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TECHNO-ECONOMIC ASSESSMENT STUDY
FOR ROGUN HYDROELECTRIC CONSTRUCTION PROJECT

PHASE II REPORT (FINAL):
PROJECT DEFINITION OPTIONS

VOLUME 3: ENGINEERING AND DESIGN

Chapter 1: Design Criteria

TECHNO-ECONOMIC ASSESSMENT STUDY FOR ROGUN HYDROELECTRIC CONSTRUCTION PROJECT

PHASE II: PROJECT DEFINITION OPTIONS

1 GENERAL

1.1 Applicability of the Design criteria

The present design criteria will be used for Phase 0, I and II of the project. More detailed design criteria will be elaborated for later phases of the studies and, in particular for detailed design:

- Phase 0: Assessment of the salt dome issue at the project site
- Phase I: Assessment of the Existing Rogun HPP site and Works
- Phase II: Rogun HPP Project Definit4(i)1716.96 37.8 Tm 0 1 74W373.75/F10 1n1 0 0 1 405.1 611.5 Tm

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2.2.1 10,000 year Flood

The frequency analysis carried out in order to determine the 10 000 years flood (and floods for other return periods) will be based on a regional approach carried out in several steps:

- First step ± Regional sample based on Vakhsh gauging stations,
- Other steps ± First regional sample and transposed floods from rivers of the region having the same flood regime.

2.2.2 Probable Maximum Flood (PMF)

The derivation of Probable Maximum Flood will take into account the following guidelines / criteria. We recall that there is no standard method for PMF derivation. As stated by WMO in its publication about PMP derivation (1986), each case is specific due to data availability and climate patterns.

<u>Data for PMF Derivation</u>

The approach will be adapted to the available data. These data should encompass several types of data:

- Daily discharges at Rogun dam site.
- Monthly and seasonal rainfall at selected stations.
- Daily mean temperature at selected stations.

<u>PMF Derivation</u>

In a first stage of the study, the relation of daily discharge versus daily temperature will be investigated. This relation will be assessed for the rising limb of the hydrograph until the precipitation and discharge data. &DUH ZLOO EH HHUFLVHG ZKHQ LWWLQ WUHQGV WR FRQWHPSRUDU\ GDWD and then extrapolating them into the future. Exploratory data analysis will be part of the initial data audit. Similarly, literature about Climate Change will be investigated in order to present an assessment about the period 2000 / 2100.

<u>Glacial Lake Outburst Floods (GLOFs)</u>

Additional freeboard has been taken into consideration for the risk of GLOFs as detailed in section 3.1. Detailed criteria will be elaborated during the next Phases of the studies.

<u>Landslides within the Reservoir</u>

The risks of landslides being triggered by reservoir impoundment, reservoir operation or earthquakes will be assessed and taken into account in the design as appropriate.

2.2.3 Construction Flood

In order to manage hydrological risks, it is essential that the construction of the dam is continuous above the level of the cofferdam.

A contingency plan will be developed in order to mitigate the hydrological risks in case this condition would not be possible.

The mean period of return of construction floods will be selected on the basis of the probabilistic approach; the accepted probability should be adapted to the construction planning (time of exposure) and the gravity of potential consequences in the case of flood occurrence.

The flood evacuation system should be such that at any step of construction, the reservoir level remains lower than the dam elevation less the adapted dry freeboard.

Allowance shall be made during intermediate construction stages for the appropriate discharge/safety against construction floods, as determined in Section 2.2.3 above.

Appropriate spillway capacity should be in place to handle the design floods at any stage of construction.

2.3 Geological/geotechnical data

The design, including design of any required remedial treatment will use the existing data from previous geological investigations and also findings of the supplementary geological investigations undertaken in 2012.

2.4 Seismic design parameters including MCE acceleration, fault movement

In general, the Consortium will follow the recommendations of ICOLD bulletin 148 (2010). In brief:

- At this stage of the study, only two levels of earthquake will be considered: OBE and MCE. No consideration will be given to MDE.

- The Maximum Credible Earthquake (MCE) is the largest reasonable conceivable earthquake that appears possible under the presently known or presumed tectonic framework. It is determined by regional and local studies that include a review of all historic earthquake data of events sufficiently nearby to influence the project, and a review of the parameters attached to the local faulting.
- The Operating Basis Earthquake (OBE) is the level of earthquake for which only minor damage is accepted. The probability of occurring of the OBE should be about 50% during the service life (100 years); the corresponding return period is 150 years.
- Ratio of the horizontal to vertical design accelerations derived for MCE and OBE earthquakes will be selected on the basis of the outcomes of the studies on seismic hazard assessment.
- The studies on the seismic hazard assessment will allow determining the design spectra to be adopted in the analyses.

As active faults (Ionaksh, #35 and possibly others) cross the structures, evaluation of their co-seismic displacements has to be made for MCE and OBE events, in addition to the a-seismic displacements.

2.5 Sedimentation

At this stage of the studies, as no measurement of sediment content in the Vakhsh river was made recently, compilation will be made of the information presented in the HPI reports dated 2009.

3 DESIGN CRITERIA FOR THE DAM

3.1 Freeboard

The freeboard will be calculated on the basis of the recommendations of the USBR given in the GRFXPHQW ³)UHHERDUG FULWHULD DQG JXLGHOLQHV IRU FRPSXWLQJ IUHHERDUG DOORZDQFHV IRU VWRU GDPV´ UHYLVHG LQ

Furthermore, for the embankment dam, a dry freeboard shall include the allowance for permanent settlements, wave run up and GLOF. The freeboard for GLOF allowance will be estimated by using the following formula:

Additional freeboard I L $\frac{944}{Ì:Þà·;}$

S(km^2) being the area of the reservoir for the maximum water level. Therefore a very significant additional volume of 500 hm3 is available for damping unexpected artificial flood events.

The adequacy of the proposed freeboard will be reviewed when more information is collected, related to GLOFs and risk of slope instabilities (further phases of the studies).

3.2 Embankment

Stability

For all design stages, stability of the embankment dam will be checked on the basis of a two dimensional analysis, by using the effective strength parameters and the Bishop method. The usual design values of the USBR will be applied for the static cases (see following table extracted from Design standards n°13 ± Chap 4):

Loading condition	Shear strength parameters

These recommendations are not standards; they will be generally adhered to; if, for any reason, it is not possible for one of them, then it will be replaced with an alternative solution. For instance one of the recommendations of this bulletin is to have a longitudinal core foundation slope less steep than 2h:1v. The shape of the valley does not allow following such recommendation. The criterion to be used will therefore be to place against the bank about 4 m of plastic material, with a water content significantly higher than the water content at OPS (about 4%).

3.5 Criteria for faults crossing

3.5.1 Embankment

The dam design should accommodate foundation fault creep and displacement. Within a **distance of 50 m of the active fault, the thickness of any layer in the direction of the** movement of the active fault should be at least 1.5 times the fault displacement.

3.5.2 Tunnels

Measures shall be put in place to ensure that long term fault movements do not jeopardise the performance of the hydraulic operations of tunnels. The tunnels routes shall be studied so to avoid or minimize the crossing of active faults with pressure stretches; special structures (intakes, gates rooms, transitions, etc.) shall be located as far as practicable from faults. In correspondence with faults crossing, provisions shall be made to allow relative movements of tunnel short sections, designed to support large external loads, avoiding the tunnels lining collapse. The need for programmed maintenance interventions is anticipated.

3.6 Salt wedge

In addition to treatment of the upper, weathered part of the wedge, the following measures will be defined:

- installation of a monitoring system to follow-up performance of the treatment works during reservoir filling and operation;
- definition of a contingency plan which identifies remedial measures to be implemented in case the monitoring system triggers pre-defined indicators (see also paragraph 3.3).

3.7 Banks slopes

The banks presenting risks of future instability during reservoir impoundment shall be assessed and provisions shall be planned for necessary support, drainage or reshaping.

should be not higher than RL less the total dry freeboard. Note that it is the tunnel with the largest expected discharge which should be considered as being not in operation.

- For the PMF, with the N orifice spillways and the n gates of the surface spillway, the maximum water level should be not higher than reference level (RL) less the total dry freeboard.

Concrete surface treatment

Whenever the spillways surfaces are constituted by concrete slabs/lining only, provided that high standard strength and surface finishing are adopted, the speed of the water flow in the spillways can reach 30 m/s or so.

Above that value, proper aeration devices shall be provided at the bottom and lateral sides of the hydraulic facilities working in free-flow conditions, to prevent cavitation problems.

Aeration shall also be provided in those stretches in which change of working conditions (from pressure flow to free flow or vice-versa) is expected.

Whenever the flow may carry solid material coming from sediments deposits in the reservoir, steel lining or other anti-erosion material should protect the surfaces likely to the eroded.

Some criteria to be adopted for specific structures of the hydraulic facilities are provided in the next paragraphs.

4.4 Specific Design Criteria

7 SEDIMENT MANAGEMENT

Mitigation measures addressing the sediment impacts shall be considered to confirm the long term dam safety.

The reservoir operating rules will have a large influence on the way sediment deposits take place. Attention has therefore to be paid in the operation simulations to the variation of reservoir elevation throughout the year, particularly during the flood season.