scenario | Average energy (TWh) | Firm energy (TWh) |
|---|---|---|
| Without Rogun (a) | 19.9 | 13.0 |
| Without Rogun (b) | 19.1 | 12.5 |
| With Rogun 1290 (a) | 35.3 | 22.8 |
| With Rogun 1290 (b) | 34.4 | 22.4 |
| With Rogun 1255 (a) | 33.3 | 21.7 |
| With Rogun 1255 (b) | 32.5 | 21.2 |
| With Rogun 1220 (a) | 31.0 | 20.1 |
| With Rogun 1220 (b) | 30.2 | 19.6 |



# 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

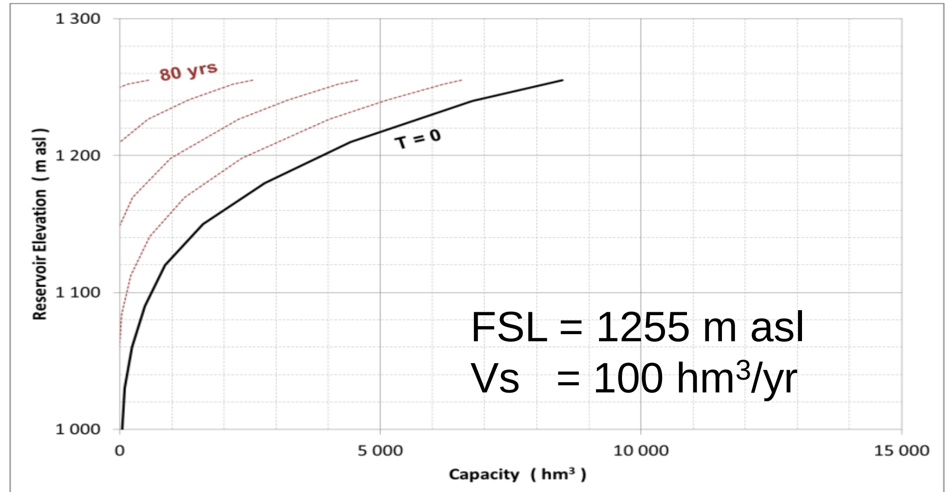
- Potential impacts
  - Sediment deposit in reservoir
    - ⇒ loss of storage
    - ⇒ plugging of tunnels entrance (intakes, tunnels spillway,..)
  - Transport in tunnels and equipment
    - => erosion

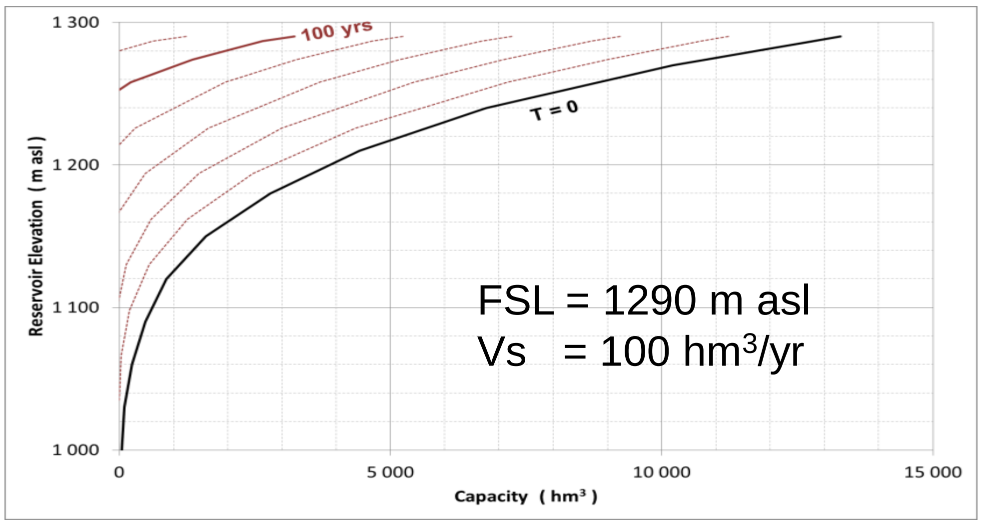
# SEDIMENTATION

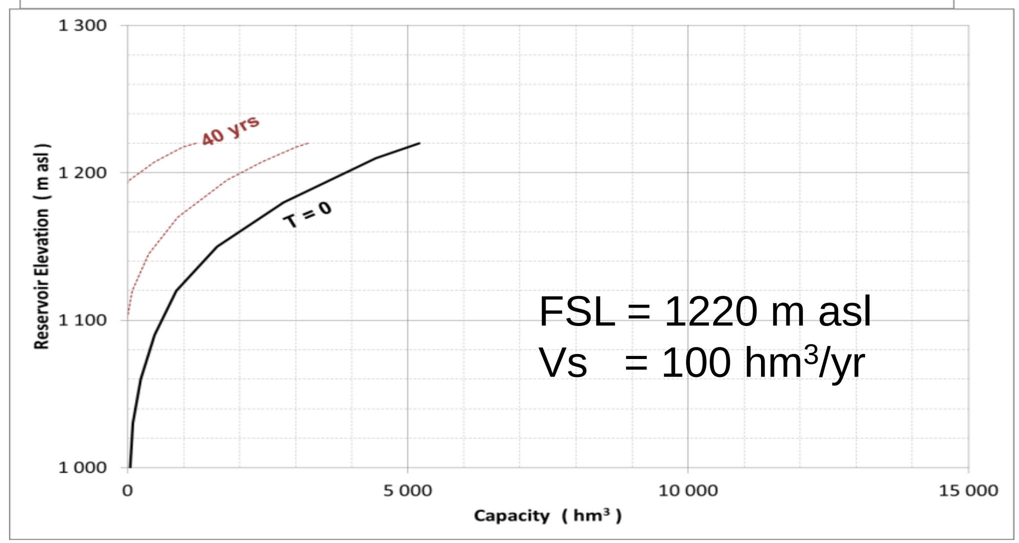
- Sediment transport estimation:
  - 87-140 Mt per year
  - 62-100 $hm^3$ per year
- 100 $hm^3$ taken as main assumption for the study
- No feasible solution to significantly reduce this amount

# SEDIMENTATION

- Impact on reservoir:

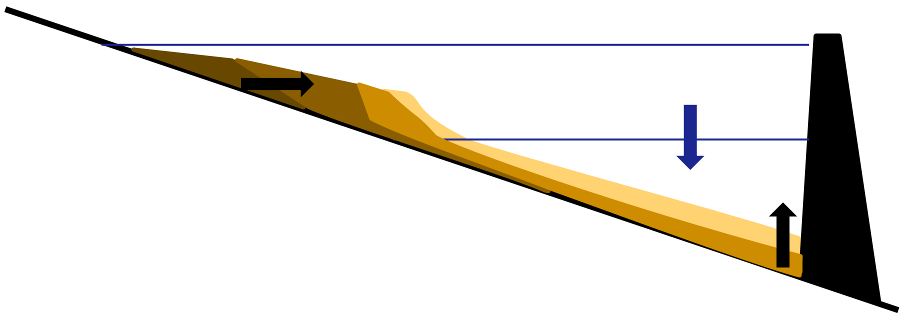


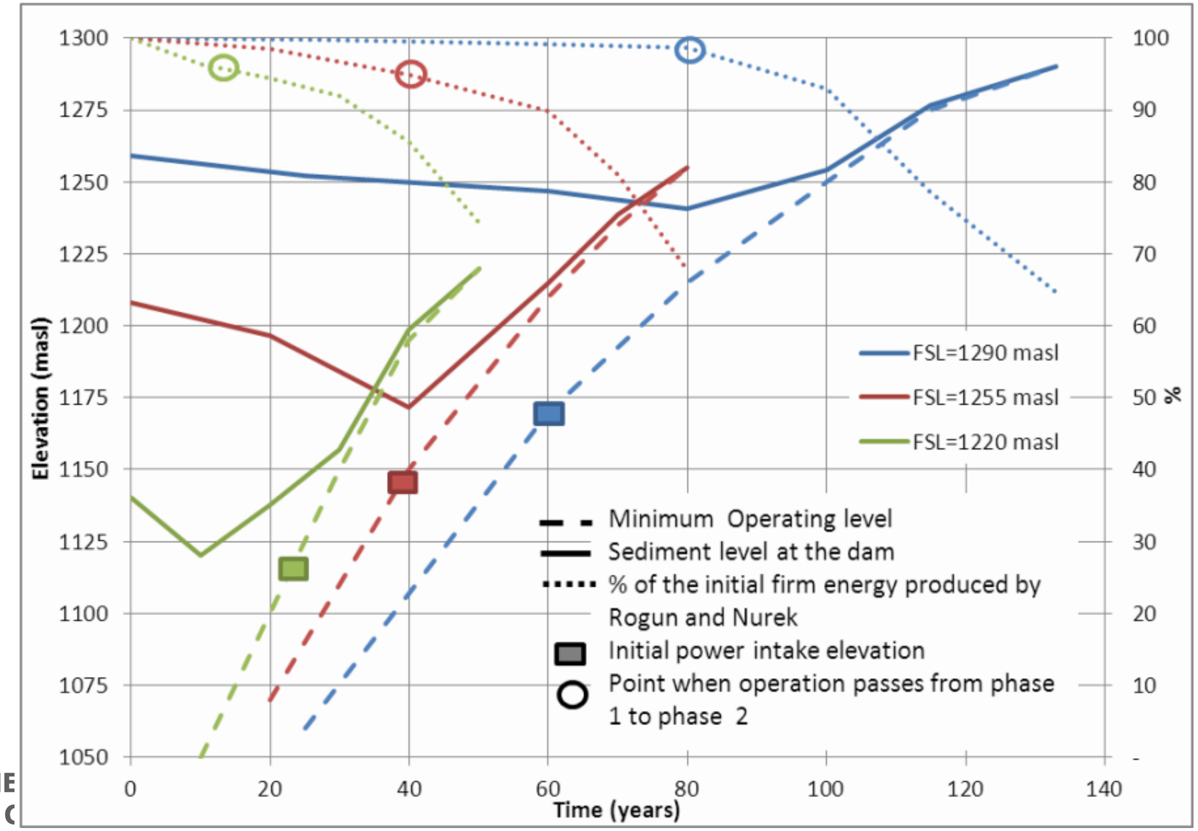



# SEDIMENTATION

- 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

| | Total volume (hm3) | 100 $Mm^3$/year |
|---|---|---|
| **FSL=1290 masl** | 13 300 | 115 years |
| **FSL=1255 masl** | 8 600 | 75 years |
| **FSL=1220 masl** | 5 200 | 45 years |

- 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