Mekong River Commission

Information and Knowledge Management Programme
Component 4: Modelling

Review of the Hydraulic Study for Discharges from the NT2 Regulating Pond and Impacts on the Xe Bang Fai

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Contents Amendment Record

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Abbreviations and Acronyms

BDP	Basin Development Plan Programme of MRCS
COD	Commercial Operation Date
DC	Downstream Channel
DC1	Downstream Channel between regulating pond and point below tunnel
DC2	Downstream Channel from DC1 to junction with XBF
DSF	Decision Support Framework (modelling system at MRCS)
EdL	Electricite du Laos
EGAT	Electricity Generating Authority of Thailand
MRC	Mekong River Commission
MRCS	MRC Secretariat
MT	Modeling Team at MRCS
NMC	National Mekong Committee
NT2	Nam Theun 2 Hydropower Project
NTEC	Nam Theun 2 Electricity Consortium
NTPC	Nam Theun 2 Power Company Ltd.
PICCO	Phannita Irrigation Consultant Company Limited
POE	Panel of Experts
PPA	Power Purchase Agreement
TSD	Technical Support Division at MRCS
UNDP	United Nations Development Program
XBF	Xe Bang Fai River

Glossary

Annual recurrence interval (ARI)	The average annual rate of occurrence of an event and is equal to 1/(exceedance probability)
Dispatch schedule	Discharge released through NT2 turbines to meet electricity demand.
Downstream boundary	Usually an input water level time series that forces the model to use this value at the downstream end of the model. Can also be a rating curve
Electricity demand	The amount of electricity consumed at any moment. Consumers "demand" that electricity is generated when they need it.
Load	The amount of electricity currently produced in the system. Unit MW.
Load factor	Ratio of mean flow to turbine capacity
Marginal cost	The cost of producing one additional kWh at the current load. Unit: US cent/kWh or USD/MWh
Rating curve	A single-valued curve relating a specific discharge to a specific water level in a specified cross-section
Spill	Water released from dam bypassing turbines. Water is released through spillways or gates during flooding periods when inflow is greater than turbine capacity and dam is full
Steady flow	The discharge is unchanged in time in each cross-section
Unsteady flow	The discharge varies with time in the cross-section
Upstream boundary condition	Usually an input flow time series that "drives" the model
Water Level Fluctuation	Variation of the water level during a limited period of time, for example one week
Water Level Increase	Difference between pre-project water level and water level under NT2 operation, under the same natural hydrological conditions

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1 Summary

This is a review of the NTPC report “Simulation of Flow Releases from Regulating Dam”, model and simulation results, from 2006. The NTPC report has been reviewed with respect to:

- Software used;
- Model schematization;
- Input data (topography, cross-sections, structures, boundary conditions, model coefficients);
- Calibration process and accuracy;
- Dispatch schedule and release from regulating pond;
- Model results, with emphasis on fluctuation of water levels; and
- Comparison of model results with previous estimates.

The review was based on the model input data files, reports and information supplied by NTPC. Information on the electricity demand in Thailand, used to evaluate the plausibility of EGAT dispatch schedules, was obtained from internet sources. Model results were re-run as checks, and some sensitivity tests were done. A field trip to the modelled area was done to assess the representativeness of cross-sections and structures used in the model setup.

Consultant’s general assessment of the study:

It was found that the model setup, boundary conditions and calibration was satisfactory for the purpose of assessing the Water Level Fluctuations in the river during the dry season.

It was found that the range of release scenarios from the regulating pond was realistic. Thus a weekly fluctuation in the range of 1.5-2.4 m at Mahaxai and 0.9-1.5 m at the bridge on Route 13 is to be expected. Previous estimates (see Ref [9]) give the impression that the variation could even be as high as 5 m at Mahaxai.

Comparing the results of absolute Water Level Increase at Mahaxai and Keng Peng and the tributaries Xe Noy and Nam Phit with the estimates in the Downstream Restoration Program report for the dry season it was found that the estimates in the Downstream Restoration Program report were far to low. The rise in water level at Mahaxai is about 3.2-3.6 m, not 1.5-2 m as mentioned in the report. For Nam Phit the rise is 2 m, not 1-1.6 m, and for Xe Noy the rise is about 4 m, not 1-1.6 m.

Consultant's comments and recommendations:

The consultant has some comments and recommendations, however, it is pointed out that these comments and recommendations do not invalidate the results or conclusions presented in the NTPC report; they are mentioned to increase the accuracy of future results obtained with the model:

1. The NTPC model valid in dry season conditions only; the model setup is not suitable for flooding studies

2. Model and model calibration:

    - It is recommended that some missing cross-sections should be added to sections in the river at two junctions, and that at least one new tributary, Nam Ou La, should be added to the schematization for increased accuracy.

    - The calibration process should be refined, it was found to be somewhat crude. Some caution is required when assessing the absolute water levels obtained by the model due to the coarse calibration.

3. EGAT dispatch and water management of regulating pond:

    - It was concluded that the main uncertainties in the estimate of weekly fluctuations lies in the assumptions of EGAT dispatch during weekends, and of the efficiency of operating the regulating pond. If EGAT chooses to drastically limit dispatch on dry season weekends (including Saturdays) the fluctuation will be higher. On the other hand, it was found that intelligent operation of the regulating dam and good cooperation with EGAT (EGAT gives prior notice when dispatch will be changed) the fluctuations can be reduced. It was found that the software used to optimise the regulation of the pond works quite well, but that it could be optimised to reduce Sunday flow variations. We understand that NTPC is now working towards this objective.

4. Regulating pond release constraints:

   - It was found that giving more flexibility in operation of the regulating pond by increasing the permissible change in flow from 20 m^3/s per hour during the falling stage to 70 m^3/s per hour will decrease weekly discharge variations. However, the effect on bank stability and human safety issues should be taken into account before any changes in operation flexibility are implemented

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2 Introduction

2.1 Background

The Nam Theun 2 (NT2) Hydroelectric Project is being implemented by the Nam Theun 2 Power Company Limited (NTPC) and is located in Bolikhamsai, Savannakhet and Khammouane Provinces, Lao PDR.

The scheme is currently under construction, and will start its commercial operations in December 2009 (COD - Commercial Operation Date).

Water from the Nam Theun will be stored on the Nakai Reservoir, and diverted to the Xe Bang Fai (XBF) after being turbined in the powerhouse located at the foot of the Nakai escarpment. Before reaching the XBF, the water will be temporarily stored in a regulating pond, and then released to the XBF via a 27 km long Downstream Channel.

The storage capacity of the regulating pond is not enough to completely mitigate the expected discharge fluctuation from the turbines especially during the weekends. Several assessments of these fluctuations have been made over the development of the project. The most recent one was carried out by NTPC in October 2006, based on a set of probable dispatch schedules by EGAT. These schedules were translated to upstream conditions for a hydrodynamic model of the hydrographical network downstream of the power house, using the HEC-RAS Software package (hereafter will be referred as the NTPC modelling study).

The largest fluctuations in water level are expected to occur in the dry season when the natural flow in Xe Bang Fai is the smallest and thus the relative change in flow due to hydropower operation will be the biggest. This dry season fluctuation may have consequences on bank stability. The results of the completed modelling indicate that during the most critical period of the year (April) for riverbank erosion, fluctuations are in the range of 1.5 – 2.5 m over the weekend in the upper part of the XBF, and 1 – 1.5 m in the lower regions of the XBF. This is less than the first assessments made a several years ago in the Social Development Plan (SDP), which (i) were based on dispatch from EGAT anticipated at that time, and (ii) did not take into account the dampening effect of the downstream channel and other structures such as the aeration weir and the siphon. The readers are advised to look into the NTPC report (NTPC, 2006) for more details.

External monitors of the NT2 project (including the Panel of Experts – POE) have requested that the hydraulic simulation made by NTPC be independently reviewed. It was agreed by all parties that this task shall be submitted to the MRCS (The Consultant). Subsequently, contract no. C1113 titled "Review of the Hydraulic Study for Discharges from the NT2 Regulating Pond and impacts on the Xe Bang Fai" was agreed by the NTPC and MRCS in July 2007.

The present report contains results of the reviewing work on the NTPC modelling study conducted by the MRCS Modelling Team.

2.2 Objectives of the Study

The primary purpose of the study is to assess the validity of the NTPC modelling including its data representation, model set-up, calibration and verification, and comparison with past studies. The study concentrates on the dry season impact, as the impact of the Nam Theun 2 hydropower station on Water Level Fluctuations is greatest during this time of the year. During the wet season both the relative and absolute impact is smaller. These main objectives are as follows.

- To assess the upstream and downstream conditions in the NTPC modelling study (NTPC assumptions of EGAT dispatch and the resulting releases from the regulating pond, management of the regulating dam, inflows from the tributaries and outflows into Mekong main stream);

- To assess of the NTPC modelling schematization, data input, calibration and verification of the NTPC model between the regulating pond and Mekong river; and

- To analyse NTPC model results, and compare with previous calculations and estimates.

The sources in the NTPC modelling work which are expected to influence the accuracy of NTPC modelling results were also highlighted whenever considered as necessary.

2.3 Outline of Report

This document is written to explain a review analysis of the NTPC modelling work for discharges from the NT2 regulating pond and their impact on the flow in Xe Bang Fai river, considering objectives mentioned above in Section 2.2. The Summary (Section 1) is general and intended to be accessible to policy makers as well as to hydrologic scientists and modellers. The remainder of the report details the critical assessment of the model input topographic and hydrologic data, model set-up and schematization, model calibration, and model output comparisons with measured data and past studies.

Section 2 presents background of the present review study, its objectives and methodology used. The background section introduces the NTPC hydraulic model study which used well-known software, HEC-RAS of the US Army Corps of Engineers, and highlights its most important results. The methodology for reviewing is also described in this section which was designed as close as possible to common international practices.

Section 3 and 4 outline the reviews of the NTPC modelling schematization and assessment of data inputs in a way that one can identify possible sources of modelling unreliability. Section 5 outlines all possible outcomes from studying the NTPC model calibration and sensitivity analysis.

Furthermore, the release of flow from the regulating pond is reviewed extensively in Section 6 which contains also results of discussion with experts from MRCS and NTPC.

Section 7 compares model performance to other modelling studies, critically evaluates some of the model shortcomings and then briefly summarizes future modelling work. Section 8 is the report conclusions and Section 9 lists all references used in the review work.

The Appendix to this document (Section 10) contains supplementary information on the work plan. The affiliations for each work item are also provided to show their qualifications and demonstrate that they are a credible reference.

2.4 *Methodology of the Review Study*

The present review study was based on documents provided by NTPC (model reports, all model input files, design of constructions, impact studies, etc), a field trip 18-20.7.2007 to the Xe Bang Fai, and data and models available at the MRCS. The process of reviewing the NTPC model is described in the following.

- The assessment of the NTPC modelling procedure was based on standard international practices, e.g. modelling guidelines by the US Army Corps of Engineers (USACE) and recent publications in international journals. This step includes assessment of the HEC-RAS package for its hydraulic simulation capacity and the quality of the NTPC modelling team.

- The input data set that was used by NTPC was evaluated for representativeness and correctness. Flow control and diversion structures, especially along the Downstream Channel (DC) in the schematization were also compared with design data supplied by the NTPC. The cross-sections were spot-checked for their dimensions and position using surveyed data. The boundary conditions of flow time series data at upper Xe Bang Fai and its tributaries were compared with DSF simulation and measured data available at MRCS for their representativeness. (DSF = modelling system used at MRCS).

- The set-up files of the NTPC model were compared with NTPC survey data and construction design drawings, data obtained from the field trip conducted during 18-21 July 2007, available data in DSF maintained by the MRCS Modelling Team and impact studies conducted in the past for Nam Theun 2 project.

- For the dispatch schedules and release scenarios two meetings between the Consultant and NTPC were organized to get further insight in the approach used by NTPC. The Consultant has also been able to download some public documents concerning the electricity demand in Thailand;

- The plausibility of the EGAT dispatch was reviewed based on the current daily and monthly electricity demand in Thailand, and the Consultants experience on hydropower operation practices. The Consultant made efforts to look at the operation of the regulating pond during the weekend, trying to check the effect of different dispatch schedules on the release.

- By re-running the NTPC HEC-RAS model, the calibration process was closely looked at. The Consultant made some extra model run tests to find out the effect of improved schematization and some parameter values.

- The results of the NTPC model output were also compared with previous similar modelling studies. Most of the scenarios and all sensitivity tests were re-run to check the output presented in the NTPC report.

Detailed review and assessment of the NTPC will be described in the following chapters.

3 Review of the NTPC Modelling Procedure and Setup

3.1 Modelling Software, HEC-RAS

One-dimensional (1D) flow routing approaches such as Mike 11, ISIS or HEC-RAS, based on the St. Venant/Shallow Water Equations or variations, still form the majority of traditional numerical hydraulic models used in practical river engineering. The widespread usage in practice might be explained not only by the fact that 1D models are (in comparison to higher dimensional models) simpler to use and require a minimal amount of input data and computer power, but also because the basic concepts and programs have already been around for several decades (Stoker, 1957; US Army Corps of Hydraulic Engineers, 2001; Pappenberger, 2005). The HEC-RAS modelling package is the product of US Army Corp of Engineers. HEC-RAS and its predecessors HEC-2 and UNET have long been the industry standard for modelling steady and unsteady flow in rivers and is widely used worldwide (USACE, 1990). HEC-RAS is designed to perform one-dimensional steady and unsteady hydraulic calculations for a network of channels. HEC-RAS solves the mass and momentum conservation equations using implicit finite difference approximations and Preissman's second-order scheme. The computation engine for the HEC-RAS 1-D unsteady flow simulator is based on the USACE's UNET developed by Barkau (1985; USACE, 2002).

For the current NTPC case, which considers only in-bank flows (no flow to floodplains) and uses straightforward boundary conditions, the HEC-RAS software is quite acceptable for determining the Water Level Fluctuations along the river.

3.2 Schematization

The model covers most of the Xe Bang Fai River basin and is divided into 5 major sections to cover the flow from the Upper Xe Bang Fai, Nam Kathang (called Nam Gnom in lower part), Nam Phit, Downstream Channel (DC), Middle Xe Bang Fai, Xe Noy and Lower Xe Bang Fai to the confluence with the Mekong River.

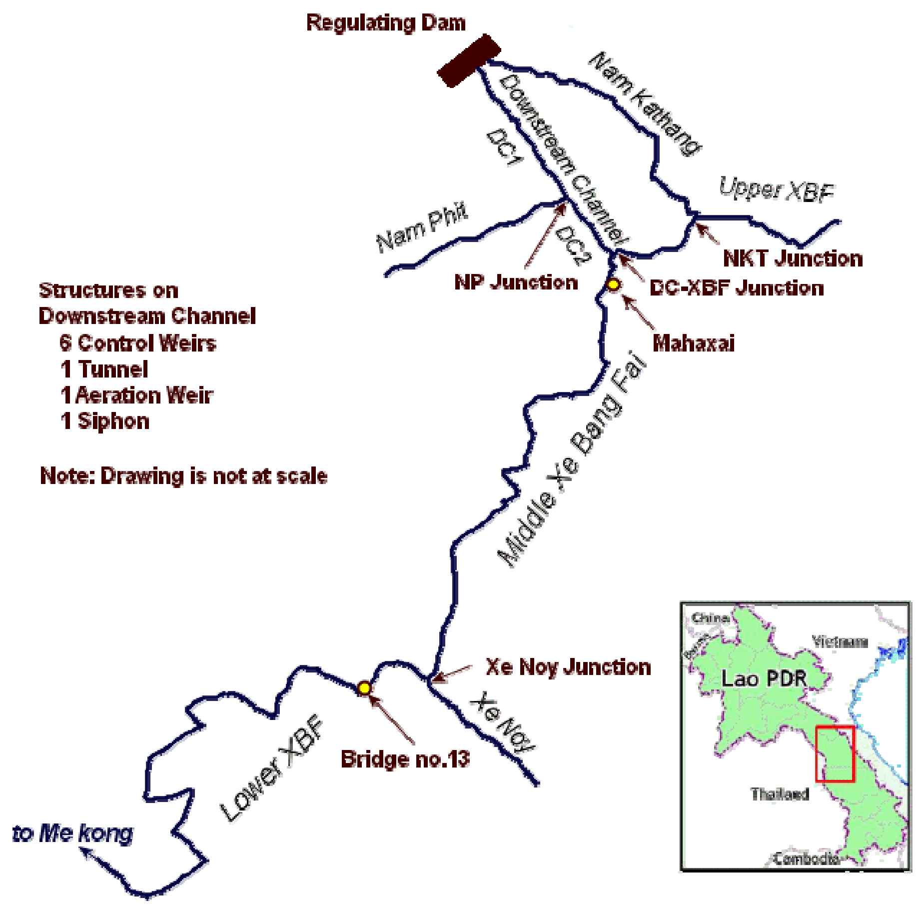

Figure 1 NTPC model general schematization

The major sections in the NTPC schematization are described in the following where the Downstream Channel in the model schematization is divided into two sections (DC1 and DC2).

- The downstream channel 1 (DC1) starts from the regulating dam and then follow the canal through Gnommalat paddy field down to the siphon and then the junction with Nam Phit. There are 40 cross sections, 3 weirs and one siphon and one aeration weir in this reach. No bridge is included in the schematization in this portion of canal. The length of this reach is 19 km

- Downstream channel 2 (DC2) covers the reach from the junction with Nam Phit to the junction of the downstream channel with the Xe Bang Fai (Nam Pith river mouth). There are 20 cross sections and 3 weirs. The length of this reach is 7 km. The tunnel has not been included in the schematization. The spacing between cross section of the DC is 500 m. The data of the cross section and structure are taken from the drawing design of the project. All the cross sections and structures are man-made.

- Nam Phit: This small river also been considered by the model for simulating the impacts of the flow release from the regulating pond. There are a total of 24 cross sections and 3 of them are interpolated cross sections. The spacing interval between the cross section is 500 m. The length of this reach is 11.5 km. No physical structures have been included in this reach.

- Nam Kathang: This tributary is described by 126 river cross sections, 76 of them are surveyed cross sections and 50 cross sections are interpolated. The length of the reach is about 33 km. No physical infrastructure is included in this branch.

- Xe Bang Fai from Ban Na Den down to the junction with Mekong river. Ban Na Den is located approximately 12 km upstream of the junction of Nam Kathang and Xe Bang Fai. From Ban Na Den to the junction with the Mekong River there are 191 cross sections in the model, 56 of them are surveyed cross sections and the remaining are interpolated cross sections. The total reach length is about 175 km.

- Xe Noy: Along the middle reach of the Xe Bang Fai, there are some tributaries that contribute flow to the Xe Bang Fai but only the tributary Xe Noy has been included in the model. It joins the Xe Bang Fai about 9.6 km upstream the bridge of Route 13. Along the Xe Noy down to the junction there are 16 cross section but only 3 observed cross sections and the remaining are thus interpolated. The length of the Xe Noy reach included in the NTPC model is about 7 km.

The surveyed cross-sections have been found being correctly incorporated in the NTPC model. Table 1 presents resume of cross-sections and flow control structures which are planned and those were represented in the NTPC model.

Table 1. Cross-sections and structures planned/included in the NTPC model

No	DC1	DC2	Nam Phit	Nam Kathang & Nam Nhom	Xe Bang Fai	Xe Noy
Surveyed Cross-sections (CS)	43 (from design)	20 (from design)	21	76	56	3
Interpolated	0	0	3	50	135	13
Total no of CS	43	20	24	126	191	16
Checked CS				76	56	3
Weirs	3/3*	3/3				
Tunnels	1/0					
Bridges	2/0				3/0	
Agricultural bridge	3/0	4/0	-	-	-	-
Siphons	1/1					
Aeration Weirs	1/1					
Remarks	Tunnel not incl.			No floodplains	Cross-sections checked	

*NOTE: * number of structures in the NTPC designed channel and number of structures were included in the NTPC HEC-RAS model.*

Two tributaries are missing in the schematization, namely Nam Ou La and one upstream Nam Ou La. Their effect on the overall results may be small but could have been included for completeness, as there are at least 6 cross-sections available from Nam Ou La. Including these rivers would also have given results on the fluctuation along these rivers.

There is a problem with the river junctions in the model. There is an almost 10 km gap between the cross-sections from the bridge of Route 13 to the next upstream cross-section. The junction between Xe Noy and the Xe Bang Fai is situated between these two cross-sections but there is no cross-section at the junction. There is also a gap of more than 10 km between cross-sections downstream and upstream the junction with the DC. Neither of these gaps are included in the model, these reaches are missing from the model setup. These gaps should be included in the model setup, and some (interpolated) cross-sections added. These missing sections will have some, but not significant effect on the final results. A quick check showed that the effect on fluctuation is about 2 cm at Mahaxai and 10 cm at the bridge (fluctuation will decrease if cross-sections are added).

Despite these remarks the model schematization can be considered adequate and sufficiently accurate for the purpose of this study which is concerned with inbank flows, and no flooding of floodplains has to be considered.

3.3 *Conclusions on Model Setup*

With the available information at NTPC and MRCS, the model schematization of the river and channel network and flow structures can be considered satisfactory for the study.

The schematization of the NTPC model does not include two small tributaries (Nam Ou La and one smaller tributary), 9 bridges on the Downstream Channel (DC), and 3 bridges on Xe Bang Fai. The siphon and aeration weir in DC were represented by rating curves derived previously by the head contractors. These simplified representations will not have much effect on the simulation results.

The current model can only be used to calculate the relative fluctuation of water levels during the dry season. For this task the NTPC model setup is sufficiently accurate. It cannot be used for calculating flood levels because of missing sections (total of 20 km) in the Xe Bang Fai, because of the crude calibration of the model and because cross-sections cover only inbank flow. The modelled absolute water elevations in the Xe Bang Fai River are not completely accurate even for the dry season flows due to the uncertainty of friction coefficient values used.

The Consultant checked the effect of the missing 20 km sections from the model on final results by adding interpolated cross-sections. The fluctuation decreased by about 2 centimetres at Mahaxai, and with about 10 cm at the Bridge. The added length to the modelled river gave a greater dampening of the fluctuation compared to the original model. Thus adding the missing sections to the model decreased the fluctuation reported in the NTPC model report.

4 Review of the Input Data

4.1 *Topographical Data*

The cross-section surveys have been conducted for most cross-sections by NTEC mainly in 2002/2003 (in Xe Bang Fai) and PICCO (in Nam Kathang) in 2001. The levelling of cross-section benchmarks was done mainly by PICCO, starting from reference benchmarks from the National Levelling Network. The survey reports do not make an assessment of accuracy of the datum used, but from Excel-sheets produced by the PICCO study indicate that the misclose for benchmarks was in the order of a few mm. The surveys were performed with high accuracy instruments and certified personnel which gives credibility to results of the cross-section measurements.

A field trip to the area 18-20 July, 2007, confirmed that the cross-sections used for Xe Bang Fai appear to be representative for the river and topography. The river looked very regular, with no sudden transitions in width. There is a series of small rapids from Mahaxai and 30 km downstream, from where on the river profile is quite flat. Apparently there are not cross-sections available from the rapids, and their influence is thus compensated by using a high friction coefficient value.

4.2 *River Characteristics and Flow Control Structures*

A field visit to the area showed that the river banks are prone to erosion, with mostly steep banks. There is a stretch on the river downstream Maxaxai with several small rapids, but upstream and downstream of this section the river seemed to flow quite smoothly. The sum-effect of these is that there is little backwater effect from the Mekong River on water levels at Mahaxai. At the Bridge the backwater effect of the Mekong is significant.

The structures (6 normal weirs, one aeration weir and a siphon) in the DC have been correctly incorporated.

The normal weirs have been modelled using a discharge coefficient suggested by the head contractor (ref. IH_NTCO_X_073_352006_A1).

The aeration weir has been modelled as a rating curve suggested by the head contractor (ref. IH_NTCO_X_073_352003_A0).

The head loss at the siphon has been modelled as a rating curve based on tests by the head contractor (ref. IH_NTCO_X_073_352002_A3).

HEC-RAS modelling was used in some of the tests. In reality the siphon is affected by the backwater from the downstream channel, and the obtained rating curve is strictly speaking valid only for steady flows using the same downstream channel dimensions and channel roughness as in the head contractor's tests. For unsteady flows the discharge at the siphon will differ slightly from the values given by the rating curve, but the rate of change in flow in the DC is modest (20 m^3/s per hour at most), so the effect of this will be negligible on the model results further downstream. Furthermore, the flow in the DC was steady for most of the time in the NTPC model runs.

The tunnel in the downstream channel is not included with its tunnel dimensions; the upstream and downstream cross-sections have been used as dimensions. As the tunnel is short compared to the total channel length the omission is not significant. More importantly, the water levels will be controlled by the weirs upstream and downstream the tunnel.

The seven bridges crossing the DC and the bridge on Route 13 are not included in the model, but their influence is probably negligible for the flow range considered in the NTPC study.

4.3 Data for Boundary Conditions

The boundary conditions used in the NTPC model for the scenario runs consists of constant flow input at the DC, Nam Phit, Nam Kathang, Upper Xe Bang Fai and Xe Noy, and imposed water level at the junction of Mekong River and Xe Bang Fai.

The flow to the DC is the assumed release from the regulating pond. The flow for Nam Phit was assumed to be 0 m^3/s (these rivers are almost dry during the dry season), the natural flow in the Upper Xe Bang Fai 15 m^3/s (corresponds roughly to average flow in February at Mahaxai) and the release to Nam Kathang from the regulating pond also 15 m^3/s. The flow at Xe Noy was assumed to be 10 m^3/s. The flow increase between Mahaxai and the bridge just downstream the confluence with Xe Noy corresponds to the assumed ratio of flows at these sites, which is 1.66 according to NTPC. The Consultant could not find a verification of this ratio, but the MRCS calibrated hydrological model gives a ratio of 1.54 between these stations, which is close to the value used by NTPC.

The assumed water level at the downstream boundary at the junction with Mekong River was 129.4 m, which corresponds to typical water levels observed during the dry season.

The boundary conditions used are typical for the dry season months, but no extreme situations with respect to boundary conditions have been considered in the NTPC model report.

For model calibration other sets of data have been used, and they are discussed in Chapter 6.

4.4 Conclusions on Input Data

With the available information at NTPC and MRCS, the model input data can be considered satisfactory for the purpose of the study, which is to assess the weekly fluctuation of water levels in different sections of the river.

The rating curve used for the siphon is accurate only for steady flow, but as the rate of change in flow in the DC is modest (20 m^3/s per hour at most), the effect of this is negligible on the model results further downstream. Furthermore, the flow in the DC was steady for most of the time in the NTPC model runs.

The missing sections and structures in the model schematization may have some minor effect on the model results. Considering shortcomings of the NTPC study with respect to input data, the following recommendations might be useful to increase the accuracy of future simulation studies on impact assessment for Xe Bang Fai river basin.

- Additional flow measurement/monitoring of flows at upstream main stream and at main tributaries of Xe Bang Fai (Nam Kathang and Xe Noy);

- Better topographical surveyed data (cross-section data)

5 Model Calibration, Verification and Sensitivity Analysis

5.1 Calibration Process

The NTPC model has been calibrated by comparing observations from 2 cross-sections, Mahaxai and the bridge on Road 13 with modelled results from the same cross-sections. The calibration was done using 9 different steady flow situations, with assumed flow for each situation. No real observed flow situations have been used, as will be explained below. The discharge at Mahaxai varied between 50 and 657 m^3/s. This range does not cover extreme flood events, but includes mean flows expected in the wet season. Most importantly, it covers the flows in the dry season which are expected from turbine and gate operations. The natural dry season flows are much lower than 50 m^3/s, but presumably NTCP anticipates flows to be at least this amount during operation of the NT2 dam.

The modelled water levels for each discharge at Mahaxai were compared with the water levels acquired from the established rating curve. This procedure is in principle acceptable, though it is unclear from the report how the contribution of discharges should be distributed between the Xe Bang Fai and its tributaries downstream of the calibration point. Nor was the discharge contribution below Mahaxai observed, it was only estimated based on long-term average correlation relationships, whose source was not mentioned.

The calibration at the bridge assumed that the discharge at this point was 1.66 times that of Mahaxai for each flow situation. The coefficient 1.66 is derived from the long-term average flow values at Mahaxai and the Bridge, but no reference is provided. The MRCS calibrated hydrological model gives a ratio of 1.54 between these stations, which is close to the value used by NTPC. Neither is information on how this flow increase is distributed in the model between the Mekong confluence and the Bridge is given, but the model input files reveal that inflow is given only for Upper Xe Bang Fai and Xe Noy for the calibration runs.

It also assumed that the water level at the Bridge (which is used to compare observations with model results) can be directly obtained by correlation with observations at Mahaxai. Furthermore, the downstream boundary water level at the confluence of Xe Bang Fai and Mekong was estimated based on the correlation between observed water levels at the Bridge and at the confluence.

Thus the calibration is done with a long chain of indirect data, assuming average conditions for each situation. No direct observations of flow and corresponding water levels have been used.

The calibration procedure for the Bridge is inaccurate for several reasons:

1. The flow assumed at the Bridge (1.66 times flow at Mahaxai) is an average, based on comparison of mean flows at Mahaxai and the bridge. This ratio may differ for different magnitudes of flow at Mahaxai. How the ratio 1.66 has been derived is not explained

2. The water level at the Bridge used for calibration is an average water level for the corresponding discharge, with a total 2-3 meter range of possible values (range from Table on p. 6 in NTPC Model Report). This makes the "observed" water levels only indicative.

3. The same procedure was applied to the downstream boundary condition at the confluence

4. Only two calibration points were used (Mahaxai and the Bridge)

When only two points are available for calibration the same Manning's friction coefficient has to be used for long river reaches. As the calibrated coefficients differ very much from each other, indication big differences in river roughness properties, more calibration points are desirable to get a more refined description of the river roughness at different sections.

The preferred way to perform a steady state calibration would be to measure the longitudinal water surface profile along the whole river, with water level measurements in several cross-sections during a period with known (observed) discharges for the contributing tributaries. Also, the observed water level at the confluence should be used as a downstream boundary condition. At least two water surface profiles should be measured, and calibration should then be done against these measured surface profiles. The calibration process used for the NTPC model can be expected to give only a crude estimate of friction coefficients to be used.

The calibration process used for the NTPC model can be expected to give only a crude estimate of friction coefficients to be used.

5.2 *Accuracy of Calibration*

The accuracy of calibration at Mahaxai is acceptable, considering the data availability and the range of flows included. The average deviation from observations is about 8 cm. As the discharge contribution from tributaries below Mahaxai is estimated, not observed, this sets limits on what one can expect of a calibration. Using different friction coefficients for different river segments between the Bridge and Mahaxai may improve the calibration, but as there are no reference points for this reach other than the Bridge, no justification for the use different individual friction values can be given.

However, one should note that the deviation at the lower end of the discharge range (50-280 m^3/s used in the model runs) is much larger than the average 8 cm for the whole discharge range. The deviation range in the low discharge end is 4-24 cm with an average deviation of 12 cm. Concentrating on getting the lower end values closer to the observed would have given a more accurate calibration for the discharges actually used in the model runs. A general impression is that the adopted coefficient value n=0.07 is on the high side, but the field visit confirmed that there are several rapids in the river below Mahaxai making the use of a high friction coefficient value more plausible. NTPC has used a n=0.04 from cross-section XBF (Mekong River junction) to cross-section XBF24 (about 30 km downstream Mahaxai).

The accuracy of calibration at the Bridge is very crude, as earlier pointed out, as the model results are not compared with real observations but water levels based on correlations. However, the adopted friction coefficient value, n=0.04, is reasonably close to what one would expect for that river reach, but is maybe also on the high side. Lower values, about 0.03, are used for the mainstream Mekong in applications by MRCS. In the SMEC study of 2004 friction values of 0.025-0.03 were used for the Xe Bang Fai.

For the Nam Ngum tributary values n=0.02-0.04 have been used by MRCS.

Table 2. Comparison of results of Consultant's calibration check using direct observations and NTPC calibration using average data

Place of obs.	*Date*	*Q (m^3/s)*	*Observed H (m)*	*Simulated H (m)*	*Difference sim.-obs. (m)*	*Mekong confluence (m)*
Consultant's calibration check						
Mahaxai	12.7.1996	60.3	142.91	142.92	0.01	
Mahaxai	22.10.1997	136.7	144.10	144.07	-0.03	
Mahaxai	11.9.1996	143.9	144.19	144.16	-0.03	
Mahaxai	20.11.1996	199.2	144.96	144.79	-0.17	
Mahaxai	9.7.1997	341.7	146.37	146.13	-0.24	
Bridge	12.7.1996	80.4	132.85	132.62	-0.25	132.37
Bridge	22.10.1997	271.1	134.06	134.48	0.42	133.33
Bridge	11.9.1996	240.8	136.43	136.14	-0.29	135.80
Bridge	20.11.1996	221.6	133.86	133.50	-0.36	131.95
Bridge	9.7.1997	579.4	136.36	136.60	0.24	134.06
NTPC Calibration Results						
Mahaxai	N/A	50	142.56	142.70	0.14	
Mahaxai	N/A	105	143.56	143.64	0.08	
Mahaxai	N/A	200	144.56	144.80	0.24	
Mahaxai	N/A	280	145.56	145.60	0.04	
Mahaxai	N/A	334.2	146.06	146.06	0.00	
Bridge	N/A	83	132.07	131.62	-0.45	130.88
Bridge	N/A	174	133.52	133.42	-0.10	132.60
Bridge	N/A	332	134.94	135.23	0.29	134.05
Bridge	N/A	465	136.30	136.58	0.28	135.29
Bridge	N/A	555	136.94	137.27	0.33	135.84

The Consultant made a check of the calibration using measured discharge and water level at the Bridge. Discharge measurements at the Bridge were available from the MRCS database, with about 110 measurements during 1996-2002. For Mahaxai the discharge and water level from the records of MRCS for the same day were used. The observed water level at the confluence of Xe Bang Fai and Mekong for these days was also taken from MRCS records. Five separate occasions with different flows were chosen. An effort was made to pick situations when the flows seemed to be more or less stable at Mahaxai, but this was not always possible for the higher flow situations. The Consultant then used the same friction coefficients as in the NTPC study. The comparison of results is shown in Table 2.

It seems that the Consultant's check gives no more consistent results than the NTPC calibration, even though direct observations were used. This is probably due to the unsteady nature of the flows which makes accurate simultaneous observations impossible and which is also not captured by the steady state model calculations. In the light of this the NTPC calibration becomes more acceptable, even if it is crude.

5.3 Sensitivity Analysis

In the NTPC model report the results from a sensitivity analysis of the friction coefficient is presented. It shows that a 10 % change in roughness value will change the computed Water Level Fluctuations with 1-6 % in the river reach of Xe Bang Fai downstream the junction with Nam Kathang. The uncertainty of computed fluctuations will thus in general be about 10 cm for realistic variations of the friction coefficient.

Changing the downstream boundary water level at the junction of Xe Bang Fai and Mekong by -0.7 or +1 m from the baseline case had no influence on Water Level Fluctuations at Mahaxai, and only 1-3 cm influence at the Bridge and downstream from there.

This confirms that the main uncertainty in estimating the downstream fluctuation lies in the estimation of the release pattern from the regulating pond. The uncertainty in the value of the friction parameter makes only a small contribution to the overall uncertainty.

NTPC used a value of 1.0 for the weighting parameter theta in the HEC-RAS model. This adds to the stability of the model calculations, but at the same time it has an artificial smoothing effect on the fluctuations. Normally a value in the range 0.5-0.6 is desirable for increased accuracy. The Consultant re-ran the NTPC scenario 1.2 using a theta-value of 0.6, without encountering any stability problems. Using this theta value increased the fluctuation with 2-3 cm at Mahaxai and at the bridge, and had thus no significant impact on the results, presumably due to the relatively smooth flow changes. However, it is recommended to change the value of theta in future applications for increased accuracy.

6 Dispatch Schedules

6.1 *Turbine Discharge Capacity*

The total turbine discharge capacity of the 4 turbines used to produce power for export to EGAT is 300 m^3/s (can momentarily be 315 m^3/s) and the total capacity of the 2 EdL turbines used for national use is 30 m^3/s. The average load factors as reported by NTPC are 67 % and 48 %, respectively. The mean available flow for the EGAT turbines is thus 216 m^3/s and for the EdL turbines about 15 m^3/s. A load factor of 67% is quite high for a hydropower station.

Due to the large storage capacity of the NT2 reservoir the expected average dispatch from the turbines during the dry season will not differ significantly from that of the wet season. The available storage at the end of the wet season (with a full reservoir in November) is equivalent to approximately 200 days (or 6.6 months) of generation at 67 % load factor (average load factor of the project) not considering inflows. This means that there will be enough water to generate electricity at the 67 % load factor for almost the whole dry season. Therefore an average daily discharge of about 200-230 m^3/s will be expected also during the dry season. The discharge from all turbines will be directed to the regulating pond.

6.2 *Regulating Capacity of the Pond*

The regulating pond downstream the power station will smooth the dispatch variation to a significant degree. The variability of flow downstream the regulating pond will be determined by the dispatch controlled by EGAT and the operation of the regulating pond controlled by NTPC. The volume of the regulating pond is 8 million m^3. There are restrictions on how fast the discharge may be changed: during the rising period the release can change 30 m^3/s per hour at most, and during the falling stage by maximum 20 m^3/s per hour. The discharge released from the regulating pond and affecting downstream flow variation can be estimated using information from Table 3, which shows the regulating capacity of the pond.

There might be a constant release of up to 15 m^3/s from the regulating pond to the Nam Kathang River, which decreases the capacity to regulate the discharge to the downstream channel with the same amount unless the discharge from EdL turbines compensate this flow.

From Table 3 it can be seen that a release of 250 m^3/s can be maintained for almost 9 hours and a release of 50-70 m^3/s during a 32 hour long weekend. The anticipated average flow during weekdays, with 300 m^3/s dispatch during 16 hours and 150 m^3/s dispatch during 8 hours gives a daily average dispatch of 250 m^3/s. Due to the restrictions in release change at the regulating pond water will be "wasted" during the falling stage before the theoretical 70 m^3/s steady weekend flow is reached. There will be less water left in the pond than without any restrictions in change of flow, and will result in a smaller final discharge, maybe 50 m^3/s. From this up to 15 m^3/s to Nam Kathang should be deducted if the EdL turbines do not make up for this deficiency.

Table 3. Maximum capacity of the regulating pond

No	Discharge into or from regulating pond (m^3/s)	Time to fill up or empty pond (hours)
1	300	7.4
2	250	8.9
3	200	11.1
4	70	31.7
5	50	44.4

This water "waste" from the regulating pond during the falling stage can be decreased with proper regulation of the pond. By correctly taking the turbine shutdown into account and starting to reduce the release from the regulation pond in advance the effect of the restriction of maximum allowable change can be decreased. Then the weekend discharge can be maximised. Of course, some planning has to precede this stage of operation, so that there is room in the pond to allow a decrease in release before the NT2 turbines shut down. This shows that intelligent regulation of the pond will be crucial for making the weekly (and also daily) fluctuations as small as possible.

6.3 EGAT Dispatches as Anticipated by NTPC

According to the power purchase agreement (PPA) between NTCP and EGAT a two-tariff system is used, a high tariff for weekdays (including

Saturdays) between 6 and 22 o'clock (16 hrs/day) and a low tariff between 22 and 06 o'clock weekdays (8 hours) and whole Sunday. During weekdays the length of the low-tariff period is 8 hours and during the weekend 32 hours. The high-tariff period covers 96 hours of the weeks 168 hours, or 57 % of the week. NTPC declares each month what they will (or can) produce with regards to the water and generation units available. NTPC will naturally declare to produce as much as possible during the high-tariff period, and only use surplus water during the low-tariff period. Long-term simulation presented by NTPC show that NTPC can declare full load during all high-tariff periods, also during dry years. The agreement gives EGAT flexibility dispatch according to its need. The two-tariff system reflects the need of electricity; the price is higher during peak hours and lower during off-hours.

The daily electricity demand in Thailand for April, 2005 is shown in Figure 2. It can be seen that peak hour production during daytime is about 20-30 % higher than during night-time. It can be also seen that the load during Saturdays is only a somewhat lower than on weekdays, but much higher than on Sundays, which is in concordance with the two-tariff system used between NTPC and EGAT. The average demand on Sundays is somewhat lower than during weekday nights, suggesting almost same marginal generation costs of electricity during these periods. If one has many sources for electricity production it is normally more economic to use hydropower for peaking and thermal power for the base load. Therefore, NTPC has anticipated EGAT to dispatch more or less full load during the high-tariff period, and less during the low-tariff time. These assumptions seem very logical.

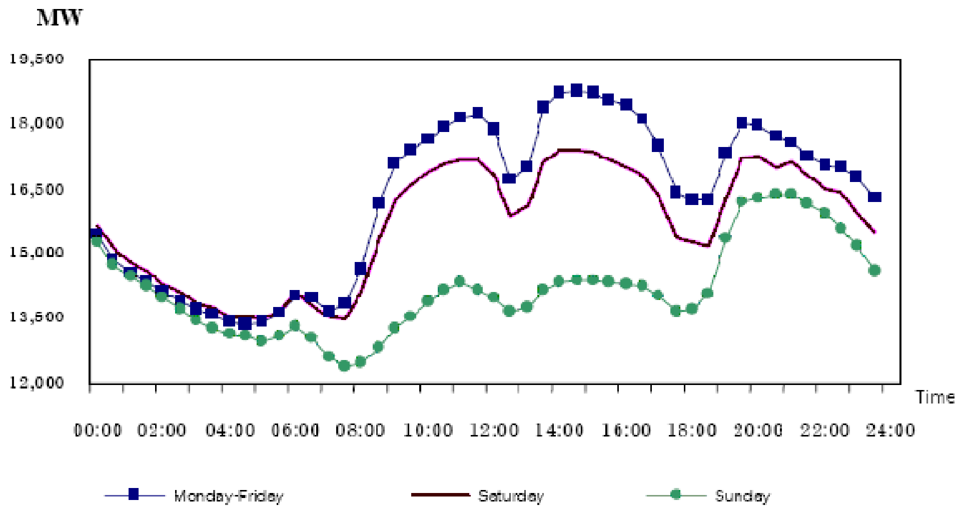

Figure 2. Daily load curve for April, 2005 (Source: Ministry of Energy, Energy Policy and Planning Office (EPPO) (*source: www.eppo.go.th/info/index.html*)

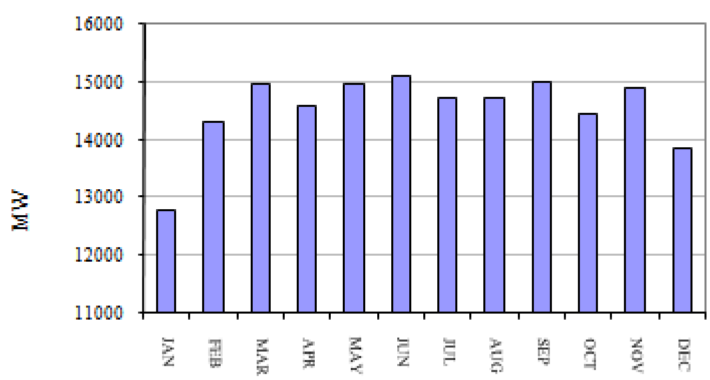

Figure 3. Monthly electricity demand 2006 in Thailand 2006 (Adapted based on data from Ministry of Energy, Energy Policy and Planning Office (EPPO). (*source:* www.eppo.go.th/info/index.html)

NTPC has presented 8 cases depicting different releases from the regulating pond (Table 4). The difference between maximum and minimum flow downstream the regulating pond in the 8 cases varied between 137.5 and 220 m^3/s.

Table 4. Summary of the NTPC scenarios

Case	Weekdays daytime	Weekdays nighttimes	Sunday all day	Weekly average	Flow variation	Fluctuation at Mahaxai	Fluctuation at bridge
1.1	250	250	80	219	170	1.82	1.18
1.2	250	250	100	222	150	1.56	1.04
1.3	270	270	50	219	220	2.40	1.5
1.4	280	280	80	230	200	2.06	1.35
1.6	250+/-10%	250+/-10%	80+/-10%	219	170	1.83	1.18
1.7	275	225	100	232	175	1.75	1.08
1.8	275	175	100	218	175	1.71	0.95
1.9	250	250	112.5	224	137.5	1.42	1.00

(Source: NTPC model report)

6.4 *Most Probable and Extreme Case According to NTPC*

The features of the most probable case anticipated by NTPC and presented in the NTPC model report is shown in Table 5.

Table 5. Most probable case 1.2 presented in the NTPC model report

No	Most probable case (NTPC 1.2)	Turbine discharge, m^3/s	Release from reg. pond, m^3/s
1	Weekdays daytime	300	250
2	Weekdays night time	150	250
3	Sunday all day	75	100
4	Max variation during week	225	150
5	Weekday average	250	250
6	Weekly average	226	226

(Source: NTPC model report)

Table 6. Extreme case 1.3 presented in the NTPC model report

No	Extreme case (NTPC 1.3)	Turbine dispatch, m^3/s	Release from reg. pond, m^3/s
1	Weekdays daytime	300 *	270
2	Weekdays night time	210 *	270
3	Sunday all day	Not mentioned	50
4	Max variation during week	Not mentioned	220
5	Weekday average	270	270
6	Weekly average	Not mentioned	226

* The use of these values will give a weekday average of 270 m^3/s

(Source:: NTPC model report)

Information on the turbine dispatch and corresponding release from the regulating pond has been provided only for cases 1.2, 1.6 and 1.9 in the NTPC model report, for other cases only the discharge from the pond. For the most extreme case (case 1.3 in report) a possible turbine discharge can be deduced, and is presented in Table 6.

6.5 *Uncertainties in NTPC Assumptions*

Although the most probable dispatch schedule presented by NTPC is realistic some important facts cause uncertainty about this, which may result in greater fluctuation downstream than the anticipated 150 m^3/s. These facts can be summarized as follows:

1. EGAT has full control of the dispatch and will optimize its dispatch from NT2 according to its total generation costs, not according to the two-tariff system agreed upon between NTPC and EGAT. NT2 is only a small part of the EGAT generation system. Normally hydropower is used to regulate the marginal cost of generation from thermal power plants, which generally means large variations in dispatch from hydropower stations. However, a load factor of 67 % is rather high and will somewhat limit this flexibility.

2. The dispatch on Sunday has crucial impact on the weekly variation. EGAT may want to save water on Sundays and dispatch more during weekdays if the marginal costs are higher. Electricity demand is at a minimum Sundays between 3 and 19 o'clock.

3. If Saturday demand in the area of consumption turns out to be much lower than during other weekdays EGAT may save also this water to be used during other weekdays and thus create a long weekend, longer than the currently anticipated 32 hours. The effect of this may cause the regulating pond to run out of water. It may be noted that in a review of electricity tariffs it was suggested that Saturday can be classified as a low-demand period (National Energy Policy Office of Thailand, 2000). However, the economic development in Thailand since then has changed the demand pattern and a new review recommended declaring Saturday as a weekday (National Energy Policy Council Resolution, 2005).

4. The electricity produced by NT2 will probably to a large extent be consumed in the Isan area. The generation capacity in this area is 20-25 % smaller (or 300 MW smaller) than the peak demand, requiring imports during peak hours.

5. For the purpose of the simulation NTPC has assumed a steady dispatch of 15 m^3/s from the EdL turbines to meet the release obligation to Nam Kathang. NTPC expects the local (EdL) demand of electricity to be more or less even due to continuous industrial activity during weekends in the area. The EdL turbines have a total capacity of 30 m^3/s and expected mean load of 50 %. This means they have high relative capacity of peak power production. It may be economically sensible for EdL to produce peak power with full turbine capacity for sale to Thailand, and to buy cheaper electricity from Thailand during off–peak hours, if the obligation to release to the Nam Kathang is lifted, as has been indicated by NTPC. This would lead to an increased difference of 10-20 m^3/s between weekday and weekend releases from the regulating pond. However, due to the expected increase in local electricity demand exports to Thailand may be unlikely.

6. Some margin for the high and low storage levels of the regulating pond has to be maintained to handle unexpected changes in the planned dispatch so the whole (theoretical) storage volume is not necessarily always available for regulation. The Consultant was shown some preliminary test results of the software intended to be used for the regulation of the pond. During weekdays the software performed very well and the downstream fluctuation was close to optimal even if the planned dispatch differed from the actual. But the software seemed not to be tuned to minimise the weekend fluctuations and to use the regulating capacity to its full extent. Some fluctuations also emerged for cases when the actual dispatch continued much longer than planned (and if the discharge was high). We are understanding that NTPC is now refining it water level management system.

7. March to May are months with high electricity demand (Figure 3), and the marginal cost of electricity generation is thus also high. EGAT may shift water use from earlier dry season months to be used in March-May. This shift could lead to high weekday dispatch in March-May as more water is available. In this case the weekly flow variation downstream the regulating pond would increase in the March – May period.

All the above mentioned reasons are all somewhat speculative, as not much is known how EGAT will actually dispatch at NT2.

The Consultant made some theoretical calculations of the effect of Sunday dispatch schedules on Sunday releases from the regulating pond. The limit of change in release (20 m^3/s per hour) during the falling stage was taken into account, and it was assumed that 90 % of the 8 Mm^3 volume of the regulating pond could be utilized. It was also assumed that the release to Nam Kathang (15 m^3/s) was offset by the same discharge from the EdL turbines. The calculation was then repeated for different values of the Sunday dispatch from the power station.

The results are shown in Figure 4. It can be seen that Sunday dispatch can significantly reduce the weekly fluctuation downstream the regulating pond. It should be noted that the release on the Y-axis is the release at the moment when the turbine discharge is shut down, and does not necessarily represent the weekday average discharge. Proper planning of operation of the regulating pond may allow lower release rate at shutdown of turbines than what the average weekday release would suggest.

In the NTPC report the scenario 1.9 a faster flow reduction rate from the regulating pond is used, 70 m^3/s instead of 20 m^3/s as in the base case. This results in a higher weekend flow, as the water saved during the more rapid falling stage can be used to increase the flow on Sunday (Figure 5). Thus the weekly fluctuation will be reduced. However, the benefit of increased flow reduction gradient has to be weighed against increased risk for bank instability and impact on human safety issues.

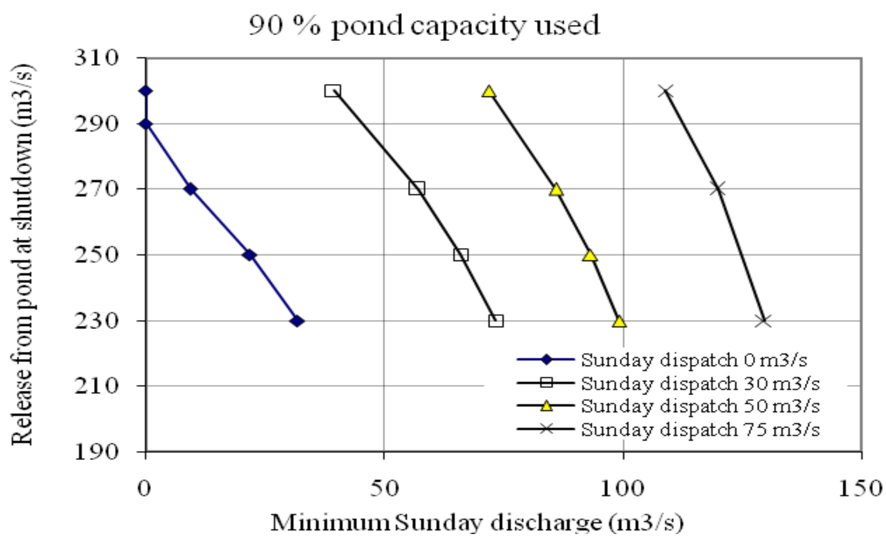

Figure 4. Sunday release from regulating pond as a function of Sunday dispatch under optimal conditions. (*Source: John F*)

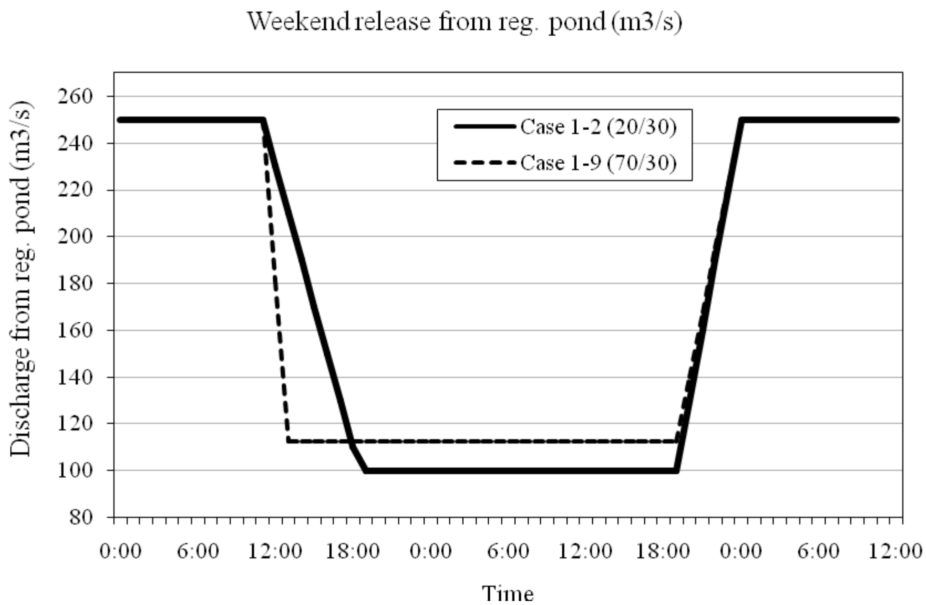

Figure 5. Effect of increasing flow reduction gradient on weekend flow (*Source: Adapted from the NTPC report, NTPC, 2006)*

6.6 *Facts Favouring the NTPC View*

The load factor of NT2 turbines is quite high, almost 70 %, and it is higher than for power stations especially designed to be used for peaking. Thus no very long periods with low flow can be expected, because this would later increase the risk of spill.

Two new plausible dry season dispatch schedules was presented to the Consultant during a separate meeting, and the discharge fluctuation in the downstream channel was 170 and 120 m^3/s, respectively, being in the same range as the most probable scenario suggested by NTPC.

In discussions with the Consultant NTPC has mentioned transmission grid voltage control as a reason for why an extreme dispatch situation, such as full dispatch during weekdays and zero dispatch on weekends is not likely to occur. It is beyond the scope of this study to check the EGAT power grid system, but generally speaking transmission line stability and distribution optimization is very important for large distribution systems, and the NTPC anticipation may thus be well founded. It is mentioned that 65 % of feeders are overloaded in the Northeast region (PWC report 2000).

EGAT may also use NT2 as a standby unit to secure unexpected changes in demand. Then at least one turbine would be running Sundays, maybe not at 100% capacity but at least 70 % capacity (50 m^3/s) for efficiency reasons.

It is very possible that the local electricity demand at a mine and a cement factory in the NT2 area will be steady over the whole week and consume most of the EdL production. Then there would be no fluctuation in discharge from EdL turbines. The local electricity demand has increased rapidly in the area due to these activities.

Test cases with the new software to be used to regulate the pond discharge seemed to work quite well during weekdays, with hardly any change between daytime and night time flows. This was true even if the actual dispatch differed from the planned. In the test cases presented to the Consultant the planned dispatch varied between 315 and 60 m^3/s during weekdays and was a constant 60-75 m^3/s during Sunday, and included deviations in actual dispatch from the planned dispatch. The pond release suggested by the software varied between 230 and 60-65 m^3/s, a variation of 165-170 m^3/s. A fine-tuning of the software to take better care of Sunday flows would lessen the variation considerably, to be in the range of 150 m^3/s or lower under the same circumstances.

If the cooperation between EGAT and NTPC works well NTPC will be notified in advance of changes in expected dispatch. This will give NTPC an opportunity to plan the release from the regulating pond to maximise the regulating capacity of the pond and thus to minimise the discharge variation from the regulating pond.

6.7 Conclusions on NTPC Scenarios

It is the Consultant's opinion that the scenarios covered in the NTPC model report are based on sound judgement and that the scenarios cover a reasonable range of expected fluctuations. However, the Consultant believes the most likely weekly fluctuation will be somewhat higher than the NTPC case 1.2, mainly due to lower Sunday turbine discharges.

It needs to point out that in the end the main factors that affect the actual fluctuations that will occur depend on the following:

- The actual EGAT dispatch schedule on Sundays (ref. Fig. 2)

- The capability of the software to optimise the operation of the regulating pond.

All hydrological boundary condition assumptions in the NTPC scenarios, such as the inflow from the upper Xe Bang Fai, the release from the regulating pond to Nam Kathang, the tributary inflows and the water level at the Mekong junction seem to be realistic for the purpose of the study. The flow used as boundary for the upper Xe Bang Fai, 15 m^3/s, is typical for the dry season.

In the NTPC model report turbine discharges are given for case 1.2, 1.6 and 1.9 only. These turbine discharges have been correctly translated to a release from the regulating pond, and a safe regulation margin was taken care of. Only half of the maximum regulating capacity was used in the NTPC scenario runs. For the other cases no turbine discharge has been mentioned, only the release from the regulating pond. If this information had been provided a better assessment of the anticipated EGAT dispatch schedules could have been made.

7 Comparison with Previous Results

7.1 Social Development Plan Report

In a previous study (Social Development Plan, Final Draft, March 2005, vol. 3, public document) an estimate of change in absolute water levels from natural at Mahaxai and the Bridge during the dry season months January-April. The Consultant checked these estimates with corresponding results from the HEC-RAS model and comparison to the rating curve at Mahaxai for year 2005. The results are shown in Table 7.

Table 7. Comparison of water levels using the NTPC model with previous estimates in the Social Development Plan Report (2005)

	Water Level Increase at Mahaxai, m			**Water Level Increase at Bridge, m**	
Discharge	SDP estimate	Consultant's estimate	Rating curve 2005	SDP estimate	Consultants estimate
330 m^3/s (maximum)	5.2 - 5.8	4.2 – 4.6	4.2 – 4.4	3.5	4.3
220 m^3/s (average)	4.2 – 4.9	3.2 – 3.6	3.1 -3.2	-	3.2
30 m^3/s (Sunday)	0.5	0.76 – 1.01	0.4-0.7	-	0.7

The modelled values are more than 1 m lower than the estimates in the SDP report for Mahaxai. The modelled values at Mahaxai are consistent with the rating curve of year 2005, and this means that the increase in water levels presented in the SDP report for Mahaxai are overestimated. It is possible that the SDP report relied on a different (old) rating curve for Mahaxai, which would explain the difference.

The SDP report does not give any estimate for the weekly fluctuation in water level, but from the data presented one may get the impression that the fluctuation would be the difference between maximum flow and Sunday flow. The fluctuation during one week using the SDP values in the table (difference between maximum and Sunday flow) would then be 4.7-5.3 m. It does not take into account the effect of the regulating pond or the storage in the river. The NTPC model results, taking these factors into account, give a fluctuation of 1.5 – 2.4 m, which is much more realistic.

The change in water level at the Bridge depends very much on the backwater of Mekong. The Consultants model check gave a Water Level Increase of about 4.3 m at the Bridge for a discharge increase of 330 m^3/s and 3.2 m for a 220 m^3/s increase when the Mekong water level at the confluence was 129.5 m. This is more than the estimated rise in the SDP report. For higher Mekong water levels the change will be lower.

7.2 Downstream Restoration Program Report

The Consultant was requested to compare the results from NTPC's modelling report with results on Water Level Fluctuations presented in the Downstream Restoration Program Report, (Final Main Report, Nov 2006). No mentioning of the expected Water Level Fluctuations could be found in the report given to the Consultant. However, in Table 5.3.3.5-1 "Access across XBF and tributaries" it is mentioned that the water level will rise with 1.5-2 m during the dry season at the Mahaxai crossing. This estimate is far too low; a mean increase of 220 m^3/s in dry season flows will increase the water level with 3.2-3.6 m from natural at Mahaxai. The same is true for the rise at Keng Pe, it will be closer to 3 m than the 1.3-1.8 m given in the report. Likewise, in the tributary Xe Noy the water level will rise about 4 m in the dry season, not 1-1.6 m as mentioned in the report, and in Nam Phit the rise will be about 2 m, not 1-1.6 m as mentioned in the table in the report. The increase in water level in the tributaries depend to some extent how far from the junction the investigated crossings lie, but no clear indication of location of the crossings is given in the report. The values of expected water level rise mentioned in the Downstream Restoration Report are clearly underestimated.

8 Conclusions and Recommendations

The present report is intended to give an overview and assessments on the NTPC study based on data provided by NTPC, data and literature available at MRCS. It was found that:

- The model setup, boundary conditions and calibration was satisfactory for the purpose of assessing the Water Level Fluctuations in the river during the dry season.

- The range of release scenarios from the regulating pond was realistic. Thus a weekly fluctuation in the range of 1.5-2.4 m at Mahaxai and 0.9-1.5 m at the bridge on Route 13 is to be expected. Previous estimates (see Ref [9]) give the impression that the variation could even be as high as 5 m at Mahaxai.

- The results of absolute Water Level Increase at Mahaxai and Keng Peng and the tributaries Xe Noy and Nam Phit estimated in the Downstream Restoration Program report for the dry season were far to low. The rise in water level at Mahaxai is about 3.2-3.6 m, not 1.5-2 m as mentioned in the Downstream Restoration Report. For Nam Phit the rise is 2 m, not 1-1.6 m, and for Xe Noy the rise is about 4 m, not 1-1.6 m.

Even if the accuracy of the NTPC computation is acceptable for the purpose of computing the weekly fluctuation of water levels in the Xe Bang Fai the following improvements to the model and model report is recommended. These recommendations do not invalidate the results obtained in the NTPC report and reviewed in this report, they are mentioned to improve the accuracy of future applications of the model.

1. Additional sensitivities analysis on values of inflow at upper Xe Bang Fai and its important tributaries (Nam Kathang and Xe Noy);

2. More model calibration and verification for flow regime;

3. Add cross-sections to the missing river sections close to the junctions;

4. Add at least the tributary Nam Ou La to the schematization;
5. Refine calibration by making simultaneous water level observations at more stations than Mahaxai and the bridge. Good existing benchmarks at cross-section locations would make this rather easy;
6. Refine calibration by using (simultaneous) discharge measurements at Mahaxai, the bridge and possibly some other places (tributary contributions);
7. Use a value of 0.6 for the theta weighting coefficient in scenario runs;
8. Give also the assumed turbine discharge (EGAT dispatch) when presenting the release from the regulating pond for clearer assessment of plausibility of scenarios; and
9. Give further examples of how turbine discharge (EGAT dispatch) is translated to release from regulating pond by showing results from the pond operation software

9 References

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10 Appendices

10.1 List of Meeting/Consultations/Field trips

Table A1 List of events.

No	Descriptions	Purpose	Date
1	Field trip to Nam Theun 2 project site and Xe Bang Fai river basin	To visual survey of the channel network including flow control structures, cross- and longitudinal sections.	18-20 July 2007
2	Meetings with NTPC at NTPC office	To discuss dispatch and regulating pond and related issues.	4 July, 2007, and 13 August, 2007
3	Meeting with the NTPC Panel of Experts	To present preliminary results of the review study to the members of NTPC Pannel of expert.	19 August 2007

10.2 Work Schedule

Table A2 Work plan.

No	Task ID[1]	Task descriptions	Responsible persons	Contract Milestones	Scheduled Time		
					Jul '07	Aug '07	Sep '07
1		Contract signing, 01 Jul	-		**01 Jul**		
2	2.1	Meeting on dispatch schedules, 5 Jul Reviewing dispatch schedules	John John		5 Jul 5-10 Jul		
3	2.2	Reviewing of HEC-RAS software Writing report	John, Binh John		5-15 Jul		
4		Receipt of NTPC documents & files	John		**11 Jul**		
5	2.3	Preliminary assessment of the model set-up and input files 5.1 Checking readability of the files 5.2 Contact NTPC for additional files 5.3 Re-checking files 5.4 Preliminary confirm readability of the NTPC files 5.5 Extraction of morphological data from the model which will be evaluated during the field visit	 Binh, Dat, Oulaphone John & Binh Binh, Dat, Oulaphone Dat, Oulaphone Dat, Oulaphone, Phouangphanh		11-17 Jul		
6	2.10	Field visit with the main objective as for assessment of NTPC input data Writing field report	Binh, John, Phouangphanh, Vongsar, Oulaphone, Dat John		18-20 Jul 21 Jul		

[1] Task ID as shown in the C113 Agreement for the Supply of Services between NTPC Ltd. and MRC

No	Task ID[1]	Task descriptions	Responsible persons	Contract Milestones	Scheduled Time		
					Jul '07	Aug '07	Sep '07
7		Mission to NTPC for assessment of input data based on the NTPC investigation reports	Binh, John		23-24 Jul		
8	2.3-2.7	**HEC-RAS re-computations** 8.1 Reviewing set-up files, baseline 8.2 Reviewing input files 8.3 Reviewing scenarios 8.4 Re-run model and extract the results 8.5 Sensitivity analysis	 Binh, Phouangphanh, Dat, Oulaphone		15-31 Jul		
9	2.7	**Analysis of results of the NTPC study**					
10	2.8	Comparison with previous studies	John, Phouanphanh, Vongsar				
11		Writing report, 1st draft	Binh, John		25 – 31 Jul	01 Aug	
12	2.11	**Completion of the draft report** 12.1 Additional HEC-RAS re-computations and reviewing 12.2 Writing report, 2nd draft 12.3 Internal reviewing & approval of the draft report	Binh, Dat, Oulaphone Binh, John		25 – 31 Jul	01 - 05 Aug 02 - 10 Aug 11 - 15 Aug	
13	2.11	Submission draft report/slides	-	after 6 weeks[2]		**15 Aug**	
14	2.11	Presentation of the results	Binh, John	after 6 weeks		15 Aug	
15	2.11	Meeting with POE	Binh, John			Before 20 Aug	

[2] Weeks after the effective date of the contract and all documents due by the Client to the Consultant have been deemed given, e.g. 11 July 2007 as shown in item no.7

No	Task ID[1]	Task descriptions	Responsible persons	Contract Milestones	Scheduled Time		
					Jul '07	Aug '07	Sep '07
16	2.11	**Finalization of the report** 16.1 Writing 16.2 Internal consultations and approval 16.3 Consultations with NTPC	Binh, John			 21-31 Aug	 1-7 Sep 7-14 Sep
17	2.11	**Submission final report**		after 10 weeks			**15 Sep**
18	2.11	**Public release report**		after 12 weeks			**31 Sep**