EXECUTIVE SUMMARY

DRAFT INCEPTION REPORT

TECHNO-ECONOMIC ASSESSMENT STUDY

NOTE: Inception Reports are, by design, based on existing documentation. They are intended to provide a starting point for more detailed information gathering and analysis that will follow. Draft Inception Reports are used to seek input on the work program, informed by the Consultants’ Terms of Reference.
EXECUTIVE SUMMARY OF DRAFT TEAS INCEPTION REPORT

Preamble
The Techno-Economic Assessment Study (TEAS) for the Rogun Hydroelectric Power Project, as carried out for Barki Tojik by a consortium composed of Coyne et Bellier, ElectroConsult and IPA, covers studies which are composed of the following four inter-related phases:

Phase 0: Geological and Geotechnical Investigation of the Salt Dome in the Dam Foundation and Reservoir.
Phase I: Assessment of the Existing Rogun HPP Works
Phase II: Rogun HPP Project Definition Options
Phase III: Assessment Report of the Selected Option

In addition, an assessment of a proposed Stage 1 of the project (up to El.1110) was required. This Stage would comprise raising the embankment dam to an intermediate height, completion of intake structures, diversion tunnels and spillways, as well as the installation of the first two generating units with replaceable runners.

Consistent with the Contract, an Inception Report had to be presented shortly after the beginning of the studies. This Inception Report presents the outcome of the analysis of the main existing documentation. The available documentation was assessed during the mission in Tajikistan which took place during the second half of March 2011.

The Inception Report includes an appraisal of the existing basic data, provides a history of the Rogun Project, proposes additional geological and geotechnical investigations, and discusses the work programme.

The present inception report in fact goes further. It also includes a presentation of the most recent studies on the completion of Rogun project, as carried out in 2009 and 2010 by Hydroproject Institute of Moscow. Comments are provided in the Report on the design options and criteria so that these can be discussed at an early stage of the study.

The section below provides the main comments and recommendations which result from the studies carried out in the framework of the preliminary tasks. It is emphasized that this Inception report is, by design, based on only existing documentation. It is intended only to provide a starting point for more detailed information gathering and analysis that will follow.

Documentation
The Rogun archives, as available at the Rogun site, are very extensive. The Consultant carried out a selection of those of the documents which would be useful for this assessment study. The most recent studies are those presented in the report “Project of Completion of Rogun HPP” (2009), by Hydroproject Moscow, and some subsequent modifications leading to additional reports issued in 2010.

Topography
A 3D topographical model of the project site has been made available. It should be sufficient for the phase II studies of the structures, provided that no significant change in the location of the dam or of the appurtenant works is required. The available topographical mapping
however does not cover the zone of a potential large landslide on the right bank, downstream of the dam site.

**Hydrology**

The hydrological database is very substantial. The various hydrological parameters and data are, compared with many other projects, are particularly robust. It appears that, with the exception of the estimates of the floods, only relatively little changes have been brought to the estimates over the years during the past studies.

In this context, attention is drawn to the following:

- The maximum discharge observed in year 2006 necessitated a revision in the estimates of the flood peak discharges.
- The Probable Maximum Flood (PMF) peak discharge, presently estimated at 7,100 m³/s, will be reviewed during the assessment studies. This is particularly important for the present project, where the capacities of the spillway tunnels vary in proportion to the square root of the head, with therefore a relatively limited increase of the discharge with the water elevation.
- The risks related to potential floods which could be created by landslides upstream or by possible glacial lake outburst floods (GLOF) need to be assessed.

An issue of concern is the impact of the PMF on the existing dams downstream of Rogun. This issue requires further studies for the whole cascade.

**Geology**

*Foundation of the dam*

If the construction is to be carried out in two successive steps, two distinct projects, namely the Stage 1 project (up to El. 1110) and the final height project (up to El. 1300), are to be considered from the engineering geology point of view. For each of these two stages, the assessment will involve (i) the geotechnical characteristics and (ii) the impact of active and continuous movements on faults.

The Stage 1 project has specific constraints which derive from a different dam footprint and a significantly lower dam height. It is foreseen that the geotechnical characteristics of the foundation at the proposed location would be adequate, including for a 100 or 120 m high RCC dam, after the upper decompressed and weathered fringe, i.e. about 20 – 30 m, would have been duly excavated.

Despite these favourable geotechnical conditions, the concrete gravity dam alternative could be put at risk by tectonic movements.

For a final dam exceeding 300 m in height, and taking into account the rates of continuous deformation recorded by precision monitoring, the hazard associated with a rigid structure

---

1 The Probable Maximum Flood (PMF) is the flood that may be expected from the most severe combination of critical meteorological and hydrologic conditions that are reasonably possible.
would appear to be excessively high. Because of this, only the embankment alternative seems adequate.

In any case, it is recommended that a monitoring based on appropriate methodology should be immediately resumed.

Investigation of the upper parts of the abutments

The existing boreholes and galleries are concentrated in the lower part of the abutments. Because of the significant thickness of the weathered and distressed zones, it is necessary to complement the investigation of the upper part of the abutments, so that this part of the site should be better known in terms of rock condition, water level, etc. It is therefore recommended that some boreholes be drilled in the upper part of the abutments and that rock mechanics tests be carried out on selected cores.

Downstream landslide

The largest landslide, which has been identified since the Technical Design (TD) of 1978, lies in the right bank. It could threaten a section of the valley located immediately downstream of the dam and opposite the Obishur valley.

For the time being, all the displacements seem to be concentrated in the upper part of the slope. It is possible that these displacements may result from a sliding of the rock mass. Another possible interpretation is that the particular flat morphology at the top of the bank could have resulted from sinking. Such a process could be the consequence of the plastic deformation of relatively large evaporitic rock masses lying below the plateau.

The current geological model for this landslide therefore needs further study and upgrading. The nature of the risks could be one of the following:

(i) risk of a slide and of the formation of a natural dam and reservoir which could flood the project structures.

Or

(ii) risk of significant deformation of rock masses in the vicinity of the right abutment of the dam.

This area deserves further investigations and monitoring which are proposed.

Risk related with salt wedge

The dissolution of salt could potentially result in (i) uncontrolled leakage from the reservoir and (ii) deformations in the dam foundation. Some preventive treatment, including a protection cap above the upper part of the salt wedge, and grouting galleries for creating hydraulic barrier and hydrochemical stabilization, have been designed and partially implemented.

This preventive treatment appears to have been designed based on a geological model which considers that the top of the salt wedge stays at low elevations everywhere in the abutments. The review of the results of available investigations has however shown that few or no boreholes have been carried out in the middle and upper parts of the abutments, and the assumption that the salt wedge is leached above the water table in the dam abutments needs confirmation. For a better assessment of the risks after impounding, additional investigations are recommended.
In addition to the preventive treatment to be adopted, it would be extremely important:

- to make sure that adequate monitoring be set up to assess the effectiveness of the mitigation measures, and
- to make arrangements that would permit the mitigation measures to be reinforced, if required.

**Comments on the 2009 design**

The documents made available to the Consultant to date did not include the detailed investigations for the dimensions of the main structures such as the dam, the spillways, the diversion tunnels, etc. The Consultant requests receiving as soon as possible the relevant reports/analyses.

As a general comment, the first impression is that the broad approach to the design of the dam itself appears as safe and safety-conscious. In particular, the filters, which are a critical issue for fill embankments, appear to be conservatively dimensioned with their minimum thickness of 4 m.

The site topography characterized by the narrow valley and the double meander of the river, has led to a unique configuration for the two diversion tunnels crossing the valley under the embankment shell. Their utilization as tailrace tunnels during Stage 1 for the early commissioning of the two first units results in a relatively complex phasing of the works. This point deserves more detailed attention in the project supporting documents.

Fine-tuning excavation would be required before starting the earthfill works, particularly within the foundation area underneath the central impervious core of the dam. The excavations entailing the adjustment of the local topography may be quite substantial. Such fine-tuning works are necessary to limit differential settlement of the fill.

**Hydraulic Facilities**

The hydraulic facilities needed for providing safety against floods appear adequate when the Stage 1 would have been completed (dam at El. 1,110 m.a.s.l.), as the dam reaches El. 1,185 m.a.s.l., and constructed up to El. 1,300 m.a.s.l. At these elevations, the system would be capable to evacuate a flood with a 7,100 m³/s peak flow, i.e. the value of the PMF presently assessed. During the study, the flood-handling adequacy at intermediate elevations will be analysed.

As the discharge capacity of a tunnel varies in proportion to the square root of the head, the design flow of the spillway tunnels system must be established with a sufficient margin of safety, or a surface chute spillway should be considered.

The design of the hydraulic facilities, and more generally of the underground works, appears to have been highly influenced by the presence of faults and sub-horizontal discontinuities. In particular, it is reported that faults present in the project area exhibit continuous relative movements (i.e. creep). Whenever some underground structures are crossing these geological discontinuities, the risks associated with possible movements require that proper provisions be implemented, in order to guarantee its long term stability.

It shall be noted that the two most downstream spillway tunnels discharge in a zone which could be prone to sliding, i.e. the right bank of Vaksh River after the sharp bend to the right.
The zone requires to be carefully investigated and the boundary of the potentially instable area clearly identified; obviously this aspect will also be duly taken into consideration when selecting the tunnel routes and designing outlet solutions.

The location of the powerhouse and transformer hall caverns appears to be adequate, having been selected so as to avoid major geological discontinuities. The powerhouse cavern has already been partially excavated. An additional supporting system is currently being implemented. Such stabilization measures have been analyzed in detail by the designer and their suitability to provide stability to the cavern both during the construction stage and in the long term will be assessed during the study.

**Equipment**

The generating equipment will consist of 6 Francis units, each rated at 600 MW, working under a baricentric head of 268 m. The layout of the generating units foreseen by Hydroproject is different from that normally adopted for units of large capacity, with the thrust bearing located below the generator and supported by a cone fixed on the turbine head cover.

Furthermore, as an inlet valve would not be feasible for such a large unit and the intercepting gate is located far from the turbine, a flow intercepting device is provided between the stay ring and guide vanes. The device is a ring gate raised and lowered by oil servomotors acting in the vertical direction. This device was invented by Neypic of France, and it was adopted in some plants. We understand that two manufacturers, i.e. the Ukraine turbine manufacturer and a second one from Russia, have experience of this intercepting device.

If the above solutions are maintained, it might result in difficulties in attracting a sufficient number of perspective suppliers.

Another important aspect is related with the main transformers, which at present are proposed in a three-phase arrangement, with a 700 MW rated power. The dimension and weight of these transformers are exceptional and the possible arrangements for transport of these huge transformers will need to be studied.

This aspect of the project, as others which are strictly related to the procurement procedure and therefore also to the financing source, shall be carefully examined.

**Comments on the Stage 1, project of 2009**

**Dam**

*Internal watertight features in Stage 1*

The main characteristic of the Stage 1 embankment is the arrangement adopted for the internal water tightness of the dam, consisting of an impervious membrane. To our knowledge the arrangement is a "première" in the world for a structure of such a size. Impervious membranes are usually used for repair works of existing structures, particularly for concrete ones. In such cases membranes are applied to the upstream face of the concrete works in order to replace the original water tightness which has failed.

The use of such membranes in fill dams, which are deformable and subject to significant settlements during construction, is not standard practice. Some existing examples refer to cofferdams, i.e. temporary structures under full pressure conditions limited in time to flood duration. We found no reference in our records or in the literature for an embankment higher
than 100 meters where the internal water tightness would have been insured by an impervious membrane. The use of an impervious membrane also entails the additional delicate issue of the contact to be maintained with the foundation.

The Consultant therefore considers that the proposed impervious membrane system cannot be accepted for such a high dam. Classical options such as impervious clay core or bitumen core wall should be utilized.

*Stage 1 dam designed for a halt in the works possibly much longer than anticipated*

With a dam at elevation 1110, the new elevation of lower right bank discharge tunnel would allow evacuating the PMF as presently estimated. If, as a result of the hydrological studies, the present value is judged underestimated or uncertain, then the dam concept should be reviewed. It would be advisable to allow flood spilling over the embankment. A solution might be to construct a composite dam, with a fill upstream shell and a concrete downstream shoulder capable of being used as spillway; the water tightness would be provided by a core installed between the upstream shell and the concrete shoulder. Similar schemes have been built and have been operational for many years, such as Mae Suai (Thailand, 2001) and R'Mil (Tunisia, 2003).

*Equipment*

As far as the first stage generating units are concerned, a provisional arrangement is foreseen which implies the use of temporary runners to be substituted when the minimum normal head range is reached (final stage).

Provisions are made to guarantee the coupling of the provisional runners with the other turbine components that are not to be substituted in the final stage, basically constituted by rings to be fixed on the head and bottom cover.

Since this procedure is unusual for manufacturers other than the original ones, the only possibility to make use of the existing equipment would be to request to the original manufacturers to complete the provision of the missing equipment (only one generator was supplied) and carry out the erection. This would be also the only way to obtain operational guarantees.

It is ought to highlight that by maintaining the existing units, it has to be accepted the fact that the other four turbines, probably supplied through international tender, will be different from the first two. The only alternatives are to decide not to make use of the existing equipment, or to request a proposal from the same original manufacturers for the remaining four units.

*Schedule of the Studies*

A revised schedule of services is given in the inception report. This revised schedule remains tentative, because its implementation will depend:

1. On the timely supply by the Client of the documents and data necessary for the studies, and

2. On the actual starting dates and duration of the additional investigations.

Any change in the dates of supply of the documents and data, any change in the starting dates and any increase in the durations of the investigations and surveys would mean a corresponding postponement of the dates of submission of the reports.