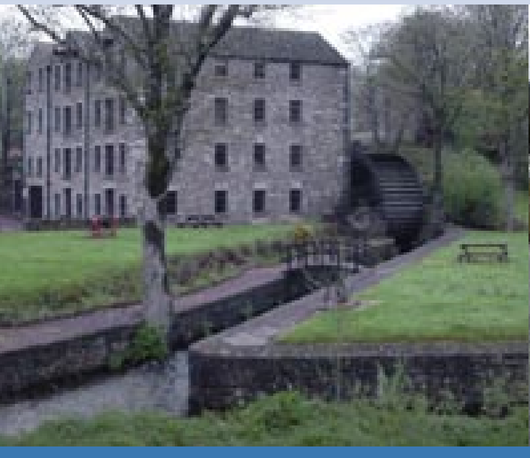
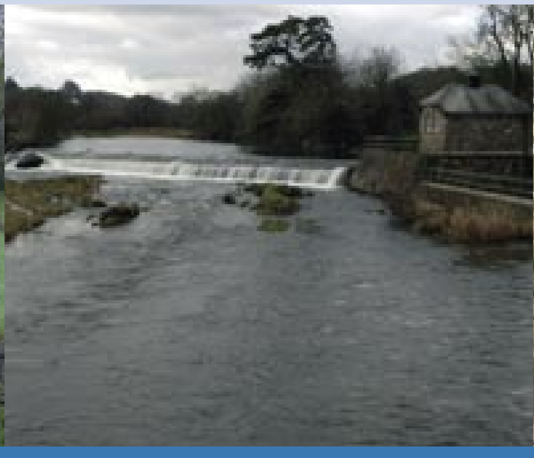
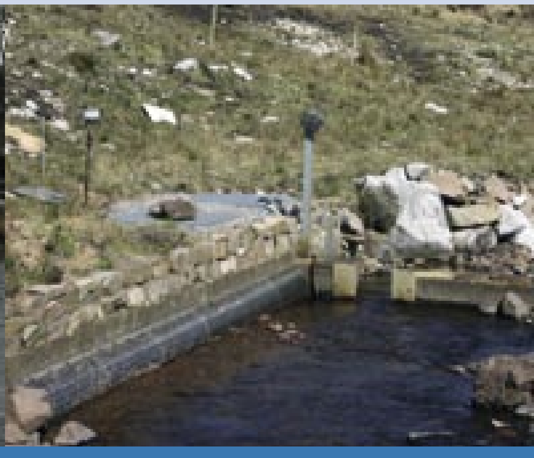
Department of Communications, Energy and Natural Resources
Roinn Cumarsáide, Fuinnimh agus Acmhainní Nádúrtha

Fisheries Ireland
Our Natural Heritage

Guidelines on the Planning, Design, Construction & Operation of Small-Scale Hydro-Electric Schemes and Fisheries

CENTRAL & REGIONAL FISHERIES BOARDS
& ENGINEERING DIVISION, DEPARTMENT OF AGRICULTURE, FISHERIES & FOOD

Eamon Ryan
Minister for Communications, Energy & Natural Resources

Minister's Foreword

I am delighted to be associated with these Guidelines on the Planning, Design, Construction and Operation of Small-scale Hydro Electric Schemes and Fisheries. This is the first publication dealing comprehensively with environmental fisheries issues and the development of small-scale hydro schemes for electricity generation and will be an invaluable reference document for all those proposing to develop hydro schemes in this country.

While hydro electricity generation has been a feature of our waterways since the nineteen hundreds, many sites have now fallen into disrepair. There is now renewed interest in the restoration and development of small-scale schemes. This is associated with Ireland's requirements under the Kyoto Protocol to reduce carbon emissions and our international commitment under the EC Directive 2001/77/EC and higher national targets to increase the consumption of electricity from renewable energy sources to 15% by 2010 and 33% by 2020. Several EU funded programmes e.g. VALOREN, ALTENER and THERMIE part financed research into new small scale and micro hydro technology which allow generation from smaller volumes of water. Also they increase the range of waters which can be utilized for hydro schemes. To achieve our renewable energy resource targets it is likely that the numbers of small and micro scale hydro developments will increase in the coming years. In this context the publication of the guidelines at this time is opportune.

The Guidelines will provide information for developers, planners and interested groups on specific requirements for fisheries water and habitat protection, on the requirements of the Fisheries Acts and will provide a useful assessment tool for determining and addressing potential impacts of proposed hydro schemes on fisheries when preparing Environmental Impact Statements. These guidelines also have relevance to the Water Framework Directive (2000/60/EC) where the overall objective is to ensure there is no deterioration in water quality. In this context hydro-morphological pressures must be addressed so as to ensure the biological status and, by association the fishery status of waters is maintained.

The Guidelines were developed through consultation over a period of three years in collaboration with the Engineering Division, Department of Communications, Marine & Natural Resources (now part of the Department of Agriculture, Fisheries & Food) and the Central and Regional Fisheries Boards and include helpful suggestions from contributing organisations, interested parties and from engineering experts. I wish to thank all those who participated in this significant achievement.

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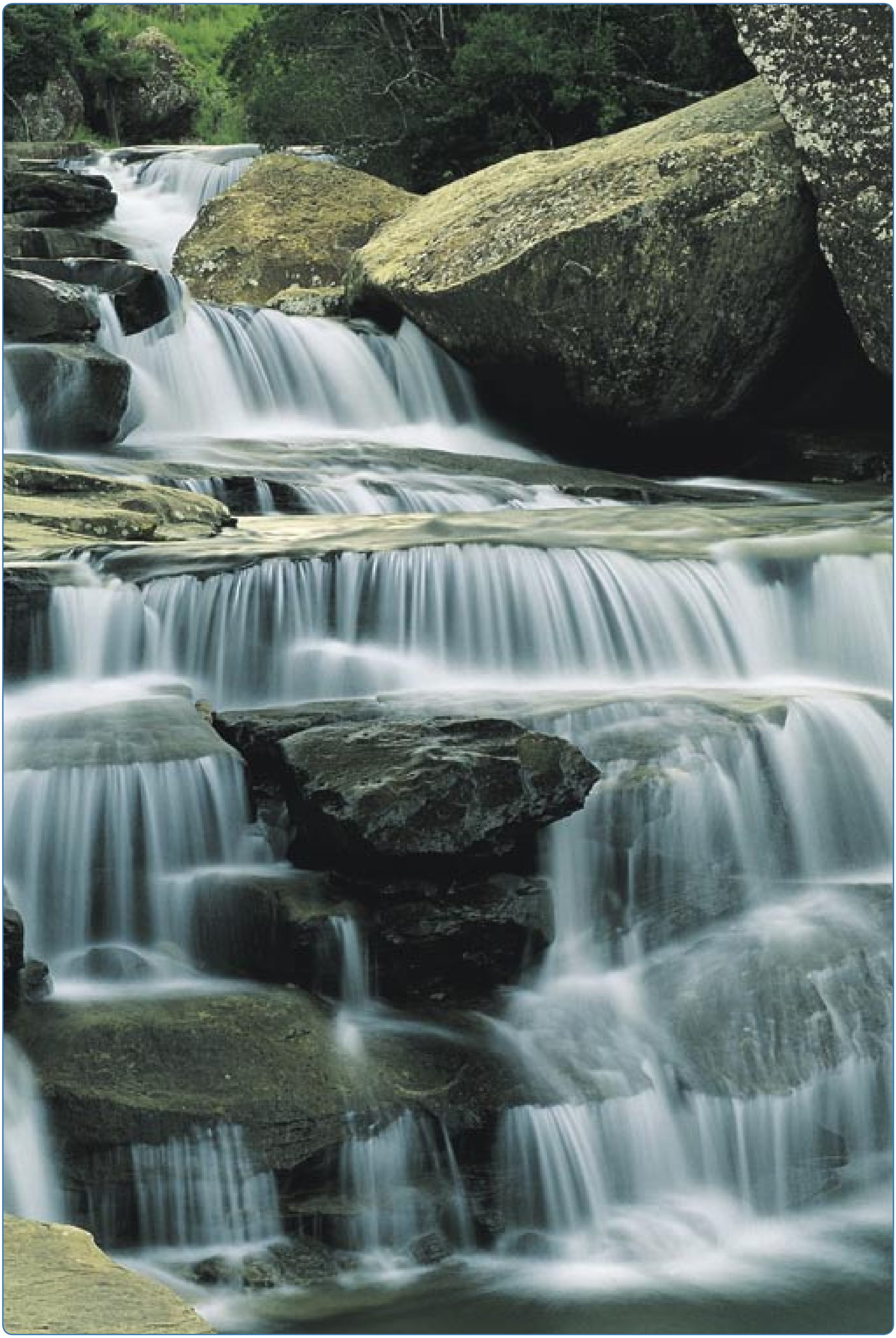


Guidelines

On the Planning, Design, Construction & Operation of Small-Scale Hydro-Electric Schemes and Fisheries

October 2007

Copies of this publication are available from
Central Fisheries Board,
Swords Business Campus,
Swords Co. Dublin.

1. Introduction

Irish Government policy is to encourage the production of energy from renewable resources through the "Alternative Energy Requirements Scheme". The European Union has also supported the generation of electricity through hydro-power under the Alternative Energy Resources Programme (Altener) as a means of reducing CO_2 emissions from fossil fuel sources. The introduction of these schemes and recent advances in turbine and pipeline technology has lead to an increased interest in the development of small-scale hydro-electric schemes in Ireland. This resource has previously been assessed when the then Department of Energy published among several documents "Small-Scale Hydro-Electric Potential of Ireland" which identified 568 sites thought suitable for possible development (Anon, 1985).

Hydro-power developments have the potential for significant impact on the aquatic resource and it is essential that where such schemes are permitted, the fisheries resource is adequately protected, without interference to fish movement, habitat or water quality, (O'Connor, 2002). There are many examples from Britain and Europe (Cowx, 1998) where serious impact on migratory salmonids has resulted from hydro-electric power developments. Even small-scale hydro-electric schemes can have an effect through excessive water abstraction, inadequate fish passage provisions or inadequate smolt screening procedures. The commonest problems affecting the migration of salmonids in Irish rivers have been listed by Murphy (2000).

This paper draws on available information on the potential impact of small-scale hydro-electric schemes on the fisheries resource and recommends guidelines for the protection of the fisheries interest which should be followed. Experience of the impact of small-scale hydro-electric developments in Northern Ireland, England, Wales and Scotland are examined and the recommendations made to resolve these impacts are considered in drawing up these guidelines. The problems relating to large hydro-electric schemes (e.g. Shannon, Erne, Lee, Liffey, Clady) are on a different scale and not likely to be encountered frequently in the future in Ireland. The operation of these large schemes are been reviewed elsewhere (O'Farrell et al.,1996, Mathers et. al., 2002).

2. Current Legislation Relating to Fish Passage and Hydro-Electric Developments in Ireland

The primary fisheries legislation in relation to hydro-power, dams etc. is provided in Part 8, Chapter 5 of the Fisheries (Consolidation) Act 1959. In addition to the 1959 Act the Fisheries Act 1980 charged the Fisheries Boards with the protection, conservation and management of fisheries (Section 18) and the Fisheries (Amendment) Act 1999 further expanded this remit to include Sustainable Development of the Inland Fishery Resource (this included inter alia other species of fauna and flora, habitats and the biodiversity of inland water ecosystems (Section 8(1) (i)).

Consideration must also be given to protection of fisheries afforded by other relevant Legislation e.g. the Water Framework Directive, Habitats Directive and other EU Legislation.

The legislation relevant to fish passes and screens is summarized below and has been previously reviewed by Farrell, (1992).

2.1 Fish Passes

The legislation relating to fish passage requires that every dam in or across any salmon river shall be constructed as to permit and allow, in one or more parts thereof, the free and uninterrupted migration of all fish at all periods of the year, (Section 115 subsection 2 and 3) of the Fisheries (Consolidation) Act 1959. Fish passes must be approved individually by the Minister for Communications, Energy & Natural Resources, (1842 Act, Section 62/63). Good practice requires that fish passes be capable of being negotiated by fish without undue effort, should not expose the fish to risk or injury, and be easily located by the fish. Section 116 relates to fish passage over dams and requires free passage of fish as in Section 115. There is provision within Section 116 for penalties to be imposed and this section is useful when operators fail to comply with a notice from the Minister.

Section 119 describes the offences relating to fish passes. These offences relate to obstruction, destroying or killing fish in a fish pass. Failing to preserve a fish pass free of an obstruction is also an offence.

2.2 Screens / Gratings

A serious problem with any hydro-electric development arises from the attraction of upstream and downstream migrants to outfalls and intakes. To prevent upstream and downstream migrating fish from entering a tailrace or headrace, Section 123 (a & b) of the 1959 Act stipulates that at the points of divergence from and return to the river, the channel shall have bar screens with gaps not greater than 2-inch fitted. During the months when the brood of salmon or trout are descending, the legislation requires a wire lattice to be stretched across the gratings at entry to a headrace to prevent the entry of smolts into the headrace. There is provision for the Minister to grant an exemption, Section 123 (3).
It is the duty of an operator of a hydro-electric turbine to provide a grating or other efficient means to prevent salmon smolts entering turbines, (Section 124). Section 124 is also important in the context of protecting spent salmon.

Section 131 is a general provision protecting the free passage of salmon or trout, or smolts or fry during the close season. Section 173 provides this protection on a year round basis.

2.3 Adequacy of Current Legislation

The current legislation relating to hydro-schemes relates primarily to fish passage and screens. It does not address such issues as compensation flow and water diversion to the turbine. This shortcoming is dealt with in this document.

There are also a number of shortcomings in the current legislation relating to fish passes and screens. A two-inch spacing at outfall screens of tailraces is too wide to prevent entry of sea trout and small salmon in most circumstances. Rigidity of the bars also requires to be specified. Many screens are now made of flat bars which, particularly in high screens, have a degree of flexibility that allow fish of a certain size either get through or become stuck between the bars.

This document takes account of the current fisheries legislation in relation to hydro-scheme developments and sets out guidelines in the area of turbine water abstraction, compensation flow, screening, assessment of performance of screens and siting of hydro-schemes. These guidelines are set out, taking account of past experience, current practice and recent developments in hydro-power technology and recent planning decisions relating to hydro-scheme development.

Recommendations regarding legislative changes required are not presented in this document but will be addressed separately.

3. Types of Small Hydro Schemes

Hydro-electricity is produced by using the power of water under pressure to turn the turbines of generating sets in power stations. There are two main types of small hydro-schemes operating in Ireland, low head and high head schemes.

3.1 Low Head Schemes

Traditionally, low head run of the river schemes were located in lowland areas, abstracting water from rivers through the use of weirs with diversion of river flow to a headrace and from there to a turbine house. Water is returned to the river downstream of the turbine through a tailrace. The power produced in a hydro scheme varies directly with the head (the vertical distance between the headrace and tailrace level) and water flow. Generally the head is less than 5 m in low head schemes and the schemes have little impoundment or provision for storing water. Because the head is low, compared to that at high head schemes, the volume of water used per unit of power is high. Therefore the use of the term "small" (the term 'micro' commonly also used) can be misleading with regard to the volume of water being diverted from the main channel, (Murphy, 2000). Such schemes are generally designed to use the long term mean flow of the river when on full load. In many rivers, especially spate rivers, the long term mean flow can be ten or more times the dry weather flow. Because low head schemes have little provision for storing water, the economic imperative is to use as much as possible of the total river flow at any time. More recently a number of these "low head" schemes have been redeveloped with the introduction of modern more efficient turbines with higher generating capacities. Modern turbines can operate efficiently with flows as low as one quarter or less of their full load design flow. Accordingly, a station with one turbine can keep running over a large range of flow. This has obvious implications for fish passage. Low head schemes are the most common small-scale hydro-power type in Ireland.

3.2 High Head Schemes

High head schemes can be divided into a) Run of the river schemes and b) Impoundment schemes. Both high head run of the river and impoundments schemes utilize upland catchments where sufficient head is available. Water is drawn through a pipeline/tunnel from a high level to a powerhouse.

A. Run of the River High Head Schemes.

Run of river schemes have little or no storage and exploit the natural river flow which is piped to a power house sometimes distanced kilometers downstream. The schemes usually incorporate a pool area above a natural or manmade weir across the river; a fully submerged intake arrangement which feeds the pipe is positioned along the bank of the pool. These schemes are generally designed to operate at all times, even under low flow. Maximum turbine flow rates typically correspond to 1-1.5 of average daily flow (ADF) and can generally operate down to 10% of maximum turbine flow rate. These schemes are now receiving more interest along the mountain areas of the North-West and South of Ireland.

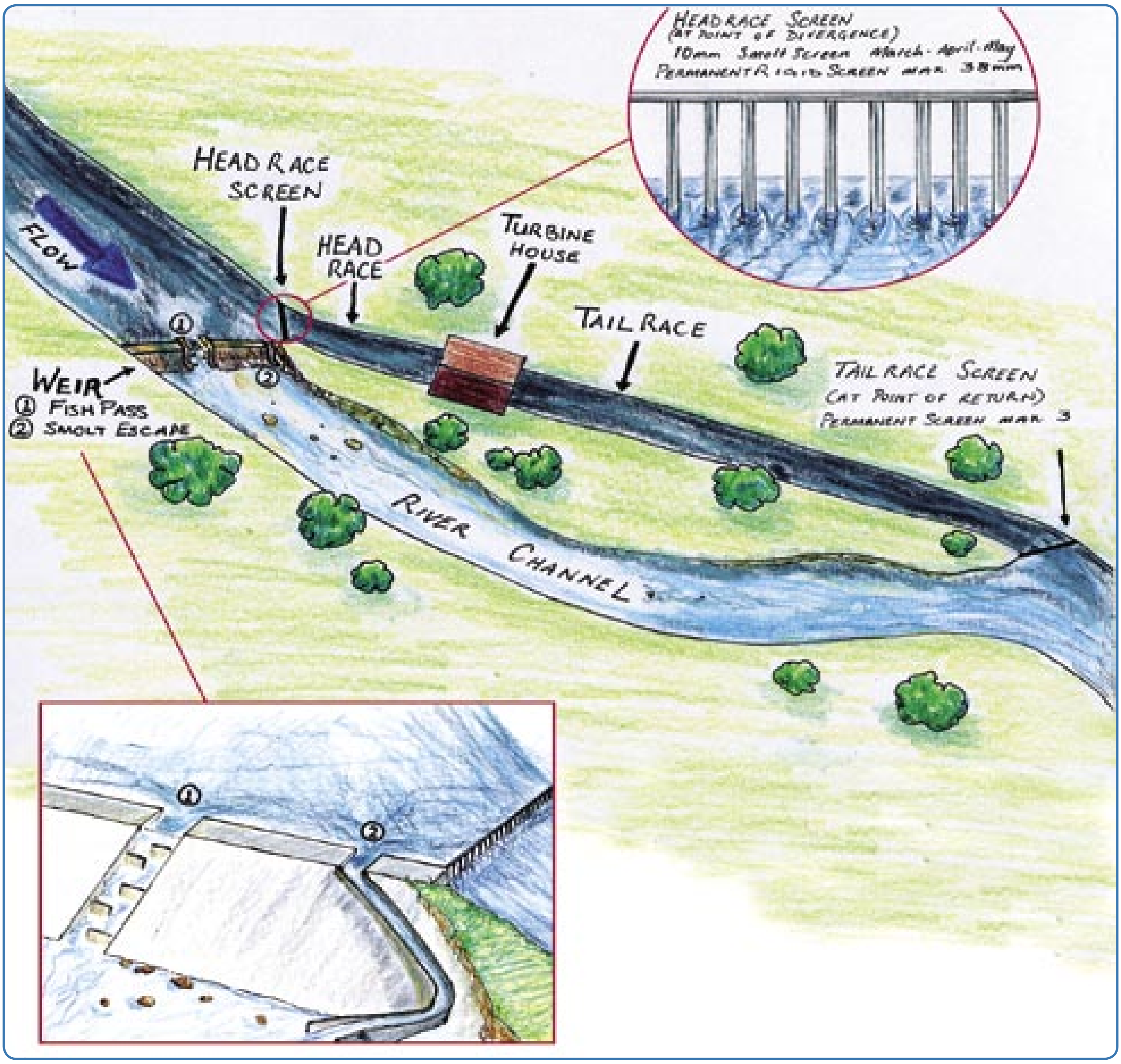
B. High Head Impoundment Schemes on Lakes.

Some high head schemes incorporate storage utilizing upland lakes whereby enhanced storage in the lake is used to augment the flow available for abstraction. These schemes are likely to cause fish passage problems and restrict access to spawning areas or render spawning areas unusable. A number are currently in operation in Ireland.

Example of small Hydro Scheme

Low head hydro scheme on the Bandon River. The intake is located above the weir (right background) and the tailrace discharges back to the main river (right foreground).

Two examples of a natural rock head weir downstream of intake on a high head run of the river scheme.

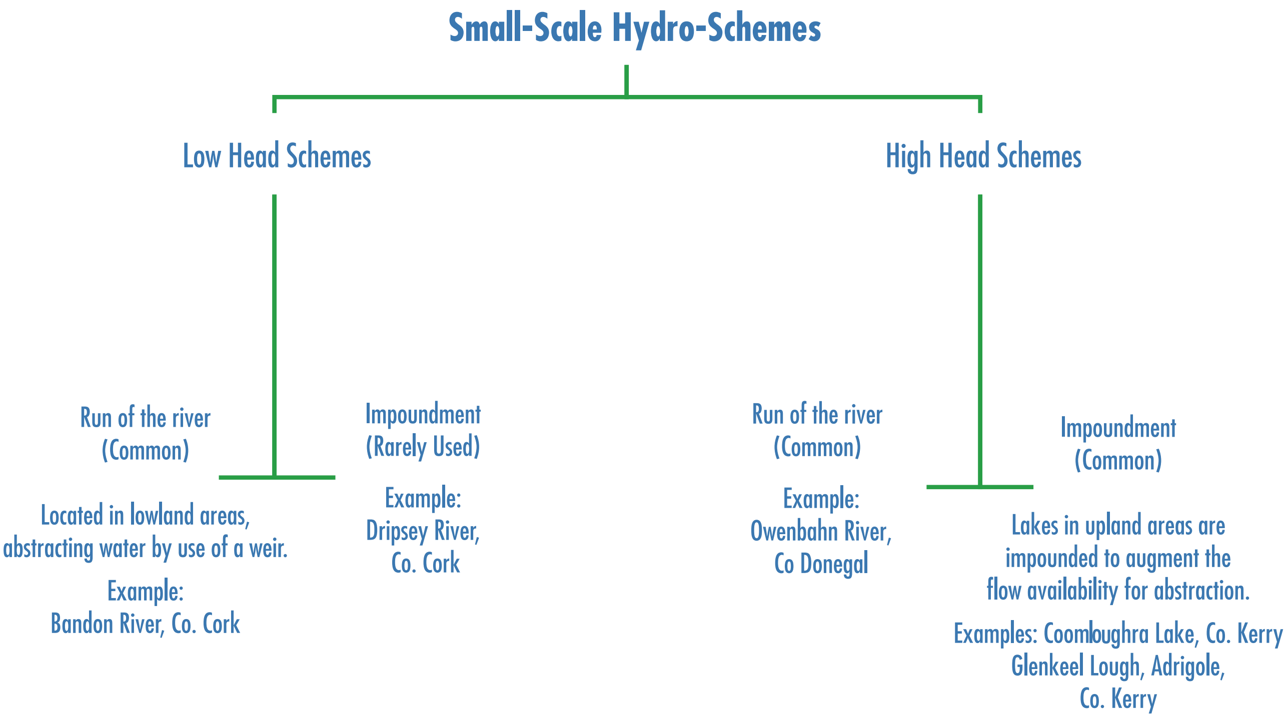


Low head run of the river Hydro-Scheme

High head run of river intake with constructed head weir.

High head run of river return point.

Turbine intake on a high head lake impoundment.



4 The Application Process for Hydro-Electric Schemes

4.1 Environmental Impact Assessment

Environment Impact Assessment (EIA) is a process for anticipating the effects on the environment caused by a development. An Environmental Impact Statement (EIS) is the document produced as a result of that process. Where effects are identified that are unacceptable, these can then be avoided or reduced during the design process. The EIA procedure commences at the project design stage where it is decided whether an EIS is required. If it is required, then the scope of the study is determined, after which the EIS is prepared as part of the application for development consent, (Anon, 2002). The competent authority examines the EIS and comes to a decision on the application.

EIA requirements derive from European Communities Directive 85/337/EEC (as amended by Directive 97/11/EC) on the assessment of the effects of certain public and private projects on the environment. The primary objective of the EIA Directive is to ensure that projects which are likely to have significant effects on the environment are subject to an assessment of their likely impacts. EIA is defined as "a statement of the effects, if any, which a proposed development, if carried out, would have on the environment" (S.I. No. 349 of 89). An EIA is mandatory for all Annex I projects while in the case of Annex II projects, Member States must determine on a case by case basis whether or not a project should be subject to an EIA. Thresholds have been set in Ireland for each of the project classes in Annex II, (S.I. No. 93 of 1999). Statutory Instrument No. 93 of 1999 (European Communities Environmental Impact Assessment, Amendment Regulations, 1999) specifies that an EIA is required for the following hydro-electric schemes:

"Installations for hydroelectric energy production with an output of 20 megawatts or more, or where the new or extended superficial area of water impounded would be 30 hectares or more, or where there would be a 30 per cent change in the maximum, minimum or mean flows in the main river channel".

Most proposed small-scale hydro schemes would have an output well below 20 megawatts and may not impound any water. ***A change in 30% of mean river channel flow is likely to occur and it is in this context that an EIA is required.***

4.2 Initial Screening Process

Screening is the process which examines whether or not a development should be a candidate for EIA. The local authority has the role of assessing the need for an EIA for a particular development. Not withstanding the criteria laid out in S.I. No. 93 above on the requirements for an EIA, because of the considerable potential negative impact of hydro-electric development on fisheries and the environment, it is considered that an Environmental Impact Assessment should be prepared for all proposed developments. In circumstances where the competent authority does not see the need for a full EIA to be undertaken, an Environmental Appraisal should be undertaken.

The guidelines contained in this document should be assessed relative to the proposed location and operation of schemes so that an initial screening process can be conducted. If the criteria set out in these guidelines cannot be met then the development should not proceed to the scoping stage.

4.3 Scoping Stage

Scoping is the process whereby the terms of reference of the EIS are decided. It identifies the issues and emphasizes what are likely to be important during EIA. This document would draw up a list of possible impacts of the development and in the case of hydro-scheme development, set out the issues relating to hydrology, hydrography of the channel, fish movement and flow etc. and the fisheries information which needs to be addressed in an EIS. This will ensure that the EIS contains sufficient information on possible impacts of the development for the competent authority to make a decision on the application. A decision could be made at the scoping stage that issues deemed of minor importance for the development at a particular location could be covered less intensively in an EIS. Scoping provides an opportunity for an exchange of views at an early stage when there is still flexibility in the design of the development.

The information can be compiled in a formal process, whereby the competent authority consults with relevant agencies to draw up the scope of the information required. More informal scoping can also be carried out to ensure that all relevant issues are identified and addressed to an appropriate level of detail, (Anon, 2002). Authorities to whom aspects of a development may be referred for comment are usually contacted at the scoping stage. With regard to hydro-power developments, these would include the relevant Department of Agriculture, Fisheries & Food Engineer and the relevant Regional Fisheries Board. These bodies are contacted to determine the level of information they require in an EIS. This consultation has been informal to date. As part of these guidelines the information which should be required in an EIS from a fisheries perspective in the scoping stage for small-scale hydro-electric developments is set out in (Appendix 1).

The scoping stage should provide the information to assess whether the developer should proceed to prepare a full EIS for the type of development at the proposed location. There may be circumstances where the authorities may decide that having gone through the scoping stage, the development is unacceptable. This issue is fully dealt with in Section 7.

4.4 Issues of Relevance to Fisheries at the Scoping Stage.

Provision of adequate baseline data.

The scoping process will lead to an Environmental Impact Statement being prepared which should provide a fair and accurate description of the proposal. Statutory Instrument No. 93 of 1999 (European Communities Environmental Impact Assessment, Amendment Regulations, 1999) specifies that an EIS should contain the following information describing:

- *The proposed development*
- *The existing environment*
- *The impacts of the proposed development*
- *The measures to mitigate adverse impacts*
- *A non-technical summary*

The existing environment and the impacts of the development are explained by reference to its possible impact on a series of environmental topics including; fauna and flora, soil, water, the landscape and the inter-relationship between these factors. Impacts should address direct, indirect, secondary, cumulative, short, medium and long-term, permanent, temporary, positive and negative effects. The document "Advice notes on current practice in the preparation of Environmental Impact Statements" (Anon, 1999) contain detail and offer guidance on current practice for the structure and content of EIS's. Section 3 provides guidance on the topics which would usually be addressed when preparing an EIS for installations for hydroelectric energy production (Project type 2,) and water impoundment including hydroelectric generation (Project type 12,).

In the context of hydro-scheme proposals, assessment of impacts will require baseline studies, particularly in relation to the fisheries resource, fish migration and flow, habitat, and the efficacy of fish passes where present. Inadequacy of baseline data was a major problem identified in a recent survey of sites in Northern Ireland (Anon, 2000). Bodies such as the Central and Regional Fisheries Board, the Marine Institute and the Engineering Division of the Department of Agriculture, Fisheries & Food may contribute to the EIA process by providing data which may be relevant to the project. Consultation with these authorities may identify information gaps at an early stage and identify the information required to be set out in the scoping stage. The developer will be required to supply or collect adequate fisheries data for a proper assessment to be made of the impact of the scheme.

Treatment of fisheries data in existing Environmental Impact Statements for hydro-electric schemes has often been inadequate, partly due to the lack of specified fisheries criteria which needs to be addressed. In order to ensure that an EIS adequately addresses the relevant issues, from a fisheries perspective, guidelines setting out the fisheries information which should be included in an EIS are set out, Appendix 1.

4.5 Role of State Agencies

4.5.1. Central and Regional Fisheries Boards

The Central and Regional Fisheries Boards are the statutory bodies charged with the protection, conservation, development and management of inland fisheries, (Section 11, 1980 Fisheries Act). The Fisheries Board can advise both the developer and the planning authority in relation to proposed hydro schemes.

When a Planning Authority receives a planning application, where it appears to the authority that:

- *The development might cause the significant abstraction or addition of water either to or from surface or ground waters whether naturally occurring or artificial*
- *The development might give rise to significant discharges of polluting matters or other materials to such waters or be likely to cause serious water pollution or the danger of such pollution*
- *The development would involve the carrying out of works in, over, along or adjacent to the banks of such waters, or to any structures in, over or along the banks of such waters, which might materially affect the waters*

the planning authority *shall* notify the appropriate Regional Fisheries Board and where relevant Waterways Ireland, Planning and Development Regulations 2001 Part 4, Article 28 (1) (g).

4.5.2. The Department of Communications, Energy & Natural Resources

Fish passes and screens must be approved by the Minister for Communications, Energy and Natural Resources. His Engineering advisors can provide technical advice to the developer, the Fisheries Boards and the planning authority.

4.5.3. Local Authorities / Planning Regulations

Small hydro schemes are subject to planning regulation and the planning authorities have the power to stipulate provisions for the protection of the aquatic environment and fisheries. Statutory Instrument S.I. No 600 of 2001, Planning and Development Regulations 2001, Part 4, requires a planning authority to notify prescribed bodies on receipt of a planning application.

4.5.4. The Office of Public Works (OPW)

The Office of Public Works responsibility in relation to hydro-electric development relates to any implications which the development may have for land drainage and flooding, (Arterial Drainage Act, 1949). The OPW is also responsible for the provision of hydrometric information at OPW hydrometric stations.

4.5.5 Department of Environment Heritage, & Local Government

If the development is within a Special Area of Conservation as set out in the EU Habitats Directive, or if outside an SAC and likely to adversely affect the SAC, National Parks & Wildlife Service (NPWS) require an EIS to be undertaken.

Overall responsibility for the co-ordinated implementation of the EU Water Framework Directive (WFD) (2000/60/EC) resides with the DEHLG. The purpose of the Directive is to prevent deterioration in aquatic ecosystems and the Directive requires an improvement of all waters to good status by 2015. The Directive was transposed into Irish legislation in December 2003 by Statutory Instrument (S.I. 722/2003) which imposes a statutory obligation on every public authority to –

(a) exercise its functions in a manner which achieves compliance with the Directive
(b) take such actions as may be appropriate to it to secure compliance with the Directive and any River Basin Management Plan made under the Regulations, and
(c) consult, co-operate and liaise with other public authorities for co-ordinated implementation.

The quality elements and definitions of ecological status are set out in Annex V of the Directive. The WFD requires that waters currently at high status are maintained in that category. River continuity (the ability of sediment and migratory species to pass freely up/down rivers) is an important quality supporting ecological status under the hydromorphological element. In high status waters, “the continuity of the river is not disturbed by anthropogenic activities and allows undisturbed migration of aquatic organisms and sediment transport”. If any structure impedes or prevents the passage of fish in waters of high status, to the extent that species composition and abundance are changed even slightly from the type-specific communities, then such a structure contravenes the terms of the WFD. Likewise, with regard to the biological quality elements of fish, fauna and river continuity, anthropogenic activities must not result in a downgrading of water bodies in any category, for example from good status to moderate status. Accordingly, the installation of hydro-schemes must not downgrade the status of a water body. (WFD, 2003)

A major programme of activities for implementation of the Directive is underway by local authorities in the context of their River Basin Management Projects which are co-ordinated at national level by the DEHLG and the Environmental Protection Agency.

4.5.6. Environmental Protection Agency

Under the provisions of the Environmental Protection Agency Act, 1992, planning authorities may require that Environmental Impact Statements be submitted for projects deemed likely to have a significant effect on the environment. The EPA has prepared a document entitled "Guidelines on the information to be contained in Environmental Impact Statements" which sets out general guidelines, (Anon, 2002). A second document entitled "Advice Notes on Current Practice in the preparation of Environmental Impact Statements" has also been published by the EPA. This document contains greater detail and provides guidance on the topics which would usually be addressed when preparing an EIS for a particular class of development, including a hydro-electric development.

In addition, the Hydrometric Division of the EPA provide data on local authority hydrometric stations.

5. Potential Effects of Small Hydro-Electric Development on Fisheries.

The impact of a hydro-electric development on a fishery ecosystem will be determined by the location, scale, nature and design of the development and the type, size and location of the associated fishery. The individual nature of each hydroelectric installation, coupled with the turbine technology used, means that the effect can range from negligible to total mortality, (Cada & Francfort, 1995). The effect is likely to be considerable with large-scale installations with high dams and a review of the potential effects of such installations in Ireland has been undertaken (Mathers *et al,* 2002). The potential impacts of small-scale hydro-electric developments are reviewed below.

5.1 Low Head Schemes

Impacts on the Natural Channel

In low head schemes the volume of water being diverted from the main channel is large relative to total flow and may reduce the residual flow in the natural channel to such an extent that there is habitat loss, and floral and faunal communities and native fish populations are severely affected. Assimilation capacity may also be affected. Adverse repercussions can result from indirect effects such as disruption of food webs downstream, drying out of redds or egg masses, stranding of fish, and siltation of spawning gravels due to the absence of high flows, (Cowx, 1998). Water temperature regimes are also important with respect to egg development and hatching rates and as a cue for fish migration, thus any changes may disrupt these processes.

Impact of over-abstraction on river flow.

Impacts on Downstream Migrants

Smolts and kelts tend to be attracted to the main flow which, in non-flood conditions and during power generation, may be towards the head-race intake. Fish impingement on intake screens can cause considerable mortality unless the approach velocities are sufficiently low to allow fish to escape, (Cowx, 1998). Downstream migrants, particularly smolts, which are allowed to enter a headrace may be drawn onto turbine screens or may have difficulty finding a by-pass to the main channel. Smolts may enter the head-race and suffer injury or death in passing through the turbine, (Solomon, 1992). Delays in smolt migration above weirs and dams may increase mortality due to predation, (Jepsen et al, 1998).

Other fish that may be impacted include downstream migrating silver eel and downstream migrating lamprey. Both the silver eel and recently-transformed anadromous lamprey migrate in the autumn – early winter period and may be susceptible to entrainment during power generation in all flow conditions.

Impacts on Upstream Migrants

Upstream migrants may linger at or be attracted into the tailrace when the flow from it is more attractive than the flow down the natural channel. This may delay upstream migration and leave the fish more vulnerable to poaching. Fish may be delayed or subjected to exhaustion or injury in surmounting the weir (Murphy, 2000). Late running fish held up at weirs may be prevented from reaching their spawning areas. Fish held up in high numbers during periods of high temperature are at risk of disease outbreaks. Obstruction at barriers has been shown to severely restrict dispersal of sea lamprey in summer flow conditions in Irish rivers. Such barriers are considered causative agents of hybridisation among the two shad species – Allis and Twaite.

Angling upstream of an obstruction or in the depleted stretch may be affected if migratory fish are delayed in their progress upstream. This may be particularly important for spring salmon as it reduces angling opportunity. Even if upstream passage provisions are adequate, fish may not be inclined to run unless there is adequate compensation flow or sufficient freshets to induce upstream migration.

Obstruction to upstream fish passage.

Salmon rescue within a tail-race. Inadequate screening at the point of return of the tailrace to the main river or overtopping of fixed screens can allow upstream migrants entry to the tailrace where their migration can be halted.

5.2 High Head Schemes

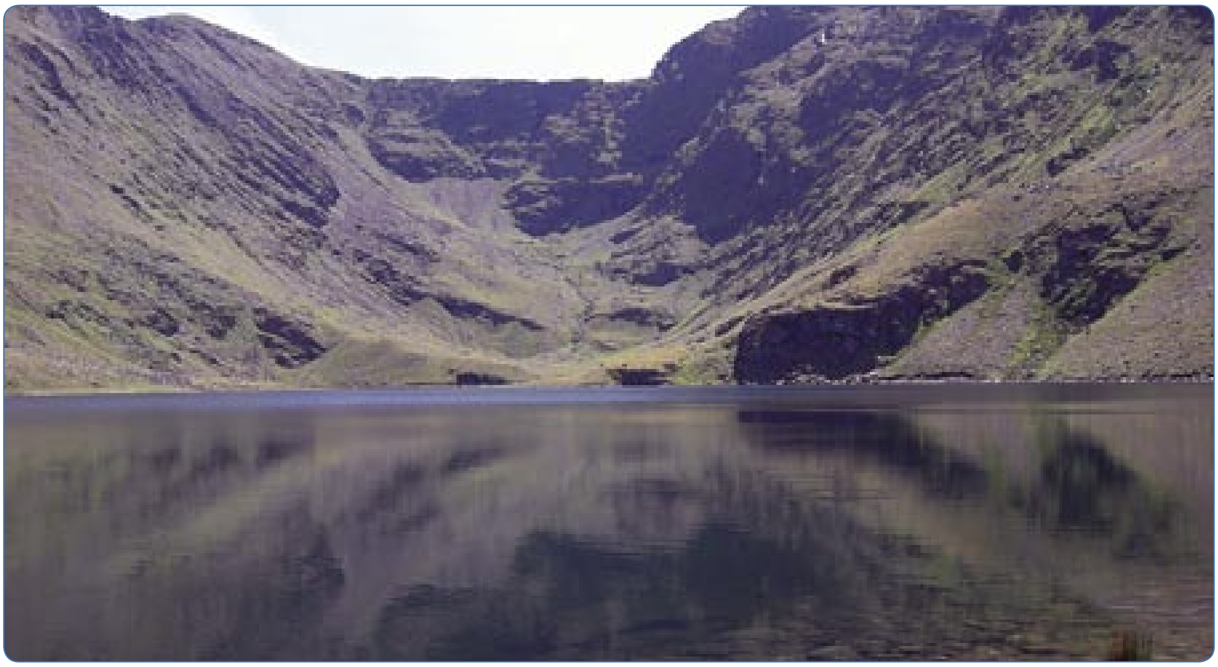
The "spaty" nature of run of the river schemes in upland catchments is far from ideal to support hydropower abstraction. The range of flows within which the turbine can operate is such that there is often either insufficient water or more water available than the turbine can accept, (Anon, 1996a). The result is, that to maximize economic returns, hydropower abstractions take a significant portion of the hydrograph above low flows and below very high flows, i.e. the portion of the hydrograph the developer wishes to generate often equates to flows suitable for salmonid migration. This also has an affect on the hydrograph of the reach between the points of abstraction and return, by eliminating many of the peaks in flow or reducing their extent. Such schemes, diverting water away from the main channel under low flow conditions may cause problems for upstream migration, particularly if obstacles have to be negotiated, (Cowx, 1998). There may also be an impact on spawning and nursery potential due to reduced flow.

Barrier without fish pass on outflow of impounded lake.

5.3 Impoundment Schemes

Increasing the storage area of lakes to ensure a readily available source of water for hydro-electric generation can have serious consequences for fish. A weir or dam may obstruct the upstream migration of adult salmonids or prevent downstream passage. Large fluctuations in water levels may present major difficulties in designing a satisfactory fish pass.

The increase or decrease in the normal fluctuation in lake levels of lakes will inevitably result in loss of habitat and spawning and nursery potential and lead to a reduction in juvenile fish production. These will be subject to unnatural variation in levels, periodically causing littoral areas to dry out with consequential effects on flora, fauna and fish stocks. This may be particularly important for arctic char, trout and coarse fish which spawn in the shallow littoral area of lakes and the lower reaches of inflowing streams.



Impounded lake at high water level.

Littoral lake area dried out due to excessive drawdown.

5.4 Fish Passage Through Turbines

The nature of small-scale high head turbines (impulse turbines) means that the operator must prevent fish or other objects from entering the turbine so as to avoid turbine damage. It is therefore presumed in the context of this review, that high head schemes will totally exclude the entry of fish.

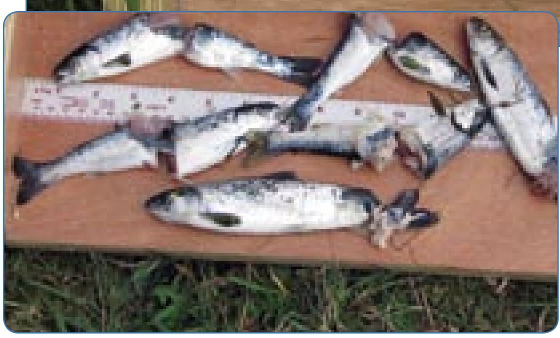
5.4.1 Fish Damage Through Turbines

Larinier & Travade (2002) have summarized the data available on fish passage through turbines. Fish passing through low head turbines are subjected to various forms of stress that are likely to cause damage or mortality. These include strike from stationary or moving parts of the turbine, sudden acceleration or deceleration, shear, very sudden variations in pressure.

The increased mortality caused by turbine passage varies greatly, depending on the type of turbine, the size of the head of water and several other factors, (Ruggles 1980). Numerous studies have been carried out, mainly on juvenile salmonids, to determine their mortality rate when passing through the main types of turbines (EPRI, 1992). The mortality rate for salmonids in Francis and Kaplan turbines varies greatly, depending on the properties of the runner (diameter, speed of rotation, etc,), their mode of operation, the head, and the size of the fish concerned. The mortality rate of turbines varies between fish species, Larinier & Travade (2002). Generally, the mortality of adult eels is high because of their length and may be 4 to 5 times higher than that in juvenile salmonids.

Fish that survive the stressful conditions associated with turbine passage are often damaged and susceptible to predation and mortality due to their injuries, (Bouch & Smith 1979). Many attempts have been made to develop behavioural systems to direct fish away from intakes using lights, bubble curtains, electric fields and sound. The behaviour pattern in the downstream migration of juvenile salmon is surface orientated and involves following flow. No combination of these artificial stimuli has been demonstrated as being effective enough to guide fish away from intakes at large hydroelectric projects and only intake screens and spillways have been found to be effective, Coutant & Whitney (2000). These comments would also apply to small scale schemes.

Experience has shown that fish passage through turbines does infer a mortality factor. In the light of this experience, it is essential that when designing a new scheme, that fish passage provisions include appropriate intake screening to exclude fish.



Salmon smolts passing through turbines can suffer severe scale loss and mortality due to strike from blades.

6. Review of Current Operation of Small Scale Hydro-Electric Schemes

Recent reports and publications on the operation of small-scale hydro-schemes are reviewed below and where appropriate, comments and recommendations made in these reviews are incorporated into the guidelines set out in Chapter 7.

6.1 Fish Passage

6.1.1 Fish Passage for Upstream Migrants

Cowx (1998) reviewed issues relating to fish passage in the UK. He concluded that while the basic design of most passes appear to be adequate for the target species, little attention has been paid to the location and flow regime under which the pass functions. Key problems are that the flow characteristics of the pass are not appropriate for the target species and the entrances to the passes are poorly positioned. Anon (2000) reviewing the efficacy of existing fish passage facilities note that it is often not enough to have a fish pass in a weir, even if such a pass is of acceptable design. Other factors such as the approach and holding conditions in the natural channel, the structural condition of the weir, and the relationship between weir flow and flows through the fish pass must be taken into account. Murphy (2000) considers that undue reliance is generally placed in the legislation on simply providing fish passage and there is no stipulation of the volume of flow which should be provided by a fish pass. He suggests that fish passes should be so designed as to discharge the required residual flow when the head water is at the lowest level at which the operator might draw it down, which, in turn, should be no lower than the crest of the weir.

The Report of the Salmon Advisory Committee in the UK on Fish Passes and Screens for Salmon (Anon 1997) refers to the entrance of a pass being an integral part of the whole structure and points out that, if a salmon cannot find the entrance, the pass is useless. In too many cases, passes have been built with badly located entrances and with flows from the entrances which do not attract upstream migrants. The flow of water from the downstream end of the pass must therefore have sufficient velocity to attract fish. Tests have shown that if the ratio of the outflow velocity from the pass to the velocity in the receiving pool is at least 3:1 then fish will be attracted to the pass, (Anon 1997). However, the velocity must not exceed that which salmon can overcome and an optimal velocity of 2 to 2.4 m/sec has been recommended, (Larinier, 1992). More recent work (Anon, 2002a) recommends that the velocity of the water at the fish pass entrance should not exceed 2 m/sec even at low water. Strong turbulence and current velocities over 2m/sec should be avoided at the exit area of the fish pass so that fish leave the pass more easily.

Depth of the approach channel to the fish pass is important. Larinier (1992) notes that at the entrance to fishways, the occurrence of a hydraulic jump must be prevented. It must also be ensured that the water depth immediately downstream from the entrance is adequate and there must be a pool of sufficient depth at the foot of the fish pass to allow the fish to rest without any difficulty. Sometimes gravels tend to accumulate downstream of long weirs making it difficult for fish to approach. In such cases a self-cleaning approach channel may be necessary.

Anon (1997) notes that the influence of the angle between the flow from the pass and the main flow is also important. The attraction of fish to a pass falls away very quickly as this angle increases, and the best configuration has the attraction flow parallel to the main flow. In addition, fish should not be able to reach a position where they have to turn back to find the entrance to the pass. It is also critically important that there is sufficient depth of water for fish at the entrance to the pass at all times.

Eel Passage

The European eel, *Anguilla anguilla,* stock is currently outside safe biological limits, eel fisheries are no longer sustainable and an action plan for stock recovery is urgently required (ICES 2002, EIFAC 2006). ICES have also advised that fishing and other anthropogenic mortality should be reduced to a minimum pending the implementation of an Eel Stock Recovery Plan. Recruitment is at an historical minimum and most recent observations do not indicate any recovery. In 2003, the EU issued a Draft Action Plan for the Recovery of the Eel Stock in 2003(COM 2003, 573) and a Draft Regulation in March 2005 (COM 2005, 472). The Regulation proposes to achieve a recovery in the global eel stock through a combination of eel River Basin Management Plans, coupled with spawner escapement targets (i.e. 40% Spawning Stock Biomass), and controls on fishing and other anthropogenic influences.

Denil fish pass to allow upstream movement of fish.

Vertical slot pool pass.

Vertical slot pool pass.

Pool pass.

Upstream passage of juvenile eel, migrating as either elvers or juvenile "bootlace" yellow eel, requires a fundamentally different approach to that for upstream migrating adult "swimming" fish such as salmon, trout or coarse fish. Therefore, traditional upstream passes designed for salmon, such as pool passes or denil type ladders are largely ineffective for eel. The primary aim in the design of upstream eel passes is to provide suitable conditions to allow the ascent of a hydraulic drop, natural or man-made, or where ascent may be difficult and upstream recruitment rendered sub-optimal, such as at a road culvert. Eels are incapable of jumping, or swimming through strong laminar flows, so vertical falls of more than 50% of their body length (an elver is approximately 75mm in length) represent a barrier to upstream migration (Knights & White 1998). However, they are adept at exploiting boundary layers and rough substrates which can be utilized in eel pass design. Solomon & Beach (2004) presented a comprehensive review of the design of eel and elver passes including facilities based on ramps with substrate, pipe passes, lifts and locks, easements or complete barrier removals. This important manual is available from the Environment Agency, UK.

Pool pass.

6.1.2 Screening for Upstream Migrants

Screening at the tailrace is essential to prevent the entry of fish. This becomes more important when the bias of flow is from the tailrace.

In Scotland, heavy vertical barred screens are installed to prevent the entry of upstream migrants, (Anon 1996). The maximum recommended spacing is 40mm (1.6 inch) for salmon and 31-37.5mm (1.22-1.47 inch) for sea trout. In Ireland, to prevent upstream migrating fish from entering a tailrace, Section 123 of the Fisheries (Consolidation) Act 1959 stipulates that at the point of return to the river, the channel should have bar screens with 2-inch gaps fitted. Murphy (2000) notes that 2 inch bar spacing (50mm) is too wide to exclude sea trout. This screen spacing should be reduced to 1.5 inch (38mm). This recommendation should be reviewed in specific cases where the entry of coarse fish (or listed species under the Habitats Directive) into tailraces is an issue. Rigid bar screens should be used to avoid flexing.

Bar screens often cause migration problems if they are set even a short distance up from the mouth of the tail race, as they often are for construction reasons, because it is difficult and expensive to install them across the mouth or "point of return" as envisaged in the legislation, Murphy (2000). In such cases fish are lured into a cul-de-sac where they may linger until the turbine flow ceases.

Tailrace bar screens at low head schemes can get constantly clogged with leaves and debris which can cause loss of head and cleaning of screens at the tailrace is essential for the efficient operation of hydro-schemes. Cleaning of screens can be difficult and time-consuming and also can involve safety issues. This has led operators to apply for exemptions to use electric barriers over conventional screens. There is a provision (Section 123, Part 8, Chapter 5 of the Fisheries (Consolidation Act 1959) to apply for an exemption. Current legal advice does not support the view that an exemption can be granted on the basis that another type of fish barrier would be used in place of a grating on a permanent basis.

6.1.3 Fish Passage for Downstream Migrants

The optimum location of a fish pass in many weirs can be difficult to establish because of the weirs diagonal orientation relative to the river channel. The upstream migration favors a fish pass located towards the upstream end of the weir. However, the downstream migration suggests an optimum location close to the headrace. For long weirs two fish passes or an additional smolt/kelt escape may be necessary.

Barriers and turbines pose particular threats to the downstream passage of migrating silver eels. Silver eel are the potential spawners and their migration takes place during the darkest nights between September and January/February, particularly when water levels and flow rates are high and there is considerable entrainment of rubbish which can block nets and screens. As discussed in Section 6.1.1, the eel stock has fallen below biologically safe levels and protection of the spawning stock must be a priority. Mortality caused by hydroelectric turbines is well documented (ICES, 2002). Direct mortality varies depending on site characteristics, generator system design and turbine management procedures. Mortality of eels can be caused by a number of mechanisms such as, jamming on the protection screens, collision with parts of the turbine, rapid changes in the hydrostatic pressure and predation in the tailwater. ICES (2002, EIFAC 2003) concluded that obstruction to downstream migration and mortality caused by turbines are likely to reduce silver eel escapement considerably and therefore have a detrimental impact on the overall stock..

Fixed screen installation at point of return of tailrace flow to main river. This screen will prevent the entry of upstream migrating salmon entering the tailrace.

A site specific approach should be taken when evaluating the impact of existing installations and proposing mitigating measures. The Environmental Impact Assessment for any new barriers and/or turbine installations should include an evaluation of their potential impact on direct and indirect mortality of silver eel and should also be included in any catchment based plans for the management of eel stocks.

6.1.4 Screening for Downstream Migrants

Section 123 (a) of the Fisheries (Consolidation) Act 1959 specifies that gratings be placed at the point of divergence of a headrace to prevent entry of salmonids. Section 123 (b) specifies that during the months of March, April and May, and at such other times as the young of fish may be descending, a lattice shall be placed over the gratings to prevent the entry of juvenile salmon. In practice, as permitted in Sect 124, the Department of Communications, Marine and Natural Resources accept a screen with 10mm spacing as an alternative to a lattice. Even when smolt screens are placed at the point of divergence of a head-race, it may be necessary to provide a smolt pass or "bypass and return system" at the weir for fish to find a suitable exit downstream.

A number of physical screen types may be used to prevent entry of fish into intakes namely fixed mesh or bar screens, moving or traveling screens and cylindrical wedge-wire screens. While the latter two types may prove effective in some situations, only fixed bar screens are discussed below and remain the most practical solution to prevent entry of fish into intakes.

Studies in Scotland (Anon 1996) have found that while the placement of small mesh screens at intakes prevents the entry of smolts into high-head turbines, smolt mortalities have occurred due to excessive water velocities through the screens, resulting in smolts being drawn onto them, (impinged). This occurs where the screened area is either too small or is reduced due to being blocked by an accumulation of water-borne debris. The likelihood of this problem arising can be predicted by routinely monitoring water levels immediately upstream and downstream from screens. If a significant head loss across the screens is observed, especially during the smolt migration period, this will provide early warning of a potentially hazardous situation. This problem has been resolved in some locations by creating a much deeper and wider area into which the screens are set. The increased screening area was designed to ensure that the approach velocities at the screens do not exceed the maximum speed at which salmon smolts have been found to be able to maintain position for long periods, about two body lengths per second, McCleave and Stred (1975).

Intake screen arrangement at a high-head site.

High head run-of-river intake screen.

If a fish approaching an intake is to avoid entrapment it must be capable of swimming faster than the approach velocity in order to escape. Two types of swimming speed have been identified, cruising or sustained swimming and burst speed. The findings of Turnpenny (1988) indicate that fish near intake screens swim gently to avoid impingement and argues that it is cruising speed that is appropriate for consideration as a critical approach velocity. Solomon (1992) recommends 0.3m/s as a broadly appropriate approach velocity for avoidance of entrapment. Murphy (2000) also recommends that the approach velocity cited by Ruggles (1992) of less than 0.3m/sec should be followed as closely as possible. Aitken et al., (1966) also recommend an approach velocity of 0.3 m/sec for salmon smolts (12-15cm).

Trashing, which effectively reduces the sievage area, may result in increased velocities through the remaining clean sections of screen and must be allowed for. Experiments in Scotland have shown that smolts of 13-14cm were unable to hold station at speeds greater than about two body lengths/sec, or 0.26m/sec, (Anon, 1995). Salmon smolts in Ireland can vary in length from about 10-15cm. Therefore, allowing for 50% blockage of screens by debris, it is recommended that the approach velocity at smolt screens should not exceed 0.3m/sec. when turbines are on full load. If trashing is a particular problem, trash booms or similar devices should be incorporated in the layout.

The above recommendation is critical if the design of screens are such that fish may linger at screens. To reduce the maximum current speed through screens, the size of the screened area must take into consideration the volume of water to be extracted. If the screen is at the point where the offtake leaves the river, then the screen should be set so that fish should be able to easily swim along the face of the screen and on down the river. In situations where fish can make their way down the headrace, to assist fish to locate the entrance to the fish pass at screened intakes, studies indicated that during generation, the provision of a supplementary flow of water across the upstream face of the fish screens towards the fish pass encourages passage through the pass, (Struthers, 1989).

Intakes to turbines should abstract water at 90 degrees to the main river flow so that the intake screen array is more or less continuous with the river bank, i.e. the screen array is aligned parallel to the main flow (Anon 1995a). This will help to lead downstream migrating fish along the face of the screens towards the fish pass intake, which should be adjacent to the downstream end of the array. However, this may not always be the case and depends on the angle of the weir, width of the river etc. Weirs on large rivers are normally built diagonally and more than one fish pass or smolt escape may be required. If the intake screen array is at right angles to the main flow, downstream migrants are more likely to be drawn onto them and the fish will less easily locate the bypass.

The angle of the screen in relation to the current should be as small as possible so that fish may be easily guided towards the bypass placed at the downstream end, (Larinier & Travade, 2002).

6.1.5 By-Pass and Return Systems for Downstream Migrants

Murphy (2000) argues that common sense and pragmatism dictate that in most cases, from the operators viewpoint, the best option is to allow fish down the head-race to a point adjacent to the power house where they can be returned to the main channel. At old mill sites or where the exact point of divergence changes with flood conditions the provision of a by-pass and return system may be worth considering, but for any new small hydro schemes, smolt screens must be provided at the point of divergence to the head-race to divert smolts down the natural channel.

In exceptional cases where smolts are allowed down a headrace, they must be prevented from passing through the turbine by means of a screen which will safely divert them via a by-pass and return system to the natural channel. Murphy (2000) describes the basic principle of aligning the screens at an angle so as to maximise their surface area, thereby minimising the velocity of the flow normal to the screen face and maximising the flow component along the screen face towards the by-pass and return facility. The recent Termonbarry Bord Pleanala decision incorporated that recommendation and also required screens to be so designed and angled to encourage and facilitate the diversion of fish to proposed fish passes and bypasses.

Anon (2000) made recommendations for bypass and return systems for smolts. The mouths of all bypasses should be so designed as to be readily found by fish which have been diverted to them by the screens. To accommodate spent salmon as well as smolts, the by-pass should be at least 225mm wide and have a minimum depth of flow of 150mm, Murphy (2000). There should be a positive attraction flow to the by-pass channel at all times when smolts may congregate near the intake screens. Ideally, the flow through the pass should never fall below an appropriate predetermined volume. To make this possible, the mouth of the pass should be fitted with an overshot sluice gate which would rise and fall with the head race water level. A covered area to create shade at the approach to the bypass is recommended so that the fish are naturally attracted to the mouth of the bypass. This might be desirable but may catch debris and at some sites may be impractical. The chute or pipe through which the fish descend to the natural river channel should be smooth, well supplied with water, and should discharge the fish into a pool deep enough to cushion their landing. Murphy (2000) recommends that at typical low head sites, where the drop is less than 5m, the simplest option is to allow the fish to free-fall, provided they will land in open water of adequate cushioning depth of about 0.5m minimum.

6.1.6 Assessment of Screen Performance

It is critical that all screens are regularly inspected, cleaned and maintained to ensure that they are operating efficiently. Screens must be inspected regularly for damage. Relatively small holes caused by damage or badly fitted screens can create an attractant flow that can result in significant numbers of fish being killed. There is a deficit in the Fisheries legislation to assess the performance of screens or to ensure that screens are maintained. Requirements for the maintenance of screens are in place in the UK. Screens must be constructed and located so as to ensure that salmon or migratory trout are not damaged or injured by them, and that screens are maintained, (Anon, 1997).

The recent An Bord Pleanala decision regarding an application for a hydro scheme at Tarmonbarry recommended that the efficiency of the screens be monitored for a period of three years from the commissioning of the project and if so directed by the Planning Authority, screens may be modified within the first year of operation of the turbines. The monitoring of screen efficiency is part of the assessment of operation of small-scale hydro-schemes recommended in Chapter 7.

6.2 Residual Flow and Compensation Flow

The term residual flow is the flow remaining in the river when abstraction is taking place. A compensation flow is a minimum flow that must be maintained by the operator at all times in the natural channel. These are designed to ensure an adequate flow regime downstream of intakes/weirs and dams to accommodate upstream migration, safeguard juvenile salmonids, spawning sites and invertebrate life and maintain holding pools for adult fish, even at low summer flow. To ensure an adequate residual flow, some planning authorities stipulate that the hydro station throughput should never exceed 50% of the total available flow. Murphy (2000) points out that if this provision is made on its own, it fails to address the broader issue of ensuring that the residual 50% is an adequate allocation for the natural channel. Accordingly an additional requirement is usually added that the “compensation / residual flow” in the depleted natural channel never be allowed to fall below a particular absolute value during abstraction.

Attempts to quantify the flow requirements of fish in rivers has rarely been successful and regulation flows are often too high or too low to maintain the fish population in their pre-regulation state (Petts, 1988). It is dangerous to assume that provision of a 95%ile flow (i.e. the flow which is exceeded for 95% of the time) will protect the ecology of a river (Anon 1995) and the preferred approach by the National Rivers Authority in the UK is to estimate minimum survival and migration flows by reference to measurements of riverbed width. Stewart (1969) regarded a flow of 0.03cumecs per meter of stream bed as an absolute survival flow for salmonids. Information from fish counters indicates that upstream migration of salmon typically commences at a flow of 0.08 cumecs per meter width.

The adequacy of residual flow depends largely on the type of river bed in the depleted reach and varies greatly from site to site. Murphy (2000) argues that it is more important to protect the macro-invertebrate fauna and ensure that resident fish have adequate cover as it is unlikely that any significant fish run will occur in low flow conditions. He suggests an initial approach of estimating what flow would be required in the existing channel to protect invertebrates and provide adequate cover for fish. If this figure proved to be unrealistically high, then one could carry out river-bed works to achieve the objective with a smaller flow. This would consist of creating a string of pools, interconnected by a channel of deeper flow (thalweg) along the depleted reach. This would preserve the fauna, provide adequate refuge and cover for resident fish and allow any fish that want to run upstream to do so. This was done successfully by the Southern Regional Fisheries Board in a mile long channel in the River Suir at Holycross. However while the fish stocks have been maintained, the effects on angling of intermittent large fluctuations in water levels caused by the operation of the turbines has been significant.

Baxter (1961) undertook an extensive review of the flow requirements for the preservation of migratory fish life. He concluded that, excepting for freshets, the heights of water required are substantially those represented by the dry weather flow, subject to the maintenance of a minimum flow of 12.5% average daily flow during periods of hot weather.

7. Guidelines for the Planning, Design, Construction and Operation of New Small-Scale Hydro-Schemes from a Fisheries Perspective

Having reviewed the legislation in place and set out the potential problems posed by small-scale hydro-schemes for fisheries and having assessed the current operation of schemes, the following guidelines are set out for the operation of small-scale hydro-schemes.

7.1 Guidelines for the Application Stage and Environmental Impact Statements.

A review of small hydro-electric schemes on river fisheries in Northern Ireland (Anon 2000) found about 5% of the original capital costs was an estimate of the expenditure required on modifications as a result of problems identified. Developers of future hydro-schemes should make allowance at the application stage for such a figure for post-commissioning modifications.

Good quality baseline data, particularly in relation to fish migration and flow, low flow conditions in the natural channel, efficacy of fish passes and details of weir structure affecting fish passage is essential. These aspects should be studied at the pre-design stage, along with other issues peculiar both to the site or the proposed installations. The lack of such data was a major problem identified at sites in a recent survey of hydro-scheme sites in Northern Ireland. Proposals for hydro-schemes should not be allowed to proceed through the application stage unless adequate baseline data is available. Because of the considerable negative potential impact of hydro-electric development on fisheries, and in circumstances where the competent authority does not see the need for a full EIS to be undertaken, an Environmental Appraisal should be carried out.

Treatment of fisheries data in existing Environmental Impact Statements for hydro-electric schemes has often been inadequate, partly due to the lack of specified fisheries criteria which needs to be addressed. In order to ensure that an EIS adequately addresses the relevant issues, from a fisheries perspective, guidelines setting out the fisheries information which should be included in an EIS are set out in Appendix 1.

7.2 Guidelines for Location of New Small Scale Hydro-Electric Schemes

7.2.1 Locations considered suitable for siting of new small-scale hydro-schemes.

From a fisheries perspective, certain locations may be considered appropriate for the location of small-scale hydro-electric schemes on rivers:

7.2.1.1. Locations Upstream of Impassable Falls.

Construction of small-scale schemes at these high head locations may not result in significant impact to the fisheries environment provided the following criteria are met;

- *The discharge from the turbine is returned directly below the impassable fall.*
- *That compensation flow described for Category 1 / Category 2 rivers as appropriate below is adopted.*
- *That provision is made for the movement of resident fish and elvers within the reach above the impassable fall.*
- *That there is no deterioration in water quality downstream resulting from the development.*

7.2.1.2. High-head locations at rapids/falls where upstream migration exists.

Construction of small-scale schemes at these high head locations may not result in significant impact to the fisheries environment provided the following criteria are met;

- *That fish passage through the affected reach is not compromised.*
- *That compensation flow described for category 3 rivers below is adopted.*
- *That there is no deterioration in water quality downstream resulting from the development.*

Typical example of a high head location at impassable falls

7.2.1.3. Low head schemes where there is an existing weir / millrace.

Old mill sites continue to receive attention for development of small-scale hydro-power. These facilities traditionally operated in daylight hours and had a much lower water demand than modern hydro-power turbines. Where it can be demonstrated that development of modern small-scale hydro-power will provide/improve fish passage and have no fisheries impact, these locations may be considered. Operation of small-scale schemes at these low head locations are unlikely to impact on the fisheries environment provided the following criteria are met;

- *That fish passage through the depleted stretch is not compromised.*
- *That compensation flow described for category 2 or Category 3 rivers below (as appropriate) is adopted*
- *That in cases where the length of the depleted stretch is significant and angling is important in the depleted stretch, additional flow provisions are provided to maintain the angling amenity.*
- *That there is no deterioration in water quality downstream resulting from the development.*

7.2.2. Locations Considered Unsuitable for Siting of Small-Scale Hydro Schemes.

The following types of scheme are likely to be detrimental to the fisheries resource:

7.2.2.1 New low head schemes that entail creation of new and significant obstacles to fish movement.

7.2.2.2 Schemes proposed in catchments/sub-catchments of importance as a spring salmon fishery where the development is likely to have any appreciable impact.

7.2.2.3 Schemes which propose placing structures/weirs at the outlet of lakes or creating new impoundments, because there are likely to be significant negative fisheries impacts.

7.2.2.4 Schemes proposing the transfer of water from one catchment to another.

7.2.2.5 River channel sections of high fisheries value where the impacts of the proposed hydro scheme development would be significant and unacceptable from a fisheries perspective. i.e where it can be demonstrated that an important angling stretch is located in the area of the proposed scheme or where the proposed scheme is located in important spawning or nursery area for salmonids, coarse fish or lamprey in the context of the specific catchment.

7.2.2.6 Where there are existing competing uses of the water resource, such as water abstractions, dilution of licensed discharges etc.

7.2.2.7 Where there may be potential impact on river continuity, and fish migration, or may cause mortality to migrating fish such as maturing silver eel.

7.2.2.8 Schemes proposed in protected areas for Annex II fish species.

7.3 Guidelines on the Design of Fish Passes and Screens

Designing fish passes and screens is a highly specialized business and the appropriate expertise must be applied to each scheme. Fish Passage should be designed to allow the upstream and downstream passage of all species using the river system. The correct location of the fish pass is critical to its success, The weir length, plan form and spillway profile will influence the locations and number of fish passes required. Developers should be aware that weirs as low as 600mm in height can cause obstructions if inadequately designed.

7.3.1 Fish Passage Provisions for Upstream Migrants

7.3.1.1 The flow of water from the downstream end of the pass must have sufficient velocity to attract fish. Recent work recommends that the velocity of the water at the fish pass entrance should not exceed 2 m/sec for salmon and 1.5m/sec for trout even at low water. At the exit area upstream of the fish pass, strong turbulence and current velocities over 2m/sec should be avoided so that fish leave the pass more easily. Other fish species may require even lower velocities through the pass.

7.3.1.2 Species other than salmonids may require even lower fish pass velocities. The type of fish pass required for non-salmonids requires special attention.

7.3.1.3 The attraction of fish to a pass falls away very quickly as the angle increases, and the best configuration has the attraction flow parallel to the main flow. In addition, fish should not be able to reach a position where they have to turn back to find the entrance to the pass. There should therefore be no holding area between the pass entrance and the obstruction itself. It is also critically important that there is sufficient depth of water at the entrance to the pass at all times.

7.3.1.4 At the entrance to fishways, the occurrence of a hydraulic jump must be prevented.

7.3.1.5 The efficacy of existing fish passes must be examined where they are being incorporated into new small-scale hydro-schemes.

7.3.2 Screening for Upstream Migrants

7.3.2.1 While the current legislation stipulates a bar spacing of 2 inch minimum, it is recommended here that the maximum spacing to prevent upstream migrating fish from entering a tail-race should be 1.5 inch (38mm). This recommendation should be reviewed in specific cases where the entry of coarse fish into tailraces is an issue. Rigid bar screens should be used to avoid flexing.

7.3.2.2 Tailrace screens should be placed across the mouth or "point of return" as set out in the legislation to avoid fish being lured into a cul-de-sac where they may linger until the turbine flow ceases.

7.3.2.3 In the exceptional cases where an exemption might be granted under Section 123 of the Fisheries (Consolidation) Act 1959, to replace bar screens with an electric barrier, the minimum requirements to achieve safety and effectiveness recommended in the review of small-scale hydro-schemes in Northern Ireland (Anon, 2000) should be followed as set out below.

7.3.2.4 The energizing system should be based on approved electro-physiological principles which are guaranteed to cause no injury to fish- or to other animals and humans.

7.3.2.5 The electrode arrangement should be of approved design, and it should have a light to indicate when the barrier is in operation.

7.3.2.6 The manufacturer should supply means of establishing that the electrical field in the water body in which the electrodes are set conform to specification.

7.3.2.7 The operational status of the barrier should be continuously logged, and the operator should regularly check and record the electrical field generated in the water body.

7.3.3 Fish Passage Provisions for Downstream Migrants

The efficacy of a fish pass depends very much on where it is located and the recommendations of Beach (1984) and Larinier (1992) should be followed. The location of fish passes for upstream migrants may not meet the requirements of downstream migrants. The determining factor is the configuration of the weir and separate facilities may be necessary for downstream migrants.

7.3.4 Screening for Downstream Migrants

In addition to the stipulations set out in Section 123 & 124 of the 1959 Fisheries Consolidation Act, the following recommendations are made.

7.3.4.1 Smolt screens with 10mm bar spacings should be placed at the point of divergence to a head-race to prevent entry of fish and to divert smolts down the natural channel.

7.3.4.2 With due allowance made for blockage of screens by debris, the approach velocity at smolt screens should not exceed 0.3m/sec.

7.3.4.3 The smolt screen should be at the point of divergence from the river, and the screens should be set so that smolts should be able to easily swim along the face of the screen and on down the river. Intakes to turbines should (where feasible) abstract water at 90 degrees to the main river flow so that the intake screen array is more or less continuous with the river bank, i.e. the screen array is aligned parallel to the main flow. This will help to lead downstream migrating fish along the face of the screens towards the fish pass intake or bypass, which should be adjacent to the downstream end of the array.

7.3.4.4 Smolt screens should be angled as above or so as to maximise their surface area, thereby minimising the velocity of the flow normal (90^0) to the screen face and maximising the flow component along the screen face towards the by-pass and return facility. The screens should be of sufficient area to ensure that, when the station is on full load, the velocity of approaching water is low enough to avoid any risk of smolts or other small fish becoming impinged on them.

7.3.4.5 In certain circumstances, it may be necessary to provide a by pass adjacent to the screens so that migratory fish will readily find a suitable passage downstream.

7.3.4.6 In specific cases where smolts are allowed down a head-race, they must be prevented from passing through the turbine by means of a screen which will safely divert them via a by-pass and return system to the natural channel. The by-pass should be at least 225mm wide and have a minimum depth of flow of 150mm. The mouths of all bypasses should be so designed as to be readily found by fish which have been diverted to them by the screens. The flow through the pass should never fall below an appropriate predetermined volume. The chute or pipe through which the fish descend to the natural river channel should be smooth, well supplied with water, and should discharge the fish into open water of adequate cushioning depth of about 0.5m minimum. If fish are allowed a free-fall into the river, the drop should not exceed 5m.

7.3.5 Assessment of Performance of Screens

7.3.5.1 It is critical that all screens are regularly inspected, cleaned and maintained to ensure that they are operating efficiently.

7.3.5.2 If trashing is a particular problem, trash booms or similar devices should be incorporated in the layout.

7.3.5.3 The efficiency of screens should be monitored for a period of three years from the commissioning of a project and, if so directed by the planning authority (within that three year period), screens should be modified as directed.

7.4 Guidelines on Residual Flow

The criteria to be set regarding residual flow has to be determined in light of the fisheries importance of the depleted stretch, the requirements for fish passage, angling, spawning, etc.

Murphy (2000) recommended that fish passes should be so designed as to discharge the required residual flow when the head water is at the lowest level to which the operator might draw it down, which, in turn, should be no lower than the crest of the weir. It should be noted that the fish pass discharge may not meet the residual flow requirement in many systems and if so, an additional flow should be discharged over the weir.

The flow limit definitions for this document are as follows;
Base Compensation Flow: Is the minimum compensation flow rate stipulation i.e. it is the minimum flow that should be provided to the depleted natural river channel when abstraction is taking place. (12.5% Qm).

Abstraction not to exceed half of the available flow: For category 2 and category 3 rivers below, this abstraction limitation applies in combination with the base compensation flow stipulation. (see worked example Appendix 3).

In exceptional cases, where small hydro-schemes are being considered at lake outflows, recommendations regarding compensation flow for fisheries should be dealt with on a case by case basis because of the complexity of potential impacts and are not referred to below.

In general, for small hydro-schemes on rivers, four identifiable categories can be made and the following recommendations are made regarding compensation flow for fisheries:

Category 1 Rivers:
River channel sections where there is no upstream migration in the river channel depleted stretch due to an impassable natural barrier. Normally a steep fall is present between the intake and outlet locations. The impacted stretch is short with no substantial trout population or no spawning potential. However rock pools are present and pools are sufficient to maintain resident fish stocks.

- *Compensation flow provision of 12.5% of the long term mean flow (Qm) is recommended.*

This is a fixed compensation flow regime

Category 2 Rivers:

River channel sections that include an impassable barrier but within which fish movement is possible.

- *Compensation flow provision of 12.5% of the long term mean flow(Qm) or 50% of the available flow upstream of the intake point, whichever is the greater.*

For category 2 Rivers the compensation flow for fisheries may also be defined by the following formula:

QFish	=	max {QBC , 0.5Q }
		where
QFish	=	compensation flow for fisheries
QBC	=	base compensation flow
Q	=	available river flow upstream of intake point

or in words as follows :

'The compensation flow for fisheries to be provided during hydroelectric abstraction should be the higher of two values – the base compensation flow or half of the available river flow'.

This is a varying compensation flow regime (unlike for category 1 rivers) and the compensation flow rate depends much on the available river flow at the time.

In effect the above compensation flow requirement for category 2 rivers means that when the available river flow upstream of the intake point is less than twice the base compensation flow value the compensation flow to be provided during abstraction is the base compensation flow. When the available river flow upstream of the intake point is higher than (or equal to) twice the base compensation flow value, the compensation flow to be provided during abstraction is half the available flow upstream of the intake point.
The worked example in appendix 3 also refers.

Category 3 Rivers :
River channel sections where there is internal fish movement within the depleted stretch, where there is spawning and nursery potential and where there is also fish movement through the stretch.

- *Compensation flow provision of 12.5% of the long term mean flow(Qm) or 50% of the available flow upstream of the intake point, whichever is the greater*

- *Further fisheries impact mitigation measures to be recommended if deemed necessary on a site specific basis. These could include an increased base compensation flow provision (the base compensation flow may be set at a higher percentage of the mean flow than 12.5%).*

- *To enable fish passage, an adequate number of freshets (short term simulated floods) to allow upstream movement of fish , should be stipulated as part of the operating conditions at the appropriate times required*

- *In situations where the compensation flow for fisheries is through a long channel section, fish may be enticed up and become stranded when the 'freshet' has passed. Allowance must therefore be made for site specific recommendations in these cases.*

In summary, for category 3 rivers the compensation flow for fisheries recommended is that for category 2 rivers plus additional site specific measures which may include higher base compensation flow provision, freshet provision, fish escapement measures etc. It is a varying compensation flow regime.

Category 4 Rivers:

River channel sections of high fisheries value where the impacts of the proposed hydro scheme development would be unacceptable from a fisheries perspective.

- *Where it can be demonstrated that an important angling stretch is located in the area of the proposed scheme or where the proposed scheme is located in very important spawning and nursery areas for salmonids, coarse fish or lamprey in the context of the specific catchment, these locations are deemed to be particularly sensitive to any alteration in the flow regime in the natural channel.*

It is recommended in these circumstances that the development does not proceed.

The above criteria should apply for all new small scale hydro electric proposals and compensation flow provisions currently in place at existing schemes should be reviewed in light of these recommendations. It may be possible to develop site specific flow management strategies at some time after commencement of a scheme if the developer can monitor flow and fish movement and satisfy the Fishery authority that a change from the above recommendations is warranted.

7.5 Guidelines on the Measurement of Water Abstraction and Residual Flows

There must be a satisfactory means of measuring and recording how much water a hydropower scheme abstracts. Integrating flowmeters are likely to be best for high head sites. The devices should be connected to the upstream end of pipelines. In low head sites, the most effective method of measuring water abstraction is to calculate quantities on the basis of the hydraulic characteristics of the site together with the performance characteristics of the turbine.

It will also be necessary to measure compensation flow for fisheries at all sites. A staff gauge should be in place. Where feasible, there should be a notch in weirs designed to take 12.5 % of the long-term mean flow (Qm). The notch will normally form part or all of the fish passage arrangement and must be to satisfactory design standards.

As many sites will be unattended for long periods, it will be necessary for the developer to ensure that the control system for abstraction will meet the planning conditions and there will be no adverse effect on flow in the natural channel in the event of a machinery or control failure. Electronic/ hydrostatic measuring must be backed up with physical measurement for confidence with anglers and the fishery authorities.

Where required (e.g. a Category 2 river site), in addition to the 12.5% Qm control notch, for high head schemes, the developer will need to put in place a system which ensures a 50/50 split in the available river flow – i.e. a 50/50 split between residual flow to the depleted natural channel and abstraction flow taken by the turbine intake - once the available river flow exceeds a certain threshold level (twice the base compensation flow value). Where possible a control cill behind the intake screen should be so designed relative to the overflow section of the weir to allow at least half the available river flow to overflow to the depleted channel section as a residual flow when the available river flow exceeds the 2 QBC threshold. Such a control cill should also where possible facilitate shutdown checking by an observer from the Fishery authority.

Anon (2001a) notes that for low head schemes the only way of ensuring that turbines are not operated when the river level is too low is by the use of properly calibrated flow sensors which will automatically turn the turbine off when the river level falls below the minimum residual flow level. It is important that the exact position of the sensor is indicated on the approved plans.

7.6 Guidelines on Fish Passage Through Turbines

Experience has shown that fish passage through turbines does infer a mortality factor on migrating salmon smolts and other fish species and for new hydro-electric developments, it is critical that details relating to intake screening and fish passage are included at the design stage and fish are not allowed to pass through turbines.

7.7 Recommendation On Assessment Of The Current Operation Of Hydro-Electric Schemes In Ireland.

An evaluation of the effect of existing small-scale hydro-electric stations on fisheries has recently been undertaken in Northern Ireland (Anon, 2000) and shortcomings have been identified. A similar survey of all small hydro-electric schemes should be undertaken in Ireland examining their effect on all fish species. This would identify existing problems or potential negative environmental impacts and draw up measures to mitigate such problems and be beneficial in drawing up general recommendations for existing and future schemes.

7.8 Relevance of these Guidelines.

The guidelines outlined in this document are intended to:

- *Inform Local Authorities in the preparation of County Development Plans.*
- *Provide guidance for the issuing of Planning decisions.*
- *Provide guidance regarding ecological status and hydromorphological pressures in relation to the Water Framework Directive.*
- *Provide guidance for applicants on fisheries information required in EIS/EIA's*

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10. Steering Committee

These guidelines were prepared by a Steering Committee representing the Central and Regional Fisheries Boards and the Engineering Division, Department of Agriculture, Fisheries & Food.

Members of the Committee were:

Patrick Gargan	Central Fisheries Board
Patricia O'Connor	South-Western Regional Fisheries Board
Brendan Maguire	Northern Regional Fisheries Board
Michael Fitzsimons	Shannon Regional Fisheries Board
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11. List of Respondents to Consultation Document.

Department of Environment, Heritage and Local Government.
The Environmental Protection Agency.
Irish Hydropower Association.
T.L. Shaw, Shawater Ltd. Ston Easton, UK.
National Parks and Wildlife Service.
Marine Institute, Newport, Co. Mayo.
The Electricity Supply Board.

APPENDIX 1

Information Required in Environmental Impact Statements / Environmental Appraisals.

Treatment of fisheries data in existing Environmental Impact Statements (EIS) for hydro-electric schemes has often been inadequate, partly due to the lack of specified fisheries criteria which need to be addressed. In order to ensure that an EIS adequately deals with the relevant issues from a fisheries perspective, guidelines setting out the fisheries information which should to be included in an EIS are set out.

General considerations:

- *As with all developments which may impact the aquatic environment, it is advisable to consult with the Fisheries Authorities at the scoping stage of the process. At this time, fundamental issues e.g. location suitability with reference to criteria and evaluation practices will be considered and the extent of the fisheries requirements can be determined.*
- *The scope, detail and quality of information must cover the nature and extent of fisheries present, the current demands on the fisheries, competing demands on the water resource, and potential impact on fisheries during the various phases of development.*
- *The fisheries assessment should provide sufficient accurate and relevant data to allow complete and objective predictions and evaluation of potential fisheries impacts.*
- *Information should be relevant to the river system in question and of such quality that it can be used as a baseline against which changes can be measured in the future.*
- *Drawings should be properly scaled and of sufficient detail to show the proposed development as designed for that particular site.*
- *The objective of these guidelines is to insure that impacts to fisheries are avoided or at worst limited. With this in mind it may be possible, in certain circumstances and where development is permitted, to offset effects which inevitably will occur as a result of development. To this effect there will be a requirement to insure there is, what is termed, a "No Net Loss" to the fishery. (See SWRFB 2005) whereby potential impacts are quantified and programmes are then sought, preferably in the same river catchment and after mitigation, to offset this impact to an amount equal to that agreed.*

FISHERIES IMPACT ASSESSMENT STUDY:

1. *Description of the existing environment.*
2. *Description of the proposed development*
3. *Prediction of likely impacts.*
4. *Evaluation of the significance of impacts.*
5. *Proposed avoidance/ mitigation measures.*
6. *Monitoring Programme/Regulation.*

1. DESCRIBING THE EXISTING ENVIRONMENT

1:1 Site and Structures.

A map of appropriate scale should be submitted providing information on the physical nature of the river catchment and on existing manmade structures.

Details-

1. *Location of the development relative to watercourses, rivers and lakes.*
2. *Roads, bridging and access routes relative to watercourses.*
3. *Description and location of existing river weirs.*

4. *Detail of river bed composition at the intake and outfall locations.*
5. *Description of other usage of waters in the affected reach e.g. public/private water abstractions, effluent discharges, fish farms, etc*
6. *Description of any obstructions, natural or manmade, within the depleted reach, and the extent of their interference with fish passage.*

1.2 Fisheries Information:

In all cases an overview should be given of the fisheries of the entire river system.

A catchment map of appropriate scale should be submitted, showing, inter alia, the location of the proposed development.

A brief description should be given of the nature and importance of the fisheries of the entire system, in classification terms such as "Salmon", "Sea trout", "Coarse", "Eel" and other species.

A more detailed description should be given of any local fishery resource which might be affected by the development. Such effects will vary with the location and nature of the proposed scheme, as listed in chapter 7. This description should be accompanied by a map of suitable scale clearly showing the relevant features, all of which should be annotated with cross-reference to the text.

Details:

Fish Stocks:

1. *List of species and their statutory designation status.*
2. *Stock composition.*
3. *Stock distribution.*
4. *Population assessment*[1] *— methodologies to be Water Framework Directive(WFD) compliant*[2].
5. *Relative importance of local stock in relation to gross catchment stocks.*
6. *Schedule of spawning times of species concerned.*

Habitat:

1. *Location, nature and condition/productivity of salmonid spawning and nursery habitats.*
2. *Location and extent of coarse and other fish habitats, above and below the site.*
3. *Local and overall importance of these habitats.*
4. *Factors perceived as limiting stock diversity and/or abundance.*
5. *Importance of local habitat in relation to the gross catchment habitat.*
6. *Habitat mapping, including details of the riparian zone, should be presented.*

Migration:

All information currently available on:

1. *Upstream and downstream migration of adult and juvenile salmon and sea-trout.*
2. *Migration of eels, elvers and lamprey.*
3. *Migration of adult coarse fish.*
4. *Down river migration of juvenile coarse fish.*

Commercial Resource and Angling Amenity:

1. *Information regarding any local commercial activities e.g. eel fishing, draft-net fisheries.*
2. *Details of ownership and occupancy rights liable to be affected.*
3. *General information on angling activities and facilities, liable to be affected by the scheme*
4. *Detailed information on (3) in the immediate vicinity of the site.*

[1] All fish stock surveys are subject to Authorisation by the Department of Communications, Marine and Natural Resources or Regional Fisheries Board.
[2] At the time of print the methodologies for fish population assessments for Ireland under the WFD are being finalised.

1.3: Describing the Existing Hydrology and Hydrography.

In all hydroelectric developments the impacts on fisheries arise mainly from changes to the localized flow regime. In run-of-the-river schemes flow allocation is usually the critical consideration, but in schemes involving lakes or any element of storage or lowering of water levels above the site, the nature of the effects may be more complex.

To deal first with run-of-the-river schemes, the main requirements may be summarized as follows;

1. *The allocation of flow between power-generation and the depleted natural channel should safeguard fish habitats and passage conditions in the natural channel.*
2. *Water level above the head-weir should be regulated to ensure adequate attraction to, and sufficient flow through, the fish passage facilities provided.*

In other schemes, the main requirements are likely to be as follows:

1. *In sites involving abstraction from (or reduced flow to) a lake, the rate of abstraction for power-generation purposes has to be regulated so as to protect its limnological status and tributary streams (see 7.22).*
2. *High-head schemes must be so designed and operated as to avoid over-use of the natural water resource available at and above the abstraction point.*

For proper evaluation of any scheme it is important to have adequate hydrological data. The following section sets out what is needed and how it should be presented.

<u>Hydrological Data — Flows.</u>

Flow data should be presented in the following forms:

1. *Long-term mean annual, monthly and daily flows as tables and histograms.*
2. *Flow -exceedence curves, in 5%ile increments.*
3. *"Sustained low flows" expressed as 7-day and 14-day duration at specified return periods.*
4. *Peak and mean annual and monthly flood flows.*

The provenance of the flow data should be stated and authenticated.

If the available data do not relate specifically to the site, they should be adjusted scientifically to do so, and the methodology used for this purpose should be set out.

The adequacy of the available data should be discussed with the fisheries authorities at the scoping and consultation stages. If deemed inadequate, the developer will have to undertake additional assessment to provide the data needed by the authorities

<u>Hydrological Data — Water Levels.</u>

Information on water levels in relation to river flows should be provided as set out below. The objective is to establish a picture of the aquatic environment in relation to the macro invertebrate populations, resident stock composition and fish ranging and migration.

Run-of-the-river schemes - Low Head.

The flow-depth relationship over the full length of the depleted natural channel, and for an adequate distance below it, should be monitored and presented in graphical form. (See Monitoring). The distance to be covered downstream of the diversion should be fixed by agreement with the local fishery authority. As a general principle it should extend to the next flow control feature in the river channel – e.g., a natural ledge, weir or other natural control feature.

Run of the river high-head schemes at waterfalls or other cascades.

Conditions in the downstream reach should be established as for low-head sites, but with additional attention to hydro-geological features of the site e.g. in gorges etc.

On the upstream side, what is needed can best be characterized as the "backwatering" profile – that is, the flow-depth relationship in the reach hydraulically controlled by the river-bed topography at the fall or cascade.
The data to be collected and presented should be as set out for depleted natural channels.

Sites involving abstraction from lakes.

In addition to full morphological, hydrological and limnological reports on the lake, the following information should be supplied.

1. *Inflow data for all feeder streams.*
2. *Outflow data for the channel to be used in the scheme.*
3. *Outflow data for any other outlets and for all consumptive abstractions.*
4. *Estimated evaporation losses.*
5. *Range of water-levels in relation to the above, including the extent of lake shore exposure resulting from drawdown.*
6. *Where the abstraction is to be made at a point in the natural channel downstream of the lake, a full report should be furnished on the characteristics of the depleted reach and on its hydraulics — with particular reference to flow-depth relationship.*

2. DESCRIBING THE PROPOSED DEVELOPMENT

The project description required for planning purposes will usually cover much of the issues relating to impacts on fishery interests. What is set out below is aimed to highlight the most critical issues and to advise on how best they might be dealt with.

Appendix 2 lists the drawings required by the fisheries authorities, but as mentioned earlier on this current appendix, these drawings should be annotated and cross- referenced to the text.

Site features:

The scheme should be described and categorized in terms of how it conforms to the locations and types of development listed in Section 7.2 of this document.

The following should be fully detailed on the drawing and described in the text.

1. *Head water control structure — fixed weir, mechanized barrage etc.*
2. *Means of controlling and monitoring head water level.*
3. *Provision in the control-structure for upriver migration of fishes.*
4. *Provision for downriver migration of fishes.*
5. *Any proposed provisions such as groynes or boulder weirs in the natural channel – above and below the control structure – to assist migration and /or to protect aquatic habitats.*
6. *Characteristics of all artificial channels — head-races, tail-races etc;*
7. *Hydraulic control structures in artificial channels —sluices, by-washes etc;*
8. *Fish exclusion provisions as required by statute.*
9. *Fish-diversion and return provisions.*

Turbines:

The types and number of turbines will be shown on the drawings, but for fisheries purposes considerable detail must be furnished of their hydraulic characteristics and operational protocols.

The aim should be to provide a clear exposition of all factors which will determine the allocation of available flow between the power-generation and fisheries requirements.

If only one turbine is to be installed, the following details should be furnished.

1. *Generic type and regulation characteristics - e.g. Francis: Kaplan – single or double regulation.*
2. *Critical aperture dimensions – e.g. guide-vane opes.*
3. *Design RPM.*
4. *Flow throughput on full load.*
5. *Flow throughput on overload - if applicable.*
6. *Minimum flow throughput.*

If two or more turbines are to be installed, all of the above information should be provided in respect of each turbine.

In either case, a comprehensive exposition should be given of the proposed operational protocol, clearly setting out the proposed flow-management regime and how it will be implemented.

The following issues should be fully addressed and described:

1. *The provision for controlling the head-water level.*
2. *Methods for control on the rate of abstraction and how it will be measured and displayed.*
3. *The regulation and verification of the ratio between flows for power generation and fisheries needs.*

Post Development Flow Environment:

Having provided the relevant information describing the pre-development flow environment and the anticipated abstraction flow regime (including compensation/ residual flow proposals), it is then necessary as part of the assessment to clearly describe what the post development flow regime is likely to be at the river/stream/lake sections of interest. The post development flow environment downstream of the abstraction point needs to be described in similar detail and terms to that of the predevelopment flow environment. (1.3).
This requires that the post development flow regime (e.g. immediately downstream of the intake or elsewhere in the depleted natural channel or further downstream as appropriate) be depicted graphically in the same form of annual hydrographs and flow duration curves as used earlier to describe the predevelopment environment. Showing both flow regimes (pre and post development) as 2 curves on the same single graph is helpful to aid understanding of the predicted impact on river flows

It is also necessary to furnish the following estimates of flows downstream of the intake or in the depleted natural channel section:

1. *Mean daily flow.*
2. *Sustained low flows and their return periods.*
3. *Flood flows of 1, 5 and 10 year return periods.*

The post development flow environment description should include a description of significant changes that are likely to occur in depth, velocity and wetted perimeter terms, at representative sections along the impacted stretches of watercourse.

3. PREDICTION OF LIKELY IMPACTS.

Potential impacts affecting fisheries can be divided into two categories — those which may occur during the Construction Phase - which will primarily be associated with physical interference and water quality issues affecting habitat and fauna - and those which may occur during the Operational Phase, relating to impacts of flow modification on habitat, fauna, migration and angling etc;

In addition to the environmental impact prediction requirements of the EIS, the assessment should address the following fisheries aspects —

Construction Phase.

1. *Timing of works and potential conflict with seasonal sensitive fisheries requirements e.g. spawning seasons, fishing amenity.*
2. *Impact of intake, river weir and outfall construction on the physical nature of the river, fish habitat, water quality and fish passage.*
3. *Water pollution potential from chemicals, cement and hydrocarbons.*
4. *Silt emissions from construction sites including roads, bridging and pipeline routes.*
5. *Interference with ground stability.*
6. *Surface water management and watercourse crossing implications.*

Information is available on potential impacts on fish and fish habitats in the document (Murphy, 2003)

Operational Phase

1. *Interference with fish migration and local fish movement.*
2. *Effects of flow modification on fish passage at natural and manmade obstructions.*
3. *Effects of reduction and/or loss of wetted areas during critical periods e.g. loss of spawning grounds, reduced holding areas, etc.*
4. *Likely loss of aquatic habitat or change in habitat quality in the depleted stretch.*
5. *Effect on aquatic invertebrates and macrophytes.*
6. *Potential for an increase in fish predation.*
7. *Interference with angling and angling tourism.*
8. *Delay or prevention of passage of fish at the outfall.*
9. *Increase in poaching opportunity.*
10. *Impact on other water-resource usages, e.g. abstractions, assimilative capacity, amenity.*
11. *Interference with the operation of hydrometric gauging stations controlled by Agencies e.g. EPA, OPW and ESB.*
12. *Potential to cause water quality change, directly or indirectly*
13. *Cumulative effects on water quality and flow.*
14. *Impact from use of oils, chemicals and corrosive materials e.g. cement and pipe cleaning liquids. (Type, method and frequency of use).*

Because all developments have many unique features, care should be taken to identify potential impacts not listed above.

4. EVALUATION OF THE SIGNIFICANCE OF IMPACTS.

An assessment of the extent and severity of impact of the proposed development on the aquatic habitat and fisheries should be presented. This should describe the net effect of the development on fish stocks, productivity, angling etc, both in terms of the depleted stretch and the catchment as a whole.
In addition, a description of the site's value in fisheries and aquatic bio-diversity terms and its tourism amenity value - taking account its international, national or local significance - should be presented.

The EPA Guidelines 2002 provide a comprehensive description of the criteria required to identify the likely significant impacts. These provide for an assessment of the impact level or significance based on magnitude and intensity, integrity and duration, and consequence of the proposed development. (Anon 2002)

Where development is considered acceptable, impact mitigation will include the requirement that there will be "No Net Loss" to the fishery as a result of the development after mitigation. This may involve off-site compensatory measures to insure that the fishery will not be subjected to a net loss to the system. (Anon 2005)

This evaluation will then be used to determine the nature and extent of mitigation required.

5. MEASURES TO MITIGATE ADVERSE IMPACTS.

The most desirable mitigation practices are those which avoid impacts to the fishery -- for example: the siting of a high-head intake at a natural rock weir feature, utilizing this as the river control weir; locating outfall at pool zones; locating low head sites at existing weirs or natural structures etc. Where avoidance is not possible the extent of impact should be limited by using the most appropriate and effective mitigation practices.

The following general approach should be adopted.

1. *Proposals for mitigation should give priority to avoidance of impact.*
2. *Mitigation should aim to reverse, minimize or compensate for an impact, and should also afford opportunities to enhance existing conditions.*
3. *Measures proposed should be practicable, clearly detailed and implementable.*
4. *The reliability, design, programming, monitoring, maintenance and management of the proposed mitigation measure should be clearly stated in the EIS report.*
5. *The reasons for site selection and location of intakes and returns points relative to environmental/fisheries considerations should be presented.*
6. *Reference should be made to other sites considered but not selected, with reasons stated.*

Some examples of mitigation measures are presented below,

Location and Design.

1. *Intake and return-point locations selected to minimise the extent of instream and riverbank disturbance.*
2. *Intakes and return points sited to avoid conflict with sensitive fish habitats, interference with spawning/nursery sites, angling etc.*
3. *At Category 2 high-head run-of-the-river sites, control weirs and associated fish-passes should be designed to facilitate and ensure the specified partition allocation of flows.*
4. *Unfavourable approaches to fish passes may be modified by instream works to provide ease of access.*
5. *River weirs should be designed or modified so as to minimise deterrence or impedance of fish passage.*
6. *Modifications to existing fish passes should be carried out to improve their efficiency.*

Construction phase

1. *Mitigation measures proposed for control, containment and prevention of silt emissions should be undertaken prior to works commencing on site.*
2. *Timing of instream and bankside works which may impact on fisheries, should be confined to months specified by the local Regional Fisheries Board. (Murphy et al. 2003)*
3. *Fish passage at the work site should be facilitated throughout.*
4. *Cofferdams or bunds should be built where required to prevent water pollution.*
5. *Trenchless techniques should be used where practicable for river crossings.*
6. *Drainage channels bounding or traversing pipeline routes should be safely channeled past the work area.*
7. *Adequate lands should be available to provide silt settlement areas within the site to prevent pollution.*
8. *Unwarranted machinery movement should not be permitted along riparian zones.*
9. *Damage to river-banks should be minimized, and they should be reinstated and restored on completion of site works to pre-development conditions using local materials and indigenous plants. (Anon 2003a)*

Additional information and guidance on current best practices in the field of water pollution prevention at Construction sites is available in CIRIA publications (Anon 2005a, 2006 ; Masters-Williams *et al*, 2001; Murnane *et al*, 2002).

Operational phase.

1. *A maintenance programme should be set up to keep screens clear and remove obstructions in fish passes etc.*
2. *Seasonal close down periods should be planned to accommodate fish migration periods.*
3. *Provision should be included for occasional closures to facilitate fish movement.*
4. *Standard Operating Practices (SOPS) should be introduced for the use of chemicals and toxic materials to prevent harmful emissions to waters.*
5. *Consideration can in certain circumstances be given to the easement of passage of fish at natural physical barriers within the depleted reach, and for development of instream fish habitats. However these must not be in conflict with other ecological requirements.*

All of the above should form part of a comprehensive management protocol approved by the fisheries authorities and continually reviewed in light of monitoring results.

6. MONITORING /REGULATION.

Monitoring.

It is essential that the development conforms to the environmental conditions agreed, and this should be determined by the introduction of an ongoing and long-term monitoring programme to assess specific aspects of operation relevant to fisheries protection and to confirm the predictions of the EIS. Monitoring should focus on mitigation measures, biological status, fish stocks and flow rates.

This programme should include the following.

1. *Ongoing assessment of the effectiveness of environmental mitigation practices during construction.*
2. *Post-Construction fish population studies to monitor impacts on fish stocks.*
3. *Assessment of the cross sectional wetted bed area in the depleted natural channel within the flow range 12.5% to 100% of mean flow.*
4. *Assessment of the efficiency of fish-passes and fish passage over weirs, under the full range of flow conditions.*
5. *Monitoring of screening efficiency for a period of three years from the commissioning of the project.*

6. *A three monthly review of river and abstraction flow data in the first year of operation to assess effectiveness of calibration and operation of flow measurement devices.*
7. *A review of flow conditions to assess the effectiveness of permitted abstraction rates and to determine if a review of conditions granted should be considered.*

This programme, together with avoidance and mitigation measures, should be presented in the context of an Environmental Management Plan for the overall project.

Regulation:

1. *Site management plans and environmental mitigation measures should be stipulated in Contract Documents and contained in Construction Method Statements.*
2. *All managers, contractors and site personnel should be familiarized with environmental requirements of the project.*
3. *Personnel with expertise in Environmental Management should be available to oversee works of an environmental nature.*
4. *Protocols for notification of and consultation with the relevant authorities in the event of any incident giving rise to pollution of waters, or when works might impact on the aquatic habitat, to be provided.*
5. *The provisions for apportioning flow between abstraction and river should be described, and full details given of the telemetry involved.*
6. *On-line flow data should be available to the relevant authorities to assess the abstraction regime at any time.*
7. *Details to be provided on the type and location of visual inspection aids e.g. the erection of a calibrated gauge board in the vicinity of the intake, displaying pond/river levels which must be reached before abstraction commences and during abstraction. The exact location should be agreed, identified on drawings and included in conditions.*
8. *A Liaison Officer should be appointed to provide avenues of communication between the developer and regulatory authorities.*

APPENDIX 2: Drawings and Detail required in the EIS.

The EIS should include the following

- *Powerhouse – layout, front elevation, and section*
- *Details of outfall.*
- *Details of intake structure, intake weir and river weir.*
- *Details of fish passes.*
- *Details of excavations and retaining walls for intake and outfall structures.*
- *Detail of type and location of water monitoring devices*
- *Elevations of intake and outfall screens.*
- *Riverbed and bank details.*
- *Riverbed survey showing the bed profile and proposed weir elevations at intake and proposed bed profiles at the return point.*
- *Detail of any watercourse crossings.*
- *Detail of any new bridge crossings or modifications to existing structures.*

Drawings

- *Weir drawings should be to 1:100 scale or greater and should show in detail the plan, elevation and cross section views of the proposed structure. Shown on the sectional views should be sufficient level information on crest, apron and other parts of the weir structure, as well as the range of upstream and downstream water levels.*
- *Detail of fish passes should be shown on drawings on a scale of 1:50.*

- *Drawing to a scale of 1/500 should show longitudinal sections of the bed and banks of the natural channel from the weir to 100 meters below the final outfall along with representative cross sections.*
- *All sections should show profiles of the water surface in low and high flow conditions along with descriptions of the materials forming the bed of the channel.*
- *Detail to include the height of the river weir cill level above the riverbed downstream of the weir.*
- *Information therein should be scaled and referenced to datum levels.*
- *Drawings should be of such detail and scale as to be read easily and without reference to text.*

APPENDIX 3:

The following is a worked example of the fisheries compensation flows that are recommended for a Category 2 river small scale hydro-electric scheme site.

The long term mean flow of the river at a proposed hydroelectric site is 480 l/s. The proposed development is a single turbine installation. The turbine will allow hydroelectric power generation in the abstraction flow range 40 l/s up to 400 l/s (i.e. the minimum inflow that the turbine needs to operate is 40 l/s and it's maximum operating flow intake is 400 l/s).

The Fisheries authority considers that the proposed depleted channel section of the river at this development site meets the definition of a Category 2 river and accordingly recommends the following as the compensation flow regime for fisheries that should apply for abstraction to occur : -

- *Compensation flow provision of 12.5% of the long term mean flow (Qm) or 50% of the available flow upstream of the intake point, whichever is the greater*

QFish = max {QBC , 0.5Q}

where

QFish = compensation flow for fisheries

QBC = base compensation flow

Q = available river flow upstream of intake point

QBC = 12.5%(480) = 60 l/s

Therefore QFish = max {60 , 0.5Q }

In this case the above formula reduces to the following

if Q < 120 l/s, QFish = 60 l/s
and
if Q ≥ 120 l/s, QFish = Q ∏ 2

Applying the above criteria the recommended compensation flow regime for fisheries protection is described in the table below. Also shown is the pattern of hydroelectric abstraction and flow regime in depleted natural channel.

Flow: liters per second

River flow available upstream of intake Q	Recommended Compensation flow for fisheries Qfish	Hydroelectric Abstraction (Actual)	Flow in depleted natural channel
10	60	0	10
40	60	0	40
60	60	0	60
80	60	0	80
100	60	40	60
120	60	60	60
140	70	70	70
200	100	100	100
480	240	240	240
800	400	400	400
900	450	400	500
1000	500	400	600
2000	1000	400	1600

Note that when available river flow is ≤ 60l/s there is insufficient flow quanitity available to provide the minimum base compensation flow and allow a surplus flow for hydroelectric generation

Note that when available river flow is 80 l/s there is sufficient flow available to provide the minimum compensation flow (60 l/s) necessary for abstraction to occur but hydroelectric abstraction cannot actually take place because the quantity of flow that potentially could be abstracted for hydroelectric generation (20 l/s) is less than the minimum turbine operating flow of 40 l/s.

Note that at high flood river flows (> 800 l/s in this case) the flow which would actually be provided to the depleted natural channel section will exceed the recommended compensation flow - this extra residual flow provided can be very important for fish movements past obstacles in river channels.

Appendix 4: Glossary of Terms:

ADF. Average Daily Flow. An average of the daily mean flows available.
Arctic Char. A member of the salmonid family.
Available flow. The flow quantity available in the river at a particular point before it is impacted on by hydro electric abstraction.
Base Compensation Flow. Is the minimum compensation flow rate stipulation i.e. 12.5% of Mean Flow(Qm). This flow may also be set at a higher percentage on a site specific basis.
CFB. Central Fisheries Board.
Coarse Fish. For the purposes of this document, all freshwater fish other than salmonid, eels and lamprey.
Compensation flow. Flow in the depleted stretch comprising the base compensation flow or 50% of the available flow upstream of the intake point, whichever is the greater. This flow may also be required to be augmented by Freshets.
Cumec, one cubic meter per second.
Daily Mean Flow. The flow which if maintained steadily for the course of a day would give the same volume of water as that which actually flowed during that day.
Dam. Any dam, weir, dyke, sluice, embankment or other structure built or placed in or in connection with any river for or in connection with the sustaining of water for any purpose.
DCMNR. Department of Communications, Marine and Natural Resources.
Depleted Natural Channel. The full stretch of river channel from the point of abstraction to the point of return of the abstracted water to the natural river channel.
Elvers. Juvenile eels.
Equi-partition. Equal allocation of flow between river and intake.
Fish Pass. A channel for the free run or migration of fish in, over or in connection with an obstruction in a river, lake or watercourse and includes a fish ladder or any other contrivance which facilitates the passage of fish.
Freshet. An increase in river flow following a period of rainfall or release from an impoundment.
Grilse. A salmon returning to freshwaters after one winter at sea. (Also known as peel)
Head race. Manmade channel conveying water from the river to the turbine house.
High head. hydro schemes where the vertical drop from the intake to the turbine house is greater than 5 meters.
ICES. International Council for Exploration of the Seas.
Kelt. Any salmonid after spawning. (see spent fish)
Littoral. Marginal areas of lakes subject to water level variations.
Long-Term Mean Flow: as for Mean Flow (Qm)
Low head. Hydro schemes where the vertical drop from the intake to the turbine is less that 5 meters.
Macroinvertebrates. Aquatic insects without a backbone visible to the eye.
Mean Flow (Qm). Long term average flow value derived from hydrometric records or from hydrological data for the river in question. The period of record should preferably be in excess of 10 years and be a full number of hydrological (or calendar) years.
Where long term flow data is unavailable the long term mean flow is to be estimated on the basis of catchment area and long term rainfall records (preferably 30 years record) and evaporation and transpiration data.
Megawatt MW. A unit of power equivalent to one million watts.
Multi Sea Winter Salmon (MSW): a salmon which has spent more than one winter at sea. (see spring salmon)
" No Net Loss" Where development is permitted there will be on occasion unavoidable loss to aquatic resource functions due to developmental impacts. The principle of 'no net loss' ensures that there should always be compensatory gains built in to augment the aquatic resource affected. This may be provided through restoration, establishment, enhancement, or preservation.
Parr. Juvenile salmon which spends one to three years in freshwater. (Pre-smolt)
Redd. The mound of gravel on a river bed beneath which salmonids fertilized eggs are deposited.
Run of river. Hydro schemes which exploit the natural river flow without use of impoundment.

RFB. Regional Fisheries Board.
River Continuity: Providing for the unhindered movement or migration of aquatic organisms and sediment transport.
Salmonid. Family of fish which includes salmon, sea trout, brown trout and arctic char.
Silver Eel. Maturing downstream-migrating eel.
Smolt Screen. A screen with apertures of dimensions which prevent the entry of juvenile fish.
Smolt. A juvenile salmon which has undergone physiological change before migrating from fresh water to the sea.
Spate. A "flash" flood flow, typically occurring in high gradient short river catchments or in extensively drained catchments with reduced ground water storage.
Spent Fish. As for Kelt.
Spring Salmon: a salmon which has spent more than one year at sea returning to freshwaters before June **(MSW)**
Tail race. Man made channel conveying water from the turbine house to the river.
Thalweg. A narrow channel formed naturally or dug along a river bed conveying low flow.
Weir. Any structure fixed across or partly across a river for the purposes of raising the water level.