AN ASSESSMENT OF THE IMPACT OF CULVERTS ON ATLANTIC SALMON (*SALMO SALAR*) MIGRATION THROUGH FRESHWATER

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ABSTRACT

The Atlantic salmon (*Salmo salar* L.) is a migratory fish species that spends a number of years in freshwater before migrating to the sea to feed and grow, and then returning to freshwater to spawn. It requires unhindered access to upstream spawning areas in order to complete its life-cycle. Culverts are structures that allow rivers to flow under roads or embankments and, if poorly designed and constructed, they may restrict the upstream passage of Atlantic salmon.

Five spawning streams on the River Moy, a productive Atlantic salmon river in Co. Mayo, were surveyed and a total of seventy culverts were inspected. The suitability of these culverts, in terms of unhindered salmon migration, was assessed based on specific fish passage criteria detailed in the National Roads Authority (NRA) guidelines. Further analysis of salmon spawning, fish survey and water quality information from the River Moy was conducted in order to validate the findings from the field work. In order to assess the level of awareness within local authorities of fish passage issues, a culvert questionnaire was sent to senior engineers within each of the twenty-nine Irish Local Authorities.

Preliminary results indicate that poorly installed culverts have restricted the distribution of Atlantic salmon in several parts of the River Moy catchment. Where culverts were found to breach a number of the key fish passage criteria outlined in the NRA guidelines, there was no evidence of any salmon being present upstream of these culverts. Similarly, where salmon were found upstream of culverts, the majority of those culverts matched the NRA criteria. However, such findings can only be confirmed by baseline electrofishing surveys upstream and downstream of the studied culverts. Such surveys would positively confirm the presence or absence of salmon.

Water quality was not found to be a factor limiting salmon distribution on the River Moy, with the majority of spawning streams having a biological quality class of Q4 or greater. Twenty out of twenty-nine culverts questionnaires were returned and results indicated that the level of fish passage awareness within the Local Authorities is low. It is apparent that the NRA guidelines need to be expanded and improved, to cover existing problem culverts, and that further field surveys are required to determine the extent of the problem across the wider River Moy catchment.

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1. INTRODUCTION

The Atlantic salmon (*Salmo salar* L.) is a native Irish fish species that is found in rivers on both sides of the North Atlantic Ocean. In Ireland, the species is distributed in rivers around the coast, with the most productive salmon river being the River Moy in Co. Mayo (Collins *et al*., 2006). Atlantic salmon are an anadromous species i.e. they spawn in freshwater and feed at sea. In recent years, salmon numbers returning to Irish rivers have been in steady decline for a variety of reasons.

Where a road or path crosses over a salmon spawning stream, a structure is installed that allows water to flow under the road. Such a structure is termed a culvert and can consist of a variety of types, from clear span bridges to round concrete pipes. As salmon make their annual upstream migration through freshwater, they must ascend through these culverts in order to access upstream spawning habitat and complete their life-cycle. In Ireland, the majority of culverts are installed by Local Authorities; Mayo and Sligo County Councils are the only two Local Authorities that install culverts within the River Moy catchment.

The aim of this study is to assess whether or not culverts have restricted the distribution of Atlantic salmon through the River Moy catchment. A total of seventy culvert sites across five of the main River Moy spawning tributaries were inspected and a field sheet was completed at each site. A number of key fish passage criteria, identified in both Irish and international guidelines, were recorded at each site. Photographs and GPS readings were taken at each site and observations (e.g. evidence of pollution, salmon spawning) were also recorded.

In order to attempt to validate the findings of the field inspections, a review was conducted of all available spawning and fish survey data for the River Moy, as well as a review of the EPA's biological water quality monitoring programmes. The aim of these reviews was to confirm the presence or absence of salmon on the River Moy relative to the location of the various inspected culverts, and also to determine if pollution problems could be a factor limiting salmon distribution within certain parts of the catchment.

Apart from the research that was conducted into culverts specifically on the River Moy, an attempt was made to assess the level of awareness within Local Authorities across Ireland, with regards to culverts and related fish passage issues. Within each of the Irish Local Authorities, area engineers are the individuals primarily involved in culvert design and installation. In order to assess both the level of fish awareness within Local Authorities and the type of approaches taken to culvert design and installation, a culvert questionnaire was sent to the senior engineers within each of the twenty-six Local Authorities in Ireland.

2. LITERATURE REVIEW

2.1 Introduction

This literature review looks at the impacts that culverts can have on the movement of Atlantic salmon (*Salmo salar* L.) through freshwater river catchments, with focus on a productive salmon catchment in the west of Ireland (River Moy). An assessment of the current status of Atlantic salmon was carried out. A review was made of existing legislation that deals with salmon and their safe passage through freshwater habitat, as well as an assessment of the guidelines that are in place, both in Ireland and abroad, to ensure safe salmon passage and effective culvert design.

2.2 Conservation of Atlantic salmon (*Salmo salar* L.) in Irish Waters

Ireland's natural freshwater resource consists of 16,000km of main river channel, a further 10,000km of tributary streams and over 200,000ha of lakes, which make up over 2% of the country's land area (Whelan, 1991). The presence of Atlantic salmon (*Salmo salar* L.) is a distinctive feature of many inland waters and attests to the relatively good water quality that exists in Ireland today; the depletion of salmon stocks is a reflection of ecological degradation on a wider scale (EPA, 2000). Atlantic salmon has a specific relevance in respect of the EU Habitats Directive (92/43/EEC) and Ireland is considered to be of particular importance for salmon conservation by virtue of the number of freshwater salmon habitats it possesses and the fact that salmon migrating to rivers in the United Kingdom and Europe must swim through Irish coastal waters (O'Keefe and Dromey, 2004).

2.2.1 Status of Atlantic salmon stocks

Stocks of Atlantic salmon in Ireland have been in a steady state of decline since the 1970s (Collins *et al.*, 2006). The returns of salmon to Ireland today are the lowest in thirty-five years and the most recent report from the National Salmon Commission (NSC, 2006) estimates that, compared to the 1970s, there are now less than a third of the fish returning annually to the Irish coast. This appears to be a problem for salmon stocks in many countries bordering the North Atlantic (Reddin, 2002). Watson (1999) reviewed the distribution of Atlantic salmon across its range and noted that the only area where the stocks have been relatively unaffected by industrial and commercial pressures is along the northern coast of Russia.

In 2006, a report by the Independent Salmon Group (Collins *et al.*, 2006) to the Minister for Communications, Marine and Natural Resources recommended an end to driftnetting along the Irish coast. The Group had examined information from the Standing Scientific Committee (NSC, 2006), which found that only thirty-four out of one hundred and thirty-two Irish salmon fisheries were meeting their conservation limits. The conservation limit is defined as the spawning stock level that produces maximum sustainable yield (NASCO, 2002). As driftnetting is a mixed stock fishery (i.e. a fishery exploiting a significant number of salmon from two or more river stocks), it was seen by the European Commission as being in contravention of the EU Habitats Directive. In November 2006, the Irish Government announced an end to the mixed stock fishery in 2007 and a €30 million compensation package for commercial fishermen and their communities (Irish Times, 2006).

2.2.2 Irish salmon fisheries

Historically, a number of Ireland's rivers (such as the Erne and the Shannon) produced runs of salmon that were comparable with any in Europe (Mathers *et al.*, 2002). While the stocks of Atlantic salmon have declined substantially across their geographical range (Reddin, 2002) over the past thirty years, a number of Irish rivers continue to produce large numbers of salmon each year. Figure 2.1 shows the catchment area of the River Moy, the most productive Atlantic salmon river in Ireland (O'Reilly, 1998).

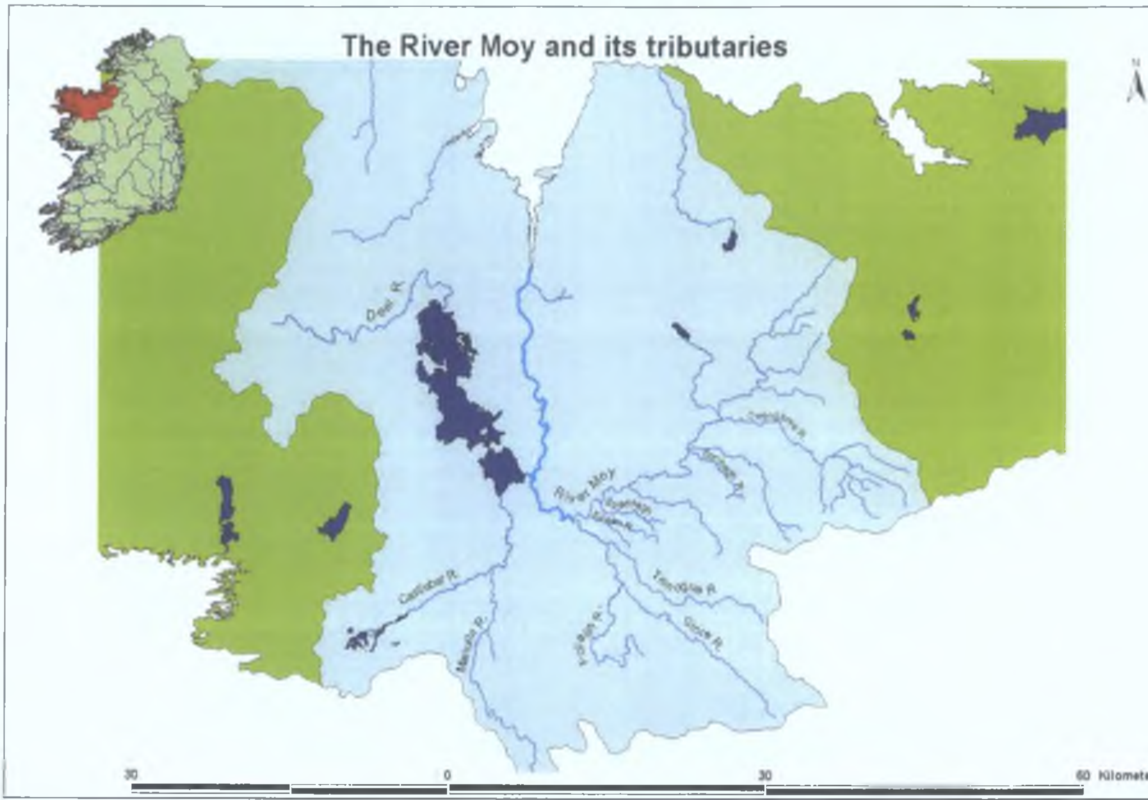

Figure 2.1 Map of River Moy and its main salmon spawning tributaries (Cooke, 2006)

The River Moy rises in the Ox Mountains in Co. Sligo and enters the sea at Killala Bay in Co. Mayo. It is 100km long and drains a total catchment area of over 2000km^2, within the Western River Basin District. The average annual salmon rod catch on the Moy over the last ten years is 7,362 fish (North Western Regional Fisheries Board, 2004). The Ridge Pool fishery, located in the tidal stretch of the river at Ballina, Co. Mayo, is regarded as one of Ireland's most sought after fishing locations and has produced 2,260 salmon to rod and line in a single year (D. Cooke, North Western Regional Fisheries Board, pers. comm.). A number of the Moy's tributaries are regarded as being good salmon fisheries including the Glore, Trimogue, Manulla, Castlebar, Gweestion and Deel Rivers (O'Reilly, 1998).

Other salmon fisheries of note include the Blackwater River in Co. Cork, the Boyne River in Co. Louth, the Slaney River in Co. Wexford, the Lee River in Co. Cork, the Bundrowes River in Co. Donegal, the Laune River in Co. Kerry and the Corrib River in Co. Galway. While there are numerous other rivers in Ireland that receive small runs of one-sea-winter salmon (or grilse), the aforementioned rivers are the remaining multi-sea-winter salmon (or spring salmon) fisheries in Ireland.

2.3 Threats to Atlantic salmon

2.3.1 Climate change and reduced sea survival rates

Collins *et al.* (2006) point to the climate at sea and suggest that the evidence is growing that sea temperatures can affect migration speeds and routes, can impact on the extent to which migrating salmon are preyed upon and can restrict food availability. The number of Atlantic salmon surviving the marine phase of their life-cycle (that is the period between smolt migration from freshwater into the sea and their subsequent return as adults to their rivers of birth) is now much lower than in the past (Hutchinson *et al.*, 2002). Fish farms and associated levels of sea lice have also been identified as being a contributory factor to the poor survival rates among smolts in some estuaries (Whelan, 1993).

2.3.2 Exploitation in coastal and inland waters

Salmon face many natural predators in both freshwater and at sea, including otters, herons, mergansers, cormorants, seals, cod, pike, trout and shark. However, commercial and recreational exploitation of the stock by humans is regarded as being the most significant exploitation threat (Whelan, 1991). It has been estimated that Irish driftnets have annually taken over 20% of the entire stock of salmon returning to rivers in the south of England, with one particular river (River Test) seeing 28% of its spawning stock being intercepted along the Irish coast (Hendry and Cragg-Hine, 2000). The removal of Irish driftnets from 2007 is likely to have significant benefits for many English salmon rivers (Collins *et al.*, 2006).

2.3.3 Water pollution

Atlantic salmon are susceptible to deteriorating water quality as a result of both point source discharges and diffuse discharges arising from land use practice and industrialisation (Hendry *et al.*, 2003). The EPA has identified organic pollution (with agriculture the primary source) and eutrophication as the most widespread pollutant threat to freshwater fish in Ireland (EPA, 2000). The Urban Waste Water Directive (91/271/EEC) defines eutrophication as being the enrichment of waters by nutrients, especially compounds of nitrogen and phosphorus, causing an accelerated growth of algae and higher forms of plant life to produce an undesirable disturbance to the balance of organisms and to the quality of the water concerned.

The siltation of spawning gravels, as a result of forestry and peat harvesting practice, has been identified as a significant threat to the viability of Atlantic salmon populations in some areas (Fitzsimons and Igoe, 2004). Siltation can result in eggs being deprived of oxygen, resulting in lower survival rates. Siltation has also been noted in a number of overgrazed catchments in the west of Ireland, where loss of bog and associated vegetation has increased erosion effects in rivers. Severe examples of this have been noted in some salmon spawning rivers that discharge into Lough Corrib (O'Grady *et al.*, 2002).

Chemical pollution has been noted in a number of rivers in Ireland and generally is directly toxic to aquatic species. Such pollution can include acid mine drainage, water treatment chemicals, heavy metals, acid deposition from forestry, hydrocarbon oils and discharge of chemical pesticides (Fitzsimons and Igoe, 2004).

2.3.4 Drainage

O'Grady and Gargan (1993) detailed the impacts that drainage activity can have on salmon, including loss of fish habitat, loss of stream gradient and riffle/glide/pool sequences, and altered hydraulic regimes. While some rivers have naturally recovered from large scale arterial drainage works, the majority do not and extensive rehabilitation works are generally required to assist with the recovery (O'Grady, 1994).

2.3.5 Aquaculture

The growth in salmon farming in coastal and inshore waters has impacted on salmon in a number of ways. Intensive production of Atlantic salmon has resulted in the generation of high levels of sea lice, which have been found to infest salmon and sea trout smolts (Scottish Office, 1997; Gargan *et al.*, 2003). Escaped farmed salmon can compete with wild salmon and spread disease. Escaped male salmon are often larger than wild fish, making them more attractive to females and more successful in spawning, even though they may be less fit genetically (Hendry and Cragg-Hine, 2003).

2.3.6 Obstructions to migration

Unhindered access to spawning areas is a key requirement for the completion of the Atlantic salmon's life cycle (O'Grady, 2003). Poorly designed or constructed culverts and bridge sills can inhibit the upstream migration of salmon by presenting a physical barrier during low flows, or by creating a hydraulic barrier with increased water velocity during spawning migration periods (Fitzsimons and Igoe, 2004). River diversions or temporary realignments can also inhibit the movement of salmon upstream (Murphy, 2005).

2.4 Agencies with responsibility for Atlantic salmon management in Ireland

2.4.1 Department of Communications, Marine and Natural Resources

The Department of Communications, Marine and Natural Resources (DCMNR) has overall policy responsibility for the development of policy and legislation, regulation and enforcement in the inland fisheries sector. Its stated aim is to conserve the inland fisheries resource in its own right and to maximise its long-term economic and social contribution at national and local community level (DCMNR, 2003).

2.4.2 Central and Regional Fisheries Boards

Set up under the Fisheries Act, 1980, and subsequently re-modelled under the Fisheries (Amendment) Act, 1999, the Central and Regional Fisheries Boards (RFB) are responsible for the conservation, protection, management and development of inland fisheries (CFB, 2005). Apart from the protection of salmon in freshwater and out to the twelve mile limit off the coast, the Boards are also responsible for the protection and conservation of sea trout, sea bass, molluscs, eels and all freshwater fish.

2.4.3 Marine Institute

The Marine Institute was set up under the Marine Institute Act, 1991, and is responsible for directing, co-ordinating and evaluating marine research and development in Ireland. It has major research facilities in Galway (Oranmore) and Mayo (Burrishoole). The Burrishoole facility co-ordinates the Institute's salmon research efforts and contains the longest unbroken record of Atlantic salmon and eel migrations on any river in Europe (Marine Institute, 2002).

2.4.4 National Salmon Commission

The National Salmon Commission is a statutory body that was set up by the National Salmon Commission (Establishment Order), 2000. Its purpose is to assist and advise the Minister of Communications, Marine and Natural Resources in relation to the management, development and conservation of wild salmon and sea trout stocks.

2.4.5 National Parks and Wildlife Service

The National Parks and Wildlife Service (NPWS) operates under the Department of Environment, Heritage and Local Government (DEHLG) and is responsible for the implementation of both domestic legislation (e.g. Wildlife Act, 1976) and European legislation (e.g. Habitats Directive). Its role in relation to Atlantic salmon is in the designation, protection, management and maintenance of Special Areas of Conservation (O'Keefe and Dromey, 2004).

2.4.6 Electricity Supply Board

The construction of large dams to harness hydropower has resulted in the effective blockage of salmon migration on a number of important salmon rivers, such as the Shannon, Erne and Lee. To compensate for the loss of salmon fishing on the Shannon, the ESB was required to buy out all the fishing rights (Shannon Fisheries Act, 1935). The ESB now operates a salmon management programme on the aforementioned rivers; the mainstay of this programme is the stocking of hatchery produced Atlantic salmon into waters upstream of the dams (ESB, 2001). This programme has been the subject of controversy and the sustainability of its operation has been called into question (Mathers *et al*., 2002).

2.5 Life cycle of the Atlantic salmon

The Atlantic salmon displays an anadromous life cycle (i.e. the young are born in freshwater and migrate to sea after a defined period, in order to feed and grow). Salmon eggs are deposited in late autumn (November and December) in gravel nests on the stream bed that are called redds. A redd is a depression in the gravel bed, up to 30cm deep, created by the flapping movement of the salmon's tail (Whelan, 1991). Research has determined that salmon will actively seek out gravel beds with moderate velocity and depth (Fleming, 1996). Water temperatures regulate the rate of egg hatching, but normally a redd will protect the eggs for three to four months.

In mid to late March, the eggs begin to hatch and yolk sac fry emerge from the gravel. This normally takes place at night (Crisp and Hurley, 1991). As the yolk sac is absorbed, the fish become fry or alevins. At this stage, they move around the redd and begin to actively feed. They are territorial and weaker fry, or fry whose hatching was delayed, are dispersed downstream. Fry normally seek out areas of the stream with moderate current velocities rather than calm water (McCormick *et al*., 1998).

Fry quickly develop into parr with distinctively camouflaged vertical stripes. They may grow up to 10cm in length by the end of their first summer of feeding. While some larger parr may migrate to sea the following May, at one year of age, the majority stay in freshwater for another twelve months. If food is scarce, then the parr may remain in freshwater for up to three years (Whelan, 1991). Parr are typically found in fast flowing riffles in association with rough gravel substrate and they actively defend feeding territories against other parr (Gibson, 1993). Parr may also move out of main river channels and into smaller tributary streams during the summer, remaining there until they leave as smolts one or more years later. These smaller streams may have rougher substrate than the spawning areas and may produce more food organisms, as well as providing the parr with more suitable winter habitat (Armstrong *et al*., 1997).

At six to eight weeks prior to migration, the parr begin to turn silvery and are then known as smolts. These fish experience a number of physiological and behavioural changes in preparation for entry into sea water. Physiologically, the changes include development of a high level of salinity tolerance, increased scope for growth in seawater, a shift in visual pigments from porphyropsin to rhopdopsin (the latter a characteristic of marine fish) and increased buoyancy (Saunders, 1964). As the smolts migrate downstream, they experience behavioural changes such as increased negative rheotaxis (downstream orientation), decreased territorial behaviour and increased salinity preference (Hoar, 1988). They leave freshwater generally around May and migrate northwards to a feeding area east of the Faroe Islands to the west of Greenland (Reddin, 2002). They may remain feeding here for a period of one to four years, before returning to the natal river that they migrated from.

Salmon that return to freshwater at one year of age are known as grilse, and weigh approximately 2kg. These fish enter Irish rivers between May and August each year (O'Reilly, 1998). Fish that have fed at sea for two years (two-sea-winter fish) normally return to freshwater between the months of January and May and are often referred to as spring fish. These fish can weigh between 4.5 and 9kg, although the average weight of these multi-sea-winter fish, and their overall numbers, has declined markedly in recent years (Collins *et al*., 2006). Fish that spend three or four years feeding at sea can weigh up to 15kg on return to freshwater, although such fish are increasingly rare within the Irish stock.

On return to freshwater, salmon do not feed but live for periods of eight to fourteen months off the fats and proteins stored in their body musculature. Many productive salmon fisheries in Ireland are nutrient poor and acidic in nature; scarce food supplies are thus not an impediment to productivity. As November approaches, the salmon have lost their silvery flanks and become dark; the males develop a brown, orange or red colouring, with the jaw growing a distinctive kype or hook. The female salmon can go black, with their bodies becoming swollen and distended from the developing eggs inside. During November, the salmon experience a strong spawning urge and begin their journey to the spawning beds. It is at this time when the fish can be in a significantly weakened state that culverts can prove to be an impediment to their progress towards the spawning areas from where they originated.

Following spawning, the adult salmon are known as kelts and are weakened and emaciated following the spawning process (Buller *et al*, 1992). The majority of kelts die soon after spawning, although a very small number may return to the sea to feed and then re-enter freshwater to spawn a second or third time. These fish are predominantly female, as research has found that male salmon use up more energy during the process of securing a female mate and spawning (Watson, 1999).

2.6 Migration and movement of Atlantic salmon

2.6.1. Importance of unhindered fish passage through freshwater catchments

According to Mirati (1999), the free movement of fish through a river catchment is necessary to meet a number of life history needs:

1. Upstream migration of the adults to access suitable spawning area.
2. Juvenile salmon must be able to move upstream and downstream to adjust to changing habitat conditions.
3. Resident fish need continuity of stream networks to prevent population fragmentation, which decreases gene flow and genetic integrity.

4. Catastrophic events can displace entire resident fish populations, with barriers then preventing recolonisation of these habitats.

Mirati concluded that migration barriers can substantially impact on anadromous fish populations, with the extent to which fish migration can be impeded appearing to be substantial. Botkin *et al.* (1994) and the National Research Council (1996) arrived at a similar conclusion. O'Grady (1994) and Watson (1999) stress the importance of safe fish passage upstream in order to allow for successful completion of the Atlantic salmon's life cycle.

2.6.2 Motivation for fish movement

Kahler and Quinn (1998) found that there are a number of combinations of environmental stimuli and internal motivation that can result in fish movement, with the most obvious being the spawning urge. However, apart from movement by adult Atlantic salmon, there can also be significant movement by juvenile salmon within freshwater. A comprehensive paper by McCormick *et al.* (1998) examined the variety of movements that characterise the behaviour of juvenile Atlantic salmon and divided their movements into the following five phases:

1. Movement of fry from the vicinity of their redds.
2. Establishment and occupation of feeding territories.
3. Spawning movements of sexually mature male parr.
4. Movement from summer feeding territories to winter habitat.
5. Descent from nursery streams to lower reaches of rivers during smolt migration.

Cunjak *et al.* (1989) found that there could be significant movement of Atlantic salmon parr from summer feeding areas to winter habitat and that the parr take advantage of seasonally warm water to maximise food intake and growth. However, they must conserve energy during winter when food is less available and maintaining station in rapidly flowing water would have a high energy cost. While winter habitat can often be in the same area as summer feeding territory, upstream movement of parr was noted by Saunders and Gee (1964) in response to changing physical conditions and the availability of food.

Hvidsten *et al.* (1995) examined the factors that affected the timing of smolt migration and found that the smolt run was significantly related to water temperature, water flow and moon phase. Extensive studies on a salmon index river (Burrishoole) in the west of Ireland have identified photoperiod and water temperature as being the two factors dominating smolt migration (Byrne *et al.*, 2003).

2.6.3 Swimming capabilities of Atlantic salmon

The swimming capabilities of Atlantic salmon are an important consideration in the design of culverts. Barber and Downs (1996) broke down the swimming capabilities of salmon into three categories:

1. Sustained or cruising speed – the speed that can be sustained for an extended period of time without fatigue.
2. Prolonged speed – the speed that can be maintained for a considerable period of time (up to 500 minutes), but which eventually results in fatigue.
3. Burst speed – the speed that a fish can maintain for only a very short period of time (< 1 minute).

Kane and Wellen (1985) concluded that the sustained speed or cruising speed should be the benchmark for all culvert design. While the swimming capabilities of salmon are obviously a key consideration during culvert design and construction, it is an area that has received little study in Ireland. The Eastern Regional Fisheries Board guidelines (Murphy, 2005) state that, as a key design principle, the velocity of flow should be less than the swimming speed that can be comfortably maintained by the weakest upstream migrants. They do not, however, detail what species are considered to be the weakest upstream migrants, or what speeds these species can attain. The National Roads Authority (NRA, 2005) is similarly vague in its assessment of fish swimming capability. There also appears to be little recognition in any of the Irish guidelines that salmon may migrate at times other than on approach to the spawning period.

Bell (1990) looked at the relative swimming speeds of two species of salmon; adult Chinook salmon (*Oncorhynchus tshawytscha*) and Coho salmon (*Oncorhynchus kisutch*). He found that these salmon could achieve a sustained swimming speed of 2.5-3 m s^{-1}. However, this speed varied among different sizes and age classes. Other factors such as the sex of the fish, sexual maturity and physical condition were also found to affect swimming capability. It appears that many culvert design guidelines wrongly assume that all fish of a particular species are uniform in terms of swimming performance.

Colavecchia *et al.* (1998) measured the swimming performance of Atlantic salmon by radio-tagging a number of adults between 48 and 54cm in length. Using an 18m long pipe, at a mean water temperature of 10°C, they found that the salmon could achieve swimming speeds of 2.55-3.6 m s^{-1}, where the water velocity was 1.92-2.85 m s^{-1}. The maximum swimming speed recorded was 4.13 m s^{-1}; however, no salmon were able to ascend the entire pipe where the water velocity was >1.92 m s^{-1}.

Armstrong *et al.* (2004) looked at the swimming capabilities of different fish species and size ranges within the one species. It was found that large fish such as adult Atlantic salmon could ascend structures where the water velocity may be up to 5 m s^{-1}, since the maximum swimming speed and endurance of a fish normally increases with increasing length of the fish. However, it was also noted that smaller fish such as first year returning sea trout of 30cm in length may have difficulty in ascending jets of water at a velocity >3 m s^{-1}. Baker and Votapka (1990) also detail the difficulties that migrating juvenile salmon may face at drainage structures that are only designed for the passage of adult salmon.

2.7 Culverts

A culvert is any conduit or waterway used to allow the passage of flow underneath a roadway or embankment (Barber *et al.*, 1996). The NRA recommend that all internationally or nationally important watercourses are bridged rather than culverted, in order to leave the natural bed and banks undisturbed, and leave natural bank paths in place for mammal movement and angler access (NRA, 2005).

The NRA defines an internationally important watercourse as one designated as a Special Area of Conservation (SAC) or Special Protection Area (SPA) under the Habitats Directive (92/43/EEC), a major salmon river fishery or a major salmonid (salmon, trout or char) lake fishery. Nationally important watercourses are defined as being those designated or proposed as Natural Heritage Areas (NHA), statutory nature reserves, undesignated sites containing significant numbers of Annex II species or species protected under the Wildlife

(Amendment) Act, 2000, major trout river fisheries or commercially important coarse fisheries (NRA, 2004).

A clear span bridge is normally the most economically expensive river crossing option (NRA, 2005) but provides little or no hindrance to fish movement. If properly constructed, it should allow for retention of the natural river bed substrate and the riparian zone. Clear span bridges are the preferred river crossing option in a number of publications (O'Grady, 2003; Murphy, 2005).

2.7.1 Type of culverts

2.7.1.1 Bottomless arch culvert

This type of culvert normally allows for retention of the stream bed and allows for the natural hydraulic conditions within the channel to be maintained. While this is preferable to the use of other culvert types, the installation of a bottomless culvert typically involves significant disturbance of the stream bed and bank due to excavation for the culvert footings (Baker *et al.*, 1990). The most common type of material used for culvert construction is concrete; the use of metallic bottomless arch culverts appears to be relatively uncommon in Ireland (M. Kirrane, Eastern Regional Fisheries Board, pers. comm.)

2.7.1.2 Box culvert

This type of culvert normally contains a smooth bottom, which can increase velocity and reduce depth variation, thus restricting fish passage. Modifications can be made to these culverts (e.g. use of natural substrate within culvert, installation of culvert beneath stream grade) to improve fish passage conditions. The installation of these culverts normally results in habitat loss, as the stream bed has to be dredged and prepared prior to culvert placement.

2.7.1.3 Round or oval culvert

This type of culvert is the least favourable culverting option. Murphy (2005) recommends that its use be confined to temporary crossings or short runs. It must be set below the bed level of the stream to allow for ease of fish passage (NRA, 2005).


Plate 2.1 Bottomless arch culvert on Sonnagh River, Co. Mayo (S. Neylon)


Plate 2.2 Box culverts on Brusna River, Co. Mayo (S. Neylon)

Plate 2.3 Round culvert on Gweestion River, Co. Mayo (S. Neylon)

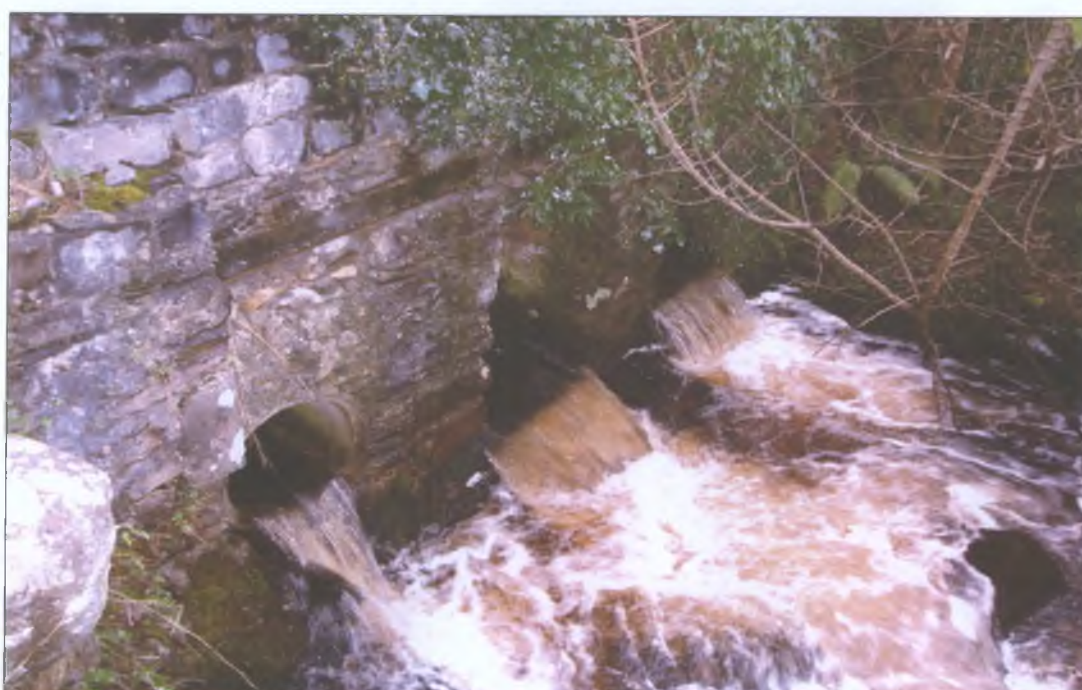

Plate 2.4 Round and box stone culverts on Yellow River, Co. Mayo (S. Neylon)

2.7.2 Culvert maintenance

The NRA (2004) recommends that Local Authorities establish schedules and protocols for the maintenance of culverts, with a further recommendation that the NPWS and the relevant RFB are consulted prior to any such works. Where shot-creting of masonry structures is proposed, the NRA recommends that a full assessment of bat presence is undertaken, under licence from NPWS. This licence is in accordance with requirements under the Wildlife (Amendment) Act, 2000. Where existing bridges with raised aprons require rehabilitation, the NRA recommends that fish passes should be incorporated as necessary to overcome any impediment to fish passage.

A number of the culvert guidelines from the United States (WDFW, 2003; Michaud, 2004) recommend that screens are placed on the inlet of culverts to prevent debris or rubbish from clogging up the culvert and preventing fish movement. However, this measure is only effective if the screens are being regularly maintained and cleared of any collected debris. Murphy (2005) and the NRA (2004) recommend against the use of trash screens in any culvert design.

Baker and Votapka (1990) recommend that a culvert should be large enough to allow debris to pass through them, even though it may be larger than is needed just for the passage of water flow. They also believe that the use of trash screens should be avoided, because of the requirement for regular maintenance.

2.7.3 Barriers to fish movement in freshwater systems

There are a range of physical and hydraulic barriers to the movement of salmon through river systems. A comprehensive document produced by the Washington Department of Fish and Wildlife (WDFW, 2003) identified three types of barrier to salmon passage:

1. Complete barrier – one that blocks fish migration at all times during all flows.
2. Temporal barrier – one that blocks fish migration some of the time and that may result in loss of production as a result of the delay.
3. Partial barrier – one that blocks the smaller and weaker swimming fish species and that may limit genetic diversity.

The document also details five common conditions at culverts that create migration barriers:

1. Excess drop at the culvert outlet.
2. High velocity within the culvert barrel.
3. Inadequate depth within the culvert barrel.
4. Turbulence within the culvert.
5. Debris and sediment accumulation at the culvert inlet or internally.

Kane (1985) looked at two hundred culvert installations in interior and northern Alaska, to assess any hydraulic problems with regard to fish passage. The two major problems identified were high velocities and perching (where there is a hydraulic drop from the outlet of the culvert to the downstream pool). A high density of fish below a temporal barrier for an extended period of time can also leave them vulnerable to predation (Buller *et al.*, 1992). Michaud (2004) detailed best management practice for fish passage through bridges, pipes and culverts. Culverts should reproduce, as closely as possible, the hydraulic conditions of the stream. Undersized culverts can constrict the flow and increase velocity above fish swimming capability, while an oversized culvert can reduce the flow depth, thus making it too shallow for fish to migrate through. In both cases, the culvert may function as a hydraulic barrier to fish movement.

2.7.4 Culvert design criteria

The NRA (2004) recommends that the following criteria are applied to any culverts that are designed for the passage of fish:

- Diameter: >900mm.
- Slope: 0.5% for a culvert >24m in length and 1% for a culvert <24m in length.
- Water velocity: <1.2 m s^{-1} for culverts <24m in length and 0.9 m s^{-1} for culverts >24m in length.

The NRA further recommends that outlet pools of adequate dimensions with tail-water control should be provided at the culvert exit and entrance and must be designed in such a way so as not to create an impediment to fish passage. All culverts should be over-sized to allow them be set below bed-level by a minimum of 500mm. In all cases, the NRA recommend that the culvert should be laid at a level and grade that allows the upstream invert to remain drowned (by backwatering) under low-flow conditions, to a depth suitable for the easy passage of the largest species frequenting the stream (150mm for Atlantic salmon).

The guidelines produced by the State of California Department of Fish and Game (2002) contain criteria that meet both hydraulic and fish passage objectives, while minimising impacts on adjacent aquatic and riparian zones. They recommend that there should be no hydraulic drop between the water surface in the culvert and the pool below the culvert. If a culvert is to allow for unhindered fish passage, then it must be a large percentage of the wet channel width, as well as allowing for natural variations in bed elevation, and providing a bed and bank roughness of similar character to that found within the upstream and downstream channel.

Increasing use is being made of stream simulation techniques (NMFS, 2000). Stream simulation is an approach to culvert design that both avoids flow constriction during normal conditions and creates a stream channel within culverts that resists scouring during flood events. Stream simulation culverts are wider than the natural channel in order to simulate channel forming processes and the entire channel including margins can be installed at the same slope or at slightly steeper slopes than the natural stream.

Construction of a channel within the culvert ensures adequate water depth during low-flow conditions. Particular attention is paid to construction of the streambed within the culvert, using bed material that interacts with the stream as a natural bed. This process avoids the need to determine high and low fish passage flows and water velocity information, as the hydraulic conditions within the culvert are designed to mimic the conditions that are to be found both upstream and downstream of the culvert. The most commonly used structures are clear span bridges and bottomless arched or box culverts.

2.8 Guidelines for the crossing of watercourses

2.8.1 Ireland

A number of guidelines have been produced that deal with the passage of migratory fish through culverts. The most recent set of guidelines in Ireland were produced by the National Roads Authority (NRA, 2005). These guidelines were introduced for use at the detailed design and construction phase of road projects, and are intended to provide information that will facilitate dialogue between statutory bodies and stakeholders. They describe and detail measures aimed at reducing the impacts of road development and construction works on the general ecology of affected watercourses, with a particular focus on mammal passage, angling amenity and the protection of fish stocks. The specifications in relation to culvert design are more detailed than any previous guidelines produced in Ireland.

The Eastern Regional Fisheries Board (ERFB), a statutory body under Article 28 (1) of the Planning and Development Regulations, 2001 (as amended), produced a short booklet of notes that identified the likely impacts on fisheries habitat during the course of construction and development works, and outlined practical measures for the avoidance and mitigation of damage (Murphy, 2005). Notes were also provided on the legislative protection afforded to fisheries habitat. The ERFB is one of seven Regional Fisheries Boards, all of whom have a statutory role to conserve the inland fisheries and sea angling resources of Ireland in their own right and to manage, restore, enhance and promote them in a sustainable manner (CFB, 2005).

The Central Fisheries Board, the Marine Institute and the seven Regional Fisheries Boards contributed to an older document that was produced by the Department of Marine and Natural Resources (DMNR, 1998), which detailed the impacts on fisheries that public works can have. These included destruction of habitat, release of polluting materials and interference with fish migration. The guidelines stressed the importance of early consultation between local authority staff and fisheries personnel, especially at the initial planning works stage. Under the Local Authority (Works) Act, 1949, where a Local Authority is executing works pursuant to the Act, it must take such precautions and make such provision for the protection of fisheries as the Minister for the Marine may advise.

2.8.2 United Kingdom

The Scottish Executive produced a consultation paper (Scottish Executive, 2000) that details the requirements for the passage of Atlantic salmon at river-crossing structures. It discusses design requirements for fish passage, design considerations and procedures for improving existing problem sites. It also details an assessment process that should be followed during the evolution of road projects to ensure that requirements for fish passage are adequately addressed.

The UK Environment Agency produced a fish passage manual (Armstrong *et al.*, 2004) that detailed the Agency's approval process for fish passes. Designs for prospective fish passes are submitted via the local Environment Agency area office to a national group of fish pass specialists, who then advise whether to issue approval or not. The manual deals mainly with dams, weirs and mill structures.

2.8.3 United States of America

Guidelines for culvert design and salmon passage criteria have been produced by a number of agencies in America. The United States Department of Agriculture – Forest Service produced a comprehensive report that concentrated on road drainage structures that are most commonly used in fish passage situations, but not including bridges.

Washington Department of Fish and Wildlife produced a detailed document (WDFW, 2003) looking at fish barriers and the main conditions present that create an impediment to the safe passage of migratory fish. The document, which is an update of previous technical guidelines from 1999, also deals with other issues related to habitat loss, water quality degradation and construction impacts.

The National Marine Fisheries Service produced guidelines in 2000 (NMFS, 2000) designed to aid upstream and downstream passage of migrating salmon by facilitating the design of new stream crossings.

The Maine Department of Transportation produced a fish passage policy and design guide (Michaud, 2004), and identified four objectives that culverts must satisfy in order to allow for the effective passage of salmon: peak flow, maximum velocity, minimum depth and gradient.

2.9 Legislation protecting Atlantic salmon and salmon migration

2.9.1 The Fisheries Acts

The Acts relevant to the protection of salmon, trout and other fish species are the Fisheries (Consolidation) Acts, 1959, the Fisheries Act, 1980 and the Fisheries (Amendment) Act, 1999. These Acts are enforced by seven Regional Fisheries Boards, and key sections of these Acts are as follows:

2.9.1.1 Section 131 of the Fisheries (Consolidation) Act, 1959

Section 131 of the Fisheries (Consolidation) Act, 1959, protects spawning salmon and trout and creates the offence that where any person during the annual close season *'wilfully obstructs the passage of salmon, or trout, or the smolts or fry thereof, or injures or disturbs any salmon or trout, or any spawn, fry or smolts thereof, or...'* commits an offence with a maximum penalty of 12 months imprison.

2.9.1.2 Section 173 of the Fisheries (Consolidation) Act, 1959

Section 173 of the Fisheries (Consolidation) Act, 1959, creates a number of offences, which include that where any person '*wilfully obstructs the passage of the smolts or fry of salmon, trout or eels, or injures or disturbs the spawn or fry of salmon, trout or eels, or injures or disturbs any spawning bed, bank or shallow where the spawn or fry of salmon or trout or eels may be, shall be guilty of an offence...*'. The key difference between Section 173 and Section 131 is that Section 173 provides for the protection of juvenile fish outside of the close season. This season is set by the Regional Fisheries Boards and may extend to the month of May.

2.9.1.3 Section 171 of the Fisheries (Consolidation) Act, 1959

Section 171 of the Fisheries (Consolidation) Act, 1959 creates the offence of '*throwing, emptying, permitting or causing to fall into any waters deleterious matter...*' Deleterious matter is later defined as '*any substance liable to injure fish or to injure the spawning grounds or the food of any fish or to injure fish in their value as human food or to impair the usefulness of the bed and soil of any waters as spawning grounds or their capacity to* *produce the food of fish...*'. The installation of culverts can result in the entry into waters of deleterious matter (e.g. silt, cement, fuel). Such matter can be directly toxic to fish and can impact on aquatic invertebrates, thus reducing the diversity of food available to juvenile salmon. Suspended solids can alter habitat by reducing light penetration and limiting primary production. A further impact of excess suspended solids is the compaction of spawning substrates, which reduces recruitment potential (Fitzsimons and Igoe, 2004).

2.9.1.4 Section 8 (1) of the Fisheries (Amendment) Act, 1999

Under Section 8 (1) of the Fisheries (Amendment) Act, 1999, the role of the Regional Fisheries Boards expanded beyond its traditional fisheries brief to include sustainable development and the conservation of other species of flora and fauna, and biodiversity in water ecosystems. The Boards must also ensure that their activities protect the natural heritage with the meaning of the Heritage Act, 1995.

2.9.2 Wildlife Act

The Wildlife Act, 1976, and the Wildlife (Amendment) Act, 2000, provide for the conservation of wildlife and the protection of listed flora and fauna. The Wildlife Act, 1976, provided for the designation of nature reserves and National Heritage Areas (NHA). Statutory protection was provided for NHA under the Wildlife (Amendment) Act, 2000. This Act also strengthened protection for the Special Areas of Conservation (SAC), and the protection of Atlantic salmon. Responsibility for the enforcement of the Wildlife Acts rests with the National Parks and Wildlife Service (NPWS).

2.9.3 Planning Acts

The Planning and Development Act, 2000, resulted in the modernisation of a planning system that had changed little since 1963 (Fitzsimons and Igoe, 2004). The Planning and Development Regulations, 2001 (S.I. No. 600 of 2001), implemented the provisions of the 2000 Act. Article 28 (1) (g) and (p), and Article 82 (2) (f), lay out the criteria whereby the Regional Fisheries Boards, as prescribed bodies, are to be notified in relation to proposed developments in their respective areas. Where a proposed development may impact on fisheries, fish or fish habitat, the relevant Regional Fisheries Board must be informed and receive full details about the proposed development. Thus, where a development may impact on the movement of fish through freshwater catchments, the Regional Fisheries

Boards can make a submission on that proposed development and, if necessary, appeal a decision to An Bord Pleanala.

2.9.4 European Directives

European legislation in the form of European Directives has had a significant impact on Irish fisheries, and is normally implemented in Ireland by way of regulations and statutory implements. The Habitats Directive (92/43/EEC) was implemented in Ireland by the European Communities (Natural Habitats) Regulations, 1997 (S.I. No. 94 of 1997). The Directive provided for the designation of Special Areas of Conservation (SAC) and gave protection to listed species within these designated sites.

S.I. No. 94 of 1997 gave protection under Irish statute to five fish species that are of European importance and listed under Annex II of the Directive (O'Keefe *et al.*, 2004). These species, which occur and breed in Ireland, are the Atlantic salmon (*Salmo salar* L.), twaite shad (*Alosa fallax fallax* L.), brook lamprey (*Lampetra planeri* B.), river lamprey (*Lampetra fluviatilis* L.) and sea lamprey (*Petromyzon marinus* L.) Each of their life cycles involves spending a period of time travelling upstream into freshwater and they are vulnerable to migration barriers; Igoe *et al.* (2004) identified upstream barriers as the single biggest factor limiting the distribution of anadromous lamprey in Ireland. A sixth fish species that is listed under Annex II, the allis shad (*Alosa alosa* L.), is found in small numbers in several Irish rivers but is not known to spawn in Ireland. Other aquatic species listed under Annex II include the freshwater pearl mussel (*Margaritifera margaritifera*), white-clawed crayfish (*Austropotamobius pallipes*) and the otter (*Lutra lutra*).

Responsibility for implementation of the Habitats Directive rests with NPWS, under the Department of Environment, Heritage and Local Government. Annex III of the Habitats Directive governs the site selection process for SAC. The criteria for site selection are as follows:

- Size and density of the population of the species present at the site in relation to the populations present within the national territory.
- Degree of conservation of the features of the habitat that are important for the species.

- Degree of isolation of the population present at the site in relation to the natural range of the species.
- Global assessment of the value of the site for the species concerned.

In response to a decline in water quality and wetland ecosystems throughout Europe, the European Parliament and Council passed into law EC Directive 2000/60/EC establishing a framework for community action in the field of water policy. The Directive (known as the Water Framework Directive) was transposed into Irish law by the European Communities (Water Policy) Regulations, 2003 (S.I. No. 722 of 2003). It supersedes and amalgamates a number of other Directives and aims to maintain (and where necessary to improve) the ecological status of surface, ground, transitional and coastal waters. It aims to do this by the implementation, within designated River Basin Districts (RBD), of River Basin Management Plans (RBMP) designed to establish an integrated approach to catchment management. The Directive will set scientifically robust quality standards relevant to the individual European member states.

2.10 Summary

In summary, this literature review highlighted a number of issues associated with the movement of Atlantic salmon through freshwater systems in order to complete its life cycle. The review detailed the current status of Atlantic salmon across its geographical range, the various threats facing the species and the agencies involved in its management and protection. An examination of its life cycle was carried out, and this highlighted the importance of the fish having unhindered passage through freshwater systems.

A review of the literature that deals with culvert installations indicated that culverts will have at least some impact on salmon migration, both upstream and downstream. If culverts are properly installed, then the impact on migration may be minimal. However, there are examples of where culverts can be a hinderance to salmon movement, especially the smaller and weaker members of the species (i.e. juveniles).

The review concluded with an assessment of the river crossing guidelines that are in place in Ireland and abroad, and of the domestic and European legislation that offers protection to Atlantic salmon. The recent NRA guidelines on road projects and river crossings are important insofar as they embrace the experience of other countries, particularly the United States, and produce a series of specific culvert criteria that will allow for unhindered fish passage. The key requirement of the EU Water Framework Directive 2000 (that the ecological status of aquatic environments must be improved or, at least, maintained) places extra focus on proper culvert design and installation, to ensure that the life cycle of the Atlantic salmon is not interrupted and that the river's ecological status is not diminished.

3. METHODOLOGY

3.1 Introduction

In order to assess the fish passage conditions at salmon river crossings, a combination of field surveys (data gathering) and desk research (data analysis) was undertaken. Five Atlantic salmon spawning tributaries within the River Moy catchment (Sonnagh, Gweestion, Spaddagh, Yellow and Brusna Rivers) were examined in three ways:

1. Assessment of culverts at river crossings on the five spawning tributaries
2. Assessment of redd count and fish survey data on the five spawning tributaries
3. Assessment of water quality data

Local Authorities are the main bodies with responsibility for the installation and maintenance of culverts in Ireland. In order to assess the general awareness within these Authorities of fish passage issues, a questionnaire was produced (Appendix I) and distributed to each of the twenty-nine Local Authorities in Ireland.

3.2 Assessment of culverts on a number of River Moy spawning tributaries

A total of seventy culverts were examined over the five spawning tributaries and a fish passage information sheet was completed at each site (Appendix II). Discovery Series map numbers 24, 31 and 32 were used to identify river crossing locations. The various fish passage guidelines that exist both in Ireland and abroad recommend a variety of design criteria that must be met to allow for the free passage of migratory fish through culverts. In order to assess both the conditions that were present at each culvert inspected, and also the risk that these culverts were proving to be a barrier to the free movement of Atlantic salmon, the following details were recorded at each site:

1. Type of culvert (i.e. clear span bridge, boxed culvert, bottomless arched culvert).
2. Length of culvert (m).
3. Width of culvert (m).
4. Depth of flow in culvert (cm).
5. Presence of hydraulic drop and height of drop (cm).
6. Presence of downstream transition pool and depth of pool (cm).
7. Average width of stream (m).
8. Average depth of stream (cm).

9. Grid point reference (Irish Grid).
10. General comments and observations.

Width and depth measurements were taken using a 30m tape measure and a 1m measuring stick (marked at 5cm intervals). A photograph of each culvert was taken using a digital camera; each photograph was taken from a downstream location looking upstream. The maps used in this thesis were generated using ArcMap™ version 9.1 computer software.

3.3 Assessment of redd count and fish survey data on spawning tributaries

The presence of Atlantic salmon upstream of a given culvert indicates that the culvert is not a total barrier to the upstream movement of salmon. It may, however, be a barrier to salmon below a certain size or it may only be passable during certain hydrological conditions. In order to identify culverts that may be total barriers to upstream salmon migration, a review of redd count data and fish survey data was conducted.

Salmon redds are shallow depressions of gravel found on the bed of a spawning river, which are formed by the sweeping movement of the female salmon's tail during spawning preparation. It is in these nests or redds where female salmon lay their eggs and these depressions are visible from the river bank during clear flow conditions. Staff from the North Western Regional Fisheries Board carry out surveys of spawning during the winter and early spring months of each year and record their observations. A review of these records was conducted, along with interviews with fishery protection staff, in order to identify salmon spawning areas relative to culvert locations. Salmon redd counts are now being used as an index of spawning on rivers without fish counters (Gargan and McGinnity, 2006).

In 1993. Dr. Martin O'Grady oversaw a comprehensive survey of the River Moy catchment where a total of two hundred and forty-six sites were surveyed and results detailed in a subsequent report (O'Grady, 1994). A detailed examination of this report was conducted in order to identify areas upstream of studied culverts where Atlantic salmon were present.

3.4 Assessment of biological water quality at culvert sites

In order to determine if water quality conditions, rather than poorly installed culverts, could be responsible for restricting the distribution of Atlantic salmon within certain River Moy tributaries, a review of the most recent EPA biological survey data was undertaken. This was done by way of examination of the EPA's published interim report on the biological monitoring within Hydrometric Area 34 during 2004 (EPA, 2004). The River Moy and all of its tributaries are located within Hydrometric Area 34.

Atlantic salmon require good water quality conditions, particularly high levels of dissolved oxygen, in order to thrive (O'Grady and Gargan, 1993). The EPA carries out biological surveys on a representative 13,200km baseline length of channel on a three-year cycle. Routine water quality monitoring programmes are of most value in assessing the effects of more or less continuous inputs of polluting matter but random short-term pollution events may well escape detection, particularly by routine chemical surveys that generally rely on relatively infrequent grab samples. However, the biological effects of such random events on macroinvertebrate populations are usually detectable for some considerable time afterwards, so that the biological surveys are likely to detect them in many instances (EPA, 2004).

The EPA has devised a biological river quality (Q or biotic index) classification system, which is related to four water quality classes:

Quality Class	Quality Status	Biological Index
Class A	Unpolluted	Q5, Q4-5, Q4
Class B	Slightly Polluted	Q3-4
Class C	Moderately Polluted	Q3, Q2-3
Class D	Seriously Polluted	Q2, Q1-2, Q1

The EPA classifies any river of less than Q4 status as being in an unsatisfactory condition because of the potential risk to Atlantic salmon and trout populations from nocturnal dissolved oxygen depletion that may occur in such waters, particularly during times of low flow and elevated temperature conditions. There are certain biological and physico-chemical characteristics that distinguish Q4 waters from other quality classes. Q4 waters display diverse macroinvertebrate and macrophyte communities, while having a high amenity value and being suitable for a range of uses including water abstraction. Such waters rarely display significant levels of siltation or sewage fungus, with development of filamentous algae being limited. Physico-chemically, these waters display certain characteristics e.g. Biochemical Oxygen Demand (BOD) of < 3mg/l, dissolved oxygen levels of 80% - 120% and annual median ortho-phosphate levels of <0.03mg/l P (EPA, 2004). Any substantial deviations from these levels can impact on the water's quality rating.

3.5 Awareness within Local Authorities of fish passage and culvert issues

A questionnaire was sent to senior engineering staff in the twenty-nine Local Authorities in Ireland. The purpose of this questionnaire survey was to ascertain the level of awareness within Local Authorities regarding fish passage issues at culvert locations. When drawing up the questionnaire, it was hoped that the questions chosen might reveal trends in the Local Authorities' approach to culvert planning, design and construction, and to the long term maintenance of these structures. All the questions within the questionnaire could be answered by ticking the relevant box. This design was chosen to facilitate ease of response and to make the information received easier to interpret and tabulate.

4. RESULTS

4.1 Assessment of culverts on the River Moy spawning tributaries

The NRA guidelines (NRA, 2005) specify a number of key design criteria that culverts must meet in order to allow for ease of upstream movement of Atlantic salmon:

1. Depth of flow
2. Absence of hydraulic drop
3. Presence of downstream pool

4.1.1 Depth of flow

The NRA recommends that all culverts should be laid at a level that allows the upstream invert to remain drowned under low flow conditions to a depth of 15cm, in order to allow for the unhindered passage of Atlantic salmon. Figure 4.1 shows the depths recorded on the seventy study sites.

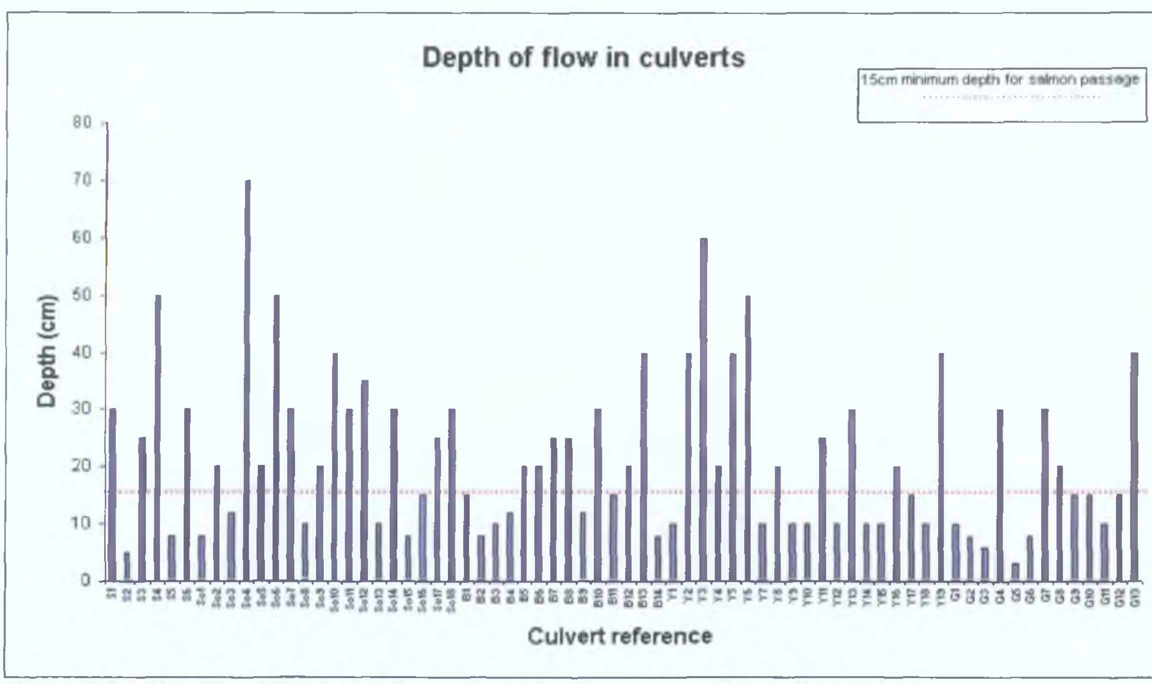

Figure 4.1 Depth of flow in culverts on the five spawning tributaries

A total of twenty-six culverts had a depth of flow of <15cm, which is 37% of the total sites that were inspected. Table 4.1 shows the breakdown across the five studied rivers.

Table 4.1 Culverts with <15cm depth of flow

River	Total number of culverts inspected	Number of culverts with <15cm depth of flow	Percentage of total
Yellow	19	8	42
Gweestion	13	6	46
Brusna	14	5	36
Spaddagh	6	2	33
Sonnagh	18	5	28

4.1.2 Absence of hydraulic drop

The NRA recommends that there should be no hydraulic drop at either the inlet or outlet of any culvert. Of the seventy culverts examined, thirty-one displayed hydraulic drops ranging in height from 5cm to 100cm. The two most substantial drops (100cm) were on the Brusna River (B3) and Yellow River (B10). Figure 4.2 shows the locations where hydraulic drops were recorded across the five spawning tributaries.

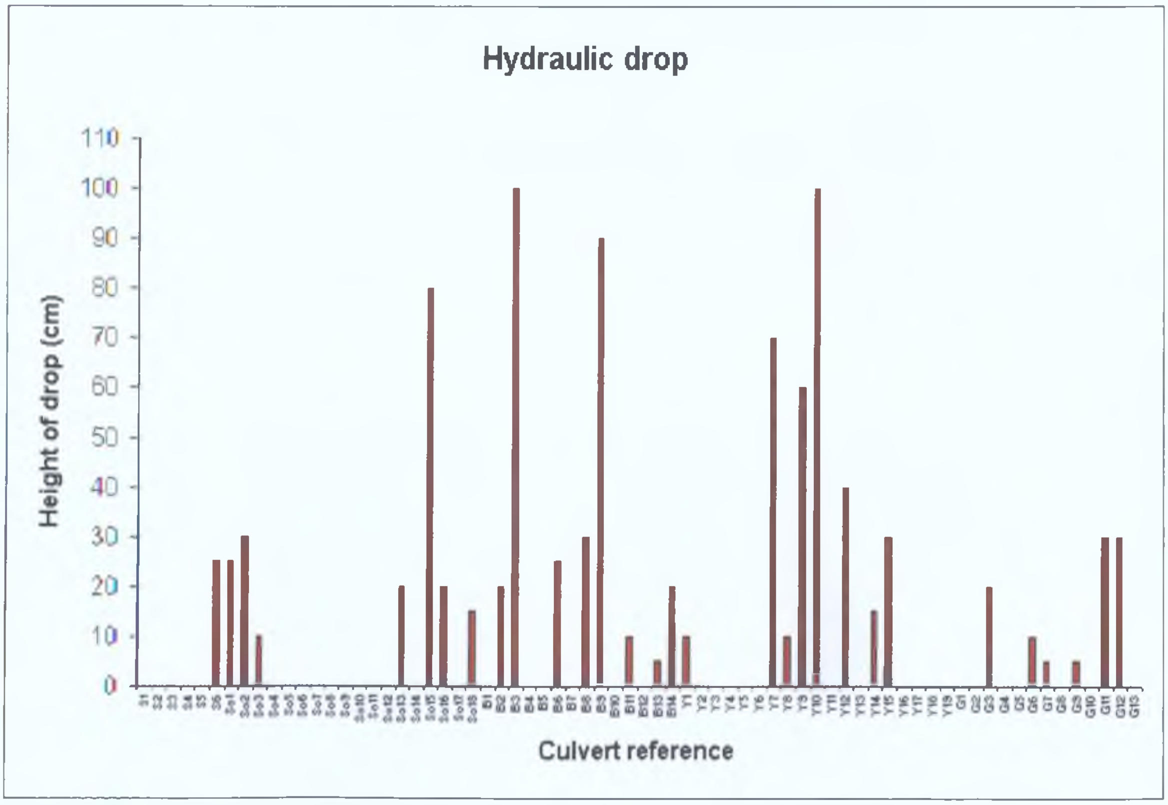

Figure 4.2 Hydraulic drops at culverts on the five spawning tributaries

4.1.3 Presence of downstream pool

A downstream pool provides a resting area for salmon prior to their progress through the culvert. It also provides for take-off conditions if there is a hydraulic drop that has to be negotiated. Of the seventy culverts examined, fourteen (20%) did not have any downstream pool; another three had pools less than 15cm deep.

A total of nine culverts displayed an absence of all three key fish passage features i.e. downstream pool, no hydraulic drop and a depth of flow >15cm. These culverts are detailed in Table 4.2 below.

Table 4.2 Culverts with no downstream pool, inadequate depth and hydraulic drop

River	Culvert reference	Depth of flow (cm)	Height of hydraulic drop (cm)
Sonnagh	So13	10	20
Sonnagh	So15	8	80
Brusna	B3	10	100
Yellow	Y1	10	10
Yellow	Y9	10	60
Yellow	Y10	10	100
Yellow	Y12	10	40
Yellow	Y14	10	15
Gweestion	G3	6	20

4.1.4 Types of culverts

The various fish passage guidelines that exist, both nationally and internationally, give a number of definitions for a culvert; for the purpose of this thesis, a culvert was defined as any structure or conduit used to allow for the passage of water flow under a roadway or embankment. Four main types of culverts were identified during the field surveys:

1. Round concrete culvert.
2. Clear span bridge.
3. Boxed culverts.
4. Bottomless arched culverts.

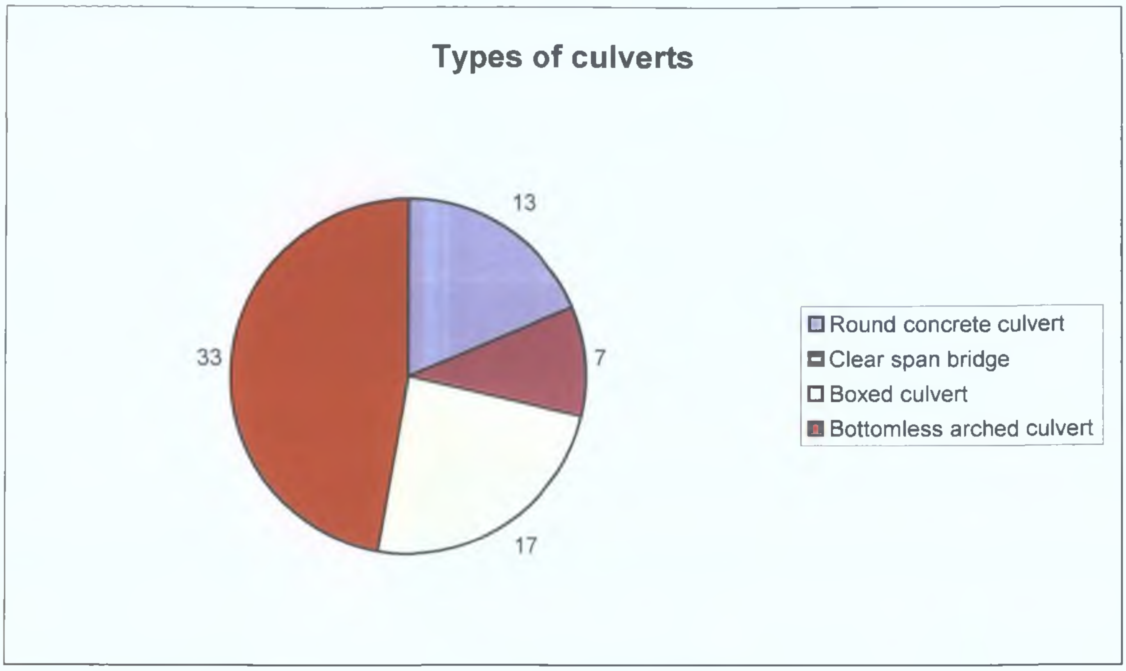

Figure 4.3 Type of culverts recorded at the study sites

The bottomless arched culvert was the dominant type of culvert encountered during the surveys and accounted for nearly 50% of the culverts inspected. The clear span bridge accounted for 10% of the field culverts inspected; this structure was mainly confined to streams >3m wide.

4.2 Salmon redd count and fish survey data

4.2.1 Salmon redd count and spawning data for the five spawning tributaries

Figures 4.4 to 4.8 show the salmon spawning locations and the inspected culvert sites on the five spawning streams. The information was compiled from a review of historic spawning notes and from interviews with Fisheries Inspector Michael Lennon and Fishery Officer Desmond Moyles of the North Western Regional Fisheries Board.

As detailed in Table 4.2, nine culverts displayed no downstream pool, a depth of flow of <15cm and a hydraulic drop. There are no recent salmon spawning records for any areas upstream of the nine culverts.

Figure 4.4 Atlantic salmon spawning areas on Brusna R. (Discovery Series No. 24)

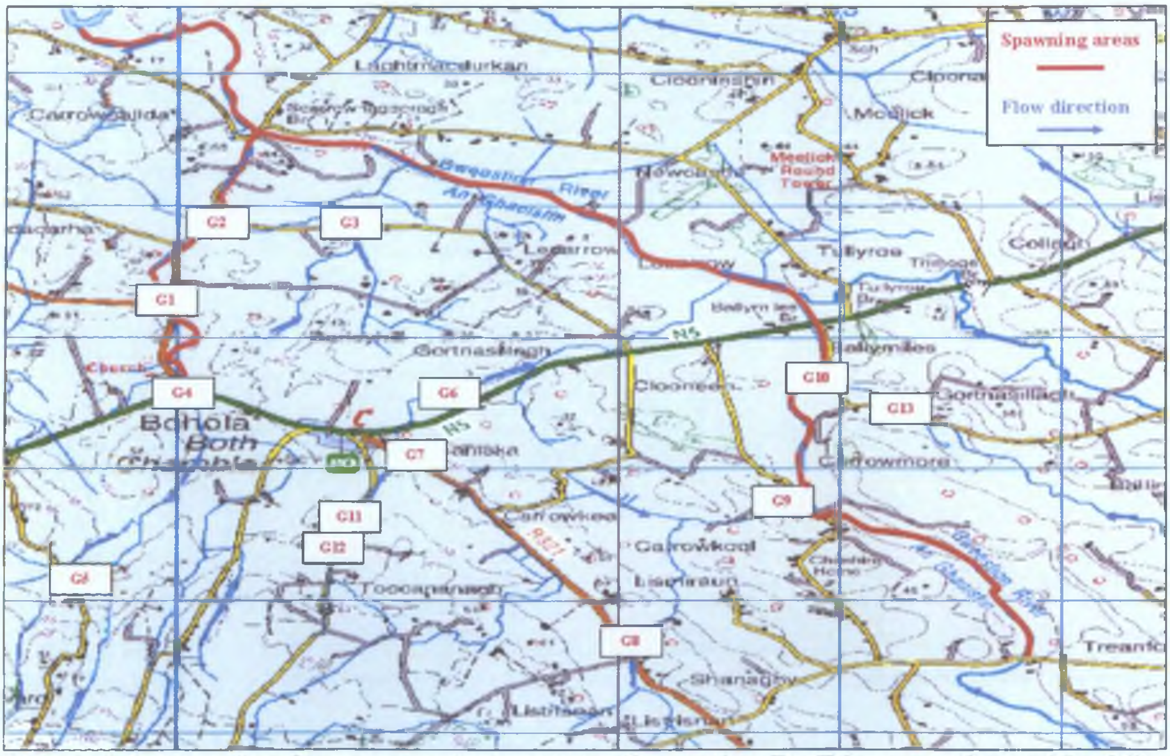

Figure 4.5 Atlantic salmon spawning areas on Gweestion R. (Discovery Series No. 31)

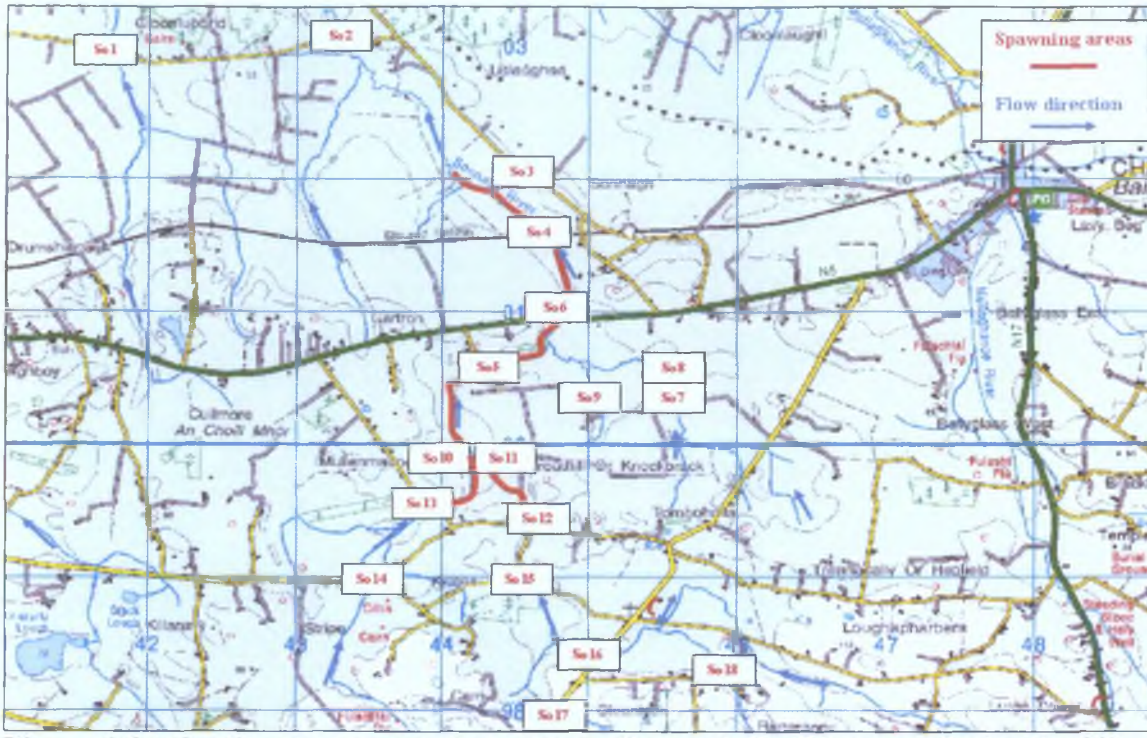

Figure 4.6 Atlantic salmon spawning areas on Sonnagh R. (Discovery Series No. 32)

Figure 4.7 Atlantic salmon spawning areas on Spaddagh R. (Discovery Series No. 32)

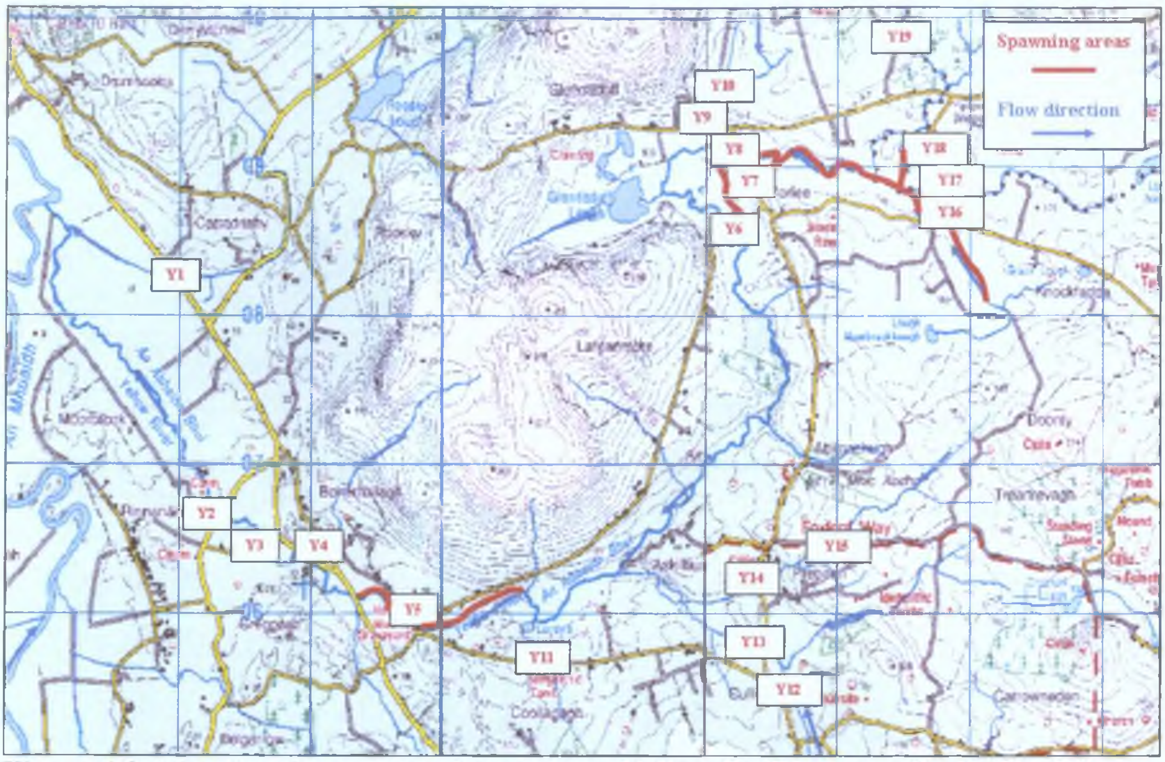

Figure 4.8 Atlantic salmon spawning areas on Yellow R. (Discovery Series No. 24)

4.1.5 Fish survey data

In 1993, a total of two hundred and forty-six sites were electrofished across the River Moy catchment and a subsequent report was produced by Dr. Martin O'Grady (O'Grady, 1994). This report was examined in order to determine the presence or absence of Atlantic salmon within the various sections of stream channel that were studied. Table 4.3 shows the location of a number of survey zones, relative to culvert locations, and the salmon status (presence or absence) within each of these zones. A total of sixty sites across the five spawning tributaries were surveyed in 1993; however, the majority of these were on sections of channel not inspected over the course of this study and they have been omitted from these results.

Table 4.3 Status of salmon at sites on the five spawning tributaries (O'Grady, 1994)

River	Electrofishing site location	Salmon status
Brusna	Zone 205 – upstream of B9	Absent
Brusna	Zone 204 – downstream of B9	Present
Brusna	Zone 194 – downstream of B6	Present
Brusna	Zone 195 – upstream of B6	Present
Brusna	Zone 206 – between B5 and B7	Present
Brusna	Zone 207 – between B2 and B3	Absent
Gweestion	Zone 62 – downstream of G10	Present
Gweestion	Zone 64 – between G9 and G10	Present
Gweestion	Zone 63 – between G8 and G9	Present
Sonnagh	Zone 44 – between So2 and So4	Present
Sonnagh	Zone 45 – between So4 and So6	Present
Sonnagh	Zone 46 – between So5 and So10	Present
Spaddagh	Zone 58 – downstream of S3	Present
Spaddagh	Zone 59 – between S1 and S3	Present
Spaddagh	Zone 60 – between S4 and S6	Present
Spaddagh	Zone 61 – downstream of S5	Present
Yellow	Zone 187 – between Y5 and Y6	Present
Yellow	Zone 188 – between Y5 and Y6	Present
Yellow	Zone 189 – between Y6 and Y8	Present
Yellow	Zone 190 – between Y8 and Y19	Present

4.3 Water quality at culvert sites

A review of the EPA's interim report on biological monitoring during 2004 (EPA, 2004) revealed that all the EPA monitoring sites on the five streams that were studied have a biological quality status of Q4 or greater (see Table 4.4).

Table 4.4 Biological status of the five spawning tributaries and site details

River	EPA code	Site description	Irish Grid Reference	Year of assessment	Q status	Culvert reference
Brusna	34B080400	Behy Br.	G128781 318132	2002 2004	Q4-5 Q4-5	-
Brusna	34B080300	Br. S.W. of Oatlands	G132461 317077	2002 2004	Q4-5 Q4-5	**B14**
Brusna	34B070400	Br. W. of Cloonta	G130170 320971	2002 2004	Q4-5 Q4-5	**B6**
Brusna	34B070600	Br. u/s Glenree conf	G128606 319110	2002 2004	Q4 Q4-5	**B13**
Brusna	34G010050	Br. 2km E. of Cloonta	G132476 320877	2001 2004	Q5 Q5	**B8**
Brusna	34G010053	Br. S.E. of Cloonta	G132477 320857	1998 2001	Q4-5 -	-
Brusna	34G010060	Br. 700m u/s Brusna	G129058 319332	2001 2004	Q4-5 Q4-5	-
Yellow	34Y010100	Br. W. of Corlee	G132281 308623	2001 2004	Q5 Q5	**Y6**
Yellow	34Y010200	Br. S. of church	G129813 305925	1989 1993	Q5 Q5	**Y5**
Yellow	34Y010400	Br. u/s Moy confluence	G128298 306680	2001 2004	Q4-5 Q4-5	**Y2**
Gweestion	34C090300	Br. N.W. of Bohola	G130046 295630	2001 2004	Q4 Q4	**G4**
Gweestion	34C090700	Br. u/s Moy confluence	G128935 298320	2001 2004	Q4 Q4-5	-
Spaddagh	34S030200	Br. u/s Moy confluence	G132382 299368	2001 2004	Q4 Q4	-
Spaddagh	34S030100	Br. N.E. of Esker	G136332 298662	2001 2004	Q4 Q4	**S1**
Sonnagh	34S020060	Br. W. of Tomboholla	M143523 298879	2001 2004	Q4 -	**So14**
Sonnagh	34S020075	Br. N. of Trouthill	G144789 301029	1999 2001	Q4 Q4-5	**So6**

4.4 Awareness within Local Authorities of fish passage issues

A culvert questionnaire was sent to each of the twenty-nine Local Authorities in Ireland. Approximately 69% (i.e. twenty out of twenty-nine) of the questionnaires were completed and returned, although a number of these were only partially completed.

4.4.1 Culvert type

Of the twenty questionnaires returned, details regarding culvert type were completed on nineteen of them. Round and box concrete culverts were the dominant type identified, with an average length of <10m and an average width of 1-2m. Twelve of the Local Authorities utilise plastic and metal as construction material for culverts (see Table 4.5).

Table 4.5 Culvert types utilised by the Local Authorities

Local authority	Round	Oval	Box	Arch	Concrete	Stone	Plastic	Metal
Cavan		x	x	x	x	x	x	
Clare					x			
Donegal	x		x	x	x	x		x
Dublin	x		x		x			
Dun. Lao. R.			x		x			
Galway					x	x		
Kildare	x	x	x	x	x	x		x
Kilkenny	x		x		x	x	x	
Laois			x	x	x	x		
Leitrim			x		x			
Mayo	x		x		x			
Monaghan			x		x	x		x
Offaly			x		x	x		x
Sligo			x	x	x	x		
South Tipp.	x		x	x	x	x	x	
Waterford	x			x		x		x
Westmeath	x		x	x	x	x	x	
Wexford					x	x	x	
Wicklow	x		x	x	x	x		x

4.4.2 Culvert features

Of the twenty questionnaires returned, details regarding features that impact on salmon movement through culverts were completed on nineteen of them. Table 4.6 details the Local Authorities, which utilise the various features that may impact on salmon migration through freshwater.

Table 4.6 Culvert features that may impact on salmon migration

Local authority	Rubbish screen	D/s pool	Fish passage baffles	U/s pool	Ponding weirs	Raised aprons	Gravel beds
Cavan							
Clare							
Donegal							x
Dublin	x						
Dun. Lao. R.	x						
Galway							x
Kildare	x		x				x
Kilkenny							
Laois	x					x	x
Leitrim							
Mayo	x	x					
Monaghan	x						x
Offaly							
Sligo	x		x		x		x
South Tipp.	x			x	x	x	
Waterford	x						x
Westmeath	x						
Wexford							
Wicklow				x	x	x	x

Out of the nineteen Local Authorities, only three have constructed upstream or downstream pools during culvert installation. Over 50% of the Local Authorities utilise rubbish screens on culvert openings, while over 30% stated that they did not utilise any of the aforementioned features during culvert design and construction.

4.4.3 Stakeholder consultation

Five of the Local Authorities do not engage in any stakeholder consultation during the design and construction of culverts, while fourteen stated that they consult with the relevant Regional Fisheries Board (see Figure 4.9).

Figure 4.9 Stakeholder consultations by Local Authorities

Three other stakeholders that were recorded as consultees include local landowners, a local authority flood study group and local area engineers.

4.4.4 Time of year during which culvert construction and repair takes place

Table 4.7 details the time of year during which culvert construction and repair takes place within each of the Local Authority areas. 70% of the Local Authorities stated that they carry out this activity between the months of April and September, with five of them confining the work to the period July to September. Three Local Authorities did not specify when they carry out this type of works and another four carry out the works between October and March.

Table 4.7 Time of year during which culvert construction or repair takes place

Local authority	Jan to Mar	Apr to Jun	Jul to Sept	Oct to Dec
Cavan		x		
Clare		x	x	
Donegal			x	
Dublin	x	x	x	x
Dun. Lao. R.				x
Galway		x	x	
Kildare		x	x	
Kilkenny				
Laois	x	x	x	x
Leitrim		x	x	
Longford			x	
Mayo				
Monaghan		x		
Offaly		x	x	
Sligo		x	x	
South Tipp.			x	
Waterford	x	x		x
Westmeath			x	
Wexford		x		
Wicklow			x	

4.4.5 Age of culverts

Within the questionnaire, each Local Authority was asked to give a percentage breakdown of culverts within five specific age categories. Sixteen of the Local Authorities completed this section of the questionnaire (Table 4.8).

Table 4.8 Percentage age profile of culverts in Local Authority areas

Local Authority	<10 yrs	10-20 yrs	20-30 yrs	30-40 yrs	>40 yrs
Clare	5	5			90
Donegal	5	5	10	30	50
Dublin	5	10	20	30	35
Dun. Lao. R.	15	50	15	20	
Galway					70
Kildare	10	5	5	5	75
Kilkenny	20	10	10	1	50
Laois	5	15	15	25	40
Longford			10		90
Mayo	5	10	10	15	60
Monaghan	5	5	5	5	80
Offaly	5	45	50		
Sligo	15	15	10	1	50
South Tipp.	5	10	5	20	60
Waterford	10	8	1	1	80
Westmeath	5	5	10	10	70

5. DISCUSSION

5.1 Assessment of culverts on the River Moy spawning tributaries

A total of seventy culverts were inspected on the Brusna, Gweestion, Sonnagh, Spaddagh and Yellow Rivers. Out of the three key design criteria that were assessed (depth of flow, absence of hydraulic drop and presence of downstream pool), the only one that can be said to be subject to seasonal changes is the depth of flow. Over one third of the seventy culverts had a depth of flow of <15cm; however, it is difficult to assess what impact these culverts are having on salmon distribution as there is no spawning or fish survey information available for locations upstream of these culverts (Table 5.1).

Table 5.1 Culverts with <15cm depth of flow

River	Culvert reference	Depth of flow (cm)	Type of culvert
Brusna	B2	8	Boxed concrete
Brusna	B3	10	Arched stone
Brusna	B4	12	Boxed concrete
Brusna	B9	12	Boxed concrete
Brusna	B14	13	Boxed stone
Gweestion	G1	10	Bottomless arched stone
Gweestion	G2	8	Round concrete
Gweestion	G3	6	Arched stone
Gweestion	G5	3	Boxed concrete
Gweestion	G6	8	Round concrete
Gweestion	G11	10	Bottomless arched stone
Sonnagh	So1	8	Boxed concrete
Sonnagh	So3	12	Boxed stone
Sonnagh	So8	10	Bottomless arched concrete
Sonnagh	So13	10	Round concrete
Sonnagh	So15	8	Boxed stone
Spaddagh	S2	5	Round concrete
Spaddagh	S5	8	Round concrete
Yellow	Y1	10	Round concrete
Yellow	Y7	10	Round concrete
Yellow	Y9	10	Boxed stone

Yellow	Y10	10	Round concrete
Yellow	Y12	10	Bottomless arched stone
Yellow	Y14	10	Bottomless arched stone
Yellow	Y15	10	Bottomless arched stone
Yellow	Y18	10	Bottomless arched stone

In the NRA guidelines, bottomless arched or boxed culverts are recommended in preference to round culverts. However, both may be equally ineffective if poorly installed. Of the surveyed culverts that had a depth of flow of <15cm, 30% were of the round concrete type and the remaining 70% were an equal combination of bottomless arched and boxed culverts. The status of Atlantic salmon upstream of these locations is unknown.

A programme of qualitative electrofishing operations upstream of these twenty-six culverts would be required to confirm the presence or absence of Atlantic salmon. Such operations are most safely and effectively conducted during the summer months (O'Grady, 1994) and, as such, are not within the scope of this thesis.

While the round design may be the least preferable culverting option detailed in the guidelines (NRA, 2005), it appears that the actual installation method is of as equal importance as the culvert type. Two culvert sites on the Sonnagh River (see Plates 5.1 and 5.2) illustrate the importance of proper culvert installation, in order to adhere to the NRA guidelines. Both the culverts in question are of the round concrete type, and are installed on streams of similar gradient, width and depth. In Plate 5.1, the culvert (So7) has been laid beneath the grade line of the natural stream bed, with the result that the depth of flow through the culvert is the same as the average depth both upstream and downstream of it. In Plate 5.2, another culvert (So13) has been laid approximately 20cm above the grade line of the natural stream bed, thus reducing the depth of flow within the culvert to 50% of the average stream depth. Again, the status of Atlantic salmon upstream of these two culverts is unknown.

Plate 5.1 Round concrete culvert (So7) on Sonnagh River, Co. Mayo (S. Neylon)

Plate 5.2 Round concrete culvert (So13) on Sonnagh River, Co. Mayo (S. Neylon)

Out of the seventy culverts inspected, a total of nine displayed no downstream pool, a hydraulic drop and a depth of flow of <15cm (see Table 5.2).

Table 5.2 Culverts with depth of flow <15cm and hydraulic drop

River	Culvert reference	Depth of flow (cm)	Height of hydraulic drop (cm)	Type of culvert
Brusna	B3	10	100	Bottomless arched
Gweestion	G3	6	20	Arched stone
Sonnagh	So13	10	20	Round concrete
Sonnagh	So15	8	80	Boxed stone
Yellow	Y1	10	10	Round concrete
Yellow	Y9	10	60	Boxed stone
Yellow	Y10	10	100	Round concrete
Yellow	Y12	10	40	Bottomless arched
Yellow	Y14	10	15	Bottomless arched

There are no records of salmon spawning activity upstream of these locations, nor is there any fish survey information available; however, it may be the case that some of these areas (e.g. upstream of Y10) are not suitable as salmon habitat by virtue of a steep gradient or lack of suitable spawning substrate. Similarly, the fact that salmon numbers in Ireland have declined by two thirds since the 1970s (NSC, 2006) may mean that salmon are not moving as far upstream (and through some poorly designed culverts) as they may have in the past, by virtue of less competition for available spawning habitat further downstream (Hendry and Cragg-Hine, 2003).

An analysis of culvert type at these nine locations does not reveal any particular trend; round, bottomless and boxed culverts each comprise one third of the total. The following section will review the available spawning and fish survey data in order to identify the type and design of culverts that may be impeding upstream migration of Atlantic salmon on each of the five spawning rivers.

5.2 Interpretation of Atlantic salmon redd count data and fish survey data

Staff from the North Western Regional Fisheries Board carry out surveys of salmon spawning on the River Moy during the winter and early spring months of each year and record their observations. However, there are a number of difficulties associated with this activity:

- Observations are not currently recorded in a standard electronic format that would be GIS compatible
- Due to limited staff numbers, only a small number of the spawning tributaries will be surveyed in a given season
- Redd counting is highly weather dependent; low and clear water conditions are required to be able to identify redds accurately. Elevated water levels can disrupt an entire season of redd counting on certain tributaries, which can make it more difficult to identify long-term trends.

The Central Fisheries Board is currently preparing a standard template for counting salmon redds in Irish catchments (Gargan and McGinnity, 2006). This information will be put into a central database for use in determining conservation limits on rivers that do not have fish counters on them.

In 1993, a total of two hundred and forty-six sites were electrofished across the River Moy catchment; however, only twenty of these sites were on sections of channel where culvert inspections were carried out. Salmon were found in eighteen out of the twenty sites; the two sites where salmon were noted to be absent were on the Brusna River. One of these is upstream of B9. The culvert at B9 displayed a hydraulic drop of 90cm and depth of flow of 12cm. Salmon were recorded just downstream of this location during the same survey. A review of the Brusna spawning records indicates that salmon spawn up as far as B9 but there are no records of any spawning upstream of this location.

Following a review of this redd count and fish survey, it was possible to compile a list of the culverts that allow for the upstream movement of Atlantic salmon (i.e. where salmon spawning has been noted upstream, or salmon located during electrofishing surveys). This information is collated in Table 5.3.

Table 5.3 Culverts above which salmon are located

Culvert reference	Culvert type	Depth of flow (cm)	Presence of hydraulic drop	Downstream pool
B5	Boxed concrete	20	N	Y
B6	Boxed concrete	20	Y	Y
B8	Bottomless arched stone	25	Y	N
G1	Bottomless arched stone	10	N	Y
G9	Bottomless arched stone	15	Y	Y
So4	Clear span bridge	70	N	Y
So5	Clear span bridge	20	N	N
So6	Bottomless arched stone	50	N	Y
So10	Bottomless arched concrete	40	N	Y
So11	Bottomless arched concrete	30	N	Y
S1	Bottomless arched stone	30	N	Y
S3	Bottomless arched concrete	25	N	Y
S4	Bottomless arched stone	50	N	Y
S6	Boxed concrete	30	Y	Y
Y5	Bottomless arched stone	40	N	Y
Y8	Bottomless arched stone	20	Y	Y

Out of the sixteen culverts that were identified as having salmon upstream of them, only one of these had a depth of flow of <15cm and only two did not have a downstream pool present. Similarly, the majority of the culverts did not display a substantial hydraulic drop. These results suggest that the various fish passage criteria outlined in the NRA guidelines are appropriate, at least in terms of the upstream migration of Atlantic salmon. Further research would be required to confirm that the guidelines equally apply to other migratory fish species (e.g. migratory brown trout, river and sea lamprey).

While this research did not confirm the presence of salmon above culverts of the round pipe design, the majority of the monitored spawning and fish survey sites are located on sections of river channel where bottomless arched culverts are the more dominant type utilised (i.e. rivers with a base width >3m; the round culverts detailed in this research were located on streams with an average base width of 1.3m).

5.3 Water quality at culvert sites

The EPA has seventeen biological monitoring sites across the five spawning tributaries. The most recent interim report (EPA, 2004) indicates that all of these sites have a biological quality status of Q4 or greater. Such status indicates that these rivers are suitable for Atlantic salmon populations, due to the low risk of nocturnal dissolved oxygen depletion and the presence of diverse communities of macroinvertebrates and macrophytes. However, during the field surveys, signs of localised pollution problems were evident at a number of culvert locations. These locations are detailed in Table 5.4.

Table 5.4 Culvert locations where localised pollution problems were noted

Culvert ref.	**Culvert type**	**Pollution type**	**Suspected source**
S2	Round concrete	Enrichment / algae growth	Agriculture
Y16	Round concrete	Enrichment and siltation	Forestry
So1	Boxed concrete	Siltation / compaction of gravels	Road construction
So3	Boxed stone	Siltation / compaction of gravels	Forestry
So14	Bottomless arch	Siltation / compaction of gravels	Quarry
G2	Bottomless arch	Enrichment	Agriculture

At three of these locations (S2, So3 and So14), there are no spawning or fish survey records and water quality deterioration is likely to be a factor limiting salmon productivity in these channels. Although So14 had a biological status of Q4 in 2001, the quarrying activity in the area has intensified significantly since then and the EPA did not re-sample in 2004.

5.4 Awareness within Local Authorities of fish passage issues

A total of twenty questionnaires were returned by the original specified deadline, out of the initial twenty-nine that were sent out. A follow up phone call and letter did not result in any of the remaining nine being returned. A number of the questionnaires were only partially completed; whether this was due to a reluctance to provide the information or to a lack of knowledge is unclear. The analysis was broken down into three areas: culvert type, culvert features and stakeholder consultation.

5.4.1 Culvert type

Concrete box culverts are the dominant type of culvert that is now used by Local Authorities, with an average length of <10m and an average width of 1-2m. If these types of culverts are properly installed, then adverse impacts on upstream salmon migration can be minimised (Baker and Votapka, 1990). An average of 65% of all the culverts in the Local Authority areas are >40 years of age; most of these are constructed of stone materials.

5.4.2 Culvert features that may impact on salmon migration

Two features that the NRA guidelines recommend should not be installed at any culverts are rubbish screens and raised aprons. The rubbish screens can clog with debris and create a physical impediment to upstream fish movement, while the raised apron can create a hydraulic drop and reduce the depth of flow. Half the Local Authorities surveyed stated that they utilise rubbish screens during culvert design, with two of these also using raised aprons. Although Mayo County Council stated that it utilises rubbish screens in its culvert design, none of the seventy culverts that were inspected during the field surveys had screens on them (two had livestock barriers against them, which were placed there by local landowners).

Mayo County Council was the only respondent who stated that it creates a downstream pool during culvert installation. A downstream pool provides a resting area for salmon prior to their passage through the culvert, while also providing for take-off conditions in the event that there is a hydraulic drop present that has to be crossed (NRA, 2005). In the various guidelines that were reviewed for this research, the presence of a downstream pool is regarded as being a key feature of culvert design. The NRA guidelines specifically refer to having an outlet pool of adequate dimensions with tail-water control at the culvert exit. The importance of this feature does not appear to be widely appreciated within the Local Authorities.

Six of the Local Authorities stated that they did not install any of the features that may improve habitat or assist with upstream fish movement (i.e. upstream or downstream pools, ponding weirs, gravel beds, fish passage baffles). Confusingly, three of these Authorities (Wexford, Offaly and Leitrim County Councils) also claim that they consult with the relevant Regional Fisheries Board during culvert design and installation.

5.4.3 Stakeholder consultation

While fourteen of the Local Authorities stated that they consult with the relevant Regional Fisheries Board during culvert design and installation, three of these also stated that they install culverts between October and March (effectively the spawning season of the Atlantic salmon). The NRA guidelines recommend that culvert installation is confined to outside of the close season (i.e. October to May).

Two of the Local Authorities stated that they routinely consult with the EPA during culvert design, while another five stated that they consult with the CFB. Neither organisation appears to have any particular functional role in this area and the CFB (Trevor Champ, pers. comm.) is not aware of any routine consultation between its staff and Local Authority personnel regarding culvert design and installation issues. Regional Fisheries Boards are generally regarded as being the more appropriate stakeholder for such routine local consultation.

Five of the Local Authorities (Kilkenny, Clare, Cavan, Waterford and Longford County Councils) do not appear to engage in any stakeholder consultation regarding culvert design and installation. Whether or not this is official Council policy is not known; it may be that the engineering staff members who completed the questionnaires do not engage in consultation but that other field staff within the Local Authority may informally consult with relevant stakeholders during culvert construction activity.

6. RECOMMENDATIONS

The following are a number of recommendations proposed by the author based on the findings of this research:

6.1 Fish baseline survey

A comprehensive baseline survey should be undertaken on each of the five spawning tributaries of the River Moy, at locations upstream and downstream of the surveyed culverts, in order to identify areas where Atlantic salmon are absent. If such a study confirmed the absence of salmon upstream of culverts that do not meet NRA fish passage criteria, then the study should be expanded to all of the major spawning tributaries across the River Moy catchment. If a spawning surplus of Atlantic salmon does enter the River Moy, as a result of the end of drift netting during 2007, then it is important that all available spawning habitat is accessible and utilised. Where culverts have been positively identified as being an impediment to the movement of Atlantic salmon, a joint approach between the Regional Fisheries Board and the Local Authority should be undertaken to modify, repair or replace the culvert and create conditions that allow for unhindered fish movement.

Apart from Atlantic salmon, there are a number of other migratory fish species, such as anadromous brown trout and river lamprey, whose upstream migration may also be hindered by culverts (Fitzsimons and Igoe, 2004). An assessment of these populations would also need to be conducted during any baseline survey, in order to assess whether the NRA guidelines appropriately apply to these species also.

6.2 Development and improvement of NRA guidelines

The NRA guidelines for watercourse crossings need to be broadened to cover existing problem culverts and to look at approaches to the rehabilitation of such culverts. At present, the guidelines are only designed for new culvert installations and do not deal with situations where poorly installed culverts currently exist. Such culverts are likely to be a significant issue, as many of the older culverts were installed at a time of limited environmental awareness and modern road schemes generally have professional environmental staff involved at the planning and design stage (Kirrane, 2003). Comprehensive guidelines for the rehabilitation of problem culverts have been produced by a number of agencies and these could be utilised by the NRA for referencing purposes; the most detailed guidelines that were identified during this research were produced by the U.S. Department of Transportation (Baker and Votapka, 1990).

6.3 Annual salmon spawning surveys

The annual spawning surveys that are conducted during the winter and early spring months of each year are not recorded or filed in a format that can be easily accessed and interpreted. A standard reporting sheet should be utilised for the cataloguing of spawning information in the field. This information should subsequently be integrated into a Geographic Information System of spawning areas. The development of such a GIS would mean that trends in spawning would be more readily apparent. Where there are changes in water quality or habitat status in spawning areas, this information could also be mapped in order that the status of the various fisheries can be more accurately determined.

6.4 Local Authority consultation

Analysis of the responses from the various Local Authorities to the culvert questionnaire revealed that the level of awareness of fish passage issues is low. While two thirds of the Local Authorities claim that they consult with the relevant Regional Fisheries Boards during culvert design and installation, a number of them also stated that they install culverts during the spawning season and one third of them stated that they did not install any of the features that may improve habitat or assist with upstream fish movement (e.g. pools, ponding weirs).

In order to improve the level of awareness within Local Authorities, a series of presentations should be given by Regional Fisheries Board staff to Local Authority area engineers; these presentations should cover the criteria detailed in the NRA guidelines and rehabilitation measures where culverts are found to be hindering the upstream movement of migratory fish.

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APPENDIX I

Culvert Questionnaire

CULVERT QUESTIONNAIRE

Installation of culverts on Irish Rivers

Name:	
Position:	
Local authority:	
Section:	

What types of culverts are utilised in your area?

Round ☐	Oval ☐	Box ☐	Arch ☐
Concrete ☐	Stone ☐	Plastic ☐	Metal ☐

What are the average culvert dimensions?

Length	<10m ☐	10-20m ☐	20-30m ☐	>30m ☐
Width	<0.5m ☐	0.5-1m ☐	1-2m ☐	>2m ☐

Are any of the following features constructed during culvert installation in your area?

Rubbish screens or grids ☐	Tailwater control ☐
Downstream pool ☐	Ponding weirs ☐
Fish passage baffles ☐	Raised aprons ☐
Instream piers ☐	Stone pitching ☐
Upstream pool ☐	Gravel bed ☐

To what depth are round or box culverts laid relative to gradeline of stream?

<0.5m below gradeline ☐	0-0.5m above gradeline ☐
>0.5m above gradeline ☐	

Are any of the following bodies notified of culvert installation or repair works?

- National Parks and Wildlife Service ☐
- Regional Fisheries Board ☐
- Central Fisheries Board ☐
- Environmental Protection Agency ☐
- Office of Public Works ☐
- Department of Environment ☐
- Other: ______________________

Is there an ongoing bridge or culvert maintenance or repair programme in your area?

Yes ☐ No ☐

Are flow or gradient measurements carried out during culvert installation?

Yes ☐ No ☐

At what time of year is culvert installation or repair mainly carried out? January to March ☐ April to June ☐ July to September ☐ October to December ☐
Have you any preference as to the type of culvert used in your area? Round ☐ Oval ☐ Box ☐ Arch ☐ Concrete ☐ Stone ☐ Plastic ☐ Metal ☐
What % of culverts in your area would fall into each of the following categories? <10 yrs old _____ 10-20 yrs old _____ 20-30 yrs old ____ 30-40 yrs old ____ >40 ___
Under what circumstances would culverts be repaired or upgraded in your area? Risk assessment ☐ Road upgrade ☐ Flood damage ☐ Drainage ☐ Other: ______________________________ **How are such repairs or upgrades carried out?** Removal and replacement of structure with similar type ☐ Removal and replacement of structure with new type ☐ Re-inforcement of existing structure using concrete ☐ Other: ______________________________
Any other comments or suggestions? ______________________________ ______________________________ ______________________________ ______________________________ ______________________________
Thank you for taking the time to complete this questionnaire. I would be grateful if you could return it to the following address: **26, The Hawthorns,** **Killala Road,** **Ballina,** **Co Mayo.** ______________________ **Stephen Neylon (087 2379906).**

APPENDIX II

Fish Passage Information Sheets

Fish Passage Information Sheet			
Inspection: 11.02.07	**River:** Brusna	**Townland:** Carrownlabaun	
Culvert ref: B1	**GPS co-ord:**	G 131033 318966	
Type of culvert:	Bottomless arched stone culvert		
Length of culvert:	7.3m	**Width of culvert:**	80cm
Depth of flow in culvert:	15cm		
Hydraulic drop (Y/N):	N	**Height of drop:**	-
Downstream pool (Y/N):	Y	**Depth of pool:**	25cm
Width of stream:	1.3m	**Depth of stream:**	20cm

Comment:

Substrate consists mainly of fine silt with some loose gravels.

Fish Passage Information Sheet			
Inspection: 11.02.07	**River:** Brusna	**Townland:** Carrownlabaun	
Culvert ref: B2	**GPS co-ord:**	G 131325 318789	
Type of culvert:	Boxed concrete culvert		
Length of culvert:	6m	**Width of culvert:**	1.5m
Depth of flow in culvert:	8cm		
Hydraulic drop (Y/N):	Y	**Height of drop:**	20cm
Downstream pool (Y/N):	Y	**Depth of pool:**	20cm
Width of stream:	2.1m	**Depth of stream:**	30cm

Comment:

These culverts have been recently constructed. There was a flow of approximately 8cm through each of the culverts on the day of inspection.

Fish Passage Information Sheet			
Inspection: 11.02.07	**River:** Brusna	**Townland:** Rathreedaun	
Culvert ref: B3	**GPS co-ord:**	G 132786 319189	
Type of culvert:	Arched stone bridge		
Length of culvert:	7.5m	**Width of culvert:**	4m
Depth of flow in culvert:	10cm		
Hydraulic drop (Y/N):	Y	**Height of drop:**	>1m
Downstream pool (Y/N):	N	**Depth of pool:**	-
Width of stream:	3m	**Depth of stream:**	25cm

Comment:

There is a substantial hydraulic drop at this location. However, the bed rock and gradient of the river may be a natural barrier to upstream salmon migration, as opposed to the culvert.

Fish Passage Information Sheet

Inspection: 14.02.07	**River:** Brusna	**Townland:** Rathreedaun	
Culvert ref: B4	**GPS co-ord:** G 132552 320280		
Type of culvert:	Boxed concrete culvert		
Length of culvert:	14m	**Width of culvert:**	80cm
Depth of flow in culvert:	12cm		
Hydraulic drop (Y/N):	N	**Height of drop:**	-
Downstream pool (Y/N):	Y	**Depth of pool:**	15cm
Width of stream:	1.5m	**Depth of stream:**	20cm

Comment:

No substantial change in depth or profile of river at this location.

Fish Passage Information Sheet

Inspection: 14.02.07	**River:** Brusna	**Townland:** Cloonta	
Culvert ref: B5	**GPS co-ord:**	G 131005 320701	
Type of culvert:	Boxed concrete culvert		
Length of culvert:	4.1m	**Width of culvert:**	2.7m
Depth of flow in culvert:	20cm		
Hydraulic drop (Y/N):	N	**Height of drop:**	-
Downstream pool (Y/N):	Y	**Depth of pool:**	20cm
Width of stream:	2.2m	**Depth of stream:**	15-20cm

Comment:

No substantial change in depth or profile of river at this location.

Fish Passage Information Sheet

Inspection: 14.02.07	**River:** Brusna	**Townland:** Cloonta	
Culvert ref: B6	**GPS co-ord:**	G 130170 320971	
Type of culvert:	Boxed concrete culvert		
Length of culvert:	4.1m	**Width of culvert:**	4.7m
Depth of flow in culvert:	20cm		
Hydraulic drop (Y/N):	Y	**Height of drop:**	25cm
Downstream pool (Y/N):	Y	**Depth of pool:**	30cm
Width of stream:	4m	**Depth of stream:**	25cm

Comment:

This section of river has a biological classification of Q4-5 (EPA, 2004).

Fish Passage Information Sheet

Inspection: 14.02.07	**River:** Brusna	**Townland:** Loughnagore	
Culvert ref: B7	**GPS co-ord:**	G 132703 321348	
Type of culvert:	Bottomless arched culvert		
Length of culvert:	7.1m	**Width of culvert:**	1.6m
Depth of flow in culvert:	25cm		
Hydraulic drop (Y/N):	N	**Height of drop:**	-
Downstream pool (Y/N):	Y	**Depth of pool:**	20cm
Width of stream:	1.8m	**Depth of stream:**	25cm

Comment:

No substantial change in depth or profile of river at this location.

Fish Passage Information Sheet

Inspection: 17.02.07	**River:** Brusna	**Townland:** Loughnagore	
Culvert ref: B8	**GPS co-ord:**	G 132476 320877	
Type of culvert:	Arched stone culvert (3 no.)		
Length of culvert:	6.5m	**Width of culvert:**	2.3m
Depth of flow in culvert:	25cm (middle culvert), 5cm (outer two culverts)		
Hydraulic drop (Y/N):	Y	**Height of drop:**	30cm
Downstream pool (Y/N):	N	**Depth of pool:**	-
Width of stream:	4.3m	**Depth of stream:**	25cm

Comment:

This section of river has a biological classification of Q5 (EPA, 2004).

The middle culvert of the three carries the main river flow during non-flood conditions. The adjoining two culverts are dry during low flow periods.

Fish Passage Information Sheet

Inspection: 17.02.07	**River:** Brusna	**Townland:** Loughnagore	
Culvert ref: B9	**GPS co-ord:**	G 134076 320613	
Type of culvert:	Boxed concrete culvert		
Length of culvert:	3.4m	**Width of culvert:**	4.2m
Depth of flow in culvert:	12cm		
Hydraulic drop (Y/N):	Y	**Height of drop:**	90cm
Downstream pool (Y/N):	Y	**Depth of pool:**	25cm
Width of stream:	6m	**Depth of stream:**	30cm

Comment:

Substantial hydraulic drop and low flow at this culvert. Upstream gravels appear to be clean and suitable for spawning purposes.

Fish Passage Information Sheet

Inspection: 17.02.07	**River:** Brusna	**Townland:** Carrownlabaun	
Culvert ref: B10	**GPS co-ord:** G 130919 318399		
Type of culvert:	Bottomless arched stone culverts (2 no.)		
Length of culvert:	7.3m	**Width of culvert:**	2.3m
Depth of flow in culvert:	30cm		
Hydraulic drop (Y/N):	N	**Height of drop:**	-
Downstream pool (Y/N):	Y	**Depth of pool:**	25cm
Width of stream:	2.5m	**Depth of stream:**	20cm

Comment:

No change in depth or flow at this location. Gravels appear to be clean and uncompacted.

Fish Passage Information Sheet

Inspection: 17.02.07	**River:** Brusna	**Townland:** Carrownlabaun	
Culvert ref: B11	**GPS co-ord:** G 130518 318486		
Type of culvert:	Bottomless arched stone culvert		
Length of culvert:	7.6m	**Width of culvert:**	1.2m
Depth of flow in culvert:	15cm		
Hydraulic drop (Y/N):	Y (u/s end)	**Height of drop:**	10cm
Downstream pool (Y/N):	Y	**Depth of pool:**	30cm
Width of stream:	1.8m	**Depth of stream:**	20cm

Comment:

No change in depth or flow at this location. Gravels appear to be clean and uncompacted.

Fish Passage Information Sheet

Inspection: 17.02.07	**River:** Brusna	**Townland:** Carrownlabaun	
Culvert ref: B12	**GPS co-ord:**	G 129955 318218	
Type of culvert:	Clear span bridge		
Length of culvert:	5m	**Width of culvert:**	6m
Depth of flow in culvert:	20cm		
Hydraulic drop (Y/N):	N	**Height of drop:**	-
Downstream pool (Y/N):	Y	**Depth of pool:**	20cm
Width of stream:	4m	**Depth of stream:**	25cm

Comment:

No change in depth or profile of river at this location.

Fish Passage Information Sheet				
Inspection: 17.02.07	**River:** Brusna	**Townland:** Corimla south		
Culvert ref: B13	**GPS co-ord:**	G 128606 319110		
Type of culvert:	Boxed stone culverts			
Length of culvert:	8.3m	**Width of culvert:**	9m	
Depth of flow in culvert:	40cm			
Hydraulic drop (Y/N):	Y	**Height of drop:**	5cm	
Downstream pool (Y/N):	Y	**Depth of pool:**	40cm	
Width of stream:	5.3m	**Depth of stream:**	30m	

Comment:

This section of river has a biological classification of Q4-5 (EPA, 2004).

Fish Passage Information Sheet			
Inspection: 20.02.07	**River:** Brusna	**Townland:** Bunnyconnellan west	
Culvert ref: B14	**GPS co-ord:**	G 132461 317077	
Type of culvert:	Boxed stone culverts (8 no.)		
Length of culvert:	6.2m	**Width of culvert:**	80cm
Depth of flow in culvert:	8-13cm		
Hydraulic drop (Y/N):	Y	**Height of drop:**	20cm
Downstream pool (Y/N):	Y	**Depth of pool:**	10cm
Width of stream:	4.5m	**Depth of stream:**	30cm

Comment:

This section of river has a biological classification of Q4-5 (EPA, 2004).

Fish Passage Information Sheet

Inspection: 03.02.07	**River:** Gweestion	**Townland:**	Ardacarha
Culvert ref: G1	**GPS co-ord:** G 129970 296245		
Type of culvert:	Bottomless arched culvert		
Length of culvert:	9.6m	**Width of culvert:**	3.6m
Depth of flow in culvert:	10cm		
Hydraulic drop (Y/N):	N	**Height of drop:**	-
Downstream pool (Y/N):	Y	**Depth of pool:**	20cm
Width of stream:	2.8m	**Depth of stream:**	30-40cm

Comment:

No change in depth or profile of river at this location. A water pipe crosses the channel at this location and could cause an accumulation of debris during flood conditions.

Fish Passage Information Sheet

Inspection: 03.02.07	**River:** Gweestion	**Townland:**	Ardacarha
Culvert ref: G2	**GPS co-ord:**	G 130140 296884	
Type of culvert:	Round concrete bottomless; modified break in base of culvert.		
Length of culvert:	6m	**Width of culvert:**	70cm
Depth of flow in culvert:	8cm		
Hydraulic drop (Y/N):	N	**Height of drop:**	-
Downstream pool (Y/N):	N	**Depth of pool:**	-
Width of stream:	2m	**Depth of stream:**	20cm

Comment:

This culvert is an unusual shape and combines both arched and round features. The stream is 2m wide upstream of this culvert and, while the culvert is 70cm wide, the effective width at the base is 40cm with a flow of <10cm. The stream is at a shallow gradient at this location, and the flow is sluggish. There are signs of nutrient enrichment upstream of this culvert; there is relatively rich agricultural land in the area.

Fish Passage Information Sheet

Inspection: 03.02.07	**River:** Gweestion	**Townland:**	Barleyhill
Culvert ref: G3	**GPS co-ord:**	G 130768 296842	
Type of culvert:	Arched stone culvert		
Length of culvert:	7.4m	**Width of culvert:**	1m
Depth of flow in culvert:	6cm		
Hydraulic drop (Y/N):	Y	**Height of drop:**	20cm
Downstream pool (Y/N):	N	**Depth of pool:**	-
Width of stream:	1-1.5m	**Depth of stream:**	20-30cm

Comment:

A round steel structure was pinned against the downstream opening of this culvert and appears to be used for keeping cattle from accessing the culvert. The upstream opening is blocked by a wooden pallet, against which a large amount of woody debris has collected. The depth of flow through the culvert is no more than 6cm.

Fish Passage Information Sheet

Inspection: 03.02.07	**River:** Gweestion	**Townland:**	Lissaniska
Culvert ref: G4	**GPS co-ord:** G 130126 295575		
Type of culvert:	Bottomless arched concrete culvert		
Length of culvert:	25m	**Width of culvert:**	2.5m
Depth of flow in culvert:	30cm		
Hydraulic drop (Y/N):	N	**Height of drop:**	-
Downstream pool (Y/N):	Y	**Depth of pool:**	20cm
Width of stream:	2.8m	**Depth of stream:**	20cm

Comment:

No change in depth or profile of stream at this location. This section of river has a biological classification of Q4 (EPA, 2004).

Fish Passage Information Sheet

Inspection: 03.02.07	**River:** Gweestion	**Townland:**	Carroward
Culvert ref: G5	**GPS co-ord:**	G 129537 294146	
Type of culvert:	Boxed concrete culvert		
Length of culvert:	5.3m	**Width of culvert:**	1.6m
Depth of flow in culvert:	3cm		
Hydraulic drop (Y/N):	N	**Height of drop:**	-
Downstream pool (Y/N):	N	**Depth of pool:**	-
Width of stream:	1.2m	**Depth of stream:**	10-15cm

Comment:

This section of stream appears to have been drained; there are mainly riffle and glide features present, with limited pool areas.

Fish Passage Information Sheet

Inspection: 03.02.07	**River:** Gweestion	**Townland:**	Gortnasillagh
Culvert ref: G6	**GPS co-ord:** G 131225 295602		
Type of culvert:	Round concrete culvert		
Length of culvert:	5m	**Width of culvert:**	1.3m
Depth of flow in culvert:	8cm		
Hydraulic drop (Y/N):	Y	**Height of drop:**	10cm
Downstream pool (Y/N):	Y	**Depth of pool:**	40cm
Width of stream:	2.5m	**Depth of stream:**	30cm

Comment:

This appears to be a recently installed culvert; it is on private land and has been set about 40cm above the natural gradeline of the stream. It could potentially have a significant impact on fish movement by virtue of its location; it is situated in the lower stretches of one of the Gweestion spawning tributaries, with over 2km of spawning habitat upstream.

Fish Passage Information Sheet

Inspection: 03.02.07	**River:** Gweestion		**Townland:**	Lissaniska
Culvert ref: G7	**GPS co-ord:**	G 131031 295082		
Type of culvert:	Round concrete culvert			
Length of culvert:	15m		**Width of culvert:**	2m
Depth of flow in culvert:	30cm			
Hydraulic drop (Y/N):	Y		**Height of drop:**	5cm at u/s invert
Downstream pool (Y/N):	Y		**Depth of pool:**	20cm
Width of stream:	1.6m		**Depth of stream:**	20-30cm

Comment:

This culvert has not been laid at the same slope as the stream, with the result that there is a lip at the upstream invert. There are three round culvert sections in line and the upper section is offline with the other two, resulting in a shallow flow (<10cm) at the upstream end.

Fish Passage Information Sheet

Inspection: 03.02.07	**River:** Gweestion	**Townland:**	Shanaghy
Culvert ref: G8	**GPS co-ord:**	G 132065 293598	
Type of culvert:	Bottomless arched concrete culvert		
Length of culvert:	45m	**Width of culvert:**	2.4m
Depth of flow in culvert:	20cm		
Hydraulic drop (Y/N):	N	**Height of drop:**	-
Downstream pool (Y/N):	Y	**Depth of pool:**	30cm
Width of stream:	2.6m	**Depth of stream:**	15-20cm

Comment:

This culvert was installed in 2005 during a road widening operation. The existing bridge had been removed and a river diversion was carried out, under Board supervision. Bottomless arch culverts were used, and works to install gravel and pools were carried out prior to the culverts being placed *in situ* .

Fish Passage Information Sheet

Inspection: 03.02.07	**River:** Gweestion	**Townland:**	Carrowmore
Culvert ref: G9	**GPS co-ord:**	G 132808 294822	
Type of culvert:	Bottomless arched stone culvert		
Length of culvert:	7.3m	**Width of culvert:**	2m
Depth of flow in culvert:	15cm		
Hydraulic drop (Y/N):	Y	**Height of drop:**	5cm
Downstream pool (Y/N):	Y	**Depth of pool:**	20cm
Width of stream:	3m	**Depth of stream:**	c.20cm

Comment:

4 salmon redds were evident just upstream of this culvert on inspection day.

Fish Passage Information Sheet

Inspection: 03.02.07	**River:** Gweestion	**Townland:**	Ballymiles
Culvert ref: G10	**GPS co-ord:**	G 132995 295649	
Type of culvert:	Bottomless arched concrete culvert		
Length of culvert:	5.6m	**Width of culvert:**	2.8m
Depth of flow in culvert:	15cm		
Hydraulic drop (Y/N):	N	**Height of drop:**	-
Downstream pool (Y/N):	Y	**Depth of pool:**	40cm
Width of stream:	3m	**Depth of stream:**	30cm

Comment:

No substantial change in depth or profile of the river at this location.

Fish Passage Information Sheet

Inspection:	06.02.07	**River:** Gweestion		**Townland:**	Toccanagh
Culvert ref:	G11	**GPS co-ord:**	G 130892 294850		
Type of culvert:		Bottomless arch culvert			
Length of culvert:		5.8m	**Width of culvert:**	2.7m	
Depth of flow in culvert:		10cm			
Hydraulic drop (Y/N):		Y	**Height of drop:**	30cm	
Downstream pool (Y/N):		Y	**Depth of pool:**	10cm	
Width of stream:		1.8m	**Depth of stream:**	20cm	

Comment:

Bridge wall has partically collapsed due to a crash impact.

Fish Passage Information Sheet			
Inspection: 06.02.07	**River:** Gweestion	**Townland:**	Toccanagh
Culvert ref: G12	**GPS co-ord:** G 130755 294507		
Type of culvert:	Bottomless arched culvert		
Length of culvert:	8m	**Width of culvert:**	1.6m
Depth of flow in culvert:	15cm		
Hydraulic drop (Y/N):	Y	**Height of drop:**	30cm at u/s end
Downstream pool (Y/N):	Y	**Depth of pool:**	25cm
Width of stream:	1.6m	**Depth of stream:**	15cm

Comment:

Portion of culvert has collapsed.

Fish Passage Information Sheet

Inspection: 06.02.07	**River:** Gweestion	**Townland:**	Gortnasillagh
Culvert ref: G13	**GPS co-ord:**	G 133312 295440	
Type of culvert:	Boxed concrete culvert		
Length of culvert:	5m	**Width of culvert:**	2.5m
Depth of flow in culvert:	40cm		
Hydraulic drop (Y/N):	N	**Height of drop:**	-
Downstream pool (Y/N):	Y	**Depth of pool:**	40cm
Width of stream:	3.2m	**Depth of stream:**	50cm

Comment:

No change in depth or profile of river at this location.

Fish Passage Information Sheet			
Inspection: 06.02.07	**River:** Sonnagh	**Townland:** Cloontubrid	
Culvert ref: So1	**GPS co-ord:**	G 141729 302960	
Type of culvert:	Boxed concrete culvert		
Length of culvert:	4.8m	**Width of culvert:**	1.4m
Depth of flow in culvert:	8cm		
Hydraulic drop (Y/N):	Y	**Height of drop:**	25cm
Downstream pool (Y/N):	Y	**Depth of pool:**	30cm
Width of stream:	2.1m	**Depth of stream:**	20cm

Comment:

There is a shallow concrete apron under this culvert; the depth of flow across the apron was less than 10cm. The spawning gravels were covered in fine mineral silt at this location.

Fish Passage Information Sheet			
Inspection: 06.02.07	**River:** Sonnagh	**Townland:** Cully	
Culvert ref: So2	**GPS co-ord:** G 143367 303101		
Type of culvert:	Clear span bridge		
Length of culvert:	5.7m	**Width of culvert:**	6.2m
Depth of flow in culvert:	20cm		
Hydraulic drop (Y/N):	Y	**Height of drop:**	30cm
Downstream pool (Y/N):	Y	**Depth of pool:**	50cm
Width of stream:	4m	**Depth of stream:**	40cm

Comment:

No substantial change in depth or profile of river at this location.

Fish Passage Information Sheet

Inspection: 06.02.07	**River:** Sonnagh	**Townland:** Sonnagh	
Culvert ref: So3	**GPS co-ord:**	G 144588 302032	
Type of culvert:	Boxed culverts (3 no.)		
Length of culvert:	6m	**Width of culvert:**	50cm
Depth of flow in culvert:	12cm		
Hydraulic drop (Y/N):	Y	**Height of drop:**	10cm
Downstream pool (Y/N):	Y	**Depth of pool:**	50cm
Width of stream:	1.5m	**Depth of stream:**	30cm

Comment:

During normal flow conditions, it appears that the stream utilises only the middle of the three culverts. There is an extensive forestry plantation upstream of this culvert and the gravels in this area are heavily compacted.

Fish Passage Information Sheet			
Inspection: 06.02.07	**River:** Sonnagh	**Townland:** Cartron	
Culvert ref: So4	**GPS co-ord:**	G 144734 301588	
Type of culvert:	Clear span bridge		
Length of culvert:	6m	**Width of culvert:**	8m
Depth of flow in culvert:	70cm		
Hydraulic drop (Y/N):	N	**Height of drop:**	-
Downstream pool (Y/N):	Y	**Depth of pool:**	70cm
Width of stream:	5.5m	**Depth of stream:**	70cm

Comment:

No change in depth or profile of river at this location. The substrate was coated in a layer of mineral silt approximately 10cm deep, with thicker deposits evident along the bank edges.

Fish Passage Information Sheet

Inspection: 06.02.07	**River:** Sonnagh	**Townland:** Cartron	
Culvert ref: So5	**GPS co-ord:**	G 144369 300604	
Type of culvert:	Clear span bridge		
Length of culvert:	3.4m	**Width of culvert:**	7.3m
Depth of flow in culvert:	20cm		
Hydraulic drop (Y/N):	N	**Height of drop:**	-
Downstream pool (Y/N):	N	**Depth of pool:**	-
Width of stream:	3m	**Depth of stream:**	30cm

Comment:

No change in depth or profile of river at this location. The substrate was coated in a layer of mineral silt approximately 10-15cm deep, with thicker deposits evident along the bank edges.

Fish Passage Information Sheet

Inspection: 06.02.07	**River:** Sonnagh	**Townland:** Cartron	
Culvert ref: So6	**GPS co-ord:**	G 144869 300974	
Type of culvert:	Arched stone culvert		
Length of culvert:	10.7m	**Width of culvert:**	5m
Depth of flow in culvert:	50cm		
Hydraulic drop (Y/N):	N	**Height of drop:**	-
Downstream pool (Y/N):	Y	**Depth of pool:**	60cm
Width of stream:	4m	**Depth of stream:**	40cm

Comment:

No change in depth or profile of river at this location. This section of river has a biological classification of Q4-5 (EPA, 2001).

Fish Passage Information Sheet

Inspection: 06.02.07	**River:** Sonnagh	**Townland:** Trouthill	
Culvert ref: So7	**GPS co-ord:**	G 145594 300290	
Type of culvert:	Round concrete culvert		
Length of culvert:	4.8m	**Width of culvert:**	70cm
Depth of flow in culvert:	30cm		
Hydraulic drop (Y/N):	N	**Height of drop:**	-
Downstream pool (Y/N):	Y	**Depth of pool:**	40cm
Width of stream:	1.1m	**Depth of stream:**	25cm

Comment:

Depth of flow in culvert is similar to flow upstream and downstream.

Fish Passage Information Sheet

Inspection: 08.02.07	**River:** Sonnagh	**Townland:** Trouthill	
Culvert ref: So8	**GPS co-ord:**	G 145579 300492	
Type of culvert:	Bottomless arched culvert		
Length of culvert:	40m	**Width of culvert:**	3m
Depth of flow in culvert:	10cm		
Hydraulic drop (Y/N):	N	**Height of drop:**	-
Downstream pool (Y/N):	Y	**Depth of pool:**	50cm
Width of stream:	2m	**Depth of stream:**	25cm

Comment:

Bottomless arched culvert installed in 2006 during construction of N5 Charlestown bypass.

Substantial siltation of spawning gravels downstream of this location.

Fish Passage Information Sheet

Inspection: 08.02.07	**River:** Sonnagh	**Townland:** Trouthill	
Culvert ref: So9	**GPS co-ord:**	G 145080 300357	
Type of culvert:	Round concrete culvert		
Length of culvert:	35m	**Width of culvert:**	2m
Depth of flow in culvert:	20cm		
Hydraulic drop (Y/N):	N	**Height of drop:**	-
Downstream pool (Y/N):	Y	**Depth of pool:**	20cm
Width of stream:	1m	**Depth of stream:**	20cm

Comment:

Round concrete culvert installed in 2006 during construction of N5 Charlestown bypass.

Substantial siltation of spawning gravels downstream of this location.

Fish Passage Information Sheet

Inspection: 08.02.07	**River:** Sonnagh	**Townland:** Mullenmadoge	
Culvert ref: So10	**GPS co-ord:**	G 144104 299958	
Type of culvert:	Bottomless arched culvert		
Length of culvert:	40m	**Width of culvert:**	3m
Depth of flow in culvert:	40cm		
Hydraulic drop (Y/N):	N	**Height of drop:**	-
Downstream pool (Y/N):	Y	**Depth of pool:**	30cm
Width of stream:	2m	**Depth of stream:**	30cm

Comment:

Bottomless arched culvert installed in 2006 during construction of the N5 Charlestown bypass.

Substantial siltation of spawning gravels downstream of this location.

Fish Passage Information Sheet

Inspection: 08.02.07	**River:** Sonnagh	**Townland:** Mullenmadoge	
Culvert ref: So11	**GPS co-ord:**	G 144169 299982	
Type of culvert:	Bottomless arched culvert		
Length of culvert:	40m	**Width of culvert:**	3m
Depth of flow in culvert:	30cm		
Hydraulic drop (Y/N):	N	**Height of drop:**	-
Downstream pool (Y/N):	Y	**Depth of pool:**	40cm
Width of stream:	2.8m	**Depth of stream:**	40cm

Comment:

Bottomless arched culvert installed in 2006 during construction of the N5 Charlestown bypass.

Substantial siltation of spawning gravels downstream of this location.

Fish Passage Information Sheet

Inspection: 08.02.07	**River:** Sonnagh	**Townland:** Trouthill	
Culvert ref: So12	**GPS co-ord:**	G 144603 299407	
Type of culvert:	Arched stone bridge		
Length of culvert:	6m	**Width of culvert:**	6.2m
Depth of flow in culvert:	35cm		
Hydraulic drop (Y/N):	N	**Height of drop:**	-
Downstream pool (Y/N):	Y	**Depth of pool:**	30cm
Width of stream:	2m	**Depth of stream:**	30cm

Comment:

No change in depth or profile of river at this location.

Fish Passage Information Sheet

Inspection: 08.02.07	**River:** Sonnagh	**Townland:** Mullenmadoge	
Culvert ref: So13	**GPS co-ord:**	G 143971 299504	
Type of culvert:	Round concrete culvert		
Length of culvert:	8m	**Width of culvert:**	1.6m
Depth of flow in culvert:	10cm		
Hydraulic drop (Y/N):	Y	**Height of drop:**	20cm
Downstream pool (Y/N):	N	**Depth of pool:**	-
Width of stream:	1.3m	**Depth of stream:**	20cm

Comment:

There is a depth of 40cm at the upstream invert of this culvert, but it is set too high for the stream gradient. The lack of a downstream pool may make this a difficult structure to ascend through.

Fish Passage Information Sheet

Inspection: 11.02.07	**River:** Sonnagh	**Townland:** Mullenmadoge	
Culvert ref: So14	**GPS co-ord:**	M 143517 298958	
Type of culvert:	Arched stone culvert		
Length of culvert:	6m	**Width of culvert:**	2.6m
Depth of flow in culvert:	30cm		
Hydraulic drop (Y/N):	N	**Height of drop:**	-
Downstream pool (Y/N):	Y	**Depth of pool:**	25cm
Width of stream:	2m	**Depth of stream:**	20cm

Comment:

This gravels is this area are heavily silted up and compacted, as a result of extensive quarrying activity upstream of this location in the townland of Stripe. This section of river has a biological classification of Q4 (EPA, 2001).

Fish Passage Information Sheet			
Inspection: 11.02.07	**River:** Sonnagh	**Townland:** Killeen	
Culvert ref: So15	**GPS co-ord:**	M 144634 298979	
Type of culvert:	Boxed stone culvert		
Length of culvert:	4.7m	**Width of culvert:**	3.8m
Depth of flow in culvert:	8cm		
Hydraulic drop (Y/N):	Y	**Height of drop:**	60cm and 80cm
Downstream pool (Y/N):	N	**Depth of pool:**	-
Width of stream:	1.8m	**Depth of stream:**	20cm

Comment:

There is a substantial hydraulic drop of 80cm at the culvert, and a further drop of 60cm located approximately 10m downstream. The depth of flow between the two drops and under the culvert is <10cm, with no transitional pool present.

Fish Passage Information Sheet			
Inspection: 11.02.07	**River:** Sonnagh	**Townland:** Cloonlyon	
Culvert ref: So16	**GPS co-ord:**	M 145158 298501	
Type of culvert:	Round concrete culverts (2 no.)		
Length of culvert:	7.7m	**Width of culvert:**	1.4m
Depth of flow in culvert:	15cm		
Hydraulic drop (Y/N):	Y	**Height of drop:**	20cm
Downstream pool (Y/N):	Y	**Depth of pool:**	20cm
Width of stream:	2m	**Depth of stream:**	20-30cm

Comment:

Wooden pallets have been fixed to the upstream and downstream ends of these culverts. There is also a large quantity of woody and flood debris, which has collected at the upstream ends of the culverts.

Fish Passage Information Sheet

Inspection: 11.02.07	**River:** Sonnagh	**Townland:** Cloonlyon	
Culvert ref: So17	**GPS co-ord:**	M 144768 297958	
Type of culvert:	Clear span bridge		
Length of culvert:	5.6m	**Width of culvert:**	6.2m
Depth of flow in culvert:	25cm		
Hydraulic drop (Y/N):	N	**Height of drop:**	-
Downstream pool (Y/N):	Y	**Depth of pool:**	20cm
Width of stream:	1.2m	**Depth of stream:**	20cm

Comment:

No substantial change in depth or profile of river at this location.

Fish Passage Information Sheet

Inspection: 11.02.07	**River:** Sonnagh	**Townland:** Cloonlyon	
Culvert ref: So18	**GPS co-ord:**	M 145919 298267	
Type of culvert:	Bottomless arched stone culverts		
Length of culvert:	4.3m	**Width of culvert:**	80cm and 1m
Depth of flow in culvert:	30cm		
Hydraulic drop (Y/N):	Y	**Height of drop:**	15cm at upstream end
Downstream pool (Y/N):	Y	**Depth of pool:**	20cm
Width of stream:	2m	**Depth of stream:**	20cm

Comment:

Woody debris has collected against the upstream ends of these culverts.

Fish Passage Information Sheet

Inspection: 10.01.07	**River:** Spaddagh	**Townland:** Esker	
Culvert ref: S1	**GPS co-ord:**	G 136314 298733	
Type of culvert:	Bottomless arched culverts (2 no.)		
Length of culvert:	9.4m	**Width of culvert:**	2.4m
Depth of flow in culvert:	30cm		
Hydraulic drop (Y/N):	N	**Height of drop:**	-
Downstream pool (Y/N):	Y	**Depth of pool:**	40cm
Width of stream:	5m	**Depth of stream:**	40-50cm

Comment:

This section of river has a biological classification of Q4 (EPA, 2004).

Fish Passage Information Sheet

Inspection:	10.01.07	**River:** Spaddagh		**Townland:**	Carrowreagh
Culvert ref:	S2	**GPS co-ord:**	G 135201 298285		
Type of culvert:	Round concrete				
Length of culvert:	9.2m			**Width of culvert:**	80cm
Depth of flow in culvert:	5cm				
Hydraulic drop (Y/N):	N			**Height of drop:**	-
Downstream pool (Y/N):	Y			**Depth of pool:**	10cm
Width of stream:	1.3m			**Depth of stream:**	<20cm

Comment:

Stream is heavily enriched with thick growths of watercress and grass in the main channel. The substrate consists of mud and silt, with a layer of gravel beneath. There is a large agricutural entre-prise upstream and a point source effluent discharge was noted during the inspection. The stream upstream of this location is also overgrown and there may be significant diffuse run-off of nutrients in this area.

Fish Passage Information Sheet			
Inspection: 10.01.07	**River:** Spaddagh	**Townland:** Lisbrogan	
Culvert ref: S3	**GPS co-ord:**	G 135216 299132	
Type of culvert:	Bottomless arched culvert		
Length of culvert:	4.4m	**Width of culvert:**	3m
Depth of flow in culvert:	25cm		
Hydraulic drop (Y/N):	N	**Height of drop:**	-
Downstream pool (Y/N):	Y	**Depth of pool:**	30cm
Width of stream:	4.6m	**Depth of stream:**	40cm

Comment:

Four salmon redds were noted approximately 40m upstream of this culvert on the day of the site inspection.

Fish Passage Information Sheet			
Inspection: 10.01.07	**River:** Spaddagh	**Townland:** Lislackagh	
Culvert ref: S4	**GPS co-ord:**	G 136949 298012	
Type of culvert:	Bottomless arched culvert		
Length of culvert:	6m	**Width of culvert:**	90cm
Depth of flow in culvert:	50cm		
Hydraulic drop (Y/N):	N	**Height of drop:**	-
Downstream pool (Y/N):	Y	**Depth of pool:**	50cm
Width of stream:	3m	**Depth of stream:**	50cm

Comment:

No substantial change in depth or profile of river at this location.

Fish Passage Information Sheet

Inspection: 10.01.07	**River:** Spaddagh	**Townland:** Newpark	
Culvert ref: S5	**GPS co-ord:**	G 137009 298513	
Type of culvert:	Round concrete culvert		
Length of culvert:	35m	**Width of culvert:**	1.4m
Depth of flow in culvert:	8cm		
Hydraulic drop (Y/N):	N	**Height of drop:**	-
Downstream pool (Y/N):	N	**Depth of pool:**	-
Width of stream:	1m	**Depth of stream:**	20cm

Comment:

This culvert is over 30m long and has a number of sills and breaks in it. There is suitable spawning gravels upstream of this culvert location. The depth of flow is uniformily shallow throughout the structure.

Fish Passage Information Sheet

Inspection: 06.02.07	**River:** Spaddagh	**Townland:** Carrowcanada	
Culvert ref: S6	**GPS co-ord:**	G 137988 297582	
Type of culvert:	Boxed concrete culvert		
Length of culvert:	3.3m	**Width of culvert:**	3m
Depth of flow in culvert:	30cm		
Hydraulic drop (Y/N):	Y	**Height of drop:**	25cm
Downstream pool (Y/N):	Y	**Depth of pool:**	30cm
Width of stream:	2.6m	**Depth of stream:**	30-40cm

Comment:

There is a raised apron at this culvert, which may restrict movement during low flow conditions.

Fish Passage Information Sheet

Inspection: 04.01.07	**River:** Yellow	**Townland:** Corradrishy	
Culvert ref: Y1	**GPS co-ord:**	G 128529 308319	
Type of culvert:	Round concrete		
Length of culvert:	7.4m	**Width of culvert:**	60cm
Depth of flow in culvert:	10cm		
Hydraulic drop (Y/N):	Y	**Height of drop:**	10cm
Downstream pool (Y/N):	N	**Depth of pool:**	-
Width of stream:	1.5m	**Depth of stream:**	

Comment:

Hard rocky substrate downstream. Clean gravels noted upstream of culvert.

Site is heavily overgrown and difficult to access.

Fish Passage Information Sheet			
Inspection: 04.01.07	**River:** Yellow	**Townland:** Rinnananny	
Culvert ref: Y2	**GPS co-ord:**	G 128298 306680	
Type of culvert:	Arched concrete bridge (two eyed)		
Length of culvert:	6.3m	**Width of culvert:**	4.3m
Depth of flow in culvert:	40cm		
Hydraulic drop (Y/N):	N	**Height of drop:**	-
Downstream pool (Y/N):	Y	**Depth of pool:**	70cm
Width of stream:	11m	**Depth of stream:**	70cm

Comment:

Good spawning substrate in this area. Gravels are clean with no evidence of enrichment.

River conditions at culvert are similar to conditions upstream and downstream.

No change in depth or profile of river bed at this location.

A small quantity of woody debris was caught at the upstream mouth of the culvert.

This section of river has a biological classification of Q4-5 (EPA, 2004).

Fish Passage Information Sheet

Inspection:	04.01.07	**River:**	Yellow	**Townland:**	Rinnannay
Culvert ref:	Y3	**GPS co-ord:**	G 128688 306486		
Type of culvert:		Clear span bridge			
Length of culvert:		2.9m		**Width of culvert:**	6.4m
Depth of flow in culvert:		60cm			
Hydraulic drop (Y/N):		N		**Height of drop:**	-
Downstream pool (Y/N):		Y		**Depth of pool:**	70cm
Width of stream:		9m		**Depth of stream:**	70cm

Comment:

No change in depth or profile of river bed at this location.

Fish Passage Information Sheet

Inspection: 04.01.07	**River:** Yellow	**Townland:** Boherhallagh	
Culvert ref: Y4	**GPS co-ord:** G 129084 306493		
Type of culvert:	Two boxed culverts made of individual stones		
Length of culvert:	4.2m	**Width of culvert:**	70cm
Depth of flow in culvert:	20cm		
Hydraulic drop (Y/N):	N	**Height of drop:**	-
Downstream pool (Y/N):	Y	**Depth of pool:**	30cm
Width of stream:	2.1m	**Depth of stream:**	30cm

Comment:

Bridge is in a poor condition and part of it is collapsing on the downstream side. The substrate is clean and uncompacted, with a mixture of fine silt and coarse gravels up to 6cm diameter.

Stream is heavily overgrown at this location and further upstream.

Fish Passage Information Sheet

Inspection:	04.01.07	**River:** Yellow		**Townland:**	Creggagh
Culvert ref:	Y5	**GPS co-ord:**	G 129813 305925		
Type of culvert:		Double arched stone bridge			
Length of culvert:		5.8m		**Width of culvert:**	10.6m
Depth of flow in culvert:		40cm			
Hydraulic drop (Y/N):		N		**Height of drop:**	-
Downstream pool (Y/N):		Y		**Depth of pool:**	50cm
Width of stream:		-		**Depth of stream:**	50cm

Comment:

River conditions at culvert are similar to conditions upstream and downstream.

No change in depth or profile of river bed at this location.

This section of river has a biological classification of Q5 (EPA, 2004).

Fish Passage Information Sheet			
Inspection: 04.01.07	**River:** Yellow	**Townland:** Corlee	
Culvert ref: Y6	**GPS co-ord:**	G 132281 308623	
Type of culvert:	Clear span bridge		
Length of culvert:	4.6m	**Width of culvert:**	6.3m
Depth of flow in culvert:	50cm		
Hydraulic drop (Y/N):	N	**Height of drop:**	-
Downstream pool (Y/N):	Y	**Depth of pool:**	50cm
Width of stream:	6m	**Depth of stream:**	50cm

Comment:

Good spawning substrate in this area. Gravels are clean with no evidence of enrichment.

River conditions at culvert are similar to conditions upstream and downstream.

No change in depth or profile of river bed at this location.

This section of river has a biological classification of Q5 (EPA, 2004).

Fish Passage Information Sheet

Inspection: 04.01.07	**River:** Yellow	**Townland:** Corlee	
Culvert ref: Y7	**GPS co-ord:**	G 132223 309045	
Type of culvert:	Stone bridge - two concrete box and one round culvert.		
Length of culvert:	4.8m	**Width of culvert:**	60cm (round culvert)
Depth of flow in culvert:	10cm		90cm (box culvert)
Hydraulic drop (Y/N):	Y	**Height of drop:**	70cm
Downstream pool (Y/N):	Y	**Depth of pool:**	30cm
Width of stream:	3.5m	**Depth of stream:**	40cm (variable)

Comment:

This bridge was constructed in 1984, following a flood event which destroyed the original bridge.

There is good spawning substrate upstream of this location.

Fish Passage Information Sheet

Inspection: 04.01.07	**River:** Yellow	**Townland:** Corlee	
Culvert ref: Y8	**GPS co-ord:**	G 132209 309135	
Type of culvert:	Three bottomless arched culverts		
Length of culvert:	4.9m	**Width of culvert:**	3.1m (bridge is 11.3m)
Depth of flow in culvert:	20cm		
Hydraulic drop (Y/N):	Y	**Height of drop:**	<10cm
Downstream pool (Y/N):	Y	**Depth of pool:**	20cm
Width of stream:	9m	**Depth of stream:**	20-40cm (variable)

Comment:

River conditions at culvert are similar to conditions upstream and downstream.

Juvenile Atlantic salmon recorded upstream of this location during electrofishing survey of 09.10.06.

Fish Passage Information Sheet

Inspection: 04.01.07	**River:** Yellow	**Townland:** Corlee	
Culvert ref: Y9	**GPS co-ord:**	G 132066 309294	
Type of culvert:	Box culvert		
Length of culvert:	5.1m	**Width of culvert:**	2.4m
Depth of flow in culvert:	10cm		
Hydraulic drop (Y/N):	Y	**Height of drop:**	60cm
Downstream pool (Y/N):	N	**Depth of pool:**	-
Width of stream:	2.5m	**Depth of stream:**	20cm

Comment:

There is a concrete apron at this bridge, which extends approximately 5m downstream of the culvert. There is a hydraulic drop here of about 60cm, with a depth downstream of 10cm.

Fish Passage Information Sheet

Inspection: 04.01.07	**River:** Yellow	**Townland:** Corlee	
Culvert ref: Y10	**GPS co-ord:**	G 132075 309400	
Type of culvert:	Round culverts (2 no.)		
Length of culvert:	4.8m	**Width of culvert:**	90cm
Depth of flow in culvert:	<10cm		
Hydraulic drop (Y/N):	Y	**Height of drop:**	100cm
Downstream pool (Y/N):	N	**Depth of pool:**	-
Width of stream:	2.5m	**Depth of stream:**	10-30cm (variable)

Comment:

These culverts appear to have been recently constructed. This bridge allows for access to a number of adjoining fields.There is a significant hydraulic drop at this location, with no substantial pool areas. The gradient is quite steep along this section of river.

Fish Passage Information Sheet

Inspection: 05.01.06	**River:** Yellow	**Location:** Coollagagh	
Culvert ref: Y11	**GPS co-ord:**	G 130809 305667	
Type of culvert:	Round concrete		
Length of culvert:	8m	**Width of culvert:**	40cm
Depth of flow in culvert:	25cm		
Hydraulic drop (Y/N):	N	**Height of drop:**	-
Downstream pool (Y/N):	Y	**Depth of pool:**	40cm
Width of stream:	1m	**Depth of stream:**	20-30cm

Comment:
This culvert is well embedded into the substrate and is laid at a similar gradient to that of the stream. There are clean gravels and cobbles in this area. A blockage consisting of tree and shrub debris and a large metallic plate was noted approximately 15m upstream of this culvert.

Fish Passage Information Sheet			
Inspection: 05.01.07	**River:** Yellow	**Location:** Cullin	
Culvert ref: Y12	**GPS co-ord:**	G 132665 305437	
Type of culvert:	Stone bottomless arched culverts (2 no.)		
Length of culvert:	5.4m	**Width of culvert:**	50cm
Depth of flow in culvert:	<10cm		
Hydraulic drop (Y/N):	Y	**Height of drop:**	40cm
Downstream pool (Y/N):	N	**Depth of pool:**	-
Width of stream:	1.7m	**Depth of stream:**	20cm

Comment:

There are two steps at the downstream mouth of this culvert and no transition pool of any depth downstream. One of the culverts is partially collapsed and, while the average depth of flow in the stream is 20cm, the flow through the culvert is approximately 5-10cm. Upstream, the substrate is uncompacted and consists of good quantities of gravels up to 8cm diameter.

Fish Passage Information Sheet

Inspection: 05.01.07	**River:** Yellow	**Location:** Cullin	
Culvert ref: Y13	**GPS co-ord:**	G 132443 305818	
Type of culvert:	Stone boxed culverts (2 no.)		
Length of culvert:	5.8m	**Width of culvert:**	70cm
Depth of flow in culvert:	30cm		
Hydraulic drop (Y/N):	N	**Height of drop:**	-
Downstream pool (Y/N):	Y	**Depth of pool:**	40cm
Width of stream:	2m	**Depth of stream:**	20-30cm

Comment:

Substrate consists of uncompacted cobbles, gravel and boulders .

There is a small step at the upstream mouth of the culvert.

Fish Passage Information Sheet			
Inspection: 05.01.07	**River:** Yellow	**Location:** Askillaun	
Culvert ref: Y14	**GPS co-ord:**	G 132421 306218	
Type of culvert:	Stone bottomless arched culverts (2 no.)		
Length of culvert:	5.8m	**Width of culvert:**	70cm
Depth of flow in culvert:	<10cm		
Hydraulic drop (Y/N):	Y	**Height of drop:**	15cm
Downstream pool (Y/N):	N	**Depth of pool:**	-
Width of stream:	1m	**Depth of stream:**	20cm

Comment:

Heavily overgrown stream with no transition pool downstream. There is a 15cm step at the downstream mouth of the culvert with no transition pool downstream. The substrate is this area consists mainly of a cobble and gravel mixture, up to 6cm diameter.

Fish Passage Information Sheet			
Inspection: 05.01.07	**River:** Yellow	**Location:** Attimachugh	
Culvert ref: Y15	**GPS co-ord:**	G 133062 306469	
Type of culvert:	Stone bottomless arched culvert		
Length of culvert:	6.2m	**Width of culvert:**	1.6m
Depth of flow in culvert:	10cm		
Hydraulic drop (Y/N):	Y (2 no.)	**Height of drop:**	30cm
Downstream pool (Y/N):	Y	**Depth of pool:**	20cm
Width of stream:	1m	**Depth of stream:**	10-30cm

Comment:

Riffles and glides in this section of the stream with no pool areas. There are two steps under this culvert, which each display a hydraulic drop of approximately 30cm. There are no transition pools downstream of these steps, except for the main pool downstream of the culvert itself. On the upstream mouth of the culvert, a small tree had fallen across the river and woody debris had collected at this tree.

Fish Passage Information Sheet			
Inspection: 05.01.07	**River:** Yellow	**Location:** Corlee	
Culvert ref: Y16	**GPS co-ord:**	G 133756 308645	
Type of culvert:	Round concrete (2 no.)		
Length of culvert:	6m	**Width of culvert:**	60cm
Depth of flow in culvert:	20cm		
Hydraulic drop (Y/N):	N	**Height of drop:**	-
Downstream pool (Y/N):	Y	**Depth of pool:**	25cm
Width of stream:	90cm	**Depth of stream:**	30cm

Comment:

The substrate of this stream appears to be heavily compacted and there are extensive growths of filamentous algae on the rocks and gravels. There is a large forestry plantation upstream of the culvert and possible excessive levels of silt and nutrient run-off are entering the river from this plantation. Six salmon redds were recorded upstream of this culvert in December 2005.

Three salmon redds were noted upstream on 9 January 2007.

Fish Passage Information Sheet

Inspection: 05.01.07	**River:** Yellow	**Location:** Corlee	
Culvert ref: Y17	**GPS co-ord:**	G 133769 308778	
Type of culvert:	Stone bottomless arched culvert		
Length of culvert:	6m	**Width of culvert:**	60cm
Depth of flow in culvert:	15cm		
Hydraulic drop (Y/N):	N	**Height of drop:**	-
Downstream pool (Y/N):	Y	**Depth of pool:**	25cm
Width of stream:	1m	**Depth of stream:**	15-20cm

Comment:

Stream is heavily overgrown upstream of the culvert with little light penetration to the bed.

Fish Passage Information Sheet

Inspection:	05.01.07	**River:** Yellow		**Location:**	Corlee
Culvert ref:	Y18	**GPS co-ord:**	G 133655 309148		
Type of culvert:		Stone bottomless arched culvert			
Length of culvert:		5.8m		**Width of culvert:**	90cm
Depth of flow in culvert:		<10cm			
Hydraulic drop (Y/N):		N		**Height of drop:**	-
Downstream pool (Y/N):		Y		**Depth of pool:**	20cm
Width of stream:		1m		**Depth of stream:**	10-20cm

Comment:

There are limited pool areas in this section of river; riffles and glides being the predominant features. While the stream averages 1m wide, it is heavily overgrown downstream and the mouth of the culvert was blocked by a quantity of heavy woody debris.

Fish Passage Information Sheet

Inspection: 06.01.07	**River:** Yellow	**Location:** Derrynabaunshy	
Culvert ref: Y19	**GPS co-ord:**	G 133490 309910	
Type of culvert:	Stone bottomless arched culverts (3 no.)		
Length of culvert:	3.8m	**Width of culvert:**	80cm
Depth of flow in culvert:	40cm		
Hydraulic drop (Y/N):	N	**Height of drop:**	-
Downstream pool (Y/N):	Y	**Depth of pool:**	50cm
Width of stream:	3m	**Depth of stream:**	10-40cm

Comment:

Substrate both upstream and downstream is heavily compacted. There is an extensive forestry plantation on both the right and left hand banks upstream and large deposits of silt are evident at the locations where forestry drains enter the river.