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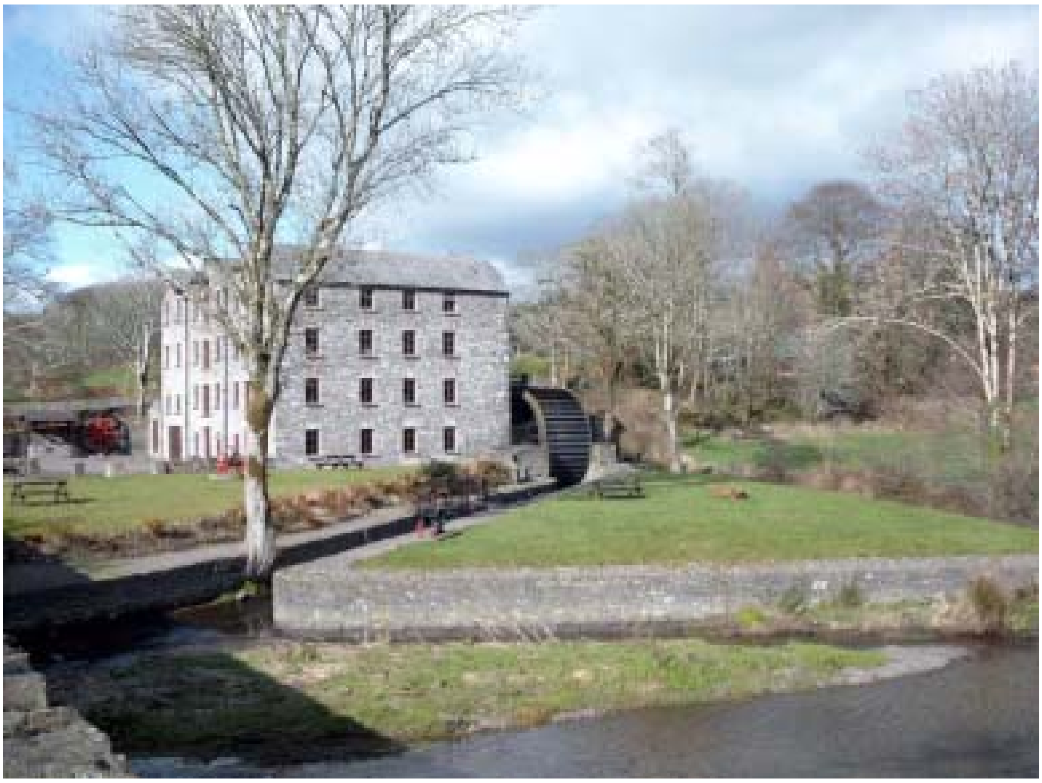
Central Fisheries Board
An Príomh-Bhord Iascaigh

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



Consultation Document

June 2005

CENTRAL & REGIONAL FISHERIES BOARDS

&

ENGINEERING DIVISION,
DEPARTMENT OF COMMUNICATIONS, MARINE & NATURAL RESOURCES

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Guidelines on the Operation of Small-Scale Hydro-Electric Schemes and Fisheries

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 2, 1998-2002) as a means of reducing CO2 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.

Hydro-power developments have the potential for significant impact on the aquatic resource and it is essential that where such schemes are permitted, that 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 affect through excessive water abstraction, inadequate fish passage or improper smolt screening procedures. The commonest problems affecting the migration of salmonids in Irish rivers tend to arise at small hydro-electric sites, (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 from a fisheries perspective which should be followed for proposed small-scale hydro-electric schemes. 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 Covering 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. The relevant legislation is summarized below.

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, Marine & 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. S 116 relates to fish passage over dams and requires free passage of fish as in S 115. There is provision within S 116 for penalties to be taken 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 potential problem with any hydro-electric development is the attraction of upstream and downstream migrants to outfall and intake areas. To prevent downstream and upstream migrating fish from entering a headrace or tailrace, 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). S 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 Relating To New Small-Scale Hydro-Schemes

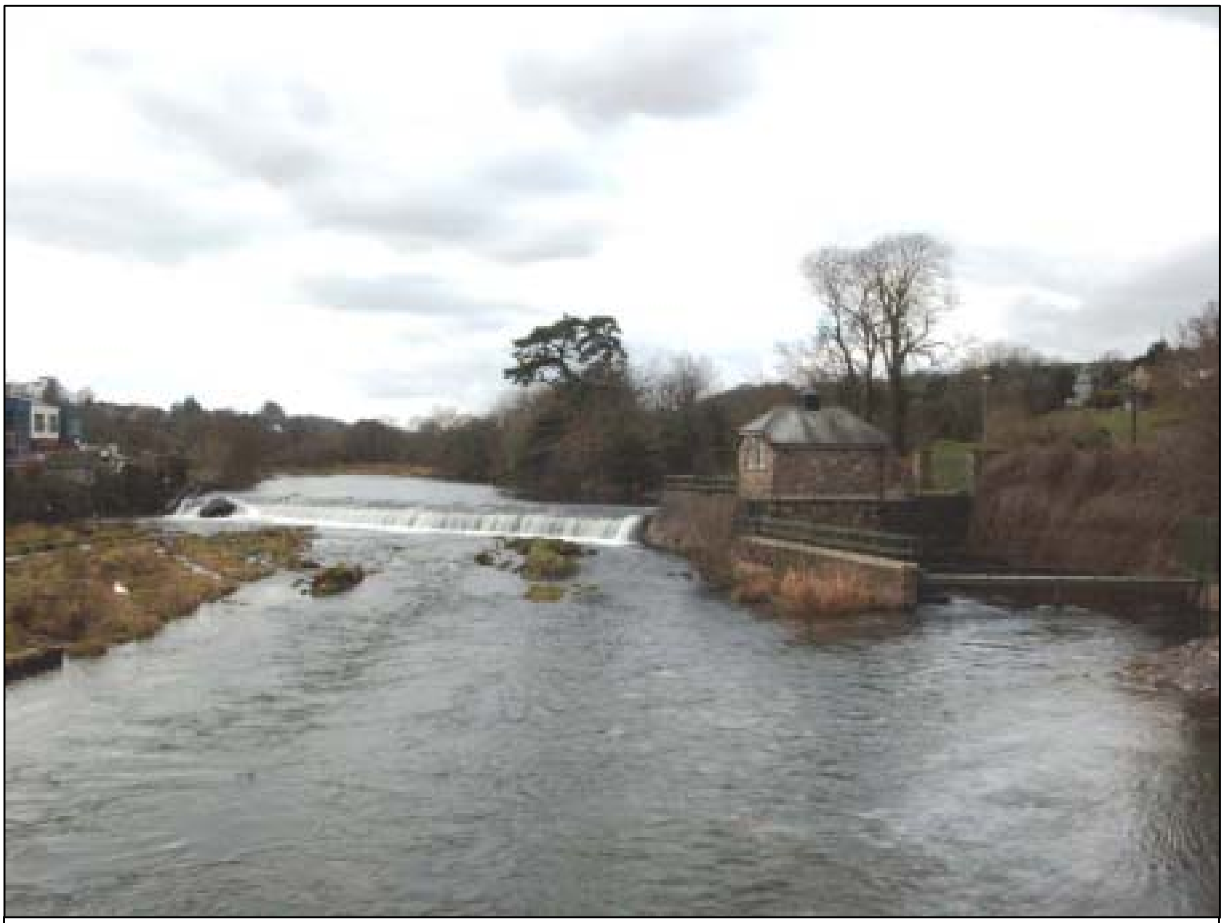
The current legislation relating to hydro-schemes relates primarily to fish passage and screens. It does not address such issues as compensation flow and water abstraction to the turbine. These issues are dealt with in this document.

There are 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, 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

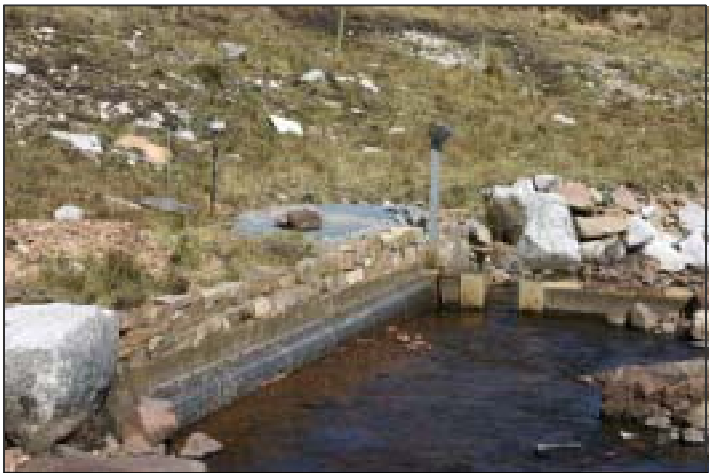


Low head hydro scheme on the Bandon River. The intake is located above the weir (right background) and the tailrace discharges back to the main river (right foreground).

Hydro-electricity is produced by using the power of water under pressure to turn the turbines of generating sets in power stations. There are three main types of small hydro-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 daily mean flow of the river when on full load. In many rivers, especially spate rivers, the long term daily 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 for much of a spell of dry weather flow. This has obvious implications for fish passage. Low head schemes are the most common small-scale hydro-power type in Ireland.



An example of the intake structure of a high-head run of the river using a constructed river weir. Downstream

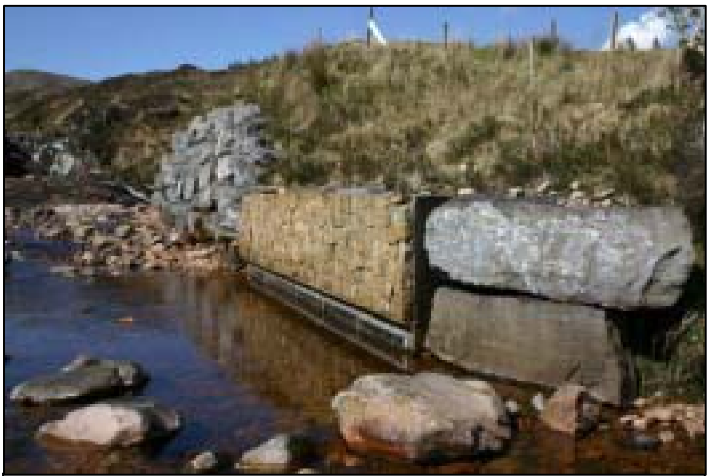
3.2 High Head Schemes

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.

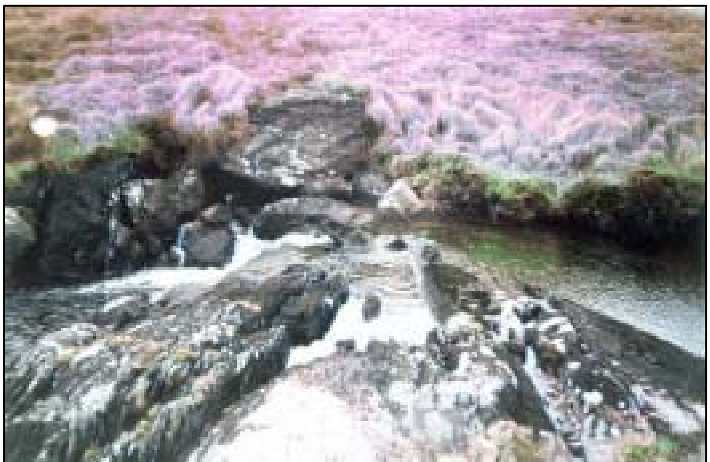
A. Run of the River Schemes.

Schemes which draw water through a pipeline/tunnel from a high level intake in upland areas to turbines at distances downstream. With the height difference, a head of water can be achieved. 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.

A high-head run of the river intake using a constructed river weir. Downstream view.



High head return point showing hidden powerhouse.



Natural rock river weir at Intake facilitating fish passage.

B. Impoundment Schemes on Lakes.

Some high head schemes incorporate storage utilizing upland lakes whereby the natural 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.

Impounded lake, Co. Kerry.

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.

It is proposed that the guidelines contained in this document (location of new small scale hydro-electric schemes, the level of compensation flow / residual flow in the natural channel, fish migration, angling, other uses etc.) be assessed relative to the proposed location and operation so that an initial screening process can be conducted. *If the criteria proposed 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 is asked to consult 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 Communications, Marine & Natural Resources 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 below (Appendix 1).

The scoping stage should provide the information to assess whether the developer should proceed to prepare a full EIA 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.*

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, 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 Communications, Marine and Natural Resources 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. *Proposals for hydro-schemes should not be allowed to proceed through the application stage unless adequate baseline data is available or can be collected.*

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 to 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, Marine & Natural Resources

Fish passes and screens must be approved by the Minister for Communications, Marine and Natural Resources. The Engineering Section 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, allows a planning authority to notify prescribed bodies on receipt of a planning application.

4.5.4. The 0ffice of Public Works

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, and for its consequences for cultural heritage.

4.5.5 Department of Heritage, Environment & 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 implementation of the EU Water Framework Directive (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).

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 is an important quality supporting ecological status under the hydromorphological element. In high status, “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 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. The installation of hydro-schemes must not downgrade the status of a water body.

The operation of the Water Framework Directive will be achieved through River Basin District Management groups.

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, such as hydro-electric development.

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 considerably greater 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. This may affect the assimilation capacity of the natural channel. 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.

Downstream Migrants

Smolts and kelts tend to be attracted to the main flow which, in non-flood conditions and during generation, may be towards the head-race and turbine intakes. 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).

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 much more prone to disease outbreaks. 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 is adequate, fish may not be inclined to run unless there is adequate compensation flow or sufficient freshets released to induce upstream migration.

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. This has a profound 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.

5.3 Impoundment Schemes

Increasing the storage area of existing 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 existing 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.

Littoral lake area impacted by excessive water level fluctuation due to water draw down

5.4 Fish Passage Through Turbines

The nature of 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.

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 stresses include strike from stationary or moving parts of the turbine, sudden acceleration or deceleration, shear, very sudden variations in pressure and cavitation.

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 delayed 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 of juvenile salmon is surface orientated and involves following flow. No combination of these artificial stimulants 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 and for new hydro-electric developments, it is critical that appropriate intake screening and a fish pass are included at the design stage and fish are not be allowed to pass through turbines.

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

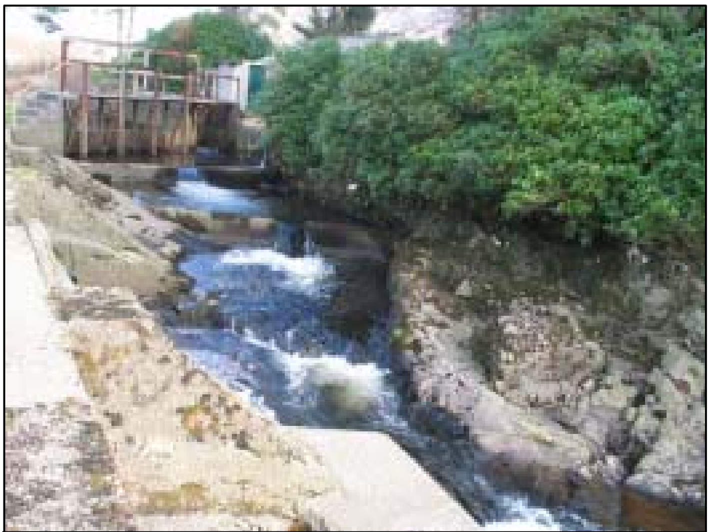
Cowx (1998) reviewed issues relating to fish passage in the UK. He concluded that while the basic design of most passes appear to be adequate for the target species, little attention has been paid to the location and flow regime under which the pass functions. Key problems are that the flow characteristics 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 being 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, (Larinier1992). 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. Gravels tend to accumulate downstream of large weirs. In such cases a self-cleaning approach channel should be designed and built in as part of the plan.

Anon (1997) also 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 at the entrance to the pass to allow for changes in water level at different river flows.

Denil fish pass to allow upstream movement of fish.



Pool pass.

Vertical slot pool pass.

6.1.2 Screening for Upstream Migrants

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 size 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.

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 involve safety issues. This has lead operators to apply for exemptions to use electric barriers over conventional screens. Current

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.

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 and wire lattice on a permanent basis. There is a provision (Section 123, Part 8, Chapter 5 of the Fisheries (Consolidation) Act 1959 to apply for an exemption.

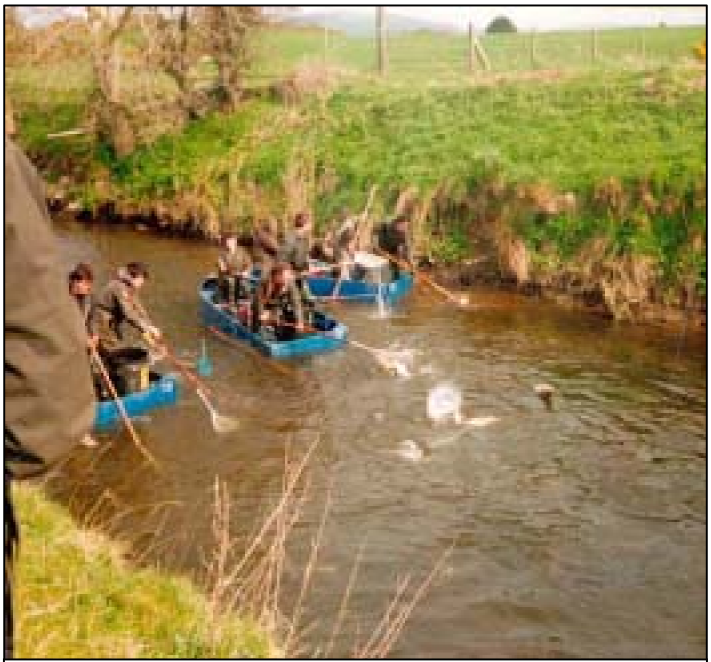
6.1.3 Fish Passage for Downstream Migrants

There is a conflict between the optimum locations of a fish pass in many weirs because of the weirs diagonal orientation relative to the river channel (plan view). 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.

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, a lattice shall be placed over the gratings to prevent the entry of juvenile salmon. In practice, the Department of Communications, Marine and Natural Resources require such “smolt screens” to have 10mm spacing. It is not practical to have a ‘lattice’ across a grating, because of the difficulty of keeping it clean. Efficient self-cleaning closely spaced grating are more acceptable. 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 a weir for fish to find a suitable exit downstream.

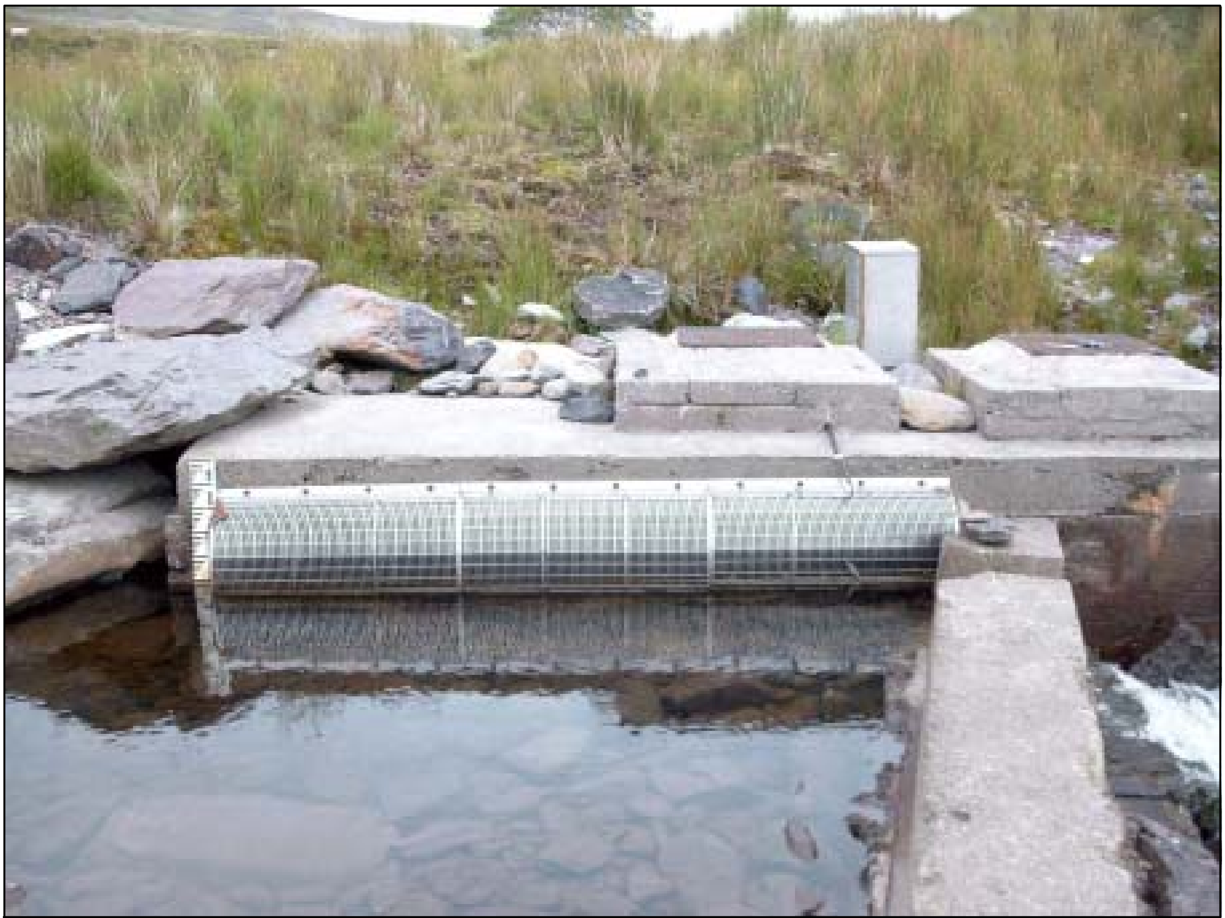
A number of physical screen types may be used to prevent entry of fish into intakes namely fixed mesh or bar screens, moving or traveling screens and cylindrical wedge-wire screens. While the latter two types may prove effective in some situations, only fixed bar screens are discussed below and remain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



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.

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. This occurs where the screened area is either too small or is reduced due to being blocked by an accumulation of water-borne debris. This problem 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 was resolved by creating a much deeper and wider area into which the screens are set. The increased screening area was designed to ensure that the velocities through 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).

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 are possible, 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



Intake screen arrangement at a high-head site.

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 0.15m/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. 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, and also to ensure that the screen is self-cleaning as far as possible, (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 safely diverted and 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 also required screens to be so designed and angled to encourage and facilitate the diversion of fish to proposed fish passes.

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. If the channel is long and/or the gradient steep, water will be either very shallow or very fast. Intermediate pools may be necessary in such circumstances. If fish are allowed a free-fall into the river, the drop should not exceed 5m, subject to there being sufficient depth in the receiving pool.

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 can create an attractant flow that can result in significant numbers of fish being killed. There is no requirement to assess the performance of screens or to ensure that screens are maintained in Fisheries legislation. 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 Compensation Flow / Residual Flow

A compensation flow refers to the minimum flow of water to be maintained at all times in the natural channel. The residual flow is the (varying level of) flow remaining in the river when abstraction is taking place. 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 indicated that upstream migration of salmon typically commenced 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 an area 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 required 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 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, guidelines are set out below for the operation of small-scale hydro-schemes.

7.1 Application Stage and Environmental Impact Assessment

Adequacy of 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 either 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 the fisheries and the environment, it is recommended that an Environmental Impact Assessment should be prepared for all new and upgrading of existing developments. 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 to be included in an EIS are set out, Appendix 1.

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 for such a figure for post-commissioning modifications at the application stage.

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:-

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;

- *That the return point is located 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.*

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.*

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

Old millraces are now receiving 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 should not impact on 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 2 or Category 3 rivers below (as appropriate) is adopted*
- *In cases where the length of the depleted stretch is significant and angling is important in the depleted stretch, additional flow provisions may be required 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 schemes are considered detrimental to the fisheries resource:

- *New low head schemes that entail creation of new and significant obstacles to fish movement.*
- *Schemes proposed in catchments/sub-catchments of importance as a spring salmon fishery where the development is likely to have significant impact.*
- *Schemes which propose placing structures/weirs at the outlet of lakes or creating new impoundments, where there are likely to be significant negative fisheries impacts.*
- *Schemes proposing the piping of water from one catchment to another.*
- *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.*
- *Where there are existing competing uses of the water resource, such as water abstractions, dilution of licensed discharges etc.*

7.3 Guidelines on the Design of Fish Passes and Screens

A review of the current operation of small-scale hydro schemes (Chapter 6) allows Guidelines to be prepared on the design of fish passes and screens.

7.3.1 Fish Passes for Upstream Migrants

- 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 flow of water from the downstream end of the pass must have sufficient velocity to attract fish. The velocity from the pass to the velocity in the receiving pool should be at least 3:1 for fish to be attracted to the pass. More 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. 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. Other fish species may require even lower velocities through the pass.

- 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 to allow for changes in water level at different river flows.

- 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.

- 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

- The maximum recommended 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. Specifications for materials used in screens needs to be defined.

- 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.

- 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.

- 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.
- The electrode arrangement should be of approved design, and it should have a light to indicate when the barrier is in operation.
- The manufacturer should supply means of establishing that the electrical field in the water body in which the electrodes are set conform to specification.
- 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 Passes for Downstream Migrants

There is a conflict between the optimum location of a fish pass in many weirs because of their diagonal shape. 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.

7.3.4 Screening for Downstream Migrants

- 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.

- Allowing for 50% blockage of screens by debris, it is recommended that the approach velocity at smolt screens should not exceed 0.15m/sec.

- 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.

- Smolt screens should be angled as above or 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 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.

- It is necessary to provide a smolt pass adjacent to smolt screens, positioned so that migrating fish will readily find a suitable exit downstream.

- 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. Ideally, 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

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

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

- 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. This should become a routine requirement for all new hydro-power schemes and any alterations to existing schemes.

7.4 Guidelines on Compensation Flow / Residual Flow

Depending on the location, the fisheries value of the depleted stretch and the probability of fish passage, different criteria can be set regarding compensation flow / residual flow and water extraction for hydro-power generation. There may be locations where there is sufficient data on flow and fish movement to determine specific compensation flow requirements regarding fish passage and these should be incorporated into the planning conditions.

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 at 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 an additional flow should be discharged over the weir and not through the turbine.

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: Except for category 1 rivers below, this abstraction limit stipulation applies in addition to the base compensation flow stipulation for development. It <u>supplements</u> and does not replace the base compensation flow requirement. (see worked example, Appendix 4).

In exceptional cases where small hydro-schemes are being considered at lake outflows, because of the complexity of potential impacts, recommendations regarding compensation flow should be dealt with on a case by case basis 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:

Category 1 Rivers:

Where there is no upstream migration in the river channel in the depleted stretch due to an impassable natural barrier. Normally a steep falls is present between the intake and outlet locations. The impacted stretch is short with no substantial trout population or no spawning potential and rock pools are present and sufficient to maintain any resident stocks.

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

Category 2 Rivers:

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

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

- Abstraction should not exceed 50% of the available flow upstream of the intake point, provided the minimum base flow provision above is satisfied.

Category 3 Rivers:

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

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

- Abstraction should not exceed 50% of the available flow upstream of the intake point, provided the minimum base flow provision above is satisfied.

- Further fisheries impact mitigation measures to be recommended if deemed necessary on a site specific basis. This could include a recommendation on increased base flow provision above 12.5%.

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

- In situations where the compensation flow is through a long channel fish may be enticed up and then become stranded in shallow water when the ‘freshet’ has passed. Allowance must therefore be made for site specific recommendations.

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 or nursery area 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 criteria 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 at all sites. A staff gauge should be in place. 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.

In addition to the 12.5% control notch, for high head schemes, a control cill behind the intake screen should be so designed relative to the overflow sections of the weir which would allow for simple 50-50 flow splitting or shutdown checking by an observer.

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 the Irish Republic 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.

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10. Steering Committee

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Patrick Gargan,	***Central Fisheries Board.***
Patricia O'Connor,	***South-Western Regional Fisheries Board.***
Brendan Maguire,	***Northern Regional Fisheries Board,***
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APPENDIX 1

Fisheries Related Information Required in Environmental Impact Statements / Environmental Appraisals for the Application of Hydro-electric Developments.

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 needs 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 below. This information complements data required in the EIS and augments issues to be addressed under the environmental topics Fauna, Flora and Water.

This appendix also provides information on specific measures, which may be considered for mitigation of fishery impacts.

The information required can vary for each site and will be determined by the size and location of the proposed hydro scheme therefore each proposed development should be assessed on a site specific basis.

A scoping document should be agreed before preparation of an EIS. Fisheries Boards may be able to provide data on fish stocks, flora and fauna, and habitat status of relevance to the EIS and additional issues can be highlighted at an early stage.

Guidance on information requirements in relation to the significance of Impacts and mitigation measures provided in the EPA Guidelines 2002 for EISs should be used and supplemented by the additional requirements in this document.

General considerations:

- All potential impacts on fisheries need to be fully assessed as part of an EIS.
- The Fisheries assessment should provide sufficient accurate and relevant data to allow complete and objective predictions and evaluation of potential fisheries impacts.
- The extent, detail and quality of information required must confirm the nature and extent of fisheries present, the current demands on the fishery, competing demands on the water resource and potential impact on fisheries during the various phases of development.
- Information gathered should be of such quality that it can be used as a baseline against which, changes can be measured in the future.
- Information should be clearly presented and relevant to the river system in question.

- Drawings should be properly scaled and of sufficient detail to show the proposed development as designed for that particular site.

Fisheries Impact Assessment Study:

The following information should be presented.

- **Description of the existing environment, the project, natural resource, aquatic habitats and hydrology relative to fisheries.**

- **Prediction of impacts on fisheries.**

- **Evaluation of the significance of the impacts predicted.**

- **Recommendations for mitigation measures and alternatives, including other sites considered but not selected.**

- **Recommendations for an appropriate monitoring programme.**

1. Description of the existing environment, the project, natural resource, aquatic habitats and hydrology relative to fisheries.

1: The Project, Site Description and existing environment.

1:1 Site and Structures:-

- Location of the development relative to all watercourses, rivers and lakes.
- Details of roads, bridging, site access and pipeline routes relative to watercourses.
- Description and location of river weirs, intakes and outfalls. (existing and proposed)
- Proposed provision for and location of fish passes.
- Proposed screening to upstream and downstream migrants
- Details of flow monitoring devices and locations including visual references.
- Detail of river bed structure at the intake and outfall locations.
- Proposed alterations to the natural channel at intake and return points.
- Description of other use of waters in the affected reach e.g. public/private water abstractions, effluent discharges, fish farms, etc
- Description of any obstructions natural or manmade within the affected reach and the extent of interference with fish passage.
- Details on any chemicals, toxic materials to be used on site.

1.2 Fisheries Information:

- Type of fishery present.
- Description of the fishery and nature, species, composition and age structure of fish stocks present.
- Quantitative baseline data on fish above and below the abstraction point and other representative locations in the catchment (covering riffle/glide/pool habitats). (The Methodologies for fish population assessment are those agreed for use in the Water Framework Directive)
- The extent and productivity of impacted reach in terms of spawning and nursery habitat in comparison to other areas of the catchment, relative importance to overall catchment. (habitat mapping should be presented)
- Description of the existing environment relative to the presence of Statutory Designations (e.g.., Annex 11 listed species under the Habitats Directive, Special Areas of Conservation for Salmon, etc.).
- Salmonid/coarse fish spawning and redd count data.
- All available information on angling ,
    - Description of angling status and compilation of salmon and sea trout catch data, both commercial and angling.
    - Compilation of brown trout or coarse fish angling catches data.
- Available quantitative data on fish stocks in the catchment.
- Information on seasonal migration patterns and spawning times of fish within the river catchment, particularly within the affected stretch.

1.3: River Flow and water abstraction information

It will be necessary to describe the existing (pre-development) environment in river flow terms and secondly to describe the post development flow environment in terms of (changed) river flows as well as the project flow abstraction regime. In run of the river schemes the section of channel in which river flows are of interest and need to be assessed is usually only between intake and outfall of the hydro electric scheme i.e. the depleted natural channel.

(In developments which involve damming or impoundment at the intake location or abstraction from a natural lake, the depleted natural channel is not the only section of interest as flow patterns in the river for some distance downstream of the depleted natural may also be affected significantly by the hydro-electric scheme. In such cases river flow details at points downstream of the depleted natural channel should be provided also. In lake abstractions water levels of lake as well as lake inflows + outflows will need to be fully described also.)

We recommend that all water flow rates be expressed throughout in m^3/s.

1.3.1 Describing the predevelopment flow environment

The developer will need to provide reasonably accurate estimation of low, average and flood flow rates as they currently occur at the proposed abstraction/intake site. The developer will also need to provide a basis for an understanding of water level variation with flow at the site.

The developer should provide within the EIS dependable river flow data – this may be in two general forms : -

(a) a flow measurement record of reasonably long duration (greater than 10 complete years) from an appropriate flow gauging station in the Irish gauging network [appropriate means being proximate to and representative of the proposed development site and with a good/fair accuracy quality rating for all/most of the flow range over the period of flow record in question.

(b) a site specific/project specific flow record generated by on site gauge installed by the developer. Such a record should include at least a full continuous 12 month measuring period and preferably be much longer where other sources of flow data are lacking.

The above data should be provided in the processed form of a sequence of daily mean flow over the period in question – this daily mean flow record should be provided in both tabular (tables of daily mean flows for each calendar year) and graphical (A4 landscape size annual hydrographs for each calendar year) formats. This processed data should be in one of the Appendices to the EIS document.

In the main text of the EIS, the flow environment should be described in summary terms and should include :

i) Flow duration curve (or flow exceedence plot) for the flow record period and a listing of percentile flow values (in 5%ile increments)

ii) Estimate of average flows including long term daily mean flow (Qm) value for the site

iii) Estimate of drought flows at the site (stating criteria used – dry weather flow, lowest recorded flow, lowest daily mean flow etc.) and their duration

iv) Estimate of flood flows at the site

As well as flow rate information above, the existing flow environment description should include for an assessment + description of the relationships that exist between flow and depth, between flow and wetted perimeter and between flow and velocity at representative cross sections along the depleted natural channel. The flow environment description should also obviously include details about the catchment itself (such as it's area in Hectares, a summary of pertinent available rainfall data, evapotranspiration records, etc) and a description of it's hydrogeology. Where tributary streams drain to the depleted natural channel their flow contribution should be described also.

1.3.2 Describing the proposed development and the post development flow environment

The abstraction flow pattern needs clear description so that when superimposed on the predevelopment (existing) river flow environment, the post development river flow environment may be readily deduced and understood :

1.3.2.1 Proposed development (abstraction flows)

The scale and pattern of flow take by the proposed hydro electric development is an essential part of the project description section of an EIS and needs to be explained in detail and without ambiguity. It should include the following (as appropriate to the particular development proposed) :-
Turbine type and number
Turbine abstraction flow (minimum)
Turbine abstraction flow (maximum)
Impellor type, clearances, speed of rotation
Flow capacity of intake structure/pipe
Operating abstraction flow range proposed
Description of how turbine operation will be started and stopped in response to water level and river flow
Detailed description of what compensation or residual flows will be provided into the depleted natural channel and when these may be triggered and how these might vary with river flow/abstraction flow or water level as the case may be

1.3.2.2 Post development flow environment

Having provided the relevant information to describe 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 of development impact on flows to clearly describe what the post development flow regime is likely to be at the river streams /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 (1.3.1)

This requires that the post development flow regime (eg immediately downstream of the intake or elsewhere in depleted natural channel or further downstream as appropriate) be depicted in graphical format on similar format annual hydrographs and flow duration curves to those included earlier to describe the predevelopment environment. Showing both flow regimes (pre and post development) as 2 curves on the same single graph at this juncture is helpful to aid understanding of the predicted impact on river flows

As well as providing the basic (as modified) flow record hydrograph(s) and the (as modified) flow duration curves it would be necessary to provide the following as supplementary information about flows downstream of the intake or in the depleted natural channel section:

i) Estimate of average flow
ii) Estimate of lowest flow (and in particular the duration of low flow periods)
iii) Estimate of flood flow

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

2: Predicted Fisheries Impact

Description of potential impacts likely to occur as a result of site selection. These should be based on objective and scientific criteria.

This assessment should include the following Information.

2.1 Construction Phase

- Timing of works and potential conflict with seasonal sensitive fisheries requirements e.g. spawning seasons, fishing amenity.
- Extent of interference with river banks, river bed and water flow.
- Assessment of impact of intake, river weir and outfall construction on physical nature of the river and water quality.
- Potential for water pollution from chemicals, cement and hydrocarbons.
- Potential for silt emissions from construction sites, roads, bridging and pipeline.
- Potential to cause destabilization of ground conditions.

2.2. Operational Phase

- Potential Interference with fish migration and internal fish movement.
- Potential to exacerbate existing fish passage obstructions.
- Effects of reduction and loss of wetted areas during critical periods e.g. during the spawning season.
- Potential to cause change in habitat quality in the depleted stretch.
- Potential loss of aquatic habitat in depleted stretch.
- Potential effect on aquatic invertebrates and macrophytes.
- Potential increase in predation.
- Potential interference with angling along the depleted stretch.
- Potential angling tourism impact.
- Potential to delay or prevent passage of fish at the outfall.
- Potential to increase poaching opportunity.
- Potential impact on other water resource usages, e.g. abstraction, discharges, amenities.
- Potential to cause water quality change, directly or indirectly.
- Potential accumulative effects on water quality and flow.
- Potential impact from use of chemicals and corrosive materials e.g. oils and pipe cleaning liquids. (Type, method and frequency of use).

3: Evaluation of significance of the impacts predicted

An assessment of the extent and severity of impact of the proposed development on the aquatic habitat and fisheries should be provided.

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. (EPA 2002)

In addition a description of the sites value in fisheries terms and its tourism amenity value taking account its international, national or local significance should be presented. Appendix 3 presents criteria for a site evaluation scheme. (NRA 2004)

This evaluation will then be used to determine the extent of mitigation measures required. A further reference is provide by the NRA (NRA 2004) on Criteria for Assessing Impact Significance in Aquatic sites and is included here as Appendix 5.

4. Measures to mitigate adverse impacts

- Proposals for mitigation shall give priority to avoidance of impact.
- In addition it shall aim to reverse, minimize or compensate for an impact and shall also be given an opportunity to enhance existing conditions.
- Mitigation measures proposed should be practicable, clearly detailed and implementable.
- The reasons for site selection and location of intakes and returns points relative to environmental/fisheries considerations should be presented.
- Reference should be made to other sites considered but not selected with reasons stated.
- Avoidance and mitigation measures should be included in an Environmental Management System for the overall project.

Mitigation can most easily be employed where impacts are avoided or minimized. For example: high head intakes located at natural rock pool features and outfalls to pool zones. Low head sites located at an existing weir or natural structure.

Other examples of mitigation measures are presented below,

Location and Design.

- Intake and return point locations selected to reduce the extent of instream and riverbank interference required.
- Location of intakes and return points selected to avoid conflict with sensitive fish habitats, e.g. interference with spawning/nursery sites.
- River weir, fish passes and intake weirs at Category 2 high head run of river sites designed to provide for specified division of river flow above 12.5% Qm flow.
- Approaches to fish passes may require associated instream works to provide ease of access.
- River weirs should not increase impedance to fish passage by their design.
- Modifications to existing fish passes may be considered.

Construction phase

- Mitigation measures proposed for control, containment and prevention of silt emissions undertaken prior to works commencing on site.
- All watercourses traversing pipeline routes should be identified and water runoff piped past the work area.
- Timing of Instream and bankside works, which may impact on waters, should be confined to the months May – September.
- Fish passage past the work site should be facilitated throughout.
- Cofferdams to be introduced where required preventing water pollution.
- Bore Technology should be used where practicable for river crossings.
- Adequate lands should be available to provide silt settlement areas within the site.
- Unwarranted machinery movement prohibited along riparian zones.

- Proposals for the reinstatement and restoration of river banks stipulated.

Operational phase.

- A maintenance program should be introduced to keep screens clear and remove obstructions in fish passes etc.
- Seasonal close down periods may be necessary to accommodate fish migration periods.
- In the case of the operation of the intake causing smolt mortalities, it may be necessary to consider additional screening measures and/or a six-week generation shut-down.
- If necessary, provision should be included for occasional shut down periods to facilitate fish movement past the depleted reach.
- Standard operating practices should be introduced for the use of chemicals and toxic materials to prevent harmful emissions to waters.

Additional Measures:

- Consideration can in certain circumstances be given to the easement for passage for fish at natural physical barriers within the depleted reach.

5. Monitoring/Regulation

Monitoring

- A long-term monitoring program should be established to confirm the predictions of the EIS. Monitoring should focus on biological status, flow rates and fish stocks.
- The sensitivity of the fish population present within the system will dictate the nature and extent of fish stock assessment required. Methodologies to be used should be determined at the scoping phase of the EIA.
- An assessment of fish passage at weirs is required to determine the efficiency of structures put in place.
- The efficiency of screens should be monitored for a period of three years from the commissioning of a project.
- Three monthly reviews of river flow data and abstraction flow data should be undertaken in the first year of operation to assess effectiveness of river calibration and operation of flow devices.
- A review of flow conditions should be undertaken to assess the effectiveness of permitted abstraction rates and to identify if a review of conditions granted should be considered.

Regulation:

- The mechanism for splitting flow between the intake and river should be detailed and the location of automatic sensors given.
- On-line flow data should be available to the relevant authorities to assess the abstraction regime at any time.
- 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 exceeded before abstraction commences and during abstraction. The exact location should be agreed, identified on drawings and included in conditions.
- Protocols for notification of and consultation with the relevant authorities in the event of an incident, giving rise to pollution of waters or where works may impact on the aquatic habitat to be provided.
- Site management plans and environmental mitigation measures should be stipulated in Contract Documents and contained in Construction Method Statements.
- All managers and contractors should be familiarized with environmental requirements of the project.
- A Liaison officer should be appointed to provide avenues of communication between the developer and regulatory authorities.

References :

EPA (Environmental Protection Agency) (2002) Guidelines on the information to the contained in Environmental Impact Statements. Prepared by CAAS (Environmental Services) EPA Wexford.

National Roads Authority (2004) Guidelines for Assessment of Ecological Impacts of National Road Schemes. NRA . Dublin Prepared by *NATURA* Environmental Consultants.

Appendix 2: Drawings and Detail required in the EIS.

The EIS should include the following

- Powerhouse – front elevation, section and layout,
- Detail of outfall.
- Detail of intake structure, intake weir and river weir.
- Detail of fish passes.
- Details of excavations and retaining walls for intake and outfall structures.
- Elevations of intake and outfall screens.
- Riverbed and bank details.
- Riverbed survey showing the bed profile and proposed weir elevations at intake and existing plus proposed bed profiles at point of return of abstracted water.
- 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 the sufficient level information on crest, apron and other part so 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 include reference to datum levels.

- Drawings should be of such detail and scale to be read easily and without reference to text.

Appendix 3 Site Importance Evaluation Scheme & Criteria for Assessing Impact Significance of Aquatic Sites

Rating	Qualifying Criteria
A	**Internationally important** Sites designated (or qualify for designation) as SAC* or SPA* under the EU Habitats or Birds Directives. Undesignated sites containing good examples of Annex 1 <u>priority</u> habitats under the EU Habitats Directive. Major salmon river fisheries. Major salmonid (salmon trout or char) lake fisheries.
B	**Nationally important** Sites or waters designated or proposed as an NHA or statutory Nature Reserves. Undesignated sites containing good examples of Annex 1 habitats (under EU Habitats Directive). Undesignated sites containing <u>significant numbers</u> of resident or regularly occurring populations of Annex 11 species under the EU Habitats Directive or Annex 1 species under the EU Birds Directive or species protected under the wildlife (Amendment) act 2000. Major trout river fisheries. Water bodies with major amenity fisheries value. Commercially important coarse fisheries.
C	**High value, locally important.** Sites containing semi-natural habitat types with high biodiversity in a local context and a high degree of naturalness, or significant populations of locally rare species. Small water bodies with known salmonid populations or with good potential salmonid habitats. Sites containing <u>any</u> resident or regularly occurring populations of Annex 11 species under the EU Habitats Directive or Annex 1 species under the EU Birds Directive. Large water bodies with some coarse fisheries value.
D	**Moderate value, locally Important.** Sites containing some semi-natural habitat or locally important for wild life. Small water bodies with some coarse fisheries or some potential salmonid habitats. Any water body with unpolluted (Q- value rating 4-5.
E	**Low value, locally important,** Artificial or highly modified habitats with low species diversity and low wildlife value. Water bodies with no current fisheries value and no significant potential fisheries value.

*SAC = Special Area of Conservation
SPA = Special Protection Area
NHA = National Heritage Area

Criteria for Assessing Impact Significance of Aquatic Sites

Site Category*

A Site

	Temporary	Short-term	Medium term	Long-term
Extensive	Major	Severe	Severe	Severe
Localised	Major	Major	Severe	Severe

B Site

	Temporary	Short-term	Medium term	Long-term
Extensive	Major	Major	Severe	Severe
Localised	Moderate	Moderate	Major	Major

C Site

	Temporary	Short-term	Medium term	Long-term
Extensive	Moderate	Moderate	Major	Major
Localised	Minor	Moderate	Moderate	Moderate

D Site

	Temporary	Short-term	Medium term	Long-term
Extensive	Minor	Minor	Moderate	Moderate
Localised	Not significant	Minor	Minor	Minor

E Site

	Temporary	Short-term	Medium term	Long-term
Extensive	Not significant	Not significant	Minor	Minor
Localised	Not significant	Not significant	Not significant	Not significant

In line with EPA Guideline (EPA 2002), the following terms are defined when quantifying duration

Temporary: up to 1 year.
Short Tern: from 1-7 years.
Medium Term: 7-15 years
Long-term: 15- 60 years.
Permanent: over 60 years.

Localised impacts on rivers are loosely defined as impacts measurable no more than 250m from the impact source, Extensive impacts on rivers are defined as impacts measurable more than 1250m from the impact source. Any impact on salmonid spawning habitat or nursery habitat where it is in short supply, would be regarded as an extensive impact as it is likely to have an impact on the salmonid population beyond the immediate vicinity of the impact source.

* Site categories A to E are defined above.

Appendix 4:

Abstraction not to exceed half of the available flow. (Worked example)

For a hydroelectric development on a category 2 or 3 river section with a long term mean flow = 480l/s and proposed turbine flow range = 40 – 400l/s

The Fisheries Flow requirement would be as follows:-

Baseflow of 60 l/s (=12.5% Qm) and in addition abstraction shall not exceed half of the available flow upstream of the intake point.

Flow: litres per second

Available	Fisheries Compensation.	Hydroelectric Abstraction.	Actual Residual
10	10	0	10
40	40	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
1000	500	400	600
2000	1000	400	1600

Appendix 5: Glossary of Terms:

Abstraction not to exceed half of the available flow: This abstraction limit stipulation applies in addition to the base compensation flow stipulation for development. It supplements and does not replace the base compensation flow requirement

ADF. Average Daily Flow. An average of the daily mean flows available.

Arctic Char. A member of the salmonid family

Available flow: The flow resource available (before abstraction) at the intake point.

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

CFB. Central Fisheries Board.

Coarse Fish. For the purposes of this document, all freshwater fish other than salmonid, eels and lamprey.

Compensation Flow. Minimum flow legally required to be maintained in the river when that or a greater flow is available.

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 quantity 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 intake point of hydroelectric abstraction to point of return of the abstracted water to the river channel.

Elvers. Juvenile eels.

Equi-partition. Equal division of flow between river and intake.

Fish Pass. A channel for the free run of 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 fish passage.

Freshet. An increase in river flow following a period of heavy rainfall.

Grilse. A salmon returning to freshwaters after one winter at sea.

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.

Kelt. Any salmonid after spawning. (see spent fish)

Littoral. Marginal areas of lakes subject to water level variations.

Long Term 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 estimated on the basis of catchment area and long term rainfall records (preferably 30 years record) and evaporation and transpiration data.

Low head. Hydro schemes where the vertical drop from the intake to the turbine is less that 5 meters

Macroinvertebrates. Aquatic insects visible to the eye without a backbone

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)

Parr. Juvenile salmon which spends one- three years in freshwater.

Redd. An excavated area of clean gravel bed in a river used by salmonids to incubate fertilised eggs.

Residual Flow. The flow remaining in the river when abstraction is taking place.

RFB. Regional Fisheries Board

Run of river. Hydro schemes which exploit the natural river flow without need for impoundment

Salmonid. Family of fish which includes salmon, sea trout, brown trout and arctic char.

Smolt Screen. A screen of dimensions to exclude the entry of juvenile fish.

Smolt. A young salmon which has undergone physiological change before migrating to the sea from fresh water.

Spate. A flash flood flow typically occurring in high gradient short river catchments or more recently in extensively drained catchments with reduced water storage.

Spent. As for Kelt

Spring Salmon: a salmon returning to freshwaters before June and which has spent more than one year at sea. **(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 to carry low flow.

Weir. (As in "fishing weir") any erection, structure or obstruction fixed to the soil across or partly across a river.