TECHNO-ECONOMIC ASSESSMENT STUDY
FOR ROGUN HYDROELECTRIC CONSTRUCTION PROJECT

OSHPC BARKI TOJIK

Phase II Report: Project Definition Options

Conclusion and Recommendations

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1. Introduction

TEAS: Technico-Economical Assessment Studies

Participants
Coyne et Bellier of France
Electroconsult of Italy
IPA of the United Kingdom

Phase **0**: assessment of the **SALT WEDGE**
Phase **1**: assessment of all **EXISTING WORKS**
Phase **2**: assessment of all **ALTERNATIVES** of the ROGUN HPP

ESIA: Environmental & Social Impact Assessment
Consultant: POYRY ENERGY Ltd. of Switzerland

2. Brief History

1950s & 1960s : soviet regional development for irrigation + power

1970s: project design

1980 : construction starts. Then interrupted by political changes

2008 : construction starts again

2010 : updated design by HPI-Moscow

2011

2014

TEAS
+
ESIA

3. Design Approach

As per Terms of Reference:

extensive TEA. Study required taking into account:
- original data and investigations
- original and 2010 updated design

design changes complying with:
- internationally accepted standards
- state of the art engineering practice
- same design criteria for all alternatives

4. Project Alternatives Considered

Full supply levels (FSL) of 1290 m asl; 1255 m asl; 1220 m asl.

1290: as in original design
1220: minimum acceptable reservoir life because of sediments
1255: intermediate value

Corresponding dam heights: 335 m; 300 m; 265 m

Three installed capacities for each FSL: total of 9 alternatives

FSL 1290:	3600 MW; 3200 MW; 2800 MW
FSL 1255:	3200 MW; 2800 MW; 2400 MW
FSL 1200:	2800 MW; 2400 MW; 2000 MW

5. FACTORS CONSIDERED IN DEVELOPMENT OF PROJECT ALTERNATIVES

5.1 NATURAL CONDITIONS

5.1.1 Geology and Salt Wedge

Complex site geology: data + add. investigations = understanding. Safe design (international standards) + monitoring / mitigation.

Salt Wedge (Phase 0). Physical investigation + Num. modelling x2 → dam safety evaluation: design hydraulic curtain+grouting cap

Monitoring (pressure, conductivity, deformation), also prepared remedial measures.

5.1.2 Seismicity

Deterministic Seismic Hazard Assessment: PGA-MCE = 0.71 g + response spectra.

3 dam alternatives checked for this condition in compliance with international dam safety design criteria. Co-seismic displacements evaluated.

Probabilistic Seismic Hazard Assessment performed for detail design phase: preliminary check confirms adequacy of dam design

Monitoring recommended prior, during and after construction.

5. FACTORS CONSIDERED IN DEVELOPMENT OF PROJECT ALTERNATIVES

5.1 NATURAL CONDITIONS

5.1.3 Hydrology

76 years of daily records (consistent & reliable). Extreme floods; PMF=7,800 m^3/s + 10,000yr= 5,700 m^3/s

Design floods for each construction stage.

Data for Reservoir Operation.

5.1.4 Sedimentation

Sediment input: 60-100 $M.m^3$/year. Reservoir life (100 $M.m^3$/yr): 115 yr; 75 yr; 45 yr for FSL= 1290; 1255; 1220, resp.

Limited possibility of evacuation to extend generation, raise intake & control delta.

Eventually reservoir filled up: specific end-of-life strategy required: surface spillway.

5. FACTORS CONSIDERED IN DEVELOPMENT OF PROJECT ALTERNATIVES

5.2 EXISTING FACILITIES AND EQUIPMENT

Phase 1 studies assessed suitability of previously constructed facilities or equipment.

Phase 2 alternatives appropriately incorporate them.

5.3 RESERVOIR FILLING AND OPERATION

Assumptions consistent with existing agreements and practice for water allocation. Reservoir filling uses only unutilized share.

Subsequently GoT intends to continue using it for irrigation. Rogun+Nurek operated ensuring Summer-Winter transfer as in present conditions.

5. FACTORS CONSIDERED IN DEVELOPMENT OF PROJECT ALTERNATIVES

5.4 ENVIRONMENTAL AND SOCIAL IMPACTS

ESIA based on technical features of alternatives. No alt. eliminated on E+S basis (highest dam larger resettlement).

ESIA costs incorporated in overall capital cost of alternatives. Loss of agricultural production included in economic analysis.

5.5 ELECTRICITY DEMAND FORECAST

Today in Tajikistan: summer surpluses and winter energy shortages and load-shedding.

Forecast horizon 2050, included: unmet demand, economic growth and tariffs, expansion electric system, control of losses.

Median Compound Annual Growth Rate 2013-50: 2.6% (25^{th} and 75^{th} centiles: 2.0% and 3.6%)

6.1 SELECTION OF THE DAM SITE, TYPE AND AXIS

6.1.1 Dam Site

Minimum incidence of faults and minimum dam volume.

6.1.2 Dam Type

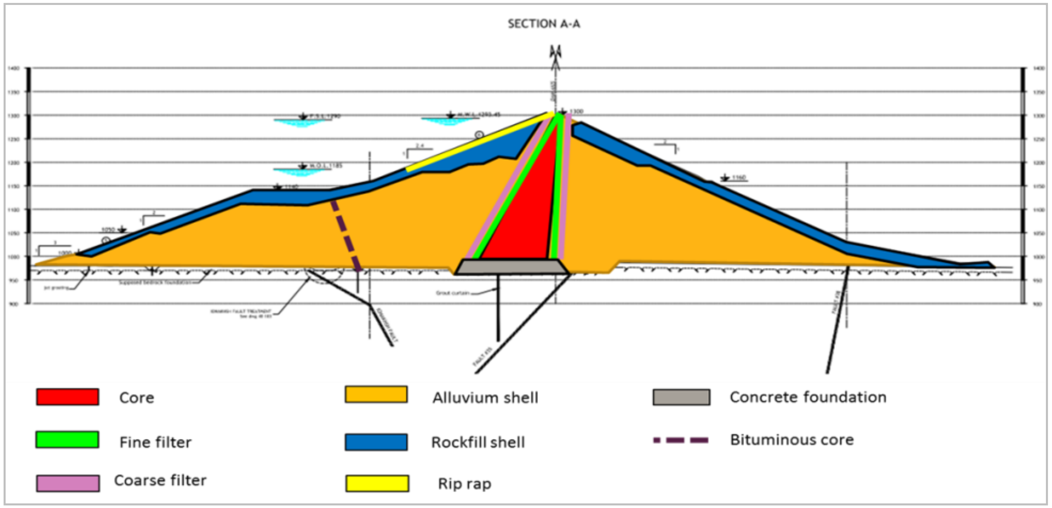
Rock-fill with clay core. Ability to:

- withstand large EQ,
- accommodate to salt wedge,
- avoid excessive stresses on siltstone,
- withstand differential settlements,
- Staged construction.

6.1.3 Dam Axis

Same as in original design and for the 3 alternatives.

6.2 DESIGN OF THE DAM



- Dam slopes of 2H/1V (D/S) 2.4H/1V (U/S) found sufficient to ensure the stability of the dam.
- Filters and transitions thickness, at least 10 m to ensure effectiveness in case of large earthquakes.
- Freeboard at least 6 m to accommodate the settlement occurring during a large earthquake.
- In the upper part of the dam (top 50 m), rock-fill instead of alluvium as it has a higher friction angle.

6.3 POWERHOUSE CAVERN

Cavern partly excavated in sandstone/siltstone area. Set of support measures to stabilize convergence.

Possible alternative powerhouse locations also considered. But it was concluded that with appropriate stabilization measures, the existing location is the most appropriate for implementation, from an economic point of view.

6.4 FLOOD MANAGEMENT

Significant modifications introduced to the 2010 design:

- During Diversion: remedial measures for the two existing tunnels, higher cofferdam required; 3rd diversion tunnel required for derivation.
- Construction phases: new tunnels required as the reservoir level increases.
- Operation phase: in original design, only tunnel spillways with submerged intakes, risk of cavitation by high water velocities and by abrasive sediments.
  Long term solution developed to safely pass floods. Nurek & Cascade protected against PMF during decades.

6.5 CONSTRUCTION STAGES

Pre-cofferdam (25m): river diversion and closure in 1st dry season

Cofferdam (75m) : 1st wet season

Stage 1 dam (135m-115m-100m): allows for early generation

Main dam (335m-300m-265m) for FSLs=1290; 1255; 1220 m asl.

6.6 IMPLEMENTATION SCHEDULE AND LOGISTICS

Two main critical paths (from TEAS validation and GoT's decision to proceed with the Project):

Early generation: 6yr+03m; 6yr+03m; 7yr+00m

End of construction: 13yr+07m; 11yr+10m; 10yr+00m.

6.7 EARLY GENERATION CONCEPT

Additional energy produced by the Cascade during Rogun filling (compared to the No-Rogun option):

FSL	Filling time (years)	Sum of Energy (TWh)	Equiv. nb of years of normal Rogun op
1290	16	111	7.7
1255	13	69	5.5
1220	9	37	3.7

6.8 ENERGY GENERATION AND DATE OF COMMISSIONING

Annual energy (in TWh) estimated to be produced by ROGUN HPP :

FSL	Annual Energy Max Installed Capacity	Annual Energy Int Installed Capacity	Annual Energy Min Installed Capacity
1290	14.4	14.3	14.1
1255	12.4	12.4	12.1
1220	10.1	10.0	9.8

Combined Rogun-Nurek operation will also results in higher energy produced at Nurek.

6.9 INVESTMENT COSTS

Detailed cost analysis with the same level of accuracy for all the 9 alternatives.

The cost estimates were used in the economic comparison of alternatives.

6.10 PROJECT LIFE

Based on an input of sediments of 100 M.m^3/yr the time at which no more regulation is possible in the reservoir is:

FSL=1290: 115 yr; FSL=1255: 75 yr ; FSL=1220: 45 yr.

7.1 TECHNICAL ASSESSMENT FROM SAFETY CONSIDERATIONS

TEAS showed that:

- subject to the application of specified design modifications,
- subject to the implementation of identified mitigation and monitoring measures,

Any of the Rogun dam alt. can be built & operated within international safety norms

7.2 ECONOMIC ASSESSMENT

Detailed economic analyses have been performed for the different project alternatives and compared with no-project scenarios.

The economic assessment demonstrates the economic viability of all the Rogun alternatives under a wide range of assumptions.

The FSL 1290 masl alternative with installed capacity of 3200 MW shows the highest total system cost saving and the highest net present value of economic benefits.

7.3 CONCLUSIONS

The highest dam (FSL 1290):

- can be built and operated at the Rogun site within international safety norms;
- has the longest project life, thereby guaranteeing low cost energy production for the longest period to the Tajik energy system;
- can attenuate the PMF sufficiently to safeguard the entire Vakhsh cascade;
- would provide a longer delay in the sedimentation of the Nurek reservoir and the consequent impact on electricity generation from the entire cascade;
- provides the maximum potential for augmenting dry year flows for downstream riparians;
- is part of the least cost generation expansion plan for Tajikistan in preference to other Rogun alternatives as well as No Rogun alternatives;
- provides the highest net present value of economic benefits.

7.4 RECOMMENDATIONS

Based on the above assessment, the Consultant has recommended that the 1290 FSL Rogun alternative be taken forward for detailed consideration.

As the economic results provided by different installed capacities are relatively similar, it is recommended that the optimization of the installed capacity be studied further in the detailed design stage.

A number of recommendations have been made on further investigations and analyses that should be carried out for the detailed design of the project.

Thank you !