Terms of Reference

Consultancy service to perform stability analysis (Back Analysis) of Victoria Dam to study the Alkali-Aggregate Reaction, assess its impact on the dam's safety, and to propose remedial measures on identified issues

Contract No: LK-MoMDE-433807-CS-QCBS

1.0 Background

1.1 Introduction

Victoria dam is a double curvature concrete arch dam having a crest length of 520 m and a maximum height of 122 m above foundation. The dam has been constructed in 35 numbers of monolithic mass concrete vertical cantilevered blocks each having a 15 m width and which were cast in 2 m vertical lifts. Reinforced concreted structural components were adopted only at locations such as: spillway, bottom outlets and crest road pre-stress bridge beams. In-situ concrete temperature during casting has been controlled by circulating water at 22^0 C in cooling pipe system embedded in the dam. Construction joints between independent cantilevers were pressure grouted before the stoppage of cooling to guarantee a uniform arch action. The thickness of the dam is 6 m at the crest and 25 m near the foundation and seven galleries are positioned with the dam body. The construction works of the dam has been commenced in 1980 and impounding was completed in 1984. Thus, almost 35 years has been elapsed after the commissioning of the dam.

Typically, the arch dams at empty reservoir condition (i.e. during construction stage), transfer its gravity load to the foundation rock by the vertical cantilever block action. Subsequent reservoir impounding causes both cantilever and arching actions and jointly transfer the hydrostatic pressure to the underlying foundation and abutments increasing deformations of the foundation rock at the valley floor and flanks. However, this flexural context has been reduced with the aging of the dam over the years and now it is apparent that a permanent non re-bound upward and upstream movement is observable.

Further, dam monitoring instrumentation analyses showed an increasing trend of distortion patterns in both directions of cantilever and arching actions. Irreversible expansive deformation patterns have been further evidenced by variation patterns of strains within the dam body. Apparently, no any significant foundation movement occurred. Therefore, possible causes and their level of existence influencing for the observed expansive distorted deformations are needed to be further investigated and verified, as this phenomenon may occur due to various reasons such as: Alkali-Aggregate Reaction (AAR), Delayed Ettringite Formation (DEF) or any other possible consequences occur within the aged dam body and which may probably augment by the seasonal fluctuation of reservoir waters. However, the entire upstream face has been coated with a chemically impregnated layer during the construction stage to protect the dam concrete from reactions of chemically aggressive water if presence in the reservoir. However, present status of chemically impregnated layer remains unknown and need to be assessed concerning the quality of water in the reservoir too. Further, cracks have been identified at Block no. 9 and 10 where located at left bank and right bank end piers of the spillway opening structure.

A new automated monitoring system was designed and installed in 2017-2020 and includes optical total stations, GNSS receivers and other structural monitoring instrumentation including 3D vibrating wire crack meters were installed and have provided continuous monitoring since their installation.

The original monitoring system installed during construction consists of pendulums, clinometers, extensometers, piezometers, survey targets and strain gauges.

Previous studies have included detailed evaluation and interpretation of monitoring data. These reports shall be shared. Poyry Energy AG, Comprehensive Surveillance Report-Victoria Dam, Dam Safety and Water Resources Planning Project, October 2010.

Thus, on such background, the present status of structural integrity is required to be analysed and need to propose most appropriate remedial measures to improve the structural health of the dam.

1.2 Objective of the Consultancy Service

The objective of the consultancy service is to determine the level of structural integrity of Victoria dam and to propose remedial measures in order to improve the structural health of the dam.

1.3 Scope of Work for the Consultancy Service

Scope of work covers the following activities which ultimately direct to improve the structural health of the Victoria dam.

a. Critically review all available design reports, as-built drawings, and construction records, including geological reports, foundation investigations, materials testing, and instrumentation data along with recent O&M records.

b. The Consultant shall conduct the necessary sampling and testing required for the analysis.

c. Develop a suitable structural simulation model for understanding the behaviour of the dam and to ensure the stability (integrity) of the structure in future. Simulation shall consider, on the results of an appropriate Back Analysis including following but shall not be limited to following:
   i. In-situ movement of the dam.
   ii. Geodetic survey and instrumentation data.
   iii. Testing of concrete at different locations of the dam body.
   iv. Additional surveys etc.

d. Preparation of comprehensive report based on the results of simulations performed and including recommendation over the present condition of dam and its safety to operate for all the water levels. This shall consider,
   i. All key water levels including maximum flood levels Probable Maximum Flood considering the present climate change.
   ii. Propose remedial measures to improve the structural health of the dam with cost estimates.
   iii. Propose additional monitoring, testing and/or additional studies required.

Task 1: Review of existing studies and submission of Inception Report

Specific activities under the Task 1 shall include, but not necessarily be limited to:

a) Review and analysis of the documentation including existing studies, reports, and safety assessments related to the dam and any relevant data provided.

b) Describe the findings of the site visit including a review of the condition and observed cracking in relation to the safety of the dam.
c) Perform a detailed review and interpretation of the available monitoring compare the observed deformation with the previous observations.
d) Assess the adequacy and reliability of the data and findings, and where appropriate, propose modifications in consultation with the Client to the proposed modelling approach with assumptions and limitations.
e) Perform a "Gap Analysis" to identify any gaps, inconsistencies, missing elements and areas requiring further investigations.
f) Gather all relevant data, including dam design and construction details, geotechnical data, seismic hazard assessments, and historical performance records.

The key findings and recommendations shall be outlined in the Inception Report. The report shall reconfirm the Consultant's approach, methodology, assumptions and schedule on completion of scope of work.
Within four weeks of contract award the Consultant shall submit the Inception Report.
The Inception Report shall be based on the review of the available information confirming the Consultant's by the initial review of existing information and include initial review of geological conditions including geological mapping of areas accessible during the visit.
The Inception Report should outline the work plan, key issues requiring guidance and decisions and include an updated study schedule.

Task 2: Investigations

Sub Task 2.1 Concrete Testing - Scoping

The Consultant shall prepare the proposed concrete testing schedule including sampling and testing methodology. It is anticipated that this will consist of the recovery multiple concrete cores of varying lengths in both locations with suspected AAR and areas with no apparent deterioration. Sampling locations shall cover different concrete mixes including the main dam body mass concrete and reinforced concrete at the spillway. A detailed plan and specification shall be prepared and submitted to the Client for their review and acceptance. Sampling cost shall be covered under p.s item. The plan shall include, but not be limited to, a detailed location plan of the proposed cores and their lengths, the reinstatement methodology, safe access requirements and a proposed concrete testing schedule with references to relevant internationally recognized tests (Eurocode, ASTM, RILEM). necessary health and safety guidelines asper the international standards shall be followed during the sampling process.

Sub Task 2.2 Intrusive Surveys

The Consultant, through their sub-Contractor, shall be responsible for the coring and recovery of concrete samples, the reinstatement of the holes, the wrapping and storing of samples, shipping and testing in an approved laboratory competent to perform the required testing. All samples shall be photographed on extraction.
The Consultant shall liaise on a daily basis with the Dam Operator and confirm with them that the chosen locations will not affect any existing services, instrumentation or their cables.

Sub Task 2.3 Laboratory campaign and reporting

Although the sampling shall be performed in one phase the testing shall be split into two phases.

In the first phase as a minimum testing of the compressive strength, static modulus of elasticity and Poisson's ratio of concrete in compression, alkali content, Petrographic (including Polarizing Microscope Examination) to ASTM C856 or equivalent shall be performed. Additional testing to support the interpretation of the results or of use for the FEA could also be recommended by the Consultant.
In the second phase longer term expansion test (up to 12 months) shall be performed and shall include the compressive strength, static modulus of elasticity and Poisson's ratio of concrete in compression, Petrographic (including Polarizing Microscope Examination) to ASTM C856 or equivalent on the samples subject to the expansion tests.
An initial report at the end of the first phase summarizing the findings, with all testing results and their interpretation including whether presence of AAR or DEF has been demonstrated shall be prepared. The report shall recommend the need or otherwise to continue with the longer duration expansion tests.
If the second phase testing is completed, a comprehensive report with all testing results and their interpretation shall be prepared at the end of the laboratory campaign. The interpretation shall discuss the likely remaining potential for continued expansion and shall also include a risk assessment of the impact of AAR or DEF on key components of the dam (dam body, spillway structure, gates and stop logs etc…) and recommendations on additional monitoring and/or modifications to the operation and maintenance as required. The Consultant is expected to consider the latest guidance on this subject such as RILEM's *Diagnosis & Prognosis of AAR Affected Structures*

Task 3: Dam Stability

Sub Task 3.1 Stability criteria and methodology report

Following the completion of the Inception Report the Consultant shall prepare a detailed modelling methodology and criteria report. The report shall confirm the assumed loading cases to be studied including their assessment criteria. The report shall also outline the data to be used for the calibration of the model. A separate section describing the modelling of the cracked sections (adjacent to the spillway) and their assessment shall be provided.
The methodology report shall also consider

- Application of relevant national and international standards (e.g., ICOLD, USBR, USACE, Eurocode) for dam safety.
- Consideration of site-specific conditions, including geological, hydrological, and seismic factors.
- Description of material and joint modelling assumptions
- Sensitivity analysis to assess the impact of varying input parameters on the analysis results.
- A robust quality assurance plan to ensure the accuracy and reliability of the analysis.
- A naming nomenclature for all files

Although this methodology report will be based on that provided in the technical offer the detail will be developed to reflect the findings from the inception phase.

Sub Task 3.2 Modelling and Reporting

The Consultant shall develop a three-dimensional FEA model of the dam and its foundations. The extents of the foundations shall be in line with best practice to avoid boundary effects.
The model it anticipated to be a non-linear model allowing stress and deformation analysis it shall be capable of modelling thermal actions and stresses analysis, concrete expansion and seismic

impact analysis too. The model shall be sufficiently detailed to understand whether localized restraint effects may be causing or exacerbating cracking notably in the vicinity of the spillway.

Prepare a detailed report summarizing the analyses and findings. The report should include but not be limited to:

- Description of the Model: Provide a comprehensive overview of the model used for the analyses, including the finite element mesh, boundary conditions, and material properties.
- Assumptions: Clearly state all the assumptions made during the modelling process.
- Methodology: Describe the methodology adopted, including the types of analyses performed and the software tools utilized.
- Modelling scenarios to be performed in terms of Reservoir water level is at FSL and all gates are closed, Reservoir water level is at HFL and all gates are open, Sudden Drawdown of the reservoir (water level at minimum operating level) and for any other modelling scenarios which give the worst stability condition including seasonal temperature variations where appropriate.
- Results: Present the results of the analyses, highlighting key findings
- Recommendations:

Sub Task 3.3 Results presentation

The Consultant shall present the findings and recommendations in a hybrid physical/virtual training. The training should also include the findings of the concrete sampling and testing.

Task 4: Proposed Remedial measures and Recommendations;

Based on the analysis results, describe the impact of the findings (cracking of concrete, potential AAR, etc…) on dam safety and provide recommendations for any necessary remedial measures or safety improvements. This may include recommendation for physical remedial works, additional monitoring and testing and/or additional studies. All recommendations shall be described at the pre-feasibility level and provided with cost estimates.

1.4 Expected Outputs (Key Deliverables) from the Successful Consultant

This section outlines the key deliverables to be submitted by the Consultant. All major reports and outputs required for the assignment—including the Inception Report, Sampling and Testing Plan, First-Phase Laboratory Report, Second-Phase Laboratory Report, Modelling Methodology Report, Simulation Model, Model Interpretation Manual, and Final Study Report—are included in this list of deliverables.

The Consultant's proposal shall separately describe the methodology, staffing, and work plan, but the above items constitute the mandatory deliverables to be submitted during the assignment.

1.4.1 Technical Approach, clearly outlining the plan for preparing for the following areas,

i. Testing, sampling bore hole etc. (i.e. including number of tests and types).
ii. Simulation model/ Back analysis
iii. Staff qualifications
iv. Design procedures and criteria, standards (i.e. BS, Euro etc.)
v. Detailed time schedule expected for completion of scope (testing, model operation, back analysis and final report).

vi. Any other suggestions

1.4.2 Simulation model including the training for the MASL staff and model interpretation manual

The Consultant shall develop the full simulation model together with all associated input, calibrated, and output files. In addition, the Consultant shall provide basic operational training for MASL technical staff covering: (i) operation of the model software; (ii) execution and modification of simulations; (iii) understanding key modelling assumptions and limitations; and (iv) interpretation of the analytical outputs for dam safety decision-making. This training shall be treated as a sub-task of the modelling work.

The Consultant shall also prepare a Model Interpretation Manual to support MASL staff in independently reviewing, rerunning, and assessing the results of the model. All model files (input, calibrated model, scenarios, and output files) shall be handed over in an accessible and fully usable format.

1.4.3 Simulation model report (final result but consultant must have continuous participation with client time to time).

1.5 Details to be provided by the client

Following annexures are included as supporting documents and contain necessary details on,

a. As built drawings to understand the dam geometry.

b. Historical records of available rainfall data.

c. Historical records of available reservoir hydrological and instrumentation data.

2.0 Selection Procedure

Consultant will be selected through Quality and Cost Based Selection (QCBS) pursuant to procedures set out in the World Bank procurement guide lines "Procurement regulations for IPF borrowers (dated July 1, 2016, revised in November 2017 and August 2018).

3.0 Experience and Qualifications of Key Consultants

It is expected that the Consulting team would comprise a team of competent Specialists mainly in the following disciplines. But it is optional for the Consulting firm to suggest a suitable manning schedule and for short or whole term duration for each specialist. While these specialists must be professionally competent in their own field of expertise, preferably they also have experience in implementing similar projects.

Individual Qualifications required for the key specialists in the study team are mentioned below:

No	Key Staff	Qualification and Experience Requirements	Key -Staff Inputs in Person – Minimum Months
K1	Dam Safety Management	Master's Degree in Civil Engineering or equivalent, specialized in subjects related to all types of dam design and	10

	Specialist - Team Leader	construction. At least of 15years working experience in large dams' safety assessment and management, including similar experiences on back analysis studies conducted for 3 arch dams.	
K2	Concrete Arch Dam Specialist	Master's Degree in Civil Engineering or equivalent, having at least 15 year experience in concrete dams, including maintenance and safety management of one concrete arch dam.	1.5
K3	Dam Instrumentation Specialist	Master's Degree in Engineering or equivalent at least 15 years working experience in instrumentation data procedures, analysing, and interpretation for large dams.	2
K4	Numerical Modelling Expert - Deputy Team Leader	Master's Degree in Structural Engineering or equivalent, with 15 years of experience especially in concrete dam related structural health monitoring and assessment.	6
K5	Electro-Mechanical Specialist	Master's Degree or equivalent in Electro or Mechanical Engineering with at least 15 years of work experience including electro-mechanical and hydro-mechanical equipment for dams' operation, such as gates/ valves of spillway, outlet works, etc.	0.5
K6	Geologist/ Geotechnical Engineer	Master's Degree in Geology, Engineering Geology or Civil Engineering with at least 20 years of experience in the assessment of geological risks and design of required treatment works in foundation, abutment, reservoir rim, etc. for large dams including petrographic analysis.	1
K7	Specialist Material Engineer	Master's Degree in Materials Engineering, Civil Engineering, or an equivalent field, with a strong background in concrete materials technology**.** The Specialist shall have at least 15 years of experience in materials testing and analysis related to dam structures, (AAR) and (DEF).	2

4.0 Deliverables and Payment Schedule

The payments are linked with the abovementioned Deliverables. The payments will be release only upon the acceptance of the deliverables by the Critical Review Committee.

D-1	Inception report	10 %
D-2	Technical approach for the proposed study	5 %
D-3	Site Investigation and Survey report	15 %
D-4	Simulation Model	20 %
D-5	Manual for the Simulation Model	20 %
D-6	Final Study Report	30 %
	Total	**100%**

5.0 Reporting Requirements

The Inception Report will be required within four weeks from the date of commencement of the study. A monthly progress reports are to be submitted at the end of every month after Inception Report.

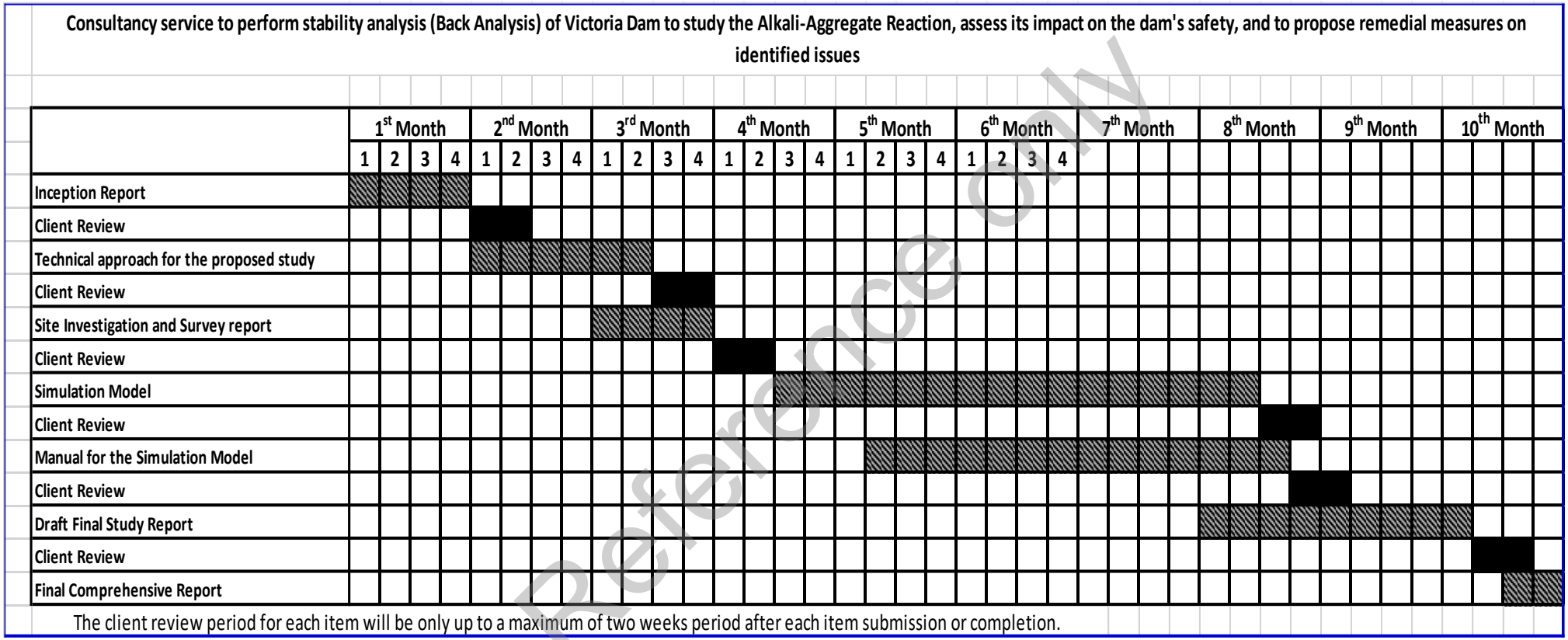
No	***Reporting***	***Number of copies***	***Time line***
1.	Inception report	5 hard copies and 1 Flash Drive	4 weeks after signing the Contract
2.	Technical approach for the proposed study	5 hard copies and 1 Flash Drive	10 weeks after signing the Contract
3.	Site Investigation and Survey report	5 hard copies and 1 Flash Drive	12 weeks after signing the Contract
4.	Simulation Model	5 hard copies and 1 Flash Drive	30 weeks after signing the Contract
5.	Manual for the Simulation Model	5 hard copies and 1 Flash Drive	30 weeks after signing the Contract
6.	Final Study Report	5 hard copies and 1 Flash Drive	40 weeks after signing the Contract
7.	Monthly Progress Reports	5 hard copies and 1 Flash Drive	To be submitted monthly

** Note*

The Consultant shall present a detailed presentation on each report immediately after submission

6.0 Work Plan

Consultant is requested to submit a comprehensive work plan for Deliverables.



Consultant shell follows the necessary safety procedures to be followed during all phases of the project.

7.0 Duration

The Assignment is expected to be completed within 10 Months period.

8.0 Facilities to be provided by the Client

PMU will facilitate to coordinate relevant implementing agencies and supports to get relevant information. Also, the PMU shall coordinate with relevant institutes to get necessary approvals.