REPORT

Annex G

PROPOSED DON SAHONG HYDROPOWER PROJECT- MEKONG RIVER

Technical Review for Prior Consultation Project Review Report: Assessment of Impacts on Sediment Transport and Geomorphology of the Lower Mekong River

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EXECUTIVE SUMMARY

The Government of the Laos People's Democratic Republic proposes to construct the Don Sahong Hydropower Project (DSHPP) in the main stem of the Mekong River. The Prior Consultation Review Process requires consideration of the potential impacts of the project on sediment transport and geomorphology of the Lower Mekong River, which is the subject matter of this report.

The project review reveals that the DSHPP will have no significant cumulative effects on sediment transport and geomorphology of the Lower Mekong River. However, some doubt exists about the potential for transboundary impacts in the river reach immediately downstream of the project.

The review identifies potential uncertainty about the rate and volume of sediment deposition in the DSHPP headpond. If the actual amount of sediment depositing in the headpond is greater than presently predicted it could result in unanticipated operational impacts, implying much greater maintenance cost. Accelerated actual sedimentation may also lead to transboundary impacts requiring mitigation.

Maintaining power production will require more elaborate sediment removal from the headpond if the actual amount of deposited sediment increases beyond what is currently expected. This may require reconsideration of sediment management approaches, including the potential use of low-level-outlets for drawdown flushing in lieu of dredging. Ways to dispose of sediment thus removed has not been considered by the project proponent. Limited space may deny disposal of sediment on land, while discharging it into the downstream river could lead to undesirable potential transboundary impacts.

A number of uncertainties and gaps in information are itemized in the report, which the Consultant should address.

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1.0 INTRODUCTION

The Government of the Laos People's Democratic Republic (Government of Laos) proposed construction of the Don Sahong Hydropower Project (DSHPP) and invited signatories to the Mekong River Agreement to review the proposal as part of the Prior Consultation Project Review process. The purpose of this report is to inform the prior consultation process as it relates to anticipated impacts of the DSHPP on sediment and geomorphology of the Mekong River.

The review draws upon reports containing the results of environmental and engineering studies executed by consultants commissioned by Don Sahong Power Company (DSPC), the developer. It was found that these studies were generally well executed as it relates to sediment and geomorphologic impacts on the Mekong River.

The assessment finds that DSHPP project will have no significant cumulative impacts on sediment and the geomorphology in the Lower Mekong River, but that transboundary impacts of limited extent are conceivable immediately downstream of the dam to just across the border with Cambodia. The extent and severity of such impacts are not known and it is recommended that the DSPC consultants investigate the same.

Moreover, the review identifies a number of operational challenges related to sustainable hydropower production. These concerns are relevant to the Government of Laos, who has an interest in ensuring that the plant is operable and efficient at the end of the concession period when the project is transferred to the Government.

2.0 SCOPE OF REVIEW

The scope of this review is prescribed by the requirements for the MRC Prior Consultation Review process:

- Identification of potential consequences and impacts once the DSHPP has been constructed and operates as it relates to sediment quality and quantity, and changes in the sediment balance up- and downstream of DSHPP,
- Evaluation of the sediment management approach proposed by the Developer to avoid, manage and mitigate those impacts and consequences,
- Modifications to the sediment management approach to mitigate the identified impacts, if necessary,
- Identification of gaps and uncertainties in provided information and knowledge,
- Proposing ways to overcome existing knowledge and information gaps,
- Identification of possible negative cumulative and transboundary impacts,
- Recommending long-term monitoring and adaptive sediment management approaches ensuring sustainable hydropower generation.

3.0 DATA

The review relied upon the following information:

- AECOM. 2011a. Don Sahong Hydropower Project: Engineering Status Report: Completion of Reference Design, Volume 1 – Report, AECOM New Zealand Limited.
- AECOM. 2011b. Don Sahong Hydropower Project: Engineering Status Report: Completion of Reference Design, Volume 2 – Drawings, AECOM New Zealand Limited
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- SMEC. 2014. Don Sahong Hydropower Project, Sediment Deposition Modelling, (Revision E), Prepared for Don Sahong Power Company.
- SMEC. 2014. Don Sahong Hydropower Project, Extended Computational Hydraulic Modeling: Modelling of Upstream Channels, (Revision A), Prepared for Don Sahong Power Company.

Other publications that informed this review are listed in the References section (Section 9.0).

4.0 METHODOLOGY

The intent of this report is to provide the findings and recommendations in a succinct manner, thereby facilitating decision making. The methodologies used to analyze and assess the DSHPP reports are presented in Appendix A where the reader may find explanations of how the conclusions were derived.

Appendix A contains the following information:

- An assessment of how the recently observed reduction in the sediment flux of the Lower Mekong River might affect the DSHPP
- Consideration of anticipated sedimentation of the headpond of the DSHPP and how it might impact transboundary concerns and operations
- An assessment of potential cumulative effects introduced by DSHPP
- Identification of potential transboundary impacts
- Assessment of the potential success of implementing alternative sediment management techniques, such as drawdown flushing.

5.0 CONSEQUENCES AND IMPACTS

5.1 Background

5.1.1 Suspended Sediment Flux in Lower Mekong River

Recent research found that the sediment flux in the Lower Mekong River changed from the previously estimated 160Mt/yr (Walling 2008; 2009) to about 72.5Mt/yr (Koehnken 2012, 2014). This observed reduction corroborates the predictions by Kondolf et al. (2014) and is mainly attributed to upstream sediment deposition in dams along the Lancang Cascade, China. The Consultant did not possess this new information during preparation of the design and environmental impact assessment of the DSHPP.

5.1.2 Sediment Inflow to DSHPP

The amount of sediment that will flow into DSHPP determines its rate of sedimentation and, eventually, cumulative and transboundary impacts. The suspended sediment flux into the DSHPP is expected to increase by about 3.5 times relative to undeveloped conditions due to increased flow of water required for power production[1].

Exactly how much sediment will flow into DSHPP is still subject to uncertainty. Between field measurements (SMEC 2014b) and assumptions by the Consultant (SMEC 2104c) the bedload discharge estimates range between 440t/yr and 700,000t/yr. The range of estimated suspended sediment flux into DSHPP, once operational, is 2.4Mt/yr (by the reviewer) to 7Mt/yr (by SMEC 2014c).

The discrepancy in bedload is due to a general lack of information and difficult field conditions making measurement difficult (SMEC 2014b). The difference in suspended sediment discharge estimates are attributed to recently observed reductions in suspended sediment flux in the entire Lower Mekong River (LMR) (Koehnken 2012, 2014).

5.1.3 Sediment Particle Sizes

The sampling campaign by the Consultant (SMEC 2014b) found that suspended sediment almost exclusively consists of very fine sediment, mostly silt (d_{50} = 10µm), while bedload consists of fine sand (d_{50} = 0.3mm). The Consultant expresses the opinion that the bedload material may be coarser than sampled, which conforms to sampling results by others. Koehnken (2014) reports that some bedload samples collected in other locations contain gravel.

5.1.4 Sediment Hardness

The petrographic analysis of deposited sediment by AECOM (2011c) indicates that the sediment is predominantly angular in nature and that the quartz / quartzite content may be very high; on the order of 80%.

[1] See Appendix A

5.1.5 Headpond Sedimentation

Simulations by the Consultant (SMEC 2014c) indicate that most of the suspended sediment will pass through the headpond of the DSHPP and that all bedload will deposit in the headpond until a new geomorphic equilibrium has been reached, which is estimated by the Consultant to occur within three years. The estimate of the time to reach a new equilibrium is based on a simulation period of five years, which may be too short to make such a conclusion.

The Consultant estimates that virtually all suspended and bedload sediment will pass through the reservoir once 3Mt to 4Mt of sediment deposited, signifying a new geomorphic equilibrium. However, review of the Consultant's results implies that a new geomorphic equilibrium may only emerge later (see Appendix A). This observation implies that it is possible that greater amounts of sediment may still deposit in the headpond after three years. In the extreme case the headpond may contain about 23.9Mt of sediment, once completely filled.

Prior to reaching a new geomorphic equilibrium, or prior to the headpond filling with sediment, the sediment passing through the turbines will primarily consist of very fine suspended sediment. Once the headpond is filled with sediment or has reached a new geomorphologic equilibrium both the bedload (fine sand and possibly gravel) and the suspended load (very fine sediment) will pass through the turbines and may cause abrasion.

5.2 Cumulative Impacts

Based on the assumed range of deposited sediment (3Mt to 23.9Mt) it is determined that DSHPP may remove 0.07% to, at most, 0.4% of the original, undeveloped sediment flux in the river (i.e. 160Mt/yr) over a period of at most 35 years.

When compared to the amount of sediment that will be removed by all other mainstream dams, which amounts to about 38% of the original sediment flux in the LMR (Kondolf et al. 2014), the cumulative impact of DSHPP is insignificant.

It is concluded that DSHPP will not significantly contribute to cumulative impacts related to sediment and geomorphology of the Lower Mekong River.

5.3 Transboundary Impacts

Given that the cumulative impact of DSHPP is insignificant, it is envisaged that transboundary impacts will either be non-existent or very limited. This is true for the LMR in its entirety. However, the potential for limited transboundary impacts exist due to the increase in sediment flux through the DSHPP headpond by about 3.5 times relative to natural conditions.

The increase in sediment flux downstream of the dam will mirror the increase in flux into the headpond due to the fact that the vast majority of suspended sediment will pass directly through without deposition. The amount of coarse bedload released downstream of the DSHPP will increase as sedimentation in the headpond approaches a new geomorphologic equilibrium.

Removal of large amounts of deposited sediment from the headpond by dredging or other means, as part of a long-term sediment management plan, may present disposal challenges. If disposal on land is barred by space limitations, releases of sediment into the downstream river reach might be required.

The potential transboundary impacts of such releases, which have not been evaluated at this time, may include increased turbidity, potential sediment deposition in the deep pool straddling the boundary with Cambodia and potential sedimentation at the transboundary islands in Cambodia. The potential manifestation of these transboundary impacts requires further consideration by the Consultant.

5.4 Operational Impacts

5.4.1 Maintenance Requirements at End of Concession Period

It is in the best interest of the Government of Laos to be informed about reservoir sedimentation and its impact on hydropower production at the end of the concession period. A potential long term operating challenge includes a need to regularly remove deposited sediment from the headpond. Disposal of such sediment may pose difficulties, because it could potentially result in transboundary impacts if released into the downstream river (see Section 5.3). Modeling reveals that sediment will deposit immediately upstream of the turbine intakes (SMEC 2014c), which will result in coarse bedload sediments discharging into the intakes, exposing the turbines to abrasion.

5.4.2 Sedimentation at Inlet to DSHPP Headpond

SMEC (2014a) updated earlier studies to refine the headpond inlet design. AECOM (2011c) found that average inflows to the DSHPP would amount to roughly 300m^3/s unless excavations up- and downstream of the headpond inlet are provided. SMEC (2014a) confirmed that the proposed excavations would increase average inflow to the DSHPP to 1,600m^3/s, which is required for power production.

A concern related to the sustainable performance of the inlet to the headpond is how sedimentation of the excavations at the inlet might affect inflow. In the extreme case, should the excavations completely fill with deposited sediment, it is reasonable to conclude that conditions will revert back to what they were prior to excavation. In such a case inflows may reduce from 1,600m^3/s to about 300m^3/s, which is significantly lower than what is required for power production. Determination of the potential for inlet sedimentation, particularly over the long term, is therefore of critical importance.

6.0 MITIGATION

Mitigation relating to sediment and geomorphology may be required to address transboundary and operational impacts.

6.1 Transboundary Impacts

Whether the potential transboundary impacts identified in Section 5.3 are a matter of concern should be established by the Consultant. Mitigation measures will only be required if found to be a concern.

6.2 Develop Effective Headpond Sedimentation Management Approach

The DSHPP is a pure run-of-river project making storage loss due to sedimentation of lesser concern. However, sedimentation at the turbine intakes and at the upstream inlet to the headpond may pose operating challenges. Sedimentation at the intakes ensures that coarse bedload will discharge through the turbines, likely leading to abrasion of the turbines. Sedimentation at the inlet to the headpond may result in reduced inflow to the DSHPP, thereby weakening power generation potential.

The Consultant's current sediment management plan is to implement dredging if removal of sediment is required and to install abrasion resistant turbines. These plans are based on the conclusion that a new geomorphic equilibrium will be reached within three years after plant commissioning and that the maximum amount of sediment to ever deposit in the headpond will not exceed 3Mt to 4Mt. As already indicated, these conclusions require verification.

Although the Consultant indicates that abrasion resistant turbines will be used, it is noted that the angular nature of the sediment, its high quartz content and relative coarseness (AECOM 2011c; SMEC 2014b) promote abrasion. Regular refurbishment of the turbines may be required in addition to requirements to regularly remove deposited sediment from the headpond, both at the turbine intakes and possibly at the headpond inlet.

The Consultant may reconsider its recommendation to omit construction of low-level-outlets. Having available low-level-outlets offers greater flexibility and greater economy to manage sediment over the long term. The bathymetry of the DSHPP headpond is ideal for successful implementation of drawdown flushing and the availability of low-level-outlets will allow its implementation[2].

6.3 Disposal of Sediment Removed from Headpond

The need to dispose of sediment removed from the headpond may increase the potential for local transboundary impacts. Disposal of abundant amounts of sediment on land may be prohibited by space limitations. Releasing sediment removed from the headpond into the downstream river reach increases

[2] See analysis in Appendix A

the potential for deep pool sedimentation, increased turbidity and increased potential for sedimentation at transboundary islands immediately downstream of the dam.

The development of an effective headpond sediment management approach requires evaluation of the potential impacts of disposed sediment and development of appropriate mitigation, if necessary.

7.0 MONITORING

The monitoring recommendations by the Consultant include regular bathymetric surveys of the headpond and measurement of suspended sediment concentrations up- and downstream of the DSHPP. The reviewer agrees with these recommendations.

Installation of monitoring equipment that may jointly benefit operations and environmental compliance is desirable. This may be accomplished by installing laser-diffraction devices, such as the LISST devices provided by Sequoia Scientific. Installing these devices provides the opportunity to concurrently, in real time, measure sediment concentration and particle size distributions of the suspended sediment flowing through the turbines and at the headpond inlet.

Such information allows the operator to shut down turbine operations if sediment concentrations and particle sizes become large enough to cause abrasion damage. Concurrently, knowledge of particle sizes and sediment concentrations fulfill environmental compliance data needs.

8.0 GAPS, UNCERTAINTIES AND RECOMMENDATIONS

8.1 Potential Transboundary Impacts

Virtually all suspended sediment will pass through the DSHPP headpond without deposition, a flux estimated to be three to four times greater than what would flow through the Hon Sahong under natural conditions (Sections 5.1.2 and 5.1.5). Moreover, the amount of bedload released downstream will gradually increase over time as the headpond converges to a new geomorphologic equilibrium (Section 5.1.5). This means that not only will the total amount of sediment (the sum of suspended sediment and bedload) discharging from the DSHPP increase, but it will also become coarser over time. These releases could conceivably lead to transboundary impacts immediately downstream of the dam, which have not been addressed by the Consultant.

It is recommended that the Consultant address the potential for the following transboundary impacts to occur and determine whether they may be important:

- Potential sedimentation in the deep pool straddling the boundary with Cambodia
- Potential increases in turbidity immediately downstream of the dam
- Potential increases in sedimentation at cross-boundary islands in Cambodia

8.2 Suspended Sediment Discharge Rating Curve

The suspended sediment discharge into DSHPP is estimated using the sediment rating curve at Pakse. The data collected at this location results in poor correlations between water discharge and suspended sediment concentration[3], thereby creating uncertainty affecting estimates of the turbidity that may evolve in the river reach downstream of the dam[4].

Little can be done to improve these estimates. Sensitivity analyses using computer simulation may aid in decision making. Once constructed, monitoring of suspended sediment flux into and out of the headpond will provide data informing the desirability of implementing adaptive management approaches in the future, if necessary.

8.3 Suspended Sediment Discharge

The suspended sediment discharge into DSHPP may be considerably lower than estimated by the Consultant (SMEC 2014c). The reviewer estimates 2.4Mt/yr and the Consultant 7Mt/yr. The difference is

[3] The best correlation of the sediment rating curve used by the Consultant based on data at Pakse from 1985 to 2013 is about r^2 = 0.2. The data for the period 2011 to 2013 provides a better correlation at r^2 = 0.45, although still relatively low. At most of the other gauging stations along the LMR the correlations are much better; on the order of about r^2 = 0.7 and higher.

[4] Recall that virtually all suspended sediment will pass through the headpond for release downstream (Section 5.1.5).

attributed to the overall reduction in suspended sediment flux in the LMR recently identified by Koehnken (2012, 2014). This information was not previously known to the Consultant.

It is recommended that the Consultant review the suspended sediment discharge estimate into DSHPP.

8.4 Bedload Discharge

Accurate estimates of bedload discharge are important because it determines the rate of sedimentation of the DSHPP headpond and the amount of sediment that may be discharged into the river reach immediately downstream of the dam once a new geomorphic equilibrium is reached in the headpond. If the relative increase in bedload flux due to increased diversion of water into the DSHPP is significant it may contribute to the transboundary impacts identified in Section 8.1.

Current bedload flux estimates are characterized by great uncertainty attributed to lack of information and difficult field conditions thwarting accurate measurement. No simple solution to this problem exists, except to execute sensitivity analyses using computer simulation.

8.5 Headpond Sedimentation

The degree of sediment accumulation in the headpond will impact operations and maintenance, and possibly the timing of potential transboundary impacts. As the headpond gradually approaches a new geomorphic equilibrium the amount of bedload discharged downstream will progressively increase. Once the new geomorphic equilibrium has been reached the amount of sediment flowing out of DSHPP will equal the amount flowing in.

All bedload will be released through the turbines, increasing the potential for abrasion damage as the flux increases over time. Estimates of when the new geomorphic state will be reached are therefore important. Based on a simulation period of 5 years SMEC (2014c) predicts that the headpond would reach a new geomorphic equilibrium within 3 years. The short simulation period leads to uncertainty regarding the reasonableness of this conclusion.

It is recommended that the Consultant executes sediment transport simulations through the headpond using a much longer duration, possibly on the order of about 35 years. The results of such simulations will reduce the uncertainty regarding the impacts of sedimentation, the volume of deposited sediment, and how soon a new geomorphologic equilibrium will transpire in the headpond.

8.6 Inlet Design and Sedimentation

Uncertainty exists about the long-term efficiency of the current inlet design and its ability to divert the right amounts of flow to the DSHPP and Khone Falls. The Consultant determined that excavations up- and downstream of the headpond inlet will guarantee adequate flows into the DSHPP for power generation.

Plausibly, sediment deposition in the excavations could significantly reduce inflow to the headpond and the ability to control flows to Khone Falls. It is important for the Government of Laos to have the ability to generate power without excessive maintenance at the inlet after the concession period has expired; emphasizing the importance of adopting a long term view as it relates to sediment management.

It is recommended that the Consultant investigates the potential for sedimentation in the excavations at the inlet and how it might affect the ability to control discharge into the DSHPP and towards Khone Falls over the short, medium and long term. If necessary, the Consultant may reevaluate headpond sedimentation management approaches and alter the inlet design to ensure adequate inflows for power production.

8.7 Headpond Sedimentation Management Plan

Deposition of significant amounts of sediment in the headpond will expose the turbines to abrasion. The mitigation proposed by the Consultant entails using abrasion resistant turbines. Experience has shown that such turbines still require maintenance, the frequency of which accelerates when exposed to large amounts of angular, hard, coarse sediment flowing through them; as anticipated at DSHPP. Uncertainty exists about the abrasion of the turbines.

It is recommended that the Consultant uses the results of improved headpond simulation modeling suggested in Section 8.5 to assess the potential for turbine abrasion and how to manage it. The use of low-level-outlets below the turbines may be desirable.

The Consultant may also wish to reconsider its recommendation to omit the use of low-level-outlets facilitating drawdown flushing in lieu of dredging. The reviewer concluded through preliminary calculations that drawdown flushing could be an effective means of removing deposited sediment from the headpond.

Regardless of the sediment management technique (Section 6.2) it is noted that removal of abundant amounts of sediment from the headpond requires close attention to disposal methods (Section 6.3) preventing potential transboundary impacts (Section 6.1), which should be addressed by the Consultant.

9.0 CONCLUSIONS

The review resulted in the following conclusions:

- The DSHPP will have no significant cumulative impacts on the Lower Mekong River.
- Transboundary impacts in the river reach immediately downstream of the dam are conceivable, although remote. Potential impacts still requiring evaluation by the Consultant are:
  - Sedimentation of the deep pool straddling the boundary with Cambodia
  - Sedimentation at the islands just across the border with Cambodia
  - Increased turbidity in the river reach immediately downstream of the dam
- Increased future need to remove greater amounts of deposited sediment from the headpond, beyond what is currently predicted, may pose disposal challenges:
  - Disposal of sediment on land may be hampered by limited availability of suitable sites
  - Disposal of sediment into the downstream river reach might exacerbate the potential for transboundary impacts
- Operational challenges due to headpond sedimentation may include:
  - Sedimentation of the headpond is expected to lead to turbine abrasion.
  - Sedimentation of the inlet to the headpond may lead to a reduction in discharge of water to the DSHPP, hampering the ability to achieve power production goals.
- Gaps and uncertainties identified in Section 8.0 should be addressed by the Consultant.

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