Mekong River Commission Secretariat

MRC Initiative for Sustainable Hydropower

Final Report

ISH01 PILOT TESTING IN THE SRE POK SUB-BASIN

on the Identification of Ecologically Sensitive Sub-Basins for Sustainable Development of Hydropower on Tributaries

July 2015
**LIST OF ACRONYMS**

| Acronym | Full Form |
|---------|-----------|
| CEA     | Candidate Ecological Area |
| EP      | MRC Environment Programme |
| ESA     | Ecologically Sensitive Area |
| GIS     | Geographic Information System(s) |
| FP      | MRC Fisheries Programme |
| IKMP    | MRC Information and Knowledge Management Programme |
| IWRM    | Integrated Water Resources Management |
| ISH     | MRC Initiative on Sustainable Hydropower |
| JC      | MRC Joint Committee |
| LMB     | Lower Mekong Basin |
| MRC     | Mekong River Commission |
| MRCS    | Mekong River Commission Secretariat |
| NMC     | National Mekong Committee |
| NMCS    | National Mekong Committee Secretariat |
| NGO     | Non-Governmental Organisation |
| PDIES   | Procedures for Data and Information Exchange and Sharing |
| PIP     | Project Implementation Plan |
| RBM     | River Basin Management |
| RBO     | River Basin Organisation |
| TNMC    | Thai National Mekong Committee |
## IMPORTANT DEFINITIONS AS USED WITHIN THE ISH01 STUDY

| Definition                    | Description                                                                                                                                                                                                 |
|-------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| **Candidate Ecological Area (CEA)** | An ecological area listed in a catalogue before analysis on its ecological sensitivity. A CEA is chosen based on its (i) spatial importance, (ii) conservation status and (iii) the level of human pressures (except hydropower) affecting it. |
| **Driver**                    | A human activity that may have an environmental effect (e.g. hydropower generation, industry, agriculture, etc.)                                                                                             |
| **Ecologically Sensitive Area (ESA)** | An Ecologically Sensitive Area that contains  
- Contains high ecological importance/value,  
- Sustains ecological processes in support of socio-economic and ecological importance/value, and/or  
- Might be at risk of losing its support of ecological importance/value, and  
- Is relatively intact but sensitive/fragile to impacts (human and/or natural). |
| **Expert judgement**          | Technical expertise that is given in case of lacking data. Expert judgement is used as an interim/preliminary step before factual assessments are undertaken delivering the data that was lacking beforehand. Within the ISH01 study expert judgement is e.g. applied within the risk-based approach and the application of risk criteria that are used to assess possible impacts on ESAs and adjacent river stretches. Expert judgment does not replace assessments with data but is a sufficient tool for pre-assessments that are based on solid expertise. Findings stemming from expert judgement are usually validated with data and replaced in follow-up. |
| **Fragility**                 | A fragile environment is one that is both easily disturbed and difficult to restore in case of negative impacts. The environment can be fragile to both natural and human impacts. |
| **Impact**                    | The environmental effect of a pressure (e.g. degraded water quality; fish mortality; interruption of fish migration).                                                                                           |
| **Pressure**                  | The direct effect stemming from a driver (e.g. an effect causing a change of the riverine flow regime).                                                                                                                                                           |
| **Response**                  | The mitigation measures that are taken to improve the state/quality of the impacted water reach (e.g. reducing pollution; construct fish bypass facilities).                                                                 |
| **Risk**                      | Likelihood of occurrence and the magnitude of consequences of a specific pressure/impact that being realised.                                                                                                                                                   |
| **Risk analysis**             | - A process undertaken to deal with matters that pose a potential challenge/impact on e.g. systems, managed according to a certain standard procedures that involve (i) impact identification, (ii) risk assessment/estimation, (iii) risk assessment/estimation. |
management and (iv) risk communication.

- Analytical process to provide information regarding undesirable events;
- A process of estimating probabilities and expected consequences for identified risks.
- Detailed examination including risk assessment, risk evaluation and risk management alternatives, performed to understand the nature of unwanted outcome.

**Risk management**

- Based on the results of the risk estimation and the judgement of the ‘risk managers’ (= LMB water resources managers), decisions are taken and policy is formulated.
- A process of weighting policy alternatives in consultation with all interested parties considering risk assessment and other factors.

**River density**

Is an index of the development of surface runoff in the territory under consideration. Its value depends on the geological structure and relief of the locality, the climate, and the plant and soil cover. The drainage density is greater in mountainous regions than on plains, both because the amount of precipitation is greater in the mountains.

**Sensitivity of conservation status**

Concerns the ecological area’s species vulnerability regardless of the human impacts.

**State**

The condition of a riverine water resulting from both natural factors but also human pressures.

**Vulnerability**

Vulnerability is the likelihood that the environment/species will be exposed to and adversely affected by a hazard/pressure. It is the interaction of place (risk and mitigation) with the characterisation of the environmental condition (based on Cutter, 1993).
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1 INTRODUCTION TO THE ISH01 STUDY

The ISH01 study on the ‘Identification of Ecologically Sensitive Sub-Basins for Sustainable Development of Hydropower on Tributaries’ has been kicked-off through an Inception workshop (Vientiane, Lao PDR) in November 2013 and is intended for finalisation in June 2015. The study aims to contribute to the achievement of the Strategic Priority number 4 of the MRC’s Basin Development Strategy 2011. The Strategy emphasises ‘the need for evaluation options for development of sustainable hydropower on tributaries, addressing the risks of mainstream hydropower, and assessing alternative energy options to mainstream hydropower’. In this context, the need to move towards sustainable development of hydropower on tributaries is highlighted through ‘identifying sub-basins with high ecological value to be protected and those where hydropower can be developed with limited and environmental impacts’.

The outcomes and risk-based approach of the ISH01 study aim to support sustainable hydropower in the Lower Mekong Basin sub-basins, enabling hydropower development and thus the socioeconomic benefits it can provide, while at the same time ensuring the protection of identified Ecologically Sensitive Areas (ESAs) and their environmental quality. Hence, the hydropower planning and management framework that is being developed within the ISH01 study aims towards integrated, transparent and balanced decision making for sustainable LMB development.

Large river systems, such as the Mekong and its tributaries have complex dynamic ecosystems, which interact with and are impacted by a range of human activities. Not only do these ecosystems have their own intrinsic value, ecological character and sensitivity, but they also significantly support a variety of livelihoods in their provision of ecosystem services (e.g. fisheries, agriculture, navigation, tourism, etc.). These LMB ecosystem services contribute to the sustainability of the LMB’s food security, socio-economic development and wellbeing.

There is no single, common definition for the term Ecologically Sensitive Area (ESA) nor has one been introduced for the LMB yet. As a study pre-requisite, based on a literature review and in consultation with the LMB countries, a definition for ESA has been developed for the LMB context, which is presented in the box below.

A functioning ‘Ecologically Sensitive Area’ in the LMB context is defined as an area that

- contains high ecological value/importance (locally, nationally or globally), and, hence,
- supports sustainable ecological processes in support of socio-economic and ecological value,
- supports the sustainability of ecosystem services and, hence, livelihoods (ecosystem services),
- is fragile to impacts no matter if human and/or natural, and, hence
- is at possible risk to lose its support of ecological value and processes due to potential impacts.

Over the last 15 months and aligned to three study Components and 17 Activities, the experts of the ISH01 Study together with the LMB countries have been working to develop technical approaches for (i) the identification of ESAs and (ii) the development of a planning and management framework for sustainable hydropower in the LMB covering 3 Modules and 10 Steps. The implementation of all study activities will support the achievement of the four key outcomes of the ISH01 study that are summarised here:
An approach to identify Ecologically Sensitive Areas.

An easy-to-apply framework for planning and management in LMB tributaries combining the identified ESAs with hydropower to support sustainable decision making.

Findings are available from assessments in selected LMB pilot sub-basins.

A proposal for up-scaling the identification of ESAs as well as the hydropower planning and management framework to the LMB basin-wide scale.

While the first Component of the ISH01 Study was dedicated to the development and consultation of the technical approaches, the ongoing Component 2 has been focusing on pilot testing the approaches. Component 3 will focus on the feasibility of LMB wide up-scaling taking into account the entire LMB comprising 104 LMB sub-basins (see Map 1). The up-scaling proposals will take account of related data and capacity needs as well as time spans needed for implementation.

Map 1: 104 LMB sub-basins (Significant Tributary Study, 2013).
This report’s focus is to present the interpreted results and GIS maps of the ISH01 pilot testing in the Sre Pok Sub-Basin. Besides the presentation of results the report provides (i) an outlook to the implementation of ISH01 Component 3, (ii) a reflection on the implications of results and remaining challenges, (iii) key conclusions and (iv) links to other ISH/MRC activities. The content of the report aims to stimulate discussion at the upcoming regional consultation in Ho Chi Minh City (7 – 8 April 2015) after which this pilot testing report will be revised based on comments from the LMB country representatives.

2 AIM, TASKS AND ACTIVITIES OF THE ISH01 PILOT TESTING

2.1 Overall aim of ISH01 pilot testing

Pilot testing represents one of three components in the ISH01 study (see Component 2 in Table 1) with the aim to contribute to a successful implementation of the ISH01 study.

Table 1: General implementation objectives of the three ISH01 study components.

| GENERAL OBJECTIVES | STUDY COMPONENT 1 | STUDY COMPONENT 2 | STUDY COMPONENT 3 |
|--------------------|-------------------|-------------------|-------------------|
|                    | Study pre-requisites & approach development for implementation | Pilot testing of approaches in selected sub-basins | Proposal for basin-wide upsizing of approaches |

Piloting in the Sre Pok river basin served to test the developed ISH01 approach under practical conditions using real data sets and expert capacities. Therefore, this practical implementation aimed to contribute to the improvement of the ISH01 technical approach including the calibration of all its underlying assessment criteria. In consequence, the pilot testing enables the adaptation of the ISH01 approaches to the exact needs of the MRC countries and to provide the basis towards a proposal for up-scaling to the basin wide level during Component 3. The latter will be the last implementation step before closing the ISH01 study with a final report.

2.2 Tasks of ISH01 pilot testing and this Pilot Testing Report

The task was to summarise the findings and lessons learned of the pilot testing in the Sre Pok river basin in a related report with the objective to establish a common understanding among all involved LMB countries and stakeholders. In this context, this ISH01 Pilot Testing Report reflects on the overall approach and data collection in the Sre Pok river basin as well as the respective analysis and results.

These reflections should stimulate a discussion regarding the overall potential to implement the ISH01 technical approach in the LMB. The findings of the report shall contribute to answering several questions like:

- Is the approach to identify ESAs, and to assess risks from hydropower that may impact ESAs as well as riverine ecosystems, relevant to be implemented in LMB sub-basins and the basin-wide scale?

- What are the added values to apply the ISH01 approach?
Will the implementation of the ISH01 approach contribute to informed and better decision making towards sustainable hydropower planning and management?

To contribute to the above, the ISH01 Pilot Testing Report presents the following aspects:

- Information? Pre-requisites and approach that has been implemented for the pilot testing in the Sre Pok Basin;
- Findings and analytical results of the ISH01 pilot testing following the steps of the technical ISH01 approach. This includes the presentation of:
  - Candidate Ecological Areas;
  - Identified Ecologically Sensitive Areas assigned to three classes of sensitivity;
  - Linkage of ESAs with existing and planned hydropower schemes;
  - An assessment showing what ESAs and related river reaches are at risk to be impacted by hydropower pressure types (allocation to three risk categories);
  - Illustration of the results in thematic GIS maps, tables and figures.
- Interpretation of results as a basis towards a common understanding and a discussion how to use the ISH01 approaches and results in the LMB towards sustainable hydropower;
- Key conclusions including an outline of strengths and weaknesses of the approach, possible benefits for the LMB as well as remaining challenges.
- Outline of the linkage to potential use in Basin Development planning and strategy and other relevant MRC IWRM issues;
- A brief outlook regarding a proposal for possible basin-wide upscaling of the ISH01 approach.

2.3 Structure and content of this report

In order to set the scene, the first two chapters of this report focus on recalling the basic principles of the ISH01 study and the description of the aims of pilot testing. As a pre-requisite for the presentation of pilot testing results, Chapter 3 provides a summary of the ISH01 technical approach (i) to identify ESAs and (ii) the development of a planning and management framework for sustainable hydropower in the LMB. Chapter 4 describes the pilot test in the Sre Pok basin including an outline of its preparation, the data collection process before and during the joint field visit in November 2014 and the sites visited and assessed.

Chapter 5 forms the report’s centrepiece where the pilot testing results are presented and illustrated. In order to provide a best possible overview on the findings of the pilot testing in the Sre Pok River Basin, the findings of the pilot testing in the Sre Pok River Basin are presented aligned to the 10 implementation steps of the three ISH01 Modules (see Figure 2). To ensure orientation throughout the report, the link to the modules is always highlighted at the beginning of the sub-chapters 5.1.1. to 5.3.3.

Chapter 6 is wrapping-up the findings of the pilot testing with key conclusions. Chapter 7 provides a brief outlook towards a proposal for basin-wide upscaling of the ISH01 approach. This chapter should inform the LMB countries what to expect of the ISH01 upscaling proposal, its purpose and its intended content.
**Figure 2:** ISH01 approach aligned to three Modules with 10 implementation steps that results in a proposal for basin-wide up-scaling *(taken from the consolidated ISH01 Interim Report, July 2014).*
3 ISH01 TECHNICAL APPROACH: A SUMMARY AS PILOT TESTING BASIS

3.1 General

The technical approach has been developed within ISH01 Component 1 to support the implementation of pilot testing during Component 2. This chapter provides a summary of the ISH01 technical approach in order to recall its basic principle as a pre-requisite to understand the pilot testing results. Details on the technical approach are available in the consolidated ISH01 Interim Report (July 2014) and partly in Annexes of this report.

3.2 The ISH01 technical approach in a nutshell

The ISH01 technical approach includes a methodology (a) to identify Ecologically Sensitive Areas and (b) to provide a framework for sustainable hydropower planning and management in LMB tributaries. The latter includes a component that allows the assessment of risks from hydropower on ESAs and river reaches. Drawing on international, regional and national experience, the developed approach provides a universal, practical and replicable tool developed through three modules and 10 implementation steps as illustrated in Figure 2 and Figure 3.

ESA identification

The basic principle of the approach to identify ESAs in selected pilot basins, firstly aims at the identification of areas of ecological interest – so called Candidate Ecological Areas (CEA). CEAs are based on national planning documents but also can be identified drawing on previous surveys and their findings. CEAs may for example include protected areas, wetlands, floodplains, Ramsar sites, hot spots, national parks, wildlife conservation areas and areas of high biodiversity. The CEAs are then assessed against criteria and, according to a coherent scheme (see Table 10 and Annex 2), are further allocated to three classes of ecological sensitivity (Table 2). The criteria and the allocation scheme have been tested and calibrated in the selected pilot basins.

Table 2: Three classes of Ecologically Sensitivity for the identification of ESAs.

| Classes of Ecological Sensitivity | ESA Identification                                      |
|----------------------------------|--------------------------------------------------------|
| High Ecological Sensitivity      | Identification as ESA                                  |
| Medium Ecological Sensitivity    | Identification as possible ESA<br>Besides medium ranked ESAs, this category also includes ESAs that can currently not be identified due to data gaps; identification need to be repeated |
| Low Ecological Sensitivity       | No identification as ESA                               |

Combining ESAs with hydropower and related risk estimation

In follow-up, identified ESAs will be combined with existing and planned hydropower information resulting in the framework for sustainable hydropower planning and management in LMB tributaries. The link is established (a) by overlaying the locations of ESAs and hydropower in GIS maps and then (b) through a comprehensive risk estimation approach that is based on the frequently applied Driver-Pressure-State-Impact-Response (DPSIR) method that was initially developed by OECD (1994).

The scheme on risk estimation (Figure 3) includes criteria to estimate if specific pressure types that result from hydropower put ESAs at risk of impact (local, downstream and upstream effects). The

1 In the case of this ISH01 study the Sre Pok Sub-Basin has been chosen for pilot testing.
implementation of the risk criteria results in an allocation of identified ESAs and the related river reaches to three risk classes that indicate if an ESA and/or river reach is 'not at risk', 'at risk' or 'possibly at risk' to be impacted by pressures from hydropower (Table 3).

Table 3: Risk classes to estimate impacts from hydropower on ESA related river reaches.

| Risk Class                        | Description of Risk Classes                                                                 |
|-----------------------------------|---------------------------------------------------------------------------------------------|
| Identified ESA related river reach ‘Not at Risk’ of being impacted by hydropower | The ESA / related river reach are not at risk of being negatively impacted by pressures from the assessed hydropower scheme |
| Identified ESA related river reach ‘At Risk’ of being impacted by hydropower    | The ESA / related river reach are at risk of being negatively impacted by pressures from the assessed hydropower scheme |
| Identified ESA related river reach ‘Possibly At Risk’ to be impacted through hydropower | It is uncertain whether the ESA / related river reach are at risk to be negatively impacted by pressures from the assessed hydropower scheme. |

The technical approach for LMB purposes including the risk estimation criteria have been tested in the Sre Pok pilot sub-basin. This testing allowed appropriate adjustments and calibration of the approach to the exact needs of the MRC countries and may enable the proposal for up-scaling to the basin wide level. Pilot testing is aimed at ensuring practicability in order to make the ISH01 approaches easy-to-apply for energy planners, water and environment regulatory authorities of the MRC countries for balanced decision making.

The development of the ISH01 study aims to ensure that the planning and management framework is interactively developed with the MRC Member Countries so that it is reflective of national policy on the protection of ESAs, and that it is useful for both the energy planners as well as the water and environment regulatory agencies.

Consultations have been and will again be organized at an effective and regular frequency with the MRC Member Countries and stakeholders through national as well as regional consultations. ISH01 approach benefits from these consultations and receives guidance as well as inputs from the countries, the MRC’s Initiative for Sustainable Hydropower and relevant MRC Programmes to ensure meaningful results.

The ISH01 Technical Approach in this Pilot Testing Report

Chapter 5 of this report presents the findings of the ISH01 pilot testing in the Sre Pok River Basin. The structure and, hence, sub-chapter heading of Chapter 5 follows the 10 Implementation Steps of the three ISH01 Modules (see Figure 2). Therefore, it is easy for readers of this report to catch-up on technical details on the approach when looking at the Module’s implementation steps and link these to the results.
Figure 3: Basic concept of the ISH01 risk based approach towards a planning and management framework for sustainable LMB hydropower combining all three ISH01 Modules.
4 PILOT BASIN TESTING IN THE SRE POK SUB-BASIN

Pilot testing has been integral part of the ISH01 concept from the beginning. The need to select an appropriate LMB pilot basin has been discussed during consultations with MRC member countries. In the frame of the 2nd ISH01 regional consultation in Phnom Penh (July 2014) both Cambodia and Viet Nam proposed testing the ISH01 approach in the Sre Pok sub-basin. This was agreed by all countries and in addition it was decided that Lao PDR and Thailand join the pilot testing exercise as observers to enable full capacity building on their side as well. In order, to set the scene for the presentation of results, this Chapter 4 informs about the ISH01 pilot testing exercise and its data collection in the Sre Pok Basin.

4.1 Brief description of the Sre Pok sub-basin

As illustrated in the below overview Map 2, the Sre Pok river basin is part of the LMB 3S sub-basin with its three key main rivers of Sesan, Sekong and Sre Pok that drain an area of about 79,000 km². The three LMB countries of Cambodia, Lao PDR and Viet Nam share the 3S sub-basins. The Sre Pok catchment area spreads over approximately 30,940 km² covering parts of Cambodia (41%) and Viet Nam (59%).

Map 2: Overview Map of the Lower Mekong Basin including Sre Pok Sub-Basin. Maps 2 and 14 provide an overview on the Sre Pok sub-basin itself including the mainstream hydropower schemes.

The Sre Pok River originates in the central highlands of Viet Nam, flows within Cambodia when joining the Sesan and Sekong rivers before they jointly flow - over a length of 38 km - into the Mekong mainstream close to the provincial city of Stung Treng. The length of the Sre Pok mainstream between the confluence with the Sesan and Sekong rivers and the merging with the
Krong Ana with Krong No tributaries is about 381 km. There is discussion on the overall length of the Srepok River depending if either the length of the Krong No or Krong Ana tributaries are added or neither of these. Adding the Krong No tributary (156 km) the overall length of the Srepok River is 537 km, while adding the Krong Ana (215 km) it is 596 km$^2$.

As the ISH01 study has a focus on hydropower, the analysis took into account the Krong No tributary as part of the Srepok River due to the fact that the hydropower scheme of Buon Tua Srah is located in it (41 km upstream the merging of the Krong No / Krong Ana tributaries). The Krong Ana is free flowing without any hydropower scheme. An overview on the Srepok River and its length is shown in Map 2a.

Map 2a: River length along the Sre Pok River focusing on the location of hydropower schemes. Reach 1-2: 38 km. Reach 2-3 (Sre Pok mainstream): 381 km, 3-4 (merging Krong No / Krong Ana tributaries to the Buon Tua Srah dam): 41 km, 4-5 (Buon Tua Srah to source of Krong No): 115 km. Following the Srepok mainstream and the Krong No the overall river length sums up to 537 km.

The Vietnamese parts of Sre Pok River basin holds a population of over 2.2 Million people (MRC, 2006). The Sre Pok river originates in Dak Lak and Lam Dong provinces, the natural catchment in Vietnam’s territory is 18,480 km$^2$ and river density is 0.55 km/ km$^2$. The Sre Pok river has two main tributaries, namely Krong Ana and Krong Kno. The Krong Kno river originates in mountains at elevation of 2000 m, has a catchment area of 3,920 km$^2$ and the length of the mainstream is 156 km. The Krong Ana river has a catchment area of 3,960 km$^2$ and length of the main stream is 215 km.

The Sre Pok river flows for more than half of its length (250 km) within Cambodian territory. The reported population is about 78,000 people (MRC, 2011). There are eleven larger secondary

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2 The length indication of the Krong No and Krong Ana are based on measurements from the GIS maps used within the ISH01 study.
tributaries draining into the Srepok River: Or Kaong, Or Patinh Thum, Prek Dokyong, Prek Drang, Prek Nam Lieou, Prek Rue, Or Phlay, Prek Rouei, Prek Tramet, Prek Chbar and Prek Dak Dam.

The Topography and geology of the Sre Pok basin is generally diverse, encompassing rolling hills, mountains, plateaus, and lowland watershed. The climate and hydrology have been well described by ITC (2010)3 and are summarized below.

The climate of the basin is governed by the monsoons, the Southwest Monsoon brings rains in the period from May till September-October. Here 90% of the annual rainfall occurs, with August generally being the wettest month. During the Northeast Monsoon the temperatures drop and rainfall becomes less. This makes evapotranspiration particularly high in March and April (MRC, 20094). The annual rainfall for Lumphat ranges between 1,100 mm and 2,700 mm, with an average of 1,705 mm.

The runoff pattern closely follows the rainfall pattern but is slightly buffered by retardation of runoff by the tropical evergreen rainforests in the mountains, and recharge and runoff from substantial groundwater aquifers under extensive plateaus of basaltic volcanic rocks. Usually the minimum flow in the river occurs in April (SWECO, 20075). Recurrent flooding takes place during short periods late in the wet season (September–November), and may be aggravated by intense rainfall and flash floods with tropical cyclones from the South China Sea. Mean annual runoff has been established with 26.7x10^9 m3.

Flooding plays an important role in the Sre Pok basin and contributes to the abiotic characterisation. In the Krong Ana tributary of the Sre Pok river basin, the flood season usually lasts 4 - 5 months (from August to December) and the dry season 7 months (from January to July). In the Krong Kno river, flooding takes place one month earlier (July to November) than in Krong Ana river. On the Sre Pok mainstream, flood season usually lasts from August to November and even to December in some years.

Water quality data for the basin based on information collected at Lumphat, during the period from 2004 to 2008 (MOWRAM database, 2004-2008) shows good results with the water quality suitable aquatic life and for agricultural use (MRC, 20096). The Sre Pok sub-basin holds a high number of protected as well as other environmentally valuable areas.

The Sre Pok sub-basin holds a high number of protected as well as other environmentally valuable areas. Based on national information, these have been recorded and listed with in this ISH01 study (see Chapter 5) as basis to identify Ecologically Sensitive Areas. Many upland areas provide a variety of micro-environments that support semi-aquatic plants in the forms of wetlands, seasonal flooded forest, flooded grassland, and/or flooded shrubland. The marsh or swamp area that is directly connected to the river tributaries is usually cultivated.

The total aquatic ecosystem area within the Sre Pok basin is estimated with 11,579 ha of which the largest proportion is open water in the forms of rivers and streams (60.8%), marsh or Swamp (32.9%), crater lakes (3.8%) and seasonally flooded forest (0.12%). Deep pools as part of the open

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3 Institute of Technology of Cambodia (ITC), 2010, First draft. Catchment profile of the Sekong, Sesan and Sre Pok (3S) Rivers (in Cambodia)
4 Mekong River Commission (MRC), 2009. First Draft: profile of SA-7C (Cambodia), October 2009.
5 SWECO Groner (in association with Norwegian Institute for Water Research, ENVIRO-DEV, and ENS Consult, and Electricity of Vietnam), 2007. Environmental Impact Assessment on the Cambodian part of the Se San River due to Hydropower Development in Vietnam, December 2006.
6 Mekong River Commission (MRC), 2009. First Draft: profile of SA-7C (Cambodia), October 2009.
water are very important habitats for fauna and flora in the Sre Pok basin. According to the assessment by the communities in this region (CEPA, 2008), 11 deep pools with specific fish, bird and plants species were found along the Sre Pok River. Most deep pools (10) have become shallower due to flow modification, which led to bank erosion and sedimentation.

Various water uses also characterize the rivers and ecosystems of the Sre Pok basin. These include hydropower, irrigational abstraction for agriculture including rice farming, water abstraction for household and water supply, fisheries, aquaculture, navigation and soft tourism. As is evident from the difference in population between Vietnam and Cambodia; water use is much more intensive in the upstream Vietnamese parts of the Sre Pok than in Cambodia.

**Sre Pok Characteristics – Ideal Basis for Pilot Testing**

The Sre Pok basin contains both existing as well as planned hydropower schemes (Map 13; Figure 6), which is – besides the natural characteristics - an ideal pre-condition for testing the ISH01 technical approach regarding its entire spectrum (ESA identification; hydropower planning and management framework in combination including the risk based approach).

### 4.2 Data collection

#### 4.2.1 Overall approach

Pilot testing in the Sre Pok river basin tackled all three modules of the ISH01 technical approach and, therefore, the below activities have been tested and implemented:

| 1. Identification of Ecologically Sensitive Areas (ESAs) |
|---------------------------------------------------------|
| 2. Classification of hydropower and related pressure types |
| 3. Risk estimation of possible hydropower impacts on the identified ESAs |

In order to enable pilot testing, the related GIS mapping and analysis, the collection of data was a crucial first step of Component 2. In July 2014 a small workshop was held at the MRCS in Vientiane, where data collection templates were discussed and fixed with the national consultants and a representation of the ISH01 team. Decisions were made on the timeline and deliverables of the to-be-collected information on hydropower projects, ecological candidate areas, and human pressures. A guidance document on Pilot Testing Data Collection was compiled which

1. Outlined of the basic principles, road map and activities of pilot testing, and
2. Described the data collection for all involved but, specifically, to guide the ISH01 national consultants.

The ISH01 Component 2 on pilot testing takes place over a time period of seven months between September 2014 to end April 2015 including preparation, implementation (field visit) and analytical activities. In order to provide an overview, the four key activities related to ISH01 pilot testing are summarised in **Table 4**. The timeline has been adapted to current schedule of the ISH01 study.
Table 4: Activities and timeline for pilot testing in the Sre Pok sub-basin including a brief description and an outline of planned consultations with the MRC countries.

| ISH01 COMPONENT 2 – PILOT TESTING IN LMB SUB-BASINS / SRE POK SUB-BASIN |
|--------------------------------------------------------------------------------|
| **Activity 2.1: Plan and perform data collection in the Sre Pok sub-basins** |
| Based on a list of required data, detailed information and timing on data collection has been provided to enable the testing of the approaches in sub-basins. In consequence, information has been compiled and, where necessary, data has been collected on-site in the Sre Pok basin through the national ISH01 consultants. Information collection took place with the support of national and regional expert networks.

*July 2014: General information data collection and status of availability of information in the frame of the 2nd Regional Consultation. Workshop on ISH01 data collection between the ISH01 international and national experts followed by the circulation of a ‘Guidance Document on ISH01 Pilot Testing and Data Collection’ (July, 2014).*

| **Activity 2.2: Implementation of the ISH01 technical approaches in the pilot basins** |
| Testing of the ISH01 approaches in the Sre Pok sub-basin regarding the (i) identification of ESAs and (ii) the hydropower planning and management approach. This included the estimation of significant pressures and risks of possible impacts on ESAs and river reaches. Preliminary maps and analysis were developed as basis to develop a Draft Report on Pilot Testing.

*November 2014: Field visit to the Sre Pok sub-basin with the LMB ISH01 representatives to close data gaps, undertake a test run of the ISH01 technical approach and present preliminary results of pilot testing, eventual shortcomings and solutions how to overcome these towards finalisation.*

| **Activity 2.3: Further develop thematic maps and perform analysis** |
| Based on the findings of the field visit to the Sre Pok basin in November 2014, all thematic GIS maps have been developed to be part of the Draft Report on Pilot Testing. The thematic maps are entirely based on the list of maps that has been elaborated during Component 1.

| **Activity 2.4: Draft Report on pilot testing in sub-basins** |
| Report on the pilot testing and overall ISH01 approach. This report now reflects the results of the pilot testing including a detailed description of the approach to identify ESAs and hydropower planning. Further, it highlights uncertainties, information gaps, and remaining challenges. An outlook on Component 3 will be provided.

*April 2015: Regional consultation with MRC countries on Activity 2.4 in Ho Chi Minh City (Viet Nam) regarding the draft pilot testing report, final results and remaining eventual shortcomings. Received comments are part of this final ISH01 Pilot Testing Report.*

The NMCs and relevant Line Agencies supported and guided the ISH01 team during the entire pilot basin exercise in order to fully meet the needs of the LMB countries. In order to simplify the implementation of pilot testing, National Experts (one for each LMB country) pro-actively supported the related work including the collection of data in and for the selected sub-basins. All possible data sources have been screened for readily available information according to the list of required data. In case, data was not readily available the National Experts supported the study team to collect data on-site according to a coordinated procedure.
The ISH01 data collection aimed to prevent ‘graveyards’ of data and that country representatives are burdened unnecessarily with the collection of data that would not be used in the end. The data collection was closely linked to the needs for GIS mapping but also other analysis that had to be undertaken. Information was collected in a targeted way and exploited for analysis to the highest possible extent. Therefore, a two-way approach for data collection was applied. As a general rule, collected information to be used for ISH01 analysis in pilot sub-basins

- are based on existing datasets that are readily available as of today and are compiled accordingly for mapping and analysis, and
- are collected on-site as far as possible and feasible in case important information is lacking.

The data collection was guided and undertaken by the ISH01 team in support of the MRCS and MRC countries (NMCs and Line Agencies). The work of the ISH01 national consultants to collect has been crucially important. In total the two National Consultants of Vietnam and Cambodia worked each two months full time to get to this level of detail in data collection, preparation and exchange of the GIS files.

The data collection implementation plan goes into technical detail about the different data templates and describes in detail which attributes are required, as well as providing proper and detailed reference to source information. The schematics of the different data in the templates and workflow for ESAs look as follows.

![Data templates of the to-be-collected data, and how these feed into the ESA identification](Figure 4)
4.2.2 Sources of Information Regarding CEAs and ESAs

In the ISH01 Guidance Document for Data Collection (July 2014), the following list was outlined that captured the foreseen candidate ecological areas and suggested possible sources for this information. Some of the local information was found not to be available for all of the identified features.

| Candidate Ecological Areas | Ecological Feature | Possible Source                          |
|---------------------------|--------------------|-----------------------------------------|
| Valuable Wetlands         |                    | MRC                                     |
| Environmental Hotspots    |                    | MRC                                     |
| Freshwater Habitats       | Wetlands           |                                         |
|                           | Floodplains        |                                         |
|                           | Deep pools         | MRC                                     |
|                           | Rapids, Cascades   | Google Earth                            |
| Ramsar Site               |                    | Ministry of Environment, IUCN           |
| Protected Area            | National Protected Area | Ministry of Environment                |
|                           | Provincial Protected Area | Ministry of Environment, Provincial Level |
|                           | District Protected Area | District Level                         |
| Key Biodiversity Area     | Important Bird Area | www.birdlife.org                        |
|                           | Important Plant Area | www.plantlife.org                       |
|                           | KBA                | IUCN, authors                           |
| Corridors                 | protected area     |                                         |
|                           | KBA                | IUCN, authors                           |
| Flagship freshwater species | Irrawaddy Dolpin     | scientific assessment, IUCN Redlist     |
|                           | Siamese Crocodile  | scientific assessment, IUCN Redlist     |
|                           | Eastern Sarus Crane| scientific assessment, IUCN Redlist     |
|                           | Giant Catfish      | scientific assessment, IUCN Redlist     |
|                           | Giant Shoftshell Turtle | scientific assessment, IUCN Redlist     |
| Migratory fish species (species lists) | Long distance | EIA, Universities, MRC                 |
|                           | Medium distance    | EIA, Universities, WorldFish, FISHBIO   |
|                           | Spawning sites     | EIA, Universities, FISHBIO             |
| Species diversity         | endemic species’ range | IUCN Redlist, Universities, EIA       |
|                           | species richness   | IUCN Biodiversity assessment, EIA       |
|                           | conservation status| IUCN Redlist                           |
| Ecosystem Services        | fishery zone       | WWF, other NGOs                        |
|                           | recreation         | Ministry of Tourism                    |
|                           | eco-tourism        | Ministry of Tourism, NGOs              |
|                           | drinking water catchment | Ministry of Water Resources         |
|                           | rice paddies/irrigation | Ministry of Agriculture             |
|                           | fish pond          | Ministry of Agriculture, Provincial Level |
For mapping out the *human pressures*, the following list of source information was outlined:

| **Confirmed Source** | **Possible source** |
|----------------------|---------------------|
| Upstream population density | http://www.worldpop.org.uk/ |
| Upstream urban area | http://www.worldpop.org.uk/ |

| **land cover** | Upstream natural area | MRC Landcover Map, GlobCover Map 2009 |
|---------------|-----------------------|-------------------------------------|
| Upstream forest | http://earthenginepartners.appspot.com/science-2013-global-forest | |
| Upstream deforestation 2000-2012 | http://earthenginepartners.appspot.com/science-2013-global-forest | |
| Upstream agricultural area | MRC Landcover Map, GlobCover Map 2009 |

| **Infrastructure** | Roads | openstreetmap.org, ADB-GMS |
|---------------------|-------|---------------------------|
| Irrigation | MRC, Ministries, GIAM (IWMI) |
| Embankment/flood control | Rapid Google Earth Survey |
| Mining | MRC |
| Sand mining | Local Government, Rapid Google Earth Survey |

During the field visit all criteria and data sources were revisited in order to assess their accuracy and/or reiterate some of the criteria. Yet, some of the local information was found not to be available for all of the identified features.

### 4.2.3 Sources of information regarding hydropower and related data

Data regarding hydrology, hydropower schemes and reservoir as well as related pressures that may stem from hydropower have been collected by the ISH01 national consultants based on the ISH01 Data Collection Guidance document. In addition, the collected information has been validated during the ISH01 field visit to the Sre Pok sub-basin.

Data used for the hydropower assessments are summarised in the Table below and are part of Annex 3. The outlined information has been collected for each individual hydropower site in the Sre Pok basin using a data template. The template was filled in (i) for each existing hydropower dam in the Sre Pok sub-basin and (ii) for each planned hydropower dam in the Sre Pok basin.

Among a broad spectrum of information sources Environmental Impact Assessments and Feasibility Studies for hydropower schemes in the Sre Pok sub-basin were useful sources. Five thematic areas that hold clearly outlined attributes were filled with data:

- General hydropower dam data
- Specific hydropower dam data
- Data on the hydropower scheme reservoir
- Hydropower turbine data
- Hydrological data
The following data has been collected for the ISH01 hydropower assessments:

| Thematic Area        | Parameter for ISH01 data collection                                      |
|----------------------|-------------------------------------------------------------------------|
| **Dam Data**         | Dam height (m)                                                          |
|                      | Dam crest elevation (masl)                                               |
|                      | Functioning fish pass in place (Yes/No)?                                |
|                      | Tailrace weir type                                                      |
|                      | Main purpose of dam                                                      |
|                      | Sediment management structures                                           |
|                      | Riparian outlet valve (Yes/No)?                                         |
| **Reservoir Data**   | Total reservoir storage volume (m³)                                      |
|                      | Live reservoir storage volume (m³)                                       |
|                      | Reservoir area (km²)                                                    |
|                      | Reservoir length (km)                                                   |
|                      | Sediment management plan                                                 |
|                      | Water quality data availability                                          |
|                      | Eutrophication signs? (existing dams)                                   |
|                      | Eutrophication expectations? (planned dams)                             |
| **Hydropower Turbine Data** | Turbine type                                                              |
|                      | Intake type                                                              |
|                      | Rated turbine head (m)                                                  |
|                      | Design turbine discharge (m³/s)                                         |
|                      | Design mean monthly flow (m³/s)                                         |
|                      | Max turbine discharge (m³/s)                                             |
|                      | Operation schedule                                                      |
|                      | Peak power operation?                                                    |
|                      | Length of downstream influence of flow fluctuations (km)                 |
| **Baseline site hydrology (before construction of the dam)** | Catchment area (km²)                                                   |
|                      | Average annual flow at site (m³/s)                                      |
|                      | Mean monthly flow at site (m³/s)                                        |
|                      | Min monthly flow at site (m³/s)                                         |
|                      | Max monthly flow at site (m³/s)                                         |
|                      | Min recorded flow at site (m³/s)                                        |
|                      | Average annual sediment yield at site (Mm³/a)                           |
|                      | Minimum ecological flow requirement (m³/s)                              |

4.2.4 **Challenges and gaps**

As the setup of the ISH01 was such that its results would possibly be kept internal to the Member Country concerned and not necessarily be shared with others, there might have been some restriction in approaching institutions for possible valuable information. The institutions may be concerned that they would provide their information without the guarantee of hearing back how the data has been used. In addition, it should be mentioned that although data has been collected effectively and to a largely sufficient degree, an extended timeframe would have likely improved the data collection regarding detail. All together, these issues caused specific challenges and gaps within the data sets, which are outlined here assigned to thematic areas:

**Spatial Importance:**
- No consistent data was available on freshwater species distributions inside the pilot basin. This includes information on flagship freshwater species and/or relevant migratory fish species in the Sre Pok basins’ tributaries.
- No consistent information was available on the location of deep pools.
• The MRC database on wetlands was in the process of being updated and its revised values have, therefore, not been assessed and integrated.

• A rapid Google Earth-based assessment was done on the location of rapids and cascades on the Sre Pok mainstream, but did not achieve the level of detail or level of consistency that is required to assign 100% certain spatial importance.

• The subset of candidate ecological areas that was collected for the pilot basin was the same one as in the national/regional datasets. However, it was expected that more information would be available after the ISH01 data collection. Hence, it is recommended to allocate more time to this part of the data collection during basin-wide upscaling in order to increase the level and quality of information.

Human Pressures:
• No consistent spatial information on actual mining operations was identified.

• No consistent information on sand mining of the river beds was identified, though industrial scale sand mining has been observed during the field trip.

• No consistent information on flood control or protection along rivers but also regarding dam operation was identified.

• No up-to-date information on irrigated areas or irrigation dams and weirs was available.

• Though there are reports of over-fishing (e.g. in Ho Lak lake), no consistent information has been available as of this ISH01 pilot testing exercise.

Description of hydropower schemes in Sre Pok sub-basin
• The full list of required data and information could not be obtained for all hydropower schemes in the Sre Pok sub-basin. Respectively uncertainties will remain for those schemes/parameters.

• Insufficient information was available regarding both (i) small hydropower schemes and (ii) irrigation schemes along tributaries to the Sre Pok. No detailed information was accessible regarding the number and location of small hydropower and irrigation schemes. However, the ISH01 team was informed that the number is supposed as very high. This caused limitation for the risk assessment for tributaries (Chapter 5.3.2 and 5.3.3). Due to this uncertainty the category ‘possibly at risk’ has been implemented in the risk assessment approach, which indicates lack of data and the need to fill gaps.

Identification of hydropower pressure types
• Not all required information was available in the Sre Pok basin but collected as far as possible to enable a sufficient analysis. Some uncertainties remain for some aspects and shall be clarified in future.

Risk estimation of possible impacts from hydropower
• The risk category ‘possibly at risk’ indicates data gaps. A full risk assessment has not been possible because of lacking information. However, this category automatically has an implication for decision making in that sense that data information gaps have to be filled as soon as possible in order to support comprehensive hydropower planning and management in the future.

• This is in particular valid for the tributaries of the Sre Pok basin for which no detailed information has been made available and key information has been collected for the Sre Pok mainstream.
5 RESULTS OF THE ISH01 PILOT TESTING IN THE SRE POK SUB-BASIN

The following sub-chapters present the results of the ISH01 pilot testing following the same logic throughout: (i) the chapters are assigned to the three ISH01 Modules and their implementation steps; (ii) in the beginning each chapter the aims and expected outputs of the pilot testing analysis are presented for a basic orientation; (iii) the undertaken analysis and possible challenges are described, and finally (iv) results are presented in a highlighted box and are presented in thematic GIS maps, figures and/or tables.

5.1 Identification of Ecologically Sensitive Areas

Module 1 of the ISH01 technical approach tackles the identification of ESAs through four implementation steps. These steps and the findings in relation to the Sre Pok sub-basin are reflected in the following Chapters 5.1.1. to 5.1.4.

Main Result presented in this chapter

The main result of this Module are the identified ESAs in the Sre Pok sub-basin aligned to three classes of ecological sensitivity and illustrated in a thematic map. The identified ESAs will then be merged with existing and planned hydropower in the basin in order to estimate possible impacts on them.

5.1.1 Basic abiotic characterisation and typology of the Sre Pok sub-basin

Aim of the ISH01 Pilot Test Analysis:

Charactrise the Sre Pok sub-basin regarding different abiotic types.

Expected outputs of the ISH01 Pilot Test Analysis:

River types for the Sre Pok sub-basin are in place as basis for the analysis.

Module 1, Step 1 as described in the ISH01 technical approach (see Figure 2)

The development of river typologies is a commonly used approach to identify and characterise riverine ecosystems. For the purpose of River Basin Management/IWRM, including conservation planning, riverine ecosystems are often defined as stream networks that share a distinct geomorphology, similar environmental characteristics and processes (e.g. hydrological, nutrient and temperature regimes)\(^7\). These distinct characteristics can be assigned to different riverine types that respectively represent type specific aquatic species regarding fauna and flora. Broad river typologies can be derived from often more readily available physical data and maps. The number of types in river basins can vary from low to high numbers, depending on the scale as well as abiotic and biotic diversity.

Within ISH01, the approach to develop river types will provide a basis for transparent as well as consistent assessments and identification of ESAs, both in terms of ecology and sensitivities to impacts that may result from hydropower. It shall be noted here that while a basic river typology is a pre-requisite for a range of assessments (e.g. for assessing ecological status in relation to baseline conditions), it can also be applied as basis to identify ESAs and, in particular, to assess possible impacts on ESAs that result from other water uses than hydropower (e.g. agriculture, industry, etc.). The river typology will help to inform about the relevant system characteristics, which will also guide specific considerations of comparisons among the different pilot tributaries.

\(^7\) Groves et al. (2002), Higgins et al. (2005); Sowa et al. (2007); Thieme et al. (2007); Heiner et al. (2011).
The typology for the entire Mekong river system identifies 13 different types. The typology for the rivers of the Mekong basin is based on four abiotic master variables (Table 5).

### Table 5: The four abiotic master variables of the Mekong typology.

| Master variable | Association                                                                 | Class breaks     |
|-----------------|-----------------------------------------------------------------------------|------------------|
| A: Elevation    | Temperature, climate, geography, plateau, upstream/downstream relations, delta/tidal influences, local runoff | 100 MSL; 3,000 MSL |
| B: Slope        | Elevation drop in rivers, stream gradient, erosion/sediment rates, cascades/rapids | 10 % slope       |
| C: River length | Scale, seasonality, discharge, floodplain/wetlands, river-landscape interaction | 250 km; 1,000 km |
| D: Karst geology| Chemistry, caves, endemism                                                  | Karst presence   |

Five of the LMB types occur in the Sre Pok basin are summarised in Table 5a and illustrated in Map 3. with a prominent absence of karstic formations, which is normally found throughout other sub basins in the Mekong.

### Table 5a: The five river types identified in the Sre Pok sub-basin.

| Type                           | Characteristics                                      |
|--------------------------------|------------------------------------------------------|
| Lower plateau                  | <100 MSL, <10% slope, <250km length                  |
| Upper plateau                  | >100 MSL & <3,000 MSL, <10% slope, <250km length     |
| Upland slopes                  | <3,000 MSL, >10% slope, <250km length                |
| Tributaries of lower plateau   | <100 MSL, <10% slope, >250km & <1,000 km length      |
| Tributaries of upper plateau   | >100 MSL & <3,000 MSL, <10% slope, >250km & <1,000 km length |

One key characterisation issue to be highlighted here is the location of the Dray Nur waterfalls on the Sre Pok mainstream that provokes a significant difference in upstream versus downstream typology but also represents a natural barrier for fish migration (see also Chapter 5.1.3). The Dray Nur waterfalls are captured by the Mekong-wide river typology where streams from the type ‘Upland Slopes’ change into rivers of the river type ‘Upper Plateau’. The change of types results from the change in slope and gradient; with higher slopes in the upstream, lower slopes downstream of the location.

### Key ISH01 Pilot Testing Results - Typology

Based on the ISH01 pilot testing and its field visit the typology methods has been validated and it captures the most relevant characteristics of Sre Pok Sub-Basin. The most prominent distinction in abiotic characteristics is whether streams are located in upland (sloping) areas or on the upper plateau. The Dray Nur waterfall is not only located where a change of stream type occurs, but also forms an important natural barrier for fish migration and therefore a relevant characteristic of river connectivity.

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8 Due to this uncertainty the category ‘possibly at risk’ has been implemented in the risk assessment approach, which indicates lack of data and the need to fill gaps.
Map 3: River typology and its five river types for Sre Pok Sub-Basin.
5.1.2 Identified Candidate Ecological Areas in Sre Pok pilot basin based on existing information

**Aim of the ISH01 Pilot Test Analysis:**
Identify *Candidate Ecological Areas* for further analysis based on existing information.

**Expected output of the ISH01 Pilot Test Analysis:**
*Candidate Ecological Areas* are identified for analysis on their individual ecological sensitivity.

*Module 1, Step 2 as described in the ISH01 technical approach (see Figure 2)*

The second step within Module 2 of the ISH01 approach towards ESA identification aims at the identification of areas of ecological interest in order to get the most complete and holistic overview of a tributary’s ecological layout. The areas of ecological interest are called *Candidate Ecological Areas* (CEA) and are compiled in a sub-basin’s *Catalogue of CEAs*.

The *Catalogue of Candidate Ecological Areas* for the Sre Pok sub-basin was compiled within the ISH01 data collection and has been validated during the ISH01 field visit in November 2014. The *Sre Pok Catalogue of CEAs* is based on information from national planning/legal documents as well as from previous surveys and their findings. Currently, the national conservation plans of each LMB country include around twenty different types of environmental designations for areas with a certain ecological background and most of the plans still acknowledge significant gaps in ecological information. However, with support of the ISH01 national consultants, these conservation plans have been screened and relevant areas have been extracted into the *Sre Pok Catalogue of CEAs*. In addition to the national conservation plans, updated regional assessments (such as the ones on wetlands and Key Biodiversity Areas), or other studies at the tributary level were used to capture specific ecological values (specific wetlands, ecosystem services, floodplains, hotspots, or eco-tourism locations). A comparison and merging of ecological candidate areas (i) that are recognized by law and (ii) that have been identified based on other assessment allowed the compilation of a final *Sre Pok Catalogue of CEAs*.

#### Final Sre Pok Catalogue of CEAs through merging ecological candidate areas that are recognized by law with those from other assessments.

In one column of the catalogue, for each entry it is checked whether the area is recognized as a conservation area by law, or not. When comparing the full catalogue to only those areas as recognized by law, the following points stand out:
- the full catalogue covers a larger area,
- the full catalogue contains overlapping areas,
- the areas-by-law often follow administrative and national boundaries, and
- the areas-by-law often have rivers and streams as their boundaries.
All countries in the LMB acknowledge in their national biodiversity conservation plans that their current networks of protected areas are being revised and updated, and that more areas will be added. As such, the map that shows only those areas-by-law can only be considered as a work in progress, yet by law, only these areas need to be considered for spatial planning exercises, such as hydropower planning. Inherently, some important ecological areas as recognized in the catalogue would not need to be included. This will miss out areas that are recognized to contain very high ecological importance, it also means that the catalogue fills in a relevant gap by including those important ecological areas.

The combination of CEAs into one coherent list and map posed a technical challenge to the catalogue: the diverse information sources that have been used for CEA extraction varied a lot and harmonization took an important role. Due to the fact that the assessments showed different levels of analysis, it was important to capture the most detailed representation of each candidate area, without discarding relevant ecological candidates. Technically, each area was scrutinized for its shape and source references within the compilation process towards coherency and harmonisation.

**Key ISH01 Pilot Testing Results – Identified Candidate ecological Areas**

For the Sre Pok basin 29 CEAs have been identified and illustrated (Table 6 and illustrated in Map 4) and are now part of the CEA Catalogue. The CEAs include protected areas, key biodiversity areas, nature reserves, protected forests, areas of high biodiversity and fish sanctuaries.

It should be highlighted here, that this Sre Pok Catalogue of CEAs (Table 6) is a snapshot of the 2015 situation; most LMB countries are currently updating their protected area networks. This means, more types of ecological areas, lakes, wetlands and streams will likely be added in the near future. However, it can be said that the ISH01 catalogue of CEAs is the most comprehensive collection of ecological candidates for the Sre Pok basin.

Based on the above, it is recommended that Catalogues of CEAs need regular updating in order to reflect the real situation. This recommendation is highly relevant for the proposal regarding the LMB-wide upscaling of the ISH01 approach.
Table 6: The ISH01 Catalogue of Candidate Areas shows 29 records for the Sre Pok Sub-Basin.

| #  | Name or Description               | Country     | Designation                          |
|----|-----------------------------------|-------------|--------------------------------------|
| 1  | Srepok River                      | Cambodia    | Key Biodiversity Area                |
| 2  | Lomphat KBA                       | Cambodia    | Key Biodiversity Area                |
| 3  | Chu Prong                         | Vietnam     | Key Biodiversity Area                |
|    |                                   |             | protection proposed/pending          |
| 4  | Upper Srepok Catchment            | Cambodia    | Key Biodiversity Area                |
| 5  | Ya Lop                            | Vietnam     | Key Biodiversity Area                |
| 6  | Yok Don KBA                       | Vietnam     | Key Biodiversity Area                |
| 7  | Cu Jut                            | Vietnam     | Key Biodiversity Area                |
| 8  | Dak Dam                           | Vietnam     | Key Biodiversity Area                |
| 9  | Ta Dung                           | Vietnam     | Key Biodiversity Area, Nature Reserve|
| 10 | Chong Troi                        | Vietnam     | Key Biodiversity Area                |
| 11 | Bidoup - Nui Ba                   | Vietnam     | Key Biodiversity Area, National Park |
| 12 | Chu Yang Sin                      | Vietnam     | Key Biodiversity Area, National Park |
| 13 | Snoul/Keo Sema/O Reang            | Cambodia    | Key Biodiversity Area                |
| 14 | Lomphat                           | Cambodia    | Wildlife Sanctuary                   |
| 15 | Phnom Prich                       | Cambodia    | Wildlife Sanctuary                   |
| 16 | Phnom Nam Lyr                     | Cambodia    | Wildlife Sanctuary                   |
| 17 | Mondulkiri                        | Cambodia    | Protected Forest                     |
| 18 | Yok Don Extension                 | Vietnam     | National Park                        |
| 19 | Dak Mang                          | Vietnam     | protection proposed/pending          |
| 20 | Nam Nung                          | Vietnam     | Nature Reserve                       |
| 21 | Nam Ca                            | Vietnam     | Nature Reserve                       |
| 22 | Ho Lak                            | Vietnam     | Nature Reserve                       |
| 23 | Chu Hoa                           | Vietnam     | none                                 |
| 24 | Trap Kso                          | Vietnam     | National Nature Reserve              |
| 25 | Nsok                              | Cambodia    | National Protected Forest            |
| 26 | Mega First Berhad Fish Sanctuary  | Cambodia    | Fish Sanctuary                       |
| 27 | Yok Don NP                        | Vietnam     | National Park                        |
| 28 | Lower Srepok Fish Migration       | Cambodia/Vietnam | none                              |
| 29 | Upper Srepok Fish Migration       | Vietnam     | none                                 |
Map 4: The 29 ISH01 identified Candidate Ecological Areas in the Sre Pok Sub-Basin.
5.1.3 Implementation of specific criteria to determine spatial importance and human pressures on CEAs as basis to identify Ecologically Sensitive Areas

| Spatial Importance | Description |
|--------------------|-------------|
| Global:            | e.g. if a CEA/stream supports the last stronghold of a globally endangered species. |
| Regional, or basin-wide: | e.g. if a CEA/stream contains a characteristic of importance to basin-wide processes, such as Tonle Sap, or the only spawning site for a fish species. Includes Key Biodiversity Areas |
| National:          | e.g. if a CEA/stream contains the last surviving population of species in a country, or if a wetland acts as a water source for a city. |
| Local, or sub-basin-wide: | e.g., if a CEA/stream act as a corridor between two important sites, or contains a fishing zone. |

The setting of spatial importance has been a difficult exercise within the ISH01 pilot testing analysis. Due to the fact that consistent data have been lacking and not every CEA’s uniqueness or species richness in the Sre Pok sub-basin is known to be up to date. Next to this, it was difficult to set the relative spatial importance in relation to other ecological candidates. On site spot-checking, validation and quality control of collected data played a significant role during the Sre Pok sub-basin field visit in November 2014.

In order to determine spatial importance the following three analytical steps have been taken:

In a first step of the ISH01 pilot testing, the CEAs (Table 6; Map 4) have been assigned to the four levels of spatial importance taking into account (i) national planning decisions (e.g. national protected areas; national parks, etc.) and (ii) relevant classifications that have been undertaken within the MRC framework beforehand (e.g. the 32 environmental hotspots, introduced by the MRC (2010), are already classified according to geographic significance; IUCN categories; Ramsar sites). Cases for which the ecological importance of an area is not very clear have been flagged.

Table 7 shows the default scheme how spatial importance has been assigned to CEAs during the analysis based on information from national planning documents. Annex 1 provides an example on assigning spatial importance to CEAs based on Vietnamese planning documents. As guided by the default setting and in absence of other information, hierarchy was assigned according to national priorities. In case more information was available for individual CEAs, importance could individually be upgraded or downgraded. It should be noted here that based on insights and interactions during the field visit, Key Biodiversity Areas have always been reassigned to regional importance instead of global importance in order not to overrule the importance of other CEAs.
In a second step of the ISH01 pilot testing, the assigned spatial importance has been discussed with the participating representatives of the LMB countries during the ISH01 field visit in November 2014 and has been validated as well as adapted accordingly based on on-site findings.

In a third step of ISH01 pilot testing, the different datasets have been combined resulting in a single GIS layer and illustration of spatial importance for the Sre Pok sub-basin. While compiling the single combined layer, the highest priority went to the areas with the highest spatial importance. If a river of regional importance overlaps with a national park of global importance, the river automatically will get assigned global importance inside the park. Possible overlaps of spatial importance for each CEA are also visualized in Map 4.

Fish migration routes and their spatial importance in the Sre Pok sub-basin

River continuity and fish migration takes an important role when it comes to the determination of spatial importance in river basins. In general, fish migration routes can serve as indicators to assess river and habitat continuity as well as their interruption. The importance of migration for the viability of fish populations is considered to vary considerably among species. Differences exist in terms of migration distances, direction (upstream, downstream, lateral), spawning habitats, migration seasons and the life stage in which migration takes place. In general, one differentiates between long-, medium- and short distance migratory fish species.

Especially in the LMB and, hence, Sre Pok sub-basin, fish migration is a relevant part ecological balance and functions as a driver for processes related to basin-wide aquatic biodiversity, and also of local fisheries, on which a large percentage of the local population depends on for their food security. Therefore, the indication of fish migration routes in the Sre Pok sub-basin has been tackled within the ISH01 study. The assigning of spatial importance regarding fish migration routes (see Figure 5) has been as specific challenge and due to the lack of data a pragmatic approach has been followed. This approach is briefly outlined here:

- Upfront it should be highlighted that the knowledge on fish migration routes in LMB tributaries including the Sre Pok sub-basin is very scarce. Information on fish distributions is not consistently available up to a level where a well-informed decision can be based upon. Due to the mandate of

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Table 7: Default level of spatial importance in the LMB countries as assigned with regard to national planning documents.

| ISH01 Spatial Importance | Cambodia | Laos | Thailand | Vietnam |
|--------------------------|----------|------|----------|---------|
| Very high                |          |      |          |         |
| Global, high             | National Park | National Biodiversity Conservation Area | National Park | National Park |
| Tonlé Sap Biosphere Reserve |            |      |          |         |
| Ramsar wetland           | Ramsar wetland | Ramsar wetland | Ramsar wetland | Ramsar wetland |
| High                     |          |      |          |         |
| Regional, Mekong basin, International | Wildlife sanctuaries | Corridors | Wildlife sanctuary | Nature Reserve |
| Key Biodiversity Area    | Key Biodiversity Area | Key Biodiversity Area | Key Biodiversity Area | Key Biodiversity Area |
| Medium                   |          |      |          |         |
| National, large tributary | Protected Landscape | Heritage Site | Non-hunting area | Species-Habitat Conservation Area |
| Low                      |          |      |          |         |
| Local, low, small tributary | Multiple Use Site | Provincial and district conservation areas and protection forests | Forest park | Waterfalls |
the MRC, the general capacity and focus on mapping fish migration within the Mekong River Basin. The available information on fish migration focuses on the Mekong mainstream. Though different studies express the importance of the connection between tributaries and the Mekong mainstream, none of these go into consistent detail inside the tributaries. This means that not much detail is known on fish migration and interactions between the Sre Pok sub-basin’s headwaters and the rest of the system.

- Due to the knowledge gaps, the ISH01 approach to designate fish migration routes and to allocate spatial importance was forced to be rather pragmatic. Hence, any related conclusions in this ISH01 study are based on currently available information that has been compiled during data collection and pilot testing. Conclusions have been drawn on expert judgement that is based on the following hypotheses:

1. Waterfalls and specific rapids have been considered to form natural barriers to river connectivity and migration in case these are not passable for fish. In the Sre Pok, only one such natural barrier has been validated during the ISH01 field visit, which is Dray Nur waterfall. More downstream of Dray Nur there are Dray H’lin and Thác Bây Nhánh waterfalls, due to channels that provide seasonal connectivity (Thác Bây Nhánh) and to a layout of stepwise pools that might allow fish passage (Dray H’linh), these were assumed not to be act as natural barriers. Though Dray H’linh is considered an artificial barrier, since it houses several hydropower projects in parallel on the waterfalls.

2. Any artificial interruption of fish migration (e.g. through hydropower schemes) is considered as an impact on fish migration, related ESAs and the environmental condition. This is specifically relevant for the risk assessment (see Chapter 5.3).

3. The connectivity between the Mekong mainstream and its tributaries is considered as very important for fish migration, fish reproduction and maintenance of fish populations in the Sre Pok sub-basin. This is in particular relevant for the lowland river sections up to natural continuity interruption of the Dray Nur waterfall, which also provokes a change of river type (also see Chapter 5.1.1).

4. There are also two other waterfalls in the Sre Pok sub-basin that have also been identified in Google Earth. In the ISH01 analysis, these waterfalls are not identified as continuity interruptions and in fact, thorough investigations would be needed to assure this assumption (e.g. if they are passable during flood season also ensuring fish migration).

5. Fish migration in the rivers upstream the Dray Nur waterfall is also considered as important but not regarding its direct connectivity to the Mekong mainstream. However, the overall fish species diversity is considered as specialized and unique. Fish migration interruptions in the headwaters might not only isolate species, but also destroy their access to essential life cycle requirements and, hence, fish migration and river continuity in the rivers upstream the Dray Nur waterfall plays a specific role.

6. Based on the above, a higher spatial importance has been allocated to the Sre Pok river and its tributaries below the Dray Nur waterfall than to the river network upstream the waterfall. Figure 5 shows the result of the ISH01 pragmatic approach to determine fish migration routes in the Sre Pok sub-basin and to assign spatial importance to its rivers. In summary,
(i) **regional spatial importance** is assigned to the Sre Pok river and its tributaries below the Dray Nur waterfall, and

(ii) **national spatial importance** is assigned to the Sre Pok river and its tributaries upstream the Dray Nur waterfall.

In order to capture the seasonality, floodplain characteristics (islands, sandbanks, braided networks) and the importance of internal connectivity to smaller river and streams that feed into these systems, a 2 kilometre buffer is assigned around each river, while for the main stem Sre Pok, a 5 kilometres buffer is assigned.

![Figure 5: Spatial importance for the rivers in the Sre Pok sub-basin based on fish migration patterns.](image)

**Table 8** provides an overview on the assigned spatial importance to each CEA, while **Map 5** illustrates these.
Table 8: CEAs and assigned spatial importance.

| #  | Name or Description            | Spatial Importance | Importance Assigned by                                      |
|----|--------------------------------|--------------------|-------------------------------------------------------------|
| 1  | Srepok River                   | Regional           | Connectivity to mainstem Mekong                             |
| 2  | Lomphat KBA                    | Regional           | Key Biodiversity Area                                       |
| 3  | Chu Prong                      | Regional           | Key Biodiversity Area                                       |
| 4  | Upper Srepok Catchment         | Regional           | Key Biodiversity Area                                       |
| 5  | Ya Lop                         | Regional           | Key Biodiversity Area                                       |
| 6  | Yok Don KBA                    | Regional           | Key Biodiversity Area                                       |
| 7  | Cu Jut                         | Global             | The area supports the last stronghold of a globally endangered species |
| 8  | Dak Dam                        | Global             | The area supports the last stronghold of a globally endangered species |
| 9  | Ta Dung                        | National           | Nature Reserve                                              |
| 10 | Chong Troi                     | To be determined   |                                                             |
| 11 | Bidoup - Nui Ba                | Global             | National Park                                               |
| 12 | Chu Yang Sin                   | Global             | National Park                                               |
| 13 | Snoul/Keo Sema/O Reang         | To be determined   |                                                             |
| 14 | Lomphat                        | Global             | Home to variety of endangered animals                       |
| 15 | Phnom Prich                    | Global             | Breeding ground sarus crane, important to endangered animals |
| 16 | Phnom Nam Lyr                  | To be determined   |                                                             |
| 17 | Mondulkiri                     | To be determined   |                                                             |
| 18 | Yok Don Extension              | To be determined   |                                                             |
| 19 | Dak Mang                       | Local              |                                                             |
| 20 | Nam Nung                       | National           | Nature Reserve                                              |
| 21 | Nam Ca                         | National           | Nature Reserve                                              |
| 22 | Ho Lak                         | National           | Nature Reserve                                              |
| 23 | Chu Hoa                        | Local              |                                                             |
| 24 | Trap Kso                       | To be determined   |                                                             |
| 25 | Nsok                           | To be determined   |                                                             |
| 26 | Mega First Berhad Fish Sanctuary | To be determined | Fish sanctuary                                              |
| 27 | Yok Don NP                     | Global             | National Park                                               |
| 28 | Lower Srepok Fish Migration    | Regional           | Importance of fish migration                                |
| 29 | Upper Srepok Fish Migration    | National           | Importance of fish migration                                |
Map 5: Spatial Importance of Candidate Ecological Areas in the Sre Pok sub-basin-
Assessment of CEA sensitivity to human pressures

In combination with spatial importance, the combination with human pressures supported the identification, which CEAs can be identified as ESAs. Specific human pressures that may already impact the CEAs in the Sre Pok basin have been identified and consulted with the LMB countries when the ISH01 technical approach has been developed. These are listed in Table 9. It needs to be highlighted here that the human pressures investigated here do not include these from hydropower since hydropower related pressure types are addressed in another step of the ISH01 technical approach.

The analysis serves the purpose to understand (i) which CEAs are sensitive to the pressures in Table 9, (ii) if CEAs are already impacted and (iii) to what degree/level they are impacted. When identifying final ESA, the latter contributes to the following conclusions: The higher the level of impact from human pressures, the lower the sensitivity level of an ESA (see also the ESA decision scheme in Annex 2).

Human pressures have been analysed and mapped for the entire Sre Pok sub-basin using GIS techniques. An allocation to four levels of human pressures has been undertaken (see Table 9):

- Near natural or low pressured
- Medium pressured
- High pressured
- Too impacted

Table 9: Criteria ranges allocated to four classes of pressure levels (high, medium or low pressure and too impacted) to assess a Candidate Ecological Area’s current sensitivity to existing human pressures

| Human pressures          | close to pristine low pressure | medium level of pressure | high level of pressure | too impacted to be considered as an ecological area | unit | source of criteria |
|--------------------------|-------------------------------|--------------------------|------------------------|--------------------------------------------------|------|-------------------|
| Human population density |                               |                          |                        |                                                  |      | http://www.gwc.org/ |
| upstream population density | < 10                           | 10 - 50                  | 50 - 500               | 500+                                             |      |                   |
| upstream urban area      | < 2%                           | 2 - 30%                  | 10 - 50%               | 50%                                              |      |                   |
| Land cover               |                               |                          |                        |                                                  |      |                   |
| upstream natural area    | 85%                            | 50 - 85%                 | 10 - 50%               | < 30%                                            |      | percentage of total area of interest |
| upstream forest          | 85%                            | 50 - 85%                 | 10 - 50%               | < 30%                                            |      | percentage of total area of interest |
| upstream deforestation 2000-2012 | < 2%                          | 2 - 30%                  | 10 - 50%               | 50%                                              |      | percentage of total area of interest |
| upstream agricultural area | < 2%                          | 2 - 30%                  | 10 - 50%               | 50%                                              |      | percentage of total area of interest |
| Infrastructure           |                               |                          |                        |                                                  |      |                   |
| roads                    | 0.05                           | 0.05 - 0.1               | 0.1 - 0.5              | 0.5+                                             |      | http://www.gwc.org/ |
| irrigation               | 0                              | 0 - 5%                   | 5 - 10%                | <10%                                             |      | MBC planning area |
| embankment/road control  | no overlap                     | single sided overlap     | double sided overlap   | -                                                |      |                   |
| mining                   | 0                              | 1                         | 2                      | 2+                                               |      | amount of upstream mining |
| land mining              | not securing                   | incidental               | public                 | industrial                                       |      |                   |

Key ISH01 Pilot Testing Results – CEA sensitivity to human pressures

The following presents the ISH01 pilot testing results regarding Sre Pok basin-wide sensitivity for each human pressure listed in Table 9. In addition, the results are merged presenting the level of impact for all human pressures together. In follow-up the CEA sensitivity to human pressures has been merged with the spatial importance of each CEA resulting in the final ESA identification.
ISH01 analysis of the human pressure ‘Forest Cover’

The Lower Mekong Basin is largely characterised by dry forests as its natural landcover. Hence this forest type also plays an important role in the Sre Pok sub-basin. A new dataset on Global Forest Change 2000-2012 was recently launched by Hansen et al. (2013) providing global canopy\(^9\) cover at a high resolution\(^{10}\). For each 1x1 arc-second of the global land surface (called a pixel), the dataset provides a percentage on how much of the area is covered by (tree-) canopy, for the years of 2000 and canopy loss/gain in the year 2012. This data set has been used to undertake the related ISH01 analysis that is based on the below criteria and iteration.

**Analysis criteria and Iteration in the Sre Pok sub-basin**

Initially, it was assumed that any land with more than 85% of canopy cover would classify as the near-natural condition. Yet, when ground checked (Google Earth and field visit) it became evident that, at this high resolution, larger areas with 0% canopy cover could also be considered to represent near-natural conditions as forest meadows. Next to this, the dry forest regions (largest part of the Sre Pok basin), in their natural condition, do not offer high densities of canopy coverage, which makes any deviation or human pressures from historic land cover change difficult to identify. Due to these observations, it was decided to exclude canopy coverage as representative of a human pressure on CEAs.

Recently a new analysis has been done to map the status of the Southeast Asian dry forests (Wohlfart et al, 2014). At the time of this ISH01 study, the data was not yet ground-checked and available to be included. However, in future this dataset might be better than the global forest canopy cover map, since the analysis was focused on the Southeast Asian region.

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\(^9\) Canopy is defined as any vegetation that reaches higher than 4 meters above the ground surface; this includes both natural and planted vegetation.

\(^{10}\) 1 arcsecond resolution, which corresponds to about 30 meters resolution at the equator.
**ISH01 analysis of the human pressure ‘Forest Loss’**

The dataset on Global Forest Change 2000-2012 (Hansen et al., 2013) also offers insights into change in canopy cover between 2000 and 2012. It allowed a distinction between canopy gain and canopy loss in the Sre Pok sub-basin. The ISH01 analysis on this human pressure took into account exclusively canopy loss in order to assess downstream impact on CEAs.

**Canopy gain** is defined as any pixel that did not have 100% canopy cover in 2000, regrowing 100% canopy coverage *any time* in the period between 2000-2012. Gain can both be achieved by natural regrowth as well as by plantations. Checks by Google Earth confirm that 100% regrowth is mainly achieved by (industrial) plantations (such as rubber and palm oil).

**Canopy loss** is defined as any pixel with some canopy cover in 2000, being cleared from any canopy coverage (i.e. reach 0%) *any time* in the period between 2000-2012. Loss can be driven by natural phenomena (e.g. hurricanes) as well as by human deforestation.

Canopy loss will result in pressures to (downstream) CEAs, since it will affect local runoff processes. Much research has been done (see e.g. Bonell and Bruijnzeel, 2006), but no general conclusions can be drawn on how hydrologic systems will change under deforestation. There are also reports of increased flooding, or increased drought, or both, or changes in sediment transport or water quality. The main denominator of the combined research is that natural water balances will change. Therefore, canopy loss can be considered as a pressure to CEAs, since it will affect the natural hydrologic conditions of the area.

**Analysis criteria and Iteration in the Sre Pok sub-basin**

The (downstream) signal of canopy loss cannot be understood as a land cover change in isolation. Deforestation is an important process, but to get full overview of the pressures it poses, it is important to consider what is happening to land cover after deforestation. Thus, the main pressure, which is captured here is what is happening to CEAS that (naturally) were forested, and now have lost those forest-like characteristics. In addition, the analysis helps identify those locations where industrial-level deforestation might be taking place, which is an acute reality in the LMB. Often the process of industrial deforestation results in soil compaction (by heavy machinery), erosion and disturbance of soils through uprooting and transportation of felled trees. This can cause severe impacts if it happens inside CEAs, but also on downstream rivers and streams. These disturbances last several years after the actual deforestation, and since the dataset provides change from the 2000 situation, the analysis effectively captures these pressures for the Sre Pok sub-basin.

The canopy loss range of 1-2-10-50-100% in an upstream area is used in this analysis. These are set while keeping in mind downstream impacts. A river system with more than 50% of its forest lost, will be too impacted by deforestation to become an ecologically sensitive area. While it is likely that pressures are building up very early at the onset (>1%) of deforestation. The classes are chosen to be the same as those of (upstream) urban areas; the pressures of loosing forest-like hydrological characteristics are somewhat comparable to pressures of urban (hardened surfaces) on local hydrology. Analysis results are presented in Map 7.
ISH01 analysis of the human pressure ‘Population Density’

There is common understanding on how people pressure the river systems in which they live. The capacity of a river system to sustain human populations is a function of population density, at threshold population densities it will start to experience pressures such as increased pollution of the water resources, opening the possibility to impact downstream ecological areas.

Key to mapping the population pressures on high resolutions for the Sre Pok sub-basin was a spatial dataset that offers population distributions at the relevant scale. Since 2013 WorldPop (http://www.worldpop.org.uk/) offers open access high resolution (3s ~90m) population numbers, based on satellite imagery interpretation linked to country census data. The used methodologies are published online at the above website.

Analysis criteria and iteration in the Sre Pok sub-basin

As a first iteration to assess relevant population density thresholds in the Sre Pok pilot basin, it became evident that population densities in Viet Nam are much higher than in Cambodia. Initially, this lead to a background population density in the Vietnamese share of the basin, which resulted in too high population densities, even inside the national parks. Though some small (tribal) settlements do occur inside national parks, there is no general high population density. This was double checked in Google Earth and – as far as possible – during the ISH01 field visits (e.g. discussions with ISH01 national consultant and others). The second iteration raised the threshold such that the background population density became less evident, while respecting the higher population density thresholds. Map 8 illustrates the results of the ISH01 analysis.
ISH01 Pilot Testing Report

Map 8: Upstream population density in the Sre Pok sub-basin.

ISH01 analysis of the human pressure ‘Urban Areas and Roads’

Where population densities in the upstream are mainly an issue on water quality, the same dataset can be used to assess downstream hydrological influence of urban areas (as hardened surfaces). The influence of sealed areas (such as roofs, streets, roads) will - specifically in the LMB and Sre Pok sub-basin - be very local. The pressure of having urban areas upstream is that these areas produce very different runoff patterns; where natural areas dampen the impact of rain storms by retention in vegetation, soils and natural drainage systems, in urban areas the storm runoff directly, causing peak flows directly downstream, which can have devastating effects on ecological areas. Often cities are designed to get rid of excessive rainfall as fast as possible in order to prevent flooding inside the city.

Roads on themselves are hardened surfaces, but specifically in rural areas, also pose additional risk to connectivity in streams and rivers. Depending on the design of the road, the crossing of streams and number of culverts/bridges are often a tradeoff between finance and ecological concerns. Not every stream can have its culvert and not every culvert or bridge offers adequate passage to the local variety in aquatic biodiversity, often resulting in -very local- problems with aquatic connectivity. While a single, ecologically well designed, road will only pose minimal pressure; watersheds with high road density might experience high pressure from all the roads combined.

Analysis criteria and iteration in the Sre Pok sub-basin

The first step was to identify the critical threshold in population density at which areas would classify as ‘human agglomerations’. Following the Global Rural-Urban Mapping Project (GRUMP, 2005) that identified rural from urban areas, this threshold was set at 500 persons/km². This assumes that, starting at 500 people/km², landscape requirements in supporting populations become such, that urban infrastructure (hardened surfaces) are the norm. This allows clear distinction between urban and rural areas.
The second step was to set the relevant thresholds at which urban areas and road densities pose increased levels of pressure to (downstream) ecological areas. These thresholds were taken from a study on freshwater conservation planning in the Southeastern USA (Matson & Angermeier, 2007). As road and urban areas concern infrastructural pressures on ecological areas, they will not be treated as separate pressures, but merged together, where priority was given to the highest score on pressure. Map 9 illustrates the results of the ISH01 analysis.

Map 9: Upstream urban areas and road densities in the Sre Pok sub-basin.

ISH01 analysis of the human pressure ‘Agriculture, Plantations and Irrigated Areas’
For the agriculture layer, the 2003 MRC landcover map was used for the ISH01 analysis in the Sre Pok sub-basin as the 2009 update was not yet available. From that map the following landcovers were extracted as agricultural pressures:

- Field Crops
- Industrial Plantations
- Orchard
- Paddy Field
- Swidden Cultivations

Though agro-ecology is acknowledged an important aspect of overall landscape biodiversity, the baseline of ESAs is the near-natural condition. With that respect, agriculture can be considered as a pressure that deviates away from the near-natural status. Apart from conversions of natural lands to agriculture, pressures concern the local and downstream influence of pesticide and fertilizers use. Map 10 illustrates the results of the ISH01 analysis.
ISH01 analysis – Combination of all human pressures

The final Map 11 combines all human pressures as described above (forest canopy loss; population density; urban areas and roads; agriculture, plantations and irrigated areas) for the Sre Pok sub-basin. In combination with the results on spatial importance of each CEA, it forms the base for the identification of the ESAs.

Each of these human pressure layers have been discussed and calibrated according to the defined criteria into the four classes (too impacted, high, medium, low). A weighted approach has been applied in GIS in order combines the different pressures in a transparent way. The weighted approach assigns values to each of the classes (low, medium high, too impacted), maps out the combined results, and reiterates the assigned values when necessary. Initial values to be assigned, or tested, are:

- low: test-value 0
- medium: test-value 1
- high: test-value 2
- too impacted: test-value 4

Key ISH01 Pilot Testing Results – Combination of all human pressures

Human pressures (forest canopy loss; population density; urban areas and roads; agriculture, plantations and irrigated areas) have been combined successfully into the thematic GIS Map 11. Map 11 clearly assigned the combined human pressures to the four levels of human pressures (high; medium; low; too impacted). In combination with the spatial importance that has been assigned to each CEA, the results on human pressures (Map 11) are the basis to identify final ESAs in the Sre Pok sub-basin.
Map 11: Combined human pressures (forest canopy loss; population density; urban areas and roads; agriculture, plantations and irrigated areas) allocated to the four levels of human pressures (high; medium; low; too impacted).
5.1.4 Identification of Ecologically Sensitive Areas in the Sre Pok sub-basin

**Aim of the ISH01 Pilot Test Analysis:**
Identify and illustrate ESAs in thematic GIS maps based on previous steps.

**Expected output of the ISH01 Pilot Test Analysis:**
ESAs are identified for the Sre Pok sub-basin and are illustrated in thematic GIS maps.

*Module 1, Step 4 as described in the ISH01 technical approach (see Figure 2)*

After assigning (i) spatial importance to CEAs (Table 8; Map 5) and (ii) after the analysis on the relevant levels of human pressures sub-basin wide (Maps 6 to 11), both have been overlaid in GIS in order to come to a final ESA classification in the Sre Pok sub-basin.

The final ESAs have been identified using a GIS-based overlay of (i) spatial importance of *Candidate Ecological Areas* and (ii) the level of human pressures for each *Candidate Ecological Areas* (high/medium/low/too impacted). Table 10 (from the consolidated ISH01 Interim Report, July 2014) as well as the flow diagram in Annex 2 describe the classification scheme and the combination options how to allocate *Candidate Ecological Areas* to high, medium/possible or low ecological sensitivity.

**Table 10:** Combination options to identify high, low or possible ESAs in case conservation status is assessed as vulnerable/fragile/unique. The identification is based on the combination of (i) spatial importance of Candidate Ecological Areas and (ii) the level of human pressures (high/medium/low/too impacted). *Taken from the ISH01 Interim Report (July, 2014).*

|                          | Low pressures | Medium pressures | High pressures | Too impacted |
|--------------------------|---------------|------------------|---------------|--------------|
| **Local importance**     | High ESA      | Medium ESA       | Low ESA       | Low ESA      |
| **National importance**  | High ESA      | Medium ESA       | Low ESA       | Low ESA      |
| **Regional importance**  | High ESA      | High ESA         | Medium ESA    | Low ESA      |
| **Global importance**    | High ESA      | High ESA         | High ESA      | Medium ESA   |
| **Undefined Importance** |               |                  |               |              |

The GIS- and data-specific workflow to identify ESAs in the Sre Pok sub-basin is described in Annex 2.

The final ESA classification can be expressed both for the entire are of the Sre Pok basin, but also on its rivers, since the methodology makes use of upstream functions. Linking the ESA classification back on the rivers facilitates the linking of the identified ESAs to the hydropower risk assessment.

The final interpretation and definition of these three classes of ecological sensitivity and the meaning of the linkage to hydropower pressures is presented in Table 11.
Table 11: Interpretation and definition of the three different levels of sensitivity.

| Level                        | Description                                                                                                                                                                                                 |
|------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| **Highly Ecological Sensitive** | The area contains important ecological features with high conservation value and low/no pressures from drivers other than hydropower. Hydropower pressures are considered as significant and that they can cause impacts on the ESAs and the related river reaches. |
| **Medium Ecological Sensitive** | The area contains important ecological features but has already experienced some pressures from drivers other than hydropower. Hydropower pressures are considered as additional ones to the already existing human pressures in such ESAs and that they can still cause significant impacts on the ESAs and the related river reaches. |
| **Low Ecological Sensitive**   | The area contains ecological features and has already experienced significant pressures from drivers other than hydropower. Hydropower pressures are not considered as significant human pressure on the ecological area as other human pressures are already causing significant impacts. Still hydropower pressures can contribute to relevant ecological tipping points and, hence, impacts on ESAs and related river reaches. |

**Key ISH01 Pilot Testing Results – Identification of ESAs**

The identified ESAs for the Sre Pok sub-basin are illustrated in Map 12. ESAs are illustrated for areas but are also reflected in the directly corresponding river reaches. Linking the ESA classification back on the rivers facilitates the linking of the identified ESAs to the hydropower risk assessment. In order
Map 12: Final identification of Ecologically Sensitive Areas (ESAs) in the Sre Pok sub-basin.
5.2 Classification of Hydropower and Pressure Types

Module 2 of the ISH01 technical approach tackles (i) the classification of existing and planned hydropower schemes in the Sre Pok sub-basin. In addition, (ii) pressures types are described that can stem from hydropower with the potential to impact on ESAs and the water status/quality of related river reaches. These steps and the findings are presented in the following Chapters 5.2.1. to 5.1.2.

Main Result presented in this chapter

The main result of this Module is a list and map of existing and planned hydropower schemes in the Sre Pok sub-basin. In addition, a description of each dam is provided. Further, all pressure types are described that may possible impacts on ESAs and on water status/quality of related river reaches. In this context, pressure types are assigned with tailor made criteria to estimate the risk within ISH01 Module 3, in which hydropower and ESAs will be merged to provide a basis for decision making.

5.2.1 Description of hydropower schemes in Sre Pok sub-basin

**Aim of the ISH01 Pilot Test Analysis:**
Compile, update and describe comprehensive baseline information about hydropower.

**Expected output of the ISH01 Pilot Test Analysis:**
Database holds information and description of Sre Pok hydropower schemes for following analysis.

**Module 2, Step 5 as described in the ISH01 technical approach (see Figure 2)**

The description of existing and planned hydropower schemes in the Sre Pok basin was carried out based on available data, collected by ISH01 national and international consultants. The hydropower description is also based on observations and findings during the ISH01 field visit to the Sre Pok sub-basin in November 2014. The collected data and descriptions form the base for the analysis carried out in following implementation steps. Up-front it should be highlighted that the data collection focused on the Sre Pok mainstream. Information on small hydropower and irrigation schemes that can impact on ESA related river reaches have not been available as of the ISH01 pilot testing and would need targeted surveys.

Figure 6 and Map 13 illustrate the eight existing and four planned hydropower schemes along the Sre Pok river, their location regarding country and river kilometres. The existing dams include the Lower Sesan 2, which is currently under construction on Cambodian territory. In consolidation, with the LMB countries it was decided to include this dam although it is outside the Sre Pok sub-basin but still is very relevant for it when it comes to the analysis within this study. Overall, eight hydropower schemes are located in Vietnam and four in Cambodia.

![Figure 6: Existing and planned hydropower schemes along the Sre Pok river's profile including dam location regarding country & river kilometre. Sre Pok 4A is not shown as located off the river channel.](image-url)
Map 13: Existing and planned hydropower schemes in the Sre Pok sub-basin.
Most of the schemes are operated as run-of-river operation and, hence, the corresponding reservoirs are not too large. Major reservoirs can be found at the hydropower dams of Buon Tua Srah, Sre Pok 3, Lower Sre Pok 4, Lower Sre Pok 3B, Lower Sre Pok 3A and Lower Sesan 2. The latter two schemes hold the largest reservoirs. Lower Sre Pok 4, 3B and 3A are planned hydropower dams and, in addition to the existing dams in Vietnam, cause a continuous reservoir chain with hardly any free flowing river section in-between. This means that the natural riverine character will be changed to a lake-like condition. More of this will be outlined in Chapter 5.3.3.

The description of dams in Table 12 follows the chain of hydropower schemes from upstream to downstream along the Sre Pok river mainstream. More detailed information on technical features of the dams is provided in Annex 3. All dams are also illustrated in Map 12 and Figure 6.

Table 12: Description of existing and planned hydropower schemes in the Sre Pok sub-basin as well as of the Lower Sesan 2 dam that is located outside the Sre Pok basin.

| Hydropower Dam   | Status | Description                                                                                                                                                                                                 |
|------------------|--------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| **VIETNAM**      |        |                                                                                                                                                                                                             |
| Boun Tua Srah    | existing | 83m high multipurpose dam with Francis turbines (86 MW); no fish bypass; reservoir length of 8 km; reservoir volume of 787 mill m³ and an average natural river flow of 102 m³/s (3,217 mill m³); The catchment area is 2,930 km². The dam is operated for peak power generation. |
| Buon Kuop        | existing | 34 m high multipurpose dam with Francis turbines (280 MW); no fish bypass; reservoir length of 3 km; reservoir volume of 73 mill m³ and an average natural flow of 217 m³/s (6,843 mill m³). The catchment area is 7,980 km². The dam is operated for peak power generation. |
| Hoa Phu          | existing | 6m high power generation dam with Kaplan turbines; no fish bypass; no significant reservoir; average natural flow and size of catchment area are not exactly known; The dam is operated for peak power generation. |
| Dray Hlin        | existing | Dry Hlin is a hydropower complex of three small hydropower dams in close proximity that were constructed in different years. no fish bypasses; Their purpose is hydropower generation using Kaplan turbines. They have no significant reservoir. The average natural flow at the site is 241 m³/s. The catchment area is 8,880 km² |
| Sre Pok 3        | existing | 53m high power generation dam with Francis turbines; no fish bypass; reservoir length of 6 km; reservoir volume of 219 mill m³ and an average natural flow of 250 m³/s. The catchment area is 9,410 km². The dam is operated for peak power generation. |
| Sre Pok 4        | existing | 25m high multipurpose dam with Kaplan/Bulb turbines; no fish bypass; reservoir length of 4 km; reservoir volume of 29 mill m³ and an average natural flow of 258 m³/s. The catchment area is 9,586 km² |
| Sre Pok 4A       | existing | Power generation dam with Kaplan/Bulb turbines; no fish bypass; It is connected to the Sre Pok 4 dam through a bypass canal and is located off the Sre Pok mainstream. Hydraulically it is dependent on the Sre Pok 4 dam and respectively carries similar characteristics. |
### CAMBODIA

| Scheme                  | Planned Status | Description                                                                 |
|-------------------------|----------------|-----------------------------------------------------------------------------|
| Lower Sre Pok 4         | planned        | 32m high power generation dam with Kaplan turbines; reservoir length of 15 km, a reservoir volume of 204 mill m³ and an average natural flow of 378 m³/s. The catchment area is 13,727 km². No information if a fish bypass will be constructed. |
| Lower Sre Pok 3B        | planned        | 29m high power generation dam with Bulb turbines; reservoir length of 10 km, a reservoir volume of 240 mill m³ and an average natural flow of 396 m³/s. The catchment area is 14,341 km². No information if a fish bypass will be constructed. |
| Lower Sre Pok 3A        | planned        | 43m high power generation dam with Bulb turbines, a reservoir length of 65 km, a reservoir volume of 5863 mill m³ and an average natural flow of 713 m³/s. The catchment area is 25311 km². No information if a fish bypass will be constructed. |
| Lower Sesan 2           | under construction | Located on the Sesan River downstream the confluence with the Sre Pok river and, hence, actually outside the investigation area but with a large reservoir reaching significantly into the Sre Pok sub-basin. It has no fish bypass. |

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**Key ISH01 Pilot Testing Results – Description of hydropower schemes in Sre Pok sub-basin**

A comprehensive set of information and data has been collected to assess possible risks stemming from hydropower as basis for decision making on sustainable hydropower. For some dams and parameters information is incomplete or missing, leading to uncertainties in the risk assessment.

Existing gaps: The full required data and information could not be obtained for all hydropower schemes in the Sre Pok sub-basin. Respectively uncertainties will remain for those schemes/parameters. It needs to be highlighted here that no information has been available regarding both (i) hydropower schemes and (ii) irrigation schemes along tributaries of the Sre Pok. National as well as MRC databases currently do not include these aspects for tributaries, and, hence, could not be considered. This caused limitation for the risk assessment for tributaries (Chapter 5.3.2 and 5.3.3). Risk in tributaries is allocated to the category ‘possibly at risk’ to be impacted due to these data gaps.

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**5.2.2 Identification of hydropower pressure types**

**Aim of the ISH01 Pilot Test Analysis:**
Identify key pressure types resulting from hydropower schemes and their operation that may impact on ESAs and related river reaches in order to be used as basis for further analysis.

**Expected output of the ISH01 Pilot Test Analysis:**
Key pressures types are identified for further analysis and illustration in a thematic GIS maps.

**Module 2, Step 6 as described in the ISH01 technical approach (see Figure 2)**

Various pressure types can stem from hydropower and may have potential negative impacts on the water status/quality of riverine systems as well as ESAs. According to the analytical framework of the DPSIR (Driver-Pressure-Status-Impact Response) approach (OECD, 1994) - a pressure type or pressure is defined as: ‘Direct effect on the environment stemming from a driver’ (in this case the driver is hydropower).

In line with the DPSIR definition Table 12 identifies the five key pressure types and ten allocated pressures stemming from hydropower that have been addressed within the Sre Pok sub-basin pilot testing exercise and its analysis.

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11 More details on the DPSIR approach can be found in the ISH01 Inception Report (Chapter 4.5.1/Page 34).
Table 13: Five pressure types and ten allocated pressures stemming from the ‘driver’ hydropower and that have been addressed within the ISH01 pilot testing in the Sre Pok sub-basin.

| # | Pressure Type                                      | # | Allocated pressure                                           |
|---|---------------------------------------------------|---|--------------------------------------------------------------|
| 1 | Fish migration barrier                            | 1a | Interruption of river, habitat and fish migration continuity |
| 2 | Sediment transport barrier                        | 2a | Interruption of sediment transport continuity                |
| 3 | Alteration of characteristic water quality parameters | 3a | Nutrient increase /eutrophication (N/P);                    |
|   |                                                   | 3b | Alteration of water temperature;                            |
|   |                                                   | 3c | Alteration of oxygen;                                       |
| 4 | Hydrological and hydraulic alterations             | 4a | Significant fluctuations in water level and current velocity downstream of the dam due to peaking operation (short term); |
|   | (= changes regarding natural flow regime and patterns upstream and downstream a dam) | 4b | Altered/reduced downstream flooding and inundation areas (long term/annual); |
|   |                                                   | 4c | Insufficient ecological flow below the dam                  |
|   |                                                   | 4d | Shift to lake-like character upstream the dam due to reservoir effect causing changes in flow velocities, habitat structure and possible continuity interruption |
| 5 | Reservoir area inundation                         | 5a | Inundation of areas in new reservoir area through impoundment |

Based on the pressure types and allocated pressures (Table 13), respective data and information has been collected in the Sre Pok sub-basin and compiled accordingly. The knowledge of pressure types themselves but specifically the following analysis of the data enables a good overview on possible alterations in river reaches. In case of data gaps (e.g. Drang Phok dam) open questions remain that are recommended to be filled in future.

The identified key pressure types have then be prepared and used for further analysis in the Sre Pok basin to identify the direct risk of **significant** pressure types/pressures\textsuperscript{12} to the ESAs and related river reaches. This analytical step and criteria to determine possible impacts on ESAs from hydropower are applied in the risk assessment approach as described in the Interim Report (Module3/Step 8) and in Chapter 5.2.4.

**Key ISH01 Pilot Testing Results – Identification of hydropower pressure types**

Key pressure types have been identified for the Sre Pok sub-basin (see Table 13). Based on these pressure types, related data has been collected for the mainstream of the Sre Pok sub-basin and compiled for further analysis. The detail of collected information varies as e.g. for Drang Phok dam no information is available at all, while for other schemes collected information has been sufficient for direct or indirect allocation to most of the pressure types.

\textsuperscript{12} **Definition:** Significant pressures are pressures with a very high potential to impact on the river system as well as ESAs. Pressures that are identified as **significant** have been considered in the risk assessment.
5.3 Merging of identified ESAs and hydropower

5.3.1 GIS merging of information: ESAs and hydropower

**Aim of the ISH01 Pilot Test Analysis:**
Overlay and illustrate hydropower, pressures types and ESA information in their spatial context

**Expected output of the ISH01 Pilot Test Analysis:**
Hydropower, pressures types and ESAs are illustrated in thematic GIS maps.

*Module 2, Step 7 as described in the ISH01 technical approach (see Figure 2)*

**Map 14** illustrates the simple combination of ESAs with hydropower schemes in the Sre Pok sub-basin. Although this map does not include any detailed analysis yet, it provides a spatial overview of potential conflict areas (e.g. if a hydropower dam is planned in an ESA with high sensitivity). The overlay **Map 14** also provides insights to understand possible impacts that may result from hydropower chain effects considering the river network. Hence, such a map allows first, rough conclusions before doing a risk assessment of possible impacts.

**Key ISH01 Pilot Testing Results – GIS merging of information: ESAs and hydropower**

**Map 14** illustrates and overlay of existing and planned hydropower schemes in the Sre Pok sub-basin allowing a first spatial overview of potential conflict areas.

Existing gaps: A good spatial overview has been obtained for the Sre Pok sub-basin. Nevertheless some uncertainty exists with regards to impact length downstream of schemes as well as impacts on tributaries.

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**Map 14: Combination of Ecologically Sensitive Areas with hydropower schemes in the Sre Pok sub-basin.**
5.3.2 Risk estimation of possible impacts from hydropower on ESA related river reaches based on criteria

Table: Aim of the ISH01 Pilot Test Analysis:
Use the introduced risk criteria to estimate possible impacts on downstream/upstream river reaches and ESAs stemming from significant hydropower pressure types/pressures. Implementation of the risk estimation through allocating river reaches related to ESAs to three risk classes (ESA is (1) not at risk, (2) at risk or (3) possibly at risk to be negatively impacted by hydropower pressures.

Expected output of the ISH01 Pilot Test Analysis:
Risk criteria to estimate possible impacts on ESAs have been implemented in the Sre Pok sub-basin. River reaches related to ESAs are estimated to be (i) at risk, (ii) not at risk or (iii) possibly at risk to be impacted by hydropower pressures.

Module 2, Step 8 as described in the ISH01 technical approach (see Figure 2)

Based on the data collected for the Sre Pok sub-basin (ISH01 data collection and field visit) and the developed criteria, a risk assessment has been carried out for each pressure type (Table 13). The risk assessment is based on (i) risk criteria that are partly qualitative and quantitative (Annex 4) with the aim to assess if hydropower pressures (see Table 13) possibly impact negatively on ESA related river reaches. Both existing and planned dams have been taken into account allowing a basis for various aspects of decision making (see Chapter 6.3.1). The results of the risk assessment for each pressure type give an indication if significant pressures from hydropower schemes put ESA related river reaches at risk to be degraded in their status and condition. In the end the individual risk assessments the pressure type (as presented in this chapter) have been combined as an overall risk assessment for the Sre-Pok sub-basin (see Chapter 5.3.3.).

Figure 7 shows the basic principle of the risk assessment extracted from Figure 3 of the basic concept of the ISH01 risk based approach towards a planning and management framework for sustainable LMB hydropower. Figure 8 summarises once more the steps of the risk assessment as it has been proposed within the ISH01 technical approach and as it has been applied within the ISH01 pilot testing exercise. Finally, Table 14 outlines the three risk categories that indicate if and ESA related river reach is ‘not at risk’, ‘at risk’ or ‘possibly at risk’ to be impacted by pressures from hydropower. The detailed risk criteria that have been used for the assessment in the Sre Pok sub-basin are listed in the table of Annex 4.

Figure 7: Implementation focus of the ISH01 risk assessment excerpted from Figure 3 of the basic concept of the ISH01 risk based approach towards a planning and management framework for sustainable LMB hydropower.
The results of the risk assessment for the Sre Pok basin are illustrated in figures, tables and are described in text as part of Chapters 5.3.2 and 5.3.3. Identified significant pressures vary in character in relation to each dam and spatial extent. The spatial extent of the risk from pressures results from both (i) the character of the dam and (ii) the criterion of the pressure type. Negative impacts have been assessed where set criteria (Annex 4) are exceeded and, hence, impact on ESA related river reaches.

**Key ISH01 Pilot Testing Results – Risk estimation of possible impacts from hydropower**

The assessment of individual pressure types and related risks these pose on ESA related river reaches has been successfully undertaken for the Sre Pok sub-basin. These results are presented in:

- Table 15 shows if ESA related river reaches (downstream/upstream) are ‘not at risk’, ‘at risk’ or ‘possibly at risk’ to be impacted by hydropower. The risk assessment considers each pressure type (Table 13) applying the respective risk criteria (Annex 4) for each Sre Pok river hydropower dam;
- Maps 15 – 24 illustrate the risk assessment result for each individual pressure type;
- Figures 9 – 18 supplement Maps 15 – 24 and describe the risk assessment result for each individual pressure type in more detail.

Existing gaps: The risk category ‘possibly at risk’ indicates data gaps. A full risk assessment has not been possible because of lack of information. This is in particular valid for the tributaries for which no detailed information has been available and key information has been collected for the Sre Pok mainstream. This category ‘possibly at risk’ automatically has an implication for decision makers. Data gaps have to be filled as soon as possible in order to support comprehensive hydropower planning and management in the future.
Table 15: Results of the risk assessment in the Sre Pok sub-basin indicating what dams and pressure types put ESA-related river reaches ‘not at risk’ (green colour), ‘at risk’ (red colour) or ‘possibly at risk’ (orange colour). The risk assessment is based on the criteria for each pressure type in Annex 4.

| SPECIFIC THEMATIC ASPECT | Fish Migration Barriers / River Continuity Interruption | Sediment Transport and Balance | Sediment Flushing: Possible Impacts on Aquatic Environment | Hydrological Alteration: Change of downstream flow regime Peak Operation | Hydrological Alteration: Change of downstream flow regime Altered or reduced downstream flooding and altered | Hydrological Alteration: Change of downstream flow regime Insufficient environmental flow below the dam | Hydrological Alteration: Change of upstream flow regime Shift from river to lake-like character due to reservoir effect | Alteration of Water Quality | Habitat Change/Reduction |
|--------------------------|---------------------------------------------------------|--------------------------------|---------------------------------------------------------------|---------------------------------------------------------------------|-------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------|---------------------------------|
| Buon Tua Sra | No bypass | Not an issue | Not an issue | Peaking | Expert judgement | No env flow implemented | 20 km | Residual reservoir time is > 1 month | Unknown |
| Buon Kep | No bypass | Not an issue | Not an issue | Peaking | Expert judgement | Unknown | 3 km | Residual reservoir time is < 1 month | No Impact |
| Hoa Phu | No bypass | Unknown | Not an issue | Peaking | Expert judgement | Unknown | No reservoir | Residual reservoir time is < 1 month | No Impact |
| Dray Hinh | No bypass | Not an issue | Not an issue | Upstream dependence | Expert judgement | Unknown | No reservoir | Residual reservoir time is < 1 month | No Impact |
| Sre Pok 3 | No bypass | Not an issue | Not an issue | 12 hour peaking | Expert judgement | Flows are higher | 6 km, cumulative effect | Residual reservoir time is < 1 month | No Impact |
| Sre Pok 4 | No bypass | Not an issue | Not an issue | Some peaking | Expert judgement | Flows are higher | 4 km, cumulative effect | Residual reservoir time is < 1 month | No Impact |
| Sre Pok 4A | No bypass | Not an issue | Not an issue | Upstream dependence | Not relevant | Not relevant | Not relevant | Residual reservoir time is < 1 month | No Impact |
| Drang Phok | no information | Unknown | Unknown | Unknown | Unknown | Unknown | Unknown | Unknown | Unknown |
| Lower Sre Pok 4 | no information | Unknown | Unknown | Unknown | Run of river | Unknown | 15 km, cumulative effect | Residual reservoir time is < 1 month | Unknown |
| Lower Sre Pok 3b | no information | Unknown | Unknown | Unknown | Run of river | Unknown | 10 km, cumulative effect | Residual reservoir time is < 1 month | Unknown |
| Lower Sre Pok 3a | no information | Unknown | Unknown | Unknown | Run of river | Unknown | 85 km, cumulative effect | Residual reservoir time is < 1 month | Unknown |
| Lower Sesan 2 | No bypass | n/a | n/a | n/a | n/a | n/a | reservoir effect | Unknown | Unknown |
Map 15 / Figure 9: Risk assessment results for the pressure type fish migration barriers / river and habitat continuity interruptions depending on the presence of a fish bypass channel that allows functioning fish migration.

Several dams starting with the Lower Sesan 2 dam, for which no fish bypass facilities are planned, interrupt fish migration in the Sre Pok River. Going further upstream of Lower Sesan 2, no information on fish bypasses is available for the planned Lower Sre Pok dams in Cambodia. Hence, it is not known if fish migration will be completely interrupted as the migration between the tributaries and the mainstream can still contribute to complete and self-sustaining fish populations. Respectively the related mainstream river reaches are categorized as “possibly at risk”. For the dams in Viet Nam no fish bypass facilities are in place. Hence, the risk for impacts on related river reaches was classified as “at risk”.

An important point to note is that in the absence of detailed knowledge about fish species the risk classification has been conducted on a “per dam” basis, i.e. it has not been considered whether the construction of Lower Sesan 2 alone would lead to a complete collapse of fish migration in the Sre Pok river or whether a Sre Pok internal fish migration may still take place and may be interrupted by the other dams further upstream. Further, fish migration in the tributaries has not been investigated specifically due to significant data shortcomings. Respectively the tributaries have been classified as “possibly at risk”.

As a result of this risk assessment, 51% of the total investigated river length\textsuperscript{13} were classified as “at risk” and 49% as “possibly at risk”. No river reaches are classified as “not at risk”.

\textsuperscript{13} River reach upstream the Lower Sesan 2 dam up to the source of the Sre Pok river (see Chapter 4.1/Map 3).
Map 17 / Figure 10: Risk assessment results regarding the pressure type altered sediment transport and/or interruption based on the change in sediment transport through the dams/reservoirs leading to altered sediment budgets.

Sediment transport interruption may have strong impacts on downstream ecosystems. Based on available information and especially information collected from hydropower operators during the ISH01 field visit, the sediment transport situation on the upper Sre Pok has mostly been assessed as ‘not at risk’ based on the fact that reservoir sizes are small and hydropower schemes are operated as “run of river”. Sedimentation and respective sediment transport interruption in these small reservoirs is mostly negligible. An exception is Hoa Phu with a larger reservoir.

For the hydropower schemes planned in the downstream part of the Sre Pok no information was available of possible sediment transport management, facilitation structures or operations so that the respective schemes with their larger reservoirs were rated as “possibly at risk”. The same applies for the tributaries for which narrative evidence indicates the possible presence of irrigation dams, hydropower schemes and weirs, which may impact on ESAs and related river reaches.

As a result of this risk assessment, 0% of the total investigated river length\textsuperscript{14} was classified as “at risk”, 51 as “possibly at risk” and 49% as “not at risk” regarding possible impacts from hydropower.

\textsuperscript{14} River reach upstream the Lower Sesan 2 dam up to the source of the Sre Pok river (see Chapter 4.1/Map 3).
Sediment flushing can have significant impacts on the aquatic ecosystems downstream dams if not conducted in an environmentally friendly manner. As described in the sediment transport analysis, hydropower operation in the upper part of the Sre Pok is conducted in a run-of-river mode, respectively leading to near natural sediment transport conditions. For the schemes in the lower part of the Sre Pok no information on sediment management was available, respectively resulting in a “possible at risk” classification. It has been assumed that no larger dams causing respective flushing impacts are located on the tributaries. Hence, these have been categorised ‘not at risk’.

River reaches downstream of dams with questionable sediment management and respective potential flushing impacts were assumed to show an impact for an estimated length downstream, mostly down to the next tributary. This assessment is based on expert judgement and the assumption that with the next tributary confluence the sediment releases will mix with waters from the tributaries and that respectively the sediment content and blast effect would be buffered.

As a result of this risk assessment, 0% of the total investigated river length\textsuperscript{15} was classified as “at risk”, 19% as “possibly at risk” and 81% as “not at risk”.

\textsuperscript{15} River reach upstream the Lower Sesan 2 dam up to the source of the Sre Pok river (see Chapter 4.1/Map 3).
Information for hydropeaking operations was available for the existing dams in Vietnam, while for the planned dams no information about their operation mode could be obtained. Respectively, schemes with hydropeaking were classified as “at risk”, schemes with no hydropeaking operation as “not at risk” and schemes for which no information was available as “possibly at risk”. As beyond the scope of the study and due to existing data shortcomings, no detailed information is currently available on hydropower schemes and possible hydropeaking impacts in the tributaries. Therefore, these have been categorised ‘possibly at risk’ also indicating that more specific investigations need to be undertaken in future.

As a result of this risk assessment, 9% of the total investigated river length\(^{16}\) was classified as “at risk”, 9% as “possibly at risk” and 82% as “not at risk” regarding possible impacts from hydropower.

\(^{16}\) River reach upstream the Lower Sesan 2 dam up to the source of the Sre Pok river (see Chapter 4.1/Map 3).
The annual flood cycle is of great importance for the Sre Pok, its ecosystems and livelihoods. Depending on the operation of a hydropower scheme the annual flood cycle may get interrupted. Potential reservoir storage in relation to reservoir inflow has been used as an indicator in the risk assessment, yielding “no risk” conditions for all existing and planned schemes despite Drank Phok, for which no information regarding its reservoir size is available. Based on regional expert information and investigations using Google Maps, it has been assumed that no larger dams with the potential to cause hydrological alteration regarding downstream, flooding and inundation are located on the tributaries. Hence, these have been categorised ‘not at risk’.

As a result of this risk assessment, 0% of the total investigated river length\(^{17}\) was classified as “at risk”, 1% as “possibly at risk” and 99% as “not at risk” regarding possible impacts from hydropower.

\(^{17}\) River reach upstream the Lower Sesan 2 dam up to the source of the Sre Pok river (see Chapter 4.1/Map 3).
Environmental flow in the Sre Pok river has been assessed based (i) on available information regarding hydropower scheme operation, considering given turbine discharge figures as compared to the natural flow and (ii) on site checks during the field visit. If not proven differently on site, the distance downstream of a scheme, which was assumed to be possibly affected was taken to the next downstream tributary, assuming that flow from the tributary would - to some extent - replenish the water in the Sre Pok. Analysis was partly hampered by non-availability of respective data and situations that were even unclear when checking on site as no information regarding seasonal variations have been available. Respectively those schemes and the related river reaches were classified as ‘possibly at risk’. No information regarding insufficient environmental flow below dams is currently available for potential irrigation and hydropower dams in the tributaries and, hence, these have been categorised as ‘possibly at risk’ also indicating investigations are needed in future.

As a result of this risk assessment, 4% of the total investigated river length\textsuperscript{18} was classified as “at risk”, 43% as “possibly at risk” and 53% as “not at risk” regarding possible impacts from hydropower.

\textsuperscript{18} River reach upstream the Lower Sesan 2 dam up to the source of the Sre Pok river (see Chapter 4.1/Map 3).
Map 22 / Figure 15: Risk assessment results regarding the pressure type impoundment / shift from river- to lake like character of river stretches due to reservoir effect.

A lake like character with respective changes to the river flow (the riverine character) and reduction of free flowing river reaches is caused by reservoirs with extended resident times of the inflowing waters before release. Such a situation has been found in several schemes that were respectively classified as “at risk” while schemes with “run-of-river” type of character and small volumes were classified as “not at risk”. Tributaries have been assessed as “possibly at risk” as impacts that may stem from potential dams or weirs.

As a result of this risk assessment, 46% of the total investigated river length\(^{19}\) was classified as “at risk”, 0% as “possibly at risk” and 54% as “not at risk” regarding possible impacts from hydropower.

\(^{19}\) River reach upstream the Lower Sesan 2 dam up to the source of the Sre Pok river (see Chapter 4.1/Map 3).
Water quality degradation can be a potential problem in reservoirs due to eutrophication effects. If concrete monitoring results are not available, water quality problems can be roughly estimated identified either through a proxy: (i) Residual reservoir time can be calculated to provide hints for potential water quality deterioration e.g. for Buon Tua Srah residual reservoir time is > 1 month, respectively the reservoir was classified as “at risk”. For Drang Phok the reservoir dimensions are unknown, respectively the classification is “possibly at risk”. For the other existing and planned dams along the Sre Pok main stream reservoir times are below one month and respectively have been classified as “not at risk”. (ii) In addition, a visual check on eutrophication during the ISH01 Field visit signs contributed to the estimation regarding water quality. Based on regional expert judgement, water quality in the tributaries have been rated as being not significant.

As a result of this risk assessment, 3% of the total investigated river length\(^{20}\) was classified as “at risk”, 7% as “possibly at risk” and 90% as “not at risk” regarding possible impacts from hydropower.

\(^{20}\) River reach upstream the Lower Sesan 2 dam up to the source of the Sre Pok river (see Chapter 4.1/Map 3).
Habitats may be changed and/or reduced due to the impoundment of reservoirs. The risk assessment was conducted through overlaying reservoir shapes with ESA’s, respectively yielding results where ESA’s were affected by impoundments. As detailed processes are unknown, reservoirs that would affect ESA’s have been classified as “possibly at risk”.

As a result of this risk assessment, 0% of the total investigated river length21 was classified as “at risk”, 38% as “possibly at risk” and 62% as “not at risk” regarding possible impacts from hydropower.

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21 River reach upstream the Lower Sesan 2 dam up to the source of the Sre Pok river (see Chapter 4.1/Map 3).
5.3.3 Combination and interpretation of results towards sustainable hydropower planning

**Aim of the ISH01 Pilot Test Analysis:**
Illustrate the outcome of the risk assessment in one GIS map from the Sre Pok sub-basin.

**Expected output of the ISH01 Pilot Test Analysis:**
One GIS map combines the risk assessment from the individual pressure types from hydropower in the Sre Pok sub-basin. Hence, this map illustrates the overall risk assessment from hydropower on the ESA related river reaches in the Sre Pok sub-basin.

*Module 2, Step 9 as described in the ISH01 technical approach (see Figure 2)*

This chapter presents the overall risk assessment results for the Sre Pok sub-basin. For this purpose, the individual risk assessments of the pressure types (as presented in Chapter 5.3.2) have been combined applying the ‘One-Out, All-Out-Principle’. The ‘One-Out, All-Out-Principle’ makes use of the simple rule that the worst rating of the risk assessment for each pressure type determines the final and overall risk assessment result. Findings are presented and illustrated in Map 25, Table 16 and Figure 18.

**Key ISH01 Pilot Testing Results – Combination of results / overall risk assessment**

The overall risk assessment has been successfully undertaken for the Sre Pok sub-basin, which combines all individual findings of Chapter 5.3.2 applying the ‘One-Out-All-Out-Principle’\(^{22}\). These overall risk assessment as a key outcome of the ISH01 pilot testing besides the identification of ESAs. The results of the overall risk assessment for the Sre Pok sub-basin are presented in:

- Map 25, Table 16 and Figure 18 showing the overall risk assessment that combines the individual significant pressures into one single result applying the ‘One-Out-All-Out-Principle’

Existing gaps: The risk category ‘possibly at risk’ indicates data gaps. A risk assessment has not been possible because of lacking information. This is in particular valid for the tributaries for which no detailed information has been available and key information has been collected for the Sre Pok mainstream. The category ‘possibly at risk’ automatically has an implication for decision making in that sense that data gaps have to be filled as soon as possible in order to support comprehensive hydropower planning and management in the future.

\(^{22}\) ‘One-Out, All-Out-Principle’ makes use of the simple rule that the worst rating of the risk assessment for each pressure type determines the final and overall risk assessment result.
Figure 18: ISH01 risk assessment including overall risk for the Sre Pok River. Individual significant pressures have been assessed and are displayed with their respective description. In addition the individual risks have been combined into an overall risk result applying the ‘One-Out, All-Out-Principle’, shown in the top of the graph. The results are allocated to the three risk categories ‘at risk (red)’, ‘possibly at risk (orange)’ and ‘not at risk (green)’ that indicate possible impacts from hydropower on ESA related river reaches as shown along the x-axis.

Table 16: Overall ISH01 risk assessment. Figures are indicated in % in relation to the entire river length starting at the dam of Lower Sesan 2 and the Sre Pok River

| Overall Risk                | At risk | Possibly at risk | No risk |
|----------------------------|---------|-----------------|---------|
| Fish migration barrier     | 51      | 49              | 0       |
| Sediment transport balance| 0       | 51              | 49      |
| Sediment flushing          | 0       | 19              | 81      |
| Hydrological alteration - peaking | 9    | 9               | 82      |
| Hydrological alteration - flood regime | 0 | 1               | 99      |
| Hydrological alteration - insufficient flow | 4  | 43              | 53      |
| Hydrological alteration - lake character | 46 | 0               | 54      |
| Water quality - eutrophication | 3   | 7               | 90      |
| Habitat change / reduction | 0       | 38              | 62      |

As a result of this overall risk assessment, 76% of the total investigated river length was classified as “at risk”, 24% as “possibly at risk” and 0% as “not at risk” regarding possible impacts from hydropower.

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23 River reach upstream the Lower Sesan 2 dam up to the source of the Sre Pok river (see Chapter 4.1/Map 3).
Map 25: Overall ISH01 risk assessment for the Sre Pok sub-basin combining the individual significant pressures into one single result applying the ‘One-Out, All-Out-Principle’. The Map shows the identified ESAs (Chapter 5.1.4) in the background.
6 BENEFITS OF THE ISH01 APPROACH AND KEY CONCLUSIONS

| Aim of the ISH01 Pilot Test Analysis: |
| Integrate all steps in such a way that they are a sound basis for interpretation, decision-making, planning and management of sustainable hydropower |

| Expected output of the ISH01 Pilot Test Analysis: |
| A framework for sustainable hydropower planning and management is presented based on the findings from ISH01 pilot testing that can be used for basin-wide upscaling. |

Module 2, Step 10 as described in the ISH01 technical approach (see Figure 2)

6.1 Key benefits of the ISH01 approach as planning and management tool

The ISH01 approach has strong potential to contribute to sustainable hydropower planning and management in the LMB. Taking into account that the ISH01 approach is based on expert judgement, it provides a basic framework for first stage decision making, specifically, regarding the planning of hydropower schemes but also the management of existing dams. The ISH01 pilot testing and its results contribute to this finding. Key issues that justify this conclusion are listed here:

- The illustrations and maps of the ISH01 approach enable a display of results that is easy to develop, to understand and most importantly to be communicated to all involved stakeholders including decision as well as policy makers.

- A simple GIS overlay of ESA and planned/existing hydropower scheme locations already gives a first and informative indication on potential areas of conflict. In case a planned scheme is planned to be located in an ecological area with high sensitivity, an alternative site may be considered before the development of costly EIAs and feasibility studies is initiated.

- The implementation of the risk assessment applying the ISH01 criteria deepens the knowledge of the simple ESA and hydropower overlay. The results of the risk assessment allow for more concrete conclusions clearly indicating possible impacts from key pressure types that may stem from hydropower on ESA related river reaches.

- Based on the risk assessment results sound decisions for hydropower planning can be met. In case planned hydropower would cause significant pressures and impacts on ESA related river reaches, related steps can be taken to ensure the maintenance and conservation of ESAs, river reaches and also socio-economics aspects.

- In the above context, decision makers and water managers in close cooperation with the developers can address mitigation measures for impact compensation in a very targeted way as part of EIAs and feasibility studies as the pressure types are known from the risk assessment.

- Further, if no effective mitigation measures are possible to be implemented, decision makers and water managers can initiate the search for alternative sites in river reaches of sub-basins where negative impacts would be lower. The benefit is wise and sustainable planning with no loss of energy generation while also ensuring the achievement of environmental requirements.

- Regarding existing hydropower schemes, the ISH01 approach enables integration of all dams (existing and planned) into one holistic assessment. This approach goes beyond looking at only one individual dam but integrates all pressures and possible risks in river basins. Overall
and integrated risks are described and illustrated towards integrated hydropower planning, management and sustainability.

- The latter and, hence, the ISH01 approach, also enables basic considerations regarding cumulative effects that are understood as additive negative consequences that may occur from multiple hydropower schemes or other interventions on the riverine environment and, in some cases, on socio-economic conditions.

- In addition, the knowledge on risks stemming from existing hydropower schemes enables effective considerations for ‘retrofitting’ of dams that cause impacts. This means that mitigation measures (e.g.) can be implemented to reduce negative impacts on rivers, ESAs and socio-economics. Again such steps usually guide hydropower towards sustainability.

- The results of the assessments provide a sufficient basis to design monitoring programmes and networks in order to validate findings.

- From experiences in other river basins, where similar approaches like the ISH one have been applied, it can be said that such approaches provide a well informed basis for decision making before larger investments into EIAs, feasibility and other studies. While assessment effort is not too high as based on experts judgement and cost effective the related output is high.

- It should be noted here that the ISH01 approach and tool does not replace EIAs and feasibility studies but provide an effective planning as well as management step before EIAs are developed.

### Six reasons that can make the ISH01 technical approach a good hydropower-planning tool:

1. Effective as well as simple planning and management tool for sustainable hydropower development and ESA protection;
2. Basin-wide overview at one glance on possible impacts on ESAs stemming from hydropower;
3. Risk estimation based on expert judgement enabling preliminary compensation of data gaps;
4. Basis for effective decision making before financial investment into detailed case-by-case considerations, EIAs and feasibility studies;
5. Easy-to-apply and flexible tool based on technically secured basis;
6. Coherency and transparency in implementation and interpretation of results establishing
   - a common ground for discussion between decision makers and involved stakeholders, and
   - comparability among different LMB tributaries on sub-basin level as planning basis;

### 6.2 Possible limitations of the ISH01 approach as planning and management tool

- Although the ISH01 approach is largely based on interim expert judgement, data gaps might hamper its application to a certain extent. Hence, all data gaps need be highlighted, which is considered by the ISH01 approach through an own risk category ‘possibly at risk’ in order to be aware of the gaps and to fill these effectively in future.
As the ISH01 approach is largely based on expert judgement, it does not replace Environmental Impact Assessments and case-by-case consideration but provides a good basis for it. This need to be understood and communicates as a pre-requisite when applying the approach in order to prevent limitations and misinterpretations.

In order to reflect current conditions as planning/management basis, risk assessments - as proposed by the ISH01 approach - need to be repeated in regular frequency (e.g. every 4-6 years). This prevents limitation and ensures improved data sets and investigations on changes including positive effects of mitigation measures. This regular procedure is essential to support sustainable water resources management through this low-cost overview approach on any developments.

ISH01 outcomes and findings focus exclusively on impacts from water uses stemming from hydropower but not yet on any other water uses. However, and as indicated above, the approach can be extended in future regarding other water uses and their related impacts.

6.3 Key results of the ISH01 pilot testing

This ISH01 Pilot Testing Report presents a broad spectrum of results that are aligned to the three Modules of the ISH01 approach. The key findings are summarised here.

6.3.1 Identification of Ecologically Sensitive Areas

- A river typology that is based on basic abiotic characteristics is now in place for the LMB and the Sre Pok sub-basin (Map 3). This typology has potential to further improve the description of riverine ecosystems and ESAs in the LMB sub-basin as basis of assessments.

- 29 Candidate Ecological Areas (CEAs) have been identified and illustrated for the Sre Pok sub-basin (Table 6 and Map 4). These CEAs have been used as the basis to identify ESAs. These areas provide the most comprehensive collection of ecological priority areas for the Srepok sub-basin.

- Spatial importance has been allocated to each CEA in the Sre Pok sub-basin (Table 8), with reference to national planning documents.

- Human pressures on each CEA have been assessed and have been summarised in one final Map 11 illustrating the combined pressures.

- Final Ecologically Sensitive Areas have been successfully identified following the ISH01 technical approach.

- ESAs are allocated to three categories that indicate their level of sensitivity (high; medium; low) and, hence, show how important they are in the Sre Pok basin-wide context (Map 12).

6.3.2 Classification of hydropower and pressures types

- Planned and existing hydropower schemes along the Sre Pok river have been identified characterised and illustrated in a Map (Map 13 and Figure 6).

- Pressure types that can stem from hydropower schemes have been identified (Table 13) as well as risk criteria (Annex 4) have been allocated to each of these to enable the assessment on possible impacts on ESA related river reaches.
6.3.3 Merging of identified ESAs and hydropower

- ESAs and hydropower schemes in the Sre Pok sub-basin have been successfully merged (Map 14) giving a first and informative indication on potential areas of conflict.
- Possible impacts from each pressure type have been assessed and are illustrated in Maps (Maps 15 – 24).
- An overall risk assessment combines all individual risk results from each pressure type (Map 25; Table 16; Figure 18). The results indicate that 76% of the total investigated river length was classified as “at risk”, 24% as “possibly at risk” and 0% as “not at risk” regarding possible impacts from hydropower.
- A set of 25 thematic GIS maps has been developed providing an overview on all implementation steps of the ISH01 approach and illustrating related findings.

6.4 Linkage of the ISH01 study with relevant MRC Programmes and activities

- As stated in the beginning of the report, the ISH01 study aims to contribute to the achievement of the Strategic Priority number 4 of the MRC’s Basin Development Strategy 2011. The Strategy emphasizes ‘the need for evaluation options for development of sustainable hydropower on tributaries, addressing the risks of mainstream hydropower, and assessing alternative energy options to mainstream hydropower’. In this context, the need to move towards sustainable development of hydropower on tributaries is highlighted through ‘identifying sub-basins with high ecological value to be protected and those where hydropower can be developed with limited and environmental impacts’.
- From the point of view of the authors, the ISH01 approach has potential to contribute to the Strategic Priority number 4 of the MRC’s Basin Development Strategy.
- In this context of the latter bullet point, it is recommended to discuss the ISH01 approach and findings with the MRC’s BDP. In follow-up, the BDP views will be integrated into the ISH01 upscaling proposal to be targeted and to fully fit the needs of BDP regarding basin-wide, strategic planning and development.
- The ISH01 approach has potential to contribute to other projects under the MRC’s ISH including the projects of ISH02, ISH03 and ISH06 specifically when it comes to LMB sub-basins. It is recommended to discuss the ISH01 approach and findings with ISH staff as well as the ISH project’s leaders in order to identify overlaps, synergies and possible ISH01 inputs.
- The ISH01 approach opens a door to link sub-basin and tributary management with Mekong mainstream planning. This can be of particular interest for the national level taking into account the principle of country sovereignty. On this level ISH01 can contribute to improved hydropower planning and management also contributing to the regional assets.
- ISH01 proposes a risk assessment approach that allows basic conclusions on impacts from hydropower on riverine systems. In case such assessments would be available on the LMB-wide level, these could contribute to transboundary assessments also taking into account cumulative effects. Hence, the ISH01 approach may be of interest for on-going MRC initiatives like the Council Study as well as projects under the MRC’s Environmental Programme.

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24 River reach upstream the Lower Sesan 2 dam up to the source of the Sre Pok river (see Chapter 4.1/Map 3).
In general, it is proposed by the ISH01 team to raise the above issues on the possible linkage and added values from the ISH01 study to other MRC Programmes, initiatives and projects at the upcoming ISH01 regional consultation in Hoc Cho Minh City (7-8 April 2015). Conclusions and findings will then be added to this chapter in follow-up.

7 BRIEF OUTLOOK TOWARDS BASIN-WIDE UPCALING

According to the ISH01 Study Implementation Plan, a proposal to test the feasibility of basin wide upscaling of the ISH01 approach is planned to be considered within ISH01 Component 3 and over a period of three months. Aligned to the current timeline of the ISH01 study a proposal for upscaling would be implemented until June/July 2015. The completion of this activity, including consultation with the LMB countries, will also close the ISH01 study.

The proposal for basin-wide upscaling of the ISH01 technical approach will be based on the experience, activities and findings within ISH01 Components 1 and 2. It should be highlighted here that the ISH01 Component 3 does not implement the upscaling but to consider the feasibility and benefits and to provide a related proposal. Hence, the ISH01 basin-wide upscaling activities will focus on the development of an upscaling concept that will allow for future implementation. Therefore, the concept will thoroughly outline the aspects needed for LMB-wide upscaling of the ISH01 approach.

The tasks that will be tackled for basin-wide upscaling are:

- Preparation of a concept to upscale the developed ISH01 approaches (ESA identification; hydropower planning and management approach) for the LMB basin-wide scale;
- Inclusion of a Road Map for basin-wide upscaling that indicates how long planning and implementation phases would take;
- Indication of main and most immediate implementation steps;
- Outline of data needs to implement the ISH01 approach on the basin-wide scale and, hence, the 104 LMB sub-basins;
- Outline of linkages to other ISH, BDP and MRC projects in order to understand if information from these could be used for the ISH01 upscaling purposes to identify ESAs and to sustainably plan hydropower;
- Rough outline of technical and personnel capacities that would be needed to implement upscaling taking into account the national and regional level;
- Preparation a concise ISH01 Upcaling Report that will be consulted it with the MRC countries.

At the regional consultation on this ISH01 Pilot Testing Report a presentation on LMB-wide upscaling of the ISH01 approach will be given in order to trigger a related discussion. The discussion should serve the collection and thoughts of the LMB country representatives that should support the development of the ISH01 upscaling report. All ideas will be taken up and reflected accordingly in ISH01 Component 3.
ANNEX 1: CRITERIA AND CONSIDERATIONS THAT PROVIDE A FRAMEWORK TO ASSIGN SPATIAL IMPORTANCE ACCORDING TO AN EXISTING HIERARCHY. (VIETNAM EXAMPLE) THIS NEEDS TO BE REFERENCED AT TABLE 7 IN THE PILOT TESTING REPORT.

Vietnam

Criteria, considerations

A conservation area consists of one or more samples representing the major ecological regions, the species, and the geological phenomenon particularly valuable for scientific, educational, spiritual, recreation or for health rehabilitation in national and/or international.

Each national park must have at least 2 endemic species or 10 species listed in the Red Data Book of Vietnam.

Total area of a National Park should be large enough to maintain ecological sustainability, the minimum area of 7,000 ha (on mainland), on 5,000 ha (on the sea), and over 3,000 ha (wetlands), which was at least 70% of the area is the natural ecosystem with high biodiversity values.

Percentage of agricultural land and residential land compared to the national park area must be less than 5%.

The area must have the species, habitats and natural landscapes especially valuable for scientific, educational, spiritual, recreation or recuperation.

The area must have at least 1 endemic species or 5 species listed in the Red Book of Vietnam.

The minimum area of nature reserve is 5,000 ha (on the mainland), 3,000 ha (on the sea), 1,000 ha (wetlands). In Nature Reserve, an area of natural ecosystems have high biological diversity must occupy at least 70%.

Percentage of agricultural land and residential land area compared to the nature reserve area must be less than 5%.

The area is important habitat (for shelter, foraging, reproduction), have implications for the survival and development of species that are national and/or global important.

The area must have at least 1 endemic species or three species listed in the Red Data Book of Vietnam

The area, depending on the habitat requirements of the species to be protected, but at least 1,000 ha, of which natural ecosystems account for over 70% of the total area of the Reserve.

Percentage of agricultural land and residential land area compared to the SHCA to less than 10%.
Inland Water Protected Area

There is a unique or representative of a natural wetland;
The place of residence, or reproduction regular seasonal varieties, animals and plants endemic, rare or threatened with extinction;
As the frequent presence of more than 20,000 water birds or more than 1 % of the global population or wage sector of any breed, any species;
Keep important role regulating water resources, the ecological balance of a region and particularly valuable to landscape and environment;
There is a special value of human ecological, historical, and cultural to national and local.

Ramsar Site

Wetlands should be selected for the List on account of their international significance in terms of ecology, botany, zoology, limnology or hydrology” and indicates that “in the first instance, wetlands of international importance to waterfowl at any season should be included

Biosphere Reserve

Areas of terrestrial and coastal ecosystems promoting solutions to reconcile the conservation of biodiversity with its sustainable use. They are internationally recognized, nominated by national governments and remain under sovereign jurisdiction of the states where they are located.
ANNEX 2 - DECISION SCHEME TO IDENTIFY ECOLOGICALLY SENSITIVE AREAS

The Table below and the corresponding decision flow diagram describe the classification scheme and the combination options how to allocate Candidate Ecological Areas to high, medium/possible or low ecological sensitivity. The classification is only done in case the conservation status of a Candidate Ecological Area was assessed as vulnerable, fragile and/or unique. The identification is based on the combination of (i) spatial importance of Candidate Ecological Areas and (ii) the level of human pressures on each Candidate Ecological Areas (high/medium/low/too impacted).

Table: Combination options to identify high, low or possible ESAs in case conservation status is assessed as vulnerable/fragile/unique. The identification is based on the combination of (i) spatial importance of Candidate Ecological Areas and (ii) the level of human pressures (high/medium/low/too impacted).

| Local importance | Low pressure | Medium pressure | High pressure | Too impacted |
|------------------|--------------|-----------------|--------------|--------------|
| High ESA         | Medium ESA   | Low ESA         | Low ESA      |
| National importance | High ESA   | Medium ESA      | Low ESA      |
| Regional importance | High ESA   | High ESA        | Medium ESA   |
| Global importance | High ESA    | High ESA        | High ESA     |
| Undefined Importance |          |                 | Medium ESA   |
Figure 5: Decision flow diagram of combination options to identify high, low or possible ESAs in case conservation status is assessed as vulnerable/fragile/unique.
# ANNEX 3: DATA COLLECTION TABLES REGARDING HYDROPOWER VIETNAM AND CAMBODIA

| Damsite name | Boun Tua Sra | Boun Koup | Hoa Phu | Drey H’linh | Sre Pok 3 | Sre Pok 4 | Sre Pok 4A | Drang Phok | Lower Sre Pok 3a | Lower Sre Pok 3b | Lower Sre Pok 4 |
|--------------|--------------|-----------|---------|-------------|-----------|-----------|-----------|-----------|----------------|----------------|---------------|
| **General:** |              |           |         |             |           |           |           |           |                 |                 |               |
| Country      | Vietnam      | Vietnam   | Vietnam | Vietnam     | Vietnam   | Vietnam   | Vietnam   | Vietnam   | Cambodia        | Cambodia        | Cambodia       |
| District/Province | Dak Nong District, Krong No District in Dak Nong Province; Lak District of Dak Lak Province and Lam Ha District, Lam Dong Province | Dak Nong District, Krong No District in Dak Nong Province; Lac District of Dak Lak Province and Lam Ha District, Lam Dong Province | Dak Nong District, Krong No District in Dak Nong Province; Lac District of Dak Lak Province and Lam Ha District, Lam Dong Province | Dak Nong District, Krong No District in Dak Nong Province; Lac District of Dak Lak Province and Lam Ha District, Lam Dong Province | Dak Nong District, Krong No District in Dak Nong Province; Lac District of Dak Lak Province and Lam Ha District, Lam Dong Province | Dak Nong District, Krong No District in Dak Nong Province; Lac District of Dak Lak Province and Lam Ha District, Lam Dong Province | Dak Nong District, Krong No District in Dak Nong Province; Lac District of Dak Lak Province and Lam Ha District, Lam Dong Province | Dak Nong District, Krong No District in Dak Nong Province; Lac District of Dak Lak Province and Lam Ha District, Lam Dong Province | Dak Nong District, Krong No District in Dak Nong Province; Lac District of Dak Lak Province and Lam Ha District, Lam Dong Province | Dak Nong District, Krong No District in Dak Nong Province; Lac District of Dak Lak Province and Lam Ha District, Lam Dong Province | Dak Nong District, Krong No District in Dak Nong Province; Lac District of Dak Lak Province and Lam Ha District, Lam Dong Province |
| River        | Krong No     | Krong No  | Sre Pok  | Sre Pok     | Sre Pok   | Sre Pok   | Sre Pok   | Sre Pok   | Sre Pok        | Sre Pok        | Sre Pok       |
| Latitude (dd.ddd) | 12.2811 | 12.5309 | 12.6494 | 12.6713 | 12.7532 | 12.8078 | 12.8942 |          | 4.2 km upstream of Vietnamese/Cambodian border | 13.431 | 13.175 | 13.044 |
| Longitude (dd.ddd) | 108.0366 | 107.9241 | 107.9099 | 107.9076 | 107.8766 | 107.8560 | 107.8112 |          |                | 107.014 | 107.38 | 107.423 |
| Status (planned/built) | operating | operating | operating | operating | operating | operating | operating | planned | planned | planned | planned |
| Dam height (m) | 83 | 34 | 6 | 7.5 | 52.5 | 25 | not applicable as in canal | - | 43 | 29 | 32 |
| Damsite name | Buon Tua Sra | Boun Koup | Hoa Phu | Drey H’linh | Sre Pok 3 | Sre Pok 4 | Sre Pok 4A | Drang Phok | Lower Sre Pok 3a | Lower Sre Pok 3b | Lower Sre Pok 4 |
|-------------|-------------|-----------|---------|-------------|----------|----------|----------|-----------|----------------|----------------|---------------|
| Dam crest elevation (masl) | 492.3 | 415.5 | 302 spillway, 307 dam crest | 308 | 277.5 | 218.8 | not applicable as in canal | - | - | - | - |
| Functioning fish pass in place? | no | no | no | no | no | no | - | not mentioned in pre-feasibility report | not mentioned in pre-feasibility report | not mentioned in pre-feasibility report | - |
| Tailrace weir type | flooded chute | unknown | flooded chute | flooded chute | flooded chute | flooded chute | flooded chute | - | - | - | - |
| Main purpose of dam | multi purposes power, irrigation water provision | multi purposes | power generation | power generation | power generation | multi purposes | power generation | power generation | power generation | power generation | power generation |
| Sediment management structures | no, no sedimentation problem | no, no sedimentation problem | sediment trap dredged when necessary | none | none | unknown | none | sand flushing sluice | sand flushing sluice | sand flushing sluice | - |
| **Reservoir data:** | **Total reservoir storage volume (m3)** | 786,900,000 | 73,780,000 | 2900000 (no reservoir, only approach canal) | 218,990,000 | 29,320,000 | 29,320,000 | - | 5,863,000,000 | 240,000,000 | 204,000,000 |
| | **Life reservoir storage volume (m3)** | 522,600,000 | 25,630,000 (operator stated 50,000,000) | 1,000,000 | 1400000 (no reservoir, only) | 62,850,000 | 8,440,000 | 8,440,000 | - | 3,931,000,000 | 66,000,000 | 44,000,000 |
| Damsite name       | Buon Tua Sra | Boun Koup | Hoa Phu | Drey H'linh | Sre Pok 3 | Sre Pok 4 | Sre Pok 4A | Drang Phok | Lower Sre Pok 3a | Lower Sre Pok 3b | Lower Sre Pok 4 |
|-------------------|-------------|-----------|---------|-------------|-----------|----------|-----------|------------|-----------------|-----------------|----------------|
| Reservoir area (km²) |            |           |         |             |           |          |           |            |                 |                 |                |
|                   |             |           | 37      | 6           | n/a       | -        | 18        | 4          | 4               | 721             | 39              |
| Reservoir length (km) |            |           |         |             |           |          |           | 6          | 4               |                 | 15              |
| Sediment management plan |            |           |         |             |           |          |           |            |                 |                 |                |
|                   |             |           |         |             |           |          |           |            |                 |                 |                |
|                   |             |           |         |             |           |          |           |            |                 |                 |                |
| Water quality data availability |            |           |         |             |           |          |           |            |                 |                 |                |
|                   |             |           |         |             |           |          |           |            |                 |                 |                |
| Eutrophication signs? (existing dams) |            |           |         |             |           |          |           |            |                 |                 |                |
|                   |             |           |         |             |           |          |           |            |                 |                 |                |
| Eutrophication expectation? (planned dams) |            |           |         |             |           |          |           |            |                 |                 |                |
|                   |             |           |         |             |           |          |           |            |                 |                 |                |
| Hydropower turbine data: |            |           |         |             |           |          |           |            |                 |                 |                |
| Turbine type       | Francis     | Francis   | Kaplan (Bulb) | Kaplan | Francis | Kaplan | Kaplan | - | Kaplan | Bulb | Bulb |
| Intake type        | tower, un gated, | direct (no tower) | dam wall | direct (no tower) | direct (no tower) | direct (no tower) | direct (no tower) | - | - | 3 orifices |
| Dam site name | Buon Tua Sra | Boun Koup | Hoa Phu | Drey H'linh | Sre Pok 3 | Sre Pok 4 | Sre Pok 4A | Drang Phok | Lower Sre Pok 3a | Lower Sre Pok 3b | Lower Sre Pok 4 |
|--------------|-------------|-----------|---------|-------------|----------|---------|----------|----------|----------------|----------------|--------------|
| **Intakes height (m)** | 22.5m | 46.5 | 98.5 | 15.8 / 18.5 | 60 | 17.07 | 14.8 | - | 30.2 | 14.6 | 11.9 |
| **Rated turbine head (m)** | 48.3 | 316 (2x 158) | 432 | 76.5 / 101 | 412 | 506 | 500 | 1699.2 | 817.2 | 736.8 |
| **Design turbine discharge (m³/s)** | 48.3 | 316 (2x 158) | 432 | 76.5 / 101 | 412 | 506 | 500 | 1699.2 | 817.2 | 736.8 |
| **Design mean monthly flow (m³/s)** | depends on upstream release | 220.8 | | | | | | | | | |
| **Max turbine discharge (m³/s)** | 204.9 | 316 | 94.9 / 101 | 412.8 | 507 | 498 | 1699.2 | 817.2 | 736.8 |
| **Operation schedule** | peaking, depending on reservoir level, power demand and irrigation demand | peaking | peaking | water availability dependent, no specific peaking | peaking | depends on season | depends on flow from upstream Sre Pok 4 | run of river | run of river | run of river |
| **Peak power operation?** | yes | yes | 10hrs/day | no, flow dependent / unknown | 12 hrs | sometimes | sometimes | | | |
| **Length of downstream influence of flow fluctuations (km)** | 10 | 10 | 10km | 3 | | | | | | | |
| Damsite name | Buon Tua Sra | Boun Koup | Hoa Phu | Drey H'linh | Sre Pok 3 | Sre Pok 4 | Sre Pok 4A | Drang Phok | Lower Sre Pok 3a | Lower Sre Pok 3b | Lower Sre Pok 4 |
|--------------|-------------|-----------|---------|-------------|---------|---------|---------|-----------|-------------|--------------|--------------|
| Baseline site hydrology (before construction of the dam): | Catchment area (km²) | 2930 | 7980 | 8880 | 9410 | 9586 | 9560 | 25311 | 14341 | 13727 |
| Average annual flow at site (m³/s) | 102... sure? this is exactly single turbine discharge... recheck | 217 | 241 | 250 | 258 | 245 | 713 | 396 | 378 |
| Mean monthly flow at site (m³/s) | 56,9/39,0/3 | 1,5/32,2/48 | 3,79,5/101,2 | 188,0/207,5/230,8/14,8,9/101,1 | spillway is spilling about 4 months/yea r | 148/88/63,4 | /66,2/113/1188,233/347 | /434/530/433/315 | 153/91/67/69/118/195 | /238/355/445/543/439 | /322 | 713 | 396 | 378 |
| Min monthly flow at site (m³/s) | 18,8/15,8/1 | 3,9/13,9/20 | 9/27/23,3/6 | 7,0/87,9/60 | 5/34,2/23,5 | 4400 | 160 m³/s min discharge from us hydropower plants | 36,9/24,4/1 | 8,3/22,0/32,9/39,3/96,1 | /111,8/218,3/144,3/95,9/90,8 | 63,7/40,9/2 | 7,1/39,8/47,2/114,3/139,6/236,8/17 | 2,8/120,5/1 | 11,8 | 3,4 | 1.7 |
| Max monthly flow at site (m³/s) | 145,2/110,9 | /106,8/102,0/158,8/237,4/192,1/39,2,8/327,1/7 | 31,7/331,6/ | 281,5 | 8000 (operator says 1000) | 360,5/168,8 | /104,7/132,6/388,8/490,5/370,6/95 | 0,8/739,9/1 | 322,3/1040,2/942,5 | 366,0/156,8 | /119,3/141,8/406,0/506,0/397,1/11,08,5/908,8/1392,1/108,6,5/921,4 | 3536,4 | 1794,2 |
| Min recorded flow at site (m³/s) | 0.9 | unknown | unknown | 13.4 | 8.2 | depends on upstream Sre Pok 4 release | | | | 0 | 0 |
| Average annual | negligible | negligible | unknown | 0.21 | unknown | negligible | 336 | 87 |
| Damsite name | Buon Tua Sra | Boun Koup | Hoa Phu | Drey H’linh | Sre Pok 3 | Sre Pok 4 | Sre Pok 4A | Drang Phok | Lower Sre Pok 3a | Lower Sre Pok 3b | Lower Sre Pok 4 |
|-------------|--------------|-----------|---------|-------------|-----------|-----------|-----------|-----------|----------------|----------------|--------------|
| sediment yield at site (Mm3/a) | | | | | | | | | | | |
| Minimum ecological flow requirement (m3/s) | not implemented but minimum 70 m3/s discharge required during irrigation season | 5 | 10 | unknown | 0.7 in original riverbed (between dam and HPP), not valid for river downstream of HPP | 8.23 (operator says 27) | 8.23 m3/s will be maintained in section between Sre Pok 4 and Sre Pok 4a | not mentioned in pre-feasibility report | - | |
| | | | | | | | | | | | Power generated |
ANNEX 4: RISK CRITERIA FOR IMPLEMENTATION WITHIN THE RISK ESTIMATION APPROACH TO ANALYSE POSSIBLE IMPACTS ON ESAS STEMMING FROM HYDROPOWER. THE TABLE SHOWS CRITERIA THAT ARE APPLIED USING EXPERT JUDGEMENT IN ORDER TO DETERMINE IF AN ESA CAN BE IDENTIFIED TO BE ‘AT RISK’ AND ‘NOT AT RISK’ REGARDING SIGNIFICANT IMPACTS STEMMING FROM HYDROPOWER PRESSURE TYPES. THE THIRD CATEGORY IS NOT INCLUDED HERE BUT APPLIES IN CASE NO SUFFICIENT CRITERIA DATA ARE IN PLACE.
| SPECIFIC THEMATIC ASPECT TO ASSESS RISK | SPECIFIC RISK CRITERIA ACCORDING TO THREE RISK CATEGORIES | Risk Categories |
|----------------------------------------|----------------------------------------------------------|----------------|
| Fish migration barriers / River and Habitat Continuity Interruption | Functioning fish bypass facility in place? | No functioning fish bypass channel is in place | True = At Risk |
| | | Functioning fish bypass channel is in place | True = Not At Risk |
| | | Currently no sufficient data are available and detailed data investigation is needed before doing a risk assessment. | Possibly At Risk |
| Sediment Transport and Balance | Is the natural sediment transport ensured? | Existing Dams: Sediment transport is not ensured and the sediment equilibrium between hydraulic, river morphology and ecology is disturbed. | True = At Risk |
| | | Planned Dams: The dam design does not ensure that sediment transport causing a disturbed sediment equilibrium between hydraulic, river morphology and ecology. | |
| | | Existing Dams: Sediment transport is ensured and the sediment equilibrium between hydraulic, river morphology and ecology un-disturbed. | True = Not At Risk |
| | | Planned Dams: The dam design does ensure that sediment transport and, hence, the sediment equilibrium between hydraulic, river morphology and ecology will be in place. | |
| | | Currently no sufficient data are available and detailed data investigation is needed before doing a risk assessment. | Possibly At Risk |
| Sediment Flushing and Possible Impacts on Aquatic Environment | Is the sediment management done in an environmentally friendly operation mode? | Existing Dams:  
(i) Sediment flushing is not operated/planned in an environmentally friendly way but in strong pulses. The sudden release of sediment can in consequence negatively impact on the downstream river section and in particular the aquatic environment.  
(ii) The inter-relationships between hydraulics, river morphology and ecology are not considered/planned (individual dams) and when assessing the cumulative effect of sediment changes due to operation of a cascade of dams. | True = At Risk |
| Hydrological alteration: Change of downstream flow regime Peak Operation | Are hourly/daily water level & flow regime fluctuations within the limits considering natural conditions? Is the peak-flow management sufficient to support downstream ecosystem health for | Existing Dams:  
Sediment flushing is operated in an environmentally friendly way and not in strong pulses. Release of sediments does not negatively impact on the downstream river section and in particular the aquatic environment.  
(ii) The inter-relationships between hydraulics, river morphology and ecology are considered/planned (individual dams) and when assessing the cumulative effect of sediment changes due to operation of a cascade of dams.  
Currently no sufficient data are available and detailed data investigation is needed before doing a risk assessment. | True = Not At Risk |
| | | True = At Risk |
| | | Possibly At Risk |
### aquatic species/fish?

- **(i) For rivers with small & medium catchment areas <1,000 km²:**
  - Discharge amplitude operated/ planned < 1.5 (monthly basis)

- **(ii) For rivers with large catchment areas >1,000 km²:**
  - No peaking is operated and discharge amplitudes are not observed.

- **(iii) The discharge of turbines is not significant compared to the overall discharge from the dam (spillway).**

Currently no sufficient data are available and detailed data investigation is needed before doing a risk assessment.

| True - Not At Risk |
|--------------------|

### Hydrological alteration:

**Change of downstream flow regime**

**Altered or reduced downstream flooding and altered inundation areas**

Does the dam operation significantly alter the flow regime as it existed prior to dam construction? Are flooding and inundation areas maintained compared to conditions prior to dam construction?

- **(i) Annual flow- and inundation cycle is altered and not within the average min/max monthly discharge range based on historic monthly flow records**
- **(ii) The life dam storage is larger than three times the monthly inflow and this storage capacity can alter the natural flow regime/aquatic fauna and flora in case of sudden storage release.**

| True - At Risk |
|----------------|

- **(i) Annual flow- and inundation cycle is near natural and within the average min/max monthly discharge range based on historic monthly flow records**
- **(ii) The dam storage is smaller than three times the monthly inflow and this storage capacity cannot alter the natural flow regime/aquatic fauna and flora in case of storage release.**

Currently no sufficient data are available and detailed data investigation is needed before doing a risk assessment.

| Possibly At Risk |
|------------------|

### Hydrological alteration:

**Change of downstream flow regime**

**Insufficient environmental flow below the dam**

Is the environmental flow below the dam sufficient to maintain aquatic ecosystem health for species/fish?

- **(i) No water below dam (full year or temporary)**
- **(ii) Flows < Mean Monthly Low Discharge (=environmental flow). Hence, the discharge below the dam is not sufficient to maintain aquatic ecosystem health for species.**
- **(iii) No implementation of the operator to maintain the environmental flow below the dam (see above).**
- **(iv) No regulative policy framework to ensure environmental flows is in place.**

| True - At Risk |
|----------------|
| Hydrological alteration: Change of upstream flow regime | Is the free flowing river character upstream the dam maintained instead of shifting to a lake-like character? |
| --- | --- |
| Shift from river to lake-like character due to reservoir effect | (i) Environmental flow below the dam is ensured (flow > Mean Monthly Low Discharge) and aquatic ecosystem health for species is ensured.  
(ii) Dam operator maintains the environmental flow.  
(iv) Regulative policy framework to ensure environmental flows is in place.  
Currently no sufficient data are available and detailed data investigation is needed before doing a risk assessment. |
| | True - Not At Risk |
| Hydrological alteration: Change of upstream flow regime | Is the free flowing river character upstream the dam maintained instead of shifting to a lake-like character? |
| --- | --- |
| Shift from river to lake-like character due to reservoir effect | (i) For rivers with small & medium catchment areas < 1,000 km²:  
Length of reservoir > 1,000 m  
or  
(ii) hydropower chain causing cumulative reservoir effects  
(iii) For rivers with large catchment areas >1,000 km²:  
Length of reservoir > 2,000 m  
or  
(iv) hydropower chains causing cumulative reservoir effects  
Currently no sufficient data are available and detailed data investigation is needed before doing a risk assessment. |
| | True - At Risk |
| Alteration of Water Quality | Is the near-nature like water quality regime upstream and downstream the dam maintained? |
| --- | --- |
| | (i) Water quality data are not available and thresholds are exceeded  
or  
(ii) Reservoir water is impacted by obvious eutrophication signs like algal blooms  
or  
(iii) Residual reservoir time > 1 month (reservoir volume > monthly flow)  
or  
(iv) Turbine intakes are drawing water from the entire reservoir water column  
Currently no sufficient data are available and detailed data investigation is needed before doing a risk assessment. |
| | True - At Risk |
### Water Quality Criteria

(i) Water quality data are available and thresholds are not exceeded
or
(ii) Reservoir water is not impacted by obvious eutrophication signs like algal blooms
or
(iii) Residual reservoir time < 1 month (reservoir volume < monthly flow)
or
(iv) Turbine intakes are not drawing water from the entire reservoir water column

- **Currently no sufficient data are available and detailed data investigation is needed before doing a risk assessment.**

### Habitat Change/Reduction

| Question | Decision |
|----------|----------|
| Are ESA’s affected by newly inundated reservoir areas? | Habits are significantly altered due to dam | **True - At Risk** |
| | Habits are not significantly altered due to dam | **True - Not At Risk** |
| | Currently no sufficient data are available and detailed data investigation is needed before doing a risk assessment. | **Possibly At Risk** |
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