Management Strategies and Mitigation Measures Required to Deliver the Water Framework Directive for Impoundments

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APPENDIX 1

WFD29: MANAGEMENT STRATEGIES AND MITIGATION MEASURES REQUIRED TO DELIVER THE WATER FRAMEWORK DIRECTIVE.

INTERNATIONAL REVIEW OF IMPOUNDMENT MANAGEMENT STRATEGIES
SUMMARY OF THE INTERNATIONAL REVIEW

This report presents the findings of the international review of impoundment management practices, which provides a legislative, planning, management and regulatory context for impoundments across five countries (Norway, France, Germany, Australia and USA) and identifies typical and good practice mitigation measures. The review considered impoundments for hydropower, water supply and flow regulation.

A two-tiered approach to licensing appears to be a common theme throughout the five countries and Environmental Impact Assessment is used by all five for large impoundments. Consultation with statutory and non-statutory bodies was evident in all the countries reviewed, both for the licensing and re-licensing of dams. The multiple stages for consultation and extent to which the public is involved are considered to be a valuable element of the (re)licensing procedures in Norway, the USA and France.

The majority of the countries evaluated apply the concept of time-limited licensing and the incorporation of conditions in the license to mitigate impacts on the surrounding environment. These concepts are deemed as effective regulatory techniques, worthy of consideration in the UK.

A preliminary analysis of the mitigation techniques tried and tested by the five different countries showed that a substantial number are commonly used by all (eg. compensation flows, fish passes, fish screens and measures to improve dissolved oxygen levels and maintain natural temperatures). Novel approaches were also identified (eg. salt interception systems close to the coast in Australia, fish friendly turbines to prevent fish damage in USA, fish passes specifically for eels and a retaining weir dam to maintain water levels in an isolated area of the impounded water (Norway)).

Decommissioning of at least three large dams was identified in France in recent years, whilst the USA was clearly actively decommissioning large dams. Decommissioning is not currently a major issue in Norway and Australia.

This international review helped to identify best practice mitigation measures and to develop a guidance manual. An evaluation of the main problems facing impoundment management in the UK helped determine which methods are most relevant for further investigation. In addition, information about which techniques have been tried in the UK and their success or failure will help to focus the project on those mitigation techniques which show the most promise.
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1 INTRODUCTION

1.1 Background and Objective of the International Review

The background to this project is detailed in Section 1.1 of the main report (Volume 1) to which this report is an Appendix. The international review of impoundment management practices aims to provide a legislative, planning, management and regulatory context for impoundments across five countries: Germany, France, Norway, Australia and the United States (see Figure A1.1). The review further aims to identify typical and good practice mitigation measures.

The five countries were selected by the Steering Group on basis of their relevance to the situation in the UK. The selection was based on their knowledge of the procedures and work being done in these countries and the following subjective criteria:
- decision making in the country is similar to that of the UK;
- environmental issues are high on the agenda; and
- the urgency of addressing environmental concerns in impoundment construction, management and decommissioning is felt, due to a combination of environmentalist pressure groups, a environment protective regulatory framework.

Further, practical matters, such as having good contacts in the countries played a role. An assessment of the mitigation measures adopted in the UK was beyond the aim of this project, because it was assumed that these are already available elsewhere and, in addition, the environmental regulators are already familiar with the UK experience. It is important to note that this fact does not mean that the project dismissed the good practices adopted in the UK. On the contrary, the objective of this international review was to provide elements for comparison between measures adopted in five representative countries with comparable situations in the UK.

![Figure A1.1: Five Countries selected for International Review](image-url)
1.2 Methodology

The methodology for this international review included a search of specialised literature, web search and semi-structured questionnaires. A literature search was undertaken and documents were reviewed. A semi-structured questionnaire was prepared and consultation undertaken with up to five key consultees per country. The key contacts are presented in section 1.5 while a complete list of contacts is presented in section 6. The consultation letter and questionnaires are presented in Annex A and the results of the consultation exercise were used in the identification of the management strategies and mitigation measures for impoundments for each country.

National position statements were prepared for each country and are presented in Section 3 of this report. The key similarities and differences between the mitigation and management strategies used in each country were compared and the results presented in Section 4.

1.3 Consultation

The key responses received to the questionnaire and / or telephone interviews included those named in Table A1.1 overleaf. For the full list of consultees (and their contact details) that were identified, approached or responded, refer to Table 6.1 in Section 6.
### Table A1.1: Key Consultees during International Review

<table>
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<tr>
<th>Country</th>
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<td>Professor John Brittain</td>
<td>University of Oslo</td>
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<tr>
<td></td>
<td>Job Hottentot</td>
<td>KPMG Global Sustainability Services</td>
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<td></td>
<td>Knut Gakkestad</td>
<td>NVE – Norwegian Water Resources and Energy Directorate</td>
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<tr>
<td>France</td>
<td>M. Devos</td>
<td>DRIRE Limousin</td>
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<td></td>
<td>M. Hofleur</td>
<td>Direction Departementale de l’Agriculture et de la Foret (DDAF), Lozere</td>
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<td></td>
<td>M. Coffin (directeur)</td>
<td>Direction Departementale de l’Equipement (DDE), Haute-Vienne</td>
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<td></td>
<td>Mme Calentier</td>
<td>Direction Regionale de l’Industrie, de la Recherche et de l’Environment (DIREN), Auvergne</td>
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<td></td>
<td>M. Cruchon</td>
<td>CTPB</td>
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<td></td>
<td>M. Paquier</td>
<td>CEMAGREF</td>
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<td></td>
<td>M. Lamoureux</td>
<td>SOMIVAL</td>
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<tr>
<td>Germany</td>
<td>No response in timescale of project</td>
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<tr>
<td>Australia</td>
<td>Mr D. Barma</td>
<td>Department of Infrastructure Planning and Natural Resources</td>
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<td></td>
<td>Mr. B. Dunn</td>
<td>Snowy Hydro Ltd</td>
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<td>Ms. J. Lovette-Cameron</td>
<td>Institute of Chartered Accounts of Australia</td>
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<td>USA</td>
<td>Mr. A. Hoar</td>
<td>US Fish and Wildlife Service</td>
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<td></td>
<td>Mr. D. Conrad</td>
<td>National Wildlife Federation</td>
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<td>Mr. D. Murch</td>
<td>Department of Environmental Protection (Maine)</td>
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<td>Mr. L. Crowe, Mr. B. Greeve</td>
<td>The Federal Energy Regulatory Commission (FERC)</td>
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<td>Mr. M. Horn</td>
<td>US Bureau of Reclamation</td>
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2 INTERNATIONAL OVERVIEW

2.1 International Legislative Framework

There are a wide range of international conventions that are applicable to dam and impoundment projects across the world. These include *inter alia*:

- 1998 Aarhus Convention on the Access to Environmental Information and Public Participation in Environmental Decision Making;
- 1983 Convention on the Conservation of Migratory Species of Wild Animals and Agreement (Birds and Mammals and their Habitats, 1994);
- 1971/1982 International Convention on Wetlands of International Importance Especially as Waterfowl Habitat (Ramsar Convention) and the 1982 Protocol;
- 1979 Convention on Migratory Species of Wild Animals (The Bonn Convention);

2.2 World Commission on Dams (2000)

The World Commission on Dams was set up in 1998, following a workshop in 1997 to discuss highly controversial issues associated with large dams. The mandate was to:

- Review the development effectiveness of large dams and assess alternatives for water resources and energy;
- Develop internationally acceptable criteria, guidelines and standards, where appropriate, for the planning, design, appraisal, construction, operation, monitoring and decommissioning of dams.

The final report of the World Commission on Dams: Dams and Development: A New Framework for Decision-Making was released in November 2000. The key findings of the Overview Report relevant to this project are provided below:

Whilst there has been a decline in dam building since the peak in the 1970s, the top five dam building countries (China, USA, India, Japan and Spain) account for more than three-quarters of all large dams worldwide, with approximately two-thirds of the world’s existing large dams found in developing countries. Hydropower accounts for more than 90% of the total electricity supply in 24 countries, such as Brazil and Norway. Half of the world’s large dams are built exclusively for irrigation and, in at least 75 countries, large dams have been built to control floods.

The issues surrounding dams relate to:

- The effect on river flow;
- The rights of access to water and river resources;
- Whether the dam will uproot existing settlements, disrupt the culture and sources of livelihood of local communities;
- Whether the dam will deplete or degrade the environmental resources; and
- Whether the dam is the best economic investment of public funds and resources.
The remaining, and controversial issues include:

- The extent to which alternatives to dams are viable for achieving various development goals and whether alternatives are complementary or mutually exclusive;
- The extent to which adverse environmental and social impacts are acceptable;
- The degree to which adverse environmental and social impacts can be avoided or mitigated; and
- The extent to which local consent should govern development decisions in the future.

The report identified the generic nature of the impacts of large dams on ecosystems, biodiversity and downstream livelihoods, where it showed that large dams have led to:

- The loss of forests and wildlife habitat, the loss of species populations and the degradation of upstream catchment areas due to inundation of the reservoir area;
- The loss of aquatic biodiversity, of upstream and downstream floodplains, wetlands, and riverine, estuarine and adjacent marine ecosystems;
- Cumulative impacts on water quality, natural flooding and species composition where a number of dams are sited on the same river.

In some cases, however, enhancement of ecosystem values does occur, for example, through creation of new wetland habitat and the fishing and recreational opportunities provided by new reservoirs.

Efforts to date to counter the ecosystem impact of large dams have met with limited success due to the lack of attention to anticipating and avoiding such impacts, the poor quality and uncertainty of predictions, the difficulty of coping with all impacts, and the only partial implementation and success of mitigation measures. More specifically:

- It is not possible to mitigate many of the impacts of reservoir creation on terrestrial ecosystems and biodiversity, and efforts to ‘rescue’ wildlife have met with little long-term success;
- The use of fish passes to mitigate the blockage of migratory fish has had little success, as the technology has often not been tailored to specific sites and species;
- Good mitigation results from a good information base; early co-operation between ecologists, the dam design team and affected people; and regular monitoring and feedback on the effectiveness of mitigation measures;
- Environmental flow requirements (which include managed flood releases) are increasingly used to reduce the impacts of changed streamflow regimes on aquatic, floodplain and coastal ecosystems downstream.

Given the limited success of traditional mitigation measures, increased attention through legislation is now given to avoidance or minimisation of ecological impacts through setting aside sections of rivers or basins in their natural state and through the selection of alternative projects, sites or designs. In addition, governments are trialling the ‘compensatory’ approach, offsetting the loss of ecosystems and biodiversity caused by a large dam through investment in conservation and regeneration measures and through the protection of other threatened sites of equivalent ecological value (whether this approach will be acceptable within the terms of the Water Framework Directive is yet to
be determined, but is a common approach in achieving the requirements of the Habitats Directive).

Finally, in a number of industrialised countries, but particularly in the United States (see Section 3.6 below), ecosystem restoration is being implemented as a result of the decommissioning of large and small dams.

The selected recommendations from the World Commission on Dams (2000) report include recommendations for a number of stakeholders, including the following:

**National Governments** can:

- Require a review of existing procedures and regulations concerning large dam projects;
- Adopt the practice of time-bound licences for all dams, whether public or privately owned;
- Establish an independent, multi-stakeholder committee to address the unresolved legacy of past dams.

**Professional Associations** can:

- Develop processes for certifying compliance with World Commission on Dams guidelines;
- Extend national and international databases such as the ICOLD World Register of Dams, to include social and environmental parameters.

These recommendations should be considered in Phase 2 of this project.

### 2.3 World Commission on Dams and the Water Framework Directive

The WWF Dams Initiative (2004) prepared a briefing note on Dams in Europe, the Water Framework Directive and beyond (based on a legal and policy analysis by Barreira, 2004) ([www.panda.org/dams](http://www.panda.org/dams)). The paper compares the strategic policies of the WCD to the WFD, and finds that many of the WCD guidelines (such as public participation, river basin wide understanding of ecosystems, options assessment, and cross-border cooperation) are encompassed within the WFD. It notes, however, that the WFD has the broader scope of water management compared to the WCD, which relates only to dams, and hence it is predictable that not all the WCD’s recommendations are reflected in the WFD. It recommends, however, that the WCD guidelines should be used to provide additional guidance to governments and dam developers to ensure that existing and new dams in the European Union meet the highest possible standards.
3 NATIONAL POSITION STATEMENTS

3.1 Introduction

National position statements have been prepared for each of the five countries selected for review: Norway, France, Germany, Australia, and United States. The statements present the findings of the international review for the following:

- A general description of the types and number of impoundments in the country;
- The legislative and institutional framework, including policy, laws and regulations, who is involved, licensing procedures, environmental objective setting and environmental impact assessment requirements. This is supported by a summary table of the key points;
- Lessons learnt, during the planning, construction, operation and decommissioning stages. This is supported by a summary table of the key mitigation measures and management strategies that have been used in each country (where information is available);
- Case-studies (provided in Annex B);
- Supporting information (provided in Annex C).

3.2 Norway

3.2.1 General Description

Norway has many thousand watercourses and over 1100 of these are used for hydropower production (Kronen Helgestad 1999). Hydropower accounts for 99% of the electricity generated in Norway and the average production capability of Norway's hydropower plants is estimated to be about 119 TWh/year with 1 tetrawatt hour equalling 1 billion kWh (Ministry of Petroleum and Energy 2002)

3.2.2 Legislative and Institutional Framework

The legislative and institutional framework for Norway is described below and summarised in Table 1 (Annex D).

**Policy Framework**

The Norwegian Parliament (the Storting) determines the political framework for the energy sector and water resource management in Norway while the Norwegian Water Resources and Energy Directorate (NVE), a Directorate of the Ministry of Petroleum and Energy (MPE) are responsible for licensing hydropower schemes with its prime objective being to ensure sound management, in both economic and environmental terms of water and hydropower resources (and other domestic energy sources). ([www.nve.no](http://www.nve.no)).

**Laws and Regulations**

Licenses to construct and operate impoundment structures are issued by the Norwegian Water Resources and Energy Directorate (NVE) under the provisions of the Watercourse Regulation Act 2000, which permits the use of a impoundment structure, the Water Resources Act 1991, which applies to all types of works in a watercourse and the Planning an Building Act which permits the construction of the impoundment.

Licenses issued under the provisions of the Watercourse Regulation Act 2000 contain provisions to reduce the damage caused to the watercourse by the impoundment
structure and could include establishing a fishing fund of the impoundment impacts upon fish stocks in the river and include conditions controlling the rate of discharge and could incorporate seasonal variations. In addition conditions requiring the establishment of a business fund to compensate for any adverse affects of the structure, including environmental impacts are imposed.

The Water Resources Act 2001 is a general act which governs all types of works being undertaken on watercourses and ground water to ensure that these waters are used and managed in accordance with the interests of society. In order for a license to be granted under the provisions of this Act, the damage and inconvenience of the works to the environment and society must be less than the over all benefits. The legislation allows conditions to be applied to the license to compensate for and to mitigate against adverse impacts of such activities.

The Planning and Building Act governs land use in general and relates equally to watercourses and groundwater. It includes provisions relating to land use planning, procedures relating planning applications and environmental impact assessments (incorporating the requirements of the European EIA Directive).

There are numerous other forms of Norwegian legislation which can have an influence on the decision to license an impoundment structure in this country, including:

- The Neighbouring Properties Act;
- The Pollution Control Act;
- The Cultural Heritage Act;
- The Outdoor Recreation Act;
- The Nature Conservation Act;
- The Wildlife Act; and
- The Aquaculture Act.

Institutional Framework

The licensing of impoundment structures under the provisions of the above mentioned legislation is undertaken as one process lead by the Norwegian Water Resources and Energy Directorate (NVE), which is the competent authority. The relevant municipality and county are consulted and feed back their comments to NVE following discussions with various experts and politicians while various Directorates and Ministries provide expert comment and propose conditions relating to environment, pollution, cultural heritage, mining, roads, sea fishing and agriculture. In addition various NGO's, local residents and landowners are also given the opportunity to comment on both the plan/notification and the application and supporting Environmental Impact Assessment.

Protection Plans and the Master Plan

As noted above, over 1100 of Norway's watercourses are used for hydropower production (Kronen Helgestad 1999). In order to protect this valuable natural resource, the idea of developing protection plans for watercourses was developed. The first Protection Plan was developed in 1973 and since this time a further three plans have been produced, the most recent one being prepared in 1993 and affording protection to some 341 river systems in which no further hydropower development will be permitted. In 1980, as a result of conflict between hydropower developers, environmental interests and the authorities, the development of the Master Plan to control the development of Hydropower Schemes began. The first Master Plan was accepted by Norway's Parliament in 1986 and it has been updated since then.
Licensing Procedures

The licensing procedure comprises several key stages: notification; public consultation; determination of the impact assessment (IA) requirements (including EIA requirements); the submission of the application and supporting EIA; public consultation; approval of the EIA and evaluation of application; and granting of license. The first stage of the process is the notification process where the developer submits a proposal to NVE detailing the description of the proposed works, a general description of the area, alternative options and the proposals for an IA. This information is then sent to central and local authorities and the public for consultation, with the proposals being posted in local post offices and libraries. A public meeting is held to enable the public to present their views and find out more about the proposals and separate meetings with government and other consultees may be held. (Gakkestad, 2003)

Following this consultation period, NVE determine the scope of the impact assessment. Only after this point can the impact assessment process begin. This process is discussed in further detail below. Following submission of the application, a further period of consultation involving central and local administrations and the public begins. At the end of the consultation period, the IA is assessed and only once this is approved can the application be considered. If the proposal is considered to be acceptable, a license, subject to conditions which cover the life of the project, from construction through operation to decommissioning is issued. The conditions can relate to methods of construction, requirements to install fish passes and ladder, landscaping issues and general environmental issues. These conditions which act as mitigation measures are discussed in further detail in section 3.2.3 below.

Environmental Objective Setting

No specific information relating to environmental objective setting was identified during the literature review and consultation. However, the Protection Plans provide strategic objectives for the watercourses within the plan (Kronen Helgestad, 1999 and Ministry of Petroleum and Energy, 2002).

Requirement for an EIA

The requirement for an EIA in Norway is determined with reference to the original EIA Directive prepared in Europe and its subsequent review in 1999. These directives and the need for an Impact Assessment have been transposed into Norwegian legislation and the requirements of the legislation incorporated into the licensing process. The IA must cover environmental issues such as hydrology; geology; landscape; local climate; water quality; freshwater biology; terrestrial biology; and cultural monuments, as well as natural resources (agriculture; forestry; freshwater resources; minerals and gravel) and community issues (industries, populations; services; local finance; infrastructure; social conditions; health; and outdoor life) (Gakkestad, 2003 and Ministry of Petroleum and Energy, 2002).

Water Framework Directive

The European Directive has been adopted by Europe and, like Australia, Norway is of the opinion that water quality, in watercourse systems where impoundment structures are common place, is largely driven by compensation flows. These compensation flows have traditionally been determined based on minimum flows, below which the discharge cannot fall. However, this approach has not considered the ecological status of the watercourse and consequently, the Norwegian Water Resources and Energy Directorate (NVE) has commissioned a five year research and development programme on environmental instream flows. This project aims to increase the knowledge on the
effects of greatly reduced flows in order to develop methods to enable the setting of ecologically sound compensation flows during the licensing procedure (Brittain, 2002).

3.2.3 Lessons Learnt (Mitigation and Management Strategies)

Table 2 (Annex D) provides a summary of the mitigation measures and management strategies applied in Norway and are expanded upon below.

Planning

The planning process for impoundments, particularly those relating to hydropower schemes is comprehensive and operates effectively fully incorporating the requirements of the developer, the local community and the environment. The effectiveness of the process is the result of one hundred years of legislating for hydropower schemes with the first licensing laws being passed in 1906. The fact that the licence can contain conditions to mitigate against impacts during all life stages of the impoundment from construction to decommissioning is highly beneficial.

The planning process is undertaken in a similar manner to that in the UK. However, the consultation process, particularly with the public, is much more proactive. In Norway there are two distinct stages of consultation, the first at the beginning of the process when the proposal is in the initial idea stage and again once the proposal has been developed. In addition, the detail of the EIA in Norway is determined before the EIA is undertaken as a statutory requirement, while in the UK there is no legal requirement for this to be undertaken (although the developer can submit a screening request to the Planning Authority under the provisions of the EIA Regulations).

Construction

As discussed above, conditions are applied to the licence to mitigate against impacts during construction as well as to ensure that the impoundment structure is built to exacting standards. In addition a deadline for the construction of the scheme is imposed and is generally 5 – 10 years from the date of the licence. Conditions preventing pollution during construction are imposed as are conditions requiring the construction fish ladders etc in weirs to enable the safe passage of migratory fish.

Conditions relating to the sourcing of materials for impoundment structures and the operation of the quarries being used are incorporated into the licence. Where possible material should be excavated from the area covered by the reservoir and if this is not possible the quarry should be contoured such that visual impacts are minimised. Conditions relating to access roads can be incorporated to cover their construction and operation, limiting access to protect the surrounding habitat. A condition requiring the removal of the road following construction of the impoundment can also be incorporated into the licence.

Operation

Hydropower licences granted to the State Company and companies owned by municipalities and counties are granted for an unlimited period of time while licences to private companies are issued for a period of 60 years, after which time the impoundment is handed back to the State. Licence conditions can be reviewed 30 – 50 years after the licence has been granted.
Conditions relating to operation include setting highest and lowest regulated water levels within the impoundment structure as well as the minimum water flow that must pass through the impoundment structure (compensation flow) which can be subject to seasonal variations to ensure minimum water flows downstream of the impoundment structure at all times. These conditions are determined with reference to the natural situation and ensuring that the existing habitat and species dependant on an adequate water supply are protected, and that breeding of native fish is not disrupted. In addition, flows may be set to ensure that outdoor activities such as fishing, swimming and rafting are not disrupted and that pollution as result of the loss of dilution does not occur. In some instances the first five years can be used as a test period to determine the optimal compensation flow to meet all requirements.

Conditions requiring the installation of weirs to improve the aesthetic appearance of the watercourse downstream of the impoundment structure can be included in the license. In addition to the aesthetic improvements afforded by weirs, the weirs, providing they are designed to be passable for fish, can be designed to channel water into a narrower, but deeper stream, enabling fish to pass upstream and thereby improving opportunities for spawning and survival.

Conditions requiring the use of artificial areas of rocks and stones in watercourses downstream of impoundment structures to stabilise the riverbed, and create a variety in the substrate, flow conditions and depth are also used. River restoration is becoming increasingly important and conditions to facilitate this are being incorporated into licences for impoundment structures. This includes conditions to re-profile watercourses, improve the substrate of the rivers, and enhance vegetation cover on the banksides of the rivers.

Conditions to enhance the area of wildlife are also imposed and include conditions to protect, enhance or create wetland areas and river corridors which not only enhance wildlife but also reduce pollution of watercourses.

**Decommissioning**

Besides the fact that conditions to govern the decommissioning of impoundment structures are included in the licence, no additional information on decommissioning was found during the review.

### 3.2.4 Case Studies

Three case studies, all relating to works done to improve the ecological status of reservoirs and controlled waters impacted upon by impoundments associated with hydropower schemes in Norway, are summarised in Annex B:

- Erosion of Shore Zones in Meltingen Reservoir, Nord-Trondelag Country, Norway;
- Creation of a Retaining Dam in Innerdal Reservoir, Innerdalen, Norway;
- The Creation of Increased Spawning Grounds in Inlet Streams, Oppland, Norway
3.3 France

3.3.1 General Description

Impoundments are defined in France as ‘all structures which are built across the river in order to divert water or to accumulate water’ and this definition includes structures which are built across the wider river bed as well as the structures which were built only across the narrower river bed.

The French hydrographic network is heterogeneous due to the diversity of the natural geological and topographical conditions which results in impoundments of differing types, uses, size and implementation including:

- Small fishing lakes (in the Limousin area and in the Northern part of Auvergne)
- Hydropower stations in mountainous areas
- Drinking water reservoirs in Brittany and in the Limousin area.

The website, http://www.cig.ensmp.fr/~hhgg/gest/barnombr.htm, reports that there are 468 impoundments in France which are 15 m high or higher while the French Committee of the large impoundments (Comité Français des Grands Barrages) advises that there are some 558 such impoundments.

As detailed in Table A1.2, the main types of dams in France are constructed of mass, arch and rock which represent more than 80% of the large French dams. Eighty-five percent of these impoundments were constructed after 1930 (see Table A1.3). (www.barrages-cfgb.org).

<table>
<thead>
<tr>
<th>Table A1.2 : Types of impoundments</th>
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<tr>
<td>Type</td>
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<td>Multiple arches</td>
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<td>Rock / earth</td>
</tr>
<tr>
<td>Counter forts</td>
</tr>
<tr>
<td>Mass / Arches</td>
</tr>
<tr>
<td>Mass / Barrage mobile</td>
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<td>Mass / Earth</td>
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<th>Table A1.3: Construction date of French impoundments</th>
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<tr>
<td>Implementation date</td>
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<td>1951 - 1970</td>
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<td>1971 - 1990</td>
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<td>1991 - 1998</td>
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3.3.2 Legislative and institutional framework

The legislative and institutional framework for France is described below and summarised in Table 1 (Annex D).

Policy framework

The implementation, operation and decommissioning of impoundments in France is regulated by the following statutory orders and laws:

- Law of the 8th of April 1898 on the water flow rate
- Law of the 16th of October 1919 regarding hydropower
- Law No. 92-2, 3rd of January 1992 on water.

These laws were issued by the following Ministries:

- The Ministry of Industry (for hydropower)
- The Ministry of Agriculture
- The Ministry of Environment
- The Ministry of Infrastructure

Licensing Procedures

The information comes from the review of the following documents:

- Decret no 93-743, mars 1993. relatif a la nomenclature des operations soumises a autorisation ou a declaration ;
- Decret no 99-736, modifiant le decret no 93-743;
- Decret no 93-942, mars 1993 relatif aux procedures d’autorisation et de prevention prevues par l’article 10 de la loi no 92-3 du 3 janvier 1992 sur l’eau ;
- L’etude d’impact sur l’environnement, Patrick Michel, Ministere de l’aménagement du territoire et de l’environnement ; and.
- Code de l’environnement (partie legislative).

Institutional framework

Hydropower impoundments are owned and managed by EDF (Electricité de France). All impoundments are regulated by several water regulatory bodies, which were interviewed (in French) by telephone using the set questionnaire (see Annex A).

Regional Departments of Industry, Research and Environment (La Direction Régionale de l’Industrie, de la Recherche et de l’Environnement (DRIRE))

The DRIRE deals with the administrative and technical control of the hydropower impoundments of a power above 4500kW. Hydropower stations of a lesser capacity are controlled by the DDE and/or the DDAF (see definitions below). The DRIRE generally requires technical and financial guarantees from the hydropower
management for a duration of 75 years for new impoundments and 40 to 45 years for old impoundments.

Regional Departments of Infrastructure – county level (La Direction Départementale de l’Equipement (DDE))
The DDE is a regulatory body with jurisdiction for water, fluvial navigation and flood protection. The DDE controls hydropower stations with a capacity of less than 4500kW. Since 1999, power stations generating more than 100MW must be authorised by the local authority. Power stations generating more than 100MV must seek authorisation from the government (however the authorisation procedure is similar in both cases).

Regional Departments of Agriculture and Forestry - county level (La Direction Départementale de l’Agriculture et de la Forêt (DDAF))
The DDAF regulates the small size impoundments and acts as a fishing regulatory body.

Regional Departments of Environment (La Direction Régional de l’Environnement (DIREN))
The DIREN is not a water regulatory body but is a consultee for projects involving the construction of impoundments and provides advice as to whether or not impoundments should be founded by the European funds. In the case of hydropower impoundments, the DIREN requests the undertaking of an appraisal study to justify the benefits of the project.

The Permanent Technical Committee for Impoundments (Le Comité Technique Permanent des Barrages (CTPB))
The CTPB is an inter-ministerial committee which advises on impoundment projects coming from the ministerial or county levels. The CTPB checks the safety of impoundments of 20m high or above and carries out improvement / maintenance studies on impoundment (structural integrity, water drainage, etc.).

Environmental Objective Setting
No specific information relating to environmental objective setting was identified during the literature review and consultation.

Licensing Procedures / EIA Requirements
The licensing procedure (based on the statutory law of the 9th of March 1993) includes the following:

- Name and address of the applicant;
- Location of the impoundment (grid reference and map);
- Technical data (construction methodologies and materials, dimensions, cubage, type of the impoundment);
- Impact on water resources, aquatic life, water-flow, water level, water quality, including water run-off;
- Mitigation measures;
- Compatibility of the project with water management measures/policies (SAGE & SDAGE) and water quality objectives;
• Impact assessment (power above 500kW) or impact statement (power below 500kW);
• Supervision procedure and emergency procedure;
• Graphical data, maps, other useful data helping the understanding of the application.

The licensing procedure also considers the impact of the impoundment on the land owners and assesses the need for the impoundment and the need to serve compulsory purchase notices where required.

The departments of the State give objective views on the project and advise whether or not the project guarantees adequate management of aquatic life and of water resources. Therefore, the licensing procedure must discuss the factors which are likely to be modified by the implementation of the impoundment:

• Fish obstacles and navigation obstacles (even for leisure purposes);
• Management of all fish species;
• Sediment management;
• For large impoundments: water loss by evaporation and warming of the water stoked volumes;
• Compatibility with water French management measures on the river basin scale, if present (SAGE & SDAGE);
• Submersion and land management;
• Management of flood and dam infrastructure (overflow).

During the consultation process, the general public is consulted in addition to a number of organisations including:

• The DDAF, fishing regulator;
• The DDE, water regulator;
• The DRIRE, industry and environmental regulator;
• The DDASS (Direction Départementale des Affaires Sanitaires et Sociales), Department of health and social services (county level). Water quality regulator;
• The DIREN;
• The CTPB (for dams of 20m high or above);
• The CSP (Circulation des poissons) fish traffic);
• The local commission of water (if SAGE (water management plan) present);
• County and local authority representatives;
• Civil safety for large dams;
• The Department of Youth and Sports (leisure).

**Suggested modification to the licensing process**
Currently, the owner of the site may apply for an authorisation which eventually (up to two years after the deposition of the application) is rejected by the regulatory water bodies. This has cost implications for the contractor, particularly for projects concerning rivers with migratory birds or where the public consultation requirements are significant. This could be avoided by allowing water regulatory bodies the opportunity to reject a project at an earlier stage in the planning process if it could be demonstrated that the project is not compatible with the general principles of water resources and aquatic life protection.

**Decommissioning**
Legal framework

The law of the 16th of October 1919 on hydropower generation states that licences (concessions) for hydropower impoundments are granted for a limited period, which should not exceed 75 years. These licenses/concessions can be extended as long as an appraisal of the social and economical advantages of keeping the impoundment (power, multi-uses, drinking water supply, tourism, etc.) and the environmental impacts is undertaken. Further to this appraisal results, the regulatory bodies will decide to renew the licence/concession or to decommission the impoundment.

Concessions are issued for impoundments generating more than 4,500kW (which are leased to the public service under French legislation). When the concession period is over, the impoundment is handed back to the government. The government then decides, whether the concession is renewed, the impoundment used for other purpose or the impoundment is demolished. The costs of demolition are paid by the government.

The licenses are applicable to impoundments of less than 4,500kW. When the license is revoked, the impoundment is still owned by the petitioner. If the license is not renewed, the law of the 16th of October 1919 demands that the owner of the site decommission the impoundment at its expense.

The licences granted before 1919 were maintained for a temporary duration of 75 years (i.e. until the 16th of October 1994). Out of hundreds of renewal applications for concessions/licenses, only three have been declined by the government. These impoundments were demolished, due to the lack of economical advantages and significant environmental impacts.

The Principle of Reversibility of the impoundments

As the license/concession is granted for a limited duration, impoundments for which disadvantages are greater than advantages will have to be decommissioned and the site re-instated. That is what is called the principle of reversibility.

This principle of reversibility of the impoundment was applied in France, more especially within the “Loire Grandeur Nature” framework, adopted by the French government on the 3rd of January 1994. This framework aims to protect inhabitants, prevent floods, and protect habitats and aquatic life located on the Loire River and its tributaries. Within that framework, one of the aims was the protection of migratory species including the grand salmon of Loire River, the only salmon which swim through a large European river (distance of 800km between the estuary and the spawning substrates).

The government decided that old impoundments of St-Etienne du Vigan on the Allier River and of Maisons-Rouges on the Vienne River had to be decommissioned due to low profitability. The government accepted some conversions after checking carefully the usefulness of these and minimised their impact by the implementation of mitigation measures. It contributed to the sustainable development of the Loire River.

However, with regards to the concession to the government, this principle of reversibility should be adapted as currently the concessionaire take advantage and make profit from the concession and that the government is responsible for the re-instatement of the site when the concession ends.

Consequences of the water framework directive
The Water Framework Directive has been recently introduced in French regulation and appears to date to have had little impact on existing procedures which seem comprehensive. Under this legislation, water regulatory bodies require to ensure that their decisions are compatible with the WFD when processing impoundment applications. Meetings to discuss the implications of the WFD on the quality of the large water reservoirs have been organised.

3.3.3 Lessons Learnt (Mitigation Measures and Management Strategies)

Table 3, Annex D provides a summary of the mitigation measures and management strategies applied in France and are these expanded upon below.

Planning
The planning and licensing stage allow for a high level of involvement from the public (non-)statutory bodies. Sediment management, management of flood and dam infrastructure, water loss by evaporation and warming of the water stored volumes and compatibility with French management measures on the river basin scale (if present) are all addressed during the licensing procedure, as well as environmental issues such as fish management.

Construction and operation
Following is a brief discussion of the main environmental and management issues related to the construction and operation of impoundments in France and how they are dealt with.

Flood Risk
In France, there are 89 large dams (of a height above or equal to 20 m and with a reservoir capacity of 15 millions cubic meters) which represent flood risks for downstream areas (www.environnement.gouv.fr/dossiers).

Figure A1.2: The Location of Large Dams in France
DRIRE undertakes a risk assessment so assess the risk of breaching of dams with a height of more than 20m and a storage capacity of over 50 million cubic meters) in the event of over-capacity or earthquakes. The DRIRE works in partnership with the CTPB and defines the floodplain envelope based on the worst historical flood. This information is then communicated to the civil protection department.

In the CEMAGREF’s opinion, 50% of French dams are not sufficiently controlled / checked.

**Water quality of the reservoir**

Eutrophication is a concern in some French impoundments, due to the high inputs of nutrients (nitrogen and phosphate) commonly used in fertilizers. This is particularly a problem in impoundments which have a very low water renewal / mixing rate. Small impoundments constructed on large water courses are, therefore, generally not affected by this problem. Monitoring of water quality is sometimes carried out on impoundments (for example, the impounded water at the dam of Naussac).

Poor water quality is in France as in other countries is often associated with the natural supply of degrading tree and vegetation debris from the river, but also (and mainly) due to upstream diffuse and point source pollution inputs from agriculture, industry and the towns (e.g. Sewage treatment works). The main polluting factor is diffuse pollution which drains into the impoundment from the catchment where there is no control of farming practices or land management, resulting in generating elevated levels of nitrogen and phosphorous in surface water run-off. The total nutrient load in the impoundment is also affected by the levels within the soil at the time of in-filling and hence the dissolution of contaminants present within these sediments.

Water quality in the reservoir could be easily improved through the control of point source pollution inputs from the farming industry, the industries and the towns. However, control of diffuse pollution inputs is generally more challenging (and a key requirement of the Water Framework Directive) and is caused by factors which are not directly associated with an impoundment construction project. It would be possible, however, to combine the construction of the dam with a requirement for a funding program to encourage agricultural best practice (e.g. land use change, land management, buffer strips and other measures) in the catchment. This could be partly funded with the predicted profit made from the dam.

Operational measures that could be used to minimise diffuse pollution inputs include:

- Avoid diverting water courses into the impoundments when rainfall is high (this has upstream potential flooding effects).
- Release the water of the reservoir from the bottom gate in order to flush out the water most loaded with nutrients released from the sediments (this has downstream potential adverse effects).

Mitigation measures used to increase the oxygen content throughout the impoundment (and particularly in the outflow) include mixing the water at the bottom of the lake. This method is about to be launched on Lake Aydat, which is an impounded water located on the River Veyre and is subject to eutrophication.

The storage of stagnant water in impoundments can also lead to water warming and water loss through evaporation.
**Sediment Transport**
Construction of an impoundment generally leads to storage of sediment and silt material, brought by the river flow, behind the dam.

In the impoundment of Poutès-Monistrol sur l’Allier, regular additional compensation flows (5 m$^3$/s extra) reduce the build up of solid material and encourage the continuous transportation of solid material from the impoundment to the downstream reaches of the water course. However, this method is difficult to implement on water courses with a succession of dams, especially if the dams are managed by different owners (for example, on the Dordogne)

**Impact on fish**
The main impact on fish is associated with the obstacle formed by the dam which affects the passage of fish. The presence of dams has resulted in the loss of some migratory species from the river system e.g. salmon in the Loire-Allier system. The installation of mitigation measures to facilitate fish passage (e.g. fish passes, fish lifts, baffled passes) is necessary to minimize the impact of the impoundment on migratory fish both upstream and downstream of the impoundment.

The construction and operation of a dam/impoundment leads to an alteration in the hydrology of the water course e.g. reduced flows and artificial flows in the river and the consequences of this change in hydrology are diverse. Changes in the flora and fauna, and more especially to change in fish species result with an increase of other fish species (cyprinid species, white fish, carnivorous fish) in salmonid waters. Generally in France, the managers of large impoundments financially compensate the fishery management bodies affected.

On the other hand, continuous releases of fresh and oxygenated water during the summer can be beneficial for salmon species e.g. on the River Allier downstream from the dam of Naussac. Fish counting is undertaken by the aquatic life management bodies upstream and downstream of impoundments and low water flows have been set by legislation to protect fisheries interests since the 1980s and have been raised from 1/40$^{th}$ of the total annual flow for old impoundments to 1/10$^{th}$ of the annual flow or the minimum biological flow whichever is the higher for new impoundments.

In the case of small fishing lakes located on a water course of good ecological status / first grade quality (i.e. dominated by salmonid species), the emptying of the impoundment can introduce unwanted species in the water course. In order to minimise that effect the fishing lake must be equipped with a fish screen. Moreover, supervision of the emptying should be carried out by water regulatory bodies but this is rarely done due to the large number of fishing lakes.

Emptying and flushing of the impoundments leads to two types of issues (see earlier section on sediment transportation):
- Destruction of fish life in the impoundment (for example, of the impoundment of Zola in the Bouches-du-Rhône area);
- Covering the spawning substrate and disturbance of the fish life downstream due to sedimentation from the impoundment.

Fish rescues are sometimes undertaken in order to prevent fish death from asphyxia.

**Tourism**
For some French impoundments, the creation of recreational waters has a beneficial impact on the local economy due to increased tourism although the bacteriological quality of bathing waters must be checked regularly by the Department of Health and Social Services.

In the case of impoundments used for both hydropower and tourism, some water level variations result in the impoundment being unsuitable for bathing purposes. Therefore, the installation of turbines equipped with level gauges, which maintain the water level of the impoundment above a minimum level have been trialed in France.

Moreover, the dam is an obstacle to navigation for recreational users of the waterway (i.e. canoes) and it is sometimes necessary to build a canoe passage or artificial river.

Using sluicing for hydropower management represents significant risk to life on sections of the watercourse situated downstream. The sharp increase of the river flow has resulted in many instances of human life being lost e.g. an incident on the River Drac in 1999 resulted in 10 deaths. The mitigation measures include the posting of warning signs close to the water course, prohibiting the access of some parts of the river and avoiding the use of sluices.

In order to minimise the environmental impact of the impoundment, it is necessary to consider solutions at both the river basin level (reduction of the supplies) and the impoundment level. (design, management, monitoring, maintenance).

3.3.4 Case Studies

In France, three impoundments which were located on rivers used by migratory species have recently been decommissioned. They include the impoundments of Kernansquillec sur le Léguer (Côtes-d'Armor), St- Etienne du Vigan sur l'Allier (Haute-Loire et Lozère), Maisons-Rouges sur la Vienne (Indre-et-Loire). General information on the decommissioning process was presented in section 3.3.3, whilst descriptions of the dams, the approach to demolition and the problems encountered in each case are presented in more detail in Annex B.
3.4 Germany

No responses from the consultation process were received in the timescales of this project, and therefore all the information in this project is based on information which could be found during the literature review and from web sites in the area.

3.4.1 General Description

The majority of the impoundments in Germany appear to be for water supply.

In a report titled “Wasserkraft als erneuerbare Energiequelle” (Hydropower plants as a source of renewable energy), the Federal Environmental Agency investigated the economic and ecological effect of hydropower in Germany. The study concluded that small hydropower plants producing up to 1,000 kilowatts of electricity conflict between the goals of climate protection and those of water protection. Traditionally, hydropower has been the renewable energy source most used in Germany, with about four percent of electricity generated by this method (www.umweltbundesamt.de/uba-info-presse-e/presse-informationen-e/p3301e.htm).

New hydropower plants continue to be built, whilst older plants that had been shut down are being reinstated. These are occurring with federal and Lander councils granting financial support. No strategic planning or policy documents were found relating to the overall effect of hydropower on the environment during our literature review. From research it appears that there are individual city and region plans, either relating to water resources or more likely relating to renewable energy policy and strategy, that identify hydropower as sustainable as an energy source, but not necessarily taking into account the in-river environmental impacts.

3.4.2 Legislative and Institutional Framework

The legislative and institutional framework for Germany is described below and summarised in Table 1, Annex D.

Policy Framework

Water protection policies in Germany focus primarily on maintaining or re-establishing the ecological balance of water bodies, on guaranteeing drinking and process water supplies and on providing long-term safeguards for all other water uses benefiting the general public. Current water protection policies are in particular aimed at preventing ground and surface water pollution with hazardous substances.

A core task in German water protection policy today is transposing the ambitious deadlines concept of the EU Water Framework Directive, which entered into force on 22 December 2002. The new German Federal Water Act came into force on 25 June 2002. Meanwhile the Länder (defined in Institutional Framework section below) are bringing their own legislation into line with the new Federal Water Act, but progress is thought to be slow.

Laws and Regulations
There are Land law provisions for every region in Germany. The following federal legislation is of relevance to impoundments and their development:

- Federal Water Act 2002;
- Ordinance on Requirements for the Discharge of Waste Water into Waters (Waste Water Ordinance - AbwV) 2002; and

The Federal Water Act 2002 regulates impoundments and their development and is enforced by the Länder. Under the Federal Water Act all water bodies need to be managed, if they are not artificial or heavily modified. The management of the water bodies is carried out such that:

1. any adverse changes to their ecological and chemical status is avoided and
2. a good ecological and chemical status is preserved or attained.

Under the Act, conditions may be imposed to prevent, or compensate for, any detrimental effects to other persons, or to prescribe measures necessary to compensate for impairments to the ecological and chemical status of a watercourse. In addition, monitoring is undertaken as part of the management plan required for all river basins, against which any major changes would be observed. Licenses can be revoked in the event of or fear of pollution of a watercourse, or if the holder fails to comply with conditions laid down as part of a license.

**Institutional Framework**

The Basic Law distributes responsibilities between the Federation and the Länder:

- **The Federation** - Federal Government is responsible for issuing framework provisions, and answer to the EU. The Federal Government is also responsible for transboundary cooperation in protecting inland waters and lakes, which is a key element of its water protection policy.

- **The Länder** - The Länder are responsible for the implementation and supplementation of these Federal provisions (such as the Federal Water Act 2002) and the enforcement of all legal provisions regarding water protection.

Responsibility for setting up regulatory frameworks lies with the Federal Government, while the Länder are responsible for implementing and supplementing the Federal regulations and enforcing all statutory provisions in the field of water pollution control. Any use of water or water bodies falls under the Lander regulatory control under the Federal Water Act (2002).

Several statutory consultees are approached during the consideration of an impoundment licence. Due to poor response from the consultees, the review was not able to identify the specific consultees. It is expected that the list of stakeholders consulted is similar to that of the other countries, and includes environmental protection agencies.

**Impoundment Licensing / Permitting Procedures**
Licensing and permits fall under the newly amended Federal Water Act (2002). The Lander (state) bodies are the regulating authority, to whom applications for licences or permits are made.

**Obligation to obtain a permit or licence:**

(1) The use of waters shall require an official permit or licence unless otherwise specified by the provisions of the Federal Water Act or by regulations issued by the Länder in accordance with the Act.

(2) A permit or license shall not confer a title to a supply of water in any specific quantity or of any specific quality. A permit or license shall not affect any claims under private law to a supply of water in any specific quantity or of any specific quality.

**Permit:**

A permit allows a revocable authority to use a body of water for a specific purpose, in a specific way and to a specific extent. A permit may be granted for a limited period of time. Permits for projects which are subject to environmental impact assessment under the Environmental Impact Assessment Act shall only be granted by means of a procedure which fulfils the requirements of the aforementioned Act.

For projects falling under the scope of integrated pollution prevention and control (IPPC Directive) the Länder shall adopt regulations stipulating the requirements which must be met in water permit procedures under water legislation.

**License:**

A license shall confer the right to use a body of water in a specific way and to a specific extent. It does not confer the right to utilise objects or land and installations in the possession of another person. A license may be granted only if the “user” cannot be expected to carry out a project without a secure legal position, and the use of water is for a specific purpose which is identified in a specific plan. Licenses are not granted for the discharge of waste or wastewater.

**Environmental Objective Setting for Impoundments**

Other than relevant EU objectives, e.g. dangerous substances, etc., the review did not identify any specific environmental objectives relating to impoundments for Germany.

**3.4.3 Lessons Learnt (Mitigation Measures and Management Strategies)**

Table 4, Annex D provides a summary of the mitigation measures and management strategies applied in Germany and these are expanded upon below.

**Planning and legislation**

No specific legislation, requirements, actions or strategies have been identified for impoundment planning or construction in Germany as a result of the lack of feedback form consultees.
Construction and operation

The case-studies presented in Annex B discuss management and design strategies to mitigate the effects of impoundments on the environment in Germany.

Decommissioning

There is no indication of decommissioning having occurred or anticipated in the immediate future for any form of dam, impoundment, and reservoir or hydropower project in Germany. No statutory or strategy documents have been found regarding this subject.

3.4.4 Case Studies demonstrating mitigation and management of Impoundments

Three case studies, which highlight how measures to mitigation against the impacts of impoundments have been incorporated into the design of impoundments in Germany are discussed in Annex B.
3.5 Australia

3.5.1 General Description

Australia is the driest continent after Antarctica and of all the inhabited continents has the least amount of water in its river and twice the flow variation of Europe. Over 24,000 gigalitres (1 gigalitre equal a billion litres) of water is consumed in Australia every year with 70% being used for irrigation and further 21% being consumed for urban and industrial uses. The intensive use for irrigation arose as a result of considerable variations in flow and inefficient use over the past decades has resulted in problems of national significant such as increased salinity in rivers, groundwater and soils. This is vastly different than in the UK where the majority of water is abstracted for urban and industrial use with agricultural use being limited.

Impoundments are common in Australia and are used for a wide range of purposes from large scale structures such as town water supplies, hydropower schemes and flood alleviation to smaller scale agricultural enterprises including irrigation, stock and domestic water supply. As impoundments are legislated by the State and there are several states, or Territories in Australia it is not possible to determine the number of impoundments but in general terms, large scale impoundments for potable public supplies and hydropower schemes are on a par with the numbers in the UK while there are many more small scale impoundment associated with agriculture.

3.5.2 Legislative and Institutional Framework

The legislative and institutional framework for Australia is described below, and summarised in Table 3.5.1.

Policy Framework

Australia, like the United Kingdom, has two tiers of Government, the Commonwealth and the State. The Commonwealth is the equivalent to our central government while the State (or the Territories) serves a similar role to our Local Authorities. Although under the Australian constitution management of water is vested with the State and Territory governments, in 1994 the Council of Australian Governments agreed to implement a strategic framework to achieve an efficient and sustainable water industry. The Australian water reform framework, which requires to be fully implemented by 2005, includes provisions for water entitlements and trading, environmental requirements, institutional reform, water pricing and public consultation and education (Department of the Environment and Natural Heritage website www.deh.gov.au/water). The main elements of the water reforms are:

- All water pricing is to be based on the principles of consumption-based pricing, full cost recovery and transparency of cross-subsidies. For urban water services, charges include an access and usage component. For metropolitan bulk-water suppliers, charges are on a volumetric basis to recover all costs.
- Any future new investment in irrigation schemes, or extensions to existing schemes, is to be undertaken after an appraisal indicates it is economically viable and ecologically sustainable.
- State and territory governments are to implement comprehensive water allocation or entitlement systems, which are to be backed by the separation
of water property rights from land. These should include clear specification of entitlements in terms of ownership, volume, reliability, transferability and, if appropriate, quality.

- The formal determination of water allocations or entitlements includes allocations for the environment as a legitimate user of water.

- Trading (including across state and territory borders) of water allocations and entitlements is to be within the social or physical and ecological constraints of catchments.

- As far as possible, resource management and the regulatory roles of government should be separated from water service provision.

- There should be an integrated catchment management approach to water resources and greater local-level responsibility for water resource management.

- There should be greater public education about water use and consultation in implementing water reforms.

- More research into water use efficiency technologies and related areas is to be conducted.

### Laws and Regulations

The responsibility for controlling both planning and development and water resource management in Australia lies with the State Government as opposed to the Commonwealth and each state has its own legislation to regulate the development of new water resource infrastructure projects. Such projects are now only permitted if they are technically feasible, economically viable (without State subsidies) and environmentally sustainable and all states have a formal process which will require the undertaking of an Environmental Assessment for water resource projects.

Each State, although operating in a similar way has its own legislation and this study focused on the legislative position in New South Wales (NSW). In this State, the Department of Planning, Infrastructure and the Natural Resources (DIPNR) assumes responsibility for controlling water resources developments (website: [www.dipnr.nsw.gov.au](http://www.dipnr.nsw.gov.au)). DIPNR incorporates the former Department of Land and Water Conservation and Planning NSW. The legislation under which these activities are controlled is the Water Management Act 2000. This legislation supersedes many pieces of legislation and provides a single, comprehensive Act which covers all aspects of water resource management. This Act simplifies the process of water resource management such that all approvals required for a particular activity or development will be obtained through a single application.

Further legislation under the provisions of the 2000 Act is required to enact the provisions of the 2000 Act relating to impoundment licensing, and this is due to be issued in mid 2004. Until this time the provisions of the Rivers and Foreshores Improvement Act 1948 and the Water Act 1912 will continue to regulate impoundment licensing. The delay in this transfer of legislation is due to the vast number of impoundments requiring to be transferred to the new licensing requirements.

Under the provisions of the existing legislation water licenses were held by the landowner and a right to access and use the water was tied to the actual works e.g. the
pump or bore. Under the provisions of the Water Management Act 2000, two main approvals will be required. The first is a ‘water management work approval’ which authorises the construction of the impoundment structure and the use of the works for water supply, drainage or flood management and which may be issued for a period of up to 20 years.

The second is an ‘access license’ which entitles its holder to shares in the available water from a specified water sources and to take water at specified times, rates or circumstances, and in specific areas or locations. These access licenses are tradable commodities and are issued under the provisions of the Access Licence Dealing Principles Order 2002). This new procedure will provide clearer rights, greater flexibility for businesses and will facilitate trading of water licences. Licenses under the old regime were issued for a period of 5 years, 10 years or 20 years depending on the type of licence. The new regime will see this change to 15 years and 20 years and will link the licence to the water management plans (see below for further information).

Existing impoundment structures as well as new structures will fall under this legislation with existing licences being converted to the new system when all the new legislation has been introduced.

In addition to requiring that approvals for activities with an impact on water be sought from the State, this Act includes provisions for the development of procedures to protect water resources through the development of Regional Environmental Plans under the provisions of the Environmental Planning and Assessment Act 1979 and enables the cumulative impacts of developments to be considered at the planning stage. This Act also enables the creation of Water Development Plans, which have statutory status and include amongst other controls, environmental protection provisions which identify zones in which development should be controlled and identify development which requires the Minister’s approval to the granting of consent.

Depending on the scale of the development, an environmental impact assessment may be required to be undertaken before some impoundment structures are granted licenses. The determination as to whether an EIA is required is undertaken by the Department of the Environment and Heritage and is implemented under the provisions of the Environment Protection and Biodiversity Conservation Act 1999 and this is discussed in further detail below.

**Institutional Framework**

There are several statutory consultees who are approached during the consideration of an impoundment licence. These include:

- The Department of the Environment and Heritage;
- The Environment Protection Authority; and
- Other State Government’s where a river may cross political boundaries.

Under the provisions of the Water Management Act 2000, the responsibility for the licensing of impoundments in New South Wales falls to DIPNR. There are several statutory requirements for consultation and these form the primary means of consultation with the public. These include:
• **Aboriginal groups:** Consultation is generally with the peak stakeholder body in NSW, but may also be a local Aboriginal land council;

• **Public Register:** The provision of a department operated public register ensures that all application submitted to the department, not just impoundment applications, provides another source of information for the public and other bodies;

• **Statutory Management Plans:** Some of the regulations regarding the construction of an impoundment may already be derived from a statutory management plan (eg Water Sharing Plans). Plans are prepared by local, community based committees who represent interest groups with the area defined by the plan and may include but are not limited to irrigation, stock, domestic, town water, Aboriginal, environmental and recreational users of water. These plans undergo extensive consultation with all relevant government agencies, peak stakeholder groups, local community groups and indigenous communities; and

• **General public** Consultation is undertaken via advertising the development and is designed to allow any affected party to raise concerns regarding the development. Advertising also allows any non-government organisation or a government agency to lodge an objection to the proposed development.

There are other non-statutory referrals that often occur and these include technical experts within agencies who may have an interest e.g. Local Government, NSW Fisheries, and the National Parks and Wildlife Service).

**Licensing Procedures**

In New South Wales there are two procedures for applying for a licence for an impoundment structure, depending on the purpose of the structure: one deals with impoundments for most agricultural enterprises e.g. irrigation, aquaculture, stock or domestic water supply and where the dam is privately owned, while the other is required where an impoundment is constructed as a part of a significant commercial venture such as a mine or is a State owned/ operated structure e.g. for hydropower schemes or public water supplies.

In order to consider an application for agricultural purposes or where the dam is privately owned, the applicant must supply the department with:

- map(s) showing the property boundaries, drainage lines, proposed location of impoundment;
- surveyed plan(s) for the site of the dam showing the height of proposed dam and land contours;
- design of the impoundment, showing construction details of the dam wall including crest and by-wash height, and width, location and diameter of outflow pipe and slope of batters for the impoundment;
- material from which the dam wall will be constructed;
- soil survey for the base of dam especially the soil permeability and erosivity;
- where appropriate, a design for bypassing flows around the dam (for example to pass environmental flows) or the design of a spillway if soils are prone to erosion/ dispersion;
- details of any native vegetation to be removed during construction of the impoundment;
- details of how any excavated soil is to be disposed of (or used within construction);
• plan(s) to minimise short-term erosion and loss of water quality during construction of the impoundment; and
• details of the use of the water, especially the water demand of the proposed development (i.e. the area and crops to be irrigated, number of stock, size of feedlot etc). This allows the proposed capacity of the impoundment to be reconciled with the volume of water required for the activity.

In addition, DIPNR (the department) itself would examine the impact to river flow caused by construction of the impoundment and also assess the environmental impact of the impoundment to in-stream biota (especially nominated threatened species) and other downstream consumptive water users. In NSW, the provision of this information is regarded as being too onerous for the majority of agricultural enterprises that are essentially small scale, privately run businesses.

Where an impoundment is constructed as a part of a significant commercial venture such as a mine or is a State owned/ operated structure (e.g. for town water supply, hydro-electricity, flood mitigation or irrigation supply) then the proponent is likely to be required to provide an Environmental Impact Statement (EIS). An EIS is a comprehensive study of all aspects of the proposal and would be subject to public comment. An EIS is likely to contain a detailed assessment on every aspect of the proposed impoundment including modelling of the impact to river hydrology by construction of the impoundment, ecological impacts, social and economic impacts and the benefits and disadvantages of the proposal. This is discussed further below.

For privately owned impoundment's, the applicant must also supply information regarding the use of the water from the impoundment. This is essentially a separate assessment to ensure the proposed land use is sustainable. However if this assessment recommends not approving the use of water, then the approval for the impoundment itself may also be withheld.

The information required to support the application is considered to be important as it establishes:

• the design and location of the impoundment and its engineering integrity;
• any adverse environmental impacts and how these can be mitigated, if at all;
• effects on downstream environments and water users;
• if other permits are required (e.g. permit to clear native vegetation);
• if the size of the impoundment is appropriate for the type of activity proposed (e.g. the application would be rejected if a dam of 200 megalitres was requested for a use that was only required to support 20 sheep).

The department, in conjunction with data collected during its own field assessment of the proposal, can then determine whether to provide development consent without conditions, to require consent conditions that will mitigate adverse impacts, or to refuse the proposal as impacts are unacceptable.

There are several stages to the licensing procedure and these are:

a) Pre-application interview/ inspection – scopes the likelihood that the application would be acceptable in its current format; establishes all necessary statutory requirements/ consents required by the proponent;
b) Receipt of application for development and registration within department database;

c) Place details of application on department’s public register of applications (to occur from 1 July 2004);

d) Desktop assessment of proposed development – analyse information provided;

e) Field assessment of proposed development – verify information provided by proponent is accurate; undertake assessment of environmental impact; collect data regarding native vegetation, cultural and historical sites; commence development of conditions to mitigate adverse impacts;

f) Prepare report on the potential impacts of the impoundment and (where appropriate) recommend conditions that will mitigate adverse impacts; includes recommendation to approve or refuse application;

g) Submit report to delegated manager for approval of recommendation;

h) Delegated manager approves/ refuses application (or offers further suggestions for conditions to mitigate impacts);

i) Notice of determination issued to applicant.

**Environmental Objective Setting**

Interim water quality objectives and river flow objectives were determined for 31 catchments in New South Wales. These objectives have been released as guidelines to river water and groundwater management committees preparing river, water and groundwater management plans. They were prepared following consultation with the community and for each of the catchments a one page at a glance table shows the objectives applying to areas of the catchment of categories of stream within a catchment. Information about all 31 catchments can be found on the website of the Environment Protection Authority for New South Wales, www.epa.nsw.gov.au.

Each of the reports for the 31 catchments consists of five main sections: Background; Community Comments on the Proposed Objectives; Interim water quality and river flow objectives from the catchment; interim water quality objectives explained; and interim river flow objectives explained. There is also a glossary, a bibliography and a map of the area as well as an at a glance table of the objectives.

Up to eleven *interim water quality objectives* apply. Each was based on providing the right water quality for the environment and the different uses people have for water. The objectives were based on measurable environmental values for protecting aquatic ecosystems, recreation, visual amenity, drinking water and agricultural water.

The twelve *interim river flow objectives* dealt with the way water moves down rivers and streams. Each objective aimed to improve river health by recognising the importance of natural river flow patterns. The objectives are based on achieving improved environmental results from managing the riverine system.

These interim environmental objectives were to be considered by the river, water and groundwater committees to consider and included in their water management plans, referred to as water sharing plans. The committees were responsible for developing the river flow, water quality and groundwater action plans needed to achieve the agreed environmental objectives, and they had the opportunity to recommend revision, refinement and expansion of the interim objectives to ensure the long-term health of the waterways in their catchment.

Although both river flow objectives and water quality objectives were considered initially, in New South Wales, it was decided to focus on river flow objectives rather than water quality objectives. The reason for this was that water quality and river flows are fundamentally linked and that these links can be direct or indirect and will vary over time and between river reaches. Direct influences include instances where concentrations
or transport of pollutants in streams is influenced by flows. Indirect influences refer to the ways that flow regimes influence stream habitat and ecological health, which in turn influences ecological processing occurring in those streams. Many water quality problems are caused or exacerbated by altered river flows and it was determined that a flow regime that maintains and restores the nature flow regime (as per the river flow objective framework) will protect water quality and the ecological habitats and processes that in turn modify water quality.

Consideration of the key management issues relating to the interactions of flows and water quality associated with barriers (including impoundment structures) were considered to identify the river flow objectives which would be relevant to impoundments. Impacts upstream of barriers include pooling and thermal stratification of water, trapping of sediments, accumulation of nutrients and toxicants and an increased propensity for blue-green algal blooms. The downstream water quality impacts were identified as the reduction of flow, loss of freshes relied upon by some aquatic organisms and changes in water chemistry such as increases in nutrient, manganese and iron concentrations and decreases in dissolved oxygen and temperature resulting from releases from the base of stratified weirs or dams. Management responses include consideration of removing or modifying the barriers, minimising their impact by mimicking natural flow regimes in flow release rules or varying the level of off takes rather than relying solely on deep level or shallow level off takes could be considered.

Consequently, there are three relevant river flow objectives for impoundment structures and other barriers: minimize the impact of in-stream structures; maintain or mimic natural flow variability in all streams and minimize downstream water quality impacts or storage releases.

**Water Sharing Plans**

By integrating these objectives into the planning activities of water management committees, water sharing plans will help the community to achieve an acceptable balance between environmental, social and economic needs. These plans form the basis for managing water resources for NSW rivers and groundwater systems. The plans are subject to Government approval, and progress is audited.

Interim environmental objectives will apply until the NSW Government either adopts the longer-term objectives resulting from the ‘Healthy Rivers Commission’ recommendations, or approves a water management plan for the catchment through the Minister for Land and Water Conservation and the Minister for the Environment. If the latter is this case, the environmental objectives would apply for the duration of the plan, subject to review and audit.

Thirty-six draft water management/sharing plans have now been developed by local water management committees and of these 36 plans, 35 were gazetted from late-December 2002 to the end of February 2003. It is anticipated that the Hunter regulated river plan will be gazetted at a later date. Water Management Plans come into effect on the 1st July 2004. In the Water Sharing Plan areas, the licensing provisions of the Act also come into effect on that date.

Also available are guides to each water sharing plan. These guides summarise the main points of the water sharing plans in a ‘user friendly’ way. However, if you need to know specific details of your water sharing plan, you will need to refer to the gazetted document (marked with an ‘*’).

Each water sharing plan is also accompanied by a fact sheet, which provides access licence holders with an introduction to their water sharing plan and details how it will affect them over the coming months.
An overview and an explanation of the main sections of the Water Sharing Plan for the Lachlan Regulated River Water Source document highlighting the how the Plan was developed is presented in Annex B.

**Environmental Impact Assessments**

The requirement as to whether or not an environmental impact assessment is required lies with the Department of the Environment and Heritage and is implemented under the provisions of the Environment Protection and Biodiversity Conservation Act 1999. This is commonwealth legislation but allows the Commonwealth and the States/Territories to work together to provide a ‘national’ scheme to protect the environment of Australia and enhance its biodiversity. This act replaced the Environmental Protection (Impact of Proposals) Act 1974. Further details of the implications of this Act can be found in “An Overview of the Environment Protection Act and Biodiversity Conservation Act (Department of the Environment and Heritage, 1999)

The Act requires that certain actions, in particular actions which are likely to have a significant impact on a matter of national environmental significance (NES matters), or on the environment are subject to a rigorous assessment and approval process. Matters of National significance are similar to those specified in the UK EIA Regulations and include: World Heritage properties; Ramsar wetlands; nationally threatened species and ecological communities; migratory species; commonwealth marine areas; and nuclear actions. An action is defined as including a project, development, undertaking or an activity or series of activities.

There are several stages in the process and these are discussed in detail in a series of Guidance sheets produced by the Department of the Environment and Heritage (Department of the Environment and Heritage, 2003a – Department of the Environment and Heritage, 2003g inclusive). In summary these are the referral stage, the assessment stage and the approval stage and each will be briefly described below.

**Referral stage**

Anyone planning to undertake an action which is likely to have an impact on a matter protected by the Act is required to refer their project to the Environment Minister via the EPBC Act Referrals Section of the DEH to determine whether or not approval is required. The referral process is clearly defined (Department of the Environment and Heritage, 2003a) and the Department has 20 business days, from receipt of the referral request to make their decision during which time the referral must be advertised on the website for 10 days. If insufficient information accompanies the referral request, the clock stops until sufficient information is received. If approval under the Act is required, the action is deemed a “controlled action” and an assessment is required. The person making the referral will be notified of the decision and the further actions, if any required.

**Assessment stage**

Once deciding that approval for the controlled action is required, the Department then has 20 days to determine what assessment approach will be taken. There are numerous different approaches which can be taken to compete the assessment process and these range from a preliminary assessment of the information by the developer when the number and complexity of the relevant impacts are low and locally defined, through an assessment by the preparation, by the developer or an environmental impact statement, to assessment by an accredited process when the relevant State or Territory will manage the assessment. In all cases, public consultation is undertaken as part of
the process with the reports being forwarded to the Department of the Environment and Heritage for final approval (Department of the Environment and Heritage, 2003c).

**Approval stage**

When deciding whether to approve an action and what conditions to apply the Minister must consider the relevant environmental impacts as well as social and economic matters and must take into account issue such as sustainability. Conditions to protect the environment and/or NES matters or requiring mitigation against damage to the environment and/or NES matters can be attached the approval and the approval or refusal notice will be placed on the DEH website.

**Interaction with other Legislation**

Generally there are no other licences/consents required for the construction of an impoundment. While the clearing of native vegetation would normally require consent under the native vegetation legislation, an exemption under this legislation allows the water consent to provide for clearing (or to refuse clearing) where it is necessary to construct the impoundment.

In some cases, an application may be referred to another agency for the recommendation of conditions on the approval. For example, the NSW Dam Safety Committee may want to provide conditions on the approval to construct the impoundment.

More commonly, other additional consents may be necessary for the use of the water taken from the impoundment. For example an applicant for an aquaculture development may require a permit to translocate fish (from NSW Fisheries) and a permit to discharge polluted water (from Environment Protection Authority). However these types of consents are not to do with the construction of the impoundment itself.

Occurrences have arisen where advice from another government agency (eg NSW Fisheries) is that the approval to use the water from an impoundment will be refused. In this instance the department may also refuse the approval for the impoundment, as the proponent can no longer justify the construction based on the proposed use.

**3.5.3 Lessons learnt (mitigation and management strategies)**

Table 5, Annex D provides a summary of the mitigation measures and management strategies applied in Australia and these are described in detail below.

**Legislation**

The legislation dealing with impoundment structures is new and in some cases has not yet been implemented. Consequently, there has been little opportunity (to date) to learn from its implementation. This legislation has been built upon from existing experience and it is hoped within New South Wales that this new legislation should address previous deficiencies in legislation and operation of impoundment structures.

**Planning and licencing**

The planning and licensing procedure in NSW has recently been reviewed and presently it is felt that there are few additional changes that are necessary (DIPNR pers comm). However, it was indicated that the following policy/statutory decisions during the
planning phase would support the process, by clarifying the development requirements for impoundments:

- Mandatory provision for a fish passage device on all new and modified impoundments;
- Mandatory provision for the passing of environmental flows based on a certain percentage of the inflow to the impoundment, and in order that these mimic seasonal river flow, variability on all new and modified impoundments;
- Development of a minimum standard for dam construction in relation to certain soil types, by-wash design, compaction rates, ratio of freeboard to storage area etc;
- Where appropriate, the mandatory provision of a device(s) to release water of high quality (i.e. to minimise cold water pollution and other water quality issues relating to stratification in impoundment's); and
- More emphasis on the proponent supplying all information regarding the development rather than the department having to undertake many of the assessments as this would free up resources for other areas of the department’s business.

**Operation and construction**

The following is a brief discussion of the main environmental and management issues related to the construction and operation of impoundments in Australia and how they are dealt with. Specific in formation on the mitigation measures during construction was not identified.

The main impacts associated with impoundment structures in New South Wales are the large changes in flow regime, resultant changes in the ecology of the watercourses downstream and a reduction in the supply for downstream users. The majority of the mitigation strategies employed are legislation and/or rule based and are detailed in the water sharing plans produced for 31 catchments identified in NSW. These are designed to enable the river flow objectives from these plans to be met and include:

- establish environmental water provisions (e.g. environmental accounts)
- identify water requirements for basic landholder rights (Part 4 of this Plan),
- identify water requirements for access licences (Part 6 of this Plan),
- establish rules for granting of access licences (Part 7 of this Plan),
- establish provisions that place limits on the availability of water
- establish rules for making available water determinations
- establish rules for the operation of water accounts
- establish provisions specifying circumstances under which water may be extracted
- establish access licence dealing/trading rules

Effective methods for achieving these are not fully identified as the water sharing plans do not come into effect until 2005, but these are being developed. The conflict between the needs of the environment and those of the users is significant and as it is easier to quantify the impact of a mitigation measure on the user than on the environment, the Government has been reluctant to proceed at any great pace in the area of environmental management (Darren Barma, DIPNR pers. comm.)

Some structural mitigation measures have been used to mitigate the operational impacts of impoundment structures. Unfortunately however, there has been little monitoring of the success of these measures and therefore it is not possible to determine their efficiency. This however is set to change with the implementation of the Water Sharing
Plans in New South Wales which incorporate assessments of the effectiveness of the plans.

One of the impacts associated with impoundment structures is the occurrence of blue green algae blooms either within the impoundment structure or downstream of the structure. In the event of such blooms, signs are posted advising of the situation. Blooms both within the within the impoundment have been successfully mitigated against by the release of water from the dam and the temporary diversion of additional water into the dam. In addition, activated carbon has been used during an extreme outbreak (Barry Dunn, Snowy Hydro Ltd. pers. Comm.).

An emerging issue in Australia is the issue of thermal impacts. Due to stratification of the impoundment, water lying below the thermocline can be significantly colder that that above the thermocline and if discharged this can have a significant impact on the native fish species once the temperature drops only four degrees below the required temperature for these species. However, this is only a problem if the extraction points from the dams to the watercourse are below the thermocline and plans are being implemented to replace existing extraction points with new outlet structures which allow the selective withdrawal of waters to ensure mixing of waters to meet discharge temperature requirements. Another solution is for impoundments with low water quality to be kept at as low a level as possible in the summer when the impoundment has the greatest thermal stratification to minimise the amount of water below the thermocline. This ensures that water quality is maintained at the optimum possible and regular sampling is undertaken to determine nutrient trends and effectiveness of this mitigation strategy.

One mitigation measure which is about to be progressed is the removal of weirs that impact fish passage or the augmentation of weir structures with fish ladders to allow native fish to migrate upstream for breeding purposes. There are also a number of salt interception schemes on the Murray River which are designed to reduce salt loads returning to the river from groundwater and the soil. Again, the effectiveness of these is only beginning to be monitored. NSW are currently considering buying back irrigation licences which could be extremely effective as it is a mitigation measure which cannot be circumvented although it does rely on licence holders being willing to sell their licences.

**Decommissioning**

Neither the literature review nor the consultation exercise identified any references to decommissioning of dams in Australia, suggesting that it is not a significant issue at the current time.

**3.5.4 Case Studies**

The Water Sharing Plan for the Lachlan Regulated River Water Source is discussed in Annex B.
3.6 USA

3.6.1 General Description

The number of impoundments in the United States is enormous. A recent inventory by the US Army Core of Engineers counted roughly 80,000 dams (minimum dam height 8 metres), of which 2500 are hydroelectric dams. Whilst the USA has 14% (ie. the second largest) of the world population of large dams (greater than 15m) by country, the rate of decommissioning is now greater than the rate of construction of new large dams (World Commission on Dams, 2000).

Dams and reservoirs vary greatly in size.

The projects in the western United States are generally very large, and many dams have a power generation facility at the site (pers.comm D. Murch, FERC; www.usbr.gov). Dam height varies anywhere between 30 to 300 m. Larger reservoirs, such as at Hoover Dam in Nevada and the Glen Canyon Dam in Colorado can have a total storage of 27,000,000 acre-feet (www.usbr.gov).

The projects in the east generally have longer shorelines compared to the west coast, up to thousands of miles (pers.comm. FERC). The (non-hydropower) dams are also generally smaller (pers.comm Maine DEP). For example, those in Maine are no more than 3 metres high.

Figure 3.2: Hoover Dam and Lake Mead, Nevada (source: www.usbr.gov)

Figure 3.3: Jamestown Dam, North Dakota (source: www.usbr.gov)

Due to the differences in structure and reservoir morphology as well as climate, hydropower projects in the eastern and western part of the country are characteristically faced with different (environmental) problems. In the west, the primary problems are temperature and flow levels downstream. In the east, low dissolved oxygen levels are
more often an issue. Diffuse sources of pollution and impacts on endogenous fish species pose a challenge for reservoirs throughout the country. The latter has up till now received the most attention on the western coast and in New England (East coast) (pers.comm. FERC), but is starting to be recognized as a potential problem associated with any dam (pers.comm US Fish and Wildlife Service).

3.6.2 Legislative and Institutional Framework

The legislative and institutional framework for USA is described below, and summarized in Table 1, Annex D.

Policy framework

Since the 1960’s and 70’s, there has been a general movement at the political as well as general public level in the United States towards the protection and improvement of water quality and the environment. The construction of (larger) dams and reservoirs is very rare, the Federal Energy Regulatory Commission (FERC) has reviewed three projects since 1986 (pers.comm FERC).

Instead, the impacts and management of existing dams are receiving much more attention from the government as well as the private sector. There is much research being done and money being spent in the United States to investigate and improve the construction and management of existing impoundments to mitigate negative impacts on the environment. It is not unusual for dams and levees to be ripped out because it is cheaper than renovating (pers. comm.. National Wildlife Federation). While in the past power generation and water storage were the primary interest, today environmental as well as recreational interests are also a major consideration.

Laws and Regulations

A number of laws have been passed which give the public and private, State and Federal agencies the right to challenge and append (existing) dam construction and management. These include: the Clean Water Act, Water Resources Development Act, the National Environmental Protection Act and the Endangered Species Act (pers.comm. National Wildlife Federation). In addition, the main law to regulate the construction of (hydropower) dams on public rivers, the Federal Power Act, has been amended so that these laws and the wishes of other State and federal agencies must be consulted during the (re)licensing procedure. Each State has the right to pass its own supplementary laws. The laws are described briefly below.

Federal Power Act

Hydropower development is regulated by the Federal Power Act, which is administered by the Federal Energy Regulatory Commission (FERC).

The act (indirectly) requires that a project complies with several other State and federal laws, such as the Endangered Species Act, State Historic Preservation Acts, safety regulation, and coastal zone management regulations.

The Act provides for federal regulation and development of water power and resources, authorizing the Federal Energy Regulatory Commission (FERC) to issue licenses for private hydroelectric project works, including dams, reservoirs and other works to develop and improve navigation and to develop and use power (www.ipl.unm.edu).

Under the law, FERC must give equal consideration to power and development purposes as well as (http://ipl.unm.edu/cwl/fedbook/fedpower.html):
- energy conservation;
- environmental conservation;
- protection of recreational opportunities;
- preservation of other aspects of environmental quality

This means that FERC is required by law to evaluate whether a hydropower project includes conditions for:

- improving or developing a waterway for the use or benefit of interstate or foreign commerce;
- improving and using water-power development;
- adequately protecting, mitigating and enhancing fish and wildlife affected by the development, operation and management of projects, including related spawning grounds and habitat;
- beneficial public uses, including irrigation, flood control, water supply and recreational purposes.

The law specifically states that a project must include, at the owner’s expense, the construction, maintenance and operation of fishways which allow for the safe and timely upstream and downstream passage of fish and successfully maintain all life stages of the fish.

The law furthermore decrees that relevant federal and State agencies, such as the National Marine Fisheries Service, the U.S. Fish and Wildlife Service, and State fish and wildlife agencies, and Indian tribes affected by the project must be consulted and their recommendations taken into consideration before granting a license.

**Clean water act**

The Clean Water Act (CWA) is the cornerstone of surface water quality protection in the United States (www.epa.gov). The Act applies to all water bodies and is administered by the States.

The Act empowers different federal (Environmental Protection Agency) and State agencies and tribal governments to establish and enforce water quality standards and regulate activities which can (in)directly have an impact on water quality, such as the construction of revetments, groins, breakwaters, levees, dams, dikes, and weirs.

Under the Clean Water Act a permit cannot be issued by the regulating authority (FERC or US Army Corps of Engineers) until the applicant obtains water quality certification from the Environmental Protection Agency (EPA), or the appropriate State or tribal government, and cannot be issued until all water quality concerns raised by the EPA have been addressed.

In addition, a permit cannot be issued until the US Fish and Wildlife Service, for land-based species, or the National Marine Fisheries Service for aquatic species have been consulted (http://www.usace.army.mil). In processing applications received, the federal authorities (FERC or US Army Corps of Engineers) must ask the resource agencies whether protected species are in the area. If protected species may be in the area, the authority must prepare a biological assessment evaluating any potential impacts. If the authority and the resource agencies concur that there is no jeopardy, the permit can be issued. Otherwise, no permit can be issued until all protected species issues are resolved.
The Clean Water Act does not deal directly with ground water nor with water quantity issues. The statute employs a variety of regulatory and nonregulatory tools to sharply reduce direct pollutant discharges into waterways, finance municipal wastewater treatment facilities, and manage polluted runoff. These tools are employed to achieve the broader goal of restoring and maintaining the chemical, physical, and biological integrity of the nation’s waters so that they can support "the protection and propagation of fish, shellfish, and wildlife and recreation in and on the water."

The Acts also regulates discharges of pollutants into the waters of the United States by:

- Giving the EPA the authority to implement pollution control programs such as setting wastewater standards for industry;
- Making it unlawful for any person to discharge any pollutant from a point source into navigable waters, unless a permit is obtained under its provisions;
- Funding the construction of sewage treatment plants under the construction grants program;
- Recognizing the need for planning to address the critical problems posed by nonpoint source pollution.

The key elements of the Clean Water Act are outlined in Annex C.

**Water Resources Development Act**

The Water Resources Development Act, enacted by Congress, authorizes projects of the Corps of Engineers for flood control, environmental restoration, recreation, ecosystem restoration, shore protection, aquifer storage and recovery, water resources development and conservation and related purposes and navigation mitigation (www.csc.noaa.gov). In addition, the Act allows for the modification of existing projects.

The Act was first passed in 1986. Each year, the Army Corps of Engineers can lobby Congress with new projects or projects which need to be re-evaluated. For example, the Water Resources Development Acts of 1992 and 1996 provided the U.S. Army Corps of Engineers with the authority to re-evaluate the performance and impacts of the Comprehensive Everglades Restoration Plan (CERP) and to recommend improvements and or modifications to the project in order to restore the south Florida ecosystem and to provide for other water resource needs (see case-study section below).

Besides this project, the Act modifies a large number of existing projects for flood control, navigation, habitat restoration, water supply, shoreline protection, storm damage reduction and shoreline erosion protection, recreation, levees, environmental infrastructure, mitigation of fish and wildlife losses, watersheds, canal system restoration, environmental restoration, and rediersion in a large number of States (www.csc.noaa.gov).

**Additional State and federal laws**

Under the Endangered Species Act and National Environmental Protection Act, government agencies such as the Environmental Protection Agency and the US Fish and Wildlife Service or the public can challenge the management of an existing dam if it seems that species listed as endangered or the environment are being negatively impacted.

In addition to the federal laws, each State has its own laws and procedures. For example, under the State of Maine law, hydropower development is regulated by the
Maine Rivers Policy and the Maine Waterway Development and Conservation Act (pers.comm. Maine DEP). The Maine Rivers Policy protects outstanding segments of rivers and streams in the State from the construction of new dams, and provides for more stringent review of the additional development of dams existing on these segments. The Maine Waterway Development and Conservation Act (MWDCA) requires a single application and permit for the construction of all hydropower projects, structural alteration of some projects, and certain maintenance and repair projects.

**Institutional framework**

In the United States, several different private, State and federal organizations are involved in the construction, operation and regulation of dams and reservoirs.

FERC is an independent regulatory agency within the U.S. Department of Energy that (re)licenses and inspects private, municipal and State hydroelectric projects and oversees related environmental matters (including dam safety inspections and environmental monitoring) ([www.amrivers.org](http://www.amrivers.org); [www.ferc.gov](http://www.ferc.gov)).

The US Bureau of Reclamation owns and operates a large number of dams and reservoirs in the Western United States, while the U.S. Army Corps of Engineers has ownership over a number of impoundments in the east. The Tennessee Valley Authority also owns and operates a large hydropower project.

State agencies (State “department of environmental protection”) are responsible for the regulation of State and private non-hydropower projects, and are also consulted during the planning or (re)licensing of a non-federal hydropower project.

Additional State and federal regulatory agencies such as the National Marine Fisheries Service, the U.S. Fish and Wildlife Service, State fish and wildlife agencies, the State’s dam safety department, Indian tribes and other stakeholders are consulted during the dam (re)licensing process. This is required under federal law (see section 2.6.2).

Stakeholders and State and federal fish and wildlife agencies can petition the State or federal regulatory agency to change the management of an impoundment, if current management is not meeting their needs.

**Licensing / Permitting Procedures**

The licensing and regulation can be categorized into the following three types of dams:

- non-federal hydropower projects (generally larger dams and reservoirs)
- federal projects, including dams for hydropower and water supply (generally larger dams and reservoirs)
- non-federal, non-hydropower dams (generally smaller scale than above types)

**Non-federal hydropower projects**

As mentioned in section 3.6.3, hydropower projects in the United States are regulated at the State as well as the Federal level. The Federal agency FERC is ultimately responsible for granting the license.
A potential developer of hydroelectric project must file an application for license or exemption from licensing (exemptions are discussed below) if the project is or will be located on a navigable waterway of the U.S.; occupying U.S. lands; utilizing surplus water or water power from a U.S. government dam; or located on a body of water over which Congress has Commerce Clause jurisdiction, project construction occurred on or after August 26, 1935, and the project affects the interests of interstate or foreign commerce.

A step-by-step description the (re)licensing procedure can be found in appendix # of this report.

In general, the law requires that the damowner seek the consultation and approval of a wide array of federal, state and local resource agencies, including fish, wildlife, recreation and land management agencies as well abutting landowners and members of the general public in order to assess more accurately the impact of a hydropower dam on the surrounding environment.

These agencies review the project to determine whether it complies with the various state and federal laws, including the federal Clean Water Act, the National Environmental Protection Act (NEPA), the Endangered Species Act (ESA) and the Fish and Wildlife Coordination Act (pers.comm. Maine DEP; FERC). Under the NEPA, FERC is obligated to prepare an Environmental Assessment (EA) as part of the (re)licensing procedure. Each State can have its own supplementary laws with which the project must comply (see also section 3.6.2).

Using the state of Maine as an example, the application is circulated among different departments, such as the Department of Inland Fisheries and Wildlife and the state Division of Environmental Assessment and screened to determine whether:

- The applicant has the financial capability and technical ability to undertake the project;
- The applicant has made adequate provisions for the protection of public safety;
- The project will result in significant economic benefits to the public;
- The applicant has made adequate provisions for traffic movement associated with the project;
- The project is consistent with land use zoning, where applicable;
- The applicant has made reasonable provisions to realize the environmental benefits of the project and to mitigate its adverse environmental impacts;
- The advantages of the project are greater than the direct and cumulative adverse impacts over the life of the project based upon specified environmental and energy considerations. These considerations include impacts on soil stability, wetlands, natural environment, fish and wildlife resources, historic and archaeological resources, public access, flood control, and energy generation;
- There is a reasonable assurance that the project will not violate applicable state water quality standards.

Based on the review, the project is approved or disapproved at the state level. An approval may be subject to conditions, such as the establishment of minimum flows.
After being approved at the State level, the federal regulatory agency FERC determines whether the project meets the requirements of the Federal Power Act (see section 3.6.2) and ultimately grants the license.

Licenses last 30 to 50 years and typically stipulate:

- The mandatory collection of water quality and quantity data,
- how the dams are operated,
- what minimum water flow levels are required,
- minimum temperature and dissolved oxygen standards,
- what forms of fish passage must be installed and, in some cases,
- how watershed lands are managed.

The permit can require owners to install gages to measure the flow release and water quality, though this is usually only done for larger projects (pers.comm FERC).

The permit also includes conditions which allow FERC to regulate the project. The permit stipulates that the owner is obligated to file an annual report to FERC, who evaluates the data to determine if conditions required by the permit are being met. If the owner is not meeting the set conditions, the owner must suggest how the problems can be solved. If a dam owner does not meet the objectives stipulated by the permit, he or she can be fined or, by repeated transgression, the license revoked. (pers.comm FERC)

For the decommissioning of private and state owned hydropower dams, the owner must apply to the State environmental protection agency and the Federal Agency (FERC) to “surrender” his or her license (pers.comm. Maine DEP). FERC has developed a comprehensive decommissioning policy for dams under its jurisdiction (Eos, 2003). Generally, the same policies and processes which regulate licensing apply to the decommissioning. This means impacts on the water quality, environment, recreational value and safety of the area are considered. Whereas the federal agency can force the owner to leave the dam in a certain condition (open, closed, completely removed), the State can only approve or disapprove whatever action the owner proposes.

The decommissioning of smaller, privately owned dams is the responsibility of only the states, who largely do not have any statutes regarding the removal (Eos, 2003).

**Federal (hydropower) dams and reservoirs**

There was little information found on how federally owned dams are licensed or regulated in the US. What is known is that the facilities are authorized by Congress via the Water Resources Act. The owner, the US Bureau of Reclamation, the U.S. Army Corps of Engineers or the Tennessee Valley Authority is responsible for the operation of the dam and reservoir, and carries out all studies pertaining to the (environmental) impacts on the surrounding environment. As is the case for the non-federal projects, the public and State and Federal agencies can challenge the management of a dam, for example using the Environmental Protection Act or Endangered Species Act.

**Non-hydropower dams**

The smaller (non-federal) non-hydropower dams are licensed and regulated primarily at the State level. Each state has its own procedures and in many cases supplementary laws. For this report we have chosen the licensing, regulation and decommissioning procedure for the state of Maine as an example.
To obtain a license to build a dam in Maine, one must petition the state’s Department of Environmental Protection (DEP). This authority evaluates the project to determine if it meets the requirements of the Clean Water Act (see also section 3.6.2) and state safety and environmental laws (pers. Comm. Maine DEP). Unclear is whether other stakeholders are consulted before the license is granted by the DEP, but it is assumed that the wishes of the public as well as state and federal environmental agencies play a role in the licensing process.

Existing dams are largely not regulated. Landowners, state agencies and other public interest groups (white-water rafting organizations, fishing organizations eg.) can petition the state DEP to re-evaluate and modify the dam management.

With regard to decommissioning, Maine has no law which forces an owner to run a dam. The owner can “abandon” the dam. The State does not become involved until safety, water quality or water levels become an issue (pers.comm. Maine DEP). At this point, the dam is offered to the public for a take-over at no cost. If the dam is not bought, the owner must remove the dam at own expense. If an owner wants to remove a non-hydropower dam in Maine, he or she must petition the state DEP for a permit. The permit is not granted until recreational, environmental, realty issues etc are considered.

More information on the policies and guidelines for the state of Maine can be found at [www.maine.gov/dep/blwq](http://www.maine.gov/dep/blwq). More information on the decommissioning policy of other States can be found via the internet.

**Environmental Objective Setting**

There are not many hydropower dams being built in the United States today. The view of the general public towards hydropower projects is partially responsible for this. The environmental impacts of the existing projects are becoming more and more evident and less and less accepted by the public.

This change in attitude is also evident and likely also largely responsible for the recent changes in the (non-federal) hydropower licensing process. In the past, the federal regulation agency’s (FERC) primary goal was the promotion of hydropower dams as a means to harness a river's power generation potential, often without regard for the dam's environmental impacts. A 1986 amendment to FERC’s operating law (the Federal Power Act, see also section 2.6.2 of this report), however, required FERC to take a more balanced approach to dam (re)licensing. In the licensing procedure used today, FERC must give equal consideration to energy conservation; the protection, mitigation of damage to, and enhancement of fish and wildlife, including related spawning grounds and habitat; protection of recreational opportunities; and preservation of other aspects of environmental quality. ([http://www.ipl.unm.edu/cwl/fedbook/fedpower.html](http://www.ipl.unm.edu/cwl/fedbook/fedpower.html)).

While there aren’t many hydropower dams being built, the (re)licensing of FERC-regulated dams has recently become a major tool for river conservation and restoration, with more than 150 projects re-licensed since 1993, and 250 more scheduled for re-licensing by 2010. When granting a new permit, FERC (can) stipulate limits on water level fluctuation, standards for water quality and quantity and additional (structural) mitigation techniques such as fish passages. The re-licensing thus gives FERC the
opportunity to force project owners to alter the management of the reservoir to minimize environmental impact or to consider decommissioning.

**Requirement for EIA**

An EIA and/or Environmental Risk Assessment (ERA) are often used in watershed studies and in impoundment management assessments to identify vulnerable and valued resources, prioritize data collection activity, and identify the potential effects of the different management strategies.

Under the National Environmental Protection Act (NEPA), FERC is obligated to prepare an Environmental Assessment (EA) as part of the (re)licensing procedure (see also section 3.6.2).

### 3.6.3 Lessons Learnt (Mitigation and Management Strategies)

Table 6, Annex D provides a summary of the mitigation measures and management strategies applied in America and these are expanded upon below

**Planning**

The United States (re)licensing process for non-federal hydropower dams includes the consultation of a wide array of federal, state and local resource agencies, including fish, wildlife, recreation and land management agencies as well as abutting landowners and members of the general public in order to assess more accurately the impact of a hydropower dam on the surrounding environment. The extent of environmental impact is determined by carrying out an Environmental (Impact) Assessment (EIA / EA), which is required by law for non-federal (hydropower) projects.

This approach, though very time consuming, can serve as a good example for the regulation of impoundments in Scotland and England, because it allows a thorough consideration of all (potential) environmental impacts at an early stage. By including certain conditions in the permit, as the United States does for its hydropower projects, these impacts can be mitigated as much as possible. Conditions can include any (combination of) mitigation technique(s), such as the construction, maintenance and operation of fishways, a limit on water level fluctuation or the installation of monitoring equipment, as well as mandatory monitoring and reporting to regulating agencies. The threat of a fine or the revoke of a license as applied in the United States are deemed as effective methods to enforce the dam owner to comply with permit conditions. By limiting the validity of a license, for example to 30 years, the government creates the opportunity to re-evaluate the impoundment and its management.

**Operation and Construction**

Following is a brief discussion of the main environmental and management issues related to the construction and operation of impoundments in the United States and how they are dealt with...

The primary (environmental) challenges facing (hydropower) projects in the US today are:

- fish passage up- and downstream
- Flow regime / flow levels downstream
Fish passage

In the US, there is a growing awareness that resident species can be negatively impacted just as well as migrating (anadromous) fish species, and their needs must therefore also be considered (pers.comm USA Fish and Wildlife Service; www.amrivers.org). For anadromous species, the design must be suited to passing eggs and larva as well as older individuals. For resident fish, a design which is only suited to passing larger fish (fingerlings and older) might suffice (pers.comm USA Fish and Wildlife Service).

Upstream fish passage techniques tried in the US include: fish-by pass, fish-friendly turbines, fish ladders, lifts, lock systems, trap and truck methods (www.amrivers.org; pers.comm Fish and Wildlife Service). Fish by-pass techniques include an artificial side-channel, with a low gradient, and hence the method requires a lot of space. The US Department of Energy is currently investigating the effectiveness and optimal design of "fish-friendly" turbines. The turbines have a conical (blender-like) shape. Results will not be available in time to be incorporated in this study (pers.comm Fish and Wildlife Service). Fish ladders are only suited for stronger swimmers. The American Rivers organization reports that fish transported by the lifts, locks and the trap and truck method are often injured or stressed as a result (American Rivers, www.amrivers.org). In addition, the source states little data exists evaluating the success of these techniques in passing viable numbers of a given fish species. Monitoring data from the Saco River Settlement (New Hampshire and Maine), where a combination lift, lock and trap and truck system has been installed, can potentially be a source of information for further evaluation of these techniques.

Downstream passages tried in the US include a canal over or around the dam.

The US is experimenting with passages for eels, which look much like a slide (pers.comm Fish and Wildlife Service).

Tried alternatives to fish passage construction include financial compensation and the construction of a fish hatchery. Financial compensation is only deemed as a good alternative for the duration in which a more long-term solution has been realised, such as the construction of a fish-passage structure. A fish hatchery is a good alternative in situations where other structures are not a viable option, because the hatchery fish can out/compete native populations.

The best (variety of) fish passage for a given dam depends largely on the types of fish inhabiting the river, the design of the dam, and the characteristics of the river. For phase 2, the techniques used in the US will be further investigated and recommendations for the UK made based on the above criteria. The US Fish and Wildlife service will be providing additional literature for phase 2. Worthy of mention is that there will be a two-day conference in Massachusetts (US) this autumn on the "status, effectiveness and needs" of fish passage construction (pers.comm Fish and Wildlife Service).

Fish protection
Fish screens, trash racks, drums and behavioral barriers (strobe lights) have been applied in the US to prevent fish from being swept into turbines (entrainment). Trash racks are only effective if the bar spacing is sufficiently narrow.

**Temperature downstream**

Many hydropower projects such as Shasta Dam and Reservoir in the US are being installed with multilevel intake structures (pers.comm FERQ; US Bureau of Reclamation). An issue which arises with the installation of such a structure is, at what temperature should the water be released at? This demonstrates that it is important that the objective of the installation should be clear from the start: fish conservation, recreation, agriculture?

The US Bureau of Reclamation (Chris Holdren, c.holdren@do.usbr.gov), CalFed and the Colorado State University are potential references for more information on this mitigation technique.

**Flow levels downstream**

- **natural flow regime**
  
  At many reservoirs, for example the Quinnebaug River in Massachusetts and in the restoration project of the Great Lakes, attempts are being made to mimic natural flow regimes (pers.comm US Fish and Wildlife Service; National Wildlife Federation; www.amrivers.org; Halpern, et al 2003). The US Fish and Wildlife Service is also funding a study on this mitigation technique. Benefits of the method include a more natural sediment movement and riparian habitat (pers.comm FERC, National Wildlife Federation). The idea is that by creating the appropriate hydrological circumstances, nature will restore itself.

  A number of reservoirs have been successful in achieving the desired flow regime (pers.comm US Fish and Wildlife Service). Unclear is whether the larger objective, the restoration of natural riparian habitat and species downstream, has been realised. A search of the internet and inquiry with various consultees did not deliver any information on the effectiveness of the method.

- **controlled spill/reservoir drawdown**
  
  Controlled spill has been used in the US to prevent negative impact on fish during downstream migration. With this method, water is released in order to flush fish downstream. In-season management for salmon and real-time operations are two techniques which have been applied in the Federal Columbia River Power System, owned by the US Army Corps of Engineers (US Bureau of Reclamation, 2001).

- **establishing minimum-maximum flow**
  
  In (re)licensing or management policies, stipulations are made about the required minimum base flow, as well as seasonal increases. The flow rates are based on boating, fishing, rafting and fish and wildlife needs. The “desired” flow regime is an issue which currently raises much discussion in the management of reservoirs in the United States.
**Water level fluctuation in reservoir**

To reduce impacts on fish, birds and the shoreline vegetation, the US stipulates reservoir fluctuation limitations (both annual and seasonal) in (re)licensing decisions and management policies. This includes regulations on the placement of flashboards. For example, at the Beaver River Settlement in New York, the owner is not allowed to erect or replace flashboards from May 1 to June 30th ([www.amrivers.org](http://www.amrivers.org)).

**Dissolved oxygen**

To improve the dissolved oxygen content of water released from turbines to downstream, the US employs the method of retrofitting the turbines. The method can be fairly inexpensive if atmospheric air is used, but can run into the hundreds of thousands of dollars if pure oxygen must be injected (pers.comm US Bureau of Reclamation).

The Tennesse Valley Authority and Core of Engineers (Waterways Experiment Station, [www.wes.com](http://www.wes.com)) have much experience with this mitigation method, and are a good reference for phase 2 of the study.

**Decommissioning**


The majority of dam removals have occurred in the US, where more than 75,000 dams over two-meters high obstruct some 950,000 km of waterways. In the past 75 years, hundreds of dams have been removed in the last 43 states. The dam decommissioning trend is accelerating in the US, with 177 dams removed in the past decade, including 26 small dam removals in 1999.

One reason for the increase in decommissioning activities is the poor condition of the dams, 1,800 of which are officially deemed unsafe. By 2020, 85% of all government owned US dams will be at least 50 years old, the typical design lifespan. More than 500 FERC licenses will expire in the next decade.

As discussed above, the dam re-licensing process is forcing dam owners, government decision makers, river advocates, and affected communities to re-evaluate the costs and benefits of dams, especially in light of mandates to protect endangered species, recognize tribal fishing rights, and give “equal consideration” to fisheries, recreation, and environmental quality. Dam removal costs in many cases are significantly less than estimated expenditures for long-term safety and environmental compliance, repair, and maintenance.

Even large dams may be cheaper to remove than to repair and refurbish. Removing the 40-meter-high Condit Dam in Washington, for example, is predicted to cost $15 million. Estimated repair costs are twice that amount. The full cost of purchasing and removing the Elwha River dams is expected to exceed $200 million over a 20-year period, but paying reparations to local affected people could cost much more. Decommissioning funds established before or during project operation, such as those mandated for nuclear power plants in some countries, will help offset future decommissioning costs, especially for large dams, this is not currently the case in the US. The International
Rivers Network advocate that those who build, finance, and operate dams should be held responsible for the costs of decommissioning them.

In a growing number of cases, removal of unsafe or obsolete dams represents the best river management option. A flood of river restoration campaigns currently advocates the removal of more than 100 dams from Maine to California. The most ambitious of these proposals is the effort to drain the huge “Lake” Powell reservoir and restore the desert beauty of Glen Canyon.

There are, however, a number of technical challenges associated with the removal of large dams:

**Sediment Removal**

Sediment removal is likely to represent the most costly and technically intensive aspect of decommissioning large dams. Specific sediment removal techniques vary depending upon the amount of sediment, reservoir characteristics, project age, and the effectiveness of periodical flushes, if at all feasible, to pass trapped sediment downstream. Sediment removal must be conducted carefully, as excessive release can damage sensitive downstream habitat. On Washington’s Elwha River (see Case Study in Annex B), for example, experts propose gradual, incremental drawdowns to transport sediment without harming spawning habitat or juvenile salmon.

A potential effect of sediment flushing is release of accumulated contaminants into fisheries or water supplies. Following removal of a 9-meter-high dam on New York’s Hudson River in 1973, tons of trapped toxins were suddenly exposed in the old river bed or flushed downstream. Hazardous waste in sediment poses significant health risks, degrades water quality, and ultimately requires extensive cleanup efforts. Thus, thorough sediment analysis and prior assessment of the foreseeable effects of releasing sediment must be included in decommissioning studies.

**Finding Alternatives to Dam Functions**

A key aspect of dam removal planning is early identification of alternative sources of hydropower, irrigation and public water supply, or other dam functions. Dam removal often entails trade-offs between competing river functions. However, US experience with dam removal demonstrates that replacement can often be accomplished with minimal difficulty. For example, a single hydropower dam may contribute only a fraction of a region’s overall power—alternate sources are often available, and conservation measures can eliminate demand for this electricity altogether. In other cases, such as in the removal of 12 small dams on California’s Butte Creek in 1998, dismantling dams has only negligible effects on water supplies due to mitigation measures (e.g., improving efficiency of irrigation systems). Developing a comprehensive management plan that accounts for displaced dam functions minimizes the negative impacts of removal. Where changes or impacts are unavoidable, society may accept them as the price of long-term river restoration.

**Additional Mitigation Measures**

Experience has shown that, after a dam is removed, fisheries and hospitable habitat conditions return remarkably quickly. Dam removal alone may be insufficient to fully restore river systems, however, and may need to be accompanied by additional measures, such as protection of native fisheries, pollution abatement, restoration of
riparian habitat, and stricter watershed management policies to increase the rate and extent of restoration.

3.6.4 Case Studies

The following Case Studies are provided in Annex B:

- The Florida Everglades Restoration: *The Comprehensive Everglades Restoration Plan (CERP)*

- Dam Decommissioning in Northwest USA: Elwha River and the White Salmon River, Washington
4 SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

4.1 General findings

4.1.1 Norway

Hydropower is the primary source of electricity in Norway, accounting for 99% of the country’s supply. The country is currently constructing new sizable hydropower projects, while decommissioning is not a big issue.

The licensing procedure comprises several key stages: notification; public consultation; determination of the impact assessment (IA) requirements (including EIA requirements); the submission of the application and supporting EIA; public consultation; approval of the EIA and evaluation of application; and granting of license.

Hydropower licences are granted to the State Company and companies owned by municipalities and counties are granted for an unlimited period of time while licences to private companies are issued for a period of 60 years after which time the impoundment is handed back to the State. Licence conditions can be reviewed 30 – 50 years after the licence has been granted.

Norway is well ahead with introducing innovative measures to mitigate the effects of impoundments on the surrounding environment during operation as well as construction. Conditions to govern the decommissioning of impoundment structures are also included in the licence. Decommissioning is not considered to be a big issue in Norway and information about this aspect of impoundment structures has still to be gained from consultees. Table 3.2.1 gives an overview of the mitigation techniques applies in this country.

4.1.2 France

France has roughly 500 dams of 15 m high or above. The types of French dams are mainly of mass, arch and rock construction.

The planning and licensing stage allow for a high level of involvement from the public (non-)statutory bodies. Sediment management, management of flood and dam infrastructure, water loss by evaporation and warming of the water stoked volumes and compatibility with French management measures on the river basin scale (if present) are all addressed during the authorization procedure, aside from the environmental issues such as fish management.

The law regulating hydropower generation limits the validity of a license to 75 years. The re-granting of a licence implies undertaking an appraisal of the social and economical advantages of keeping the impoundment (power, multi-uses, drinking water supply, tourism, etc.) and the environmental impacts. Further to this appraisal results, the regulatory bodies decide to renew the authorization and concession or to decommission the impoundment.

Major environmental issues identified in relation to impoundments in France include eutrophication due to erosion and point-source pollution, sediment build-up behind the dam wall, change in sediment deposition downstream, fish passage and suitable flow levels downstream. Mitigation measures which have been tried are summarised in Table
3.3.3. The techniques recommended for further investigation in phase 2 are summarized in Section 5.2

In France, three impoundments which were located on rivers used by migratory species have recently been decommissioned. The main problems encountered include silting-up of the impoundment requiring dredging before removal, adversely affecting fish populations, affecting drinking water abstraction downstream and financial consequences for the surrounding community.

4.1.3 Germany

Consultation responses have been very poor from Germany. The results are therefore primarily based on literature and internet searches.

Traditionally, hydropower has been the renewable energy source most used in Germany, with about four percent of electricity generated by this method. New hydropower plants continue to be built, whilst older plants that had been shut down are being reinstated, and these are occurring with federal and Länder councils granting financial support.

Licenses can be revoked in the event of, or fear of, pollution of a watercourse, or if the holder fails to comply with conditions laid down as part of a license.

There is no indication of decommissioning having occurred or anticipated in the immediate future for any form of dam, impoundment, and reservoir or hydropower project in Germany. No statutory or strategy documents have been found regarding this subject.

Water protection policies in Germany focus primarily on maintaining or re-establishing the ecological balance of water bodies, on guaranteeing drinking and process water supplies and on providing long-term safeguards for all other water uses benefiting the general public.

The Basic Law distributes responsibilities between the Federation and the Länder.

Flow regulation is an important tool in the mitigation of impacts, particularly for the Leibis-Lichte Dam. Additional mitigation measures which have been tried are summarised in Table 3.4.3.

4.1.4 Australia

Impoundments are common in Australia and are used for a wide range of purposes from large scale structures to smaller scale agricultural enterprises.

Australia has recently significantly reformed its water legislation, which is now not dissimilar to the Water Framework Directive: the Australian Water Reform Framework, which requires to be fully implemented by 2005. Water resource projects are now only permitted if they are technically feasible, economically viable (without State subsidies) and environmentally sustainable and all states have a formal process which will require the undertaking of an Environmental Assessment for such water resource projects.

The licensing procedure for impoundments agricultural enterprises in Australia specifies a comprehensive list of details to be provided by the proponent, such as dimensions, extent, use etc. of the impoundment. In addition, DIPNR (the department) itself would
examine the impact to river flow caused by construction of the impoundment and also assess the environmental impact of the impoundment to in-stream biota (especially nominated threatened species) and other downstream consumptive water users. In NSW, the provision of this information is regarded as being too onerous for the majority of agricultural enterprises that are essentially small scale, privately run businesses.

Where an impoundment is constructed as a part of a significant commercial venture such as a mine or is a State owned/operated structure (e.g. for town water supply, hydro-electricity, flood mitigation or irrigation supply) then the proponent is likely to be required to provide an *Environmental Impact Statement* (EIS). An EIS is a comprehensive study of all aspects of the proposal and would be subject to public comment. An EIS is likely to contain a detailed assessment on every aspect of the proposed impoundment including modelling of the impact to river hydrology by construction of the impoundment, ecological impacts, social and economic impacts and the benefits and disadvantages of the proposal.

Although both river flow objectives and water quality objectives were considered initially in New South Wales, it was decided to focus on river flow objectives rather than water quality objectives. Many water quality problems are caused or exacerbated by altered river flows and it was determined that a flow regime that maintains and restores the nature flow regime (as per the river flow objective framework) will protect water quality and the ecological habitats and processes that in turn modify water quality.

Consequently, there are three relevant river flow objectives for impoundment structures and other barriers: minimize the impact of in-stream structures; maintain or mimic natural flow variability in all streams and minimize downstream water quality impacts or storage releases.

The legislation dealing with impoundment structures is new and in some cases not yet implemented. In addition, effective methods for realising the river-flow objectives have not been fully identified in New South Wales, because the water sharing plans in which they are incorporated are still being developed. Consequently there has been little opportunity (to date) to learn from the legislation and management of impoundments in New South Wales.

Some structural mitigation measures have been used to mitigate the operational impacts of impoundment structures. These are listed in Table 3.5.3. Unfortunately however, there has been little monitoring of the success of these measures and therefore it is not possible to determine their efficiency.

No information was found on decommissioning.

### 4.1.5 USA

Whilst the USA has 14% (i.e. the second largest) of the world population of dams by country, the rate of decommissioning is now greater than the rate of construction of new large dams (World Commission on Dams, 2000).

The construction of (larger) dams and reservoirs is very rare, the Federal Energy Regulatory Commission (FERC) has reviewed three projects since 1986 (pers.comm FERC). The view of the general public towards hydropower projects is partially responsible for the low number of hydropower dams being built today. The environmental impacts of the existing projects are becoming more and more evident and less and less accepted by the public.

The impacts and management of existing dams are, therefore, receiving much more attention from government as well as the private sector. There is much research being
done and money being spent in the United States to investigate and improve the construction and management of existing impoundments to mitigate negative impacts on the environment – ie. rehabilitation.

In the non-federal hydropower licensing procedure used today, FERC must give equal consideration to energy conservation; the protection, mitigation of damage to, and enhancement of fish and wildlife, including related spawning grounds and habitat; protection of recreational opportunities; and preservation of other aspects of environmental quality.

The (re)licensing of FERC-regulated dams has recently become a major tool for river conservation and restoration. When granting a new permit, FERC (can) stipulate limits on water level fluctuation, standards for water quality and quantity and additional (structural) mitigation techniques such as fish passages and reservoir management.

Early EIA is required by law for new and re-licensing of impoundments. Also, by limiting the validity of a license, for example to 30 years, the government creates the opportunity to re-evaluate the impoundment and its management.

Major environmental issues which have been identified in the US in relation to impoundments include:

- fish passage up- and downstream
- Flow regime / flow levels downstream
- water temperature downstream
- dissolved oxygen levels in outlet water and in reservoir
4.2 Comparison of Key Similarities and Differences

4.2.1 Introduction

The following sections present a comparison of the national impoundment regulatory regimes, focussing on freshwater hydropower impoundments and dams for water supply and flow regulation for the five selected countries (Norway, France, Germany, Australia, United States).

4.2.2 Licensing Procedure

In Norway, the ability for the impoundment licence to contain conditions to mitigate against impacts during all life stages of the impoundment from construction to decommissioning is considered to be highly beneficial.

A two-tiered approach to licensing appears to be a common theme throughout the five countries. For example, in Australia, where the level of information required to be provided by the proponent for the licensing procedure, depends on whether the project is a large-scale commercial venture or a private (generally agricultural) owner. In the USA, federally owned facilities are authorised by Congress via the Water Resources Act, whilst non-federally owned hydropower dams are regulated by the Federal Energy Regulatory Commission and other non-federal dams by the State’s themselves.

The concept of time-limited licences was raised in nearly all the countries for new impoundments, although many still have historic licences that remained unlimited. In France, impoundments have been limited to less than 75 years since legislation in 1919, and the principle of reversibility has been used to revoke licences since 1994. The USA has a similar approach, with licenses being valid for 50 years. The (re)licensing of dams has enabled the United States to re-evaluate the design and management of existing dams, and where necessary enforce modifications.

4.2.3 Consultation

Consultation with statutory and non-statutory bodies was evident in all the countries reviewed, both for the licensing and re-licensing of dams. Consultation is clearly considered to be one of the most crucial issues during the modern day planning process, whilst for early dams this was rarely or inadequately done.

The level of consultation versus stakeholder participation is more likely to vary between states and projects, than countries per se. The multiple stages for consultation are considered to be a valuable element of the (re)licensing procedures in Norway, the US and France.

4.2.4 Licensing Procedures

In Norway, the United States and Germany conditions may be imposed in the license to prevent, or compensate for, any detrimental effects to other persons, or to prescribe measures necessary to compensate for impairments to the ecological and chemical status of a watercourse. For example, in the United States, when granting a new permit, FERC (can) stipulate limits on water level fluctuation, standards for water quality and quantity and additional (structural) mitigation techniques such as fish passages. In Germany and the US monitoring is required as part of the management plan. Licenses
can be revoked if the holder fails to comply with conditions laid down as part of a license, or in the case of Germany, for fear of pollution of a watercourse.

4.2.5 Environmental Objective Setting

Specific information on this subject was difficult to obtain, over and above a general requirement to seek to mitigate potential adverse impacts on the ecology where possible. However, information obtained from Australia identified interim water quality objectives and river flow objectives which have been determined for 31 catchments in New South Wales, with three river flow objectives that are particularly relevant for impoundment structures and other barriers: minimize the impact of in-stream structures; maintain or mimic natural flow variability in all streams and minimize downstream water quality impacts or storage releases.

4.2.6 Environmental Impact Assessment

Environmental Impact Assessment was evident as a tool used in all the countries reviewed. For the European Countries, this is not surprising, given the EU EIA Directive. Noteworthy is that a field assessment of the proposed development is part of the (re)licensing procedure in Australia, to verify that information provided by the proponent is accurate.

4.2.7 Mitigation Measures and Management Strategies

Preliminary analysis of the mitigation measures and management strategies identified a number of measures particularly worthy of input to Phase 2 for more detailed investigation and consideration of best practice.

The Mitigation Measures Tables for each of the countries provide evidence of a wide range of tried and tested measures that are commonly used, such as:

- Measures to minimise changed to flow regime: Compensation flows / minimum flow regimes, minimum-maximum flow regimes and variable flow regimes (to suit the natural seasonal variations);
- Measures to allow the passage of aquatic fauna, primarily fish passes / ladders and by-pass channels;
- Measures to maintain dissolved oxygen levels in the impounded water and downstream, including air / oxygen injection and circulation;
- Measures to prevent fish entrainment at intakes or to minimise damage, such as fish screens and behavioural measures such as acoustic barriers;
- Measures to minimise adverse temperature changes downstream, such as multi-level withdrawal outlet structures and surface storage.

Measures that are likely to be fairly universal include:

- Management plans, such as Water Sharing Plans which are commonly used in Australia and Water Protection Plans in Norway;
- Catchment management measures to reduce diffuse pollution inputs to the reservoir;
- Sediment management measures such as sluices to allow through flushing (carefully timed to avoid adverse impacts on spawning gravels downstream).
Novel approaches include:

- Salt interception systems, to trap salt in the soil and groundwater and prevent it from entering the water course close to the coast – Australia;
- Fish friendly turbines, where the propellers are conical shaped to allow the fish to pass through unharmed – USA;
- Retaining weir dam within the main impoundment to provide an isolated area of open water and shoreline with a consistent water level to the benefit of shore birds and fish species – Norway;
- Fish passage specifically for eels – USA.

Mitigation measures which Norway includes in its licences and which might serve as a good example for the UK include:

- Material should be excavated from the area covered by the reservoir;
- Limited (road) access to surrounding habitat during construction and road removal following construction;
- Retaining weir dam within the main impoundment to provide an isolated area of open water and shoreline with a consistent water level to the benefit of shore birds and fish species.

The use of erosion mats as a measure for erosion control in Meltingen Reservoir, Nord-Trondelag Country (see case-studies, Annex B) was unsuccessful. Additional literature review is necessary to determine whether this technique has been effective elsewhere.

4.2.8 Construction

Norway was identified as having a fairly active programme of construction, particularly for hydropower dams. The remaining countries appear to have passed their peak period for construction, with only three large dam projects reviewed in the USA since 1986. Cynically, the World Commission on Dams suggests this is as much to do with the lack of remaining suitable sites (particularly for hydropower dams) than a recognition of the environmental impacts and alternative options available.

4.2.9 Decommissioning

The international review identified at least three large dams that have been decommissioned in France in recent years, whilst the USA was clearly actively decommissioning large dams in response to environmental concerns, expired licences and because it often financially a more attractive solution than repairing and renovating existing dams.

Information on decommissioning of dams in Norway and Australia was not identified through the literature search and the consultation, suggesting that decommissioning is not currently a major issue in these countries.

Major challenges in France and the United States have been:

- sediment removal
- finding alternatives to dam functions (energy, recreation, water supply)
- financial consequences for the surrounding community
- affecting drinking water abstraction downstream

There are useful lessons to be learnt from the decommissioning experiences of these two countries.
4.3 Conclusions

To conclude, the international review of the five countries (Norway, France, Germany, Australia and the United States) identified:

1. A varying approach to the legal framework, which is expected for independent countries. Evidence of the rising influence of the Water Framework Directive is beginning to show in European policy and is likely to become dominant in future European legislation. The existence of a similar piece of legislation in Australia provides an opportunity to further explore lessons learned / currently being learned in this country.

2. A two-tiered approach is a common theme, allowing for a practical approach to both the licensing of small and major impoundment projects.

3. Similarly, the concept of time-limited licensing and the incorporation of conditions in the license to mitigate impacts on the surrounding environment are deemed as effective regulatory techniques in the majority of the countries reviewed and hence worthy of consideration in the UK.

4. A consistently good approach to consultation was demonstrated in all the countries, with consultation involving statutory and non-statutory organisations, along with the public and particularly the local community potentially affected by the impoundment. Multiple stages to consultation was considered to be good practice in at least two countries.

5. The international approach to environmental objective setting was not easy to identify, although Australia offered a practical approach.

6. Environmental Impact Assessment was evident as a tool used for licensing (and often re-licensing) in all the countries reviewed. For the European Countries, this is not surprising, given the EU EIA Directive and for all countries is considered to be good practice under the World Commission on Dams Report (2000).

7. Specific mitigation measures during construction of impoundments were rarely discussed / identified, with most of the mitigation measures focusing on operational mitigation measures. Norway, a country continuing to construct impoundments, was able to demonstrate more innovative measures during construction and operation.

8. Lessons learned during decommissioning were best exemplified by France and the USA.

9. The tables of mitigation measures and management strategies for each of the countries showed a surprising amount of overlap in terms of the solutions utilised to solve common issues. Hence, the preliminary analysis of the mitigation techniques tried and tested by the 5 different countries showed that a substantial number are commonly used by all. These include:

   • Compensation flows / minimum flow regimes, minimum-maximum flow regimes and variable flow regimes (to suit the natural seasonal variations)
   • Measures to allow the passage of aquatic fauna, primarily fish passes / ladders and by-pass channels
• Measures to maintain dissolved oxygen levels in the impounded water and downstream, including air/oxygen injection and circulation
• Measures to prevent fish entrainment at intakes or to minimise damage, such as fish screens and behavioural measures such as acoustic barriers
• Measures to minimise adverse temperature changes downstream, such as multi-level withdrawal outlet structures and surface storage

10. Additional measures that are likely to be fairly universal were also identified and these included:

• Management plans, such as Water Sharing Plans which are commonly used in Australia and Water Protection Plans in Norway
• Catchment management measures to reduce diffuse pollution inputs to the reservoir
• Sediment management measures such as sluices to allow through flushing (carefully timed to avoid adverse impacts on spawning gravels downstream).

11. Novel approaches to mitigation measures and management strategies were also identified and may be worthy of further investigation in Phase 2, particularly with respect to their relevance to the UK and a ‘best-practice’ approach.

Additional controversial issues for consideration were raised in the World Commission on Dams (2000) report:

• The extent to which alternatives to dams are viable for achieving various development goals and whether alternatives are complementary or mutually exclusive
• The extent to which adverse environmental and social impacts are acceptable
• The degree to which adverse environmental and social impacts can be avoided or mitigated; and
• The extent to which local consent should govern development decisions in the future.
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6 KEY CONTACTS AND ACKNOWLEDGEMENTS

6.1 Contacts

Table 6.1 provides the list of consultees who were contacted during the Phase 1 literature review. Many of these consultees provided responses to the questionnaire and gave specific details of the legal framework, licensing procedures and mitigation measures for impoundments in their respective countries. Their significant contribution to this project is gratefully acknowledged.
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<td>Mission InterServices de l’Eau (MISE)</td>
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<td>European Rivers Network</td>
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<td>Anti-dam organization. Case studies on dam decommissioning in France</td>
<td><a href="http://www.rivernet.org">www.rivernet.org</a></td>
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<td><a href="mailto:volker.mohaupt@uba.de">volker.mohaupt@uba.de</a></td>
<td>No response</td>
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<td></td>
<td>Britta Pielen</td>
<td>Ecologic</td>
<td></td>
<td><a href="mailto:pielen@ecologic.de">pielen@ecologic.de</a></td>
<td>No response</td>
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<tr>
<td></td>
<td>Dr. Clarita Miller-Plantenberg</td>
<td>Gesamthochschule</td>
<td>(anti-dam organisation)</td>
<td>Fachbereich 06 Nora-Platiel-Str. 5 D-34127 Kassel</td>
<td>No response</td>
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<tr>
<td>Country</td>
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<td></td>
<td>Pamela Metschar</td>
<td>Information, Alternatives and Opposition (IAO Network)</td>
<td>(anti-dam organisation)</td>
<td>Georgenkirchstrasse 70 D-10249 Berlin</td>
<td>No response</td>
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<tr>
<td></td>
<td>Heffa Schuecking</td>
<td>Urgewald</td>
<td>(anti-dam organisation)</td>
<td>Von-Galen Str. 2 D-48336 Sassenberg email: <a href="mailto:aradierker@gn.apc.org">aradierker@gn.apc.org</a></td>
<td>No response</td>
</tr>
<tr>
<td>Australia</td>
<td>Mr David Borthwick</td>
<td>Department of Environment and Heritage</td>
<td>Secretary</td>
<td>GPO Box 787 Canberra ACT 2601 AUSTRALIA</td>
<td>Letter sent 25th March 04</td>
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<tr>
<td></td>
<td>Mr Darren Barma</td>
<td>Department of Infrastructure Planning and Natural Resources</td>
<td></td>
<td>23 -33 Bridge Street Sydney NSW 2000 AUSTRALIA</td>
<td>Letter sent 25th March 04</td>
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<tr>
<td></td>
<td>Mr Barry Dunn</td>
<td>Snowy Hydro Ltd</td>
<td></td>
<td>Level 35 Norwich House 6 – 10 O’Connel Street Sydney NSW 2000 AUSTRALIA</td>
<td>Letter sent 25th March 04</td>
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<td></td>
<td>Tony McLeod</td>
<td>Murray Darling Basin Commission</td>
<td></td>
<td>GPO Box 409 Canberra ACT 2601 AUSTRALIA</td>
<td>Letter sent 25th March 04</td>
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<td></td>
<td>Ms Penny Knights</td>
<td>Sydney Catchment Authority</td>
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<td>PO Box 323 Penrith NSW 2750 AUSTRALIA</td>
<td>Letter sent 25th March 04 Email response – challenging scope and task. Asked for clarification. WJ sent email clarification.</td>
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<td></td>
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<td>Department of Environment and Heritage</td>
<td>Director Inland Waters Section</td>
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<td>Department of Environment and Heritage</td>
<td>Director Water Policy Section</td>
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<td>CSIRO Land and Water</td>
<td>State of the art in water and land management</td>
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<td></td>
<td>Catriona Shirley</td>
<td>Masters Student in Australian Water Issues</td>
<td></td>
<td><a href="mailto:catriona@icaa.org.au">catriona@icaa.org.au</a></td>
<td>Original contact provided names and websites by email</td>
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<td></td>
<td>(local contact)</td>
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<td>+61 2 9290</td>
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<td></td>
<td>Jane Lovette-Cameron</td>
<td>Institute of Chartered Accounts of Australia</td>
<td>Information and Research Manager</td>
<td>Level 11 37 York Street Sydney NSW 2000 00612 9290 5680 <a href="mailto:janel@icaa.org.au">janel@icaa.org.au</a></td>
<td>Original contact provided websites by email</td>
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<td></td>
<td>USA</td>
<td>Michael Horn</td>
<td>Project Manager. Contact for ‘Evaluating the effects of operations to avoid adverse impacts</td>
<td>USA 303-445-2203</td>
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<td>Principle Civil Engineer (member of the panel that reviewed the World Bank Sourcebook on Stakeholder Involvement in Options Assessment)</td>
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<td>input on dam and hydropower regulation in the US</td>
<td><a href="mailto:dana.p.murch@state.me.us">dana.p.murch@state.me.us</a></td>
<td>Key response</td>
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<td></td>
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<td></td>
<td>Water Resources Specialist Input on current primary environmental issues, general strategies etc</td>
<td>Phone: 202. 797. 6800/direct: 797. 6697 Washington, DC</td>
<td>Key response</td>
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<td>Dr Jean O'Neil</td>
<td>Environmental Laboratory</td>
<td>Engineer Research and Development Center</td>
<td>L.JEAN.O'<a href="mailto:Neil@wes02.usace.army.mil">Neil@wes02.usace.army.mil</a></td>
<td>No response</td>
<td></td>
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<tr>
<td>Prof. Jack Stanford</td>
<td></td>
<td>Done a lot on decommissioning impoundments has many contacts</td>
<td><a href="mailto:stanford@selway.umt.edu">stanford@selway.umt.edu</a> <a href="http://www.umt.edu/biology/flbs/People/JStanford/default.htm">http://www.umt.edu/biology/flbs/People/JStanford/default.htm</a></td>
<td>Contacted but unable to respond due to time constraints</td>
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</tbody>
</table>
| General Internatio nal | Prof Narcis Prat       | Academic                                                 | Dept Ecologia
 Univ Barcelona
 Diagonal, 645
 Barcelona Spain, E-08028
 Phone: 34-93-4021510
 Fax: 34-93-4111438
 Email: nprat@ub.edu
 Personal web page:
 http://usuarios.lycos.es/narcispratweb/ |                                                                                  |
| Larry Haas         | Canadian consultant      | Co-author of World Bank Sourcebook on Stakeholder Involvement in Options Assessment
 Team-leader for the World Commission on Dams exercise | larryhaas@tesco.org 01903 726369                                  |                                                                                                          |
| Intl. Hydropower Association (IHA) |                    | To Advance Knowledge on All Aspects of Hydropower and to Promote Good Practice | Environment Committee
 Westmead House
 123 Westmead Road
 Sutton, Surrey SM1 4JH |                                                                                                          |
<table>
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<th>Country</th>
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| United Kingdom |                                          |                                                   |                                                                      | United Kingdom  
(+44) 20 - 8288 1918  
(+44) 20 - 8770 1744  
iha@hydropower.org  
www.hydropower.org |          |
| UNEP Dams and Development Programme |                                          |                                                   |                                                                      | Nairobi                                                                 |          |
| United Kingdom |                                          |                                                   |                                                                      | United Kingdom  
(+44) 20 - 8288 1918  
(+44) 20 - 8770 1744  
iha@hydropower.org  
www.hydropower.org |          |
| International Committee on Large Dams (ICOLD) |                                          |                                                   |                                                                      | Staunch supporter of dam building, but also looking towards management and rehabilitation of existing facilities |          |
ANNEX A: CONSULTATION

AA.1 Consultation Covering Letter

Address

Your reference :
Our reference : 9P2900/B3/L001/WJ/Edin

Date :

Dear

WATER FRAMEWORK DIRECTIVE RESEARCH PROJECT (WFD29)
IMPOUNDMENT STRUCTURES, THEIR ENVIRONMENTAL IMPACTS AND MITIGATION MEASURES

Posford Haskoning in conjunction with the Centre for Ecology and Hydrology and Glasgow University have been employed by the Scottish and Northern Ireland Forum for Environmental Research (SNIFFER) to undertake research into impoundment structures. SNIFFER is an organisation that identifies and manages environmental research on behalf of their members - the Scottish Environment Protection Agency (SEPA), Environment and Heritage Service (EHS), the Scottish Executive, Scottish Natural Heritage (SNH) and the Forestry Commission - and other stakeholders and further information on this organisation can be found at www.sniffer.org.uk.

The aim of the project is to provide technical guidance on techniques to mitigate the environmental impact of impoundment projects in the UK. This project involves an international review of current practices, identification of best practice for the UK, consideration of the cost-effectiveness of mitigation measures, preparation of the draft guidance document, practical trials with impoundment managers and finalisation of the best practice guidance document.

The scope includes consideration of the planning, construction, operation, restoration and decommissioning stages for impoundments within rivers, transitional and coastal water environments. The project focuses on freshwater hydropower impoundments and dams for water supply and flow regulation. The guidance document will be used to assist in the implementation of the Water Framework Directive, particularly in relation to identifying a suite of potentially suitable measures for ameliorating the adverse effects of impoundments on water quality and ecological status.

The first phase of this project is to undertake a review of current practices with regard to the planning, construction, operation and decommissioning of impoundment structures in several countries including the United States, Australia, Germany, France and Norway. In addition to an extensive literature review using the Internet and our own professional knowledge of impoundments, their ecological impacts and methods for mitigation, we would like to consult with professionals active in impoundment management and research so that we can utilise the most up to date knowledge.
To this end, we would propose telephoning you at a mutually convenient time to arrange to discuss your views. To assist in this process, we have prepared a questionnaire which outlines the areas in which we are interested and we would be grateful if you could complete this questionnaire, seeking the views of other specialists as you see fit and return it to me at the above mentioned address. There is a space on the questionnaire for you to indicate the preferred time of the meeting and to assist, I would suggest the following three dates and times for the interview, taking into account time differences between our countries.

**INSERT THREE DATES and TIMES**

If none of these dates are suitable, please feel free to suggest alternatives and we can agree a suitable time. Returning the completed questionnaire before the telephone interview will enable me to have a better understanding of the issues and target the discussion effectively.

Thank you in advance for your cooperation and should you have any queries regarding the questionnaire specifically or the project in general, please feel free to contact me.

Yours sincerely,

**Wendy A Johnston**
Senior Environmental Scientist
AA.2 Questionnaires

Impoundment Structures, their Environmental Impacts and Mitigation Measures

Questionnaire for International Consultees

Where possible please consider each of these questions with respect to four stages of impoundment life: planning, construction, operation and decommissioning.

1. Licensing Procedures for Impoundments
1.1 What information does your organisation require from a developer before a decision on whether to grant an impoundment licence is made?
1.2 Why is this information considered to be important?
1.3 Who is consulted during the consideration of the application?
1.4 Is there anything you would change about your licensing process?

2. Environmental Impacts and Mitigation
2.1 Are impoundments the main cause of poor water/ environmental quality within the catchment, or are other issues e.g. point source inputs, diffuse source inputs more significant?
2.2 What are the main environmental impacts associated with impoundment structures with which your organisation is concerned?
2.3 What types of mitigation have been tried in your country to minimise these environmental impacts?
2.4 How successful have these measures been? (using a scale of 1 to 5 with 1 being very unsuccessful and 5 being very successful)
2.5 Have you tried mitigation measures in combination and have these proven more or less effective?
2.6 Are there other mitigation measures you would be tempted to try but which currently cannot be undertaken as a result of restrictions e.g. lack of information, legislative limitations, lack of funding (for research and implementation)?

3. Management strategies
3.1 What are the current challenges facing reclamation/reservoir/hydropower management in your country? eg, are impoundments affecting downstream water levels/ecology?
3.2 What management strategies, alone or in combination, have been applied to address these problems?
3.3 Are there particular impoundments types for which some strategies have been more successful than others?
3.4 Have the results of particular strategies been monitored (case-studies)?
3.5 If so, can you name these studies and the parties responsible for their execution?
3.6 Is there (additional) relevant current research being carried out to evaluate particular management strategies, for example the effectiveness of aeration in improving algal concentrations (transparency)?

4. Implications of Water Framework Directive (European countries only)
4.1 Are the procedures you currently have in place sufficient to meet the requirements of the Water framework Directive?
4.2 If not, what further steps will require to be taken to ensure compliance with the Directive?

Please return to: Wendy A Johnston  E-mail: w.johnston@royalhaskoning.com
Posford Haskoning  10 Bernard Street
Leith  Fax:  0131 555 0502
Edinburgh  Phone:  0131 555 0503
EH6 6PP

Please complete and return by:

Date and Time of telephone conversation to discuss:

…………………………………………………………………………………
ANNEX B: CASE STUDIES

AB.1 Norway

Three case studies, all relating to works done to improve the ecological status of reservoirs and controlled waters impacted upon by impoundments associated with hydropower schemes are summarised in Annex B:

- Erosion of Shore Zones in Meltingen Reservoir, Nord-Trondelag Country, Norway
- Creation of a Retaining Dam in Innerdal Reservoir, Innerdalen, Norway
- The Creation of Increased Spawning Grounds in Inlet Streams, Oppland

AB.1.1 Erosion of Shore Zones in Meltingen Reservoir, Nord-Trondelag Country, Norway

Due to the fluctuating levels within reservoirs, erosion of the shore line is often observed. This study, in 1989 looked to examine two methods for erosion control. The first involved the use of erosion mats and fertilisation and the second involved the planting of five species of aquatic plants. The first part of the study is summarised below and further information on this and the other study can be found in “Biotope Adjustment Measures in Norwegian Watercourses” (reference).

The use of erosion mats was largely unsuccessful with the mats being washed out by wave action despite being firmly anchored down. Lime-enriched peat was used to fertilise vegetation in the hope that the root growth of existing vegetation would be encouraged. Initially, vegetation growth increased, with increased levels of fertilisation resulting in increased growth of terrestrial grasses and annual weeds and this increased growth was noted over a few growing seasons but the grasses did not survive being submerged for any period of time. Although there was some initial increase in the growth of aquatic plant species, this was to a lesser extent, with these species being out competed by grasses particularly when higher concentrations of fertilisers were used. This research indicated that only small amounts fertiliser should be used to avoid competition between aquatic and terrestrial species and that while well developed vegetation cover, and therefore root growth can delay erosion, it cannot prevent it. In addition, increased levels of fertilisation can result in increased water pollution.

AB.1.2 Creation of a Retaining Dam in Innerdal Reservoir, Innerdalen, Norway

Innerdal reservoir was created by flooding a 6.5km² area of the Innerdalen valley on the Orkla watercourse in 1982, with the resultant loss of lush flora and fauna. This led to the loss of habitats for birds in the valley and a drop in the population although the size and number of fish in the reservoir increased dramatically for the first five years following the development.

Due to shoreline erosion, there was a resultant loss in vegetation, benthic fauna and aquatic insects in the shore line, the food sources for fish and birds. While the size and number of fish in the area had originally increased following the creation of the reservoir, there was a decrease in the growth and condition of fish by the late 1980s and the bird populations did not show any recovery.

This study was undertaken in 1989 to determine whether the creation of an area within the reservoir where the water depth did not fluctuate would result in increased habitats
for birds and fish and a resultant increase in the number of birds using the area and the size and condition of fish in the area.

A 0.4km$^2$ area of the reservoir was impounded by the construction of a weir dam, complete with a by-pass channel to enable fish to pass from one area to another, in the south-eastern section of the reservoir. This stabilised the water level within the weir dam preventing it from lowering along with the water level in the main basin of the reservoir. Both studies indicated that the weir dam had a positive impact on both vegetation and benthic fauna in the shore line and the area retained within the structure. The difference between fish populations in the weir basin and in the main reservoir was marked, with the weight of fish being caught in the weir basin being considerably greater per net night than that caught in the reservoir. However, there was no marked difference on the condition of the fish from either area.

Following the construction of the weir dam, the number of duck species and the total numbers of ducks increased significantly with a change in the species of duck present, with diving ducks predominating over dabbling ducks following the construction works. While the numbers of water birds have increased during this period, the numbers of shore birds has fluctuated.

**AB.1.3 The Creation of Increased Spawning Grounds in Inlet Streams, Oppland**

A series of measures have been undertaken in inlet streams of numerous reservoirs in Oppland including the Tesse reservoir, the Tisleia reservoir and Vangsmjosa reservoir to improve the habitat of the watercourse to encourage spawning. In an inlet steam of the Tesse reservoir a series of measures which had great success were implemented. These measures included the creation of deep pools and other hiding places, the installation of an additional culvert to facilitate fish movement upstream, the diversion of water from another watercourse to increased flows in winter, the placement of rocks in the stream to provide more cover for young fish and boulders along the banks to establish additional hiding places.

Obstacles in an inlet stream of the Tisleia Reservoir were removed by blasting to encourage fish migration and the establishment of new spawning grounds. The stream bed was modified to increase water flow during periods of low flow and weirs were installed to ease migration. Similar measures have been implemented in an inlet stream to the Vangsmjosa Reservoir and the Flyvatn reservoir and each measure has been estimated to cost between £1230 to £2500 per (15 000 and 30 000 NOK). (reference).
AB.2   France

AB.2.1 Decommissioning of Kernansquillec sur le Léguer (Côtes-d'Armor)

General Description
This dam of about 15m high and built of multiple concrete arches circa 1920 is located on the Léguer River. It was used by a concessionaire to produce power for print works. The impoundment of 400,000 m³ located downstream from farming areas was affected by a significant eutrophication and significant silting-up of about 50%. The last emptying of the impoundment undertaken every 10 years by law had a major impact on aquatic fauna which was underneath the silt. In order to have the authorization renewed, the regulatory bodies informed the concessionaire of the conditions he had to fulfill: these conditions included an increase of the capacity of the equipment enabling draining of floods and de-silting of the impoundment. The latter concessionaire preferred to cancel its authorization application and the impoundments were given back to the State when the concession ended on the 31st December 1993.

For the 1995 floods, seven houses had to be evacuated downstream further to experts’ recommendations due to insufficient number of flood draining and as the water was about to overflow above the dam. Moreover, the dam blocked the salmon and other migratory fish passage on the River Léguer. Due to its limited power generation, to its great age and the risks it caused for public safety and environment, the government decided to demolish the impoundment.

Demolition
The demolition was carried out by the government (Ministry of Industry). The cost of the demolition was 6,1 million of francs and was paid by the government and the French Water Agency.

Problems encountered
The main problems encountered include emptying, precautions to be taken due to the significant silting-up of the impoundment, presence of fish and drinking water abstraction downstream. Previously to the emptying of the impoundment, which was authorized by an order of the prefect dated 12th April 1996, dredging was undertaken in the narrower river bed removing 95,000m³ of mud which was treated in settling lagoons in order to protect the river downstream.

The demolition license was granted by the prefect on the 17th of September 1996. Impoundment demolition works were completed in 1996 and no particular problems were encountered. Re-instatement and development of the valley including a former industrial site are going to be undertaken by the Conversation Group of Léguer.

AB.2.2 Decommissioning of St- Etienne du Vigan sur l'Allier (Haute-Loire et Lozère)

General Description
The construction of the dam of St-Etienne du Vigan by a private owner was authorized in 1895 in order to supply power for the lighting of Langogne (Lozère). The dam was
about 12 meters high and was not equipped with passes for migratory fish. Therefore the dam sterilised 30 ha of excellent spawning substrates for salmon of the Haut-Allier area. At the time, the rural populations protested vigorously against the project as fishing provided significant extra income.

The town of Langogne rebuilt the dam in concrete a few meters downstream from the original dam which was partially ruined. The impoundment became EDF’s property in 1950.

Within the framework "Loire Grandeur Nature", adopted on the 3rd of January 1994 by the French government, the prefect did not renew the authorization of the impoundment when it expired on the 16th of October 1994. It required that the dam is demolished at the state’s cost in order to re-instate the flow of the water course as stated in the law of 1919.

Demolition
The demolition was undertaken by EDF. The demolition costed approximately seven millions of Francs which were paid by EDF which was helped by the Water Agency. The total cost of the decommissioning was estimated to 14 millions francs including 7.2 millions covering the drop of income for the town (the income was the professional tax that EDF had to pay to the town) and development of the site and of the salmon population.

Problems encountered
The beginnings of the works had to be delayed awaiting for a rise of water level, in order to avoid risk of pollution when emptying the impoundment. The demolition was done using explosives on the 24th of June 1998. The sediment present in the impoundment was of very good quality (gravels and sand) and there was no observed pollution. The site had soon settled back into its natural state and five spawning substrates were noted in winter 1998-1999 upstream of the site

AB.2.3 Decommissioning of Maisons-Rouges sur la Vienne (Indre-et-Loire)

General Description
The dam was built in 1922 and used as hydropower station by a concessionnaire. The dam of Maisons-Rouges is located 800m downstream from the merging of the Vienne Rive and the Creuse River and downstream from a river basin of 20,000 km². It is about four meters high. It was built in order to supply power to print works and then became part of EDF heritage. As the dam was located at the confluence of two rivers and as it is the first one from the sea, it had a great impact on numerous species of migratory fish. More especially salmon which already suffered from the fact that spawning location decreased / disappeared. Shads used an alternative spawning locations located downstream from the dam and that led to problem of hybridization. Fish passes which were built were not very efficient and the diverse projects aiming the re-introduction of the Salmon of the Gartempe River (one of Vienne’s affluent) were not conclusive.

Within the « Loire Grandeur Nature » framework dated 3rd of January 1994, the government decided that the concession would not be renewed after the concession expiration dated 31st December 1994 due to low economical benefits and significant environmental impacts. The government which was the owner of the site undertook the demolition of the dam.

Demolition
The government (ministry of environment) was responsible for the demolition of the dam. The demolition was undertaken by the DDE of the Indre area and EDF. The cost of the works was 14 millions of French francs and was covered by the Ministry of environment and infrastructures with the help of the water agency and EDF. A provision of 10 millions French francs was made in order to compensate the loss of the professional tax from EDF to the town to cover the operation of the dam.

**Problems encountered**

One of the main problems faced was the loss of money encountered by the surrounding villages which lead to opposition of the project from local authorities. Therefore financial help (equivalent to the cost of the demolition of the dam) was provided by the government, the water agency, EDF and was used for developing the local area.

The demolition was undertaken in 1998. A submerged weir was reconstructed at the bottom of the riverbed in order to minimize the headward erosion which was suspected to happen due to former sand extraction in the Rivers Vienne and Loire and to minimize sediments migration located upstream from the former dam.

The sediments were mainly sand and were of good quality. Numerous agricultural water abstractions from the impoundment were re-instated by the government. On the other hand, a land slide occurred at the campsite which was located 800m upstream from the dam. This land slide was presumably due to the change of groundwater regime due to the 4 meters drop of the surface water level.

Demolition of the dam was also beneficial for fish life: salmon re-appeared, shads and lamprey number increased.

The University of Chinon monitors the hydrology of the dam.

**AB.3 Germany**

**AB.3.1 Case Study - Herrenhausen hydroelectric station, Hannover**

The Herrenhausen hydroelectric station in Hannover (www.energie-cites.org/BD/PDF/han-mhp-en.pdf) was intended to show how an impounding structure can be designed to ensure a minimal impact on the environment.

One aspect was the design and construction of a fish ladder to enable various species of fish to pass the weir.

The environmental study identified four different site variants to ascertain a site which would minimise the impact on the in-river ecology. The study identified that building the turbine into the weir proved the best solution ecologically.

**AB.3.2 Case Study - Spree River Hydroelectric Power Plant, Cottbus**

The construction works and design were laid out to respect the countryside and environment, as well as the local historic monuments (www.energie-cites.org).

Greasing and cooling units form a secondary independent circuit to prevent the by-products from entering the watercourse.

A diversion/dam was already present in the river, and the turbines were built into this.
AB.3.3 Case Study - The Construction of the Leibis-Lichte Dam: Ecological Influences and Possibilities for their Minimisation (H Willmitzer)

Though not completed as yet, the proposed scheme comprises the construction of two reservoirs, one of which has been completed. Prior to construction, an environmental compatibility study was undertaken, which entailed extensive data collection and analysis to determine the potential environmental impacts, and to identify suitable mitigation measures. The scheme also includes extensive monitoring proposals.

The key mitigation measure is the regulation of the hydrological regime (flow/release rates) in order to maintain sufficient water levels downstream. The management regime for the proposed reservoirs has been determined using modelling and minimum water levels and flows downstream. During periods of low flows in-river, the reservoir flow can be increased to ensure a minimum depth/flow of water in the river, to maintain fish populations and the dilution effect of water.

Because the Leibis-Lichte Dam scheme is proposed to enhance water quality and be used as resource for drinking water, potential conflict may arise from the need for maintaining the proposed water management regime (release rates and volumes) and the requirements for drinking water.

The mitigation identified to offset the reduced deposition of sediment downstream of the dam would be to artificially place material downstream of the reservoirs.

In order to prevent the reservoirs from inhibiting the movement of aquatic organisms (particularly fish), the use of fish stairs and other designed features would be used.

Where potential exists for oxygen levels to be reduced up or downstream of the reservoirs due to reduced water flow, increased organic activity, etc., for example during summer, structures would be constructed as part of the scheme to provide aeration.

To minimise or offset the increase of levels of H₂S, NH₄, soluble phosphorous, and dissolved organic carbon, which can result in increased algal growth and reductions in aquatic diversity, the aerators would also be used, as well as increasing discharge flows. (www.talsperrenkomitee.de/german_research/index.cgi?page/article/article_id/16)

AB.4 Australia

AB4.1 Case Study: Water Sharing Plan: Lachlan River

The Lachlan River Water Source (hereafter the water source) is in the central west of NSW and drains an area of some 85,000 square kilometres (kms²). The volume and pattern of flows in the Lachlan has been significantly altered by the construction and operation of Wyangala Dam, two large “off river” water storages (Lake Brewster and Lake Cargelligo), and a number of weirs and diversion structures, and by the extraction and diversion of water.

Recently there has been a shift to summer-irrigated crops which has caused a further shift from the natural winter/spring flow pattern. These changes have contributed to a range of effects on the environmental health of the water source and its wetlands and to water quality problems.

In 2001, the Minister for Land and Water Conservation asked the Committee to make recommendations regarding water sharing rules for the Lachlan to be incorporated into a
statutory water sharing plan. The final statutory plan was made by the Minister for Land and Water Conservation in February 2003. It was based on the recommendations of the Committee, submissions received from the community as a result of the public display of the draft plan, and agreed Government policy as a Minister’s plan.

The provisions in the Water Sharing Plan for the Lachlan Regulated River Water Source provide water to support the ecological processes and environmental needs of the river, and direct how the water available for extraction is to be shared. The Plan also sets rules that affect the management of access licence’s water allocation accounts, the trading of access licences and water allocations, the extraction of water, the operation of dams and the management of water flows.

These were developed following the 8 key steps detailed below which relate to the relevant sections in the Water sharing plan.

**STEP 1** – Establish the flow relationships of the river and ecological processes
This is calculated with reference to historical flow records and known physical processes of the river and can involve the construction of a hydrological model to analyse various options for river management.

**STEP 2** – Water for the environment
This involves the establishment of the key environmental features of the river and devising flow related rules to provide water to sustain or improve those features. This step relates to Part 3– environmental water provisions of the water sharing plan.

**STEP 3** – Water for basic landholder rights
This step involves the estimation of the total requirements for domestic and stock rights as well as native title rights and related to Part 4– basic landholder rights of the water sharing plan.

**STEP 4** – Access license requirements
This step involves the assessment of the total share volumes of all access licenses and rules for granting additional access licenses and related to Part 6 – requirements for water under access licences, and Part 7 – rules for granting access licences of the Water Sharing Plan.

**STEP 5** – Set limits on water for abstraction and share that between different water users
This involves the setting of a limit on the volumes of water that can be abstracted on an average yearly basis and establishment of the rules required to manage the plan within these limits. There is a need to specify how the water that is available will be shared between all access licences. This step relates to Part 8 (Division 1) - long-term extraction limit, and Part 8 (Division 2) – available water determinations of the water sharing plan.

**STEP 6** – Provide flexibility for access licence holders
This step involves setting rules that specify how water accounts are to be managed, and defining the dealing rules, and related to Part 9 (Division 2) – water allocation account management, and Part 10 – access licence dealing rules of the water sharing plan.

**STEP 7** – Provide clear licensed rights
This involves the translation of the water abstraction limits set in step 5 and the rules established in step 6 into mandatory conditions on individual access licences and
approvals, and specify any system operation rules, and if and how a plan rule can be amended. This relates to Part 11 – mandatory conditions, Part 12 – system operation rules, and Part 14 – amendment of this Plan of the Water Sharing Plan.

**STEP 8 – Monitor plan**
This final step involves reviewing the Plan each year and auditing the performance of the Plan mid-term i.e. in Year 5). This relates to Part 13 – monitoring and reporting of the Water Sharing Plan.

The Act requires that river health be protected and that the Plan includes specific environmental water rules and these environmental water provisions build on pre-plan management rules. Environmental and water quality allowances provide water for a variety of purposes and on average, 75% of flows are protected from extraction and winter/spring flows and wetland inflows are increased. The Plan provides high priority to basic landholder rights and recognises that they can increase during the term of the Plan. The volume of water allocation that an access licence receives will depend on its share component volume, its access licence category and the Plan rules.

A key provision is the Plan’s long-term extraction limit – if this is exceeded, the maximum water extractions that are permitted will be reduced. The embargo on applications for new water entitlements in most access licence categories which was put into place in 1982 will continue and “off allocation” access will no longer be permitted.

The Plan specifies rules about the operation of dams and supply of water to some effluent rivers and regulates trading of access licences, water allocation and the conversion of licence categories with only high security, general security and conveyance licences being permitted to be converted into another category.

Further information on these water sharing plans can be found in NSW Department of Sustainable Natural Resources, 2003 and Aquilina J.M.P., 2003 (see section 5 for full reference details).

**AB.5 USA**

**AB5.1 Florida Everglades Restoration: The Comprehensive Everglades Restoration Plan (CERP)**

(source: http://www.evergladesplan.org/about/rest_plan.cfm)

**General Description**
The Comprehensive Everglades Restoration Plan (CERP) provides a framework and guide to restore, protect, and preserve the water resources of central and southern Florida, including the Everglades. It covers 16 counties over an 18,000-square-mile area, and centers on an update of the Central & Southern Florida (C&SF) Project. The current C&SF Project includes 1,000 miles of canals, 720 miles of levees, and several hundred water control structures. The C&SF Project provides water supply, flood protection, water management and other benefits to south Florida. For close to 50 years, the C&SF Project has performed its authorized functions well. However, the project has had unintended adverse effects on the unique and diverse environment that constitutes south Florida ecosystems, including the Everglades and Florida Bay.
The Water Resources Development Acts in 1992 and 1996 provided the U.S. Army Corps of Engineers with the authority to re-evaluate the performance and impacts of the C&SF Project and to recommend improvements and or modifications to the project in order to restore the south Florida ecosystem and to provide for other water resource needs. The resulting Comprehensive Plan was designed to capture, store and redistribute fresh water previously lost to tide and to regulate the quality, quantity, timing and distribution of water flows.

The Plan was approved in the Water Resources Development Act of 2000. It includes more than 60 elements, will take more than 30 years to construct, and will cost an estimated $7.8 billion.

**Mitigation/ restoration measures**
The principal goal of restoration is to deliver the right amount of water, of the right quality, to the right places, and at the right time.

- **Quantity**
  Significantly less water flows through the ecosystem today compared to historical times. In fact, on average, 1.7 billion gallons of water that once flowed through the ecosystem are wasted each day through discharges to the ocean or gulf. The Comprehensive Plan will capture most of this water in surface and underground storage areas where it will be stored until it is needed. Specifically, this water will be stored in more than 217,000 acres of new reservoirs and wetlands-based treatment areas and 300 underground aquifer storage and recovery wells.

- **Quality**
  The Comprehensive Plan helps improve the quality of water discharged to natural areas by first directing it to surface storage reservoirs and wetlands-based stormwater treatment areas. Further opportunities to improve water quality will be incorporated into the design of the Plan's features.

- **Timing**
  Restoring alternating periods of flooding and drying in water flows and levels is an integral part of the Comprehensive Plan. Specifically, the timing of water held and released into the ecosystem will be modified by the Plan so that it more closely matches natural patterns.

- **Distribution**
  The areal extent and movement of water through the system is the final factor in the water equation. Over 50 percent of the original Everglades have been lost to urban and agricultural development. Further, the remaining ecosystem has been separated, or compartmentalized, by canals and levees. To improve the connectivity of natural areas, and to enhance sheetflow, more than 240 miles of levees and canals will be removed within the Everglades.

**Regulation**
All CERP activities are regulated by the EPA and state agencies (water quality) and the US Army Corps of Engineers (discharging fill or dredged material in waters of the U.S; site development fill for residential, commercial, or recreational developments; construction of revetments, groins, breakwaters, levees, dams, dikes, and weirs).
In addition, the Water Resources Development Act of 2000 required that *programmatic regulations* were to be promulgated by the U.S. Army Corps of Engineers within two years of the date of enactment; after notice and opportunity for public comment, to ensure that the goals and purposes of the Comprehensive Everglades Restoration Plan (CERP) are achieved.

**Lesson for WFD 29 Project**

The project can serve as an example for an integrated approach to alleviating the negative impacts of dams on the surrounding environment. The project was initiated only a few years ago, but in Phase 2 an inquiry can be done into available results.
AB..5.2 Dam Decommissioning in Northwest USA


Elwha River, Washington
The 32-meter-high Elwha Dam and 82-meter-high Glines Canyon Dam—the highest dams ever slated for removal at government expense—were built in the early 1900s to power timber mills in the nearby town of Port Angeles. The private dams, now within the Olympic Peninsula National Park, destroyed magnificent local runs of Pacific salmon, diminishing an important cultural symbol. Extinction of Elwha River sockeye salmon, and drastic declines in the river’s ten other native species, undermines fishing rights of the Lower Elwha Klallam, a federally recognized Indian Nation. In 1992, the government finally heeded tribal demands to provide “full restoration” of the Elwha River, including dam removal. After 25 years of campaigning by the Lower Elwha Klallam Nation and conservation organizations, Congress approved funds in 1999 to purchase the dams. Once acquired, the government will begin dam removal activities estimated to cost at least $100 million. Restoration of the Elwha represents the last, best hope for resolution of Lower Klallam fishing rights and the return of a once spectacular salmon river.

White Salmon River, Washington
A historic 1999 agreement between the Yakima Tribe, government agencies, conservation groups, and the dam owner requires the removal of a 38-meter-high private hydropower dam at the owner’s expense. Dismantling the 87-year-old Condit Dam will bring back free-flowing conditions to the entire 72-km White Salmon River. Dam removal will help restore critical habitat for endangered salmon from the river’s pristine headwaters all the way to its confluence with the Columbia River. Keeping the dams and complying with FERC relicensing conditions, including modern fish ladders, could cost dam-owner PacifiCorp more than $30 million—roughly two times dam removal estimates. PacifiCorp, a major regional power company, promises to finance the removal through a decommissioning fund generated by future hydropower revenues. Successful incorporation of tribal interests and dam-owner acceptance of financial accountability for decommissioning costs are critically important lessons with far-reaching implications for river advocates around the world.
AC.1 USA: Clean Water Act

(source: www.EPA.gov)

The diagram below illustrates the key elements of the Clean Water Act (CWA).

First, water quality standards (WQS) consistent with the statutory goals of the CWA must be established. This is the responsibility of the State, territory, and/or designated tribe authorities. Although the CWA does not require WQS for ground water, states, tribes, and territories can use their own authorities to set targets for ground water.

Water quality standards (WQS) are aimed at translating the broad goals of the CWA into waterbody-specific objectives. Ideally, WQS should be expressed in terms that allow quantifiable measurement. WQS, like the CWA overall, apply only to the waters of the United States. are responsible for setting the WQS.

Followingly, waterbodies are monitored to determine whether the WQS are met.

If all WQS are met, then antidegradation policies (policy designed to prevent deterioration of existing levels of good water quality) and programs are employed to keep the water quality at acceptable levels.

If the waterbody is not meeting WQS, a strategy for meeting these standards must be developed. The most common type of strategy is the development of a Total Maximum Daily Load (TMDL). TMDLs determine what level of pollutant load would be consistent with meeting WQS. TMDLs also allocate acceptable loads among sources of the relevant pollutants.

Necessary reductions in pollutant loading are achieved by implementing strategies authorized by the CWA, along with any other tools available from federal, state, and local governments and nongovernmental organizations. Key CWA tools include the following:
- NPDES permit program
  Covers point sources of pollution discharging into a surface waterbody.

- Section 319
  Addresses nonpoint sources of pollution, such as most farming and forestry
  operations, largely through grants.

- Section 404
  Regulates the placement of dredged or fill materials into wetlands and other
  Waters of the United States.

- Section 401
  Requires federal agencies to obtain certification from the state, territory, or
  Indian tribes before issuing permits that would result in increased pollutant loads
  to a waterbody. The certification is issued only if such increased loads would not
  cause or contribute to exceedances of water quality standards.

- State Revolving Funds (SRF)
  Provides large amounts of money in the form of loans for municipal point
  sources, nonpoint sources, and other activities.

After implementation of these strategies, ambient conditions are again measured and
compared to ambient water quality standards. If standards are now met, only occasional
monitoring is needed. If standards are still not being met, then a revised strategy is
developed and implemented, followed by more ambient monitoring. This iterative
process must be repeated until standards are met.
AC.2 USA: Re-licensing non-federal hydropower dams in the U.S: *14 steps to the FERC re-licensing process*

*(source: www.amrivers.org)*


- **Step 1:** Five years before hydropower license expiration date, the dam owner files a notice of intent to seek a new license and prepares a consultation package containing information about the project. FERC provides public notice of this intent.

  Resource Agencies and interested members of the public can review the consultation package.

- **Step 2:** Dam owner conducts formal consultation with federal and state resource agencies regarding project design, studies and alternatives. Dam owner holds meeting with resource agencies.

  Interested parties can work with agencies to develop study recommendations. Resource agencies and interested parties can comment on the consultation package. Interested parties may attend the consultation meeting.

- **Step 3:** Dam owner conducts studies needed for the relicense application, and prepares a draft application. Often these studies are conducted over several field seasons. Study results and the draft application are distributed to resource agencies for comment. A meeting may be held with resource agencies.

  Resource agencies may comment on draft application and study results.

- **Step 4:** Two years before the license expiration date, the dam owner submits an application for a new license.

  Interested parties and resource agencies review the license application and identify any additional studies or information the dam owner should develop. Requests for additional information are submitted to FERC.

  To become official parties to FERC's proceeding, interested parties file a Motion to Intervene with FERC, which means FERC must consider and respond to their submitted comments and subsequent motions and recommendations. Only parties that have formally intervened may appeal a FERC licensing decision.

- **Step 5:** FERC requests additional information from the dam owner based, in part, on recommendations from interested parties and resource agencies (called "AIRs"). The dam owner conducts additional studies and submits reports to FERC.

- **Step 6:** FERC publishes notice that the application is ready for environmental analysis. This is usually (but not always) after all additional information has been submitted to FERC.
Interested parties and resource agencies review the full application, submit comments on the application, and submit proposed license terms and conditions to FERC.

- Step 7: FERC conducts a public scoping process to identify environmental alternatives to study. FERC prepares a draft scoping document, holds public hearings and requests comment on the scoping document, and releases a final scoping document.

Interested parties and resource agencies attend the public scoping meeting and submit comments on the draft scoping document.

- Step 8: FERC prepares a draft Environmental Assessment ("EA") or Environmental Impact Statement ("EIS") describing various proposed methods of operation for each area of concern, listing environmental impacts of each alternative operating scenario and identifying a preferred alternative. If a draft EIS is prepared, FERC holds a public hearing.

Interested parties and resource agencies may attend the public hearing and submit comments to FERC on the draft EA or EIS.

Interested parties and resource agencies may submit any changes to their previously recommended license terms and conditions.

Interested parties and resource agencies may call for a hearing if there are any material factual issues in dispute.

If a draft EIS is issued, interested parties and resource agencies have a second opportunity to apply for formal intervention in the proceeding.

- Step 9: If FERC intends to disregard any fish and wildlife license terms and conditions recommended by resource agencies, FERC convenes a meeting with the resource agencies to discuss the disputed conditions (often called a "10(j) meeting"). FERC and agencies seek to resolve differences between their recommendations.

Interested parties may attend this meeting as observers. Sometimes interested parties are allowed to participate.

- Step 10: FERC makes a decision whether to hold a hearing on any material issues of fact. Such a hearing is very rare in the hydropower licensing arena.

If a hearing is held, parties to the proceeding (including public and resource agency intervenors) may participate in the hearing.

- Step 11: FERC staff issues a final EA or EIS.

Interested parties and resource agencies may comment on a final EIS. A final EA is usually issued at the same time as the licensing decision (Step 12), with no interim opportunity to comment.
• Step 12: FERC staff issues its decision on relicensing, i.e., whether a new license is issued and with what conditions.

Intervening parties (including public and resource agency intervenors) and/or the dam owner may request rehearing of the licensing decision by the five FERC Commissioners. If no request for rehearing is filed within the allotted time, the license is deemed final and accepted by the dam owner.

• Step 13: The five FERC Commissioners issue a decision on rehearing. The Commissioners may confirm, reverse or revise a decision by FERC staff, or they may remand the decision to FERC staff for further analysis and a new decision.

The parties that requested rehearing may appeal the Commission's decision to the US Court of Appeals. If the Commissioners changed the decision, a new request for rehearing to the Commissioners may be needed before an Appellate Court appeal.

• Step 14: The US Court of Appeals issues its decision on appeal.

Parties to the appeal may appeal the decision to the US Supreme Court.
Michigan has over 2500 dams, many of which were built decades ago. As dams age, they require regular inspection, periodic maintenance and sometimes very costly repair. As dams outlive their usefulness, and their condition deteriorates, consideration should be given to remove, rather than repair a dam. Old dams may be less costly to remove, than they are to repair.

The driving forces for consideration of dam removal are:
1) the cost of maintenance and repair when the benefits of maintaining a dam are diminished;
2) public safety and liability concerns; and
3) potential fisheries, water quality and recreational use improvements that can be realized with dam removal.

The purpose of this guidance document is to suggest issues that may need to be considered when deciding the future of a dam, and to assist in implementing a dam removal project. The steps outlined here are by no means complete; however, they can help dam owners and their communities develop a long-term plan for the dam which includes consideration of financial, public safety and environmental issues.

First Step: Consider What Purposes the Dam Serves
A. Consider whether the dam itself provides any benefits, such as:
   a. Power production.
   b. Prevents movement of sea lamprey or other aquatic nuisance species.
   c. Fish exclusion for fisheries management purposes.
   d. Historic significance.
   e. Provides bridge, rail or road crossing.

B. Consider whether the impoundment created by the dam may serve one or more of the following services:
   a. Water supply for irrigation, fire suppression.
   b. Flood control.
   c. Navigation and transportation.
   d. Recreational boating, fishing, swimming or park use.

Second Step: Consider Problems with the Dam Structure
A. Safety and Security of the Dam
   (note drafted by the MDNR Habitat Management Unit of the Fisheries Division and the DEQ Dam Safety Program of Geology and Land Management Division)
   (see DNR Dam Removal Guidance For Owners January 2004)
   a. Do boats, canoes or swimmers frequent the site – are they at risk?
   b. Does the site attract anglers?
   c. Is the dam itself in poor condition and/or subject to an order from DEQ to repair or remove the dam?
   d. What potential property damage would occur if the dam was to fail?

B. What are the Costs and Liabilities of Keeping the Dam
a. Repair cost estimate.
b. Maintenance cost estimate.
c. Operational concerns.

C. **What Environmental Impacts Should Be Considered?** (Consult your local DNR and DEQ offices for assistance).
   a. Water quality and aquatic habitat benefits of stream restoration.
   b. Improvement of fisheries and wildlife habitat.
   c. Recreational uses of the impoundment compared to a restored stream.
   d. Other ecological or economic considerations.

**Third Step: Considerations for Dam Removal**
A. **Would Removal Eliminate or Reduce Safety and Security Problems?**

B. **Would Removal Improve Recreational Use of the Site?**

C. **Cost Estimates**
   a. Preliminary estimate of dam removal cost.
   b. Sediment removal or management.
   c. Stream bank restoration.
   d. Replacement of dam dependent services (water supply, road or bridge crossing, etc).

D. **Potential Funding Sources**
   a. Private or Community Foundation funding
   b. Environmental Grants
   c. State or Federal Assistance Programs

**Fourth Step: Working with DEQ Dam Safety Program and/or DNR Fisheries Division**
A. **DEQ Permit application and information about the condition of the dam.**
   B. **Information about the fisheries and wildlife values with and without the dam.**
      (see DNR Dam Removal Guidance For Owners January 2004)
   C. **General guidance on the removal of a dam (if a viable option).**
   D. **Information about potential funding sources for dam removal (if a viable option).**
   E. **Other requirements for planning, design and modification of the dam.**

**Fifth Step: Explore Resident and Community Concerns Including Local Watershed Council, Conservation Clubs, Economic Development Groups, others**
A. **Historic and aesthetic values of the dam and or impoundment**
   a. Does the dam help define the community or suggest specific important aspects of its history? What alternatives may be considered to retain a portion of the dam as a monument to its history in the community?
   b. Would creation of an off-channel pond retain recreational uses or aesthetic values, while allowing return of a free-flowing river?
   c. What fisheries and wildlife values would likely occur in the area with and without the dam?

B. **Property Owners Interests**
   a. Residents of the impoundment may or may not have riparian rights to the water (access).
   b. Property values may change with and without the dam.
c. Lake association or other resident or adjacent park owners may be interested in taking over ownership and maintenance of the dam.

C. Other Social Issues
a. Public safety issues with or without the dam
b. Park or other public and use of the area: projected changes and the alternatives to preserve or replace valued recreational uses
c. Flooding concerns – hydraulic analysis may be needed to project how floodplains would be altered if the dam were breached
d. Other local economic considerations (waterfront business development with and without the dam).

Sixth Step: Collect and Assess Information (Professional Engineering and/or Legal Services Necessary)
A. Legal Issues
a. Who owns the dam structure and surrounding lands?
b. Any riparian ownership or flowage rights?
c. Any potential sources of sediment contamination?
d. Regulatory concerns or limitations?
(see DNR Dam Removal Guidance For Owners January 2004)

B. Engineering Issues
a. Condition of the dam and deadlines to take action (if appropriate).
b. Accessibility to the dam for repair or removal.
c. Potentially affected structures (e.g. bridges, utility crossings).
d. Sediment quantification and removal.
e. Flood storage capacity and changes in floodway.
f. Upper limit of the impounded stream.
g. Hydrology (gage data or hydrologic model).
h. Alternatives to modify or remove the dam.

C. Economic Issues
a. Final cost estimate of dam repair/rehabilitation of the impoundment.
b. Potential liability in the event of dam failure.
c. Potential operation, maintenance and repair cost savings.

Seventh Step: Taking Action
A. Secure Local, State and Federal Permits.
B. Complete Site Land Survey, Final Design Engineering Plans.
C. Secure Funding (construction, site restoration and monitoring).
D. Determine Sediment Management Plan (may include dredge and disposal or in place stabilization as recommended by DEQ and DNR).

Resources
For further information about dam removals in Michigan:
http://www.michigan.gov/dnrdams
ANNEXD: TABLES

The first table summarises the legislative and institutional framework in all five countries while the remaining five tables show the mitigation and management strategies employed in the five countries of interest.
The Requirement for an EIA is integrated into the planning and licensing procedures and is co-ordinated by NVE. It’s a complex process undertaken in line with the EU EIA Regulations. Long established and effective planning system which follows, to some extent the UK system but offers ideas for improvement in UK. Ability to insert conditions in the impoundment license for mitigation during operation is of great benefit. FERC has had a decommissioning policy for hydropower dams since 1994. Some regulations apply as for licensing. Non-federal hydropower: regulated by FERC. Relicensing opportunity to enforce (additional) mitigation measures. Owners must monitor and report to FERC; who

<table>
<thead>
<tr>
<th>Sector</th>
<th>Strategy</th>
<th>Objective</th>
<th>Description</th>
<th>Where applied</th>
<th>Effectiveness</th>
<th>Effect(s) on watersystem</th>
<th>Source / contacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydropower (licensing)</td>
<td>Incorporation of conditions covering construction activities on</td>
<td>to minimise or prevent pollution of watercourses during construction</td>
<td>varied conditions are applied to licences granting the construction, operation and decommissioning of impoundment structures</td>
<td>Hydropower impoundments throughout Norway</td>
<td>assumed to be very effective as such conditions are routinely applied to planning applications</td>
<td>reduces pollution of watercourse downstream of construction</td>
<td>Anne Kronen Helgestad, Senior Advisor, NVE</td>
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<td></td>
<td>Incorporation of conditions requiring the construction of weirs</td>
<td>to concentrate reduced flows in watercourses to improve the aquatic environment</td>
<td>varied conditions are applied to licences granting the construction, operation and decommissioning of impoundment structures</td>
<td>Hydropower impoundments throughout Norway</td>
<td>assumed to be very effective as such conditions are routinely applied to planning applications</td>
<td>increased depth of flow in sections of watercourse downstream enhancing water quality and habitats of aquatic species including fish</td>
<td>Knut Gakkestad, Senior Advisor, NVE</td>
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<tr>
<td></td>
<td>Incorporation of conditions requiring the construction of weirs with adequate provision for the passage of native fish stocks</td>
<td>to permit the migration of native fish for feeding purposes.</td>
<td>varied conditions are applied to licences granting the construction, operation and decommissioning of impoundment structures</td>
<td>Hydropower impoundments throughout Norway</td>
<td>assumed to be very effective as such conditions are routinely applied to planning applications</td>
<td>the incorporation of fish passes and fish ladders enables fish to migrate upstream past weirs which would otherwise be impassable</td>
<td>Anne Kronen Helgestad, Senior Advisor, NVE</td>
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<td></td>
<td>Provision of Compensation Flows to be released from the impoundment structure at all times.</td>
<td>to ensure an adequate and minimal flow downstream of the impoundment at all times to ensure species dependant on the watercourse are not impacted upon</td>
<td>conditions specifying minimum flows to be reduced which can be subject to stated seasonal variation and are specific for each impoundment structure</td>
<td>Hydropower impoundments throughout Norway</td>
<td>assumed to be very effective as such conditions are routinely applied to planning applications</td>
<td>ensures that there is always a baseline flow in the watercourse which is sufficient to support aquatic life, although this is dependant on an adequate supply of water</td>
<td>Knut Gakkestad, Senior Advisor, NVE</td>
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<tr>
<td></td>
<td>Provision of Compensation Flows to be released from the impoundment structure at all times.</td>
<td>to ensure an adequate and minimal flow downstream of the impoundment at all times to prevent pollution as a result of a loss of adequate dilution</td>
<td>varied conditions are applied to licences granting the construction, operation and decommissioning of impoundment structures</td>
<td>Hydropower impoundments throughout Norway</td>
<td>assumed to be very effective as such conditions are routinely applied to planning applications</td>
<td>ensures that there is always sufficient flow to dilute existing and potentially future discharges to the watercourse thereby reducing pollution of the water and the potential impact on aquatic life dependant on good water quality</td>
<td>Knut Gakkestad, Senior Advisor, NVE</td>
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<td></td>
<td>Substrate improvement</td>
<td>to improve the stability of the river bed</td>
<td>varied conditions are applied to licences granting the construction, operation and decommissioning of impoundment structures</td>
<td>Hydropower impoundments throughout Norway</td>
<td>assumed to be very effective as such conditions are routinely applied to planning applications</td>
<td>increased stability of the bed of the watercourse provides a more consistent habitat for aquatic species and reducing waterbed and bankside erosion</td>
<td>Anne Kronen Helgestad, Senior Advisor, NVE</td>
</tr>
<tr>
<td></td>
<td>Substrate improvement</td>
<td>to improve the variability in the substrate, depth and flow in the watercourse</td>
<td>varied conditions are applied to licences granting the construction, operation and decommissioning of impoundment structures</td>
<td>Hydropower impoundments throughout Norway</td>
<td>assumed to be very effective as such conditions are routinely applied to planning applications</td>
<td>increased variability in depth, flow rates and substrate increased the biodiversity of the watercourse</td>
<td>Anne Kronen Helgestad, Senior Advisor, NVE</td>
</tr>
<tr>
<td></td>
<td>River Restoration</td>
<td>to restore improve the ecological and physiological condition of watercourses</td>
<td>varied conditions are applied to licences granting the construction, operation and decommissioning of impoundment structures</td>
<td>Hydropower impoundments throughout Norway</td>
<td>assumed to be very effective as such conditions are routinely applied to planning applications</td>
<td>improved and varied habitats results in an increased biodiversity of areas of the watercourse</td>
<td>Anne Kronen Helgestad, Senior Advisor, NVE</td>
</tr>
<tr>
<td>Hydropower (operation)</td>
<td>Erosion Matts and fertilisation</td>
<td>to reduce the wash out of finegrained particles from the shoreline of the reservoir</td>
<td>erosion mats were laid along the shore line of the reservoir and the vegetation was fertilised with lime enriched peat</td>
<td>Millioning Reservoir, Nord Trongdelag, Norway</td>
<td>The erosion mats were loosened by wave action and not seen as being terribly effective. The fertilisation did help vegetation growth, but would need to be kept at low levels to avoid unwanted competition. While the increase in vegetation worked for some time, it only delayed and did not prevent washout.</td>
<td>Over fertilisation can impact upon water quality and can result in an increase in the growth of some unwanted species of terrestrial vegetation at the expense of desirable vegetation</td>
<td>Biotope Adjustment Measures in Norwegian Watercourses, NVE</td>
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<tr>
<td></td>
<td>Retaining Dams within reservoirs</td>
<td>to improve conditions for birds and fish</td>
<td>a weir dam was constructed to isolate a 0.4km² area of a 6.5 km² reservoir to ensure that water levels in that section did not fall</td>
<td>Innerdal Reservoir, Innerdal</td>
<td>very effective with increased growth in fish due to increased food supply in weir dam, and increased numbers of water and shore birds in the initial stages but became less effective in future years.</td>
<td>Biotope Adjustment Measures in Norwegian Watercourses, NVE</td>
<td></td>
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<td></td>
<td>Creation of Spawning habitats in inlet streams</td>
<td>to increase the spawning areas and habitats for Brown Trout by determining recruitment potential</td>
<td>deep pools and other hiding places were created in an inlet stream. A culvert was installed, rocks were placed in the burn for cover for young fish and boulders were placed on the bank to provide shade</td>
<td>Tisvåg Reservoir, Oppland, Norway</td>
<td>considered to be very effective.</td>
<td>increase variety of substrate leading to increased biodiversity and increased fish in the inlet watercourses</td>
<td>Biotope Adjustment Measures in Norwegian Watercourses, NVE</td>
</tr>
<tr>
<td></td>
<td>Installation of both surface water and deepwater release facilities</td>
<td>to ensure that egg incubation and the start of initial feeding of salmon downstream of the impoundment were not affected.</td>
<td>two off lakes, one from the surface and one from depth enabling the mixing of waters to control the temperature downstream of the impoundment</td>
<td>Alta Tarn, Northern Norway</td>
<td>studies five years after installation indicate that the impact on the breeding pattern of Atlantic salmon is minimal. peak hatching is four weeks earlier, whereas the duration of the hatching period has been extended. However, time of emergence from the bottom gravels and initial feeding has not changed significantly compared to the situation prior to regulation.</td>
<td>Brittain, J and Henning L'Abbe-Lund, J. 1995.</td>
<td></td>
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<tr>
<td>Sector</td>
<td>Strategy</td>
<td>Objective</td>
<td>Description</td>
<td>Where applied</td>
<td>Effectiveness</td>
<td>Effect(s) on watersystem</td>
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<tr>
<td>General</td>
<td>Control of point source pollution inputs</td>
<td>to improve water quality in the reservoir</td>
<td>regulation of the farming industry, industries and sewage treatment works upstream</td>
<td></td>
<td>improves water quality and reduces problems in the reservoir. Additional drinking water supply and recreation.</td>
<td></td>
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<tr>
<td></td>
<td>Control of diffuse pollution inputs</td>
<td>to improve water quality in the reservoir</td>
<td>regulation of the farming industry, industries and sewage treatment works upstream</td>
<td></td>
<td>improves water quality and reduces problems in the reservoir. Additional drinking water supply and recreation.</td>
<td></td>
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<tr>
<td></td>
<td>Mix the water at the bottom of the lake</td>
<td>to improve the oxygen concentrations</td>
<td>Lake Aydat, River Veyre</td>
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<td></td>
<td>Clearing and disposal of sediments from upstream of the impoundment</td>
<td>to transfer the oxygen concentrations</td>
<td>Clearing of the sediments from upstream and disposal at an appropriate point downstream of the impoundment</td>
<td>Potes-Monistrol sur l'Allier (an impoundment on a torrential river)</td>
<td>Expensive and not very effective</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Installation and management of Sluices to flush sediments downstream</td>
<td>to transfer sediments downstream and hence reduce scour</td>
<td>As water levels rise, an additional 5 m^3^/s is released from the dam through the sluice. This reduces the storage of solid material upstream and provides continued transportation downstream.</td>
<td>Potes-Monistrol sur l'Allier (an impoundment on a torrential river)</td>
<td>Relatively effective. However, this method is difficult to implement on a water course equipped with a succession of dams, especially if the dams are managed by different owners (such as on the Dordogne).</td>
<td>The method maintains the natural geomorphological processes of the river, particularly effective on torrential mountainous areas. Operations such as on the Drac resulted in 10 deaths in 1999.</td>
<td></td>
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<tr>
<td></td>
<td>Fish pass, fish lift and baffled pass</td>
<td>to allow the passage of migratory fish species</td>
<td>Bacterial water quality monitoring of bathing water, where the impoundment reservoir is used for recreational water</td>
<td></td>
<td>effective</td>
<td>ensures minimum level in the river, prevents water being discharged when at low level, with potential impact on fisheries.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Compensation for fishery managers</td>
<td>to compensate for the change in fish species</td>
<td>Start-up of the dam transforms the hydrology of the water course from fast flowing to slow flowing. There is therefore an increase in cyprinid species within waters that previously supported salmonid species.</td>
<td></td>
<td>No mitigation benefit to the ecosystem</td>
<td></td>
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<td></td>
<td>Low Water Flow Requirements</td>
<td>to maintain flows downstream</td>
<td>Old impoundments are required to provide 1/40th of the total annual flow. Whilst new impoundments are required to provide 1/10th of the total annual flow or the minimum biological flow if the latter requirement is greater.</td>
<td></td>
<td>effective</td>
<td>Maintains the hydrology at an acceptable depth downstream.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Locate the impoundment offline</td>
<td>to minimise adverse impacts on the hydrology of the watercourse</td>
<td>Low water flows are difficult to apply during the filling up of the impoundment. Therefore, it is better to construct the impoundment alongside the water course and to fill it by diverting water during high flows.</td>
<td></td>
<td>effective</td>
<td>Monitors water level variations and prevents water being discharged at low level</td>
<td></td>
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<tr>
<td></td>
<td>Bacteriological water quality sampling</td>
<td>to minimise the risk of harmful levels of bacteria in recreational waters</td>
<td>Bacterial water quality monitoring of bathing water, where the impoundment reservoir is used for recreational water</td>
<td></td>
<td>effective</td>
<td></td>
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<tr>
<td></td>
<td>Use of water level gauges on impoundments</td>
<td>to maintain the impoundment reservoir at an acceptable depth for tourism and recreation</td>
<td>Level gauges are installed on turbines to ensure the water level variation is minimised</td>
<td></td>
<td>effective</td>
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<td></td>
<td>Canoe passage or artificial river</td>
<td>to allow navigation past the impoundment</td>
<td>Construction of a canoe passage or artificial river suitable for navigation.</td>
<td></td>
<td>effective</td>
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<td></td>
<td>Public warning notices and restrictions on access</td>
<td>to minimise loss of life resulting from sudden increases in river flow</td>
<td>Sluicing for hydropower management results in a sharp increase in river flow downstream, with potential risks to safety. Public warning signs and restrictions on access are therefore used</td>
<td>River Allier downstream of the dam at Naussac</td>
<td>(eg. The Drac resulted in 10 deaths in 1999)</td>
<td>Fish counts downstream have derived benefit of the fresher flows during the summer.</td>
<td></td>
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<tr>
<td>Hydropower</td>
<td>Compensation flows</td>
<td>to provide fresh and oxygenated water downstream, particularly</td>
<td>Hydropower dams result in an artificial supply of water to the downstream system throughout the year.</td>
<td></td>
<td>effective</td>
<td></td>
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<tr>
<td>Sector</td>
<td>Strategy</td>
<td>Objective</td>
<td>Description</td>
<td>Where applied</td>
<td>Effectiveness</td>
<td>Effect(s) on watersystem</td>
<td>Source / contacts</td>
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<tr>
<td>Hydropower (design)</td>
<td>building turbine into existing</td>
<td>reduce impact on river ecosystem</td>
<td>Herrenhausen hydroelectric station, Hannover</td>
<td>deemed to be fairly effective</td>
<td>reduced impact on flow regime, sediment transport</td>
<td>(<a href="http://www.energie-cites.org/BD/PDF/han-mhp-en.pdf">www.energie-cites.org/BD/PDF/han-mhp-en.pdf</a>)</td>
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<td></td>
<td>diversion/dam</td>
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<tr>
<td></td>
<td>building turbine into existing</td>
<td>minimise impact</td>
<td>Cottbus (Spree River Hydroelectric Power Plant)</td>
<td>not installed yet, expected to be fairly effective</td>
<td>limited additional impact on flow regime, sediment transport</td>
<td><a href="http://www.energie-cites.org">www.energie-cites.org</a></td>
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<td></td>
<td>diversion/dam</td>
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<td></td>
<td>install secondary independent</td>
<td>Prevent hydropower by-products</td>
<td>Cottbus (Spree River Hydroelectric Power Plant)</td>
<td>not installed yet, expected to be fairly effective</td>
<td>reduced chance of pollution downstream</td>
<td><a href="http://www.energie-cites.org">www.energie-cites.org</a></td>
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<td></td>
<td>circuit</td>
<td>from entering the watercourse.</td>
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<td></td>
<td>fish ladder</td>
<td>fish passage (upstream or</td>
<td>Herrenhausen hydroelectric station, Hannover; Leibis-Lichte Dam</td>
<td>deemed to be fairly effective</td>
<td>increased chance fish spawning upstream</td>
<td><a href="http://www.energie-cites.org/BD/PDF/han-mhp-en.pdf">www.energie-cites.org/BD/PDF/han-mhp-en.pdf</a>; <a href="http://www.talsperrenkomitee.de/german_research/index.cgi/page/article/article_id/16">www.talsperrenkomitee.de/german_research/index.cgi/page/article/article_id/16</a></td>
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<td></td>
<td></td>
<td>downstream)</td>
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<tr>
<td>General dam</td>
<td>flow regulation</td>
<td>flow levels / regime downstream:</td>
<td>stipulate base flow and seasonal peak flow</td>
<td>Leibis-Lichte Dam</td>
<td>improved habitat downstream</td>
<td><a href="http://www.talsperrenkomitee.de/german_research/index.cgi/page/article/article_id/16">www.talsperrenkomitee.de/german_research/index.cgi/page/article/article_id/16</a></td>
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<td></td>
<td></td>
<td>maintain sufficient water levels</td>
<td>periods in license/management plan</td>
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<td>in downstream channel for riparian vegetation, fish etc.</td>
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<td></td>
<td>sediment deposition downstream</td>
<td>reduce effects of sediment</td>
<td>artificially place material downstream of the</td>
<td>Leibis-Lichte Dam</td>
<td>improved habitat downstream</td>
<td><a href="http://www.talsperrenkomitee.de/german_research/index.cgi/page/article/article_id/16">www.talsperrenkomitee.de/german_research/index.cgi/page/article/article_id/16</a></td>
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<td></td>
<td>trapping in reservoir</td>
<td>reservoirs</td>
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<td></td>
<td>aerators</td>
<td>prevent low dissolved oxygen</td>
<td>keep stored water circulating and to reduce</td>
<td>Leibis-Lichte Dam</td>
<td>improved water quality in impoundment and</td>
<td>(<a href="http://www.talsperrenkomitee.de/german_research/index.cgi/page/article/article_id/16">www.talsperrenkomitee.de/german_research/index.cgi/page/article/article_id/16</a>)</td>
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<td></td>
<td></td>
<td>levels in impoundment and</td>
<td>the chance of low oxygen levels in water in the bottom layers</td>
<td></td>
<td>downstream</td>
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<td>prevent metals from becoming</td>
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<td>soluble.</td>
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</table>
Table 5: Australia: Mitigation Measures and Management Strategies

<table>
<thead>
<tr>
<th>Sector</th>
<th>Strategy</th>
<th>Objective</th>
<th>Description</th>
<th>Where applied</th>
<th>Effectiveness</th>
<th>Effect(s) on watersystem</th>
<th>Source / contacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydropower operation</td>
<td>Release of water from dam</td>
<td>mitigate against blue green algal blooms</td>
<td>the release of additional water from the dam to dilute algal blooms in the watercourse downstream</td>
<td>Snowy Hydro Dams, New South Wales</td>
<td>deemed to be very effective</td>
<td>reduced period of bloom</td>
<td>Barry Dun, Snowy Hydro Ltd</td>
</tr>
<tr>
<td></td>
<td>release of water from dam and</td>
<td>mitigate against blue green algal blooms</td>
<td>the release of additional water from the dam and the concurrent increase in the volumes of water taken into the dam to increase circulation within dam</td>
<td>Snowy Hydro Dams, New South Wales</td>
<td>deemed to be very effective</td>
<td>reduced period of bloom</td>
<td>Barry Dun, Snowy Hydro Ltd</td>
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<tr>
<td></td>
<td>increase in intake to dam</td>
<td></td>
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<td></td>
<td>limit depth of water in reservoir</td>
<td>to limit the amount of water below the thermocline and reduce the</td>
<td>the levels in the dam are maintained at as low a level as possible to ensure that the thermocline is close to the bottom of the dam as possible.</td>
<td>Snowy Hydro Dams, New South Wales</td>
<td>deemed to be fairly effective</td>
<td>reduce the reduction in water quality both in the dam and downstream of the impoundment structure</td>
<td>Barry Dun, Snowy Hydro Ltd</td>
</tr>
<tr>
<td></td>
<td>selective withdrawal of water</td>
<td>to enable mixing of waters of different temperatures to ensure that cold</td>
<td>New outlet structures will be designed which will enable water from varying depths to be abstracted and mixed to control the temperature of discharges from the dam.</td>
<td>throughout Australia</td>
<td>not yet implemented</td>
<td>should ensure that the temperature of the watercourse downstream of the structure does not fall such that native species breeding cycles are interrupted.</td>
<td>Barry Dun, Snowy Hydro Ltd</td>
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<td></td>
<td>from varying depths within the</td>
<td>does not get discharged into watercourses and disrupt the breeding cycle</td>
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<td></td>
<td>dam</td>
<td>of native fish species</td>
<td></td>
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<tr>
<td>General dam operation</td>
<td>installation of salt interception</td>
<td>to trap salt in the soil and ground water and prevent it from entering</td>
<td>New south Wales - Murray River Catchment</td>
<td>Darren Barma, DIPNR, NSW</td>
<td>too soon to tell</td>
<td>reduce salt loading to river, improve water quality and prevent imbalance in ecosystem</td>
<td></td>
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<td></td>
<td>systems</td>
<td>the watercourse</td>
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<tr>
<td></td>
<td>removal of weirs</td>
<td>to allow the migration of native fish upstream for breeding purposes</td>
<td>active removal of obstructions</td>
<td>Darren Barma, DIPNR, NSW</td>
<td>too soon to tell</td>
<td></td>
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<tr>
<td></td>
<td>augmentation of weirs with ladders</td>
<td>to allow the migration of native fish upstream for breeding purposes</td>
<td>New South Wales</td>
<td>Darren Barma, DIPNR, NSW</td>
<td>too soon to tell</td>
<td></td>
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<tr>
<td></td>
<td>Production of Water Sharing plans</td>
<td>to ensure that there is sufficient baseline flows in all watercourses and</td>
<td>see Annex B for details</td>
<td>Darren Barma, DIPNR, NSW</td>
<td>too soon to tell</td>
<td>water chemistry and the ecology of the watercourse will be balanced.</td>
<td></td>
</tr>
<tr>
<td>Sector</td>
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<tr>
<td>General</td>
<td>Hypolimnetic aeration</td>
<td>prevent low dissolved oxygen levels in impoundment</td>
<td>release of oxygen from reservoir bottom</td>
<td>numerous impoundments</td>
<td>not investigated yet, effectiveness expected to vary</td>
<td>improved water quality in impoundment</td>
<td>Posford Haskoning</td>
</tr>
<tr>
<td></td>
<td>Artificial destratifiers (aerators)</td>
<td>prevent low dissolved oxygen levels in impoundment and prevent metals from becoming soluble</td>
<td>keep stored water circulating and to reduce the chance of low oxygen levels in water in the bottom layers</td>
<td>numerous impoundments</td>
<td>not investigated yet, effectiveness expected to vary</td>
<td>improved water quality in impoundment</td>
<td>Posford Haskoning</td>
</tr>
<tr>
<td></td>
<td>Fish ladder, lift, lock systems, trap and truck, by-pass to allow fish migration</td>
<td>fish passage (upstream or downstream)</td>
<td>various</td>
<td>Chippewa Falls, Minnesota; Beaver River, NY</td>
<td>not investigated yet, effectiveness expected to vary</td>
<td>increased chance fish spawning upstream</td>
<td>American Rivers</td>
</tr>
<tr>
<td></td>
<td>In-river diversion structures (spillways, drop-structures)</td>
<td>fish passage: safe downstream passage for young fish to reduce injury and mortality</td>
<td>various</td>
<td>numerous impoundments</td>
<td>not investigated yet, effectiveness expected to vary</td>
<td>increased fish populations</td>
<td>Alex Hoar, US Fish and Wildlife Service</td>
</tr>
<tr>
<td></td>
<td>Impoundment water-level regulation (max flux)</td>
<td>water level regulation in impoundment</td>
<td>Beaver River settlement, NY; Montraul River</td>
<td>no data available</td>
<td>improved bank vegetation development</td>
<td>American Rivers (<a href="http://www.amrivers.org">www.amrivers.org</a>)</td>
<td></td>
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<td></td>
<td>Min-max flow release</td>
<td>flow levels / regime downstream: maintain sufficient water levels in downstream channel for riparian vegetation, fish etc.</td>
<td>Deerfield River Settlement (Massachusetts, Vermont); Salmon River Settlement, NY; Pamigewasset River, New Hampshire</td>
<td>not investigated yet, effectiveness expected to be moderate to high</td>
<td>improved habitat downstream</td>
<td><a href="mailto:mktansky@mp.usbr.gov">mktansky@mp.usbr.gov</a>, <a href="http://www.usbr.gov/research/activity/current/03-04sum.htm#WD1">http://www.usbr.gov/research/activity/current/03-04sum.htm#WD1</a>; American Rivers; American Rivers Organization (<a href="http://www.amrivers.org">www.amrivers.org</a>)</td>
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<tr>
<td></td>
<td>Controlled spill /in-season management</td>
<td>flow levels / regime downstream: maintain sufficient water levels in downstream channel for riparian vegetation, fish etc.</td>
<td>Deerfield River Settlement (Massachusetts, Vermont); Columbia River System</td>
<td>not investigated yet, effectiveness expected to be moderate to high</td>
<td>improved habitat downstream</td>
<td><a href="mailto:mktansky@mp.usbr.gov">mktansky@mp.usbr.gov</a>, <a href="http://www.usbr.gov/research/activity/current/03-04sum.htm#WD1">http://www.usbr.gov/research/activity/current/03-04sum.htm#WD1</a>; American Rivers; US Bureau of Reclamation (2001)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Natural flow regime</td>
<td>flow levels / regime downstream: re-establish natural flow (prior to dam)</td>
<td>Quinnabaug River Project, Great Lakes Restoration Project</td>
<td>not investigated yet, effectiveness expected to be vary</td>
<td>improved habitat downstream</td>
<td>Massachusetts Department of Environmental Protection, US Bureau of Reclamation, State University of NY publications</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Real time operation</td>
<td>flow levels / regime downstream: water level regulation to best meet all demands including fish and wildlife, irrigation, power, recreation</td>
<td>Columbia River System</td>
<td>not investigated yet, effectiveness expected to be vary</td>
<td>improved habitat downstream</td>
<td>US Bureau of Reclamation (2001)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dam removal</td>
<td>remove barrier</td>
<td>dam removal</td>
<td>numerous locations</td>
<td>not investigated yet, effectiveness expected to be moderate to high</td>
<td>chance to restore to pre-dam state, potential negative effects on habitat created by dam installation</td>
<td>World Commission on Damms</td>
</tr>
<tr>
<td></td>
<td>Water quality monitoring with reinimand</td>
<td>Regulation</td>
<td>the if temp/DO concentrations don’t meet standards</td>
<td>Manistee, Au Sable River Settlement, Michigan</td>
<td>not investigated yet, effectiveness expected to be moderate to high</td>
<td></td>
<td>American Rivers</td>
</tr>
<tr>
<td></td>
<td>Multilevel intake structure</td>
<td>temperature downstream</td>
<td>Use toplayer water in spring, conserve (cooler) deep water for summer/fall release</td>
<td>Shasta Dam</td>
<td>not investigated yet, effectiveness expected to be moderate to high</td>
<td></td>
<td>US Bureau Reclamation (Mr. M. Horn, Mr. C. Holdren); Tennessee Valley Authority; Steve Ashby, Core of Engineers</td>
</tr>
<tr>
<td></td>
<td>Selective withdraw structures</td>
<td>temperature downstream</td>
<td>Glen Canyon and Folsom Dams</td>
<td>not investigated yet, effectiveness expected to be moderate to high</td>
<td></td>
<td></td>
<td>Tracy Vermeyen, US Bureau of Reclamation (USA phone: 303-445-2154)</td>
</tr>
<tr>
<td>Sector</td>
<td>Strategy</td>
<td>Objective</td>
<td>Description</td>
<td>Where applied</td>
<td>Effectiveness</td>
<td>Effect(s) on watersystem</td>
<td>Source / contacts</td>
</tr>
<tr>
<td>--------</td>
<td>----------</td>
<td>-----------</td>
<td>-------------</td>
<td>---------------</td>
<td>---------------</td>
<td>-------------------------</td>
<td>------------------</td>
</tr>
<tr>
<td>Hydropower (operation)</td>
<td>Fish-friendly turbines allow fish migration</td>
<td>fish passage downstream</td>
<td>Turbines conical shape instead of propeller so fish can slide through</td>
<td>Study US Department of Energy</td>
<td>In development</td>
<td></td>
<td>Alex Hoar, US Fish and Wildlife Service</td>
</tr>
<tr>
<td></td>
<td>Screens (horizontal flat-plate Coanda-effect screen)</td>
<td>fish protection and debris-screening</td>
<td>Screen to prevent fish and debris from entering turbines and fish-screening. Relevant in situations where managers are converting to more efficient water delivery methods that require cleaner water, such as sprinkler irrigation.</td>
<td>Chippewa Falls, Beaver River Settlement</td>
<td>Not investigated yet, effectiveness expected to be high</td>
<td></td>
<td>American Rivers (<a href="http://www.amrivers.org">www.amrivers.org</a>)</td>
</tr>
<tr>
<td></td>
<td>Trash Racks</td>
<td>debris-screening and prevent fish damage death in turbines</td>
<td>Racks used to filter trash altered so that width between bars is small enough to prevent fish from getting through</td>
<td>Beaver River Settlement</td>
<td>Not investigated yet, effectiveness expected to be high</td>
<td></td>
<td>Alex Hoar, US Fish and Wildlife Service</td>
</tr>
<tr>
<td></td>
<td>Embedded pipe-screen diversion</td>
<td>fish protection - diversion with minimal (negative) side-effects</td>
<td>Screen to prevent fish from getting into turbines. “Advantages of this diversion concept include efficient water diversion, reduced cleaning maintenance, enhanced debris and fish exclusion, low public visibility, and low capital cost” (USBR).</td>
<td>Successfully demonstrated by the Oregon Dept. of Fish &amp; Wildlife at several small diversions</td>
<td>Not investigated yet, effectiveness expected to be high</td>
<td></td>
<td><a href="mailto:wahlh@do.usbr.gov">wahlh@do.usbr.gov</a>; <a href="http://www.usbr.gov/research/activity/current/03-04sum.htm#WDiv">http://www.usbr.gov/research/activity/current/03-04sum.htm#WDiv</a></td>
</tr>
<tr>
<td></td>
<td>Behavioral barriers (strobes, lights, ...)</td>
<td>Fish entrainment reduction technique</td>
<td>General</td>
<td>Not investigated yet, effectiveness expected to be moderate</td>
<td>Undesirable physiological effects on fish eyes or sensory systems from exposure to high-intensity strobe lights are being researched</td>
<td></td>
<td><a href="mailto:whiabnh@do.usbr.gov">whiabnh@do.usbr.gov</a>; A. Hoar, US Fish and Wildlife Service</td>
</tr>
<tr>
<td></td>
<td>Retrofitting turbines to oxidate outlet water</td>
<td>Prevent low dissolved oxygen levels downstream</td>
<td>Place baffles on turbines, inject either air or pure oxygen</td>
<td>Canyon Ferry, Marine; many additional projects</td>
<td>Good</td>
<td>Maintain oxygen levels in outlet water to reduce negative impacts on downstream system</td>
<td>US Bureau Reclamation (Mr. M. Horn, Mr. C. Holdren); Tennessee Valley Authority; Steve Ashby, Core of Engineers (WES)</td>
</tr>
</tbody>
</table>
APPENDIX 2

WFD29: MANAGEMENT STRATEGIES AND MITIGATION MEASURES REQUIRED TO DELIVER THE WATER FRAMEWORK DIRECTIVE

GUIDANCE ON SETTING ECOLOGICAL TARGETS
APPENDIX 2: SETTING ECOLOGICAL TARGETS

A2.1 Water framework directive targets

Mitigation measures cannot be designed without first identifying the desired target conditions. Therefore, although both the methodology for determining WFD target conditions and what constitutes good ecological status lie outside the scope of this project, the discussion below aims to set these issues in the context of impoundments.

Specific guidance on setting targets and determining good ecological status can be found in several other documents including:

- Rivers, Lochs, Coasts: The Future for Scotland’s Waters (2001);
- Heavily Modified Water Bodies: case studies Dynamics of Water Use in Scotland (ref ENV/7/03/11A);
- WFD18 - Valuing Water Use in Scotland and Northern Ireland for WFD Implementation Purposes; and
- WFD39 - Heavily Modified Water Bodies in Scotland - Identification, Designation and Environmental Objectives.

The first three documents are available at request from SEPA while the last two documents are available on request from SNIFFER. In addition, further information can be obtained from local agency offices (see Volume 2, Appendix 13).

The WFD is explicit in stating that the aim is to achieve ‘Good Ecological Status’ (GES) for natural water bodies, and ‘Good Ecological Potential’ (GEP) for those designated as either Heavily Modified Water Bodies (HMWB) or Artificial Water Bodies (AWB). It is likely that the majority of impoundments will be designated as either heavily modified water bodies or artificial water bodies and that consequently the majority will be required to meet good ecological potential. GEP is defined as a slight change from Maximum Ecological Potential (MEP), which in turn is defined as values of the biological elements that reflect conditions in the closest comparable natural water system, after taking into account the artificial or modified characteristics of the water body. Reference conditions (MEP) will therefore have to be defined for the biological elements and supporting elements of the Directive.

One of the main questions to be answered when setting targets for artificial or heavily modified water bodies is: what type of surface water do we compare them to?

The Directive states that:

*The quality elements applicable to artificial and heavily modified surface water bodies shall be those applicable to whichever of the four natural surface water categories (river, lake, transitional water or coastal) most closely resembles the heavily modified or artificial water system concerned.*

(Annex V, 1.1.5: WFD 2000/60/EC)
Table A2.1 below details recommendations for natural water systems which could be used as comparators for impoundments.

**Table A2.1 Comparators for impoundments**

<table>
<thead>
<tr>
<th>Impoundment</th>
<th>Comparable Natural Water System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reservoir</td>
<td>Lake</td>
</tr>
<tr>
<td>Downstream river</td>
<td>River</td>
</tr>
</tbody>
</table>

The biological elements for rivers and lakes are: phytoplankton; invertebrates; macrophytes; phytobenthos and fish. The hydromorphological elements supporting the biological elements are: hydrological regime and morphological conditions for rivers and lakes, along with river continuity. The chemical and physico-chemical elements supporting the biological elements include: thermal conditions; oxygenation conditions; salinity; acidification status; nutrient conditions; and (for lakes) transparency. Pollution by priority substances and other substances in significant quantities are also specified. (Annex V, 1.1.1 and 1.1.2: WFD 2000/60/EC).

How agencies choose to compare water bodies will determine the ecological targets for an impoundment and, by definition, the types of mitigation measures which are desirable. The WFD allows member states flexibility in carrying out the process within the structured framework. As emphasised above, it is beyond the capacity of this project to define reference conditions in more detail but currently there are a number of programmes of work which already do or could potentially identify reference conditions for HMWB or AWB. Those studies are focused on setting up monitoring programmes for all the biological elements.

**Methods for setting reference conditions**

It is worth considering how reference conditions may be defined as this has implications for how reference conditions are set and for the choice of mitigation measures at a site. For example, if the reference conditions for invertebrates in rivers downstream of hydropower plants in Scotland are invertebrate communities in naturally spatey Scottish rivers, the mitigation requirements are very different from those set for a reference invertebrate community in a lowland Scottish river.

RIVPACS, which is the oldest and most developed reference based system in the UK, provides a useful illustration of how invertebrate populations may function (Wright et al. 1998) and is a model which assesses riverine water quality using benthic invertebrates.

When developing RIVPACS, good quality reference sites were identified and categorised by their invertebrate communities. The membership of a category could be predicted from environmental variables. This allowed the invertebrate assemblage (observed) of an impacted river site to be compared with a predicted fauna based on the category to which it is assigned using environmental variables. The ratio of observed to predicted fauna is a measure of the site’s deviation from reference state.

As models like RIVPACS not only set the reference conditions but allow for impacts to be measured, it is possible for them to be used in the monitoring of the effectiveness of mitigation measures.

The ecological effectiveness of a mitigation measure is a measure of its ability to improve the status of one of the WFD biological elements.
Currently the RIVPACS type approach and others are being developed for all the biological elements across the two types of WFD water system comparable with impounded systems, rivers and lakes. The development projects are at an advanced phase with field data either collected or being collected this summer (2004) for initial model construction. Reservoirs form part of the strategic sampling programme in both Scotland and the Environment Agency regions in England and Wales.

If this approach is taken the reference state for HMWB and AWB will be the community composition of the biological elements in comparable natural systems. This would provide a means of setting targets for mitigation measures and identifying relevant mitigation measures.

Limitation of existing reference approaches
The most serious modifications to impounded systems are physical modifications. Modifications to physical aspects of systems have until recently been of secondary interest to impacts on the chemical quality of water. This is generally recognised and efforts are being made to address this by describing the relationships between the biological elements and physical variables under the development of diagnostic tools for the WFD, i.e. by including LIFE scores (Extence et al., 1999) into RIVPACS. LIFE scores categorise invertebrate communities on their flow regime preferences.

On new schemes the application of the CAMS methodology (Environment Agency, 2002) is advised but it should be augmented by full floral and fauna surveys to provide baseline data on the condition of the system to help identify reference condition for the future.

Simplifying the determination of reference state
It may be possible to examine a limited suite of biological or supporting elements. It is not yet clear if this approach is acceptable to the EU but it has gained favour with biologists from other EU states because of its practicality, (e.g. K. Irvine, R. Johnson pers. comm.). As an example, a recent EU project, Eurolakes, reviewed the suitability of different biological elements and supporting elements for identifying specified pressures on large, deep lakes which could be considered as heavily modified as their water levels were regulated. Specific indicator groups were identified for different pressures. A table developed during this project is reproduced as Table A2.2 overleaf to provide information on the types of information produced. This table details those biological and supporting (hydromorphological and physio-chemical) quality elements considered to be the most suitable for assessing pressures on large deep lakes to determine WFD status. Depending on the type of impoundment being assessed, this table could provide useful information when determining the reference conditions.

To relate the Eurolakes table to our mitigation measures, ‘diffuse and point source (nutrients and deoxygenation) pollution in this table would equate to ‘eutrophication’ in this report, other Annex VIII toxic pollutants would equate to heavy metals, and abstraction would equate to water level. However, this would be limited to the area above the impoundment as the table was constructed with the lakes themselves of interest and it did not address downstream impacts directly.

By targeting the monitoring to the specific circumstances of each impoundment being considered, mitigation measures could be monitored more effectively.
### Table A2.2: Pressures on large deep lakes

<table>
<thead>
<tr>
<th>Type of pressure</th>
<th>Specific pressure</th>
<th>Biological elements</th>
<th>Supporting elements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diffuse and point source pollution</td>
<td>Nutrients</td>
<td>Phytoplankton composition and abundance</td>
<td>Nutrient conditions and transparency</td>
</tr>
<tr>
<td>Deoxygenation</td>
<td>Phytoplankton abundance and profundal benthic invertebrate composition</td>
<td>Oxygen conditions</td>
<td></td>
</tr>
<tr>
<td>Other Annex VIII toxic pollutants</td>
<td>All useful depending on pollutant</td>
<td>Specific pollutants</td>
<td></td>
</tr>
<tr>
<td>Abstraction</td>
<td>Macrophyte and littoral benthic invertebrate composition</td>
<td>Quantity and dynamics of flow, dynamics of flow and water level</td>
<td></td>
</tr>
<tr>
<td>Regulation of flow</td>
<td>Macrophyte and littoral benthic invertebrate composition</td>
<td>Quantity and dynamics of flow and water level</td>
<td></td>
</tr>
<tr>
<td>Morphological alterations</td>
<td>Macrophyte and littoral benthic invertebrate composition</td>
<td>Structure of the lake shore Quality, structure and substrate of the lake bed Water level and lake depth variation</td>
<td></td>
</tr>
</tbody>
</table>

(note: abstraction can also affect river continuity)

### A2.2 Other targets: conservation

Many UK reservoirs are already managed for their conservation interest, e.g. Rutland Water. These sites can have protected status, most usually as nationally important Sites of Special Scientific Interest (SSSI). There are a number of internationally important sites designated as Special Areas of Conservation (SAC) or Special Protection Areas (SPA) (which are designated as Protected Areas under the WFD). Conservation areas are usually designated for a particular interest, either a species or habitat type. A review of designations should be undertaken to ensure that proposed mitigation measures do not risk impacting on the conservation status of the impoundment or related watercourses. For a Special Area of Conservation under the Habitats Directive, an Appropriate Assessment may be required. This is especially important when alterations to water level are being considered as many standing water sites are designated for their macrophyte interest and that group is especially sensitive to water level fluctuations. Any exceptional potential conflict between the WFD requirements and the maintenance of Favourable Condition will require careful assessment in consultation with the competent authority and Statutory Nature Conservation Body.
Occasionally, the construction of impoundments may have created habitat for rare species, e.g. freshwater pearl mussel. Before implementing mitigation measures it is important to ensure that they do not endanger any such protected species (see list below). On the other hand, some protected species may directly benefit from some mitigation measures, e.g. the Atlantic salmon and sea lamprey, where improvements to natural river flows or river continuity (for example) would achieve a more ‘natural’ system overall.

In Scotland the use of reservoirs to provide a sanctuary for endangered fish species has been pioneered and should be supported.

**Which has precedence, WFD or conservation?**

The WFD aims at protecting the natural aquatic habitat as a whole and does not target endangered taxa. Conservation targets are usually set to protect species or habitats that are rare nationally or internationally, although on occasion regional or locally rare or scarce species are considered. It is not currently clear which takes precedence and there is therefore a need for discussions between the relevant organisations to clarify the relationship between the WFD and the conservation status of HMWB and AWB.

### Habitats Directive species

There are a number of freshwater species listed in the Habitats Directive. The list below contains those freshwater species identified by the Joint Nature Conservancy Council as of interest in the UK. Although freshwater eels (*Anguilla anguilla*) are not listed under the Directive, they are thought to be endangered and there is some consideration being given to whether they should be treated as such. This list includes those species which could inhabit the impoundment as well as the upstream and/or downstream sections of the waterbody on which the impoundment is located.

**JNCC list of species of interest in the UK in relation to impoundments**

Freshwater pearl mussel *Margaritifera margaritifera*

White-clawed (or Atlantic stream) crayfish *Austropotamobius pallipes*

Southern damselfly *Coenagrion mercuriale*

Sea lamprey *Petromyzon marinus*

Brook lamprey *Lampetra planeri*

River lamprey *Lampetra fluviatilis*

Allis shad *Alosa alosa*

Twaite shad *Alosa fallax*

Atlantic salmon *Salmo salar*

Spined loach *Cobitis taenia*

Bullhead *Cottus gobio*

Great crested newt *Triturus cristatus*

Green shield-moss *Buxbaumia viridis*

Western rustwort *Marsupella profunda*

Slender green feather-moss *Drepanocladus (Hamatocaulis) vernicosus*

Petalwort *Petalophyllum ralfsii*

Shore dock *Rumex rupestris*

Marsh saxifrage *Saxifraga hirculus*

Creeping marshwort *Apium repens*

Floating water-plantain *Luronium natans*

Slender naiad *Najas flexilis*
WFD29: MANAGEMENT STRATEGIES AND MITIGATION MEASURES REQUIRED TO DELIVER THE WATER FRAMEWORK DIRECTIVE

THE EFFECTS OF IMPACTS AND MITIGATION MEASURES: AN ECOLOGICAL VIEW
APPENDIX 3: THE EFFECTS OF IMPACTS AND MITIGATION MEASURES: AN ECOLOGICAL VIEW

A3.1 Impacts downstream of impoundments

A3.1.1 Physical habitat alterations

Impoundment construction invariably results in serious alterations to the downstream flow regime and wetted area. This causes a loss of habitat which, in turn, will adversely affect the native flora and fauna. Habitat alteration is dealt with in the next section, with the focus of this section being on more direct impacts of changes on the flow regime.

Flow may be affected in four main ways: reduction; seasonal flow constancy; increased flow; and short-term flow fluctuations. Details of particular effects of these flow types are given in Armitage (1984).

Fish
There is much evidence to show that the bottlenecks to recruitment in many non-salmonids fish populations relate principally to spawning success and to the growth and survival rates of newly-hatched larvae (Mills & Mann 1985). Fish utilise a range of substrata, which Balon (1975; 1981) used to classify into a series of reproductive guilds. In general, species spawning on gravel substrata (lithophils) require higher flow velocities than do the phytophils, with phytolithophils occupying an intermediate position (Mann 1996). In addition, some species have specialised spawning requirements, such as the betterling *Rhodeus sericeus*, which lays its eggs in the mantle cavity of freshwater mussels. Based on the understanding that the level of the river will be held more or less constant, it is probable that the spawning habitat for most phytolithophils will increase at the expense of spawning habitat for lithophils. Shallow, fast flowing gravel habitat is needed for dace, chub and barbel spawning and these conditions are enhanced during the natural decrease in discharge following the winter.

Growth and survival of young of the year were shown to increase with impoundment on the Tees (IFE/CEH reports) and it is anticipated that maintaining constant depths and velocities will enhance natural survival. Critical times affecting the survival of fish larvae are when they change food sources. Any large scale releases of water at these times (variable depending on species and environmental conditions) will adversely affect the new food source and will result in increased mortality of fish larvae. It is thus imperative that the management of the water level is frequent enough to ensure that no large scale releases are necessary. After the operations of a reservoir, the overall relative density of fishes (individuals per surface area) of all ages may decrease, with the exception of 0+ fishes (erny et al. 2003). Species number may also increased, although there will probably be a change in the composition of the fish assemblages, with rheophiles generally replaced by limnophiles. The two most important microhabitat variables will be the proportion of macrophytes and gravel.
Invertebrates
Mitigation measures should be designed to fit the particular perturbation where possible. A review of compensation flows with a view to preparing guidelines for resetting reservoir operating policy and compensation releases was undertaken in the UK. Details are presented in Gustard et al. (eds; 1987), and effects on the macro invertebrates of receiving streams are described in Armitage (1987). Mitigation measures should attempt to reduce extremes of change, to preserve or protect habitat from loss or detrimental change and to consider life-history stages when regulating flow.

The suggested measures in the table prepared for the WFD project such as mimicking the natural release pattern as near as possible, reducing any prolonged extremes of low or enhanced flows and optimising any compensation flow regime will help reduce many of the adverse effects of flow change. However long term effects of “clearwater erosion” have not been addressed and it is unlikely that any mitigation procedures will provide a cure-all (over 90% of the sediment load is deposited behind the dam). Channel changes resulting from sediment loss will have far-reaching effects on riparian flora and fauna and on riverside structures such as bridges, culverts and roadside embankments (Petts 1984). Under certain flow conditions (reduction and constancy) sediment input from tributaries, eroding banks etc may accumulate because of the lack of extreme peak flows. In such cases “flushing flows” have been used to ‘clean’ the gravels (Reiser et al. 1985).

Vegetation
Variability in water flow is dependent on the degree, frequency and timing of modification to flow, i.e. whether short term i.e. daily, medium-term i.e. daily to weekly and or longer-term i.e. seasonal. More detail of typical types of management are required before the effects can be given in more detail and a clearer idea of the both established communities and habitat targets. However, stress from high flows on macrophytes is defined by the degree of change which will range from direct loss of some of the plant parts and a lowering of biomass, to total loss of plants which relates to the bed stability and the plants rooting system. Most typically an intermediate change occurs directly downstream of the discharge point with the loss of seasonal plant growth patterns leading to decreased abundance of submerged plants together with other species changes, e.g. moss growth on any stable surfaces and increased marginal reed-like plant species along the banks.

Habitat changes may be significant as water flow may often be demand-lead and not release lead, creating much larger than normal short-term change in which both plant and the preferred or former substrate are moved, modified or pass downstream. However finer sediments may ephemerally accumulate locally, creating more extreme adverse conditions for the previously resident species to either establish and to grow.

Geo-morphological changes are well documented and dealt with elsewhere but the establishment of site specific reference conditions may be derived from such national surveys as the River Habitat Survey (Raven et al 1999).
Potential mitigation measures should in general allow less rapid changes in short-term discharge, avoid downstream demand-driven water releases by fine-tuning control systems with add/increase predictive elements, allow periodic freshet/releases of water and allow increases seasonally to control species balances towards target flora:

   a. release in autumn to reset submerged plant community;
   b. modification of general seasonal release regimes towards that typical of each season for the newly accepted morphology of the discharge river;
   c. establishment of multi-stage channels, i.e. in cross-section to accommodate the different release levels and maintain acceptable condition for the growth of some typical plant species;
   d. establishment of channels with both plan-form and bed-form variation, e.g. sinuosity again to accommodate the different release levels and maintain acceptable condition for the growth of some typical plant species; and
   e. the replanting of plant species from closely adjacent un-affected section of the river system.

A3.1.2 Sediment release

One limitation on the life of a reservoir is the build of sediment. The release of sediment to alleviate this problem can cause difficulties for the biota downstream. Sediment is usually fine and can infill gravels. Fish are especially susceptible to this type of problem.

Fish
Increase of sediment loads during the spawning season would greatly impact on eggs and larvae survival due to a reduction of oxygen. More than 90% of the eggs could die as a result of high sediment loads during the embryonic period (Meyer 2003).

Invertebrates
Impoundments may generate suspended sediments during construction but as mentioned above eventually reduce sediment loads downstream below the dam. The reservoir may also generate a nutrient source in the form of plankton which will radically alter the composition of the macroinvertebrate fauna below the dam. Those species capable of trapping and consuming this food supply will prosper at the expense of other members of the faunal community. Examples of change in response to particulate output from the reservoir are given in Armitage (1984).

Vegetation
Suspended sediments may directly inhibit the growth of submerged water plants by limiting the light penetration of water. Indirect effects include the settlement of sediment on the leaves of submerged species, smothering of rooting systems or by the unstable nature of fine sediment allowing easy washout following increases in discharge. Conversely the ad- and ab-sorption by sediments may reduce the biomass of submerged plants but accumulations around the roots of marginal and emergent reed-like plants.

Potential mitigation measures include the introduction of sediment traps with regular maintenance to maintain their efficiency or some channel dredging. Inputs to the impoundment of fine materials should be minimised (see elsewhere).
A3.1.3 Water chemistry

When water becomes deoxygenated below the thermocline in a standing water body, conditions exist for the release of heavy metals from sediment. If water is then released from below the thermocline the river downstream can be exposed to toxic levels of heavy metals. The area affected is controlled by the speed with which the water is re-oxygenated. In a natural river channel with turbulent, unsteady flow this process should be rapid. Upon re-oxygenation the metals oxidise and are no longer easily bio-available.

Equally reservoirs can alter the levels of nutrients downstream of the reservoir. Under similar conditions to those where metals are released from sediment, phosphate can be released too. As a major nutrient, phosphate can significantly increase primary production downstream of a reservoir. The presence of phosphate in water coming from an impoundment as Fine Particulate Organic Matter can alter the invertebrate community.

Invertebrates

Water quality will mainly be a function of reservoir basin geomorphology/topography, climate, land use in the catchment area, position of the reservoir along the river system, release point levels and operation of the dam. Likely effects will centre on the oxygen regime (see later section) however additional changes will result from nutrient dynamics in the reservoir. Epilimnial water will in general be poor in nutrients whereas hypolimnial water is nutrient rich. Thus the nutrient budget of the receiving stream will be altered by flow regulation with varying consequences for the stream biota. In the Ruhr Valley, rising phosphate concentrations (from domestic and industrial sources) have increased eutrophication problems in impounded rivers (Albrecht 1981) resulting in algal blooms. When these die, the increased organic loading results in deoxygenation under low flow conditions. In the case of river water transfers, the water quality will depend largely on the characteristics of the donor river and the interaction of donor and recipient. Observed effects range from the introduction of unwanted species to the transference of xenobiotics. For specific examples of water quality effects in the UK and elsewhere see Armitage (1980; 1984).

The mitigation measures suggested such as the avoidance of hypolimnial releases, and re-oxygenation of water in stratified reservoirs will address many of the issues raised. It should be noted that releases may also improve water quality downstream.

Vegetation

Water chemistry controls the species and growth of a natural plant community. Basic requirements for aquatic plant growth of any plant type, large or small, are: light; a source of inorganic carbon for photosynthesis to build themselves; nutrients to assist this and other life processes; a suitable environment in which to grow and also the absence of toxic compounds. Nutrients modify the rate of plant growth just as light reduction inhibits this development thus, for example, phosphates which have been mobilised into system will enhance plant growth but if excess may inhibit the growth of larger macrophytes and favour a change firstly to epiphytic algae and perhaps subsequently to larger filamentous algae out-competing the more natural community.
Conversely toxic ‘heavy’ metals released from sediments in the lower anaerobic waters of the impoundment will be taken up and are likely to kill macrophytes and to encourage microorganisms until dispersed, adsorbed onto or absorbed by or taken up for slower recycling in the biotic community during downstream passage of the release water. Potential mitigation measures include the monitoring and mixing of release waters to reduce the inclusion of anaerobic metal-laden waters.

A3.1.4 Water temperature

The main impact is usually a reduction of water temperature downstream of impoundments. Cold water is released from the impoundment and can potentially have a significant impact on all biota present. Standing waters can thermally stratify during the summer in the UK, with a warm layer near the surface and a deep cold layer below. Because the layers do not mix the deep water remains cold. Releases of this deep water are the main source of downstream changes in temperature. However, water bodies that do not stratify can still be relatively colder than ambient river temperatures, simply because they heat up slowly.

The severity of the impact depends on the difference between normal ambient temperatures in the river and the water released from the impoundment.

Mitigation measures all require the water temperature to be raised. Mixing water at the point of release from the warm and cold layers of the reservoir has the greatest potential to allow water temperature to be matched to ambient river water temperatures. Alternatively it may be possible to mix the water in the reservoir to prevent stratification. However if a system is deep enough to stratify the water temperature may remain cold.

Fish
Survival and year class strength depends on many factors, the most important being temperature, flow (or discharge), food availability and density dependent mortality. If temperatures experienced by the population of fish downstream the impoundment were much lower than expected (5-10°C) as a result of water released from the lower part of the reservoir, then you would expect an overall delay in fish spawning with a knock-on effect on the recruitment process with lower juvenile fish sizes at the beginning of the winter responsible for a poor winter survival.

Invertebrates
Water temperature influences the distribution, growth and development of stream invertebrates. In regulated streams the temperature may be altered in six main ways: increase diel constancy; increased seasonal constancy; summer depression; summer elevation; winter elevation; and thermal pattern changes. The degree of modification in thermal regime will depend on the level of the reservoir from which the water is drawn, the thermal stratification pattern, the retention time and the operation of the dam. Changes to faunal communities will arise through affects on the life-cycles of individual species. Additional indirect effects of temperature changes following impoundment in relation to ice-break up etc are presented in Armitage (1984). The mitigation measures outlined in this project should address the issues raised.
Vegetation
Temperature effects, in simple terms, may produce changes in submerged plant growth depending upon whether the temperature is decreased, typically by water large deep impoundments which release cooler water for most of year and thus increase plant growth and thus production and accumulated biomass through decreased respiration and thus increase the metabolic efficiency of the plant. Elevated temperatures, typically from large shallow impoundments with elevated summer temperatures, decrease plant growth. Population changes may occur in favour of more marginal/emergent plants. Potential mitigation measures should consider the mixing of upper and lower levels of impounded waters towards typical un-impounded annual temperature cycle.

A3.1.5 Influence on dissolved oxygen

Oxygen is essential for almost all life but, in excess, it can be toxic. Immediately downstream of hydropower dams fish have been observed suffering from ‘Gas Bubble Disease’. The water is super-saturated with very high levels of air when released from the turbines. The air comes out of solution in the fish’s blood stream. Another possibility is very low levels of oxygen in the water immediately downstream of dams. This is caused by releasing water from below the thermocline in systems where the hypolimnion becomes anoxic. The impact will affect all groups.

Fish
Dissolved oxygen is an important factor for egg survival, particularly in the late stages of embryonic incubation. This is even more relevant for limnophil species which spawn already in poorly oxygenated waters or for phytophils spawners, which are confronted to higher diurnal changes of dissolved oxygen. Although Williams et al. (2000) showed that spatial variation of dissolved oxygen concentrations are found to be small (±10%) compare to diurnal changes (±60%), it shouldn’t be considered biologically insignificant as under conditions of high productivity, the level of dissolved oxygen could reach 50% and less in some places. As far as larvae and juveniles are concerned the level of dissolved oxygen under natural condition, a part from accidental pollution, is never an issue. Although, rapid growth is of paramount importance for young fish larvae, as mortality due to predation declines rapidly with increasing size of the larvae, the intensity of routine oxygen consumption is mass-independent in the smallest larvae and therefore do not influence larval growth rate.

Invertebrates
Deoxygenation is to be expected where deep hypolimnnial water is released into a stream during thermal stratification but the level of oxygen is rapidly restored if turbulent flow conditions prevail downstream. The situation is more serious where organic pollution occurs. Reduced flows due to hydroelectric developments on the main stem of the Saint John River lowered the capacity of the stream to assimilate organic wastes with a resultant reduction in oxygen.

Little is known of the specific effects of low oxygen concentrations on regulated stream benthos but laboratory experiments have indicated that components of the benthos will move to locations where oxygen levels are optimum for growth and development. Thus, low oxygen conditions may directly by affecting zoobenthos distribution. Alternatively low oxygen may act indirectly as a result of changes in oxidation-reduction activities in the reservoir. In
reservoirs in the Elan Valley, Wales, a black friable deposit was observed under stones in the river below the dams which impound waters rich in humic acids, iron and manganese. The deposits result in an impoverishment of the benthic fauna (Armitage 1984).

The mitigations measures presented in the table such as the avoidance where possible of hypolimnial releases will reduce adverse effects of deoxygenation.

Vegetation
Increased dissolved oxygen levels, i.e. air-saturation values, increase metabolism and decrease plant biomass. When in combined with effect of lower temperatures and low oxygen the effects are exacerbated. Effects of increased dissolved nitrogen have not been convincingly demonstrated for submerged plants.

A3.2 Impacts in the impoundment

A3.2.1 Littoral Zone Heavy Engineering / Water level fluctuation

The artificial nature of impoundment shores can compare unfavourably with the heterogeneity of a natural lake shore. The nature of the material used in construction of the shore has a direct bearing on the quality of the habitat provided. Those that are simple, like concrete, provide poor quality habitat whilst those with a more complex structure can support a more natural fauna, e.g. artificial gravel shores.

The impact of water level fluctuations differs depending on the operation of the impoundment. Hydropower schemes are typified by frequent large daily fluctuations whilst water supply reservoirs tend to draw down slowly over periods of low rainfall, usually the summer. The severity of the impact depends on the amplitude and frequency of drawdown; in severe cases a barren zone of no growth can result at the margins of a reservoir.

Fish
The predominately vertical river banks does not allow a good colonisation by marginal vegetation which could be used as refuge habitats for fish larvae as well as good spawning habitat for phytophils fish species. Suitable habitat is a dynamic concept, which evolves not only with the species but also throughout the entire life history of the fish (Kavanagh 2000, Hjelm et al. 2000). You can have a suitable habitat for feeding but not for spawning or for the young-of-the year and vice-versa. To survive after hatching, larvae which only possess rudimentary fins and no pigmentation often need to find refuge in the marginal vegetation where they can find low velocities and good cover. If this type of habitat is not available or limited during the early part of the fish larval period, detrimental consequences for fish recruitment could potentially be observed. Wild fluctuations of water level would increase the risk of fish eggs laid on marginal vegetation being stranded above the waterline and thus increasing mortality at the egg stage.

Invertebrates
Flooding the previous river channel will have profound affects on the lotic biota and eventually a purely lentic community will develop, dominated by chironomids and worms. The littoral region will be subject to changes in water level and exposure to wave action. Mitigation measures should consist of using bunded areas to retain water when levels are dropped and attempting to encourage the establishment of littoral vegetation where possible.
The mitigation measures outlined in the WFD table should address the issues raised. Where the reservoir substrate is unsuitable replacing it with stable gravel shores is an option. In trials at Lake Constance, reinstatement of the littoral zone was achieved by introducing stable gravel beaches which carried higher numbers of benthic invertebrates than natural beaches, (Friessinet et al. 2002).

Vegetation
Morphological status of impoundment margins especially slope are very dependant on the structure of the local impounded catchment conditions, such as substrate stability, ice action, operational regimes in terms of water level changes, seasonality of changes and wind fetch. Such effects in combination may result in sloping bare-earth littoral zones of several meters in vertical height from earth to rock faces in deeper impoundments to increased marginal wetlands zones in shallow impoundments. These littoral zones may dry rapidly or slowly and many macrophytes are not sufficiently adaptable to accommodate this as many marginal or emergent plants have narrow water-level tolerance ranges. Physical disturbance such as wind action, fetch, impoundment orientation to prevailing wind direction may prevent colonisation, re-colonisation, reduce or remove established water plants and result in plant movement to alter operational conditions of the impoundment.

Potential mitigation measures include re-alignment of margins with submerged berms to provide a variety of water depth protected by wetland areas to the littoral side, or by provision of semi-buoyant anchored structures ‘floating islands’ around margins. The manipulation of existing islands of vegetation has been successful in some African lakes, e.g. Denny (1985). Wave energy at the margins can remove many macrophytes and this can be minimised (NALMs 1990). Habitat creation typical of natural areas should be undertaken such as addition of large crushed rock margins topped with suitable fines to hard marginal areas, e.g. fresh mined surfaces, areas or concrete facings. Steep concrete sides can be generally poor habitat and difficult to colonise but surface roughening may enhance attachment and colonisation of some smaller species.

Continuing maintenance is also necessary to maintain a marginal fringe of reed-like species types, preferably with submerged species to the water side. Biotic surveys should be undertaken prior to amelioration as for example shaded areas with firm substrates may actually increase diversity by providing habitats for species of bryophyte, lichen or sponges.

Other potential mitigation measures might include consideration of design or re-design of impoundments, opportunities should be taken to allow orientation of the use of peninsulas, piers, promontories and bays to reduce the fetch of the prevailing wind. Enrichment of the marginal growth zones by the addition of nutrients and /or inorganic calcium, e.g. chalk, under stable conditions may enhance the growth of existing marginal vegetation and thus the tolerance of the vegetation to water level changes. A watering pipeline around the impoundment margin may provide some maintenance of near-submerged marginal vegetation during dry drawdown periods; artificial or re-circulated nutrients could be supplied in this water. Removal of bottom dwelling fish, for example carps, may reduce root disturbance in shallower impoundments and promote the maintenance of vegetation.
Potential mitigation measures include planting with more tolerant smaller submerged reed like species, e.g. spike rushes, quillworts, isoetids, although some experimental work would be necessary and the effect may not be significant when compared to biomass or observed plant density of major reed-swamp species. Non-target species should also be considered in management proposals towards improved environmental status.

Other potential mitigation measures might include consideration of the introduction of fine sward forming species of Carex, small Juncus etc. with high regeneration potential, to stabilise the margins when drying during under extreme changes in depth.

A3.2.2 Eutrophication

Eutrophication is a large and complex problem best dealt with on a catchment basis. The syndrome usually results from excessive levels of nutrients entering the reservoir and causing phytoplankton to dominate primary production at the expense of aquatic macrophytes. Phytoplankton blooms reduce water quality, they can be toxic and in extreme situations fish kills can result. The balance between phytoplankton and macrophyte dominance can be altered by the fish community too, over a range of nutrient levels. Thus biotic, as well as abiotic, mechanisms can influence the water quality of a reservoir.

The syndrome affects natural systems and artificial systems but lowland drinking water reservoirs being shallow and found in productive catchments are especially susceptible.

Fish
The increase of ammoniacal nitrogen as a result of reduced dilution is toxic for fishes in general. Although the tolerance levels vary between fish species, young stages and larval stages are in general more sensitive to ammoniacal nitrogen than adult fishes. The main problem likely to occur from the reservoir is a reduction of dilution, in particular during the period of reproduction for coarse fish (spring-early summer). A decrease of dilution will result in an increase of ammoniacal nitrogen, a reduction of dissolved oxygen with all the resulting consequences for eggs, larvae and juveniles (see above).

Invertebrates
Eutrophication is likely to increase the standing crop of benthos but, if very pronounced, will reduce oxygen levels resulting in a reduction in benthos, particularly in the profundal zone. Adverse effects will be mitigated by control of nutrient status and other measures listed in the Table.

Vegetation
Eutrophication or enrichment by nutrients may lead to loss of macrophytes by overgrowth (as above) or by reducing the light transmission of the water to the lower levels and rooting areas for plants.

Where there is a disproportionately low level of inorganic nitrogen in relation to phosphate, growths of blue-green algae may occur. Some of these algae are ‘poisonous’ to some organisms, e.g. mammals but otherwise forms surface scums with characteristic smells which can drift and may beach on impoundments margins.
Potential mitigation measures include the reduction or at least limit of nutrient inputs, rebalancing of nutrient required ratios by addition or re-suspension of mineralised sediments and control of land management practices in the catchment, e.g. timing and direction of ploughing, fertiliser application and use of correctly-managed river-side nutrient absorption strips with long-term planned nutrient removal strategies.

Other potential mitigation measures could include the introduction and encouragement of filter feeding fish or reducing fish populations to encourage elevated populations of filter-feeding planktonic crustaceans. Consideration of the periodic introduction of specially selected or prepared fine clays to adsorb phosphates before settling to the bottom, allowing the water to clarify by removal of planktonic algal growths could also be considered. Large vegetated deltas or even settlement tanks on input streams may provide for settlement of inorganic fines to reduce increased turbidity, and at the same time reduce the input of nutrients from organic materials.

A3.2.3 Recreation

Reservoirs and artificial modified water bodies are often attractive places for recreation. The impact of recreation has been studied at a number of locations in the UK. The severity of impact is often related to the intensity and type of use the system is put to. At coarse fisheries where live bait is used, reservoirs may act as stepping stones in the spread of invasive fish species.

Often recreational activity is confined to the shore zone. Here the impact is more likely to impact on bird life than any of the WFD biological elements. On the open water, pollution from boats is now thought to cause damage through the release of biological waste and toxic hydrocarbons from boat exhausts, but this area is, as yet, poorly understood.

It is worth highlighting that many standing waters have a capacity to cope with recreational activities and that the positive aspects of recreation for the environment should be carefully weighed against its impacts.

Fish

Particular attention will have to be focused on fisheries management to avoid any introduction of non-native species. Up to date regulation and policies for fish movement as well as fish stocking will apply.

Invertebrates

Chironomidae are frequently one of the most numerous components of the benthic community of standing water bodies. Their mass emergence can cause considerable nuisance to anglers, and visitors using the reservoir for recreational purposes (Armitage 1995a). Their control may prove to be an expensive and fruitless exercise, as both larvae and adults forms provide a rich source of food for fish and birds (Armitage 1995b).

Vegetation

Macrophytes are not often affected by recreational activity except for access for boats, sailboards or swimming, and it is usually the converse people complaining about weeds interfering with recreation. However, pollution (especially nutrients and hydrocarbons), excessive wave action from boat activities and general habitat disturbance will reduce the
biomass of submerged macrophytes and in combination may lead to loss of species. It is however more often the case that plant species are accidentally introduced to recreational impounded waters.

A3.2.4 Direct impacts of the impounding structure

The main impact of any impounding structure is that it acts as a barrier to the natural movement of flora and fauna. All other impacts are likely to be local to the impounding structure.

Fish
The presence of physical barriers (weirs, locks) among the river but also among the entire catchment will be responsible for the absence of migratory fish species such as (smelt, sea-trout, salmon, elvers, shad, lamprey etc.). An excellent summary of coarse fish migration is also provided in Lucas and Barras (2001). Generally, the importance of natural migrations and seasonal activity patterns for riverine coarse fish has been underestimated. Photoperiod, light intensity, water temperature, hydrology, water quality and food availability have all been correlated with fish migration. Operation of a reservoir may significantly impact on the migration of fish species both within and between reaches. The extent of this impact will depend on the agreed operating regime, with both abstraction and release of water having the potential to affect migration of key life stages of range of species.

Invertebrates
It has been theorised that dams may provide a barrier to distribution of invertebrate species but to our knowledge there is no proof of this. Adult insects can negotiate the dam by active flight or wind dispersal. However the distribution of some crustacean, mollusc (Hughes and Parmalee 1999) and other non-flying groups may be adversely affected by the impoundment.

Vegetation
Impoundment walls modify the aquatic environment enhancing the effect of wave action, locally increasing shading, and often being near vertical, remove shallow water for colonisation by marginal plants being aware of the potential for ice action. Conversely the habitat may allow colonisation of some shade preferring or tolerating smaller species such as some species of bryophytes, lichens or sponges on the firm substrates and may actually increase diversity by providing this type of habitat. A satisfactory methodology of assessing the 'target' natural habitat comparisons again needs to be established.

Morphological changes to the impoundment wall have all been shown to enhance the aesthetics of modified stream or canal sides and occasionally impoundments but whilst these may provide the main amelioration as mentioned for hard surfaces (see also above), and whilst they may increase diversity, they do not impact much on the naturalness of the general ecology of the impoundment.

Isolation of plant communities is one possible mechanism of limiting the vegetation population and can also act to limit the choice of habitats for re-colonisation. However this will probably not have a notable effect in the UK especially by comparison to the effects on fish as even small re-vegetation schemes usually involve many species mixed within transplanted vegetation and sources for re-introduction.
Potential mitigation measures include morphological changes to the impoundment wall to reduce wave wash, energy dissipation, longitudinal seiches etc., such as re-profiling or the additional of material incorporating an overlay of finer materials at or near to the wall to allow more vegetation growth.
APPENDIX 4

WFD29: MANAGEMENT STRATEGIES AND MITIGATION MEASURES REQUIRED TO DELIVER THE WATER FRAMEWORK DIRECTIVE. DRIVING PROCESSES, PRESSURES AND RESULTANT IMPACTS
## APPENDIX 4: DRIVING FORCES, PRESSURES AND RESULTANT IMPACTS

<table>
<thead>
<tr>
<th>Driving force</th>
<th>Pressure</th>
<th>Resulting state (i.e. Impact)</th>
</tr>
</thead>
</table>
| **Physical presence of**<br>dam | **Loss of system continuity** | Biological: effect sediment build up in reservoir depends on water depth, deep lakes will be little affected; shallow lakes will potentially experience (minor) negative impact on macrophytes, macrofauna and fish. Loss/change of habitat downstream negatively affects all biological elements here. Migrational fish species negatively impacted due to migration barrier. Minor impact on macrofauna in reservoir as a result of increased particulate organic matter and isolation.  
Physico-chemical: shallow impoundments might heat up more quickly as result of decreased depth. Increased organic content, anoxic conditions below thermocline.  
Hydro-morphological: Impeded transport of organic matter and (fine) sediment leading to build-up of (fine) sediment in impoundment and less (fine) sediment directly downstream (scouring). Net scour of downstream channel. |
| **Altered habitat**    |                                 | Biological: reduced macrophyte growth in the vicinity of the wall due to shading and altered morphology, increase in non-native but potentially rare species such as wall colonizers (shaded areas with firm substrate may actually provide habitat for byrophyte species and sponges).  
Physico-chemical: increased shading leads to decreased light penetration in vicinity of wall. Potential local effect on temperature.  
Hydro-morphological: loss of natural habitat, new habitat for "invasive species". |
<table>
<thead>
<tr>
<th>Driving force</th>
<th>Pressure</th>
<th>Resulting state</th>
</tr>
</thead>
<tbody>
<tr>
<td>Management of dam</td>
<td>Altered flow downstream</td>
<td>Biological: in general negatively affects all biological elements due to loss/change of habitat; specifically release of peak flows leads to selection of disturbance tolerant species (potentially non-native); non-natural highs and lows lead to stranding of fish and macrofauna.</td>
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<td></td>
<td></td>
<td>Physico-chemical: fluctuating water temperature, higher or lower than natural state</td>
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<td></td>
<td>Hydro-morphological: non-natural quantity, velocity and (seasonal) dynamics, potentially leading to altered sediment composition, channel widening, stream bank erosion and/or loss of spawning gravel. Strongest impact of increased water velocity is directly downstream.</td>
</tr>
<tr>
<td></td>
<td>Altered water level (fluctuation) in reservoir</td>
<td>Biological: Macrophyte, invertebrate and some fish species negatively affected due to non-natural fluctuation and exposure/drying out of shallow (shore zone) areas. Less macrophyte species heterogeneity due to selection of species tolerant to sudden (extreme) changes in water level.</td>
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<tr>
<td></td>
<td></td>
<td>Physico-chemical: potential increase in temperature and turbidity in shallow areas.</td>
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<tr>
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<td></td>
<td>Hydro-morphological: more extreme high and low water levels, sometimes with severe drops in water level. Exposure/drying out of shallow (shore zone) areas.</td>
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<tr>
<td></td>
<td>Altered residence time within reservoir</td>
<td>Physico-chemical: potential increase in concentrations nutrient and pollutants.</td>
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<tr>
<td></td>
<td></td>
<td>Hydro-morphological: average residence time longer than in natural state.</td>
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<tr>
<td></td>
<td>Release of water with altered temperature to downstream</td>
<td>Biological: negative effect on physiology of (native) fish and macrofauna species, effect on macrofauna and phytoplankton expected to be minimal.</td>
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<tr>
<td></td>
<td></td>
<td>Physico-chemical: Release of water hotter/colder than downstream leads to fluctuating temperatures, possibly pH levels.</td>
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<tr>
<td></td>
<td></td>
<td>Hydro-morphological: none.</td>
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<tr>
<td></td>
<td>Release of water with altered oxygen content to downstream</td>
<td>Biological: General negative impact on phytoplankton (increased concentrations), macrophytes, macrofauna and fish directly downstream. Specifically (toxic) heavy metal release affects fish negatively. High oxygen levels can lead to gas-bubble disease in fish.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Physico-chemical: release of deoxygenated water leads to an increase in phosphate concentrations directly downstream, a potential drop in dissolved oxygen concentrations and heavy metals release; release of highly oxygenated water leads to excessive oxygen levels.</td>
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<tr>
<td></td>
<td></td>
<td>Hydro-morphological: none.</td>
</tr>
<tr>
<td><strong>Driving force</strong></td>
<td><strong>Pressure</strong></td>
<td><strong>Resulting state</strong></td>
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<td>-------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>Management of dam</strong></td>
<td><em>Sediment flushing from impoundment to downstream</em></td>
<td>Biological: loss spawning area negatively affects fish, especially salmonids.</td>
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<tr>
<td></td>
<td></td>
<td>Physico-chemical: increased phosphate as result of release from silt particles.</td>
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<tr>
<td></td>
<td></td>
<td>Hydro-morphological: infilling of spawning gravels.</td>
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<tr>
<td></td>
<td><strong>Fish entrainment into intakes</strong></td>
<td>Biological: negative impact on fish fauna, salmonids in particular.</td>
</tr>
<tr>
<td></td>
<td><em>(turbines)</em></td>
<td>Physico-chemical: none.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hydro-morphological: none.</td>
</tr>
<tr>
<td>Driving force</td>
<td>Pressure</td>
<td>Resulting state</td>
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<td>-----------------------</td>
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</tbody>
</table>
| Management of reservoir | Engineering/ (intensive) maintenance of reservoir shoreline (beach, housing, steep shorelines etc) | Biological: Poor macrophyte development, reduced habitat for macrofauna, reduced spawning and breeding area for fish and birds. Negative impact on all biological elements!  
Physico-chemical: potential increased turbidity along shore due to suspended solids and/or alga.  
Hydro-morphological: loss of natural gradual transition from open water to land (little connection with floodplain), changed sediment composition and soil moisture content, reduced shore zone surface area (space for vegetation development) and habitat heterogeneity. |
| Excavation within reservoir |                                                                 | Biological: minor.  
Physico-chemical: potential increased turbidity due to suspended solids and potential release of heavy metals and/or nutrients from sediments.  
Hydro-morphological: non-natural depth of lake |
| Fish stocking         | Biological: invasive species negatively impact all biological elements within catchment and downstream.  
Physico-chemical: increase in nutrient concentrations as a result of feeding and/or increase in bottom-dwelling fish species.  
Hydro-morphological: none.  
N/B SEPA/EA have separate policies on fish stocking and farming in freshwaters. |                                                                                                                                               |
| Recreation and Boating - PAH contamination | Biological: poor development of macrophytes in shallow waters due to propeller disturbance and/or trampling. Negative effect on macrofauna and fish due to loss/disturbance of habitat. Selection of disturbance tolerant species. Introduction of invasive species from boats/PAH's.  
Physico-chemical: increase in pollutants from boating/PAH's, increased turbidity (suspended solids) in shallow areas.  
Hydro-morphological: loss of natural shore zone due to engineering (dock, pier construction etc), increased wave action due to boating. |                                                                                                                                               |
| General recreation    | Biological: poor development of macrophytes in shallow waters due to trampling, negative effect on macrofauna and fish due to loss/disturbance of habitat. Selection of disturbance tolerant spp.  
Physico-chemical: potential increased turbidity due to suspended solids and potential release of heavy metals and/or nutrients from sediments  
Hydro-morphological: loss of natural shore zone due to engineering (dock, pier construction etc) |                                                                                                                                               |
<table>
<thead>
<tr>
<th>Driving force</th>
<th>Pressures</th>
<th>Resulting State</th>
</tr>
</thead>
<tbody>
<tr>
<td>Management of river/streams</td>
<td>Reduced river channel meandering</td>
<td>Biological: less diversity in macrophyte, macrofauna and fish populations.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Physico-chemical: increased turbidity.</td>
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<tr>
<td></td>
<td></td>
<td>Hydro-morphological: less variance in flow rates within river system, potentially less depth variation.</td>
</tr>
<tr>
<td>Development of floodplains along river</td>
<td></td>
<td>Biological: absence of all biological elements which would exist in undisturbed state.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Physico-chemical: increased sediment transport downstream.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hydro-morphological: loss of flood plain area, more extreme peak flow rates (and risk of flooding downstream).</td>
</tr>
<tr>
<td>Angling</td>
<td></td>
<td>Biological: stocking will negatively affect all biological elements due to change in fish community.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Physico-chemical: potential increase in turbidity with increase bottom dwelling fish species and loss of macrophytes and/or filter-feeding invertebrates.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hydro-morphological: (minor) loss natural shoreline with introduction of fishing docks.</td>
</tr>
<tr>
<td><strong>Driving force</strong></td>
<td><strong>Pressure</strong></td>
<td><strong>Resulting state</strong></td>
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</tr>
<tr>
<td>Management of catchment</td>
<td>Agricultural use / development of reservoir catchment</td>
<td>Negative impact on all biological elements due to habitat loss and increased nutrient concentrations. Risk of poisonous algal blooms</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Physico-chemical: decreased transparency in reservoir and rivers, decreased oxygen concentrations in reservoir, increased nutrient concentrations in reservoir and downstream due to input and release from sediments</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hydro-morphological: loss of native vegetation and/or morphology leading to increased volume/rate of run-off. Increased sediment loading of receiving river and reservoir, leading to change in sediment composition</td>
</tr>
</tbody>
</table>
APPENDIX 5

WFD29: MANAGEMENT STRATEGIES AND MITIGATION MEASURES REQUIRED TO DELIVER THE WATER FRAMEWORK DIRECTIVE

BEST PRACTICE MITIGATION MEASURES FOR SPECIFIC IMPOUNDMENT PRESSURES
APPENDIX 5: BEST PRACTICE MITIGATION MEASURES FOR SPECIFIC IMPOUNDMENT PRESSURES

A5.1 Hydropower impoundments

<table>
<thead>
<tr>
<th>Pressure</th>
<th>Specific aspect</th>
<th>Mitigation measure</th>
<th>Notes</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Altered Flow Regime</td>
<td>Release of high hydro-peaking flows</td>
<td>Keep high flows within ecologically acceptable limits</td>
<td>Best practice is likely to be site specific</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Best practice</td>
<td>Likely to severely limit Hydropower production capacity</td>
<td></td>
</tr>
<tr>
<td>Multistage channels</td>
<td></td>
<td>Multistage channels</td>
<td>Engineering</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Storage facility to contain peak releases allowing</td>
<td>Engineering</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>controlled release</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Introduce flow refugia</td>
<td>Engineering</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reduce the slope of the discharge curve</td>
<td>Engineering</td>
<td></td>
</tr>
<tr>
<td>Entrainment of air in turbines</td>
<td>Gas bubble disease</td>
<td>Dissipate excess air from water immediately downstream of turbines, exclude fish from this area</td>
<td>Best Practice</td>
<td>Engineering</td>
</tr>
<tr>
<td>Water level fluctuation in the</td>
<td>Limit water level fluctuations to</td>
<td>Limit water level fluctuations to maxima of 0.5m weekly</td>
<td>Best practice</td>
<td>Engineering</td>
</tr>
<tr>
<td>impoundment</td>
<td>maxima of 0.5m weekly and 5m</td>
<td>and 5m annually (Smith <em>et al</em> 1987)</td>
<td>Would limit effectiveness of hydropower production</td>
<td></td>
</tr>
<tr>
<td></td>
<td>annually</td>
<td>Retain water in littoral using bunding, dykes or pools</td>
<td>Engineering</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Floating islands</td>
<td>Engineering</td>
<td></td>
</tr>
<tr>
<td>Entrainment of fish in turbines</td>
<td>Redesign turbine blades to prevent injury</td>
<td>Provide fish barriers, acoustic, light or bubble</td>
<td>Best practice</td>
<td>engineering</td>
</tr>
</tbody>
</table>

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### A5.2 Water supply impoundments

<table>
<thead>
<tr>
<th>Pressure</th>
<th>Specific aspect</th>
<th>Mitigation measure</th>
<th>Notes</th>
<th>Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eutrophication</td>
<td></td>
<td>Prophylactic measures</td>
<td>Best practice</td>
<td>Expensive</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Post event treatment e.g. de-stratification bubblers</td>
<td></td>
<td>Relatively cheap</td>
</tr>
</tbody>
</table>
### A5.3 General impoundments

<table>
<thead>
<tr>
<th>Pressure</th>
<th>Specific aspect</th>
<th>Mitigation measure</th>
<th>Notes</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Altered Flow Regime</td>
<td>Reduced Discharge and altered season flow variability</td>
<td>Model based Environmentally Acceptable Flows</td>
<td>Direct comparison of the effectiveness of different models not possible</td>
<td>Development cost necessary to meet WFD requirements</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Create new habitat features which function at low flows</td>
<td></td>
<td></td>
<td>Engineering</td>
</tr>
<tr>
<td>Hypolimnion releases</td>
<td></td>
<td>Relevant to water bodies that stratify only</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temperature specifically</td>
<td>Mix water from epilimnion and hypolimnion to match river T°</td>
<td>Best practice</td>
<td></td>
<td>Engineering</td>
</tr>
<tr>
<td>General covering Temperature / nutrient &amp; heavy metal release/ deoxygenation</td>
<td>Release from water surface only</td>
<td>Chemical and deoxygenation are only relevant if the hypolimnion deoxygenates</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Prevent stratification using bubblers</td>
<td></td>
<td></td>
<td>Cost possible</td>
</tr>
<tr>
<td></td>
<td>Oxygenate water immediately downstream of dam to limit impact</td>
<td>Best practice</td>
<td></td>
<td>Engineering</td>
</tr>
<tr>
<td>Pressure</td>
<td>Specific Aspect</td>
<td>Mitigation Measures</td>
<td>Notes</td>
<td>Cost</td>
</tr>
<tr>
<td>--------------------------</td>
<td>--------------------------</td>
<td>-------------------------------------------------------------------------------------</td>
<td>-------------</td>
<td>-----------------------------</td>
</tr>
<tr>
<td>Sediment flushing</td>
<td>Prevent sediment reaching reservoir</td>
<td>Best practice</td>
<td>Engineering</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Coordinate timing of releases to prevent damage to fish habitat</td>
<td>Engineering</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Littoral zone heavy engineering</td>
<td>Increase physical heterogeneity by using natural materials</td>
<td>Best practice</td>
<td>Engineering cost of materials</td>
<td></td>
</tr>
<tr>
<td>Recreation</td>
<td>Shore</td>
<td>Limit access to shore to confined areas</td>
<td>Best practice</td>
<td>Engineering/economist view</td>
</tr>
<tr>
<td></td>
<td>Invasive fish</td>
<td>Exert control on fisheries to prevent release of live bait and stocking with inappropriate species</td>
<td>Best practice</td>
<td>Cost low (Signage and coordination with angling associations)</td>
</tr>
<tr>
<td>Boating</td>
<td>Use non-motorised forms of transport</td>
<td>Best practice</td>
<td>Economists</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Limit number of craft</td>
<td>Best practice</td>
<td>Economists</td>
<td></td>
</tr>
<tr>
<td>The impounding structure</td>
<td>Migration barrier</td>
<td>Provide fish passes (orifice opening in preference to weir (Guiny 2003))</td>
<td>Best practice</td>
<td>Engineering</td>
</tr>
</tbody>
</table>

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APPENDIX 6

WFD29: MANAGEMENT STRATEGIES AND MITIGATION MEASURES REQUIRED TO DELIVER THE WATER FRAMEWORK DIRECTIVE.

CONCEPTUAL MODELS
APPENDIX 6: CONCEPTUAL MODELS

There are numerous types of impoundment structures for hydropower, water supply and flow regulation and to generate conceptual models to cover all eventualities is beyond the scope of this document. This appendix details a number of differing conceptual models to give some indication of the range of impoundments which may be encountered.

Figure A6.1

**Conceptual Model: Hydropower 1 - Online Power Station**

![Conceptual Model: Hydropower 1 - Online Power Station](image)

Figure A6.2

**Conceptual Model: Hydropower 1a - Online Power Station with Cascade**

![Conceptual Model: Hydropower 1a - Online Power Station with Cascade](image)
Figure A6.3

Conceptual Model: Hydropower 2 - Off-line Power Station

Figure A6.4

Conceptual Model: Hydropower 2a - Off-line Power Station with cascade
Figure A6.5

Conceptual Model: Water supply

Figure A6.6

Conceptual Model: In-channel Storage / Transfer
Figure A6.7

Conceptual Model: Level/Flow Regulation

Overflow

Fish Pass/Overflow

u/s River Reservoir d/s River

Compensation/Freeflow Flow (Qm³/s)
Controlled/multilevel discharge
Minimum Residual Flow (Q m³/s)

Floodplain

Mechanical sluice-flexible control

or

Fixed pipe max allowable flow determined by diameter + max head
Figure A6.8

Conceptual Model: Cross Catchment Transfer

[Diagram showing a conceptual model with water supply, reservoir, inflow, and outflow paths]

- Water Supply
- Reservoir
- In-take
- Off take
- Reduced Supply

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Figure A6.9

Conceptual Model: Pumped Storage (no reduced flow)
Figure 6.10

Conceptual Model: Cascade of Several Impoundments
APPENDIX 7

WFD29: MANAGEMENT STRATEGIES AND MITIGATION MEASURES REQUIRED TO DELIVER THE WATER FRAMEWORK DIRECTIVE

COST EFFECTIVE ANALYSIS
APPENDIX 7: COST EFFECTIVE ANALYSIS

A7.1 Cost effective analysis

When selecting a combination of measures, one important criteria will be that the financial costs and negative social/economic effects are as low as possible. Therefore, part of the implementation of the WFD is the implementation of a cost-effectiveness analysis. With help of a cost-effectiveness analysis, one can evaluate how the aims of the WFD can be reached against the lowest possible financial costs and most favourable social/economic effects.

The cost-effectiveness approach identifies the most effective way of reaching the WFD-criteria against the lowest costs, but does not indicate if the expected benefits justify the costs. Cost-effectiveness (CE) can be defined as the Environmental Improvement (EI) divided by the Costs (C) of the measures:

\[
CE = \frac{EI}{C}
\]

Box A7.1: Example cost-effectiveness analysis

For example, the cost-effectiveness of measures to improve fish populations by introducing compensation flows in the management of a dam as follows:

- Measure 1: The conservation of 10 000 kg of fish costs £50 000, \( CE = \frac{10 000}{50 000} = 0.2 \) kg fish conservation / pound sterling
- Measure 2: The conservation of 7000 kg of fish costs £60 000, \( CE = \frac{7000}{60 000} = 0.12 \) kg fish conservation / pound sterling

This means that the cost-effectiveness of Measure 1 is higher: namely more fish can be conserved with each pound sterling spent.

\[
1 \text{ In a cost-benefit analysis, the benefits of an action are compared to its costs to determine whether the action is worth undertaking. The approach is used to compare alternative options, and requires that benefits can be identified and translated into monetary values. In a number of cases, a traditional benefit-cost analysis may not be feasible or desirable. It may not be possible to make monetary estimates of benefits. For example, some water resources may be so unique that it might be felt they should be conserved at all costs. In other cases, there might be substantial uncertainty about the benefits provided, either now or in the future, or it might be difficult to determine appropriate values in monetary terms. In those cases, a cost-effectiveness analysis may be the best approach for comparing alternative ways for achieving a certain goal.}
\]
In practice, however, the cost-effectiveness of measures is more difficult to determine particularly in relation to the difficulties in quantifying the effects:

- Different water bodies usually have different characteristics. The measures will therefore have different effects in differing water bodies e.g. through interaction of the various components dissolved in the water;
- Climatological (e.g. temperature, sun radiation), geographical (e.g. latitude, altitude, soil substrate) and environmental (e.g. run-off quality) factors also lead to differences in the reaction of the water quality to measures in different locations;
- Relevant specific research data are often not available to predict the effect reliably and accurately (partly because of the variable reaction of water quality to measures);
- Even when data are available, there is the methodological problem of isolating the effect of one measure from that of other factors influencing water quality;
- A combination of measures may result in a larger effect than the measures on an individual basis;
- Effects are only visible over time e.g. when it concerns reduction of algae growth, several summer seasons are required before the effect can be properly assessed. Even then, the variation in warm periods from one year to the other can considerably obscure the true effectiveness of algae-reducing measures.

Taken into account these difficulties to quantify the environmental effects, a specific approach is developed for the cost-effectiveness analysis. This approach is presented Volume 1, Section 3.

**A7.2 Tools to be used for implementing a cost-effectiveness analysis**

Some tools have been developed that can be used for the selection of cost-effective measures for impoundments aiming at the realisation of the WFD objectives in 2015.

The following tools are developed:
- **Practical approach** for implementing a cost-effectiveness analysis. This approach is explained in Volume 1, Section 3.
- **spreadsheets** with information on the measures that could be taken. For each measure, the following information is provided:
  - Short description of the measure;
  - Effectiveness of the measures in terms of the WFD requirements;
  - Financial costs of the measure;
  - Expected other, socio-economic effects of the measure.

These tools aim to support impoundment managers and others when implementing a cost-effectiveness analysis for the selection of measures to fulfil the WFD-objectives.
In the spreadsheet the effectiveness of each of the measures is evaluated as presented in Table A7.1 below.

Table A7.1 Criteria for evaluating effectiveness

<table>
<thead>
<tr>
<th>Effect</th>
<th>Presentation</th>
</tr>
</thead>
<tbody>
<tr>
<td>strong positive effect</td>
<td>+++</td>
</tr>
<tr>
<td>moderate positive effect</td>
<td>++</td>
</tr>
<tr>
<td>limited positive effect</td>
<td>+</td>
</tr>
<tr>
<td>no effect</td>
<td>~</td>
</tr>
<tr>
<td>negative effect</td>
<td>-</td>
</tr>
</tbody>
</table>
APPENDIX 8

WFD29: MANAGEMENT STRATEGIES AND MITIGATION MEASURES REQUIRED TO DELIVER THE WATER FRAMEWORK DIRECTIVE

CHECKLISTS AND TABLES TO BE USING DURING ASSESSMENT PROCESS
APPENDIX 8: CHECKLISTS AND BLANK FORMS

This section contains a checklist of the information you require to collate in order to fully assess the impacts of the impoundment on the waterbody and to record the information such that an auditable trail can be produced if required. The check lists and tables are meant to act as a guide to ensure that that all relevant information is collated and to provide an audit trail but these lists and tables can and should be adapted to suit local situations.

A8.1 Checklist of information for impoundment site visits/ reviews

The aim is to ensure that all relevant aspects are considered and in a structured way, and that information gaps can be identified. Information should be appropriate and sufficient to set the assessment in context, but concise! It will also help to provide a rationale for subsequent assessment of the significance of pressures later in the process.

A8.1.1 Catchment description

- General comments, e.g. predominantly natural/agricultural, urban etc. Is this a single source, or a system of interlinked reservoirs? Identify all components
- Catchment area(s) noting any catch waters
- Rainfall Site, length of any records, location of data, any assessment of catchment rainfall, validity
- Evaporation – if any records(!) or assessment, assessment method and validity
- Geology /hydrogeology
- Flow information. In catchment/ is transposition from a neighbouring catchment appropriate? Quality of information/length of record, location of data. LF2000 estimates, comment on validity. How artificial are flow regimes downstream of impoundments? Any dry stretches/length/when/under what conditions?
- Feasibility of water balance, estimates (table) if sensible
- Land use and management, noting any trends/changes known plans e.g. afforestation, felling, drainage, irrigation etc
- Ecology, availability of information on invertebrates, plants, fish, otters, mink, pearl mussels other designated species etc. Date and location of any survey information.
- Designations eg SAC, SPA, SSSI etc etc.
- Fisheries – fish species, especially migratory/non-migratory upstream and downstream
- Sediment /sediment transport/erosion – any evidence. Nature of river channels e.g. plane bed, pool-riffle upstream and downstream of impoundment(s)
- Recreational use of impoundments or downstream watercourses
- Any navigation
- Industry /other abstraction including hydropower. Are there any licences and if so what/where is information.
- WFD water bodies and characterisation location of information
A8.1.2 Reservoir system

- System/reservoir diagram showing all reservoirs and other sources (e.g. river), inputs, outputs (direct abstraction to supply/hydro etc, regulation releases, transfers, spill, compensation release, any others) and interconnections, receiving watercourses, including available information on: maximum capacities, constraints etc.
- Table listing for each impoundment:
  - Reference NGR
  - Direct catchment area
  - Indirect catchment area and location
  - Maximum gross capacity
  - Spillway crest level
  - Dead water volume
  - Active volume – if this is not say 90% of total volume give reasons why not, e.g. if it is a natural lake partially reservoired.
  - Information on drawdown extent and patterns. Ideally time series of all (!) inputs/outputs.
  - Location of depth-storage curve if any
  - Type of dam
  - Length of dam
  - Date of construction
  - Date and nature of any subsequent works, e.g. spillway alterations
  - Name, date and location of any relevant Water Order(s)
  - Summary of relevant provisions e.g. compensation releases
  - Use of dam- public water supply, hydropower, fishery, recreation, industry, navigation, irrigation, flood management, maintenance of adequate dilution/temperature downstream– list all relevant
  - Monitoring arrangements for all inputs/outputs current/historic
  - Length, dates, and location of any records. Comments on validity.
  - Site-specific pollution issues e.g. ragwort growth on bed
- operational practice, including any control curves (location), relationship between use of system components. System/hydraulic constraints, periodic releases e.g. to avoid sediment build up, artificial spates
- information on performance in drought, any evidence of problems, Drought Orders. Date and location of Drought Plan if available.
- current assessment of reliable system yield, method and report reference. Comments on validity
- list any known related studies & location of reports, e.g. acid rain, climate change etc

A8.1.3 Treatment works/Hydropower Scheme

- NGR
- Area and population supplied
- description, process description (e.g. single/two stage, gravity or pumped, age.
- maximum and normal throughputs, constraints, any information on works losses
- any historical problems, water quality and/or quantity. Risk/implications of shutdown e.g. due to pollution e.g. 90% of supply to Glasgow etc
- future issues/plans e.g. needs upgrading by a specific date to meet DWI standards for e.g. arsenic etc.
- Any other works in this supply zone? If so list and provide diagram to show links and constraints.
A8.2 Blank tables for step by step approach

The table references in this appendix correspond to those used in Volume 1, Section 3 and in Appendix 10, Volume 2 for the sake of consistency.

**STEP 1: Scoping of impoundment characteristics**

*Table 3.1a: Summary of information relating to catchment*

<table>
<thead>
<tr>
<th>Impoundment</th>
<th>Impoundment 1</th>
<th>Impoundment 2 etc</th>
</tr>
</thead>
<tbody>
<tr>
<td>Catchment area</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surface area of reservoir</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total capacity/volume</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximal Depth</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximal draw down depth*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Compensation flow</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dam height</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dam length</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dam type</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dam purpose</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* report in metres above bed of reservoir i.e. maximal depth of reservoir is 28m and the depth at maximal draw down is 15m from bed of reservoir (13m of water can be drawn down)

*Table 3.1b: Characteristics of impoundment and / or cascade system*

<table>
<thead>
<tr>
<th>System description1</th>
<th>Impoundment 1</th>
<th>Information Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Characteristics of Impoundment2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type of Impoundment3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Use of Impoundment4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land use in the catchment5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conservation status6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Comments on upstream water course7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Comments on downstream water course8</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 Suggestions: single impoundment; a cascade system (characteristics to be scoped per unit, add tables of columns as preferred).
2 Suggestions provided per characteristic, lists are not exhaustive and multiple options may be selected per characteristic.
3 Suggestions: hydropower on-line, hydropower offline; Water supply; in-channel storage; level/flow regulation; pumped storage (see also Conceptual models, Volume 2, appendix 6).
4 Suggestions: irrigation; navigation; disused; industrial; winter storage; compensation flows; swimming; fishing; rafting etc.
5 Suggestions: Pastureland; agriculture; flood storage; urban development; nature conservation; recreation; forestry etc.
6 Suggestions: SSSI’s, SAC’s; SPA’s; RAMSAR sites; Wildlife countryside act; local nature reserves.
7, 8 Suggestions: channelled; developed flood plains; scoured; deepened etc
STEP 2: Identification of current WFD waterbody status

Table 3.2: Identified pressures on water body / water bodies

<table>
<thead>
<tr>
<th>Pressure</th>
<th>Impoundment 1</th>
<th>Impoundment 2</th>
<th>Impoundment 3 etc</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waterbody ID</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Modified (yes/no)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Artificial (yes/no)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Point source pollution</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diffuse source pollution</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abstraction</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flow regulation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Morphological alteration</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alien species</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Risk category</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

STEP 3: Identification of WFD target status
No tables

STEP 4: Comparison of current status of impoundment with target WFD status
No tables
**STEP 5: Analysis of water system**

**Table 3.4 Driving forces and related pressures**

<table>
<thead>
<tr>
<th>Driving force</th>
<th>Pressure</th>
<th>Issue</th>
<th>Comments / location of the pressure in a cascade of impoundments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical presence of dam</td>
<td>Loss of system continuity</td>
<td>Yes/no/unknown</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Altered habitat</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Management of dam</td>
<td>Altered flow downstream</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Change to river habitat</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Altered water level (fluctuation) in reservoir</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Altered residence time within reservoir</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Release of water with altered temperature to downstream</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Release of water with altered oxygen content to downstream</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Release of water with heavy metal and/or nutrient contamination</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sediment flushing from impoundment to downstream</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fish entrainment into intakes (turbines)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Management of reservoir</td>
<td>Engineering/ (intensive) maintenance of reservoir shoreline (beach, housing, steep shorelines etc)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Excavation within reservoir</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fish stocking</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Recreation and boating - PAH contamination</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>General recreation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Management of river/streams</td>
<td>Altered river channel meandering</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Development of floodplains along river</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Angling</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Management of catchment</td>
<td>Agricultural use / development of reservoir catchment</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Table 3.5 Potential impacts and issues

<table>
<thead>
<tr>
<th>Potential Impacts/Issues</th>
<th>WFD objectives being met? (yes/no/unknown)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Impound-ment 1</td>
</tr>
</tbody>
</table>

**Ecology**
- Macro-fauna
- Phytoplankton
- Macrophytes / phytobenthos
- Benthic invertebrates
- Fish fauna

**Hydromorphology**
- Quantity and dynamics of flow
- Connection to groundwater bodies
- Residence time (lakes)
- River continuity
- Morphological conditions

**Physicochemical**
- Temperature
- Oxygen concentration
- Nutrients
- Pollutants
- Transparency (lakes)
- Priority substance pollutants

### STEP 6: Identification of potential mitigation measures based on effectiveness

### Table 3.6a Presentation of effectiveness of individual measures

<table>
<thead>
<tr>
<th>Effectiveness of single measures</th>
<th>Presentation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effect per biological element</td>
<td></td>
</tr>
<tr>
<td>strong positive effect</td>
<td>+++</td>
</tr>
<tr>
<td>moderate positive effect</td>
<td>++</td>
</tr>
<tr>
<td>limited positive effect</td>
<td>+</td>
</tr>
<tr>
<td>no effect</td>
<td>~</td>
</tr>
<tr>
<td>Negative effect</td>
<td>-</td>
</tr>
</tbody>
</table>
Table 3.6b Criteria for evaluating the likelihood of single measures realising the WFD target

<table>
<thead>
<tr>
<th>Period in which the effect is expected</th>
<th>Likelihood that the WFD target is realised in 2015</th>
<th>Presentation</th>
</tr>
</thead>
<tbody>
<tr>
<td>before 2015</td>
<td>Very likely</td>
<td>+++</td>
</tr>
<tr>
<td>Between 2015 and 2021</td>
<td>Likely</td>
<td>++</td>
</tr>
<tr>
<td>Between 2021 and 2027</td>
<td>Maybe</td>
<td>+</td>
</tr>
<tr>
<td>After 2027</td>
<td>Not clear</td>
<td>~</td>
</tr>
<tr>
<td>Unlikely</td>
<td></td>
<td>-</td>
</tr>
</tbody>
</table>

Table 3.7: Potential mitigation measures, indicating effectiveness and period for improvement

<table>
<thead>
<tr>
<th>Mitigation measure</th>
<th>Effectiveness per biological element</th>
<th>Period for improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Example: provide freshets (measure 19 in table section 5)</td>
<td>++</td>
<td>+++ (if implemented before 2008)</td>
</tr>
</tbody>
</table>

STEP 7: Identification of suitable combinations of measures

Table 3.8a Presentation effectiveness combinations of measures

<table>
<thead>
<tr>
<th>Effectiveness of single measures</th>
<th>Presentation</th>
</tr>
</thead>
<tbody>
<tr>
<td>strong positive effect</td>
<td>+++</td>
</tr>
<tr>
<td>moderate positive effect</td>
<td>++</td>
</tr>
<tr>
<td>limited positive effect</td>
<td>+</td>
</tr>
<tr>
<td>no effect</td>
<td>~</td>
</tr>
<tr>
<td>Negative effect</td>
<td>-</td>
</tr>
</tbody>
</table>
Table 3.8b Criteria for evaluating the likelihood of combination of measures realising the WFD target

<table>
<thead>
<tr>
<th>Period in which the effect is expected</th>
<th>Likelihood that the WFD target is realised in 2015</th>
<th>Presentation</th>
</tr>
</thead>
<tbody>
<tr>
<td>before 2015</td>
<td>Very likely</td>
<td>+++</td>
</tr>
<tr>
<td>Between 2015 and 2021</td>
<td>Likely</td>
<td>++</td>
</tr>
<tr>
<td>Between 2021 and 2027</td>
<td>Maybe</td>
<td>+</td>
</tr>
<tr>
<td>After 2027</td>
<td>Not clear</td>
<td>~</td>
</tr>
<tr>
<td></td>
<td>Unlikely</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 3.8c Criteria for evaluating the likelihood of single measures realising the WFD target

<table>
<thead>
<tr>
<th>Effectiveness combination of measures</th>
<th>Period in which the effect is expected</th>
<th>Likelihood that the WFD target is realised in 2015</th>
<th>Chance</th>
<th>Presentation</th>
</tr>
</thead>
<tbody>
<tr>
<td>strong positive effect</td>
<td>before 2015</td>
<td>Very likely</td>
<td>+++</td>
<td></td>
</tr>
<tr>
<td>moderate positive effect</td>
<td>Between 2015 and 2021</td>
<td>Likely</td>
<td>++</td>
<td></td>
</tr>
<tr>
<td>limited positive effect</td>
<td>Between 2021 and 2027</td>
<td>Maybe</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>no effect</td>
<td>After 2027</td>
<td>Not clear</td>
<td>~</td>
<td></td>
</tr>
<tr>
<td>Negative effect</td>
<td></td>
<td>Unlikely</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

Table 3.9: Potential combinations of mitigation measures.

<table>
<thead>
<tr>
<th>Combination</th>
<th>Mitigation measures</th>
<th>Effectiveness</th>
<th>Period for improvement</th>
<th>Chance of realising WFD aim</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
STEP 8: Calculation of financial and socio-economic costs

Table 3.10: Identifying financial costs and other socio-economic effects

<table>
<thead>
<tr>
<th>Nr.</th>
<th>Combination of measures</th>
<th>Net Present Value</th>
<th>Other socio-economic effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C3</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

STEP 9: Ranking of combinations according to cost-effectiveness

Table 3.11: Selecting the most cost-effective combination of measures

<table>
<thead>
<tr>
<th>Nr.</th>
<th>Combination of measures</th>
<th>Likelihood of reaching WFD target</th>
<th>Period</th>
<th>Chance to reach WFD- aim in 2015</th>
<th>Net Present Value</th>
<th>Other socio-economic effects</th>
<th>Ranking of measures based on cost-effectiveness</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

STEP 10: Selection of most cost-effective combination of measures

No tables

STEP 11: Identification of actions to be taken to comply with WFD

No tables
APPENDIX 9

WFD29: MANAGEMENT STRATEGIES AND MITIGATION MEASURES REQUIRED TO DELIVER THE WATER FRAMEWORK DIRECTIVE

WFD29: STAKEHOLDER WORKSHOP
APPENDIX 9: WFD29: STAKEHOLDER WORKSHOP

A stakeholder workshop was held at Castle Leazes Halls, Newcastle, on 17th June 2004. The aim of this workshop was to advise stakeholders of the work done to date on the project and to seek their reviews. This appendix summarises the results of the day’s activities.

A9.1 Delegate list

Kirsty Irving  SNIFER (Project Director) – Research Co-ordinator
Antonio Ioris  SEPA (Project Manager) - Policy Development Officer
David Crookall  SEPA – Policy Development
John Aldrick  Environment Agency – Water Resources Policy Manager
Dave Corbelli  SEPA – Senior Hydro-ecologist
Paul da Cruz  SEPA – Senior Water Resources Officer
Paul Copestake  SEPA – Senior Hydrologist
Peter Donaldson  Scottish and Southern Energy plc
Alistair Stephen  Scottish and Southern Energy plc
David Summers  Tay Fisheries Board
Andrew Hughes  British Dam Society
Chris Buxton  Cabinet Office
Olivia Lassiere  British Waterways
Steve Mayall  Environment Agency (Wales)
Louise Lund  Environment Agency – Water Resources Officer
Katie Harper  Environment Agency – CAMS Management Strategies
Theresa Baird  Posford Haskoning – Project Manager (Phase 1 and 2)
Wendy Johnston  Posford Haskoning – Project Manager (Phase 3)
Ina Konterman  Royal Haskoning – Economist
Mathew O’Hare  Centre for Ecology and Hydrology

A9.2 Workshop objectives

Explain the purpose of the project

Discuss the work carried out so far:
- International review of best practices
- Tables with the proposed mitigation measures
- Impoundment conceptual models and Cost Effectiveness Analysis

Discuss the appropriateness of the mitigation measures to deliver the objectives of the Water Framework Directive regarding the mitigation of dam impacts
A9.3 Workshop programme

<table>
<thead>
<tr>
<th>Activity</th>
<th>Start</th>
<th>End</th>
<th>Lead</th>
</tr>
</thead>
<tbody>
<tr>
<td>Welcome coffee and initial remarks</td>
<td>9:30</td>
<td>10:00</td>
<td>SNIFFER/EA/SEPA</td>
</tr>
<tr>
<td>Project background and future application</td>
<td>10:00</td>
<td>10:20</td>
<td>David Crookall</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>John Aldrick</td>
</tr>
<tr>
<td>Review of international practice</td>
<td>10:30</td>
<td>11:00</td>
<td>Wendy Johnston</td>
</tr>
<tr>
<td>Mitigation measures (tables)</td>
<td>11:00</td>
<td>12:00</td>
<td>Theresa Baird</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mathew O’Hare</td>
</tr>
<tr>
<td>Impoundment conceptual models and cost effectiveness analysis</td>
<td>12:00</td>
<td>12:30</td>
<td>Ina Konterman</td>
</tr>
<tr>
<td>Discussion over lunch</td>
<td>12:30</td>
<td>13:15</td>
<td></td>
</tr>
<tr>
<td>General instructions about small groups</td>
<td>13:15</td>
<td>13:30</td>
<td>SNIFFER/EA/SEPA</td>
</tr>
<tr>
<td>Groups discussion: mitigation tables and cost effectiveness analysis</td>
<td>13:30</td>
<td>14:30</td>
<td>Theresa Baird</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mathew O’Hare</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Wendy Johnston</td>
</tr>
<tr>
<td>Coffee break</td>
<td>14:30</td>
<td>14:45</td>
<td></td>
</tr>
<tr>
<td>Report of the small groups</td>
<td>14:45</td>
<td>15:15</td>
<td>Theresa Baird</td>
</tr>
<tr>
<td>Discussion and workshop conclusions</td>
<td>15:15</td>
<td>16:00</td>
<td>Antonio Ioris</td>
</tr>
<tr>
<td>Final words</td>
<td>16:00</td>
<td></td>
<td>SNIFFER/EA/SEPA</td>
</tr>
</tbody>
</table>

A9.4 Results from the discussion groups

A9.4.1 Workshop / minutes of discussion-group 1

Questions:

1. What is critical information required (may not always be available) for deciding about the mitigation of negative environmental impact created by impoundments?

   - Before you decide upon mitigation of impacts, you have to understand how your impacts actually work.
   - Only as much information as needed should be collected in order to make the decisions (information collection is not a goal in itself)
   - The scale/significance of issues is important: are the issues big enough to really justify the taking of mitigating measures.
   - The emphasis should be on the questions “where do you want to go to?” instead of analyzing where we are standing now, so focus on targets.
   - The question needs to be answered whether you are really confident in the effects of your mitigating measures. Confidence can be acquired when measures are proven.
   - It should be indicated in which particular conditions the ‘best practices’ are truly best practices.
- **Experimenting with alternative measures should be stimulated** (research projects which analyze whether innovative measures work)
- **The precautionary principle is important**: if it is not known what the effect would be of a particular measure, estimate the effects conservatively.
- **Monitoring will be essential in future in order to enable better understanding of the impacts of measures.**

2. **How do the measures from the mitigation table compare with your day-to-day practice?**

   - A number of practices from the mitigation table are current practice. Examples are fish passes.
   - Also compensation flows, based on the legal framework, are current practice.
   - Practices that are hardly ever/not used in Scotland are measures to influence the temperature. In England, more experience has been gained with these types of measures.
   - Stakeholders (for instance fishery and ecologists) might have different needs, and the importance of these needs should be taken into account.
   - It is important to quantify your environmental objectives

3. **How do you address costs in relation to potential benefits?**

   - In practice, expert judgment is often used in order to assess whether the costs are worth the potential benefits of an action.
   - In CAMS, a similar approach as the cost-effectiveness approach in this project, is used to appraise sustainability. We could compare approaches in the two projects and see where we can learn from each other.
   - In the CAMS project, a stakeholders group is involved in order to make sure that the activities of the project are appropriate.
   - Operators could be asked in this project to help estimating the costs of the measures.
   - When implementing mitigating measures, the PR of implementing the measures might be an additional benefit for the operator.
   - It might be that the decision as to which measure is implemented is decided based upon the limited money available and not so much on the effectiveness of measures.
   - The benefits of a measure should be taken into account and accept that it is not necessarily the 'least-cost-measures'.
   - Monitoring activities are essential to implement in future in order to ensure that more information becomes available about potential benefits of measures.
   - The concept of BATNEEC (best available technology not exceeding excessive costs) might be useful if it is applied in the right way. Sometimes BATNEEC techniques are just inexpensive but not very effective.

### 9.4.2 Workshop / minutes of discussion-group 2

Q1 - What is critical information required (may not always be available) for deciding about the mitigation of negative environmental impact created by impoundments?

- Biology info – lacking
- Flow data – available
- Baseline conditions
- How scheme operated
- Ecol-hydro link – poor
- What parameters is the ecology sensitive to?
- What is GEP?
- Other activities in the catchment and socio-economic value of these

Q2 – How do the measures from the mitigation table compare with your day-to-day practice?
(Thoughts on the proposed mitigation table)
- Viewed UK as ahead of the game already (hydropower)
- Need added column giving circumstance/reason for measure so know if appropriate in a different situation

Q3 - How do you address costs in relation to potential benefits? (Wider issues):
- Who pays?
- Are there resources for non-statutory bodies to collect data as this could be a cost effective way of getting it.

9.4.3 Workshop / minutes of discussion-group 3

Questions:
1. What is critical information required (may not always be available) for deciding about the mitigation of negative environmental impact created by impoundments?
   - There are methodological difficulties to differentiate between natural biological variation and variation due to human interference
   - It is not always clear how serious each impact individually is, when considering a sum of impacts
   - Information that is necessary to understand the operational requirements can be extremely complicated and depends on the purpose of the schemes
   - For example, British Waterways have specific operational (drawdown patterns) than water supply and hydropower (OL of BW)
   - For new schemes the information requirements are different, but there are more opportunities to incorporate mitigation measures than existing schemes
   - Assessment should consider wider land use impacts, because in some cases eutrophication can be more environmentally important than water abstraction
   - Sometimes the environmental regulator do not know/understand the specific measures adopted by hydropower operators (PD of SSE)

2. How do the measures from the mitigation table compare with your day-to-day practice?
   - Most measures mentioned in the workshop today are already used by hydropower in Scotland; since ~15 years ago the practices have been improved to satisfy environmental requirements (PD of SSE)
   - There are differences in the adoption of measures when they are mandatory (e.g. salmon protection) or non-mandatory (e.g. recreational demands)
   - Additional conceptual models were proposed: discharge into a loch, sequence of dams, running over schemes
3. How do you address costs in relation to potential benefits?

- Normally, the first step is to identify disproportionate measures and rank the alternatives.
- Difficult to decide about ‘disproportionate costs’.
- CAMS makes use of ‘Sustainability Appraisal’, which assesses social-economic impacts and the costs of negative impacts (KH suggested Environment Agency publications on CAMS).
- The Cost-Effectiveness Analysis proposed in this project could be used by CAMS for a broader screening (KH of EA).
- However, no method is capable of giving totally impartial answers and final decisions involve value judgments.
APPENDIX 10

WFD29: MANAGEMENT STRATEGIES AND MITIGATION MEASURES
REQUIRED TO DELIVER THE WATER FRAMEWORK DIRECTIVE

EXAMPLE OF USE OF GUIDANCE TO DETERMINE THE MITIGATION
MEASURES REQUIRED FOR IMPOUNDMENTS
A10.1 Introduction

This is a fictitious example (Blue Catchment) that aims to demonstrate the use of the methodology for choosing combinations of mitigation measures. A further example can be found in Appendix 12.

In the Blue catchment there are three reservoirs (named Alpha, Beta and Gamma) each of which has different uses and specific environmental impacts. These three impoundments form a cascade system and the impacts of each of the impoundments individually and in combination require to be considered.

Figure A10.1 Schematic of Blue catchment

A10.2 Identification of potential mitigation measures for the Blue catchment

The process to be undertaken follows the process detailed in section 3 of the main report to which section is an appendix and used the forms which are reproduced in Appendix 8. The table references correspond to those used in the main guidance document and Appendix 8 for the sake of consistency.

A10.2.1 STEP 1: Scoping of impoundment characteristics

Further information relating to the requirements of this step can be found is Section 3.4 of the main report (Volume 1).

The step involves the collation of the existing data available to determine the key issues relating to the impoundment and to identify potential data gaps in the existing data. The first stage in the data gathering exercise to collate data relating to the dimensions and
capacities of the reservoirs and associated impoundments and this is tabulated in Table 3.1a below.

Table 3.1a: Summary of information relating to catchment

<table>
<thead>
<tr>
<th>Reservoir</th>
<th>Alpha Reservoir</th>
<th>Beta Reservoir</th>
<th>Gamma Reservoir</th>
</tr>
</thead>
<tbody>
<tr>
<td>Catchment area (upstream)</td>
<td>3,590 ha</td>
<td>560 ha</td>
<td>2,450 ha</td>
</tr>
<tr>
<td>Surface area of reservoir</td>
<td>68 ha</td>
<td>48 ha</td>
<td>115 ha</td>
</tr>
<tr>
<td>Total capacity/volume</td>
<td>5,600 Ml</td>
<td>4,450 Ml</td>
<td>16,000 Ml</td>
</tr>
<tr>
<td>Maximal Depth</td>
<td>26 m</td>
<td>36 m</td>
<td>52 m</td>
</tr>
<tr>
<td>Maximal draw down depth</td>
<td>16 m</td>
<td>22 m</td>
<td>38 m</td>
</tr>
<tr>
<td>Compensation flow</td>
<td>none</td>
<td>23 Ml/day (depend on water level at downstream gauging station)</td>
<td>30 Ml/day (Apr-Oct)</td>
</tr>
<tr>
<td>Dam height</td>
<td>29 m</td>
<td>42 m</td>
<td>57 m</td>
</tr>
<tr>
<td>Dam length</td>
<td>233 m</td>
<td>160 m</td>
<td>195 m</td>
</tr>
<tr>
<td>Dam type</td>
<td>Earth embankment</td>
<td>Concrete gravity</td>
<td>Concrete gravity</td>
</tr>
<tr>
<td>Dam purpose</td>
<td>Flow regulation, Irrigation, Recreation</td>
<td>Water supply, Fishery, Hydropower</td>
<td>Water supply, Hydropower, Flow regulation</td>
</tr>
</tbody>
</table>

Further information relating to the characteristics of the impoundment system (cascade system) is collated in Tables 3.1(b)(i) to 3.1(b)(iii) below. A separate table for each of the three impoundments is included to enable the source of all the information to be cited.

Table 3.1(b)(i) : Characteristics of impoundment Alpha

<table>
<thead>
<tr>
<th>System description – Cascade system</th>
</tr>
</thead>
<tbody>
<tr>
<td>Characteristics of Impoundment</td>
</tr>
<tr>
<td>Impoundment Alpha</td>
</tr>
<tr>
<td>Information Source</td>
</tr>
<tr>
<td>Type of Impoundment</td>
</tr>
<tr>
<td>Water flow regulation</td>
</tr>
<tr>
<td>Operator</td>
</tr>
<tr>
<td>Use of Impoundment</td>
</tr>
<tr>
<td>Recreation</td>
</tr>
<tr>
<td>Recreation</td>
</tr>
<tr>
<td>Irrigation water demand</td>
</tr>
<tr>
<td>Operator, Local Authority</td>
</tr>
<tr>
<td>Land use in the catchment</td>
</tr>
<tr>
<td>Agriculture, nature conservation, forestry</td>
</tr>
<tr>
<td>Official census, Local authority</td>
</tr>
<tr>
<td>Conservation status</td>
</tr>
<tr>
<td>SAC and SSSI</td>
</tr>
<tr>
<td>Environmental regulator</td>
</tr>
<tr>
<td>Comments on upstream water course</td>
</tr>
<tr>
<td>Intensive agriculture production upstream</td>
</tr>
<tr>
<td>Farmer association</td>
</tr>
<tr>
<td>Comments on downstream water course</td>
</tr>
<tr>
<td>Water is released to maintain level in the Beta Reservoir below</td>
</tr>
<tr>
<td>Operator</td>
</tr>
</tbody>
</table>
Table 3.1(b)(ii) : Characteristics of impoundment Beta

<table>
<thead>
<tr>
<th>Characteristics of Impoundment</th>
<th>Impoundment Beta</th>
<th>Information Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of Impoundment</td>
<td>Water supply</td>
<td>Operator</td>
</tr>
<tr>
<td></td>
<td>Hydropower</td>
<td></td>
</tr>
<tr>
<td>Use of Impoundment</td>
<td>Electricity generation</td>
<td>Operator</td>
</tr>
<tr>
<td></td>
<td>Urban water supply</td>
<td></td>
</tr>
<tr>
<td>Land use in the catchment</td>
<td>Natural reserve</td>
<td>University</td>
</tr>
<tr>
<td>Conservation status</td>
<td>SSSI</td>
<td>Environmental regulator</td>
</tr>
<tr>
<td>Comments on upstream water course</td>
<td>Industrial activity</td>
<td>Local authority</td>
</tr>
<tr>
<td></td>
<td>Fishery production in the reservoir</td>
<td></td>
</tr>
<tr>
<td>Comments on downstream water course</td>
<td>Migratory fish present</td>
<td>Environmental regulator, universities</td>
</tr>
</tbody>
</table>

Table 3.1(b)(iii) : Characteristics of impoundment Gamma

<table>
<thead>
<tr>
<th>Characteristics of Impoundment</th>
<th>Impoundment Gamma</th>
<th>Information Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of Impoundment</td>
<td>Water supply</td>
<td>Operator</td>
</tr>
<tr>
<td></td>
<td>Hydropower</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Flow regulation</td>
<td></td>
</tr>
<tr>
<td>Use of Impoundment</td>
<td>Urban water supply</td>
<td>Operator, Local authority</td>
</tr>
<tr>
<td></td>
<td>Electricity generation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Flood mitigation</td>
<td></td>
</tr>
<tr>
<td>Land use in the catchment</td>
<td>Natural reserve, forestry</td>
<td>University, Official census</td>
</tr>
<tr>
<td>Conservation status</td>
<td>National park</td>
<td>Local authority</td>
</tr>
<tr>
<td>Comments on upstream water course</td>
<td>Intensively urbanised areas</td>
<td>Local authority</td>
</tr>
<tr>
<td></td>
<td>Interbasin transfer from adjacent catchment (28 Ml/day)</td>
<td></td>
</tr>
<tr>
<td>Comments on downstream water course</td>
<td>Critical flooding areas downstream</td>
<td>Local authority</td>
</tr>
</tbody>
</table>

A10.2.2 STEP 2: Identification of current WFD waterbody status

Further information relating to the requirements of this step can be found in section 3.5 of the main report (Volume 1).

The second step in the process is to collate data relating to the current status of the impoundment and the adjacent upstream and downstream watercourses. This information has been assembled by the agencies during their characterisation process.

Table 3.2 should be completed to record the identified pressures for the impoundment system under consideration, together with the risk category from the characterisation process (see table 3.3, Section 3.5 of the main report (Volume 1) for further information).
Table 3.2: Identified pressures on water body / water bodies

<table>
<thead>
<tr>
<th>Pressure</th>
<th>Impoundment 1</th>
<th>Impoundment 2</th>
<th>Impoundment 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waterbody ID</td>
<td>#10058</td>
<td>#10059</td>
<td>#10115</td>
</tr>
<tr>
<td>Modified (yes/no)</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Artificial (yes/no)</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Point source pollution</td>
<td>No significant</td>
<td>Yes (industrial activity and fisheries)</td>
<td>Yes (from urban areas)</td>
</tr>
<tr>
<td>Diffuse source pollution</td>
<td>Yes (farm production)</td>
<td>No</td>
<td>Yes (from urban areas)</td>
</tr>
<tr>
<td>Abstraction</td>
<td>Yes (Irrigation - 36 Ml/day from May to Sep)</td>
<td>Yes (water supply: 35 Ml/day to ‘Blue WTW’)</td>
<td>Yes (water supply: 25 Ml/day to ‘Blue WTW’)</td>
</tr>
<tr>
<td>Flow regulation</td>
<td>Yes (16Ml/day)</td>
<td>No</td>
<td>Yes (control of high flows)</td>
</tr>
<tr>
<td>Morphological alteration</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Alien species</td>
<td>Yes (Ragwort)</td>
<td>Yes (Fish)</td>
<td>No</td>
</tr>
<tr>
<td>Risk category</td>
<td>1b</td>
<td>1a</td>
<td>1a</td>
</tr>
</tbody>
</table>

A10.2.3 STEP 3: Identification of WFD target status

Further information relating to the requirements of this step can be found in section 3.6 of the main report (Volume 1).

For the purposes of this example, all three water bodies have been identified as Heavily Modified Water Bodies and therefore under the provisions of the WFD require to meet good ecological potential (GEP).

A10.2.4 STEP 4: Comparison of current status of impoundment with WFD target status

Further information relating to the requirements of this step can be found in section 3.7 of the main report (Volume 1).

Based on the characterisation information and on the preliminary guidance related to the implementation of the Water Framework Directive, the three water bodies are at risk of not achieving Good Ecological Potential. This is due to the presence of the three impoundments in the catchment. Therefore, mitigation measures are required to reduce the negative impacts and achieve Good Ecological Potential.
A10.2.5 STEP 5: Analysis of water system

Further information relating to the requirements of this step can be found in section 3.8 of the main report (Volume 1).

The background data assembled in step 1 will be applied in this step to examine the impoundment system in significantly more detail. The objective of this step is to identify the pressures which are contributing to the current ecological status. This information will be used in step 6 to assess the need for and select appropriate mitigation measures.

Table 3.4 Driving forces and related pressures

<table>
<thead>
<tr>
<th>Driving force</th>
<th>Pressure</th>
<th>Issue</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical presence of dam</td>
<td>Loss of system continuity</td>
<td>Yes</td>
<td>Impact on sediment dynamics and fish migration</td>
</tr>
<tr>
<td></td>
<td>Altered habitat</td>
<td>No</td>
<td>Not significant</td>
</tr>
<tr>
<td>Management of dam</td>
<td>Altered flow downstream</td>
<td>Yes</td>
<td>Negative impacts on natural communities Positive impact of flood defence</td>
</tr>
<tr>
<td></td>
<td>Change to river habitat</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Altered water level (fluctuation) in reservoir</td>
<td>Yes</td>
<td>Hydropower generation require peak releases during peak demand periods</td>
</tr>
<tr>
<td></td>
<td>Altered residence time within reservoir</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Release of water with altered temperature to downstream</td>
<td>Yes</td>
<td>Evidences of reduction in water temperature downstream Beta Reservoir</td>
</tr>
<tr>
<td></td>
<td>Release of water with altered oxygen content to downstream</td>
<td>Yes</td>
<td>Monitoring demonstrated depleted oxygen levels downstream of Alpha Reservoir</td>
</tr>
<tr>
<td></td>
<td>Release of water with heavy metal and/or nutrient contamination</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sediment flushing from impoundment to downstream</td>
<td>Yes</td>
<td>Monitoring demonstrated high sediment levels downstream of Gamma Reservoir</td>
</tr>
<tr>
<td></td>
<td>Fish entrainment into intakes (turbines)</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Management of reservoir</td>
<td>Engineering/ (intensive) maintenance of reservoir shoreline (beach, housing, steep shorelines etc)</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Excavation within reservoir</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fish stocking</td>
<td>Yes</td>
<td>Fish farms in Bet Reservoir</td>
</tr>
<tr>
<td></td>
<td>Recreation and boating - PAH contamination</td>
<td>Yes</td>
<td>Recreation is an important economic activity in the Alpha Reservoir</td>
</tr>
<tr>
<td></td>
<td>General recreation</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Management of river/streams</td>
<td>Altered river channel meandering</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Development of floodplains along river</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Angling</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Management of catchment</td>
<td>Agricultural use / development of reservoir catchment</td>
<td>Yes</td>
<td>Intensive agriculture upstream Alpha Intensive urbanisation upstream Gamma Reservoir</td>
</tr>
</tbody>
</table>
### Table 3.5 Potential impacts and issues

<table>
<thead>
<tr>
<th>Potential Impacts/Issues</th>
<th>WFD objectives being met?</th>
<th>Impoundment Alpha</th>
<th>Impoundment Beta</th>
<th>Impoundment Gamma</th>
<th>comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ecology</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Macro-fauna</td>
<td></td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>• Phytoplankton</td>
<td></td>
<td>Unknown</td>
<td>Yes</td>
<td>Unknown</td>
<td></td>
</tr>
<tr>
<td>• Macrophytes / phytobenthos</td>
<td></td>
<td>Unknown</td>
<td>Unknown</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>• Benthic invertebrates</td>
<td></td>
<td>Unknown</td>
<td>Yes</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>• Fish fauna</td>
<td></td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Hydromorphology</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Quantity and dynamics of flow</td>
<td></td>
<td>No</td>
<td>No</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>• Connection to groundwater bodies</td>
<td></td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>• Residence time (lakes)</td>
<td></td>
<td>Unknown</td>
<td>Yes</td>
<td>Unknown</td>
<td></td>
</tr>
<tr>
<td>• River continuity</td>
<td></td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>• Morphological conditions</td>
<td></td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Physicochemical</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Temperature</td>
<td></td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>• Oxygen concentration</td>
<td></td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>• Nutrients</td>
<td></td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>• Pollutants</td>
<td></td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>• Transparency (lakes)</td>
<td></td>
<td>Yes</td>
<td>Unknown</td>
<td>Unknown</td>
<td></td>
</tr>
<tr>
<td>• Priority substance pollutants</td>
<td></td>
<td>Unknown</td>
<td>Unknown</td>
<td>Unknown</td>
<td></td>
</tr>
</tbody>
</table>

**A10.2.6 STEP 6: Identification of potential mitigation measures based on effectiveness**

Further information relating to the requirements of this step can be found in section 3.9 of the main report (Volume 1).

Once the water system has been characterised and driving forces and pressures on the system have been identified, consideration can be given to the potential measures which could be implemented to mitigate specific impacts on the water system being examined to ensure that the waterbody meets the requirements of the WFD.

When selecting the measures, impacts on existing natural habitat (SSSI’s etc) and other uses of the impoundment and downstream should be considered. An assessment of the effectiveness of each of the potential mitigation measures for the specific situation under consideration needs to be determined. Because the effectiveness is difficult to quantify, we suggest using a relative scale as presented in table 3.6a.

It is also important to estimate when the measure might take effect (before 2015, between 2015 and 2021, between 2021 and 2027 and after 2027). The timescale is then
used as a further way to rank effectiveness. Table 3.6b demonstrates how this should be done for each mitigation measure selected. The timescale depends on the year of implementation as well as the measure itself: does it deliver direct results, or gradually over time?

**Table 3.6a Presentation of effectiveness of individual measures**

<table>
<thead>
<tr>
<th>Effectiveness of single measures</th>
<th>Presentaion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effect per biological element</td>
<td></td>
</tr>
<tr>
<td>strong positive effect</td>
<td>+++</td>
</tr>
<tr>
<td>moderate positive effect</td>
<td>++</td>
</tr>
<tr>
<td>limited positive effect</td>
<td>+</td>
</tr>
<tr>
<td>no effect</td>
<td>~</td>
</tr>
<tr>
<td>Negative effect</td>
<td>-</td>
</tr>
</tbody>
</table>

**Table 3.6b Criteria for evaluating the likelihood of single measures realising the WFD target**

<table>
<thead>
<tr>
<th>Period in which the effect is expected</th>
<th>Likelihood that the WFD target is realised in 2015</th>
<th>Presentation</th>
</tr>
</thead>
<tbody>
<tr>
<td>before 2015</td>
<td>Very likely</td>
<td>+++</td>
</tr>
<tr>
<td>Between 2015 and 2021</td>
<td>Likely</td>
<td>++</td>
</tr>
<tr>
<td>Between 2021 and 2027</td>
<td>Maybe</td>
<td>+</td>
</tr>
<tr>
<td>After 2027</td>
<td>Not clear</td>
<td>~</td>
</tr>
<tr>
<td></td>
<td>Unlikely</td>
<td>-</td>
</tr>
</tbody>
</table>
### Table 3.7: Potential mitigation measures, indicating effectiveness and period for improvement

<table>
<thead>
<tr>
<th>Mitigation measure</th>
<th>Effectiveness per biological element</th>
<th>Period for improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Phytoplankton</td>
<td>Macrophytes and phytobenthos</td>
</tr>
<tr>
<td>Introduce fish pass for movement downstream (9)</td>
<td>~</td>
<td>~</td>
</tr>
<tr>
<td>Basic compensation flow (17)</td>
<td></td>
<td>+</td>
</tr>
<tr>
<td>Provide freshets to mimic minor natural floods and encourage upstream migration of fish (also used for recreational river use) (19)</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>Environmentally acceptable flow rates (21)</td>
<td>~</td>
<td>++</td>
</tr>
<tr>
<td>Draw off water at a number of pre-determined levels through use of a multi-level intake structure (39)</td>
<td>~</td>
<td>++</td>
</tr>
<tr>
<td>Design / retrofit turbines to inject atmospheric oxygen into releases (48)</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>Provide and regulate a spatial zoning system to balance recreation and wildlife needs (designate areas as ‘no entry’ to boats) (90)</td>
<td>~</td>
<td>+</td>
</tr>
<tr>
<td>Nutrient control (110)</td>
<td>+++</td>
<td>++</td>
</tr>
</tbody>
</table>

**A10.2.7 STEP 7: Identification of suitable combinations of measures**

Further information relating to the requirements of this step can be found in section 3.10 of the main report (Volume 1).

After the assessment of the effectiveness of each of the potential mitigation measures in meeting each WFD objective, various combinations of measures should then be considered in order to ensure that objectives of the WFD can be realised. Interactions between measures should be taken into account as individual measures can strengthen
or weaken the effects of other measures. The effectiveness of combinations is difficult to quantify and is also case-specific.

When considering each potential combination, the probability of the combination of measures realising the WFD objectives in the timescales required can be indicated and presented in a similar way to that used to assess the effectiveness of single measures as shown in Tables 3.8a, 3.8b and 3.8c below.

**Table 3.8a Presentation effectiveness combinations of measures**

<table>
<thead>
<tr>
<th>Effect per biological element</th>
<th>Presentation</th>
</tr>
</thead>
<tbody>
<tr>
<td>strong positive effect</td>
<td>+++</td>
</tr>
<tr>
<td>moderate positive effect</td>
<td>++</td>
</tr>
<tr>
<td>limited positive effect</td>
<td>+</td>
</tr>
<tr>
<td>no effect</td>
<td>~</td>
</tr>
<tr>
<td>Negative effect</td>
<td>-</td>
</tr>
</tbody>
</table>

**Table 3.8b Criteria for evaluating the likelihood of combination of measures realising the WFD target**

<table>
<thead>
<tr>
<th>Period in which the effect is expected</th>
<th>Likelihood that the WFD target is realised in 2015</th>
<th>Presentation</th>
</tr>
</thead>
<tbody>
<tr>
<td>before 2015</td>
<td>Very likely</td>
<td>+++</td>
</tr>
<tr>
<td>Between 2015 and 2021</td>
<td>Likely</td>
<td>++</td>
</tr>
<tr>
<td>Between 2021 and 2027</td>
<td>Maybe</td>
<td>+</td>
</tr>
<tr>
<td>After 2027</td>
<td>Not clear</td>
<td>~</td>
</tr>
<tr>
<td>Unlikely</td>
<td></td>
<td>-</td>
</tr>
</tbody>
</table>

**Table 3.8c Criteria for evaluating the likelihood of single measures realising the WFD target**

<table>
<thead>
<tr>
<th>Effectiveness combination of measures</th>
<th>Period in which the effect is expected</th>
<th>Likelihood that the WFD target is realised in 2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>strong positive effect</td>
<td>before 2015</td>
<td>Very likely</td>
</tr>
<tr>
<td>moderate positive effect</td>
<td>Between 2015 and 2021</td>
<td>Likely</td>
</tr>
<tr>
<td>limited positive effect</td>
<td>Between 2021 and 2027</td>
<td>Maybe</td>
</tr>
<tr>
<td>no effect</td>
<td>After 2027</td>
<td>Not clear</td>
</tr>
<tr>
<td>Negative effect</td>
<td></td>
<td>Unlikely</td>
</tr>
</tbody>
</table>

Chance  | Presentation |
---------|--------------|
Very likely | +++ |
Likely     | ++  |
Maybe      | +   |
Not clear  | ~   |
Unlikely   | -   |
Table 3.9: Potential combinations of mitigation measures.

<table>
<thead>
<tr>
<th>Combination</th>
<th>Mitigation measures</th>
<th>Effectiveness</th>
<th>Period for improvement</th>
<th>Chance of realising WFD aim</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>9, 17, 39, 110</td>
<td>limited positive effect</td>
<td>Before 2015</td>
<td>+</td>
</tr>
<tr>
<td>C2</td>
<td>9, 19, 21, 110</td>
<td>moderate positive effect</td>
<td>Between 2015 and 2021</td>
<td>++</td>
</tr>
<tr>
<td>C3</td>
<td>9, 21, 48, 90, 110</td>
<td>moderate positive effect</td>
<td>Between 2015 and 2021</td>
<td>++</td>
</tr>
<tr>
<td>C4</td>
<td>9, 19, 21, 39, 48, 90, 110</td>
<td>strong positive effect</td>
<td>Between 2015 and 2021</td>
<td>+++</td>
</tr>
</tbody>
</table>

A10.2.8 STEP 8: Calculation of financial and socio-economic costs

Further information relating to the requirements of this step can be found in section 3.11 of the main report (Volume 1).

For each of the selected combination of measures, the financial costs and other possible issues including the socio-economic impacts need to be identified. Impacts on existing natural habitat and other uses of the reservoir, catchment and up- and downstream (recreation, flood control etc) should have been considered when selecting the measures in step 6. They should also be brought into scope again in this step because they can be important and help in deciding which combination of measures to choose when:

- Two or more (combinations of) measures turn out to be very close regarding their calculated (financial) cost effectiveness;
- The impacts on these related issues are large, in which case water managers may have a potential argument to request derogation from the WFD for a particular water system or the selected (combination of) measures should be re-evaluated.

Table 3.10: Identifying financial costs and other socio-economic effects

<table>
<thead>
<tr>
<th>Nr.</th>
<th>Combination of measures</th>
<th>Net Present Value</th>
<th>Other socio-economic effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>9, 17, 39, 110</td>
<td>£ 150,000</td>
<td>Reduction in farming activities</td>
</tr>
<tr>
<td>C2</td>
<td>9, 19, 21, 110</td>
<td>£ 170,000</td>
<td>Reduction in farming activities</td>
</tr>
<tr>
<td>C3</td>
<td>9, 21, 48, 90, 110</td>
<td>£ 220,000</td>
<td>Reduction in farming activities</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Impacts on recreation</td>
</tr>
<tr>
<td>C4</td>
<td>9, 19, 21, 39, 48, 90, 110</td>
<td>£ 400,000</td>
<td>Reduction in farming activities</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Impacts on recreation</td>
</tr>
</tbody>
</table>
A10.2.9 STEP 9: Ranking of combinations according to cost-effectiveness

Further information relating to the requirements of this step can be found in section 3.11 of the main report (Volume 1).

Having completed steps 1 through 8, the combinations of measures can now be ranked according to cost-effectiveness (financial costs vs. effectiveness in reaching target WFD status as defined for 4 biological elements). This can be done with help of a scheme as presented in Table 3.11. The table collates the information from steps 7 and 8 and shows that the ranking of cost-effectiveness is based on the chance to reach the WFD-aim, the financial costs of the combination of measures (Net Present Value) and the other expected socio-economic effects.

Table 3.11: Selecting the most cost-effective combination of measures

<table>
<thead>
<tr>
<th>Nr.</th>
<th>Combination of measures</th>
<th>Likelihood of reaching WFD target</th>
<th>Net Present Value</th>
<th>Other socio-economic effects</th>
<th>Ranking of measures based on cost-effectiveness</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Effect Period</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C1</td>
<td>Combination of M9, M17, M39, M110</td>
<td>limited positive effect Before 2015</td>
<td>++ £ 150,000</td>
<td>Reduction in farming activities</td>
<td>3</td>
</tr>
<tr>
<td>C2</td>
<td>Combination of M9, M19, M21, M110</td>
<td>moderate positive effect Between 2015 and 2021</td>
<td>++ £ 170,000</td>
<td>Reduction in farming activities</td>
<td>1</td>
</tr>
<tr>
<td>C3</td>
<td>Combination of M9, M21, M48, M90, M110</td>
<td>moderate positive effect Between 2015 and 2021</td>
<td>++ £ 220,000</td>
<td>Reduction in farming activities Impacts on recreation</td>
<td>2</td>
</tr>
<tr>
<td>C4</td>
<td>Combination of M9, M19, M21, M39, M48, 90, M110</td>
<td>strong positive effect Between 2015 and 2021</td>
<td>+++ £ 400,000</td>
<td>Reduction in farming activities Impacts on recreation</td>
<td>4</td>
</tr>
</tbody>
</table>

STEP 10: Selection of most cost-effective combination of measures

Combination 2 was selected because has the best balance between ‘net present value’, socio-economic effects and likelihood of reaching the WFD target of good ecological potential by 2015.

STEP 11: Identification of actions to be taken to comply with WFD

Other actions which have been identified as being required include a need for additional environmental monitoring to confirm that the improvements in ecological status of the impoundments and the upstream and downstream reaches of the watercourses predicted as a result of the implementation of the mitigation measures. In addition, due to the impact of agriculture and urban development in the catchment, there is a requirement to
consider how current and future agricultural and urban development policies will impact on the ecological status of the impoundments. An ideal vehicle for these deliberations is the river basin catchment management plan being prepared for the area.
APPENDIX 11

WFD29: MANAGEMENT STRATEGIES AND MITIGATION MEASURES REQUIRED TO DELIVER THE WATER FRAMEWORK DIRECTIVE.

REFERENCES FOR TECHNICAL APPENDICES
APPENDIX 11: REFERENCES FOR TECHNICAL APPENDICES


Freissinet, C, Walther, R, O'Hare, M.T., Murphy, KJ. and Wahl, B. (2002). Wave impact on the lake shores / reed beds: A report to the European Union for the Eurolakes project on Loch Lomond, Lake Constance and Lac de Bourget.


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APPENDIX 12

WFD29: MANAGEMENT STRATEGIES AND MITIGATION MEASURES REQUIRED TO DELIVER THE WATER FRAMEWORK DIRECTIVE.

TRIAL OF DRAFT PRELIMINARY GUIDANCE
EXECUTIVE SUMMARY

The draft preliminary guidance was trialled in two different catchments with both trials being undertaken in a different manner. The trial on River Dee catchment did not use the guidance document to undertake a step by step analysis of the impoundments, their impacts and mitigation measures required but rather compared the mitigation measures already in place in the catchment with those detailed in the mitigation measures spreadsheet of the original guidance. The result of this trial was the identification of additional measures which have proven effective in the catchment which should be added to the mitigation spreadsheet.

The trial undertaken in the Glendevon water treatment works catchment was undertaken following an assessment of the guidance document and the proposed methodology. This assessment identified several areas where the document required clarification, largely to make the document more user friendly and also resulted in the addition of four additional steps in the step by step analysis.
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A12.9 MONITORING DATA RELATING TO THE RIVER DEVON CATCHMENT
A12.9.1 Water Quality Data
A12.9.2 Discharge Data
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A12.1 INTRODUCTION

A12.1.1 Background and objectives of trial exercise

The background to this document is detailed in section 1.1 of volume 1 to which this report is an appendix. The purpose of the trials was to test the best practice guidance on two catchments which are impacted by impoundments and identify a program of cost effective mitigation measures which would be required to achieve maximum ecological potential/good ecological potential (MEP/GEP).

Initially it was proposed that the two trial catchments would be the Tummel in Scotland and the Dee in North Wales. The Tummel catchment contains the Tummel Hydropower Scheme and incorporates a range of natural and artificial impoundments,(i.e. natural lakes and reservoirs which have been created where no lake previously existed) and from large-scale dams to small diversion weirs on some of the smaller watercourses which feed into the system. In addition large quantities of water are transferred from one catchment to another via tunnels. However, following discussions between the Hydropower operators on the Tummel and SEPA it was decided that this catchment would be replaced by the Glendevon system operated by Scottish Water which provides drinking water for large areas of Fife and comprises five impoundment structures on the River Devon and two of its tributaries.

The River Dee is very heavily managed. The flow is regulated from several reservoirs in the headwaters to maintain flows for abstraction, mainly near the tidal limit. Water is abstracted for potable and non-potable water supply, as well as canal navigation. Another reservoir provides direct supply outside the catchment. The system is also managed to reduce flood risk, to generate hydropower, and to maintain adequate flows and water quality in the Dee estuary. Releases are also made for white-water canoeing. The catchment is a designated SAC for salmon and supports extensive recreational fisheries.

The recommendations made during this trial exercise have been incorporated into the preliminary guidance document (Volumes 1 and 2) and are detailed in this document to record the development of the project.

A12.1.2 Methodology

Guidance was provided through the brief, the proposal, the Client Steering Group and internal steering by the project team, which included international specialists. A list of the steering group members can be found in Appendix 13, Volume 2.

Both trials involved undertaking a site visit collating background information on the site and then asking the potential users (the agency staff and the site operators) to apply the best practice guidance which will help them identify which mitigation measure to implement, the likely costs and implications, the feasibility and monitoring etc., with assistance being offered by the consultants. The results of the trials were then used to improve the guidance.
A12.1.3 Structure of the report

Section 1 of this report provides the background to the project and an introduction to Trial exercise. Sections 2 and 3 discuss the methodology and results of the Glendevon and Dee catchment trials. Section 4 discusses the limitations of the draft guidance document and problems identified during the trials while Section 5 details the recommended amendments to the Guidance document.
A12.2 GLENDEVON WATER TREATMENT WORKS CATCHMENT TRIALS

A12.2.1 Introduction

A site visit was made to the five dams within the Glendevon WTW catchment before a meeting to trial the guidance the following day. Owen Bramwell and David Duff of Scottish Water, Antonio Ioris and Paul da Cruz of SEPA and Wendy Johnston of Posford Haskoning attended both days with Hilary Smithers from SEPA being present on the second day only.

It is important to emphasise that this was recognised by participants as purely a desk top exercise. Formal assessment of these impoundments and any resulting mitigation measures will be undertaken by SEPA at a later date.

A12.2.2 Description of the catchment

There are five reservoirs which supply raw water to Glendevon WTW; Upper Glendevon, Lower Glendevon; Glensherup, Glenquey and Castlehill and these are shown in Figure A12.2.1. In addition Frandy Fish Farm lies on the River Devon, downstream of Lower Glendevon reservoir and there is an impoundment weir in the river which is also considered. A series of photographs of each of the five reservoirs are shown below.

Table 12.1: summary of Information relating to catchment

<table>
<thead>
<tr>
<th>Reservoir</th>
<th>Upper Glendevon</th>
<th>Lower Glendevon</th>
<th>Glensherup</th>
<th>Glenquey</th>
<th>Castlehill</th>
</tr>
</thead>
<tbody>
<tr>
<td>Catchment area</td>
<td>4627 acres</td>
<td>1160 acres</td>
<td>1300 acres</td>
<td>1377 acres</td>
<td>6370 acres</td>
</tr>
<tr>
<td>Surface area of</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>reservoir</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total capacity/volume</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Active volume</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dead space volume</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximal depth</td>
<td>102 ft</td>
<td>30 m</td>
<td>140 ft</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximal draw down depth*</td>
<td>15ft</td>
<td>15 ft</td>
<td>8m</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Compensation flow</td>
<td>No legal requirement</td>
<td>4.6 million gallons/day; 0.343 m³</td>
<td>0.375 mgd or 0.02 m³</td>
<td>6.5 mgd or 0.342 m³</td>
<td></td>
</tr>
<tr>
<td>Dam height</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dam length</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* report in metres above bed of reservoir i.e. maximal depth of reservoir is 28m and the depth at maximal draw down is 15m from bed of reservoir (13m of water can be drawn down)

Upper Glendevon Reservoir

Upper Glendevon Reservoir was constructed in 1955 and was built as a result of concerns that the lower Glendevon reservoir could dry up and thus it was felt that a second reservoir was required to make the supply more reliable with population increase in the Fife region. The construction of the dam resulted in the flooding of the valley with
the loss of a farm which was relocated in the hills behind the new reservoir. A penstock pipeline was constructed through the embankment to allow water to pass downstream via the River Devon to Lower Glendevon reservoir. Although there is no statutory compensation flow, this draw down mechanism generally passes between 0.5 -1 m$^3$ of water from this reservoir to Lower Glendevon. The flows can be increased mechanically on the site if the level in the lower reservoir falls. This reservoir can be drawn down by 80ft.

A concrete spillway carries excess waters from this reservoir downstream and a 24 inch pipe carries water, via gravity to the WTW. The reservoir is not currently used for recreational purposes and while there is a small population of brown trout in the reservoir these fish are small in size and the reservoir is not used for fisheries. The area is potentially attractive for local tourism due to the scenic beauty of the landscape.

There are plans to install a turbine in this dam to generate power for the national grid but to date these plans have not been submitted to SEPA for comment.

Figure A12.1: Upper Glendevon Reservoir (Wendy Johnston, Posford Haskoning Ltd.)

Lower Glendevon Reservoir
Lower Glendevon reservoir is a long narrow reservoir some 1.5km in length. The reservoir was constructed in 1924 and supplies 80% of the total raw water to the WTW. A 30 inch pipe and a 24 inch pipe carry raw water from Lower Glendevon to the WTW.

A 15 inch pipe carried compensation flows from the reservoir to a point some 100m downstream of the dam and discharges into the River Devon. While Scottish Water are satisfied that compensation flows are exceeded, there is no flow measurement operating
on this system as the existing venturi measurement system is no longer in operation. Flow measurement will be required to meet the requirements of the WFD but it was agreed that this should not be too difficult to fix. A 100m stretch of the River Devon is dry but it was agreed that the costs of mitigating against this may well be disproportionate in relation to the benefits which would be accrued.

The Impoundment is used for fisheries and is stocked with rainbow trout grown locally in Blairgowrie.

**Figure A12.2: Lower Glendevon Reservoir (Wendy Johnston, Posford Haskoning Ltd.)**

![Image of Lower Glendevon Reservoir](image)

**Frandy Fish Farm**
Frandy Fish Farm hatches and grows on rainbow trout. The fish farm extracts water from the River Devon downstream of the compensation flow discharge from Lower Glendevon with a weir across the river. It currently has consent to discharge 19008 m³/day (220 l/sec) of effluent into the watercourse, with a BOD no greater than 3 mg/l more than the inlet BOD and a suspended solids concentration no greater than 5 mg/l more than the inlet suspended solids concentration. In future Frandy Fish Farm is also likely to be required to obtain specific authorisation to abstract water and to manage the weir, although the details of the new regulatory regime were not available at the time of this exercise and the fish farm was not included in the study.
Figure A12.3: Glendevon Reservoirs Location Plan
Glensherup Reservoir
Glensherup reservoir lies on the Glensherup Burn and dam spills via a concrete step spillway to the Glensherup Burn. Compensation flow this flow was previously undertaken via a flume but this is no longer in operation and some form of flow measurement will require to be installed. The reservoir is used for fisheries and is stocked with Rainbow Trout from Blairgowrie.

Figure A12.4 – Glensherup reservoir (Wendy Johnston, Posford Haskoning Ltd.)
Glenquey Reservoir
Glenquey reservoir lies on the Glenquey Burn and was constructed in 1905 and the dam is an earth embankment is which was reinforced in 1995 as a result of concerns over its structural integrity. A concrete spillway discharges flows from the reservoir to the Glenquey burn which subsequently discharges to the River Devon.

Figure A12.5: Glenquey Reservoir compensation flow and spillway channel
(Wendy Johnston, Posford Haskoning Ltd.)
Castlehill Reservoir
Castlehill reservoir is the lowest of the five reservoirs in the catchment. The dam is a concave structure, and the spill way runs along the top of the dam and cascades down the front edge of the structure. Flows downstream of the reservoir are monitored by means of a gauge board at a notch weir some 100m downstream of the reservoir and
there a flow measuring facilities maintained by SEPA (See section 6 of this report for more information)

Raw water from this reservoir is pumped to Glendevon WTW via an 800mm pipe to Glendevon WTW and as a result of this energy requirement is only used when levels in the other reservoirs are low.

A12.2.3 General catchment issues

The reservoirs have a good fishery with populations of brown trout, rainbow trout, perch and pike. There do not appear to be any fisheries issues downstream of the WTW and SEPA has advised that no complaints have been received from local fisheries bodies about the impact of the reservoirs on fish populations in the River Devon catchment. The Devon Angling Association is the main fisheries organisation, and it owns the fisheries rights in Glenquey reservoir. Little data appears to exist relating to the invertebrate populations in the catchment as although Scottish Water undertake chemical analysis of the water within the reservoir no biological analysis is undertaken. SEPA undertake monitoring of water quality at five sites in the catchment (see section 6 for more information).

A12.3 DESCRIPTION OF THE WATER TREATMENT WORKS AND ASSOCIATED ISSUES

Glendevon WTW supplies drinking water to a large area of Fife including Dumferline, Kincardine, Moss Moran, Lochgelly and part of Glenrothes, serving a population of 180 000. Treatment is via a single stage gravity flow filtration with aluminium sulphate and sulphuric acid being used to assist in the removal of suspended matter

Figure A12.6 – Castlehill Reservoir Dam (Wendy Johnston, Posford Haskoning Ltd.)
and balance the pH and a maximum of 90 megalitres of water being treated daily, with a normal daily average of about 75-80 Ml/day.

The reservoirs in this catchment are covered by a Water Order, an act of parliament which specifies the compensation flows which must be released below four of the five reservoirs. Although releases are being made they are currently not measured. The Water Order also requires that 1000 megalitres of water is retained within the system for release in the event of a pollution incident downstream but as yet there has never been a requirement to release this water.

SEPA staff advised that under the implementation of the new Controlled Activities Regulations, existing Water Order conditions, including specifications for compensation flow release, will be transferred into a SEPA impoundment / abstraction licence that will be required for the operation of the impoundments and abstractions that form part of the scheme. There is unlikely to be any assessment of the environmental impact of the scheme operation at the time of the ‘transfer’ of the consent from a Water Order into a SEPA licence. If necessary, this will be undertaken as part of a future WFD ecological status objective review programme.

In the last thirty years of operation the quality of the raw water has deteriorated with an increased suspended solids loading. There have been no noticeable changes in land use in the catchment to account for this increased loading although there has been increased afforestation in the catchment by Scottish Woodlands Trust. While the exact increase in Suspended Solids has not been determined, Scottish Water advise the amount of aluminium sulphate required to treat the water has increased from 19 ppm to 40 ppm.

There is a low to medium cryptosporidium risk associated with the reservoirs and while cryptosporidium had been detected in the raw water it has not passed through the treatment process and been detected in the treated water. Blue green algal blooms were noted in Castlehill reservoir in 1989 and 2001 but these were not serious and the intake from the reservoir was shut down to prevent contamination of the treatment plant. Growths of ragwort, introduced as a result of fish restocking are prevalent in Glensherup reservoir and during periods of reduced water levels in the reservoir this weed rots rapidly giving off a strong metallic odour and taste and the intake to the water treatment works is shut down during these periods to prevent contamination of the water supply. This highlights that the current management of the reservoirs enables the water quality in each of the reservoirs to be considered separately.

Leakage reduction is being addressed in the Fife area. A 35Ml target for leakage reduction has been set for the area, of which 15Ml has been achieved so far.

**A12.4 METHODOLOGY**

The planned methodology was to use the case studies as a trial of the draft guidance document as written. However, at the beginning of the meeting it was agreed that some changes to the document were required, and it was sensible to trial the revised guidance.
A12.4.1 Summary of changes to the guidance document

The changes made are discussed in detail in section 5 but for convenience they are summarised here. It was generally accepted that the main body of the guidance was good, with good supporting information but it was felt that the sheer volumes of information made it difficult to identify the key sections of the guidance. Although changes were made throughout the guidance, the main ones summarised in this section were to the actual step by step guidance. The original guidance detailed 7 main steps in the process while the new process has 11 steps. This new 11 step procedure is detailed in figure A12.7 overleaf.
Figure A12.7: Flow diagram to assist in identifying appropriate mitigation measures

1. Scoping of Impoundment Characteristics
2. Identification of current WFD waterbody status
3. Identification of WFD target status
4. Comparison of current status of impoundment with target WFD-status
   - If current status is not target WFD-status in 2015
     - Take remedial action
   - If current status is target WFD-status in 2015
     - No further mitigation required
5. Analysis water system (driving forces, pressures, related status/impact)
6. Identification of potential mitigation measures based on effectiveness
7. Identification of suitable combinations of measures, taking into account interactions between measures
8. Calculation of financial and socio-economic costs
   - Too expensive and/or too little effect
   - Costs and effectiveness ok
9. Ranking of combinations according to cost-effectiveness and, if relevant, other effects
10. Selection of most cost-effective combination of measures
    - Disproportionate costs, reassess or apply for derogation
    - Implement selected combination of measures
11. Identification of actions to be taken to comply with the WFD

Results of steps 2 and 4: Section 3.8 (Drivers and Pressures Models); Section 4 (Guidance sheets); Appendix 4: Agencies, impoundment managers, Stakeholders.

Results of step 5: Section 3.9 (Mitigation Measures models); Section 4 (Guidance sheets); Section 5 (Mitigation Measures Spreadsheet); Agencies, impoundment managers, Stakeholders.

Results of step 6 and other sources of information used in step 6

Results of step 7: Section 6 (costs spreadsheet); Appendix 7: Agencies, impoundment managers, Stakeholders.

Results of step 8 and other sources of information used in step 8

Results of step 9 and other sources of information used in step 9

Results of Steps 1 - 10
A12.5 IDENTIFICATION OF APPROPRIATE MITIGATION MEASURES FOR THE GLENDEVON RESERVOIRS

As discussed above, appropriate mitigation measures for the Glendevon reservoirs were determined following the step by step guidance and the decisions made in each step are discussed below.

A12.5.1 Step 1: Scoping of Impoundment Type

This step involved collating the key characteristics of the impoundment as shown in table 2.1 below. This information was gained from the site visit and information provided by Owen Bramwell of Scottish Water. An artificial impoundment is one where there was no reservoir prior to construction i.e. where a valley has been flooded and a dam constructed to permit the storage of water while a natural impoundment is an impoundment where there as already some form of loch or lake in situ prior to operation of the waterbody as an impoundment.

Table A12.2: Characteristics of Impoundment(s)

<table>
<thead>
<tr>
<th>Characteristics of Impoundment</th>
<th>Upper Glendevon (1)</th>
<th>Lower Glendevon (2)</th>
<th>Glensherup (3)</th>
<th>Glenquey (4)</th>
<th>Castlehill (5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use of Impoundment</td>
<td>Water supply</td>
<td>Water supply &amp; recreation (fishing)</td>
<td>Water supply</td>
<td>Water supply</td>
<td>Water supply &amp; recreation (fishing)</td>
</tr>
<tr>
<td>Type of Impoundment</td>
<td>Artificial</td>
<td>Natural</td>
<td>Natural</td>
<td>Natural</td>
<td>Natural</td>
</tr>
<tr>
<td>Land use in the catchment</td>
<td>Forestry and rough grazing</td>
<td>Forestry and rough grazing</td>
<td>Forestry and rough grazing</td>
<td>Forestry and rough grazing</td>
<td></td>
</tr>
<tr>
<td>Conservation status</td>
<td>none</td>
<td>none</td>
<td>none</td>
<td>none</td>
<td>none</td>
</tr>
</tbody>
</table>

A12.5.2 Step 2: Identification of current waterbody status

The second step in the process was to identify the current WFD status of the waterbody and the pressures on it. The current status of the watercourse is normally determined by the collation of biological and chemical data collected by the agency and/or the impoundment managers. In this instance, as the local agency officer was not available we did not know what data was held by SEPA nor was there any available data from Scottish Water although they do routinely monitor water quality within the impoundments. Subsequent conversations within these organisations identified that there was some information held but that it was unlikely to be sufficient and that further information/monitoring would be required. Regardless of the fact that there was no data available, it was agreed that in all likelihood additional monitoring would be required.

Information relating to the pressures in the waterbodies under consideration are recorded in the document ‘Pressures and Impacts on Scotland's Waters’ prepared by SEPA and currently out for consultation (www.sepa.org.uk). The catchment is divided into three
waterbodies using SEPA’s classification with the Upper and Lower Glendevon and Castlehill reservoirs belonging to one waterbody and Glensherup and Glenquey being two separate waterbodies. From this document, the pressures for the catchment were identified (see Table 2.2). No pressures were detailed for the Glensherup and Glenquey waterbodies which highlights that the knowledge of the catchment, area and issues is vital to the assessment process although it may not always be available or have sufficient level of detail.

Table A12.3: Identified Pressures on Waterbody/Waterbodies

<table>
<thead>
<tr>
<th>Pressure</th>
<th>Upper Glendevon (1)</th>
<th>Lower Glendevon (2)</th>
<th>Glensherup (3)</th>
<th>Glenquey (4)</th>
<th>Castlehill (4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Point source pollution</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Diffuse source pollution</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Abstraction</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Flow regulation</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Morphological alteration</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Alien species</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

1 2 forestry in area not considered to be an issue (SEPA)
3 ragwort in reservoir but not considered to be an issue (SEPA)

A12.5.3 Step 3: Identification of Water Framework Directive targets

The determination of good ecological status or good ecological potential for water bodies is beyond the scope of the guidance so during this trial it was assumed that the WFD target was to return the waterbodies in question to good ecological potential.

A12.5.4 Step 4: Compare current status of impoundment with desired WFD status

In this instance we did not have the information relating to the WFD targets required in step 3 and hence it was not possible to accurately compare the current status of the waterbodies with the target status. It was therefore assumed that the waterbodies did not currently meet the WFD requirements and therefore the next step in the process was undertaken. In future, targets will be set and the details of how the comparisons will be made are highlighted in the Phase 2 report.

A12.5.5 Step 5: Analyse water system

Consideration was then given to the reasons why the waterbodies were failing to comply with the requirements of the WFD. In order to do this, Table 2.3 was completed and if the pressures were considered to be an issue with respect to any of the impoundment structures, the impoundment number was added in the ‘Issue (yes/no)’ column with the impoundment structures being numbered as detailed in Tables 2.1 and 2.2 above. It was not possible to fully complete this exercise as there was a lack of data regarding potential issues as a result of the lack of data relating to the site. In reality, it is likely that a table for each of the impoundment structures would require to be completed (table 2.3).
Due to the lack of data there was considerable reliance on the local and specialised knowledge within the group in assessing the water systems and some of the decisions made were only possible as a result of this specialist/expert knowledge.

Table A12.4 Driving forces and related pressures

<table>
<thead>
<tr>
<th>Driving force</th>
<th>Pressure</th>
<th>Issue</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical presence of dam</td>
<td>Loss of system continuity</td>
<td>No</td>
<td>Presence of dams is an obvious break to continuity but not considered to be causing a real issue as there is a compensation flow from each of the reservoirs.</td>
</tr>
<tr>
<td>Altered habitat</td>
<td></td>
<td>No</td>
<td>It was not considered that the habitats had been altered significantly primarily as the reservoirs have been there for several decades and the habitats have adapted but also due to the compensation flows. However as this is a steady rate this is not ‘natural’ and consideration should be given to altering for</td>
</tr>
<tr>
<td>Management of dam</td>
<td>Altered flow downstream</td>
<td>1,2,3,4,5</td>
<td>Reduced but constant flow downstream due to compensation flow requirements</td>
</tr>
<tr>
<td>Change to river habitat</td>
<td></td>
<td>No</td>
<td>It was not considered that the habitats had been altered significantly primarily as the dams have been in situ for several decades but also due to the compensation flows</td>
</tr>
<tr>
<td>Altered water level (fluctuation) in reservoir</td>
<td></td>
<td>No</td>
<td>Water level fluctuations although significant in some of the dams are not considered to be having a significant impact on the water bodies.</td>
</tr>
<tr>
<td>Altered residence time within reservoir</td>
<td></td>
<td>No</td>
<td>Not considered to be an issue. Castlehill has had to shut down its intake due to a tainting of the water supply but the causes of this have not been determined. There were minimal reports of algal blooms presumably due to the lack of nutrient input</td>
</tr>
<tr>
<td>Release of water with altered temperature to downstream</td>
<td></td>
<td>No</td>
<td>No evidence to suggest this is an issue but may need monitoring to confirm</td>
</tr>
<tr>
<td>Release of water with altered oxygen content to downstream</td>
<td></td>
<td>No</td>
<td>No evidence to suggest this is an issue but may need monitoring to confirm</td>
</tr>
<tr>
<td>Release of water with heavy metal and/or nutrient contamination</td>
<td></td>
<td>No</td>
<td>No evidence of this but sampling may be required to confirm</td>
</tr>
<tr>
<td>Sediment flushing from impoundment to downstream</td>
<td></td>
<td>No</td>
<td>No evidence of sediment flushing downstream. Neither is there evident to suggest sediment starvation downstream but this may require further investigation</td>
</tr>
<tr>
<td>Fish entrainment into intakes (turbines)</td>
<td></td>
<td>No</td>
<td>No turbines and no evidence of dead fish in reservoirs or downstream</td>
</tr>
<tr>
<td>Management of reservoir</td>
<td>Engineering/ (intensive) maintenance of reservoir shoreline (beach, housing, steep shorelines etc)</td>
<td>No</td>
<td>No regular maintenance of the reservoir shoreline so no impacts</td>
</tr>
<tr>
<td>Excavation within reservoir</td>
<td></td>
<td>No</td>
<td>No excavation of material routinely undertaken in reservoir and no record of sediment build up</td>
</tr>
</tbody>
</table>
Fish stocking 2,3,4,5 4 of reservoirs stocked with rainbow trout which are non-native. Rainbow trout releases have been observed and there are salmon in the lower reaches of the Devon

Recreation and boating - PAH contamination No No power boating is undertaken and therefore no PAH contamination issues are likely. Rowing boats and kayaks occasionally.

General recreation No Small scale fisheries interests and footpaths and picnic tables above Castlehill but not considered to be an issue

Management of river/streams Altered river channel characteristics 1,2,3,4,5 River is highly mobile and alterations to the channel are reduced as the reservoirs control the flow. This was not considered to be a big issue but further discussion with morphologists may be required.

Development of floodplains along river No There is no development along the floodplain with only agricultural land flooding

Angling No There is minimal angling which is not considered to be an issue in these catchments

Management of catchment Agricultural use / development of reservoir catchment No There is minimal development in the catchment and agricultural use is limited to rough grazing

Forestry No Although afforestation has increased in recent years there is no evidence that this has resulted in impacts on the catchment.

At the end of this step it was identified that the main pressures on the impoundments associated with Glendevon water treatment works are altered flow (both a reduction in flow and a lack of variation in flow); fish stocking and altered channel characteristics. However, there were a lot of questions that could not be answered which highlighted the importance of having the correct people with the right knowledge and expertise involved in the process and also highlighted the importance of having all the available data to hand prior to undertaking the analysis process.

A12.5.6 STEP 6: Identify potential mitigation measures based on effectiveness

This step was undertaken making reference to the mitigation measures spreadsheet (section 8 of the guidance document), the guidance sheets (section 5 of the guidance document) and the technical appendices (section 8 of the guidance document) and once again using expert judgement. Each mitigation measure was assessed against the following criteria (see Table 2.4): effectiveness in meeting the requirements of the WFD (Good Ecological Potential, (GEP)), the date by which this improvement is likely to be realised, and the chance of realising GEP by 2015. Again there was much discussion about the mitigation measures and their effectiveness, and knowledge of the area, the issues and the use of professional judgement were vital.
Table A12.5: Potential mitigation measures.

<table>
<thead>
<tr>
<th>Pressure</th>
<th>Mitigation measure</th>
<th>Effectiveness</th>
<th>Period for improvement</th>
<th>Chance of realising WFD aim</th>
</tr>
</thead>
<tbody>
<tr>
<td>Altered flow</td>
<td>Provide environmentally acceptable flows</td>
<td>++</td>
<td>Before 2015</td>
<td>++</td>
</tr>
<tr>
<td>22</td>
<td>Provide seasonally &amp; environmentally acceptable flows</td>
<td>+++</td>
<td>Before 2015</td>
<td>+++</td>
</tr>
<tr>
<td>Fish stocking</td>
<td>Complete removal of non-native species</td>
<td>+++</td>
<td>Before 2015</td>
<td>+++</td>
</tr>
<tr>
<td>87</td>
<td>Install screens/barriers to prevent fish migration</td>
<td>+</td>
<td>Before 2015</td>
<td>++</td>
</tr>
<tr>
<td>Altered channel characteristics</td>
<td>Restore riparian habitats eg riffles</td>
<td>++</td>
<td>Before 2015</td>
<td>++</td>
</tr>
</tbody>
</table>

A12.5.7 STEP 7: Identify suitable combinations of measures

The next stage was to identify suitable combinations of measures, and to repeat the assessment from Step 6 for these. Table 2.5 summarises the results.

Table A12.6: Potential combinations of mitigation measures.

<table>
<thead>
<tr>
<th>Combination</th>
<th>Mitigation measures</th>
<th>Effectiveness</th>
<th>Period for improvement</th>
<th>Chance of realising WFD aim</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>21, 86, 98</td>
<td>++</td>
<td>Before 2015</td>
<td>+++</td>
</tr>
<tr>
<td>C2</td>
<td>22, 87, 98</td>
<td>++</td>
<td>Before 2015</td>
<td>+++</td>
</tr>
<tr>
<td>C3</td>
<td>21, 87, 98</td>
<td>++</td>
<td>Before 2015</td>
<td>+++</td>
</tr>
<tr>
<td>C4</td>
<td>22, 86, 98</td>
<td>+++</td>
<td>Before 2015</td>
<td>+++</td>
</tr>
</tbody>
</table>

A12.5.8 STEP 8: Calculate costs and identify other effects

The next step in the process was to identify the costs of each of the combinations of measures and to identify whether there were other socio-economic issues which would require to be considered. The costs spreadsheet did not help with the issues in question and therefore professional judgement was again used. It was agreed that while we could
not determine the actual or even predictive costs of installing screens as required by mitigation measure 87 in combinations C1 and C4, the costs of this would be substantially less than the costs involved in removing all non-native fish from the reservoirs required by mitigation measure 86 in combinations C2 and C3. The costs spreadsheet had indicated that the costs of electro-fishing were high and were only possible in waterbodies of less than 3m in depth. As the reservoirs in question are all deeper than this, the reservoirs would require to be drained which would be costly. In addition to the costs involved, Scottish Water would have to pump water from other catchments to Glendevon WTW and there would be a loss of revenue in the area as a result of the loss of tourism and fisheries during the period of the works and while the reservoirs filled up again.

The results of the deliberations are shown in table 2.6 below.

A12.5.9 STEP 9: Rank combinations according to cost-effectiveness

Once the cost effective analysis had been completed, the next step was to rank the combinations to determine the most cost effective combination. As can be seen from table 2.6 below, combinations C2 and C3 were the most cost-effective options as a result of their medium costs and lack of other impacts with combination C1 being ranked last as a result of its high costs, socio-economic impacts and its lower chance of meeting good ecological status.

Table A12.7 Selecting the most cost-effective combination of measures

<table>
<thead>
<tr>
<th>Nr.</th>
<th>Combination of measures</th>
<th>Chance to reach WFD-aim</th>
<th>Net Present Value</th>
<th>Other socio-economic effects</th>
<th>Ranking of measures based on cost-effectiveness</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Effect</td>
<td>Period</td>
<td>Chance to reach WFD-aim in 2015</td>
<td></td>
</tr>
<tr>
<td>C1</td>
<td>21, 86, 98</td>
<td>++</td>
<td>Before 2015</td>
<td>+++</td>
<td>High</td>
</tr>
<tr>
<td>C2</td>
<td>22, 87, 98</td>
<td>++</td>
<td>Before 2015</td>
<td>+++</td>
<td>Medium</td>
</tr>
<tr>
<td>C3</td>
<td>21, 87, 98</td>
<td>++</td>
<td>Before 2015</td>
<td>+++</td>
<td>Medium</td>
</tr>
<tr>
<td>C4</td>
<td>22, 86, 98</td>
<td>+++</td>
<td>Before 2015</td>
<td>+++</td>
<td>High</td>
</tr>
</tbody>
</table>

A12.5.10 STEP 10: Select most cost-effective combination of measures

This step can generally be straight forward with the combination of measures which was ranked first in step 9 being the most cost-effective. However, in this instance two combinations were ranked first equal and it was therefore necessary to make use of the expert knowledge held by those undertaking the trial. In this instance combination 2 was deemed to be the most cost effective, with the costs not being considered to be disproportionate as for a similar price you could implement flows which were both environmentally acceptable and offer seasonal variation.
A12.5.11 STEP 11: Actions to be taken to comply with WFD

In this case it was agreed that there was no need to consider seeking a derogation as the costs involved although not quantified were not considered to be disproportionate, as discussed above. However as in reality Scottish Water would face significant costs because of the need to implement mitigation measures at a number of their impoundments it was suggested that these could be implemented in a phased manner beginning immediately with mitigation measure 22 (seasonally varying and environmentally acceptable flows) followed by measure 98 (restoration of riparian habitats) and then mitigation measure 86 (installation of screens).
A12.6 RIVER DEE CATCHMENT TRIALS

A12.6.1 Introduction

The trialling of the guidance document on the River Dee catchment was undertaken in a slightly different way than the trial in Glendevon WTW catchment. The site visit to the catchment was undertaken by a CEH employee following a meeting and a telephone interview with staff from the Environment Agency. The site visit was undertaken on 10th August 2004.

A12.6.2 Description of the catchment and associated issues

The River Dee system is a heavily regulated catchment, figure 1. The original reason for controlling the catchment was to supply water to the dense population centres in the lower reaches of the catchment. Initially Llyn Tegid (Lake Bala), a natural lake in the upper catchment, was regulated by a low weir, allowing additional storage to be retained in the lake during winter. This water was then released into the Dee to augment supplies in the drier summer months.

The River Dee is used as the main conduit for transferring water, to abstraction points which are mainly situated near the tidal limit. The catchment was further modified to increase water supply capacity with the construction of Llyn Celyn reservoir. This impoundment also produces hydropower and provides releases for white water rafting and canoeing. Water from Llyn Celyn feeds directly into Llyn Tegid above the control weir. There are two other major impoundments in the system, Llyn Alwen and Llyn Brenig. Alwen is a direct supply reservoir feeding a separate supply area while Brenig was built to increase abstraction capacity in the Dee by 860ML/d.

United Utilities (UU) is the major public water supply abstractor from the Dee. This water is fed into UU's Integrated resource zone, which supplies 95% of customers in NW England. Other main sources are from the Lake District, Vyrnwy in Wales, groundwater, and numerous reservoirs in the Pennines. The Dee abstraction is managed by control curves which reflect system constraints, and protect security of supply. Because of the range of sources, and interconnectivity of the system, UU is able to maximise abstractions up to the licence limit when the river is not being regulated, and cut back to the reliable yield when indicated by the control curves. The other abstractors (Dwr Cymru-Welsh Water and Dee Valley) do not have the range of alternatives so are highly dependent on the Dee.

In addition to the original purpose to supply water the system is also managed to alleviate flooding, mitigate against ecological impacts and maintain water quality. In short there is a wide range of requirements placed on the system.

Management is coordinated by a Consultative Committee set up under the ‘The Dee and Clwyd River Authority Act 1973’ on which both major abstractors and river interests are represented. The “Dee General Directions”, i.e. the complex rules used to operate the system, are prepared with this Committee’s advice, and the special conditions for operation in severe droughts require the approval of all members of the Committee.
Summary of the Dee Regulation Scheme:
- abstractions in its lower reaches for public supply exceed the combined lower supply of the reservoirs of the English Lake District;
- the frequency of flooding of the low lying land alongside the river below Bala has been reduced;
- proper consideration towards the preservation of the fishery has been achieved;
- recreational activities have been developed at appropriate locations;
- hydroelectric power is generated at Llyn Celyn; and
- despite all these issues, the catchment is designated as an SAC under the Habitats Directive
Figure A12.8: Schematic diagram of the River Dee system

1 North West Water
2 Dee Valley Water
3 Dwr Cymru Welsh Water
4 British Waterways
A12.6.3 Means of Regulation

For historical reasons the EA has an unusual role in the catchment having direct control over the day-to-day running of the system in conjunction with a variety of other organisations. In practice this means the EA manipulate the height of the weir gates at the outflow of Llyn Tegid effectively controlling discharge in the River Dee downstream of the weir. This is the main means of controlling discharge. The system is automated and uses telemetry to gather data on river levels throughout the catchment but is overseen and executive decisions made by an on-site officer. The system is manned continuously.

Abstraction volume in the lower reaches usually remains constant but can change at 48 hours notice. It is up to the EA to provide additional water if required. Water can be requested from Llyn Celyn and Llyn Brenig to provide for the requirements of the system. If there is a danger of flooding in the lower reaches water can be retained in Llyn Tegid and released from Llyn Tegid if flooding threatens Bala or the Upper Dee. Llyn Tegid is operated within an environmentally acceptable range but no such limitation is placed on the operation of Llyn Celyn which is sacrificed for the benefit of Tegid.

A12.6.4 Integration of Requirements

Water level in Llyn Tegid forms the basic measure for controlling the system. Target water levels are set which differ throughout the year (figure 2). The operators aim to maintain water level within the operational boundaries which are hierarchical and seasonal.

- There is a baseline (lower amenity level) water level which alters in Llyn Tegid depending on season; being higher in summer than winter.
- During summer months Llyn Tegid water levels are maintained between the lower amenity level and an upper conservation level which is 0.4m above baseline. This may be exceeded during periods of heavy rainfall.
- If water level rises above the ecological threshold because of rising water then a series of other priorities come into play, aimed at reducing flood risk to the local town of Bala and the downstream reaches of the R. Dee. The kick-in point for these other priorities is water levels in Llyn Tegid.

This operating procedure allows for a basic compensation flow to be released at all times to the River Dee. The compensation discharge, combined with additional releases maintains a residual flow of at least 364 Ml/d over Chester Weir which is located just above the tidal limit. Furthermore, power generation activities and releases for recreation from Llyn Celyn must not compromise the operation of Llyn Tegid.

A12.6.5 Known Serious Impacts

Under the current management scheme major winter floods are reduced and summer flows increased. A recent report on the state of the fisheries within the R. Dee identified a significant reduction in the number of salmon within the system compared to other Welsh rivers and there has been a shift in the coarse fish community. Llyn Tegid is known to suffer from blue-green algal blooms, a sign of serious eutrophication. Water level in Llyn Celyn can drop by as much as 30m.
Figure A12.9: Annual water levels in Bala Lake
A12.6.6 Mitigation measures on the Dee System

Several mitigation measures have already been implemented in the Dee catchment due primarily to its operation by the Environment Agency. Many of the pressures mentioned in the WFD 29 Phase I & II reports are relevant to the Dee system and the mitigation measures already in place. However some measures implemented in this catchment are novel and these are identified in the text below in italics.

Hydropower peaking flows
- Hydropower peak discharges from Llyn Celyn are slowly ramped up and down over a period of six hours. This prevents stranding of fish and invertebrates.

Barrier to migration
- The dam at Llyn Celyn is not by-passed: instead fish reaching the base of the dam are trapped and stripped of eggs which are the hatched, reared, and used for re-stocking. The stripped fish are then re-conditioned. Multi-sea-winter fish are preferred. No smolts are introduced directly to the river but release ponds are used. Parr/fry are used to stock areas identified as having good nursery habitat. The reason for not by-passing the dam is not clear. The dam is high and building a pass may have been difficult and the available up-stream habitat for juveniles so reduced that accessing these areas was not considered worthwhile.
- The weir at Llyn Tegid has a by-pass for fish.
- A buy-out of nets in the estuary has been suggested to increase the number of fish returning to spawn. This process is on-going.

Entrainment of fish in turbines
- There are no screens to exclude fish from the turbines. Fish do enter the settling ponds above the turbines and these are periodically netted out by EA officers.

Changes to water chemistry/temperature
- By directing fish into the fish traps downstream of the dam they are excluded from the immediate vicinity of the dam wall and would not be subject to conditions which lead to gas-bubble disease.
- Water is abstracted from behind the dam at a number of different levels. This is to provide the best possible head for turbine operation. Currently water quality and temperature are not known to impact on the system directly downstream but by mixing water from different depths it would be possible to mitigate against this type of impact.
- It is believed that a reduction in water temperature caused by system regulation below Llyn Tegid has led to decreases in the coarse fish population. Backwaters have been created to act as spawning and nursery areas for coarse fish where ambient temperatures are more suitable than in the main channel. They are effective at increase coarse fish populations but silt up easily.
- In addition to the basic compensation flow ‘environmental flows’ are released to improve water quality in downstream reaches. The cause of reduced water quality is due to inputs of pollutants in the lower reaches.

Sediment Management
Sediment is released from Llyn Celyn from a scour valve on a monthly basis. It is released as a small proportion of larger releases. The fate of the sediment within the system is not clear but the most likely scenario is that it is transported downstream to Bala by the large flows released for canoeing, rafting and hydropower generation. Here the river is canalised and water slows; sediment is known to have slowly accumulated in this area. Plans are being considered to physically remove sediment from the canalised section to prevent flooding. Redds are found in the reaches between Bala and Llyn Celyn suggesting that the gravels are in good condition. It is the opinion of the EA fisheries officers that the area does provide good spawning gravels.

Environmentally Acceptable Flows
- A compensation flow is in place.
- The existing regimes include an artificially spatey (i.e., unnatural—it does not mimic rainfall) system below Llyn Celyn created by the production of hydropower and releases for rafting and canoeing. The impact on the system is considered to be minor. The system downstream of Llyn Tegid has had the peak flood events reduced during all seasons and increased discharge in summer. This has lead to increased macrophyte growth downstream. This in turn may explain the increase in grayling populations as weedy riffles are their preferred habitat.

Habitat Modification
- Riparian zones have been fenced to improve bankside vegetation. Although monitoring is difficult it is accepted that this has had the desired effects.
- Habitat enhancement of juvenile salmonid habitat has been undertaken as part of a wider objective 1 programme taking place throughout Wales.
- Underwater reefs are to be introduced to prevent cormorants predating on juvenile coarse fish.
- Habitat alterations to improve the area for otters are also being introduced.

Eutrophication
- Llyn Tegid has suffered from a series of blue-green algal blooms indicating that the system has undergone a trophic shift. The Snowdonia National Park Authority has published a symposium proceedings about Llyn Tegid, which tackles the question of eutrophication. CEH Bangor and the University of Bangor were both involved. The problem seems to be multifactorial. The Park Authority advocates the use of best farming practice to help alleviate pressure to the system.

Recreation Impacts
- As mentioned above the release of water for recreation may have altered the system considerably but without detailed data on the state of the biological elements it is impossible to judge the impact. A cursory look at the site suggests that some of the catchment the area sustains an abundance of moss species and according to EA officers fish populations are healthy.

A12.6.7 Assessment of the Catchment using the draft guidance document

A formal assessment of the catchment using the draft guidance was not undertaken as there were already several mitigation measures in place in the catchment and as there has been
no confirmation as to what would constitute good ecological potential in this catchment, undertaking the process would be of limited value. The main outcome of this trial was therefore identifying additional mitigation measures which would require to be added to the mitigation measures spreadsheet.
A12.7 LIMITATIONS OF DRAFT GUIDANCE

A12.7.1 Introduction

As discussed above, the guidance used in the trials for the Dee catchment undertaken by a member of the project scheme from CEH was the original draft guidance which was revised during the trial on the Glendevon reservoirs and subsequently trialled on this catchment. 

This section of the report looks at the limitations of the guidance which were identified and the solutions suggested are detailed in Section 5.

A12.7.2 Limitations of Draft Guidance Identified from Glendevon Trials

The trial on the Glendevon catchment was undertaken following a discussion about the guidance and suggested amendments to the document layout and in particular the step by step guidance.

In general all involved in the trials felt that the information within the guidance was extremely detailed and would be invaluable to the determination of the mitigation measures required on a case by case basis. As there was considerable detail in the guidance document, it was highlighted that the document had to be clearly described and all sections clearly referenced in order that the user could negotiate their way though the process with ease.

It was felt that there was too much emphasis on cost effectiveness at the beginning of section 5 which was confusing and it was also felt that for some of the steps, the user may be unclear of what was actually required. Finally it was felt that the references to the mitigation measured and costs database were too confusing and that there should be referred to as excel spreadsheets.

A12.7.3 Limitations of Draft Guidance Identified from Initial Dee Trials

The limitation of the guidance identified as a result of the initial trials on the Dee catchment was that the mitigation measures spreadsheet did not identify all the mitigation measures which had already been implemented in the catchment.
A12.8  RECOMMENDATIONS FOR AMENDMENTS TO DRAFT THE GUIDANCE

A12.8.1  Introduction

As well as identifying the limitations of the draft guidance, it was important to get the views of the future users of the document on how these limitations could be overcome. The recommendations from the trails in Glendevon were incorporated into the revised guidance and this guidance was subsequently trialled on the later Dee trial. The Recommendations from both trials on the Dee catchment were subsequently incorporated in to the final guidance document.

A12.8.2  Recommendations for amendments to the Draft Guidance Identified from the Glendevon Trials

In order to make the document more user friendly, it was recommended that the document be restructured slightly, with the transfer of the conceptual models from section 4 to the technical appendices and the incorporation of the pressures and drivers models into the existing section 5 which would subsequently become section 4. The introductory section should emphasise which sections of the report are critical to applying the guidance and which ones provide background and/or supporting information.

Additional steps should be added to the beginning of the process to highlight the work required to determine whether or not the impoundment complied, or fail to comply with the requirements of the WFD. These steps were:

Step 1 - Scoping of the impoundment(s);
Step 2 - Identification of current waterbody status; and
Step 3 - Identification of WFD targets

and a final step,

Step 11 – Actions to be taken to comply with the WFD

was also recommended.

In addition, it was felt that additional information could provided for each of the steps to make the guidance easier to follow and that tables for the recording of data, information and decisions make should be produced. Within each step, reference should be made to the other sections of the report which were relevant at that stage and that within each of the other sections there should be some cross referencing to other sections of relevance.

It was felt that the guidance sheets could be improved by the inclusion of the generic flow chart which details all the steps in the process and that while the additional information in the guidance sheets was useful, it could be come slightly confusing and should be differentiated
from the main text by either moving the additional information to the back if the guidance sheet or perhaps more appropriately highlighting it in boxes.

Since these initial changes were recommended further changes have been proposed and the preliminary guidance produced has altered somewhat form the draft guidance produced. Much of the supporting information has been moved to a second volume as a series of appendices with the first volume comprising the step by step guidance and the guidance sheets. In addition, there have been some additional columns added to the tables and some of the tables have been subdivided for clarity.

A12.8.3 Recommendations for amendments to the Draft Guidance Identified from Initial Dee Trials

The recommendations for amendments to the draft guidance were limited in the main to the incorporation of additional mitigation measures into the mitigation measures spreadsheet. These measures were ones which were seen in the Dee catchment but not included in the draft guidance namely:

- buy out of estuary nets to increase returning stock to freshwater systems
- Netting to remove fish from settling ponds upstream of turbines
- The creation of backwaters to encourage coarse fish is advocated but the technique needs improvement before application to avoid siltation.
- Underwater reefs are potentially a more general way of improving habitat in deep river reaches for coarse fish and their application could be considered in areas where predation from birds is not a serious issue.
- The release of environmental flows to help improve water quality.

Other recommendations were that the an additional conceptual model to depict systems like the River Dee where the river is used as the conduit for water for abstraction should be incorporated into the guidance document. However, it was felt that the report contained several conceptual models already and that as it was beyond the scope of the guidance document to cover all situations, this would not be taken forward.

It was also recommended that emphasis be placed on the importance of integrated management of systems and when targets are set it should be acknowledged that the ecological status of some impoundments must be sacrificed for the ecological benefit of other sections of the system and this has been incorporated into the revised document.
A12.9 MONITORING DATA RELATING TO THE RIVER DEVON CATCHMENT

Following the undertaking of the trial, the following data was provided by SEPA. The trial was not re-addressed as a result of the provision of this information but the information is included to give an idea about the types of data SEPA holds.

A12.9.1 Water Quality Data

Figure A12.10: Map showing chemical sampling points in the Devon Catchment

There are five water quality monitoring sites in the study area at which water quality monitoring is undertaken. None of these sites are located within the impoundments and no biological sampling is undertaken. The locations of the sites are detailed in figure 6.1 above (green dots) and are:

- U/S FRANDY FF. Location code: 1970;
- D/S FRANDY FISH FARM @ PIPE BRIDGE Location code: 2202;
- River Devon @ BLACKLINN Location code: 3590;
- River Devon U/S FOSSOWAY Location code: 3374 (d/s Castlehill); and
- River Devon @ FOSSOWAY Location code: 3589 (d/s Castlehill)
Water quality and the resultant water classification at these sites in 2003 is portrayed in table 6.1 while table 6.2 details the water classification at these sites over the past five years.

### Table A12.8: Water quality classification in 2003

<table>
<thead>
<tr>
<th>Year</th>
<th>Stretch</th>
<th>Description</th>
<th>Length(km)</th>
<th>Biol</th>
<th>Chem</th>
<th>Nutr</th>
<th>Aes</th>
<th>B_lab</th>
<th>pH</th>
<th>NH3</th>
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<td>2003</td>
<td>11606</td>
<td>(u/s Upper Glendevon)</td>
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<td>11604</td>
<td>(between Upper and Lower Glendevon)</td>
<td>R DEVON U/S FRANDY FF.</td>
<td>0.68700</td>
<td>A2</td>
<td>A1</td>
<td>A1</td>
<td>A2</td>
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<tr>
<td>2003</td>
<td>11602</td>
<td>(Lower Glendevon and u/s Castlehill)</td>
<td>R DEVON U/S FRANDY FF.</td>
<td>5.96600</td>
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<td>A1</td>
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<td>A1</td>
<td>A2</td>
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<td>2003</td>
<td>11601</td>
<td>(stretch u/s Castlehill)</td>
<td>R DEVON @ BLACKLINN</td>
<td>0.52500</td>
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<td>2003</td>
<td>11599</td>
<td>(d/s Castlehill)</td>
<td>R DEVON U/S FOSSOWAY FF.</td>
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### Table A12.9: Water quality classification in recent years

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<tr>
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<th>1606</th>
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<td></td>
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<td>A2</td>
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<td>A1</td>
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<td>2001</td>
<td>A2</td>
<td>A1</td>
<td>A1</td>
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<td>2002</td>
<td>A1</td>
<td>A1</td>
<td>A1</td>
<td>A1</td>
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<td>A2</td>
<td>A2</td>
<td>A1</td>
<td>A1</td>
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</table>

### A12.9.2 Discharge Data

There are five consented discharges to the catchment detailed in figure 6.1 as red dots:

- Frandy Fish Farm discharge No 1 Location code: 1856 (NN9480404767) ;
- Frandy Fish Farm No 2 Lower Discharge. Location code: 2203 (NN9487804861) ;
- Frandy Fish Farm Discharge No 2 Upper Discharge. Location code: 4686 (NN9484804819) ;
- WPC/E/5307 Tormaukin Hotel Bioclere Plant Final Effluent Location code: 5278 (NN9923404349) ; and
- Fossoway Fish Farm Discharge. Location code: 4691(NO0095301999).
A12.9.3 Gauging Station Data

SEPA also has two gauging stations on the River Devon both of which are located downstream of the lowest impoundment, Castlehill:

• River Devon flow gauging station @ Castlehill Reservoir Location code: 14908; and
• River Devon @ Fossoway Bridge Location code: 116004.

Fossoway Bridge Gauging Station

The following information has been provided by SEPA regarding the gauging station at Fossoway Bridge:

**Table A12.10: Data relating to Fossoway Bridge gauging stations**

<table>
<thead>
<tr>
<th>Grid Reference:</th>
<th>37 (NO) 011 018</th>
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<tbody>
<tr>
<td>Operator:</td>
<td>SEPA</td>
</tr>
<tr>
<td>Catchment Area:</td>
<td>69.5 km²</td>
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<tr>
<td>Level of Station:</td>
<td>160.1 mOD</td>
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<tr>
<td>Max. Altitude:</td>
<td>720.0 mOD</td>
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<tr>
<td>Mean flow:</td>
<td>2.14 m³s⁻¹</td>
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<tr>
<td>95% exceedance (Q95):</td>
<td>0.428 m³s⁻¹</td>
</tr>
<tr>
<td>10% exceedance (Q10):</td>
<td>4.928 m³s⁻¹</td>
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<tr>
<td>61-90 Av. Ann. Rainfall:</td>
<td>1575 mm</td>
</tr>
</tbody>
</table>

**Figure A12.11: Sample Hydrograph of Gauged Daily Flows**
Max. and min. daily mean flows from 1986 to 1991 excluding those for the featured year (1990; mean flow: 2.46 m³/s)
Station Description

Velocity-area station d/s of Castlehill reservoir. A poor site with an insensitive and unstable broad gravel control and banks which did not contain all flows; it was closed in 1990 and replaced by a new station immediately below the reservoir. There are several other reservoirs in the catchment.

Catchment Description

A rural catchment with rolling hills used for sheep grazing.

Factors Affecting Runoff

- Reservoir(s) in catchment affect runoff.
- Regulation from surface water and/or ground water.
APPENDIX 13

WFD29: MANAGEMENT STRATEGIES AND MITIGATION MEASURES REQUIRED TO DELIVER THE WATER FRAMEWORK DIRECTIVE.

CONTACTS
## APPENDIX 13: CONTACTS

### A7.1 International Review Contacts

<table>
<thead>
<tr>
<th>Country</th>
<th>Name</th>
<th>Organisation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Norway</td>
<td>Professor John Brittain</td>
<td>University of Oslo</td>
</tr>
<tr>
<td></td>
<td>Job Hottentot</td>
<td>KPMG Global Sustainability Services</td>
</tr>
<tr>
<td></td>
<td>Knut Gakkestad</td>
<td>NVE – Norwegian Water Resources and Energy Directorate</td>
</tr>
<tr>
<td>France</td>
<td>M. Devos</td>
<td>DRIRE Limousin</td>
</tr>
<tr>
<td></td>
<td>M. Hofleur</td>
<td>Direction Departementale de l’Agriculture et de la Foret (DDAF), Lozere</td>
</tr>
<tr>
<td></td>
<td>M. Coffin (directeur)</td>
<td>Direction Departementale de l’Equipement (DDE), Haute-Vienne</td>
</tr>
<tr>
<td></td>
<td>Mme Calentier</td>
<td>Direction Regionale de l’Industrie, de la Recherche et de l’Environment (DIREN), Auvergne</td>
</tr>
<tr>
<td></td>
<td>M. Cruchon</td>
<td>CTPB</td>
</tr>
<tr>
<td></td>
<td>M. Paquier</td>
<td>CEMAGREF</td>
</tr>
<tr>
<td></td>
<td>M. Lamoureux</td>
<td>SOMIVAL</td>
</tr>
<tr>
<td>Germany</td>
<td><strong>No response in timescale of project</strong></td>
<td></td>
</tr>
<tr>
<td>Australia</td>
<td>Mr D. Barma</td>
<td>Department of Infrastructure Planning and Natural Resources</td>
</tr>
<tr>
<td></td>
<td>Mr B. Dunn</td>
<td>Snowy Hydro Ltd</td>
</tr>
<tr>
<td></td>
<td>Ms. J. Lovett-Cameron</td>
<td>Institute of Chartered Accounts of Australia</td>
</tr>
<tr>
<td>USA</td>
<td>Mr. A. Hoar</td>
<td>US Fish and Wildlife Service</td>
</tr>
<tr>
<td></td>
<td>Mr. D. Conrad</td>
<td>National Wildlife Federation</td>
</tr>
<tr>
<td></td>
<td>Mr. D. Murch</td>
<td>Department of Environmental Protection (Maine)</td>
</tr>
<tr>
<td></td>
<td>Mr. L. Crowe, Mr. B. Greeve</td>
<td>The Federal Energy Regulatory Commission (FERC)</td>
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<tr>
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<td>Mr. M. Horn</td>
<td>US Bureau of Reclamation</td>
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### A7.2 Members of Steering Group

<table>
<thead>
<tr>
<th>Name</th>
<th>Role</th>
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</tr>
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<tbody>
<tr>
<td>Antonio Ioris</td>
<td>Project Manager</td>
<td>SEPA</td>
</tr>
<tr>
<td>Rebecca Badger / Kirsty Irvine</td>
<td>Project Director</td>
<td>SNIFFER</td>
</tr>
<tr>
<td>David Crookall</td>
<td>Water Resources / Hydropower</td>
<td>SEPA</td>
</tr>
<tr>
<td>David Corbelli</td>
<td>Water Resources / Hydrology</td>
<td>SEPA</td>
</tr>
<tr>
<td>Eric McRory</td>
<td>Economics</td>
<td>SEPA</td>
</tr>
<tr>
<td>John Aldrick</td>
<td>Water Resources / Hydropower</td>
<td>Environment Agency</td>
</tr>
</tbody>
</table>

### A7.3 Main SEPA Offices

**Aberdeen Office**  
Greyhope House  
Greyhope Road  
Torry  
ABERDEEN  
AB11 9RD  
Tel: 01224 248338  
Fax: 01224 248591

**Dingwall Office**  
Graesser House  
Fodderty Way  
Dingwall Business Park  
DINGWALL  
IV15 9XB  
Tel: 01349 862021  
Fax: 01349 863987

**Edinburgh Office**  
Clearwater House  
Heriot Watt Research Park  
Avenue North  
Riccarton  
EDINBURGH  
EH14 4AP  
Tel: 0131 449 7296  
Fax: 0131 449 7277

**East Kilbride Office**  
5 Redwood Crescent  
Peel Park  
EAST KILBRIDE  
G74 5PP  
Tel: 01355 574200  
Fax: 01355 574688

**SEPA Corporate Office**  
Erskine Court  
Castle Business Park  
STIRLING  
FK9 4TR  
Tel: 01786 457700  
Fax: 01786 446885
### A7.4 Main Environment Agency Offices (telephone 08708 506 506)

<table>
<thead>
<tr>
<th>Region</th>
<th>Office Name</th>
<th>Address 1</th>
<th>Address 2</th>
</tr>
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<tr>
<td>Anglian Regional Office</td>
<td>Environment Agency</td>
<td>Kingfisher House</td>
<td>Goldhay Way</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Olton</td>
<td>Goldhay</td>
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<tr>
<td></td>
<td></td>
<td>Peterborough</td>
<td>PE2 5ZR</td>
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<tr>
<td>Midlands Regional Office</td>
<td>Environment Agency</td>
<td>Sapphire East</td>
<td>550 Streetsbrook Road</td>
</tr>
<tr>
<td></td>
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<td>Solihull</td>
<td>West Midlands</td>
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<td>Environment Agency</td>
<td>Rivers House</td>
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<td>Knutsford Road</td>
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<td>EX2 7LQ.</td>
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<tr>
<td>Southern Regional office</td>
<td>Environment Agency</td>
<td>Guildbourne House</td>
<td>Chatsworth Road</td>
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<td>Environment Agency</td>
<td>Kings Meadow House</td>
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<tr>
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<td>Wales South East Regional Office</td>
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<td>Bangor</td>
<td>LL57 4DE</td>
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</table>
A7.5  Main Environment and Heritage Service Office

Environment and Heritage Service  
Environmental Protection  
Calvert House  
23 Castle Place  
Belfast  
County Antrim  
Northern Ireland  
BT1 1FY  
Tel: 028 9054 6514  
Fax: 028 9054 6513