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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Distribution:

December 5, 2014

Project No.141-5902

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
- AECOM. 2011a. Don Sahong Hydropower Project, Design Studies: Hydrology, Hydraulics and Sedimentation Studies Report, 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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Engineering Earth's Development, Preserving Earth's Integrity

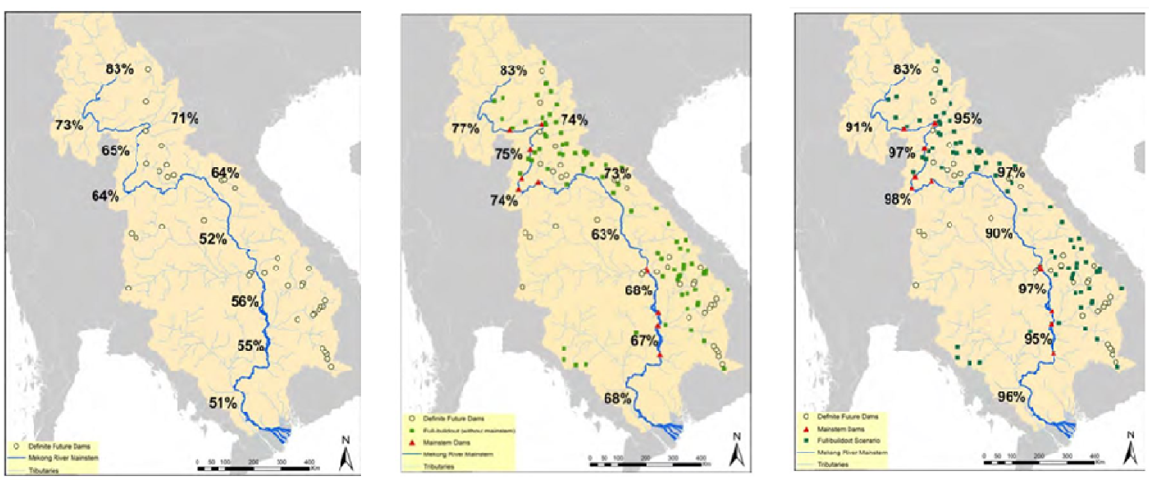
Appendix A: Don Sahong Sediment Transport and Geomorphology Review and Analysis

METHODOLOGY

1.0 EXPECTED SEDIMENT INFLOW TO DSHPP

Kondolf et al. (2014) provide a current estimate of cumulative sediment starvation due to the construction of existing and planned dams on the Mekong River for three scenarios as defined by the MRC:

- Definite Future (Figure 1 (a))
- Full build-out, without the main stem dams (but including Xayaburi Dam) (Figure 1 (b))
- Full build-out (Figure 1 (c))



(a) (b) (c)

Figure 1 Sediment Starvation in the Mekong River due to Dam Construction: (a) Definite Future (b) Full Build-out without Main Stream Dams (except Xayaburi) (c) Full Build-out (Kondolf et al. 2014)

Figure 1 indicates that the sediment flux to the Mekong Delta is expected to reduce by 51% for the Definite Future Scenario, and by 68% and 96% respectively for the other two scenarios. Of particular interest when assessing the sediment load at DSHPP is the impact of the Lancang Cascade of Dams, which is expected to reduce the sediment flux from China by 83%.

Walling (2008), Milliman and Syvitski (1992), Liu et al. (2013) and others estimated that the sediment flux from China amounted to about 80Mt/yr prior to dam construction, which equals half of the total sediment flux of 160Mt/yr in the Mekong River. Based on Kondolf et al. (2014) the sediment load from China will reduce by 66Mt/yr (83% of 80Mt/yr), i.e. it is expected that the sediment flux from China will equal about 14Mt/yr once the impact of the dams are fully realized.

This estimate is confirmed by current measurements at Chiang Sean (the first gauging station downstream of the border between Laos and China) indicating that the annual sediment flux since

2009 ranged between 7.3Mt/yr and 12.8Mt/yr (Figure 2). This reduction in sediment flux from China affects the entire Lower Mekong River (LMR) (Table 1). Of particular interest is the reduction in the average annual sediment flux at Pakse, which changed from 147Mt/yr to 65Mt/yr.

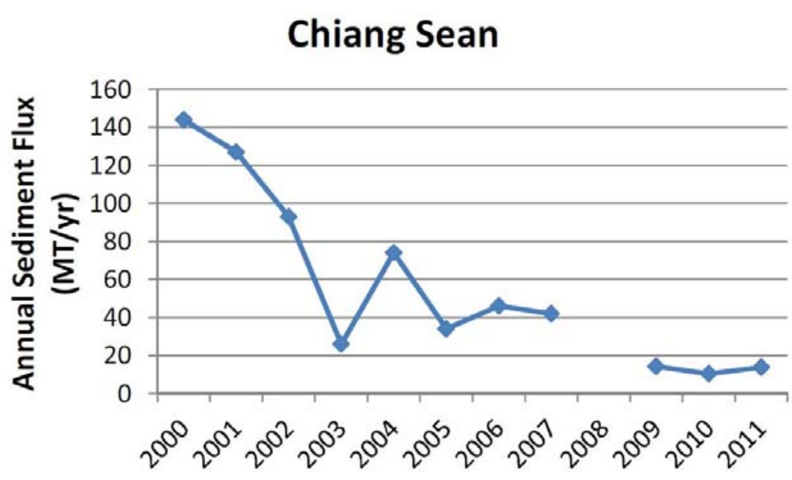


Figure 2 Annual Sediment Flux at Chiang Sean (Koehnken 2012)

Table 1 Historic and Current Estimates of Sediment Load in the Mekong River

Location	Load – Historic (Mt/yr)**	Suspended Load (2011 – 2013) (Mt/yr)*	Bed Load (2011-2013) (Mt/yr)*	Bed Load as Percent of Suspended Load (%)
Chiang Saen	85	7.3 to 12.8	1.6	12.5 to 21.9
Luang Prabang		22		
Nom Khai		22	1.3 to 4.1	5.9 to 18.6
Nahon Phanom		50		
Pakse	147	65		
Stung Treng		77		
Kratie	160	72.5	1.2 to 2.1	1.7 to 2.9

Notes: *Data from Koehnken (2014); **Average of data collected by DSMP program 1960-2003.

In order to determine whether the most recent data is statistically different from historic data a non-parametric test can be performed using box-and-whisker plots. Figure 3 compares water discharge and Total Suspended Solids (TSS) for the periods 1985 to 2009, and 2011 to 2013.

The box-and-whisker plots are interpreted as follows. Each contains a vertical line and a transparent box. The upper end of the vertical line represents the maximum value in a data set, and the lower end the minimum value. The upper end of the box represents the 75 percentile, and the bottom the 25 percentile of the data. Within the box is a dot, which represents the median value of the data.

The box-and-whisker plots for water discharge in Figure 3 indicate that the spread of discharge values is roughly similar for the two data sets, as are the median and percentile values. This implies that the two discharge data sets are likely from the same statistical population. It means that the nature of water flow at Pakse did not change.

Consideration of the two total suspended solids (TSS) data sets arrives at a different conclusion. The spread of the two data sets differ quite substantially, and the median value of the 2011 to 2013 data set is about equal to the lower quartile of the data set for the period 1985 to 2009. The inner quartile (25% to 75% percentiles) for the 2011 to 2013 data set is also much smaller than that of the other set. Based on these observations it may be concluded that the two TSS data sets are not from the same statistical population.

It is concluded that the reduction in sediment flux at Pakse is due to a reduction in the amount of sediment that is available for transport. It did not change because of a reduction in the sediment transport capacity of the flowing water, which essentially remained the same.

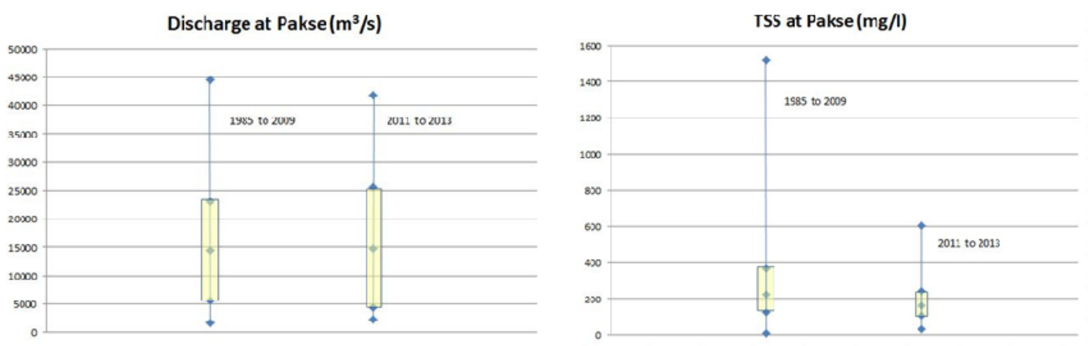


Figure 3 Box-and-Whisker Plots for Discharge and TSS at Pakse for Two Different sampling periods at Pakse

The reduction in sediment flux at Pakse means that the sediment rating curve at this location also changed. Figure 4 shows the rating curve for data over the period 2011 to 2013. Using this rating curve and the duration curves for water flow provided by SMEC (2014d) it is possible to derive suspended sediment load duration curves at Pakse (Figure 5) and at Don Sahong, pre- and post-construction (Figure 6).

The areas underneath the sediment load duration curves represent the expected annual suspended sediment load at these locations (the true mean). Using this approach the expected annual suspended sediment load at Pakse is 47Mt/yr, and at Don Sahong it is 675,000t/yr and 2.4Mt/yr respectively for pre- and post-construction conditions. It is noted that the estimate for post-construction conditions at DSHPP is about 34% of the assumed sediment flux used by the Consultant. SMEC (2014c) estimates that the suspended sediment flux into DSHPP is about 7Mt/yr.

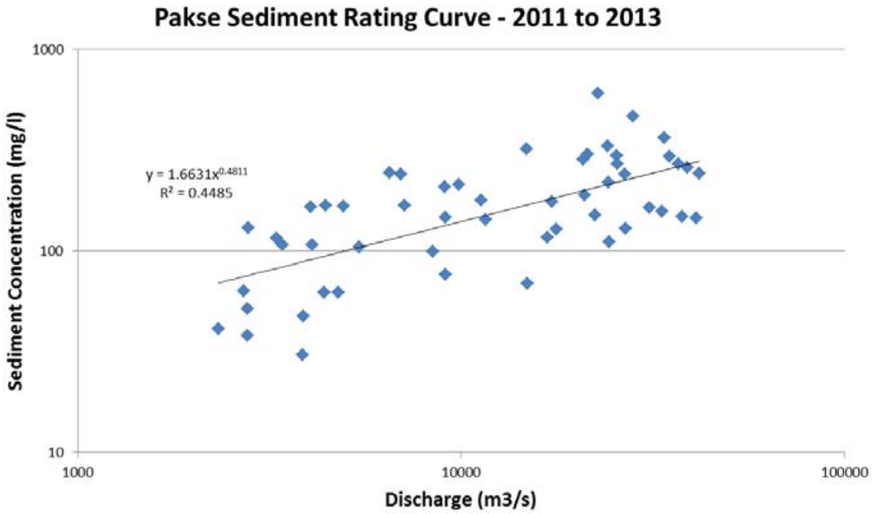


Figure 4 Sediment Rating Curve at Pakse for period 2011-2013 (data from Koehnken 2014)

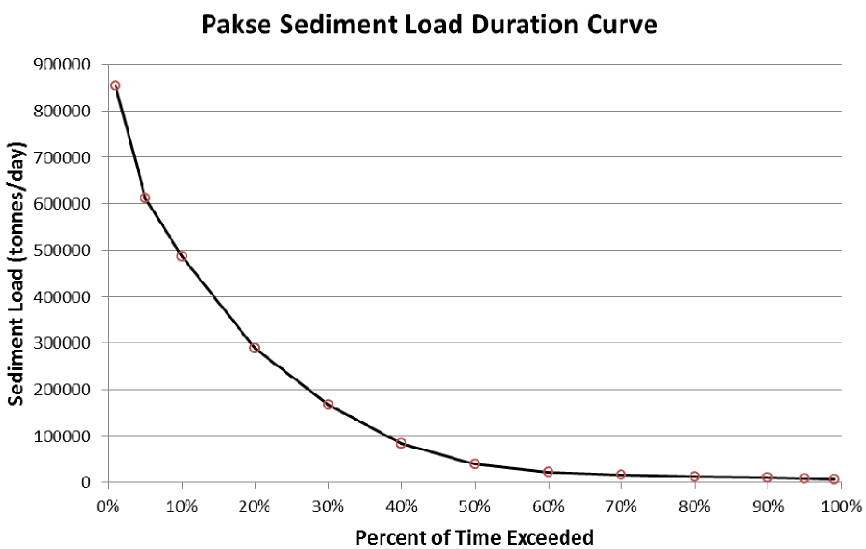


Figure 5 Suspended Sediment Load Duration Curve for Pakse

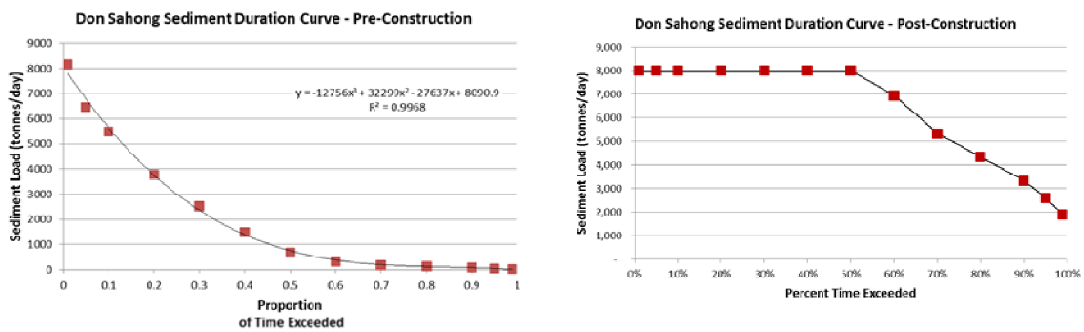


Figure 6 Suspended Sediment Load Duration curves for Don Sahong, Pre- and Post-Construction

The bedload transport that was used in the computer simulations of sediment deposition in the DSHPP is on the order of about 700,000t/yr (10% of 7Mt/yr) (SMEC 2014c). This estimate is much larger than the bed load flux measured by the Consultant (SMEC 2014b), which ranges between 1.1t/yr per meter width to 34.4t/yr per meter width of the river. Assuming a width of about 400m at the inlet to Don Sahong implies that the bed load into the DSHPP may range from 440t/yr to 13,760t/yr.

These measured bedload fluxes are relatively low when compared to other measurements in the Mekong River. Assuming river widths at Kratie and Nong Khai to be about 2,500m and 700m respectively, information on Figure 7 can be used to quantify the bedload transport rate per meter width at each location. Assuming an average bedload transport rate of 10,000t/day at Kratie (Figure 7), it is estimated that the river transports on average about 1,460t/yr per meter width of the river. In the case of Nong Khai (assuming an average bedload transport rate of about 3,000t/day - Figure 7) the transport rate amounts to about 1,533t/yr per meter width of the river.

The estimated unit width bedload transport values at Kratie and Nong Khai are significantly larger than those measured at Don Sahong, as presented in Table 2. It is reasonable to question the accuracy of the bed load measurements at Pakse, as indicated by SMEC (2014b).

Table 2 Comparison of Bedload Transport Rates

Location	Bedload Transport (tonnes/year per meter river width)
Pakse	1.1 to 34.4
Kratie	1,460
Nong Khai	1,533

If it is assumed that the unit bedload transport rate is about 1,500t/yr per meter width of river, and it is assumed that the river width at the inlet to the DSHPP is about 400m, then the annual bedload transport into the DSHPP is estimated at 600,000t/yr; which is close to the assumed value by the Consultant equalling 700,000t/yr.

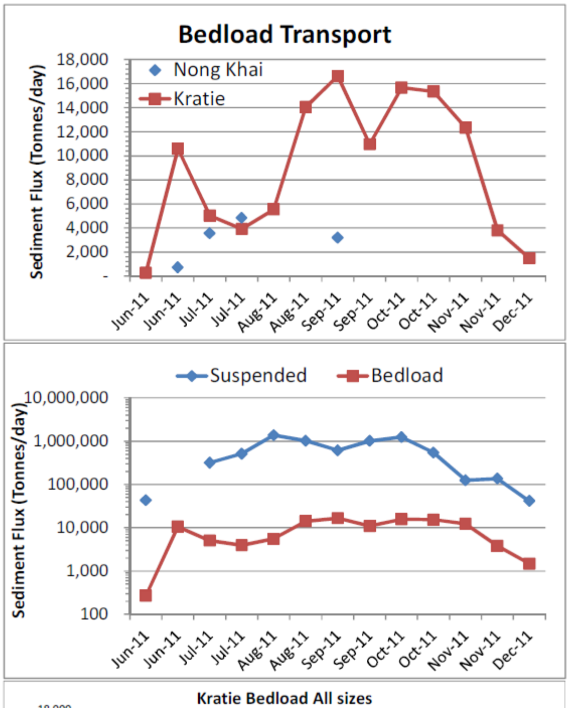


Figure 7 Bedload Transport at Nong Khai and Kratie (top graph) and Suspended and Bedload transport at Kratie (lower graph) (Koehnken 2012)

Table 3: Table 8 extracted from Koehnken (2012) showing the particle sizes for suspended sediment at Pakse and Luang Prabang

Table 8. Estimated masses (Tonnes/day) of sand (0.063 mm), Coarse silt (0.045 - 0.063 mm) and Medium silt (0.02-0.045 mm) transported at Luang Prababng and Pakse during June – December 2011.

Site	Sand (>0.063 mm) (Tonnes/yr)	Coarse Silt (0.045 – 0.063 mm) (Tonnes/yr)	Medium Silt (0.02–0.045 mm) (Tonnes/yr)	Total (Tonnes/yr)
Luang Prabang	14.0	8.4	3.2	25.6
Pakse	39.4	28.2	5.4	73.0

The sampling campaign by SMEC (2014b) determined the particle size distributions (PSD) for suspended sediment and bed load. The d_{50} of the suspended load is about 10µm and that of the bedload 0.3mm. It means that the suspended sediment principally consists of silt sized material, and that the bedload primarily consists of fine sand. These sizes are generally consistent with measurements at Pakse, Nong Khai and Kratie; except that bedload at the other locations sometimes also contains coarse material such as gravel (Koehnken 2012).

The very fine nature of the suspended sediment indicates that it will most probably flow through DSHPP unhindered. Furthermore, the fact that the amount of sediment that will be released downstream of DSHPP is approximately equal to historic conditions (2.4Mt/yr vs. 2.0Mt/yr) indicates that it is unlikely to deposit in the river reach downstream of the dam. However, this statement requires confirmation by the Consultant.

The true nature of the bedload material remains unknown, and may be coarser than indicated by the samples (SMEC 2014b). Coarser bedload material may result in downstream deposition if it is released into the river during future headpond sediment management activities, such as dredging or drawdown flushing.

2.0 SEDIMENTATION DUE TO CONSTRUCTION

The construction activities that will potentially result in increased sediment loads during the construction period are construction of the dam, excavation at the inlet to the reservoir, the Tailrace excavation, construction of a number of access roads and storage and processing of construction materials.

- The dam is 7km long and consists mainly of RCC and rock fill placed on both sides. The rock fill is intended to originate from the excavations at the inlet and Tailrace.

- Roads are linear structures that may generate significant amounts of sediment during construction, over large distances.

- The excavation at the inlet is proposed to be down to level 66masl, while that at the Tailrace is planned to level 44masl. The earth material to be excavated likely consists of bedrock. Excavation will likely require the use of explosives. The use of blasting mats may be required to prevent uncontrolled spreading of blast material.

- To use the blasted rock for dam construction will require large storage areas where the rock will be further processed. These areas combined with areas where cement, sand and gravel for preparation of RCC materials will be stored are potential sediment sources, requiring careful planning to prevent uncontrolled release of sediment into the Mekong River.

Accidental and unplanned releases of sediment due to construction activities will principally have local transboundary impacts. The principal impacts will likely affect fish and dolphins due to higher than normal turbidity, could result in sediment deposition in deep pools and possibly deposition of increased amounts of sediment at the cross-border islands in Cambodia.

The need for careful implementation of BMP's is of critical importance to prevent unnecessary releases of sediment generated by construction activities.

3.0 HEADPOND SEDIMENTATION

The amount of sediment that is expected to deposit in the Don Sahong Headpond can be determined by means of computer simulation, as reportedly executed by the SMEC (2014c), or by means of empirical techniques. The limited resources and time available for this review excluded the use of computer simulation. Rather, the review relied on the use of acknowledged empirical techniques that are generally used to estimate the sediment trap efficiency of reservoirs. The two empirical techniques relied upon are the Churchill (1948) method (as modified by Roberts (1982)) and the Brune (1953) method.

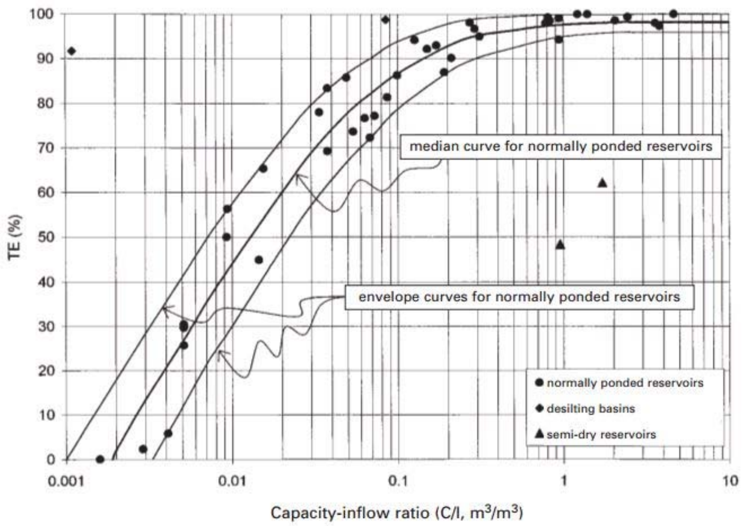


Figure 8 Brune (1953) curve for estimating sediment trap efficiency

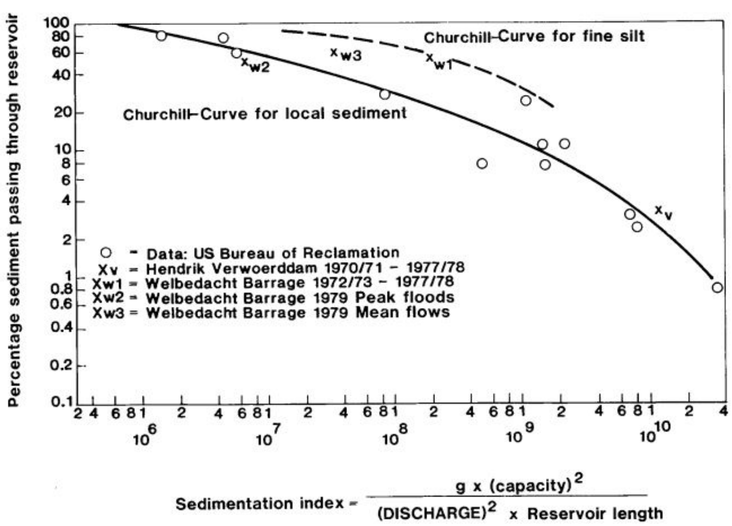


Figure 9 Churchill (1948) curve for estimating the percent of sediment passing through a reservoir, as modified by Roberts (1982)

The Brune (1953) curve relates the sediment trap efficiency of a reservoir to the capacity-inflow ratio of the reservoir (Figure 8). The capacity-inflow ratio of a reservoir is calculated by dividing the reservoir volume expressed in cubic meters by the average annual inflow of water into the reservoir, also expressed in cubic meters. The relationship between the capacity-inflow ratio and trap efficiency is expressed in terms of a median curve surrounded by an envelope. The amount of inflowing sediment that will be deposited in a reservoir is determined from the ordinate of the graph in Figure 8 once the capacity-inflow ratio is known.

The Churchill (1948) curve provides a means of estimating the percentage of sediment that will pass through a reservoir (Figure 9). Subtracting that amount from 100% provides an estimate of the amount of sediment that will be trapped. The Churchill curve contains more information than the Brune curve due to the fact that the Sedimentation Index on its abscissa incorporates the reservoir volume, discharge and reservoir length. The Sedimentation Index is calculated by using dimensionally consistent units.

The input data used to calculate the indices for the two methods are as follows:

Table 4 Parameter Values used to Calculate Indices for Brune (1952) and Churchill (1948) methods

Variable	Value	Units	Comment
Headpond Total Storage Volume =	15,000,000	m^3	
Q_{Don_Sahong}	1,333	m^3/s	
Expected Annual Sediment Flux	2,400,788	tonnes/year	From sediment load duration curve analysis by reviewer
Mean Sediment Flux assumed by Consultant	7,000,000	tonnes/year	SMEC (2014c)
Reservoir Length	4,790	m	from Google Earth

From the values in Table 4 the estimated trap efficiency and mass of suspended sediment expected to deposit in the DSHPP headpond are shown in Table 5.

Table 5 Estimated average annual amounts of deposited suspended sediment in DSHPP according to the methods of Churchill (1948) and Brune (1952)

Variable	Churchill (1948)	Brune (1952)
Index	2.59E+05	3.57E-04
Percent Passing	100%	100%
Percent Trapped	0%	0%

All the bedload will deposit in the reservoir, except if a new geomorphic equilibrium is reached that would result in high enough sediment transport capacity to carry the bedload through the headpond. The budget for this review precludes the reviewer from executing detailed reservoir sedimentation modeling, similar to that executed by SMEC (2014c), to check their conclusion that the reservoir would reach a new geomorphic equilibrium in about three years. The conclusion by the Consultant is founded on only five years of computer simulation and may not be long enough.

Using the results provided by SMEC (2014c) it can also be argued that the modeling results indicate a continued increase in sedimentation of the headpond, though at a slower rate after the second year of operation. The reviewer added a trend line on Figure 10 which implies that a new geomorphic equilibrium has not been reached by year 3, but that sediment deposition is expected to continue in the headpond of DSHPP. It implies that the reservoir may eventually completely fill with sediment.

This is less of a concern for the developer than what it is for the Government of Laos. If the headpond of DSHPP is substantially filled with sediment at the end of the concession period it may compromise the ability of the Government to generate hydropower unless substantial maintenance cost is incurred.

In the worst case it is estimated that the reservoir could completely fill with deposited sediment in about 34 years, assuming that the total bedload of 700,000t/yr will remain in the reservoir every year and that the density of the deposited sediment is 1,590kg/m^3 (SMEC 2014c). The reviewer concedes that this is a worst case scenario; thereby requesting the Consultant to extend the computer simulation of the headpond sedimentation for a much longer period than five years. It is deemed in the best interest of the Government of Laos to gain more certainty about reservoir sedimentation and its potential implications on hydropower production in the long term.

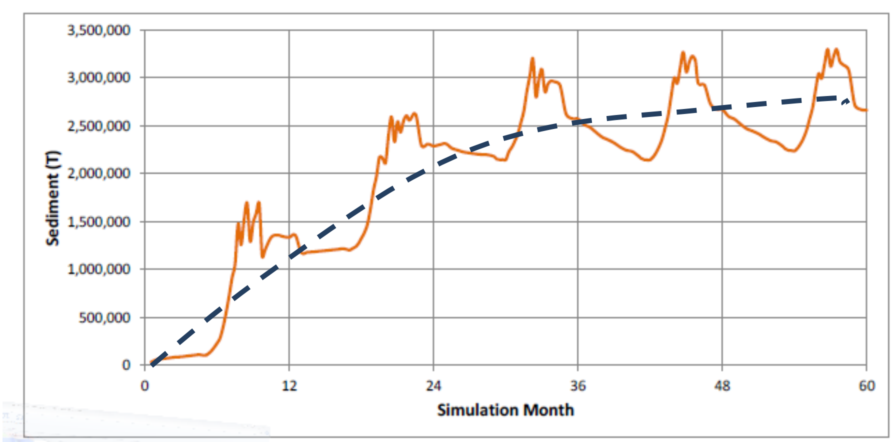


Figure 10 Predicted cumulative mass of deposited sediment in DSHPP head pond (SMEC 2014c) with trend line added by reviewer.

4.0 CUMULATIVE IMPACTS - CHANGES IN SEDIMENT BALANCE

The potential impact of DSHPP on sediment transport and geomorphology of the Mekong River and Delta requires consideration of changes in the sediment balance of the river system. Two sediment sources require consideration, viz. inflow of sediment from the Mekong River to DSHPP and sediment originating from construction activities.

Implementation of best management practices (BMP's), although not detailed (National Consulting Company 2013a, 2013b and 2013c), is intended to limit releases of sediment from construction activities. This should be possible and is not considered further.

The Consultant estimates that once the new geomorphic equilibrium is reached in DSHPP that the amount of deposited suspended sediment will fluctuate between 0.4 and 1.2 million tonnes every year and that the amount of deposited bedload will roughly remain at 2.5 million tonnes (no additional deposition of bedload after three years). Based on these values the Consultant guesstimates that the maximum amount of sediment that will remain in the headpond throughout its life will range between about 3 million tonnes and 4 million tonnes in total.

This estimate may be misleading, as already indicated in Section 3.0. The claim by the Consultant that the headpond will reach a new geomorphic equilibrium in three years has not been convincingly demonstrated. The simulation period used by the Consultant is only five years, which is deemed too short for making such a conclusion. The reviewer is of the opinion that a greater amount of sediment many deposit in the headpond and that a new geomorphic equilibrium will be reached much later.

In the absence of this result, it is deemed prudent to consider the impact that estimates of maximum and minimum amounts of deposited sediment in the headpond will have on the overall sediment balance of the Mekong River. In the extreme case the total amount of sediment that may be removed from the river could be 15million m^3, i.e. the total headpond volume. This is unlikely, but may be considered a maximum.

Again, assuming that the bulk density of deposited sediment equals 1,590kg/m^3 the estimated maximum mass of sediment that may be removed from the river system amounts to 23.9Mt over a period of, say, 34 years.

If it is assumed that the sediment flux at Pakse has changed from 147Mt/yr to somewhere between 47Mt/yr and 65Mt/yr (plus 10% bedload in each case) the maximum total amount of sediment captured may range between 33.4% and 46.5% of the mean annual sediment flux at Pakse, which differs from the Consultant's estimate of about 3% (SMEC 2014c).

However, using the annual sediment flux as a frame of reference skews conclusions because in the assumed extreme case the sediment will gradually deposit over a period of 34 years. It is also better to relate the amount of sediment removed from the system to the total sediment flux in the Mekong River. For the assumed maximum amount of deposited sediment and a sediment flux of 160Mt/yr, the total amount of sediment removed from the river over a period of 34 years equals 0.4%. To consider the cumulative effect using the current sediment flux in the Mekong River (72.5Mt/yr), the amount of sediment removed during 34 years amounts to 1%.

These estimates should be compared to the minimum amount of deposited sediment estimated by the Consultant, again using a period of 34 years. If the total removal of sediment from the river system due to the presence of DSHPP amounts to, say, 4Mt, then the amount of sediment removed over 34 years equals 0.07% (for a total sediment flux equaling 160Mt/yr) and equals 0.2% if the total Mekong River sediment flux is 72.5Mt/yr (current estimate).

It is concluded that the presence of DSHPP may remove 0.07% to, at most, 0.4% of the original, undeveloped sediment flux in the river (i.e. 160Mt/yr). Incrementally, DSHPP will remove another 0.2% to 1% of the sediment flux currently remaining in the river (i.e. 72.5Mt/yr).

5.0 TRANSBOUNDARY IMPACTS

With the cumulative impact of DSHPP being negligible, transboundary impacts are of limited extent. Potential transboundary impacts are only identified in the immediate vicinity of the dam, in the river reach up to and just beyond the border with Cambodia:

- 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

These potential impacts exist due to the estimate that the amount of sediment that will be discharged immediately downstream of the Hon Sahong channel will be 3.5 times greater with the DSHPP project than without the project (See Section 1.0).

The Consultant has not investigated these transboundary impacts, and the reviewer did not execute additional analysis. The opinion is expressed that assessment of these potential impacts requires 2-D or 3-D sediment transport modeling in the river reach between the DSHPP to just beyond the Cambodia border.

6.0 MITIGATION

6.1 Sediment Management Alternatives

The sediment management techniques that are potentially viable for implementation at Don Sahong Reservoir are drawdown and pressure flushing, sluicing (routing) and dredging. In this section of the report the essential characteristics of the three methods are briefly discussed, followed by a description of the methods used to assess their potential usefulness at Don Sahong.

Dredging can be accomplished in various ways. The most common method is to use suction dredging, which consists of a pump on a barge that is connected to a pipeline. The suction pipe removes deposited sediment from the bottom of a reservoir, which is then pumped out of the reservoir for disposal. In the case of reservoir sedimentation the most effective use of dredging is usually to clear sediment from specific areas; e.g. immediately upstream of a powerhouse intakes (Palmieri et al. 2003).

Pressure flushing is used to remove deposited sediment immediately in front of an outlet when water is discharged through the outlet and the water surface elevation in the reservoir remains high (Figure 11).

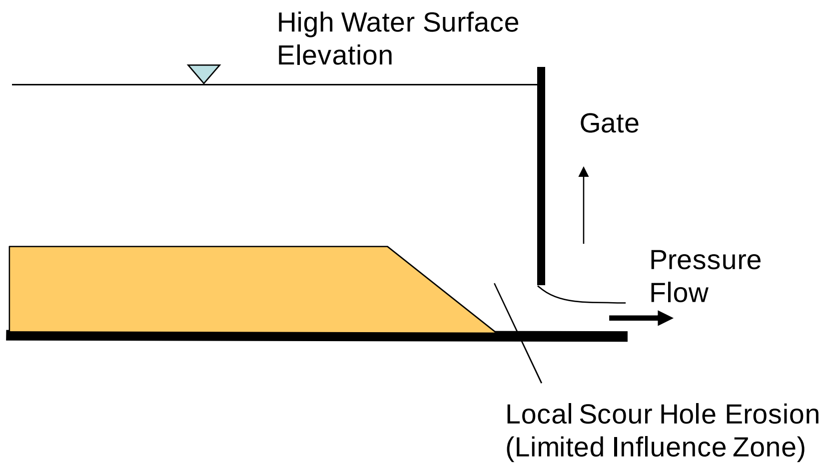


Figure 11 Pressure flushing to remove localized sediment deposits

Sediment sluicing and drawdown flushing could be used individually or in tandem to minimize the amount of sediment deposited in a reservoir. The objective with sluicing is to minimize the amount of sediment depositing in a reservoir. It is accomplished by creating and maintaining high sediment transport capacity within a reservoir, high enough to keep sediment flowing through the reservoir in suspension. The sediment remaining in suspension passes through a reservoir, is released downstream and does not deposit in the reservoir[1]. Sluicing is generally implemented during the monsoon when water and sediment flows are high. Under such conditions the sediment transport capacity in the reservoir is maintained by opening outlets at the dam and lowering the water surface elevation at the dam to increase the flow velocity through the reservoir (Figure 12). Sluicing is often described as “releasing the dirty and storing the clean water”.

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[1] Bedload (i.e. sediment transported along the bed of a river and not carried in suspension in the flowing water) will normally deposit in a reservoir; even if sluicing is implemented.

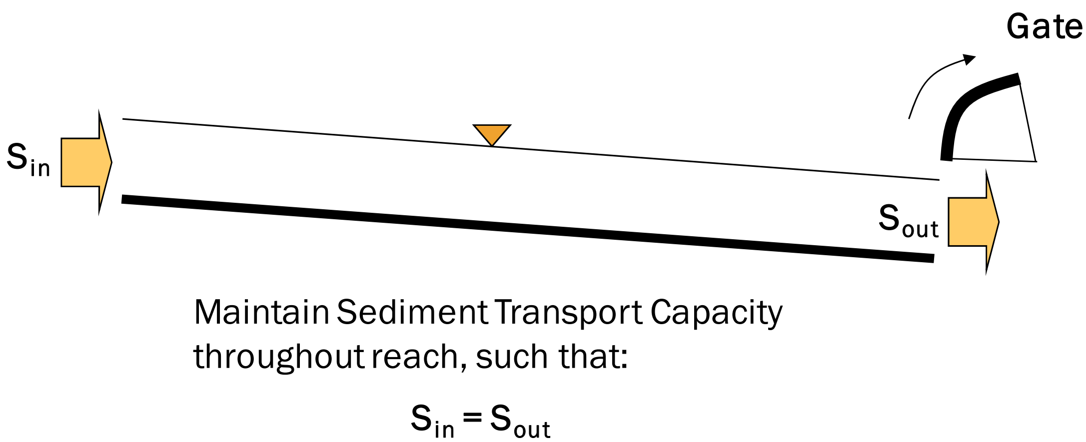


Figure 12 Schematic illustrating the concept of sluicing

Sediment that has deposited in a reservoir can be removed by ***drawdown flushing***. This is accomplished by creating river-like flow conditions in a reservoir. The water flowing through the reservoir must flow fast enough to erode the deposited sediment. Importantly, the water must also flow freely through the outlet, without damming. Obviously, such flow conditions cannot be created during the monsoon. Drawdown flushing is generally implemented during the dry season. Water flow must be low enough to allow full drawdown and free-flow conditions at the outlet, and high enough to erode the deposited sediment in the reservoir for release downstream. Drawdown flushing is accomplished by drawing the water surface elevation at the reservoir down, far enough to create the desired conditions (Figure 13).

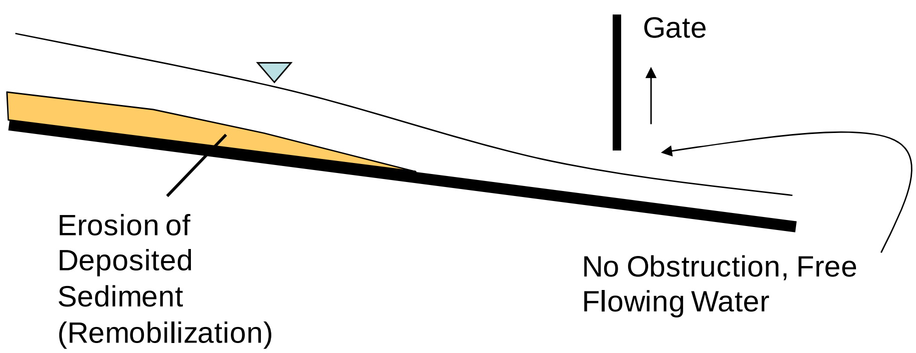


Figure 13 Drawdown flushing operations require the use of high flow capacity low-level outlets that can draw the water level at the dam down far enough to create free-flow conditions at the outlet and river-like flow conditions in the reservoir. This flow condition erodes deposited sediment and releases it downstream.

6.2 Drawdown Flushing Criteria

The potential to successfully implement drawdown flushing at DSHPP can be determined through computer simulation (e.g. MIKE 21C, TELEMAC-MUSCARET, HEC-RAS 5.0 beta version) or through the use of empirical techniques. Computer simulation is beyond the scope of this review, and the potential for implementing drawdown flushing at Don Sahong has therefore been determined using a well-known empirical approach (Palmieri et al. 2003; White 2001), briefly described in what follows.

Importantly, a number of criteria to identify the potential for successful drawdown flushing are provided. These are known as the Long-Term Capacity Ratio (LTCR), the Sediment Balance Ratio (SBR), the Flushing Width Ratio (FWR), Top Width Ratio (TWR) and the Drawdown Ratio (DDR). It should be noted that these criteria are only aids to help in decision making and that they should all be considered in concert to decide whether drawdown flushing may or may not be successful.

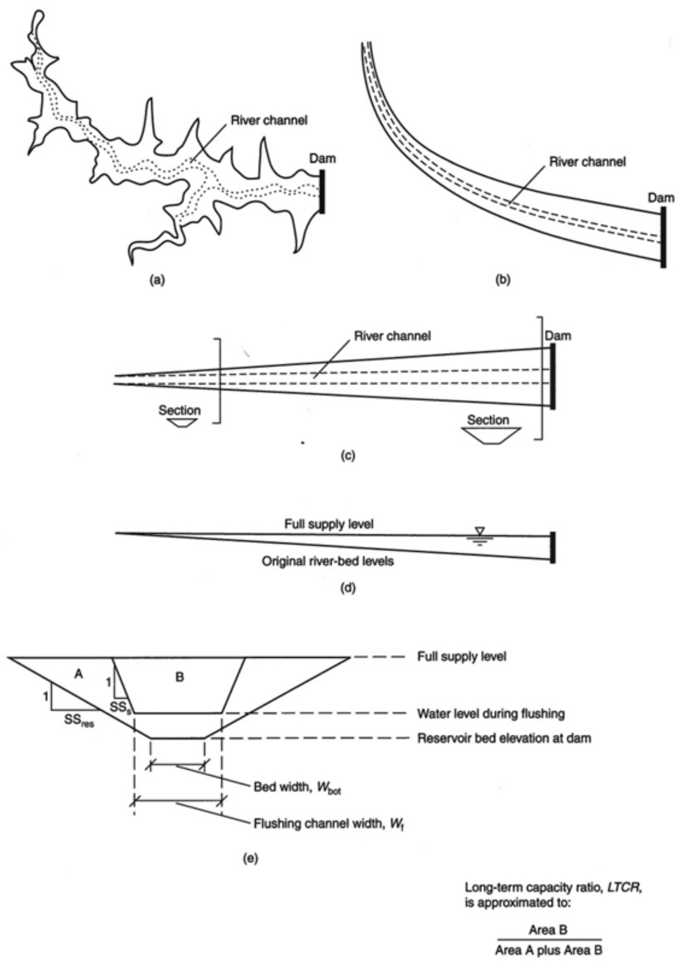


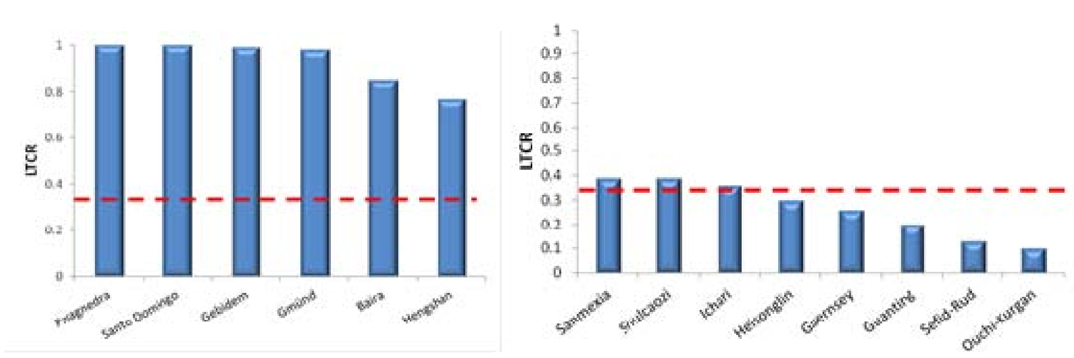
Figure 14 Essential geometric parameters used in empirical technique to assess the potential for drawdown flushing (White 2001)

The essential data required to assess drawdown flushing potential include geometry (such as reservoir geometry, dam height, outlet characteristics), water flow and sediment flow (incoming sediment load and sediment discharge capacity of the flushing flows). The method developed by White (2001) simplifies the reservoir geometry as shown in Figure 14. The actual reservoir (Figure 14 (a)) is simplified to be finally represented by Figure 14 (c) in plan and Figure 14 (d) in long section. The cross sectional flow area is simplified as shown in Figure 14 (e), further assuming that the flushed channel remains at the same width along the reservoir length. The shown cross section represents conditions after the reservoir has been flushed, once having been completely silted.

6.2.1 Long-Term Capacity Ratio

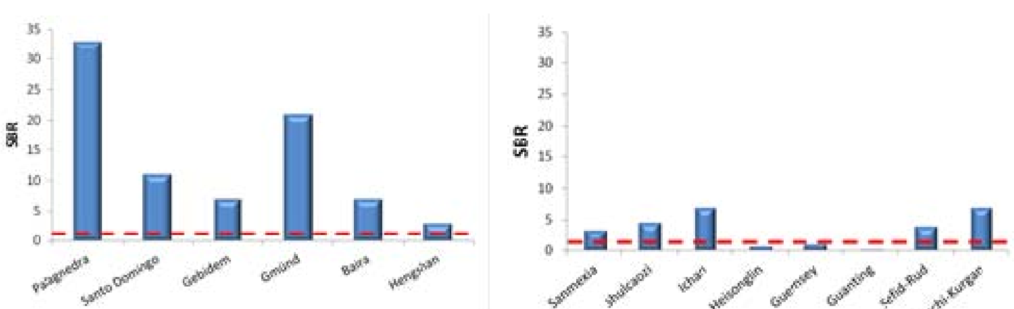
The Long-Term Capacity Ratio (LTCR) is defined as shown on Figure 14. This ratio determines the potential success of drawdown flushing. In Figure 14 (e) the area “B” represents the flushed flow area, and the area “A” the remaining sediment. In cases where the area “B” is less than the area “A” it means that only some of the sediment can be removed by drawdown flushing. In the ideal case, when area “B” is equal to area “A” all the sediment has been removed. In such a case the LTCR = 1. This is not always possible, and it is therefore necessary to set practical criteria defining when drawdown flushing may be deemed successful in removing sediment. Guidance in this regard is provided by White (2001) for cases where drawdown flushing was deemed successful and unsuccessful (

Figure 15). Palmieri et al. (2003) assumes that drawdown flushing is successful if LTCR > 0.35, while White (2001) assumes LTCR > 0.70.



(a) (b)

Figure 15 LTCR values for (a) successful and (b) unsuccessful drawdown flushing



(a) (b)

Figure 16 SBR for (a) successful and (b) unsuccessful drawdown flushing

6.2.2 Sediment Balance Ratio

The Sediment Balance Ratio (SBR) is the ratio between the amount of sediment that can potentially be removed from a reservoir through drawdown flushing and the amount of sediment deposited in a reservoir between flushing events. If the amount of sediment that can potentially be removed by the flushing flows is equal to or greater than the amount of sediment that deposits in a reservoir between flushing events, implementation of drawdown flushing may be potentially successful. Figure 16 provides relevant guidance for the use of SBR, based on experience at fourteen reservoirs.

6.2.3 Flushing Width Ratio

The flushing width is defined as the bottom width of a channel that may be eroded into a sediment deposit (Figure 14 (e)). If the flushing flow width is greater than the width of the natural valley in which the reservoir resides, the potential of removing large volumes of sediment from a reservoir increases. High flows would erode wider channels than low flows, identifying a need to empirically estimate the width of a flushing channel. This may be accomplished through an equation developed at Tsinghua University, Beijing (Figure 17).

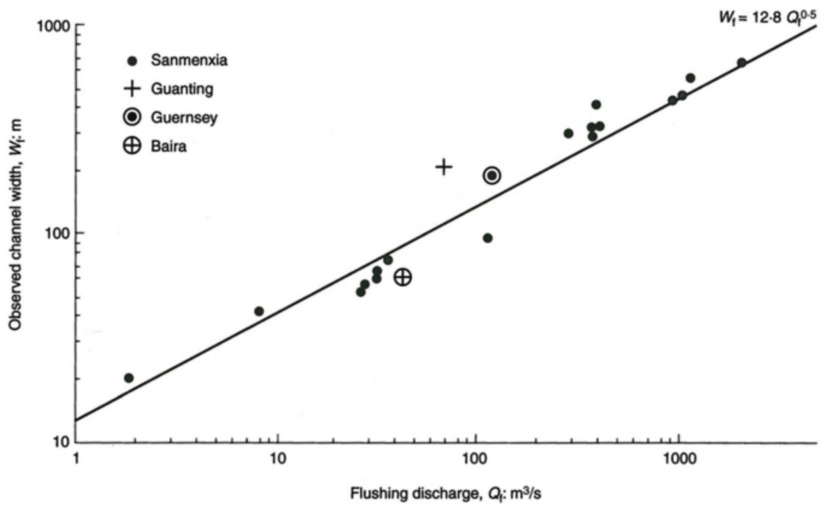
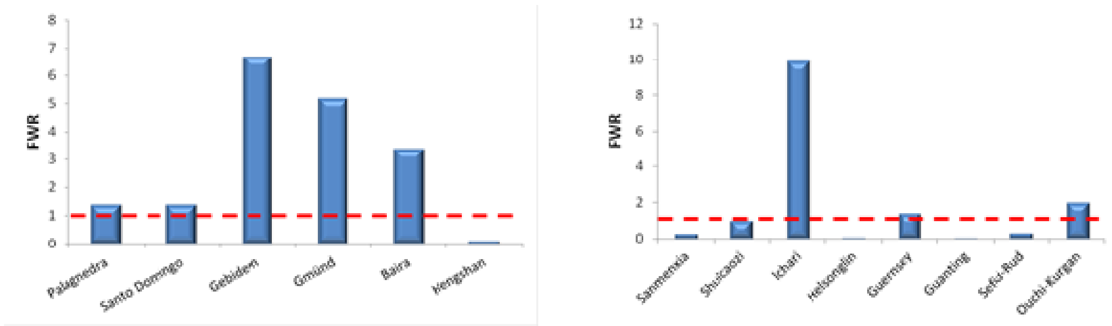


Figure 17 Relationship between flushing flow width and flushing discharge measured at four Chinese reservoirs



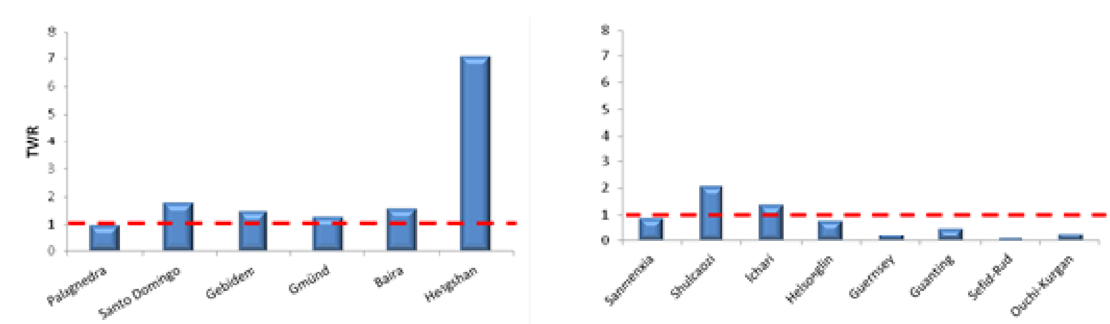
(a) (b)

Figure 18 FWR for (a) successful and (b) unsuccessful drawdown flushing

The Flushing Width Ratio (FWR) is defined as the ratio between the flushing width W_f and the bottom width of the natural valley containing the reservoir W_{bot} (Figure 14 (e)). Ideally the FWR should be greater than one, as explained above. Measured FWR for cases where drawdown flushing was successful and unsuccessful are shown in Figure 18.

6.2.4 Top Width Ratio

The Top Width Ratio (TWR) is the ratio between the top width of the flushing channel (represented by the area “B” in Figure 14 (e)) and the top width of the natural valley containing the reservoir, both measured at full supply level. If the top width of the flushing channel is equal to or greater than the top width of the natural valley, it is possible for drawdown flushing to be successful. Guidance is provided in Figure 19.



(a) (b)

Figure 19 TWR for (a) successful and (b) unsuccessful drawdown flushing

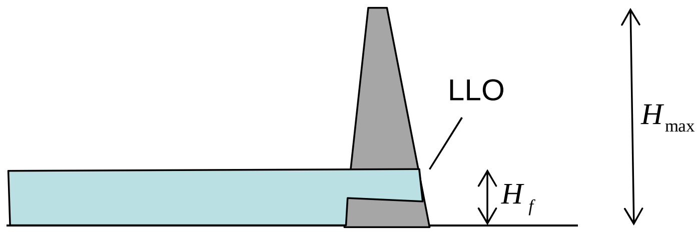


Figure 20 Schematic showing heights of dam and low-level outlet (LLO)

6.2.4.1 Drawdown Ratio

For drawdown flushing to be successful it is critical to have available low-level outlets, required for drawing down the water surface elevation in the reservoir. Experience has shown that the maximum height of the soffit of a low-level outlet, measured from the bottom of the dam, should not exceed 30% of the dam height. The Drawdown Ratio (DDR) is defined as

$$DDR = (1 - \frac{H_f}{H_{max}}) \tag{1}$$

The variables H_f and H_{max} are defined in Figure 20. DDR values for the 14 case studies considered by White (2001) are shown in Figure 21 for successful and unsuccessful drawdown flushing.

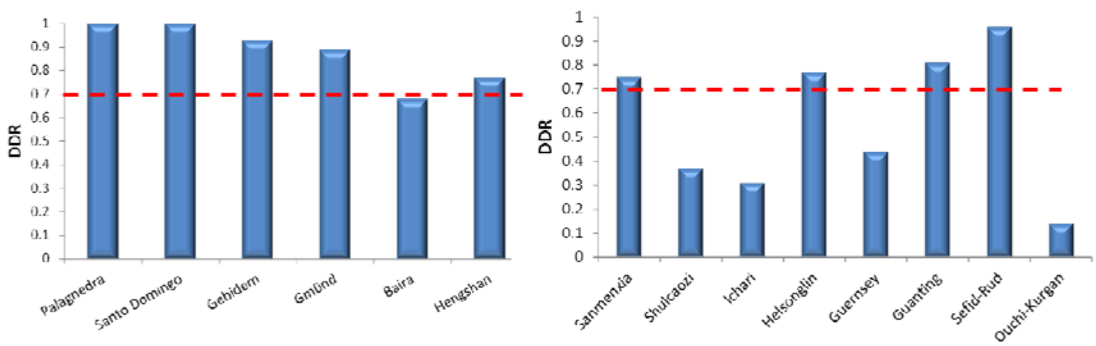


Figure 21 DDR for (a) successful and (b) unsuccessful drawdown flushing

6.2.5 Summary

The criteria for successful drawdown flushing are summarized in Table 6. The RESCON software (Palmieri et al. 2003) that calculates the values of the parameters discussed above was used to determine whether drawdown flushing could be successfully implemented at DSHPP.

Table 6 Criteria for successful drawdown flushing

Parameter	Criterion
SBR	>1
LTCR	>0.35
DDR	>0.7
	Desirable
TWR	>1
FWR	>1

6.3 Implementation at Don Sahong

6.3.1 Dredging

Dredging, although not analyzed in detail, is deemed a practical approach to remove deposited sediment in the vicinity of the power intakes and inlet, should it become a problem. However, its economic viability remains unknown.

6.3.2 Sluicing

Sluicing to convey suspended sediment through the reservoir with minimal deposition is deemed a viable approach, as demonstrated by computer simulations (SMEC 2014c). This is also supported by the empirical analysis by the reviewer, using the Churchill (1948) method (see Section 3.0). The results of the empirical analysis indicate that virtually no suspended sediment will deposit in the headpond. Sluicing of suspended sediment is expected to naturally occur during standard operations due to the short residence time of flowing water and sediment through the reservoir.

However, it is noted that bedload, once deposited, may not be re-suspended through sluicing; which implies that another sediment management technique such as dredging or drawdown flushing will be required to remove deposited bedload material.

6.3.3 Potential Flushing Success at Don Sahong

Following the empirical technique outlined in Section 6.2 the analysis indicates that drawdown flushing may be a viable approach for removing deposited sediment, should the DSPP reservoir substantially fill with sediment. The preliminary calculations, executed using the RESCON approach (Palmieri et al. 2003), indicate that sediment removal may be accomplished by drawing down the reservoir water level to elevation 42.1m or lower and allowing water to freely flow through low-level outlets and, possibly, through the four turbines. Maintaining the flushing flow through low-level outlets and the turbines, and through the reservoir at about 80m^3/s will erode the previously deposited sediment to sustain about 60% of the original headpond volume.

The calculated values of the relevant parameters indicating potential success of drawdown flushing at DSHPP are compared in Table 7 to the criteria presented in Section 6.2. It is noted that the parameter values calculated for DSHPP substantially meet the criteria, indicating potential successful application of drawdown flushing, if needed.

Table 7 Drawdown Flushing parameters for Don Sahong HPP

Parameter	Criterion	Don Sahong
SBR	>1	11
LTCR	>0.35	0.6
DDR	>0.7	0.9
	Desirable	
TWR	>1	0.45
FWR	>1	1.28

The requirement for a flushing discharge equaling about 80m^3/s can only be accomplished through flow control at the inlet to the headpond, which may be obtained by constructing a gated flow control structure at the inlet to the headpond. Such a structure may be required to exclude bedload material from entering the reservoir and to control flows to the Khone Falls at a minimum discharge of 800m^3/s, as required by the environmental and social impact assessment.

Abrasion damage is conceivable should drawdown flushing take place through the bulb turbines. A decision whether such damage is tolerable should sediment removal be required by drawdown flushing will determine whether low-level-outlets are required.

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