Himalayan Aquatic Biodiversity and Hydropower: Review and Recommendations

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Report

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ABSRTACT
Hydropower is an important source of electricity for Nepal, with 86 existing hydropower projects and over 200 planned projects. This report gives a status of biodiversity mitigation measures in Nepal's hydropower plants, and it gives recommendations for authorities and hydropower utilities to improve the sustainability in existing and future projects. The study revealed that river flows and aquatic habitats are seriously impacted by hydropower in Nepal. Dams cause habitat fragmentation and disrupt fish migration. The main mitigation measures needed are continuous release of environmental flows the whole year, and facilities to ensure safe up- and downstream fish migration passed dams. Recommendation for urgent actions for the Government, several Ministries and hydropower developers are given. It is recommended to develop a Master Plan for hydropower development in Nepal, to clarify the roles of different ministries and other authorities, and to strengthen the capability of monitoring and reviewing mitigation measures.

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Preface

This report is written for the World Bank supported project "Himalayan aquatic biodiversity and hydropower: Review and Recommendations." The objective of the study was to review and compare good international practice for mitigation of hydropower impacts on aquatic ecosystems to current practice of mitigation in Nepal. This report is based on two previous reports, "Good international practice for mitigating hydropower impacts on ecosystems and aquatic biodiversity" by Harby et al (2020) and "Nepal Hydropower -Biodiversity Mitigation Status Report" by Shah et al (2020).

In addition to the authors, Pravin Karki (Lead Hydropower Specialist), Josefo Tuyor (Senior Environmental Specialist), Scott Hanna (Senior Environmental Advisor), and Nicholas Zmijewski (Environmental Engineer) from the World Bank have contributed with comments and review of the report, as well as have taken part in important discussions to improve the outcome.

The report does not rely upon a comprehensive use of references. However, most statements are based on scientific journal articles, reports and information combined with the authors own experience and judgement.

What is in this report?

The report provides a comparison between good international practice for biodiversity mitigation inhydropower with current established practices implemented in Nepal. The report determines key gaps and provides targeted recommendations for Nepal to improve and enhance the biodiversity impact mitigation and management as related to hydropower development and operation.

The report includes a brief description of aquatic biodiversity mitigation measures in hydropower, especially recommended for Nepal. The report describes the most relevant legislation and regulationsthat is necessary to ensure sustainable development of hydropower, and it provides a brief description of the identified gaps as well as recommendations for strengthening the system in Nepal.

The report continues to detail common biodiversity mitigation measures, the status of implementation in Nepal, gaps, and finally makes recommendations for specific mitigation measures. The impacts related to hydropower on aquatic biodiversity are focusing mostly on fish, as well as possible mitigation measures are categorized according to five specific hydropower impact categories:

- Changes to flow and temperature regime
- Alteration and loss of aquatic habitat
- Disruption of upstream fish migration
- Disruption of downstream fish migration
- Decline in fish populations

For each of these categories, gaps are identified, and specific recommendations are made to the Nepal government and relevant ministries, and to hydropower developers and operators for achieving environmentally and socially sustainable hydropower. At the same time, key actions for planning, construction and operation of hydropower plants are provided.

Acronyms

ADB: The Asian Development Bank
BES: Brief Environmental Study
CIA: Cumulative Impact Assessment
DoE: Department of Energy
DoED: Department of Electricity Development
EFlow: Environmental Flow
EIA: Environmental Impact Assessment
EPA: Environmental Protection Act
EPR: Environment Protection Rules
ESIA: Environmental and Social Impact Assessment
GoN: Government of Nepal
HEP: Upper Arun Hydroelectric Project (HEP)
HPPs: Hydropower projects
IEE: Initial Environmental Evaluation
IFC: international Finance Corporation
LDC: Load Dispatch Center
MoEWRI: Ministry of Energy, Water Resources and Irrigation
MoFE: Ministry of Forests and Environment
NEA: The Nepal Electricity Authority
PPA: Power Purchase Agreement
USAID: US Agency for International Development
WWF: World Wildlife Fund

Executive summary

Introduction to Hydropower and Biodiversity in Nepal

Around the world, countries struggle with the challenge of providing energy for their citizens without negatively impacting their natural environment. All electrical energy generation methods result in some impacts and governments seek to find a balance to achieve "sustainable development."

Hydropower is an important source of electricity for Nepal, with 86 existing hydropower projects (HPPs) with an installed capacity of 1200 MW and more than 200 hydropower projects with the total capacity of more than 7000 MW are under construction at present (DoED, 2021). Additionally, the country's theoretical hydroelectricity generation potential is estimated at 83,000 MW, out of which 42,000 MW is economically viable (WECS, 2010). HPPs inevitably have negative impacts on the aquatic species and habitats of the Himalayan rivers in which the HPPs are located. Dams change the flow, water temperature, sediment and nutrient transport and aquatic habitats (considering physical factors prevailing in the river and riverbed), and block fish migration. HPPs can also have severe impacts on the natural resources and livelihoods of the people living in the watershed.

Nepal harbors a large array of aquatic biological diversity of great importance to the region, including fish such as the endangered Golden Mahaseer, Tor putitora, that migrate from lowland rivers to high mountain streams for spawning. Nepal's rivers also contain a diverse array of macroinvertebrates (e.g. crabs and shrimps, aquatic insects) which are an important source of food for many larger animals and indicators of good water chemical quality. Many migratory and resident birds also depend on the rivers of Nepal for feeding and breeding grounds.

Nepal has environmental regulations designed to mitigate the negative impacts of HPPs. These include the Environment Protection Act 2019 (EPA 2019), Environment Protection Rules (EPR 2020), Aquatic Life Protection Act (1961 AD) and First Amendment (1998 AD), which require HPPs to develop a fish ladder or hatchery. Legislation also includes the Hydropower Development Policy 2058 BS (2001 AD) that requires downstream Environmental Flows (EFlows) of either 10% of the minimum mean monthly flow or the quantity identified in the EIA study, whichever is higher and also ensures the implementation of the mitigative measures proposed in the EIA report.

Under EPA 2019 and EPR 2020, the Ministry of Forests and Environment (MoFE) and the Department of Environment (DoE) are the agencies principally responsible for monitoring and auditing environment and social impacting activities of HPPs. In the past, HPP monitoring was carried out by the Ministry of Energy, Water Resource and Irrigation.

Current Status of Biodiversity Mitigation in Nepal HPPs

The World Bank commissioned a study to evaluate the present status of 50 active HPPs in Nepal regarding how they mitigate their project impacts on aquatic ecosystems, including flow regimes, aquatic habitat, and fish migration. The study evaluates the current practices of Nepal HPPs for biodiversity mitigation as compared to international good practices for hydropower and biodiversity.

The study revealed that in Nepal:

River flows are seriously impacted by HPPs.

- None of the 50 HPPs conducted any studies of the Environmental Flows (EFlows)[1] to determine the flow rate to be released to ensure that fish and other aquatic life can survive in the river, but instead defaulted to the baseline 10% minimum flow release based onthe Hydropower Development Policy, 2001.
- The HPPs reported that the Load Dispatch Center (LDC) requires all HPPs to produce maximum power (per their PPA) during the dry season, which often results in no EFlows released fromthe HPPs for 3-4 months.
- Peaking production changes the timing and duration of water and sediment flows, impactingthe downstream aquatic habitats and the species living in the river, including the cues for fishmigration and breeding.

Aquatic Habitats are changed or eliminated both upstream and downstream of HPPs.

- Lack of release of EFlows during the dry season results in a dry riverbed downstream, in somecases for more than 10 kilometers. Fish must retreat to pools where they are easily caught bylocal people or go downstream. Aquatic macroinvertebrates (fish food source) may die when the riverbed dries up.
- Upstream river habitat is changed to a lake environment within the reservoir, fostering lake species which often include invasive fish species such as Chinese carp which compete with native river fish for food.

Dams cause habitat fragmentation and disrupt upstream and downstream fish migration

- None of the 50 HPPs conduct any mitigation activities to enhance or restore stream beds, ensure channels for fish passage, or manage the reservoir for native species.
- Most of the rivers in Nepal have at least one HPP that blocks fish migration. Only a few rivers,such as the Karnali River, remain free-flowing and allow long-range migration of the globallyendangered Golden Mahseer and other migratory fish.
- Twelve of the 50 HPPs have fish ladders for upstream fish migration. However, none of the fish ladders were designed for the specific migratory fish in the river and only one has been monitored to assess if fish are successfully passing through the fish ladder.
- None of the 50 HHPs have any specific mitigation to facilitate downstream fish migration.

Effectiveness of fish stocking is limited.

- Three of the 50 HPPs have done fish stocking, but only one HPP (Kaligandaki) has continuous(annual) rearing and stocking of fish, mainly for local human consumption rather than for ecosystem preservation.
- Only a few native fish species have been successfully raised in Nepal hatcheries (mostly *Labeo* species), and the survival rate of the stocked fish is not monitored.

[1] See Brisbane Declaration for full description

Good International Practice for HPP Mitigation for Biodiversity

- Good International Practice for mitigating HPP impacts from around the world show examples of design and successfully implemented engineering and ecological solutions to reduce HPP impacts on aquatic biodiversity, while maintaining electricity production, including fish passage (ladders, lifts, bypass channels), EFlows, modifying and regulating peaking regimes, riverbed restoration, as well as guidance systems and barriers for downstream fish migration.
- Many countries have developed and implemented strategic planning for hydropower development, as well as a system of licensing and permitting that includes terms to mitigate impacts on the ecological and social environment. The terms and conditions are subject to oversight by the authorities, and there are usually penalties for non-compliance to the regulations or legislation.

In particular, we recommend that the following set of critical and urgent actions be implemented toset Nepal on the path to environmental sustainability for its HPPs.

Urgent Actions for the Government of Nepal	
Action #1	Clarify and strengthen the roles of government agencies in reviewing and EIAs for HPPs, and in monitoring of hydropower for compliance with environmental commitments, including release of minimum EFlow and mitigation for biodiversity. In the recent past, the Department of Electricity Development (DoED) within the Ministry of Energy, Water Resources and Irrigation (MoEWRI) and The Nepal Electricity Authority (NEA) have conducted monitoring of hydropower projects. Under EPA 2019 and EPR 2020, the Ministry of Forests and Environment (MoFE) and the Department of Environment (DoE) are the agencies principally responsible for monitoring and auditing environment and social impacting activities of HPPs.

Urgent Actions for the Ministry of Energy, Water Resources and Irrigation (MoEWRI):	
Action #1	Prepare a Master Plan for hydropower development in the country that seeks balance power generation with electricity demand, power sources (including renewable energies), and environmental and societal needs. The Master Plan should include hydrological studies of hydropower potential and consider initiatives that are evaluating priority areas for aquatic protection in Nepal, such as the mapping of sensitive aquatic habitats by the World Wildlife Fund (WWF)/US Agency for International Development (USAID) and input from MoFE (see below)
Action #2	When considering licensing for hydropower projects, MoEWRI should require HPPs carry out a Cumulative Impact Assessment to evaluate the cumulative impacts of their project in relation to other basin-wide developments. When possible, MoFE should assist and support a Basin-wide Cumulative Impact Assessment in order to evaluate the impacts of multiple HPPs with other development, to make better decisions at the basin scale.
Action #3	Require continuous release of minimum EFlows from HPPs, including during the dry season. NEA and the Load Dispatch Center must respect the minimum EFlow release requirement and require HPPs to release EFlow during the dry season even when there is high demand for power. Fines should not be imposed on HPPs that adhere to legislation and release minimum EFlows thereby making it impossible to generate full power.

Urgent Actions for the Ministry of Forests and Environment (MoFE):	
Action #1	Enhance the ability of the environmental staff to review EIAs and IEEs, fish ladder designs, and to monitor implementation of mitigation measures committed in these documents, by hiring additional staff, offering training in biodiversity management and monitoring, and providing incentives to retain staff so that expertise may be maintained.
Action #2	Conduct Strategic Environmental and Social Impact Assessments for each River Basin to feed into the Hydropower Master Plan for Nepal.
Action #3	Visit and monitor the release of EFlows from HPPs and other mitigation measures committed in the EIA. Levy fines on HPPs that do not release adequate EFlows. Require HPPs to provide real-time EFlows release data to MoFE, preferably online.
Action #4	Require monitoring reports from HPPs on fish ladder efficiency and other mitigation for biodiversity, including data on the number of fish passing through the fish ladder monthly. Visit and monitor fish ladders to ensure they are functioning adequately and have sufficient water flow.

Urgent Actions for Hydropower Developers:	
Action #1	Conduct a robust EIA that includes comprehensive biodiversity surveys that provide the baseline for assessing project impacts and developing mitigation measures for biodiversity. EIA should include a Cumulative Impact Assessment and Biodiversity Management Plan or Biodiversity Action Plan.
Action #2	Design and implement an operating mode that minimizes impacts on downstream aquatic biodiversity. Consider adjusting peaking frequency and amplitude to reduce impacts during fish spawning and hatching seasons.
Action #3	Conduct EFlow assessment and provide adequate continuous minimum EFlow (24 hrs/day throughout the year) Ensure there are adequate structures to release EFlows to the diversion reach of the river. Provide continuous data on EFlows release to MoFE, preferably online.
Action #4	Flush sediments from reservoirs only during the high flow monsoon season. Flushing with other HPPs in the river basin to ensure downstream flow fish connectivity for fish movements.
Action #5	Ensure adequate habitat for fish and aquatic biodiversity, particularly in the diversion reach, spawning tributaries, and reservoir. Mitigation measures may include habitat modification, adequate water levels and invasive species management.
Action #6	Implement design and mitigation measures to allow for upstream and downstream fish migration, such as fish ladders for upstream migration (if appropriate) and downstream mitigation such as a gate or curved spillway that can release surface water, and measures to prevent fish from entering the turbines (trash rack, bubbles, guidance nets, etc.). Spillway designs should avoid creation of plunge pools that could result in entrainment of air bubbles at depth causing supersaturation of dissolved gases that could in turn lead to gas bubble disease in fish.

1. Introduction

Himalayan countries, with their immense water resources and steep mountain gradients, have greatpotential for hydropower development, which can provide much needed electricity to their citizens.Despite this tremendous hydropower potential, the countries are facing shortages for both base load energy and peak demand energy. Currently in Nepal, only about 70 percent of the country's households have access togrid electricity. The Government of Nepal (GoN) has set a target of providing electricity to the entire population of the nation by 2027 (90 percent through the national grid and 10 percent from decentralized generation solutions) and to export a substantial amount of power.

Large hydropower projects (HPPs) are planned for almost all the major rivers across the Himalayas,in India, Nepal, Bhutan, Pakistan, and China. Nepal has great potential for hydropowerdevelopment with a rough estimate of more than 80 GW (Kaini and Annandale, 2019). However, theinstalled hydro capacity in 2018 was less than 1,000 MW. Basins of Nepal with great hydropower potential include (from Kaini and Annandale 2019):

1. Karnali and Mahakali river basins with a catchment area of 48,811 km^2 and 16,097 km^2, withapproximate hydropower potential of 36,180 MW (the catchment area of the Mahakali Riverlies in India and Nepal)
2. Gandaki river basin with a catchment area of 36,607 km^2 and approximate hydro potential of 20,650 MW
3. Koshi river basin with a catchment area of 57,700 km^2 and hydro potential of 22,350 MW (thewatershed area lies in Tibet/China and Nepal)
4. Other river basins (i.e., southern rivers) have a catchment area of 3,070 km^2 and hydro potential of 4,110 MW

Nepal also harbors a large array of aquatic biological diversity of great importance to the region. Hydropower projects inevitably cause alteration to the physical conditions such as flow, water temperature, sediment transport and habitats, which again will impact the aquatic ecosystems. Thedisruption of river continuity due to the dam weir is one of the main causes of impact to aquatic organisms, such as migratory fish. Long-range migratory fish in Nepal, which seasonally migrate fromlowland rivers to high mountain streams for spawning, include:

- Mahaseer, (*Tor putitora*), IUCN Red List and Nepal listed as Endangered (EN)
- Sahar, (Tor tor), IUCN Red List Near Threatened and Nepal listed as Endangered
- Alwyn's or Common Snow trout, (*Schizothorax richardsonii*) or (*Schizothorax plagiostomus*), IUCN Red List and Nepal listed as Vulnerable
- Dinnawah snow trout, (*Schizothoraichthys progastus*), IUCN Red List Least concern, Nepal listed as Vulnerable
- Katli, (*Neolissichilis hexagonolepis*), IUCN Red List Near Threatened and Nepal listed as Endangered
- Mottled eel (*Anguilla bengaliensis*), IUCN Red list, near threatened

Nepal's rivers also contain a diverse array of macroinvertebrates (e.g. crabs and shrimps, aquatic insects) which are important sources of food fish as well as for many larger animals and also help to break down nutrients in the aquatic ecosystem, as well as riparian plants, and aquatic mammals such as otters. Many migratory and resident birds also depend on the rivers of Nepal for water and feeding and breeding grounds.

Studies and reviews of the effectiveness of mitigation measures for aquatic biodiversity impacts inNepal have left room for improvement. Surprisingly, a recent review of hydropower potential and the stepsforward for Nepal by Kaini and Annandale (2019) did not mention the impacts of hydropower development on the rich aquatic biological diversity of Nepal. The Asian Development Bank (ADB) recently reviewed general mitigation for aquatic biodiversity protection options for hydropower in relation to Nepal hydropower development. However, the report did not evaluate mitigation practices applied to hydropower projects or provide specific guidance for future hydropower projects (ADB 2018). Shrestha et al (2020) provide a summary of the ecological status of rivers impacted by hydropower projects, stating that the impact of hydropower dams on aquatic ecologiesand the natural environment has not been well researched in Nepal because it is generally acceptedthat the hydropower projects in Nepal are almost all small, run-of-the river types, and they have little impact on aquatic ecologies. However, recent studies on fish populations showed that there are significant impacts. For example, on the Modi River fish populations have declined, and some species have vanished. In addition, despite EIA studies providing details of the potential impacts, very few studies have implemented mitigation measures, such as EFlow, or fish ladders, and if they have, there is virtually no systematic monitoring being carried out. Hydropower projects often divert or bypass water from downstream sections of the river. It is therefore crucial to ensure that diverted river sections receive continuous water flows.

Safe[2] two-way fish passages are one of the key mitigation measures often proposed for hydropower dams. Upstream fish passages, including fish ladders, fish lifts, and nature-like fishways, are structures that assist fish to pass over or around a weir to continue their migration upstream. Downstream fish passage are structures that seek to guide fish to a safe route past dams, weirs, and intake structures normally diverting fish away from the turbines. Upstream fish passages for low dams (<10 m tall weir)are fairly feasible, while the common perception is that fish ladders are prohibitive for high dams(>10 m tall weir). Upstream fish passages have been proven to be effective in hydropower projects inNorth and South America for both low and high dams (see review in Roscoe and Hinch 2010). Downstream fish passage has gained a lot more attention over the last decade. Trash racks, guidance structures and even fish-friendly turbines have been developed and applied at many power plants. However, there are still remaining challenges to secure a safe downstream passage for fish, especially at larger power plants. In the United States, hydropower licensing requires that projects monitor anddemonstrate passage of a high percentage of the fish population across the dam. Furthermore, only asmall number of fish passages in Asia and Africa have been reviewed to evaluate their effectiveness (see

[2] "safe two-way migration" it is concept usually associated with the idea of minimum delay and low levels of injury in relation to the fish passage. This concept is also commonly connected to the concept of "transparency" (Castro-Santos & Haro, 2010) in terms of negligible fitness costs and the idea that the mitigation measure should provide the condition that existed before to the introduction of the barrier.

Schmutz and Mielach 2015 for the Mekong and Kim et al. 2015 for Korea). However, limited information is available on the design and success of both upstream and downstream fish passages in Nepal.

A common alternative to a fish passage structure such as fish ladders is the practice of "trapping and trucking" in which fish are collected on one side of the dam and transported to the other side. This process can range from simple catching of fish with cast nets and transport in small fish tanks, to large-scale collection using a small fish lift and transport in specialized tanker trucks. Another alternative to a fish ladder is the construction of a fish hatchery to supplement native stocks of fish and compensate for the percentage of juvenile fish that are killed during their passage past hydro projects. However, safe passage of fish past the dams should be the primary goal. Some of the Himalayan countries require a fish passage as part of a hydropower project. Nepal's Aquatic Animal Protection Act, regulation 5B, (2017, updated from 1960) requires the construction of a fish ladder or a fish hatchery for hydropower and other water diversion projects.

In addition to ensure safe two-way fish migration past hydropower dams and weirs, it is important to ensure there are suitable living conditions for the migratory species in the reaches between the dams. It is crucial that fish are not led to migrate upstream to unsuitable areas, and the hydro-morphological conditions must meet required standards.

The World Bank and IFC have a long history in the area and are currently engaged in several hydropower projects in Nepal, including Khimti HPP, Kali Gandaki HPP, Upper Trishuli-1 HPP, Upper Arun Hydroelectric Project (HEP), and Kabeli-A HPP. All these hydropower projects will have significant impacts on the aquatic ecosystems and migratory fish species, particularly with cumulative impacts of many hydropower projects within the same basin. It is important to understand the feasibility of mitigation measures for managing hydropower impacts on aquatic biodiversity to maintain key fish migrations and the aquatic biodiversity in Nepal.

This report provides a gap analysis that compares good international practice to mitigate hydropower impacts on fish populations, with practices currently implemented in Nepal. The aim is to determine gaps in current practice and provide recommendations for Nepal to improve its legislation to mitigate the effects of hydropower on biodiversity.

1.1 Relevant legislation and regulation for aquatic biodiversitymitigation measures

Strategic planning of the use of available natural resources ensures that the most beneficial development path is selected. Despite the well-meaning intentions of providing energy, the regulation of the river flow for hydropower production has considerable impacts on the river and surrounding environment. To limit the overall impacts from hydropower on the communities, biodiversity and important ecological values, a good strategy is to develop a **Master Plan** to guide development of hydropower to the most suitable sites with respect to power potential, economy, and environmentaland social impacts. The Master Plan is based on a comprehensive strategic assessment of the environmental and social impacts and values, allowing for a clear consideration of potential gains andlosses from development in key areas in coordination and consultation with relevant ministries, stakeholders, and communities. The Master Plan can, in practice, be revised and updated at regular intervals as additional information is collected and serves as guidance for public and private investorson Government priorities and considerations.

Informed governmental policy, regulation, and enforcement is necessary for sustainable management of natural resources and maintenance of assets. Licenses and permits need to be issued with certain terms and conditions to mitigate impacts on the ecological and social environment (Figure 1). The terms and conditions should be based on a thorough assessment of the potential impacts and risks associated with the design, construction, and operation and maintenance practices of hydropower development. The impact assessment should adapt a structured approach following Environmental and Social Impact Assessment (ESIA) methods which assesses the potential impacts and suggest measures to mitigatethe impacts which can be used to set the terms of the license. It is also crucial to understand the **cumulative impacts through a Cumulative Impact Assessment (CIA)** of several hydropower projects and dams on a given river system when designing mitigation measures. For instance, dams in the lower end of a catchment may have a strong impact on fish populations further upstream, as they may block the access to upstream river sections if not mitigated properly. The terms and conditions need to be subject to oversight by the authorities, and there should be penalties for non-compliance with the terms.

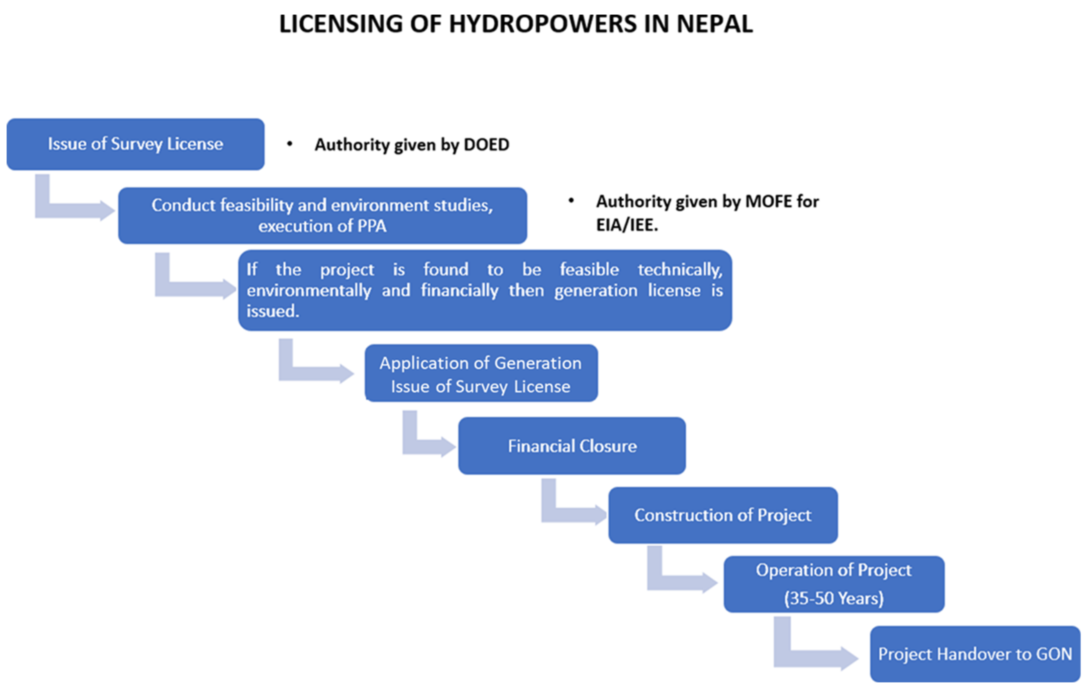

Figure 1. Steps of Development of Hydropower Project:

Source: https://www.lawimperial.com/hydropower-project-development-in-nepal/

Current Nepal Legislation. Nepal has environmental regulations designed to mitigate the negative impacts of HPPs. Legislation includes the EPA 2019, EPR 2020, Aquatic Life Protection Act (1961 AD) and First Amendment (1998 AD) which require HPPs to develop a fish ladder or hatchery. In addition, the Hydropower Development Policy 2056 BS (2001 AD) requires downstream EFlows of either 10% of the minimum monthly flow or the quantity identified in the EIA study, whichever is higher. It also requires implementation of the mitigative measures proposed in the EIA report.

However, in Nepal, the IEE/EIA studies are considered more an administrative requirement than real commitments to environmental mitigation. This limits the effectiveness of the instrument as the results of the studies may not be fully considered during design, construction, and/or operation and maintenance. TheHPPs operated before the year 2000 AD have not undergone ESIA studies and thus have no planning ofmitigation measures, or any implemented measures in place.

It is important that there is an obligation to monitor and evaluate how the mitigation measures function and their effectiveness, and eventually adapt the measures to better meet the objectives through adaptive management. Under EPA 2019 and EPR 2020, MoFE and DoE are the agencies principally responsible for monitoring and auditing ESIA of HPPs. In the past, HPP monitoring was carried out by MoEWRI. Nevertheless, the monitoring activities from NEA, DoED and MoFE (see Annex 1 which includes flowcharts for the monitoring process and institutions involved) do not prioritize monitoring of environmental impacts and are focused on the condition of the power plant and its associated infrastructure since most projects are IPP projects that are mandated to be transferred to the GoN after 35 years of operation.

Recommendations
Nepal Government
Clarify and strengthen the roles of government agencies in reviewing and approving EIAs for HPPs, and in monitoring of hydropower for compliance with environmental commitments, including release of minimumEFlow and mitigation for biodiversity.
Ministry of Energy, Water Resources and Irrigation (MoEWRI)
Prepare a **Master Plan** for hydropower development in the country that seeks to balance power generation with power electricity demand, power sources (including renewable energy), and environmental and societal needs. The Master Plan should include hydrological studies of hydropower potential and consider initiatives that that are evaluating priority areas for aquatic protection in Nepal, such as the mapping of aquatic sensitive habitats by WWF/USAID and input from MoFE (see below) When considering licensing for hydropower projects, MoEWRI should require HPPs to carry out a **CumulativeImpact Assessment** to evaluate the cumulative impacts of their project in relation to other basin-wide developments. When possible, MoFE should assist and support a Basin-wide Cumulative Impact Assessment to evaluate the impacts of multiple HPPs with other development, to make better decisions at the basin scale.
Ministry of Forests and Environment (MoFE)
Enhance the ability of the environmental staff to review EIAs and IEEs, fish ladder designs, and to monitor implementation of mitigation measures committed in these documents, by hiring additional staff, offering training in biodiversity management and monitoring, and providing incentives to retain staff so that expertisemay be maintained. Conduct **Strategic Environmental and Social Impact Assessments** for each River Basin to feed into theHydropower Master Plan for Nepal.
Nepal Hydropower developers
Conduct a **robust EIA** that includes **comprehensive biodiversity surveys** that provide the baseline forassessing project impacts and developing mitigation measures for biodiversity. EIA should include a Cumulative Impact Assessment and Biodiversity Management Plan or Biodiversity Action Plan.

2. Hydropower impacts and recommendations for improved aquatic biodiversity mitigation measures in Nepal

Good practice indicates that the development of hydropower plants and reservoirs should strive towards incurring a no-net-loss or net-gain of biodiversity in the affected areas. This is achieved byimplementing mitigation actions according to the Mitigation Hierarchy (Figure 2, left, adapted from the World Bank Group, 2018). Avoiding predicted impacts (during the planning phase) and implementingmitigation measures (through the operation and maintenance phase) will have an initial and planned investment that will allow the increase of the biodiversity value to reach the objectives. It is also important to consider the need to carry out combined measures such as EFlow, safe upstream and downstream migration routes, and sediment management to improve habitat connectivity and, the biodiversity value. If avoidance or mitigation measures are not considered during the planning phase, the costs and risks of not reduced or non-effectiveness might be higher. In addition, there is a need to carry out maintenance of the measures that includes related costs for maintaining the level of biodiversity value (Figure 2, right).

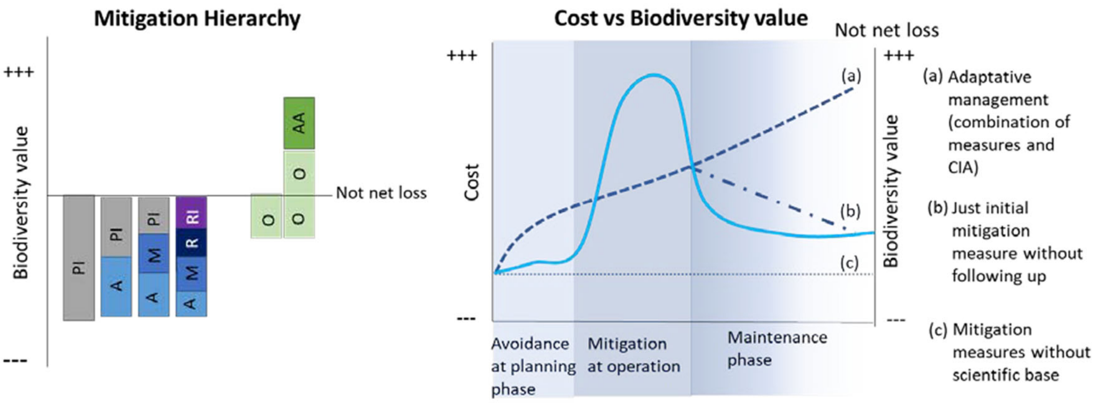

Figure 2. Mitigation hierarchy (left from World Bank Group, 2018) where PI: Predicted Impact, A: Avoidance, M: Mitigation, R: Restoration, RI: Residual Impact, O: Offset and AA: Additional Actions. On the right, Cost for the developer and operator versus Biodiversity value: the blue solid line indicates the cost and the dashed lines the biodiversity value. The cost does not include the natural capital cost, it is cost related to the investment related to design and construct mitigation measures.

The review carried out for Nepal which consisted of field visits to select the HPPs, selection of the 50 HPPs, virtual interviews and review of the HPP IEEs/EIAs and other available literature. Several criteria were taken in account to select the HPPs such as: region, main stem or tributary, type of ownership, age of the HPP, capacity, height of the dam, operation (peaking or not), and type of power plant. Results shows that indicate that the hydropower plants in Nepal seldom implement any aquatic biodiversity mitigation measures, despite requirements for EFlows and fish passages specified by the government (Table 1).

Table 1. Summary of mitigation measures from the Nepal review (n=50 HPPs).

Measures to mitigate the following impacts:	**# HPPs with mitigation**	**% HPPs with mitigation**
Changes to Flow and temperature regime		
Conducted an EFlow assessment as part of ESIA or IEE	0	0%
Dam includes an EFlow dedicated mechanism	0	0%
Report that they release 10% minimum monthly EFlow as required by Nepal Government	33	66%
EFlows released by visited HPPs	0	0%
Report that they release more than 10% EFlow	3	6%
Alteration and loss of aquatic habitat		
Sediment Management- not focused on habitat	50	100%
Disruption of Upstream and Downstream Migration		
Dam including a Fish Ladder	10	20%
Designed Fish Ladder for specific fish species	0	0%
Monitor fish through Fish Ladder	1	6%
Conduct Fish Stocking	4	8%
Conduct Fish Stocking	4	8%
Cumulative Impact Assessment	0	0%

In this report the impacts related to hydropower and aquatic biodiversity (focusing on fish), as well aspossible mitigation measures, are categorized as follows: (i) Flow and temperature regime; (ii) Alteration and loss of habitat; (iii) Upstream fish migration; (iv) Downstream fish migration; and (iv) Declining fish populations.

2.1 Flow regime and water temperature

Flow regime mitigation measures typically consist of the release of water, often called *environmentalflow*, *ecological flow* or just *EFlow,* to river sections with altered flow regime or where water is diverted or bypassed. It can be released during the design, construction operations phases of the project (Table 2). The implementation of EFlows through operational measures (operation planning and scheduling) may require some technical measures (e.g. a technical setup that allows release of waterthrough gates or EFlow turbine(s)) and may be combined with structural measures or hydro-morphological measures carried out in the riverbed or in reservoirs. Carrying out a specific EFlow assessment and consideringa combination of measures could reduce the challenge of releasing large amounts of water outside the turbines which could result in loss of energy and income.

EFlows are often suggested as mitigation measure in ESIAs, or in licensing processes from the authorities as a requirement in certain cases for sustainable management (see section 1.1). Direct monitoring of the effectiveness of the implemented EFlow regime to maintain fish populations is seldom possible. However, overall studies of the fish population through different methods (e.g. electro-fishing, environmental DNA) at representative sites may give a good indication of how well EFlows are helping to sustain fish populations.

Many power plants are doing hydropeaking operations, meaning that they vary the generation rapidly according to the needs in the electricity system. Peaking operations are necessary to maintain systemstability in the electricity grid such as frequency and voltage control, providing balancing services, inertia, reserves and storage, as well as changes due to variations in electricity generation elsewhere, load following or simply lack of sufficient inflow to generate electricity continuously. Hydropeaking operation may have a large effect in the downstream river, as water levels, flow, currents, sedimentload, water temperature and water quality may change rapidly with a large magnitude. In Nepal, the Load Dispatch Centre plays an important role to regulate hydropeaking.

In Nepal, 66% of the studied HPPs reported that they release approximately 10% of the mean monthlyriver flow as EFlow during the dry season, but this was not actually observed in the field. None of theseven HPPs visited were releasing EFlows during the inspection, despite ESIA commitments for most of them. None of the 50 interviewed HPPs measure and document EFlows.

It is not well known how hydropeaking affects biodiversity and fish populations in Nepal. From international experience and literature, it is commonly known that hydropeaking may lead to stranding of fish and other organisms (with or without associated mortality). Rapid changes in habitat conditions lead to the need for fish and other species to move, which increase mortality due to increased stress levels in fish and other organisms as they have to move or being flushed (Harby and Noack 2013).

The following gaps were identified for the 50 HPPs reviewed in Nepal:

- All the HPPs use an EFlow equal to the minimum requirement established by Nepali law, which is 10% of the minimum monthly flow or the quantity identified in the EIA study, whichever is higher.
- EFlow releases of 10% of the minimum monthly flow (as required by Nepal law) are committed in the ESIA but not implemented in practice. Problems can derive from the uncertainty fromhydrological predictions and in the minimum energy production which leads HPPs to not release the EFlow in order to meet the power purchase agreement (PPA).
- The Load Dispatch Centre (LDC) controls the power generation in Nepal for HPPs for HPPs with >5 MW. The HPP is required to prioritize energy production rather than considering biodiversity mitigation (e.g. EFlows).
- The HPPs less than 5 MW are not closely regulated by the LDC and thus should be able to release EFlows. This should be investigated and enforced.
- In national parks and reserves, the Department of National Parks and Wildlife Conservation (DNPWC) have a working policy (Working Policy on Construction and Operation of Development Projects in Protected Areas, 2008) that requires the release of 50% of monthlynatural flow as EFlows. This is not implemented by any of the HPPs in national parks.
- Water temperature data was not included in the initial inventory carried out by the Nepal team but based on the availability of flow regime data it can be assumed that availability of water temperature data will be very limited.

Recommendations
Ministry of Energy, Water Resources and Irrigation (MoEWRI)
Require HPPs to continuously release minimum EFlows, particularly during the dry season. NEA and the LDC must respect the minimum EFlow requirement and require HPPs to release EFlow during the dry season even when there is high demand for power. Fines should not be imposed on HPPs that release minimum EFlows when doing so makes it impossible to generate full power.
Ministry of Forests and Environment (MoFE)
Visit and monitor the release of EFlows from HPPs and other mitigation measures committed inthe EIA. Levy fines on HPPs that do not release adequate EFlows. Require HPPs to provide real- time EFlows release data to MoFE, preferably online.
Nepal Hydropower developers
Conduct EFlow assessment and provide adequate continuous minimum EFlow releases, especially during dry season. Ensure there are adequate structures to release EFlows to thediversion reach of the river. Provide continuous data on EFlow releases to MoFE, preferably online. The type and resolution of EFlow assessment should be determined following the IFC guidance document (World Bank Group, 2018). Design and implement the operating mode to minimize impacts on downstream aquatic biodiversity.Consider adjusting peaking frequency and amplitude to reduce impacts during fish spawning and hatching seasons.

Table 2: Possible River Flow Mitigation Actions per Project Phase

Impact on Biodiversity	Design	Construction	Operations
River Flow	• Operating mode (Run-of-River, Peaking, etc.) • Amplitude/frequency/ ramping of peaking • Height of dam • Reservoir size • EFlows modeling • Include EFlows release mechanism • Intake position in reservoir • Impoundment management	• Release EFlows as needed • Maintain flow through diversion tunnels • Release EFlows during reservoir filling per plan (impoundment)	• Release EFlows • Monitor EFlows release • Follow peaking rules for ramping & flow • Monitor flow rate downstream

2.2 Alteration to habitats

The aquatic habitat is defined in part by the flow regime, the hydraulics and the morphology of the river or reservoir. The physical habitat determines the biotic composition and supports the productivity andsustainability of aquatic ecosystems. Different impacts will occur at different locations in the hydropower system.

The hydropower dam creates a **reservoir or a ponded river** where there previously was a free-flowingriver or a natural lake. The dam will create artificial changes in water level according to hydropoweroperations and inflow. Societal imposed flow discharge regulation and daily filling and drawdown of the reservoir may influence the freshwater species in the reservoir.

Downstream of the dam, **the bypassed or diverted river reaches** between the dam and the powerhouse outlet, will have in general no water flow (Figure 3); unless there is inflow from tributaries or groundwater, thus water must be released as EFlow through gates or by other means. A certain minimum of water is necessary to sustain aquatic life. Habitat and substrate in **river reaches downstream of the powerplant outlet** will receive the same total amount of water as in natural conditions, but it may be distributed differently throughout the year, month, week, and day.

Riverbanks are often covered with embankments and/or flood protection measures, and they may belacking riparian vegetation. This is normally not due to the hydropower project, but it must be considered whenplanning mitigation measures.

In Nepal, none of the studied HPPs have implemented habitat mitigation measures to support the productivity and sustainability of the aquatic ecosystem. Habitat mitigation measures can be implemented during the design, construction, and operations phases of the project (Table 3). Hydropower companies mainly focus on theprotection of their infrastructure such as intakes, settling basins and riverbank protection works for safe power generation. HPP representatives reported that high floods with heavy sediment load every year during the monsoon season hinder activities such as stream bed restoration, ensuring channels forfish passage, and managing the reservoir for native species. Simultaneously, the lack of EFlow beingreleased in the river reaches that were visited and the lack of measurements and monitoring of the 50interviewed HPPs highlights the need of first ensuring the release of EFlows to support any other mitigation measure that could be implemented. This is of special importance in bypassed or diverted reaches, since 98% of the studied HPPs in Nepal have a diversion reach, ranging from 300 m to 36 km.During the dry season these diverted reaches will be completely or partially dried out if the EFlow is not released and no tributaries or groundwater enters these reaches. A combination of a specific EFlow with possible habitat measures (such as hydro- morphological changes) could support the mitigation of habitat-related issues, such as lack of appropriate water depths, water velocities, and habitat connectivity. However, it is also important toknow the specific habitat requirements for the specific fish species in the river systems.

Figure 3. Diverted or bypassed reach downstream Upper Trishuli-3A HPP dam.

In terms of sediments in Nepal, issues vary depending upon the river basin and location. Heavy sediment loads are transported during the monsoon season, with several flood events that transportlarge amounts of silt, sand, gravel, and stones. However, most HPPs (80%) have no problem with sediment management because of the infrastructure installed to handle flushing and stable slopes in the upstream catchment area. Generally, sediment management is done through flushing gates, where the sediments are flushed out by water gravity flow through a sluice gate. Some HPPs are also managing sediments in different ways, such as removing sediments with SediCon technology which uses a serpent pipe that vibrates the sediment deposits and removes them through a sand flushing canal gate. The release of sediment through the sluice gate can be done by stopping the HPP and the power generation for some hours while drawing down the reservoir or flushing sediments during floods. It is important to avoid the sediments being deposited downstream of the gates, since this can block the connectivity between habitats, block possible migration (Figure 4), and clog interstitial spaces with fine sediments affecting, for example, species that lay their eggs within the interstitial spaces and macroinvertebrates.

Figure 4. Sediments deposited after the monsoon downstream Kaligandaki HPP dam. The deposits are

a barrier for connectivity and migration.

Recommendations
Ministry of Forests and Environment (MoFE)
Monitor the release of EFlows from HPPs and other mitigation measures committed in the EIA. Levy fines on HPPs that do not release adequate EFlows. Require HPPs to provide real- time EFlows release data to MoFE, preferably online. Require monitoring reports of habitat quality from HPPs. Visit and monitor fish ladders to ensure adequate functioning and water flow.
Nepal Hydropower developers
Flush sediments from reservoir only during high flow monsoon season. Coordinate flushing withother HPPs in the river basin to ensure downstream connectivity for fish and downstream flushing of sediments. Ensure adequate habitat for fish and aquatic biodiversity, particularly in the diversion reach,spawning tributaries, and reservoir. Mitigation measures may include habitat modification,adequate water levels and invasive species management.

Table 3: Possible Aquatic Habitat Mitigation Actions per Project Phase

Impact on Biodiversity	Design	Construction	Operations
Aquatic Habitat	• Dam location • Length of diversion reach • Flushing plan • Quarry location • Model peaking flows and diversion reach to quantify impact on aquatic habitat • Regulating dam design	• Ensure quarry is not within riverbed or sensitive areas • Maintain river flow through construction period • Monitor aquatic biodiversity	• Release EFlows • Adjust EFlows if too low in diversion • Enhancement of diversion reach • Enhancement of downstream reach (mitigate peaking) • Flushing per plan • Monitor aquatic biodiversity • Operate regulating dam

2.3 Upstream fish migration

Dams and weirs blocking the river can be an impassable barrier for fish to move upstream, leading tofragmentation of habitats and disrupting the longitudinal connectivity of the river.

Different **fish passage facilities** are implemented. The most common are **pool-type fish ladders** for jumping fish that are strong swimmers, and **vertical slot fish ladders** for fish that swim close to the bottom. The pool-type fish ladder is easy to adapt to different locations, and it is the most commonly used. However, the vertical slot fish ladder has a wider suitability for different species even under changing flow conditions. **Baffle-type**

fishways consist of a series of special deflectors on the floor and on the channel sides, applicable for use in steep terrain where space may be limited. They create relatively strong flow conditions, which are suitable for large fish that are good swimmers. **Nature-like fishways** look like small creeks or side channels to the main river that has a much lower slope to make it possible for fish to swim upstream. These fish passage facilities must be carefully designed to meetthe requirements of the local fish population. The main challenge is to make sure fish can find the entrance to the fishway, and to adapt the flow in the fishway to attract the fish to the fishway ratherthan towards the typically higher flow at the water outlet of the power plant. Fishway structures needto be maintained to avoid blockage, clogging or reduced capacity, and it is important to monitor theirefficiency. It is possible to do adjustments after construction or in design flow for most types of fishways if they are not working well.

In Nepal, only 10 out of the existing 86 HPPs have a fish passage facility. Of the 10 fish ladders, 8 fishladders are vertical slot with pool type (Figure 5), one is rip-rap stone type, and one is a nature like fish pass. Only one, the nature-like fish pass, has been monitored (for 6 years from 2001-2007) (Kaasa, 2008). However, it has not been monitored after that period. The structure is degrading every year due to high floods and heavy sediment loads during the monsoon season and lack of routine upkeep and maintenance.

Figure 5. Vertical slot fish ladder at Upper Trishuli -3A HPP

The main aspects that needs to be considered for fish passage facilities recommendations are the lifestage requirements of the different fish species, including migration periods, the characteristics of the dam and the fish passage design, the availability of water through the fishway, especially during themigration period of the different species, and the location of the fish passage under consideration inrelation to the complete HPP system (for example whether or not there are additional dams and barriers upstream or downstream).

Pool-type fish ladders and vertical slot fish ladders are suitable for both small to medium heights, andboth are suitable for several fish species. However vertical slot fishways can

handle higher dischargesfor suitable attraction flow conditions. This is defined as the flow release at the entrance or through the fish ladder to help the fish to locate the entrance of the fish ladder. This type of fishway is less prone to clogging with sediment and debris than the pool-type fishways. For higher dams where technical fishways are not feasible, other options are available, such as guiding fish into locks, lifts, pumps or, once trapped, transporting the fish with trucks to the upstream areas. Most of these solutions require advanced and specialized technical and operationalprocedures, as well as constant surveys to ensure the functionality and maintenance of these measures for the upcoming years.
In Nepal, out of the 50 HPPs studied, 20 have a dam less than 5 m tall (Figure 6), 11 have a dam lessthan 10 meters tall and 9 have a dam less than 20 meters tall. Only four HPPs have dams with a heightgreater than or equal to 20 m.

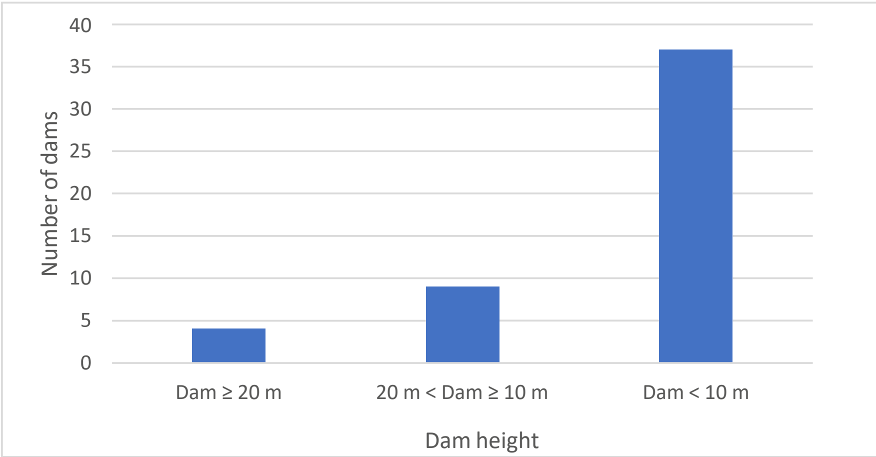

Figure 6. Dam height (m) from the 50 HPPs studied under the Nepal review (>20 m dam is considered as high, 10-20 m as medium, and <10 m as low).

Depending on the project phase, different measures can be considered (Table 4). It is important to highlight that during the construction phase, which can take up to 5 years, fish needs to able to continue to move upstream through the diversion tunnel. This is not possible for most, if not all, HPPs in Nepal. The diversion tunnels have high flow (> 15 m^3/s), are usually steep, and do not have the pools and other substrate to help fish climb up. Thus, fish cannot move upstream during construction at all. Fish can and will move downstream through the diversion tunnel during construction, but upstream migration is blocked. This can have an impact on the fish population as fish accumulate downstream and cannot reach their spawning grounds upstream.

Since most of the dams studied in the Nepal review are small to medium height (<20 m), and the HPPs are considered a representative sample for all the HPPs in Nepal, there is a high potential to construct fish passage facilities that should work efficiently if designed to consider the life-stage requirement for water releases for the fish. In addition, the fish passages that are already constructed in Nepal could work more efficiently if the design is adapted to the conditions required by the different fish species.Some of the main problems with the current fish ladders reported are:

- Most reported that the fish ladder designs have not considered the indigenous fish species andlocal river morphology. The representatives reported that the steps of the fish ladders are not designed to meet the requirements of the fishes but, instead, are constructed to match the height of the dam. This makes it difficult for fish to jump from one level up to the next.
- The fish ladders are rarely connected to the downstream river channel/flow and the end pointof fish ladder is not designed properly to attract the fish or facilitate entry of fish into the fishway (Figure 7).
- None of the fish ladders have been monitored using any scientific methods for efficiency except Khimti1 HPP. However, some of the HPP representatives reported that their fish ladders are working well. They mentioned that during the migratory season (June, July) they observe a lot of fry and fingerlings jumping to migrate upstream in the lower chambers of the fish ladder.
- The flow released through the fish ladder is not maintained as required, in addition it can be either too high or too low compared to the flow that meets the functioning requirement.
- In general, these fish ladders are poorly designed and have inadequate throughflow and attraction flow.

Figure 7. Pool type fish ladder at the Andhi Khola HPP (left) and entrance to the fish ladder (right).

Recommendations for Upstream and Downstream migration
Ministry of Forests and Environment (MoFE)
Enhance the ability of the environmental staff to review EIAs and IEEs, fish ladder designs, such asthe course for Fish Passage Engineering that is integrated in master's degree programs in engineering under Tribhuvan University. Also, provide enhanced training in biodiversity management and monitoring so knowledge about life-stage requirements of the different fish species are considered when designing mitigation measures. Require monitoring during construction phase to observe whether fish congregate at the base of the diversion tunnel during upstream migration season. If this is the case, fish can be moved and transported upstream until the construction phase is finished. Require operational HPPs with a fish ladder to evaluate the design and improve any flawed designs, making possible to improve these fish ladders which could greatly improve fish passage in their respective rivers. Require monitoring reports from HPPs on fish ladder efficiency and other mitigation for biodiversity, including data on the number of fish passing through the fish ladder monthly. Visitand monitor fish ladders to ensure adequate functioning and water flow. Monitoring should also consider upkeep and maintenance to ensure it continues functioning.
Nepal Hydropower developers
Implement design and mitigation measures to allow for upstream and downstream fish migration, such as fish ladder for upstream migration (if appropriate) and downstream mitigation such as a gate or curved spillway that can release surface water, and measures to prevent fish from enteringthe turbines (trash rack, bubble curtains, guidance nets, flashing strobe lights, etc.)

Table 4: Possible Upstream Fish Migration Mitigation Actions per Project Phase

Impact on Biodiversity	Design	Construction	Operations
Upstream Fish Migration	• Dam location • Fish ladder design • Flow rate through ladder • Attraction flow for Fish ladder • EFlows and attraction flows in diversion reach • Connectivity of river to tributaries • Model peaking flows and diversion reach to quantify impact on fish migration	• Monitor if fish congregate the construction site near to the outflow of the diversion tunnel. • Move fish upstream if deemed necessary	• Release EFlows • Maintain fish ladder • Release flow through fish ladder in migration season • Release attraction flow in migration season • Adjust EFlows if too low in diversion reach • Modify channel for better fish migration • Maintain connectivity to tributaries • Monitor fish movements

2.4 Downstream fish migration

The aquatic habitat is defined in part by the flow regime, the hydraulics, and the morphology. When fish migrate downstream from hydropower dams, they risk being drawn (entrained) into the power plant turbines and sustain anything from minor to lethal injuries. Floating guidance structuresand trash racks are common installations in front of turbine intakes to stop debris from entering thepowerhouse. However, conventional trash racks normally have wide enough openings between barsto allow most fish to pass, and they also pose a risk of trapping individuals that cannot pass between the bars (i.e., impingement against the bars). Even though new designs of fine trash racks are improving the capability to safeguard downstream fish migration, there have been not many evaluations on their long-term performances.

Other ways of guiding fish to avoid passing through the turbines while migrating downstream can include **operational measures** such as reducing flows through turbines at the same time as flow is increased through alternative routes like spillways, gates, fishways and other installations to attract the fish to these other routes. If the migratory season is short, this alternative may be a good option. The migratory season often coincides with the monsoon/rainy season when water is typically spilled anyway due to the high inflow rates. During the monsoon, fish may go over the spillway or through the gates when opened for high water flow, but they may be injured if they have to fall a great distance over the dam. A deep pool and curved spillway will aid in preventing injuries to fish that go over the da, with consideration of avoiding super saturation that might cause injure in fish, particularly fry.

Sensory and behavioral barriers created by electricity, light, sound, or air (i.e., bubble curtains) may be effective if designed properly. More solid guidance structures like **skimming walls** and **louvers** orsimilar can be effective. These are technically more difficult to construct, install and maintain and, therefore, potentially more costly. For low-head turbines, there has lately been a focus on creating **fish-friendly turbines**. In contrast to ordinary turbines, fish-friendly turbines have low rotational speed, large diameter and small spaces between turbine blades and turbine housing which can allow fish tosafely pass through them.

It is also possible to construct the intake in a way that fish will not be sucked into the turbines. In **bottom-type intakes** (Tyrolean intakes, Coanda intakes), water passes over a horizontal or inclined rack where water to the turbines is "filtered" vertically, and fish and debris are passed downstream tothe river.

Assessments of functionality and effectiveness of measures for downstream fish migration may be difficult, but targeted mark/recapture and telemetry studies can provide good data to assess most types of measures for downstream migration. It is important to consider adequate measures during the different project phases (Table 5). During the construction phase, it is important to monitor the fish strandings in the diversion tunnel during emergency shutdown of the diversion tunnel, or during maintenance of the tunnel and ensure that fish is not stranding.

In Nepal, most of the migratory fish species spawn during the monsoon season. After spawning they take a resting period ranging from a few days to a month, and then they start the downstream migration just after the monsoon season during September, October, and November. In these months, water levels are medium to high in the river. If the dam height is between 1 to 2.5 meters and the water level is high, dam overflow can facilitate downstream fish migration. However, if the dam is higher than 5 meter the big fishes tend to get trapped in the spillway pools and are often caught by the local populations.

Recommendations for Upstream and Downstream migration
Ministry of Forests and Environment (MoFE)
Enhance the ability of the environmental staff to review EIAs and IEEs, fish ladder designs, such asthe course for Fish Passage Engineering that is integrated in master's degree programs in engineering under Tribhuvan University. Also, provide enhanced training in biodiversity management and monitoring so knowledge about life-stage requirements of the different species are taking in consideration when designing mitigation measures. Require monitoring to observe stranding during the construction phase, to avoid stranding during diversion tunnel emergency shutdown or maintenance. Require operational HPPs with a downstream fish passage to evaluate the design and improve any flawed designs. Require monitoring reports from HPPs on fish ladder efficiency and other mitigation for biodiversity, including data on the number of fish passing through the fish ladder monthly. Visitand monitor fish ladders to ensure adequate functioning and water flow.
Nepal Hydropower developers
Implement design and mitigation measures to allow for upstream and downstream fish migration, such as fish ladder for upstream migration (if appropriate) and downstream mitigation such as a gate or curved spillway that can release surface water, and measures to prevent fish from enteringthe turbines (trash rack, bubble curtains, guidance nets, flashing strobe lights, etc.)

Table 5: Possible Downstream Fish Migration Mitigation Actions per Project Phase			
Impact on Biodiversity	Design	Construction	Operations
Downstream Fish Migration	• Dam location • Type of turbines • Trash racks bar spacing • Intake screens • Guiding screens • Spillway design • Plunge pool • Flushing gates and process • Fish ladder also for downstream migration	• Maintain flow through diversion tunnels • Ensure fish are not stranded within/below diversion tunnels	• Open gates in monsoon season to allow downstream fish passage • Release flow through fish ladder in migration season • Flushing per plan • Monitor fish

2.5 Fish stocking to mitigate declining populations

Hydropower development may lead to declining fish populations for various reasons, and in many cases, there are expectations of reduced or extinct fish populations. For decades, stocking hatchery-reared fish has been used as a compensatory measure to counteract reductions in fish populations,for conservation of endangered species or to improve fishing activities. In hatcheries, brood stock is normally taken from the actual river and used for breeding eggs. Juvenile fish are often brought up toa suitable size for stocking.

In Nepal, out of the 50 HPPs studied, only four HPPs have done fish stocking in their respective rivers.Out of these four HPPs, Kaligandaki A HPP is the only HPP that has stocked fish yearly, from 2003 to2019. The Kaligandaki A HPP is currently (2020) stocking approximately 200,000 to 300,000 fingerlings of *Labeo* spp. annually upstream and downstream of the dam and also further upstream of the main tributary at Andhi Khola.

However, there is no monitoring of the survival rates of the released fish. The stocking is done for biodiversity mitigation and also for the livelihood of the local fishing community.

According to the Mitigation Hierarchy, stocking fish is the last option as it is mainly a compensatory measure. A successful fish stocking program should be based on:

- Developing and applying clear, specific, quantifiable harvest and conservation goals for natural and hatchery populations.
- Designing and operating hatchery programs in a scientifically defensible manner.
- Monitoring fish populations, evaluating effectiveness, and adapting the hatchery programsaccordingly.

The traditional practice of replacing natural populations with hatchery fish from rearing ponds (Figure 8) to mitigate habitat loss and mortality due to impacts from hydropower is no longer regarded as consistent with international good practice in conservation. Fish stocking must be seen in combination with other mitigation measures and managed without compromising the genetic and health integrity of natural fish populations in thecatchment. Fish stocking and hatcheries may still play an important role in conservation of endangered species, and hatcheries will still be important for aquaculture and for nutrition and fisheries in somecases.

Figure 8. Fish rearing ponds at Kali Gandaki hatchery

Recommendations
Ministry of Forests and Environment (MoFE)
Develop a systematic approach for fish stocking to ensure that the target of the measure is clearlydefined, and the protocol is adequate to successfully raise native fish species that comply with international hygiene and genetic standards. Require a monitoring program to evaluate the efficiency of the survival of fish released into thewild and of the stocking compared with the target objective.
Nepal Hydropower developers
Carry out the stocking in agreement with the systematic approach developed. Maintain a dialog with the locals and stakeholders to consider the needs to retain access to fishingresources.

3. Recommendations for Nepal from a holistic perspective

Integrating interdisciplinary fields such as hydrology, hydraulics, biology, ecology, hydropower operation, civil, electrical, and mechanical engineering, geology, and geomorphology is often necessary to understand how aquatic ecosystems function in hydropower-regulated rivers. Social development, political issues, governance, and benefit sharing among others are also required to assess the impacts across multiple spatial scales ranging from a single habitat or morphological unit to the wholecatchment from a **holistic perspective**.

The review of the findings based on 50 HPPs of Nepal show that there is a clear need to improve theknowledge about various aspects concerning the aquatic biodiversity. Therefore, a general recommendation is to continue with the inventory that was started during review of the 50 HPP for this project and map the rest of the current hydropower plants and their characteristics, impacted reaches and their ecological criteria (Figure 9). This mapping should also extend to river systems in which future hydropower development is planned. Monitoring of current and potential mitigation measures is of particular interest when changing strategies or redesigning the measures if they are not working according to the objectives, meeting the requirements for **adaptive management**.

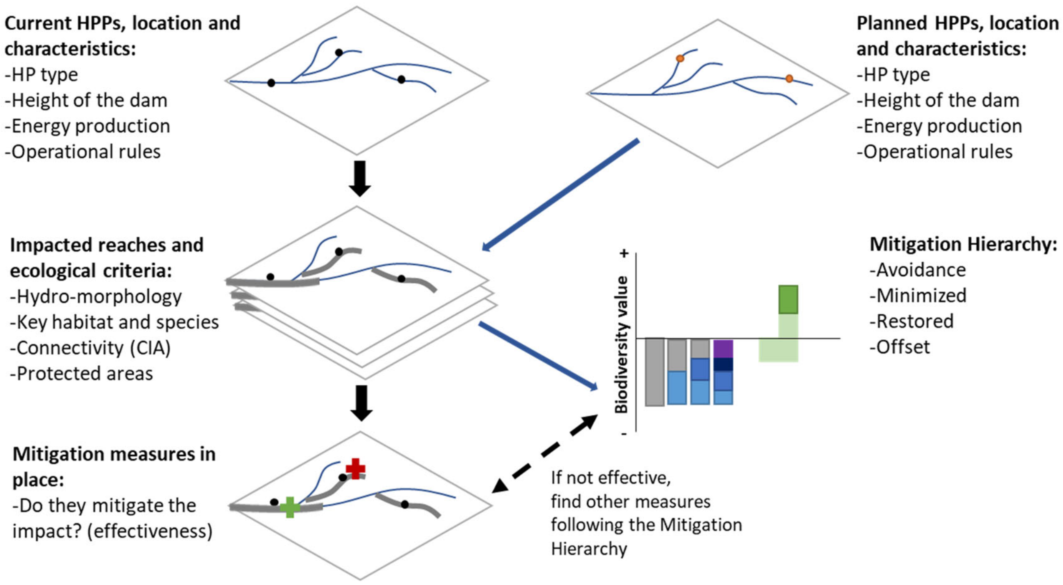

Figure 9. Example of the information needed to build a detailed inventory for the current and planned HPP characteristics, the river systems impacted, ecological criteria, and planned and implemented mitigation measures, which should follow the Mitigation Hierarchy (adapted from the World Bank Group, 2018) with adaptive management strategies.

In Nepal, generally no current mitigation measures are being monitored. However, since EFlows, which are one of the main drivers of aquatic biodiversity, are not implemented or monitored in most of the cases, the rest of the mitigation measures will most likely not be effective.

An environmental and social monitoring program should be implemented for each HPP to monitor the impact of the project, as well as the effectiveness of mitigation measures, in support of improved long- term adaptive management of the natural resources. The monitoring program should be implemented and managed by both the HPP operators, local government, and the regulatory government agenciesto measure the effectiveness of mitigation measures, supporting adaptive management, as well as communities, to promote inclusive understanding and ownership of the management of the resources.

It is also very important to consider the **Cumulative Impacts** of several hydropower projects and damswhen designing mitigation measures.

FINAL REMARKS

The decisions that will be made about mitigation measures for current and future hydropowerplants will determine the future of Nepal's diverse aquatic ecosystems and exceptional fish populations, including the revered Golden Mahseer (*Tor putitora*). This report provides a summary ofenvironmental impacts of hydropower projects and suggest a series of recommendations at differentlevels for achieving more sustainable hydropower in Nepal.

Good International Industry Practice for mitigation HPP impacts from around the world show that mitigationmeasures can be successfully implemented to reduce the HPP impacts on aquatic biodiversity whilemaintaining electricity production. Therefore, there is a significant potential for Nepal to produce hydropower generated electricity that is environmentally and socially sustainable.

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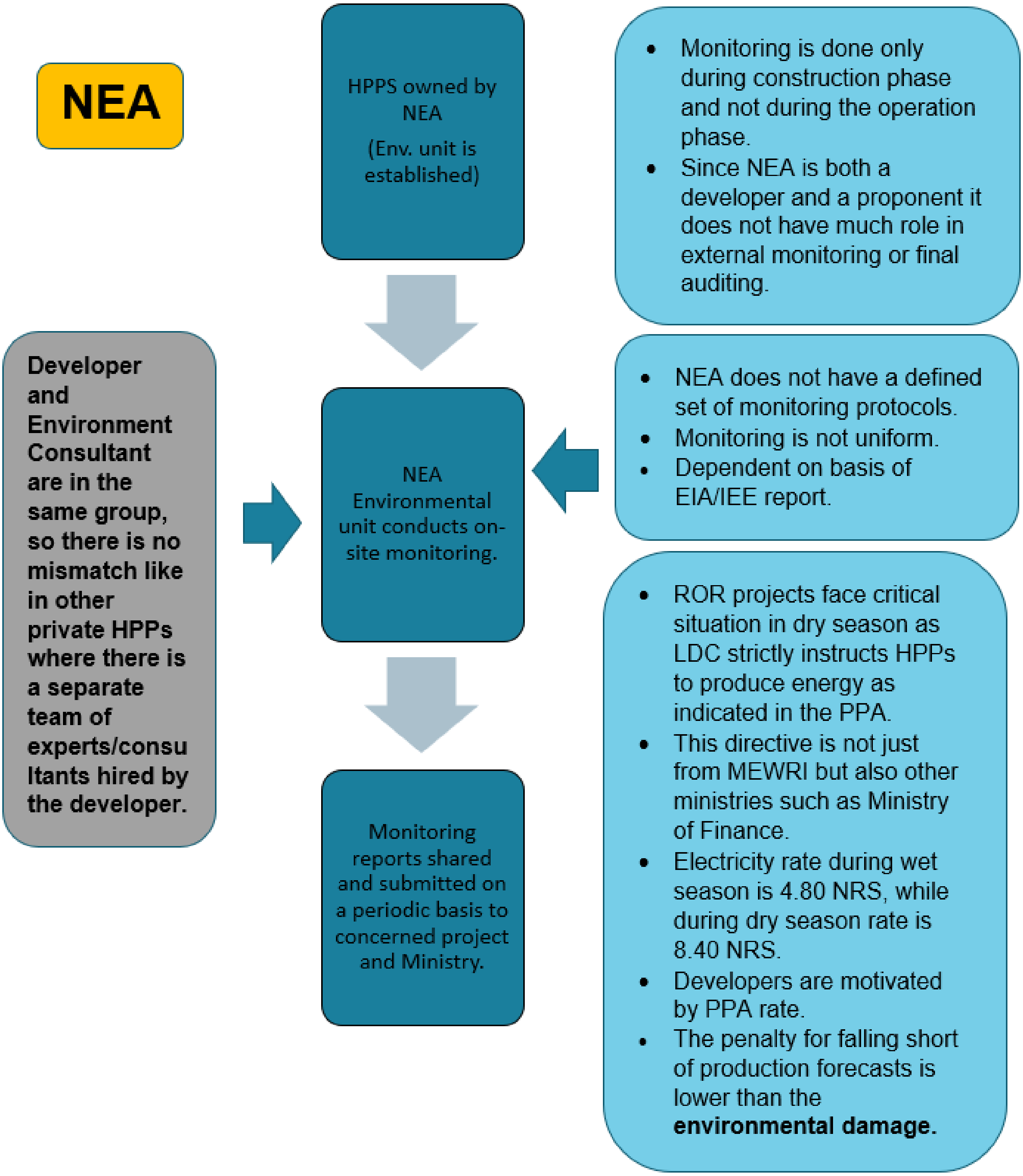
5. ANNEX 1: Nepal Electricity Authority (NEA)

In the case of internal monitoring related to NEA's hydro powers, a unit is established at the beginning of the construction and is there until the construction or environment related work is complete. An onsite monitoring unit was established for UT-3A HPP, Kulekhani and Chameliya which are the latest projects of NEA, and the monitoring reports are shared and submitted on a periodic basis to the concerned project and concerned Ministry. Internal monitoring is important because public issues and concerns arise time and again, but a developer will not comply with everything mentioned in the EIA. Normally there is a separate team of experts/consultants who develop the EIA report, and a different developer develops the project because of which there is a mismatch. But in the case of NEA the easy way is that the developer and environment consultant are the same group. NEA monitoring is done only in the construction phase and not while the project is in operation because it is the responsibility of MOFE. The external monitoring part is however under the concerned ministry who approves the EIA report. If it is an IEE report then DOED or MEWRI is responsible for external monitoring of the HPP (in construction or post construction) but in the case of EIA the external monitoring is the responsibility of MOFE.

For Marshyangdi HPP there was a provision for auditing two years after the completion of the project as per the EPR 1997, and that responsibility is of the Department of Environment (DOE). They have just started and very few environmental monitoring has been carried out. Since NEA is both a developer and a proponent it doesn't have much role in external monitoring or final auditing. The provision given to Independent Power Producer (IPP) is the same for NEA as well. The DOED has an environment division whose role is to approve EIA/IEE and also conduct on site monitoring, but they have very limited manpower. Their focus is more on reporting of EIA and IEE rather than implementation and enforcement which is one of their main limitations.

The NEA does not have a defined set of monitoring protocols. They usually monitor as per the directives of the EIA/IEE such as monitoring parameters, frequency, indicators defined on the report and also look at compliance monitoring of the contractor and environmental compliances. But the main problem is they do not have a defined set of monitoring protocols. The monitoring is not uniform and is dependent on the basis of the EIA report in the case of NEA when they conduct monitoring mainly during the project construction. In private sectors there are some good monitoring mechanisms that they have established, and some developers have also hired private consultants for monitoring.

In the dry season most of the ROR projects have critical problems and the Load Dispatch center strictly instructs the HPPs to produce as much energy as they can as Nepal has to depend upon energy import during the dry season. This directive is not just from MEWRI but also other ministries such as the Finance Ministry. In the case of project developers, the power purchasing rate (PPA) of dry season is almost double than that of wet season. If the PPA rate of wet season is 4.80 NPR, the dry season PPA rate is 8.40 NPR. This difference in PPA rate is very attractive and motivates the developers, and even if restriction or penalty is imposed, they will bear the penalty.


NEA
HPPS owned by NEA
(Env. unit is established)
Monitoring is done only during construction phase and not during the operation phase.
Since NEA is both a developer and a proponent it does not have much role in external monitoring or final auditing.
Developer and Environment Consultant are in the same group, so there is no mismatch like in other private HPPs where there is a separate team of experts/consultants hired by the developer.
NEA Environmental unit conducts on-site monitoring.
NEA does not have a defined set of monitoring protocols.
Monitoring is not uniform.
Dependent on basis of EIA/IEE report.
Monitoring reports shared and submitted on a periodic basis to concerned project and Ministry.
ROR projects face critical situation in dry season as LDC strictly instructs HPPs to produce energy as indicated in the PPA.
This directive is not just from MEWRI but also other ministries such as Ministry of Finance.
Electricity rate during wet season is 4.80 NRS, while during dry season rate is 8.40 NRS.
Developers are motivated by PPA rate.
The penalty for falling short of production forecasts is lower than the environmental damage.

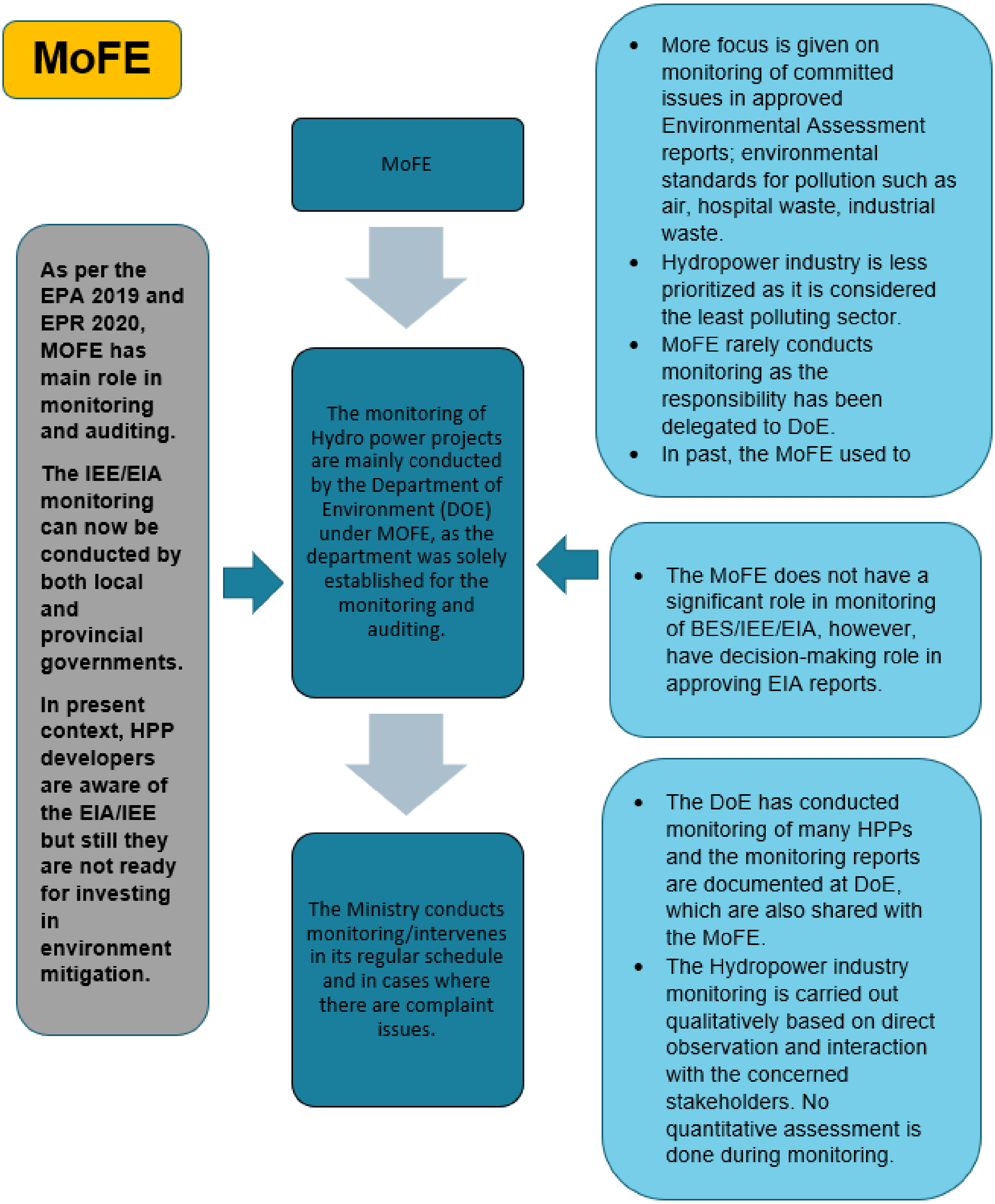
6. ANNEX 2: Ministry of Forest and Environment (MoFE)

The monitoring of Hydro powers is mainly conducted by the Department of Environment (DOE) under MOFE, as of which the department was solely established for which is monitoring and auditing. However, more focus is given on monitoring pollution such as air, hospital waste, industry waste as the Hydropower industry is considered to be the least polluting. The Ministry (MOFE) conducts very less monitoring as the responsibility has been given to DOE. More than environmental monitoring, environmental auditing is the sole responsibility of DOE, but the Environment Inspectors were also able to conduct environmental monitoring. Only in cases where there are complaints then the Ministry conducts the monitoring. Two years ago, the ministry used to conduct annual programs, but this has been halted for now.

As per the Environment Protection Act (EPA) and Environment Protection Regulation (EPR) of 1997, the concerned authority for monitoring is the concerned Ministry for any kind of project. This means that the Hydropower monitoring should be done by the Ministry of Energy, Water Resource and Irrigation under which the Department of Energy Development (DOED) is the concerned authority for monitoring as well as auditing. The Ministry does not have a big role in monitoring as per the old acts and regulations, but as per the new act and regulation the roles and responsibilities are mainly of MOFE and DOE. The IEE and EIA can now be conducted by both local and provincial governments. Earlier, the DOED (Department of Energy development) had more roles but now as per the new EPA and EPR 2019, the MOFE and DOE will have a higher role in monitoring. But this new EPA and EPR has just been endorsed in 2019 so the implementation may take a while.

The DOE has conducted many monitoring and the reports are all kept by them which are not shared with the MOFE. In cases of penalty then only the reports are sent by DOE to MOFE. The DOE mainly focuses on pollution as this is a more highlighted topic and more focus is given on monitoring of pollution such as air, hospital waste, industry waste. The Hydropower industry and aquatic biodiversity is given very little attention and seriousness. Apart from the Hydro sector, the monitoring is rapid in other sectors such as hospitals and industries and more focus is given because of which the Environment assessment proponents have been taken seriously by them. Technical monitoring by MOFE is not possible, but DOE may be able to do it to some extent. In recent days, the Hydropower developers and also the local people have become aware of the term EIA and IEE and MOFE has played an important role to some extent.

The Nepal Electricity Authority (NEA) have their own technical team and the environmental assessment and monitoring is conducted by their team. The monitoring report is also shared with the MOFE sometimes. In the case of DOED, they must be hiring a third party (a hydro specific group) for monitoring. The channelization of reports is taking place slowly and reports of transmission lines are being sent by the NEA from time to time. Private sectors are also slowly sharing their reports to the ministry, but this has not been completely channelized. The reason why this has not taken place may be because there is only one EIA section in the ministry and the workload is very high with very little manpower.


MoFE
MoFE
The monitoring of Hydro power projects are mainly conducted by the Department of Environment (DOE) under MOFE, as the department was solely established for the monitoring and auditing.
The Ministry conducts monitoring/intervenes in its regular schedule and in cases where there are complaint issues.
As per the EPA 2019 and EPR 2020, MOFE has main role in monitoring and auditing.
The IEE/EIA monitoring can now be conducted by both local and provincial governments.
In present context, HPP developers are aware of the EIA/IEE but still they are not ready for investing in environment mitigation.
More focus is given on monitoring of committed issues in approved Environmental Assessment reports; environmental standards for pollution such as air, hospital waste, industrial waste.
Hydropower industry is less prioritized as it is considered the least polluting sector.
MoFE rarely conducts monitoring as the responsibility has been delegated to DoE.
In past, the MoFE used to
The MoFE does not have a significant role in monitoring of BES/IEE/EIA, however, have decision-making role in approving EIA reports.
The DoE has conducted monitoring of many HPPs and the monitoring reports are documented at DoE, which are also shared with the MoFE.
The Hydropower industry monitoring is carried out qualitatively based on direct observation and interaction with the concerned stakeholders. No quantitative assessment is done during monitoring.

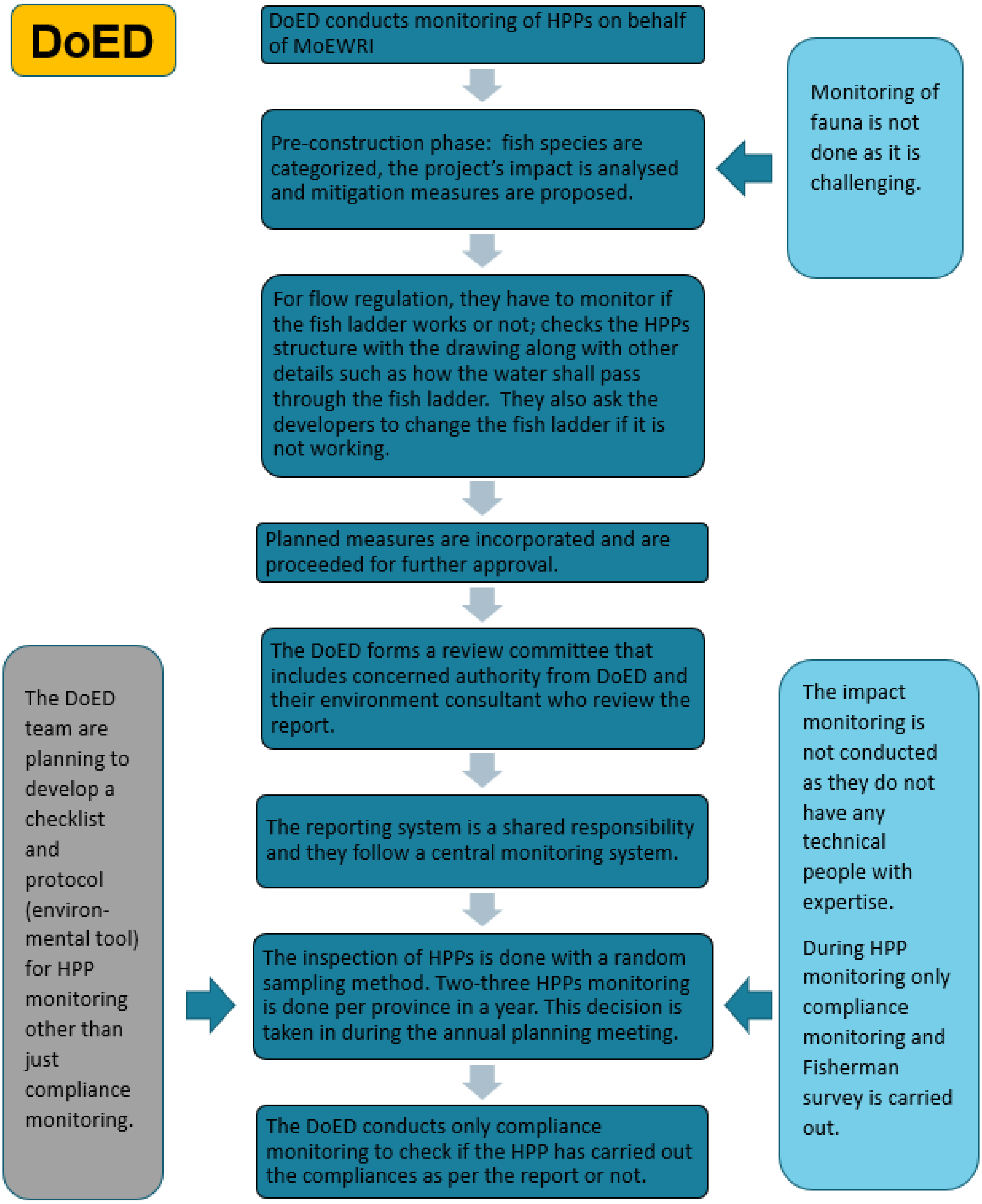
7. ANNEX 3: Department of Energy Development (DOED)

The DOED conducts the monitoring of Hydro powers on behalf of MoEWRI (Ministry of Energy, Water Resources and Irrigation) but as per legal mandate they have to pre-inform the HPPs before their visit. As per DOED the main impact is more during the construction and in terms of physical aspects of the HPP mock is the main issue while in terms of biological aspects they usually monitor trees. Monitoring of fauna is not done as it is challenging.

The DOED conducts only compliance monitoring to check if the HPP has carried out the compliances as per the report or not. However, they have also planned to make an environmental tool as a protocol other than just compliance monitoring. The impact monitoring is not conducted as they do not have any technical people with expertise. During HPP monitoring only compliance monitoring and Fisherman survey is carried out. During the Pre-construction phase of HPPs the fish species are categorized, the project's impact is analyzed and mitigation measures are proposed. The DOED forms a review committee that includes concerned authority from DOED and their environment consultant who review the report. Planned measures are incorporated and are proceeded for further approval. The reporting system is a shared responsibility, and they follow a central monitoring system. During the construction phase there are more HPPs to monitor.

For flow regulation, they have to monitor if the fish ladder works or not. The DoED team also checks the HPPs structure with the drawing along with other details such as how the water shall pass through the fish ladder. They also ask the developers to change the fish ladder if it is not working. The inspection of HPPs is done with a random sampling method. Two-three HPPs monitoring is done per province in a year. This decision is taken in during the annual planning meeting.

The DoED team are planning to develop a checklist and protocol for HPP monitoring.


DoED
DoED conducts monitoring of HPPs on behalf of MoEWRI
Pre-construction phase: fish species are categorized, the project's impact is analysed and mitigation measures are proposed.
Monitoring of fauna is not done as it is challenging.
For flow regulation, they have to monitor if the fish ladder works or not; checks the HPPs structure with the drawing along with other details such as how the water shall pass through the fish ladder. They also ask the developers to change the fish ladder if it is not working.
Planned measures are incorporated and are proceeded for further approval.
The DoED forms a review committee that includes concerned authority from DoED and their environment consultant who review the report.
The reporting system is a shared responsibility and they follow a central monitoring system.
The inspection of HPPs is done with a random sampling method. Two-three HPPs monitoring is done per province in a year. This decision is taken in during the annual planning meeting.
The DoED conducts only compliance monitoring to check if the HPP has carried out the compliances as per the report or not.
The DoED team are planning to develop a checklist and protocol (environ-mental tool) for HPP monitoring other than just compliance monitoring.
The impact monitoring is not conducted as they do not have any technical people with expertise.
During HPP monitoring only compliance monitoring and Fisherman survey is carried out.

8. ANNEX 4: Department of Environment (DOE)

Interview with Department of Environment (DOE)

Interviewee:

Mr. Bhupendra Sharma

Department of Environment (DOE)

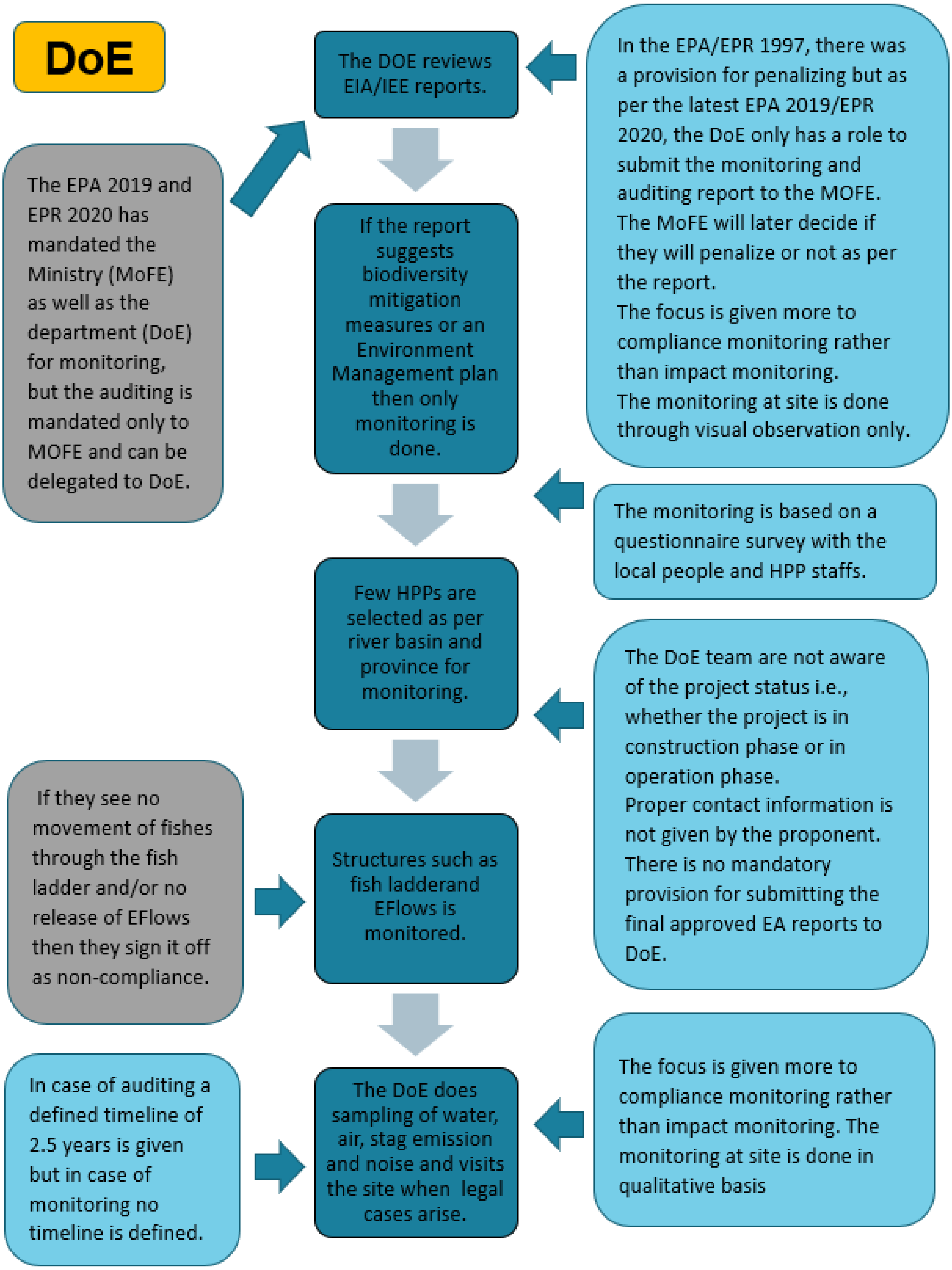
DOE has not been recognized as a monitoring party, as per the EPA/EPR 1997 the act. The sole responsibility of monitoring is given to the Ministry (MOFE). The MOFE usually approves the EIA report while DoED approves the IEE report. The NEA report approval is done by the Ministry

(MOFE). The new EPA/EPR 2020 has made amendments and now the responsibility of monitoring is given to the Ministry (MOFE) as well as the department (DOE), but the auditing is only to be done by the Ministry (MOFE).

The DOE checks EIA/IEE reports and if the report suggests or mentions biodiversity, aquatic flora/ fauna or any mitigation measure or an Environment Management plan then only monitoring is done. The focus is given more to compliance monitoring rather than impact monitoring. The monitoring at site is done through visual observation only. In case the developer has proposed a fish ladder but there is no flow through the fish ladder then they sign off the document as non-compliance but if their fish ladder was not mentioned in the EIA/ IEE, but they release water or somehow the water is maintained then they sign it off as compliance. The fish movement is observed visually in the fish ladder for about half an hour. If they see no movement of fishes through the fish ladder, then they sign it off as non-compliance. The developers usually don't do any sampling of fishes during the pre-construction or construction phase, rather the sampling is based on a questionnaire survey asked to the local people.

The HPPs are selected as per river basin and topography (terai, hilly and mountains) for monitoring. Usually, 20-30 HPPs are selected for monitoring. The DOE team don't know if the proposed project has started with the construction or not. They are not made aware of the status of the project, whether the project is in construction phase or operation phase. Proper contact information is not given by the proponent. There needs to be a mechanism where the proponent informs the Department of start and end of the project's construction. In case of auditing a defined timeline of 30 years is given but in case of monitoring no timeline is defined. There is no provision of any punishment if a report is not sent by the developer or if sampling standard is not met. The DOED does sampling of water, air, stag emission and noise and visits the site when legal cases arise.

Other than EPA/EPR 1997, there are no protocols for monitoring as such except for the Hydropower Manual, 2018. In the EPA/EPR 1997, there was a provision for penalizing but as per the latest EPA/EPR 2019/20, the DOE only has a role to submit the monitoring report to the MOFE. The Ministry will later decide if they will penalize or not as per the report.


DoE
The DOE reviews EIA/IEE reports.
In the EPA/EPR 1997, there was a provision for penalizing but as per the latest EPA 2019/EPR 2020, the DoE only has a role to submit the monitoring and auditing report to the MOFE. The MoFE will later decide if they will penalize or not as per the report. The focus is given more to compliance monitoring rather than impact monitoring. The monitoring at site is done through visual observation only.
The EPA 2019 and EPR 2020 has mandated the Ministry (MoFE) as well as the department (DoE) for monitoring, but the auditing is mandated only to MOFE and can be delegated to DoE.
If the report suggests biodiversity mitigation measures or an Environment Management plan then only monitoring is done.
The monitoring is based on a questionnaire survey with the local people and HPP staffs.
Few HPPs are selected as per river basin and province for monitoring.
The DoE team are not aware of the project status i.e., whether the project is in construction phase or in operation phase. Proper contact information is not given by the proponent. There is no mandatory provision for submitting the final approved EA reports to DoE.
If they see no movement of fishes through the fish ladder and/or no release of EFlows then they sign it off as non-compliance.
Structures such as fish ladderand EFlows is monitored.
In case of auditing a defined timeline of 2.5 years is given but in case of monitoring no timeline is defined.
The DoE does sampling of water, air, stag emission and noise and visits the site when legal cases arise.
The focus is given more to compliance monitoring rather than impact monitoring. The monitoring at site is done in qualitative basis

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