

PDG 2023 Section 4 – Water Quality



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Water Quality: **outline**

- PDG Objectives
- Understanding water quality perspectives
- Outline of risks to water quality status from HPP developments
 - Understanding risks during construction and operational phases
 - **Transboundary and cumulative impacts – environmental flows**
- Monitoring requirements during all phases of development
- Mitigation options
- Lessons learnt from previous PNPAs



Section 4.1: Water Quality Objectives

Overall Objective: To understand the size and extent of the impact of designated HPP(s) on the water quality of the Lower Mekong mainstream.

Design guidelines intended to:



- i. Reduce the risks of **water quality impacts** within the reservoir.
- ii. Reduce **water quality impacts** downstream of the reservoir.
- iii. Align water quality standards with the *Procedures on Water*

Quality under the Mekong Agreement

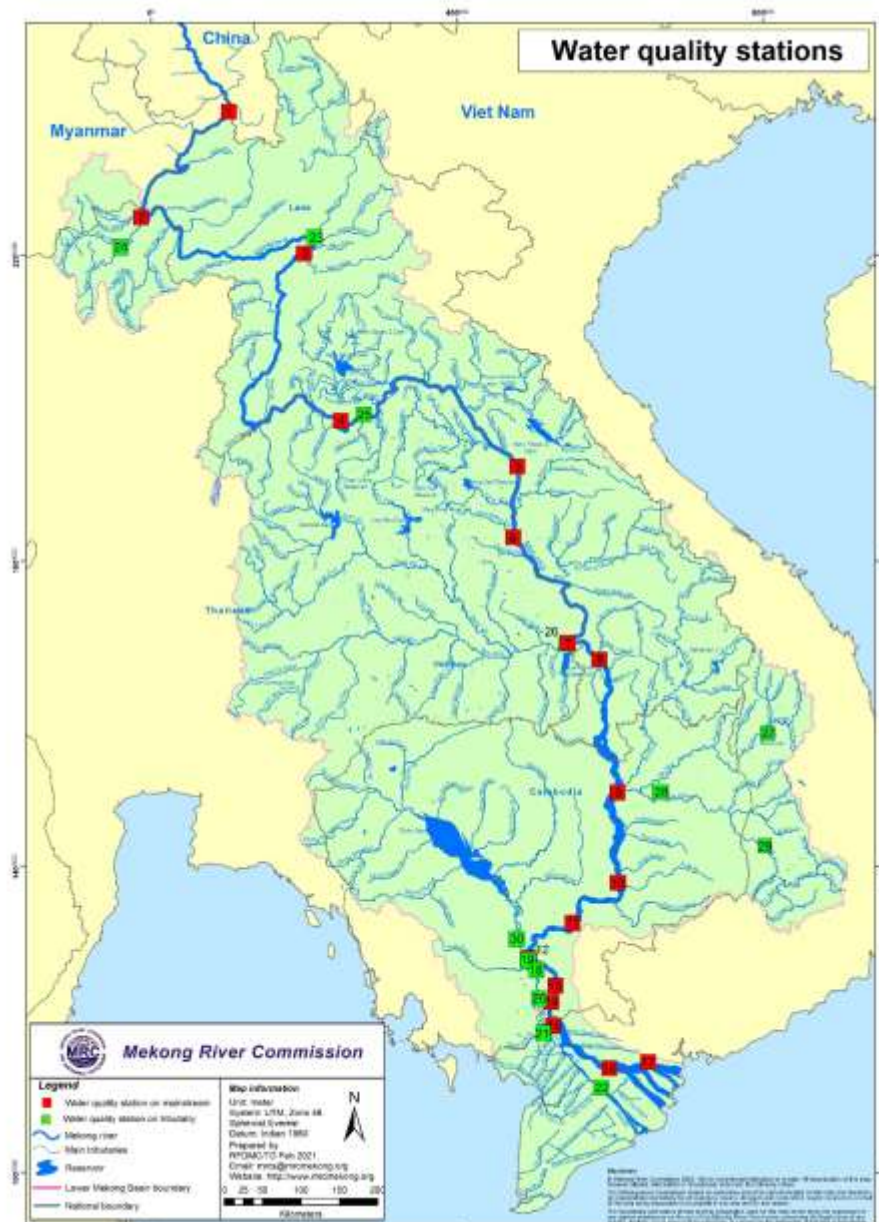


Changes from PDG 2009 version

- Water quality and aquatic ecology now separated.
- Water quality clauses extended (previously only seven paragraphs)
- Water quality guidelines now risk-based.



Water Quality Perspectives: **site locations**



Existing water quality monitoring:

- Sampling at 17 mainstream and 22 tributary locations with different frequencies for different parameters
- Analysis conducted by national laboratories
- Data analysed and used for **annual water quality report cards** and state of the basin reporting.
- **Main objective** of monitoring to assess **status and trends** of water quality basin-wide.

Water Quality Perspectives: **parameters**

Current water quality monitoring parameters

Monitored Monthly throughout Year	Monitored from April to October
Temperature	Calcium (Ca)
pH	Magnesium (Mg)
Conductivity (Salinity)	Sodium (Na)
Alkalinity/ Acidity	Potassium (K)
Dissolved Oxygen (DO)	Sulphate (SO ₄)
Chemical Oxygen Demand (COD)	Chloride (Cl)
Total phosphorous (T-P)	
Total Nitrogen (T-N)	
Ammonium (NH ₄ -N)	
Nitrite (NO ₂₋₃ -N)	
Faecal Coliform	
Total Suspended Solid	
Biochemical Oxygen Demand*	



- Methodologies agreed between countries and documented
- Quality assurance procedures in place
- Data analysed, used by countries and available to stakeholders

Water Quality Perspectives: collection methods

Methods used for environmental indicators



Physical characteristics are measured at the site, including altitude, GPS coordinates, and river width



Light penetration is recorded by slowly lowering the Secchi disk into the water until it just disappears



Temperature, DO, pH, EC are recorded using an electrical metre



River width is measured using a laser rangefinder



Water depth determined by dropping a weighted rope directly to the river bottom

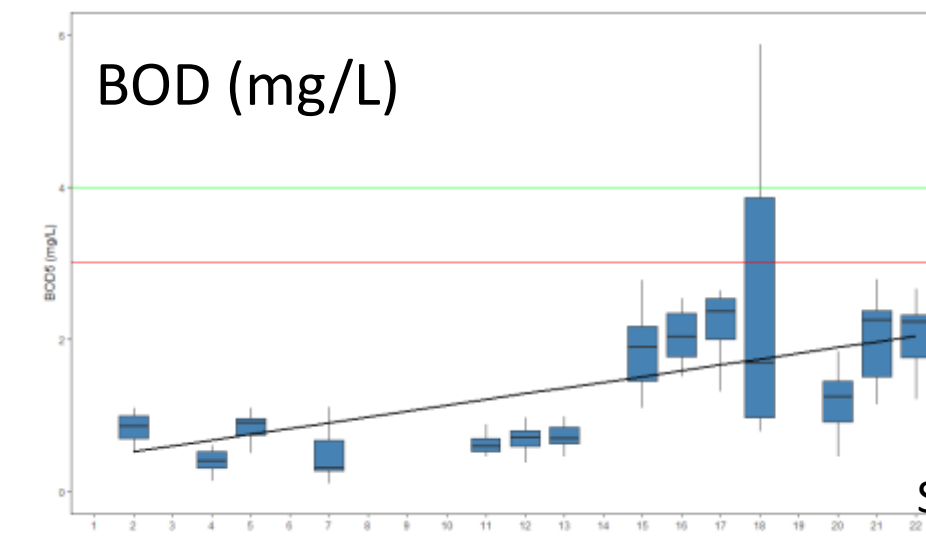
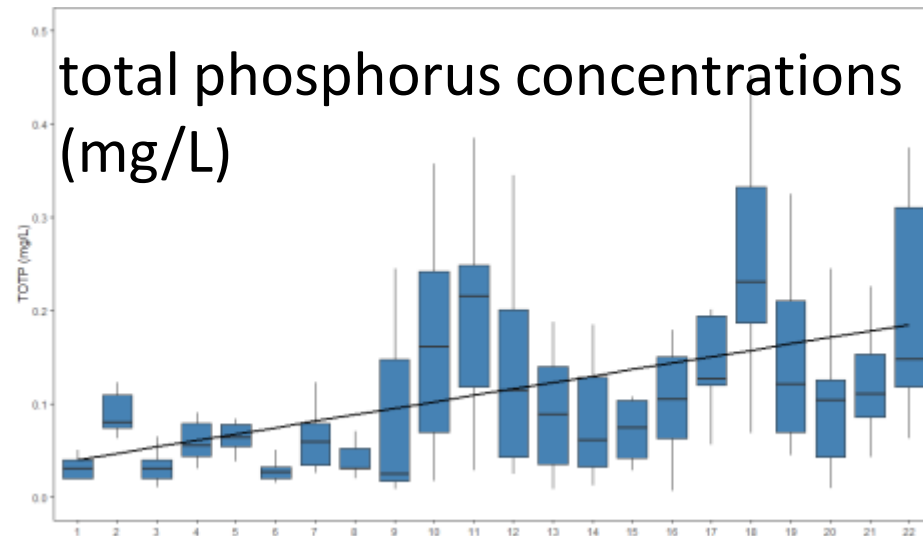
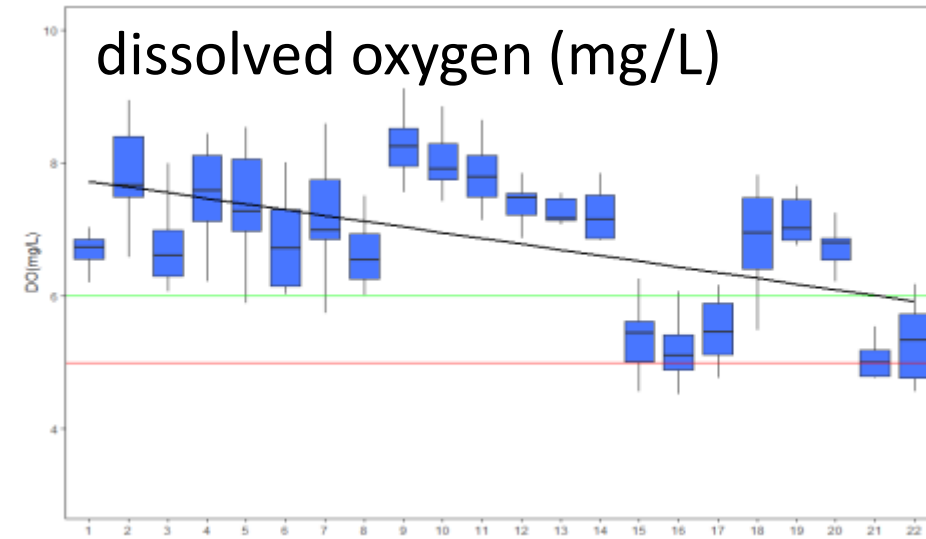
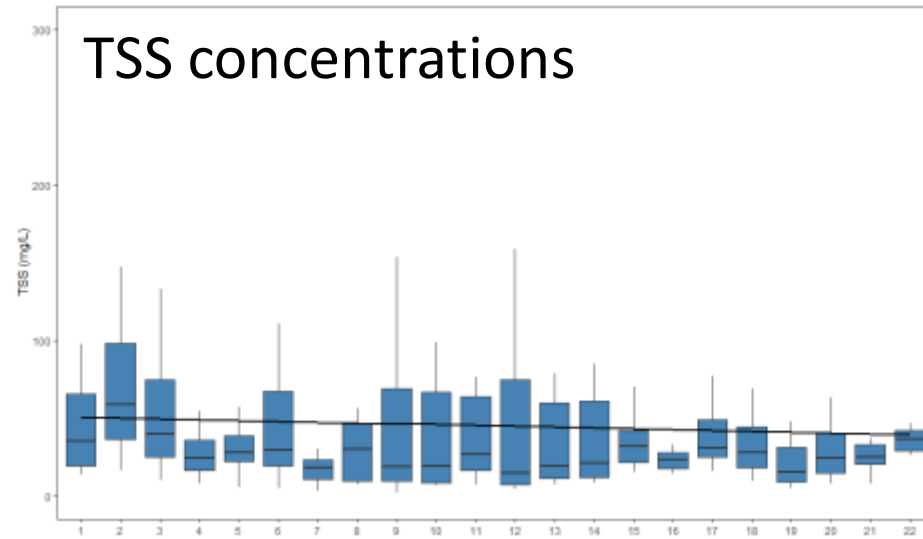


Altitude and coordinates of the sampling site are measured using a GPS device

- Methodologies agreed between countries and documented
- Quality assurance procedures in place
- Data analysed, used by countries and available to stakeholders

Water Quality Perspectives: trends in WQ parameters

Spatial variation in WQ parameters in Mekong (1-17) and Bassac Rivers (18-22) in 2019



Source: MRC (2022)

Water Quality Perspectives: aquatic life protection

No.	Station names	Countries	Class											
			2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
1	Houa Khong	Lao PDR	A	A	A	A	B	B	B	B	B	B	B	A
2	Chiang Saen	Thailand	A	B	B	A	B	B	A	B	B	B	B	A
3	Luang Prabang	Lao PDR	A	A	B	A	A	B	B	B	A	B	A	A
4	Vientiane	Lao PDR	A	A	A	A	A	B	B	A	A	A	A	A
5	Nakhon Phanom	Thailand	B	A	B	A	B	B	A	A	B	B	B	A
6	Savannakhet	Lao PDR	A	A	A	A	A	B	B	B	A	A	B	A
7	Khong Chiam	Thailand	B	A	A	A	A	B	A	A	A	B	A	A
8	Pakse	Lao PDR	A	A	A	A	A	B	B	B	A	A	B	A
9	Stung Trieng	Cambodia	B	B	B	B	B	B	B	B	B	A	A	A
10	Kratie	Cambodia	B	B	B	B	B	B	B	B	A	B	B	B
11	Kampong Cham	Cambodia	B	B	B	B	B	B	A	B	A	A	B	B
12	Chrouy Changvar	Cambodia	B	B	B	B	B	B	B	B	A	A	B	B
13	Neak Loung	Cambodia	B	B	B	B	B	B	B	B	A	A	B	A
14	Kaorm Samnor	Cambodia	B	B	B	B	B	B	B	B	A	A	B	A
15	Tan Chau	Viet Nam	B	B	B	B	B	B	B	B	B	A	B	B
16	My Thuan	Viet Nam	B	B	B	B	B	B	B	B	B	B	B	B
17	My Tho	Viet Nam	C	C	C	C	B	C	C	C	D	C	B	C
18	Takhmao	Cambodia	B	B	B	B	B	B	B	B	B	B	B	B
19	Koh Khel	Cambodia	B	B	B	B	B	B	B	B	B	B	B	B
20	Koh Thom	Cambodia	B	B	B	B	B	B	A	B	B	B	B	A
21	Chau Doc	Viet Nam	B	B	B	B	B	B	B	B	B	B	C	C
22	Can Tho	Viet Nam	B	C	C	C	C	C	B	B	B	B	B	C
A – High			B – Good			C – Moderate			D – Poor			E – Very Poor		

Water quality classes for Mekong River (1-17) and Bassac River (18-22) for the protection of aquatic life 2008-2019

Source: MRC (2022) 2019 Lower Mekong Water Quality monitoring Report

Water Quality Perspectives: Human health classification

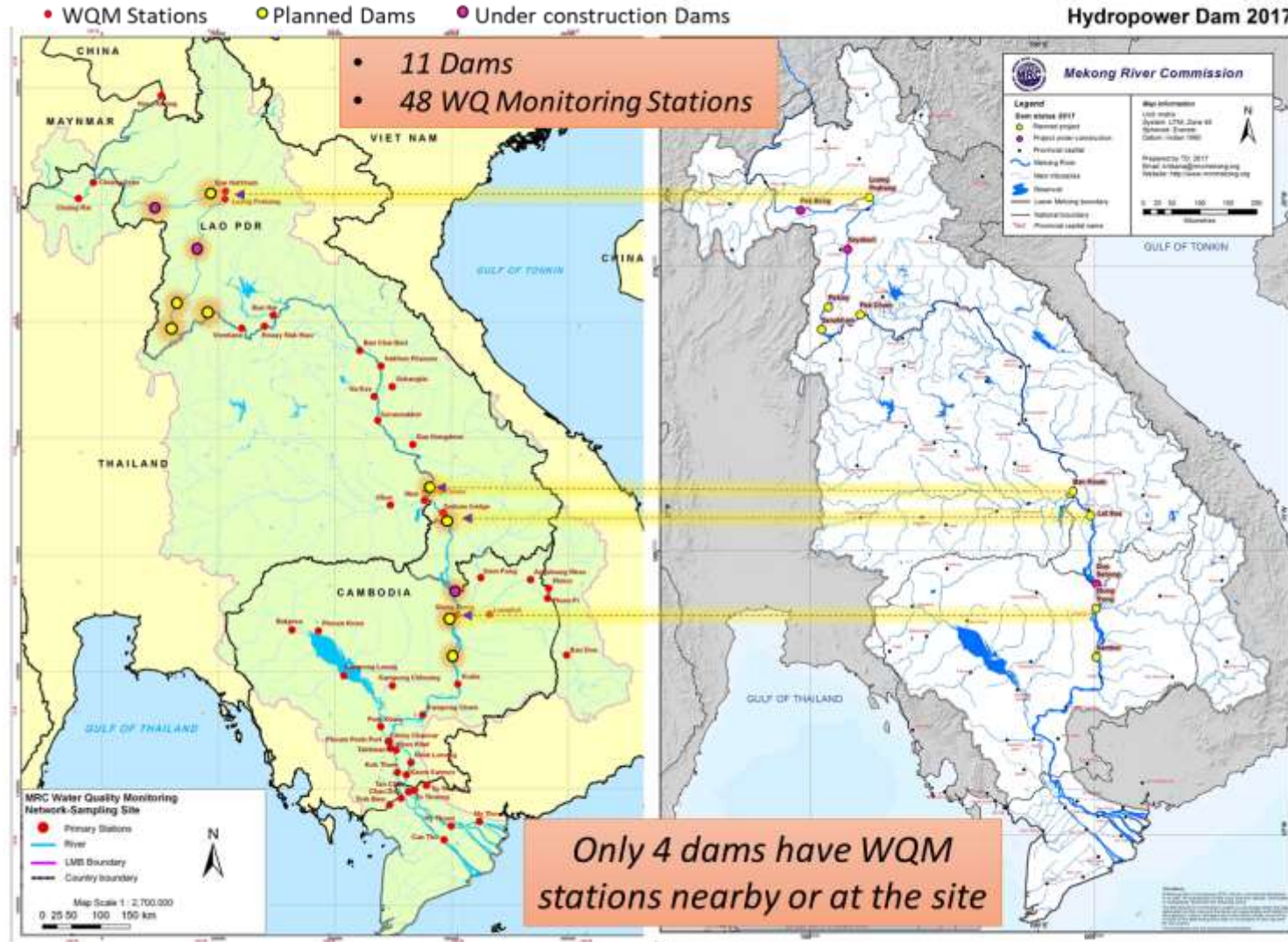
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A – High
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Water quality classes for Mekong River (1-17) and Bassac River (18-22) for the protection of human health 2008-2019

Source: MRC (2022) 2019 Lower Mekong Water Quality monitoring Report

Water Quality perspectives: **issues with sampling**



Weaknesses of MRC current water quality monitoring for HPPs:

- Inadequate quality assurance procedures
- Frequency of sampling not appropriate
- Sampling locations not appropriate for dam locations
- Insufficient sampling locations
- Some additional parameters required (at some sites)

Water Quality Perspectives: Recommendations from JEM

- Modify the established water quality monitoring network to assess the impact of individual dams and detect issues in the reservoir (e.g. stratification, algae blooms) and downstream.
- Three campaigns of HPP coverage:
 - High frequency for temperature, turbidity, DO and pH to detect changes due to hydropeaking, sediment flushing etc.
 - Monthly for longer term changes
 - Less frequent for large scale long term changes (existing WQN).
- Add additional parameters – Light penetration, water transparency or turbidity; Chlorophyll-*a*

Photosynthetically
Active Radiation meter
for light penetration



Field based fluorometric
method for Chl *a*

Water Quality Perspectives: **Recommendations from JEM**

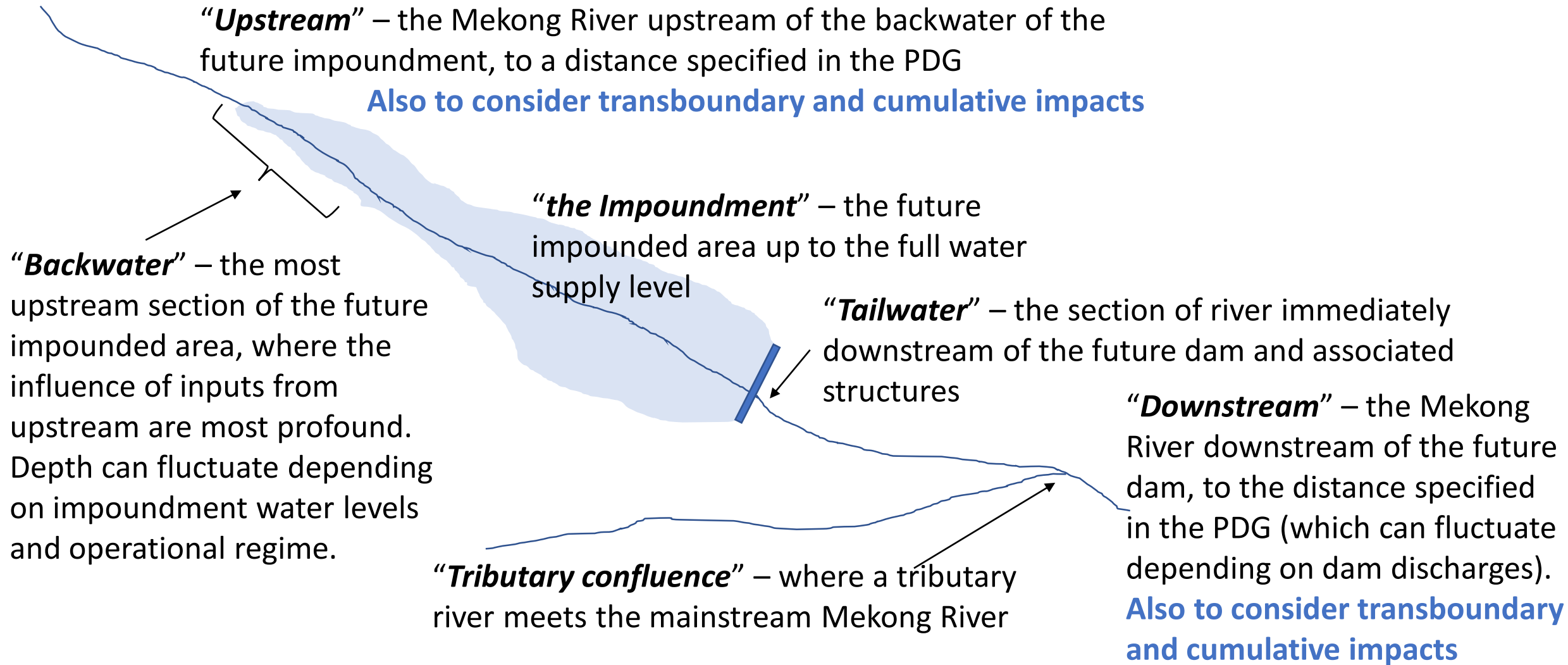
Campaign	Frequency	Location	Parameters	Purpose
1	Every 1-4 hours	Within 500 m downstream of each impoundment	Dissolved oxygen, pH, Conductivity, Turbidity, Temperature	To detect potential acute toxic events arising from reservoir stratification, gas supersaturation, algal blooms, chemical spillages, sediment flushing etc.
2	Once per month	Single location within each impoundment	Temperature, Dissolved oxygen, pH, Conductivity, Turbidity, Light	Vertical profile to detect stratification and risks of algal blooms
	Once per month	One location upstream and 4 locations downstream of each impoundment	Dissolved oxygen, pH, Conductivity, Turbidity, Temperature, Light, Chlorophyll, Total P, NO _x ,	To detect medium term dam impacts, and extent of dam impacts
3	At most once per month	Selected sites across the basin	COD, Conductivity, Dissolved oxygen, pH, temperature NO _x , Total P, Chlorophyll, Faecal coliforms.	To detect large scale water quality trends across the basin
	Annually or less often, as required	Selected sites across the basin	Toxicants (metals, pesticides)	To evaluate risk of specific toxicity issues

Section 4.2 Risks

- Risks to water quality can arise from quality of water in the river being dammed, which, in turn, is influenced by human activities in the catchment upstream of the dam.
- Forestry, agriculture, urbanisation and industrialisation are all activities which can lead to degradation of water quality in rivers.
- Risks are from:
 - **Construction Activities**
 - **Impoundment form and function, including stratification**
 - **Altered hydrological conditions downstream**
 - **Sediment flushing**
 - **Transboundary impacts**



Section 4.2: Risks



Main risks: buildup of nutrients in impoundment; reduced WQ downstream

Risks: **during construction**

Risks during construction:

- Sewage and contaminated runoff from labour camps & workshops
- Runoff from waste dumps
- Fuel, oil and chemical spills
- Sediment wash off



Views of Xayaburi HPP during construction
(source: *The Mekong Eye*)

Risks: associated with impoundment

- Increasing nutrients and reduced turbidity cause algal blooms
- Stratification leads to:
 - Low dissolved oxygen in bottom water – loss of fish habitat
 - Low pH in bottom water – high metals and toxicants, corrosive water
 - High dissolved Fe and Mn (from sediment)– deposits on infrastructure
 - High toxic metals (from sediment) – e.g. Hg – toxic metals in fish
 - High sulphides and nutrients (from sediment)– algal blooms at turnover

Note: Argued no stratification in RoR hydropower dams but depends on topography and operational regime

Risks: **downstream**

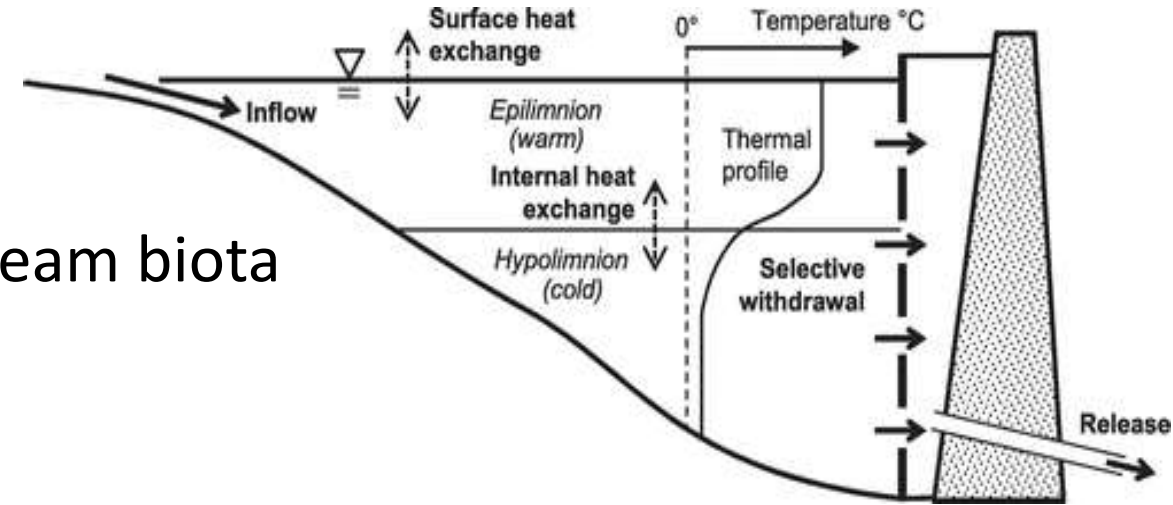
- Rapid flow changes, especially by hydropeaking causing rapid fluctuations in water quality
- Altered water temperature regime
 - warmer or colder than upstream
- Reduced turbidity – increased algal and plant growth
- Reduced nutrient concentrations and primary productivity affecting instream and floodplain biota
- Gas supersaturation – can cause fish and invertebrate death



Risks: downstream

- **Reservoir Stratification**

- Low dissolved oxygen – impacts downstream biota
- Low pH – impacts downstream biota
- High Fe^{2+} and Mn^{2+} concentrations – cause downstream precipitates
- High toxic metals concentrations from sediments – cause high levels in downstream biota



Risks: **downstream**

Reservoir Sediment Flushing

- Downstream pulse of sediment
- Downstream pulse of turbidity
- Downstream pulse of reduced dissolved oxygen
- Downstream pulse of toxicants
- Accretion of material on banks and bed materials



Section 4.4 – Specific Design Guidance: **mitigation options**

Mitigation options to address identified risks.

- During construction
- Externally Generated Risks
- Risks Within the Impoundment
- Downstream Risks

WQ mitigation measures additional to those identified for hydrology, hydraulics, sediment transport and geomorphology



Mitigation options: **construction risks**

Construction Risks and Mitigation

- Sewage and contaminated runoff from labour camps & workshops
- Runoff from waste dumps
- Fuel, oil and chemical spills

Proactive: Treatment systems (sewage and wastes), site selections, bunds, cleanup equipment, staff training.

Reactive: Continuous monitoring with **procedures to respond immediately to accidents and problems**



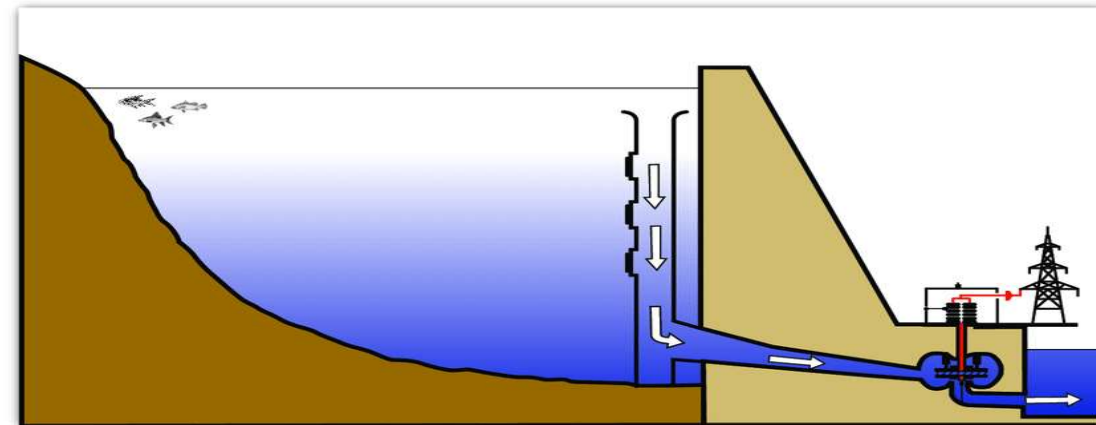
Mitigation options: **external risks**

- **Decreasing upstream water quality** – work with local and national agencies to promote good land and wastewater management practice
- **Increased runoff and wastewater from local populations** – provision of sanitation and improvement of land management



Mitigation options: **impoundment issues**

- **Reservoir stratification**
 - employ destratification technology
 - multilevel offtakes



Mitigation options: **downstream risks**

- **Risks from rapid flow changes** – operational rules to avoid rapid flow changes, or reregulation weir
- **Altered water temperature** – mixing outflowing water, destratification
- **Gas supersaturation** – spillway deflectors to reduce flow into plunge pools
- **Sediment Flushing** – limit sediment concentrations during flushing, remove sediment by dredging and dispose on land



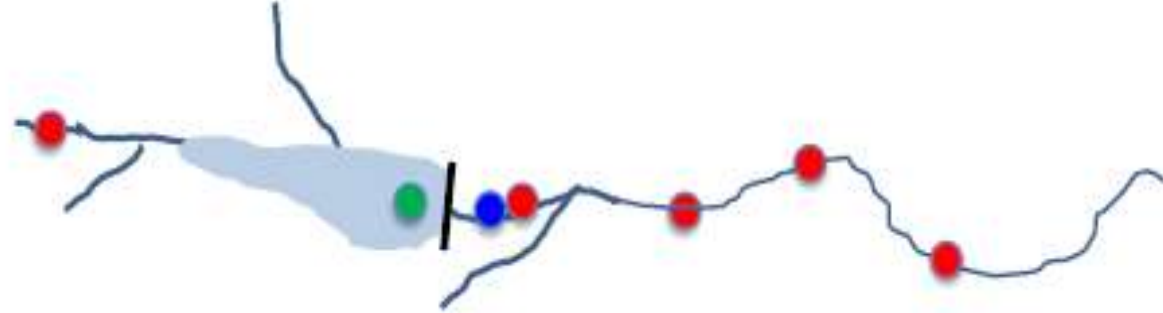
Section 4.5 – Monitoring

- PDG contains details of monitoring objectives and methods for governments/developers
- Monitoring should provide baseline status before PNPCA submitted
- **Focus on informing decisions: for design, operations, mitigation and compensation**
- Outputs of monitoring should be made publicly available, to ensure transparency
- Monitoring programme should be funded by the developer during construction and operational phases

Monitoring: **site location**

Data Collection

- Monitoring locations as defined by JEM, up and downstream of impoundment
- Multiple sites upstream and downstream of dam site
- The number of downstream sites necessary depends on the nature of the river downstream (e.g. size and location of tributaries)
- Multiple samples per site, to allow statistical analysis of data



Monitoring: **parameters**

Parameters as defined by JEM but include additional parameters

Parameter Proposed	Reason
Iron (Fe) and Manganese (Mn)	These are two elements which frequently occur in high concentrations in deoxygenated water, and which can cause substantial habitat changes if they deposit downstream
Light penetration, water transparency or turbidity	Water in reservoirs may become less turbid (clearer) as sediment settles, which can lead to increased algal and plant growth
Chlorophyll- <i>a</i>	A measure of the biomass of algal cells present in the water
Cyanobacteria (blue-green algae)	If levels of chlorophyll are high (> 5 µg/L) tests for cyanobacteria should be conducted, because some cyanobacteria produce toxins which may affect invertebrates, fish and people.

Monitoring: **sampling frequency**

Frequency

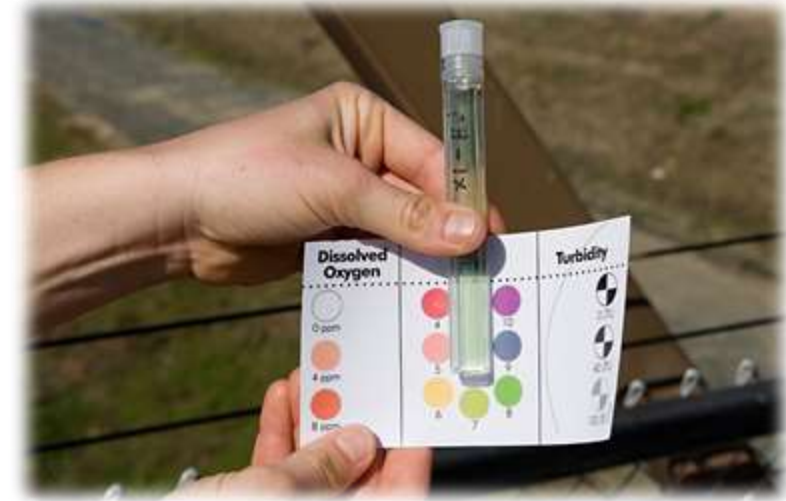
Sampling frequency as defined by JEM, up and downstream of impoundment

In the River

- **Weekly during key periods:**
 - When the reservoir is stratified if bottom water is released.
 - When stratification breaks down (over turn)
- **Monthly at other times**

In the Impoundment

- Weekly vertical profiles – DO and temperature near dam



Monitoring: **Impact Analysis**

Impact Analysis

- Compare PNPCA results to National Guidelines and MRC recommended limits.
- Compare data from upstream and downstream for statistical and ecologically important differences
- Ensure high frequency monitoring of temperature, dissolved oxygen (DO) and turbidity in downstream water to detect changes due to hydropeaking, sediment flushing etc. Include at least monthly measurements of all parameters in the MRC WQN.



Monitoring: **Impact Analysis**

Data Integration of between disciplines

Discipline	Linkages with water quality
Hydrology	Water quality varies with hydrograph Water quality varies with seasonal flow pattern
Sediment Monitoring	Many nutrients (e.g. P and N) and contaminants (e.g. metals and pesticides) are mainly transported attached to sediment particles
Ecological Health Monitoring	Invertebrates and algae influenced by DO, pH and toxicants Algae and plants influenced by light penetration and nutrients
Fisheries	Fish influenced by DO, pH and toxicants Turbidity and light availability

Use above / below HPP results to understand local impacts

Use time-series to track seasonal & long-term changes associated with HPPs

Monitoring: **Roles and responsibilities**

- **Responsibilities of Developers**

- Share information about monitoring design and strategy
 - Locations, parameters, frequency, methods
- Adopt MRC standard methods where applicable
 - Or contract same line-agency
- Share monitoring results relevant to water quality with Notifying Country and MRC

- **Responsibilities of MRCS**

- Manage and maintain water quality database and management system
- Provide QA/QC of reported data sets
- Organise workshops to analyse, integrate and understand results in context of WQN results
- Prepare reports summarizing findings at local and catchment level

Lessons learnt from previous PNPAs- **General**

- Considerable information provided by the developer in multiple volumes
 - **Information fragmented**, repetitive and inconsistent
 - **Information often outdated** and inappropriate to assess the potential impact of designated HPP on water quality.
 - Little use made of MRC Water Quality data other than WQ health scores
- Information **inadequate to establish baseline conditions** to measure potential impacts of water quality on aquatic ecology and fisheries
- **Procedures to respond immediately to accidents and problems should be provided.** Inspections should be daily and **continuous water quality monitoring is required**
- **Little sharing of data beyond initial PNPCA submission**

Lessons learnt from previous PNPAs: **WQ monitoring**

- Assessment of Water Quality generally acceptable but may need additional monitoring – e.g. continuous monitoring needed of some parameters
- Developers propose **monitoring programmes** for water quality during the construction and operational phases but do not provide **procedures to respond immediately to accidents and problems**
- Main actions relate to:
 - Water quality issues during construction period largely managed through good practice.
 - Water quality during operational phase managed through vegetation management in reservoir.

Lessons learnt from previous PNPAs: **habitat degradation**

- One key WQ issues is decay of flooded aquatic vegetation and the consequent increased **nutrient concentrations** and **anoxic conditions**
- No modelling of likely impacts of water quality on aquatic habitats, and thus aquatic biota - including in downstream reaches
- **No comprehensive EFA or transboundary assessment** is considered regarding the river flows and water quality required for **all water uses**, expressed in terms of **sufficient quality, quantity, timing** and **duration** of flows

Thank you

