Mekong River Commission
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For sustainable development

Summary note

Review and Update of the MRC Design Guidance for Proposed Mainstream Dams of the Lower Mekong Basin

Final draft

In an effort to communicate openly with broader stakeholders of the Mekong River Commission (MRC) and to help them participate in MRC's regional stakeholder forums more meaningfully, the MRC Secretariat has prepared this summary report to present key and substantive points from selected on-going technical work of the MRC which is in the process of development and finalization in consultation with its member countries.

9 September 2018

Contents

Tables

Figures

1. Introduction and Background

1.1 Objective of the Review and Update

As specified in the MRC Strategic Plan SP2016-2020 the objective of the review is that:

> The updated *Design Guidance for Proposed Mainstream (and Tributary) Dams on the Lower Mekong Basin (DG2018)* provides contemporary, research-based performance standards, design and operating principles; which also cover compliance monitoring and adaptive management; endorsed by the Joint Committee in 2018.

1.2 Knowledge Gained since the Initial Preparation of the PDG in 2009

The PDG was developed while a number of important MRC studies, to understand the impact of mainstream dams, were in progress. The PDG therefore referenced these studies and noted that further guidance would be forthcoming once they were completed. However, it was deemed important to have the document available to ensure the developers had "timely guidance" for the mainstream projects that were imminent. Hence the Design Guidance was termed "Preliminary" pending additional detailed investigations.

Since the drafting of the PDG in 2009 three mainstream projects have come up for review under the PNPCA. In addition, a number of related studies have been completed that provide valuable additional regionally relevant information regarding the mainstream and tributary dams.

1.2.1 Lessons Learned from PNPCA Review of Mainstream Dams

The three mainstream dams that have been reviewed under the PNPCA over the last 6 years have used the PDG as the primary guidance to assess the proposed design and operations of the hydropower project (Xayaburi in 2011, Don Sahong in 2014, and Pak Beng in 2017). In each case there have been useful lessons learned concerning the areas of the PDG that may need to be clarified, enhanced and improved. Detailed comments from the international and regional experts as well as the hydropower developers and their consultants have been gathered in the course of the preparation of this DG2018.

1.2.2 MRC Hydropower Mitigation Guidelines

The work most immediately relevant to the review is the Study undertaken by the MRC entitled "*Guidelines for Hydropower Environmental Impact Mitigation and Risk Management in the Lower Mekong Mainstream and Tributaries*" (MRC, 2017).

The MRC Mitigation Guidelines provide concrete evidence-based options for the design of impact mitigation for mainstream and tributary dams. This evidence base may be updated as further information and research is undertaken across the basin. These detailed technical Guidelines for Mitigation are referenced in the DG2018 where appropriate.

There are a number of other important and relevant studies that have also be used as background for the review of the PDG such as the draft Transboundary Environmental Impact Assessment (Tb EIA) Guidance and the MRC Council Study.

2. Scope and Approach to the Review

2.1 Scope

The approach provided for a thorough review of all sections to bring the document up to date and provide a sound technical platform of contemporary standards and principles for mitigation and operations. The intention is that the DG2018 standards remain appropriate for development that may take place in the next five to ten years.

2.2 Approach and Steps to Review the Design Guidance

The following steps and timeline to the review have been completed:

Table 1: Key Steps in the Review of the DG

Item	Date
1. Agree the Objectives and Scope of the Review; Consultations with MC on the Concept Note, JC Approval	July – December 2017
2. Mobilise a Team of Key Regional and International Experts and gather inputs from other regional and national experts who have familiarity with the PDG2009.	January - March 2018
3. Draft revised and updated DG Clauses - DG2018 Draft V0.1 (Internal) and V0.2 (for discussion with Member Countries);	By April 2018
4. Draft V0.2 of DG2018 circulated to Member Countries for their national agency review; consultations with Member Countries;	May 2018
5. Briefing and Consultation with Mekong hydropower developers to test for practicality and to gain alternative views and DG2018 V0.3 Publication via MRC website for public comment;	21 June 2018 27 June to 18 July 2018
6. Regional Meeting of MRC members– to seek resolution of final common issues arising from comments;	6 August 2018
7. Finalise DG2018 V1.0 Based on input from all stakeholders, and MCs and table draft DG2018 V1.0 at JC for consideration and guidance	15 August 2018 29 August 2018

2.3 Stakeholder Engagement

The DG2018 has been extensively discussed within the Secretariat senior and technical management who have provided valuable insights and technical knowhow to the review process.

The MRC Joint Committee has provided support at the Concept stage to the review and have put a high priority and sense of urgency to the update of the PDG.

National Mekong Committees have also been supportive and have been provided with Drafts over the last four months to allow time for consultation and national agency comments.

MRC relevant External Stakeholders have been involved through the process to ensure a broad range of advice and views are included. This includes international NGOs, developers, consultants.

The Concept Note for this review was discussed first at the MRC Regional Stakeholder Platform on 14-15 December 2017. During the review process a copy of DG2018 Version 0.3 was available through the MRC website between 27 June to 18 July 2018 to allow public comment. This summary of the Final DG2018 V1.0 is to be tabled and presented at the 5th MRC Regional Stakeholder Forum on 20-21 September 2018.

2.3.1 Comments Received from Stakeholders

A number of detailed comments were received either through the consultation process (DG2018 V0.2 and V0.3), or through public comments on DG2018 V0.3. Each of these comments (clause by clause) were tabulated and addressed by the expert team. In the following sections of this Summary some of the key aspects of those comments are addressed. Responses to the more detailed comments on technical aspects will be found in the DG2018 V1.0 when published.

3. Key Elements of the Design Guidance for Mainstream Dams

The description below is extracted from the Section 1.0 of the DG2018 and describes the context, content, and principles of the Guidelines.

Note: This is an abridged version; the full Guidance will be made available on the MRC's website after approval by the MRC Joint Committee.

3.1 Purpose and Objectives

The objective of the Guidance is to provide performance targets and principles for the design and operation of mainstream dams that can help avoid, minimise and mitigate harmful effects (Mekong Agreement Article 7) and cease substantial damage (Mekong Agreement Articles 7 & 8). Specifically, the Guidance aims to ensure that:

i. All mainstream hydropower projects have a common design and operational approach, aiming to meet common objectives and mitigate commonly understood risks.
ii. Developers can plan for and undertake the assessments and designs for mitigation and management measures as early as possible in the project cycle.
iii. Developers have flexibility to identify and propose the solutions that will meet the objectives, performance standards, and recommendations in the Guidance.
iv. Joint operations within a mainstream hydropower cascade are guided by a common framework informed by the Guidance. This framework is ideally expressed in Cascade Joint Operating Rules developed by the responsible Member Country, as shown in the Figure below.

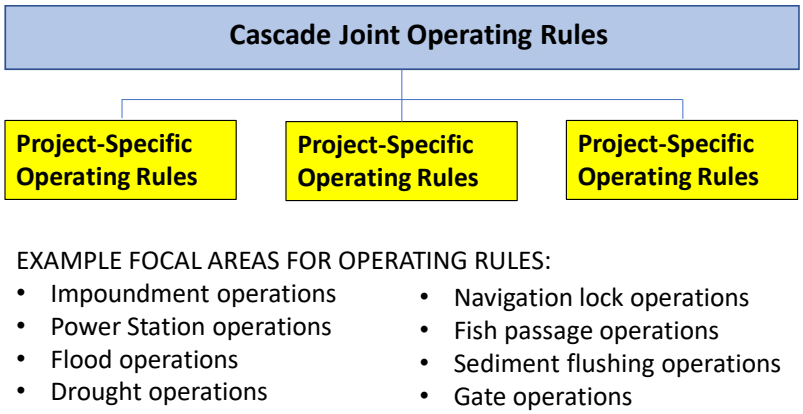

Figure 1: Cascade Joint Operating Rules and Project-Specific Operating Rules

The Guidance is founded on the agreed objectives and principles of cooperation set out in Chapter III of the Mekong Agreement, and Integrated Water Resource Management (IWRM) principles.

3.1.1 Mitigation Hierarchy

The "mitigation hierarchy" that underpins the Guidance is a concise expression for what is understood to be a sequential process. Measures to avoid or prevent negative or adverse impacts should be prioritised. Where avoidance is not practicable, then minimisation of adverse impacts is sought. Where avoidance and minimisation are not practicable, then mitigation measures are undertaken. In the Guidance, as per the provisions of Mekong Agreement Articles 7 and 8, these terms are understood as follows:

i. Avoid means that the measure, if implemented, would ensure that any harmful effects will be negligible;
ii. Minimise and Mitigate mean that the measure, if implemented, would reduce harmful effects, or the risk of harmful effects, considerably.

Residual impacts are those impacts that remain after all viable avoidance, minimisation and mitigation measures have been applied. Measures should be considered to address any residual impact or loss.

3.1.2 *Performance Standards*

Wherever practical, the Guidance outlines "performance standards" rather than prescriptive designs, so developers can innovate and propose alternative mitigation and operational measures to meet the stated objectives.

3.1.3 *Uses and Users*

According to the Mekong Agreement, before Member Countries may initiate any large-scale infrastructure development constituting an intra-basin use on the Mekong mainstream in the dry season, they should notify and consult with other riparian states in the basin. Under Article 5.2.1 of the Procedures for Notification, Prior Consultation and Agreement (PNPCA), the notifying Country should provide available and additional technical data.

Users of the Guidance will include Member Countries, developers, and interested stakeholders.

The Guidance is most fundamentally directed at guidance for mainstream dams. However, under the Mekong Agreement Article 7 the Member Countries have accepted a Duty of Conduct to avoid, minimize and mitigate harmful effects wherever they occur, including tributaries. Therefore, the Guidance may be considered useful for tributary dam developments notified under the PNPCA, while recognising the limitations in scope of the guidance provided.

3.1.4 *National Standards*

Developers should follow National Standards in the development of mainstream dam projects, where they are equal to or more stringent than the Guidance.

i. For impacts that are of basin-wide concern, either because they are transboundary, cumulative or affect basin-wide ecological processes, and the National Standard does not give adequate protection for these areas of impact, the more stringent standard between the Guidance and the National Standard should guide the project design.
ii. Member Countries may wish to embed aspects of good practice outlined in the Guidance into their National Standards for dam developments.

The Guidance does not replace national guidelines or regulations for the project Environmental and Social Impact Assessment (ESIA). ESIA guidelines are issued by the Member Country for developments within that country, for review by the relevant National Agency as part of the statutory approvals process for a dam development. ESIA guidelines cover a broader scope than the Guidance. The Guidance is limited to information requirements for impacts of basin-wide concern relating to the potential harmful effects of mainstream dams.

3.2 Timing of Use

The Guidance should be referred to throughout the project development cycle.

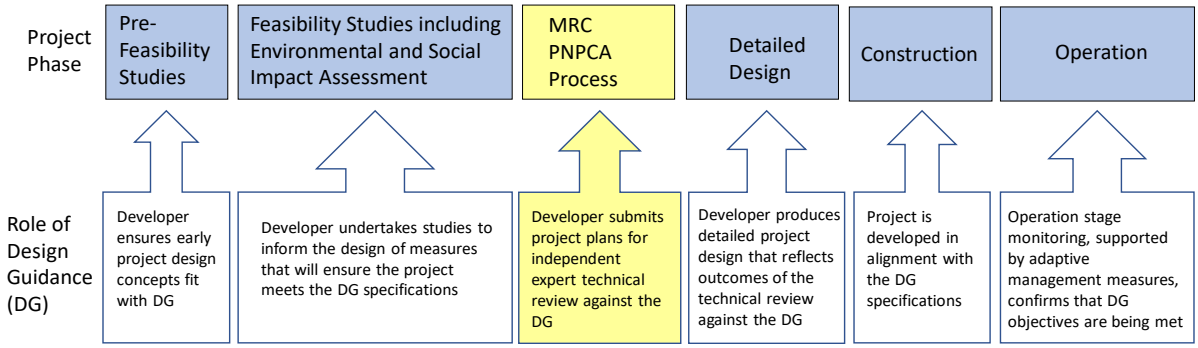

Figure 2: *Role of the Design Guidance during the mainstream dam project life cycle*

3.3 Scope

The Guidance is tailored to the Mekong mainstream hydropower projects, which largely involve infrastructure for hydropower generation incorporated into the dam facilities and river flows returned to the Mekong immediately downstream. These projects may also include irrigation and other uses associated with the mainstream developments.

Projects with seasonal or interannual water storage or projects that incorporate diversion of flows out of the main channel for substantial distances downstream of the dam are not directly addressed, although many of the same principles and performance standards may apply. Guidance on mitigation of the impacts of these types of projects can be found in the MRC Hydropower Mitigation Guidelines. Guidance for minimising the impacts of major abstraction of water at the dam sites for additional purposes such as irrigation is excluded, noting these would be subject to requirements of the MRC Procedure for Maintenance of Flows on the Mainstream.

3.3.1 Basin Scale focus

The Guidance focusses on impacts that are of basin-wide concern, either because they are transboundary, cumulative, or affect basin-wide processes. There are a number of important processes and/or outcomes for aspects of the shared water resources of the Mekong River that have extensive and even basin-wide dependence or influence.

i. The focal areas for the Guidance include the environmental areas of **hydrology and hydraulics, sediment transport and geomorphology, water quality, aquatic ecology, and fisheries** (Sections 2 to 6). Physical aspects of the environment are addressed first, and then the biological aspects.
ii. **Navigation and Dam Safety,** (Sections 7 and 8) are included, because the actions of one project can have ramifications much beyond the individual project and cooperation is essential.
iii. **Riparian Communities and River-Based Livelihoods** (Section 9) is included because environmental and infrastructure changes that are not able to be fully mitigated (i.e. the residual impacts) can in turn have socio-economic consequences for river-dependent communities.
iv. There are many **linkages and inter-dependencies** amongst the topics covered by the Guidance. Hydrology and hydraulics link to all other topics. Navigation and dam safety

are strongly influenced by flow conditions. Physical changes to habitats (river geomorphology) and water quality arise due to flow changes, and have significant influences on aquatic ecology. Fish and fisheries are dependent on conditions and processes relating to flow, habitat, water quality and aquatic ecology. River-based livelihoods are strongly influenced by all of these factors, and in particular on the effectiveness of mitigation measures or supplementary approaches where livelihoods are dependent on the river environment.

v. A number of these focal areas have dedicated procedures and guidelines within the Mekong Agreement Framework, and monitoring programmes within the MRC Secretariat. Where relevant, these have informed the specific objectives for each topic.

3.3.2 Short and Long-Distance Impacts

Both short-distance and long-distance impacts are addressed in the Guidance.

i. Hydrological and hydraulic modelling (as described in Section 2.3) should be used to investigate how far downstream and upstream that changes to aspects of the flow regime attributable to the project can be detected.
ii. The pre-project analyses should always identify those impacts that may be transboundary in nature. The MRC Transboundary Environmental Impact Assessment (TbEIA) Guidelines are an important reference for Member Countries in identifying and addressing issues of transboundary concern.

3.3.3 Planning, Design, Construction and Operations

This document provides guidance to inform design and planning that will have implications for both the construction and operation stages of a dam development. Further to this:

i. Some design measures mitigate construction stage impacts, and many others mitigate longer-term operation stage impacts.
ii. It is important to take into account intended or likely future operational practices when considering the specifications for and likely effectiveness of design features.
iii. Some risks may be able to be mitigated by operational practices rather than through design of built infrastructure.

3.4 Structure of the Document

The eight topics in the Guidance follow a common logical flow, in which the objectives for each topic inform the identification of risks, potential impacts, mitigation measures, and mitigation effectiveness. The sub-sections in Sections 2 to 9 are as follows:

i. Objectives: This sub-section states the objectives in a manner that clarifies what the guidance is aiming to achieve, and that reflects the commitment and principles in the Mekong Agreement framework.
ii. Risks: This sub-section outlines the types of risks that may prevent achievement of objectives, and where relevant, highlights interlinkages with other topics.

iii. Pre-Project Monitoring and Analyses: This sub-section provides guidance on the data and analyses that would sufficiently inform and justify the specific design and operational choices presented in the PNPCA documentation.
iv. Specific Design and Operational Guidance: This sub-section guides the process of identification and evaluation of mitigation options, and provides a basis to justify those mitigation options proposed for implementation. In cases, more specific outcome targets are presented for particular mitigation measures. Guidance is included on measures that will enable future adaptations if shown to be required by the post-project monitoring.
v. Project Monitoring and Adaptive Management: This sub-section advises on the monitoring during project construction and operations that will help show if design and operational measures have been effective, or whether adaptations should be implemented.

3.4.1 Pre-project Monitoring and Analysis

To adequately inform project design, the Guidelines note that pre-project monitoring and analyses should be conducted by personnel with appropriate qualifications and expertise relevant to each discipline to provide an accurate, quantitative and qualitative understanding of the pre-project conditions and trends.

Monitoring should be guided by design of a monitoring network and program that takes into account all topics considered in the Guidance. Locations, timing of sampling, methodologies, and duration of data collection should be designed to adequately inform on the variability and risks relevant to the topic.

Monitoring should draw on and supplement existing information and data collection in the Mekong River and tributaries (including the MRC data and protocols), which may be under the responsibility of national agencies or institutions. Tributaries can have an important influence on the mainstream conditions and should be taken into account.

The Guidelines also seeks to ensure that monitoring is of sufficient duration to inform projections of future trends and changes, and to provide a certain degree of overlap with existing data sources so that the project-specific data can be extended.

3.4.2 Analysis and Modelling

The Guidelines reinforce the idea that appropriate analyses, including modelling, should be used for predictive purposes to indicate whether particular risks are relevant to the project, the magnitude and consequence of these risks, and the likely effectiveness of various mitigation approaches.

The Decision Support Framework (DSF) developed by the MRC provides an important resource for assessing cumulative and transboundary impacts in the Mekong River, and for informing development of Cascade Joint Operating Rules. The DSF includes basin-scale hydrological, sediment and water quality models and relevant input data for these models. The Mekong DRIFT (Downstream Response to Imposed Flow Transformations) model is associated with the

DSF, and allows evaluation of changes to biological parameters arising from hydrology and sediment alterations.

3.4.3 Residual Impacts

The information presented on the extent of project impact for each topic, and the likely effectiveness of the planned mitigation measures, should also identify and analyse the residual impacts that will remain, the communities that will be affected by these residual impacts, and the consequences of those impacts on river-based livelihoods. This is a critical input to the analyses that will be undertaken relating to riparian communities and river-based livelihoods (Section 9).

3.4.4 Monitoring During Detailed Design, Construction and Operation

Project monitoring to be undertaken during the detailed design, construction and operation stages should be described in the PNPCA information.

The project monitoring plan should describe what data will be collected, how it will be analysed, what indicators will be tracked and why, and how the information will be able to inform timely management responses.

Existing MRC monitoring protocols and parameters are referenced; the Joint Environment Monitoring initiative, currently under development, is also proposed as guidance.

3.4.5 Adaptive Management

Adaptive management is a principle underpinning the Guidance. Guidance on design features to support future adaptive management is provided in the sub-section entitled Specific Design and Operational Guidance.

i. Mitigation measures may be implemented on a trial basis, and design features should be built into the project to allow for later adaptation if required.
i. Uncertainties in aspects of effectiveness of proposed mitigation measures (e.g. for built structures, operational rules) should be explained, and follow-up monitoring and review of these areas of uncertainty should be built into the project monitoring plan.
ii. The project monitoring plan submitted with the PNPCA information should show what indicators and thresholds will guide decisions to be made on adaptive management, what adaptations could be made and why, how the designs factor in the ability to implement these later adaptations, and that adequate contingency funding has been set aside to undertake these possible adaptation steps.
iii. The project monitoring plan submitted with the PNPCA information should show that both riverine and impoundment monitoring results will be reviewed annually, and should identify the decision-making process that will be used to identify and implement management actions to be taken if risks or impacts are evident from the monitoring results.

3.5 General Requirements

The PNPCA require the Notifying Country to provide technical data and information on its proposed use of the Mekong mainstream, for an evaluation of the impacts by the other Member Countries.

i. Planned Project-Specific Operating Rules, or at a minimum the **operating principles and objectives,** for the impoundment, for downstream discharges, for gates, and for any mitigation structures.
ii. **Cascade Joint Operating Rules**, or at a minimum the cascade joint operating principles and objectives, where the project is part of a cascade.
iii. A set of relevant **design drawings** with labelling in English.
iv. Clear **maps and figures**, using an appropriate scale, that are easy to understand, interpret, and relate to the explanations provided.
v. A **list of the experts** used for the topics addressed by the Guidance, and their qualifications.

4. Summary of Topic Sections 2-9

4.1 Section 2: Hydrology and Hydraulics

4.1.1 Objectives

The objectives of the Guidance on **hydrology and hydraulics** are to ensure that:

i. Project developers have a detailed understanding of the hydrological resource availability and reliability, to inform project planning, design, construction and operations, taking into account present and potential future trends (such as climate change).
ii. Mitigation measures and cascade or project operating rules dependent on hydrology and hydraulics are underpinned by sound hydrological and hydraulic assessments.
iii. Mainstream developments are able to meet the objectives of the Procedures for Maintenance of Flows on the Mainstream (PMFM) and the Procedures for Water Use Monitoring (PWUM) within the Mekong Agreement framework, which require that every effort is taken to manage and maintain a minimum flow and to minimise rapid changes in key river flow indicators to avoid harm to downstream users and the ecology.

The Figure shows the important locations of hydrology and hydraulic change that occur due to a mainstream project, and establishes some common terminology that will be used throughout the Guidance.

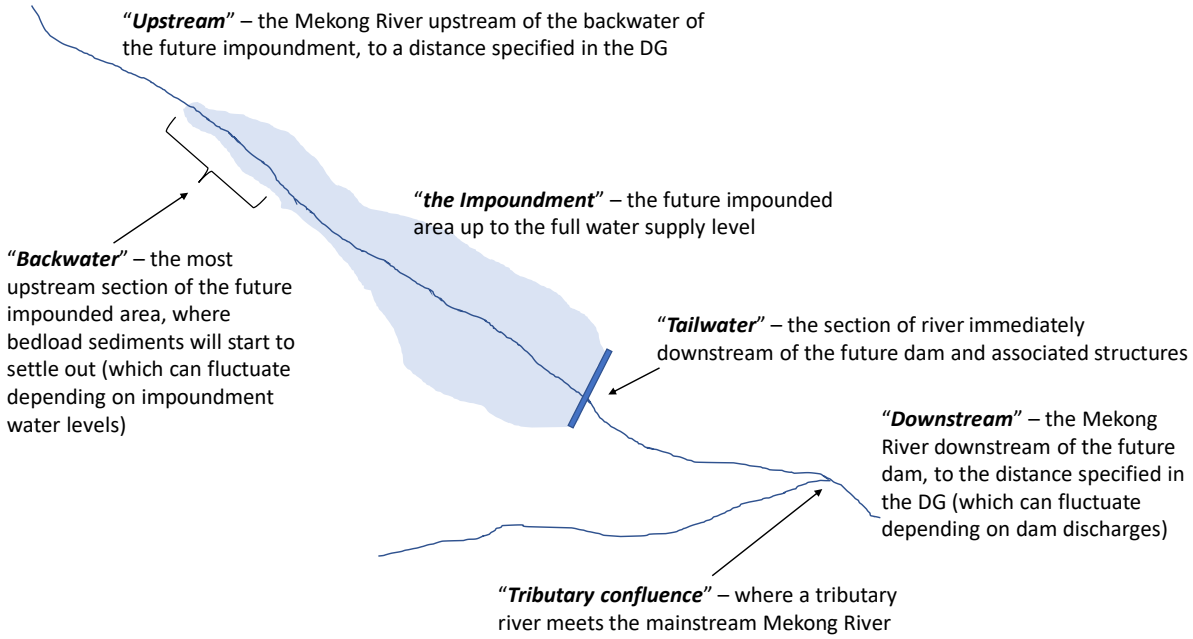

Figure 3: Locations of hydrology and hydraulic change arising from a mainstream project

4.1.2 Summary of Specific Design and Operational Guidance

Mitigation options should be evaluated to determine which ones will best address identified risks. The modelling and monitoring results should be used to help identify the underlying hydrological and hydraulics changes that have consequences for environmental and socio-economic values, and to identify and optimise appropriate mitigation measures. Mitigation measures should clearly address identified risks. The Table identifies mitigation measures that can address the core sources of impact relating to hydrology and hydraulics.

Table 2: Mitigation options to address hydrological and hydraulic changes

Hydrological or Hydraulic Changes	Mitigation Options
Daily or short-term alterations in the downstream flows	• *Siting of the project so that downstream impacts are reduced due to the river configuration or by entering tributaries* • *Cascade Joint Operating Rules to ensure harmonised operations* • *Project-Specific Operating Rules to minimise flow fluctuations downstream of the dam (note the most downstream dam in a cascade can be operated as a re-regulation dam if required during specific operational activities of the cascade)* • *Notification and warning systems for spill events or rapid water level changes*
River impoundment	• *Siting and design to minimise the inundation area* • *Siting and design to minimise the water residence time*

	• *Filling rules to address any flow interruptions following dam closure* • *Operating rules for the impoundment to minimise water level fluctuations, and prevent upstream flood damage.*

4.2 Section 3: Sediment Transport and Geomorphology

4.2.1 Objectives

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 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.

4.2.2 Summary of Specific Design and Operational Guidance

Mitigation options should clearly address the identified risks relevant to the project. Mitigation options to address potential risks relating to mainstream dams are summarised in the **Error! Reference source not found.**. Not all risks will apply to every project, and there may be additional risks that require consideration.

Table 3: Mitigation options for sediment transport and geomorphic risks for mainstream dams

Risk	Mitigation Options
Alteration of morphological balance of the Mekong River	- Site and design the project to minimise disruption of sediment supply and maximise potential for sediment management and passage.
Trapping of sediment within the impoundment	- Size and design the project to minimise retention time and maximise sediment entrainment and transport. - Include low level outlets to allow the passing of turbidity currents and implement sediment routing and sediment flushing. - Include sand trapping and passing facilities near turbines
Reduction in sediment load downstream due to increased deposition within the impoundment	- Develop operating procedures to maximise sediment passage (sediment bypass, routing). - Develop annual operating procedures to flush sediments at seasonally appropriate times, targeting high water flows and high inflowing sediment loads. - Implement physical bank protection where bank erosion poses a risk to infrastructure or communities

Risk	Mitigation Options
Water level fluctuations within impoundment leading to erosion and landslides	- Develop operating procedures that will minimise the rate and range of water level fluctuations. - Implement physical buttressing of banks to protect infrastructure
Water level fluctuations downstream leading to erosion and landslides	- Develop up- and down-ramping rates to minimise bank erosion and reduce safety issues. - Implement physical buttressing of banks to protect infrastructure and land
Disconnect between flow and sediment delivery	- Implement sediment routing or sediment flushing early in the monsoon to provide a pulse of sediment to the downstream environment. - Coordinate sediment routing and flushing within a cascade to maximise downstream sediment transport
Increased sediment generation during construction	- Contour access roads and include drains to limit sediment runoff. - Construct access roads, coffer dams and other major earth works during the dry season. - Construct and manage sediment traps
Land disturbance and landslides during construction	- Minimise land disturbance during the wet season. - Construct roads along contours using good practice engineering. - Construct access roads, coffer dams and other major earth works during the dry season. - Construct and manage sediment traps. - Rehabilitate and revegetation disturbed lands as soon as practicable

4.3 Section 4: Water Quality

4.3.1 Objectives

The objectives for water quality are to:

i. Reduce the risks that water quality within the impoundment will impact the use of the impoundment for other purposes, such as fisheries, or impact on human health, or cause interference with, and damage to, hydropower infrastructure such as turbines.
ii. Minimise water quality impacts downstream of the dam on fisheries, aquatic ecosystems and human health.
iii. Ensure alignment with the Procedures on Water Quality under the Mekong Agreement, which seek to maintain the water quality of the Mekong River mainstream.

Technical Guidelines on Implementation of the Procedures for Water Quality (TGPWQ (2016),[1] referred to as the "Technical Guidelines", have been agreed by the countries and encompass guidance for the protection of human health, the protection of aquatic life, a framework for implementation, and water quality emergency response and management.

4.3.2 Summary of Specific Design and Operational Guidance

Mitigation options should be evaluated to determine which ones will best address identified risks. The monitoring and analytical results and project information should be used to evaluate the potential water quality risks associated with the project, and identify and optimise appropriate mitigation measures. Mitigation options to address potential water quality risks relating to mainstream dams are summarised in the Table , along with appropriate indicators to monitor and assess these risks.

Table 4: Mitigation options for water quality risks for mainstream dams

Water Quality Risk	Indicator	Management / Mitigation Measures
Construction Risks		
Sewage and contaminated run-off from labour camps, workshops, etc.	Nutrient concentrations Faecal Coliforms	- Implement appropriate construction techniques to minimise run-off. - Implement wastewater treatment for camps.
Fuel, oil and chemical spills	Total Petroleum Hydrocarbons	- Ensure all storage and transfer areas have appropriately bunding, with clean up equipment onsite should spillages occur. Ensure staff members are trained in spillage control and appropriate clean-up procedures.
Within the Impoundment		
Sewage and contaminated run-off from riparian villages	Nutrient concentrations Faecal Coliforms	- Implement appropriate drainage systems to minimise run-off into the impoundment. - Implement wastewater treatment for villages.
Increasing nutrient influx from upstream and the local catchment from non-hydropower related activities	Increasing nutrient concentrations and loads entering impoundment (TN, TP, NH_3^+, etc.)	- Ongoing communication with responsible National Agency and work with provincial and national agencies to promote good land and wastewater management practice throughout the basin.

[1] Technical Guidelines for the Procedures on Water Quality (2016), Mekong River Commission, Vientiane

Water Quality Risk	Indicator	Management / Mitigation Measures
Reduced turbidity and increased light penetration, which can lead to algal blooms and/or reservoir stratification	PAR penetration Turbidity Chlorophyll levels	- Work with responsible National Agency and catchment management groups to lower nutrient inputs. If severe, treat chemically or aerate to treat surface scums.
Risks from impoundment stratification		
Low dissolved oxygen in hypolimnion (bottom water)	Water column profiles of dissolved oxygen	- Design low volume, high inflow impoundments with lower risks of stratification. - Work with catchment groups and the responsible National Agency to minimise organic loading to impoundment. - Design high dimension turbine intakes to take water into the power station over a range of impoundment depths. - Implement air injection in the turbine if low dissolved oxygen levels are entering power house. - Incorporate an aeration unit near dam
Downstream Risks		
Altered water temperature	Water temperature	- Site projects upstream of unregulated tributaries. - Include intakes that extract water over a range of depths. - Include multilevel offtakes. - Release surface water to mix with power station discharge.
Rapid alterations in water quality	Water temperature Turbidity Suspended solids Conductivity pH	- Implement operating rules to restrict ramping rates and daily water level changes
Gas supersaturation	Gas saturation	- Maintain clean trash racks to minimise turbulence and air entrainment at intake. - Site projects in steep reaches to allow degassing of outflow. - Include spillway deflectors if risk is high.
Downstream risks from impoundment stratification		

Water Quality Risk	Indicator	Management / Mitigation Measures
Low dissolved oxygen	Dissolved oxygen	Release water from surface spillways to mix and dilute. Site projects in steep reaches to allow reoxygenation via turbulence
Low pH	pH	Release water from surface spillways to mix and dilute and raise oxygen levels.
High iron and manganese	Iron and manganese	Release water from surface spillways to mix and dilute and raise oxygen levels, to cause metals to precipitate
Risks from sediment flushing		
Downstream pulse of high turbidity	Total suspended solid concentration	Limit sediment concentrations during flushing by managing flows and draw-down rates. Flush frequently to avoid large sediment loads being flushed sporadically.
Downstream pulse of low dissolved oxygen	Dissolved oxygen	Release water from surface spillways to mix and dilute. Implement measures to reduce stratification
Downstream pulse of toxicants	Iron and manganese	Release water from surface spillways to mix and dilute

4.4 Section 5: Aquatic Ecology

4.4.1 Objectives

The objectives for aquatic ecology are to:

i. Protect and conserve aquatic habitats as far as practicable during the development and operation of mainstream dams
ii. Minimise the impacts of the construction and operation of hydropower dams on the aquatic ecology and ecosystems of the lower Mekong River system
iii. Reduce the risks of the proliferation of pests, parasites or diseases within aquatic ecosystems in hydropower impoundments on the Mekong mainstream
iv. Sustain aquatic ecosystems reliant on the flow regimes of the river.

The Mekong Agreement Procedures for the Maintenance of Flows on the Mainstream (PMFM) specify that the parties will cooperate to maintain the following flows at selected mainstream stations specified in the procedures:

i. Not less than the acceptable minimum monthly natural flow during each month of the dry season;
ii. To enable the acceptable natural reverse flow of the Tonle Sap to take place during the wet season; and
iii. To prevent average daily peak flows greater than what naturally occur on the average during the flood season attributed to intentional water releases from man-made activities or other facilities.

4.4.2 Summary of Specific Design and Operational Guidance

Mitigation options should be evaluated to determine which ones will best address identified risks. The Table identifies mitigation options that should be considered to address risks relevant to the project.

Table 5: Mitigation options for aquatic ecology risks for mainstream dams

Risk	Mitigation Options
Occurrence of toxic algal blooms in the impoundment	- Ensure that local sources of nutrients, especially phosphorus, are controlled. - Encourage control of upstream nutrient sources, destratification may also help control algal blooms
Infestations of invasive plant and animal species in the impoundment	- Monitor occurrence of macrophytes and potential pest species within the impoundment to ensure early detection. - Physical removal, biological control or chemical control are the preferred mitigation strategies in order of preference
Increases in public health risks related to the impoundment	- Monitor impoundment for microbial indicators (e.g. faecal coliforms); - Ensure good liaison with local health authorities so that the owner/operator will know if public health issues are arising that are caused or exacerbated by the impoundment.
Loss of deep hole habitats	- Avoid locating impoundments on stretches of river containing deep holes.
Barrier to movement of nutrients, carbon and biota	- Impoundment bypass if possible
Benthic community degradation	- Seek to locate impoundments immediately upstream of substantial tributaries and to reduce the length of river impacted.
Increased dry season flow, decreased wet season flow, and/or delay in timing of seasonal flows	- Cascade Joint Operating Rules, and Project-Specific Operating Rules, governing impoundment and discharge management by the project
Reduction in area and/or timing of floodplain inundation, and nutrient loads	- Cascade Joint Operating Rules, and Project-Specific Operating Rules, governing impoundment and discharge management by the project. - In suitable locations, floodplain waterbodies may be managed by providing pumped water or construction of floodways to increase wet season inundation, or bunds to allow retention of water for longer periods at the end of the flood season.

4.5 Section 6: Fish and Fisheries

4.5.1 Objectives

The objectives for fish and fisheries are to:

i. Maintain fisheries and other aquatic animal (OAA) yields and fish diversity sufficient to sustain the food, livelihoods and ecological integrity of the Lower Mekong Basin.
ii. Minimise the impact of dam construction and operation on upstream migration of fish species through design of appropriate fish passage facilities, where necessary.
iii. Minimise the impact of dam construction and operation on downstream movement of fish species through design of appropriate operational regimes, fish passage facilities, fish guidance systems and appropriate turbine designs.
iv. Minimise fish and fisheries impacts arising from changes in the flow regime downstream of the dam, in the impoundment, and upstream.
v. Mitigate impacts of individual and multiple mainstream dams on local and transboundary fish and fisheries, and OAAs.

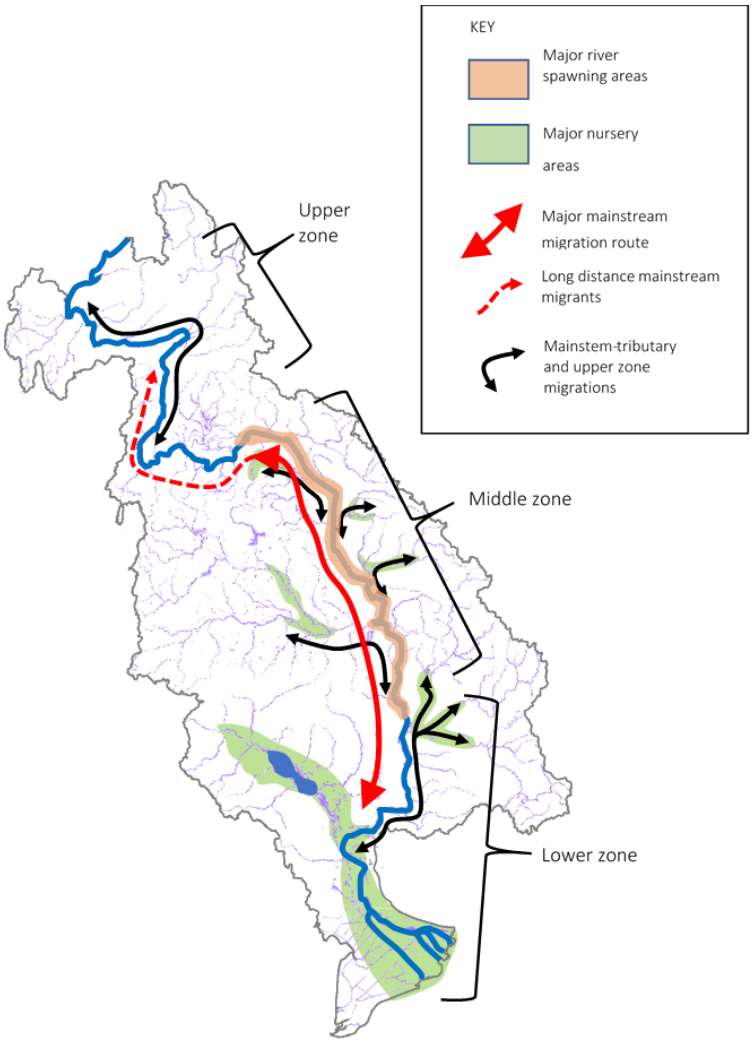

Figure 4: Generalised migration systems in the Lower Mekong Basin, modified from Poulsen et al. (2002a)

4.5.2 Summary of Specific Design Guidance

Mitigation options should be evaluated to determine which ones will best address identified risks. The Table provides a summary of mitigation approaches that can be taken to address the broad categories of risk to fish and fisheries. A holistic set of mitigation measures should be implemented to address the multiple facets of change that affect fish and fisheries. Whilst only fish-related mitigation measures are addressed below, mitigation measures for flows, sediments, water quality and aquatic ecology in the Guidance are also important influences on outcomes for fish.

Given the lack of direct and experimental data on Mekong fish pass efficacy, and the high consequence of risks to fish and fisheries, developers should engage the services of independent and knowledgeable fish passage experts with specific Mekong experience early in the design process, in order to draw on the widest possible regional and global experience. Developers are encouraged to utilise available MRCS data, resources and expertise at an early stage.

Table 6: Mitigation options for fish and fisheries for mainstream dams

Risk	Mitigation Options
Direct barrier effects on fish and fisheries	- Upstream and downstream fish passage facilities; - Catch-and-release programmes (not suitable for a river and fisheries at a Mekong scale); - Hatcheries and restocking programmes (potentially in combination with other measures).
Mortality at hydropower structures	- Dedicated design and operational choices for structures such as the turbine and gates; - Use of screens and other barrier technologies (e.g. light, acoustic) to direct fish away from areas of high mortality risk
Impacts in the impoundment on fish and fisheries	- Siting and configuration of the impoundment to minimise inundation area and important habitats such as deep holes and spawning grounds; - Management of impoundment water levels through Joint Cascade Operating Rules and Project-Specific Operating Rules; - Protection of impoundment riparian habitats through local works to protect, enhance or introduce important habitat areas (e.g. for spawning and nursery grounds, or shelter and feeding areas)
Downstream impacts on fish and fisheries	- Management of downstream water levels through Joint Cascade Operating Rules and Project-Specific Operating Rules; - Protection of natural river bank habitats through local works; - Controls and mitigation relating to potential water quality and sediment impacts

Habitats

As flowing water (lotic) habitats are key spawning areas and are essential for larval drift, dams should be sited and designed to maximise reaches with continuously flowing water.

Dams should be sited and designed to avoid permanent inundation or disconnection of floodplains, which are key, usually irreplaceable, spawning and nursery habitats. Productive fish populations are dependent on the natural inundation and drying patterns of these habitats.

In dam operation, consideration should be given to managing river edge habitats (littoral zone) of rocks and vegetation downstream of the dam, especially during the onset of the wet season when many species will be spawning. Rapid water level rises are acceptable, but draw-downs of, for example, greater than 0.5 m per day (to be determined on a site-specific basis) in the spawning season could expose eggs. Migratory fish may congregate below a dam with inadequate or no fish passage, and often spawn in the area downstream of the dam.

Fluctuations in water levels in the impoundment can create a barren unproductive littoral edge zone in the impoundment. Lagoon systems can be created in bay areas of the impoundment by installing small weirs, which buffer these fluctuations and maintain nursery areas in the impoundment during draw-down periods.

Fish passage

Fish passage facilities for both upstream and downstream migration should be incorporated into all dams on the Mekong mainstream. If fish passage is not considered viable to sustain populations (e.g. a cascade of dams is planned that eliminates flowing-water habitats upstream), then appropriate offset measures should be applied to compensate for potential ecological (biodiversity), social, food security, nutrition and economic (livelihoods) losses.

The following fish passage targets are based on population modelling and passage rates of Mekong species and hydropower dams.

i. For long-distance migratory species (i.e. Guilds 2, 3, 4 and 8) at a single dam, large fishes (>75 cm) require more than 90% passage (of numbers of each species approaching the dam) and medium-sized (50-75 cm) fish require more than 80% passage. If there are multiple dams, more than 95% passage at each dam site is required for both size groups.
ii. Small, short-distance migratory species (Guild 4) moving between/along the river to floodplains, require more than 60% passage (upstream and downstream) between spawning and feeding/refuge habitats.
iii. The above percentage passage requirements may be refined for the particular species concerned, based on its life history and the number of dams the species has to pass to complete its life cycle.

Biological and hydrological criteria for fish passage design

A primary consideration in the design of the hydropower project is allocating no more than 90% of low flows (i.e. "low flows" defined as the flow exceeded 95% of the time, or Q_{95} of present flows) for hydropower, enabling 10% for fish passage. At higher river flows, equal to the flow that is exceeded 0.5% of the time, or $Q_{0.5}$, allocation of 10% of flow for fish passage is desirable but 1% would be a minimum. A fundamental flaw of fish passes at large tropical dams has been lack of flow. At large hydropower dams, which have effective fish passage, allocating 10% of the minimum river flow for fish passage is a common standard,[2] while 5% of maximum turbine discharge has also been used. The well-known fishways on the Columbia River Dams use 10% of low flows (350 m^3/s).

Upstream Fish Passage

Upstream fish passage has two separate design components:

i. Attraction - in terms of fish approaching the dam and locating the entrance(s)
ii. Passage - through the fishways.

The Guidance provides detailed specifications for these aspects that should be tested for efficacy at the project operational stage.

Downstream Fish Passage

Downstream passage includes:

i. Larval drift through the impoundment;
ii. Passage at the fish screens / trash racks;
iii. Turbine passage of fish that pass through the fish screen; and
iv. Passage through the spillway gates.

Detailed descriptions of the design elements that should be included to address the key risks are included in the Guidance.

Alternative fish mitigation measures and offsets

Where fish passage rates are unlikely to be adequate to maintain viable regional fish stocks or local fish populations are not maintained, the developers should consider support measures including offsets for lost fisheries and OAA resources. From a fish and fisheries perspective, the following technical inputs should be considered in relation to any alternative measures. Livelihood aspects of support measures and offsets are addressed in Section 9.

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[2] Larinier, M. (2002). Location of fishways. In Larinier, M., Travade, F., Porcher., 2002: Fishways: biological basis, design criteria and monitoring. *Bull. Fr. Peche Piscic., 364 suppl.,* 208p. ISBN 92-5-104665-4.

4.6 Section 7 Dam Safety

4.6.1 Objectives

The objectives for dam safety are to:

i. Ensure that a dam does not contradict Article 7 of the Mekong Agreement by causing harmful damage to the environment (upstream or downstream) through its operation or in the event of a failure of the dam.
ii. Protect life, property and the environment from the consequences of dam operation or failure, based on an understanding of the risk imposed by the dam and the consequence of failure.
iii. Ensure a consistent approach to design criteria for mainstream dams, specifically for the safe passage of extreme floods and seismic stability.
iv. Ensure that design, construction, operation and maintenance regimes, as well as institutional arrangements, are consistent with national requirements and international good practice for the safety of dams.

4.6.2 Summary of Specific Design and Operational Guidance

The Table identifies mitigation measures for certain identified risks . The developer should demonstrate, at the PNPCA process stage, how they intend to mitigate these risks.

Table 7: Mitigation measures for dam safety risks for mainstream dams

	Risk	Mitigation Measures
Design	Failure of upstream dams	- Carry out hydraulic modelling of the impact of failure of the upstream dams and design the dam to prevent catastrophic failure due to overtopping by an upstream dam failure
	Uncertainties in flood loading	- Existing dams on the mainstream have been designed to safely pass the PMF flood. All new dams should use the PMF as the check flood. However, the design flood (i.e. no damage to the dam) should be selected based on the worst-case flood loading scenario such as the greatest differential head.
	Uncertainties in the geological and geotechnical investigations	- Detailed geological and geotechnical investigations of the dam site should be carried out before and during the construction phase.
	Poor design of dam and structures	- Use of experienced designers. - Adequate Quality Assurance systems in the design. - Dam Safety Review Panel actively reviewing at all stages of the project.
	Uncertainties in seismic loading	- Detailed seismic hazard assessment should be carried out as recommended by ICOLD Bulletins 120 and 148

	Risk	Mitigation Measures
Construction	Poor construction control and quality	- Detailed specifications should be prepared by the designers and then strictly applied during construction. - The design and construction should be carried out by experienced dam engineers and contractors with all stages peer viewed from a dam safety perspective.
	Failure of the dam during construction due to undersized or blocked diversion works causing overtopping of the partially completed dam	- Adequate sizing of the diversion works. - Active management of debris. - Implementation of flood forecasting systems during construction. - Emergency planning and dam safety monitoring during construction.
Operation	Inadequate operation, maintenance and dam safety surveillance	- Detailed dam safety management plans, operational and maintenance plans, and emergency preparedness plans based on potential failure mode assessments should be prepared by the designers and implemented by the developer and owners.

4.7 Section 8: Navigation

4.7.1 Objectives

The objectives for navigation are to:

i. Guarantee continuation of navigation on the Mekong mainstream consistent with Article 9 of the Mekong Agreement, through provision and management of ship locks at all mainstream dams.
ii. Ensure consistent design and operation of ship locks at all mainstream dams.
iii. Make sure that dam infrastructure does not impede the potential future development of mainstream navigation in terms of cargo transport capacity, passengers transport capacity and convoy transport development.
iv. Ensure safe and fast lock operations.

4.7.2 Summary of Specific Design and Operational Guidance

An essential guide for many of the design aspects for the mainstream Mekong ship locks is the PIANC[3] report from 2009 on "Innovations in Navigation Lock Design". It is the developer's responsibility to obtain the Guidance document through the PIANC procedures. The Guidance directs the user to specific sections of this PIANC reference document for important design requirements.

[3] PIANC = the Permanent International Association of Navigation Congresses; now the World Association for Waterborne Transport Infrastructure (www.pianc.org). Documents are readily available at low cost.

Mitigation options should be evaluated to determine which ones will best address identified risks. The Table sets out mitigation options for the broad areas of risk, with more detailed guidance provided in the clauses following this table.

Table 8: Mitigation options for navigation-related risks for mainstream dams

Risk	Mitigation Options
Structural integrity of the ship lock infrastructure	- Ship locks should be earthquake resistant (see Section 7 Dam Safety). - The design takes into account the geological and geomorphology conditions of the site and the effects of potential differential settlement
Issues arising in the approaches to the ship lock and the impoundment	- Provide a straight-line approach channel with good approach visibility. - Ensure the guidance wall, ship lock openings, and ship lock design in one straight line avoid the identified risks . - Navigational hazard management measures (e.g. initial surveys, clearance, markers for remaining hazards particularly in the impoundment backwater). - Sediment management measures (see Section 3). - Debris management measures (e.g. regular surveys, underwater jet system, manual mechanical clearance, create a deep hole upstream to capture potential hazards)
Issues arising within the lock chamber(s)	- Protective measures for ship impacts (e.g. gate protection; steel sliders or armour devices embedded in concrete walls). - Mooring facilities, floating bollards, line hooks, fenders. - Camera surveillance; loudspeaker for warnings; emergency stop facility
Emptying and filling produces heavy turbulence affecting vessels	- Reprogram the opening sequence of the filling valves for various types of boats/vessels/barges. - Reshape the filling orifices or eventually redesign the entire filling system. - Avoid locking big barges together with small boats, or adapt the filling program of the culvert valves.
Cavitation at tainter valves and inside culverts (in locks with locks over 25-meter lift).	- Locks with a lift over 35 meters should not be constructed as a single ship lock. The design should opt for tandem locks. - Special attention should be paid to avoid cavitation in locks with lifts of over 25m; may be designed with spare basins to substantially reduce the pressure on the culvert valves.[4] - Tainter valves with enlarged (deepened) chambers behind the valves should be considered.

[4] PIANC-InCom report from the working group 29 (Report nº 106-2009): "*Innovations in navigation lock design*", Section 4.4.5 (page 82)

	- The culvert shape behind the filling and emptying valve should be optimised. - Aeration of the tainter valve with an air intake system should be considered. - Increase and improve the resistance of the culvert walls against cavitation, e.g. by steel plates.
Interruption of existing and ongoing navigation	- Alternative ways of transshipping goods, cargo and passengers should be provided during the construction of the ship lock. - Information on construction progress should be provided to waterway users, in particular to boat associations from upstream and downstream ports and commercial waterway transport operators.
Any sudden release of water into the downstream river as a result of operations such as sediment flushing	- Cascade Joint Operating Rules and Project-Specific Operating Rules to control how water levels will fluctuate. - Early warning notifications. - Prior safety inspections ahead of major water level changes.

4.8 Section 9: Riparian Communities and River-Based Livelihoods

4.8.1 Objectives

The objectives for riparian communities and river-based livelihoods are to:

i. Evaluate the residual impacts from the project on directly-affected riparian communities in a participatory manner.
ii. Identify practical, feasible and long-term support measures that seek to ensure that directly-affected riparian community livelihoods are better or at least restored to pre-project levels.
iii. Implement these support measures, where feasible, within existing institutional frameworks (e.g. MRC, government at various levels, civil society organisations).
iv. Consider building on existing or creating new cooperative implementation mechanisms if needed (e.g. to implement offset mechanisms), such as through national, bilateral, regional and MRC-related frameworks.

Member Country governments maintain the primary responsibility for managing socio-economic impacts within their borders, and may enter into bilateral agreements to resolve transboundary issues of mutual interest or concern.

Attribution of physical and biological changes in the river system to a particular hydropower project is addressed in Sections 2 to 8. Each of these previous sections has guidance on clearly identifying the likely residual impacts after proposed mitigation measures have been implemented. This section addresses attribution of livelihood impacts from these changes in the river system. Attribution requires isolating and estimating the particular contribution of a change to a livelihoods outcome. This requires clarity about the causality, and awareness of the many other factors that may evolve alongside the physical change.

4.8.2 Summary of Specific Design and Operational Guidance

Communities should be consulted in a respectful and inclusive manner, ensuring that: they have access to relevant information; consultations are held in a timely manner to ensure results can still influence decisions on the design of the project and its mitigation measures; and community leaders as well as representatives of all relevant sub-groups (especially vulnerable groups) are heard, where necessary separately. Representatives should be selected by function (e.g. formal leadership functions), on the basis of statistically valid representation of all identified sub-groups, and self-selected on the basis of interest in the project.

Residual socio-economic impacts on riparian communities will remain, because: mitigation is rarely designed to fully eliminate impacts; mitigation may not work as intended; and impacts are cumulative, resulting from multiple projects which may or may not be using good practice mitigation approaches.

Options for support measures should be evaluated to determine which ones will best address residual impacts on riparian communities. The Guidance outlines a number of support measures that can be considered to address the residual risks, some of these are listed in the Table below . Proposed support measures should not be limited to those in the Table.

Table 9: Potential support measures to address residual risks to river-based livelihoods associated **with mainstream dams**

Potential Residual Risk	Potential Support Measures
Unexpected and extreme water releases from impoundments (as described in Sections 2 and 7).	- Measures to increase resiliency of infrastructure to changing water levels (e.g. through design of bridges, riverbank roads, boat ramps and river ports, water intakes for municipal use and for irrigation, pipelines and power and communication lines) - Emergency planning and communications - Replacements of lost assets, including boats, livestock etc.
Projects can affect sediment transport and geomorphology (as described in Section 3).	- Flushing and dredging to support navigation - Strengthening of river banks and dikes (levees, embankments) to protect high-value lands such as settlements - Adaptation or replacement of riverside infrastructure where affected, for example lowering of water intakes in case of riverbed deepening - Support in case of physical or economic displacement, such as equivalent replacement land and homes, and livelihood restitution or alternative livelihoods support (see below) - Access to alternative construction materials to replace reduced availability of sand and gravel, such as off-stream borrow pits
Projects can affect aquatic ecology and fish populations	- Offsets to increase fish populations (improvement of fish passage and habitat in other parts of the river system; hatcheries and stocking;

(as described in Sections 3-6).	- Alternative livelihoods support including training, equipment, credit schemes, job placement, and market development - Access to the reservoir, boats and other fishing gear, and facilities for landing, cooling, processing and marketing - Access to alternative food production options and markets, including high-value options such as fruit trees, aquaculture, dairy etc.
Projects can affect local and long-distance transport (as described in Section 8).	- Alternative transport if impoundment or dam becomes a barrier (ferries, bridges, bypass roads, bus services etc.) - Safety measures such as marking of submerged rocks - Provisions to allow small craft to traverse dam

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