Don Sahong Hydropower Project

Environmental and Social Impacts of Reduced Flow in Phapheng Channel, Khone Falls, Lao PDR

Don Sahong Power Company Ltd

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Abbreviations and Acronyms

DSFMP	Don Sahong Fisheries Management Plan
DSHP	Don Sahong Hydropower Project
DSPC	Don Sahong Power Company Ltd
ESMO	Environmental and Social Management Office
ESMMP	Environmental and Social Management and Monitoring Plan
FishMAP	Fisheries Monitoring and Action Plan (of DSPC)
GOL	Government of Lao People's Democratic Republic
MFCB	Mega First Corporation Berhad
MONRE	Ministry of Natural Resources and Environment
MRC	Mekong River Commission

Glossary of some Lao words for geographical features

Ban	Village
Don	Island
Haew	Large falls where it is too fast and dangerous to go fishing
Hang	Tail or downstream tip of an island
Hou	River Channel
Hua	Head or upstream tip of an island
Khone	Falls or cascades where it is possible to catch fish, and which may be so high and steep that fish cannot pass.
Taat	Rapid

1 SUMMARY

The Don Sahong Power Company Ltd (DSPC) is currently constructing the Don Sahong Hydropower Project (DSHP) on Sahong Channel, which is an anabranch of the Mekong at Khone Falls in southern Lao PDR. This report describes how diversion of water for the DSHP after 2019 will affect Phapheng Channel (the largest dry-season channel at Khone Falls). The report also describes the likely environmental and social effects as well as the proposed mitigation and management measures to be included in the Environmental and Social Management and Monitoring Plan for the Operations Period (ESMMP-OP).

Phapheng is the main dry-season channel of the seven main channels which cross the Great Fault Line at Khone Falls. Water will be diverted by deepening the upstream entrance of Sahong Channel, which will thereby reduce flows in an 8.6-km section of Phapheng Channel; there will be no change in total flows across Khone Falls. The company will maintain a minimum flow in Phapheng Channel of at least 800 m^3/s at all times. This agreed minimum flow is slightly less than the minimum flow ever recorded in Phapheng Channel. Dry season flows (January to May) will generally be about half of baseline flows, with decreases in water level by up to about 1 m compared with baseline. There will be some reduction in flow velocity, but flow will however remain generally fast and turbulent throughout the channel, which is steeply sloping. Despite the reduced flows, Phapheng Channel will continue to be a very large watercourse which can support continuation of its current uses.

Phapheng Falls, just downstream of Thakho on Phapheng Channel, is a prime site for tourism, with over 270,000 fee-paying tourists visiting the falls annually. The main visual effect of low flows in the channel will be to reduce water levels but increase the height of the falls. It is not expected that there will be any significant effect on tourist visitations, as the falls will continue to be a very impressive spectacle under all flow conditions. There are many other attractions at Khone Falls and regionally and it is expected that tourism will continue to increase in line with long-term trends, including to the DSHP site as a result of increased access via a new road bridge which was completed in 2015.

People from several nearby villages wash and bathe in Phapheng Channel, and they also collect water for potable uses. There is some minor pumping of water for irrigation. These uses will not be significantly affected because there will remain a large excess of water relative to requirements and there will be little change in river width or access. The company is incidentally providing water supply to the main affected village (Hua Sadam) to mitigate the construction period impact of closure of Sahong Channel. Phapheng Channel is also crossed by people traveling in boats between the mainland and Phapheng and Sadam Islands. The low flows will not negatively impact cross-river boat traffic, which has in any case recently declined greatly as people are using the new road and bridge to access the islands, mitigating impacts in advance of DSHP's operational period after 2019.

Phapheng is an important channel for fish and fisheries, which depend upon the quality and productivity of instream and riparian habitat. Reducing flows will cause a reduction in the surface area of the channel by up to 5-10%, with likely proportional impacts on aquatic production. The productivity of Phapheng Channel (and other channels at Khone Falls within the Don Sahong Fisheries Management Area) is to be maintained and improved by various measures, which will include replanting of riparian vegetation and reduction of destructive fishing practices, which will mitigate any low-flow impacts.

Many fish migrate upstream from Cambodia and attempt to cross Khone Falls, but Phapheng Channel is almost impassable because of the height of Phapheng Falls and blocking of its small lateral channels by fishing gears. The main alternative routes upstream are Sadam Channel and Xang Pheuak Channel which have been improved by DSPC for fish passage. Low flows if unmitigated would reduce the flow of water down Sadam Channel and down the small lateral channels at Phapheng Falls. As part of DSPC's Fisheries Monitoring and Action Plan (FishMAP) the company is progressively improving fish passage, which will include deepening these fish migration channels to maintain flows at least at baseline levels, and in addition for Sadam Channel to maintain a flow of at least 10 m^3/s. These measures will prevent any direct impacts of low flows on these channels. In addition, under the Don Sahong Fisheries Management Plan (DSFMP), large illegal gears are to be removed from these channels to enhance fish passage.

Terrestrial wildlife and birds are generally in low density along Phapheng Channel and those which are present are under constant threat from hunting, as well as habitat loss by clearing and grazing. These impacts will need to be addressed by GoL agencies if there is to be any improvement in natural resources conservation at Khone Falls. DSPC will assist GoL agencies to reduce illegal clearing and hunting within its concession area and to educate its staff and contractors on Lao laws in this regard. Low flows in Phapheng Channel will still leave a large excess of water relative to any direct requirements of wildlife and birds, so are expected to cause only minor impacts relative to existing threats. The low flows would particularly impact riparian vegetation which is important for controlling bank erosion and providing habitat and food for fish. The FishMAP and DSFMP at present allow for vegetation works along river banks to control erosion and improve fish habitat.

2 Background

2.1 Introduction and overview

The Don Sahong Power Company (DSPC) is currently constructing the Don Sahong Hydropower Project (DSHP) on Sahong Channel, an anabranch of the Mekong at Khone Falls in southern Lao PDR, just upstream of the border with Cambodia (Figure 1). Details of the DSHP are set out in the approved EIA for the project (NCC, 2013). This report has been prepared to provide more information on how diversion of water for the project will affect Phapheng Channel, which is the largest dry-season channel at Khone Falls.

Figure 1. Location of the Don Sahong Hydropower Project (DSHP) in southern Lao PDR

Khone Falls is a collective name for the location shown in Figure 2, where many falls, cascades and rapids punctuate the Mekong anabranches that run across the Great Fault Line of Southern Lao PDR. As shown on Figure 2, river flow is generally from north west to south east via seven main channels, which from west to east are: the Western channels, Somphamit, Etout, Xang Pheuak, Sahong, Sadam and Phapheng channels. Each of these channels has various small lateral channels, as well as permanent or seasonal islands that split it in places, so various names may be applied to some of the sections within each channel. The largest and most-visited water falls are the Somphamit-Lee Pee-Tam Eedeng complex on the western channels (Figure 3), Khone Pa Soi Falls on Etout Channel (Figure 4), and Phapheng Falls to the east (Figure 5). Of these, only Phapheng Falls will be affected by the low flows as discussed in this report.

As mentioned above, Phapheng is the largest channel at Khone Falls in the dry season, whereas during the wet season most of the additional flow of the Mekong runs down the western channels and over the Lee Pee-Tam Eedeng complex of falls which then pass a much larger combined flow than Phapheng Falls (Figure 2 and SMEC, 2015).

The Don Sahong Dam is being constructed at the downstream end of Sahong Channel (Figure 2) over the period 2016-2019. To ensure adequate flow for the operation of the DSHP, the upstream inlet of Sahong Channel is being excavated to increase flow into the channel, which will thereby reduce the flow down Phapheng Channel within the area

shown in dark blue on Figure 2. Therefore the scope of this study covers Phapheng Channel downstream of the Sahong-Phapheng inlet to the confluence of Phapheng Channel with the main Mekong channel downstream (Figure 2).

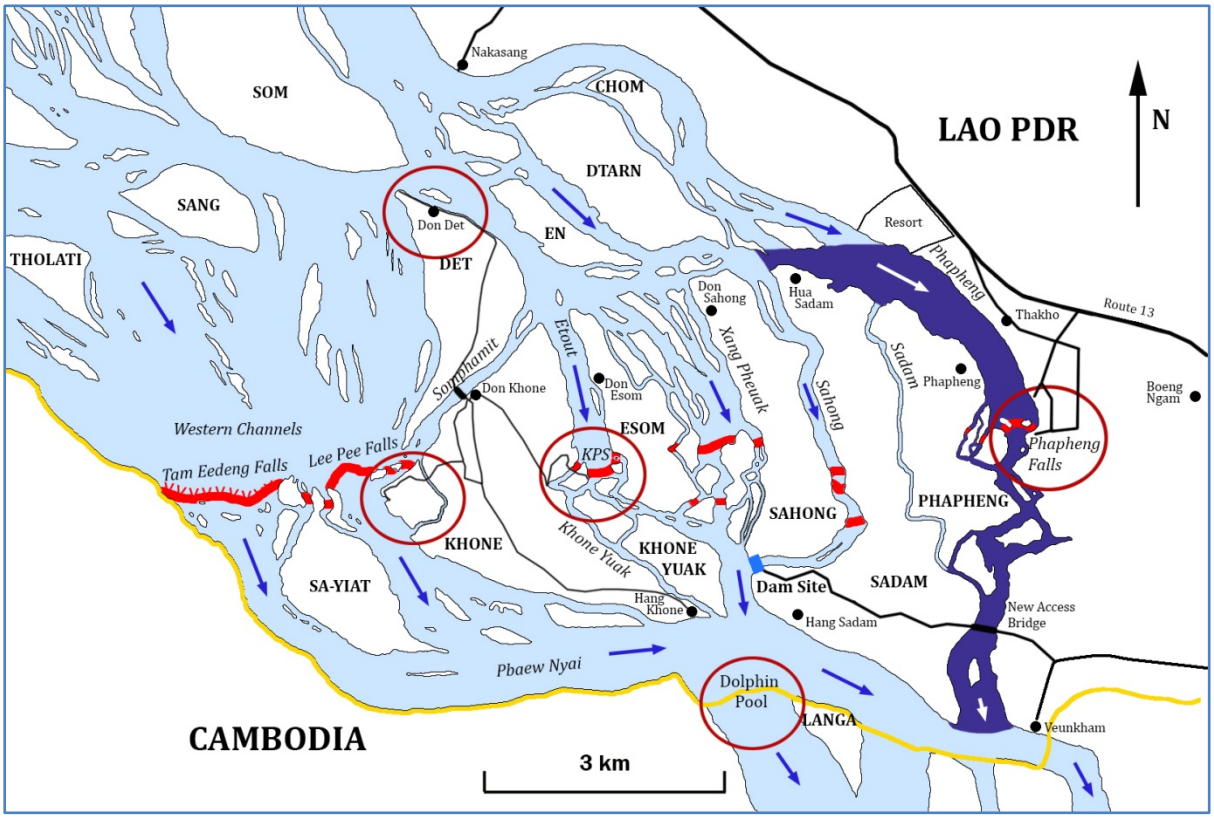


Figure 2 Khone Falls, showing the section of Phapheng Channel which will be affected by low flows in dark blue, with the main tourist attractions circled

Notes: Red lines indicate the main waterfalls or cascades, which generally follow the Great Southern Fault Line which runs east-west across the course of the river. The main tourist attractions are indicated by red circles, see Section 4 for discussion.
Islands (*Don* in Lao) are shown in upper case (e.g. DON DET).
River channels (in Lao) are shown in italics (e.g. *Phapheng*).
Waterfalls (*Khone* in Lao) are shown in italics (e.g. *Phapheng Falls*).
Villages (*Ban* in Lao) are shown in lower case (e.g. Ban Thakho).
KPS=Khone Pa Soi Waterfall

Under the approved EIA and Concession Agreement for the project (signed in September 2015) the project will maintain a flow of at least 800 m^3/s at all times in Phapheng Channel at Thakho gauging station, which is about 1 km upstream of Phapheng Falls (Figure 1). This minimum flow has been set to support the environmental and social amenity of Phapheng Channel. Despite diversion of some of the flow from Phapheng Channel, for some of the time during the dry season the DSHP plant will run at less than its full capacity, reducing the amount of hydropower generated and income derived from it. Flow is likely to be at the minimum permitted level of 800 m^3/s for about 37.5% of the time during a year, which will be mainly during the dry season months of January to April.

This report aims to:

(1) describe and assess the environmental and social effects of the reduced flows and water levels in Phapheng Channel;

(2) recommend appropriate mitigation measures where necessary to address any material impacts arising from changes in the minimum flow; and

(3) recommend plans and works suitable to be included in the Environmental and Social Monitoring and Management Plan for the Operations Period (ESMMP-OP).

DSPC prepared a Terms of Reference for the study which was approved by the Ministry of Natural Resources and Environment (MONRE) (Annex A).

2.2 Study Area

The area which will be affected by low flows is an 8.7-km section of Phapheng Channel from the inlet of Sahong Channel to the confluence of Phapheng Channel with the main Mekong Channel, as shown in Figure 2 in dark blue. The total extent of Phapheng Channel in which there will be reduced flows is about 340 ha; the area upstream of the falls is about 210 ha (4.2 kmx0.5 km) while the area downstream of the falls is about 130 ha (4.4 km x 0.3 km).

The villages of Ban Hua Sadam, Ban Thakho, Ban Boeng Ngam, and Ban Don Phapheng are located near the affected section of Phapheng Channel, so their inhabitants could possibly be affected by the reduced flows and water levels to the extent that they use the river or are indirectly affected by such use. Figure 2 also shows the main tourist attractions in the area, which are discussed in Section 4 of this report. The only significant tourist attraction which may be affected by the low flows is Phapheng Falls, as discussed in Section 4.

Figure 3 Partial view of Somphamit-Lee Pee Falls on 17 Feb 2016, dry season
These falls will be unaffected by the DSHP project

Figure 4 Khone Pa Soi Falls, 17 February 2016, dry season
These falls will be unaffected by the DSHP project

Figure 5 Phapheng Falls, 18 March 2016, mid dry-season
The tourist visitation and viewing area is on the lower right hand side; the main tourist viewing platform is within the red-roofed building.

Figure 6. The downstream section of Phapheng Channel and the new access bridge on 23 Jan 2016
The mainland is on the right and the island of Don Sadam is on the left.

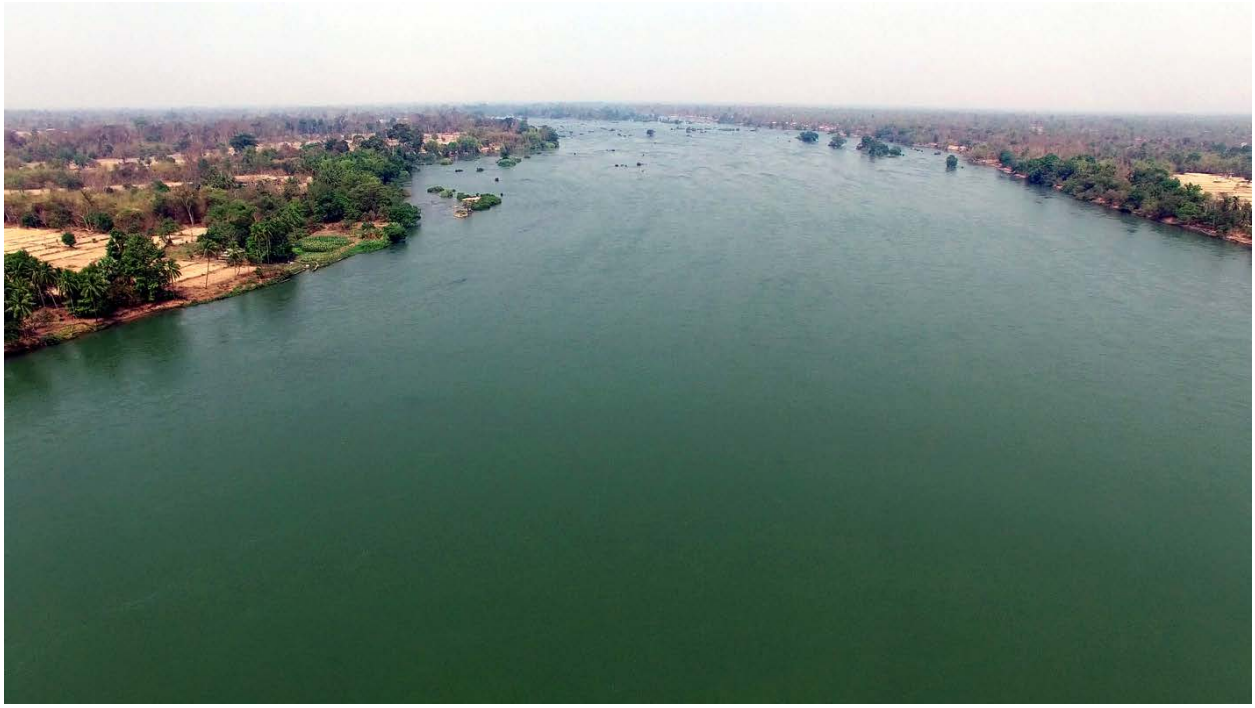


Figure 7. Phapheng Channel just upstream of the falls looking upstream
Phapheng Village is to the left and Thakho Village is to the right. Note the lack of rock bars or islands.

Figure 8. Phapheng Channel near the resort looking downstream on 14 Feb 2016
The resort is on the left. Note the rock bars and small islands.

3 Hydrological assessment

3.1 Hydrology and the effect of dams upstream

The Mekong is a large tropical monsoonal river which exhibits a pronounced seasonal change in flows and a large variation in water level of about 8-10 metres downstream of Khone Falls. Upstream of the falls, the river spreads across a wide area during the wet season, so the water level only varies by up to about 3 metres during a year. The drop in elevation across the Great Fault Line causes swift currents, rapids and waterfalls in the channels that cross the falls.

Six mainstream hydropower dams have been built on the Mekong (or Lancang) in China since the mid-1990s. These six dams have created reservoirs with a combined active storage of 23.2 km^3, which is 50% of the total Mekong basin active storage (MRC, 2011). The two largest dams account for virtually all (98%) of the active storage in China and these were only completed recently (Xiaowan Dam in 2010 and Nuozhadu Dam in 2012). On Mekong tributaries in the lower Mekong basin there are also many reservoirs which support hydropower, irrigation and urban water supplies and which together account for about 50% of the active storage in the Mekong basin. Storage of water in reservoirs during the wet season and release during the dry season has now delayed and decreased wet season flows and significantly increased dry season flows in the Mekong, including at Khone Falls. The effects of such flow regulation have been modelled by the Mekong River Commission using historical data to predict future river flows under various development scenarios (MRC 2011, Table 6; Piman et al., 2013). The main scenarios referred to by the MRC which are relevant for this assessment are as follows.

- The 1986-2000 "baseline" was chosen to be the most recent period during which regulation by large dams was relatively insignificant compared to natural variation.

- The "definite future" (DF) took into account storage and regulation by all dams built up to 2015 to model future flows based on the 1986-2000 baseline flows; this is now the existing situation prior to the development of the DSHP.

- Several other scenarios were developed for 2030 and 2060, in which the live storage in the Mekong basin could increase by a factor of between 1.4 and 2.3 times that existing now (the DF scenario), depending on which dams are ultimately built.

The large dams built since 2000 would have reduced total Mekong flows during the initial filling of their reservoirs (both dead and active storage), so the period 2001-2015 has not been used as a baseline or for predicting flows by the MRC or by DSPC for this report.

3.2 Hydrological data derivation

Flows in Phapheng Channel have been modelled based on two main sets of data.

(1) Gauge height (stage) has been read at Thakho just upstream of Phapheng Waterfall each day since April 2011 (Figures 2, 7). A rating curve was created using flow and stage measurements at the site as well as pre-2011 flow estimates with stage estimated based on a relationship between flows at Phapheng and Pakse (Figure 10). There is a very tight fit of points to the curve, so flows at Thakho can be accurately estimated from gauge height data using the regression equation:

$$Q_{Phapheng} = 482.1 \times (WL_{AR02} - 66.50)^{1.568}$$

Where Q is discharge in m^3/s and WL is water level at the gauge in metres above sea level (masl). This equation has been used to convert the gauge height records to discharge as is usual practice. Similar data have been collected by DSPC at seven other locations to model the effects of diverting water into Sahong Channel (SMEC, 2015).

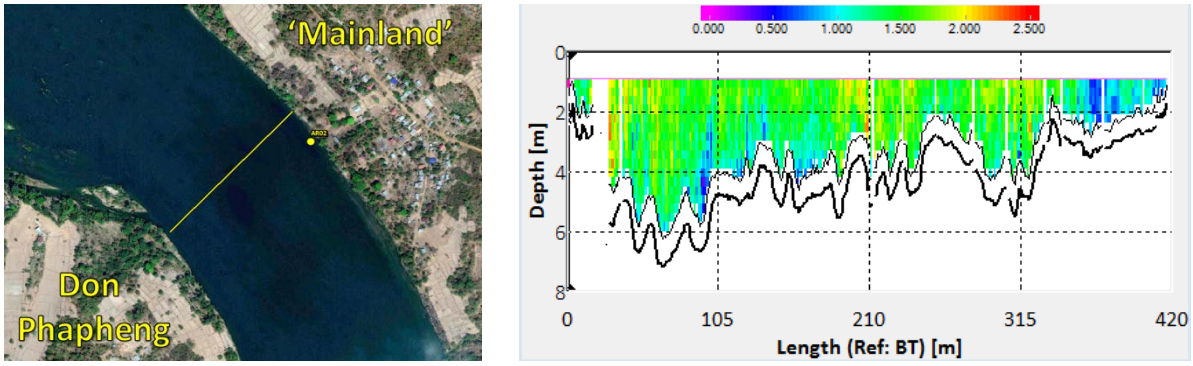


Figure 9. Cross-section location and example of ADCP measurement in Phapheng Channel at Thakho Village

The cross-section is looking from upstream to downstream (east is on the left), with current speeds in m/s, colour-coded according to the legend above the figure. Measurements were on 15 June 2010 at a flow of 2350 m^3/s and water level of 69.2 masl (SMEC, 2015).

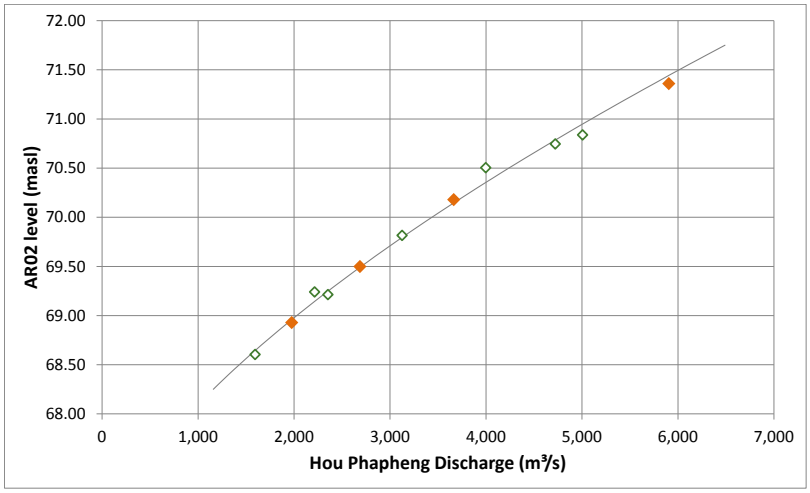


Figure 10. Regression between water level and discharge in Phapheng Channel at Thakho

Open markers represent water levels estimated based on reported Pakse discharge (i.e. pre-April 2011). From SMEC (2015).

(2) MRC flow records at Pakse from 1924 to the present are based on daily field readings of gauge height which have been converted to discharges using a stage-discharge rating relationship. At Pakse (150 km upstream of Khone Falls) the catchment area is about 98.5% of the catchment area at Khone Falls, and there are no significant water abstractions in the intervening section of the river, so Pakse flows are approximately the same as flows at Khone Falls. Flows estimated from gauging in Phapheng Channel at Thakho have been compared with flows at Pakse to derive relationships which can be used to estimate Phapheng Channel flows from Pakse flows (SMEC, 2015).

3.3 Summary of flows in Phapheng Channel at Thakho

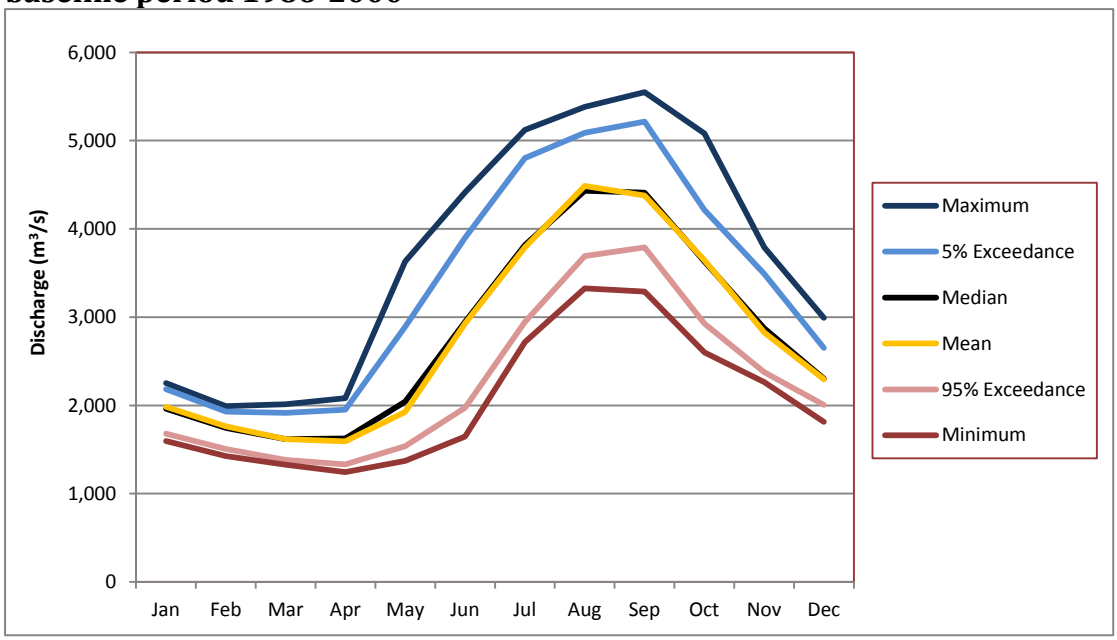
As summarised in Table 1 and Figure 11, baseline flows in Phapheng Channel at Thakho show pronounced seasonality, with wet season flows typically up to three times larger than dry season flows, but up to about five times larger when comparing minima with maxima. The wet season begins in May and continues until October; then flows progressively decline during the dry season until April. The variation in flow in Phapheng Channel is less extreme than in the entire flow over Khone Falls, because most of the additional wet season flow spills over into the large western channels (SMEC, 2015).

Table 1. Discharge parameters for Phapheng Channel at Thakho for the baseline period 1986-2000

All units are daily flow (discharge) in m^3/s.

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Maximum	2,253	1,993	2,013	2,082	3,629	4,413	5,120	5,383	5,550	5,080	3,790	2,991
5% Exceedance	2,183	1,931	1,914	1,951	2,892	3,899	4,802	5,090	5,216	4,214	3,489	2,651
Mean	1,962	1,746	1,619	1,627	2,041	2,945	3,814	4,434	4,411	3,629	2,873	2,302
Median	1,984	1,763	1,617	1,593	1,927	2,927	3,792	4,488	4,377	3,646	2,827	2,294
95% Exceedance	1,679	1,504	1,381	1,332	1,536	1,975	2,945	3,691	3,790	2,929	2,377	2,007
Minimum	1,595	1,427	1,329	1,244	1,371	1,645	2,718	3,325	3,291	2,600	2,263	1,813

Figure 11. Discharge parameters for Phapheng Channel at Thakho for the baseline period 1986-2000



Note: the figure plots the same data as Table 1 above.

Table 1 and Figure 11 show that flows during the dry season are less variable than during the wet season, because dry season flows mainly derive from groundwater, as well as glacial melt in the Mekong's headwaters, whereas the increase in wet-season flows mainly comprises surface runoff, which is highly variable depending upon rainfall and terrain.

The months of lowest flow in Phapheng Channel are March and April, and the driest months in the baseline period of 1986-2000 were as follows.

April 1993 1244 m^3/s minimum daily flow
April 1995 1301 m^3/s minimum daily flow
March 1999 1329 m^3/s minimum daily flow
March 1989 1336 m^3/s minimum daily flow
April 1989 1336 m3/s minimum daily flow

In each of these months, several other low-flow days were recorded, and in a ranking of minimum flows the seven lowest flow days during the baseline period were during April 1993, which overall was the driest month in the baseline period.

In the entire record from 1927 to 2015, the driest months were as follows:

March 2010 930 m^3/s minimum daily flow
March 1933 1028 m^3/s minimum daily flow
April 1960 1028 m^3/s minimum daily flow
May 1960 1028 m^3/s minimum daily flow.

The driest month in the entire record was March 2010, when the eight lowest daily flows in the entire record were recorded. Although 2010 was a drought year, the

naturally low river flows were likely exacerbated by the initial filling of the largest dam in the Mekong basin, Nuozhadu Dam in China, as discussed in Section 3.1.

3.4 Flows for the existing situation in 2015 or 'definite future'

3.4.1 Using Definite Future (DF) modelled flows for prediction

As mentioned in Section 3.1, the "definite future" (DF) modelled Mekong River flows using the same underlying hydrology as the 1986-2000 baseline flows and taking into account the predicted storage and flow regulation by all dams predicted to be built up to 2015 (which does not include the DSHP, scheduled for completion in 2019). The DF has now become the actual existing situation, which will continue for some time into the future, until the completion of more large dams which will further regulate river flow.

Some validation of the DF modelled flows can be gained by comparison with actual flows measured from 2011 to 2014, which however may not be entirely representative of the 'definite future' (2015 onwards), as they cover a short period which was likely still affected by dam commissioning upstream. This comparison (Table 2 and Figure 12) indicates a reasonable agreement between the measured and modelled flows (r^2=0.96); in particular dry season flows have recently increased by 10-20% as predicted by the model. As mentioned in Section 3.3, wet season flows are inherently more variable and are proportionately less-affected by damming than dry season flows, so there is less agreement between predicted and measured flows during the wet season.

Table 2. Predicted flows in Phapheng channel under the Definite Future modelling, compared with baseline and recent flows

Median daily flow (discharge) in m^3/s.

Period	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Baseline (1986-2000)	1,984	1,763	1,617	1,593	1,927	2,927	3,792	4,488	4,377	3,646	2,827	2,294
Recent (2011-2014)	2,003	1,952	1,927	1,890	2,170	2,806	3,766	4,661	4,355	3,399	2,615	2,209
Model DF 2015-(without DSHP)	2,211	2,063	1,935	1,948	2,146	2,923	3,631	4,203	4,319	3,668	2,912	2,459
Model DF/Baseline	11%	17%	20%	22%	11%	0%	-4%	-6%	-1%	1%	3%	7%
Model DF/Recent	110%	106%	100%	103%	99%	104%	96%	90%	99%	108%	111%	111%

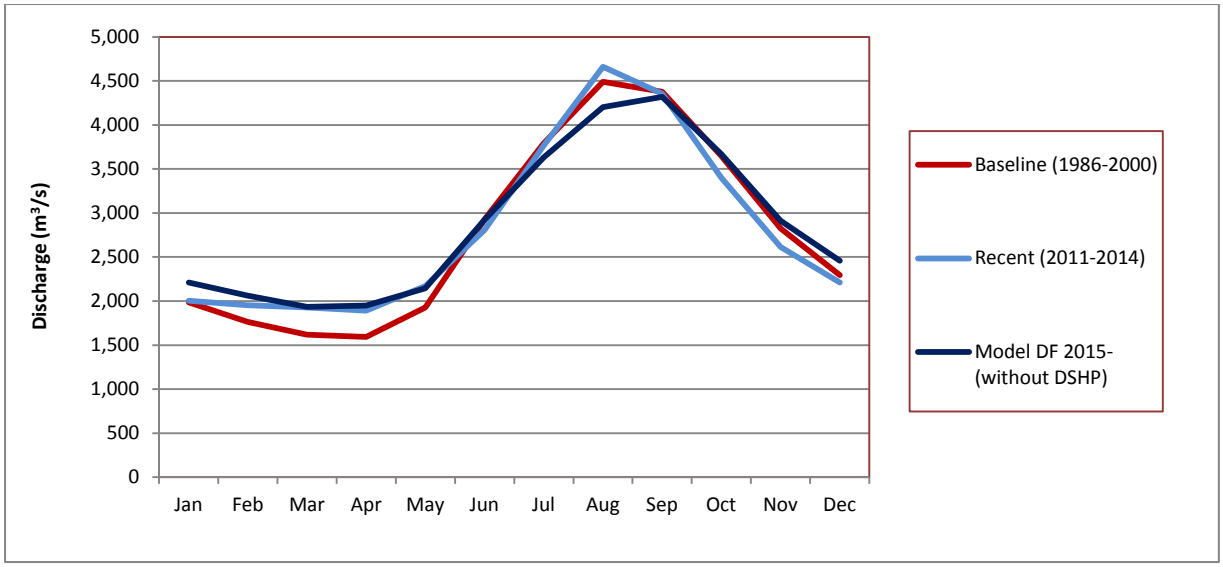


Figure 12. Predicted flows in Phapheng channel under Definite Future modelling, compared with baseline and recent flows

Median daily flow (discharge) each month in m^3/s; same data as Table 2.

3.4.2 Definite Future (DF) compared with baseline

Elaborating on the comparison in Section 3.4.1, Tables 3 and 4 and Figure 13 show that there has been a significant increase in dry season flows with the greatest effect on the minimum flow in April (+38%). The decrease in wet season flows is relatively minor as a percentage of flows, and the effect of regulation is to eliminate extreme minimum flows in the wet season, as shown by the slight increase in wet season minimum flows.

Table 3. Discharge parameters for modelled flows for the Definite Future Situation in 2015 without the DSHP

Units are daily flow (discharge) in m^3/s.

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Maximum	2,545	2,248	2,212	2,210	3,915	4,592	4,940	5,295	5,428	4,617	3,714	2,893
5% Exceedance	2,388	2,187	2,108	2,117	2,839	4,035	4,654	4,885	5,103	4,329	3,507	2,722
Mean	2,223	2,057	1,931	1,953	2,215	3,033	3,731	4,254	4,338	3,707	2,953	2,477
Median	2,211	2,063	1,935	1,948	2,146	2,923	3,631	4,203	4,319	3,668	2,912	2,459
95% Exceedance	2,106	1,921	1,776	1,759	1,867	2,270	3,080	3,682	3,821	3,179	2,512	2,290
Minimum	2,035	1,867	1,712	1,710	1,591	1,999	2,765	3,357	3,425	2,993	2,372	2,213

Table 4. Percentage change in discharge parameters for the Definite Future compared with the Baseline period

Units are daily flow (discharge) in m^3/s.

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Maximum	13.0%	12.8%	9.9%	6.2%	7.9%	4.1%	-3.5%	-1.6%	-2.2%	-9.1%	-2.0%	-3.3%
5% Exceedance	9.4%	13.2%	10.1%	8.5%	-1.8%	3.5%	-3.1%	-4.0%	-2.2%	2.7%	0.5%	2.7%
Mean	13.3%	17.8%	19.3%	20.1%	8.5%	3.0%	-2.2%	-4.1%	-1.7%	2.2%	2.8%	7.6%
Median	11.4%	17.0%	19.7%	22.3%	11.4%	-0.1%	-4.2%	-6.4%	-1.3%	0.6%	3.0%	7.2%
95% Exceedance	25.4%	27.7%	28.6%	32.1%	21.5%	15.0%	4.6%	-0.3%	0.8%	8.5%	5.7%	14.1%
Minimum	27.6%	30.8%	28.8%	37.5%	16.0%	21.5%	1.7%	1.0%	4.1%	15.1%	4.8%	22.1%

Note: the percentages are the values in Table 3 compared with the values in Table 1.

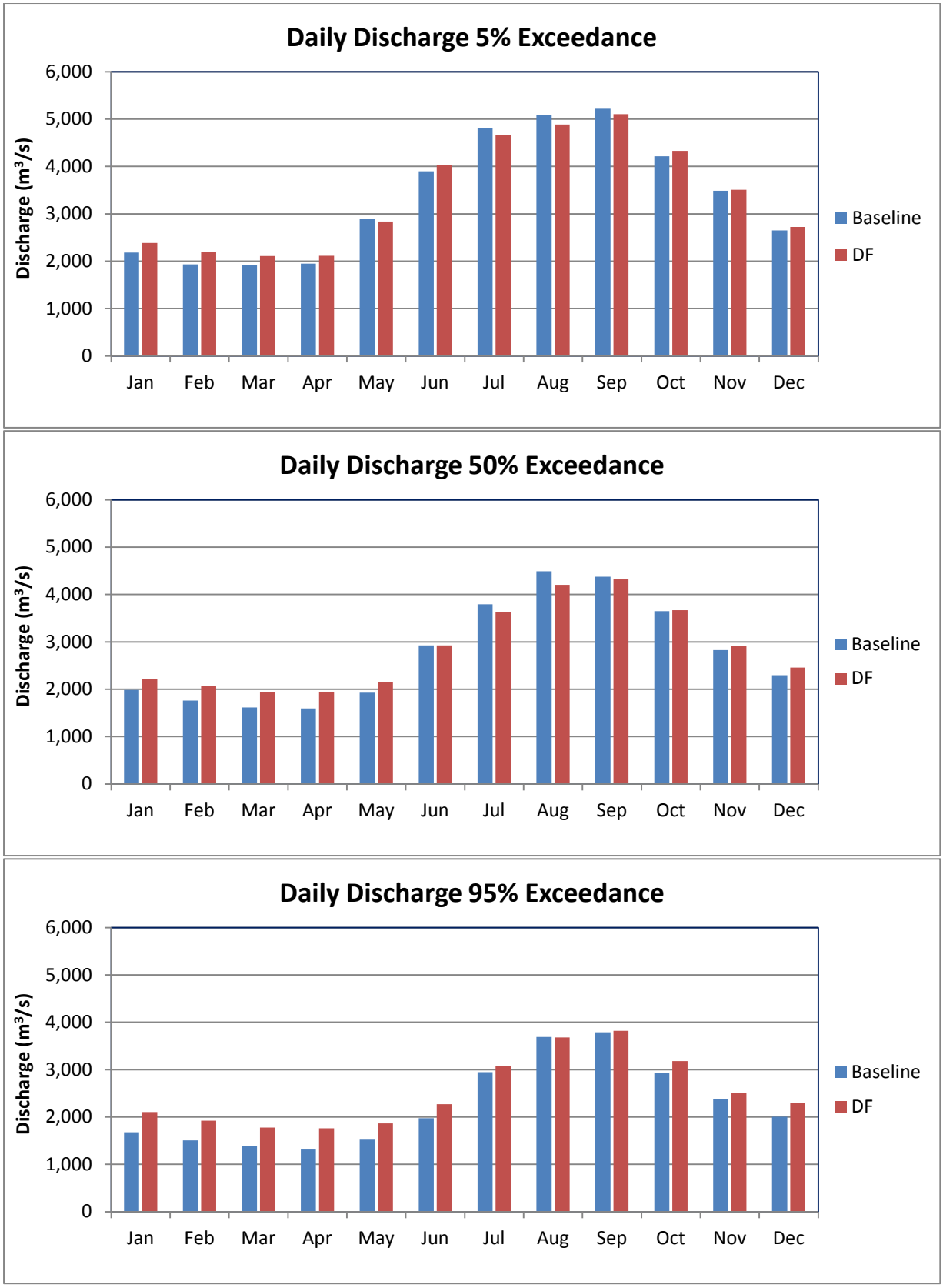


Figure 13. Phapheng Channel at Thakho, 5%, 50% and 95% exceedance flows for baseline and DF

Daily flow (discharge) parameters for each month in m^3/s. Data are from Table 1 and Table 3.

3.5 The effect of DSHP on flows in Phapheng Channel

3.5.1 Selection of minimum flow

The EIA proposed that a minimum environmental flow of 800 m^3/s be provided in the Phapheng Channel at Thakho to maintain the aesthetic quality of the Phapheng Falls, which was identified in the project EIA as one of the main potential social impacts of the project. Minimum flows recorded in Phapheng Channel are discussed in Section 3.3.

According to the "Summary of Thakho Project Presentation in the Meeting at Department of Electricity of the Government of Lao PDR on 21 April 2011":

> "Over a long period of data collection in Pakse (1920 to 2010), the minimum recorded flow was observed in March 2010. A minimum flow of 800 m^3/s was assessed for Phapheng waterfalls. This value of the minimum recorded flow has been proposed to be considered as the minimum environmental flow to be guaranteed over Phapheng waterfalls by WWF Greater Mekong Programme during the Initial Environmental Examination."

This assessment by WWF Greater Mekong Programme as quoted above for the Thakho Project concurs with DSPC's selection of the minimum flow of 800 m^3/s.

3.5.2 Flow alteration in Phapheng channel

The effect of the DSHP on Phapheng Channel were modelled based on the DF flows at Khone Falls (as shown in Table 3 for Phapheng Channel), as the DF provides the best model of flow patterns at present and for the next few years.

Table 5. Parameters for modelled flows for the Definite Future (DF) with the DSHP operating

Units are daily flow (discharge) in m^3/s.

Median	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Maximum	1,236	842	800	800	3,139	4,152	4,757	5,380	5,619	4,196	2,847	1,717
5% Exceedance	1,025	800	800	800	1,641	3,316	4,262	4,661	5,044	3,745	2,551	1,477
Mean	845	800	800	800	963	1,918	2,887	3,655	3,785	2,845	1,796	1,147
Median	800	800	800	800	800	1,760	2,727	3,559	3,730	2,780	1,745	1,120
95% Exceedance	800	800	800	800	800	871	1,971	2,800	3,001	2,104	1,192	896
Minimum	800	800	800	800	800	800	1,537	2,345	2,438	1,856	1,004	800

Table 6. Percentage change in discharge parameters for the Definite Future (DF) with DSHP compared with the Baseline period

Median	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Maximum	-45.1%	-57.8%	-60.3%	-61.6%	-13.5%	-5.9%	-7.1%	0.0%	1.2%	-17.4%	-24.9%	-42.6%
5% Exceedance	-53.0%	-58.6%	-58.2%	-59.0%	-43.3%	-15.0%	-11.3%	-8.4%	-3.3%	-11.1%	-26.9%	-44.3%
Mean	-56.9%	-54.2%	-50.6%	-50.8%	-52.8%	-34.9%	-24.3%	-17.6%	-14.2%	-21.6%	-37.5%	-50.2%
Median	-59.7%	-54.6%	-50.5%	-49.8%	-58.5%	-39.9%	-28.1%	-20.7%	-14.8%	-23.8%	-38.3%	-51.2%
95% Exceedance	-52.4%	-46.8%	-42.1%	-39.9%	-47.9%	-55.9%	-33.1%	-24.2%	-20.8%	-28.2%	-49.8%	-55.3%
Minimum	-49.8%	-43.9%	-39.8%	-35.7%	-41.6%	-51.4%	-43.4%	-29.5%	-25.9%	-28.6%	-55.6%	-55.9%

Note: percentages are the values in Table 5 compared with the values in Table 1.

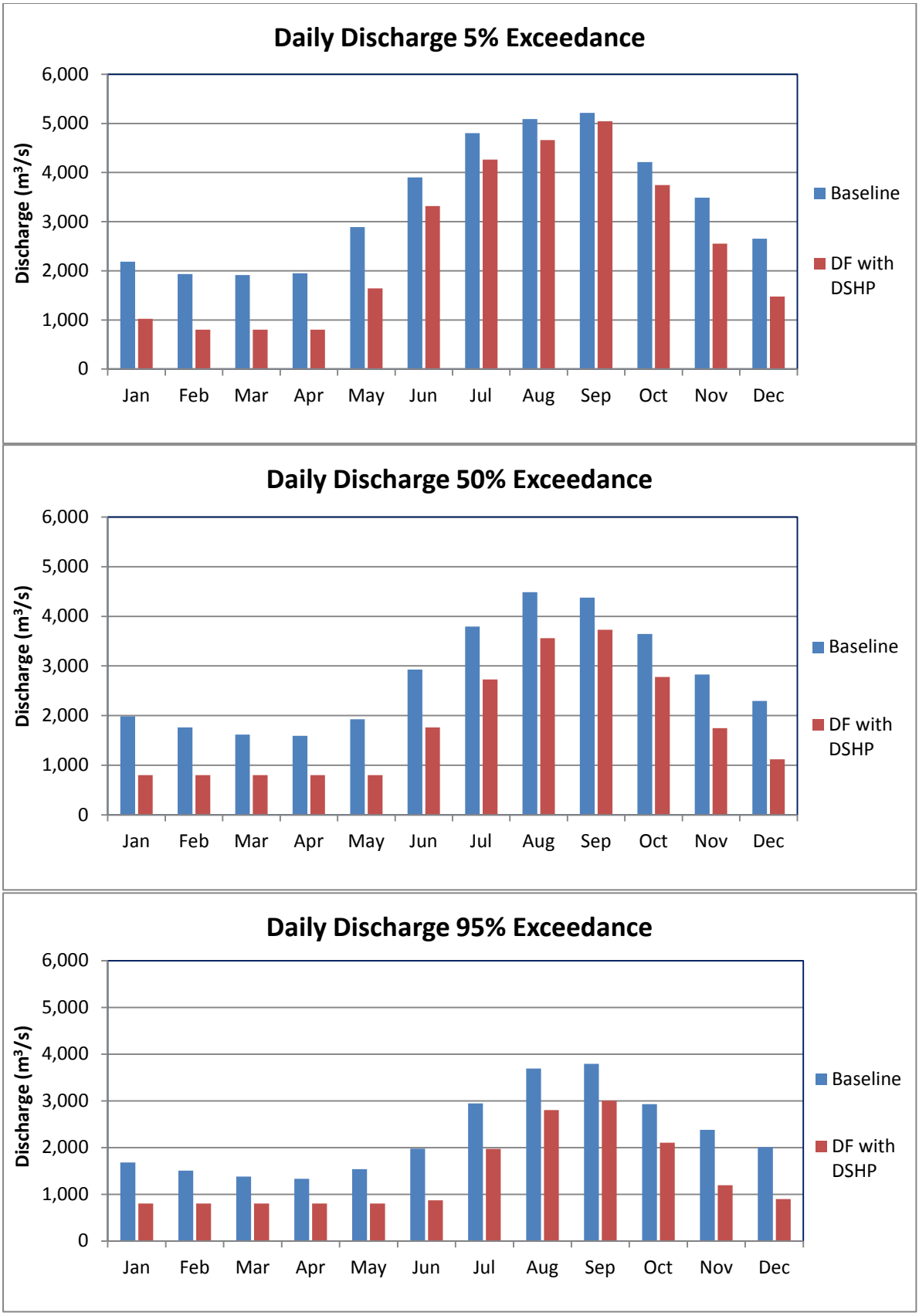


Figure 14. Phapheng Channel at Thakho 5%, 50% and 95% exceedance values, comparing DF with DSHP to baseline

Daily flow (discharge) parameters for each month in m3/s. Data are from Table 1 and Table 5.

As shown in Table 5, flows in Phapheng Channel at Thakho will be about 800 m^3/s for most of the period from January to May. Flows in excess of 800m^3/s up to a maximum of 1,600m^3/s will be diverted to the powerhouse for generation. As shown in Table 6 and Figure 15, the greatest reduction compared with baseline flows, will be in the driest months of March and April, and from December to June for most of the time flows will be half or less of former baseline flows; from February to April) flow will be almost always (more than 27-28 days on average) at the minimum flow of 800 m^3/s.

3.6 Water levels and the effect of the DSHP

At Phapheng Falls the river channel runs south across a horizontal fault. The falls are about 420 m wide upstream, and up to about 8-10 m high, depending on flow, as discussed in Section 3.7.

A relationship to determine water surface level at the Thakho gauge from discharge was developed by SMEC (2015) as follows.

GH=[(Q/482.1)^0.637]+66.5

Using this equation Table 7 was derived from Table 1. Table shows that under baseline conditions the median water level in Phapheng Channel at Thakho varies by around 2.2 m over a year (April cf. August), and the total range between the maximum and minimum daily water levels over the 15-year baseline period was about 3.4 m.

Table 7. Parameters for water level (masl) in Phapheng Channel at Thakho under baseline conditions (1986-2000)

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Maximum	69.2	69.0	69.0	69.0	70.1	70.6	71.0	71.2	71.3	71.0	70.2	69.7
5% Exceedance	69.1	68.9	68.9	68.9	69.6	70.3	70.8	71.0	71.1	70.5	70.0	69.5
Mean	68.9	68.8	68.7	68.7	69.0	69.7	70.2	70.6	70.6	70.1	69.6	69.2
Median	69.0	68.8	68.7	68.6	68.9	69.7	70.2	70.6	70.6	70.1	69.6	69.2
95% Exceedance	68.7	68.6	68.5	68.4	68.6	69.0	69.7	70.2	70.2	69.7	69.3	69.0
Minimum	68.6	68.5	68.4	68.3	68.4	68.7	69.5	69.9	69.9	69.4	69.2	68.8

When the DSHP power station is operating and maintaining 800 m^3/s in Phapheng channel, the level at the Thakho gauge will be 67.9 masl as shown in Table 8, which is based on Table 5. The predicted water levels in Phapheng channel caused by diversion of water to the DSHP are summarised in Table 8 and the reduction in levels is summarised in Table 9 and Figure 15.

Table 8. Predicted water levels (masl) in Phapheng channel at Thakho gauge when DSHP is operational, based on DF with DSHP operating

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Maximum	68.3	67.9	67.9	67.9	69.8	70.4	70.8	71.2	71.3	70.5	69.6	68.7
5% Exceedance	68.1	67.9	67.9	67.9	68.7	69.9	70.5	70.7	71.0	70.2	69.4	68.5
Median	67.9	67.9	67.9	67.9	68.0	68.9	69.6	70.1	70.2	69.6	68.8	68.2
Mean	67.9	67.9	67.9	67.9	67.9	68.8	69.5	70.1	70.2	69.6	68.8	68.2
95% Exceedance	67.9	67.9	67.9	67.9	67.9	68.0	69.0	69.6	69.7	69.1	68.3	68.0
Minimum	67.9	67.9	67.9	67.9	67.9	67.9	68.6	69.2	69.3	68.9	68.1	67.9

Table 9. Reduction in water levels in Phapheng channel at Thakho gauge when DSHP is operational, based on DF modelling with DSHP operating

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Maximum	-0.9	-1.0	-1.1	-1.2	-0.3	-0.2	-0.2	0.0	0.0	-0.5	-0.6	-1.0
5% Exceedance	-1.0	-1.0	-1.0	-1.1	-1.0	-0.4	-0.3	-0.2	-0.1	-0.3	-0.6	-0.9
Median	-1.0	-0.9	-0.8	-0.8	-1.0	-0.8	-0.6	-0.5	-0.4	-0.5	-0.8	-1.0
Mean	-1.1	-0.9	-0.8	-0.8	-1.0	-0.9	-0.7	-0.6	-0.4	-0.6	-0.8	-1.0
95% Exceedance	-0.8	-0.7	-0.6	-0.5	-0.7	-1.0	-0.7	-0.6	-0.5	-0.6	-1.0	-1.0
Minimum	-0.8	-0.6	-0.5	-0.4	-0.6	-0.8	-0.9	-0.7	-0.6	-0.6	-1.1	-0.9

Note: the table shows the difference in values between Tables 7 and 8.

Table 9 shows that the water level with the DSHP power plant operating will be reduced by the greatest amount during the dry season, with typical (median) reductions in water level of 0.8 – 1.0 m, and the largest reduction being about 1.2 m for maximum levels in April. Wet season levels will be less affected, with typical (median) reductions of 0.4-0.8 m. As is evident from Figure 15, during wet years (which will be more similar to the 5% exceedance), it can be expected that there will be less variation in level from baseline, conversely in dry years (which will be more similar to the 95% exceedance), there will be a more sustained and apparent effect of the reduced flows.

These changes in water levels will likely have the most impact on the aesthetics of the Phapheng falls during the dry season. This may have some social and ecological implications, which are discussed in Section 4.

As shown in Figure 9, at a water level of 69.2 masl, the deepest part of Phapheng Channel at the Thakho gauge is 6 m deep. So at the lowest predicted water levels of 67.9 masl, at this cross section the deepest point would be 4.7 m, and the water surface would still extend across the 420 m wide section.

Phapheng Channel has not been precisely mapped, but the upper section (above the falls) becomes generally shallower with numerous rocky islands in about one third of its upper portion (Figure 8). It can be expected that a water level decrease of about 1 m compared with background will lead to a greater exposure along the channel's edges and exposure of more rock bars and islands in that section. Downstream of the falls, the channel is relatively deep and narrow for about half the distance to the junction with the main Mekong Channel (Figure 2), so water level decreases will be greater than above the falls (as discussed below), but because of the steeply incised nature of the channel there will be limited exposure of additional banks or islands. Closer to the Mekong-Phapheng confluence, the backwater effect (which will include Sahong baseline flows plus diverted flows) will tend to limit any water level changes, and at the confluence water levels should be the same as predicted by the DF modelling without any dam.

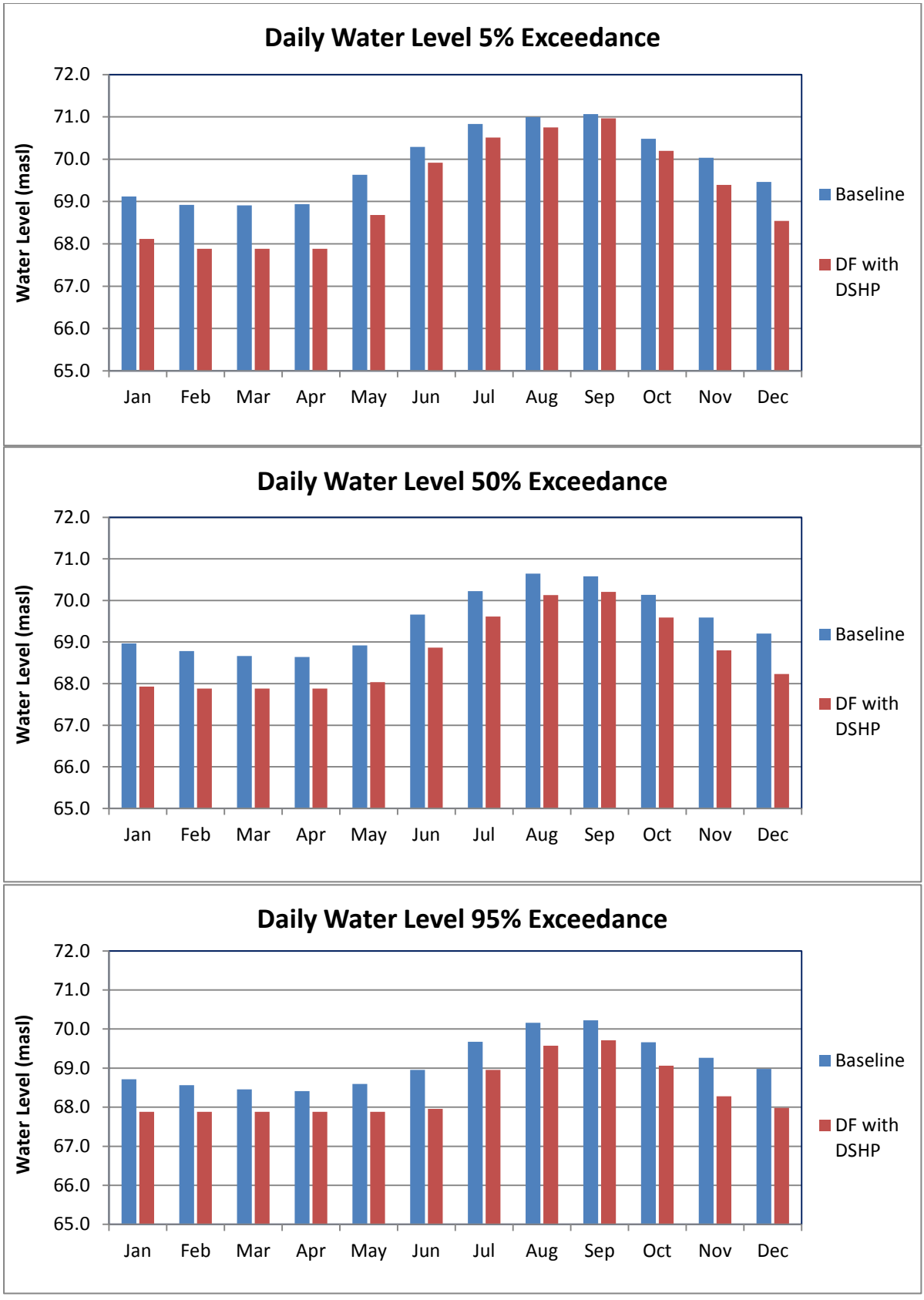


Figure 15. Phapheng Channel at Thakho, water levels at 5, 50 and 95 percentile values (masl), comparing baseline with predicted values (DF) with DSHP operating

3.7 Water level and velocity changes at Phapheng Falls

The appearance of Phapheng Falls changes greatly during the year as shown in Figures 16 to 19. Directly upstream of the falls (and downstream of Thakho), the channel width is about 450 m, whereas downstream of the falls the channel width is only about 150 m, which leads to greater annual water level variation downstream of the falls where the flow is confined to a narrower channel. Upstream of the falls, average water levels vary by up to 2 m during a year, whereas downstream of the falls water levels vary by up to 6 m. So the drop over the main falls (or the height of the falls) varies from about 4 m during the annual flood peak, to about 8 m during dry season flows. Section 3.6 provides a more precise description of water levels upstream of the falls.

Figure 16. Phapheng Falls on 5 March 2010 at a flow of 980 m^3/s
From a presentation by CNR and EDL on 21 April 2011 "Thakho Hydropower and Tourism Development Project. The appearance at the minimum flow of 800 m^3/s will be similar to this photo.

Figure 17. Phapheng falls during peak wet season flows
Undated image from the Thakho project Mid-term Workshop presentation in 2010, by Compagnie Nationale du Rhone and EDL Lao.

To quantify and illustrate the difference in water level variation above and below the falls, a simple hydraulic calculation was carried out for two flows: the minimum flow of 800 m^3/s and a flow of 1,600 m^3/s (which is approximately the baseline median flow

during the driest months of March and April – see Table 1). The water level difference between the two flow conditions is predicted to be 1.2 m upstream of the falls and 2.4 m downstream of the falls. A decrease in flows from 1,600 to 800 m^3/s will therefore lead to an increase in the drop (or height) of the falls by 1.2 m (i.e. 2.4-1.2). The appearance will be similar to that shown in Figure 16, which can be compared with the appearance of the falls during flood flows in Figure 17.

Figure 17 also shows how Phapheng Falls becomes a series of cascades and rapids during the peak of the wet season. During the dry season the falls are higher because of the greater difference in the head- and tail-water levels as discussed above; moreover the water is clean and clear as in Figure 16. Once the DSHP is operational the dry season appearance of the falls, similar to that in Figure 16, will be extended for a further 1-2 months and the height of the falls will be greater than at present, as discussed above.

It should be noted that the reduction in flows to 800 m^3/s will disproportionately affect the shallow lateral channels compared with the main central channel which is the centrepiece of the view from the visitor centre viewing platform where the photos in Figures 16-19 were taken.

For comparative purposes, Figures 18 and 19 show two views of the falls at low to intermediate flows.

Figure 18. Phapheng Falls on 19 April 2006 at a flow of 1450 m^3/s

Figure 19. Phapheng Falls on 19 January 2007 at a flow of 2300 m^3/s

As well as discharge and water level as discussed above, mean velocity of water is an important parameter which was estimated using simple hydraulic formulae. The mean velocity of water (or speed in a downstream direction) under the two flow conditions (1600 m^3/s and 800 m^3/s) upstream of the falls will be about 1.8 m and 1.4 m respectively (a difference of 0.4 m/s), and downstream of the falls will be about 2.5 and

2.0 m respectively (a difference of 0.5 m/s). So downstream of the falls mean velocity is faster than upstream, and the decline in mean velocity at minimum flows will be slightly greater downstream of the falls. While absolute values of velocity will vary, these relative upstream/downstream differences near the falls will also apply for most of the length of the channel sections upstream and downstream of the falls because of the general difference in channel width.

4 Social Impacts

Low flows may have some effects on local people's use of the river and also on tourism. These issues are discussed below.

4.1 Effects on local people

Apart from fisheries, the main uses of the river at present are as follows.

- Potable water: local people access the river along the banks in many places upstream of the falls, where they collect water to take to their houses in containers, and where many people also bathe and wash clothes in the river. There is relatively limited direct use downstream of the falls, where the river is relatively inaccessible, except near the Phapheng Falls tourist area and on the west bank near the new access bridge.

- Water is pumped in small quantities in some place for irrigating gardens and for household supply.

- Livestock including buffaloes, cows and goats use the river for drinking and bathing in many places upstream of the falls, and to a lesser extent downstream of the falls near the new access bridge from the west bank.

These uses will not be affected greatly by the predicted low flows, which will still represent a very large amount of water which is well in excess of these local requirements. As current speeds will be slightly less, and the river will be shallower, the river may be considered safer and more useable by people and livestock in places.

River channels at Khone Falls are also used for boat transport of goods and people, and are also an obstacle which must be crossed by people in some places. Phapheng Channel downstream of the falls is not used for transport and it has not been necessary to cross it by boat now since the new access bridge to the dam site was finished in 2015. In any case, most former boat traffic was from Veunkham village further downstream as the lower section of Phapheng Channel is relatively unsafe because of turbulent flows and deep water. Hence there will be no effects on boat traffic downstream of the falls.

Upstream of the falls, people formerly use boats to cross the river from Thakho to access Phapheng village (Figure 1) and from the Resort to access Hua Sadam village, where there were until recently about 15 boats operating for cross-river transport. However after the completion of the new access bridge across Phapheng Channel in 2015 (Figures 1 and 6), all cross-river traffic to Hua Sadam has stopped; and there has been some decline also at Phapheng Village where only a few boats each day cross the river for access. The river channel between Thakho and Phapheng is about 420 m wide and 5 m in depth, with no near-surface rock bars during the lowest flows at present. At reduced flows the current will be slower, which would be beneficial for crossing, and the river depth will remain more than adequate for boats. Upstream in Phapheng Channel near the resort there are numerous shallow rock bars near the surface which must be avoided by boat drivers crossing the river. Reducing levels by up to 1.2 m would cause more exposure of these bars, but at the same time the speed of the water

will be less, so navigation would not be greatly affected. However, as mentioned above, navigation effects are not an issue in this upper section because virtually all transport to Hua Sadam Village is now via the new access bridge, or by boat from Nakasang or other islands upstream via channels which will not be affected by low flows in Phapheng Channel.

Apart from transport and the need to cross river channels, the main use of boats in the Khone Falls area is for fishing, with about 20 boats routinely used by fishermen in the affected section of Phapheng Channel upstream of the falls and about 5-10 boats used downstream. The water level and flow reductions are expected to make operation of fishing boats easier.

In summary, it is considered that reduction in flows in Phapheng Channel is not likely to significantly affect people's direct use of the river, as the channel will continue to be well in excess of local requirements. Boat crossing of the river has reduced greatly since the new access bridge was opened in 2015, and any effects on the continuing cross-river traffic to Phapheng Village and on fishing boats are likely to be slightly positive, as current speeds will be slower.

4.2 Effects on tourism

4.2.1 Introduction

Tourism has increased dramatically in Lao PDR over the last decade and is now one of the country's most important industries. Broadly speaking, tourists comprise two main groups.

- Foreigners come mainly from Europe, North America, China and Australia/New Zealand, but also increasingly from ASEAN countries. Most foreign tourists visit Lao PDR during December, January or February, when the weather is cool and dry and coinciding with the northern hemisphere winter, the Australian summer, and annual holiday periods.

- Lao and Thai tourists also travel during the dry season, with a peak comprising many people who take holidays in April during the Lao/Thai New Year (Pii Mai).

As a result of these general visitation patterns, most tourists to southern Lao PDR (including the Khone Falls area) also visit during the dry season months.

Table 10 provides some indication of the overall level of direct economic activity related to tourism in Khong District, which includes Khone Falls. Based on these data, Phapheng Falls directly supports up to about 10% of the tourism income in the district.

Table 10. Tourism facilities and services in Khong District in mid-2015

Facility or Service	Khong District	Phapheng Falls
Hotels	36	1
Guesthouses	76	6
Resorts	3	0
Restaurants	150	16
Boat operators	148	12
Bus/taxi operators	34	5
Tour Guides		5

Notes: Data was provided by the Information, Culture and Tourism Office of Khong District. In Nakasang, taxi/bus station is registered in provincial level.

Figure 2 shows the main tourist attractions at Khone Falls. These include: (1) the island of Don Det where many tourists stay and from where they visit other areas; (2) the Somphamit Lee Pee waterfalls, (3) Khone Pa Soi waterfalls indicated by KPS in Figure 2 (4) the dolphin pool where five Irrawaddy dolphins currently live, and (5) Phapheng Waterfalls. There are also steam engines at Ban Don Khone and Ban Hang Khone which are remnants of a colonial-era railway line built between a wharf at Hang Khone and Don Det, as well as an historic bridge at Ban Don Khone. The Don Sahong dam site since completion of the new bridge across Phapheng Channel in 2015 (Figure 2) has also become a tourist site, with many people visiting daily to observe and photograph the construction works. Of all of these local tourist attractions at Khone Falls, only Phapheng Falls will be affected by the low flows in Phapheng Channel. Hence, because there are many other attractions at Khone Falls and regionally, it is unlikely that any changes, whether positive or negative, at Phapheng Falls will on their own significantly affect tourism to this area or within Champasak Province or elsewhere in southern Lao PDR.

The effects of the low flows on tourism at Phapheng waterfalls itself are considered in more detail as discussed below.

4.2.2 Direct effects of flow changes on tourism at Phapheng Falls

A significant aspect of the visual appeal of the falls is their height when viewed from the tourist area. As a result of the low flows the falls will appear slightly higher during dry season months as a result of the difference in channel width above and below the falls which leads to greater water level variation downstream of the falls, as explained in Section 3.7. A second factor is the volume of water passing the falls; while there will be some loss from the main central falls, the loss will be disproportionately from the shallow lateral channels, so in the dry season Phapheng Falls will continue to be spectacular and impressive, so will continue to be visited by first-time tourists to Khong District.

The dry season appearance of the falls will be extended for a further 1-2 months and the height or drop of the falls will be greater than at present, as discussed above. Therefore, it is possible that the reduced flow will improve the visual appearance of the falls and will increase the length of the viewing period, which might extend the period of favourable viewing by tourists.

It should also be noted that during the dry season the water is relatively clean and clear, which is probably more attractive to most people than the appearance in the wet season, and water clarity is not likely to be affected by the reduced flows at the falls.

4.2.3 Local opinions on the effects of low flows on Phapheng Falls

In July 2015 field interviews were conducted with the manager of the Phapheng Falls visitor centre and with three restaurant owners. The interviewees all reside at Thakho village, as do most of the people who work at the falls.

The falls were formerly open for free visitor access, but since early 2013 Nying Sok Sai company has had a concession to manage and improve the visitor area and collect fees from tourists. The manager of the visitor centre provided useful general information on tourism as well as his opinion about the possible effect of flow changes. During 2014 there were 276,152 fee-paying visitors to Phapheng Falls and 203,055 visitors to Somphamit Lee-Pee Falls, which is also managed by Nying Sok Sai company (see Figure 2 for locations). About two thirds of visitors were foreigners and about one third were Lao tourists. Currently (2016) the daily entrance fee to Phapheng Falls is 55,000 Kip for foreigners and 20,000 Kip for Lao tourists, whereas at Somphamit-Lee Pee the entrance fee is 50,000 Kip for foreigners and 5,000 Kip for Lao tourists. So the entrance fee income alone is about US$1 million per year at Phapheng Falls and US$600,000 per year at Lee Pee-Somphamit Falls. In addition there are several restaurants and clothing/souvenir vendors operating at each location. Tourists visit mainly between December and June, with a peak in April during Lao/Thai New Year. As well as visiting Phapheng Falls, many of the tourists visit other local attractions, including those mentioned above; and may also visit other regional tourist areas north of Khone Falls, including Khong Island, Hin Sieu village, the Bolaven Plateau and Wat Phou. The manager at the Phapheng Falls visitor centre felt that very high river flows could cause erosion and possible damage to some of the facilities such as viewing platforms, but also said that flood flows tend to attract some tourists to safely view the spectacle. He did not think there would be any effect of low flows after the general visual effects were explained.

The three restaurant owners (all women) interviewed at Phapheng Falls together provide seating for up to 730 customers and employ seven full-time staff and others casually, depending upon daily requirements. They all confirmed that most tourism is generally during the dry season between December and April, with more foreigners visiting in December-February, the coolest season; whereas there is a peak of Lao and Thai tourists around the Lao/Thai New Year in April. Two of the owners felt that changes in flows would have no effect on tourist numbers, and one owner felt that if there was less water there could be fewer tourists, and also that high water has no effect on visitor numbers. She mentioned as a separate issue that she believed that the existing entrance fees were too high and were affecting the number of tourists visiting Phapheng Falls. This view is certainly valid for local people, many of whom would probably visit the area repeatedly to eat at the restaurants or to pray at the new temple, but are likely dissuaded by the entrance fee.

4.2.4 Overall assessment of the effects on Phapheng Falls and mitigation measures

After DSHP begins operating Phapheng Falls will continue to be an impressive spectacle and tourist draw-card in all seasons, despite any effect of low flows. Phapheng Falls is just one of many regional attractions which are visited by tourists, for which numbers at present continue to be on an uptrend, so it is unlikely that changes at the falls on their own will have any wider effects on tourism, either positive or negative.

Because of entrance fees and the lack of any specific recreational activities, most tourists probably only visit Phapheng Falls once, despite the construction of a temple and improved restaurants and cafes by the operator. So the current business depends upon maintaining new arrivals to Lao PDR and also the continuing rise in living standards which allows Lao people to enjoy travelling and visiting tourist sites such as the falls for the first time. Any future declines in visitor numbers at the falls would most likely reflect a decline in new visitors to Lao PDR, or a decline in first-time local tourists, rather than any change in flows at the falls. Therefore to maintain and improve the business would probably require the operator to invest in supplementary attractions at or near the falls, while at the same time conserving their unique and natural appearance as the primary attraction. In this overall context, the effect of any flow changes at the falls can be considered as minor or insignificant.

Given that the impacts on tourism are not considered likely to be significant, there is no requirement for direct mitigation by DSPC. However, as an offset or compensation for any possible changes in tourism at Phapheng Falls, it should be considered that the new access bridge has already significantly increased tourist access to the islands, with many day trippers from Lao PDR already visiting to view the dam-site construction works and to see the islands. The Don Sahong Dam and reservoir will become significant tourist attractions, which will require ongoing management and investment.

5 Ecology of Phapheng Channel and low flow impacts

5.1 Low flow impacts on aquatic systems

5.1.1 Effects on aquatic productivity and habitat for fish

The total extent of Phapheng Channel in which there will be reduced flows is about 340 ha; the area upstream of the falls is about 210 ha (4.2 kmx0.5 km) while the area downstream of the falls is about 130 ha (4.4 km x 0.3 km). In a regional context, the area of habitat within the channel is small, but it is locally important for the production of fish food organisms, including algae, aquatic insects and shrimps. In general, the productivity of natural water-bodies is correlated with their area, so any reduction in area can be assumed to have a proportional effect on productivity, in the absence of any specific information. The upper section of Phapheng Channel is rocky with sandy banks. The baseline seasonal water level variation of about 2 m causes very little (~5-10%) change in the surface area of the water; the main effect is that small rocky islands emerge from shallower areas in the section upstream of the falls[1]. Downstream of the falls the river is very deep with steep banks, so there will be little downstream effect on surface area as a result of the reduced flow. Other factors which could have a positive effect on biological production include reduced current speeds and shallower depths across the channel. Thus it is expected that aquatic production may be higher after the reduction in flows, since flows velocities will be reduced in much of Phapheng Channel which will provide enhanced aquatic habitats for many of the aquatic organisms living there.

The ability of the fishery in this area to cope with flow changes will depend *inter alia* upon the quality and variability of the instream habitat. Bankside or riparian vegetation, especially native trees and bushes, is very important for fish habitat and productivity. So the impacts of any changes to flows could be mitigated by preventing further clearing of bankside vegetation and by replanting bare areas and protecting regrowth from cattle. It is in fact in farmers' interest to maintain such vegetation to protect their fields from lateral erosion, and in any case most farmers are also fishers so they benefit from improved fisheries management. Educating people on the benefits of maintaining riparian vegetation will be an important element in long-term fisheries management.

5.1.2 Impacts on fisheries – current condition of Phapheng Channel

During construction of the DSHPP (2016 to 2019) while the Sahong Channel is blocked by a coffer dam, there will be a minor increase in flows in Phapheng Channel which may cause some increase in the rate of bank erosion as well as some readjustment of vegetation within and alongside the channel. While a certain rate of bank erosion is natural – rivers tend to move laterally over time - accelerating the rate of erosion tends to make a river wider and shallower, with denuded and gently sloping banks, which in general reduces the overall quality of the habitat for fish. Trees stabilise a river's banks and can allow deep holes to scour near the edge, which are good habitats for fish, while woody debris within a river provides important habitat structure. Trees also shelter many kinds of invertebrates that are eaten by fish when they fall or are washed into the river, or when the river rises and inundates vegetation, as well leaves, flowers and fruit

[1] This effect can be seen by comparing Google Earth image from the extreme low flow on 25 March 2010 with other images (e.g. 21 October 2006). There will be little effect on area downstream of the falls, where the river is very deep.

of many kinds of trees and bushes are also eaten by fish (Phylavanh and Baird, 1999). As a result of cutting of bankside trees, cultivation and grazing by cattle, the banks of the main Phapheng Channel are now actively eroding in many places (Figures 20-22). By contrast, islands within the channel are generally covered by vegetation as they are not farmed and not grazed by cattle (e.g. Figure 23).

After the dam is completed, flows in Phapheng Channel will be reduced, which may affect fish and fisheries in several ways. Broadly speaking, the effects can be grouped as 1) the effects on fish passage into and through this area, 2) the effects on aquatic productivity and habitat for fish, and 3) the effects on fishing activities.

Figure 20. Lee traps and luang khang require a lot of wood – here a large bankside tree has been illegally cut down next to Hou Som Yai for planks

Figure 21. Eroding bank downstream of Phapheng Village

Figure 22. This large tree was undercut when the bank eroded upstream at Phapheng Resort

Figure 23. Islands in Phapheng Channel are generally well-vegetated because they are not heavily farmed nor subject to grazing by cattle

5.1.3 Fish passage effects and mitigation

Large numbers of fish attempt to migrate upstream past the Khone Falls every year at various times for reproduction, feeding or refuge, as discussed in (Baran et al., 2005). Fish become easier to catch where they accumulate below barriers or while passing through shallower sections of the channels which cross the fault line. These migrations are heavily targeted by local people making them extremely important for supporting local livelihoods, while those fish that are not captured maintain regional fish stocks. The effect of reduced water levels in Phapheng Channel in the absence of any mitigation would be to reduce the flow down Sadam Channel and down the smaller channels immediately to the west of Phapheng Falls (Figure 2) which include Hou Som Yai and Somphordan Channel. These channels are all important for fish passage.

Figure 24. Sadam Channel on 20 Jan 2016, looking upstream
Sadam is an important channel for fish to bypass Phapheng Falls

Hou Som Yai and other small channels near Phapheng Falls are currently blocked by many illegal traps during all migration periods (e.g. Figure 25 and 26) so few fish can pass, whereas the upstream entrance of Sadam Channel was enlarged by DSPC in 2013 and it now passes many fish throughout the year, although illegal fish traps obstruct fish passage and are an ongoing problem.

Figure 25. Downstream entrance of Hou Som Yai, blocked by a fence and lee trap

Figure 26. Further upstream in Hou Som Yai, 3 lee traps and 2 luang khang traps with fences block fish migration

As part of the FishMAP, Xang Pheuak Channel, Sadam Channel and Som Yai - Somphordan Channel are to be progressively improved for fish passage by eliminating large illegal fishing gears and by physical measures to improve the pathways for migrating fish. To mitigate the effect of lower flows, the main measure will be to excavate the upstream entrances of these channels (as part of the FishMAP for the construction phase) to maintain attraction flows and adequate depth for fish migration.

With the DSHP operating, Xang Pheuak Channel flows should be at least equivalent to baseline flows. For Sadam Channel, as well as maintaining baseline flows, a minimum flow of 10 m^3/s should be maintained as discussed by SMEC (2015). Som Yai/Somphordan Channels are being improved during the construction phase, which should include consideration of flows needed after the DSHP is operational.

5.1.4 The effects on fishing activities

Most of the main Phapheng Channel is deep and fast so it is relatively difficult to fish. With reduced flows in the dry season it is likely that there will be more fishable areas such as shallow backwaters behind islands in the upper part of the section upstream of the falls (Figure 8), with relatively little change downstream where the channel is deeper. Fishing pressure in Phapheng Channel may increase, as people who formerly fished in Sahong Channel seek other opportunities. The removal of large fishing gears from Sadam Channel and Hou Som Yai is also likely to result in more fish successfully migrating upstream through these channels to reach the upper Phapheng Channel above the falls, which will also tend to encourage more fishing in that area. Such an increase in fishing pressure should be mitigated by providing alternative livelihood opportunities, alternative sources of fish or other protein foods (through aquaculture and farming) and by restricting the use of large illegal gears so that the benefits of the fishery can be available to the entire community. These measures are already included in the ESMMP for the construction phase under livelihood replacement measures and under the Don Sahong Fisheries Management Plan (DSFMP), which is the responsibility of a committee which includes GoL agency staff, DSPC staff and local community representatives.

5.2 Terrestrial flora and fauna

The EIA for the project included assessments of flora and fauna near the dam site (NCC, 2013). Large proportions of Sahong and Sadam Islands have been significantly disturbed by conversion of forest into agricultural land (mainly rice fields) and by forest burning and by hunting. In the remnant forest areas most large trees have been cut down, with only small trees and shrubs remaining in most areas of the islands. Wildlife has been and is still intensively hunted by people who live on the islands, with several recorded species now extinct on the islands and the remaining wild animals now rare.

These general observations can be extended to the affected area of Phapheng Channel, where the banks have been cleared and are eroding in several places upstream of the falls (as is an ongoing problem in the region) and where terrestrial wildlife is uncommon; any animals which might live along the river are under constant threat from hunting. Birds are more common than terrestrial animals, and some species can be seen regularly on or near Phapheng Channel and other river channels at Khone Falls.

These riparian birds include resident fish eaters such as egrets (*Egretta alba* and *E. intermedia*) and bitterns (*Ixyobrychus* spp.), as well as birds which migrate into the Khone Falls area following schools of fish during the dry season; these include cormorants (*Microcarbo niger* and *Phalacrocorax carbo*) and the Oriental darter (*Anhinga melanogaster*). Some other birds migrate seasonally into the area to feed upon adult aquatic insects after they hatch during the dry and early set seasons and swarm near the river; these birds include swallows (*Hirundo* spp.) and drongos (*Dicrurus marcrocercus* and *D. remifer*) and the drongo cuckoo (*Surniculus lugubris*).

After the flow and level changes there will still be adequate water in the Phapheng Channel at all times relative to the limited requirements for birds and wildlife, so impacts of the low flows are likely to be insignificant in comparison with the ongoing impacts of habitat degradation and hunting, which are widespread in Lao PDR and regionally. Such impacts are outside the control of DSPC, as the responsibility for implementation and enforcement of forestry and wildlife laws lies with GoL agencies. However, DSPC should assist within its concession area by education and enforcement among its own staff and contractors near the dam itself.

6 Conclusions and recommendations

The general conclusions of this report and the recommended mitigation and management measures required in updated versions of the ESMMP are summarised below.

Hydrological impacts

Under the new flow regime with DSHP operating there will be a significant diversion of water from Phapheng Channel into Sahong Channel. At the minimum flow of 800 m^3/s the water level in Phapheng Channel will be up to about 1 m lower than at present, with the effect most pronounced during the dry season. There will be little change in the overall surface area of the river, except in the upper third of the section upstream of the falls, where more rock bars and islands will emerge in the dry season. The velocity of the water will also be reduced in the channel relative to baseline, but will remain generally quite fast (> 1 m/s) as the channel is steeply sloping.

Mitigation of hydrological impacts will result from the minimum flow of 800 $^3/s$, which is a reasonable compromise between the needs for hydropower production and the maintenance of environmental and social amenity in Phapheng Channel. It is worth noting that over the next few decades many more dams are planned upstream (MRC 2011), which would lead to further increases in dry season flows, including in Phapheng Channel, thereby incidentally mitigating the effects of low flows. However abstraction for irrigation in Thailand and Lao PDR will also increase, perhaps offsetting these increased flows.

Phapheng channel will be monitored by an automatic water level recording station at Thakho. The water level readings will be converted to discharges and relayed to the DSHP operators, who will then adjust the plant's operations as required to ensure the agreed minimum flow is maintained.

Social impacts

The effects on people's direct use of the river are minor or insignificant and in any case are already being mitigated by construction of the new access bridge and roads and provision of water supply at Hua Sadam Village.

The effects on tourism at Phapheng Falls are likely to be minor or insignificant and are being more than offset by increased tourism via the new access road and bridges.

Impacts on fisheries

A potentially significant effect on fisheries would be reduced flows down fish passage channels (Xang Pheuak, Somphordan-Som Yai and Sadam), which will be mitigated by works during the construction phase to maintain adequate flows in those channels once the plant is operating. Under the adaptive management approach of the DSPC FishMAP, the situation will be monitored for at least 10 years and improvements will be made when and where necessary. The principle is to maintain baseline flows for these fish

passage channels (as a minimum), and in addition to maintain a minimum flow of 10 m^3/s in Sadam Channel.

Reduced flows in Phapheng Channel are likely to slightly reduce aquatic productivity through a 5-10% reduction in the surface area of the channel in the dry season, which is however a minor issue in comparison with ongoing loss of riparian vegetation and overfishing by large illegal gears. Ongoing works under the FishMAP and DSFMP include measures to address those impacts.

Impacts on terrestrial flora and fauna

The low flows are expected to cause minor impacts on flora and fauna, which are insignificant in comparison to the ongoing loss of habitat as a result of clearance of vegetation on the islands and mainland as well as widespread hunting of birds and other animals. DSPC should commit to assist GoL agencies to reduce illegal clearing and hunting within its concession area and to educate its staff and contractors on Lao laws in this regard. The low flows would particularly impact riparian vegetation which is important for controlling bank erosion and providing habitat and food for fish. The FishMAP and DSFMP at present allow for vegetation works along river banks to control erosion and improve fish habitat.

7 References

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Annex A: Terms of Reference for an investigation of the impacts of reduced flow in Phapheng channel

1 Background

In order to maximize the water available in Sahong channel for commercial use by DSHP in generating electricity at the Don Sahong hydropower station, DSHP has proposed a minimum flow of 800 m^3/s over the Khone Phapheng falls to be in effect about 40% of the time and to be monitored by flow gauging station on Phapheng u/s of the Khone Phapheng Falls.

2 Statement of need for and objectives of the proposal

The minimum flow level proposed for Phapheng Channel is based on the aesthetic requirement for viewing the Khone Phapheng Falls, which was identified in the project EIA as the dominant impact. Accordingly the proposed minimum flow was determined by considering and accounting for the lowest flows in the Phapheng channel.
During the period of record from 1924-2009, The lowest flow at the Khone Phapheng Falls as estimated from a Pakse gauge reading in March 2010, was about 800 m^3/s. The second lowest estimated flow of about 1,050 m^3/s occurred in March 1960.
The mean annual flow in Phapheng Channel since records were started is estimated at 2,860 m^3/s based on the correlation with Pakse flows, so the proposed minimum flow equates to approximately 30% of the historical mean annual flow.

3 Purpose and application of the Terms of Reference

The purpose of this TOR is to describe the scope of works necessary to assess the potential environmental and social impacts of 800 m^3/s minimum flow for Phapheng and to develop appropriate mitigation measures where necessary. These measures will be incorporated into updated versions of the project ESMMP and other relevant plans and designs for the DSHP.

4 Applicable policy and institutional considerations

The completion of the study will not be a condition precedent for the signing of the Annex I to the Don Sahong Concession Agreement between the Developer and the GoL, which was still under negotiation in June 2014, but will form the basis for the binding obligation of the Developer to the GOL to comply with relevant mitigation measures.

5 Scope

The potentially affected area for the purpose of the study is preliminarily defined as the section of Phapheng from the upstream mouth of Sahong to the confluence of Phapheng and the main Mekong channel downstream, which is a distance of approximately 10 km. See Figure 1. The Consultant shall review and consider whether this preliminarily defined study area is appropriate. If found inappropriate, the Consultant shall immediately so inform DSPC and MONRE together with the reasons for it being inappropriate and proposed alternatives that would be more suitable.

6 Assessment of impacts

The task is to assess the environmental and social impacts that could arise from the reduction in the dry season flow in Phapheng to a minimum flow of 800 m^3/s.

7 Location of the study

Study area or impact zone(s) is the Phapheng channel and the communities of Thakho and Ban Don Phapheng who may be affected.

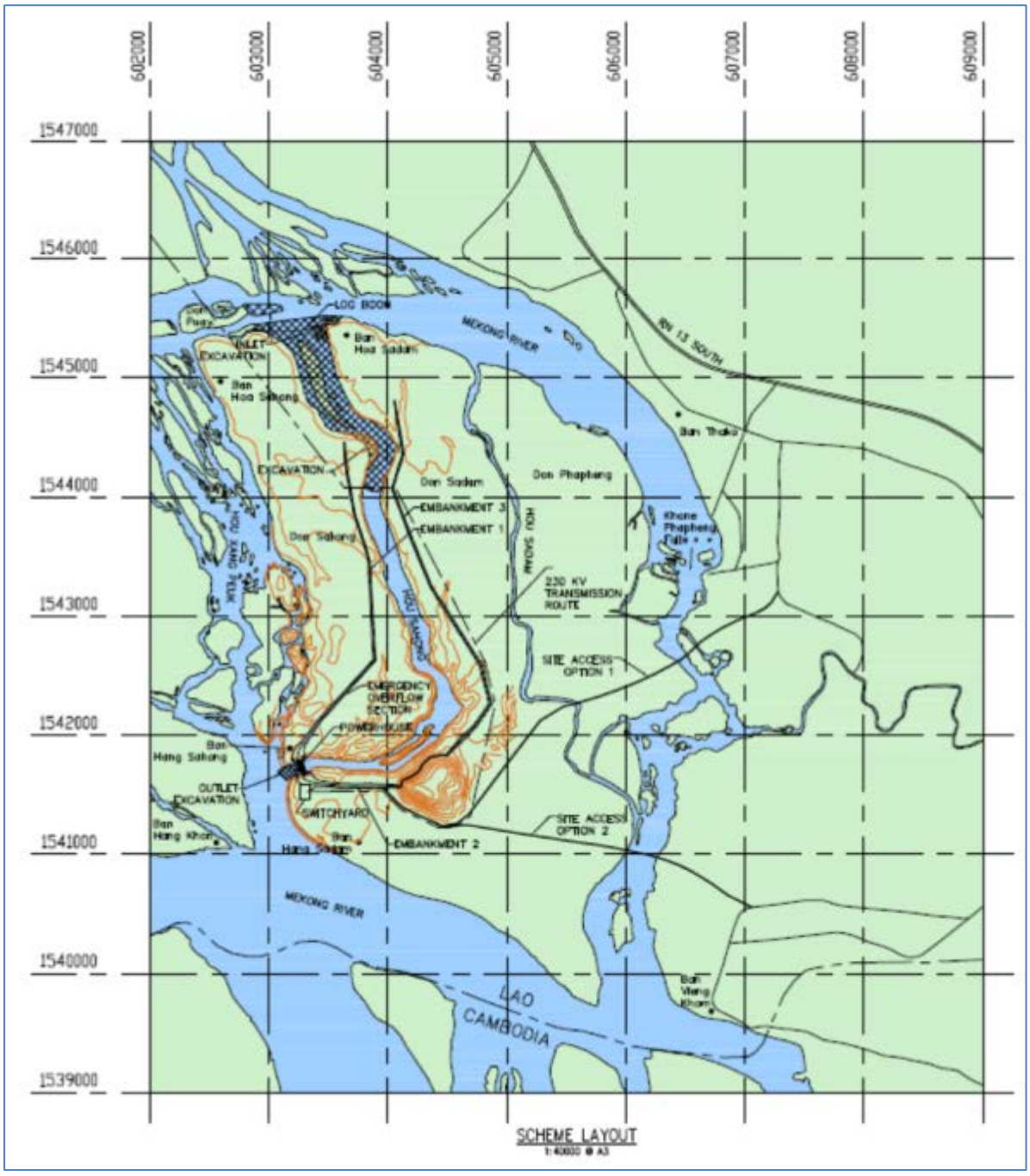

Figure 1. Location Map of DSHP Layout showing Phapheng Channel to the east

8 The studies to be carried out

The variation in the flow regime due to the project should be based on the information provided in the EIA 2013 (NCG, 2013), the Engineering Status Report (AECOM, 2011) and the report on downstream transboundary effects (SMEC, 2013).

Impacts on fisheries should anticipate complete closure of the trap fisheries in the small channels on the western side of KPP Falls. This fishery has been monitored for 20 years

by MRC fisheries program. The Developer expects to close these fisheries and compensate the fishers as part of the program to improve fish passage across the Great Fault Line.

The hydrological changes within the channel system due to the project operation should be derived from documentation prepared by the Developer and available on the DSPC web site (dshpp.com).

Social and environmental impacts from the documentation prepared by the Developer and available on the DSPC web site (dshpp.com) plus site visits, including discussions with experts of various agencies, collection and review of all relevant ecological data. In addition, DSPC will make available, periodically and at any time upon the request of the GOL, all data including remote sensing data (satellite images, aerial photos), hydraulic and hydrological data and modelling that DSPC and its consultants have gathered.

The Consultant shall also consider reliable data and information available from other sources including the Thakho Hydropower Project: http://www.thakho-sustainablehydro.com
The Study shall:

- Identify and characterize the existing flow dependent ecological and socioeconomic / livelihood assets with focus on low flow season flows
- Develop conceptual models between flows and ecological and socioeconomic / livelihood assets with focus on the low flow season flows
- Set management objectives for each asset and process
- Identify and assess and quantify the impacts and their significance on the ecological and socioeconomic / livelihood assets likely to be caused by the 800 m^3/s minimum flow
- Develop mitigation measures for any significant impact identified (this may include proposing alternative environmental flows rules) and assess the residual impacts
- Develop a monitoring program with indicators representing the potentially impacted assets.

The Consultant shall apply internationally recognized methods in environmental flow assessment.

8 Study Plan and Reporting

The Consultant shall familiarize himself / herself with the study subject and prepare a Study Plan with methodology and schedule of activities. The Study Plan shall be submitted to DSPC and MONRE within ten (10) days of contracting.

DSCP and MONRE will provide the Consultant with their mutually agreed revisions to the Study Plan and inform the Consultant to commence the work.

The Consultant shall submit all findings and reports - whether preliminary or final - to both DSPC and MONRE at the same time.

9 Timing

The desk top component to commence in late 2014 and the field component to be undertaken during the low flow period of January – April 2015.

10 Who will do it?

To be conducted by individuals or company with proven knowledge and experience in environmental impact assessment related to river hydrology and fisheries and in social impact assessment. The developer proposes the study will be led by an independent consultant (see CVs attached) with Lao social survey support staff, possibly from the Mekong Development Centre.