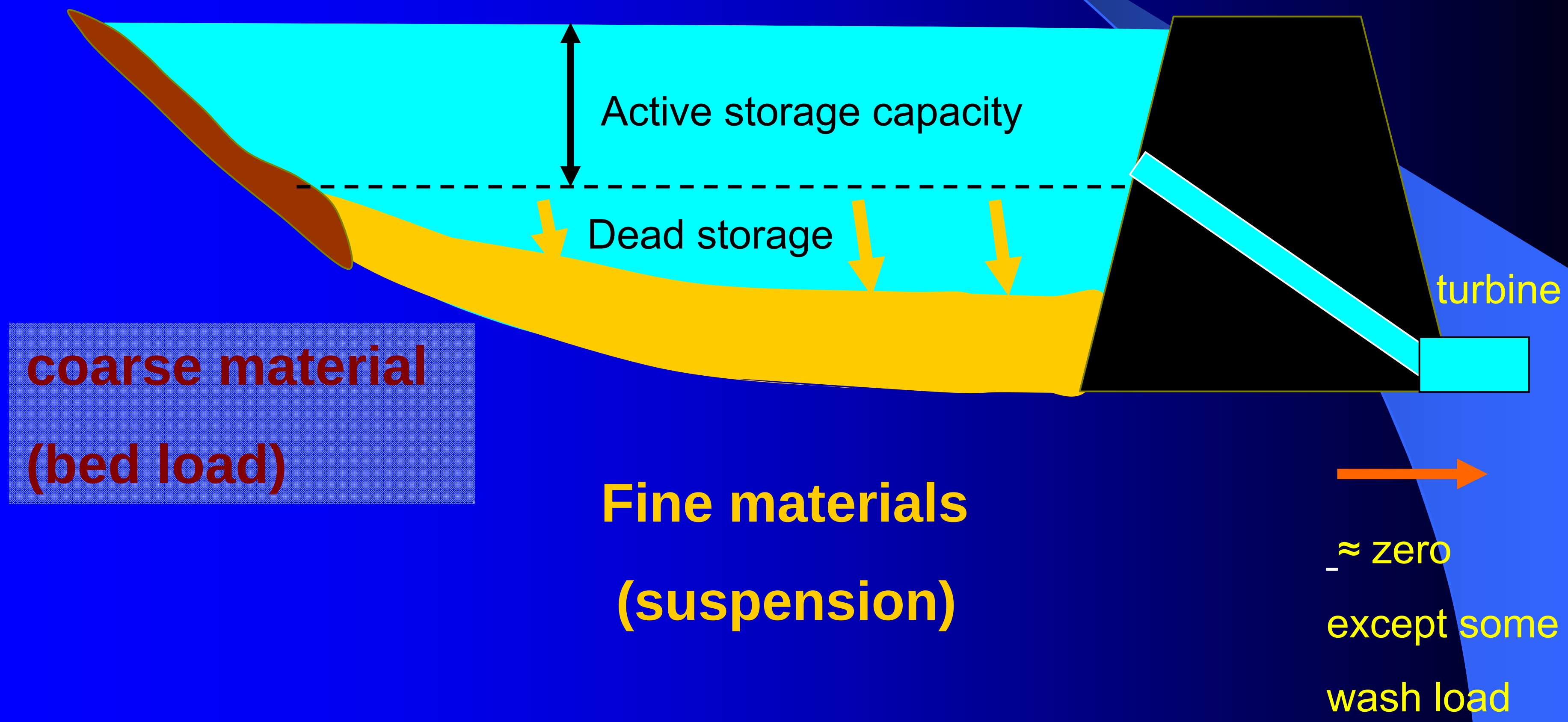
Section 3

Sediment Management and River Morphology

Dialogue Meeting
Preliminary design guidance for proposed mainstream dams in the Lower Mekong Basin

IKMP, MRCS

Sediment trapping by dams



Francis Fruchart, CNR France

Consequences of reservoir sedimentation

Bar-lin Dam, Dahan River, Taiwan

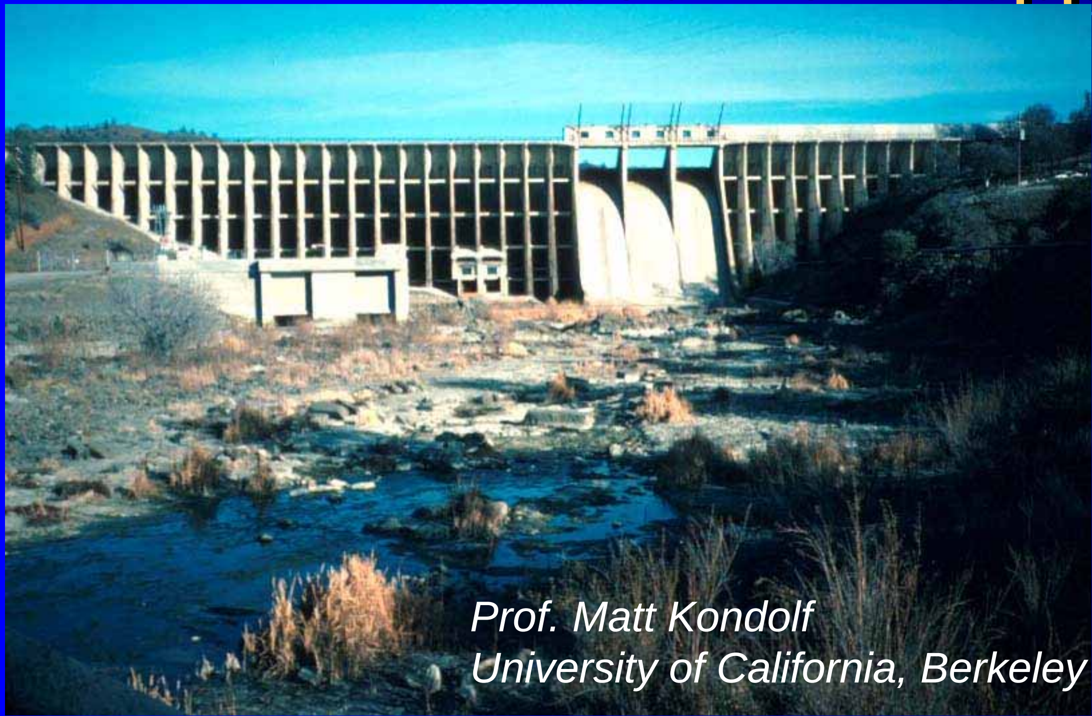
Oct 2002

Sep 2006
Complete filling

Sep 2007
Dam failure

Photos:
Prof. Matt Kondolf
University of California, Berkeley

Downstream consequences of reduced sediment supply



Prof. Matt Kondolf
University of California, Berkeley

- Dams release sediment-starved water with excess energy

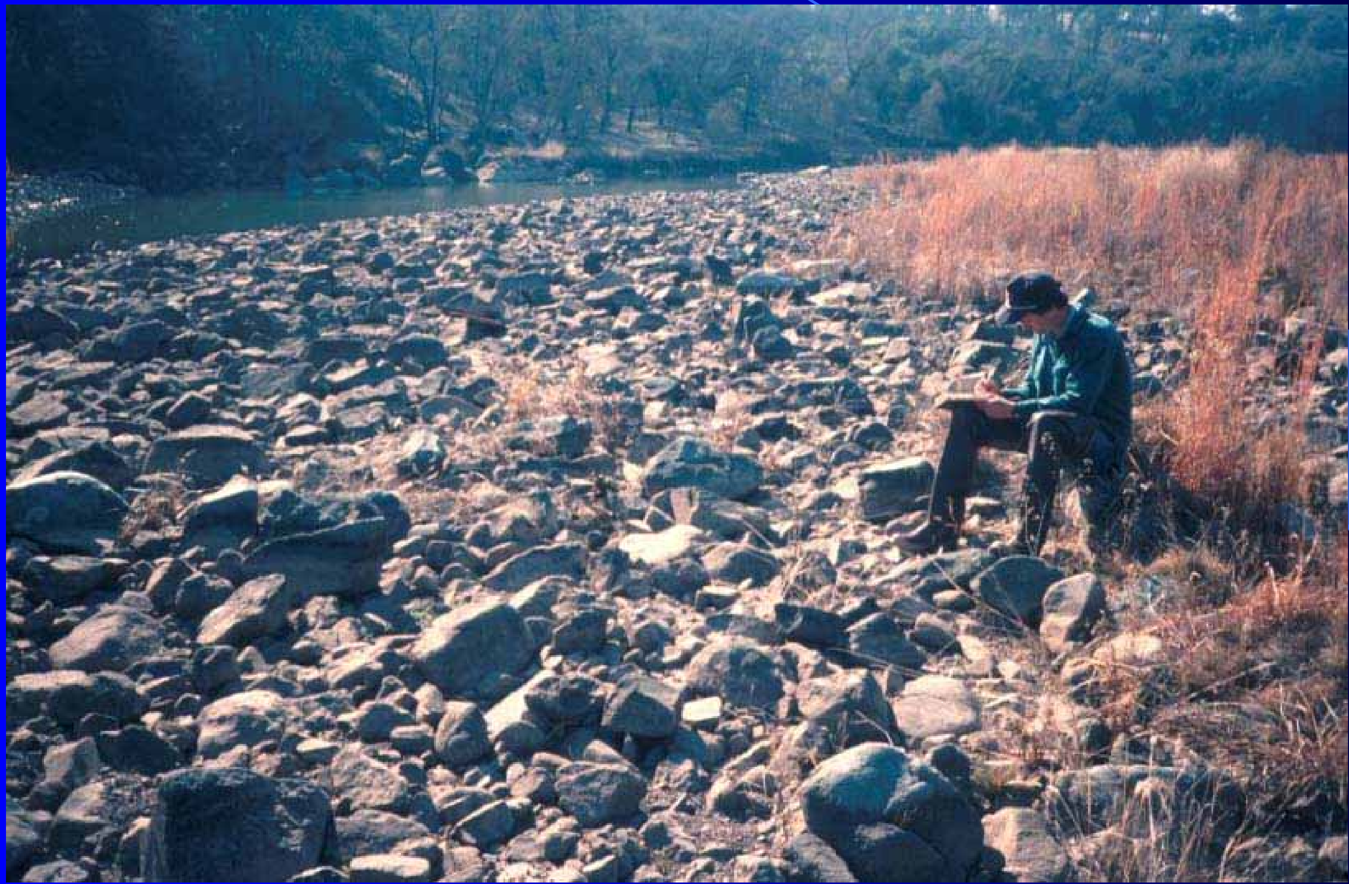
→ ***Hungry water***

- It has more stream power to transport than available sediment.

Result: erosion of bed and banks

- Bed incision, often down to bedrock
- Effects can extend +100km downstream

Channel armouring



Bed coarsens as smaller, easily transported grains are washed downstream

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Major objectives for sediment management in dams

1. Minimise sediment trapping behind the dam
   - Maximise sediment transport through the reservoir and past the dam wall
2. Maintain the seasonal distribution of sediment transport
3. Maintain the natural grain-size distribution of transported sediment

Economic & operational benefits of minimising sediment trapping

- Extend the life of the dam and reservoir
- Reduce the need for expensive dredging
- Reduce risk of blocking intakes and bottom gates
- Reduce risk of damaging turbines

Environmental benefits of minimising sediment trapping

- Reduce bed incision downstream of dam
- Maintain bank stability downstream
- Maintain the supply of nutrients to downstream floodplains, wetlands etc
- Reduce deposition in important aquatic habitats (deep pools) within the storage area

Sediment management strategies

Implemented at various stages

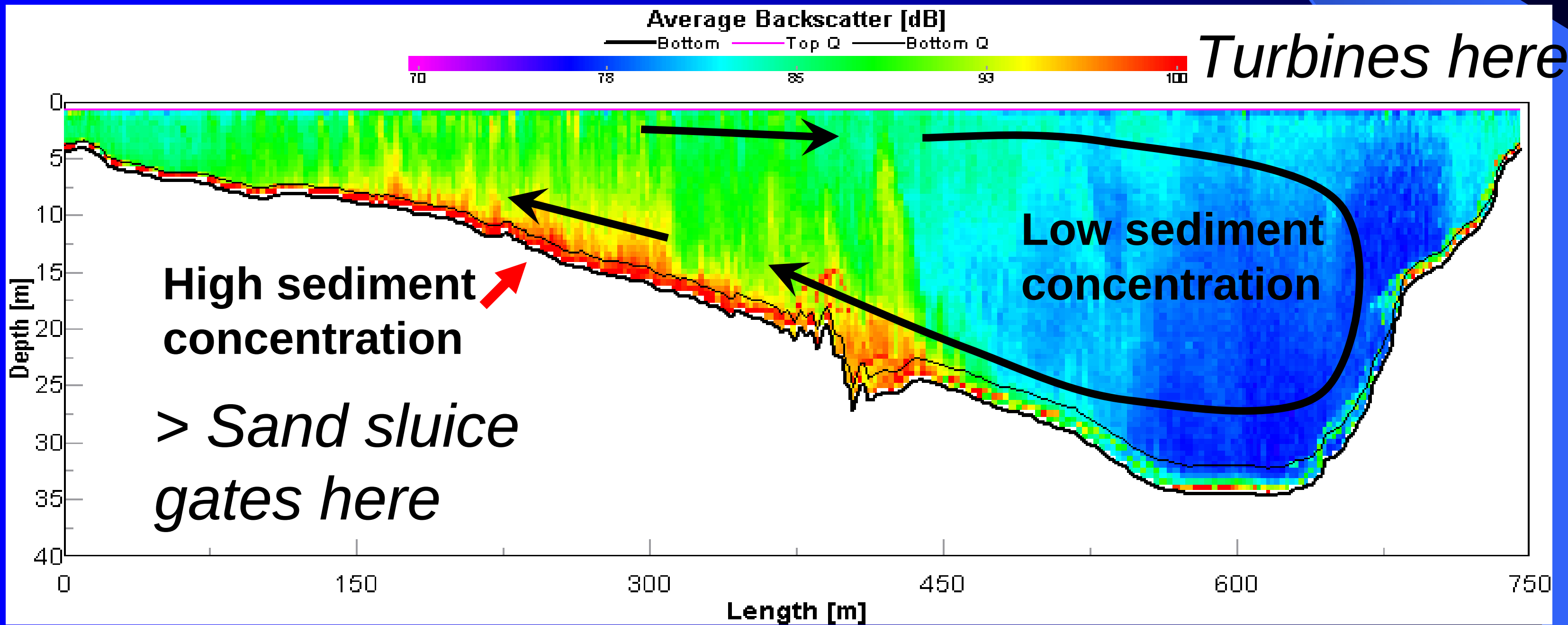
- Dam design stage
- Operation
- Decommissioning

Sediment management strategies during dam design

- Run-of-river will trap less sediment than a dam with a large seasonal storage
- Minimise dam height and storage area
  - ➔ Maximise flow velocities upstream of dam
  - ➔ Keep fine sediment suspended
- Low-level sediment sluices or diversion channels
  - – Transport sediment through the dam
- Low-level outlets to enable sediment flushing
  - – Removal of deposited sediment (sand and gravel)
- Mid-level outlets for regulating downstream water quality during sediment flushing

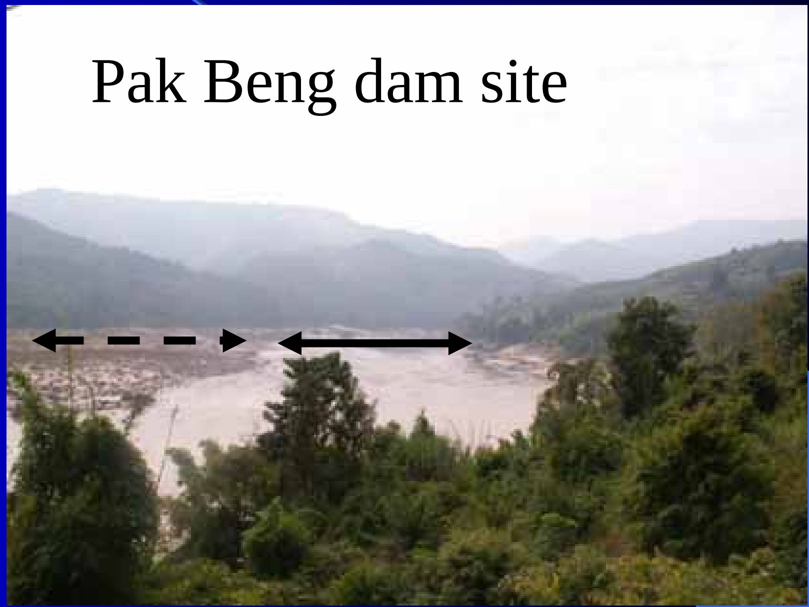
Dam design stage: Determine suitable locations for sediment sluice gates

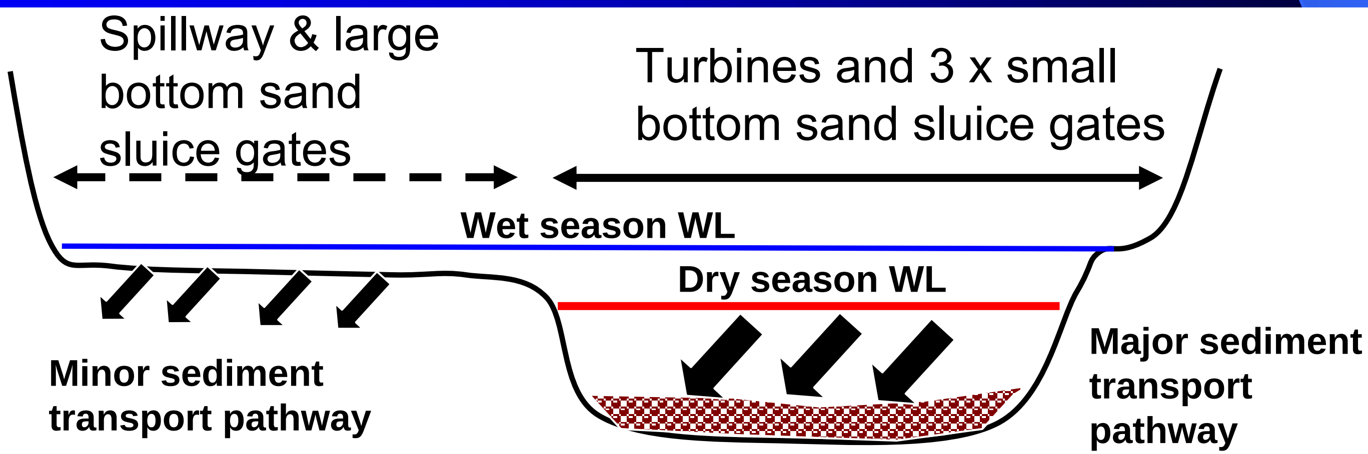
- Should have a good understand the distribution of sediment transport in the cross-section



ADCP data from Mekong River in Pakse - Sep 2006

Suitable location of sluice gates continued…





Questions that should be addressed during feasibility study

- Are the sediment sluice gates in a suitable location to be effective?
- Are the sluice gates large enough for the incoming sediment load?
- Will the sluice gates pass all grain sizes? Coarse sand gravel, cobbles?
- If not, what other strategies will need to be employed?
- Effects of irregular opening of sediment sluices on downstream water quality and fish spawning area?
- Will the location of the sediment sluices adversely affect the operation of fish ladders or navigation locks?

Information and studies needed to answer these questions

- Sediment load (suspended and bedload)
  - Annual load
  - Monthly loads
- Grain-size distribution of suspended and bed-material load
- Spatial distribution of sediment transport?
  - Pre-existing channel geometry
  - Altered geometry when dam and sluices are in place
- Run hydraulic and sediment transport models to determine the effectiveness and environmental impacts of various sluice gate designs

Sediment sluices are not likely to be sufficient

So sediment flushing or dredging will be necessary

Dam design for sediment flushing

Review by HR Wallingford (1999) and World Commission on Dams (2000)

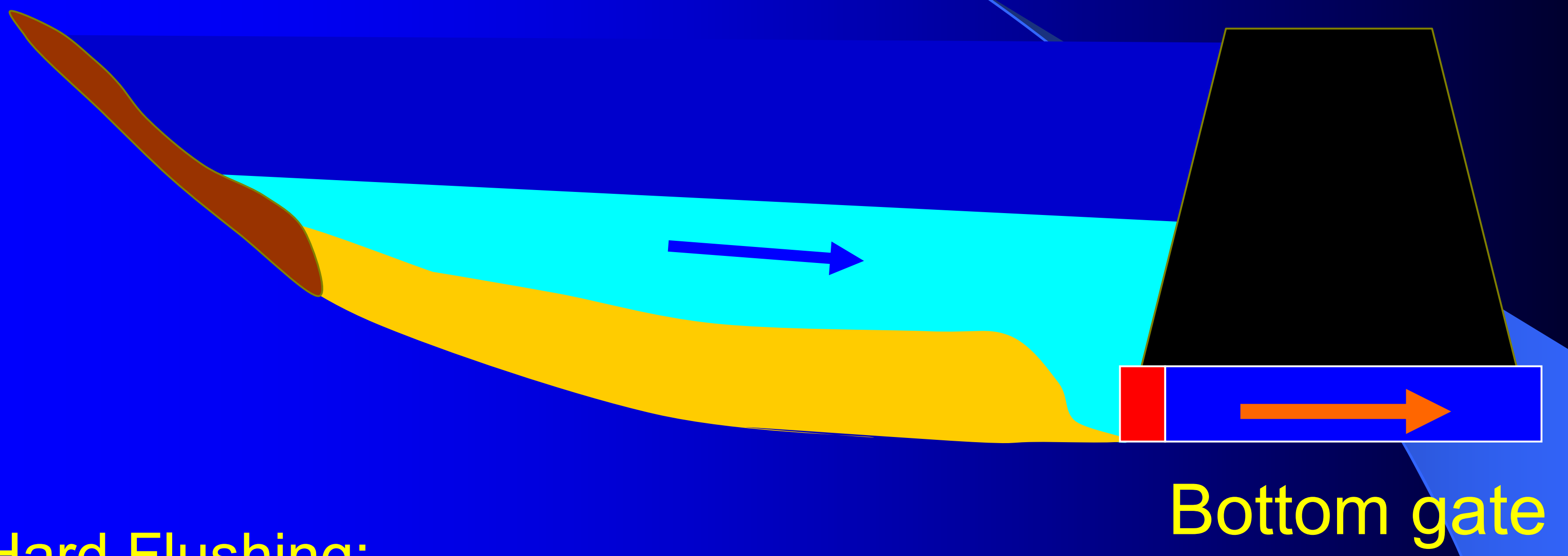
- Reservoir is drawn down, bottom and mid-level gates are held open
  - ➔ increase water slope & velocity
  - ➔ Increase sediment transport capacity
- Dam design must allow a constant low WL to be maintained during flushing
- Flushing discharge = 2 X mean annual flow

Flushing is most successful where:

- Small storage
- Long & narrow reservoir
- A regular annual cycle of flows (e.g. monsoon)
- Knowledge of grain-size of sediment to be flushed

Hard flushing

Send as much sediment as possible downstream



Hard Flushing:

High and uncontrolled concentration downstream

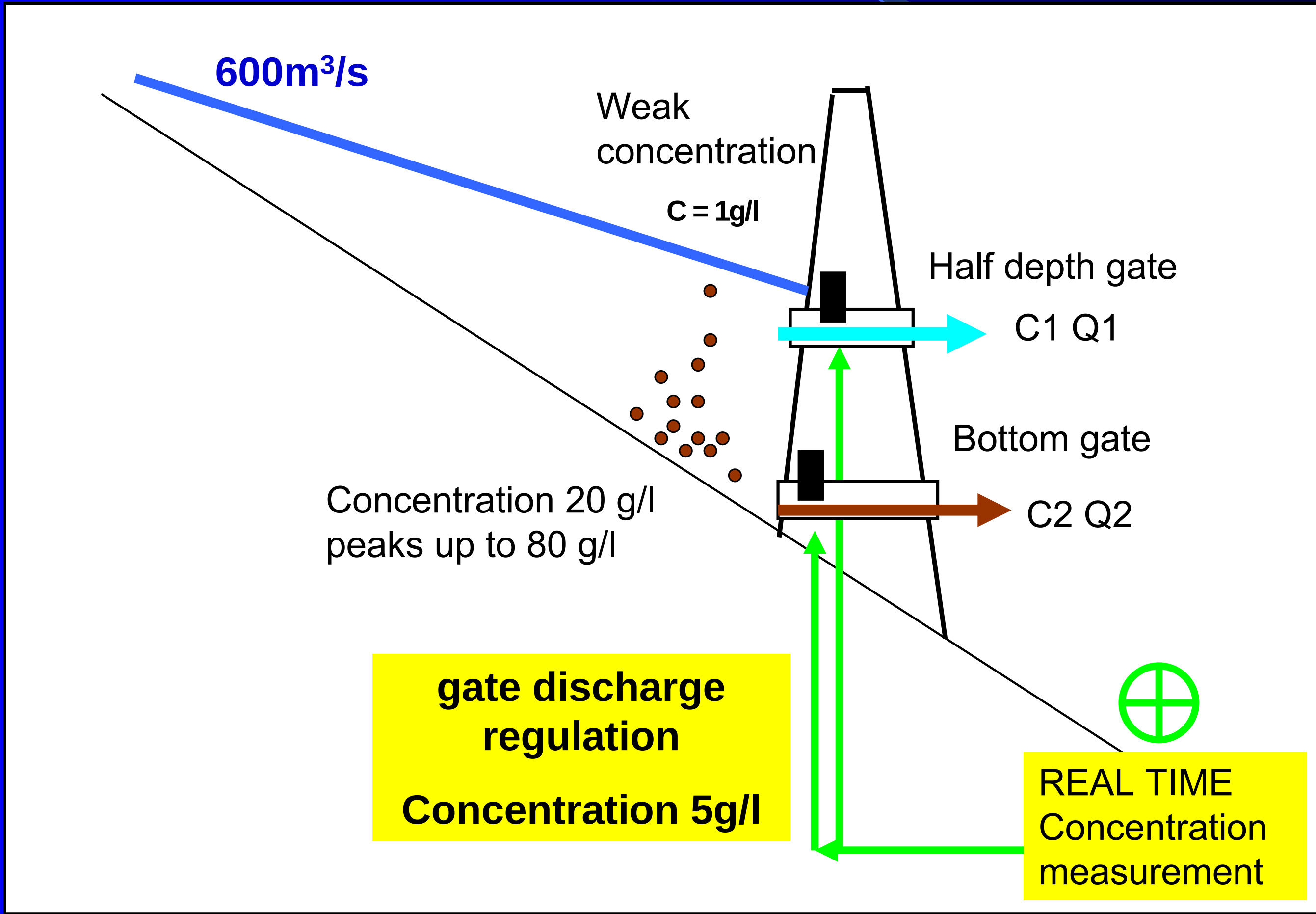
Destruction of the biodiversity downstream

Best practice : no flushing ?

Francis Fruchart, CNR France

Environmentally friendly flushing

Send downstream only the concentration of sediment that the environment can withstand



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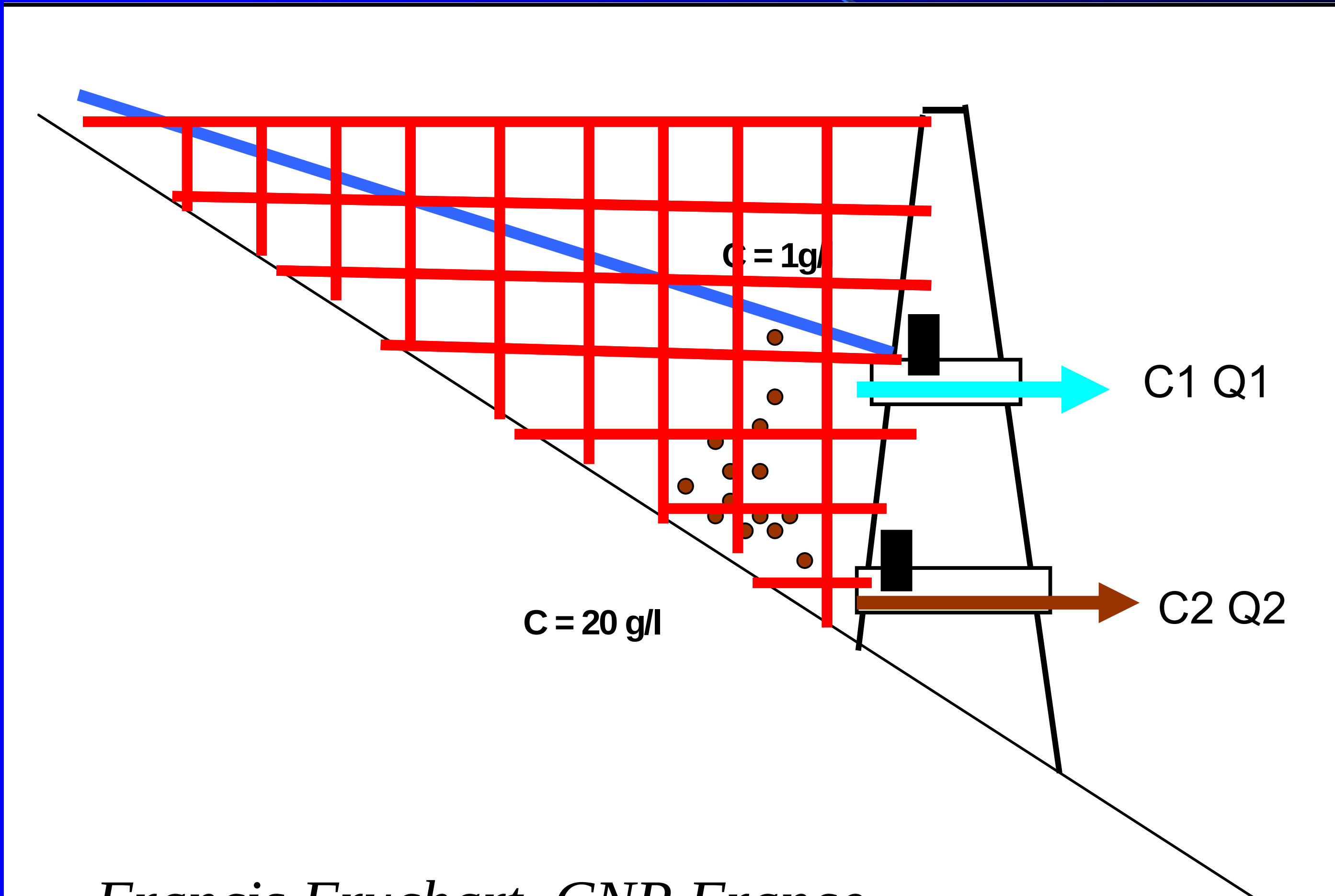
Run 2D X-Z models to assess & plan dam flushing operations



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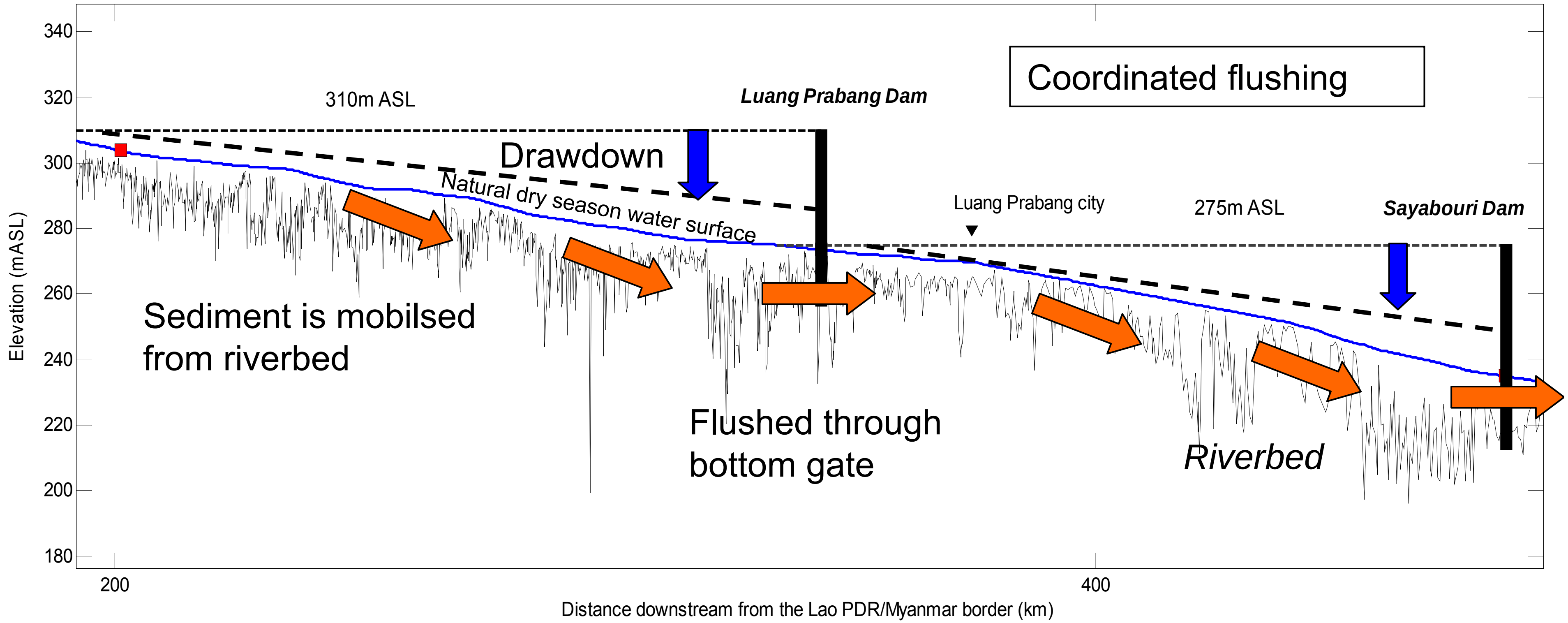
Sediment management during dam operation

- Minimise water levels during flood season
  - to maintain sediment transport through reservoir and sediment sluices
- Open sediment sluice gates during times of high sediment transport
- Operate mid-level gates together with bottom sluice gates to minimise impacts on water quality downstream
- Carry out periodic drawdown for <u>sediment flushing</u> (flood season is best)

Potential impacts on deep pools



- Backwater effect upstream of dam will reduce water velocities
- **Result:** sediment deposition & pool infilling upstream of each dam
- **Mitigation:** Periodic drawdown for sediment flushing (rising limb of flood – June-July)

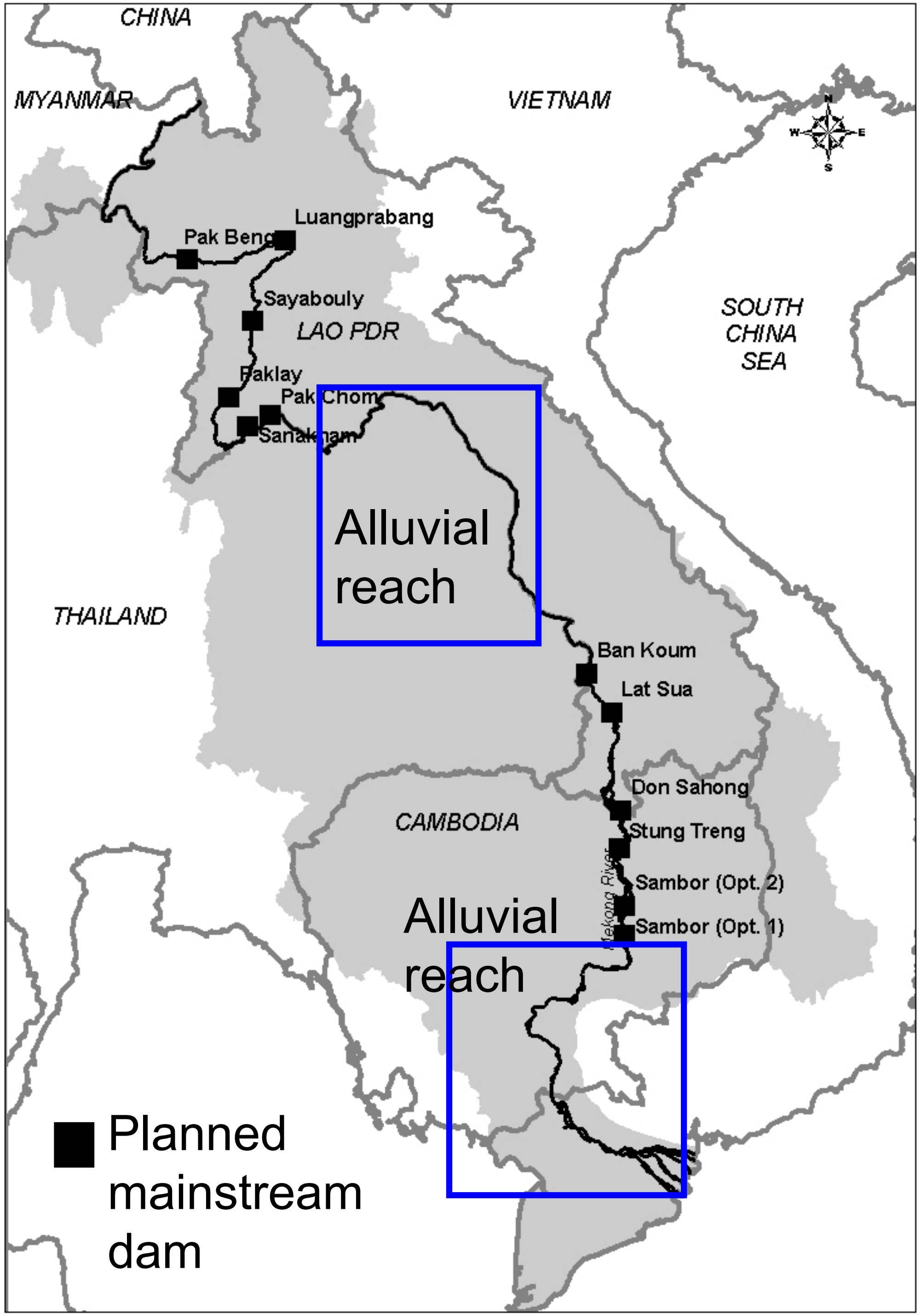
Need for a coordinating body for dam operation

Major roles

- Optimise operation of dam cascade for electricity generation
- Manage flood risk
- Coordinate and optimise sediment flushing activities
- Coordinate environmental monitoring
  - ➔ Feedback to dam operation

Cumulative impacts in sensitive areas

- Alluvial reaches are most sensitive to morphological change because they have highly erodable bed and banks



Assessment and prediction of morphological change

- Feasibility Study & Environmental Impacts Assessment
- Data collection requirements
  - Repeat cross-section surveys up and downstream of dam
  - Water surface slope surveys at different flows
  - Sampling of bed-material and bank materials (GS analysis, lithology)
- Run 2D hydraulic & sediment transport models for different design & operation scenarios to assess:
  - Changes to water surface slope & velocities (up and downstream)
  - Aggradation/degradation of riverbed
  - Bank stability
  - Changes to bed-material grain-size
  - Frequency of required sediment flushing

Dam decommissioning

- What happens after the end of the concession?

Options:

  - Ongoing operation & sediment management (flushing)
  - No action – structural instability, downstream impacts
  - Dam removal

- Who will pay?
- Concession agreement should include:

According to best world practice

  - Plan for dam decommissioning
  - Funds for decommissioning
  - A limit on the sediment volume in the reservoir at end of concession

MRC Discharge and Sediment Monitoring Project

- To be implemented by the Information Knowledge Management Programme (IKMP) in 2009-2010

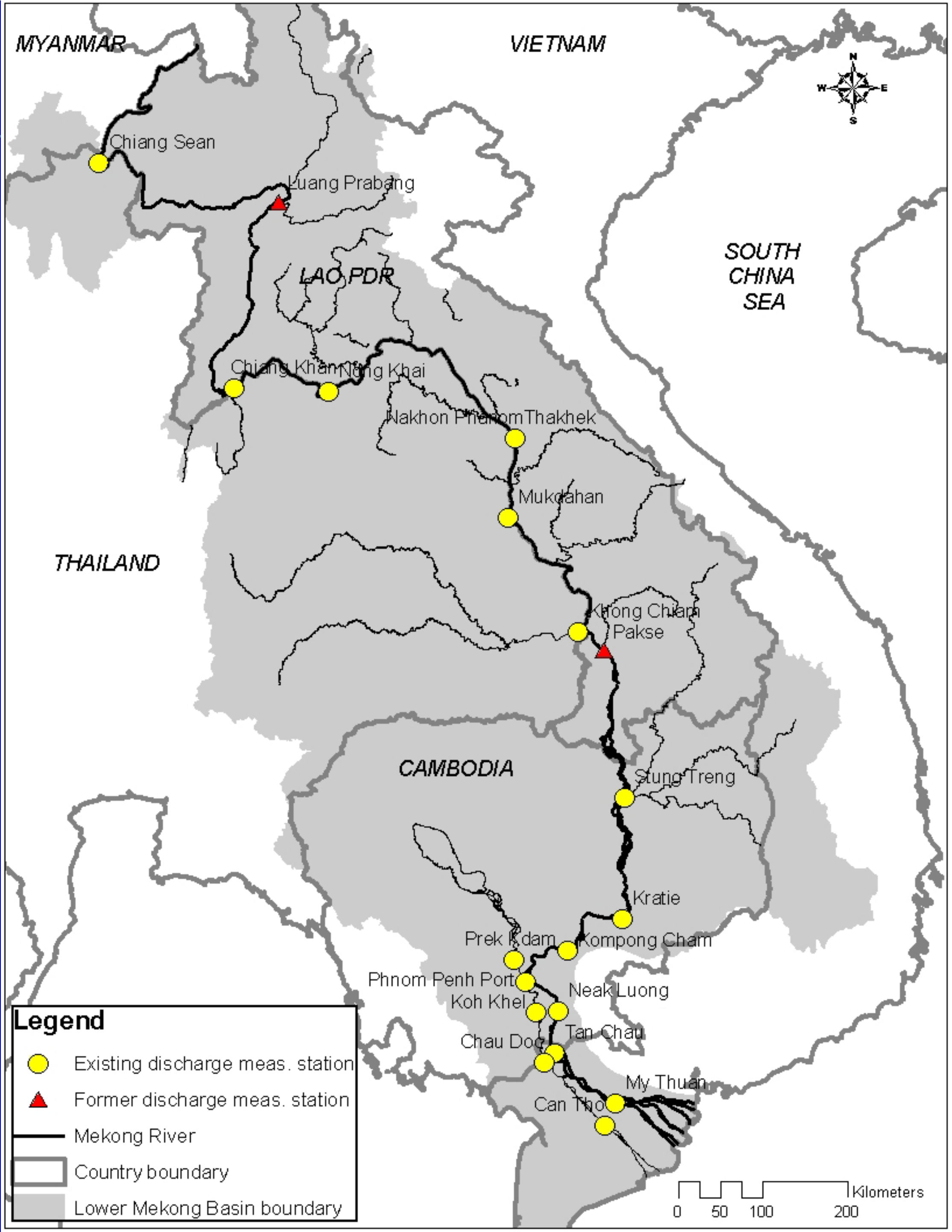
Activities

- Upgrade discharge measurement equipment and techniques

- Introduce quality controlled suspended sediment sampling at all mainstream stations (2009)
- Key tributary stations (2010)

Preliminary Design Guidance for Proposed Mainstream Dams in the LMB, Dialogue Meeting, 20 Oct 2009, Vientiane Lao PDR

Mainstream discharge & sediment monitoring sites



Additional activities

MRC Discharge and Sediment Monitoring Project

- Pilot bedload measurements in mainstream
- Grain-size analysis of suspended sediment samples
- Bed-material survey along mainstream
- Baseline cross-section surveys near proposed mainstream dam sites
- Basin-wide sediment budget
- Integrate water quality & sediment monitoring

MRC data needs from dam developers

Priority 1

- Dam designs
- Operational procedures

Priority 2

- Baseline geomorphology surveys
- Environmental monitoring data
  - Sediment transport
  - Water quality
  - Ecological surveys

Conclusions

- Good management of sediment in dams will have economic benefits and reduce environmental impacts
- Infrastructure for sediment sluicing and flushing needs to be incorporated into the dam design from the start
- The effectiveness of sediment sluices and flushing activities should be evaluated thoroughly during feasibility studies

Conclusions cont…

- Sediment sluice gates are unlikely to be sufficient

  ➔So periodic sediment flushing will also be required and should be incorporated into the operation plan

- Downstream water quality and aquatic habitats should be considered when planning sediment flushing

- Limits on downstream sediment concentrations should be set and agreed upon prior to dam operation

Conclusions cont…

- All baseline surveys and ongoing monitoring data should be made available to the Government/s and are also kindly requested by MRC

- A dam decommissioning plan (and funds) should be submitted to the Government prior to granting of consessions

- A dam operation coordinating body should be established

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Resources

- White (2000) Flushing of Sediments from Reservoirs. World Commission on Dams Thematic Review IV.5. http://www.dams.org/kbase/thematic/tr45.htm
- White et al (1999) Guidelines for the flushing of sediment from reservoirs. HR Wallingford. Report SR 563. November.
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- US Bureau of Reclamation (1999) Erosion and Sedimentation Manual. http://www.usbr.gov/pmts/sediment/kb/ErosionAndSedimentation/
- Morris and Fan (1997) Reservoir Sedimentation Handbook. McGraw-Hill.
- http://www.hydrocoop.org/reservoirssedimentationmanagement.htm

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Thankyou