



Preliminary Design Guidance 2023

Sediment Transport & Geomorphology

Dr. L Koehnken



Identified areas to address

- Greater emphasis on sediment management during **planning and design**
- Greater recognition of potential **downstream and transboundary impacts**
- **More information during the PNPCA** process regarding existing sediment transport and geomorphology conditions and identifying change
 - For both the impoundment area & downstream of the dam
- Need for greater information during the PNPCA process regarding **operating regimes**
- Increase emphasis on **adaptive management guided by monitoring**
- Increase guidance with respect to **sediment management within cascades**

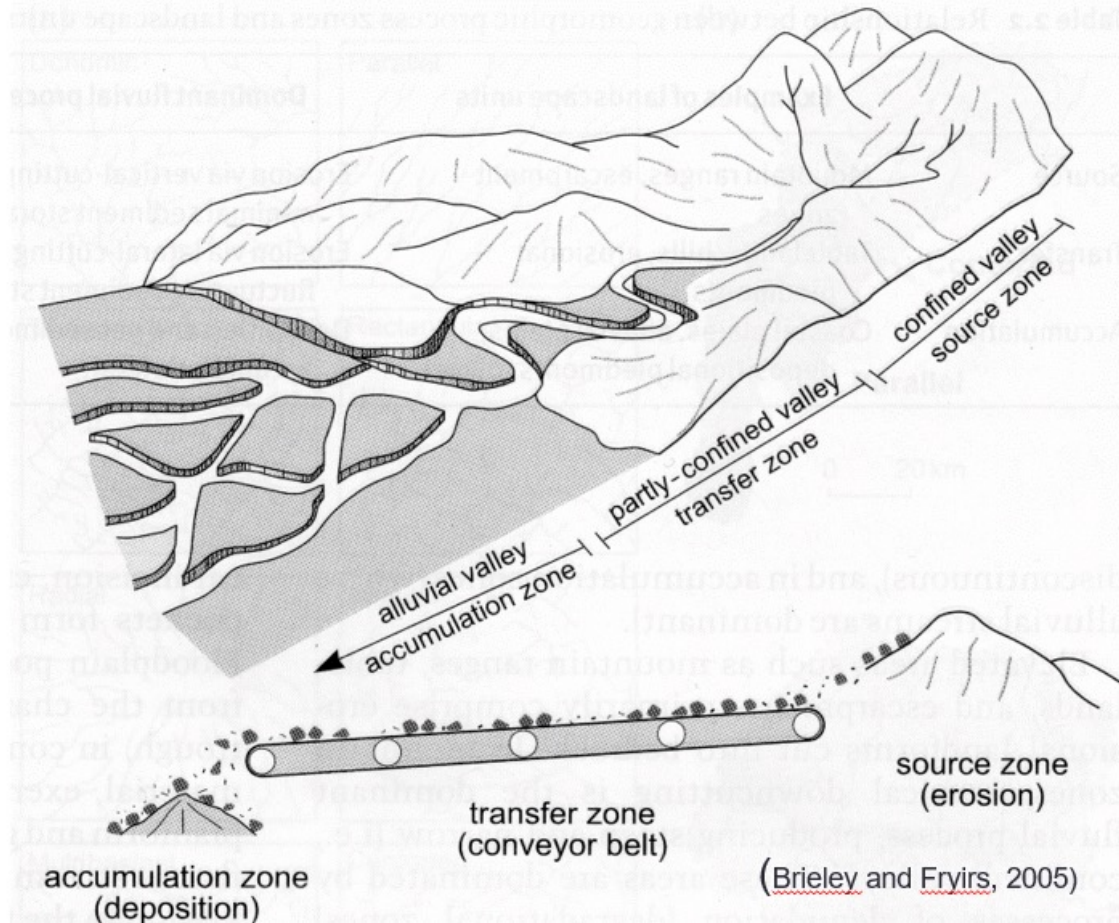


Section 3.1 Design Objectives

- 74. The **objectives** for sediment transport and geomorphology are to:
 - i. Maintain the morphological equilibrium of the Mekong River.
 - ii. Minimise changes to sediment delivery to the downstream environment with respect to sediment quantity, the seasonality of sediment delivery and grain-size composition of the sediment load.
 - iii. Minimise geomorphic impacts arising from the changes in sediment transport, including changes to river banks, river beds and aquatic and riparian habitats.
 - iv. Minimise deposition within the impoundment to prevent upstream river changes and maintain and protect project infrastructure.
- 75. No MRC Procedures directly relate to sediment, but theme is well recognised & included in MRC monitoring, Council Study, ISH, etc



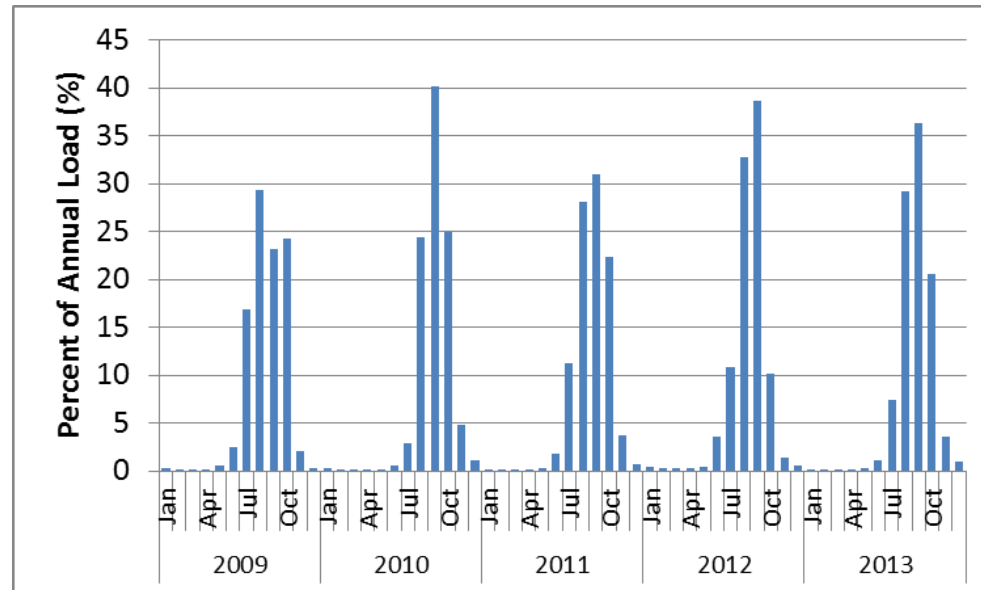
Objectives – Maintain sediment/geomorphic equilibrium



- Rivers transport sediments from the mountains to the sea
- During transport, sediment create habitats for fish, OAOs and vegetation communities
 - These underpin food security in the Mekong
- The maintenance of the Mekong delta depends on the continued delivery of sediment
- Mekong delta is rice bowl of VN and supports millions of people

Objective: Maintain sediment continuity & timing

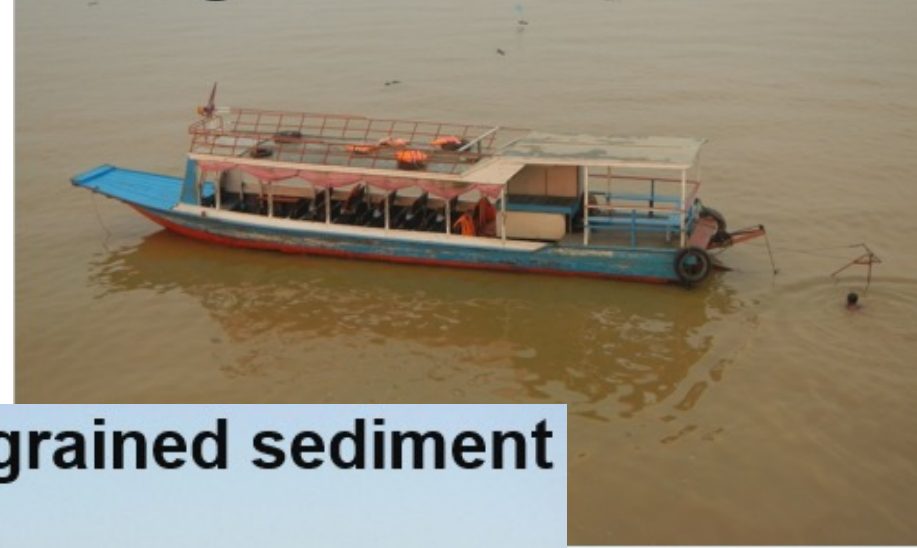
- Mekong is a flow and **sediment** pulse system
- The timing of sediment delivery is important
 - Dispersal of nutrients to floodplains, Tonle Sap system & the delta



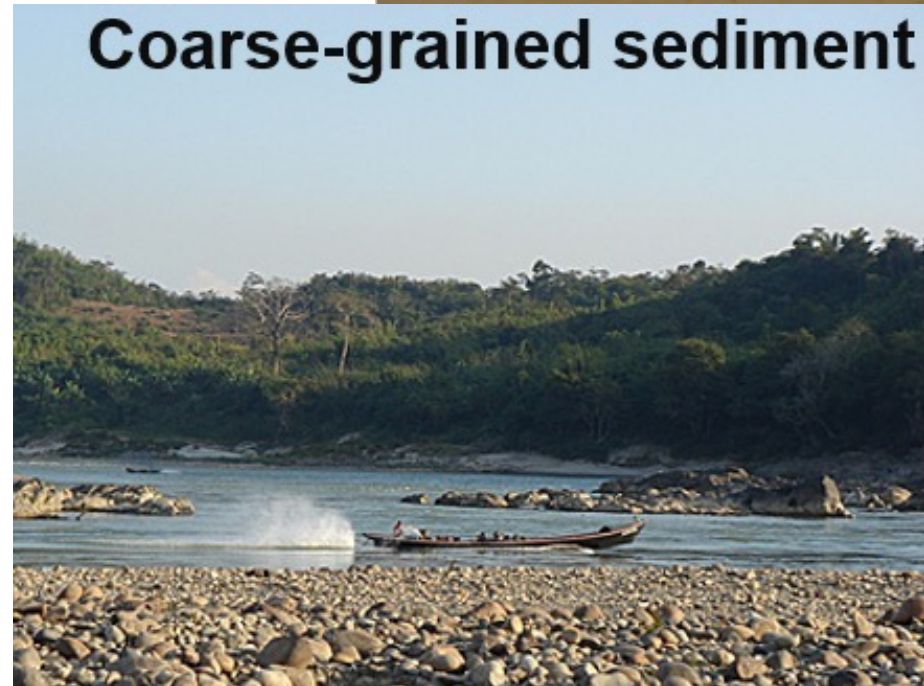
Objective: Maintain sediment grain-size distribution

- Different grain sizes perform different roles
 - Fine-grain sediment transports nutrients, controls light penetration and settles on flood plains
 - Coarse grained sediment controls river channels, provides important substrate for fish & OAO & provides building material

Fine-grained Sediment



Coarse-grained sediment



Section 3.2 Risks

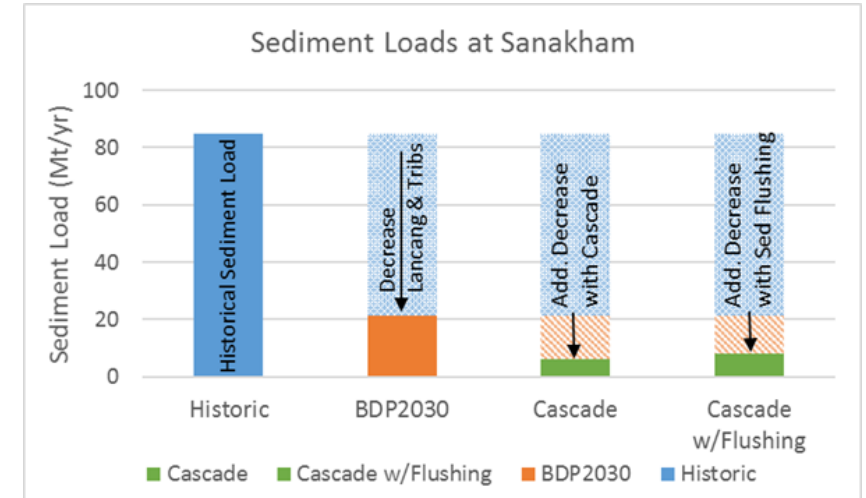
- 76. Dams interrupt the natural continuity of sediment transport in river systems, inducing deposition within the reservoir and discharging sediment starved water downstream
- 77. Specific risks identified related to following:
 - Alteration of morphological balance of the Mekong River
 - Trapping of sediment within impoundment
 - Reduction in sediment load downstream of hydropower project
 - Water level fluctuations within impoundment
 - Water level fluctuations downstream of impoundment
 - Disconnect between flow and sediment delivery
 - Increased sediment generation during construction
 - Increased land disturbance during construction
- 78. The position of a project within a cascade should be considered when identifying risks



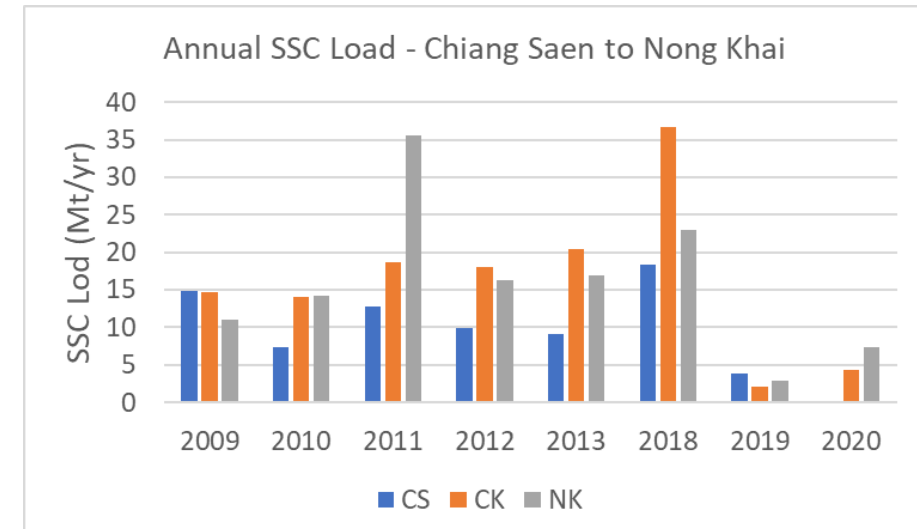
Risks: HPPs alter sediment transport

- Dams alter the water velocity & cause sediment deposition in the impoundment
 - Only very fine-grained sediment can remain in suspension
- Reduction in sediment load & grain-size in discharge from dam causes erosion of the downstream river channel & loss of habitats
- Sediment trapping is cumulative
 - Lancang, Mekong tribs, Mekong mainstream
- HPP impacts interact with natural variability
 - JEM found very low sediment loads downstream of Xayaburi during a drought period

ISH modelling looked at sediment trapping in the Upper LMB



JEM monitoring found a reduction in sediment load from CS to NK- drought was also a factor

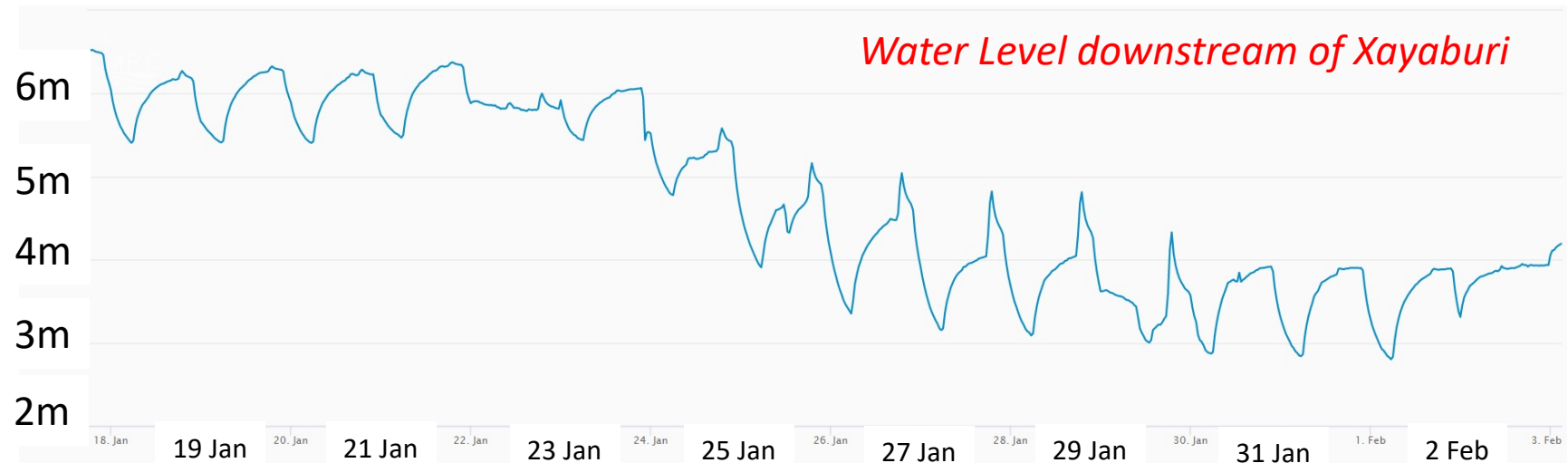


Water level fluctuations increase erosion

Seepage erosion occurs when banks are saturated and the river level drops rapidly



- Water level changes directly scour river banks
 - Wetting & drying increases susceptibility to erosion
- Saturated banks collapse when water level decreases quickly



Construction risks

Coffer dams alter river hydraulics
Faster flow = Increased erosion

1229 m

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- Coffer dams alter river hydraulics
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- 1229 m
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- Erosion of river mouths
- Creation of new bars

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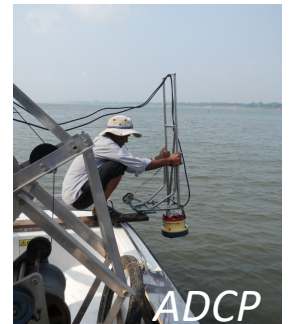
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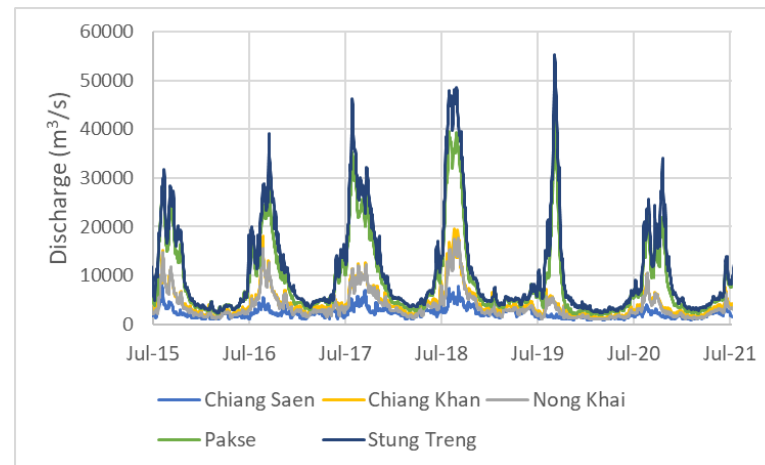
Section 3.3 Pre-Project Monitoring & Assessment

- 79. Combined monitoring and modelling approach w/ hydrology
 - Site-specific monitoring in project area linking in with larger scale MRC monitoring
 - Basic numerical sediment transport model integrated with hydrologic and hydraulic model
 - Needs to be capable of demonstrating potential trans-boundary impacts
 - Complemented with physical modelling where appropriate
- 80. Use monitoring & modelling to:
 - Quantify existing environment – strong linkage with hydrology (Clause 81)
 - Identify and evaluate potential changes associated with HPP proposal (Clause 82)
 - Identify risks and identify and optimise mitigation measures (Clause 83)
- 81-82. Guidance for information required to quantify existing environment and identify changes
 - Sediment budgets, grain-size distribution, geomorphic characteristics
 - Predicted impacts due to project development
 - How adaptive management will be implemented



Section 3.3 Pre-Project Monitoring & Assessment (cont'd)

- 83 - 88. Guidance for monitoring
 - Geographic range upstream & downstream
 - Location of monitoring sites-including MRC sites where feasible
 - Monitoring parameters - Flow, SSC, bedload, grain-size
 - Monitoring frequency - Link to seasonal flow patterns
 - Compare results with MRC sediment monitoring results

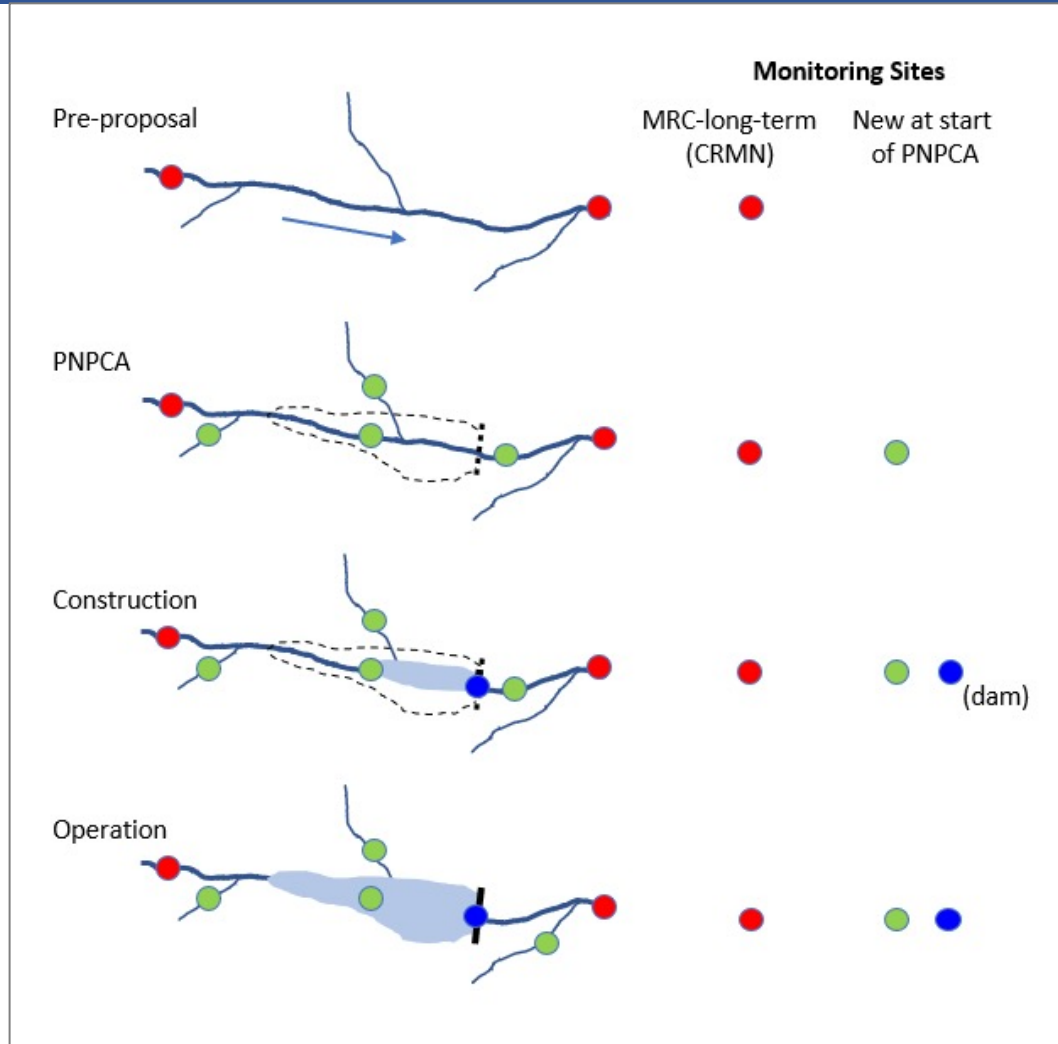


Monitoring frequency should reflect seasonality



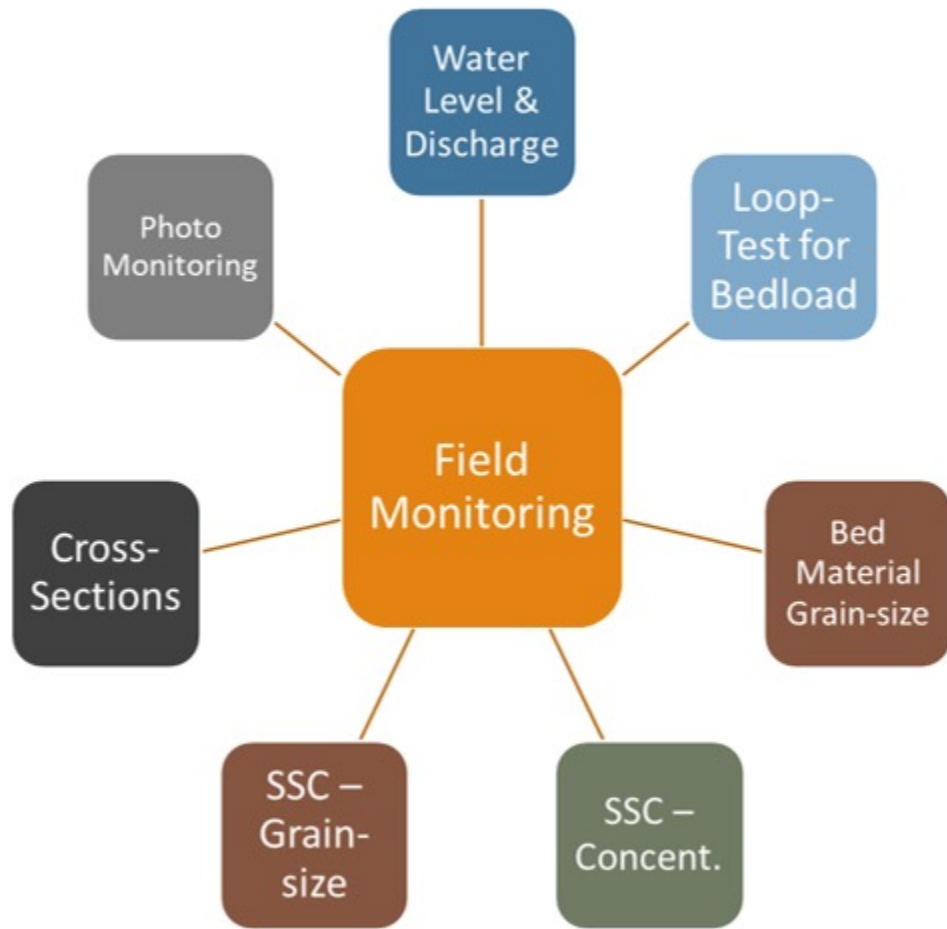
Monitoring locations should link with MRC long-term sites

Monitoring strategy



- **Accurate** monitoring required to guide all aspects of HPP planning, design & operations
- Short & long-term results required to develop hydrologic & sediment transport models
 - 2D & 3D modelling should be completed
 - Modelling results used to predict potential impacts
 - Model used to trial potential mitigation options such as sediment flushing
- New sites established to compliment long-term MRC sites
 - Upstream/downstream/within proposed impoundment area & major tributaries
- Sites maintained throughout life of project to guide adaptive management
 - Operating patterns may change over life of HPP
 - Results used to evaluate & refine mitigation measures
 - Results used for State of Basin Reporting

Monitoring: Sediment/geo information needs for HPPs



Monitoring provides the data required for all aspects of HPP planning, operations & mitigation

MRC Report: *Guiding Considerations on Transboundary Monitoring for LMB Hydropower Planning and Management (ISH11)* & JEM studies provide detailed information on monitoring

All sediment monitoring to be linked to hydrology

Flow & sediment discharge

- At locations & frequency to capture spatial & temporal patterns

Sediment grain-size

- Depth integrated suspended sediment
- Bed material & bed load

Bathymetric cross-sections

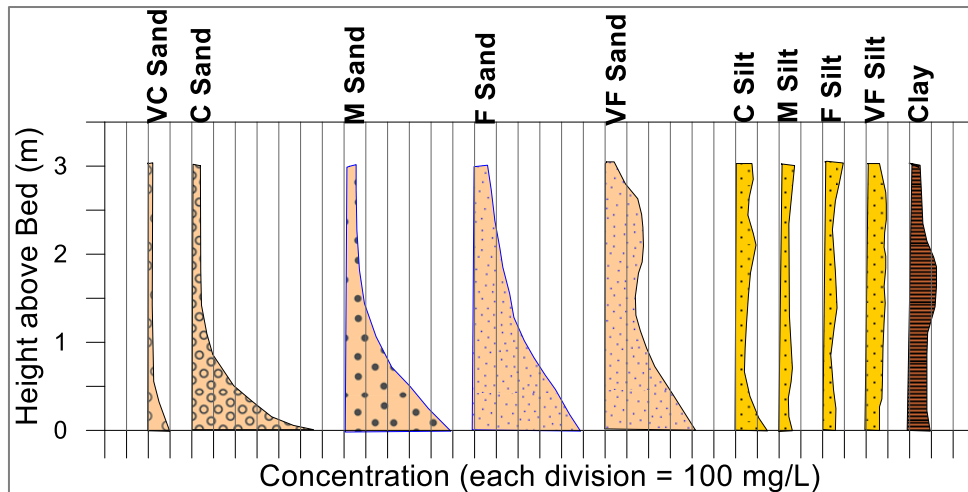
- Determine large scale channel changes

Photo monitoring

- Track river-bank and vegetation changes
- Collaborative monitoring makes best use of available resources

Monitoring: Appropriate methods for accurate data

- Sediment monitoring is DIFFICULT
 - Sediment concentrations & grain-size vary with flow rate & depth
 - Sediments can travel as suspended or bedload depending on conditions
- Accurate sediment monitoring requires
 - Accurate discharge monitoring
 - Depth-integrated sampling: Physical or remote techniques
- Results should be compatible with and linked to MRC long-term monitoring results



'Remote' sampling



Depth integrating



Point Sampling

Physical sampling



Optical



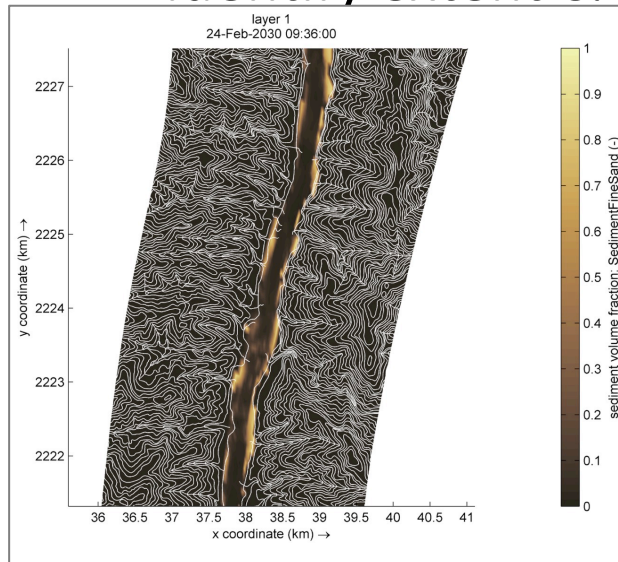
ADCP Calibration



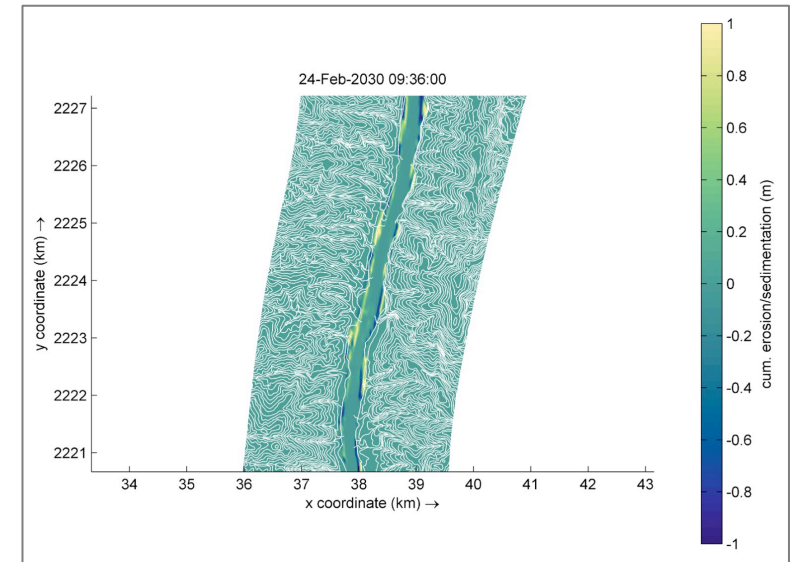
Multi-beam eco-sounder

Section 3.3 Pre-Project Monitoring & Assessment (cont'd)

- 89 - 94. Guidance for Modelling
 - Integrate with hydrologic and hydraulic modelling
 - Detailed scenarios showing effect of project & influence of operating patterns
 - Quantity and characteristics of sediment discharge from project
 - Adjustments of downstream river channel
 - Deposition / scour near project infrastructure
 - Demonstrate efficacy of mitigation measures
 - Identify extent & severity of residual impacts



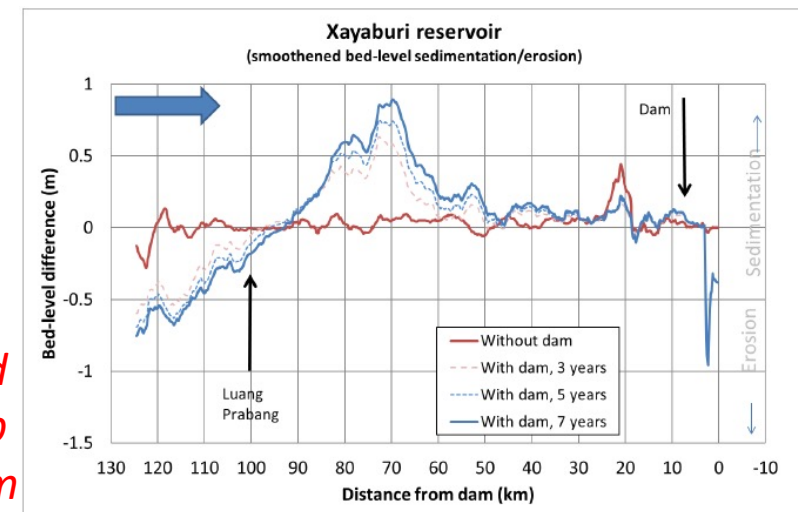
The MRC ISH Mitigation Guidelines Case Study involved a range of model types and approaches



Modelling for sediment

- Modelling required for
 - understanding sediment input / throughput in impoundments
 - Distribution of deposition in impoundments
 - Impacts on river channels downstream
 - Identifying 'best' conditions for sediment flushing
- 2D & 3D models required for understanding sediments
 - Hydraulic variability within cross-sections limit usefulness of 1D
- Both fine- and coarse-grained sediments need to be modelled
 - Different trajectories under altered flow scenarios
- Need to run a range of scenarios
 - Wet / dry seasons – avg & extreme
 - Drought / flood events
 - Interaction with other HPPs
 - Sediment flushing
- Model needs to be run over years to identify geomorphic changes
- Modelling is a powerful tool but needs to be based on accurate data

Example shows erosion at head of impoundment & deposition up to 90 km upstream of dam



Section 3.4 Specific Design & Operational Guidance

- 95. Mitigation approaches provided for each of the potential risks listed in Section 2
- 96-98. **Siting of HPP** to minimise sediment trapping and maximise potential for transport, including potential for sediment by pass
- 99 - 102. **Dam infrastructure** to facilitate sediment transport
 - Large low-level gates if sediment flushing/sluicing is applicable
 - Intake structures to minimise deposition
 - Failsafe provisions in case of gate blockage
- 103. **Sediment management** during construction
 - Minimise runoff
 - Minimise risk of landslides & disturbance



Increased landslide risk



Sediment management during construction

Section 3.4 Specific Design & Operational Guidance

- 104. Sediment management objectives during operations
 - i. Minimise deposition within impoundment
 - ii. Maintain a seasonal supply of sediment to the downstream environment, including bedload
- 105. **Targets** for sediment management during operations
 - i. The passage of sediment should be promoted during all **flood events** with low-level outlets opened in preference to high level flood gates.
 - ii. At least **70% of the fine-sediment** (grain-size<63 µm) entering an impoundment should be discharged on an annual basis to downstream of the dam, either through normal operations or via sediment flushing. **Aim is to maintain a supply of fine-sediment and nutrients to the downstream environment, including the Tonle Sap and delta.**

Section 3.4 Specific Design & Operational Guidance

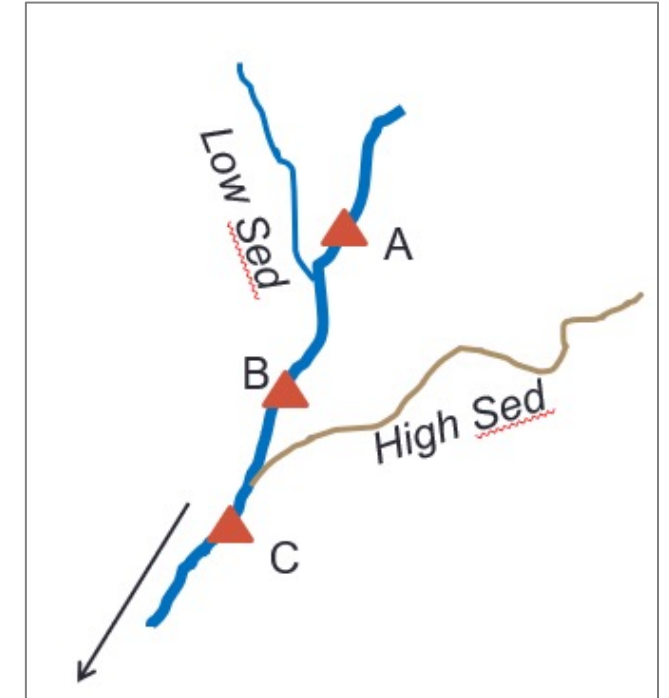
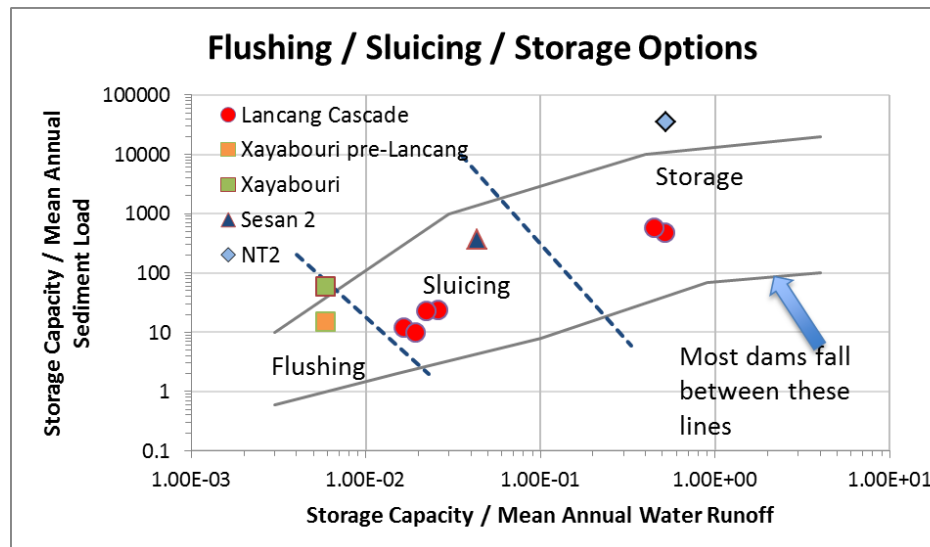
- 106 Mitigation strategies should be developed to address risks to achieve target
 - E.g., Sediment bypass, routing, pressure flushing, sediment flushing
- 107. Guidance on operating rules during flushing to minimise downstream impacts
 - Control sediment concentrations downstream
 - Implement communication strategy for downstream communities
- 108. Guidance on mechanical removal of sediment
- 109 – 112. Guidance on management of downstream geomorphic impacts
 - Catchment management, operating rules, bank erosion control
- 113-114. Management of sediments within a cascade
 - Need for communication & planning between hydropower operators
 - Need for communication between operators and MC



Mitigation starts with siting of HPP project

- Planning & siting
 - Dam position wrt tributaries – upstream & downstream
 - Unregulated tributaries enter downstream
 - Decreases percentage of flow & sediment regulated
 - Bedrock reach to limit impacts immediately downstream
 - Localised loss of sandy bars & banks
 - River bed erosion controlled by bedrock
 - Small volume reservoirs with inflow >> storage
 - Smaller impact on flow regime
 - Less sediment retention

Storage capacity & annual inflow will determine potential mitigation options. Impoundment morphology is also a factor

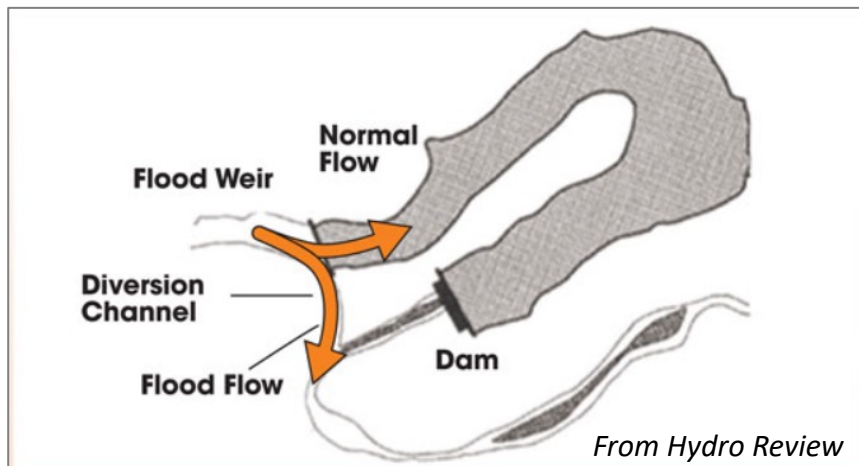


Dam sites A or B will have lower impact on downstream as compared to site C. Similar considerations apply for fish migration

Sediment Management-Minimise input/Maximise output

- Minimise inputs
 - Protected areas have low erosion
 - Also protects biodiversity
 - Reforestation of degraded land
 - Sediment bypass channels
 - Check dams/sedimentation ponds
 - Sediment extraction (bedload material)

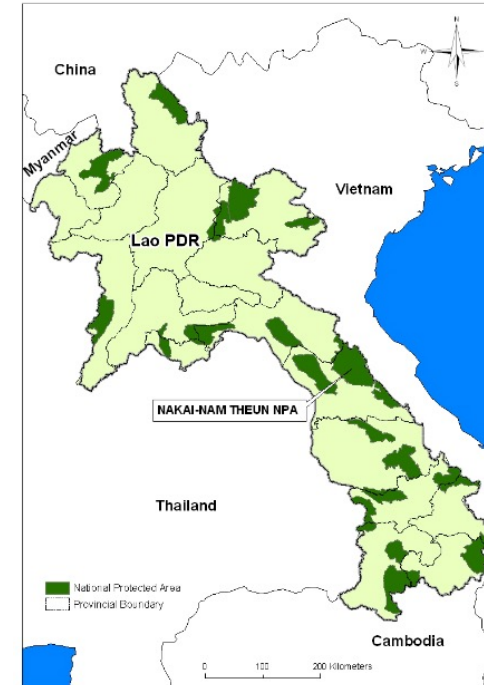
*Sediment bypass
Nagle Dam, South Africa*



Gravel mining in the upper Yangtze basin



*Dredging of bedload
Yangtze, China*



*Protected Areas in
Lao PDR*

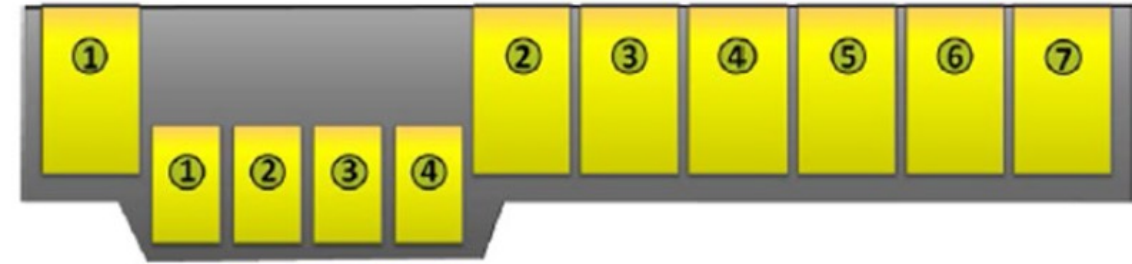


Check dams on tributary inflows

Sediment Management-Minimise input/Maximise output

- Maximise outputs – Infrastructure
- Low-level gates
 - Should be opened preferentially or at same time as surface gates to maximise sediment passage
 - Manage sediment concentrations
 - Will only pass material deposited near gates unless water level is decreased
- LL Gates should be located in natural thalweg of river
- Flow capacity of gates should be similar between projects within a cascade
 - Promote continual passage of sediment downstream

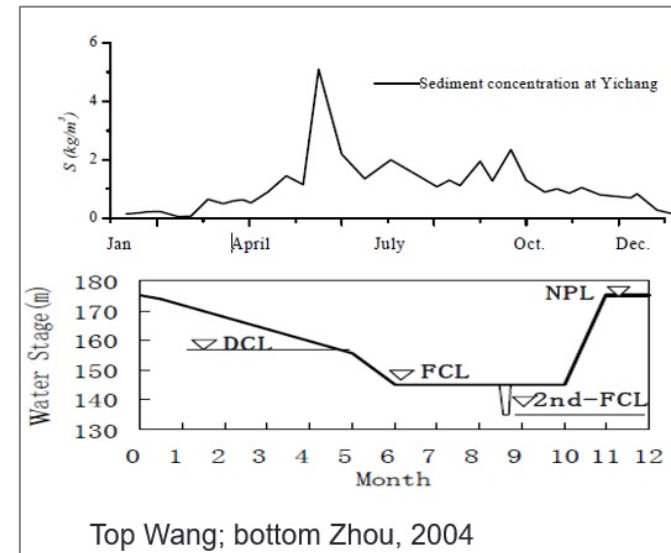
Low level gates should be located at low point of river bed



Release of clean water to dilute sediment concentrations

Sediment Management-Minimise input/Maximise output

- Maximise outputs
 - Manage water level in the impoundment
 - Lower water levels = reduced residence time = reduced sedimentation
 - Sediment routing
 - WL in impoundment remains high
 - Less efficient than flushing wrt sediment mobilisation
 - Sediment flushing
 - WL in impoundment is drawn down as gates are opened, and remains low for a period
 - Efficient at mobilising deposited sediment
 - Risk of high flows & high sediment loads downstream
 - Safety risk, ecological risk
 - Max [sed] should remain within natural range



Manage water levels to reduce sedimentation

Suitable for flood-pulse systems

*Impoundment lowered during onset of wet season
Increased at end of wet season*

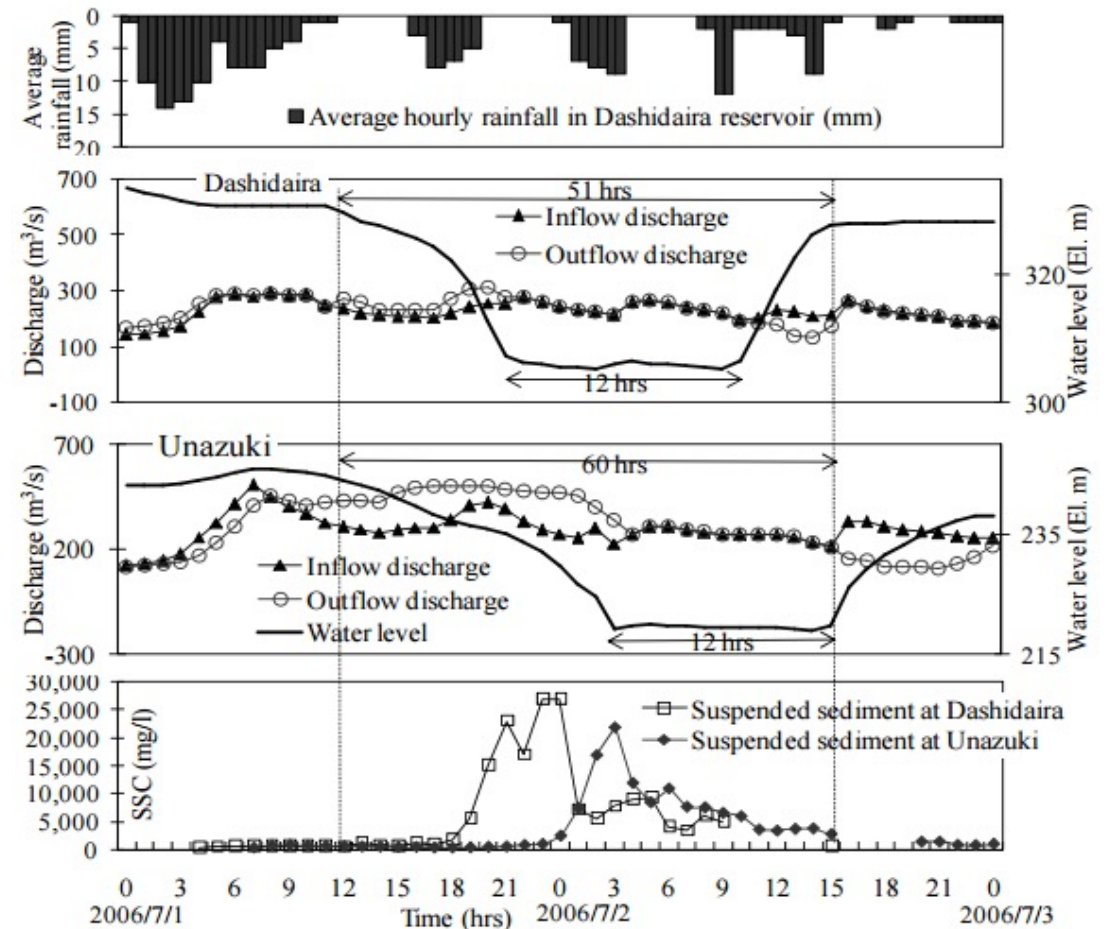


Sediment released via low-level outlets

Clean water released from surface gates

Coordination of sediment management in a cascade

- Need to coordinate sediment sluicing / flushing activities within a cascade
 - Minimise deposition in downstream impoundment(s)
 - Minimise safety risks associated with large flow releases
 - Minimise ecological risks within impoundments & downstream of final dam



Coordinated sediment sluicing/flushing in Kurobe R, Japan

Section 3.5 Project Monitoring & Adaptive Management

- 115 - 116. The monitoring implemented prior to the PNPCA should continue through construction and operations
 - Provide sufficient data for operational planning e.g. flushing
 - Identify other issues that may require management
- 117. Adaptive management to be guided by ongoing monitoring
 - Guide water level management, ramp-down rules
 - Sediment management
 - Flushing, sluicing
 - Geomorphic changes in impoundment & downstream river
 - Armouring of river banks if required
- The site-specific monitoring results should be made available to the MRC for interpretation with respect to the basin wide trends captured by the ongoing Discharge and Sediment Monitoring Program.
- Relevant basin wide information should be provided to developers & operators via the relevant NMCs the MRC



Thank you

