The Science–Policy–Stakeholder Interface and Environmental Flow

Dag Berge, David N. Barton, Dang Thi Kim Nhung and Ingrid Nesheim

Introduction

Environmental flow is an important measure to mitigate the negative impacts of hydropower regulation in watercourses. Initially, the regulation of rivers often left them dry downstream of dams or diversion points. However, during the 100-year history of hydropower regulation, it was recognized early on that a minimum release of water was necessary to protect a river's ecology, as well as to provide adequate water for other uses. Power companies and authorities were originally reluctant to introduce the concept of minimum release as it reduced power production. Due to the development of environmental management authorities in the Western world during the 1970s, minimum release, however, became increasingly common in hydropower regulations. This minimum release normally consisted of a single flow value that was released throughout the year. Thereafter, the idea of minimum flow was further developed to typically include two flow values: a low value during winter and a higher value during summer. During the latter part of the 20th century it became obvious that both the river environment and other interests associated with water use in a particular river system could benefit considerably by adjusting the minimum release more in accordance with the actual need. This gave a much more variable minimum release than before. The term environmental flow was therefore born.

The STRIVER project work on environmental flow has been fourfold—namely:

1. Review the international methodology regarding environmental flow assessment.
2. Review the concessions of the 56 hydropower regulations in the Glomma River’s 100-year-old hydropower history with respect to methodology applied to assess minimum releases in the different regulations.
3 Assess which of these methods could be used in the new hydropower development scheme that is evolving in the Sesan River within Vietnam and Cambodia.

4 Elaborate upon an assessment methodology based on the relationship between the pressure and the impact which hydropower regulation exerts on river ecology and different water use in line with the principles of the European Union Water Framework Directive (WFD).

**Review of environmental flow methods**

Internationally, more than 200 methods to assess environmental flows in regulated rivers are described (Tharme, 2003; Halleraker and Harby, 2006). It would be an impossible task to go through all of these methods singly, so they have to be treated in a group-wise fashion, as applied by several earlier reviewers (Jowett, 1997; Dunbar et al, 1998; Tharme, 2003; Scruton et al, 2005; Halleraker and Harby, 2006) as follows:

- hydrological methods:
  - hydrological reference table method;
  - identification of central hydrological events;
- hydraulic methods;
- functional connections between physical alterations and river biology;
- holistic methods;
- hybrid model framework.

Each of the groups will have methods that involve both mathematical model simulations and subjective evaluations based on expert judgements.

The principle underlying most of these hydrological methods is to find an acceptable minimum flow. This is provided as a percentage of the natural flow (i.e. usually as a percentage of mean annual flow). In order to be able to assess this daily flow, measurements are needed spanning several years. If such data do not exist, it is possible to perform calculations via modelling or by proportional scaling of the measurements available from a river situated nearby.

The hydraulic group of methods was popular during the 1970s. The methods describe, via hydraulic models, how different water flows affect an area of the river bed covered by water, as well as water velocity, sedimentation, erosion, etc. (Halleraker and Harby, 2006). The hydraulic methods provide more detailed and localized information on how regulation will impact upon the physical environment in comparison to hydrological methods (King et al, 1999); but they do not include any functional connection between the physical changes and the preferences of local flora and fauna. Such studies include habitat requirements of different species, temperature preferences, water velocity, growth relationships, etc. The impact upon the ecology of a river through physical alterations can be studied and quantified, and available data can be put into predictive models, which can describe how a certain regulation will affect local biology.

Holistic methods take into account the flow needs of the river biology and human water user interests. The concept is a structured evaluation of composite expert judgements, where experts from different disciplines (expert panels) work together in interdisciplinary workshops. At least 16 such methods (Tharme, 2003) exist. So far, the methods have only been used extensively in Australia and South Africa (Halleraker and Harby, 2006); but Dunbar et al (1998) recommend that they be further developed and adapted to British and other conditions.

The hybrid model frameworks consist of model frameworks that link the former four categories together (hydrological, hydraulic and habitat models and holistic methods). The models can be used in estimating the environmental impacts of different regulation manoeuvring rules (e.g. the impacts upon water quality, fish, etc.). The problem with these model frameworks is that they are too complex to really be used in real-life conditions to any great extent.

**The Glomma: Hydropower regulation and the application of environmental flow**

**History**

Hydropower production is an important water use in the Glomma River and has existed for more than 100 years. In the Glomma River Basin there are 56 hydropower stations and 26 hydropower reservoirs. Coordinating the manoeuvring of regulations is taken care of by a water management association, the Glommens og Laagens Bruksstyreforening (GB), among the owners of the different hydropower stations. The GB has, to date, 18 power companies as members and performs several water management responsibilities in the basin, which include ensuring that the concession conditions with respect to minimum flow in rivers and water levels in reservoirs are not violated. The GLB was established in 1918 and the association also manages the hydrological gauging stations in the river basin (water flows and water levels).

Most hydropower regulations in the Glomma River Basin (if we omit the pure run of the river regulations and the oldest regulations) stipulate some kind of minimum release, compensation flows or environmentally motivated rules for water-level variations in reservoirs. The way in which this is carried out can be roughly described as expert judgement based on baseline studies of ecological items and water-use items. In Norway this is often referred to as the expert panel method. Under the old regulations there was often only one expert allocated to take care of environmental aspects, and this was usually the regional fish inspector belonging to the Directorate for Nature Management. In more recent regulations there are several experts and river users involved in assessing the minimum water flows and the water levels. This expert group is often called an expert panel. The experts included in this panel may vary from case to case, and there is no clear methodology upon which they base their judgements, which may cause inconsistencies in the results generated. For example, when a concession is up for renewal, it is not always easy to see how the panel arrived at a certain compensation flow as their methods are neither transparent nor replicable.
With reference to international terminology, the expert panel method is used in Glomma to assess minimum flows, or compensation flows, or water levels in connection with hydropower regulations. There is, however, a need to conduct these exercises in a more structured way with respect to which type of experts and stakeholders should be involved and which ecological values and which river use values should be included. In addition, a more structured, quantifiable, replicable and transparent methodology should be applied in order to achieve a certain water flow and associated water-level manoeuvring rules.

The formal process for hydropower concession in Norway

The formal process for river regulation in Norway is dependent on the size of the project. If the hydropower project is 40GWh or more, then the project comes under the Plan and Building Law (PBL). This stipulates an environmental impact assessment (EIA), a social impact assessment (SIA) and public and stakeholder involvement and hearings, etc. If a project is between 30GWh and 40GWh, the Norwegian Water and Energy Directorate (NVE) decides if treatment in accordance with PBL is necessary or not. If the project is below 30GWh, the project does not need to be treated under the PBL and the treatment process is much simpler. For these smaller regulations there is a general requirement, after the Water Resources Law, that their minimum flow is at least the size of 'common low flow' (approximately 10 per cent of average flow). In the larger projects, the question of minimum flow is taken care of during the application process for licensing and no specific requirements for the size of the flow are provided in the legal system.

In larger projects (>40GWh), such as the Glomma River, the applicant (hydropower company) provide an announcement document (in Norwegian, Melding), including a description of the planned project, as well as a programme for impact assessment. The NVE then arranges a public meeting with representatives of all relevant stakeholders (local authorities, water users, landowners, rights holders, NGOs, etc.). The meeting is held in the municipality that is most affected by the project and is open to all. The announcement document is sent out for public hearing four weeks in advance and is open to comment. Based on the results of the hearing, the NVE presents a detailed programme for the impact assessment which the applicant has to conduct before the application can be taken any further. After the impact assessment is conducted, the applicant updates the announcement document to include the recommended mitigation measures, etc. The announcement document is then given application status, which is sent to the NVE, who then sends the application out for public hearing for three months. The NVE then evaluates the project and provides a recommendation (positive or negative) and sends it to the Ministry of Petroleum and Energy (OED). The OED conveys the recommendation on a limited hearing (to other relevant ministries, directorates, municipalities, etc.). The OED subsequently makes a proposal for a decision and sends it to the King in Council for a final decision. In addition to being assessed under the PBL, large projects are also treated under the Water Resources Law and the Watercourse Regulation Law. A requirement for environmental flow is normally in accordance with the requirements of abatement measures in new licences.

Today, only publically owned companies can obtain a licence, and the licence then has no time limit. Until recently, however, private companies could also obtain licences; but these were limited to 50 years with reversion to the state after that time. The private company could, however, then buy the hydropower plant and regulation back, and apply for a new licence. Licence conditions, rights and obligations of the licence and rules of operation are all significant. After 30 years, these conditions can be revised. In a few cases, in order to test out abatements, such as environmental flow, a licence has been given for a test period of five to ten years, after which some abatement measures are adjusted if found appropriate. When the licence lapses after a period of 50 years, the power company has to apply for renewal of the licence. Normally, this entails only some small adjustments of the conditions, such as implementing environmental flow in earlier dry stretches. A hydropower regulation licence has never yet been withdrawn in Norway.

The PIMCEFA method for environmental flow assessment

Environmental flow has mostly been used in connection with assessing minimum flows in river stretches that would have been dry after regulation (i.e. downstream of dams, diversion points, etc.). However, regulation creates many other major changes in a river, which requires a broad spectrum of abatement measures and diverse ways of thinking when it comes to environmental flows.

For example, the cascade development of hydropower dams in the Bises River in Vietnam/Cambodia (see Figure 7.1) has changed the river from a continuous water body to a cascade of lakes. Regarding fish production for local livelihoods, as well as for other local water uses, it is the lakes that will be the most important water bodies in the future. Thus, water-level management of reservoirs will be more important than the minimum flow in the river stretches between dams. The only way in which these can be regulated is through water release from the reservoirs, either via the turbines, the spillway or the bottom valves. Thus, knowledge of environmental water release is necessary so that hydropower companies can initiate and achieve environmental flow.

In our work, we therefore adopted the following definition for environmental flow:

Adopting water release manoeuvring rules for the different reservoirs to obtain as favourable water levels (and water flows) as possible for the total river ecology and the human water use interests, within the constraints set by the economical feasibility of the regulation. This applies both for reservoirs and river stretches.
The review of Glomma hydropower regulations revealed that expert judgement, often conducted by a loosely defined expert panel, was the most usual method of assessing minimum flow. According to the GLB, as well as the Norwegian Directorate for Water Resources and Energy, the expert judgement method will always be the method of choice in the future. Analysis of the projects’ impacts on the environment has been structured in international terms, the expert panel method being the method of choice for projects in the Glomma area (Kong and Louw, 1998).

Inspired by the experience gained from the most recent environmental flow assessment case in Glomma (i.e. the renewal of the concession of the Øyeren Regulation; Berge et al. 2002), the Pressure Impact Multi-Criteria Environmental Flow Analysis (PIMCEFA) method was elaborated upon as part of the STRIVER project. The method can be used to design environmental flow, as well as to assess the degree of damage done to different river values at different levels of regulation.

In this method, an expert panel consisting of local experts (fishermen, farmers, boaters, etc.) and professional experts, both on key ecological elements (ecological values) and key water use elements (water use values), is appointed for each of the different river sections that are undergoing evaluation in the context of environmental flow.

Members of the expert panel try to construct the optimum water level curve over the year for the different water values (ecological values such as water quality, water vegetation, bottom animals, fish, etc., and user values such as drinking water, transportation, irrigation, fishery, etc.) based on local knowledge and baseline studies combined with professional expert judgement. The panel members then go on to identify the critical periods for the river values that they represent (i.e. periods where certain water levels have to be kept). From the different optimum curves a preliminary resultant curve can then be structured. The curves shown in Figure 7.2 are from the work conducted during the renewal of the Øyeren Regulation Concession in the Glomma River (Berge et al. 2002).

Once the critical periods for the water value (ecological value or user value) have been identified, the next step is to evaluate how seriously the different river values are affected by the regulation. A semi-quantifiable model, called a pressure-impact curve, should be created. To illustrate this point, the river value ‘fish production’ in a regulation which includes river diversion is used as an example (see Figure 7.3). If all the water is taken and the river ends up dry, then fish production is damaged by 100 percent. If no water is taken (no regulation), then damage to fish production is 0 (zero). The simplest model to demonstrate these two points is the straight line (see Figure 7.3). However, this model can be improved considerably by expert judgement (as well as in cases where fish data exist). We know that most fish species can adapt to a 30 percent year-to-year variation in water flow, so to divert up to 30 percent of the water is not considered a very serious threat to fish stocks. At the other end of the scale, when most of the water is diverted and fish stocks are depleted, there will only be small pools of water (e.g. between the stones on the bottom), producing the...
same negative effect. Most ecosystem damage follows such a sigmoid curve, while user interests often follow a curve as noted in Figure 7.3.

To help in evaluating the different impacts against each other, a multi-criteria analytical tool (MCA software) was used in the project. From the many software products available, we chose a commercially available software package called DEFINITE (Janssen and Herwijnen, 2007) to conduct multiple-criteria and benefit-cost analysis. We used DEFINITE in PIMCEFA as a method of documenting stakeholder and expert judgement and as a tool for ranking alternative environmental flow levels under consideration. A particularly useful feature of the DEFINITE software in the context of PIMCEFA, and compared to other commercially available packages, is the function that lets the user define pressure-impact curves manually using any functional form. This is a crucial advantage, as PIMCEFA relies on being able to accurately capture expert knowledge regarding the link between river flow and impacts upon ecological and user interests in the form of pressure-impact curves. Pressure-impact curves are otherwise known as ‘value functions’ in the MCA literature (Benat, 1997).

In Figures 7.4 and 7.5 we have illustrated the main steps in using MCA software such as DEFINITE to rank river flow alternatives. The following only refers to the steps relating to DEFINITE in the PIMCEFA approach:

- Step 1: define the alternative river flow levels under consideration.
- Step 2: define the hierarchy of impact indicators.
- Step 3: convert hand-drawn pressure-impact curves to ‘value functions’ in DEFINITE.
- Step 4: elicit relative weights for impact criteria from stakeholders (or set equal default weights).

Once the MCA analysis has been completed with the DEFINITE software, the results of the ranking of river flow levels (for a given critical river stretch and period) can be compared to the equivalent levels of hydropower generation (see Figure 7.6). This trade-off curve summarizes the main user conflict between hydropower and other multiple uses. It can serve as a basis to evaluate, for example, the potential for economic compensation.

This can also be used in weighting the different river values, including sensitivity analysis of different individual weights. The results can be used to construct the best possible water-level resultant curve, which ensures that changes to ecosystem values and user interest values are within acceptable limits. The analysis of the pressure-impact curves can be used to adjust the optimum water-level curve, which again will give information on how to adjust the water release pattern from the reservoirs.

The method has been tested as an exercise in different parts of the Glomma River, as well as in different parts of the Sesan River, both in Vietnam and Cambodia. The work associated with this method is presented in two technical briefs from the STRIVER project (Barton and Berge, 2008; Nhung et al, 2008) and we recommend these briefs to those readers who are interested in the
Figure 7.4 Steps related to ranking river flow alternatives by use of DEFINITE MCA software

Figure 7.5 Steps related to ranking river flow alternatives by use of DEFINITE MCA software, continued

Figure 7.6 The results of the ranking of river flow levels (for a given critical river stretch and period) can be compared to the equivalent levels of hydropower generation.

technical details. We therefore do not go into the technical details of the method here, and only give a brief résumé of the test exercises.

The aim of the method is to address the following three items:

1. Identify the ecological values in the river (achieve good ecological potential, which is the environmental requirement in regulated rivers after the European Water Framework Directive).
2. Take into account water use interests (try to fulfil the needs for water level and water flows for a wide spectrum of water use).
3 Avoid creating excessive disadvantages for water users through regulation purposes.

The stakeholders involved at different stages should be a combination of local river users and professional experts who can evaluate the impacts of different flow levels (a technical and local knowledge task), and regional and local water authorities and interest groups, who can evaluate the relative importance of different ecological and user interests (a political task). It should be noted that environmental flow is only part of the EIA tasks in a hydropower development, as are, for example, transmission lines, switchyards, dams, power plants, access roads, etc.

The overall PIM/CEFA method consists of the following steps:

- Identify the key river ecological values (fish, river bed fauna, periphyton, aquatic macrophytes, water fowl, etc.).
- Identify the key water use values (water supply, fishing, irrigation, bathing and washing, hydropower, flood control, etc.).
- Appoint an expert panel consisting of professional experts and local experienced water users within the fields of river values above, including relevant representatives from water authorities (local, regional and central) (i.e. relevant scientists and stakeholders).
- Draw preliminary optimum water-level curves over the annual cycles that represent the river value you are treating.
- Identify critical periods (i.e. periods when you are confident that the water level needs to be at certain levels): migration periods, spawning periods, sailing depth during boating season, etc.
- For the critical periods, draw pressure-impact curves (i.e. assess maximum damage and minimum damage and draw the most likely curve between these two points).
- Load the pressure-impact curves into a multi-criteria analysis (MCA) tool (as discussed previously, we chose to use DEFINITE; but others also exist).
- Use the MCA tool to evaluate the impact curves of the different river values against each other.
- After trade-offs between the different values are completed, construct the resultant optimum water-level curve.
- Use hydrological models to convert water levels to water flow and provide advice to the hydropower companies on how to plan the dam release.

In order to provide accurate results, the method requires that baseline studies covering the relevant river values, as well as EIA studies are performed. It is important to know how the power plants are planning to operate. However, it is also possible to use the method with fewer available data; but the results may then be more ambiguous. The method can also be used without multi-criteria analysis software, but it will be more laborious to perform the trade-offs. The result could also be more easily influenced by the strongest debater.

The use of scenarios in environmental flow settings

The process of setting environmental flows (or water levels) is an iterative process, where different water flow and water-level regimes (scenarios) are tested against the different ecological values and water use values until the best balanced alternative is achieved. This resultant alternative is, in fact, the environmental flow. Thus, water release scenarios are always used in environmental flow assessment.

A very important parameter in environmental flow assessment is the area of dry river bed at different water flows/water levels. This can be modelled if a network of river profiles or air photos of the river during different water flows are available. If such data are available the river bottom areas that will be dry due to different scenarios, based on released water flow, can be illustrated efficiently.

Other types of scenarios that are relevant to environmental flow assessment are based on the master plan for hydropower development in the different rivers (i.e. how many of the hydropower plants in the master plan are likely to be built). In the Sesan River, we took two scenarios into account. The first included all the planned hydropower projects (HPDs) to be built in Vietnam, but not those in Cambodia, while the second most likely scenario is that Cambodia will also develop HPs on the Sesan. This is due to a very recent change in the Cambodian authorities' attitude towards hydropower. From having been critical of the problems caused in Cambodia by the Vietnamese HP regulations, they, however, have changed their approach by asking the Vietnamese to assist them in forming HP regulations within the Cambodian part of the Sesan River.

In the latter, the river will be changed into a cascade of large lakes. The environmental flow will then be used to plan the water levels in the lake in the best possible way also in order to produce fish for local livelihoods. In the first scenario, the environmental flow will be adjusted as close as possible to natural flows. Here the re-regulation reservoir downstream of the lowermost HP will be essential.

SPSI in environmental flow assessment

In the environmental flow setting, it is very important to have wide participation and an open, transparent and replicable process. The holistic types of assessment methods require interaction between all of these groups. In practical hydropower development assessment cases, we advocate the involvement of scientists and the usage of scientific methods.

While the scientists initiated the PIM/CEFA method, it has been decisively important to have broad participation from policy-makers and different stakeholders. They steered us towards what was useful and practical, what was possible, what was important and not important, as well as providing alternative ideas which the scientists had not considered. Without their participation, PIM/CEFA would have been a method for academics and would never have been used in practical water management.
Wider participation was not only necessary for the development of a useful method, but also proved to be an efficient way of making the method known among water managers. We have observed that the hydropower-related water management authorities in Norway, as well as the larger hydropower companies, know about the PIMCEFA method for assessing environmental flow. Despite the fact that the method is not being fully developed yet, we have already been invited to assist in assessing environmental flow in a new hydropower development project: the Lower Otta HPP. We have already contributed to the terms of reference of the different impact studies under the EIA in order to ensure that the data can be easily integrated within the PIMCEFA method. This example shows that a crucial element for developing a practical management tool is the involvement of key stakeholders.

In the expert panels used for testing the method in the Glomma River (Øyen and Høyega), we included representatives from local river users, professional experts, local water management authorities (municipalities, the hydropower association GLB, the county governor) and central water authorities (the Norwegian Water Resources and Energy Directorate). The combination of local and expert knowledge was particularly important in assessing critical periods when certain threshold water levels have to be exceeded. Hydropower experts and water managers provided the frames within which realistic water releases are determined, without excessive negative effects on HPP production. During the course of the project, between 10 and 12 individuals took part in the expert panels in Glomma.

In Cambodia, the expert panels meeting was run with experts from the STRIVER project and with local river users such as fishermen and farmers, as well as some NGOs. These local river users had a clear opinion of what water flow they needed in order to protect their interests, as well as having a clear perception of what was wrong with the regulated conditions, but they could not define critical water levels for river ecology or water use. Within the Kon Tum area of the Vietnamese Sesan, the expert panel consisted of experts from Hanoi and local river users, with much weaker participation from local authorities and hydropower authorities than was seen in Norway. One difficulty was the problem of engaging busy people in a hypothetical test case in remote areas, such as the one upon which the project was based. It would have been much easier to appoint more participants to the panel if it had been a ‘real case’.

Lessons learned and practical recommendations

The main lesson learned during this project was that it is very crucial to bring local river users, professional experts and water management authorities into the IWRM project. If not, then the IWRM can easily become just a theoretical academic exercise, providing limited relevance to the practical water management that takes place in all watercourses. The biggest loss in this respect was that we were not in a position to engage the Ministry of Water Resources and Management (MOWRAM), the government authority responsible for water in Cambodia. Thus, our environmental flow research there became difficult due to a lack of participation from the relevant water management authorities.

Another lesson was that it is not easy to get the necessary and whole-heated participation of local and regional stakeholders (water authorities, water users, professional experts, etc.) to work within an expert panel in a research project, where everything is a hypothetical case and the work is primarily an exercise. It is much easier to mobilize these types of groups in a real case project as, for example, when elaborating upon a water management plan for a certain river. If, for instance, this project was initiated by the Cambodian and Vietnamese authorities to try and set the environmental flow in the Sesan River, which the hydropower plants then had to follow, it would not have been a problem attaining participation from all levels of stakeholders. In research projects, it is possible that participation may be limited and may only include laymen living along the river and some NGOs, while the water management authorities (local, regional and central) are not properly included. The consequence of such limited participation is that the evaluation of pressure-impact curves (impact assessment) may be carried out, but the assessment of the relative importance of different impacts by relevant stakeholders is incomplete. Planning hydropower development is aimed at providing the best solution for a country as a whole. In the case of the Sesan, however, the input was very one-sided, with the majority of the input arising from the poor people living along the river.

In Glomma we included policy-makers from relevant levels, although not everyone who should have been included could participate due to lack of funding for their participation (other than travel and accommodation expenses). Their input was therefore limited to participating in expert panel meetings. A practical recommendation for this type of research project is to put much more emphasis on including the water management authorities (policy-makers) in the project and to allocate money in the project budget for their participation. Clearly, they have substantial practical experience in IWRM that can be highly relevant to the project. However, these authorities are often too busy to allocate their working time to hypothetical exercises without remuneration.

Another way of attaining better and broader-based participation is to link the research project directly to an existing real case management project (i.e. to a hydropower development that is in the development phase). That is the next step which has been taken to further the development of the promising PIMCEFA method. We have linked our work directly to the Lower Otta Hydropower Development Plan (still the Glomma River Basin), which is now at the start-up stage of the impact assessment studies. If this HPP development had started two years earlier, then we could have included it in the STRIVER project and it would have been much easier to secure participation from all relevant stakeholders, as well as policy-makers.
Pros and cons regarding the PIMCEFA method as a tool for assessing environmental flow

The pros of the PIMCEFA method include the following:

- It identifies the most important ecological values and user values.
- It includes the participation of all relevant stakeholders.
- It is a clearly defined version of the expert panel method, which is transparent and replicable.
- It has a computerized multi-criteria analytical tool that makes it easy to compare and co-weight the different river values/impacts.
- It can be used both in water-level settings in reservoirs and as water flow settings in pure river stretches.

The cons of the PIMCEFA method are:

- The optimum water-level curve and the critical periods are not easy to decide upon for all river values, often due to lack of pre-studies, EIAs or skilled personnel.
- The connection between wetted perimeter and flows is rarely established in advance.
- The multi-criteria analysis and co-weighting process of the different water values needs further testing to reveal the method's full potential. This should be done in a 'real case'.

Practical recommendations for the Glomma and Sesan with respect to environmental flow

In the Glomma River, all river stretches (rivers and reservoirs) should be evaluated with respect to environmental flows as part of the river basin management plan (RBMP) in connection with the implementation of the EU Water Framework Directive (WFD). The evaluations should not only be conducted regulation by regulation, but for the total regulation scheme in the river system. This could reveal information that may be useful in future renewals of concessions. Environmental flow should be seen in close connection to other types of mitigation measures. Experienced professional experts and experienced local river users, as well as relevant authorities, should be involved in environmental flow assessment.

The regulations in the Sesan River are more comprehensive than in the Glomma River, whereas the levels of mitigation measures and compensation measures are less developed. Vietnam and Cambodia should develop a joint water management plan for the Sesan River, and environmental flow assessment should be part of this. A joint update of the master plan for hydropower development has been developed, which could serve as a starting point. The work should also be coordinated with the ongoing research of the Mekong River Commission (MRC) and Asian Development Bank (ADB) 3-S Rivers Basin Development Programme. All river stretches (rivers and reservoirs) should be evaluated with respect to environmental flows as part of the RBMP. It is important to face the fact that it is the reservoirs that will be the most important water bodies in the Sesan River when the total regulations scheme is carried out. If these water bodies can be managed so that water-level fluctuations of less than 3 to 5m are achieved, they can produce a large amount of fish. Stocking programmes may be necessary to compensate for lost spawning conditions and there would be substantial reductions in biodiversity in the main stream river, with many important species disappearing. This is unavoidable with such a comprehensive regulation scheme. In order to abate some of this loss, fish bypass systems could be installed at the dams, but only a few species would be able to use these. The environmental flow in the river stretches should, first of all, be assessed to ensure that the river could function as a spawning and nursery area for reservoir fish, in addition to serving local river uses. Environmental flow could be released via fish ladders to achieve maximum benefit.

In conclusion, environmental flow should be viewed as closely connected with other types of mitigation and compensation measures, with the aim of achieving maximum preservation of local livelihoods and local environment within what is feasible for the regulation purpose and what is accepted by both countries.

References


