Annex F
Review of water quality and ecosystem health impacts of the proposed Don Sahong Hydropower Project – A contribution to the Prior Consultation Process.

Final report

Peter-John Meynell

For Water Quality and Ecosystem Health Expert Group

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This report has been complied based on information and data received from the Lao National Mekong Committee as provided for in Article 5.4.1 of the PNPCA, the experience and expertise of the author(s), and available reports and papers in the public domain.

Contents

1 Introduction

This is a review of the impacts on water quality and ecosystem health in order to contribute to the PNPCA process for the Don Sahong Hydropower Project (DSHPP). It takes into account comments provided by the MRC Secretariat and a meeting of the Joint Committee Working Group on 19 November 2014.

The specific tasks from the Terms of Reference for this assignment are provided in Annex 1.

2 Review process and information sources

This review draws upon a variety of information from different documents available to the consultant. The focus of the review is on the impacts of the DSHPP on water quality and changes in flow, particularly in the way that they may affect the ecosystem health of the Mekong River during construction, operation and decommissioning phases of the project. Whilst one of the main concerns of the Prior Consultation process is the transboundary impacts, the impacts on ecosystem health can only be assessed from an understanding of the scale and extent of the more localised impacts within the Siphandone area, before the river passes into Cambodia and one to Vietnam. Moreover, through Article 3 of the 1995 Mekong Agreement, the Member Countries have agreed to 'maintain the ecological balance of the 'Basin', and through Article 7 to 'make every effort to avoid, minimize and mitigate harmful effects that might occur to the environment, especially the water quantity and quality, the aquatic (eco-system) conditions, and ecological balance of the river system'. This review consequently also assesses the extent to which these commitments are met.

The review is based on data and statements provided by the DSHPP developers and submitted to the MRC via the LNMC as outlined below; as well as other information about the area. In particular, the review tests the extent to which the advice on mitigation and management measures in the Preliminary Design Guidance for mainstream dams has been taken up.

The information received from the project developers of particular relevance to this assessment includes:

- Final Environmental Impact Assessment 2013, carried out by NCC
- Final Cumulative Impact Assessment 2013 carried out by NCC
- Final Environmental Management and Monitoring Plan 2013 prepared by NCC
- Hydrology, Hydraulics and Sedimentation design studies 2011 carried out by AECOM
- Engineering status report 2011 carried out by AECOM
- Transboundary hydraulics effects study 2013 carried out by SMEC New Zealand

The information provided will be compared to the data and assessments contained in various MRC documents, including:

- Procedures for Water Quality
- Procedures for Maintenance of Flows on the Mainstream
- Diagnostic study of water quality in the Lower Mekong Basin , MRC Technical Paper no 15, 2007
- Impacts of Climate change and developments on Mekong Flow regimes – First assessment 2009, MRC Technical paper no. 29, 2010
- The Mekong River Report Card on Water Quality Volume 2, 2010 – Assessment of potential human impacts on Mekong river water quality

- 2011 Water Quality Assessment Report, MRC Technical Paper No 40, 2013
- Water quality report card 2013
- Biomonitoring of the Lower Mekong River and selected Tributaries 2004 – 2007
- Report on the 2011 biomonitoring survey of the Lower Mekong River and selected tributaries, MRC Technical paper No 43, 2014
- Aquatic ecological health report cards 2011 and 2013, MRC technical report No 20, 2008
- Preliminary Design Guidance for the proposed mainstream dams in the Lower Mekong basin, 2009

Various internal documents produced by the MRC with reference to the DSHPP.

In addition, use will be made of data and documents available to the consultant as a result of his participation in two hydropower projects in Siphandone, especially on flows in the Siphandone area and ecosystem health:

- Initial Environmental Assessment of the Thakho diversion hydropower project for CNR and WWF (2009)
- Feasibility study and IEE for three small-scale hydropower projects in Siphandone for CNR and WWF (2010)
- Case studies on climate change impacts on Wetlands in Lower Mekong Basin in Siphandone and Stung Treng, carried out with ICEM and IUCN for the MRC (2011/12)

3 Water quality

3.1 Water quality issues of hydropower dams

The main water quality issues differ between the construction and operational phases. The decommissioning phase is covered in the EIA but its impacts have not been reviewed here.

Water quality issues during construction mostly relate to:

- Increased sediment in the water due to excavation in the river bed, earth moving e.g. construction of coffer dams and preparation of embankments etc.
- Increased organic pollution from worker camps, canteens etc.
- Accidental spillage of construction materials, including washing of concrete.
- Accidental spillage of oils and grease, releases from vehicle and plant maintenance.

The release of Persistent Organic Pollutants (POPs) into the environment may also result from use during the construction. Whilst many POPs are pesticides and agricultural chemicals, there are others such as Polychlorinated biphenyls (PCBs) which may be used in electric equipment, and Hexabromocyclododecane (HBCD or HBCDD), which may be used in thermal insulation materials. Lao ratified the UN Convention on POPs on 28 June 2006. POPs are an obvious concern because of bioaccumulation in the dolphin population downstream. The confirmed avoidance of such materials by the company is important.

Construction water quality issues can largely be managed through good construction practice, treatment of waste waters, and storage of construction materials and chemicals, including fuel and oils, in appropriate compounds that contain accidental spillages.

During operation of larger storage hydropower plants, water quality issues arise mainly from the breakdown of vegetation in the reservoir, especially after impoundment until the reservoir has stabilised. Poor quality water may be passed through the turbines, which is low in dissolved oxygen

and may contain higher than normal concentrations of ammonia and hydrogen sulphide and be at lower temperatures than ambient. All of these may cause problems to the downstream ecosystem.

This is much more liable to happen in storage reservoirs where large volumes of water are kept for longer periods of time, when the water becomes stratified into an upper layer of better quality water, and a lower layer of poor quality and even anoxic water. It is less likely to occur with run-of-river plants with small storage reservoirs. It is unlikely to occur with the DSHPP.

3.2 Water quality and the proposed Don Sahong dam

The EIA of the Don Sahong hydropower project presents a baseline of water quality data from the MRC's sampling station in Pakse, generating average monthly data between the years 1985 – 2006 for the usual range of water quality parameters.

The EIA complements this with some spot samples for water quality taken at 5 stations in the Mekong river upstream of the dam site and in the Hou Sahong between 28 – 30 August 2009 with a much more limited array of parameters (Electrical conductivity, Dissolved Oxygen, Total dissolved solids, Total Phosphorus, Total Nitrogen and Total coliforms).

Some general statements are made about the baseline water quality in the Mekong River at Pakse and near the dam site, without much interpretation.

As a comment on this, it would appear that only a very basic analysis of the baseline water quality has been undertaken for the EIA:

- There is a reliance on water quality monitoring in Pakse which is a good reference point, but about 100 km upstream from the dam site.
- Spot sampling has been undertaken at the dam site in only one sampling campaign, in August 2009, i.e. when river flows are almost at their highest, which is not fully representative of water quality conditions for much of the year. There is no correlation of the results with the similar flow conditions in August in Pakse.
- The Pakse results show that Dissolved Oxygen is a key parameter that falls below the recommended standard for human and aquatic health for 6 months of the year from May to November and was generally associated with higher COD values.
- If the MRCs Index for Human Impact on Water Quality is applied to the Pakse water quality results, it generates a combined index rating of 8.54 which is on the borderline between "Slight Impact" (green) and "Impact" (yellow), with rating brought down by DO and Ammonia.
- If the same index is applied to the on-site measurements in August 2009, the score is 7 which shows a definite "Impact" from Human activity in Siphandone.

The baseline also has a section on aquatic ecology including fisheries. However, the description provided of the aquatic ecology in Siphandone only relates to fisheries and there is no information about the riverine habitats, aquatic plants and other fauna, apart from fish. This is a significant omission and there is considerable data available on the aquatic ecology of Siphandone. It would have been useful to have a geomorphological and habitat comparison of the different channels to see how significant the loss of habitat in Hou Sahong is likely to be and how the changes in flows in the Hou Phapheng, and Hou Xeng Pheauk channels may affect the habitats there.

There is also no mention of other aquatic fauna that are found in the area, especially endangered species such as soft shell turtles, which are occasionally caught in the area and are known to nest on sand bars in the channels. Without an aquatic habitat map of the channels it is difficult to assess the

overall impact on aquatic health through the lost and changed conditions in the Hou Sahong, Hou Phapheng, and Hou Xeng Pheauk.

3.3 Summary of impacts considered and measures proposed by the hydropower project proponent

3.3.1 Construction phase

The possible impacts on water quality in the construction phase are considered in the EIA. The particular areas of concern include the specific construction areas and the embankments subject to drawdown, where soil erosion and siltation may occur. These are noted as potential minor negative impacts upon water quality which can be mitigated. Mitigation measures include the implementation of best management practices for soil erosion and sedimentation at all construction sites as well as pollution control techniques. The developers propose to maximise the use of excavated rocks, with most of the excavation being undertaken behind the coffer dams, i.e. not in contact with the river water. In other land working areas they propose to develop a run-off collection system and install sediment traps. They propose to develop an appropriate water monitoring programme. These measures will be included in the Contractors EMMP.

They also propose to bund vulnerable working areas outside of the pondage. Each contractor will be required to develop a comprehensive fuels and explosive transport, handling and storage plan, including bunding of tanks and an emergency response plan. All waste waters e.g. from the worker camps and offices etc. will be collected and treated prior to release with a detailed monitoring programme.

The developers have included a provision of alternative water supplies for villages nearby, which depend upon the river for water supply. Because the water in the Hou Sahong will be dried up during construction, water supply systems will be provided for affected villages. The villages that are likely to be affected, include Ban Hang Sadam, Ban Hua Sadam and Ban Hua Sahong, that use the water from the Hou Sahong. The alternative water supply system is likely to be developed based upon consultations. No downstream villages are identified as likely to have their water supplies affected. This provision will also mitigate for any degradation of the water supply due to water pollution.

The EIA considers that with these measures in place there will be no significant impact on water quality during the construction phase. This review concludes that this should indeed be the case, assuming effective waste water treatment systems for worker camps etc., with good construction practice to minimise water pollution and with no accidental spillage of oil or hazardous chemicals.

3.3.2 Impacts upon aquatic habitats

There are no assessments of the impacts of the DSHPP upon the aquatic habitats in the Hou Sahong or around the Khone Phapheng Falls. Terrestrial habitats are covered, but as with the baseline descriptions, under impacts on aquatic ecology only fisheries impacts are considered. The EIA suggests that the area of “island, rock and water” in the Hou Sahong channel which will be inundated and affected totals 92.6 ha (Table 1). However, there is no analysis of the value and uniqueness of these these aquatic habitats or an assessment of their ecological significance in the context of the whole LMB.

In view of the concerns about impacts fish migration there is a considerable emphasis on the modifications being proposed for the Hou Xang Pheuak and Hou Sadam to facilitate fish migration, there is no assessment of what aquatic habitats may be ecologically important or impacted by the

channel modifications. It is assumed that the channels have a uniform or equally important or unimportant riverine habitats. This is obviously not the case, as illustrated by the ecological importance of sand bars that are exposed in the low flow season and used for bird and turtle nesting. It may be that the impacts on important habitat types in these channels is insignificant or temporary, but there is no evidence to confirm this.

There is no analysis of the impacts of changes in flow regime in the different channels, especially the Hou Phapheng channel, upon the aquatic habitats.

Table 1: Breakdown of types of land use affected by the DSHPP (from EIA)

(All areas in ha)

Project Features	Location	Village Area & Household (HHs)	Rice Paddy Lands		Forestry Lands		Island Rock & Vegetation & Water	Total Area
			In Use	Grazing Disused	Good	Degraded		
A. Right Bank – Working & Reservoir Areas								
1. Dam, Works & Switchyard	Hang Sahong	1.5 (10 HHs)	-	-	0.5	2.7	-	**4.7**
2. Embankments 2.1km x 10m	Don Sahong	-	-	-	1.5	0.6	-	**2.1**
3. Land Flooded at EL 75m	Don Sahong		4.5	1.5	54.3	35.5		**94.8**
B. Left Bank – Working & Reservoir Areas								
1. Dam, Plant Sites & Facilities	Hang Sadam	0.3 (1 HHs)	2.3	2.8	-	2.7	-	**8.1**
2. Lower Embankment 2.4 km X 10m	Hang Sadam	-	1.1	0.7	-	0.6	-	**2.4**
3. Land Flooded at EL 75 m	Don Sadam		3.1	6.3	45.2	23.2		**77.8**
4. Island Barge Landing	Hua Sadam	-	1.5	-	-	-	-	**1.5**
5. Road to Dam site (10mx5,700 m)	Hua Sadam to Hang Sadam	-	2.9	0.8	1.6	0.4	-	**5.7**
6. Access Site at Coffer Dam	West of Hua Sadam	-	1.2	-	-	0.7	-	**1.9**
7. Upstream Coffer Dam & Islands for Flow Channels	Hua Sadam to Hua Sahong	-	-	-	-	-	3.2	**3.2**
Subtotal Don Sahong & Don Sadam		**1.7 ha & 11 HHs**	**16.6**	**12.4**	**103.1**	**66.5**	**3.2**	**203.3**
C. Mainland Barge Landing								
1. Nominated Landing site	North of Resort	0.3	0.4	-	0.2	0.4	-	**1.2**
D. Reservoir Water Areas – Nominal not Official								
1. Community Fishing Zone	Hou Sahong		-	-	-	-	29.2	)
2. Traditional Lee Traps	Hou Sahong		-	-	-	-	10.0	) **76.3**
3. Other Fishing Zones	Hou Sahong		-	-	-	-	37.1	)
4. Two Island Flooded	Hou Sahong		-	-	-	-	11.3	**11.3**
5. Aquatic Habitats in Downstream Channel	Mekong River		-	-	-	-	5.0	**5.0**
Subtotal			**-**	**-**	**-**	**-**	**92.6**	**92.6**
D. Total DSHPP Areas		**2.1 11 HHs**	**17.0**	**12.4**	**103.3**	**66.9**	**92.6**	**296.7**

3.3.3 Comment on the mitigation measures proposed

The developer has proposed standard precautionary measures, which are likely to be effective provided that:

- Contractors follow best practice soil erosion and disposal management measures during construction
- Compliance monitoring of both the DSHPP and its contractors is effective
- Water quality monitoring specified in the EMMP is carried out, and incidents of failure to comply with water quality standards are investigated and remedial measures followed up if necessary
- Adequate emergency response measures are in place with staff trained to respond. All accidents involving spillage and water pollution are investigated and remedial measures put in place.

Despite all these measures, accidents will happen, compliance monitoring and enforcement are usually not as effective as they are designed to be and it is likely that there will be occasions when the water quality is impaired.

It is likely that the human impact water quality index in the Siphandone area will continue to be recorded as a "C Impact" rating during the construction period, and the actual scores will probably decrease within this range

There may be occasional incidents of impaired water quality associated with construction affecting the Mekong River into Cambodia. This is most likely to be increased sediment loads, which may have greater impact during the low flow seasons, when the water is clearer. Spillages and accidents and malfunction of waste water treatment plants may also occur which will have a temporary impact upon the water quality downstream perhaps as far as the Stung Treng Ramsar site. The MRC Human Impact Water Index for Stung Treng is consistently in the "C Impact" range indicating the influence of human activity. The construction activities in Don Sahong are unlikely to change that rating, though the scores will probably decrease within that range.

3.3.4 Water quality during operation

The EIA states that during the lifetime of the project, there are no significant impacts upon water quality, and no mitigation measures are required. There is a statement that it will not alter water quality downstream in Chheuteal pool where the dolphin population live, "because the maximum residence time in the headpond is only 4 hours, which is insufficient to alter water quality", and the DSHPP only affects one channel of the seven braided channels of the Mekong.

Water quality during operation is a function of; 1) the Area inundated at Full supply level, which is a total of 2.2 km^2, 2) Likelihood of reservoir stratification and the Froude number which is less than 1, and 3) Water residence time which is 0.2 days. The Water Quality Expert Group concurs with the assessment of the developer that because of these characteristics, reservoir stratification is unlikely, and that with this very short retention time there is less likelihood of change in water quality and impoundment is easy to flush.

Table 2 is excerpted from the EMMP and show the plans for water quality protection measures.

Table 2: Excerpt on water quality protection measures (Source DSHPP EMMP)

Measure 3	WATER QUALITY PROTECTION
Project Phase	Construction and Operation
Environmental aspect	Earth moving activities, blasting, excavation, other construction activities
Environmental Component	Water Pollution, soil erosion and siltation
Environmental Impact and its significance	Potential minor negative impact, can be mitigated
Cause	Inappropriate earthwork activities throughout project site, including embankments, road, bridge, and areas subjected to drawdown. Accidental spills.
Consequence	Potential large loads of silt or other pollutants entering the Mekong affecting fish and other wildlife
Environmental Objectives / Standards to be met	Meet international best management practices for control of erosion and accidental spills during construction.
Description of Environmental Management Measure	Develop best management practice on soil erosion and sedimentation at all constructed areas as well as pollution control technique Maximize the use of excavated rocks, develop runoff system , installing sediment traps, rehabilitate construction areas by planting shrubs and trees Develop appropriate monitoring program (in Contractor's EMMP) Develop site management program prior the construction Appropriate road engineering; good compacting and runoff design, reduce speed limits, developing watering schedule for all roads (in Contractor's EMMP and contract clauses, Annex C)
Performance Criteria	No erosion or pollutants from spills reach the Mekong
Effectiveness Monitoring	Random visual monitoring by DSHPP EMO or designee during construction. Violations will require action from Contractor to achieve compliance
Manpower	One person (from EMO)
Training	Person to be trained in the identification of erosion, siltation, or improper management of fuels or other substances that are subject to spillage and contamination of water courses.
Facilities, Equipment, Material and Supply	None
Responsibility	DSHPP EMO
Stakeholders	Villagers, Contractor
Public Involvement Activities	DSHPP EMO to discuss water quality monitoring procedures with affected residents. Residents encouraged to report incidences of erosion or uncontrolled spills from the construction zone.
Implementation Schedule	Monitoring once a month at random sites during construction
Costs	Manpower included in EMO budget
Reporting Requirements	Quarterly reports to be maintained by EMO and made available to MONRE or the public on request.

3.3.5 Conclusions on water quality impacts during operations

The EIA report notes that trees with a commercial value will be removed from the dam, power house, road and transmission lines, and vegetation with no commercial value will be made available to local residents for fuel, charcoal production or construction. They estimate that there are 169.9 ha of forest lands of which 40% are degraded. The clearing of vegetation from the reservoir area removes a significant part of the organic matter which causes water quality problems from reservoirs as it breaks down after inundation.

The second aspect is the residence time of the water in the reservoir or headpond. With a very short residence time, there is little opportunity for the build-up of degradation products from organic matter and the depletion of oxygen in the water discharged through the turbines, and little opportunity also for stratification of the water in the headpond.

Don Sahong HPP is a typical run-of-river hydropower system, with little impact on water quality. The water quality of the water at the tail race is likely to be very similar to the incoming water into the headpond and to the rest of the water in the Mekong at Siphandone.

If the local water quality is not changed during the operational phase, the transboundary impacts further downstream in Cambodia, including in the Chheuteal pool are very unlikely to be significant.

During the impoundment of the reservoir, it is likely that there will be a period when the water quality in the reservoir and the water passing through the turbines is poor as it flushes through cut

and decaying vegetation, discarded construction materials and other wastes. The small size of the reservoir and the short residence time should mean that this period of poor water quality is likely to be relatively short as conditions stabilise – this may be of the order of a few months rather than years which may be needed for large storage reservoirs.

3.3.6 Protecting aquatic habitat and resources

The EIA indicates that the only 2 endangered aquatic organisms in the area are the Giant Mekong catfish and Irrawaddy Dolphin, and notes that these will require special studies and management plans. Table 3 shows the measures to be taken for protection of aquatic habitats and resources. The focus for these is upon the Irrawaddy Dolphin and the fish migration, with little mention of aquatic habitat. They highlight the opinion that the DSHPP potentially has major negative impact, but that these can be mitigated. The appraisal of the fish migration management measures and impacts on the Irrawaddy Dolphin are considered by the fisheries expert group and the Dolphin expert group.

Table 3: Excerpt on measures for protecting aquatic habitats and resources (Source DSHPP EMMP)

Measure 7	PROTECTION OF AQUATIC HABITATS AND RESOURCES
Project Phase	Construction, operation and during project life
Environmental aspect	Completion of the Project, General construction activities in or near the Mekong River and the affected channels.
Environmental Component	Reduced Aquatic Habitats; Impact to Irrawaddy Dolphin downstream of DSHPP; Reduced fish migration
Environmental Impact and its significance	Potential major negative impact, can be mitigated
Cause	Permanent closure of the Hou Sahong by the DSHPP dam.
Consequence	Potential losses to the channel ecosystems. Interruption of fish migration across the GFL causing losses to the fisheries industry of the Lower Mekong Basin
Environmental Objectives / Standards to be met	Lack of impact to the fish migration process. Establishment of a sustainable fisheries management program in the area. Lack of impact to the habitat of the Mekong dolphin population.
Description of Environmental Management Measure	For dolphins, excavation not to include underwater blasting. Ensure that Mekong flows and water quality essentially unchanged in dolphin areas Implement FishMAP, (DSHPP Fisheries Monitoring Action Plan) – See Annex A
Performance Criteria	Achievement of Environmental Objectives through various monitoring programs described in the FishMAP
Effectiveness Monitoring	FishMAP (Annex A) has detailed process of monitoring during a ten-year program with adaptive changes made as necessary to the fish passage modifications.
Manpower	FishMAP will include construction of modifications to the Hou Xang Pheuak and Hou Sadam. Detailed monitoring over the ten-year period will require two qualified individuals with a long-term contract. The Environmental Manager of the EMO will provide oversight.
Training	The staff carrying out the FishMAP monitoring and adaptive modification planning will be experts in the field who have developed the program and carried out the earlier studies.
Facilities, Equipment, Material and Supply	Construction of the modifications to be carried out by Contractor using equipment already available for the Project implementation. No additional equipment needed for monitoring, other than transport.
Responsibility	DSHPP, Contractor, FishMAP Consultants
Stakeholders	Villagers, Contractor, fishers in the Lower Mekong River basin.
Public Involvement Activities	FishMAP includes numerous public involvement activities. In addition, the DSHPP SMMP (bound separately) also includes extensive public involvement activities to support an alternative livelihoods program.
Implementation Schedule	FishMAP will be implemented over a period encompassing the pre-construction time, construction, and for ten years following commissioning of the Project.
Costs	Included in FishMAP (Annex A), SMMP and RAP Construction Budgets.
Reporting Requirements	Quarterly oversight reports to be maintained by EMO and made available to MONRE or the public on request.

Error! Not a valid bookmark self-reference. shows the fish species listed as migrating through Hou Sahong in Table 3-9 of the EIA report. It should be noted that the scientific names of these fish are often misspelt in the EIA report.

Table 4: Excerpted list of fish species migrating through the Hou Sahong from the EIA report

Table 3-9 Main Fish Species Migrating though Hou Sahong

Scientific Name	Lao Name	Major Species
Dry Season Upstream Migration – 4 Months December to April		
Cyprinidae		
Scaphogenus bandanesis	Pa Pien 9	+
Scaphogenus steinegri	Pa Pien 13	+
Cirrihinus microlopis	Pa Pawn	+
Cirrihinus nolitrrella	Pa Geng	
Labeo erythropterus	Pa Wa Soong	
Bengana behri	Pa Wa Na Noor	
Erythopterus melangira	Pa Srae	
Hysibarbus sp.	Pa Pak Nout	+
Numerous Small Cyprinids	Pa Saew	+
Gyrinoichelidae		
Gyrinoichelius pennolri	Pa Goh	
Wet Season Upstream Migration – 3 Months – mid-May to mid July		
Pangasidae		
Pangasius conchophilus	Pa Por / Gae	+
Pangasius larnaudii	Pa Beung	+
Pangasius krempfi	Pa Sooai Hang Leuang	+
Heicophagus waandersii	Pa Noo	+
Pangasius macronema	Pa Nyawn	+
Pangasius pleurotaenia	Pa Nyawn Tawng Khom	+
Bagnidae		
Hemibagrus filamentosous	Pa Kot	+
Hemibagrus wyckiodes	Pa Kung	+
Siluridae		
Belodonthicthys dinema	Pa Khop	+
Hemisilurus mekongensis	Pa Nang Deng	+
Micronema spp	Pa Nang	-
Kryptopterus spp.	Pa Peekgai 1 & 2	+
Ompok hypothalamus	Pa Peekgai 3	+
Ompok bimaculatus	Pa Seum	+
Sisoridae		
Bagarius yarrelli	Pa Khe Yai	+
Bagarius bagarius	Pa Khe Noi	-
Cyprinidae		
Cyprinus carpio	Pa Nai	
Downstream Migration - 6 Months – June to December		
Cyprinidae		
Henichorychus lobatus	Pba Soi Hua Lem	+
Henichorynchus siamensis	Pba Soi Hua Bo	+
Labiobarbus spp.	Pba Lang Khon	+
Paralabuca spp.	Pba Dtep	+
Lobocheilus melanotaenia	Pba Kiang	+
Crossocheilus sp	Pba Tok Toi	+
Probarbus jullieni	Pba Eun	+
Labeo erythropterus	Pba Wa Soong	
Minimum Total Estimate – At Least 35 Major Species		

3.3.7 Comment on the EIA and EMMP:

There is no attention paid in the EIA and EMMP to the different aquatic habitats and their ecological importance. The focus is only upon addressing the potential impacts upon the migratory fish and dolphins, rather than upon the fundamental issue of the habitats.

Since the time that the EIA was carried out, the IUCN Redlisting process has been applied to fish species in the Greater Mekong, shown in Table 5 and there are now 6 'Vulnerable' aquatic species (5 fish and 1 turtle species), 3 'Endangered' species (2 fish and 1 turtle species), and 3 'Critically Endangered' species (2 fish and 1 dolphin) potentially present in the wider Siphandone area. Of the species not mentioned in the EIA list there are two critically endangered catfish *Pangasianodon*

gigas which is occasionally caught migrating up Siphandone, and *Pangasius sanitwongsei* which the IUCN Redlist considers may have two sub-populations separated by the Khone Falls. In addition, the Asiatic soft shell turtle, *Amyda cartilaginea* has been caught in the area and is classified as Vulnerable, and Cantor's Giant softshell turtle, *Pelochelys cantori*, known to nest on sandbars in Stung Treng Ramsar site, is Endangered[1]. In addition the River Tern, *Sterna aurantia,* and the Mekong wagtail, *Motacilla samveasnae*, which are both Near Threatened, may nest or otherwise use these sandbars.

Table 5: Redlist designation of fish and other species found in the Siphandone area

Name	**Red List Designation**
Scaphgnathops bandanensis	Vulnerable
Scaphognathops steinegri	Not evaluated
Cirrhinus microlepis	Vulnerable
Cirrhinus molitorella	Near Threatened
Labeo erythopterus	Not evaluated
Bangana behri	Vulnerable
Erythropterus melangira	Not evaluated
Hypsibarbus spp (of 11 species in the region)	Least Concern
H. lagleri	Vulnerable
Gyrinocheilus pennocki	Least Concern
Pangasius conchophilus	Least Concern
Pangasius larnaudii	Least Concern
Pangasius krempfi	Vulnerable
Pangasius macronema	Least concern
Pangasius pleurotaenia	Not evaluated
Helicophagus wandersii	Not evaluated
Hemibagrus filamentus	Data Deficient
Hemibagrus wyckioides	Least Concern
Belodonticthys dinema	Not evaluated
Belodonticthys truncatus	Least Concern
Hemisilurus mekongensis	Least Concern
Micronema cheveyi	Data Deficient
Kryptopterus sp	Least Concern
Ompok hypothalamus	Not evaluated
Ompok bimaculatus	Near Threatened
Bagarius yarrelli	Near Threatened
Cyprinus Carpio (non-native species)	Vulnerable (in its native range)
Henicorhynchus lobatus	Least Concern
Henicorhynchus siamensis	Not evaluated
Labeobarbus spp	Least Concern
Paralabuca spp	Not evaluated
Lobocheilos melanotaenia	Least Concern
Probarbus jullieni	Endangered
Present but not mentioned in the list	
Pangasianodon hypothalamus	Endangered
Pangasianodon gigas	Critically Endangered
Pangasius sanitwongsei	Critically Endangered
Turtles	
Amyda cartilaginea (Asian softshell turtle)	Vulnerable
Pelochelys cantorii (Cantors giant softshell turtle)	Endangered
Dolphin	
Orcaella brevirostris (Mekong River subpopulation)	Critically Endangered
Birds	
Sterna aurantia (River tern)	Near Threatened
Motacilla samveasnae (Mekong wagtail)	Near Threatened

[1] www.iucnredlist.org December 2014

Vulnerable	***6 species***
Endangered	***3 species***
Critically Endangered	***3 species***

3.3.8 Critical habitats and compliance with IFC Performance Standards

Although the IFC Performance Standards do not apply to the Don Sahong, because it is not financed through the IFC, World Bank or ADB, it is useful to compare the description of the IFC Performance Standard 6 on Biodiversity which states that Critical habitats are those areas of high biodiversity value of significant importance to globally Endangered and Critically Endangered species, and habitats supporting globally significant populations of migratory species. On both counts, the Hou Sahong and the wider area upstream and downstream, must be considered as a 'Critical Habitat'.

Box 1: Excerpt from the IFC Performance Standard 6.

Critical Habitat

16. Critical habitats are areas with high biodiversity value, including (i) habitat of significant importance to Critically Endangered and/or Endangered[11] species; (ii) habitat of significant importance to endemic and/or restricted-range species; (iii) habitat supporting globally significant concentrations of migratory species and/or congregatory species; (iv) highly threatened and/or unique ecosystems; and/or (v) areas associated with key evolutionary processes.

17. In areas of critical habitat, the client will not implement any project activities unless all of the following are demonstrated:

- No other viable alternatives within the region exist for development of the project on modified or natural habitats that are not critical;
- The project does not lead to measurable adverse impacts on those biodiversity values for which the critical habitat was designated, and on the ecological processes supporting those biodiversity values;[12]
- The project does not lead to a net reduction in the global and/or national/regional population[13] of any Critically Endangered or Endangered species over a reasonable period of time;[14] and
- A robust, appropriately designed, and long-term biodiversity monitoring and evaluation program is integrated into the client's management program.

The implications for this are shown in the excerpt above. If these criteria are applied, the DSHPP would have to be developed in such a way that it does not lead to measurable adverse impacts on the biodiversity values of the critical habitats, nor should it lead to a net reduction in the populations of Critically Endangered or Endangered species. There would have to be be a robust, appropriately designed and long-term biodiversity monitoring and evaluation programme integrated into the EMMP. At present, although there is a focus on addressing the issues of migratory fish species and the Dolphin population, there is very little mentioned on wider biodiversity management or monitoring.

3.4 Compliance with MRCS Preliminary Design Guidance

Para 161 of the main MRCS Preliminary Design Guidance for water quality (excerpted in Annex 2) specifies that the project should aim to maintain sufficiently high levels of dissolved oxygen and sufficiently low levels of phosphorus, nitrogen and biological and chemical oxygen demand.

- It is probable that with the measures they have put in place for managing water pollution during construction and the nature of the reservoir and its residence time during operation that the DSHPP will be able to comply with this guidance

Para 162 states that developers should consider the impacts of the dam and operating policies of any cascade on water levels. Developers should demonstrate the projects meet the requirements of the 1995 Mekong Agreement and Procedures to Maintain Flow in the Mainstream in the EIA.

- The EIA and the subsequent hydraulic documents show that water levels are affected marginally in distribution of water across the channels on each side of the Hou Sahong. The biggest change in water levels will be in the channel leading to the Khone Phapheng Falls which will be artificially lowered by the excavation of bed rock at the entrance to the Hou Sahong.
- The water levels are also marginally affected in the downstream channels in Cambodia, with small increases in the western channels and corresponding decrease in the eastern channels. Once these channels merge, these differences are no longer relevant.
- The DSHPP can consequently be considered to meet these requirements.

Para 163 states that minimum flow releases as well as restrictions on changes in natural variability need to be assessed using appropriate environmental flow assessment (EFA techniques and approaches.

- The DSHPP is a run of river project and would not operate in a peaking mode, and as such would have negligible impacts on the natural variability in flow.
- However, a minimum flow requirement of 800 m^3/sec is applied to the flows over the Khone Phapheng Falls as an 'environmental flow'. This reflects the minimum recorded flow. This minimum flow will be maintained for about 6 months of the year during a normal year.
- Modelling has been carried out to demonstrate the flows in different channels throughout the year, but no environmental flow assessment has been carried out to assess the impacts of these changed flows in the different channels.
- Whilst environmental flows have often been taken to cover the wider distribution of flows across the year, this consideration of the flows over the Khone Phapheng Falls is a specific but very important interpretation of Para 163.

Para 164 states that the focus of the Environmental Flow Assessment would be on systematically looking at the localised impacts on river morphological processes, erosion and bank stability, aquatic ecosystem functions as well as impacts on natural habitats such as riverine wetlands, fish habitat and related social and livelihood aspects.

- Whilst there is a considerable focus on the hydrological, hydrodynamic and hydraulic aspects of the DSHPP, there has been no assessment of the localised impacts of these changes on river morphology in each of the channels, or aquatic habitats or ecosystem functions of the different channels affected, apart from their importance for fish migration.
- There is no baseline description or analysis of the different aquatic habitats in each of the channels affected, or identification of their ecological importance.
- Although generally applicable to hydropower schemes working in a peaking mode, it is suggested that because of the changes in flows in these different channels, an EFA should be carried out to assess the impacts of these changes in these channels especially the Hou Phapheng channel.

Para 165 states that developers should utilise a core group of independent international experts to assist with the design and implementation of water quality compliance monitoring programmes.

- The water quality monitoring programme is indicated in the EMMP with numbers and frequencies of sampling and numbers of sampling stations, and associated costs. This has not been further developed, and there is no adequate baseline for water quality established.

Para 166 covers the design of monitoring systems to facilitate optimisation of hydropower operation with respect to water quality and ecological health.

- Use has been made of the MRC's water quality monitoring network, with summarised results from the results from Pakse but the more recent guidance, procedures, standards and report cards have not been referred to.
- The MRC's water quality data on Stung Treng could have been used to develop a baseline downstream of the proposed DSHPP, but these have not been described
- The water quality monitoring programme proposed does target the locations around the construction site, within the reservoir and downstream.

Para 167 suggest that the monitoring programme should be funded by the developer/project owner during the construction period and during full duration of the concession period.

- The monitoring programme proposed in the EMMP would be undertaken and funded by the developer, however as shown above the baseline and extent of the water quality monitoring have not been fully described.
- The duration of the monitoring programme is not fully described in the EMMP

3.5 Gaps and uncertainties

The main gaps and uncertainties concerning the water quality and ecosystem health include:

- Absence of an adequate and updated baseline of water quality throughout each month of the year, i.e. at different flows and water levels.
- Absence of a baseline of water quality in the different channels likely to be affected by the DSHPP, including the Phapheng, Sadam, Sahong, Xang Pheuak at the very least and preferably across the whole braid at Khone Falls. Without such a baseline it is difficult to confirm spatial differences in water quality and later changes that may occur.
- There is no baseline of downstream water quality in Cambodia presented, and since there could be occasional transboundary issues, such a baseline would be advisable so that if later changes do occur in the water quality downstream as a result of construction or operation, their cause can be more clearly identified as resulting from the DSHPP or not. This will be critical information in the event of a pollution incident in Lao PDR and the attribution of liability. This may be seen as a risk management measure by the company and the Government of Lao PDR.
- There is no description of the different aquatic habitats in any of the channels affected, either by the headpond, by the modification of the channels for fish migration, or through changes in flow regime. As a result there is no identification of which aquatic habitats are important ecologically or rare in Siphandone, or an assessment of how they will be impacted. The river channels are treated as single ecological unit with no differences, and in a relatively small area affected, and one which has such critical ecological functions, it would have been relatively easy to undertake at the EIA stage.
- There is no consideration of the impacts of the channel modifications in the Hou Sadam and Hou Xang Pheuak upon water quality and measures to prevent excess sediment being released into the water in the dry season when these works will take place.

- There is inadequate attention to address the wider biodiversity and critical habitat management and monitoring.

4 Modified flows in Siphandone and downstream

4.1 Flows and the proposed Don Sahong dam

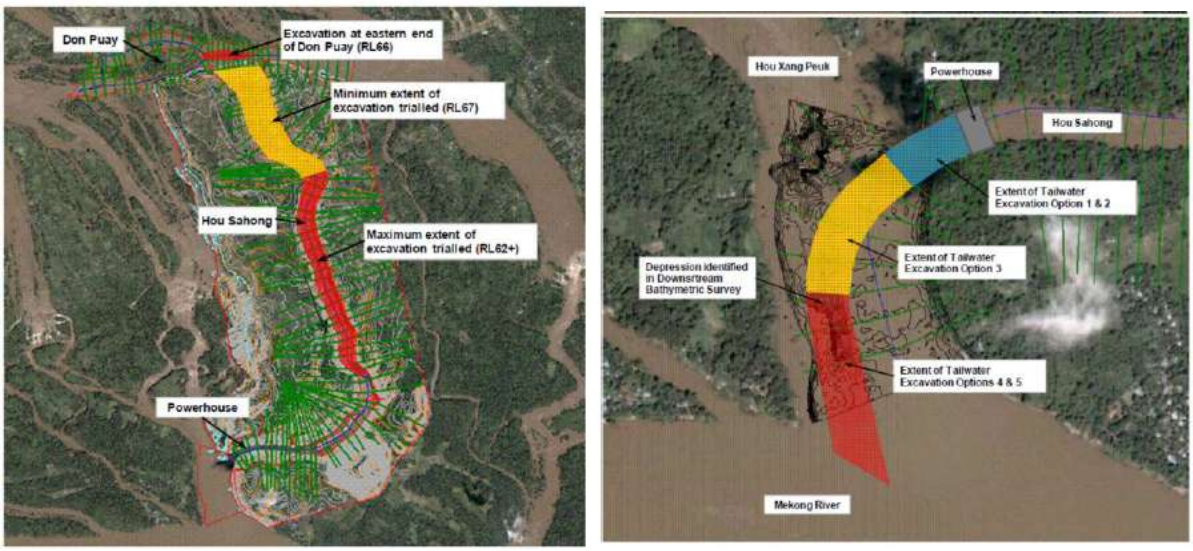
The hydrology of the river and the impacts on flow regimes have been considered in greater detail by the Hydrology Expert Group. This review considers the effects of changing flow regimes upon the ecosystem health.

4.1.1 Flow modification works

According to the hydrological studies carried out by the DSHPP, the natural flows down the Hou Sahong have an annual average of 510 m^3/sec, with high flows of about 1500 m^3/sec and low flows of under 50 m^3/sec. The aim of the DSHPP is to increase flows entering the Hou Sahong channel to maintain the design flow of 1600 m^3/sec throughout the year. At present the bed levels in the upper reaches of the Hou Sahong restrict this level of flow into the channel during periods of low flow, and in order to improve the flow through the DSHPP the river bed at the upstream end would be excavated and lowered to an average depth of 3m and a maximum depth of 5m, and by 1.5 m at the lower end of the channel. A limited area will be excavated downstream of the powerhouse.

It is stated that excavated materials will be used as concrete aggregate and for the embankments, and that any blasting and excavation will be undertaken after the coffer dams are in place, so that erosion and sediment release into the river are minimised. A total volume of material to be excavated in the Hou Sahong is estimated at 2.4 million m^3 and 72,000 m^3 in the area downstream of the power house.

Figure 2: Areas of the Hou Sahong to be excavated to increase flows to DSHPP and in the Hou Xang Pheuak to enhance fish migration and for the flood flows spillway



4.1.2 Projected changes in flow regimes in Siphandone

Because of the complexity of the flows across the whole of Siphandone, considerable effort has been put into assessing the changes in the flow regimes in different channels through hydrological and hydraulic modelling. This has been the subject of a separate set of reports looking both at the flows in the channels around DSHPP, and the transboundary hydraulics in the Mekong river downstream. The results from this modelling has been reported in the updated EIA and the Cumulative Impact Assessment, and are commented on by the Hydrology Expert Group.

The local modelling used the 2 dimensional Mike 21 model (DHI website, 2011) and is more detailed than the accepted models used for the regional analysis, allowing an assessment of flow conditions in the Hou Sahong, Hou Sadam and over the Khone Phapheng Falls.[2] The modelling of the downstream flows for the Cumulative Impact Assessment used the ISIS and IQQM models such as have been used by MRC. A hydrodynamic model based on the ISIS software was used to simulate the river system downstream of Kratie, including the Tonle Sap and the East Vaico in Vietnam where wet season flooding extends beyond the LMB boundary.

In simple terms, the DSHPP wishes to maintain a design flow through its turbines of 1600 m^3/sec. with a head of 17m that may vary by about 3 m according to the seasonal flows down the Mekong. Under natural conditions without the proposed dam, the flows down the Hou Sahong have an annual average of 510 m^3/sec with minimum flows as low as 30 m^3/sec. With the DSHPP, the annual average of flows down the Hou Sahong would be 1,500 m^3/sec

By contrast the flows over the Khone Phapheng Falls have an annual average of 2,880 m^3/sec with average minimum flows of about 1,400 m^3/sec and absolute recorded minimum of 800 m^3/sec. Under the proposed DSHPP, the average flows over Khone Phapheng Falls would be 1,880 m^3/sec, with a minimum flow for nearly six months of the year of 800 m^3/sec.

Figure 3 shows a schematic of the modelled flows down the different channels across Siphandone and Tables 7 and 8 show the results of the modelling showing the average monthly flows across these channels.

The points to note are:

1. Mean monthly flows in channels 1 and 5 are the same, indicating that flows into the system and out again are the identical and there is no change in flow between upstream and downstream with the season.
2. The flows in channels 1a, 1b and 1c i.e. on the west side do not change, but flows down the Hou Sahong (channel 2) increase from an average of 510 to 1500 m^3/sec, with high flows of 1750 m^3/sec being maintained for between 40 - 50% of the year.
3. The flows down channel 4 decrease from an average of 2880 to 1880 m^3/sec with minimum flows of 800 m^3/sec being maintained for 40 - 50% of the year.

Figure 3: Schematic of the flows down the different channels in the vicinity of DSHPP

[2] The reviewer is not qualified to comment on the appropriateness of these models and so can only interpret and comment on the results presented and the implications.

Note that the blue lines indicate channels in which the flows are not expected to change, and pink lines indicate the channels where changes in flows are expected.

Figure 4: Schematic diagram of channels in the Project vicinity

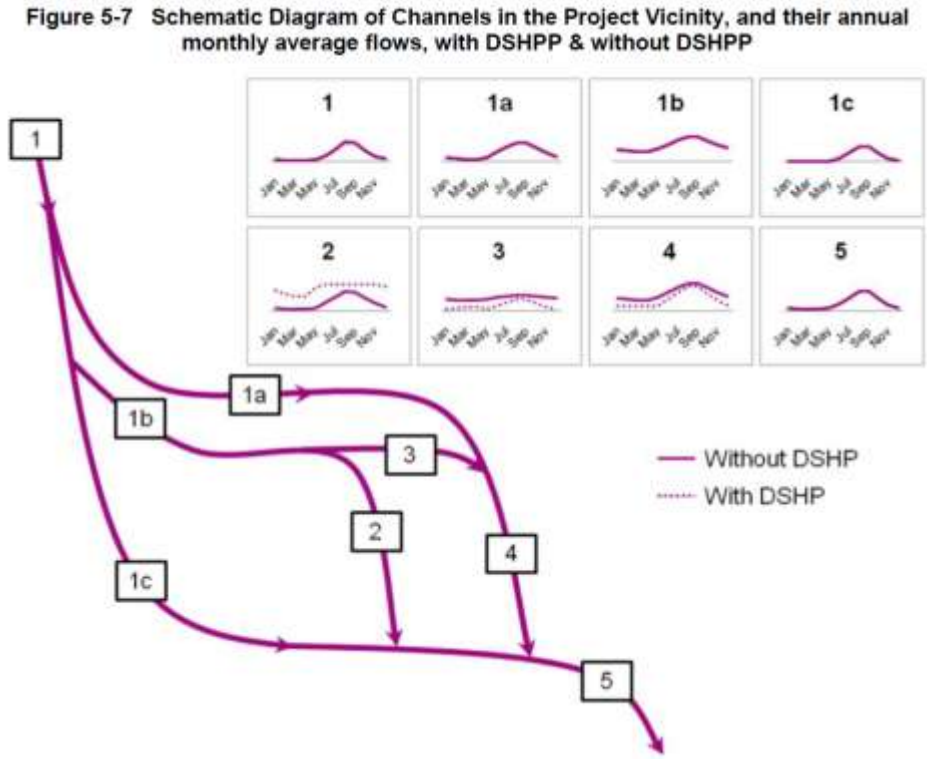


Table 6: Modelled distribution and duration of flows down the different channels listed above **without** the DSHPP

% Exceeded	1	1a	1b	1c	2	3	4	5
1%	37,400	3,100	3,700	30,700	1,620	2,070	5,130	37,400
5%	29,900	2,700	3,400	23,800	1,380	2,060	4,760	29,900
10%	25,600	2,500	3,300	19,800	1,260	2,040	4,510	25,600
20%	18,000	2,000	2,900	13,000	960	1,970	4,010	18,000
30%	12,400	1,700	2,600	8,200	730	1,880	3,540	12,400
40%	7,800	1,300	2,300	4,300	510	1,750	3,010	7,800
50%	4,700	860	1,900	1,900	300	1,650	2,510	4,700
60%	3,200	600	1,700	900	180	1,550	2,150	3,200
70%	2,500	510	1,600	400	130	1,440	1,950	2,500
80%	2,200	430	1,500	300	100	1,380	1,810	2,200
90%	1,900	340	1,400	200	70	1,310	1,650	1,900
95%	1,700	270	1,300	100	50	1,270	1,540	1,700
99%	1,500	190	1,300	40	30	1,220	1,410	1,500
Annual Average	9,600	1,200	2,200	6,200	510	1,680	2,880	9,600

Table 7: Modelled distribution and duration of flows down the different channels listed above **with** the DSHPP

% Exceeded	1	1a	1b	1c	2	3	4	5
1%	37,400	3,100	3,700	30,700	1,750	1,950	5,000	37,400
5%	29,900	2,700	3,400	23,800	1,750	1,690	4,390	29,900
10%	25,600	2,500	3,300	19,800	1,750	1,530	4,000	25,600
20%	18,000	2,000	2,900	13,000	1,750	1,180	3,220	18,000
30%	12,400	1,700	2,600	8,200	1,750	870	2,520	12,400
40%	7,800	1,300	2,300	4,300	1,750	520	1,770	7,800
50%	4,700	860	1,900	1,900	1,720	230	1,100	4,700
60%	3,200	600	1,700	860	1,530	200	800	3,200
70%	2,500	510	1,600	440	1,280	280	790	2,500
80%	2,200	430	1,500	280	1,110	370	800	2,200
90%	1,900	340	1,400	160	920	460	800	1,900
95%	1,700	270	1,300	90	790	530	800	1,700
99%	1,500	190	1,300	40	640	610	800	1,500
Annual Average	9,600	1,200	2,200	6,200	1,500	690	1,880	9,600

Figure 5 – 10 show comparisons of the average, minimum and maximum monthly flows down the Hou Sahong and Khone Phapheng channels. The following points can be noted

1. In an average year, the flows down the Hou Sahong are significantly increased in the dry season, with flows only falling below 1500 m^3/sec between February and May, whilst in the Khone Phapheng and Hou Sadam the flows are maintained at below 1000 m^3/sec from December through to May, and only when the high flows start in the wet season (June to November) do the flows over the Falls increase, though always below their original average levels.
2. These trends are even more obvious at times of minimum flows in a dry year, when the flow in the dry season in the Hou Sahong would have been almost non-existent. The flows over the Falls are maintained below 1000 m^3/sec for November through to June, and the wet season flows are significantly reduced from over 3000 m^3/sec in August and September to under 2000 m^3/sec in a dry year.

3. In a wet year, flows in the Hou Sahong are maintained above 1500 m^3/sec throughout the year, while the flows over the Falls are lower than 1000 m^3/sec for February, March and April. In the wet season of a wet year there is little difference in the flows with or without the DSHPP.

Figure 5: Changes in average monthly flows down the Hou Sahong and over Khone Phapheng Falls as a result of DSHPP

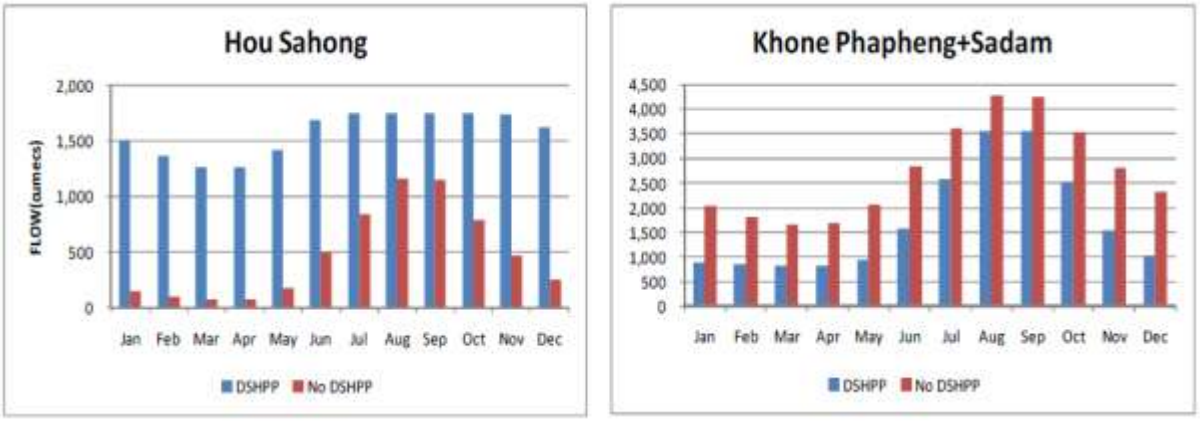


Figure 6: Changes in minimum monthly flows down the Hou Sahong and over Khone Phapheng Falls as a result of DSHPP

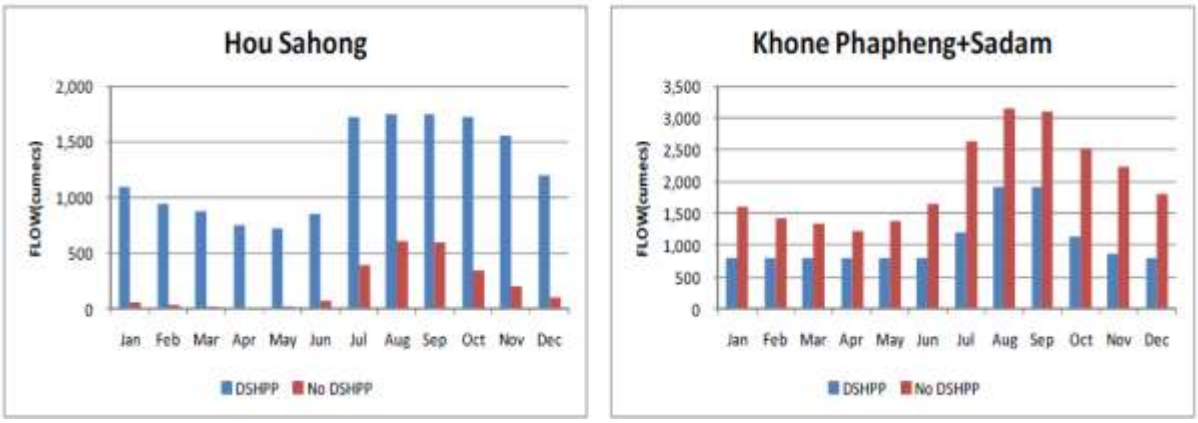
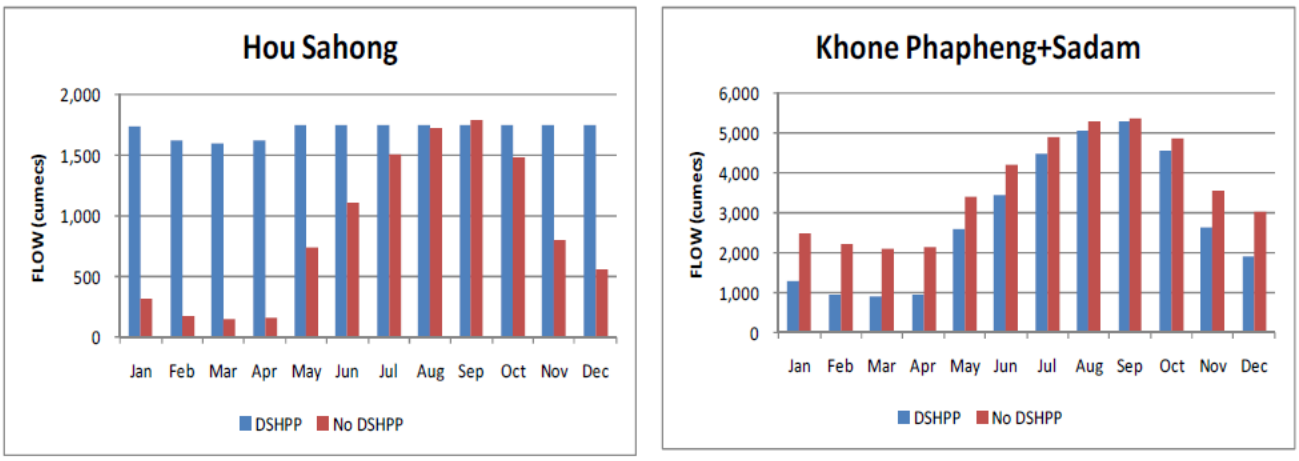


Figure 7: Changes in maximum monthly flows down the Hou Sahong and over Khone Phapheng Falls as a result of DSHPP



4.1.3 Flood flows

When the Mekong experiences very high flows, the DSHPP will provide a spillway at top end of the Hou Sahong over a lowered portion of the right embankment. Thus the crest level of the main dam is

at 76.9 m elevation, whilst the crest level of the spillway is at 75.45 m elevation providing 1.45 m of freeboard. The 1000 year flood is estimated to cause the river levels to rise to 76m elevation, i.e. 0.55 m above the spillway crest level. The spillway width is 700 m and the discharge from the spillway flows into and down the Hou Xang Pheuak which will be excavated both for the spillway and for fish migration.

4.1.4 Transboundary flow changes

The wider transboundary changes in flow in Cambodia and Vietnam are considered in the Cumulative Impact Assessment report of DSHPP. The results from the modelling exercises for both average flows and dry year flows are shown in the diagrams excerpted from the CIA report (Figure 11). This covers immediately downstream at the Lao Cambodia border, at Kratie, at Prek Dam on the Tonle Sap. These figures also include the projected changed flows with the development of hydropower projects upstream by 2030.

Figure 8: Changes in flow at different locations in the Mekong mainstream downstream of DSHPP

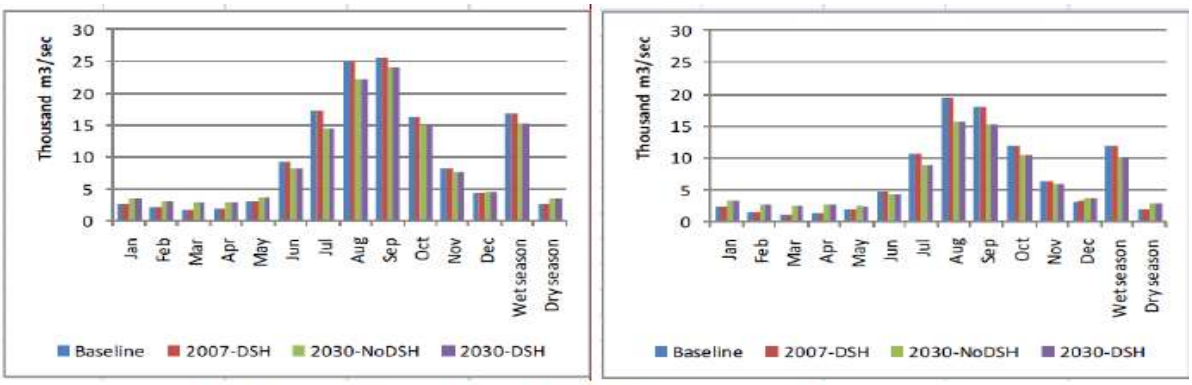


Figure 4-5 Lao PDR / Cambodia Border Average and Minimum Flows

Average flows on LHS and minimum flow on RHS in Figures 4-5 to 4-9.

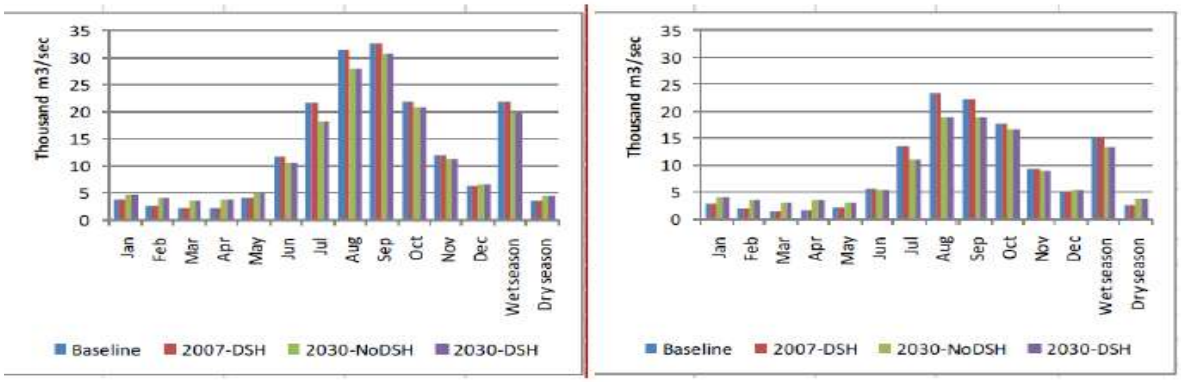


Figure 4-6 Kratie, Cambodia Average and Minimum Flows

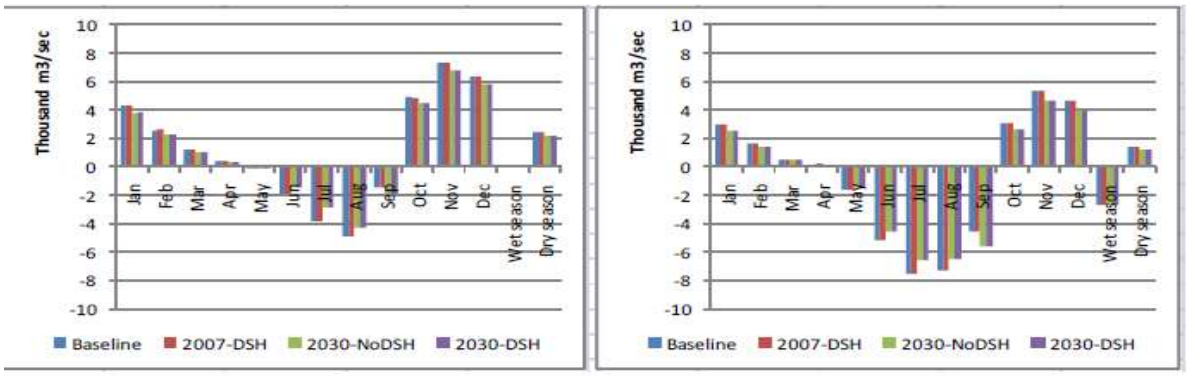
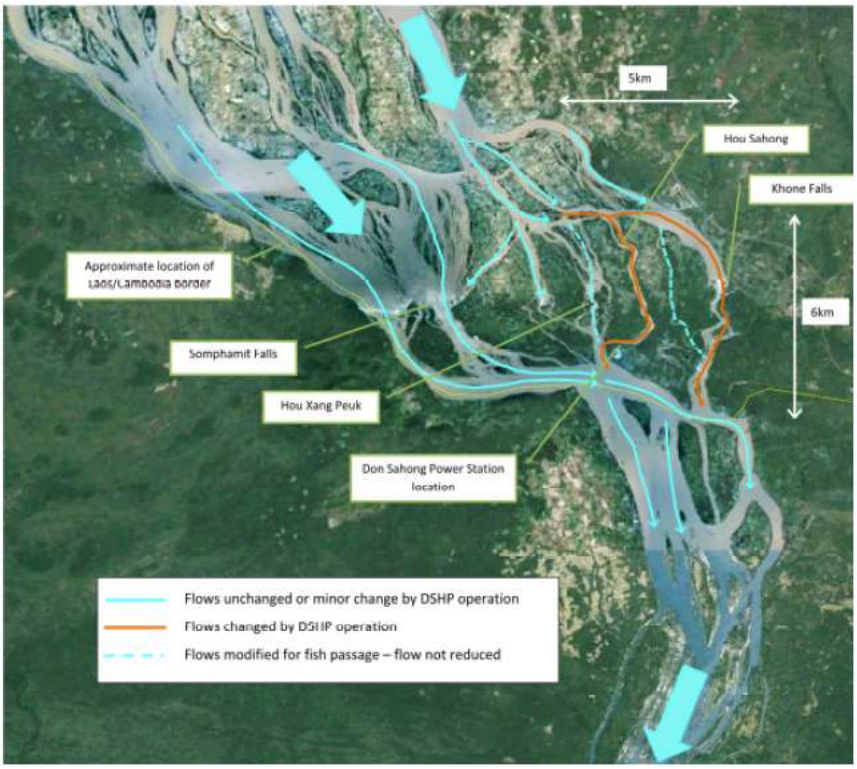


Figure 4-7 Prek Dam, Cambodia (Tonle Sap)

These figures show that there is virtually no difference when the baseline is compared to the modelled results with the DSHPP in 2007. Similarly there is no difference between the monthly flows in 2030 with and without the DSHPP in any of the three flow positions considered. There is however, a significant difference in the flows projected for 2030 because of the influence of storage dams in the upper tributaries of Mekong; wet season flows are decreased as water is stored at times of higher flow, and dry season flows are increased as a higher discharges are released from the storage dams. Nevertheless, there are very little differences in flow with and without the DSHPP in 2030 at any of the three sites. This is to be expected since the DSHPP is a run-of-river dam with 1 – 2 hours of storage. There may be a very small lag in the flows passed downstream, but this is unobservable in average monthly flows. All the channels in this braided section of the Mekong come together into a single channel about 8 km downstream from the border as shown in Figure 8.

Figure 9: View of the Mekong river channels downstream of DSHPP, showing the convergence into a single channel



However, the immediate transboundary flow changes as the flows from the DSHPP tailrace pass into the Chheuteal pool could have impacts upon the geomorphology and aquatic habitats in this stretch of the Mekong until the channels converge. The hydraulic modelling study conducted by SMEC calculated flows and water levels at key locations using a one dimensional HECRAS steady state model (V4.1.0) developed by the US Army Corps of Engineers Hydrologic Engineering Centre.

The distribution of water flows between the four main channels of the Mekong as it enters Cambodia (named South 1, 2, 3 and 4, numbering from the west to east in Figure 10) was modelled with and without the development of DSHPP. Under natural conditions there is a change in distribution of the flows depending upon the season with most of the water flowing down the western channels (1 and 2) in the wet season. This distribution shifts eastwards in the dry season with more water flowing down the eastern channels (3 and 4). This pattern will continue if the DSHPP is developed.

With the DSHPP it is predicted that there would be a modest increase in the discharge through South 1 and 2, virtually no change in the discharge through South 3 and a correspondingly modest decrease in the discharge down South 4 (eastern channel). The increase in flows in South 1 (which flows through the main Chheuteal pool) and channel 2, is negligible under high flow conditions (exceedance <10%); there is predicted to be an increase from 240 m3/sec to 290 m3/sec under mid-range Mekong flows; and, an increase of 10 m3/sec (+10%) under low flow conditions. The corresponding decreases in channels 3 and 4 are of the order of about 4%.

In terms of water level, it is expected that there would be a small increase of about 0.19 m in water level at the mouth of channel 2 for mid-range Mekong flows. In Channel 2 the water levels increase are smaller than this and the changes in water level in Channels 3 and 4 are said to be negligible.

It is noted that there is a large natural rocky outcrop close to the exit of the Hou Xang Pueak/Hou Sahong, as can be seen in the satellite image below (Figure 14). This will tend to divert the higher outflows from these channels when DSHPP is operating so that they follow a pathway eastwards, rather than flowing directly into Chheuteal pool. This rocky outcrop is likely to take a lot of the erosive energy out of the discharge.

Figure 10: Aerial photograph of the Mekong river channels at the Lao/Cambodia border

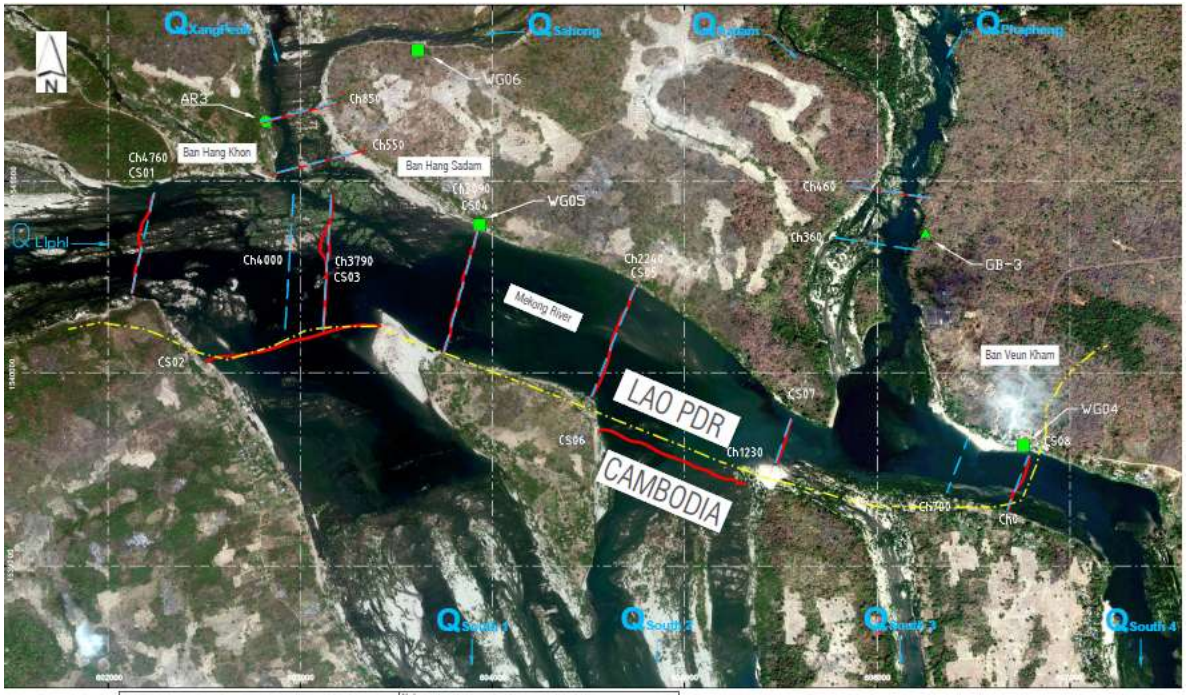
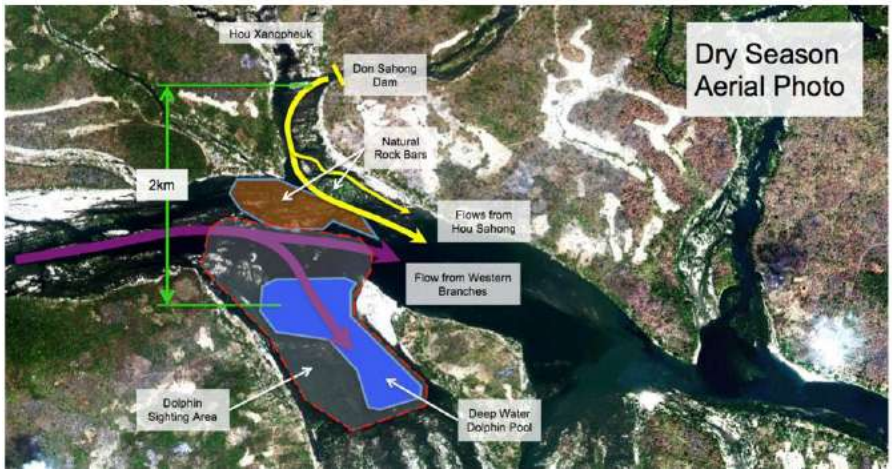


Figure 11: Dry season aerial photograph of the Mekong channels downstream of Don Sahong, showing the deep pool and rocky outcrops



4.2 Summary of impacts considered and measures proposed by the hydropower project proponent

These comments relate first of all to the local impacts of changing flows in the channels adjacent to the Don Sahong and secondly to the rather limited downstream, transboundary impacts. There are two critical areas where the flows may be changed significantly, the first is in the Khone Phapheng

Falls channel, and the second are the downstream channels described above. Only the latter have transboundary implications.

1. **Local impacts of flow changes**

The flow regimes projected above are proposed by the DSHPP, with the main mitigation measure being the minimum flow of 800 m^3/sec over the Khone Phapheng Falls. This is the minimum recorded flow in 2010 (which was an extremely dry year) over the Falls. It is noted that this was the suggested minimum flow allowable proposed for the Thakho hydropower project, although the original flow concept for that project was that the minimum flows should follow the minimum recorded flows for each month of the dry season rather than taking the 800 m^3/sec minimum in every month.

The changes in the flows over the Falls could have a significant ecological impact. These ecological impacts have not been considered at all by the EIA, and the only impact that has been considered here is the visual impact for the tourists. Photographic comparisons have been made of the Falls at different flow regimes, and the statement is made in the EIA that "While it is recognised that the Khone Phapheng waterfall is best viewed at lower flows, the amount of reduction in low season flows, the peak tourism months, is critical.", (EIA section 3-5). The opinion in the EIA is that the visual appearance of the Falls at various discharges does not vary a great deal, i.e. this does not matter.

Most visitors to the Falls will only experience them once and so they have nothing to compare the level at 800 m^3/sec with that of 1,500 – 2,000 m^3/sec which is what it would be naturally during the dry season. They will still be able to experience the weight of water falling in the high flow seasons, even if this will be marginally reduced.

However, it is the ecological impacts that have not been investigated in this channel. It has been assumed that the Khone Phapheng Falls is a barrier to fish migration. No other ecological functions have been investigated, e.g. fish spawning and feeding, turtle nesting and bird nesting on the sandbanks etc. and so we do not know what is at risk from flow reductions in the dry season.

One of the possible impacts of the reduction in dry season flows is that more of the rocks and bank areas will be exposed i.e. not under water, for six months of the year. The long term consequence of this may be that terrestrial and riparian vegetation will start to encroach on these exposed areas, because the plants can get established and become secure before the higher flows of the wet season start. Such plants are usually adapted to being temporarily underwater and will therefore be able to survive and gradually cover more of the Falls, making the channel appear narrower and less dramatic.

This is a situation where very localised environmental flow assessments can be made in a very focused way with a knowledge of the geomorphology, habitats and their different ecological functions. This has not yet been done and would have been an essential component of the impact assessment.

2. **Transboundary impacts of flow changes**

The hydraulic modelling shows that the transboundary changes in flows in the different channels downstream of the DSHPP are moderate to marginal. However, even moderate changes can cause geomorphological and habitat alterations. Whilst the exposed bedrock which characterises a lot of river channels in the Siphandone area, is likely to be very resilient to changes in flows, depositional areas are very susceptible to flow change, sandbanks and bars and alluvial deposits are very dynamic and may change with the season. Areas of backwater where channels merge or smaller streams

enter the larger channels are important areas of deposition. It is considered important to investigate such areas and assess what the impacts are likely to be.

It will also be important to describe the existing distribution of aquatic habitats as a baseline, in order to monitor any changes as the DSHPP comes into operation; it is suggested that this should be done in all the channels affected – Khone Phapheng, Hou Sadam, Hou Xang Peuak, and the downstream channels down to where the channels merge.

4.3 Comparison with the Preliminary Design Guidance

Under the MRCs Procedures for Maintenance of Flows on the Mainstream, there are three main provisions to:

1. Maintain flows of not less than the minimum acceptable monthly flows during the dry season
2. Enable the natural reverse flows in the Tonle Sap to take place during the wet season
3. Prevent average daily peak flows greater than what naturally occur on the average during the flood season attributed to flow releases from man-made activities or facilities.

The PMFM are primarily intended to ensure that there is always sufficient water to meet downstream needs. In relation to DSHPP, it could be argued that the application of the minimum recorded flow to all the monthly flows in the dry season down one of the major channels and features of the Mekong, is not within the spirit of this first provision. This is essentially a local issue with Lao PDR, rather than being a transboundary issue.

The second provision will not be affected, since the wet season flows will not be affected. The third provision will not be affected since the quantity of water being discharged through the turbines during the flood season is a small proportion of the total flood season flows, and the DSHPP is assumed not to operate in peaking mode. The Engineering studies report state that because of the run-of-river nature of Don Sahong, the daily variation in flow will be small and water will not be able to be stored for transferring generation from off-peak to peak periods. Therefore the peak and off-peak generation can be taken as 42.3% and 57.7% respectively of the energy production figures.

When considering the MRC's Preliminary Design Guidance for hydropower dams one the Mekong mainstream, Articles 168 to 175 cover the recommendations for environmental flows. Most of the comments in this section relate to impacts due to changes in flow in the local area around Don Sahong, rather than direct transboundary impacts. However, even if the main impacts are localised to the channels around Don Sahong, the changes in the local aquatic ecology may have indirect transboundary impacts, e.g. in fish and turtle populations downstream if they use the Khone Falls area for spawning and nesting.

Article 168 of the Preliminary Design Guidance states that developers should systematically assess the effect of combination of flow releases to address downstream impacts at different times of year …. by introducing appropriate environmental flow assessment methodologies at EIA and feasibility stages.

- The DSHPP have carried out a detailed modelling of the changes in flow both through the different channels and downstream throughout each month of the year. However they have not carried out an environmental flow assessment at the EIA stage, to assess the impacts of these changes in flow upon the geomorphology or aquatic habitats of the river, especially in the various channels and in the immediate cross border area of the Mekong.

Article 169 suggests that at the detailed design stage, the environmental flow regime would be established for average and low hydrology years.

- Whilst the minimum flow releases over the Khone Phapheng Falls has been established at 800 m^3/sec, the developers have indicated that the flows over the Falls will be monitored, and when they are approaching 800 m3/sec, the flows through the turbines will be automatically reduced, raising headpond levels and creating a backwater effect, thereby allowing more water to pass over the Falls. The detailed design stage would be used to provide further details on this. However, the PNPCA's hydrological review has indicated the need for some sort of flow regulating weir at the mouth of the Hou Sahong, which would indicate concerns about maintaining this flow.
- Additional provision should also be made for dry years to ensure that this minimum flow release is complied with, and it is suggested that a flow gauge be maintained on the Khone Phapheng Falls channel so that this may be monitored.

Articles 170 and 171 deal with rapid fluctuations in flow due to peak power generation and ramping rates, and this is assumed not to apply to DSHPP which will be operating continuously. Ramping rates may be important when bringing turbines up to speed after maintenance periods.

Article 172 makes it clear that the environmental flow provisions and monitoring arrangements should be included in EMMP for both construction and operation to be approved by relevant national authorities.

- The EMMP for DSHPP makes no mention of flow management or monitoring of flows apart from the need to ensure that Mekong flows and water quality are essentially unchanged in the dolphin areas (See Table 3 above). The developers have confirmed that the flows over the Falls will be monitored, and indicate that flow regulation will be done through the management of the turbines.

Article 173 states that the DSHPP should ensure that environmental flow considerations are adequately reflected in operating policies for the reservoir and sediment management and that this should be based on continuous review of monitored results in accordance with the EMMP.

- Whilst the EMMP does not mention flow management or monitoring, other project documents indicate that the inflow to the headpond will be managed through the speed of the turbines as described above.

Article 174 covers monitoring arrangements for integrating environmental flows within the overall environment monitoring system for operations stages that "comprehensively incorporates impact monitoring of all parameters, e.g. sediment monitoring, impacts on wetlands, impacts on fisheries habitats, impact on river morphology and water quality, and the socio-economic aspects related to these effects".

- Within the EMMP there are no descriptions for measures for monitoring flows or impacts on wetlands, and river morphology. However, the developer has indicated that flows over the Khone Phapheng Falls will be monitored and when reduced below 800 m3/sec, flows through the turbines will be adjusted to maintain those flows
- Sediment monitoring programmes are mentioned in the detailed study on hydrology and hydraulics.
- Impacts on fisheries habitats are monitored in terms of fish migration channels, but not for feeding or spawning habitats within the overall Siphandone area.

- Water quality monitoring is covered by specifying the number and frequency of sampling, but not integrated with flow monitoring.

Article 175 specifies that for the well-being of the natural aquatic downstream environment, monitoring should provide for "an independent review of flow release programme, including releases down the fish ladder, and releases during daily generation and water level changes"

- No such provision has been made for an independent review of environmental flows or impacts upon the natural aquatic environment.
- Because of the significant changes in flow in several of the main channels parallel to the Hou Sahong, including down the Hou Sadam and Hou Xang Pheuak, which essentially act as "fish ladders" and downstream, it is suggested that there is a comprehensive flow monitoring **over all the major channels** during operation, in order to demonstrate the reliability of the flow model findings.

4.4 Gaps and uncertainties with respect to local impacts

The main issues that remain about the flow changes concern the ecological impacts in the different channels. The modelling studies that have been carried out appear to show the changes in flow regimes in the different channels both in parallel to the Hou Sahong, immediately downstream in the Lao/Cambodia border area and in the larger Mekong downstream. However, the ecological conditions in these parallel channels, the geomorphology, aquatic habitat distribution and its ecological importance or rarity have not been described. It is therefore difficult to say whether such changes as have been modelled will have an impact on these characteristics. This will require a focused and local environmental flow study across all the major channels, including those that are not projected to change.

The other gap that has not been mentioned in the EMMP is the monitoring of the flows in the different channels. It will be important to monitor such changes as DSHPP comes into operation as a means of verification of the reliability of the models. A detailed local flow monitoring plan may be developed and started before construction starts in order to develop a baseline.

During the 4 year construction period, when the Hou Sahong channel is blocked off by the coffer dams, all the wet season flows will be diverted to other channels, especially the Hou Phapheng channel, which will experience higher than normal flows. It is suggested that the temporary impact of this upon local water levels and flows should also be investigated.

5 Conclusions and recommendations

This review of the water quality, flows and ecosystem health impacts from the Don Sahong hydropower project can conclude the following:

- The water quality issues during the construction period can be largely managed through good practice and attention to compliance and enforcement of construction and contractors for which the DSHPP holds the main responsibility. The construction activities will be largely contained within the coffer dams and there should be little opportunity for contamination of the water.
- However accidents do happen and emergency measures and plans should be in place with staff trained to manage such events. The proximity to the border, means that any accidents could cause an immediate transboundary pollution incident.

- There may be periods such as construction of the coffer dams and in the channel modification of the Hou Sadam and Hou Xang Pheuak, when sediment will be temporarily released, and considerations need to be given to managing erosion and high sediment releases into the river. There are transboundary implications for sediment deposition at such times.
- During operation of the dam, the short residence time in the reservoir, means that poor quality water will be less likely to build up and cause pollution in the reservoir itself or in downstream discharges. The removal of vegetation from the reservoir area will also reduce the initial biological oxygen demand and risks of water with low oxygen content. The water quality will be similar to the quality in the main river. There are unlikely to be transboundary water quality implications during normal operation.
- However, the EIA and EMMP are very deficient in their description of the aquatic habitats within the overall area, including the geomorphology of the channels likely to be affected, the habitats and their ecological significance. Without this information it will be impossible to assess the impacts, and indeed to monitor the ecosystem health of the river in this area. Since this part of the river is ecologically very sensitive, there may be indirect transboundary implications for populations of fish and turtles using the local area for spawning and nesting.
- In terms of flow, various modelling studies have now been carried out which demonstrate the distribution of flows between the channels throughout the months of the year, with the emphasis upon the reduced dry season flows over the Khone Phapheng Falls. However, since no environmental flow assessments have been carried out to investigate the river ecology and how it will respond to these flow changes, it is difficult to interpret the impact upon the Khone Phapheng Falls and channel. It is recommended that such a local, focused study be carried out before finalising the design.
- Areas of uncertainty also exist in terms of the temporary increase in flows through the other channels during the construction period when the Hou Sahong is blocked by the coffer dam and other construction activities.
- An integration of the monitoring of water quality, flows and habitats and ecosystem health is required. There is no provision for monitoring flows or the quality of aquatic habitats, and this is an essential component of the risk management strategy of the company in the event of a pollution incident causing transboundary damages for which the company and the government of Lao PDR might be held responsible.
- The predicted flows shown by the models will require verification and it will be necessary to establish a comprehensive flow and water level monitoring system across all of the channels, including those which are not expected to change.
- The transboundary flow regime in the immediate vicinity of the Lao-Cambodia border has been modelled to show moderate to minor changes in flow, with a slight increase in the western channels, especially Chheuteal Pool, and a corresponding decrease in flows in the eastern channels. This modelling will have to be verified through hydrological and water level monitoring and the ecological impacts upon the habitats in these southern channels also monitored regularly.
- The longer transboundary impacts on flows further down the Mekong have been modelled and the changes in flow shown to be very minor as a result of the Don Sahong HPP. This is to be expected from a run-of river hydropower project in which the braided channels come together within 8 km downstream of the tailrace.
- The EIA only lists two threatened species – the Giant Mekong catfish and the Irrawaddy Dolphin. More recent redlisting of Mekong fish species by IUCN shows that there are in fact

6 Vulnerable species (5 fish and 1 turtle species), 3 Endangered species (2 fish and 1 turtle species), and 3 Critically Endangered species (2 fish and 1 dolphin) that may be using the Siphandone and Stung Treng areas of the Mekong.

- Application of the IFC Performance Standard 6 for the definition of Critical habitats indicates that the Siphandone area should be considered as a critical aquatic habitat, both for the presence of threatened species and for migratory species. It is suggested that attention to the ecosystem health of the river in the Siphandone area and its monitoring should be an important area of focus for the DSHPP with their expressed support for the idea of establishing the area as a Ramsar wetland of international importance. This support could be realised more practically through better information about the aquatic ecosystem and monitoring of its health and with this better overall management of the Siphandone wetlands. IFC indicates that impacts on critical habitats should be addressed by application of the principles of net positive gain in biodiversity.

Annex 1: TOR for water quality and ecosystem health specialist

The Water Quality and Ecosystem Health Specialist provides advice and support to the TG and the IWRMP on specific technical aspects (particularly transboundary impacts on water quality and transboundary impacts from the changed flow over Khone Phapheng) of the PC process and the development of the Technical Review Report.

The consultant will be responsible for the following tasks:

a) Review the submitted DSHPP documentation (including the MRC Scoping Assessment) with regard to information on water quality and ecosystem health and flow over Khone Phapheng;
b) Verify the assessment of potential impacts (particularly transboundary) on water quality from the project;
c) Verify the assessment of potential impacts (particularly transboundary) from reduced flows over Khone Phapheng;
d) As a key assessment basis and tool, assess the compliance of the submitted documents with the MRC's Preliminary Design Guidance on aspects of water quality and reduced flow over Khone Phapheng;
e) Verify the adequacy of water quality management procedures during construction, operation and decommission of the project, including the measures proposed to avoid, minimize or mitigate the impacts;
f) Consider and propose (if relevant) other mitigation options that would be appropriate to include in order to avoid, minimize or mitigate the impacts on water quality;
g) Assess the adequacy of the Environmental Management and Monitoring Plan (EMMP) with regard to water quality compared with accepted international good practice;
h) Propose any further conditions related to water quality and flow over Khone Phapheng that could be considered by the JC to become part of an agreement on the conditions for the project;
i) Participate in meetings, workshops, consultations and field trips that are arranged in relation to the submitted project as needed and required (dates to be determined);
j) Participate in meetings with MRC Programmes, government agencies, hydropower developers, etc. as required.

Annex 2: MRC Preliminary Design Guidance on water quality and flows

General requirements

161. Optimization of operation of the reservoir to meet water quality objectives should aim to maintain sufficiently high levels of dissolved oxygen and sufficiently low levels of phosphorus, nitrogen, biological and oxygen demand. [35] Criteria for optimization can be derived from the MRC Technical Guidelines for Procedures on Water Quality. [36]

162. Developers should consider the impact of the dam and operating policies of any cascade on the 1995 Mekong Agreement as regard to water levels. Developers should demonstrate the projects meet the Mekong Agreement requirements (in the EIA). [37]

163. Minimum flow releases as well as restrictions on changes to natural variability need to be assessed using appropriate environmental flows assessment (EFA) techniques and approaches). [38]

164. Because the proposed mainstream dams are run-of-river with peaking or daily operation cycles for hydropower generation, the focus of the EFA would be on systematically looking at the localized impacts on river morphological processes, erosion and bank stability and aquatic ecosystem functions, as well as impacts on natural habitat such as riverine wetlands, fish habitat and related social and livelihood aspects.

165. Developers should utilise a core group of independent international experts to assist with the design and implementation of water quality compliance monitoring programmes and environmental flow assessment and provision, with all expenses covered by the developer.

Water quality monitoring

166. The monitoring systems need to be designed to facilitate the optimization of hydropower operation with respect to water quality and ecological health. The MRC Water Quality Monitoring Network and Ecological Health Monitoring Network can provide the general trends and status of the water quality and ecological health, whereas monitoring of impacts of hydropower operations need to have targeted and localized monitoring systems.

167. The monitoring and monitoring programme normally required as part of the Environment Management Plan (or environment mitigation and monitoring plan) should be funded by the developer for the construction phase, and the owner full duration of the concession period.

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[35] Other factors are faecal coliform bacteria concentrations that need to be managed.

[36] See http://www.mrcmekong.org/agreement_95/procedures-n-guidelines.htm and http://www.mrcmekong.org/publications/pubByCategory.asp?intCatalogID=7&strCatalog_NAME=Environment An example of a key parameter is the criteria for dissolved oxygen of 5 mg/l. The temperature is requested to be 'natural', which can be assessed based on historical data.

[37] http://www.mrcmekong.org/free_download/policies.htm Recognizing also that in a cascade situation, the approach to coordinate the operation of all dams is a major factor.

[38] This must consider the natural flow regime of the lower Mekong River Basin featuring four different flow seasons, the different characteristics of the river stretches and assessment of the consequences for the important ecosystems and natural resources potentially affected by the impoundment.

Environmental Flow assessment and provision

168. Developers should systematically assess the effect of combination of flow releases from the dam to address downstream impacts at different times of the year, also taking into account the position of the dam in the possible cascade series of dams. This should be done by introducing appropriate environmental flow assessment methodologies at the EIA and feasibility study stage, appropriate to the scale and significance of the flow changes, and referring to good practice techniques and methodologies. [39]

169. At the detailed design stage, the environmental flow regime would be established for average and low hydrology years (flow regime of quantity, quality, duration, and seasonality). An integrated approach should be used that takes into account the combined effect and coordination of water releases for electricity generation (i.e., turbine releases) sediment management (i.e., flushing, density current venting, etc. through low level outlets or partially open spillway gates), navigation and fish passage, as well as the relative dominance or influence of spillway releases on downstream conditions.

170. Developers should pay special attention to the possible the impact of rapid fluctuations in water levels downstream of the dam due to any daily releases for peak power generation and the ramping rates (hourly rate of change in releases, which in peaking operations, depends on how many generation units are brought on line at once, and how quickly).

171. Releases via the turbines and the spillway gates need to be ramped so change in water surface downstream (and upstream) is sufficiently slow to minimize adverse effects on downstream river bank stability and does not pose a public safety hazard. In particular, if the mainstream dams are proposed as peaking projects, with anticipated hourly fluctuations in water flows, it will be important to find agreement on satisfactory rates of ramping.

172. The environmental flow provisions and the monitoring arrangements should be incorporated in the Environmental Management Plan (EMP), or its equivalent, for both the construction and operation phases, which is to be reviewed and approved by the relevant national authorities.

Monitoring of environmental flow provision

173. The developer and operator should ensure the environmental flow considerations are adequately reflected in the operating policies for the reservoir and sediment management strategy. Good practice is to adaptively manage the downstream releases from the dam based on continuous review of the monitored results in accordance with the

[39] See IUCN Publication Flow: The Essentials of Environmental Flows http://www.iucn.org/about/work/programmes/water/wp_resources/wp_resources_toolkits/?1134/6 and Environment Flows: Concepts and Methodologies, World Bank. Water Resources And Environment, Technical Note C.1, 2003 plus other Notes in the series http://go.worldbank.org/8FF2N4VV60

environment management and monitoring plan (EMMP) for the operation phase, or its equivalent.

174. The monitoring arrangements for environmental flows should be integrated with the overall environment monitoring system for the operations stage of the project that comprehensively incorporates impact monitoring of all parameters (e.g. sediment monitoring, impact on wetlands, impact on fisheries habitat, impact on river morphology and water quality, and socio-economic aspects related to these effects, etc.). [40]

175. For the well-being of the natural aquatic downstream environment, the monitoring should provide an independent review of the flow release regime, including releases down the fish ladder and releases during daily cycling of the turbines for peak or daily generation and the daily water level changes. This should be reported, and submitted to government to check annually to ensure compliance with approved operating ranges. [41]