CAMBODIA LAO PDR THAILAND VIETNAM

REVIEW ON HYDROLOGY AND HYDRAULICS, AND SEDIMENT AND RIVER MORPHOLOGY

FINAL DRAFT OF THE TECHNICAL REVIEW REPORT FOR SANAKHAM HYDROPOWER PROJECT'S PRIOR CONSULTATION PROCESS

11TH REGIONAL STAKEHOLDER FORUM: 2ND REGIONAL CONSULTATION MEETING FOR PRIOR CONSULTATION OF SANAKHAM HYDROPOWER PROJECT

30 NOVEMBER 2021

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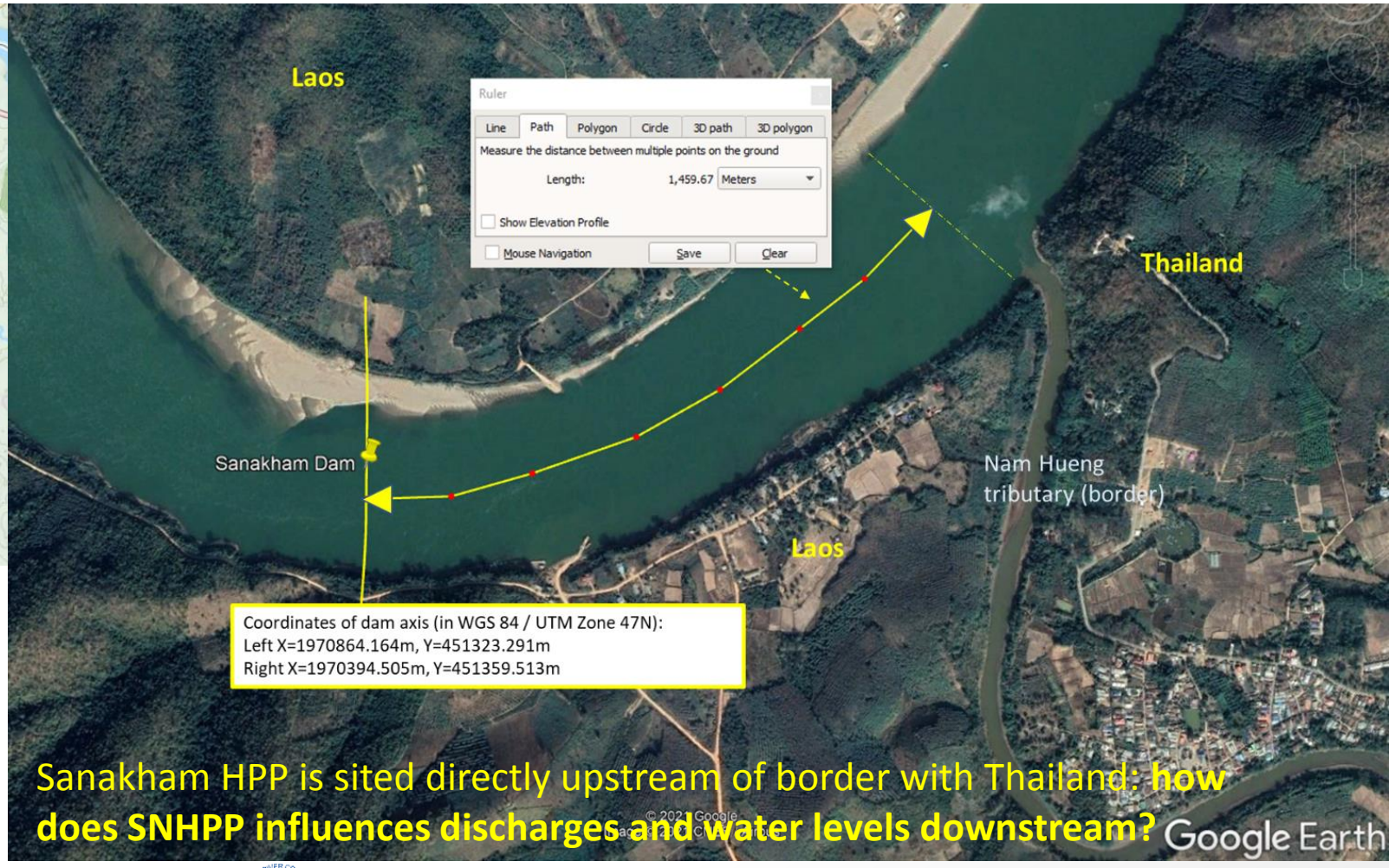
Contents of Presentation

- Background
- Technical findings
- Compliance with the PDG2009 and Good Practices based on revised draft PDG
- Findings from Rapid Assessment
- Conclusions/Recommendations

Hydrology and Hydraulics

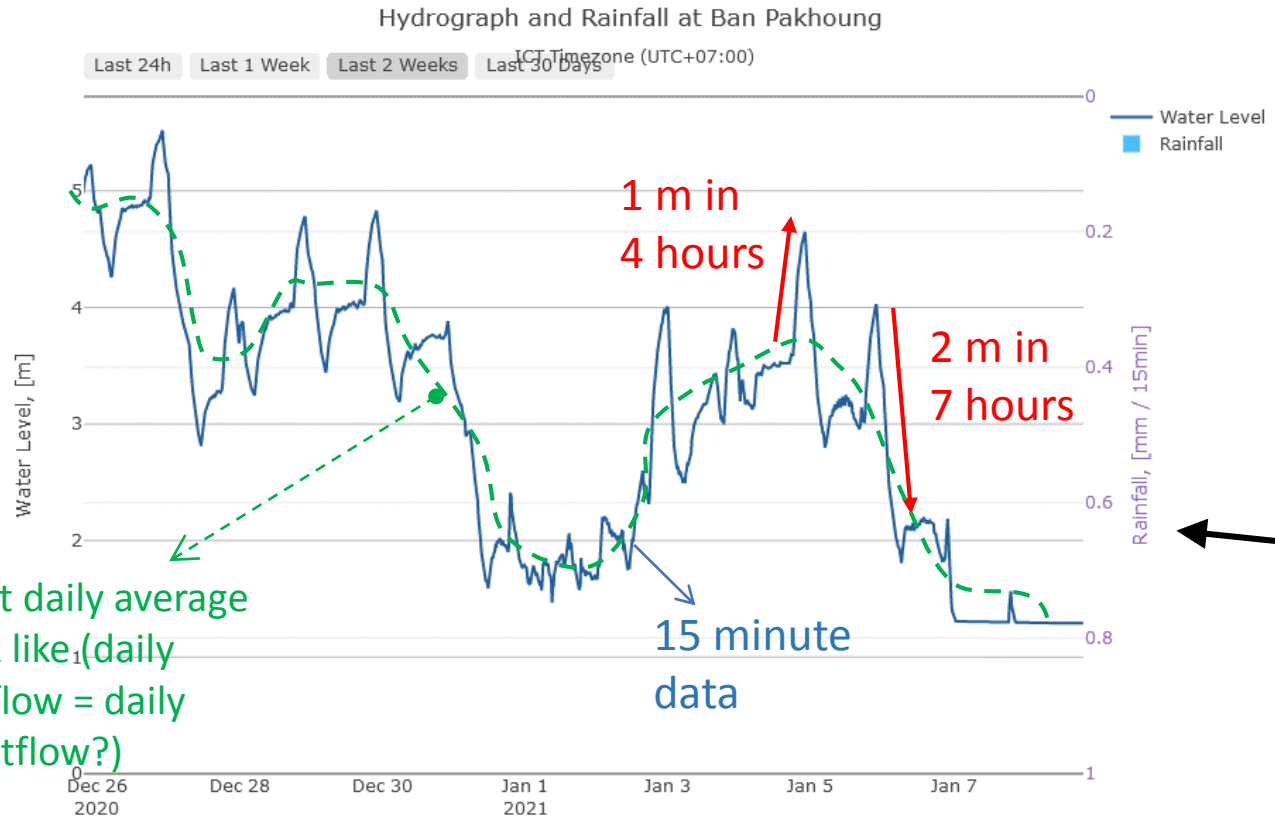
Hydrology and hydraulics determines how infrastructure is designed and operated for hydropower production, navigation, sediment routing and environmental and social considerations. Hence it is relevant for all topics and addressed up front.



- **Did the developer use proper methods to quantify the physical behavior of the river, and its variability**
- **How about the role of SNHPP in the Lao dam cascade, and its contribution to the impacts of the cascade?**

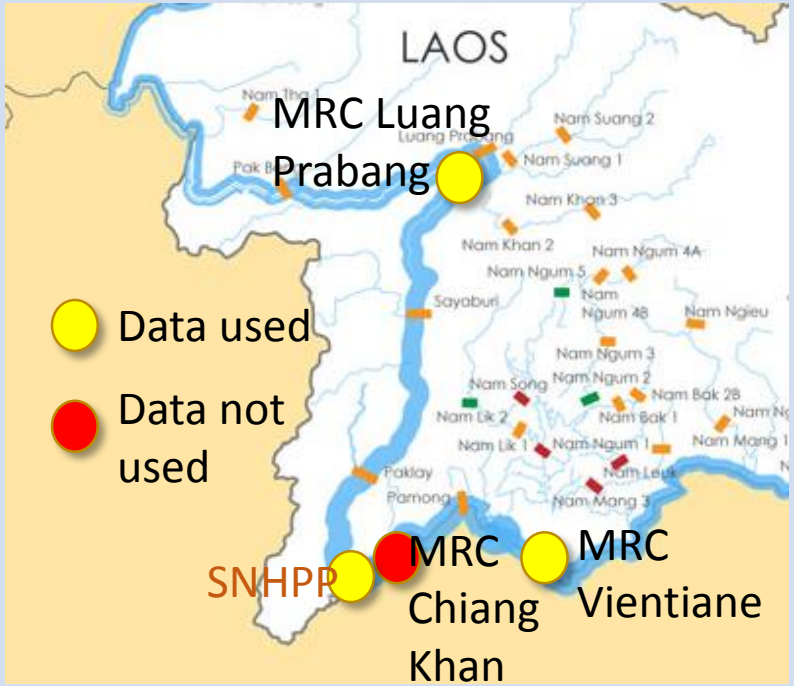
Background: concerns and risks

- What can be expected from a Run-of-river (Ror) operation of SNHPP? Example of peaking flows downstream of Xayaburi Ror scheme:

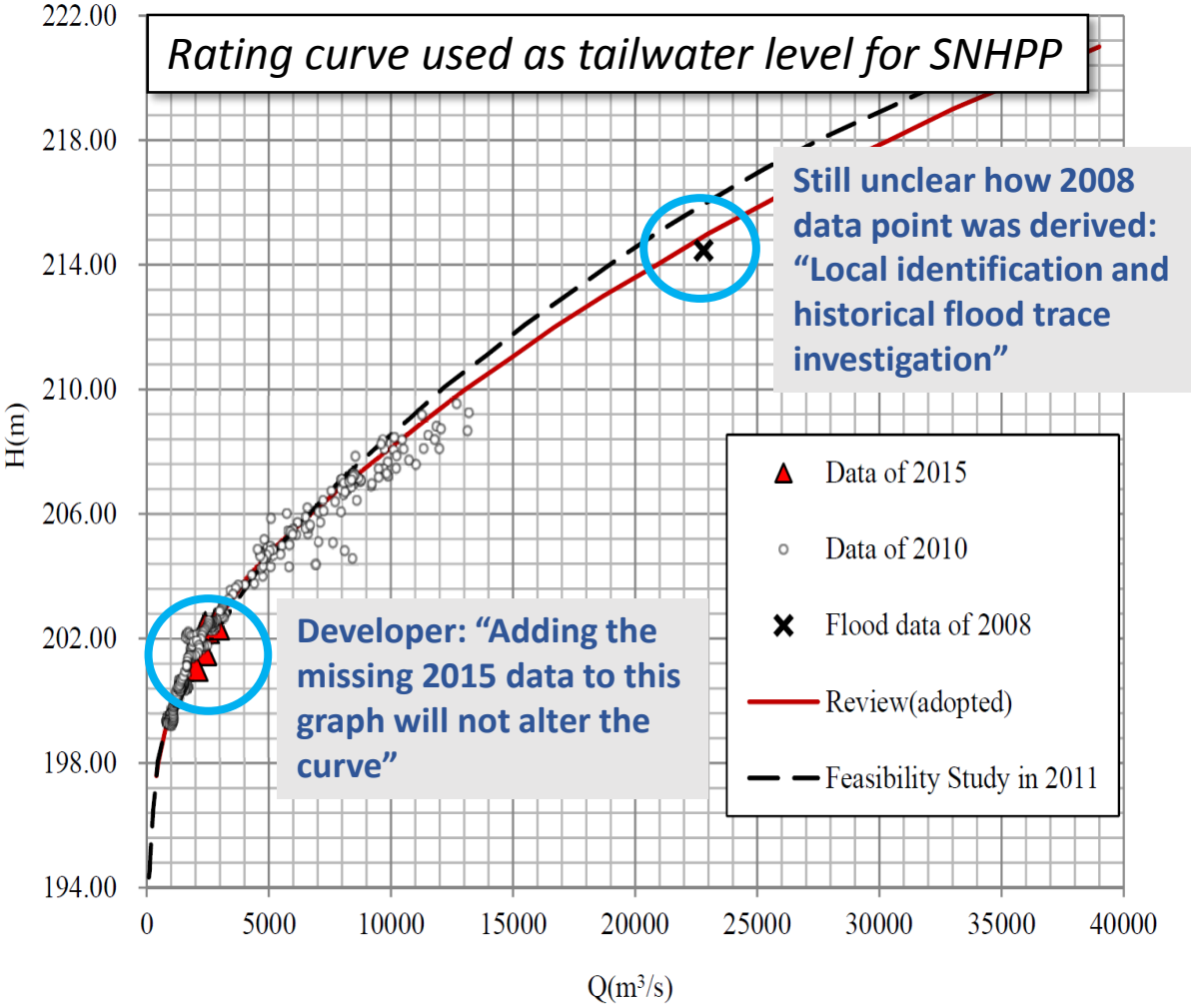


This is what daily average would look like (daily average inflow = daily average outflow?)

Pre-project monitoring & analysis

Data	Long-term data daily discharge at dam site (interpolation)	Discharge directly measured at dam site
		
Issues	• Chiang Khan data not used for computing/comparing DAILY discharge • Only data until 2012 used: excludes impacts of upstream dams (present hydrology, influence Lancang and tributary dams) • Influence of climate change not considered	• Accuracy of data cannot be judged (no information on QA/QC or comparison with Chiang Khan)

Tailwater calculations



Relevant issue: Riverbed downstream will erode, which will lower the tailwater. This will in turn affect the design of the navigation lock and fish pass entrances.

Flood frequency and design flood analyses

- **Final design values** for dam are not determined by presented extreme-value analyses. *Values from the CNR optimization study of 2009 have been copied*.
- No account for possible flood releases from upstream dams during high floods and influence of climate change

Comparison of changes to the magnitude of extreme events for the same return period over an estimated project life of 100 years (ICEM, 2010)

	EXTREME VALUE DISTRIBUTION				EXTREME VALUE DISTRIBUTION			
	Historic Return period flow (EV dist)				Project 2030 Return period flow (EV dist) with CC			
Station	*10yr*	*100yr*	*1,000*	***10,000***	*10yr*	*100yr*	***1,000yr***	*10,000*
Chiang Saen	12,252	14,551	16,808	19,061	13,209	15,769	18,282	20,790
Luang Prabang	17,137	19,912	22,637	25,357	18,783	22,362	25,876	29,384
Vientiane	18,670	21,285	23,852	26,414	19,692	22,745	25,742	28,734
Pakse	40,842	45,344	49,765	54,177	43,459	49,149	54,734	60,311
Kratie	56,254	62,934	69,493	76,040	59,000	66,886	74,629	82,358

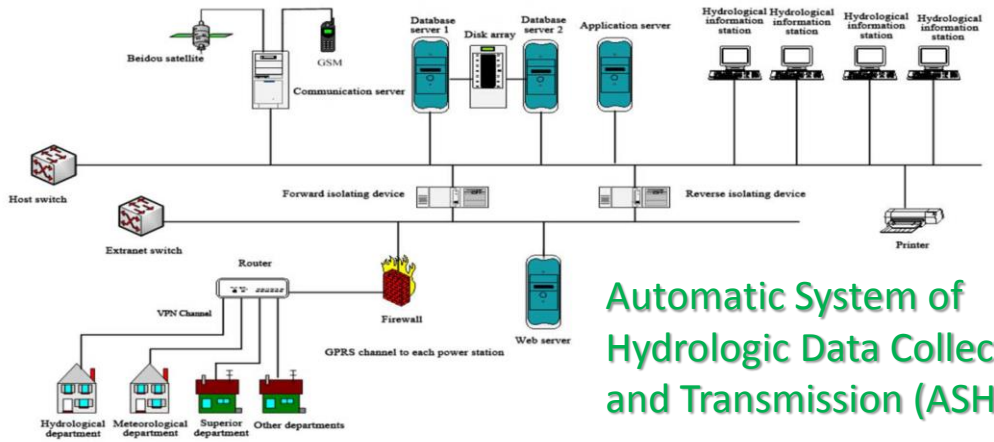
The past 1/10,000 yr flood is ~ 26,000 m³/s

In 2100 it will be the 1/1,000 yr flood

Project monitoring and adaptive management

Hydrological monitoring proposed by the developer

- Telemetry: requires extra attention for choice of upstream stations (forecast) and inclusion of downstream stations (emergency and environment)



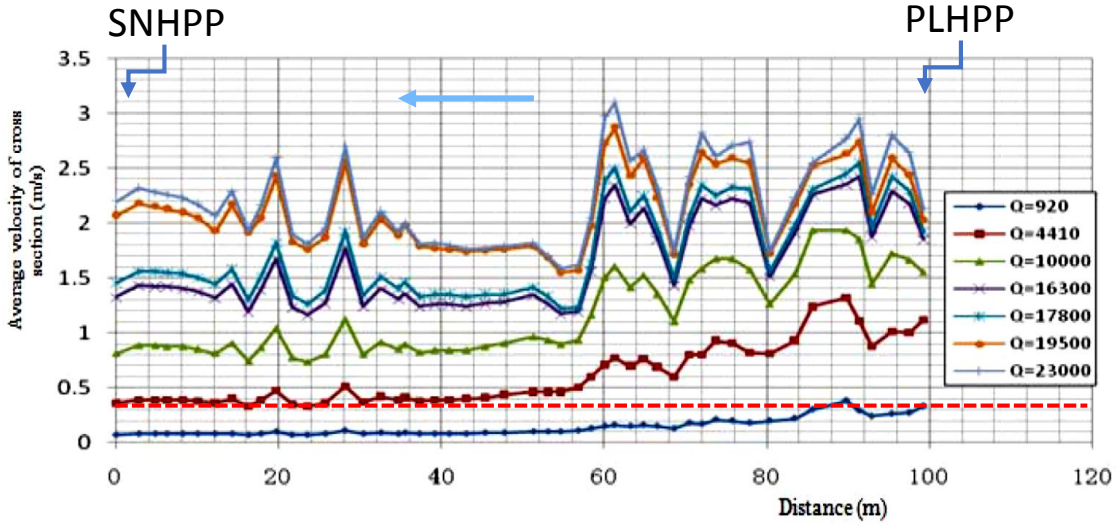
Automatic System of Hydrologic Data Collection and Transmission (ASHDCT)

Modelling tools for impact assessment

- 1D and 2D numerical models have been used, but information to judge calibration and validation is too limited
- Hydraulic impacts do not reach the Thai border

Reservoir operation rule

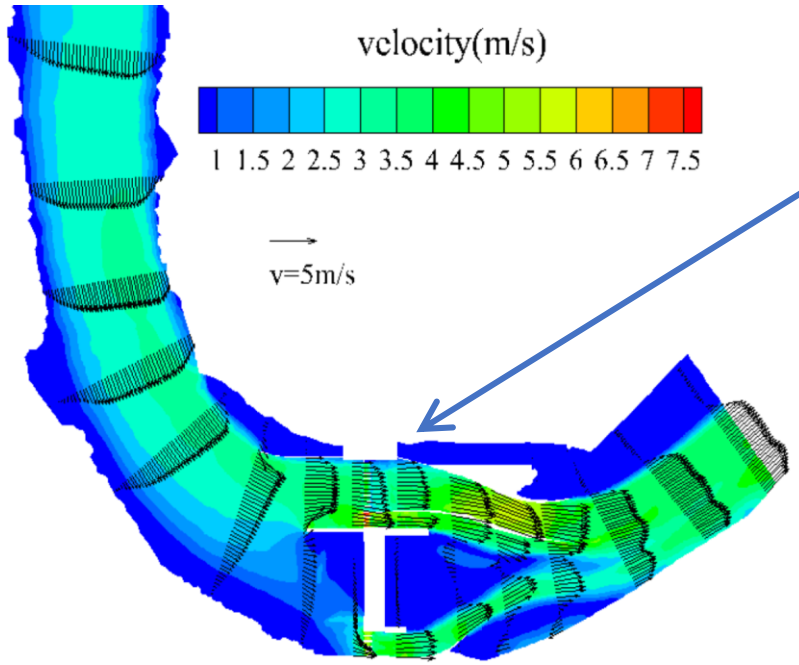
- Consideration and mitigation of downstream environmental impacts by station operations is essential but missing (direct transboundary impact)
- Decreased velocities in impoundment will impact fish larval drift (V<0.3 m/s, about 65% of time): needs to be addressed
- What will be done with Pak Lay (peaking) fluctuations?



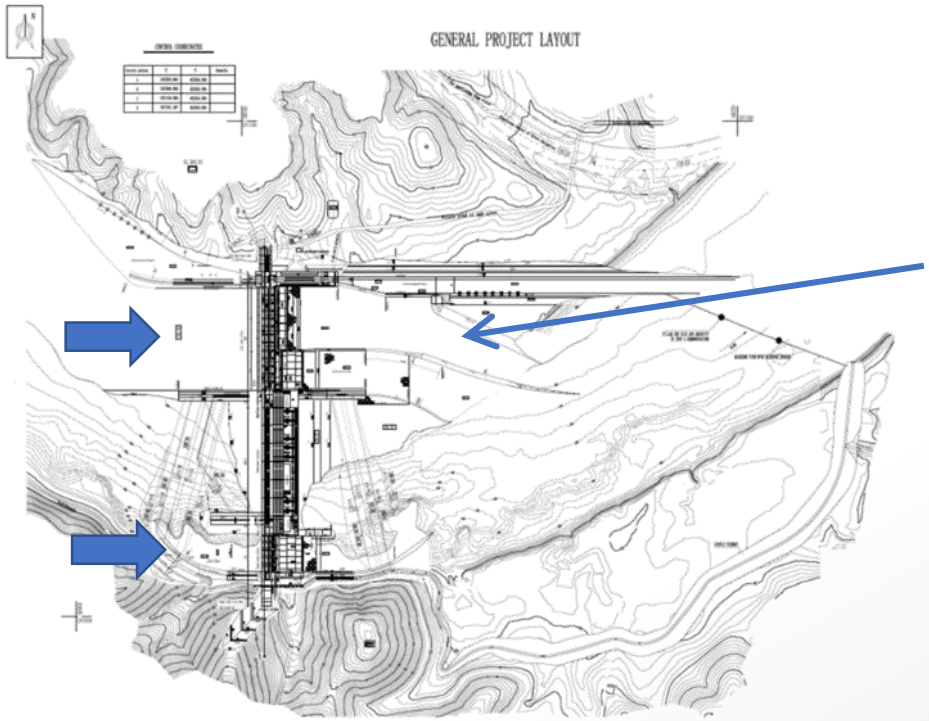
Project monitoring and adaptive management

Impacts related to hydraulics of the structure

- Some issues were raised on complex flows at the structure and in the reach downstream, and on proposed design of downstream energy-dissipation and scour protection



Flow concentrates in inner bend, unevenly distributed over the gates



Scour protection designed for T 1/100 year only (dam safety)

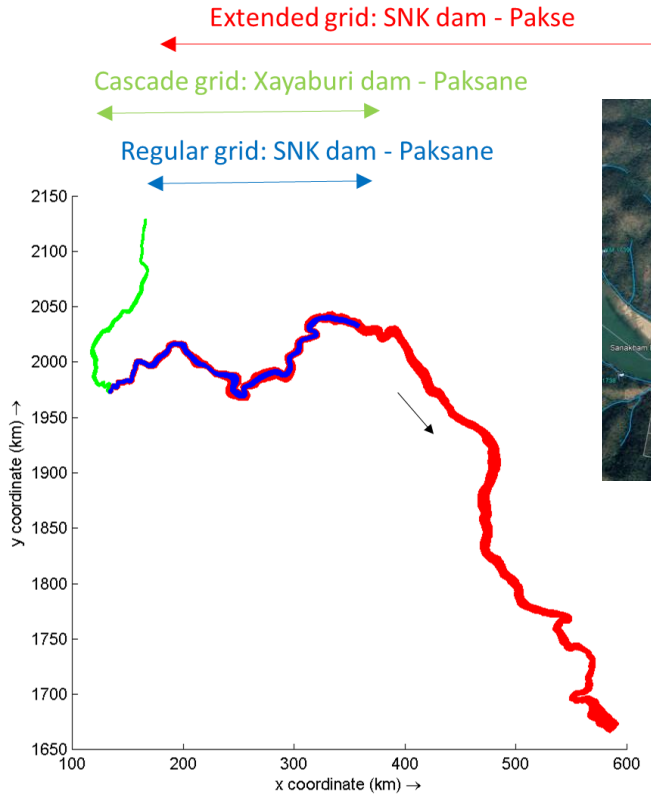
Compliance with PDG2009/Good Practices by revised draft PDG

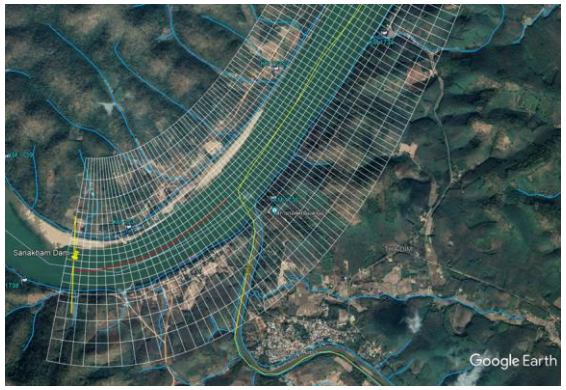
- *PDG 2009* contains no clauses for hydrology and hydraulics, but EFA is needed to determine how outflows should be managed to maintain downstream ecosystems (important because of transboundary impacts!)
- Good Practices by draft PDG2020: Most clauses have been addressed, but many of them have issues

Paragraphs	Remarks (selection of issues summarized from Annex B)
Risks/Impacts	Note comprehensively assessed (downstream impacts missed); impacts of upstream dams inadequately included; impacts on floods and droughts not well assessed
Pre-project analyses	Historic time series has issues; model and data not well combined; hydraulic models do not extend far enough downstream
Guidance for monitoring	Some more details required on monitoring framework; consider interaction with other data sources (other dams) and joint monitoring; locations of stations downstream; method of rating curve; use of WMO and HYCOS guidelines not clear
Guidance for analysis	Effect upstream dams not modelled; Climate change not modelled; Models for downstream reach missing; Downstream impacts ignored;
Operational guidance	Cascade joint operations not considered; no responses to downstream environmental conditions; ramping rates not addressed; indicators for adaptive management not defined.

Findings from Rapid Assessment

Aim of RAR: Determine the potential impacts of rapid daily flow fluctuations in the reach downstream of the upper Laos hydropower cascade, specifically downstream of Sanakham HPP (SNHPP), caused by operations of the dams for power generation.



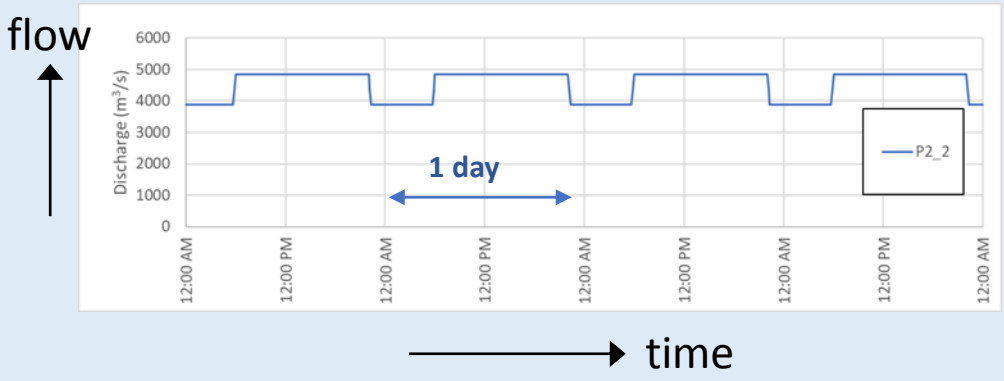


We used:

- 2D hydrodynamic model, used in ISH0306 study (Delft3D software tool)
- Sanakham runs were done with the blue grid (Sanakham to Paksane)

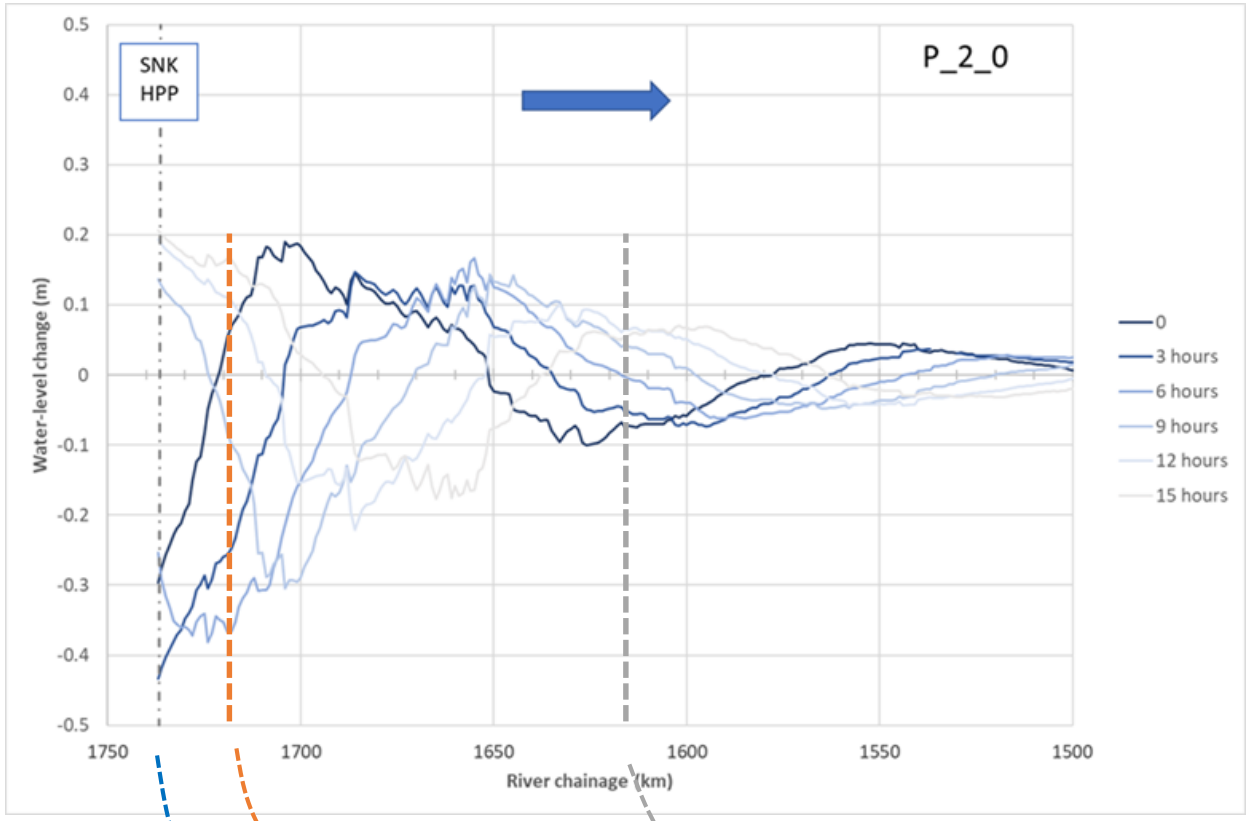
We assessed impacts of **16 scenarios** with *and* without **hydropeaking** of Sanakham, Pak Lay and Xayaburi

Example: discharge released at Sanakham HPP with hydropeaking 6AM-10PM

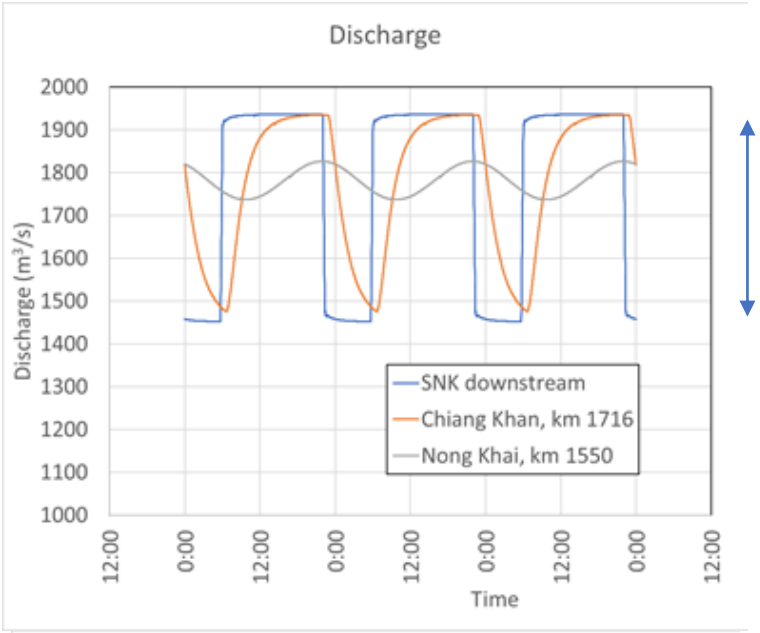


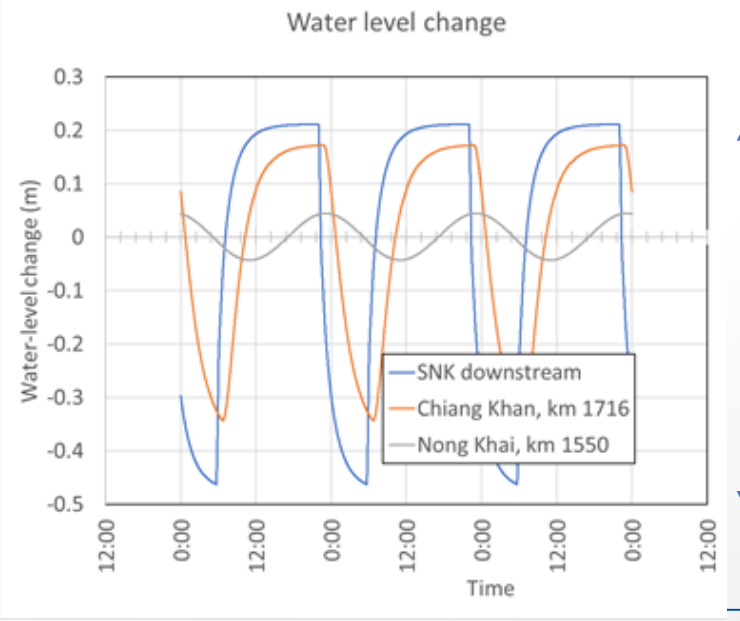
Findings from Rapid Assessment

In the downstream river, the flow fluctuations propagate down as damped waves over long distances



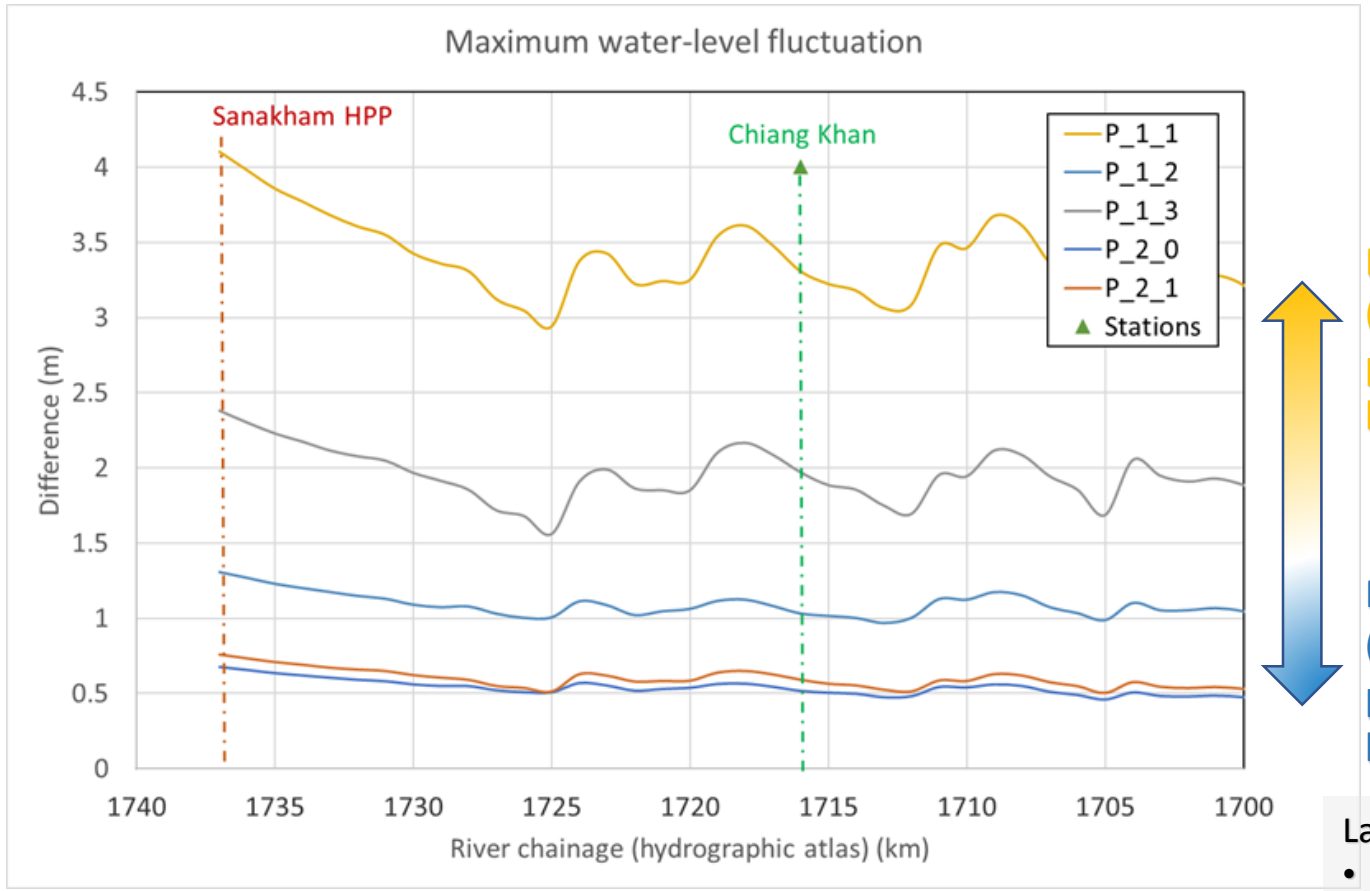
Calculated time series at 3 stations (mild peaking scenario):



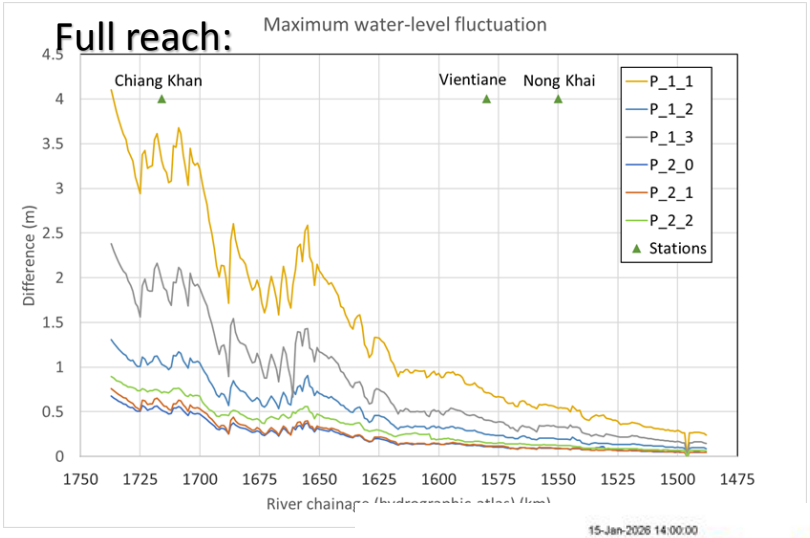


Findings from Rapid Assessment

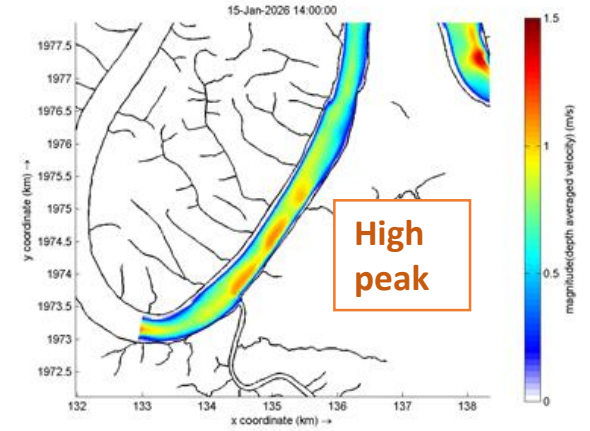
How many meters do water levels vary during a day:
(reach of interest)



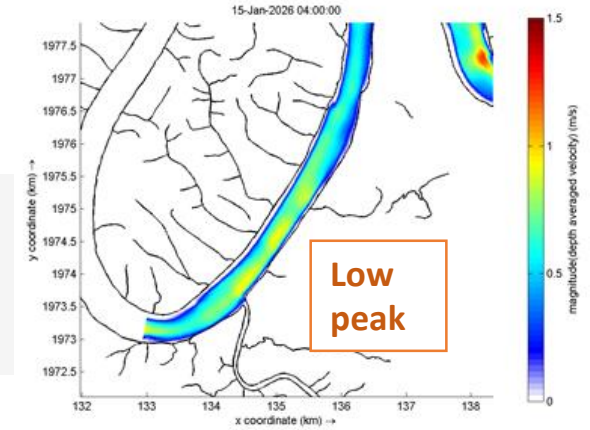
Full reach:



Extreme peaking
(1 turbine at low peak, 7 units at high peak)



Mild peaking
(2 turbines at low peak, 3 turbines at high peak)

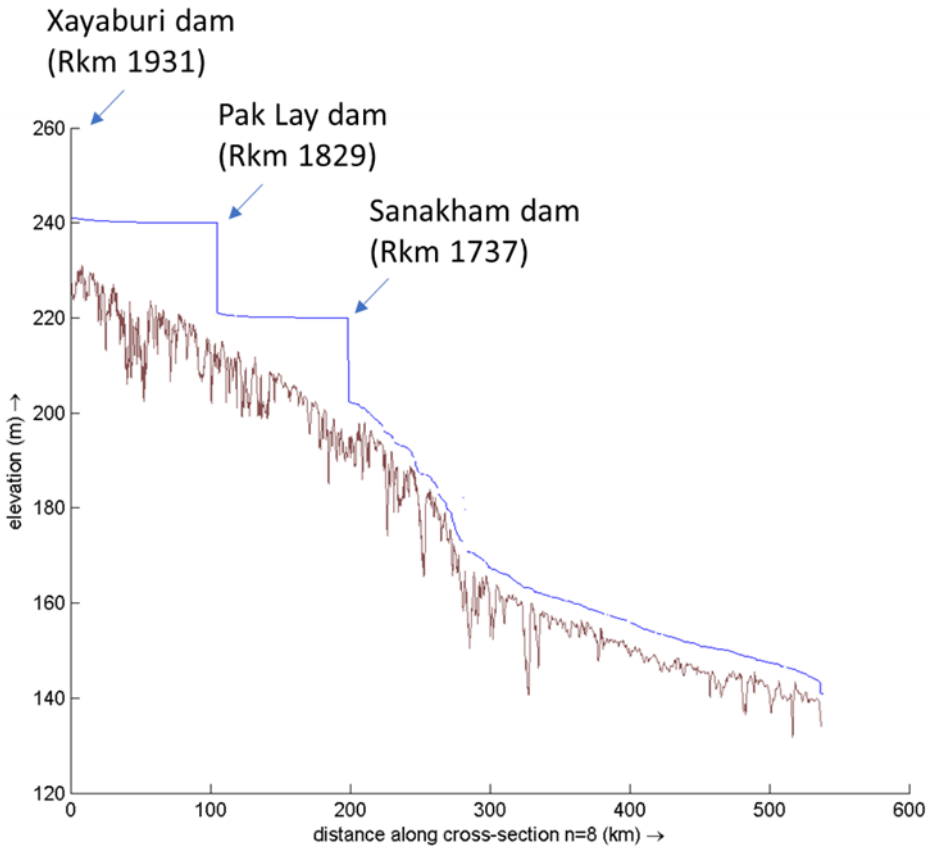


Large spatial variations at axis:

- Flow velocities can vary strongly in cross section at shallow and deep areas

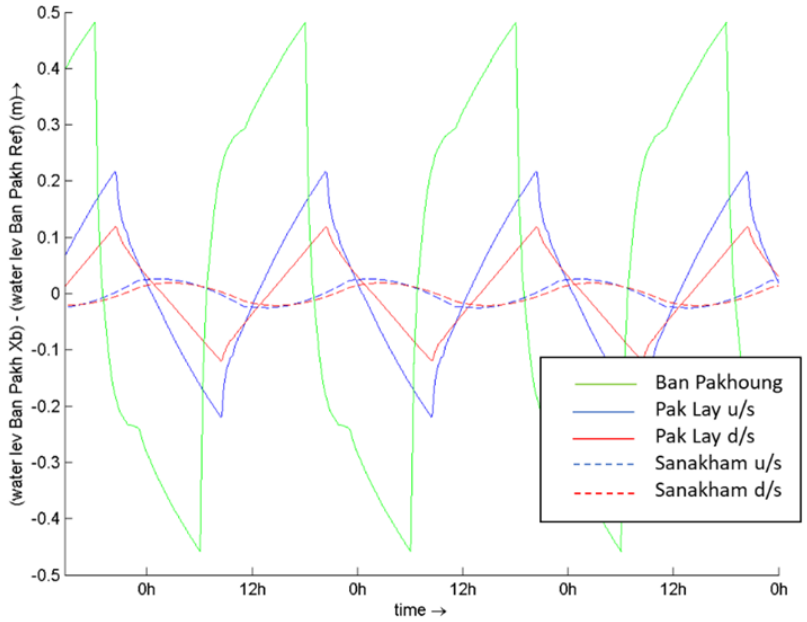
Findings from Rapid Assessment

What can we say about peaking of the cascade?



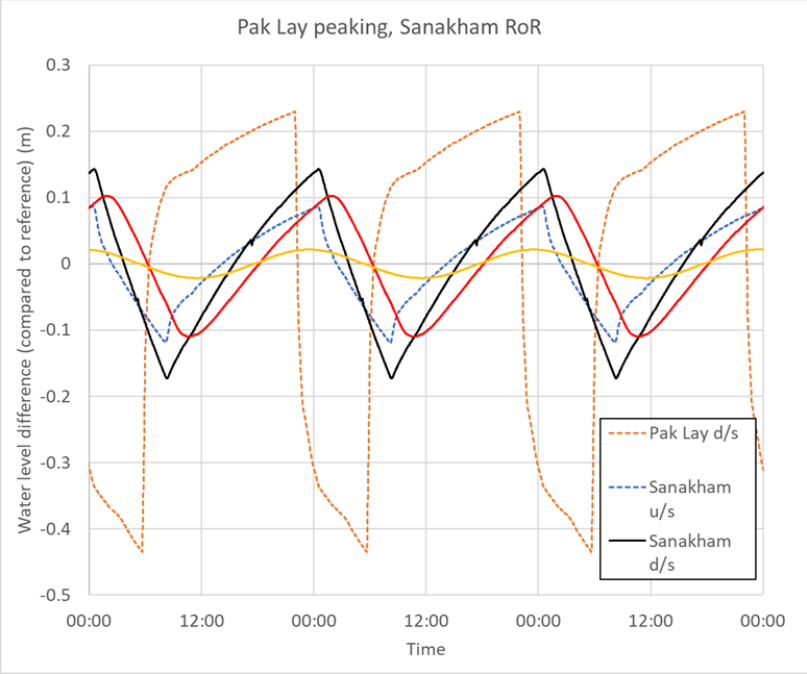
Xayaburi peaking waves travelling through the cascade (Pak Lay and SNK are not peaking):

- Remaining fluctuation downstream of Sanakham in the order of centimeters



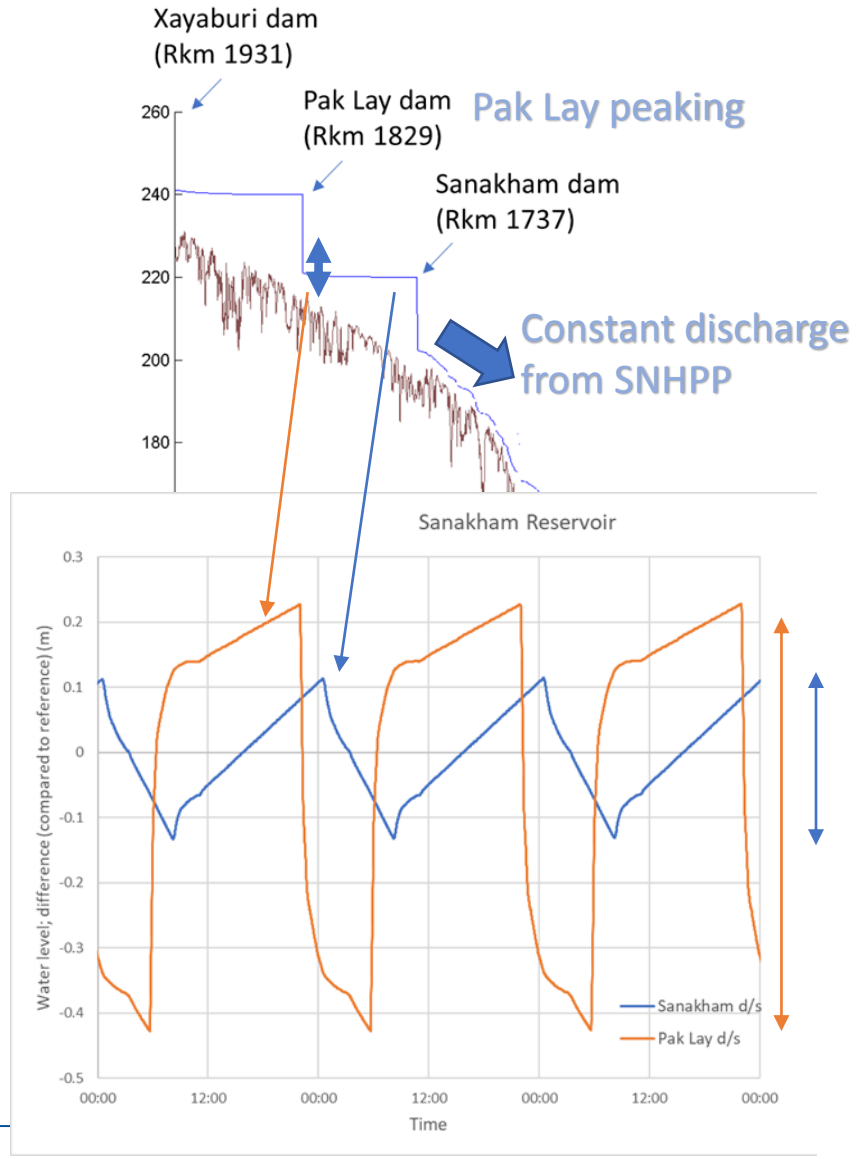
Pak Lay peaking waves travelling through the cascade (SNK is not peaking):

- Remaining fluctuation downstream of Sanakham in the order of 0.3 m



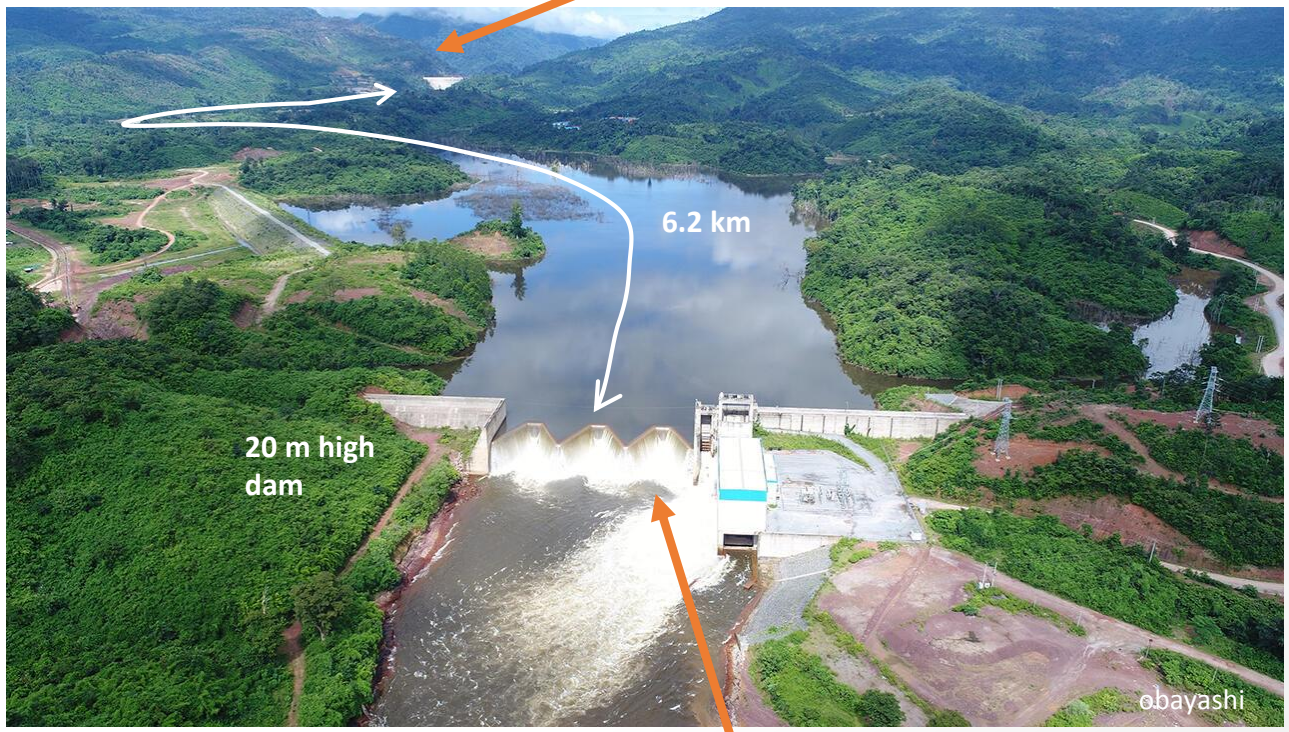
Findings from Rapid Assessment

Can Sanakham reservoir be used to attenuate the peaking waves from Pak Lay dam (use as re-regulation dam)?



Reservoir level fluctuates between 0.65 m at Pak Lay d/s to 0.25 m at SNHPP u/s

Example in the Nam Ngiep:



Findings from Rapid Assessment

- Similar operations at the SNHPP as presently in Xayaburi, will result in changes in water levels in the order of meters immediately downstream of the HPP (and into Thailand), reducing to decimetres at Vientiane and Nong Khai, and to a few centimetres at Paksane
- The rate of water-level changes is in the order of meters to decimetres per hour, which exceeds significantly the regular rate of change as observed in historic records.
- Peaking at relatively high discharges (e.g., order of 4000 m^3/s) results in smaller fluctuations of water level, notably at the high peaks, than at low discharges (e.g., order of 1700 m^3/s). At these higher flows, the peaking waves propagate much faster through the river.
- Sanakham can be used as re-regulator to attenuate or absorb the fluctuations from upstream dams. This requires some adaptation to operations at Sanakham HPP, but it will be worthwhile to further explore this option.

Overall finding for Review on hydrology and hydraulics

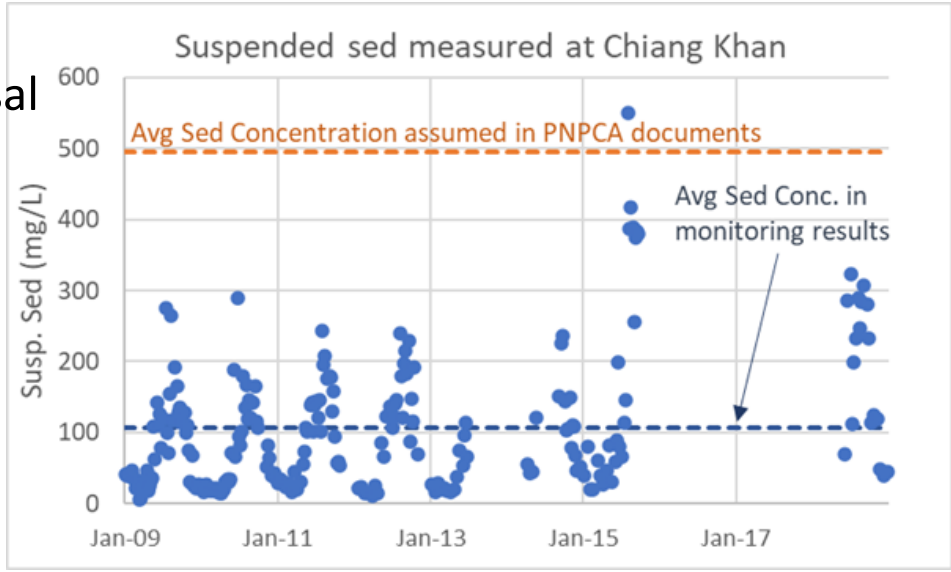
- Not full use of the wealth of data and tested methodologies available from the MRC
- Information that has later been superseded by newer studies
- Considerable inconsistencies and contradictions in the information provided
- Transboundary impacts not adequately considered and therefore not properly managed
- The rapid assessment shows that rapid fluctuations can give significant impacts to the downstream

Sediment Transport & River Morphology

- Sediment transport is critical component of river systems
  - Provides structural integrity for channel & river banks
  - Determines distribution & characteristics of riverine habitats
  - Disperses nutrients
  - Maintains Delta stability
- Sediment transport in the LMB has been impacted by HPP development
  - Large reduction in sediment loads
  - Changes to flow patterns
    - *Affects sediment transport & deposition*
- SNHPP is 1.5 km from Thailand border
  - *All impacts will be transboundary*
- Alluvial (sandy) areas of Mekong are more prone to change

Sediment data used by developer

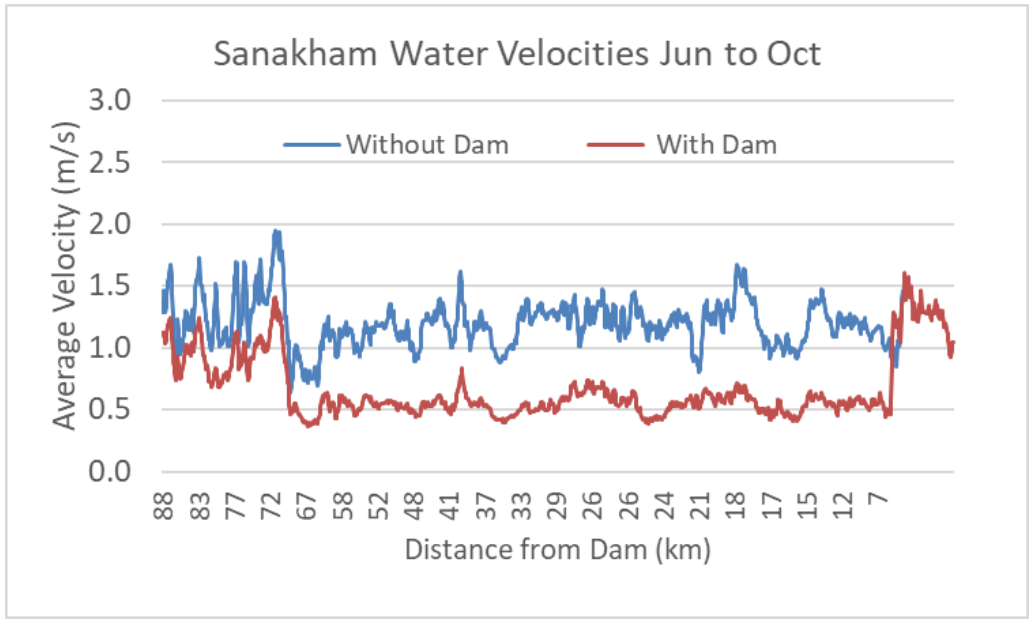
- Developer (2016) & MRC (2009 -2019) have measured sediment loads of 20 – 35 Mt/yr at SNHPP and Chiang Khan sites, respectively
- Developer uses sediment load of **69 Mt/yr** as basis for project proposal
  - Based on old data (pre-Chinese & tributary dams)
  - 2.5 times greater than **ACTUAL** sediment load
  - Does not reflect current conditions
  - No consideration of future sediment reduction due to additional HPPs in cascade or tributaries



- **Use of inaccurate data affects ALL aspects of project and does not provide a valid basis for identifying potential transboundary impacts**
  - **Modelling is inaccurate because of inaccurate sediment loads**
    - **Over-estimates sediment accumulation rates in impoundment**
    - **Under-estimates time until coarse sediment can be passed through dam to downstream river**
    - **Inaccurate understanding of sediment deposition near infrastructure**

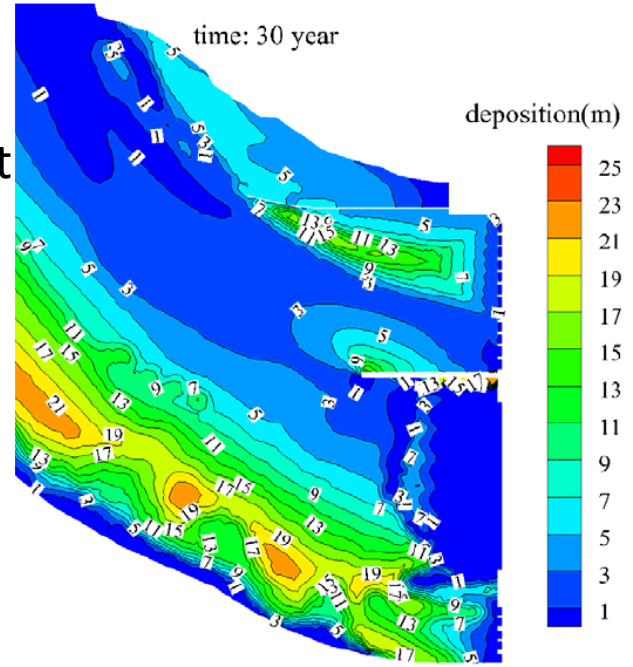
Sediment transport modelling (1-D, 2D, Physical)

- 1-D model does not **capture erosion / deposition** at sufficient detail
  - *More detailed MRC modelling shows high rate of sediment capture*
- Extreme events & climate change not included



MRC & SNHPP modelling shows large reduction in flow velocity after dam placement

- 2-D modelling shows low velocity upstream of right bank gates
  - *Low sediment transport*
  - *Sediment deposition upstream of gates*



- Physical modelling shows passage of coarse sediment through dam, but only after 50 years of sediment accumulation
  - *Likely to be far longer due to over estimate of sediment input*
- Will result in *decades* to *centuries* of coarse sediment starvation downstream

Design & operation of the sediment facilities

- Right gates have the lowest sill level and are aligned with the thalweg, but they are not aligned with **the main flow paths** through dam infrastructure – will not maximise sediment passage
- **Deep sediment deposits** required to accumulate in front of dam before bedload can be passed through gates >>50 years

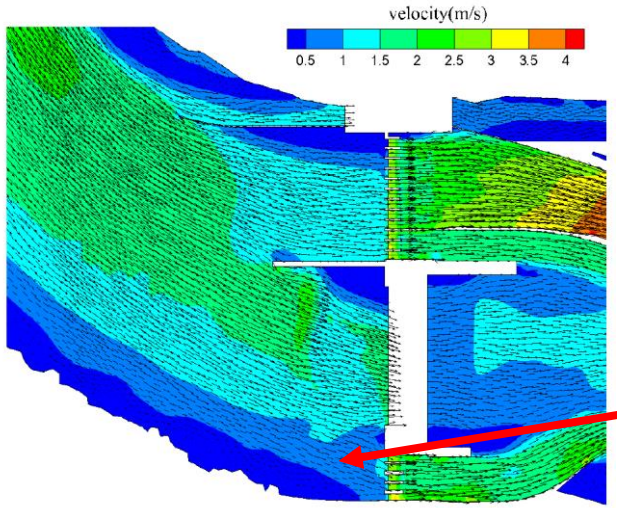


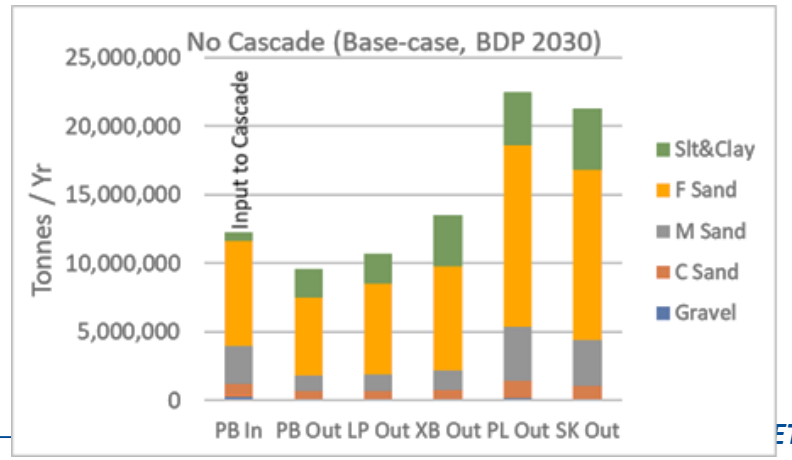
Figure 4.3-29 Flow field upstream of the dam (scheme 5)

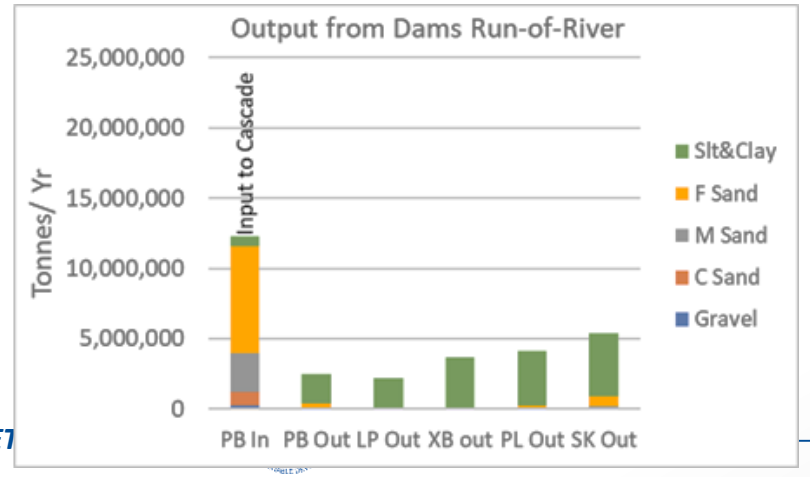
Low flow velocity in front of right gates

- No detailed information or modelling results about sediment flushing
  - Drawdown of impoundment not proposed on regular basis
- No modelling of sediment passage through right bank gates alone
- No information about sediment management at cascade scale
  - Environmental risk of multiple projects flush sediment at the same time

Transboundary impacts from sediment reduction

- **Developer states 'little' change to sediment load due to project development**
  - Based on inaccurate sediment loads
  - Grain-size distribution based on limited results & not from project location
    - *Under-estimates sand compared to long-term MRC monitoring*
  - MRC modelling shows large decrease in sediment load pre / post cascade
    - *Sediment loads at Sanakham decrease from 20 MT/yr to 5 MT/yr*
    - *Virtually all sand and gravel is trapped in impoundments*
    - *Erosional 'wave' predicted to move downstream of last dam in cascade*
  - These changes will have substantial transboundary impacts – not addressed by developer





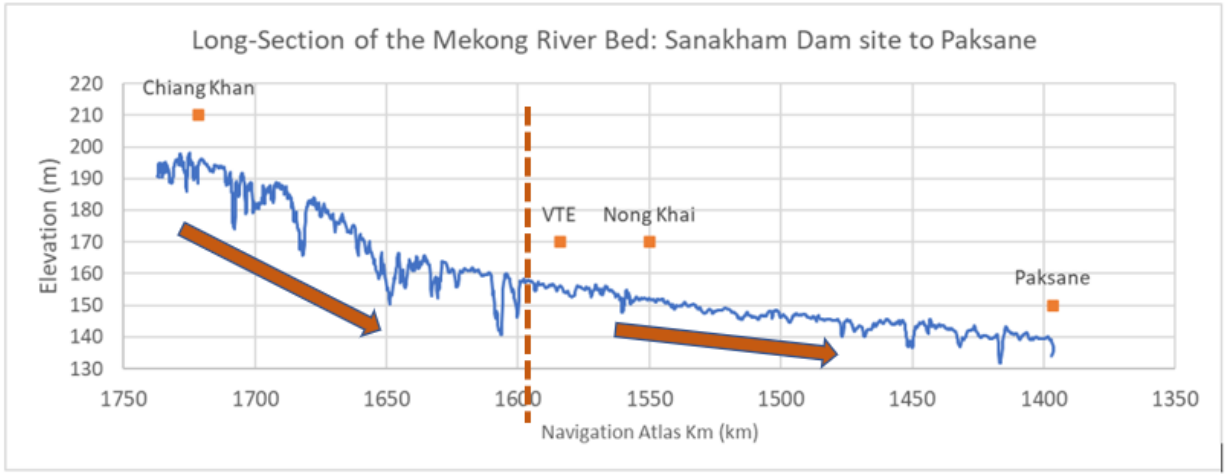
MRC modelling of sediment transport with and without cascade

Compliance with PDG2009/Good Practices by revised draft PDG

- PDG 2009 requires the use of site-specific data for developing an understanding of sediment transport at site and developing appropriate sediment management strategies. **Sediment monitoring** should be done weekly (flood season) to monthly (dry season) for a full year prior to submission of HPP for prior consultation. ***Project does not align with these requirements***.
- **Sediment facilities** at SNHPP are only ***partially aligned*** with PDG 2009.
- Project ***does not align with*** requirement to establish target sediment concentrations and flushing **strategies**.
- Potential changes to thalweg and other geomorphic characteristics are not described and included in monitoring strategy. **Project does not align with these requirements**.
- Project does not adequately consider **transboundary impacts**

Rapid Assessment into WL Changes – Approach & Method

- Assess the potential impacts of hydropower induced rapid water level fluctuations on the physical condition of the Mekong River between the Sanakham damsite and Paksane
- Consider changes in *addition* to other changes associated with HPP development, e.g. sediment trapping
- Quantified potential changes to erosion due to water level fluctuations at 8 locations between SNHPP dam site and Paksane
- Impacts will vary due to size of WL fluctuation and slope of channel
  - Both factors decrease with distance from SNHPP



Rate & Magnitude of Water Level Changes at Cross-Sections

Scenario	Km 1736 D/S SNHPP	Km 1723	Km 1716 Chiang Khan	Km 1661	Km 1559 u/s VTE	Km 1544 d/s NK	Km 1470	Km 1425 Paksane
Mild 3-4 Units								
Moderate 3-5 Units								
Strong 1-4 Units								
Extreme 1-7 Units								

Risk of increased erosion highest closest to SNHPP with strong peaking (>1 unit turned on or off)

Risk of increased erosion lowest further from the station with only 1 unit turning on or off

Color Key	Flow Changes	Risk of Increased Erosion
	Rate of Water Level change <0.05 m/hr	Low
	Rate of Water Level change >0.05 m/hr	Moderate to High
	Rate of Water Level change >0.05 m/hr *and* Magnitude of Water Level change >1 m	High to Very high

Summary & Recommendations from Rapid Assessment

- Development of the SNHPP will increase the rate of erosion due to sediment trapping, and rapid WL changes will increase the rate more
  - Highest risks associated with turning on and off more than 1 turbine in a short period
  - Highest risks closest to the SNHPP and decrease with distance downstream
- Rapid water level fluctuations will directly erode river banks and make them more susceptible to high rates of erosion during floods

Recommendations

- Avoid impacts from WL changes by operating to dampen upstream flows and minimise water level changes
- Operational constraints should be adopted that maintain water level rates of change at Chiang Khan to <0.05 m/hr except in emergency
- Developer should implement bank monitoring network and be responsible for implementing river bank protection measures
  - Based on modelling, this commitment should extend from SNHPP to at least Nong Khai

Conclusions & Recommendations

- Sediment data underpinning the proposal is not appropriate, **so the conclusions based on the models are not valid**;
- **Developer has not sufficiently considered downstream impacts**, which are likely to be substantial due to proximity of the border and impacts of water level fluctuations
- MRC modelling results shows an erosional wave progressing downstream

- Undertake additional site-specific **sediment monitoring over a full year**
- Update models based on recent information & provide more details on the 1-D and 2-D models
- Consider **redesign** of low-level gates with lower base level & better alignment with major flow path
- Transboundary impacts need to be better assessed
- Operating rules should be adopted to minimise impacts from WL fluctuations
- Update the descriptions of the proposed monitoring programme
- **Joint cascade operation** should be highlighted

THANK YOU

One Mekong. One Spirit.