EirGrid Evidence Based Environmental Studies Study 6: Water Quality & Aquatic Ecology

Literature review and evidence based field studies on the effects of high voltage transmission lines on water quality and aquatic ecology in Ireland

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SUMMARY

The construction, operation, maintenance and decommissioning of transmission infrastructure can impact on the aquatic environment. This study examines the potential impacts of electricity transmission infrastructure on water quality and the plants and wildlife that live in this environment. This report includes a review and field study of the impacts of the construction, maintenance and operation of overhead lines (OHLs), underground cables (UGCs), substations and associated works.

This is an independent, evidence-based study prepared by experts in Environment Impact Assessment (EIA).

Purpose of this study:

- To determine the impact of transmission development on water quality and aquatic ecology;

- To provide a factual basis for development of guidelines for transmission projects.

The routing of transmission projects is a complicated process. A balance is needed between a number of issues, including our obligations to make sure we have a safe, secure transmission grid, land use constraints, cost, engineering and other technical requirements. We must also consider the impacts on the natural environment. Transmission projects can have the potential to impact on the aquatic environment where works take place near drains, streams, rivers and lakes. The aquatic environment must be considered when planning transmission development.

This study includes a literature review. Sediment release is the the most significant risk to water quality and aquatic ecology from transmission and other linear type projects (such as pipelines or roads). This can occur when clearing land for construction through erosion and run-off.

Run-off is water that flows over the ground surface and into nearby waterbodies. It can also enter the ground water in certain conditions. This movement of water allows the transfer of sediment and pollutants from the land to the water environment.

Other pollutants can come from concrete and hydrocarbons. These materials are used in tower foundations and culverts. Concrete and cement can change sediment load and water pH. Sensitive species such as freshwater pearl mussel and some aquatic plants can be negatively affected. Hydrocarbons are products made from crude oil. Leaks of these contaminants into watercourses can have serious impacts on aquatic species.

As part of the literature review, Environmental Impact Statements (EISs) prepared for transmission projects and underground pipelines were also reviewed. The EISs identified the construction phase as the most likely time for impacts to occur. Most impacts were predicted to be from sediment, cement/concrete and hydrocarbons.

As part of this study, field surveys were carried out along two powerlines in construction. The Binbane -Letterkenny 110kv line and Connemara 110kv line were in construction during the period of this study. Six sites were examined before, during and after construction of towers. This involved collecting biological, physical and chemical data from watercourses near construction sites. Samples were collected and assessments were made upstream and downstream of construction points; and before and after construction. Water quality was measured. PH, oxygen levels, temperature, nutrients, and suspended solids were also measured.

The results from the field studies showed that some sites had higher sediment, oxygen and nutrient readings downstream, post-construction, than at the pre-construction stage. However, some sites had higher readings of sediment and nutrients upstream. Others showed no change before or after construction. The reasons for increased levels of sediment, nutrients, or oxygen levels varied. They included construction works near watercourses with limited or no buffer zones, site clearance, damage or alteration to river banks / riparian zones and site flooding. Most impacts during construction are temporary. In a sensitive catchment such as a FPM area, the impacts can be significant and could trigger permanent effects.

The field studies highlighted that other land uses/pressures can affect water quality. These include forestry, natural bank erosion, agricultural drainage and animal poaching. Consideration of such pressures is particularly important when assessing in-combination effects.

The field studies showed the importance of mitigation measures such as silt barriers and buffer zones. A buffer zone of 25-30 meters can stop sediment and nutrients from entering local watercourses. Storing heavy machinery or materials on the buffer zone should be avoided because compaction of the ground can provide flow paths for sediment and contaminants into local watercourses.

Physical changes to river banks were shown to increase the risk of erosion and sediment levels through a reduced ability of the riparian zone to absorb run-off. The results showed that removing bank vegetation can affect aquatic ecology. It is recommended to fully restore any physical changes to banks to avoid long-term impacts of erosion and sediment release.

Wet and boggy ground presents difficult conditions for construction. The risk of sediment release and pollutants reaching watercourses is increased. Impacts in peaty areas and soft ground can be avoided or reduced by using sensitive construction techniques like bog mats and minimising the footprint of works.

Supervising works, employing an on-site ecologist, and monitoring are all measures that can help to ensure effectiveness of mitigation in protecting watercourses and aquatic species.

Follow up field surveys in 2015 found that any post-construction impacts had been reduced. No long-term impacts on water quality or aquatic ecology were found.

Best practice measures for protecting water quality are recommended for all stages of transmission infrastructure development. Preferred mitigation is to avoid impacts at source and minimise any that can't be avoided. To avoid negative impacts, adequate site assessment and detailed mitigation planning are central to sustainable transmission infrastructure. This is particularly important for supporting the aims of the Water Framework Directive and the Habitats Directive.

This study provides a factual basis for evidence-based water quality and aquatic ecology guidelines for transmission projects in Ireland. The guidelines will help to ensure a consistent approach to ecology, including water quality and aquatic ecology, at all stages of the development of transmission projects, and will provide the basis for future specialist EIA guidelines for this sector.

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1 INTRODUCTION

1.1 THE SCOPE OF THIS PROJECT

In April 2012, EirGrid published the Grid25 Implementation Programme 2011-2016, and associated Strategic Environmental Assessment (SEA).

The SEA identified a number of Environmental Mitigation Measures envisaged to prevent, reduce and, as fully as possible, offset any significant adverse impacts on the environment of implementing the Implementation Programme.

Environmental Mitigation Measure (EMM) 3 concerns *Preparation of Evidence-Based Environmental Guidelines*. These are intended to comprise a series of authoritative studies examining the actual effects of the construction and existence of transmission infrastructure in Ireland. The studies would thereby provide benchmarks to facilitate the robust preparation of projects with an evidence-based understanding of likely environmental impact.

Three types of studies are envisaged under EMM3:-

- **Environmental Benchmarking Studies:** to determine the actual effect, in respect of a number of environmental topics, of the construction and existence of transmission projects in a representative range of Irish environmental conditions – typical, non-standard, and worst-case. The studies, while authoritative, are conceived as an ongoing body of work that can be continuously updated to take account of new information and/or developments in understanding arising from practice and research;

- **Evidence-based Environmental Design Guidelines:** deriving from the factual basis and evidence contained in the initial Benchmarking Studies, these will provide practical guidance to practitioners and consultants in the planning and design of transmission infrastructure from the perspective of a particular environmental topic. These might comprise new guidelines, or the updating of existing guidelines;

- **Guidelines on EIA for Transmission Projects in Ireland:** Accompanying, or incorporated into the Design Guidelines, these are intended to provide an agreed and authoritative format for the preparation of EIA for transmission projects in Ireland, again in respect of particular environmental topics.

This Study is one of the Environmental Benchmarking Studies – to determine the actual effect of the construction and existence of transmission infrastructure in Ireland on its receiving environment.

1.2 THE AIMS OF THIS STUDY

This study examines the potential impacts of electricity transmission infrastructure upon water quality and aquatic ecology. This includes a review of the impacts from the construction, maintenance and operation of overhead lines (OHLs), underground cables (UGCs), substations and ancillary structures. A literature review and a series of field studies have been carried out.

The field study presents quantitative data from both a pre and post-construction phase. The study is focused on the direct impacts of electricity transmission development on water quality and aquatic ecology. The most significant risks are posed during the construction phase. In an attempt to highlight impacts on water quality which construction may have, a variety of sites with different scenarios were chosen.

There is a growing need to provide sound scientific evidence to the wider environmental debate regarding predicted and actual impacts. EirGrid is committed to gathering this information and at the same time improve current/best practice.

It is intended that the results of this study will provide the factual basis for evidence-based Ecology Guidelines for transmission projects. The Guidelines will help to provide the basis for future specialist Environmental Impact Assessment (EIA) guidelines for this sector.

1.3 THE TRANSMISSION NETWORK AND WATER QUALITY & AQUATIC ECOLOGY

Electricity supply is an essential service in Ireland’s economy. The transmission system is an extensive network of high-voltage 400kV, 220kV and 110kV OHLs and cables and plays a vital role in the supply of electricity.

The development of the transmission network is the responsibility of EirGrid, the Transmission System Operator (TSO) under statutory instrument 445 (2000)[1]. EirGrid is committed to delivering quality connection, transmission and market services to its customers and to developing the transmission grid infrastructure required to support the development of Ireland’s economy.

Grid development requires a careful balance between meeting the technical requirement for a project, the costs of that project, and the environmental impact of that project.

An overview of the primary types of transmission infrastructure, including an outline of construction methodology is in **Appendix II** of this study.

[1] Statutory Instrument 445 (2000), entitled European Communities (Internal Market in Electricity Regulations, 2000)

Aquatic ecology and the ecological status of waterbodies are largely dependent on water quality. Therefore water quality is a key supporting element to the determination of the ecological status of waterbodies under the Water Framework Directive (WFD) (Directive 2000/60/EC). Transmission infrastructural projects have the potential to result in localised impacts to water quality[2] and the aquatic environment. EirGrid is committed to the preservation of the aquatic environment and ensuring that transmission infrastructure development is undertaken in an environmentally sensitive manner.

In transmission infrastructure development, every effort is made to cause least disturbance to landowners and local residents during construction. However, it is also necessary to ensure that the preferred/chosen route does not negatively impact upon the wider environment which includes waterbodies and aquatic ecology. Most potential impacts are thought to occur during the construction phase but impacts can also occur during maintenance and decommissioning periods. Impacts include increased run-off, reduced water retention in construction area, increased sedimentation, impacts on adjacent sensitive habitats, and the risk of accidental liquid/oil spills.

Many impacts are regarded as typical and unavoidable. However, through careful route selection and appropriate mitigation these impacts can be avoided or managed to negligible levels.

The significance of the effects on the aquatic environment depends on the location, extent of development and potential for screening and implementation of effective mitigation.

1.4 STUDY LAYOUT

The study begins with a comprehensive literature review (Section 2). Several sources of information on the impacts and effects of transmission infrastructure on water quality and aquatic ecology are presented. Several linear type infrastructure projects with EISs are also referred to as case studies for the assessment of the treatment of impacts. The construction techniques for the construction, operation and maintenance of 110kV, 220kV and 400kV transmission projects are then detailed (Section 3) with a focus on the construction stage. Mitigation and best practice guidance are also reported (Section 4.0) with an emphasis made on the importance of avoiding or minimising impacts. EirGrid's Ecology Guidelines are also referred to. The methodology used in the individual field surveys for four different construction projects is then presented (Section 5.0) as well as important information explaining how six survey sample sites were chosen to cover worst-case, non-standard and typical conditions/scenarios. The results from the six surveys are discussed with detailed information provided on the types of survey carried out i.e. physico-chemical, macro invertebrate and river hydromorphological assessments (Section 6.0). Conclusions from the results and discussion are

[2] The EU Water Framework Directive (WFD) classifies water into five groups based on water quality – high, good, moderate, poor and bad.

made (Section 7.0). Recommendations are also provided for future projects during the construction, operation and restoration stages with monitoring recommended throughout (Section 8.0).

2 LITERATURE REVIEW

2.1 OVERVIEW

A review of research literature has been undertaken, with the aim of summarising the present state of scientific knowledge regarding the impacts of high-voltage electricity transmission infrastructure on water quality and aquatic ecology. This literature review has been undertaken to determine the impacts from both overhead and underground electricity transmission infrastructure, during construction, operation and maintenance.

Another aspect of the operation of electricity transmission infrastructure is the effects (if any) of electromagnetic fields (EMF) produced by electricity transmission cables on freshwater species. Despite the expansion of electricity transmission networks in many countries research on the effects of EMF on freshwater species has largely been neglected (Basov, 2007; Gill *et al*., 2005). A secondary aim of the literature review is to present the current scientific evidence of the effects (if any) of EMF on freshwater species.

Scientific literature dealing specifically with water quality and aquatic ecology impacts arising directly from high-voltage electricity transmission infrastructure is extremely limited. This is not currently an issue that has received significant attention from research institutions; therefore the review has been supplemented with other relevant literature where applicable. This includes a review of literature which identifies impacts upon the water environment arising as a result of similar or related projects including gas pipeline projects. A review of scientific peer-reviewed articles was undertaken in order to assess the impacts of the key pollutants identified as having the potential to enter the water environment. The scientific literature has also been supplemented through a review of published documentation including best practice guidance and relevant Environmental Impact Statements (EISs).

Surface water quality can be affected by a wide range of factors including climate, landscape, geology, as well as land use and land management (Brainwood *et al*., 2004). As land use and land management practices are the most prone to change, they are often some of the most important aspects in catchment management. This highlights the importance of developing an understanding of the impact of land use and management practices on water quality parameters (Brainwood *et al*., 2004). However, the links between land use, land management and water resources can be extremely complex, particularly due to spatial heterogeneity (Weatherhead & Howden, 2009).

This is particularly important when considering hydrological processes that are most important in the transfer of precipitation to a watercourse. Surface water flow may be the result of a combination of a wide range of hydrological flow paths including direct runoff or overland flow, shallow through-flow, and base flow from groundwater (Weatherhead & Howden, 2009). In any given catchment the proportional contribution from each of these sources is likely to vary spatially and temporally

(Weatherhead & Howden, 2009), meaning there are likely to be substantial spatial and temporal variations in the quality of surface waters.

There is also a strong relationship between land use and groundwater quality which can have a particularly important impact on surface water during baseflow (Lerner & Harris, 2009). The impact upon water quality from groundwater discharging to surface water has often been overlooked in the past, particularly in the case of poorly productive bedrock aquifers (PPAs) (Cassidy *et al*., 2010). Activities, such as contaminant spillages, which result in the release of diffuse pollutants, can result in a pollutant building up and being stored in the aquifer (Lerner & Harris, 2009). This is a long-term water quality issue as contaminants are continually discharged to surface water, possibly for a long period after the source of pollution at the surface ceases (Lerner & Harris, 2009).

Therefore the introduction of new high-voltage electricity transmission infrastructure including OHLs, UGCs, substations and ancillary structures, has the potential to impact upon both surface and groundwater quality, through the changes to practices and land use along the length of the line, including clear felling of forest stands to facilitate the introduction of transmission infrastructure. These impacts may occur during the construction, operation or maintenance of the electricity transmission infrastructure. In order to determine the potential impacts that may arise, a review of relevant scientific literature along with EISs and best practice guidance was undertaken to indicate the parameters of interest.

Construction operations in general can have a substantial impact on water quality in an area, with run-off from construction sites having the potential to have detrimental impacts on aquatic ecosystems (Alsharif, 2010). Sediment in particular can be a significant problem as sediment export rates from construction sites vastly exceeds the export rate from agricultural land by several orders of magnitude (Harbour, 1999; USEPA, 2005; Alsharif, 2010). Construction sites have historically contributed significantly to the ecological degradation of aquatic ecosystems (Masters-Williams *et al*., 2001).

Spills of fuel and oil as well as contaminants and chemicals which bind to sediments can be significant issues and present a risk when machinery or vehicles are present anywhere on a construction site (Masters-Williams *et al*., 2001; Alsharif, 2010). A lack of adequate mitigation measures have caused, for example, the contamination of potable water supplies, major kills of fish and aquatic invertebrates, obliteration of benthic and bank-side habitats and aesthetic degradation (Masters-Williams *et al*., 2001).

Linear construction projects such as transmission lines often pose a more significant risk to the water environment than construction operations limited to one site (Murnane *et al.,* 2006). This is due to the much larger range of environments that linear projects can affect, potential cumulative impacts and the distances that require management (Murnane *et al*., 2006). There is the potential for a large number of watercourse crossings, through varied environments, topography, soil types, geology and habitats, each requiring differing water management techniques (Murnane *et al.,* 2006).

Where the route of overhead transmission lines traverses commercial forest plantations, clear felling is required in order to facilitate construction and the maintenance of the way-leave ensuring adequate clearance is achieved. Forests have the potential to have a positive or negative effect on water quality. The potential negative effects of commercial forest management on water quality have been well described (e.g. Johnson *et al.*, 2008; Marks & Rutt, 1997; Carling *et al.*, 2001; Nisbet *et al.*, 2011). Problems can occur from drainage, ground preparation, fertiliser application, thinning, harvesting and replanting and include damage to internal water networks, and exacerbation of sediment and nutrient movement from road building and machinery movement at all stages of the crop (Forest Service, 2000; Forestry Commission, 2003).

Harvesting is the main forestry activity associated with transmission line development whereby forest plantations or corridors within the plantation are felled to accommodate the transmission line and provide the required clearance. The main impacts of forestry harvesting relate to sedimentation, nutrient enrichment and flow regime (Moorkens *et al*., 2013).

Harvesting can release phosphorus (P)[3] that has remained in the soil as well as that in the needles and brash that is left on site (Piirainen *et al.* 2004, 2007). The decomposition of P-rich harvest residues (i.e. needles, twigs, roots, bark and branches) left on the harvested area could further increase P release after harvesting (Piirainen *et al.*, 2004).

Use of machinery on fragile soils is difficult to mitigate, and severe ground damage can result from forestry harvesting operations leading to increased sediment delivery, turbidity[4] and downstream siltation (Marks & Leeks, 1998). The number of vehicle movements and vehicle type is an important determinant in the level of damage, as is the temporal nature of their deployment in relation to weather conditions or seasonal patterns of relevant key species.

Up until the 1990s forestry plantations included extensive drainage practice whereby road and land drains were dug on steep gradients and discharged directly into watercourses. New drainage guidelines drain at an acute angle to the contour, and taper out before entering the aquatic buffer zone (Forest Service, 2000). Older drains can be blocked prior to, during or following harvesting. Improved drainage and buffer management can play an important role in mitigating nutrient and sediment movement. However, this may not be enough to restore natural hydrological flows to the river if the majority of the site remains drained (Moorkens *et al*., 2013).

2.2 PUBLISHED REPORTS RELEVANT TO TRANSMISSION INFRASTRUCTURE

A number of reports have been undertaken by regulatory bodies and independent commissions to assess the environmental impacts of overhead transmission lines and UGCs on the environment.

[3] Symbol for the chemical element phosphorous.
[4] Cloudiness or haziness of a fluid caused by large numbers of individual particles.

Available studies have been reviewed in order to inform the focus of this literature review. Although these studies are not authoritative peer-reviewed studies, they have been undertaken in order to inform both the public and regulatory bodies of the impact of these developments. These reports have been used as they have been undertaken or commissioned by bodies with the goal of serving public interest.

2.2.1 Ecofys study on the comparative merits of overhead electricity transmission lines versus underground cables

This independent review was commissioned by the Irish Department of Communications, Energy and Natural Resources (DCENR) and was carried out by Ecofys (Burges *et al*., 2008). The key aim of this report was to assess the relative costs and likely environmental impacts of high-voltage OHLs and UGCs.

The report highlights that OHLs generally carry some risk in the construction phase in the form of potential for increased sediment load in surface waters. An increase in suspended sediment loads has the potential to adversely affect aquatic ecosystems. However, as structures are usually placed away from watercourses, potential impacts are not usually significant and especially where effective mitigation measures are implemented. This report highlights that the operational effects on water resources are mostly in relation to visual impact on scenic water courses rather than directly affecting water quality or quantity.

The key impacts of UGCs are the disruption to groundwater including wetlands and their drainage potential; and temporary disruption to surface waters during construction. This report suggests that UGCs carry greater risk in the construction phase than OHLs when they cross watercourses as there is potential for physical disturbance during the installation of UGCs. This may result in an increase in suspended sediment loads within a watercourse, which has the potential to have adverse impacts upon aquatic ecosystems. Methods to cross watercourses include using crossings at bridges, directional drilling under the river bed and placing the cables in ducts on the river bed. However, it has been highlighted that placing cables in ducts on the river bed, where the river may require diversion, may pose a significant threat to aquatic life during construction.

2.2.2 Public Service Commission of Wisconsin (PSCW)

The Public Service Commission of Wisconsin (PSCW) is an independent regulatory agency in the United States of America dedicated to serving the public interest and is responsible for the regulation of public utilities in Wisconsin. The PSCW conducted a review of the environmental issues and concerns raised by the construction and operation of electric transmission facilities, and suitable mitigation measures to reduce the potential for adverse impacts.

For OHLs, the key issue in relation to the water environment was the potential for increased erosion and overland flow which may adversely affect aquatic habitats (PSCW, n.d. (a)). However a range of mitigation measures were proposed within the study, in order to minimise the impact on the aquatic environment. This includes re-routing the lines away from watercourses, adjusting pole placements, limiting working times during wet months and making use of wide-track vehicles to limit ground disturbance.

For UGCs the impact will depend on the construction methodology. With directional drilling there are generally fewer impacts than open trench (PSCW, n.d. (b)). However, directional drilling does require potentially large construction entrance and exit pits on either side of the resource, which may result in the release of sediment and pollutants. There are also concerns about the potential for 'frac-outs' which can release drilling fluids into the waterbody and sub-surface environment. Mitigation measures include making use of approved erosion control methods, avoiding wetlands and minimising areas of exposed soil.

2.3 SEDIMENTATION

A study into the impact that high-voltage electricity transmission infrastructure may have on soils and geology focused on the degree to which construction and maintenance operations affects soil release prior to entering water courses. The Water Quality and Aquatic Ecology Study focuses on the direct impact on water quality and aquatic ecology as a result of additional sediment entering nearby watercourses due to high-voltage electricity transmission projects.

Sediment is a natural and essential component of river systems and plays a major role in the hydrological, geo-morphological and ecological functioning of watercourses. In fact, a dynamic balance in watercourses normally exists between the particle size and amount of sediment transported by a stream or river, and the discharge and slope of that stream or river (Owens *et al.,* 2005). However, in many parts of the world, the level of human activity is such that it has led to increased rates of sediment input over a natural baseline, resulting in increased concentrations of sediment in the water column (i.e., increased turbidity) and increased deposition of sediment on the river bottom, and downstream waterbodies. Sediment loads are a widespread major pollutant of surface waters worldwide and are the most important off-site impact of soil erosion (Alsharif, 2010; Pimental *et al.,* 1995; Waters, 1995). Landscape alterations by human activities accelerates surface soil erosion by modifying basic components of the hydrologic cycle and increasing the amount of bare soil exposed to rainfall and run-off (King & Tennyson, 1984; Chamberlin *et al.,* 1991). Anthropogenically increased sediment loads are one of the most pervasive pollution pressures on surface waters and carry major ecological implications for aquatic ecosystems (Garcia Molinos & Donohue 2008, Donohue & Garcia Molinos 2009).

While sediment is considered the single greatest pollutant of watercourses in the United States of America (USA), it has not received as much focus throughout Europe (Harrod & Theurer, 2002). However, in recent years there has been increased interest in the environmental impact of sediment in rivers and streams (Walling, 2005). This has become particularly important since the introduction of the Water Framework Directive (Directive 2000/60/EC), which requires all surface water bodies to achieve **good** ecological status. While sediment is not directly specified as a parameter within the WFD Directive, it is clearly an important aspect of water quality as it has the potential to affect the achievement of WFD objectives. In particular it has the potential to impact upon the hydromorphological quality elements and ecological status of a water body (Watts *et al.,* 2003; Brils, 2008; Walling & Collins, 2008). In Annex V of the WFD, sediment as a pollutant is mentioned in so far as it affects the quality of the substrate and hydromorphology, so that it might impact on some elements such as phytoplankton and macrophytes. Annex V of the WFD makes specific reference to "Pollution by other substances identified as being discharged in significant quantities into the body of water". In this respect quality of the sediment can also refer to excess sediment above what would be natural, and therefore is covered by the WFD.

Although sediment is required as part of a natural fluvial system, significant deviations from the natural quantity and quality of sediment can result in a wide range of problems (Walling, 2005; Brils, 2008). Fine sediment in particular can be an important vector in the transport of various nutrients and contaminants such as phosphorus, pesticides, polychlorinated biphenyls (PCBs), heavy metals and pathogens through fluvial systems (Walling, 2005). This is due to the much greater surface area that fine particles have for the same unit mass in comparison with larger particles, which results in greater adsorption and transfer of contaminants (Archbold *et al*., 2010). As a result focus has increasingly been placed on assessing the role of fine sediment as an extremely important means of transferring diffuse pollutants from land into river channels (Russell *et al*., 2001).

Research indicates that the equivalent of many decades of natural or even agricultural erosion may take place during a single year from areas cleared for construction (Wolman and Schick, 1967; Dearing and Jones, 2003). Even relatively small concentrations of fine sediment reduce autotrophic production (Davies-Colley *et al*., 1992), diminish algal organic content (Graham, 1990; Yamada & Nakamura, 2002), impair invertebrate feeding and growth (Peeters *et al*., 2006; Donohue & Garcia Molinos, 2009), increase fish mortality and reduce survival of eggs and larvae (Reynolds *et* al., 1989, Suttle *et al.*, 2004; Donohue & Garcia Molinos, 2009), with substantial overall negative implications for the abundance, diversity and productivity of aquatic communities (Donohue & Garcia Molinos, 2009).

2.3.1 Effects of Sediment Loading on Aquatic Ecosystems

2.3.1.1 Aquatic Plants (Primary Producers)

In Ireland there is a strong relationship between the transfer of sediment from a catchment surface and loss of particulate P. P is generally regarded as the limiting nutrient in freshwaters (Smith *et al*., 2005; Nasr *et al*., 2007). The combined impact of both sediment and P-loss to surface waters can be significant, as it can result in excessive macrophyte and filamentous algal growth which in turn can encourage even more sediment deposition (Schulz *et al*., 2003).

Sediment loading leads to increased turbidity within watercourses, which reduces the amount of light available to aquatic plants for photosynthesis, while deposited sediments can result in the smothering of aquatic plants (Haslam, 2006). High turbidity and sedimentation rates have been shown to reduce the density (Moss, 1977), growth rates (Lewis, 1973), photosynthetic activity (Chandler, 1942), regeneration (Spencer & Ksander, 2002) and depth of colonisation (Canfield *et al.,* 1985) of aquatic plants, as well as causing considerable physical damage to their leaves (Lewis, 1973).

2.3.1.2 Macroinvertebrates

Invertebrates play a highly important role in the food-webs of aquatic ecosystems and in the sequestration and recycling of materials (Underwood, 1991; Schindler & Scheuerell, 2002). Both experimental work and field surveys (Donohue & Irvine, 2004; McIntyre *et al*., 2005) have found that anthropogenically increased sediment loading can significantly alter the size structure of populations of invertebrates. Alterations to the size structure of populations can have significant knock-on effects on both intra- and interspecific interactions, population dynamics (De Roos *et al*., 2003) and food-web stability (McCann, 2000). Macroinvertebrate populations form a vital aspect of the assessment of ecological status under the WFD.

The introduction of fine sediment to catchments containing populations of important protected species such as the freshwater pearl mussel (*Margaritifera margaritifera*), abbreviated henceforth to FPM, can continue to cause very serious effects on a long term basis (Ellis, 1936; Marking & Bills, 1979; Killeen *et al*., 1998; Araujo & Ramos, 2001; Naden *et al.*, 2003). This is particularly important, as where a water-dependent habitat or species listed under the Habitats Directive has been assessed as being at unfavourable conservation status, the status assigned under the WFD can be reduced to less than good even if all other biological water quality variables are conducive to high or good status (Mayes & Codling, 2009).

"For the purpose of calculating the ecological status of a body of surface water in accordance with Part IV of these Regulations, the Agency shall, in the case of those surface water bodies which are also protected areas requiring special protection by virtue of standards or objectives arising from specific Community legislation for the protection of water or for the conservation of habitats and species directly dependent on water at European sites, assign a status of less than good ecological status where the standards or objectives for the protected area are not met arising from a failure to meet the required water quality or hydrological standards. Where appropriate, the use of additional site specific biological, microbiological or chemical indicators will be used." (S.I. 272 of 2009)

The FPM requires very high quality rivers with clean river beds and waters, with very low levels of nutrients. In general, rivers and river bed habitat needs to be at near natural conditions. Where water quality has been depressed, mussel numbers can rapidly decline.

Direct ingestion of silt by adult mussels can lead to rapid death. However, if the mussels clam-up as a response to a siltation episode, and siltation is prolonged, they die from oxygen starvation over a period of several days (Moorkens *et al.*, 2007). During periods of high water temperatures oxygen starvation is more acute and death occurs more rapidly. The *Margaritifera* gills and the annual brooding of young in all four of the gills demand a continuous and high supply of oxygen. If the mussels survive the initial silt episode, the food/oxygen deprivation from clamming will nevertheless cause stress from which they will take a long time to recover. If during that recovery period, there are further incidents of mobilisation of silt then the stressed mussels are more susceptible to death than mussels in a cold river, in unstressed conditions. Thus mortalities may continue over a period of several months, particularly during summer (Moorkens *et al.*, 2007). The decline in adult habitat through increased turbidity can also be severe (Österling, 2010).

Sedimentation of the channel bed is a significant factor in the widespread mortality of juvenile FPM (Beasley & Roberts, 1999; Moorkens *et al.*, 2007). Although adult mussels can withstand elevated sediment levels for short durations, juvenile mussels are much more sensitive. They spend their first five years buried within the river bed substrate; therefore even one sedimentation event during this five year period can prevent oxygen exchange and result in the mortality of all juvenile mussels buried within the substrate (Buddensiek *et al.,* 1993; Buddensiek, 1995). The sediment subsequently provides a medium for macrophyte growth, which can be a negative indicator of quality in pearl mussel habitats (Laughton *et al.*, 2008). Macrophytes then smother the juvenile habitat even further, and the macrophytes trap more sediment which exacerbates the problem in the long term. Silt infiltration of river bed gravels can also have a negative effect on fish species that are essential hosts for the mussel glochidial[5] stage (Levasseur *et al.*, 2006).

Linear projects have been identified as a significant risk to pearl mussel populations, with road construction a frequently cited issue (Forest Service, 2008; NS2, 2009). Road wash and surface drainage is a source of diffuse sediment, which can be a vector in the transport of nutrients, silt and toxic substances on an ongoing basis, as well as the severe siltation risks during construction activities (Araujo & Ramos, 2001; DEFRA, 2004).

2.3.1.3 Fish

Exposure to increased sediment loads may have considerable detrimental effects on fish communities, including: reduced survival of eggs and larvae (Reynolds *et al.*, 1989); gill damage and increased gill-flaring (Sutherland & Meyer, 2007); reduced growth rates and reduced length at sexual maturity (Bruton, 1985; Sutherland & Meyer, 2007); increased mortality (Bruton, 1985; Suttle *et al.*, 2004); emigration from affected areas (Utne, 1997); increased susceptibility to toxicants (McLeay *et al.*, 1987); disrupted migration patterns through avoidance (Bruton, 1985); altered breeding behaviour (Wilber, 1983); and increased incidence of infection (Servizi & Martins, 1991). All of these culminating

[5] Early larval development stage of some freshwater mussels.

in reduced population sizes (Richardson & Jowett, 2002) and altered community dynamics and functional characteristics (Mol & Ouboter, 2004).

Some of the key concerns with elevated levels of sediment include the impact on spawning fish, through issues including the sedimentation of spawning gravels, clogging of fish gills and reduction in dissolved oxygen (Acornley & Sear, 1999; Sear *et al*., 2008; Collins *et al*., 2011). Salmonid egg incubation in the autumn often coincides with times of greatest sediment loss potential from land to water as high magnitude storm events are likely to coincide with a low soil moisture deficits and some land uses still have exposed soil surfaces (Jensen *et al*., 2009; Deasy *et al*., 2009b).

2.3.1.4 Land Use and Sediment Dynamics

The sediment within any fluvial system is made up of sediment derived from a wide range of locations and sources, which vary in their relative importance (Carter *et al*., 2003). The suspended sediment within a river is inextricably linked with the land use and land management of the catchment. A study by Kasai *et al*. (2005) highlighted the significant impact that land use change can have on the sediment fluxes in a river. Large scale deforestation and introduction of pastoral farming extensively altered sediment delivery patterns from their un-impacted state, which altered channel morphology. Although this represents an extreme scenario, it highlights the influence land use can have on sediment delivery in a catchment. Therefore changes to the land use and land management through the introduction of high-voltage electricity transmission infrastructure, particularly during the construction phase, has the potential to result in changes to sediment dynamics.

The impacts of drainage systems can also be significant, as un-drained land is more likely to result in overland flow than drained land, which can increase the potential for erosion of soil at the surface layer (Bottcher *et al*., 1981; Bilotta *et al*., 2008). Although research by Bilotta *et al*. (2008) determined that sub-surface drainage had a positive effect of reducing erosion and suspended sediment delivery to the river, there is increasing evidence that an extensive sub-surface drainage network can result in the loss of considerable quantities of sediment during storm events (Chapman *et al*., 2001; Deasy *et al*., 2009a). Deasy *et al*. (2009a) found that sub-surface drainage acted as the dominant pathway for the delivery of sediment to the river channel, which was attributed to a reduction in overland flow and limited hydrological connectivity between the hillslope and the stream. This may have implications for electricity infrastructure projects which may have the potential to affect hydrological connectivity and patterns of drainage and overland flow.

There are significant temporal variations in the mobilisation of sediment, as a large proportion of the sediment reaching a water body occurs as a result of a small number of storm events (Smith *et al*., 2003; Walling, 2005). Research conducted by Smith *et al*. (2003) into the transport of fine sediment in the River Swale in Yorkshire, UK, found that a high proportion (66%) of the transfer of fine sediment takes place during storm events that last less than 5% of the total year. Therefore storm events that coincide with construction activities which result in physical disturbance to the surface have the potential to contribute significant quantities of sediment to the water environment.

When considering the catchment surface as a source of sediment, erosion risk is a critical factor in how much sediment reaches the river, which is linked to a range of issues including soil type, rainfall, hill-slope, and in particular land use and land management practices (Evans *et al*., 2006). Construction activities and the associated changes as a result of development can result in changes to erosion risk and therefore lead to long-term changes to the sediment dynamics within a catchment (Harbor, 1999).

Hydrological connectivity is a key factor which affects the risk of erosion and subsequent delivery of sediment to the river channel. Hydrological connectivity can be broadly defined as the way upland slopes connect with a river or stream, with the greatest connectivity between those areas where conditions such as soil wetness, soil properties and surface and bedrock topography, result in the occurrence of overland flow (McGuire & McDonnell, 2010). Research by Reid *et al*. (2007) concluded that most of the sediment inputs in their study catchment were derived from areas which have high hydrological connectivity with the river channel. Therefore disturbance activities in an area with high hydrological connectivity with a river may result in a significant increase in the sediment inputs to a river from these areas (Reid *et al*., 2007).

2.3.1.5 Mitigation Measures to Prevent Sedimentation

When developing mitigation measures to tackle sediment losses, it is important to have a comprehensive understanding of the source-pathway-receptor model. This model shows that a contaminant only presents a risk where a pollutant linkage connects all three essential elements (EA, 2004) as outlined below:

- Source: A contaminant or substance that that has the potential to cause harm (e.g. case sediment)
- Pathway: A route or means by which a receptor can be exposed to a contaminant (e.g. overland flow)
- A receptor: something that on exposure to a contaminant may be adversely affected (e.g. water body)

Clearly, having an understanding of the source of sediment within a catchment, combined with knowing the mechanism by which the sediment may reach a nearby water course enables development of effective mitigation measures (Russell *et al*., 2001). However, the interactions between these three factors can be extremely complex, for example surface run-off may be identified as the pathway by which most sediment reaches a nearby waterbody from a certain area of land. Therefore sub-surface drainage may be implemented to reduce overland flow and prevent this pathway delivering sediment to the waterbody. However, this may actually introduce a new pathway for sediment to reach the watercourse more rapidly by increasing the area of hydrological connectivity

(Russell *et al.,* 2001). Therefore the most successful mitigation measures are those focused on breaking the pollutant linkage and ensuring a new pollutant linkage does not exist.

2.4 CEMENT AND CONCRETE

Cement and concrete can cause serious pollution to both surface and groundwater due to the highly alkali and corrosive properties of fresh concrete (Setunge *et al*., 2009; EA, 2011). The full impacts of the use of freshly cast concrete in contact with water have not been fully investigated in the past; however, a significant increase in alkalinity has been recorded in streams in contact with freshly installed concrete culverts (Setunge *et al*., 2009). Research carried out by Setunge *et al*. (2009) indicated that contact with fresh concrete can lead to an increase in the pH levels of water up to a pH value of 11. This research also indicated that if water comes in contact with concrete at any time within the first four days, the peak in the pH of the water will be similar. After four days if water comes in contact with the concrete the pH is significantly lower than during the first four days.

Concrete wash water is a particularly severe pollutant, as it typically has a high pH (11-12) coupled with extremely high suspended sediment content (Sealey *et al*., 2001; EA, 2011). Indeed concrete wash-water often contains several trace metals and contaminants (EA, 2011). There has been increasing research over the potential for these chemicals to be leached from concrete and cementitious materials (Hillier *et al*., 1999). The degree to which metals may be leached varies depending on environmental factors and the mechanisms involved in leaching rather than the availability of trace metals contained in concrete (Müllauer *et al*., 2012). The environmental implications of the release of heavy metals to the water environment are significant. This could result in a decline of high to good status or a failure to meet good chemical status in line with the WFD.

In the freshwater environment, pH levels which are elevated beyond natural conditions can have significant impacts upon water bodies (Setunge *et al*., 2009). In general, the optimum pH levels in the freshwater environment for fish species is 5.50 - 9.00, as defined within the Freshwater Fish Directive (Directive 2006/44/EC, Annex I). However, there are some variations between this guideline and the tolerance of different species and the natural conditions of the water body (Setunge *et al*., 2009). Indeed there is no definite pH range within which fish will be unharmed; however, there is a gradual deterioration as pH values extend outside the typical range (EIFAC, 1969). FPM (*Margaritifera margaritifera*) can be adversely affected by elevated pH levels, for examples in areas where liming is undertaken, as the increased availability of calcium means they grow at a much faster rate (Killeen *et al*., 1998), and suffer reduced reproduction periods, which is contrary to their life strategy (Comfort, 1957; Ross, 1988). Human induced acidification is also considered damaging to mussel populations through gradual dissolution of their calcareous shell, and through problems with regulation of acid-base mantle fluid homeostasis (Vinogradov *et al*. 1987), hence the relatively neutral optimum pH range of 6.5 to 7.3 for *Margaritifera* (Moorkens *et al*., 2007).

Changes in pH values can also affect various other water quality variables, which may have adverse impacts upon aquatic ecology (Franklin *et al*., 2000). There is a relationship between pH and toxicity of metals to different species of flora and fauna (Franklin *et al*., 2000), where aluminium for example has a greater toxic effect at lower pH. The toxicity of certain other notable pollutants such as ammonia increases with increasing pH (Wurts, 2003). Ammonia is toxic to aquatic organisms, particularly to early juvenile stage freshwater bivalves (Wang *et al.*, 2007). Research by Hansen (2002) demonstrates that elevated pH levels have a limiting impact on the growth rate of aquatic flora such as phytoplankton. While there were some species more tolerant than others, none of the species studied by Hansen (2002) were able to maintain their maximum rate of growth when the pH exceeded a value of 9.

2.5 HYDROCARBONS

Total Petroleum Hydrocarbons (TPH) is a term used to describe a broad range of chemical compounds (several hundred) that originate from crude oil. Oil spillage and leaks are a common source of hydrocarbon contamination of groundwater and surface water (Manoli and Samara, 1999). When there is a spill of oil or fuel it is not feasible to determine each individual hydrocarbon that is present therefore TPH is a useful indicator of contamination (ATSDR, 1999). The contamination caused by petroleum products will contain a mixture of different hydrocarbons and there may be some difference between the impacts observed (ATSDR, 1999).

When TPH is released to the environment as a result of accidental spillages, there may be some fractions that float on top of the water, forming a thin surface film. Other heavier fractions may sink in surface waters and accumulate in the sediment at the bottom of the water, which may affect bottom-feeding fish and organisms. When the spill occurs in areas where the underlying aquifers are vulnerable, there may be instances where the hydrocarbons reach the water table and float on the water table. While certain fractions may sink through the aquifer and sink to bedrock aquifer (ATSDR, 1999).

The release of hydrocarbons to the water environment can result in chronic impacts upon species living within the water-column (Bhattacharyya *et al*., 2003). The potential impacts include disruption to neurosensors, abnormal behaviour and development issues as well as direct impacts upon fertility (Bhattacharyya *et al*., 2003). Exposure to the polycyclic aromatic hydrocarbon (PAH) fractions of oil in the early life stages of fish can result in serious development defects and haemorrhaging, the effects which are known as blue sac disease (Hodson *et al*., 2008).

Bhattacharyya *et al*., (2003) highlight that spills of oil can reduce the capacity of a water body to exchange oxygen as well as result in oil coating the gills of aquatic species causing lesions on respiratory surfaces. This can result in significant oxygen-supply difficulties for aquatic organisms affecting their respiration. Benthic invertebrates can be adversely affected if fractions of hydrocarbons settle and accumulate in sediments. This can result in the mortality of populations and prevent future colonisation (Bhattacharyya *et al*., 2003). The primary route of hydrocarbon uptake is via the gills; therefore the dissolved fraction is often the greatest concern as it is the most readily available (Thomas & Rice, 1981 cited by Ramachandran *et al*., 2004).

2.6 ELECTROMAGNETIC FIELDS (EMF)

Across the world, high voltage electricity transmission lines pass over streams, rivers, lakes, and reservoirs on a frequent basis (Basov, 2007). According to Jenkins *et al.* (2010) over 65 million km of medium and high voltage power lines are currently in use around the world and this is growing by 5% each year. In Ireland it is predicted that by 2025 there will be a substantial extension of the transmission infrastructure to accommodate 60% more power to cities and towns across Ireland (EirGrid, 2008). Despite the expansion of transmission networks, research on the possible effects of electromagnetic fields (EMF) from overhead power lines on freshwater species has largely been neglected (Basov, 2007; Gill *et al*., 2005).

(For more specific information on EMF, the EirGrid Evidence Based Study on EMF is recommended.)

Many terrestrial and aquatic animals can sense the Earth's magnetic field and appear to use this magnetosensitivity for long distance migrations. Aquatic species whose long distance migrations or spatial orientation appear to involve magnetoreception include eels (Westerberg and Begout-Aranas, 2000; cited in CMACS 2003), spiny lobsters (Boles and Lohmann, 2003), elasmobranchs (Kalmijn, 2000), sea turtles (Lohmann and Lohmann, 1996), and rainbow trout (Walker *et al.,* 1997). Four species of Pacific salmon were found to have crystals of magnetite within them and it is believed that these crystals serve as a compass that orients to the earth's magnetic field (Mann *et al.,* 1988; Walker *et al*., 1988).

Natural electric fields can occur in the aquatic environment as a result of biochemical, physiological, and neurological processes within an organism or as a result of an organism swimming through a magnetic field (Gill *et al*., 2005). Some of the marine elasmobranchs (e.g., sharks, skates, rays) have specialized tissues that enable them to detect electric fields (i.e., electroreception), an ability which allows them to detect prey and potential predators and competitors. Sturgeon can utilize electroreceptor senses to locate prey, and may exhibit varying behaviour at different electric field frequencies (Basov, 1999).

Despite the wide range of aquatic organisms that are sensitive to EMF and the increasing numbers of underwater and overwater electrical transmission cables being installed in rivers and coastal waters, little information is available to assess whether animals will be attracted, repelled, or unaffected by these new sources of EMF (Cada *et al.,* 2012). This knowledge gap is especially significant for freshwater systems, where electro-sensitive aquatic organisms may interact with electrical transmission cables (Cada *et al.,* 2012).

Bochert and Zettler (2006) summarized several studies of the potential injurious effects of magnetic fields on marine organisms. They subjected several marine benthic species (i.e., flounder, blue mussel, prawn, isopods and crabs) to static (DC induced) magnetic fields of 3,700 μT for several weeks and detected no differences in survival compared with controls. In addition, they exposed shrimp, isopods, echinoderms, polychaetes, and young flounder to a static, 2,700 μT magnetic field in laboratory aquaria where the animals could move away from or toward the source of the field. At the end of the 24h test period, most of the test species showed a uniform distribution relative to the source, not significantly different from controls. Only one of the species, the benthic isopod, *Saduria entomon*, showed a tendency to leave the area of the magnetic field. The oxygen consumption of two North Sea prawn species exposed to both static (DC) and cycling (AC) magnetic fields were not significantly different from controls. Based on these limited studies, Bochert and Zettler (2006) could not detect changes in marine benthic organisms' survival, behaviour, or a physiological response parameter (e.g., oxygen consumption) resulting from magnetic flux densities that might be encountered near an undersea electrical cable.

Westerberg and Begout-Aranas (2000; cited in CMACS 2003) studied the effects electric fields from high voltage DC power cables on eels and concluded that the cables did not appear to act as a barrier to eel migration. Skauli *et al.* (2000) exposed zebrafish (*Danio rerio*) embryos to an AC magnetic field and observed a hatching delay when exposed to the magnetic field but no differences in mortality or malformations.

Schultz *et al.* (2010) conducted preliminary behavioural studies on coho salmon (*Oncorhynchus kisutch*) exposed to EMF for varying lengths of time but found no differences in the response of control specimens and those exposed to EMF. Schultz *et al.* (2010) also conducted developmental studies on Atlantic halibut (*Hippoglossus hippoglossus*) and California halibut (*Paralicthys californicus*) subjected to EMF exposures and again found no differences between non-exposed control groups and those specimens exposed to EMF.

Woodruff *et al.* (2012) conducted laboratory experiments with representative fish and invertebrate species including juvenile coho salmon (*Oncorhynchus kisutch*), Atlantic halibut (*Hippoglossus hippoglossus*), California halibut (*Paralicthys californicus*), rainbow trout (*Oncorhynchus mykiss*), and Dungeness crab (*Metacarcinus magister*) subjected to EMF exposures. EMF intensities during the various tests ranged between approximately 0.1 and 3 millitesla, representing a range of expected upper bounding conditions that might be encountered at a field location, according to values currently reported in the literature. Based on previous studies, acute effects such as mortality were not expected to occur from EMF exposures. Their measurement endpoints focused on developmental changes (i.e., growth and survival from egg or larval stage to juvenile), exposure markers indicative of physiological responses, or behavioural responses (e.g., detection of EMF, interference with feeding behaviour, avoidance or attraction to EMF) for the various species. Data analysis has shown few statistically significant laboratory responses to elevated EMF intensities for the aquatic species and endpoints tested. Further testing and replication is needed to verify and expand on these results (Woodruff *et al.,* 2012).

Laboratory experiments conducted by Cada *et al,* (2012) found no evidence that three common freshwater taxa (the snail *Elimia clavaeformis*, the clam *Corbicula fluminea*, and the fathead minnow *Pimephales promelas*) were either attracted to or repelled by a static (DC[6]) magnetic field. Similarly, with juvenile sunfish, channel catfish, and striped bass did not detect a significant change in position relative to control specimens. Cada *et* al. (2012) suggested that the predicted EMF that may be created by a single submerged DC transmission cable would not seriously affect the behaviour of common freshwater species.

The variable EMF associated with AC[7] currents caused little or no behavioural effects in paddlefish, a species that is known to be highly sensitive to electrical fields. However, another fish of known EMF sensitivity, the sturgeon, displayed temporarily altered swimming behaviour when exposed to variable magnetic fields (Cada *et al.,* 2012). Other than the brief reactions by sturgeon to the variable fields no longer-term changes in behaviour or mortalities were observed over the duration of the study (Cada *et al.,* 2012).

2.7 CASE STUDIES – OVERHEAD LINE PROJECTS

2.7.1 Donegal 110kV Project EIS

The Donegal 110kV Project (ESBI, 2008) involves the construction of over 100 km of new stretches of 110kV overhead line along with modifications to existing substations and construction of a new switching station and new substation. A review of the EIS prepared for this Project (ESBI, 2008) identified sedimentation, use of cement and grout and spills of oil or fuel as the key risks associated with the construction phase. Clear-felling of forestry was also identified as a potential impact; however, it was noted that this activity would eventually go ahead even if the project did not proceed. The EIS suggested that there are likely to be very few impacts associated with the operation of the overhead line once constructed, other than minor disturbance to the ground surface, which may result in release of sediment to nearby water bodies during maintenance activities.

Several mitigation measures were outlined for both the construction and operational phases of the project. This includes adhering to relevant good practice guidance (e.g. ESB/IFA Code of Practice), undertaking consultation with relevant bodies and making use of sediment ponds and silt traps. Overall the EIS predicted that the project will result in a low impact on water quality, if mitigation measures are employed.

[6] Direct current is the unidirectional flow of electric charge.

[7] Alternating current is an electric current in which the flow of electric charge reverses direction.

Given the nature of linear projects, where impacts can occur across the length of the project where pathways to the aquatic environment exist, the EIS lacks specific details of locations where impacts are likely to arise or a quantitative assessment of the impacts of the proposals. This makes it extremely difficult to assess the actual impacts of the proposals on the water environment, other than have a generic understanding of the wide range of potential impacts.

The consent for the construction of this transmission line includes a condition that a protocol be drawn up with the National Parks and Wildlife Service (NPWS) to establish inspection and monitoring procedures which were to be agreed with the planning authority. One of the procedures identified was the inclusion of high frequency in-situ water quality monitoring in the Clady River which is within the Fawnboy/Lough Nacung Special Area of Conservation (SAC) with FPM as a qualifying feature. Given the sensitivity of the FPM and its requirements for high status water quality and clean substrate, with no elevated silt/sediment and oligotrophic nutrient conditions, the need for this level of monitoring is apparent.

2.7.2 Connemara 110kV Project

The Connemara 110kV Project (ESBI, 2009) is similar to the Donegal 110kV Project, as it involves the construction of 48 km of 110kV overhead line; however, the project also involves installation of 4km of underground cable. The potential impacts outlined in the EIS prepared for the Connemara 110kV Project are identical to the issues identified for the Donegal 110kV Project. The impacts identified are generic and potential impacts at specific locations along the length of the route are not addressed. In addition there is no additional assessment to determine the potential impacts arising as a result of the construction of 4km of underground cable, despite the difference in construction technique and differences in long-term operation of the line.

2.7.3 Andershaw to Coalburn 132kV Overhead Line

The Andershaw to Coalburn 132kV Overhead Line involves the construction of approximately 15km of 132kV OHL from Andershaw to Coalburn in South Lanarkshire, Scotland. In addition there is a very small section (400m) of underground cable (UGC) to be installed at Coalburn substation (Faber Maunsell, 2009). A review of the EIS prepared as part of the project identified a number of potential impacts on the water environment during the construction phase of the project, including:

- Accidental spillage or release of construction materials directly into surface waters or field drains;
- Tracks used for construction may affect surface runoff patterns and promote erosion and localised flooding;
- Soil compaction due to construction vehicles and plant may affect local hydrological processes;
- Felling of trees may promote erosion;

- Excavation for wooden poles may expose sediment and increase risk of erosion;
- Changes to the hydrology of peatland.

Impacts during the operation of the transmission line outlined include:

- Potential for spills of fuel or oil during regular and emergency maintenance;
- Exposure of bare soil which may increase potential for erosion;

A wide range of mitigation measures are proposed within the EIS, primarily through implementation of best practice and adhering to relevant legislation. The EIS states that an Environmental Management Plan (EMP) would be required from the contractor undertaking the works, which must comply with all requirements of the EIS. Specific measures outlined include only excavating during dry periods and storing of excavated material away from watercourses or drains. In addition temporary bunding and use of Sustainable Urban Drainage Systems (SuDS) are to be put in place to intercept and treat polluted run-off.

Although the EIS provides a comprehensive assessment of the potential impact of the project, along with a wide range of mitigation measures, the EIS lacks details of the impacts upon the water environment from the potential risks identified. There is limited information detailing locations where mitigation measures should be implemented. In addition there are no details of any monitoring to be undertaken during or post-construction.

2.7.4 Stip (Macedonia) to Nis (Serbia) 400kV Project)

This project involves the construction of a 400kV overhead line from Stip in the east of Macedonia to Nis in Southern Serbia (WYG International, 2010). A review of this EIS prepared in relation to a 70km section of the line from Stip to the Macedonian-Serbian Border identified erosion, leakage of polluted water, oils and fuels and heavy metals from vehicle emissions as the key impacts on surface waters during the construction phase. Leakage of fuels or oils, disposal of waste and heavy metals from vehicle emissions are identified as the potential impacts during the operational phase.

The level of detail within the EIS is low and the assessment of impacts on the water environment is generic and does not identify locations where risks may be highest or where mitigation may be required. In addition this EIS does not provide details of the nature of the impacts that the risks outlined may have on the water environment. The EIS also states that there is no risk to groundwater as a result of the proposals either during construction or operation of the overhead line, yet there is no assessment of groundwater vulnerability or additional evidence to support this assumption.

2.7.5 Bemidji – Grand Rapids 230kVTransmission Line Environmental Report (Minnesota, USA)

This project involves the construction of a new stretch of 230kV overhead line from a substation located just west of Bemidji, Minnesota, to the Boswell Substation in Cohasset, Minnesota, northwest of Grand Rapids. A total of three alternative routes were considered within the Environmental Report (Minnesota Department of Commerce & USDA, 2010) with the shortest length of line 68 miles and the longest 116 miles. The Environmental Report outlines a generic list of the potential impacts on the water environment, including:

- Changes to the water quality in nearby surface water bodies and underlying groundwater;
- Changes to the water table or localised loss of groundwater;
- Soil erosion, which may result in sedimentation of water bodies affecting vegetation, aquatic wildlife and their habitat;
- Changes in watershed function.

The specific impacts arising as a result of each of the three design scenarios have been investigated individually, with specific reference to the crossings that would occur as a result of each of the alternatives. A wide range of mitigation measures are suggested including planting or seeding areas that were disturbed by transmission line structures, or avoiding crossings if requested by the appropriate authorities.

As with assessments undertaken for other overhead transmission line projects the Environmental Report for this project lacks specific details of the impacts on the water environment from the risks identified. In addition there is relatively little detail provided on the extent of the impact on the water environment between the three alternatives considered, despite the differences in the scale of the alternatives. Although a range of mitigation measures are suggested by the project, there is little information provided on the extent to which these will be utilised or locations that are likely to require additional measures.

2.8 CASE STUDIES – UNDERGROUND CABLE PROJECTS

There is a lack of available information on underground electricity cable projects in order to determine the typical impacts or expected impacts from this development. Although there are some instances where very small sections of underground cable have been constructed, these examples are usually in towns and cities or locations where the ground has already been disturbed e.g. under an existing road. The availability of information on large scale underground cable projects is extremely limited, even at a global level, indicating that OHLs are the preferred option in most instances. As a result, this aspect of the study had to be supplemented by information available from other projects likely to result in similar impacts on the water environment.

2.8.1 South-North Pipeline Project EIS

This project involved the installation of a 450mm diameter welded high tensile steel pipeline in order to transport natural gas between Meath and Antrim (KMM/Penspen, 2004). The sub-surface pipeline is approximately 156 km in length and follows a similar construction methodology to that undertaken for the installation of underground electricity cable. All construction activities took place within a fenced strip of land generally 30m wide, but up to 50m wide at locations such as road, rail, river, and service crossings. The pipeline was installed at a depth of between 1.2 – 1.6m, depending on the overlying land use.

The key impacts outlined within the EIS include the potential for silt-laden run off, spills of oils/fuels or other hazardous chemicals, due to the impacts these contaminants may have on aquatic species, particularly fisheries. An assessment of the groundwater vulnerability indicated that the pipeline does not present a significant risk to groundwater quality in the majority of areas. A comprehensive range of mitigation measures were suggested within the EIS, including adhering to best practice procedures and consulting with relevant authorities on appropriate mitigation. Emergency response procedures were outlined along with measures such as bunding for storage of fuels and chemicals and the use of silt curtains in order to provide protection to both groundwater and surface waters.

The EIS provides a comprehensive assessment of the potential impacts on both groundwater and surface waters, along with a wide range of mitigation and precautionary measures. However, the EIS does not provide any detail on the extent to which mitigation measures are likely to be implemented or details of any monitoring to be undertaken in order to determine whether the measures are effective during or after construction.

2.8.2 Spalding Energy Expansion

The Spalding Energy Expansion project involves the construction of a new combined cycle gas turbine power station adjacent to the existing power station in Spalding, Lincolnshire. The project also involves the construction of a new high pressure gas pipeline of approximately 8 km in length, which involves a similar construction methodology to the laying of UGCs (Environ, 2010).

The key impacts outlined in the EIS are in relation to the potential for sediment or construction-related pollutants to be released to watercourse or groundwater as a result of surface run-off or leaching. A comprehensive range of mitigation measures have been proposed as part of the project, with construction practices to follow best practice guidance and adhere to a Construction Environmental Management Plan (CEMP).

This EIS lacks specific details of the impacts on the water environment from the risks identified. In addition there is limited detail on the extent of the impact on the water environment or whether crossing of any watercourses may occur. Mitigation measures are based upon following best practice with limited information on the extent to which these will be utilised or locations that are likely to require additional measures. In addition there are no details of any monitoring either during or post-construction.

2.9 COMPARISON OF CASE STUDIES

Overall, the case studies highlight similar potential issues that may affect water quality although there are significant differences between the level of detail provided within the assessment. Some of the case studies such as the Donegal 110kV Project and Connemara 110kV Project provide a detailed assessment of existing water quality along the length of the line and highlight sensitive sites such as FPM habitat. The potential risks as a result of the project are outlined and the issues these risks present to the water environment are considered. In contrast the Stip to Nis 400kV Project provides an outline of the existing water quality and provides an indication of the potential risk. However, no details are provided of the impacts that may arise as a result of the risks outlined or the areas where specific mitigation measures should be implemented.

For projects similar to UGC there appears to be similar risks as to OHL. However, an additional risk identified is the potential impact from trenchless techniques, e.g. directional drilling under watercourses. Where drilling muds are used geological features such as fractures and seams may result in a “break-out” of the drilling mud which can migrate to surface or groundwaters causing sediment or chemical pollution.

Based on the review of relevant best practice guidance and EISs for high-voltage electricity infrastructure projects and similar linear developments, the key impacts upon the water environment are likely to arise during the construction phase. The most important concern is in relation to the release of specific contaminants into nearby water bodies, with contaminants of main concern being sediment, concrete and hydrocarbons.

2.10 CONCLUSION

There is a lack of authoritative scientific literature investigating the impacts on the water environment as a result of high-voltage electricity transmission infrastructure. Best practice guidance and relevant EISs indicate that the most significant risks from these projects are in relation to sediment, cement and concrete, and hydrocarbons. These risks have been identified through published documentation including best practice guidance and relevant EISs. This is considered the best available method to determine the most significant risks, while a review of scientific literature is appropriate in order to assess how the key pollutants and issues from electricity transmission infrastructure pose a risk to the water environment.

The WFD is central to the impact of these projects on the water environment, as all water bodies are required to achieve good ecological status by 2015. Each of the risks identified have the potential to affect the achievement of overall good status in both groundwater bodies and surface water bodies. Further research is required in order to determine the actual impact of high-voltage electricity transmission infrastructure on the water environment. Reviews of EISs provide an indication of the potential impacts on the water environment and the agreement of monitoring procedures with the relevant authorities are conditioned in the consents. However, there is a lack of detail of the actual monitoring undertaken to assess the impact from the development on water quality or assessment in the effectiveness of mitigation measures. This requires monitoring of the changes in water quality before, during and after construction of high-voltage electricity infrastructure.

This review has also identified that the most widely researched topic in the area of the potential effects of EMF on aquatic species is focused on the potential EMF effects from marine and hydrokinetic (MHK) devices on marine species (Gill & Taylor, 2001; Schultz *et al*., 2010; Woodruff *et al*., 2012). There is limited research available on the effects of EMF produced by electricity transmission infrastructure on freshwater species (Basov, 2007 & Gill *et al*., 2005). Of the studies conducted to date, only minor effects from EMF have been recorded for freshwater species (Cada *et al.,* 2012).

3 CONSTRUCTION/OPERATION/MAINTENANCE TECHNIQUES FOR TRANSMISSION PROJECTS

3.1 GENERAL

It is necessary to examine the typical construction techniques of high-voltage transmission lines in order to put in context the temporary and permanent works required to facilitate construction, the level of disturbance required to erect structures, and its potential to affect the states of the receiving environment through hydrological pathways. As stated in Section 1, construction is expected to be the most **at risk** period. Besides this being the time when the heaviest loads will be in place around the structures in the form of construction plant, it is also the time when temporary access and excavation works will be required and hence the time of greatest disturbance to the surrounding area.

3.2 TYPES OF STRUCTURES

The structure types used for high-voltage transmission lines depend on the voltage of the line and configuration of conductors. In Ireland transmission lines operate at 110kV, 220kV and 400kV. Support structures are double wooden pole sets with steel lattice towers at angle masts for 110kV. For 220kV and 400kV lines, all support structures are steel towers with varying configurations depending on the requirements.

For all new projects, the available tower types suitable for that voltage, are examined and selected based on optimum efficiency and suitability. The above ground configuration is evolving because the more and more so there is a need to reduce visual impact of these towers. The principles of foundations are relatively similar between similar styles of structure. The changes to steel structures have taken the form of lower towers, lower number of steel struts in the structures and varying shapes and sizes. The spacing between towers will generally depend on topography and altitude. Foundation size of each structure can vary in number and in size depending on the type, size and height of a structure and site specific conditions. The general requirements are outlined in Figure 3.1.

3.2.1 110kV Lines

110kV power lines are the most widespread existing and new transmission lines in Ireland (of various lengths). A 110kV line requires that the overhead line conductors be supported on a combination of lattice steel towers and double wooden pole sets. The steel lattice towers are required where the line changes direction (angle towers) or terminates. The average span between these poles for a line of this type is approximately 250 metres (m) but the actual span achievable depends on local topography.

The excavation required for each pole is typically 1.5-2m x 3m x 2.3m deep. No concrete foundations are required for pole sets in normal ground conditions and installation time is approximately two pole sets per day. However, a sleeper is installed to the base of the poles and buried for added stability.

Concrete foundations are required for all steel towers and base installation time is approximately one week for four excavations of normally approximately 3m x 3m x 3m deep. Given the highly alkaline nature of fresh concrete, its use in close proximity to a watercourse has the potential to significantly impact on water quality if it is allowed to enter the channel.

Table 3.1 below summarises the key features of 110kV structures and Figure 3.1 illustrates typical structures currently in use in Ireland on high-voltage transmission lines[8].

Table 3.1 110kV – Key Design Features

Key Design Features	Range
Height range (double wood pole sets)	16m to 23m (incl. buried depth normally 2.3m)
Pole centres	5m
Number of foundations	2
Height range (steel angle towers)	18m to 24m
Number of foundations	4
Maximum width at ground level	4m to 9.8m
Average span	250m

[8] EirGrid Ecology Guidelines *for* Electricity Transmission Projects

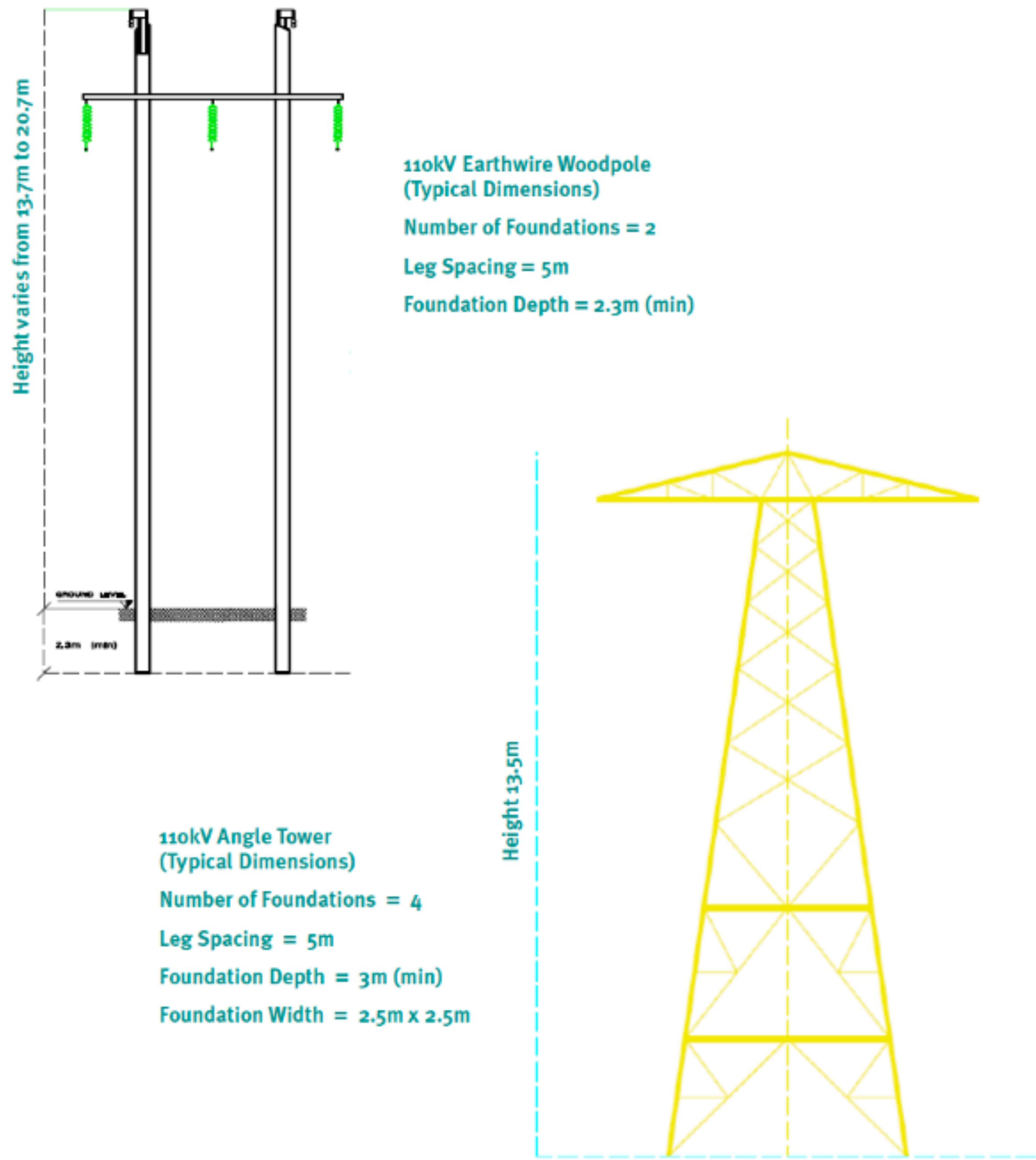


Figure 3.1 110kV Structures – Typical Dimensions (after EirGrid, Ecology Guidelines for Electricity Transmission Projects)

In addition to the excavation required at the pole set, where ground conditions dictate, further excavation is required for stay lines where more marginal soils such as peats or soft silts/clays are encountered. Four excavations, 2m x 2m x up to 1.8–2m deep, may be excavated at a distance from the pole set. The depth of the excavations depends on the extent of the bad ground. The location of the stay trenches are worked out using the following formula:

Pole height (m) – 4m / half the distance (m) from the pole set = distance (m) of the stay line trench

Where much deeper marginal ground is encountered, where a steel tower is proposed, piling may be required to transfer loads created by the structure safely into the underlying competent ground.

The location of stay lines and the installation of piles tend to expand the area of disturbance associated with erecting a pole set.

In the case of the installation of double circuit 110kV lines, the use of steel lattice tower structures are required exclusively, and so the area of disturbance is also significantly greater in this instance.

3.2.2 220kV Lines

The distribution of 220kV power lines is currently relatively limited, and it is unlikely that they will be favoured in future given the increased efficiency of 400kV lines at transmitting bulk power. A 220kV line requires that the overhead line conductors be supported exclusively on lattice steel towers. The average span on a line of this type is 320m but this is dependent on local topography.

Concrete foundations are required for all steel bases. Four foundation blocks are required to be excavated; ranging from 1.4m to 3.9m in diameter depending on the tower design (intermediate or angle tower, double or single circuit). As previously stated, highly alkaline fresh concrete has the potential to cause detriment to localised water quality and so should be prevented from entering a watercourse.

Table 3.2 below summarises the key features of 220kV structures and Figure 3.2 illustrates typical structures currently in use in Ireland on high-voltage transmission lines.

Table 3.2 220kV - Key Design Features

Key Design Features	Range
Height range	21.1m to 37.1m
Maximum width at ground level	8m to 14m
Number of foundations	4
Average span	320m

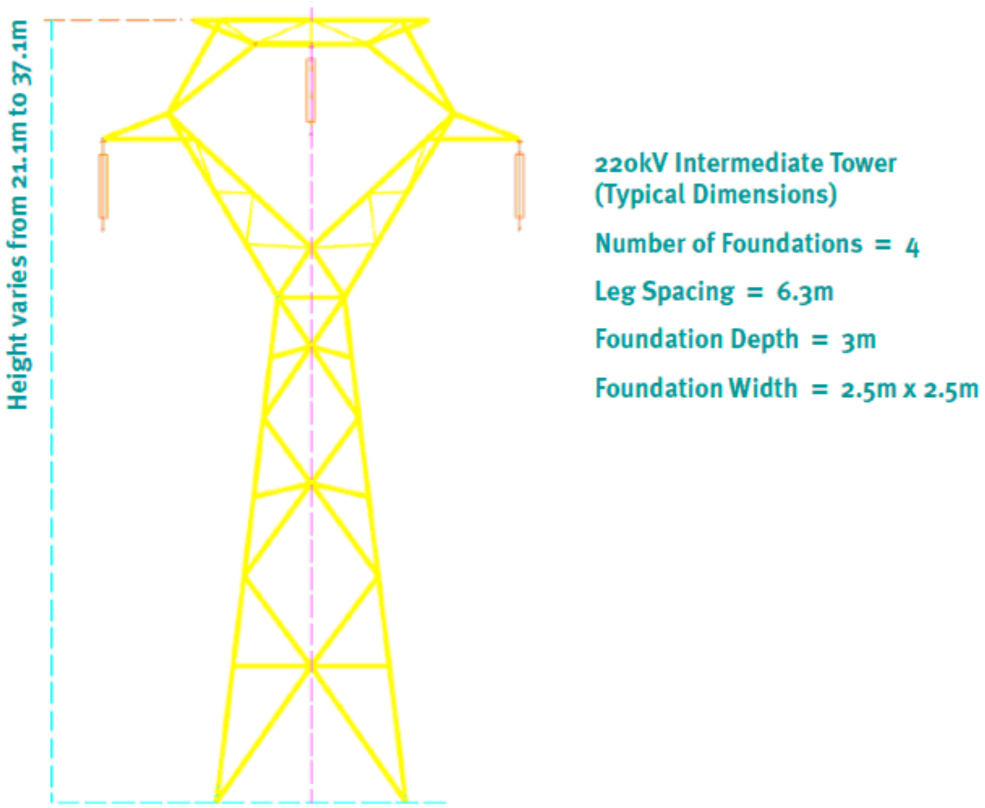


Figure 3.2 220kV Intermediate Structure – Typical Dimensions (after EirGrid, Ecology Guidelines for Electricity Transmission Projects)

3.2.3 400kV Lines

There are currently two 400kV high voltage power lines in operation in Ireland. These lines are supported exclusively on lattice steel structures. The average span on a line of this type is 250-330m but this is dependent on local topography. There are plans to expand the 400kV network in Ireland given their efficiency at transmitting bulk power and to improve the overall functioning of the grid.

For the steel lattice towers, four concrete foundations are required and the excavation for each foundation pad ranges in size from 2.2m – 5.1m in diameter depending on the tower design (intermediate or angle tower, double or single circuit). As with all associated concrete foundations, water quality is at risk from highly alkaline fresh concrete mix and so should be prevented from entering any nearby watercourses or direct hydraulic pathways.

Table 3.3 below summarises the key features of the in-use 400kV structures and Figure 3.3 illustrates typical structures currently in use in Ireland on high-voltage transmission lines.

Table 3.3 400kV - Key Design Features

Key Design Features	Range
Height range	30m to 56.75m
Maximum width at ground level	12m to 16.5m
Number of foundations	4
Average span	250m-330m (3-4 structures per km)

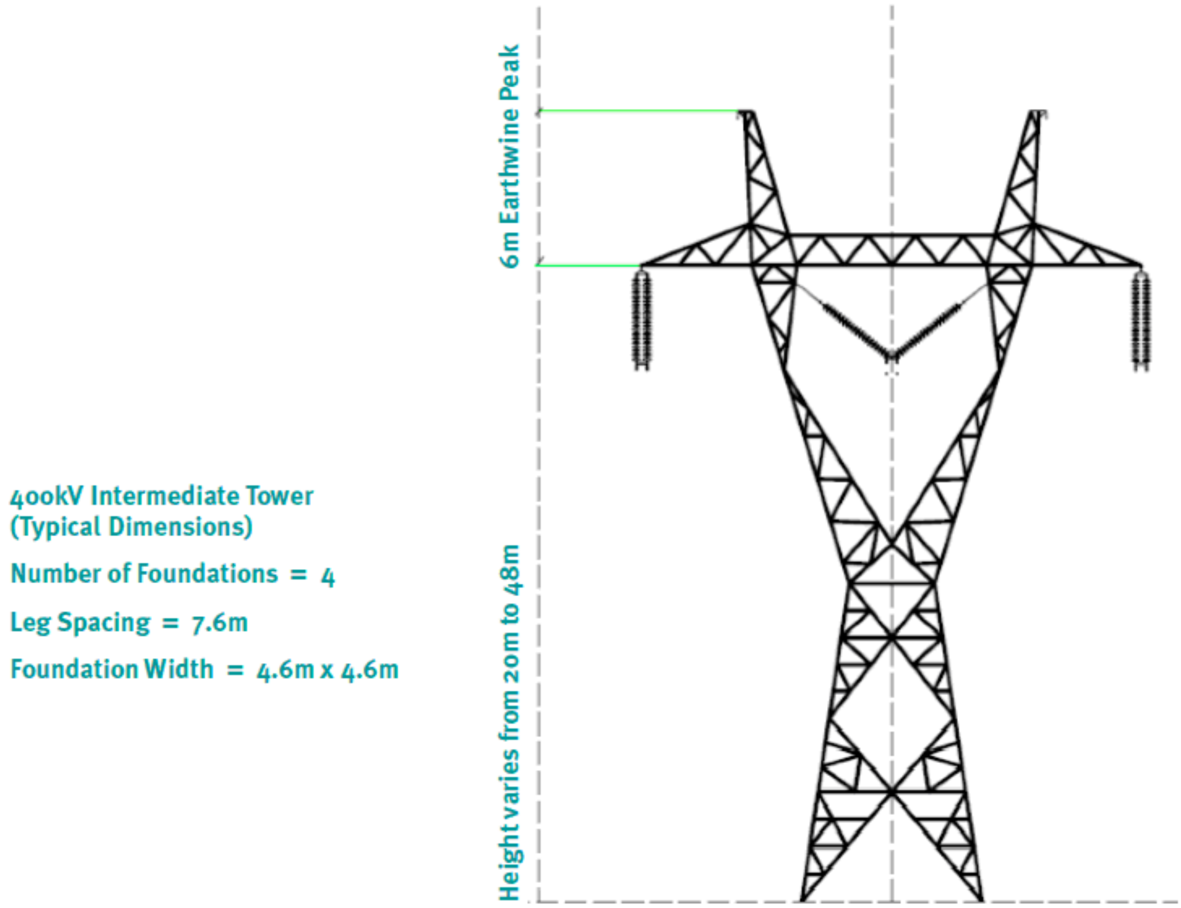


Figure 3.3 400kV Intermediate Structure – Typical Dimensions (after EirGrid, Ecology Guidelines for Electricity Transmission Projects)

3.2.4 Earth Mats

Earth mats are basically copper mesh mats that are installed under and around the base of steel lattice towers where the soil resistivity is such that it can result in a Grid Potential Rise (GPR) when a fault occurs on a line, for example a lightning strike. Furthermore, certain ground conditions dictate that earth mats need to be placed at the base of pole sets (110kV).

They are used:

- In situations where there is a possibility that a fault might occur on a line or in a station and there is a potential of the earth grid to rise relative to the remote earth – GPR.

- When resultant 'Touch and Step' voltages have potential safety implications for the general public and staff/contractors working at a tower or in a station. For example, the area of the ground around the tower is energized and the voltage is such that it is a potential hazard to people/farm animals in the vicinity of the structure.

Earth mats are not normally installed by the ESB when the towers are initially erected unless obviously required. Instead, following construction, a resistivity test is conducted along the line and structures are retrofitted at identified locations along the line. The excavation area required is not extensive but depending on soil conditions, may extend beyond the tower base by a few metres (m). The exact dimension of the trench depends on ground conditions.

Earth mats can be installed when towers and pole sets are initially erected if work is taking place in a sensitive environment, for example within a freshwater pearl mussel (FPM) (*Margaritifera margaritifera)* catchment. This way the disturbance is minimized.

3.2.5 Underground Cabling

High voltage (HV) circuits can only be laid underground using special HV cables designed specifically for underground use. The conductors in underground HV cables must be heavily insulated to avoid a short circuit between the conductor and the ground around the cable. UGCs are sometimes used in the following circumstances, where technically feasible -

- A built-up urban area where there is no space for support structures;
- An area with a multiplicity of existing overhead power lines;
- A relatively wide expanse of deep water;
- An area of unique natural beauty.

The following table (Table 3.4) shows the typical width of a cable trench at the three voltage levels, the area of the joint bays and the intervals at which they are installed.

Table 3.4 Trench Dimensions

Criteria	Trench Dimensions Width x Depth (m)	Joint Bay Dimensions Length x Width x Depth (m)	Approximate interval between joint bays (m)
110kV	0.6 x 1.25	6 x 2.5 x 2.1	700
220kV	1.1 x 1.25	6 x 2.5 x 2.1	600

Criteria	Trench Dimensions Width x Depth (m)	Joint Bay Dimensions Length x Width x Depth (m)	Approximate interval between joint bays (m)
400kV	1.1 x 1.25	10 x 2.5 x 2.1	500

UGC is generally not installed in more environmentally sensitive areas, such as Natura 2000 sites, due to the greater footprint and potential to impact on annexed habitats and species through direct (habitat) and indirect (hydrological pathways) impacts. Given that no underground projects were under construction during the evidence based study, this element of transmission line construction is therefore not included in the water and aquatic ecology study.

3.2.6 Stations

The majority of station plant and equipment was installed between 1970 and 2000. Accordingly, the older stations are now approaching 40 years in service. Station-wide condition assessments are being carried out and where necessary, options for refurbishment are being developed. Stations are generally located in low lying areas at the ends of transmission lines and connection points to other lines. They usually have permanently designed access and hard-standing areas.

3.2.7 Line Refurbishments

In general, a transmission line requires little maintenance. It is periodically inspected to identify any unacceptable deterioration of components so that they can be replaced as necessary.

A condition assessment on a line is usually carried out when it is 35 years old. The majority of existing transmission line grid was constructed after 1960 (EirGrid, 2010) and the majority of those lines constructed prior to 1960 have already been refurbished. There is an on-going programme of line refurbishment concentrating on the older lines. Refurbishment projects are condition based and once a line has been identified for refurbishment, consideration is given to the potential opportunity to upgrade the capacity or thermal rating of the line. Insulators and conductors are normally replaced after about 40 years and towers are painted every 15-20 years, or as necessary.

Where structures require replacement during a line upgrade or refurbishment, additional excavation may be required particularly where angle towers or structures require replacement. In general they are replaced within the footprint of the original structure. It is assumed that similar pressures and risk to water quality apply to both replacement structures required under refurbishment works and to new structures erected during the construction of a new transmission line.

3.3 CONSTRUCTION SEQUENCE OF WORKS

The works required to construct a high-voltage transmission line typically follow the sequence of events as outlined below:

- Prepare access
- Excavate foundation base/pole bases
- Install tower foundations
- Erect towers or wood poles
- String conductors
- Reinstate tower/pole sites as necessary
- Remove temporary access

Access is required to all structures/pole locations for construction. Table 3.5 below outlines the necessary plant[9] required for erection of different structure types.

Table 3.5 Plant Required for Construction

Structure Type	Plant Required
Double Pole Set	Conventional delivery truck either to site of poles or to storage area Excavator Lifting arm (usually using excavator) Small ancillary Items
Tower	Conventional delivery truck either to site of tower or to storage area Excavator Lifting arm (usually using excavator) Concrete trucks Crane or boom crane Small ancillary Items

Once the structures have been erected the conductors are winched to/pulled from section towers. Access in and around these towers is required for conductor drums and large winches. Therefore the access arrangements to angle towers are greater than for line structures.

Access is usually along a designated route as agreed with the relevant landowner. If the location is within or near to a protected site or species, consultation may also be required with the relevant statutory body, e.g. Local Authority, NPWS, Inland Fisheries Ireland. Access road requirements vary depending on ground conditions.

Where ground conditions are considered good, such as improved agricultural land, and excessive rutting or damage is not expected, plant will traverse existing ground. An assessment of ground conditions and suitability for plant is the responsibility of the contractor in consultation with the site supervision team, and where necessary statutory authorities.

[9] In construction this term refers to heavy machinery and equipment used during works.

However where ground conditions are poor, for example in peat areas, bog mats or a geotextile reinforced/brush reinforced access road will be put in place overlying existing ground. Generally wide tracked plant is used where possible to reduce surface damage. Low ground bearing, wide tracked plant is used to reduce loading on soft ground and mitigate risk of soil failure and resulting sediment input to nearby watercourses.

Where access has occurred on existing ground, any damage will be remediated by, for example rolling, rotavating and re-seeding, or any alternatives as deemed necessary. Where this occurs on semi-natural or natural habitat, consultation with the relevant conservation agency is undertaken. Where temporary access roads have been put in place, these will be removed upon completion of works.

Current practice is to erect temporary fencing around each structure to delineate the working area and to ensure the safety of members of the public and livestock. All mechanical plant remains within this area during construction and all excavated material is stored within the fenced off area. The size of the area can vary but will be dependent on the amount of material to be stored or the size of the structure to be erected. Generally this area would be smaller for pole erection and given the relatively low intensity of the necessary works, the erection of temporary fencing is not required. Any excavated material is maintained within the working area until reinstatement occurs with any surplus material then removed off site.

3.4 OPERATION/MAINTENANCE REQUIREMENTS

Upon completion of stringing and energisation of lines, access is generally only required by standard maintenance personnel in 4x4 vehicles using existing access roads where possible. These by and large do not require the installation of temporary access routes, except in very poor ground conditions where temporary bog mats or access roads may be required for a short period of time. Existing access roads are utilized where possible.

4 CURRENT MITIGATION MEASURES AND BEST PRACTICE GUIDANCE

4.1 INTRODUCTION

As with any construction project there is always an inherent risk of residual adverse impact as a result of required works. In order to abate the potential for such impact, mitigation measures are required to be put in place to avoid, minimise and/or recompense any environmental loss incurred as a result of the project.

This chapter provides a background to mitigation and investigates measures which could potentially be implemented and available best practice guidance which should be adhered to.

4.2 GENERAL PRINCIPLES OF MITIGATION

Based on an assessment of current mitigation measures and best practice guidance both at an Irish level as well as at International level, there are common themes running across all guidance with the ultimate aim to mitigate against negative impacts on sensitive water bodies.

Mitigation should be considered in a hierarchy consisting of avoidance, minimisation, rehabilitation/restoration and compensation. Refer to Figure 4.1.

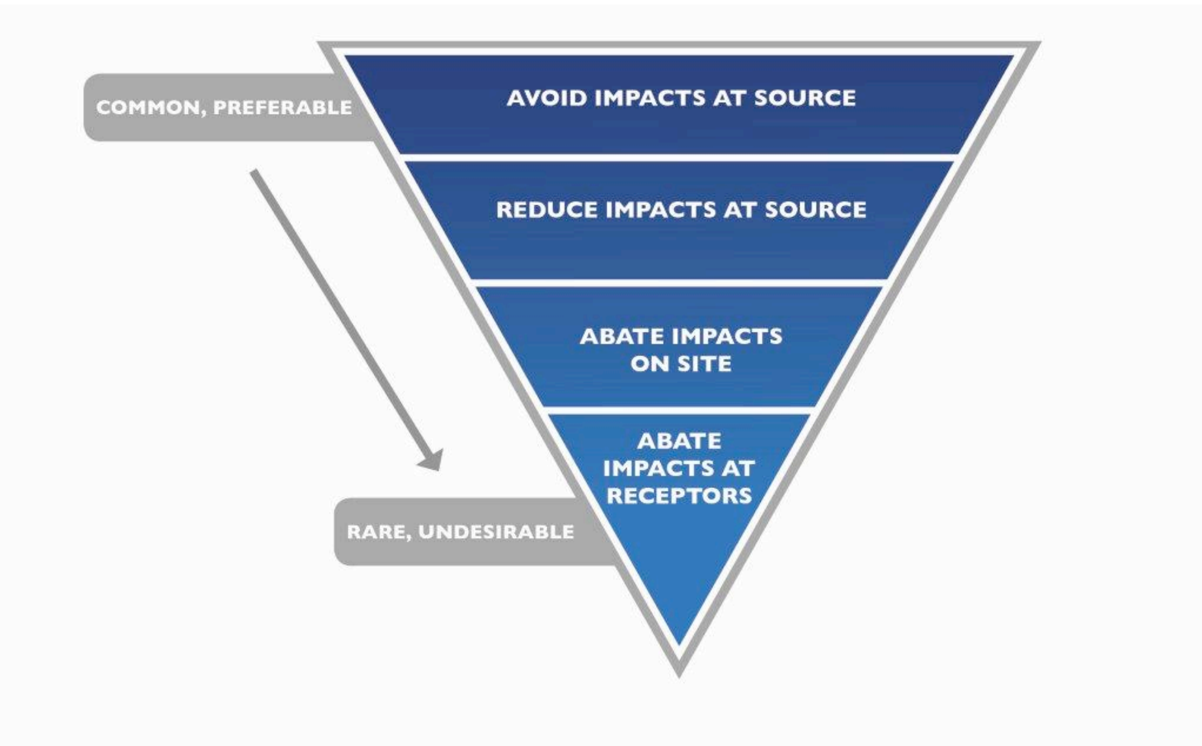


Figure 4.1 Schematic of Mitigation Hierarchy

4.2.1 Avoidance

Measures taken to avoid creating impacts from the outset, such as careful spatial or temporal placement of elements of infrastructure, in order to completely avoid impacts on certain components of biodiversity. (BBOP & UNEP 2010)

In relation to water resources and sensitive aquatic habitats the best strategy for mitigation will be avoidance through sensitive route planning that ensures damaging activities are remote from water bodies or designated areas with no discernible pathway. There are instances however given the nature of such linear development where the crossing of a watercourse cannot be prevented. Avoidance of impact can also be achieved through the elimination of the pressure at source, e.g. prevention of elevated suspended solids through strict control measures at source.

4.2.2 Minimisation

Measures taken to reduce the duration, intensity and / or extent of impacts (including direct, indirect and cumulative impacts, as appropriate) that cannot be completely avoided, as far as is practically feasible. (BBOP & UNEP 2010)

For particularly sensitive aquatic species and habitats, identified through existing appropriate channels with competent authorities and agencies, mitigation through the minimisation of impact can only be effective where the pressure does not impact on the conservation status of any water dependent habitat or species associated with the water body.

Where negative impacts cannot be avoided, it may be possible to reduce impacts by reducing the area of impact or the length of time that the area is exposed to disturbance. For example, where areas of sensitive habitat need to be crossed during the construction phase, measures to reduce the impact of vehicles on wetland or bog should be considered including the use, for example, of low pressure vehicles and the laying of protective geotextile or mats on the vegetation to be crossed.

4.2.3 Rehabilitation/restoration

Measures taken to rehabilitate degraded ecosystems or restore cleared ecosystems following exposure to impacts that cannot be completely avoided and/or minimised. (BBOP & UNEP 2010)

Restoration tries to return an area to the original ecosystem that occurred before impacts, whereas rehabilitation only aims to restore basic ecological functions and/or ecosystem services (e.g. through planting trees to stabilise bare soil). Rehabilitation and restoration are frequently needed towards the end of the construction phase, but may be possible in some areas during operation.

Measures to remedy impacts on the environmental values range from measures that immediately stabilize the site of the impacts, to measures that bring a site back to full ecosystem structure and function as existed prior to the project or activity. Restoration measures are carried out within the footprint of the project or activity, specifically within the area of the permit.

4.3.3 Compensation

Measures taken to compensate for any residual significant, adverse impacts that cannot be avoided, minimised and / or rehabilitated or restored, in order to achieve no net loss or a net gain of ecological status of a water body or any water dependent biodiversity attribute. (BBOP & UNEP 2010)

As highlighted by the European Commission's No Net Loss Working Group (EU NNL WG), the Business and Biodiversity Offsets Programme (BBOP) defines biodiversity offsets as, *"measurable conservation outcomes resulting from actions designed to compensate for significant residual adverse biodiversity impacts arising from project development and persisting after appropriate prevention and mitigation measures have been implemented. The goal of biodiversity offsets is to achieve no net loss, or preferably a net gain, of biodiversity on the ground with respect to species composition, habitat structure and ecosystem services, including livelihood aspects".*

While in some jurisdictions compensation and offset are synonyms, BBOP draws a distinction between the two terms:

- An offset programme explicitly aims to achieve no net loss (NNL) and preferably a net gain.

- Compensation involves measures to recompense, make good or pay damages for loss of biodiversity caused by a project. However some of these measures may fall short of NNL. This could be the case for direct restoration options, but also for indirect measures such as financial payments.

Following the mitigation hierarchy, offsets and/or compensation should only be pursued after efforts have been made to avoid and minimize biodiversity loss arising from a proposed development (EU NNL WG). Offsets are often complex and expensive, so attention to earlier steps in the mitigation hierarchy is usually preferable.

4.3 EIRGRID GUIDANCE

Environmental considerations form part of EirGrid's strategy from the earliest stages of a project which is made evident in EirGrid's Project Development and Consultation Roadmap as shown in Figure 4.2. This roadmap approach illustrates that environmental and other constraints are identified in Stage 1, the Information Gathering Stage.

Figure 4.2 EirGrid's Project Development and Consultation Roadmap

As part of the development of best practice in the area of transmission infrastructure development, EirGrid have identified a number of environmental mitigation measures, relevant to water quality and freshwater ecology. In 2012, EirGrid published guidance specific to Ecological Impact Assessment: Ecology Guidelines *for* Electricity Transmission Projects, A Standard Approach to Ecological Impact Assessment *of* High Voltage Transmission Projects. In addition, the SEA of the Grid 25 Implementation Programme 2011-2016 identifies generic best practice mitigation related to environmental impacts including water quality.

4.3.1 Ecological Guidelines for Electricity Transmission Projects (EirGrid, 2012)

These guidelines have been developed by EirGrid to provide best practice guidance for ecological impact assessment EcIA (flora and fauna) in the planning and construction of high voltage transmission projects. The objectives of the guidelines are:

1. To provide best practice guidance and a systematic approach for EcIA of high voltage overhead power line infrastructure projects.

2. To provide best practice guidance on ecological topics of particular relevance to high voltage overhead power lines including:
    a. The risks of collision by birds with high voltage overhead power lines, and
    b. The impacts of electricity transmission projects on sensitive habitats, particularly wetlands, peatlands and watercourses.

The guidelines therefore take into consideration the potential impacts to water quality and aquatic environments and put forward possible mitigation strategies to address these pressures.

The guidance makes specific reference to wetland and peatland habitats which are reliant on specific hydrological conditions and which are very sensitive to disturbance which can result in significant direct impact on the habitat and an indirect habitat on the aquatic environment. The disturbance (source of impact) must have a pathway (hydraulic connectivity) to a receiving water body for this to occur. The predominant pressure is disturbance of the surface and the increased erosion and potential for soil mobilisations. The scale of the impact can be determined by a number of factors:

- Operational and vehicle parameters such as speed, acceleration, wheel-track pressure.
- Surface topography.
- Degree of slope - sloping terrain is more susceptible to erosion.
- Time of year - damage maybe expected to be more severe when the ground is wetter.
- Type of vegetation - wet marshy areas experience greater disturbance than well drained areas.

The guidelines also identify the potential impact to water bodies from sedimentation, accidental spillages and also the potential for morphological impact through disturbance or alteration of the riparian zone or channel itself. The potential impact of clear felling forestry plantation to facilitate the right of way for transmission lines is also identified as a significant pressure particularly in sensitive catchments such as high status sites, where low even low levels of anthropogenic pressure (Irvine & Ní Chuanigh, 2010) such as sedimentation, nutrient enrichment and flow regime alterations due to forestry activities can have a serious impact. These key pressures can have a detrimental effect on a variety of vulnerable habitats and species have been discussed at length in the literature review section of this report.

The guidance outlines a methodology for incorporating ecological assessment at the different planning stages of transmission line development i.e. routing corridor assessment, selection of preferred route corridor (or less constrained route corridor), assessment of preferred route corridor and route within the corridor and planning approval. An indication of the level of assessment required at each stage is included as is the consultations required.

In terms of aquatic and riparian habitats where these features occur within the study area they should be adequately described and assessed. Where a river or stream is to be crossed by the construction of a temporary feature (bridge or culvert), the in-stream and riparian habitats should be assessed at the crossing point and for an appropriate distance downstream of the impact. It may be necessary to collect data on water quality if little is known of rivers/streams biological status (McGarrigle *et al*., 2002). If this is the case, physico-chemical sampling should be included as part of the ecological survey.

The guidelines outline the different mitigation strategies that can be developed to address potential impacts from electricity transmission line development. Mitigation by avoidance is the best option from the mitigation hierarchy and can be achieved through design (routeing the transmission line appropriately) and through the timing of works. Mitigation by reduction (e.g. reduced footprint) or remedy (e.g. reinstatement and reseeding with stock of local provenance or using a localised seed bank) are the next best options available when considering mitigation strategies.

The guidelines also provide an indication of the content required for an EcIA, for an EIA and an Appropriate Assessment (AA), and highlight the requirements for post EIA studies and assessments e.g. EMP and environmental monitoring.

4.3.2 Strategic Environmental Assessment (SEA) for the GRID25 Implementation Programme 2001 – 2016

The purpose of the SEA is to provide a clear understanding of the likely environmental consequences of decisions arising from the Grid25 Implementation Programme (IP).

The Environmental Report outlines the likely environmental effects of the Implementation Programme and the alternatives and their significance is evaluated. The Environmental Report provides a clear description of the likely environmental consequences of decisions regarding how transmission infrastructure will be developed at a regional level. Mitigation measures to prevent or reduce potential significant adverse effects posed by resultant projects of the IP are identified in the report and these have been integrated into the IP.

In terms of the mitigation proposed, there are two levels. Seven high level preventative measures (of which the evidence based studies is one) were incorporated into the IP. The second level of mitigation proposed represent measures that must be employed during the implementation of projects resulting from the IP. Whilst they are general and will require further augmentation on completion of the evidence based studies, they can be developed and implemented at project level for new transmission line proposals.

The second tier mitigation measures that have been listed for water resources are included below in Table 4.1:

Table 4.1 Summary of secondary mitigation measures relevant to watercourses

Potential Impact	Mitigation
EMM8B(i) Accidental spillage of fuel, chemicals or sewage causing pollution to water or ground	Develop, implement and enforce a Water Pollution Prevention and Environmental Emergency Response Plan for all work sites. This should include good site practices as described in the Good Practice Guidance notes proposed by EA/SEPA/EHS.
EMM8B(ii) Suspended solids & sediment deposition	Precautions shall be put in place to avoid or minimise the generation and release of sediments into all watercourses.
EMM8B(iii) Physical Damage to watercourses	Develop, implement and enforce a code of best practice for construction and reinstatement methods to be used for unavoidable construction works in the vicinity of watercourses.
EMM8B(iv) Flooding	▪ Within known floodplains measures shall be taken to avoid any potential impact of construction or existence of the works on the capacity for floodwater storage. ▪ Damage to any flood defence embankments shall be immediately repaired to a standard equal to or better than the existing embankments. ▪ EirGrid shall carefully examine development proposals to ensure consistency with the requirements of *The Planning System and Flood Risk Management: Guidelines for Planning Authorities* (DEHLG, 2009) ▪ EirGrid shall engage with planning authorities at an early stage, utilising arrangements for preplanning application consultation with regard to any flood risk assessment issues that may arise. ▪ EirGrid shall carry out a site-specific flood risk assessment, as appropriate, and comply with the terms and conditions of any grant of planning permission with regard to the minimisation of flood risk.
EMM8A(viii) Protected Surface	In all cases where works have the potential to impact on protected surface water or riparian habitats, the Inland

Potential Impact	Mitigation
Water or Riparian Habitats	Fisheries Ireland document *Requirements for the Protection of Fisheries Habitat during Construction and Development Works at River Sites* shall be adhered to. Development of transmission infrastructure adjacent to designated fisheries shall be carried out in consultation with Inland Fisheries Ireland to minimise the potential effects on designated surface waters.
EMM8A(ix) Freshwater Pearl Mussel Catchments	▪ Action measures as outlined in the Sub Basin Management Plans shall be taken into account where development is considered adjacent to areas associated with Freshwater Pearl Mussels. ▪ In the vicinity of waters that sustain populations of Freshwater Pearl Mussels the following additional mitigation measures shall be employed;- – There shall be no stream crossing by machinery. – Silty water will be collected in settlement ponds prior to discharge to watercourse. – Buffering strips will be provided near watercourses.
EMM8A(x) Fisheries	▪ All works adjacent to designated fisheries waters will be undertaken in consultation with Inland Fisheries Ireland. ▪ All works involving open cut crossings shall be conducted during the period May to September to avoid interruption of salmonid spawning runs, spawning, incubation of eggs and the early developmental stages. ▪ Where appropriate and practical, bank vegetation and bed material which has been removed shall be stored to facilitate its replacement when channel works have been completed. ▪ Works in the vicinity of a watercourse shall be carried out with reference to a water quality protection plan for each site which shall ensure that;-

Potential Impact	Mitigation
	▪ All necessary measures shall be taken to minimise the generation and release of sediments into all watercourses ▪ Levels of suspended solids in the river shall be monitored during the course of the works. ▪ Precautions shall be put in place to avoid spillages of diesel, oil or other polluting substances.
EMM8C Soils and Geology	
EMM8C(i) Geological Features	▪ Site investigations shall be undertaken at intervals and specific locations along the power circuit route. This information shall be used to plan sitework operations to anticipate, avoid or minimise construction impacts arising from disturbance of sub-surface conditions. ▪ Cut and fill operations should be avoided unless absolutely necessary. ▪ Route selection and lower tier assessments should consult Geological Survey of Ireland as appropriate in relation to geological heritage sites either recommended for NHA or County Geological Site designation.
EMM8C(ii) Soil	▪ Height of stockpiles should be limited to less that 3 m and storage time will be minimised. ▪ Material handling and reinstatement operations should follow good practice to avoid inadequate or over compaction of the materials. ▪ Route selection and lower tier assessments for peatland areas should consider relevant government guidelines on development in these areas as well as relevant datasets including the Geological Survey of Ireland's landslide dataset and Teagasc's subsoils dataset.

4.3.3 CIRIA Technical Guidance

The Construction Industry Research and Information Association (CIRIA) publishes technical documents that are the culmination of research projects and activities and pertain to a variety of areas within the construction industry. It is a neutral, independent, not-for-profit organisation which facilitates a range of collaborative activities that help improve the construction industry.

CIRIA works across market sectors and disciplines to deliver a programme of business improvement services and research activities for members and those engaged with the delivery and operation of the built environment. The guidance documents produced and of relevance to such transmission line projects include mitigation and control measures to address the impact from potential pollution associated with construction. Activities should follow good work practices and sound design principles as outlined in the series of technical guidance documents listed below:

- Technical Guidance C649: Control of Water Pollution from Linear Construction Projects, Site Guide (CIRIA, 2006)
- Technical Guidance C648: Control of Water Pollution from Linear Construction Projects, (CIRIA, 2006)
- Technical Guidance C532: Control of Water Pollution from Construction Sites: Guidance for Consultants and Contractors (CIRIA, 2001)

4.3.4 Forestry Guidance

Any disturbances in a peat environment can lead to elevated dissolved organic carbon (DOC), sediment and nutrient release. This includes forestry operations, particularly in a peat environment, which can cause pulses of DOC at levels that can lead to unnatural heterotrophic growth. Higher loads of DOC were evident in Irish catchments with plantation forestry on peat soils, and the elevated DOC levels were associated with acidification episodes (Feeley *et al.*, 2013).

A number of potential acidification risks from forestry were listed by Johnson *et al*. (2008) including oxidation and mineralisation of organic matter and the resultant production of organic acids, sulphate and nitrogen compounds, and short-term release of nitrate following the large-scale felling of forest sites. A consequence of acidification in forestry is the risk of increased toxicity to aquatic ecology as a result of increased availability of aluminium (Ormerod *et al.*, 1991). Research into sediment and nutrient loss from forest activities has been conducted in specific catchments and on a broader scale across a wide variety of sites. Evidence from studies undertaken on specific sites by Gallagher *et al.* (2000), Cummins and Farrell (2003), Machava *et al*. (2007) and Rogers *et al.* (2008) indicates elevated levels of both P and sediment observed post clear felling, particularly during storm conditions with high rainfall. A broader study of eutrophication and sedimentation undertaken by UCC indicated higher bedload sediment levels in catchments where clear felling had occurred as opposed to unfelled catchments. This has obvious implications for turbidity and suspended sediment levels in the water.

Elevated levels of soluble reactive P and total ammonia were also observed in catchments with high forest cover and high levels of felling activity.

Forest stands planted on peaty soil types and on steep slopes pose the greatest threat in terms of sedimentation and nutrient loss. In the latter case this is due to the poor P retentive properties of peat soils.

Compared to intensive agriculture, forest provides a semi-permanent land cover that receives infrequent inputs of fertiliser and pesticides, resulting in a relatively minor risk of diffuse pollution for most of the fell cycle. It is also acknowledged that good management of forest can be protective to aquatic habitats (Nisbet *et al*., 2011). However, certain forestry practices including drainage, fertiliser application, road construction and harvesting, do pose potential risk to nearby watercourses as already highlighted above.

A range of potential policy and management measures which may be adapted to mitigate forestry risks to water quality are available (Moorkens *et al*., 2013), including Forest Management Plans and Codes of Practice for aspects of forestry operations provided by Coillte Ireland.

Functional buffer zones are areas immediately alongside a watercourse which contain no artificial drainage. As a result, the area imposes a sponge-like effect on surface water which may otherwise have drained rapidly directly into the channel. The gradual release of the water into the channel also increases its availability to the existing vegetation within the buffer zone, allowing for increased uptake of nutrients from the surface water, and hence decrease the resultant nutrient load in the channel.

Buffer zones are required on all associated channels and feeder streams in order to be most effective, and not focussed around a single main channel running through the forest. A flat, wide buffer zone will be most effective in terms of regulation flow, sediment and nutrients.

Although installation of buffer zones can be carried out at anytime, it is recommended to undertake installation at the planting stage of forestry activity, and moreover well in advance of any harvesting or road construction operations to allow the buffer zone maximum time to generate.

Drain blocking is a further measure which can be used in conjunction with buffer zone installation as a means of regulating the flow of forest drainage and allowing water more chance to be soaked up by the buffer zone. Drains can be blocked at strategic points on the woodland side of the buffer zone at natural soakage areas and specifically in relatively small, flat drains. Blockages in drains which are too large or too steep will do little or nothing to impede the flow of water as they will simply be bypassed.

In addition to this, the re-establishment of the site should be undertaken using sensitive mounding techniques to provide the medium for replanting, no new drainage should be permitted, and the maintenance or enhancement of existing drainage should be kept to a minimum.

4.4 OTHER WATER POLLUTION MITIGATION GUIDANCE OF RELEVANCE TO TRANSMISSION

A range of pollution prevention guidance notes (PPGs) to advise industry and the public on legal responsibilities and good environmental practice have been published by the Environment Agency (UK) in partnership with the Northern Ireland Environment Agency (NIEA) and the Scottish Environment Protection Agency (SEPA).

Each PPG gives advice on law and good environmental practice, to help reduce environmental risks from business activities. The PPGs that are relevant to water pollution and concerned with activities which may be required on transmission line projects are listed below and provide detailed guidance and appropriate mitigation measures to avoid or reduce the impact on the water environment.

- PPG01 -General guide to the prevention of water pollution
- PPG02 -Correct storage of above ground oil tanks
- PPG03 -Use and design of oil separators in surface water drainage systems
- PPG05 -Works in, near or liable to affect watercourses
- PPG06 -Working at construction and demolition sites
- PPG08 -Safe storage and disposal of used oils
- PPG18 -Managing fire water and major spillages
- PPG20 -Dewatering of underground ducts and chambers
- PPG22 -Dealing with spillages on highways
- PPG23 -Maintenance of structures over water
- PPG26 -Storage & handling of drums & intermediate bulk containers

4.5 CONCLUSIONS

Having investigated the extent of available mitigation and best practice guidance which may be of relevance to projects such as linear infrastructure and its potential to cause adverse environmental impact on water quality, it is clear that there is a considerable amount of information available.

The mitigation hierarchy is an important tool assessing potential impact and measures which may require implementation, and also highlights the need to focus on the avoidance and minimisation aspects of mitigation as offsetting and compensation measures can prove to be more complex and expensive.

Adherence to the listed available best practice guidance which may be of relevance to linear infrastructure will also assist in the recommendation of appropriate and effective mitigation measures with the aforementioned aim of avoiding or minimising any negative environmental impact on water quality and aquatic ecology.

5 METHODOLOGY

5.1 INTRODUCTION

In accompaniment to the preceding Literature Review (Chapter 2), this evidence based study also called for the design and undertaking of appropriate individual field studies. These field studies aimed to investigate typical impacts across a range of sites along the length of the power line, by firstly identifying appropriate and representative sites, so that they are assessed to determine the construction impacts of power line installations.

Through consultations with EirGrid and ESB Networks, the transmission projects that were currently under construction or that were programmed to commence within the lifetime of the Evidence Based Studies were identified. These projects are listed below:

1. Donegal 110kV Reinforcement Project - Binbane to Letterkenny, and Ardnagappary to Tievebrack, Co Donegal (100 km)
2. Connemara 110kV Reinforcement Project - Lenabower to Screeb, Co Galway (48km)
3. Arvagh to Shankhill 110 kV line - Cavan, Co. Cavan (24 km)
4. Banoge 110 kV DC Link - Gorey, Co Wexford (5km)

In order to gain a representative dataset for evidence based analysis, typical, non-standard and worst case scenarios were identified. These are defined as follows:

Typical – low lying areas with adequate buffering capacity between electricity transmission infrastructure and typical water body without any sensitive water dependent habitats or species.

Reviewing effectiveness of buffer strips, Desbonnet *et al*. (1994), indicated an efficient width of vegetated buffers for sediment removal was 25 m. A width >10 m was often associated with > 80% removal of sediment (Dillaha *et al.,* 1989), but for long-term benefit >30 m was recommended (Castelle *et al.,* 1994).

The PPGs, as prepared by respective Environment Agencies across the UK (and listed in Chapter 4) recommend that to be effective the typical width of filter strips to accept run off as overland sheet flow should be at least 5-15m. However, the design of buffer strips should be site-specific, where such factors as precipitation, run-off, slope, soil type (including erodibility, current P-concentration and P-retention capacity), adjacent land use and stocking densities (where applicable) should all be taken into consideration. Larger site specific buffer strips than those recommended in the PPGs, are more appropriate as outlined in the literature listed above. Concrete and cement mixing or wash out areas are to be a minimum of 10m from surface water. In most instances as a result of the site selection process, the buffering distance will be much greater than 15m, possibly up to 50m.

Non-standard – areas where land cover is limited exposing soils, areas of steep side slopes and locations where there is limited scope for vegetative strips to provide buffering. Construction methodologies should also be considered, such as areas where the installation of the infrastructure has had a direct impact on the water body, e.g. locations where the infrastructure was proposed immediately adjacent to the river bank or where underground cabling of high voltage lines across a watercourse, as opposed to OHLs was proposed.

Worst-Case – locations where direct hydraulic connectivity to sensitive or high status water bodies exist, e.g. locations where water dependant protected areas (e.g. SAC, Special Protection Area (SPA), drinking water lakes) exist downstream of the electricity transmission infrastructure.

Based on the construction projects identified above, a site selection study was undertaken to identify potential sites upon which to base the water and aquatic ecology field based assessments. As all the case studies involve the construction of 110kV lines, the actual site selection study was focused on the locations of angle mast structures due to the greater footprint (excavation requirements) and potential impact associated with the construction of these structures (compared with wooden pole sets). However, the locations of double polesets were also reviewed, particularly in sensitive catchments e.g. FPM, and were selected to provide an indication of the potential impact from this infrastructure.

The site selection study made use of Geographic Information Systems (GIS) to select suitable sites which satisfied the criteria identified above for each of the scenarios proposed. In order to assist in this process the national constraints study carried out by RPS on behalf of EirGrid to inform the SEA of the implementation programme for Grid25 was used to assist in the site selection process.

Further to the desk-based GIS study, site identification was furthered by undertaking site visits and reconnaissance field work to ensure that sites were appropriate and representative as intended. Any potential site identified for study was visited to collect photographic evidence (Appendix I) and familiarise the study team with the locale and enable an appreciation of the flow regime and typical sediment characteristics, along with any upstream activities that might reduce the value of the scientific evidence, leading the study to be open to challenge at a later stage. In terms of the upstream catchment assessment, field sheets have been used to record all activities likely to give rise to pollutants (particularly nutrient and sediment sources).

Once appropriate sites had been identified, the study aimed to collect water quality data both prior to and following the construction of the structure given that the construction phase of the project had been previously identified in the literature review as the aspect most likely to cause adverse impact on water quality. This data would be collected at two locations along an adjacent watercourse; one upstream of the structure and one downstream. Given that this approach required pre-construction surveys to be carried out, the timing of the sampling was largely dependent on the construction programme decided on by the on-site contractors.

The key water quality parameters to be sent for laboratory analysis relevant to this project include concentrations of suspended solids, biochemical oxygen demand (BOD), molybdate reactive phosphorus (MRP) and ammonia. The results of these lab analyses would also be supplemented by the collection of data *in situ* using a handheld water quality monitoring probe called the Hydrolab Quanta, with the capability of measuring temperature, pH, turbidity, conductivity and dissolved oxygen (DO).

Initial proposals stated that each site would be sampled six times both pre and post construction throughout the duration of the project, which would be dependent on the construction programme, to allow for an analysis of the physico-chemical parameters and to allow for a high level of confidence in the sampling results. The EU WFD Monitoring Programme, developed by the EPA (EPA, 2006) recommends a minimum of 4 samples for physico-chemical monitoring; therefore, the analysis of 6 samples would ensure the monitoring carried out under this project is adequate for the classification of the water bodies under consideration.

In addition to monitoring of the aforementioned physico-chemical parameters, macroinvertebrate surveys, site condition assessments and River Hydromorphology Assessment Technique (RHAT) (NIEA, 2009) surveys, where channel conditions were suitable, have also been included in the proposed methodology.

Both the biological and the physico chemical monitoring programmes were planned in accordance with the recognised EPA monitoring programme. In essence the same techniques were deployed when undertaking Q-surveys, RHAT surveys and site condition assessments, along with a similar list of parameters monitored from grab samples for physico-chemical analysis.

Once this data had been collected it would allow for analysis to be carried out to determine any significant differences experienced in water quality as a result of the construction, in terms of sediment and/or nutrient loading in the channel arising as a direct result of the construction works.

Following on from the findings of this study, recommendations for future transmission installations will then be put forward with the aim of helping to ensure best practice to minimise impact caused as a result of such projects.

5.2 STUDY SITE SELECTION

5.2.1 Introduction

The literature review confirmed that the key likely impacts on water due to the development of electricity transmission infrastructure are associated with the construction phase of the development, with only minor impacts associated with routine maintenance activities. Therefore, the approach taken to assess the actual impacts of transmission infrastructure on water quality and aquatic ecology was to focus on the identification of case studies that included transmission lines under construction.

A suite of potential case studies was selected for more detailed data collection and/or analysis. These concentrated on ongoing construction activities and existing projects during which adequate datasets have been obtained (for example water quality monitoring upstream and downstream of construction activities near watercourses). Further details on site selection are summarised in Chapter 6, including site description, sampling periods, GPS location and so on.

5.2.2 Strategic Environmental Constraints Mapping

High level constraints mapping was prepared by RPS on behalf of EirGrid to assist in the identification of major environmental constraints which may impact on transmission development projects. The different mapping developed under the Strategic Environmental Constraints Mapping Project is summarised below:

5.2.2.1 Ecology Maps

The ecology maps include international and national nature conservation designations including SACs, SPAs, Annex I habitats (such as FPM habitat), Ramsar Sites (R) and (including proposed) Natural Heritage Areas (NHAs). In addition the CORINE (Co-ordination of Information on the Environment) dataset has been used to identify areas likely to contain Annex I habitat of the Habitats Directive (92/43/EEC).

A constraints model has been developed from the ecological designations mapping identifying the major ecological constraints nationally and to facilitate the identification of areas where ecological constraints are prominent. This mapping was used to identify ecological designations in close proximity to the Donegal and Connemara 110kV Reinforcement transmission line construction projects.

An example of the mapping for the Ardnagappary to Tievebrack line on the Donegal 110kV reinforcement project is provided in Figure 5.1. The GIS also allowed for the selection of structures or sections of the transmission line that were in close proximity to water bodies (predominantly rivers) that have a sensitive water dependent protected habitat or species. This was critical for the identification of the worst case scenario, for example the FPM which is particularly sensitive to sedimentation, nutrient enrichment and changes to the morphology and ultimately flow regime of a river.

Note: The constraints maps were produced in 2009 and the datasets upon which they are based may have been updated more recently, particularly as NPWS issue regular updates on the Natura 2000 network.

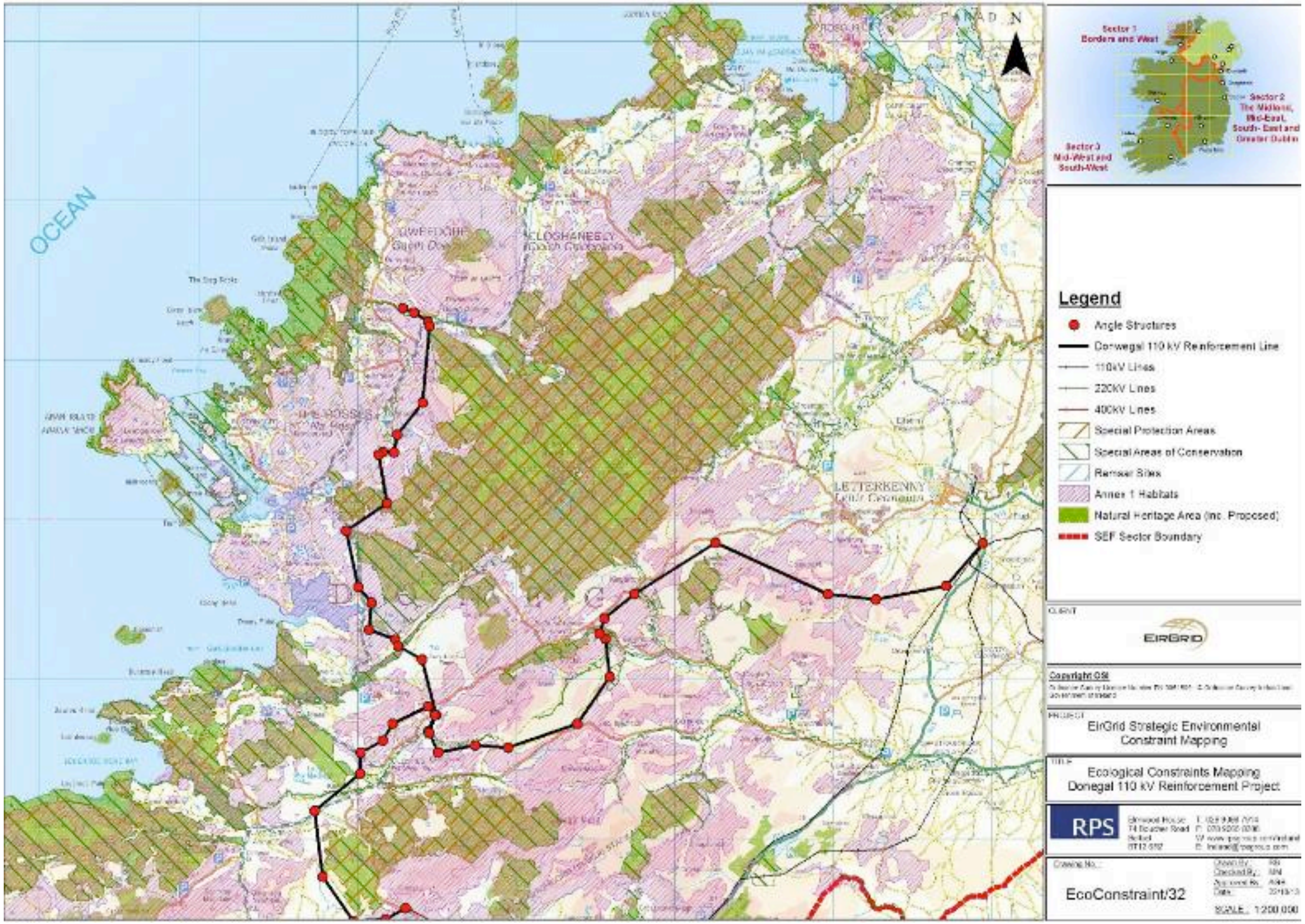


Figure 5.1 EirGrid Strategic Constraints Mapping, Ecological Constraints on Donegal 110 kV Line

5.2.2.2 Sensitive Landscape Mapping

A sensitivity land-use map was prepared – based on CORINE landcover characteristics that are likely to be indicative of conditions that will provide areas of high visual sensitivity to transmission infrastructure. This CORINE dataset has been created from satellite imagery and represents different cover/land use classifications throughout Europe. This interim map will form the basis of the evaluation of the effects upon the landscape of GRID25 implementation.

The CORINE dataset holds information on the location and extent of natural habitats and has been queried to identify landcover characteristics that are likely to be indicative of landscape sensitivity and high visual amenity.

Figure 5.2 provides an example of the mapping for the Connemara 110 kV reinforcement project and illustrates the natural habitats traversed by the proposed 110 kV line. The mapping allowed areas of natural habitat that may represent difficult ground conditions in terms of transmission line construction to be identified, e.g. areas of extensive peat bogs.

5.2.2.3 Topography Maps

The topography mapping has made use of the 50m Digital Terrain Model (DTM) available from the Ordnance Survey of Ireland. All areas greater than 200m have been identified from the DTM and plotted on the topography mapping. The 200m contour has been used as the threshold to define upland areas. This is considered as conservative and is representative of the lower limit of upland grasslands and heath habitats in Ireland.

In addition the areas where the slope is greater than 30 degrees have also been identified with the view to identifying areas where the construction of transmission infrastructure would be particularly difficult.

The topographical mapping also identifies the possible opportunities for transmission circuit development adjacent to these upland areas. The areas land areas under 200m and with a slope between 5 degrees and 30 degrees has been identified on the mapping. These areas may be suited to transmission line development given the natural screening afforded by the upland areas in the immediate vicinity. The topographical mapping therefore identifies upland areas, steep-sided slopes, catchment boundaries and possible opportunity areas where transmission circuits may be better integrated into the existing landscape.

Figure 5.3 illustrates the mapping for the Binbane to Letterkenny line on the Donegal 110 kV reinforcement project.

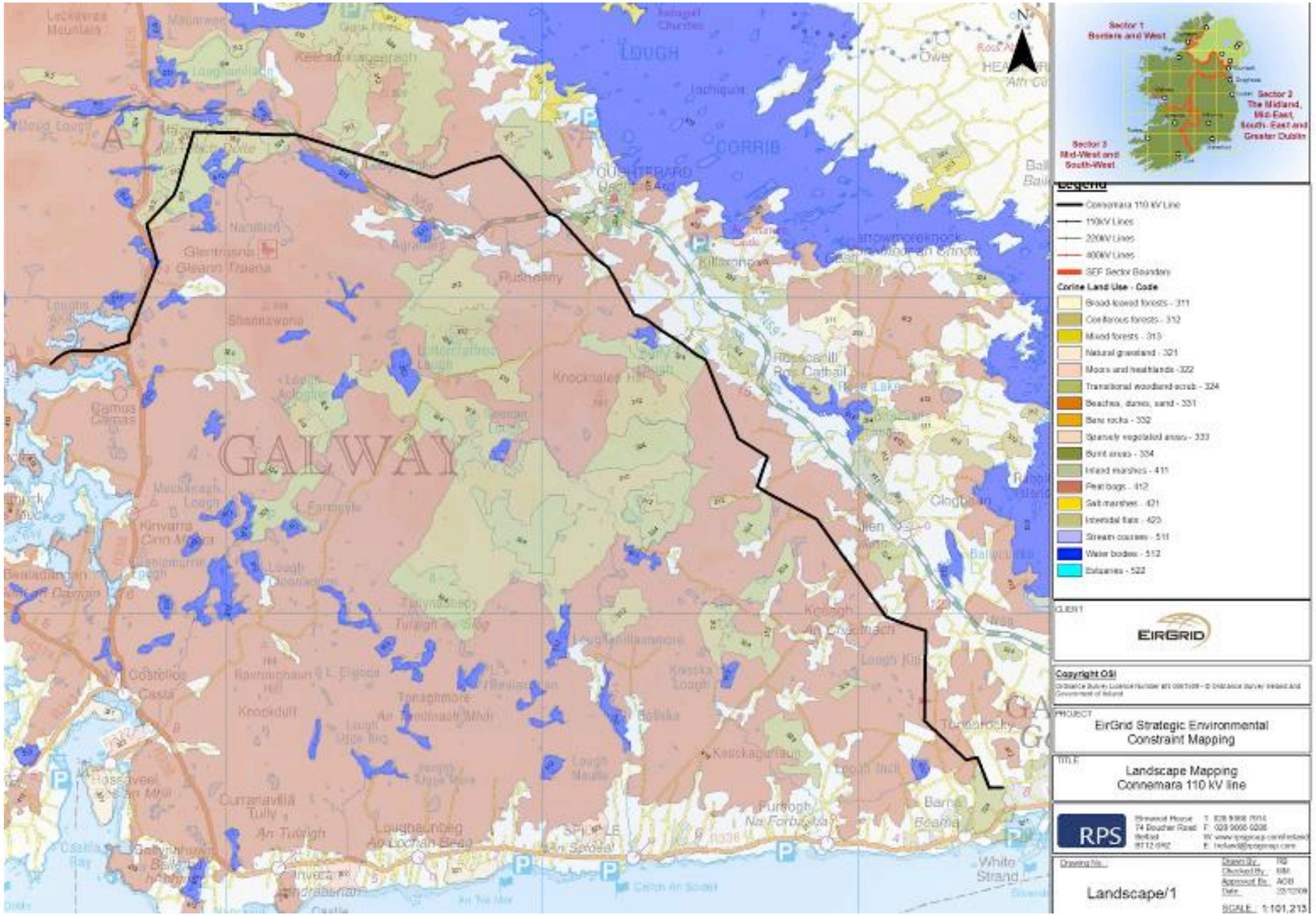


Figure 5.2 EirGrid Strategic Constraints Mapping, Landscape mapping for Connemara 110 kV Line

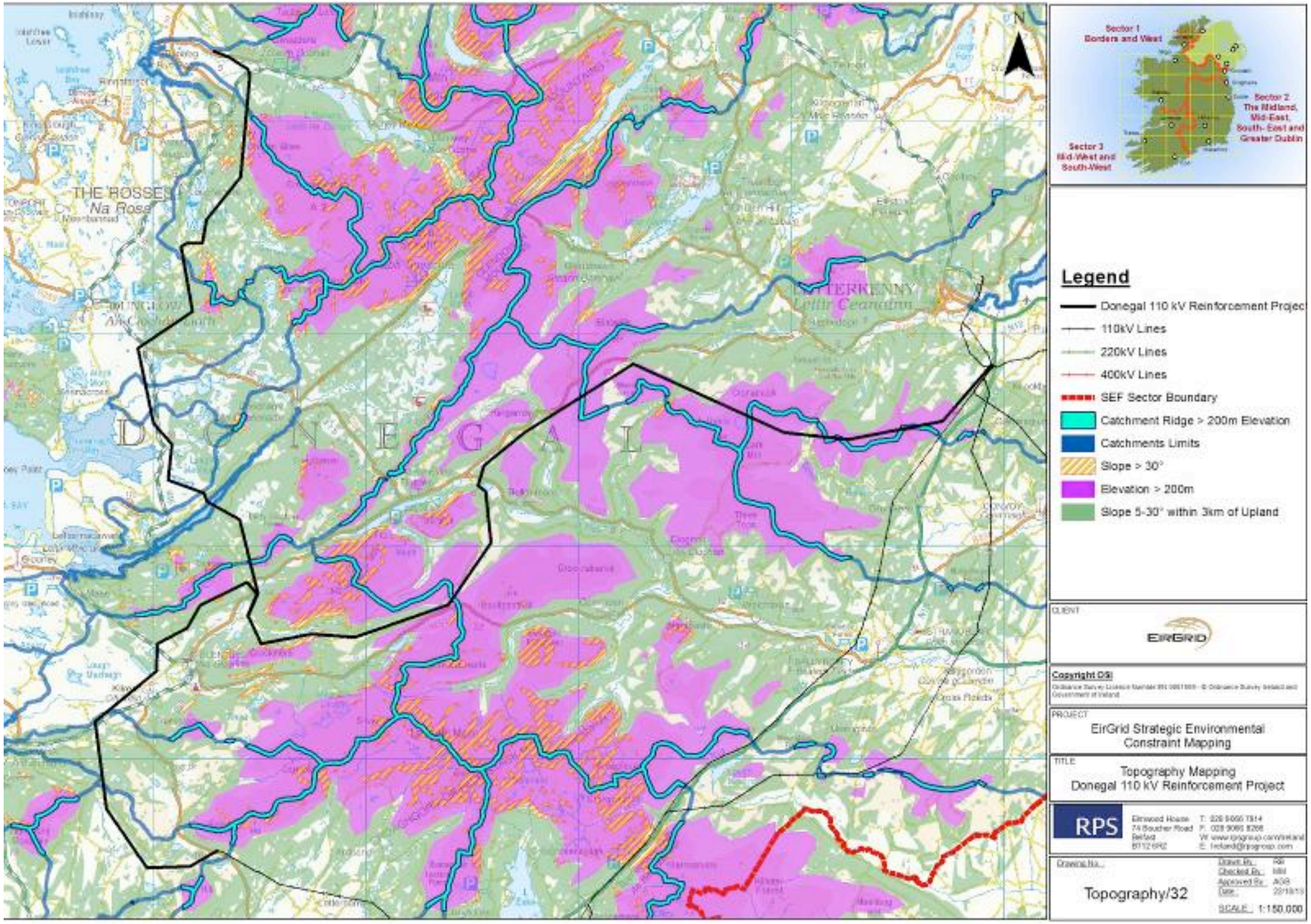


Figure 5.3 EirGrid Strategic Constraints Mapping, Topographical mapping for Donegal 110 kV Line

5.2.2.4 Constraints mapping

Given the wide geographical extent of the study areas concerned with many transmission projects and the different environmental and spatial datasets involved, a technique was developed through the Strategic Environmental Constraints Mapping Project using GIS that facilitated the evaluation of the datasets spatial correlations and juxtapositions. It assessed the degree of vulnerability of the different areas within the study area boundary and the potential for cumulative/synergistic impacts and allows sensitive areas and locations with numerous constraints to be readily identifiable through a constraints rating or score.

The composite environmental constraints mapping for the Donegal 110 kV reinforcement project, the Connemara 110 kV project and the Banoge 110 kV project are included in Figures 5.4 – 5.6 below.

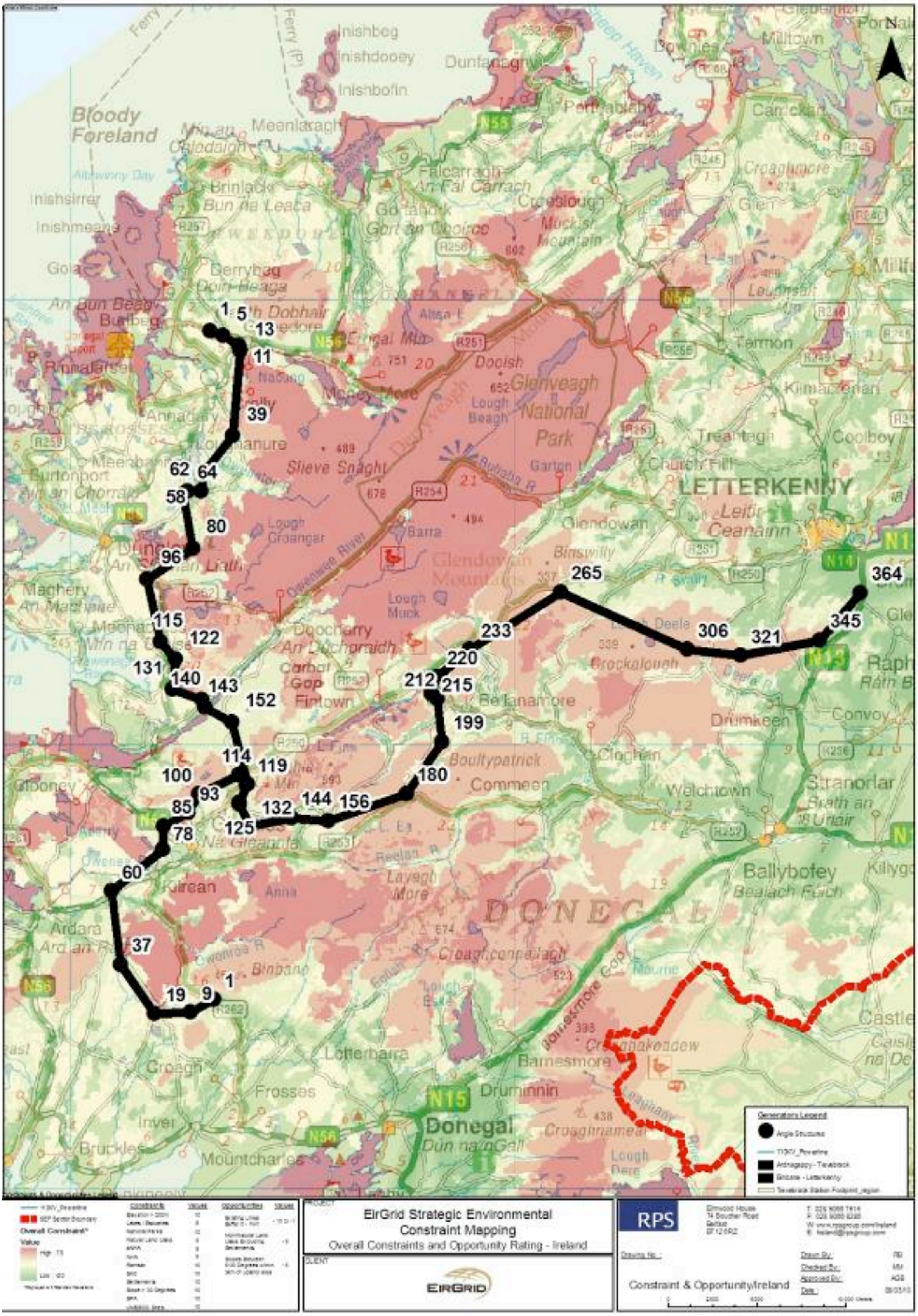


Figure 5.4 EirGrid Strategic Constraints Mapping, Constraints rating for Donegal 110 kV Line

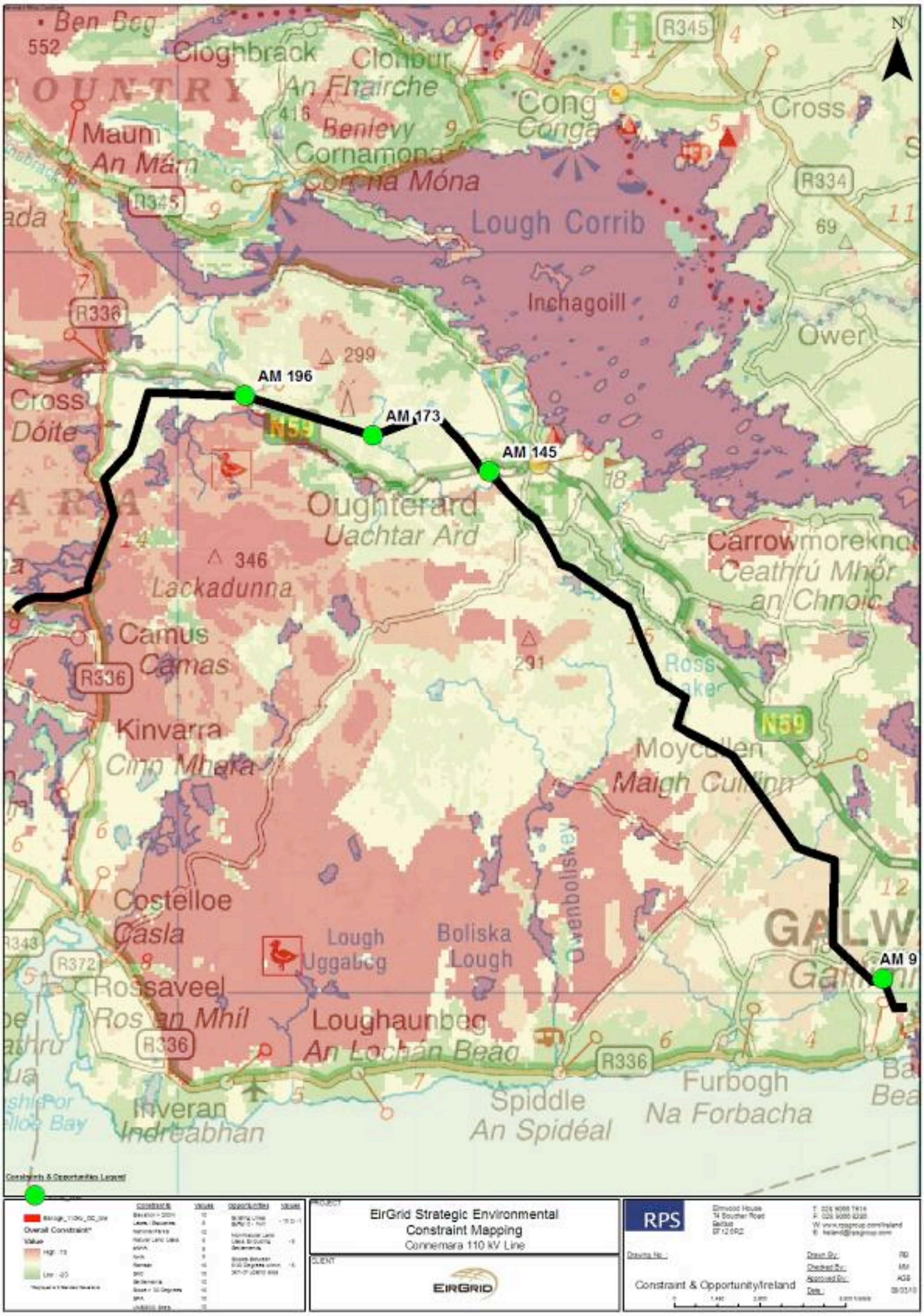


Figure 5.5 **EirGrid Strategic Constraints Mapping, Constraints rating for Connemara 110 kV Line**

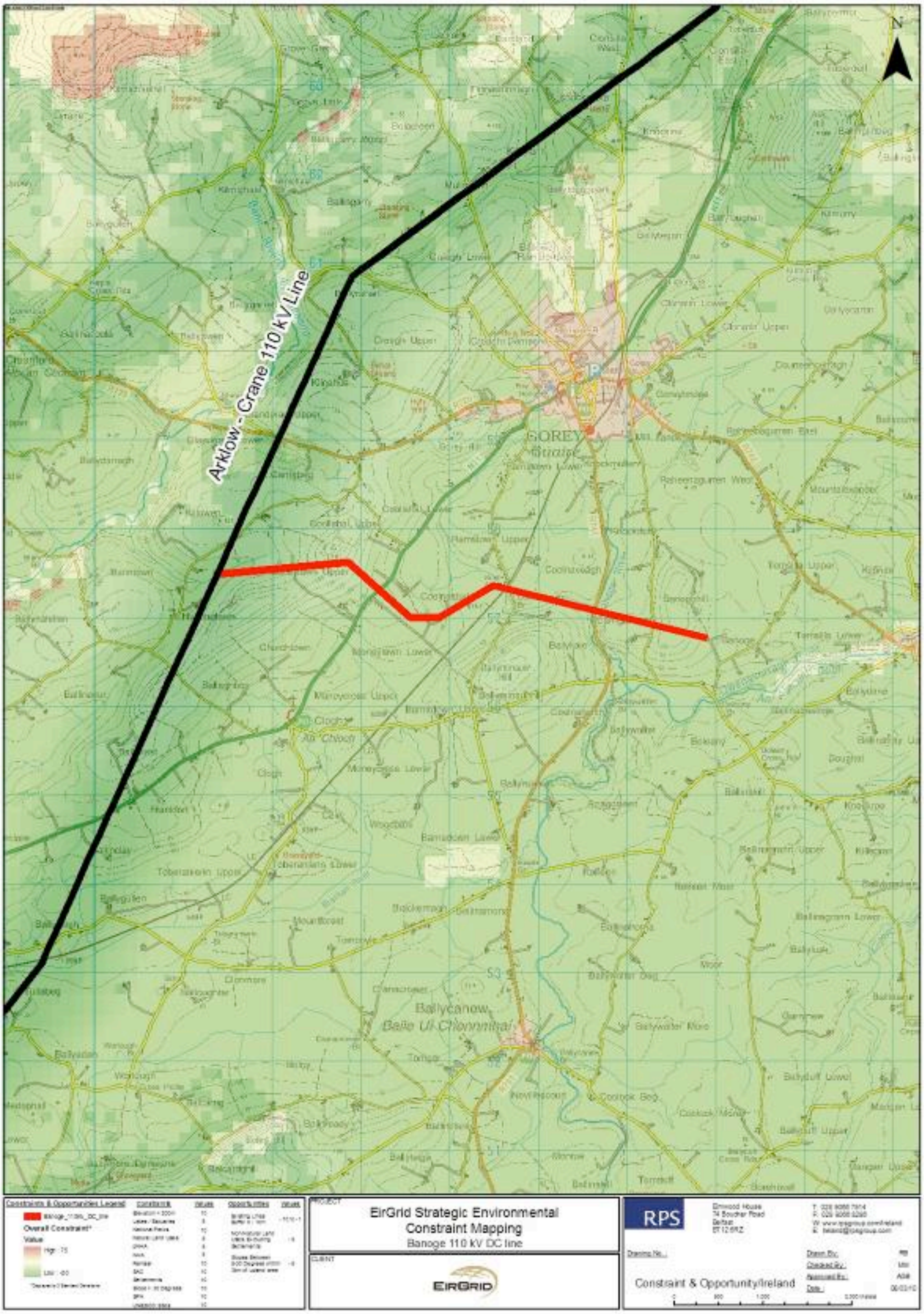


Figure 5.6 EirGrid Strategic Constraints Mapping, Constraints rating for Banoge 110 kV Line

5.2.3 Site Selection

Using the strategic constraints mapping as outlined above and carrying out a spatial analysis of the proximity to water bodies, sites were selected that would satisfy the criteria as outlined in Section 5.1. A number of sites were selected for each category and an order of preference was provided.

The locations identified during the site selection process are summarized below in Table 5.1. Sites shaded in grey were selected for the study, based upon prioritisation and availability. Key constraints to the site selection process included limited site access and restrictions due to the construction programme and the availability of the site to complete the monitoring programme within the timeframe of the study. In total 15 sites were selected and a preference given in terms of their suitability. However due to difficulties in land access and the construction programme not all first preference sites were available.

The aim of the field study was to assess two sites from each of the categories, worst case, non-standard and typical, given the methodology proposed.

Table 5.1 Site Selection based on scenario type

	Scenario	Site Description	Possible sites	Preference
1	**Worst Case**	Locations where direct hydraulic connectivity to sensitive or high status water bodies exist, e.g. locations where water dependant protected areas (e.g. SAC, SPA, drinking water lakes) exist downstream of the electricity transmission infrastructure	Clady River on the Donegal 110 kV Line (Ardnagappary - Tievebrack Line Structure 6). FPM catchment requiring high water quality	1
2			Owenriff River at Oughterard on the Connemara 110kV line (AM 145). FPM catchment requiring high water quality	4
3			Tributary of Owenea River at Gortnamucklagh on the Donegal 110kV Line (AM 78 Binbane - Letterkenny line). FPM catchment requiring high water quality	2
4			Bunowen River (Tributary of Owenriff) Connemara 110 kV line (AM 173). FPM catchment requiring high water quality	3
5	**Non-Standard**	Upland areas of steep side slopes adjacent to a water course or lake and locations where there is limited or no vegetative strips to provide buffering	Dungloe River Donegal 110 kV	3
6		New construction projects within 10-15m of a water course	Owenwee River Conemara 110kV Project (AM196)	2
7		Projects which require forestry felling adjacent to water course	Owenamarve River Donegal 110kV project (Ardnagappary - Tievebrack Line)	1
8			Shallogan River – Donegal 110 kV Project (Binbane Letterkenny Line, AM119)	4
9			Inflow to Lough Bofin on Connemara 110 kV Line (Structure 177-183	5
10	**Typical**	Locations where sub-station infrastructure has the potential to impact water quality	Tributary of the Stracashel (Tievebrack substation)	1
11		New construction projects in low lying areas >50 m from a water course	Owenea River on the Donegal 110kV Line (Structure 69 Binbane - Letterkenny line)	2
12		Low lying areas with adequate buffering capacity between electricity transmission infrastructure and water body.	Stracashel River Donegal 110kV Line (AM144 Binbane - Letterkenny line)	3
13			Swanlinbar River on Arva Shankill 110 kV Line	5
14			Barna Stream Connemara 110 kV Project (AM 9)	4
15		New construction projects in upland areas >50m from a water course	Deele Upper on Donegal 110 kV Project (Angle structure 306 Binbane - Letterkenny Line)	6

5.2.4 Worst Case Scenario Sites

Tributary of Owenea River at Gortnamucklagh (AM 78, Binbane to Letterkenny Line)

The Owenea River is located within the West of Ardara/Maas Road SAC and one of the qualifying features for the SAC is the FPM. This species is particularly sensitive to increased sedimentation, nutrient enrichment and flow regime changes as outlined in the literature review (Chapter 2). Angle mast 78 is located immediately adjacent to a tributary of the Owenea River which is located within the FPM catchment and which joins the main channel of the Owenea River in the reach that has been identified as FPM habitat. This river must be restored to favourable conservation status in the draft sub basin management plan prepared for the catchment under the European Communities Environmental Objectives (Freshwater Pearl Mussel) Regulations 2009. The construction of this structure has significant potential to impact on the FPM habitat given the proximity to the tributary at Gortnamucklagh and the FPM habitat in the main channel of the Owenea River. In addition forestry felling is required upstream of this location to facilitate the transmission line development and should consider the guidance outlined in Chapter 4.

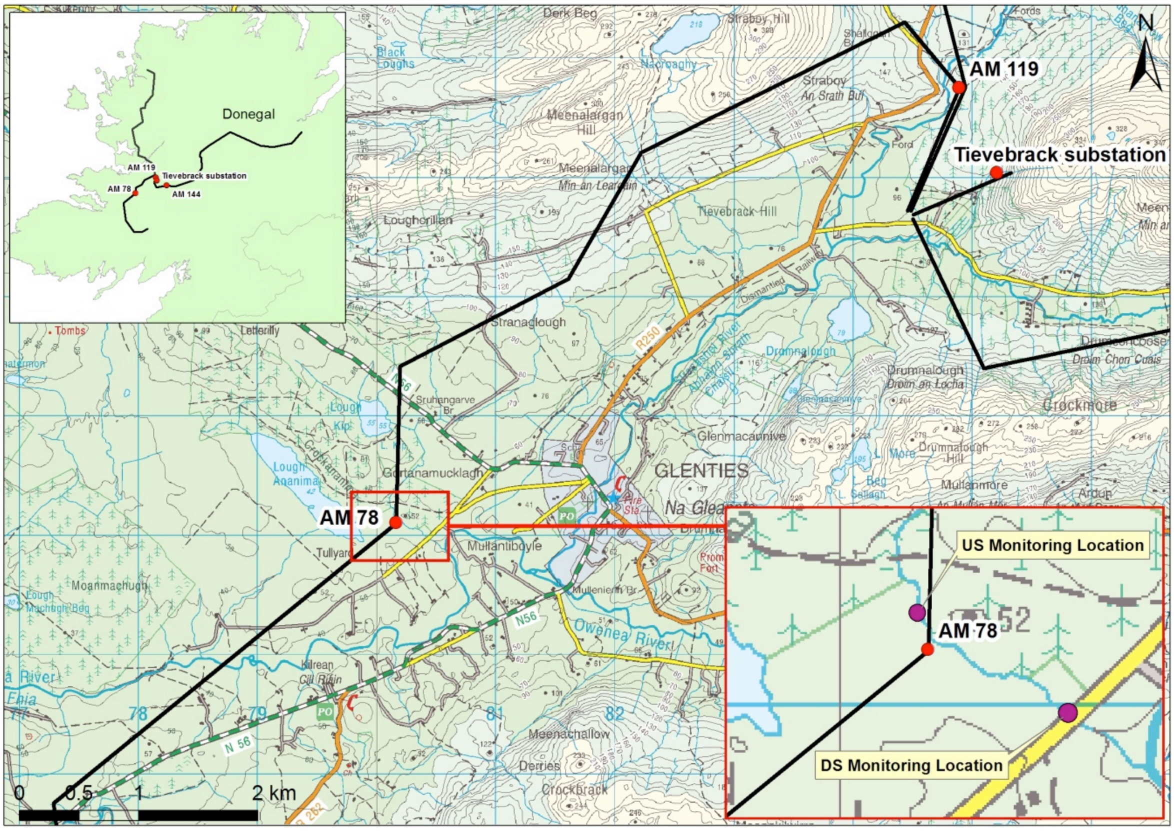


Figure 5.7 Location Map Tributary of Owenea River at Gortnamucklagh (AM 78, Binbane to Letterkenny Line)

The draft sub basin management plan (NPWS, 2010) for the Owenea identifies hydrological and morphological (hydromorphological) pressures as one of the key issues in this catchment. Hydromorphological pressures within catchments generally have the key impact of increasing sediment load to the river, and altering erosion and deposition processes within the river itself. This has a critical effect on FPM survival. During the preparation of the sub basin management plan catchment walkover surveys and risk assessments were carried out across the catchment and the tributary of the Owenea at Gortnamucklagh was considered to be a high risk location due to the condition of the riparian zone due to lack of a riparian buffer, which can intensify other pressures. It can also increase the potential impact of diffuse nutrient and sediment input. The tributary of the Owenea at Gortnamucklagh has also been classified at high status in the North Western River Basin Management Plan and there has been an increasing trend in recent years for the loss of these types of sites. Long term monitoring of rivers by the EPA has shown a dramatic and continuous decline of these sites over the last 20 years (Irvine & Ní Chuanigh, 2010).

Considering the assessment of the pressures in the draft sub basin management plan and the location of the angle mast immediately adjacent to the tributary of the Owenea, which is classified at high ecological status, this site was selected as a potential worst case scenario; given the potential morphological changes that could occur within the riparian zone and the associated potential for sediment release into the water body and impact on ecological status.

Bunowen River (Tributary of Owenriff) (AM 173 Connemara 110 kV line)

The Bunowen River is a tributary of the Owenriff River which is within the Lough Corrib SAC with FPM as one of the qualifying interests for the SAC. The Bunowen River joins the Owenriff immediately downstream of Lough Ateean and the river reach downstream has been identified in the sub basin management plan for the Owenriff FPM catchment as, "*habitat which must be restored to favourable conservation status*."

This particular structure is located over 20m from the Bunowen River at a location which is 500m upstream of the Lough Corrib SAC. However, the ground conditions are extremely difficult given the extensive peat bog present (across which the line traverses) and access to the site by construction vehicles will be particularly difficult. Given the complexities involved in accessing the site and the sensitivity of the downstream receiving water body, this site was also selected as a worst case scenario with ground stability issues and the potential for the erosion of peat fines into the Bunowen River a significant concern. In addition to this, the draft sub basin management plan for the Owenriff FPM catchment has not identified any other key pressures in this part of the catchment so this offers a good opportunity to establish the potential impact from the construction of the angle mast.

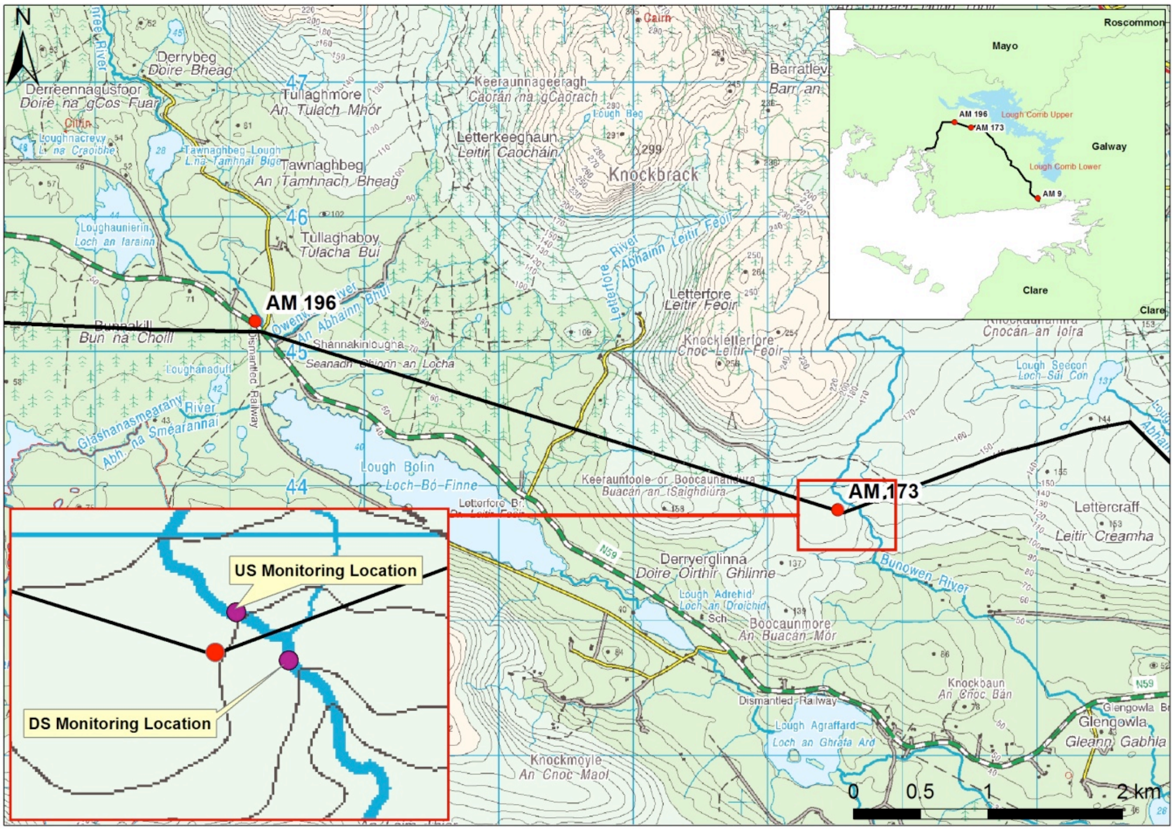


Figure 5.8 Location Map Bunowen River (Tributary of Owenriff) (AM 173 Connemara 110 kV line)

5.2.4.1 Non Standard Scenario sites

Owenwee River (AM196, Connemara 110kV Project)

Angle mast 196 is located immediately adjacent to the Owenwee River just outside the Connemara Bog Complex SAC. There is no riparian buffer zone between the structure and the river which is the predominant reason for the selection of this site as a non-standard scenario. Given the location of the structure and lack of riparian buffer there is a significant risk of impact from suspended solids and other polluting substances associated with the construction of the structure's foundations. There is also the potential for direct hydromorphological impact on the river bank and the associated pressures associated with increased erosion risk.

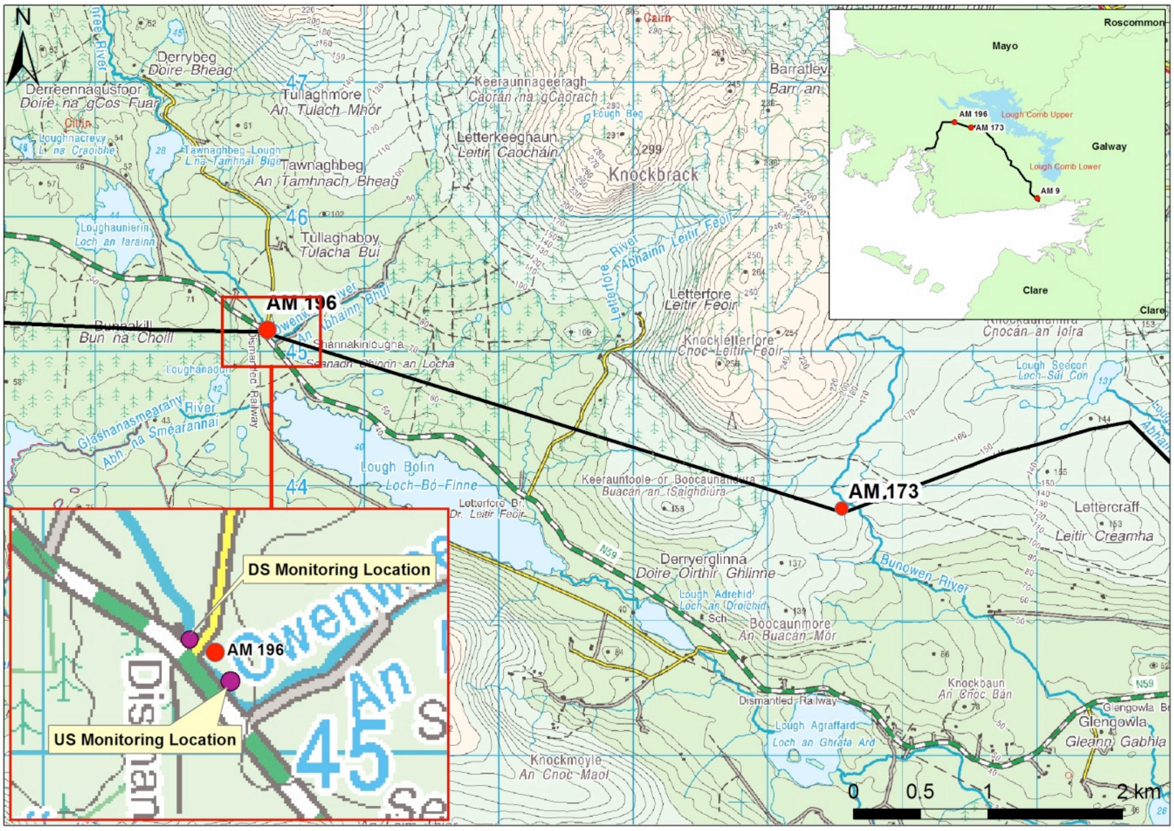


Figure 5.9 Location Map Owenwee River (AM196, Connemara 110kV Project)

Shallogan River (AM119, Binbane Letterkenny Line, Donegal 110 kV Project)

The proposed location for AM119 is adjacent to the Straboy River upstream of Gentles and the Owenea River in the Owenea FPM catchment. The erection of this structure requires the felling of part of a commercial forestry plantation to facilitate the construction of the transmission line. The Forest07 dataset, available from Forest Service, is a spatial dataset outlining the forest cover throughout Ireland. Forest 07 indicates that the Straboy Forest is a mature pine forest and therefore predates the good practice measures identified in the Forest Service guidelines (Forest Service, 2000). There is therefore a legacy issue associated with the original establishment of the forest up to the river bank with an inadequate riparian buffer zone provided.

Harvesting of commercial forestry can have a significant impact on water quality through sedimentation, nutrient enrichment and flow regime issues as outlined in the literature review (Chapter 2). The key pressure during and immediately after felling is predominantly associated with sedimentation whilst nutrient rich residues (brash, needles, etc.) can decompose over longer periods resulting in elevated nutrients in the aquatic zone long after harvesting operations have ceased.

This site was selected due to the requirement to fell part of a mature forest to facilitate the construction of transmission infrastructure. The construction programme for the site was also originally within the timeframe of the study.

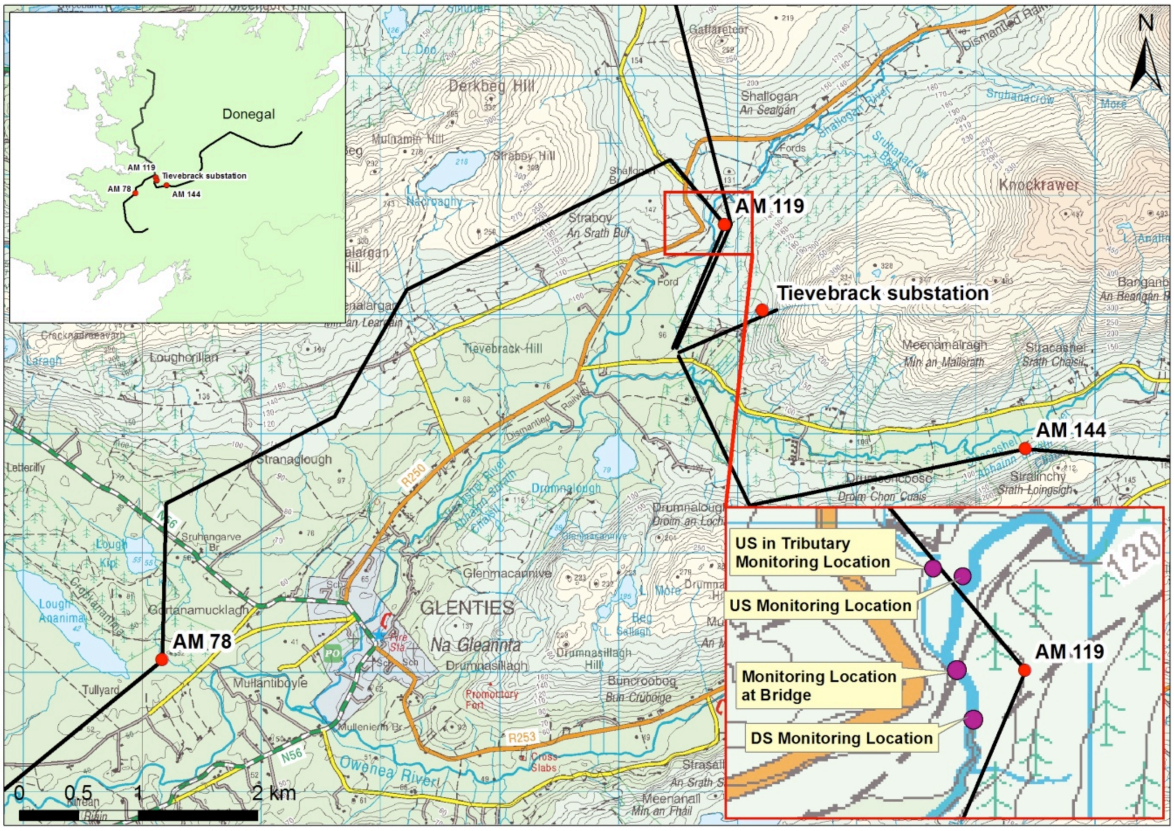


Figure 5.10 Location Map - Shallogan River (AM119, Binbane Letterkenny Line, Donegal 110 kV Project)

5.2.4.2 Typical scenario Sites

Barna Stream (AM 9 Connemara 110 kV Project)

This site was selected as it was located in a low lying area approximately 30m from the Barna Stream which is a water body with no water-dependant protected area designations. This was a good example of a typical scenario, given the low lying nature of the site, the soil conditions and land use and the distance to the water body.

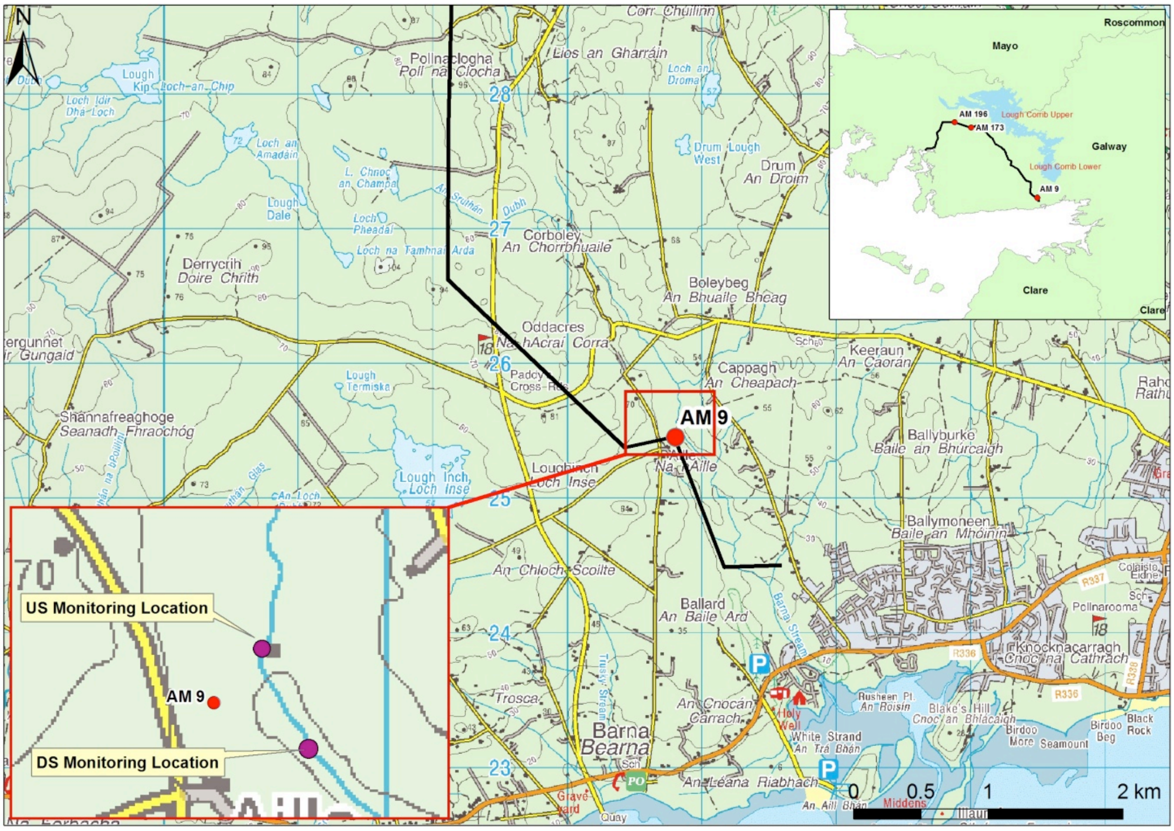


Figure 5.11 Location map - Barna Stream (AM 9 Connemara 110 kV Project)

Stracashel River (AM144 Binbane - Letterkenny line, Donegal 110kV Line)

The Stracashel River is also part of the West of Ardara/Maas Road SAC and is within the Owenea FPM catchment. However the Stracashel is more remote from the FPM habitat but still has the potential to deliver sediment load to the habitat of this species. This particular structure was chosen as it is located at the bottom of a steep slope but there is adequate buffering capacity with the structure being set back from the channel by a distance of approximately 100m.

Having selected this structure as a potential site at the commencement of the study, it was established that the construction programme for this structure had already commenced ahead of the monitoring programme.

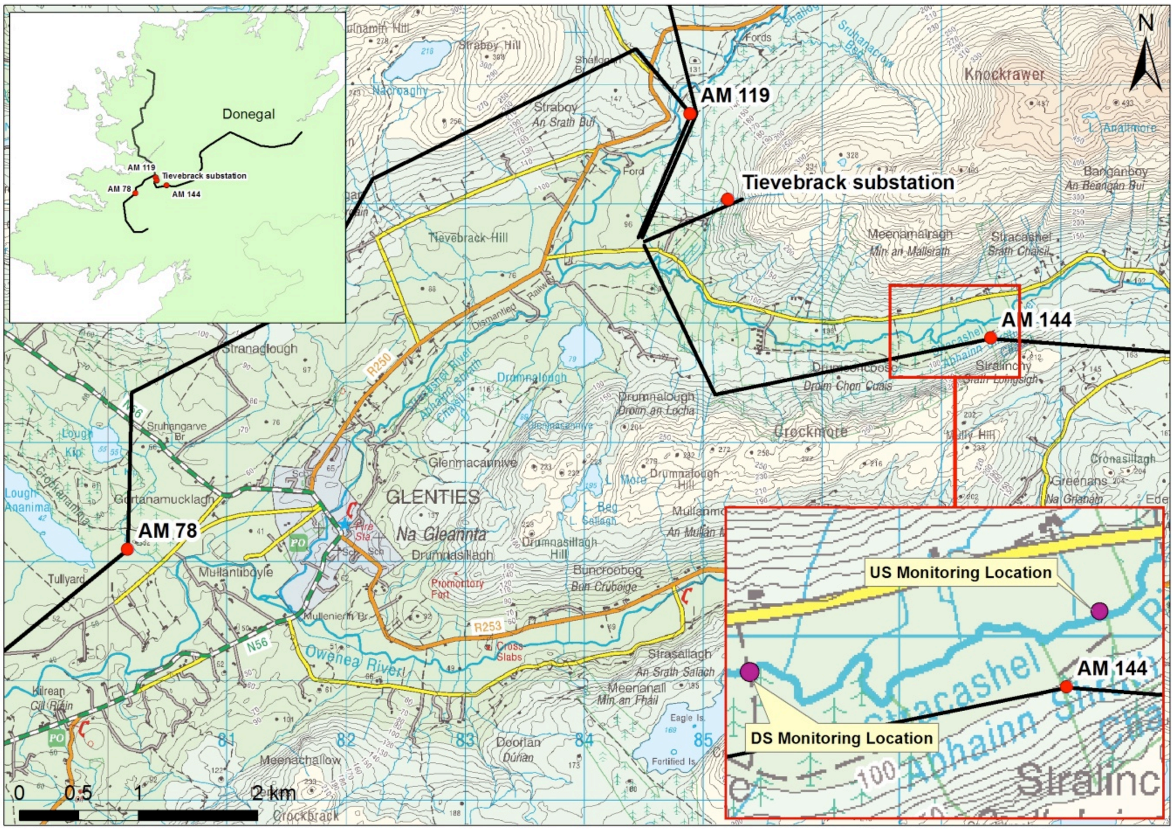


Figure 5.12 Location Map Stracashel River (AM144 Binbane - Letterkenny line, Donegal 110kV Line)

5.3 SITE SURVEYS

5.3.1 Physico-chemical sampling and analysis

5.3.1.1 Introduction

In terms of water quality standards there have been recent developments under the WFD, which address all aspects of the water environment (rivers, lakes, estuaries and coastal waters plus groundwater). These include establishment of quality standards for water and the development of quantitative standards. Of prime importance for this study are the water quality standards under the WFD for parameters such as nutrients, dissolved oxygen, temperature, and biochemical oxygen demand (BOD) as published in the European Communities Environmental Objectives (Surface Water) Regulations 2009.

The European Communities Environmental Objectives (FPM) Regulations, S.I. 296 of 2009 set out environmental quality objectives for FPM populations within designated SACs, some of which are crossed by the transmission line development. Assessment of conservation status is based on demographic features of the FPM populations set out in the Third Schedule of the regulations and on habitat criteria set out in the Fourth Schedule. Physico-chemical water quality standards are not included in the favourable conservation status criteria however published values for water quality variables required to support a sustainable population of FPM will also be considered in the context of those sites within FPM catchments.

5.3.1.2 Physico-chemical monitoring

The list of physico-chemical variables monitored is provided below:

a. Dissolved Oxygen
b. pH
c. Turbidity (as a surrogate for suspended solids)
d. Temperature
e. Conductivity
f. Nutrients (phosphates and ammonia [added at a later date in the sampling programme])
g. BOD
h. Suspended solids

As outlined in the methodology, initial proposals stated that each site would be sampled six times both pre and post construction throughout the duration of the project to allow for a robust analysis of the physico-chemical parameters and to allow for a high level of confidence in the sampling results. This was over and above EPA recommendations under the EU WFD Monitoring Programme of a minimum of 4 samples for physico-chemical monitoring. In some instances the samples were not possible as a result of access difficulties and the constraints of the construction programmes.

Water sampling was undertaken using a combination of both *in-situ* readings taken using the Hydrolab Quanta multi-parameter water quality sonde[10] and analyses of water samples collected from the channel and sent to a fully accredited laboratory.

The specification for the Hydrolab is provided in Table 5.2.

The variables analysed in the laboratory are listed in Table 5.3 along with their limit of quantification. In some instances the concentrations of certain variables were found to be lower than the Limit of Quantification (LOQ) offered by the laboratory. On the occasions where the LOQ was higher than the measured concentration, the European Communities (Technical Specifications for the Chemical Analysis and Monitoring of Water Status) Regulations, 2011 (SI 489 of 2011) were referenced, which state, *"where the amounts of physico-chemical or chemical measurands in a given sample are below the limit of quantification, the measurement results shall be set to half of the value of the limit of quantification concerned for the calculation of mean values."*

[10] A water quality monitoring probe.

Table 5.2 Instrumentation Specification for Quanta Hand-held Multi-Parameter Probe

Description	General Specification
Multi-parameter Water Quality & water level Instrument Monitoring system	
Quanta Handheld Water Quality Monitoring Sonde	•Simultaneous measurement for a maximum of 7 parameters •Easy installation, handling and maintenance thanks to modular system design and robust waterproof structure
Sensors	
Turbidity	4-beam turbidity – two measurement phases provide four independent measurements (DIN 38404/ISO 7027) **Range:** 0- 100 NTU 100-1000 NTU (automatic change) **Accuracy**: +/- 5% measured value +/- 1 NTU **Resolution:** 0.1 NTU or 1 NTU
Dissolved Oxygen	Based on Clark-cell technology – gold electrode with ion selective membrane **Range:** 0-50 mg/l **Accuracy**: +/- 0.2 mg/l **Resolution:** 0.01 mg/l
pH	Preference for re-buildable reference probe but not essential **Range:** 2-12 pH Units **Accuracy**: +/- 0.2 units **Resolution:** 0.01 units
Conductivity	4 electrode cell methodology – sensors encapsulated in graphite **Range**: 0 – 100 mS/cm **Accuracy:** +/- 1% measured value **Resolution**: 0.0001 units
Temperature	NTC **Range:** -5 – 50 **Accuracy:** +/- 0.2 ^{o}C **Resolution:** 0.01 ^{o}C
Remote communication module, Data Logging, Data Transmission and storage	
Internal memory on handheld display (max 200 frames)	•4.5 V DC power supply from internal C-cell batteries •RTC/PC dump feature to transfer max. 200 logged frames of data to PC (.csv format) •Compatible with SDI-12 Input

Table 5.3 List of Parameters and LOQ analysed by external Laboratory

Parameter	Units of Measurement	Limit of Quantification
Phosphate (Molybdate Reactive Phosphate MRP)	mg P/l	0.01
Ammonia	mg NH_3/l	0.005
Biochemical oxygen demand (BOD)	mgO_2/l	1.0
Suspended solids	mg/l	2

5.3.1.3 Sample analysis and interpretation

Analysis of the upstream and downstream water quality information has been undertaken to determine impact. The impacts in the receiving waters are being established by comparing the measured concentrations with water quality standards as defined in the European Communities Environmental Objectives (Surface Water) Regulations 2009 and peer reviewed literature on the water quality standards required for FPM populations given the stringent water quality standards required for this species.

This will allow the pressure associated with the construction of electricity transmission projects to be assessed in the context of the EU WFD or the specific requirements and standards of water dependent protected areas and species. Where relevant water quality standards indicative of sustainable conditions for FPM populations have also been used based on published literature

European Communities Environmental Objectives (Surface Waters) Regulations 2009 S.I. No. 272 of 2009

Environmental Quality Standards as listed in the European Communities Environmental Objectives (Surface Waters) Regulations, 2009 are detailed in Table 5.4 below.

Of note is the lack of an established water-based standard for suspended solids due to the paucity of data and links with ecological standards. Comparison of the turbidity and suspended solid values with values found in other studies which were associated either with no/low or high impact will be used to help interpretation of the monitoring results particularly in the context of the FPM catchments where construction of the transmission infrastructure is taking place.

Ideally measurements would relate to Total Suspended Solids (TSS) and Nephelometric Turbidity Units (NTU) compared with background levels or in the case of FPM catchments published values in the literature that are consistent with a sustainable FPM population. The effect of high rainfall at the time of survey in terms of flow conditions was also taken into account.

Table 5.4 European Communities Environmental Objectives (Surface Waters) Regulations 2009 (S.I. No. 272 of 2009).

Parameter	Standard
Dissolved oxygen lower limit (% Sat)	95%ile >80% saturation
Dissolved oxygen upper limit (% Sat)	95%ile <120% Saturation
pH (Individual Values)	Soft[11] Water 4.5< pH < 9.0 Hard[12]Water 6.0< pH < 9.0
Biochemical Oxygen Demand (BOD)(mg O_2/l)	High status ≤1.3 (mean) or ≤2.2 (95%ile) Good status ≤1.5 (mean) or ≤2.6 (95%ile)
Total Ammonia (mg NH_3/l)	High status ≤0.040 (mean) or ≤0.090 (95%ile) Good status ≤0.065 (mean) or ≤0.140 (95%ile)
Molybdate Reactive Phosphorus (MRP) (mg P/l)	High status ≤0.025 (mean) or ≤0.045 (95%ile) Good status ≤0.035 (mean) or ≤0.075 (95%ile)

Water Quality Standards in Freshwater Pearl Mussel Catchments

Water quality standards for FPM rivers are not explicitly included in the European Communities Environmental Objectives (Freshwater Pearl Mussel) Regulations, S.I. 296 of 2009. It is likely that the maximum recommended MRP concentration for high status rivers would negatively impact ecological conditions needed by FPM (see Table 5.5).

European work is underway by a task group of the European Committee for Standardization (CEN) to produce guidance in the context of the FPM that can be used across Europe for providing consistent advice based on the available scientific evidence (Boon, 2012). The format of the document has yet to be decided (e.g. CEN guidance, CEN technical report) but draft text has already been developed. The guidance document will include sections common to all CEN standards (such as "terms and definitions") and will focus on the main areas covering the principal environmental requirements of pearl mussels: water quality (phosphorus, nitrogen, BOD, dissolved oxygen, temperature, heavy metals, toxic substances, turbidity, suspended solids), hydromorphology (flow, physical habitat structure, substrate quality and stability, wood, instream modifications) and fish hosts (species, barriers to migration, genetics and stocking policies). The guidance will also cover information needed to assess plans or projects that might impact on FPM populations. CEN guidance documents typically take up to 2 years to complete publication but the proposed CEN approach is being followed in the project approach proposed below.

[11] Water hardness ≤ 100 mg/l CaCO3

[12] Water hardness > 100 mg/l CaCO3

As this guidance is not yet available published water quality standards in the literature have been reviewed and standards for sustainable FPM rivers can be summarised as outlined in Table 5.5 below. These standards will be used for those scenarios where the transmission line infrastructure traverses FPM catchments.

Table 5.5 Water quality standards for Freshwater Pearl Mussel Rivers based on published literature

Orthophosphate	High status level mandatory. Where high status is achieved and sustainable recruitment is not forthcoming, lower levels of orthophosphate should be targeted, towards 0.005mg/l P median values in shallow oligotrophic rivers or a level known to be commensurate with oligotrophic conditions in larger river systems.	All sustainable freshwater pearl mussel rivers are associated with the higher end of high status water bodies (both physic-chemical and biological attributes). Thus high status is a mandatory requirement. The target level of 0.005 mg/l P may be necessary in a water body that was oligotrophic in the past, and is based on sustainable phosphorus levels in oligotrophic waters with recruiting freshwater pearl mussel populations (Moorkens, 2006). In larger, deeper waters this target may not be necessary, While the target refers to the median values, it must be understood that short large releases of phosphorus can result in a burst of productivity, while the annual median level remains low. Any excessive releases of phosphorus create a high risk of damage to the FPM environment. Phosphorus should be included in investigative monitoring, as standard MRP analysis is not carried out to this level of determination. Investigative monitoring should be carried out if there is evidence of unnaturally high productivity in pearl mussel habitat, manifested in excessive filamentous algae or macrophyte growth.
Nitrogen, including Ammonia	Nitrate median values of 0.125mg/l N in shallow oligotrophic rivers or a level known to be commensurate with oligotrophic conditions in larger river systems. Ammonia median values of 0.01 mg/l N	Based on Moorkens (2006) analysis of Irish rivers where the highest median levels associated with effectively recruiting populations for Nitrate are 0.125mg/l N, and for ammonia are 0.01 mg/l N.
Suspended Solids	<10mg/l median values or less - if recent median levels are below this then the lower median should be used	Suspended solid levels above 10mg/l should be rare rather than chronic and attributable to natural conditions. In a conservation context, it is important to understand the causes of elevated suspended solids where they are unnatural in order to rectify problems and to be aware that no level of exceedance beyond the natural is acceptable.
Turbidity	<10NTU median values and no increasing trend- if recent median levels are below this then the lower median should be used	This value is an upper value for oligotrophic rivers. Where medians for a river are less than this, there should be no increasing trend
BOD	<1.4 mg/l and no increasing trend. If recent	Elevated BOD_5 (>1.4mg L-1) has been linked with poor

	median levels are below this then the lower median should be used as mandatory level to maintain. Further targets can be set in the future if this level is found to be inadequate.	juvenile survival in Central Europe (Bauer, 1988).

5.3.2 Macroinvertebrate Surveys and site condition assessments

Macroinvertebrate surveys have been undertaken in river sites selected for the study where the substrate conditions allow and safe access can be achieved. Ecological Quality Ratios (EQRs) are estimated on the basis of the biological data and the nature of the habitat at the sampling site.

A two minute kick and stone wash invertebrate sample was taken, at a time during the monitoring programme when conditions would allow, at each site surveyed (ISO 7828:1985) using the standard methodology employed by the EPA. This employs a zig-zag sample procedure across the wetted channel in a downstream direction in order to obtain sufficient sample and invertebrates from all micro-habitats within the river channel. All macroinvertebrates were identified to the level required for the EPA Q-rating method (Toner *et al*, 2005) on the bank side in the field. Based on the relative abundance of indicator species, a biotic index was determined for each site in accordance with the biological assessment procedure used by the EPA (Statutory Instruments No. 258 of 1998) and the macroinvertebrate classification scheme for the WFD as indicated in Table 5.6.

The EQR represents the relationship between the values of the biological parameters observed for a given body of surface water and the values for these parameters in the reference conditions applicable to that body. The ratio is expressed as a numerical value between zero and one, with high ecological status represented by values close to one and bad ecological status by values close to zero. In Ireland it is calculated as Observed Q-value/Reference Q-value (i.e., Q5). The EQR allows comparison of water quality status across the European Union as each member state has an EQR value for 'High'; 'Good' etc., based on an intercalibration of boundaries between water quality categories e.g., 'High-Good'; 'Good–Moderate'.

This macroinvertebrate sampling will assist in the determination of WFD status as it is the most commonly used biological element used to determine the ecological status of the water body, and will be supplemented by River Hydromorphology Assessment Technique (RHAT) surveys and site condition assessments. Some sampling locations were found to be unsuitable for macroinvertebrate kick sampling, if too deep or if unsuitable in terms of substrate composition for example, but the RHAT surveys and site condition assessments were completed and used to inform the potential impact of the construction on the status of the water body.

Table 5.6 EPA Q rating and equivalent WFD water quality status classes ***(including colour coding as employed under the WFD as specified in Schedule 3 of S.I. No 272 of 2009: High – blue, Good – green, Moderate – yellow, Poor – orange, and Bad – red)***

Biotic Index	EQR[13]	EPA Quality Status	Water Quality	WFD Status
Q5	1.0	Unpolluted	Good	High
Q4-5	0.9	Unpolluted	Fair-to-Good	High
Q4	0.8	Unpolluted	Fair	Good
Q3-4	0.7	Slightly Polluted	Doubtful-to- Fair	Moderate
Q3	0.6	Moderately Polluted	Doubtful	Poor
Q2-3	0.5	Moderately Polluted	Poor-to-Doubtful	Poor
Q2	0.4	Seriously Polluted	Poor	Bad
Q1-2	0.3	Seriously Polluted	Bad-to-Poor	Bad
Q1	0.2	Seriously Polluted	Bad	Bad

5.3.3 Hydromorphological Assessment - River Hydromorphology Assessment Technique (RHAT) surveys

RHAT classifies river hydromorphology based on a departure from naturalness, and assigns a morphological classification directly related to that of the WFD: high, good, moderate, poor and bad, based on semi-qualitative and quantitative criteria.

Watercourses

An objective for all water bodies, regardless of current status is to prevent deterioration. Hydromorphology is now a contributing factor under the WFD in determining high status. Therefore morphological assessment, including (RHAT) should be part of determining baseline conditions of a river so that measures can be taken to prevent a downgrade in status.

Under the WFD, a water body can only be classified as High Ecological Status if biology, chemistry and hydromorphology are all of high status. If hydromorphological status is not high, then that water body is classified as Good Ecological Status (G.E.S). This is the key role of hydromorphology under WFD classification.

If morphological status is good or high, then the default objective is to manage the waterbody to prevent deterioration.

If the morphological status of a water body is moderate, poor, or bad, there are three possible scenarios as indicated by Table 5.7.

[13] EQR = Environmental Quality Ratio (Observed/Reference)

Table 5.7: Overall Ecological Status when Morphology Status is Moderate, Poor or Bad

	Morphology Status	Other Status Elements:	Overall Ecological Status	Objectives
1	Moderate or Poor or Bad	High	Good	Manage to ensure no deterioration
2	Moderate or Poor or Bad or	Good	Good	Manage to ensure no deterioration
3	Moderate or Poor or Bad or	Moderate or Poor or Bad	Moderate or Poor or Bad	Improve Ecological Status to G.E.S

(Source: Shannon International River Basin District Project, 2008; Freshwater Morphology POMS Study, Recommendations for Programmes of Measures, DC098 (www.wfdireland.ie))

Under scenario 1 and 2 morphology status alone cannot cause a downgrade in Ecological Status below Good if it is not deemed to be impacting other status elements. Under scenario 3 morphological status could be a contributing factor to the less than G.E.S, and as such measures could be required to improve it. A typical example would be an in channel structure such as a weir causing a barrier to upstream fish migration which causes less than good fish status as a biological indicator and less than good Ecological Status as a result.

There can also be water bodies within scenario 3 that have moderate, poor or bad morphology and also have less than G.E.S, but for which other pressures are the causes of failure of the status elements, namely pollution. Based on research findings within the Freshwater Morphology POMS Study, it is recommended that where pollution pressures are identified for water bodies, these should be addressed first with morphology improvement measures, to follow as pollution is the direct cause of less than G.E.S.

At present the EPA use the RHAT tool as developed through the Shannon International River Basin District Programme of Measures Study in 2009 (http://wfdireland.ie/docs/20_FreshwaterMorphology/) in surveillance monitoring for water body status classification. This is a new addition to their monitoring programme so data is not yet widespread. To date the EPA have focused on sites that are possibly at high ecological status so that RHAT can be used to confirm it. RHAT is undertaken to check if the hydro-morphological status is also high to support such a classification. If the RHAT score is less than good, the overall Ecological Status can only be 'Good', even if all other indicators are High.

The RHAT score is based on a departure from naturalness, and assigns a morphological classification directly related to that of the WFD: high, good, moderate, poor, and bad, based on semi-quantitative criteria. The eight criteria that are scored are:

- Channel morphology and flow types

- Channel vegetation
- Substrate diversity and embeddedness
- Channel flow status
- Bank and bank top stability
- Bank and bank top vegetation
- Riparian land use
- Floodplain connectivity

The hydromorphological score is calculated by summing the scores attributed to the individual criteria above and dividing by the maximum score available (typical of natural conditions).

RHAT scores which correlate to WFD status classes as follows:

>0.8 = High
>0.6 – 0.8 = Good
>0.4 – 0.6 = Moderate
>0.2 – 0.4 = Poor
<0.2 = Bad

It is designed to be a rapid visual assessment based on supporting information from desktop studies, using GIS data, aerial photography, historical data and data obtained from previous field surveys, together with the field RHAT survey itself.

Whilst WFD hydro-morphology monitoring is currently focused on classifying high status candidates, RHAT should also be used to determine baseline conditions at sites where engineering modifications are taking place. It can assist in identifying why a water body might be failing to achieve G.E.S as it is based on the observed impact in the field. For example construction works adjacent to a watercourse can cause bank damage and heavy siltation which are known to have a direct negative impact on species such as macro-invertebrates or sensitive species such as FPM. In this example the water body is likely to be classified as less than G.E.S based on these biological elements and hydro-morphology. The departure from natural bank conditions caused by construction as recorded in a post construction RHAT survey can help identify objectives and measures to improve status and prevent further deterioration. This is important for the development of the transmission network as it will be necessary to ensure that both the construction and operational phases do not negatively impact on the hydro-morphological conditions which could impact other biological elements and therefore prevent the water course from achieving the objectives of the WFD.

5.3.4 Investigation of Long-Term Impact on Biology and Hydromorphology

Following the completion of the post-construction surveys across the full suite of study sites, EirGrid commissioned RPS to undertake a further series of surveys in 2015 to investigate the potential that any long-term impact was experienced at the sites included in the original study.

Given the nature of such studies, and the findings outlined in the original study, it was agreed that these studies would not include a physico-chemical monitoring programme, but would instead focus on the biological and hydromorphological aspects of the localised water quality. This was predominantly a result of the fact that the impact recorded during the original Evidence Based Study monitoring programme was hydromorphological in nature at two of the sites; AM78 at Gortnamucklagh on the Binbane to Letterkenny line in Co. Donegal and AM196 on the Screeb to Lenabower line in Connemara, Co. Galway. Notwithstanding this, follow up surveys were undertaken at all sites included in the original study.

6 RESULTS AND DISCUSSION

6.1 INTRODUCTION

As explained in the Site Selection section of the preceding chapter, six sites were identified for the case study based on different scenario types. The grid reference for each monitoring location and the dates on which they were sampled are shown in Table 6.1.

Table 6.1 Summary of monitoring locations and sample dates across all study sites*

	Monitoring Location	Grid Reference		Monitoring Dates		
				Biology/ Morphology	Physico Chemical Monitoring	
		X	*Y*	*Q, RHAT and SCA Survey*	*Pre-Construction*	*Post-Construction*
Connemara Sites	DS AM9	123896	225419	17/08/2012	Aug '12	Sep '12 – March '13
	US AM9	123812	225598			
	DS AM173	106648	243798	29/05/2012	Sep '12 - March '13	Sep '14 – Ongoing
	US AM173	106596	243875			
	DS AM196	102309	245122	29/05/2012	Sep '12 – Dec '12	Jan '12 – May '13
	US AM196	102242	245194			
Donegal Sites	DS AM78	180421	393994	11/10/2012	Jan '12 – July '12	July '12 – Jan '13
	US AM78	180143	394175			
	DS AM119	184797	397672	15/05/2013	Dec '12 – July '13	May '14 – July '14
	US AM119	184785	397908			
	AM119 (Trib)	184732	397928			
	AM119 (Bridge)	184772	397757			
	DS AM144	186624	395917	11/10/2012	N/A	Feb '12 – Nov '12
	US AM144	187493	396065			

**Further to these pre and post construction monitoring programmes a further long-term impact study was undertaken across all sites for both biological (Q-survey) and hydromorphological (RHAT survey) assessment in September 2015.*

Analysis of the upstream and downstream water quality information has been undertaken to estimate potential impact. The impacts in the receiving waters were established by comparing the measured concentrations with water quality standards as defined in the European Communities Environmental Objectives (Surface Water) Regulations 2009 and peer reviewed literature on the water quality standards required for FPM populations given the onerous water quality standards required for this species. Note that pH data is logarithmic and not strictly normal in distribution. Therefore statistics on pH should be considered as indicative only.

This will allow the pressure associated with the construction of electricity transmission projects to be assessed in the context of the EU WFD. Where relevant, water quality standards indicative of sustainable conditions for FPM populations have also been used based on published literature.

6.2 TRIBUTARY OF OWENEA RIVER AT GORTNAMUCKLAGH (AM 78, BINBANE - LETTERKENNY LINE – WORST CASE)

6.2.1 Physico-Chemical Monitoring

The results of the physico-chemical sampling on the tributary of the Owenea at Gortnamucklagh upstream and downstream of angle mast 78 are summarised in Table 6.2 below. This structure is located immediately adjacent to the stream and the sampling locations are illustrated in Figure 5.7.

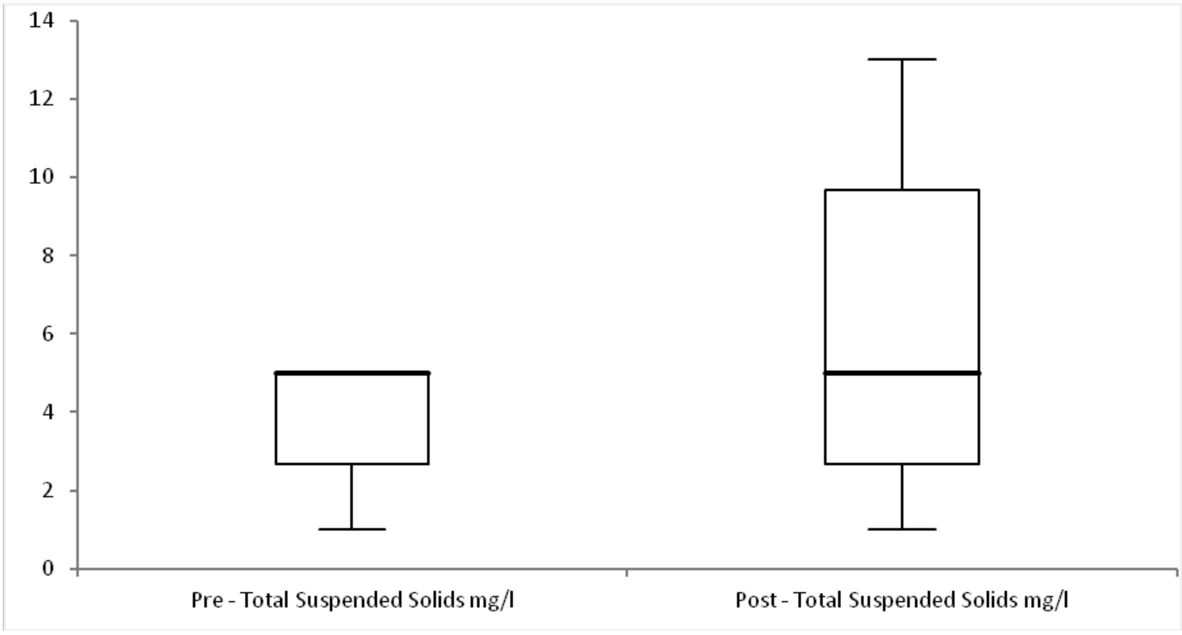
Table 6.2 Summary of water quality upstream and downstream of angle mast AM78

			pH	SpC-mS/cm	DO%-Sat	DO-mg/L	Turb-NTU	BOD mg/l	MRP mg/l P	TSS mg/l	RHAT Score
Pre con.	u/s	**Mean**	7.680	0.123	81.15	9.52	3.98	0.67	0.005	4.00	0.72 (Good)
		Median	7.480	0.127	82.40	9.53	3.85	0.75	0.005	5.00	
		95%ile	8.374	0.131	94.71	11.37	6.20	0.75	0.005	5.00	
		SD (n=4)	0.579	0.010	14.09	1.95	2.30	0.14	0.005	2.00	
	d/s	**Mean**	7.515	0.123	85.05	9.04	8.00	1.25	0.005	6.00	
		Median	7.505	0.122	85.15	8.91	6.35	0.75	0.005	5.00	
		95%ile	8.120	0.133	86.65	9.52	14.77	2.66	0.000	11.80	
		SD (n=4)	0.580	0.009	1.60	0.40	5.64	1.17	0.005	5.03	
Post-con.	u/s	**Mean**	7.515	0.123	85.05	9.04	8.00	1.25	0.010	6.00	
		Median	7.505	0.122	85.15	8.91	6.35	0.75	0.009	5.00	
		95%ile	8.120	0.133	86.65	9.52	14.77	2.66	0.015	11.80	
		SD (n=4)	0.580	0.009	1.60	0.40	5.64	1.17	0.005	5.03	
	d/s	**Mean**	7.395	0.133	85.83	8.69	12.20	1.38	0.011	12.75	
		Median	7.385	0.135	86.25	8.95	6.60	1.38	0.005	5.00	
		95%ile	8.149	0.145	86.50	9.85	26.60	2.00	0.025	32.20	
		SD (n=4)	0.711	0.014	1.04	1.30	11.89	0.72	0.012	16.17	

The result of the pre-construction monitoring at this site indicates that for the variables included in the Surface Water Regulations, the water quality would be indicative of High Status. Total Ammonia was not sampled at this location as this was the first site to be sampled and this parameter was added to the monitoring programme at a later date, but pH, dissolved oxygen, BOD and MRP values are all indicative of high status. In terms of the water quality standards indicative of sustainable conditions for FPM, all variables are within the thresholds indicated in published literature with the exception of MRP. The MRP values are indicative of high status, however the Owenea FPM population is at unfavourable conservation status with sustainable recruitment of juveniles not forthcoming and therefore a target level of 0.0005 mg/l may be necessary based on sustainable P-levels in oligotrophic waters with recruiting FPM populations (Moorkens, 2006). On this basis, other pressures along this tributary may be resulting in unsustainable P-levels.

In terms of the post construction assessment, there is an increase in suspended solids during the post construction monitoring period. The mean values recorded are higher for both the upstream and downstream locations during the post construction monitoring although the time period over which the post construction programme was carried out was generally wetter than the pre-construction programme. There was one sample in particular which was taken after a high rainfall event when the river was in spate that has demonstrated elevated suspended solids at both the upstream and downstream monitoring locations, however the mean suspended solids concentrations downstream of the construction site are much higher than those at the upstream location, 37 mg/l TSS and 13 mg/l TSS respectively. Given the proximity of the upstream and downstream monitoring locations to the construction works and the absence of any other pressures between the two monitoring points, it is reasonable to assume that the increase in suspended solids results from the construction activities. The turbidity levels also support this.

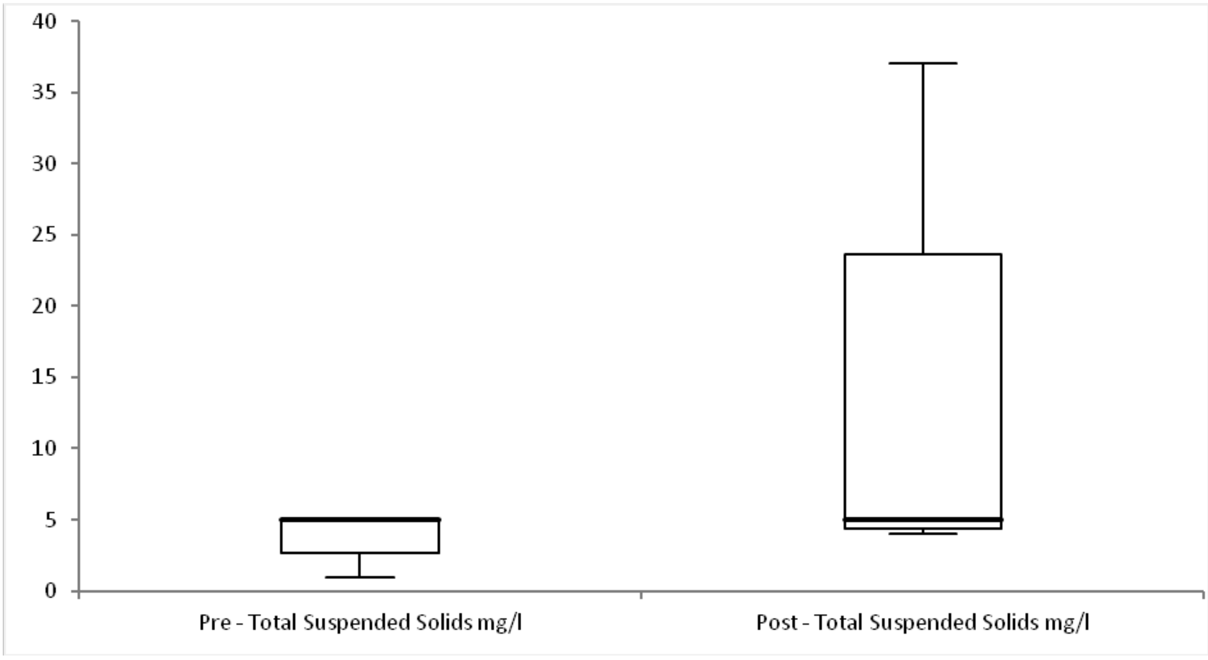
Figures 6.1 and 6.2 below shows the results of the Student's *t*-test analysis carried out on the monitoring results for TSS at both downstream and upstream sampling points respectively, suggesting no statistically significant difference. It is worth noting however that the low sample size (n-number) here affects the probability of detecting an effect, a factor which is accentuated by the high levels of variance.



Student t test

Hypothesized difference	0
t statistic	1.00
DF	3
p-value	0.3910

Figure 6.1 Student t-test analysis on TSS results at AM78 downstream

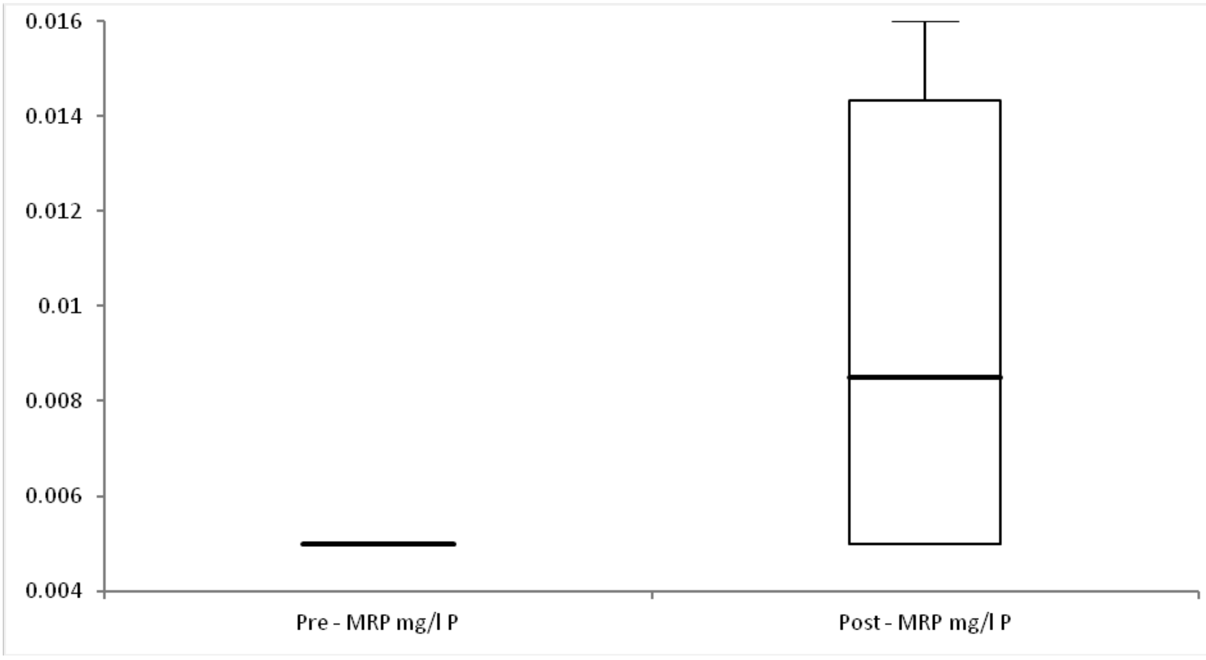


Student t test

Hypothesized difference	0
t statistic	1.12
DF	3
p-value	0.3427

Figure 6.2 Student t-test analysis on TSS results at AM78 upstream

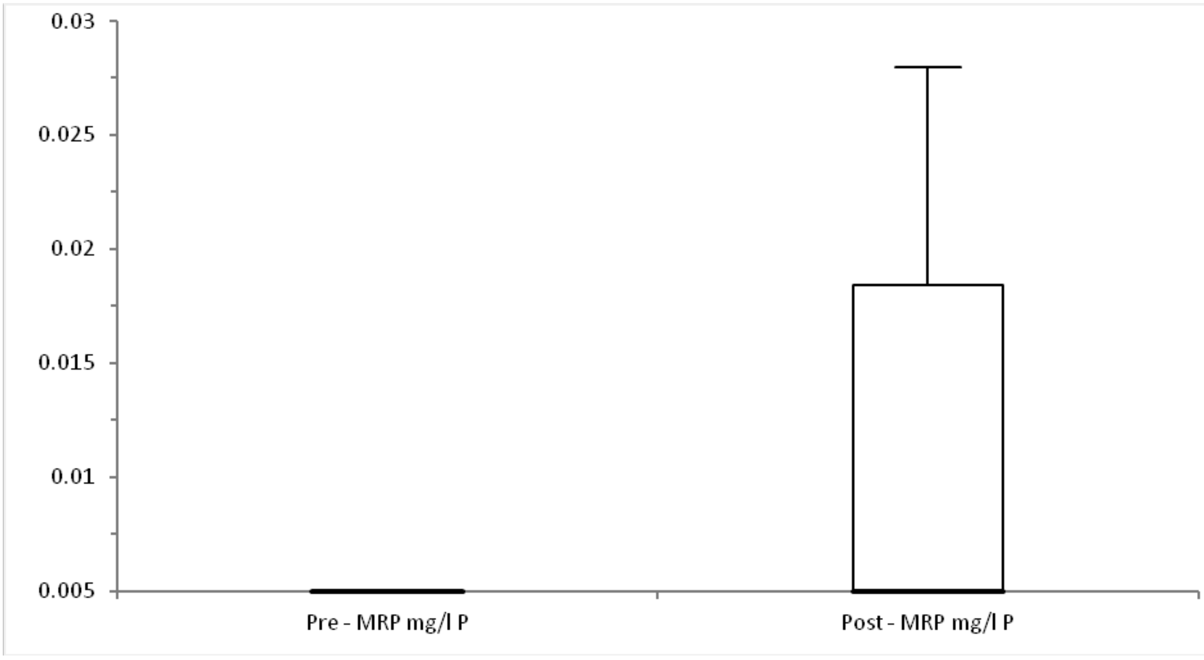
MRP levels are indicative of a high status site but may be slightly elevated above the optimal levels for the FPM populations downstream. The concentrations post-construction are elevated above those recorded during the pre-construction monitoring. Interestingly the median value at the upstream monitoring station was higher than that for the downstream station post construction however the mean is higher at the downstream station. This has occurred due to one high concentration recorded in the downstream station which is indicated by the large standard deviation. The upstream site records more frequent elevated MRP levels as indicated by the higher median. However, statistical analysis, as shown below in Figures 6.3 and 6.4 has shown no significant difference between the sites. Again, this assumption should be treated with caution given the low sample size obtained as a result of the constraints experienced during the monitoring period.



Student t test

Hypothesized difference	0
t statistic	1.65
DF	3
p-value	0.1970

Figure 6.3 Student t-test analysis on MRP results at AM78 upstream



Student t test

Hypothesized difference	0
t statistic	1.00
DF	3
p-value	0.3910

Figure 6.4 Student t-test analysis on MRP results at AM78 downstream

6.2.2 Macroinvertebrate Surveys

The tributary of the Owenea in the vicinity of AM78 was unsuitable for macroinvertebrate surveys given the river bed substrate and depth of the channel.

There is an EPA monitored site downstream of the confluence of the tributary's confluence with the Owenea main channel at a footbridge two kilometres (km) downstream of the confluence with the Stracashel River. Historically this monitoring station has been at high status pre 1990 however there was a trend towards good status (Q4) in the 1990s and early 2000s. The status at this monitoring station further deteriorated in 2006 to moderate status (Q3-4) however in the most recent survey conducted in 2012 shows an improvement to good status. The construction of Angle Mast 78 occurred after the latest survey in 2012 (15/08/2012) and therefore it is not possible to ascertain if there has been any indirect impact at this EPA monitoring station since the construction.

A survey carried out in 2015 (10/09/15) as part of the post construction studies, recorded a score of Q4, indicating Good status, with an average diversity and high density of macroinvertebrate communities recorded and the Group A Plectopteran taxa of Isoperla and Amphinemura commonly represented, and Group C species *Baetis rhodani* found to be numerous.

6.2.3 River Hydromorphological Assessment Technique (RHAT) Survey

The RHAT survey was conducted from the nearest road bridge downstream of the structure moving in an upstream direction until encountering the site. The approximate length of the survey was 240m and allowed an estimate of the baseline (i.e., pre-construction) WFD morphological status.

The surrounding land use is a mix of sheep grazing, forestry, cut over peat and there is also a County Council Road depot upstream of the site.

The overall channel type was recorded as a pool-riffle-glide channel with bedrock outcropping in places, however the river was in flood on the day in which the survey took place and therefore it was difficult to view the flow type. The width of the river was six metres and the depth was estimated to be one metre.

There were no anthropogenic impacts noted such as re-sectioning, embankments, culverts, channel dredging or animal poaching outside of the construction footprint. However at the construction site the development footprint has resulted in a significant alteration to the bank structure/stability and virtually removes the right bank of the tributary due to the location of the angle mast immediately adjacent to the river. Control measures, in the form of a single silt fence, were put in place but this was inadequate to prevent inundation of the site and therefore the prevention of surface run off into the channel during these high flow conditions.

The RHAT scoring for the watercourse surveyed indicates a WFD morphological status of good as the other criteria other than bank structure/stability and bank vegetation scored high. The morphological status for this section of the tributary has been impacted by the construction of the angle mast and has resulted in a WFD class of good where previously it would have been assessed as high.

The physico-chemical sampling suggests the river is at high status however given the morphological assessment the ecological status is considered to be, at best, good.

A survey site condition assessment was not possible at this site due to the flow conditions at the time of survey. The field sheets and site photography are included in Appendix I.

The survey undertaken in 2015 (10/09/15), as part of the post construction studies, found that overall channel type was recorded as a pool-riffle-glide channel with bedrock outcropping in places. Given that the original survey was carried out in flood conditions, the river width was recorded as significantly narrower at an average width of approximately 3 metres.

A regeneration of the right hand bank was noted, along with a return to the stability which would have been present prior to construction works, as illustrated in Plates 6.1 and 6.2. As a result, a Hydromorph score of 0.875 was recorded, showing an improvement from Good to High status since the original RHAT survey was carried out.

Plate 6.1 View looking upstream from right bank at AM78 highlighting bank stability and regeneration

Plate 6.2 View downstream from right bank at AM78 highlighting recovery of bank

6.2.4 Discussion

The results of the physico-chemical monitoring would suggest that the pre and post construction monitoring at the downstream monitoring location does show an impact from the construction of the angle mast in terms of the suspended solids concentration. Although this would be considered a short-term temporary impact as a direct result of the construction phase of the project, the potential consequences in more sensitive catchments such as FPM habitat could prove to impact for a lot longer. Increases in concentrations of suspended solids and nutrients can be fatal to both adult and juvenile mussel populations, along with the potential to destroy areas of suitable habitat. As a result, knock on effects of reproduction, recruitment and future populations can be a lot more profound.

In instances where the composition and stability of the channel bank has been compromised, and hence the potential for increased sediment load, the impact on hydromorphology would be regarded as permanent until measures are put in place to replace and reinstate the channel to its original state.

Suspended solids at the downstream site during post construction monitoring were elevated above those for the upstream site during high flow periods in particular. The proximity of the structure to the watercourse and the damage to the bank during site preparatory works have resulted in parts of the site flooding with associated increased run off which is detected in the suspended solids concentrations in the downstream monitoring station. Plate 6.3 below illustrates the damage to the bank and riparian zone and proximity of the site works to the tributary.

Plate 6.3 Site Clearance works at AM 78 and damage to riparian zone and bank structure

The MRP levels post construction at the upstream and downstream monitoring locations suggest that the impact from the felling of forestry to accommodate the line upstream of the structure may also be having an effect on the nutrient levels in the tributary. The physical disturbance of the soil through the construction activities and felling of forestry can result in the release of P from the soil (Piirainen *et al.,* 2004, 2007) particularly in peat which has a low absorption capacity for P (Tamm *et al*., 1974). In addition the needles and brash that is left on site after felling can be a source of P. The higher median values at the upstream site are indicative of the MRP being elevated for a number of samples whilst the downstream site has a higher mean which results from a single sample of particularly high concentration. Given that both the upstream and downstream sites demonstrate elevated levels of MRP which, whilst still indicative of high status classification based on the European Communities Environmental Objectives (Surface Water) Regulations, it is likely that the forestry felling is probably the source of these nutrients. In addition the levels recorded may be unsustainable in catchments where FPM is not at favourable conservation status. Such impacts require consideration in terms of cumulative or in combination effects when undertaking a Habitats Directive Assessment of other related or unrelated plans and projects in the catchment. This should include an evaluation of both statutory and non-statutory plans, and existing cumulative effects of small scale projects or activities.

Particularly in the case of FPM, individual activities that are not damaging can have additive effects and reach thresholds that eventually damage FPM. For example, relatively minor contributions from individual activities can result in a total sediment load in the river that harms FPM; small amounts of nutrients from a number of catchment activities can lead to combined damaging levels of enrichment; or minor drainage works along with other flow changes can exacerbate sediment and nutrient effects, such as erosion in high flows and sedimentation in low flows.

The morphological impact of the construction has also been noted during the RHAT surveys with the site foot print extending to the river bank and altering the bank structure and potential bank stability. Morphological and hydrological (termed hydromorphological) pressures within catchments generally have the key impact of increasing sediment load to the river, which is consistent with the elevated levels of suspended solids recorded at the downstream station, particularly during periods of high flow when the construction footprint is inundated with flood water. The riparian zone along this stretches of this tributary has been identified as at high risk in the sub basin management plan for the Owenea FPM Catchment as in certain locations it does not offer effective buffer of existing land uses. The installation of Angle Mast 78 has compromised the integrity of the riparian zone in this location and has reduced bank stability increasing the risk of bank erosion and the potential for significant sediment loading to the channel.

This site was selected as a worst-case scenario given its location immediately adjacent to the tributary of the Owenea River which is designated as an SAC with one of its qualifying interests being FPM. The tributary has also been selected as it has been classified at high ecological status in the River Basin Management Plan for the North Western River Basin District. The morphological pressures identified during the initial RHAT survey have reduced the morphological status to good. This means that the overall ecological status for the reach surveyed, which was previously high, has been reduced to good status even though the construction footprint is over a relatively short distance. Unless active intervention is taken to reinstate the bank to its original state this could have a long term impact in terms of the WFD classification, as the hydromorphological status will prevent it from attaining high ecological status overall.

This should be considered when looking at any Habitats Directive Assessment within the catchment, and knock-on effects of the alterations to the bank could also threaten the conservation status of the FPM populations and other protected species. Alterations to bank stability can result in greater levels of erosion and sedimentation of river substrate affecting macroinvertebrates and salmonid species.

The results of the Biological and Hydromorphological post construction surveys in 2015 however, indicate that the impact experienced at AM78 was short-term and bank structure/stability and vegetation have now returned to a pre-construction state.

6.3 BUNOWEN RIVER (AM173, CONNEMARA 110 KV PROJECT – WORST CASE)

6.3.1 Physico Chemical Monitoring

Construction at this site was not completed until late in the construction programme given the difficult ground conditions and associated access to the site. Work had been delayed whilst the contractor carried out detailed ground investigations to establish the best options available for access to the site. The difficult ground conditions were one of the criteria used to select this site as a worst case scenario. The location of the site is illustrated in Figure 5.8.

The pre-construction baseline and post construction monitoring for this site is summarised in Table 6.3 and indicates that the physico-chemical water quality is adequate to support high ecological status as defined in the European Communities Environmental Objectives (Surface Waters) Regulations, 2009 with the exception of the upstream monitoring results for MRP both pre and post construction where the 95 percentile concentrations are above the high status limit of 0.045 mg/l. This is supported by a site condition assessment which estimated the percentage of aquatic vegetation (macrophytes) covering the river bed substrate to be less than 20%. In a FPM catchment such as this the reference conditions would have a macrophyte coverage of five percent or less as per the fourth Schedule of the FPM Regulations (SI 296 of 2009). This suggests that there is some nutrient enrichment from upstream sources.

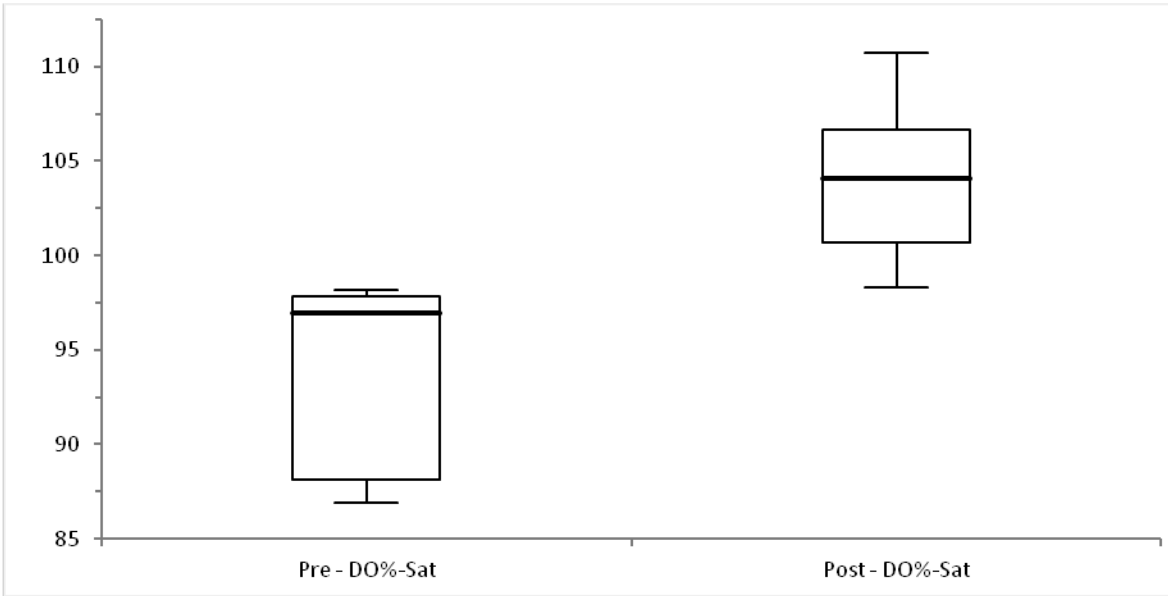
Table 6.3 Summary of water quality upstream and downstream of angle mast AM173 during pre-construction and post construction monitoring

			pH	SpC mS/cm	DO%-Sat	Turb-NTU	BOD mg/l	MRP mg/l	TSS mg/l	Ammonia (NH^3) mg/l	RHAT
Pre -construction	u/s	**Mean**	6.48	0.06	94.17	11.05	0.83	0.014	4.17	0.02	0.875
		Median	5.96	0.06	96.95	8.75	0.50	0.005	1.00	0.01	
		95%ile	7.39	0.06	98.11	15.82	1.78	0.052	4.40	0.02	
		SD (n=6)	1.36	0.02	5.18	4.75	0.58	0.022	4.31	0.01	
	d/s	**Mean**	6.51	0.06	91.70	13.92	0.83	0.005	5.50	0.02	
		Median	5.99	0.06	93.80	8.75	0.50	0.005	1.00	0.01	
		95%ile	7.41	0.06	99.21	30.69	0.71	0.005	17.15	0.03	
		SD (n=6)	1.34	0.02	6.28	10.61	0.58	0.000	7.37	0.01	
Post -construction	u/s	**Mean**	7.19	0.05	104.05	7.10	0.50	0.022	1.50	0.04	
		Median	7.33	0.04	104.55	1.70	0.50	0.011	1.00	0.02	
		95%ile	8.08	0.07	110.04	13.77	0.50	0.050	2.75	0.12	
		SD (n=6)	0.73	0.02	4.37	6.88	0.00	0.022	0.84	0.05	
	d/s	**Mean**	7.05	0.14	107.70	3.92	0.50	0.007	1.17	0.04	
		Median	7.30	0.04	108.85	0.85	0.50	0.005	1.00	0.03	
		95%ile	7.95	0.52	114.47	2.12	0.50	0.014	1.75	0.10	
		SD (n=6)	0.82	0.22	5.72	5.07	0.00	0.005	0.41	0.05	

The total ammonia levels post construction at both the upstream and downstream sites are also above the 95% percentile concentrations required for high status but within those necessary for good status. The level of nutrients upstream of the construction site are slightly elevated and are most likely indicative of other pressures within the catchment. The falling ammonia levels and low MRP levels downstream of the construction site indicate that the construction activities are not contributing to the nutrient pressures within the catchment.

With the exception of the nutrients listed above the monitoring results for the other parameters are considered consistent with the physico-chemical water quality standards required for FPM populations, which are located downstream of the site.

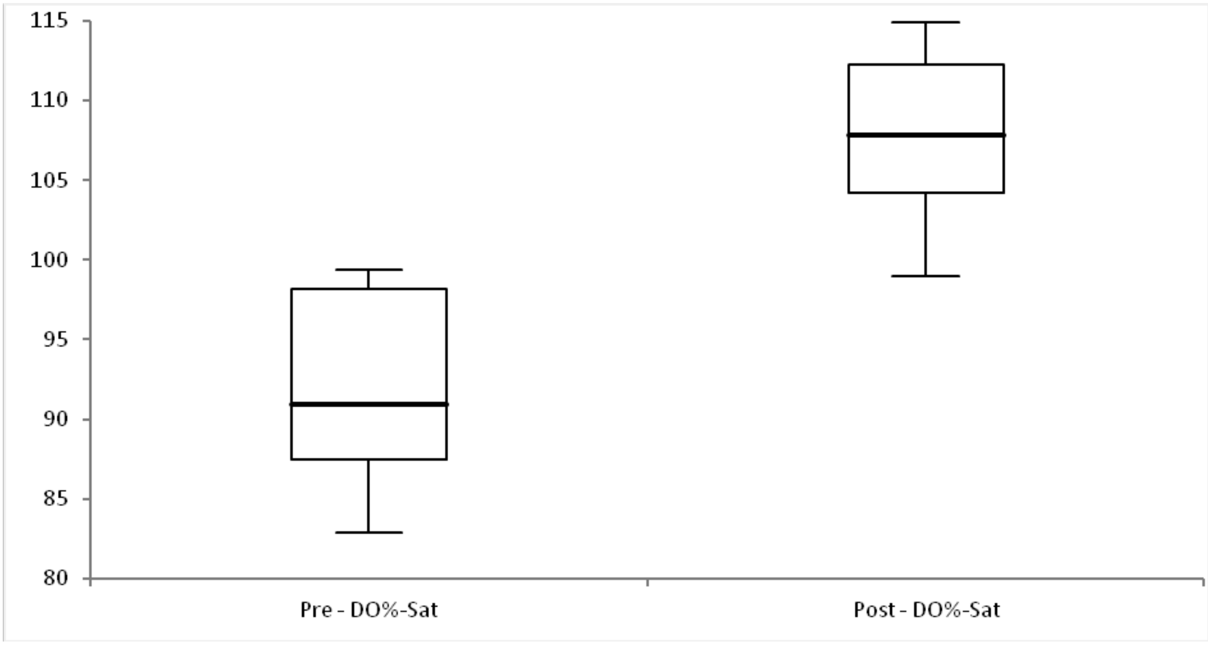
Student's *t*-test analysis carried out on the monitoring results at both downstream and upstream sampling points post and pre-construction, suggest no statistically significant difference between the datasets pre and post construction with the exception of dissolved oxygen. Figure 6.5 and 6.6 summarise the results of the student t test comparing the dissolved oxygen monitoring data for the pre and post construction monitoring programme at the upstream site and downstream sites respectively. In both the upstream and downstream monitoring locations the dissolved oxygen saturation levels increase and are statistically significant at the 95% percentile level. Whilst there is an increase in the dissolved oxygen levels from pre to post construction monitoring periods in all instances the levels are adequate to support high ecological status.



Student t test

Hypothesized difference	0
t statistic	3.28
DF	5
p-value	0.0220

Figure 6.5 Student t-test analysis on Dissolved Oxygen results at AM173 upstream



Student t test

Hypothesized difference	0
t statistic	5.63
DF	5
p-value	0.0024

Figure 6.6 Student t-test analysis on Dissolved Oxygen results at AM173 downstream

6.3.2 Macroinvertebrate Survey

The substrate composition of the channel immediately downstream of the construction works was not suitable to carry out a macroinvertebrate survey. However there is an EPA monitoring station on the Bunowen River at Glengowla Bridge 2.5km downstream. This station was last surveyed on 11th September 2012 and was assessed to be in a satisfactory condition with a biological quality rating of Q4, which is indicative of good ecological status.

As part of post construction survey the site at Glengowla Bridge was again monitored in 2015 (17/09/15). As per previous surveys, sufficient numbers of highly pollution sensitive taxa from Groups A and B were recorded, resulting in a recurring Q-score of Q4. It is worth noting that the dominance of these highly sensitive taxa would have resulted in the allocation of a High status Q-value had it not been for the small presence of the less sensitive Group E taxa of *Tubifex sp* and *Eristalis sp*.

6.3.3 River Hydromorphological Assessment Technique (RHAT) Survey

The RHAT survey was conducted 50m upstream of the overhead line crossing point and continued 110m downstream to the confluence with the next tributary below the construction site. The approximate length of the survey was 160m and allowed an estimate of the WFD morphological status and any potential impact of the construction of the angle mast.

The surrounding land use is a mix of upland blanket bog, forestry and some low intensity sheep grazing.

The overall channel type was recorded as a step-pool-cascade channel with bedrock outcropping in places. The width of the river was 1.2m and the depth was estimated to be less than 0.3m.

There were no anthropogenic impacts noted such as re-sectioning, embankments, culverts, channel dredging or animal poaching. There was a small section of the bank vegetation that had been impacted due to a small crossing point of the channel as illustrated in Plate 6.4 below but this was not significant suggesting that this crossing was used only infrequently and a temporary structure was in place to prevent significant impact.

The RHAT scoring for the watercourse surveyed indicates a WFD morphological status of high which supports the physico-chemical sampling results.

A survey site condition assessment noted slightly elevated levels of channel vegetation which whilst higher than the objective for FPM do not result in a deterioration in the morphological status. In terms of the physical condition of the river the construction has not resulted in any significant impact.

The field survey sheets are included in Appendix I.

Plate 6.4 Minor physical impact downstream of AM173

A RHAT survey was also carried out as part of the post construction survey in 2015. This survey was conducted approximately 40m upstream of the overhead line crossing point and continued 60 metres downstream to the confluence with the next tributary below the construction site.

As per previous, the surrounding land use is a mix of upland blanket bog, forestry and some low intensity sheep grazing. The overall channel type was still recorded as a step-pool-cascade channel with bedrock outcropping in places.

There were no anthropogenic impacts noted such as re-sectioning, embankments, culverts, channel dredging or animal poaching. The small section of the bank vegetation which had been impacted by a small crossing point of the channel during construction has now returned to a natural state, given the measures put in place at the time to minimise the impact of the crossing. The access routes to site and general area in the immediate vicinity of the structure have also recovered, with the comparison between during construction and post-construction shown below in Plates 6.5 and 6.6.

Plate 6.5 Ground disturbance during construction phase at AM173

Plate 6.6 Evidence of ground recovery following use as access for construction of AM173

6.3.4 Discussion

There are few other pressures in the vicinity of this site other than mature forestry upstream which has not yet been felled. The water quality reflects the relatively low land use pressures and for the most part is adequate to support high ecological status with the exception of the slightly elevated nutrient conditions upstream of the constructed angle mast.

The physico-chemical monitoring and RHAT surveys suggest that despite the sensitive location of the angle mast within an area of quaking blanket bog, where access was very difficult, the measures employed during construction in terms of the use of sensitive construction i.e. bog mats and piled foundations, have ensured that the impact on the water quality and aquatic environment was avoided.

The findings of the biological and hydromorphological post construction surveys in 2015 concluded that the construction of AM173 did not result in a long-term impact of the macroinvertebrate communities or the hydromorphology in the Bunowen River downstream of the angle mast structure

6.4 OWENWEE RIVER (AM196, CONEMARA 110KV PROJECT - NON STANDARD)

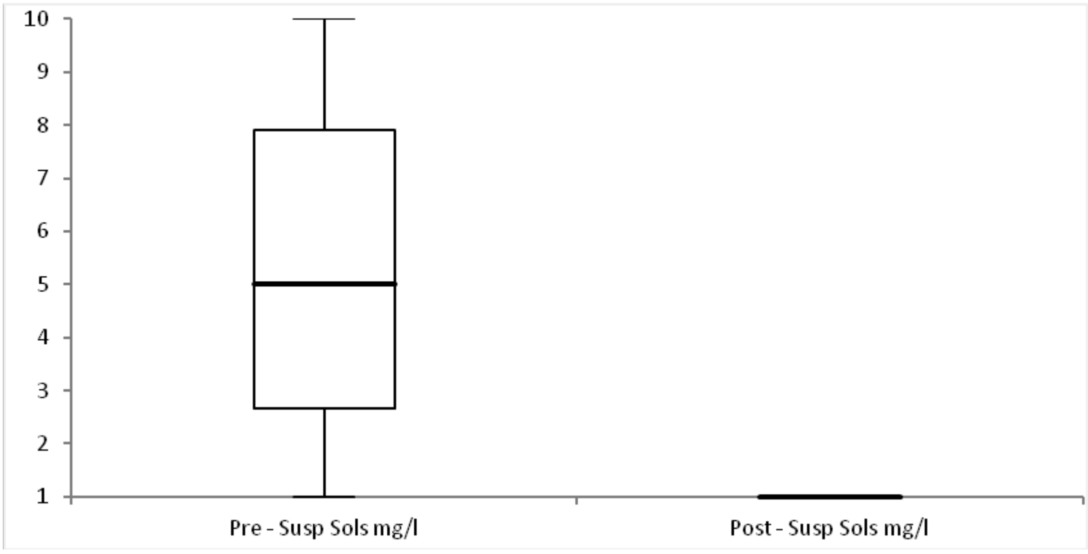
6.4.1 Physico Chemical Monitoring

Figure 5.9 illustrates the location of this structure and its proximity to the Owenwee River. The water quality results of the pre and post construction monitoring at this site are summarised in Table 6.4 for both the upstream and downstream monitoring stations and are indicative of high status waters based on the European Communities Environmental Objectives (Surface Waters) Regulations 2009.

Table 6.4 Summary of water quality upstream and downstream of angle mast AM196 during pre and post construction monitoring

			pH	SpC-mS/cm	DO%-Sat	Turb-NTU	BOD mg/l	MRP mg/l	TSS mg/l	Ammonia (NH^3) mg/l	RHAT Score	Q score
Pre Construction	u/s	**Mean**	7.44	0.11	91.45	6.03	1.06	0.005	5.25	0.011	0.6875 (Good)	Q 3-4 (Moderate)
		Median	7.43	0.12	92.10	3.80	0.75	0.005	5.00	0.011		
		95%ile	8.86	0.14	94.95	12.42	1.81	0.005	9.25	0.011		
		SD (n=4)	1.34	0.04	3.84	5.25	0.63	0.000	3.69	0.001		
	d/s	**Mean**	7.44	0.11	92.20	5.55	1.06	0.005	4.00	0.012		
		Median	7.36	0.12	92.45	3.75	0.75	0.005	5.00	0.012		
		95%ile	8.71	0.14	94.09	10.69	1.81	0.005	5.00	0.014		
		SD (n=4)	1.15	0.04	1.97	4.22	0.63	0.000	2.00	0.003		
Post Construction	u/s	**Mean**	6.73	0.08	96.73	5.13	0.50	0.005	1.00	0.018		
		Median	6.70	0.08	96.90	5.35	0.50	0.005	1.00	0.015		
		95%ile	**6.97**	0.09	97.39	5.67	0.50	0.005	1.00	0.033		
		SD (n=4)	**0.24**	0.01	0.79	0.71	0.00	0.000	0.00	0.013		
	d/s	**Mean**	**6.72**	0.08	97.05	5.30	0.50	0.005	1.00	0.018		
		Median	**6.72**	0.08	97.00	5.20	0.50	0.005	1.00	0.018		
		95%ile	**7.00**	0.09	98.24	6.34	0.50	0.005	1.00	0.021		
		SD (n=4)	**0.30**	0.01	1.09	0.92	0.00	0.000	0.00	0.003		

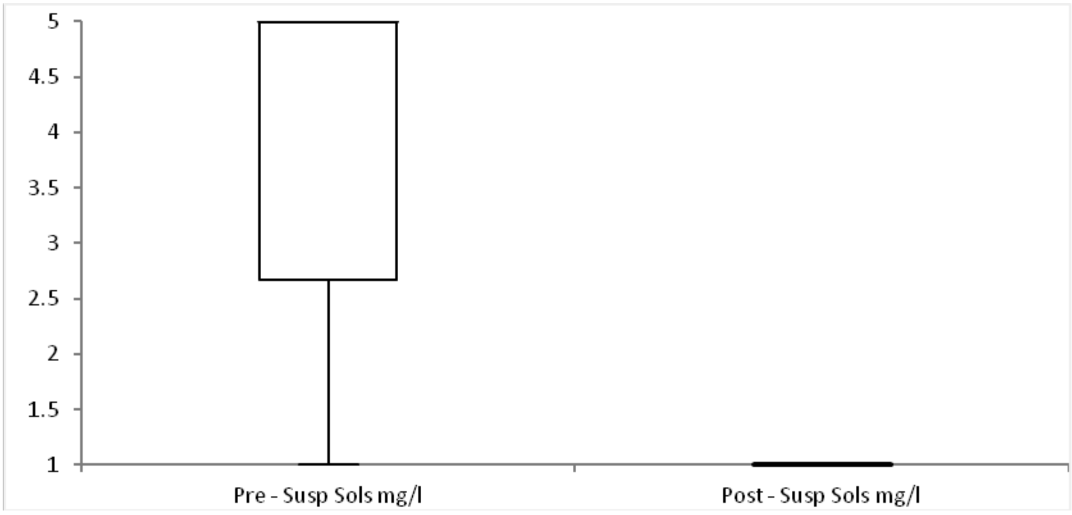
Following examination of the initial sample analysis for suspended solids, it was deemed more suitable to increase the accuracy of our results by attaining a lower limit of quantification from an alternative accredited laboratory during the end of the pre-construction monitoring and throughout the post construction monitoring. This explains the lower concentrations calculated in the statistics for both the upstream and downstream monitoring stations during the post construction monitoring. However the results do indicate that there has been no discernible impact on the suspended solids concentrations as a result of the construction, as shown below in Figures 6.7 and 6.8, with no statistically significant difference between the sites, and a decrease in concentrations of suspended solids post-construction. However, it should be noted that levels of suspended solids recorded at the downstream monitoring location during the post-construction phase were found to be lower than those recorded upstream of the structure.



Student t test

Hypothesized difference	0
t statistic	-2.31
DF	3
p-value	0.1044

Figure 6.7 Student t-test analysis on TSS results at AM196 upstream

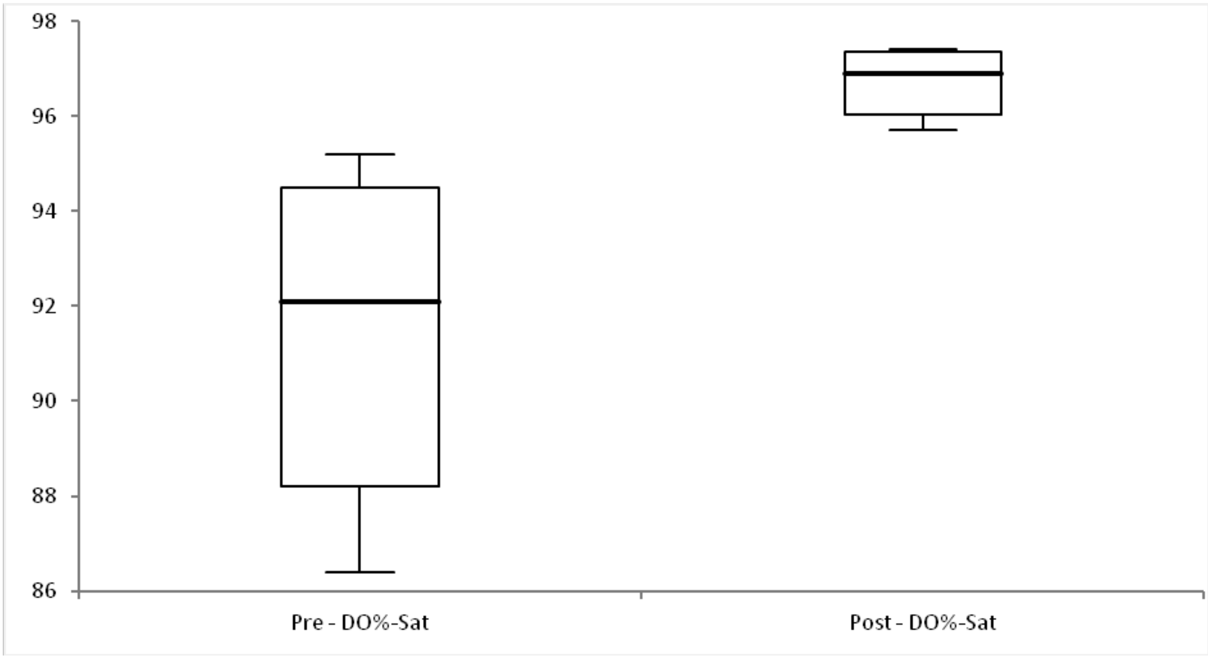


Student t test

Hypothesized difference	0
t statistic	-3.00
DF	3
p-value	0.0577

Figure 6.8 Student t-test analysis on TSS results at AM196 downstream

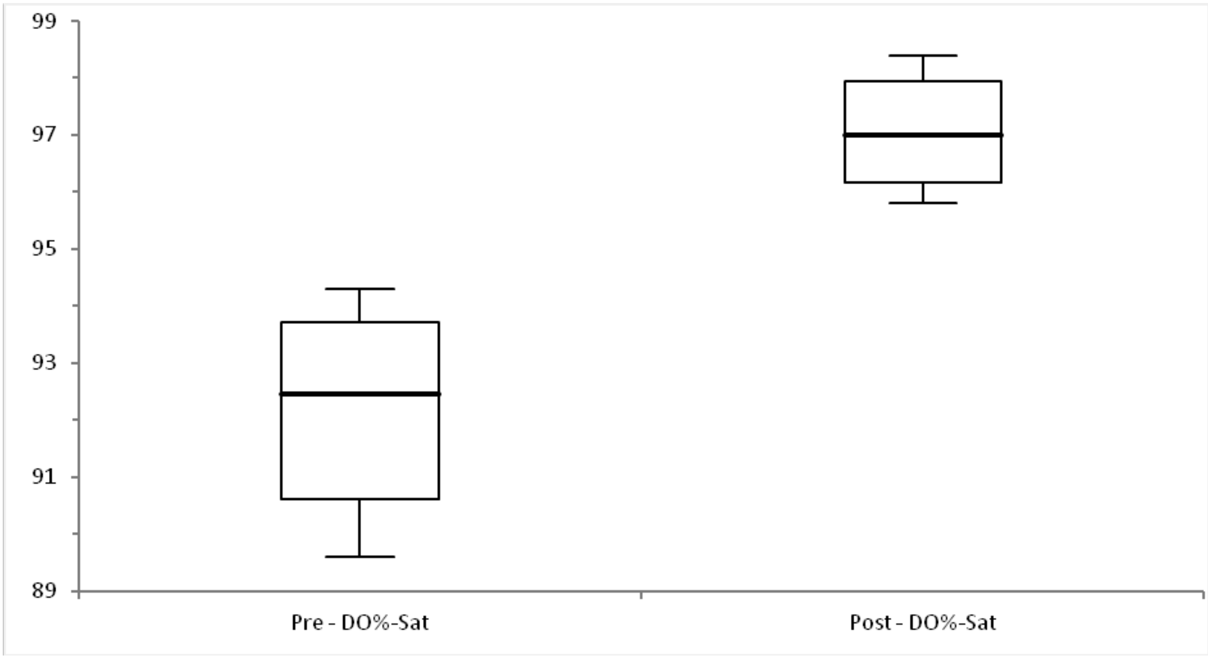
The only parameter which was found to display a statistically significant difference was in the levels of dissolved oxygen, as illustrated below in Figures 6.9 and 6.10. However, both results from both sites follow the same trend pattern, thus it can be accepted that there is no adverse impact as a result of the construction. Elevated levels of dissolved oxygen can often be associated with higher flows and the resulting increased turbulence. However, a further consequence of this would often result in increased turbidity readings and concentrations of suspended solids. As neither of these parameters were found to vary much across the range at AM196, it is more likely that the respiration of the abundant algae and aquatic fauna have contributed to the elevated levels of dissolved oxygen.



Student t test

Hypothesized difference	0
t statistic	3.45
DF	3
p-value	0.0410

Figure 6.9 Student t-test analysis on DO (% sat) results at AM196 upstream

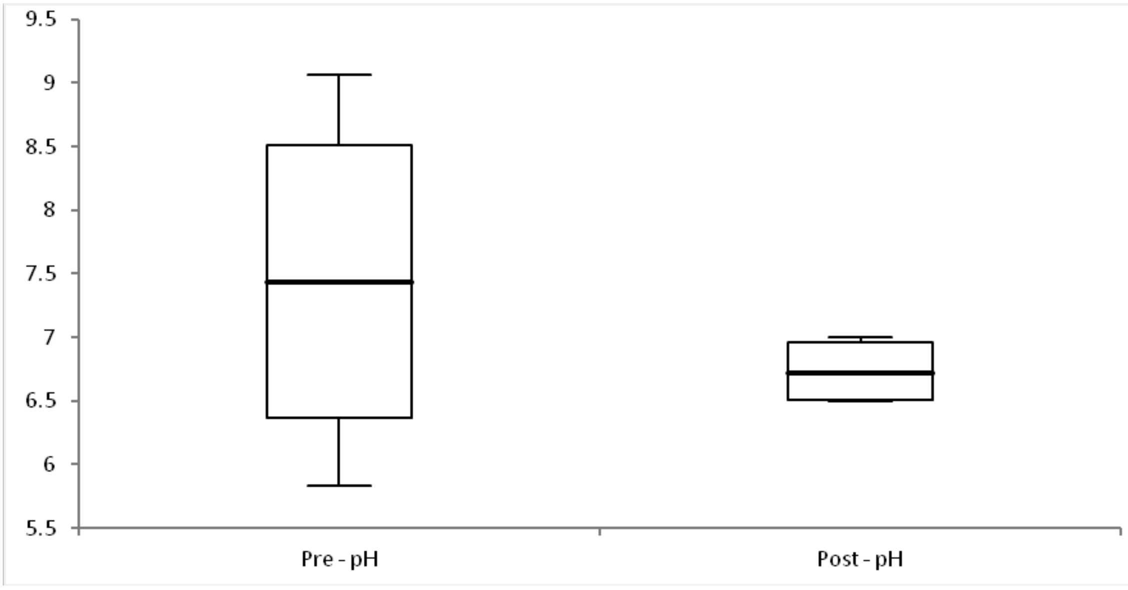


Student t test

Hypothesized difference	0
t statistic	5.68
DF	3
p-value	0.0108

Figure 6.10 Student t-test analysis on DO (% sat) results at AM196 downstream

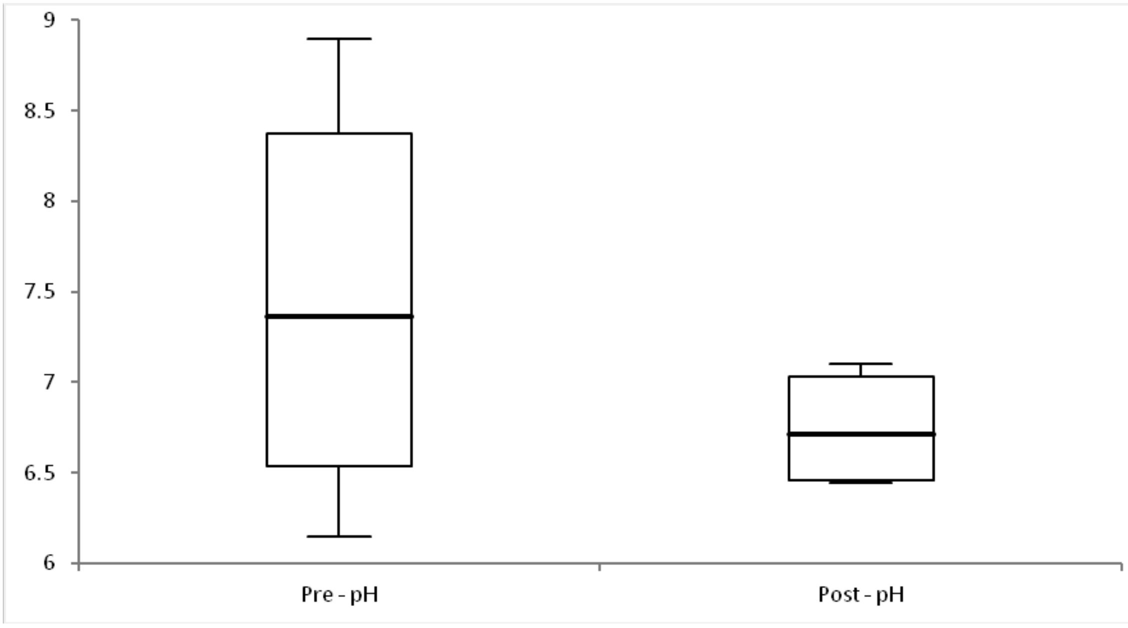
There has been a reduction in the pH at the site (Figures 6.11 and 6.12) which is possible as a result of the oxidation and mineralisation of organic matter as a result of the disturbance of peat during construction, resulting in the production of organic acids and nitrogen compounds which may also explain the slight increase in ammonia levels from pre-construction to post-construction, particularly in the downstream data. However, it is worth noting that differences were detected both upstream and downstream for the respective sampling times, which may point to an impact experienced on a wider level throughout the catchment.



Student t test

Hypothesized difference	0
t statistic	-1.02
DF	3
p-value	0.3844

Figure 6.11 Student t-test analysis on pH results at AM196 upstream



Student t test

Hypothesized difference	0
t statistic	-1.12
DF	3
p-value	0.3447

Figure 6.12 Student t-test analysis on pH results at AM196 downstream

6.4.2 Macroinvertebrate Survey

Macroinvertebrate surveys have been carried out immediately downstream of the construction site for AM196. Two surveys took place under this project both pre and post construction and RPS carried out a previous survey in 2010 at this location as part of the N59 Clifden to Oughterard Road Upgrade Scheme.

On all occasions the biological quality index (Q value) was assessed to be Q3-4 which is equivalent to moderate classification in terms of WFD ecological status. There has been no deterioration in the recorded Q-score at this location as a result of the construction of angle mast 196. However field notes recorded during the pre and post construction surveys carried out under this study indicate higher levels of siltation during the post construction monitoring with the substrate infiltrated with peat fines. This is also supported by the results of the RHAT survey and discussed below.

Field sheets for the macroinvertebrate, site condition assessment and RHAT surveys are included in Appendix I.

This site was surveyed again in 2015, as part of a post construction study, this most recent study has recorded an improvement in the moderate classification to a Q-value of Q4, representing Good ecological status. This is primarily due to the general increase in both density and diversity of the macroinvertebrate communities at this site, coupled with the presence of more pollution sensitive taxa. Previous surveys noted a high degree of siltation at this site, particularly post-construction, but this has returned to slight levels of siltation, which would help support the improvement in biological quality index from Q3-4 to Q4.

6.4.3 River Hydromorphological Assessment Technique (RHAT) Survey

The RHAT survey was conducted from the nearest road bridge downstream of the structure moving in an upstream direction until encountering the site. The approximate length of the survey was 140m and allowed an understanding of the baseline WFD morphological status to be determined.

The surrounding land use is predominantly sheep grazing with the N59 Clifden to Oughterard Road running parallel to the majority of the survey reach.

The overall channel type was recorded as a pool-riffle channel with some step pool characteristics at the upstream extent of the survey reach. Bedrock outcropping occurs in places. The width of the river was five metres and the depth was estimated to be less than 0.5m at the time of survey.

There were no anthropogenic impacts noted such as re-sectioning, embankments, culverts, channel dredging or animal poaching outside of the construction footprint. However at the construction site the development footprint and ground disturbance has resulted in an alteration to the right bank structure/stability due to the location of the angle mast immediately adjacent to the river (Plate 6.7).

Plate 6.7 Riparian zone modifications at Owenwee River AM196

Control measures in the form of a single silt fence and a series of one tonne gravel bags over a distance of 20m were put in place to mitigate potential site run-off. The silt fencing was found to be inadequate allowing peat laden water to filter underneath it where it follows a preferential flow path to a pipe discharging from the site towards the river (Plate 6.8).

Plate 6.8 Silt fence bypassed by pipe which was a source of peaty silt

The left and right banks were both damaged and trees have been removed to provide adequate clearance for the transmission line. Shading of the channel pools has been lost as a result. There is also loss of vegetation and the buffer zone on the riparian zone or the left bank, the impact of which could be increased on removal of the barrier provided by the series of one tonne gravel bags.

A drain was also noted running perpendicular to the Owenwee River and in-channel silt curtains had been installed, however it was noted that the drain was still a source of peat fines discharging to the main channel of the Owenwee on the right bank at the downstream bridge. This is consistent with the site condition assessment carried out in the channel where the macroinvertebrate sampling was undertaken which had noted infiltration of the substrate by peat fines.

The RHAT scoring for the watercourse surveyed indicates a WFD morphological status of good. The morphological status for this section of the Owenwee River has been impacted by the construction of the angle mast due to the alterations to the bank structure, the impact or the riparian zone and the condition of the channel substrate downstream of the construction site and has resulted in a WFD class of good where previously it would have been assessed as high.

The field sheets and site photography are included in Appendix I.

A further RHAT survey took place in 2015 (17/09/15) as part of a post construction study. This RHAT survey was started just upstream of the nearest road bridge downstream of the structure moving in an upstream direction and continuing past the site of the structure. The approximate length of the survey was 140m, based on the recommendation of a survey length of 40 times the width, in this case found to be an average of approximately 3m. The overall channel type was recorded as a pool-riffle channel with some step pool characteristics at the upstream extent of the survey reach and bedrock outcropping in places. The surrounding land use is still predominantly sheep grazing with the N59 Clifden to Oughterard Road running parallel to the majority of the survey reach.

There were no anthropogenic impacts noted such as re-sectioning, embankments, culverts, channel dredging or animal poaching outside of the construction footprint. However, the previous RHAT survey noted that at the construction site the development footprint and ground disturbance had resulted in an alteration to the right bank structure/stability due to the location of the angle mast immediately adjacent to the river, and subsequently lowered the hydromorphology score, with bank vegetation and riparian land cover on both banks also significantly impacted. Despite these impacts a Hydromorphology score of 0.6875 was still attained when the site was surveyed post-construction in April 2013, equating to WFD class of Good status.

This RHAT survey also closely examined the possibility that these impacts were still prevalent, but noted significant regeneration of vegetation and re-establishment of bank stability and riparian cover, as shown in Plate 6.9.

Plate 6.9 Image showing successful recovery of bankside vegetation and stability at AM196

The permanent structure of the mast on the right bank is still impacting these factors on this side, but this has not prevented the achievement of High WFD class status through an increased Hydromorphology score of 0.875. An improvement in substrate condition through lower siltation levels, as recorded in the macroinvertebrate survey, also contributed to this improvement in hydromorphological conditions.

6.4.4 Discussion

The physico-chemical and macroinvertebrate monitoring suggest that there has been limited impact as a result of the construction of this angle mast. However, the impact of the construction on the morphological status is apparent and this has resulted in deterioration in the channel substrate. This was noted during the site condition assessment carried out during the macroinvertebrate surveys but did not result in deterioration in the Q value at this location. The physico-chemical monitoring did not identify elevated suspended solid levels downstream of the site however, the changes to the bank structure and alterations to the riparian zone will increase the risk of bank erosion and reduce the ability of the riparian buffer zone to absorb potential run-off from the adjacent land area. The results of the RHAT survey indicate a deviation from naturalness which would be considered a long term or permanent impact unless rehabilitation works are undertaken.

The associated impact on morphological status may have implications for the ability of this water body to achieve high status irrespective of the improvement in biological elements of the ecological status.

Unless remediation works are undertaken, the hydromorphological status will not improve, hence the water body will be prevented from achieving high status, with good status being the best classification obtainable.

The findings of the post construction survey in 2015 show an improvement in biological quality rating at this site, it can be concluded that the construction of AM196 did not result in a long-term impact of the macroinvertebrate communities in the Owenwee River at the site of the angle mast structure.

Also the improvement in hydromorphological status in the post construction study would indicate that the impact experienced at AM196 was predominantly short-term and, despite the permanent structure of the mast in close proximity to the river, bank structure/stability and vegetation have now returned to a pre-construction state. However, it is worth noting that the permanent mast structure on this site will prevent the achievement of a full or perfect hydromorphology score based on the permanent impact on the riparian zone. As such, despite the attainment of a High status Hydromorph score, it is recommended that the siting of these structures should not take place in such immediate proximity to a watercourse and would not be deemed as good practice in future scenarios.

6.5 SHALLOGAN RIVER (AM119, BINBANE - LETTERKENNY LINE - NON STANDARD)

6.5.1 Physico Chemical Monitoring

The physico chemical monitoring results for the pre- and post-construction monitoring programme are summarised in Table 6.5. For all variables analysed, with the exception of dissolved oxygen, the concentrations are indicative of water quality that is capable of supporting high ecological status. However, it is worth noting the variation in pH measurements between the pre- and post-construction sampling periods. A significant section of the Shallogan Beg property of the Lough Finn Forest required felling for construction of and access to this structure, along with further plots felled upstream of the site along the route of the line. The process of clear felling results in the release of nitrate and hence accounts for the lowered pH values at both sites during the post-construction monitoring programme. See Figure 5.10 for location of structure.

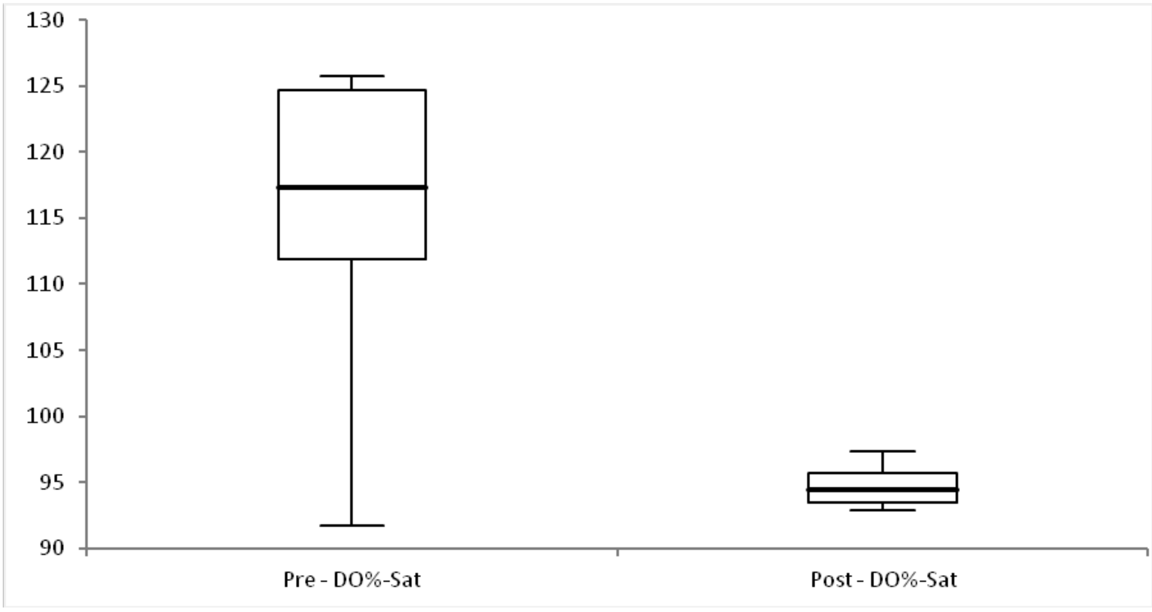
Table 6.5 Summary of water quality upstream and downstream of angle mast AM119 during pre- and post-construction monitoring

			pH	SpC-mS/cm	DO%-Sat	Turb-NTU	BOD mg/l	MRP mg/l P	TSS mg/l	Ammonia (NH^3) mg/l	RHAT Score	Q score
Pre construction	u/s	**Mean**	7.12	0.11	119.72	1.82	0.50	0.005	1.00	0.025	0.80 (Good)	Q 3-4 (Mod-erate)
		Median	7.14	0.11	117.30	1.80	0.50	0.005	1.00	0.025		
		95%ile	7.24	0.12	123.82	2.07	0.50	0.005	1.00	0.025		
		SD (n=6)	0.10	0.01	5.39	0.19	0.00	0.000	0.00	0.000		
	d/s	**Mean**	7.14	0.10	114.34	2.74	0.50	0.005	1.00	0.025		
		Median	7.13	0.10	113.10	2.35	0.50	0.005	1.00	0.025		
		95%ile	7.23	0.12	118.75	3.57	0.50	0.005	1.00	0.025		
		SD (n=6)	0.11	0.01	3.78	1.09	0.00	0.000	0.00	0.000		
Post construction	u/s	**Mean**	5.77	0.09	95.08	2.18	0.33	0.000	0.67	0.02		
		Median	7.14	0.10	113.72	2.55	0.50	0.005	1.00	0.025		
		95%ile	7.22	0.12	118.09	3.45	0.50	0.005	1.00	0.025		
		SD (n=6)	3.17	0.05	50.31	1.25	0.22	0.00	0.45	0.01		
	d/s	**Mean**	5.49	0.09	89.88	2.57	0.34	0.00	0.69	0.02		
		Median	6.45	0.10	104.40	2.36	0.42	0.00	0.83	0.02		
		95%ile	7.20	0.11	117.43	3.31	0.50	0.005	1.00	0.03		
		SD (n=6)	3.07	0.04	49.09	1.01	0.22	0.00	0.43	0.01		

The 95% percentile values for dissolved oxygen should not be greater than 120% saturation as the upper limit. The site condition assessments noted some aquatic moss (*Fontinalis*) and filamentous algae in the channel on larger cobbles and bankside boulders. However the abundance is less than 20% so is unlikely to be the reason for the high dissolved oxygen levels. The high energy of the stream, with a fast velocity noted during the macroinvertebrate surveys, is the most likely explanation for the higher dissolved oxygen levels.

Results from post-construction monitoring are largely similar across all parameters, with the one notable exception being that 95% percentile values for dissolved oxygen, at both the upstream and downstream monitoring locations, being recorded under the upper limit of 120% saturation for waters capable of supporting high ecological status.

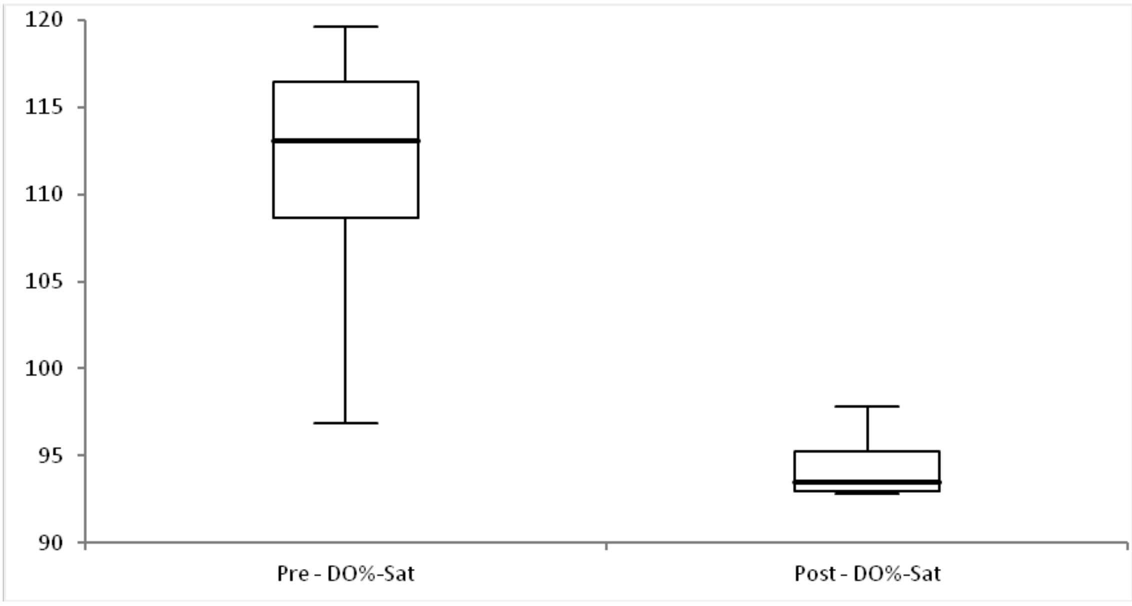
When applying a Student's *t*-test to the data, as shown in Figures 6.13 and 6.14, it can be stated that there is a statistically significant difference between the results. As previously stated, consideration should be given to the low sample size and the skewed distribution of the data as a result.



Student t test

Hypothesized difference	0
t statistic	-3.78
DF	5
p-value	0.0129

Figure 6.13 Student t-test analysis on DO (% sat) results at AM119 upstream



Student t test

Hypothesized difference	0
t statistic	-5.21
DF	5
p-value	0.0034

Figure 6.14 Student t-test analysis on DO (% sat) results at AM119 downstream

The Straboy River is within the Owenea FPM catchment but it does not support habitat that would support FPM populations. The only variable that exceeds the thresholds for a sustainable FPM population is ammonia, although considered to be indicative of high ecological status under the European Communities Environmental Objectives (Surface Water) Regulations. Median values of 0.01 mg/l NH_4-N in Irish rivers with effectively recruiting populations are quoted in literature. In this case, it is not possible to definitively comment on ammonia levels. As the levels recorded were, in most cases, below the limit of quantification (LOQ) (0.05mg/l) and so the presence/absence of impact cannot be detected. As per the European Communities (Technical Specifications for the Chemical Analysis and Monitoring of Water Status) Regulations, 2011 (SI 489 of 2011); where the amounts of physico-chemical or chemical measurands in a given sample are below the limit of quantification, the measurement results shall be set to half of the value of the LOQ concerned for the calculation of mean values.

Given the location is remote from the FPM habitat in the Owenea catchment, that the habitat is not suitable for FPM, and the water quality is indicative of high ecological status under the WFD, the existing levels of ammonia are acceptable.

6.5.2 Macroinvertebrate Survey

Macroinvertebrate surveys were carried out upstream and downstream of the proposed angle mast. This was considered appropriate as the alignment of the transmission line in this area means that structures and construction activities could have had an impact on the channel upstream of AM119 and therefore any upstream pressures could be picked up by the upstream macroinvertebrate survey.

At both locations the macroinvertebrate biological quality index (Q value) was Q3-4 which is indicative of moderate status under the WFD. The upstream location demonstrated a very clean substrate with little or no sediment in channel. The downstream station demonstrated similar conditions with a very clean substrate despite pressures from forestry drainage and natural bank erosion.

The timing of this survey was in May 2013 to ensure that it was carried out in advance of the construction and forestry felling. The nearest EPA macroinvertebrate sample station on the Shallogan River is located approximately two kilometres downstream and during the most recent survey, carried out in August 2012, the survey recorded a Q3-4 value also therefore it is assumed that, despite the timing of the survey early in the season, the results are representative of the biological quality index.

Field sheets for the macroinvertebrate, site condition assessment and RHAT surveys are included in Appendix I.

The follow up post construction survey carried out in 2015 had similar findings with a Q3-4 value found. This was due to the dominance of Group C species including *Baetis rhodani* and Simulidae, despite Group A species represented by Chloroperla and Isoperla.

6.5.3 River Hydromorphological Assessment Technique (RHAT) Survey

The RHAT survey was conducted at this location in advance of the construction due to the completion of other structures associated with the transmission line development upstream of this section. This was to establish any potential downstream impacts associated with the early construction works.

The RHAT Survey over a length of 230m included the small tributary where the additional Q survey was carried out to determine potential pressures from upstream structures that had already been constructed.

The surrounding land use is predominantly sheep grazing and forestry with a disused railway line traversing the Shallogan River via an arched masonry bridge.

The overall channel type was recorded as lowland meandering with step pool and pool riffle characteristics. Bedrock outcropping occurs in places. The width of the river was estimated to be 5m and the depth was estimated to be less than one metre at the time of survey.

There were no re-sectioning, embankments, culverts, channel dredging noted however animal (sheep) poaching was noted on both the right and left banks. The disused railway line bridge is of intermediate size and clear spans the river. There was extensive natural bank erosion and undercutting and bank slumping noted. There is also a fording point (Plate 6.10) at the upstream extent of the reach surveyed and numerous forestry drains discharge to the main channel (Plate 6.11).

The RHAT scoring for the watercourse surveyed indicates a WFD morphological status of good. The morphological status for this section of the Shallogan River has been impacted by the forestry activities in the riparian zone, the natural erosion of the bank causing stability issues and removal of bank vegetation. There are also indications of channel vegetation in filamentous algae and moss species. There has been no apparent impact from the construction of the angle masts and polesets upstream of this location where the structures run parallel to the tributary of the Shallogan River.

The field sheets are included in Appendix I.

A post construction RHAT survey was conducted in 2015 (09/09/15). It began downstream of the old railway bridge (which had been used as an access route for mast construction) and moving in an upstream direction for approximately 150m based on the channel width being recorded at approximately 4m.

The original pre-construction survey carried out in May 2013 found a Hydromorph score of 0.8, equating to Good status, with the post-construction survey recording a High status Hydromorph score of 1. This discrepancy can be largely attributed to a small variation in the scorings given to the bank structure and stability. It is worth noting however that this site is subject to natural bankside undercutting and erosion given the flashy nature of the flow at this point, hence the different scores recorded at different times.

The RHAT survey carried out in 2015 found that bank structure and stability was still improved in comparison to its pre-construction state, but not quite to the level experienced during the post-construction survey. As a result, a Hydromorph score of 0.94 was recorded, which still represents a WFD class of High status.

6.5.4 Discussion

There has been no apparent impact from the construction of the angle masts and polesets upstream of this location where the structures run parallel to the tributary of the Shallogan River. This is demonstrated in both the physico-chemical and macroinvertebrate surveys, which are consistent with the EPA monitoring carried out in August 2012, and the RHAT survey which has identified other pressures along the reach that have resulted in a reduced morphological score. The occurrence of the forest drains means the forestry felling and access to accommodate the construction of AM119 could result in sediment and nutrient pressures with a direct pathway to the Shallogan River. However extensive silt trapping measures were deployed with a series of triple silt curtains installed around the site for the construction phase, as shown in Pates 6.12 and 6.13.

Plate 6.10 Fording area across Shallogan River

Plate 6.11 Forestry Drain discharging to main channel

Plate 6.12 Silt curtain installation around AM119

Plate 6.13 Silt curtains installed in drainage run-off from AM119

The results of macroinvertebrate surveys in the post contruction survey in 2015, still only represent Moderate status, but this is consistent with previous surveys undertaken both pre and post construction of the angle mast structure, and it can be concluded that the construction of the 110 kV structure has not had a long term impact on the biological quality of the water at AM119. Other pressures within this catchment are having an effect on the macroinvertebrate community that would be expected under reference conditions.

The RHAT post construction survey in 2015 score still represents a WFD class of High status. Therefore it can be concluded that the construction did not have a long term impact on the hydromorphology at AM119.

6.6 BARNA STREAM (AM 9, CONNEMARA 110 KV PROJECT - TYPICAL)

6.6.1 Physico Chemical Monitoring

As outlined in Section 5, access to the wayleave at AM9 on the Barna Stream was only granted at a late stage in the landowner negotiations. This seriously impacted on the ability to establish a full pre-construction baseline with construction commencing as soon as wayleave access was provided allowing only time for a single sample run to be made. See Figure 5.11 for location of structure.

A full post construction baseline was completed. All the variables analysed are within acceptable limits and are indicative of water quality which is adequate to support high ecological status. The suspended solids levels were higher in the pre-construction period with the levels post-construction lower, with mean values of <2 for both the upstream and downstream stations. Therefore there was no discernible impact detected associated with the installation of the angle mast 65m from the watercourse.

Slightly elevated MRP concentrations were noted in the preconstruction samples and also in the upstream monitoring stations in the post construction monitoring indicating an upstream nutrient pressure not associated with the construction of the transmission line, however, the concentrations are still indicative of water quality capable of supporting high ecological status.

Table 6.6 Summary of water quality upstream and downstream of angle mast AM9 during pre-construction and post-construction monitoring

			pH	SpC- mS/cm	DO%- Sat	Turb- NTU	BOD mg/l	MRP mg/l	TSS mg/l	Ammonia (NH^3) mg/l
Pre-con	US		7.06	0.17	104.50	9.50	0.50	0.011	11.00	0.02
	DS		7.01	0.17	102.20	7.90	0.50	0.012	2.00	0.01
Post -Construction	US	**Mean**	6.88	0.17	97.70	7.18	0.50	0.007	1.00	0.02
		Median	6.91	0.17	98.35	7.10	0.50	0.005	1.00	0.02
		95%ile	7.02	0.17	100.74	7.53	0.50	0.013	1.00	0.03
		SD (n=4)	0.17	0.00	3.44	0.30	0.00	0.005	0.00	0.01
	DS	**Mean**	7.00	0.17	98.70	7.28	0.50	0.005	1.25	0.02
		Median	7.01	0.17	101.25	7.15	0.50	0.005	1.00	0.02
		95%ile	7.05	0.17	101.77	7.88	0.50	0.005	1.85	0.02
		SD (n=4)	0.06	0.00	5.48	0.51	0.00	0.000	0.50	0.01

6.6.2 Macroinvertebrate Survey

Macroinvertebrate surveys were conducted upstream and downstream of the location of AM9 subsequent to construction to determine the ecological status of the Barna Stream. The substrate at the upstream station consisted of fine gravels, sand with moderate siltation. Submerged macrophytes were noted in the channel including *Apium* species which are rooted plants (indicating silted nature of substrate) which are tolerant to enrichment. The macroinvertebrate composition resulted in a biological quality index (Q value) of Q3 which is indicative of poor ecological status.

At the downstream station the substrate displayed similar characteristics as the upstream site with fine gravels and sand infiltrated with silt. *Apium* species were again present and the macroinvertebrate composition, dominated by gammurus and baetis species, resulted in a Q value of Q3 again indicating poor status.

The site condition assessment at both the stations noted the infiltration of silt with a visible silt plume arising when the substrate was kicked. Cattle poaching, along the entire reach was also noted.

As part of a post construction survey, the site was surveyed again in 2015 (17/09/15) to identify any change in status which may have taken place since the completion of construction.

Conditions identified were found to be similar to the original survey results, in that the substrate consisted of fine gravels and sand with moderate siltation. Submerged macrophytes were still present in the channel including *Apium* species which are rooted plants (indicating silted nature of substrate) which are tolerant to enrichment. The macroinvertebrate composition however did note a slight improvement in ecological status from the original survey by increasing the Q-value from Q3 to Q3-4. This is due to the slightly better macroinvertebrate diversity observed, specifically the common presence of *Rhithrogena sp.*, along with small numbers of both cased (*Sericostomatidae sp.* and *Glossostomatidae sp*.) and uncased (*Hydropsyche sp*. and *Polycentropus sp*.) trichopterans.

6.6.3 River Hydromorphological Assessment Technique (RHAT) Survey

The RHAT survey was conducted 200m upstream of the structure moving in a downstream direction to a location approximately 100m beyond the structure. The approximate length of the survey was 300m and allowed an understanding of the baseline WFD morphological status to be determined.

The surrounding land use is predominantly unimproved pasture with one off housing apparent along the roadsides resulting in ribbon development.

The overall channel type was recorded as a pool-riffle glide channel with some step pool characteristics at the upstream extent of the survey reach. Bedrock outcropping occurs in places. The width of the river was 1m and the depth was estimated to be less than 0.5m at the time of survey.

Significant animal poaching along the entire reach was noted with direct animal access to the channel noted on the left and right banks. The location of these heavily poached areas coincided with the submerged macrophytes which was indicative of increased nutrients and siltation of the substrate. The damage to the banks through animal poaching resulted in poor scores for substrate condition, bank structure/stability and riparian land cover. Plate 6.14 illustrates one of the numerous animal access points along this reach of the river. There were no re-sectioning, embankments, culverts, channel dredging noted.

While the bank structure and stability is effected by cattle poaching through direct access for drinking water it does not affect more than one third of the bank length therefore the bank stability score remains good and whilst the substrate condition and riparian zone scores are reduced the overall RHAT scoring for the watercourse indicates a WFD morphological status of high.

Plate 6.14 Cattle poaching on left bank of Barna Stream

The field sheets and site photography are included in Appendix I.

A RHAT survey was conducted in 2015 (17/09/15) as part of a post construction survey beginning approximately 100m upstream of the structure moving in a downstream direction to a location approximately 50m beyond the mast. With average stream width at this location only estimated at approximately 1 metre, this survey length was deemed sufficient to get an understanding of the hydromorphology at this site.

The surrounding land use is predominantly unimproved pasture with one off housing apparent along the roadsides resulting in ribbon development.

The overall channel type was recorded as being the same as that identified in the original RHAT survey carried out in August 2012; a pool-riffle glide channel with some step pool characteristics at the upstream extent of the survey reach and some bedrock outcropping occurring in places.

Significant animal poaching was evidently still an issue on both banks, with visible signs of livestock crossing points (Plate 6.15).

Plate 6.15 Example of cattle crossing point on Barna Stream at AM9 with elevated levels of sand and silt

Cattle were also present in the adjacent fields at the time of survey but it is worth noting that the field used for construction access was adequately reinstated, as shown in Plate 6.16.

The presence of submerged macrophytes was still evident, indicative of increased nutrients and siltation of the substrate as a result of the obvious cattle poaching. Despite these pressures having a negative impact on the bank structure and stability, the areas are still limited to less than one third of the bank length therefore the bank stability score remains good. Following recent flooding at the site it was noted that floodplain connectivity was improved in comparison to the previous study, and whilst the channel and bank vegetation zone scores have been reduced the overall RHAT scoring for the watercourse still indicates a WFD morphological status of high, with a rise in Hydromorph score from 0.83 to 0.875.

Plate 6.16 Evidence of complete recovery of field used for access during construction of AM9

6.6.4 Discussion

The physico chemical monitoring at this site was restricted to one sample (n=1) in pre-construction as result of construction being found to have already begun on the second site visit. The physico-chemical analysis of the samples collected indicates that there is no impact from the construction of the angle mast and the environmental quality standards included in the European Communities Environmental Objectives (Surface Water) 2009 are all adequate to support high ecological status (with regard to chemistry). However there is a significant poaching pressure noted during the macroinvertebrate and RHAT survey which is having an impact on the condition of the channel substrate both in terms of siltation levels but also nutrient conditions which is the most probable explanation of the poor ecological status recorded at the upstream and downstream locations where macroinvertebrate surveys were undertaken. The RHAT and macroinvertebrate surveys have established that the major pressure associated with the Barna Stream is cattle poaching however the field surveys also noted certain issues associated with the construction of the angle mast and whilst they have not had a significant impact on the water quality they have been highlighted here to identify practices that should not be undertaken.

The main issue relates to the fact that whilst the structure was approximately 30m from the Barna Stream, site clearance works were undertaken up to the bank of the river. Whilst it is recognised that there is a requirement for adequate working areas when constructing an angle mast the extent of the site clearance works seems excessive and has resulted in an increased risk of impact from the construction works reducing the riparian buffer to two to three metres (Plate 6.17).

Plate 6.17 Site clearance works adjacent to the Barna Stream at AM9

The results of the post construction macroinvertebrate surveys in 2015 shows an improvement in water quality, it can be concluded that there was no long-term impact on the macroinvertebrate communities at AM9 as a result of the construction of the angle mast. The RHAT survey also still indicates a WFD morphological status of high, with a rise in Hydromorph score from 0.83 to 0.875 in the post construction survey. However, there was still significant animal poaching evident on both banks, with visible signs of livestock crossing points.

6.7 STRACASHEL RIVER (AM144, BINBANE - LETTERKENNY 110KV LINE - TYPICAL)

6.7.1 Physico-chemical monitoring

Construction has already been substantially completed at this site when the monitoring programme commenced. However the post construction monitoring programme was carried out at the upstream and downstream sites of this angle mast as shown in Figure 5.12. The results of the post-construction monitoring are summarised in Table 6.7 below. The results indicate that the water quality is in good quality and capable of supporting high ecological status. The Stracashel River is one of the upland tributaries of the Owenea FPM catchment and the concentrations of the variables are consistent with those quoted in the literature for sustainable FPM populations. Whilst this tributary is remote form the FPM habitat in the Owenea River and the substrate in the channel is not capable of supporting FPM as it is predominantly peat, the water quality along this reach will not compromise the FPM habitat further downstream.

There is a slight elevation in the mean suspended solids levels downstream of the construction site however the site condition assessment and RHAT survey noted recent excavate field drains between the upstream and downstream monitoring points and given the location of the angle mast over 125 metres from the water course the key pressure in this instance is the agricultural field drainage.

Table 6.7 Summary of water quality upstream and downstream of angle mast AM144 during post construction monitoring

			pH	SpC-mS/cm	DO%-Sat	Turb-NTU	BOD mg/l	MRP mg/l	TSS mg/l	RHAT Score
Post construction	US	**Mean**	7.73	0.08	85.32	8.28	0.75	0.008	5.00	0.88 (High)
		Median	7.77	0.07	87.30	6.50	0.75	0.005	5.00	
		95%ile	8.32	0.09	96.13	15.30	0.75	0.019	5.00	
		SD (n=4)	0.57	0.01	10.53	4.78	0.00	0.007	0.00	
	DS	**Mean**	7.75	0.08	84.90	7.58	0.75	0.009	7.17	
		Median	7.80	0.08	83.70	6.75	0.75	0.005	5.00	
		95%ile	8.35	0.09	102.75	12.53	0.75	0.023	14.75	
		SD (n=4)	0.58	0.01	13.89	3.61	0.00	0.010	5.31	

6.7.2 Macroinvertebrate Survey

Due to the peaty nature of the substrate in this location a macroinvertebrate survey was not possible at this location. However there is an EPA monitoring station approximately two kilometres downstream which was surveyed in August 2012 after the construction of angle mast 144. The ecological status of the Stracashel in this location was assessed to be good on the basis of a Q-Value of Q4. The next EPA monitoring station downstream on the Stracashel is assessed to be at poor status (Q2-3) and therefore there is a pressure between these two EPA monitoring stations impacting on the Q values.

A post construction survey took place in 2015 and this survey was undertaken approximately 300m further downstream based on safety of access but returned a similar Poor status Q-score of Q3. Despite the presence of taxa from Group B (*Ephemera sp.*) and Group C (*B. rhodani* and *Hydracarina*), overall abundance and diversity were found to be low.

6.7.3 River Hydromorphological Assessment Technique (RHAT) Survey

The RHAT survey was conducted over a 160m reach extended upstream and downstream of the angle mast structure. The surrounding land use is predominantly rough grazing and forestry.

The overall channel type was recorded as lowland meandering. The width of the river was four metres and the depth was estimated to be two metres at the time of survey.

There was significant bank erosion and undercutting noted and new field drains had been recently excavated. Animal poaching is a feature along this reach and there are significant stands of forestry in the area.

Other anthropogenic impacts such as dredging, re-sectioning, embankments and reinforcement are absent and whilst there is some bank side erosion and undercutting on both banks and the riparian zone has been slightly altered through drainage and grazing, the riparian vegetation remains intact for the most part with the exception of the poached and eroded areas. All other morphological features such as channel form and flow, channel vegetation, substrate condition score high and the overall morphological status is considered to be high.

A post construction RHAT survey was conducted in 2015 (09/09/15) over a 160m reach beginning approximately 100m upstream of the angle mast structure. The surrounding land use is predominantly rough grazing and forestry, as shown in Plate 6.18.

Plate 6.18 Illustration of land use in vicinity of AM144

The overall channel type was recorded as lowland meandering. The width of the river was four metres and the depth was estimated to be two metres at the time of survey.

As noted in the original hydromorphological survey carried out in October 2012, there was significant bank erosion and undercutting evident and new field drains had been recently excavated. Animal poaching is a recurring feature along this reach, as shown in Plate 6.19, and there are also significant stands of forestry in the area. All other morphological features such as channel form and flow, channel vegetation, and substrate condition scored high and the overall morphological status was considered to be high, as per the previous survey.

Plate 6.19 Example of livestock trampling/poaching and field drainage adjacent to AM144

6.7.4 Discussion

The monitoring and field assessment has indicated that there is no significant impact from the construction of AM144. The structure is well set back from the main channel and there is no obvious hydraulic connection to the Stracashel River. Other pressures within surrounding area are apparent and may be the reason for the slightly elevated suspended solids levels downstream of the site. However, these pressures have not resulted in a significant deterioration in the water quality or the morphological status of the reach surveyed.

The results of the post construction surveys in 2015 indicate that the construction of AM144 has not had a long-term impact on the macroinvertebrates or the hydromorphology of the Stracashel River at this site.

7 CONCLUSIONS

In terms of the worst case scenario, Angle Mast 78 on the Binbane to Letterkenny Line, is within a FPM catchment and is classified as a high status site in the North western River Basin Management Plan. The monitoring and surveys undertaken at this site would suggest that there has been an impact from the works predominantly due to the physical changes to the river bank immediately adjacent to the site. These changes resulted in a morphological status of good where it would have been high had the alterations not taken place. It is worth bearing in mind that impacts to hydromorpholgy can be regarded as long-term impacts, as deterioration in hydromorphological status as a result of any works cannot be rectified until reinstatement and rehabilitation works have been undertaken and sufficient time has been given to restore the physical condition of the channel to its original state.

However the results of the Biological and Hydromorphological post construction surveys in 2015 indicate that the impact experienced at AM78 was short-term and bank structure/stability and vegetation have now returned to a pre-construction state.

There was also a noticeable increase in suspended solids in the downstream monitoring station which suggests the physical impact of the bank structure combined with high flows in the river resulting in inundation of the site footprint has resulted in increased suspended solids levels downstream. These findings are in keeping with the conclusions of the literature review in that the most likely impact to water quality from linear infrastructure arises from potential sediment movement. Other potential impacts highlighted in the literature review included pollution from hydrocarbons or concrete and cement, neither of which has been identified as impacts through the field study.

There were also slight increases in nutrient levels which may be indicative of the forestry felling that was undertaken to accommodate the line. It is imperative that any mitigation measures recommended for future projects take into consideration best practice guidance for any ancillary activities also required to facilitate the project.

Angle Mast 173 on the Connemara Line 110 kV Project represents a site selected as a worst case scenario for the construction of transmission system infrastructure due to the difficult ground conditions and sensitive nature of the receiving environment given the FPM interests in the Owenwee FPM catchment immediately downstream of the Bunowen River. The detailed pre construction investigations by the contractor to establish the best access route across the blanket bog and the sensitive construction techniques used on site, including piled foundations with limited excavation, meant that the impact at this location was not significant and demonstrates that these methods can ensure that the impact on water quality and aquatic ecology from transmission system development in these locations can be minimised.

Similar issues to that at Angle mast 78 on the Donegal 110 kV reinforcement project arose with AM196, which was considered as non-standard on the basis of its location immediately adjacent to a water course. Site clearance works had an impact on the bank structure and riverbed substrate. However there was no noticeable impact on the macroinvertebrate community or water quality. The location of these types of structures so close to a water body represents issues in terms of the potential for physical modification to the morphology of the river which can result in bank stability issues, loss of bank vegetation, a reduction in the riparian buffer zone and infiltration of the riverbed substrate with silt and fines.

For those structures representative of the typical scenario in the construction of overhead line transmission projects, i.e. those that are set back from the channel and which retain an effective riparian buffer zone in the range of 25 – 30m based on literature reviewed, no discernible impact was established and the water quality, ecological status and morphological status should not be affected. However, it is important that the riparian buffer zone is a fully functional buffer and is not bypassed by hydraulic pathways such as drainage ditches or preferential flow paths that could provide a pathway for the potential pressures associated with site clearance works and construction of the transmission structures.

Any phyisco-chemical impacts identified throughout the field study can be described as short-term and are most likely to recede following the completion of the construction phase of the structures. However, in sensitive catchments, such as FPM designations, increases in nutrients and suspended solids have the potential to have a much longer and more serious adverse impact. As previously discussed, alterations in nutrient concentrations and pH can affect the growth rate of mussels, hence altering their life history strategy and decreasing their reproductive periods. Increases in suspended solids can have a more immediate and direct effect in terms of choking and killing of mussels, but ultimately both of these impacts will cause a decline not only in numbers but in potential reproduction and recruitment rates for future populations, resulting in an irreversible long-term impact.

The findings of the post construction biological and hydromorphological surveys carried out in 2015 indicate that the impact caused by these constructions has now reduced and can be identified as short-term. However the construction of the angle masts so close to water courses can have a significant impact in the short term, as identified in the original study and, where technical constraints permit, should be sited to ensure an adequate, functioning buffer zone between the structure and adjacent water courses.

The surveys across all other study sites also showed either a continuation, or in some cases an improvement, of the biological and hydromorphological conditions, and as such indicate that there has been no long-term impact on these elements of water quality as a result of the infrastructure installed as part of these projects.

8 FUTURE RECOMMENDATIONS

The following section outlines issues to consider with respect to location, design, construction and operation of transmission infrastructure on future projects, especially relevant to sensitive designated sites such as FPM catchments.

Best practice measures are suggested that, alone or in combination, may mitigate risk during different phases of the development.

As outlined in Chapter 4, the preferred sequence of mitigation measures is first to avoid impacts at source and then minimize pressures through measures that will reduce and abate possible impacts at source or on site. Measures to prevent impact can include siting activities in areas where there is no pathway to allow impact to occur, or eliminating the pressure at source, e.g. prevention of elevated suspended solids in FPM habitat through strict control measures at source.

Adequate site assessment and detailed planning are fundamental to sustainable operations within this sector and should be afforded sufficient time in advance of operations. Construction, operation and decommissioning/reinstatement, and all ancillary activities pose risk of impact to water quality.

8.1 PLANNING/SITE ASSESSMENT

Future plans and projects which pose a threat to water quality should document a clear understanding of baseline environmental, topographical and hydrological conditions in the operational area and within the catchment as a whole. This should include a site assessment to investigate any other pressures or risks which may be apparent within the catchment, a necessity when considering the cumulative or in-combination effects required as part of any AA.

Clearly documented plans for the proposed project should set out:

i) a detailed schedule of works required during construction and operation;
ii) all machinery and operational methodologies, including protocols for fuel and other hydrocarbon use and storage;
iii) all relevant mitigation measures which must be proposed on the basis of site specific assessment;
iv) the planned timescale and seasonality of proposed works.

Having established the effectiveness of buffer zones through the findings of the literature review, it can be said that these should be incorporated during the initial planning phase of transmission infrastructure with regard to selecting the locations for powerline structures. Given the ability of buffer zones to retain sediment and nutrient and vastly decrease potential loading to the channel arising from construction works, site locations should be planned to be set back a sufficient distance from the channel bank.

As previously identified, buffer zones of up to 30m have proved effective in increasing sediment and nutrient retention rates (approximately 80%). It should be noted however that this buffer zone should begin at the boundary of any site works, and not from the centre location of the structure itself. As found in the instance of AM9 on the Connemara 110kV line, although the mast structure was set back approximately 30m from the channel, site clearance works were undertaken right up to the river bank, and hence negating any buffering effect which this setback zone may have been able to provide.

A summary of all mitigation and monitoring undertaken and the results of that monitoring should be held to improve understanding of when and where mitigation measures can be successfully used, and to inform future guidance.

8.2 SITE ESTABLISHMENT

The construction and site establishment phase of facilities associated with transmission infrastructure can be damaging to water quality through sediment and nutrient release, and changes to hydrology and flow regime associated with provision of necessary infrastructure e.g. new roads, dams, bankside reinforcement, hard engineering. In addition the delivery, use, storage and disposal of construction materials, spoil and overburden material, hydrocarbons and other chemicals on site pose a significant risk of impact. Standard best practice for pollution prevention is a basic requirement for all work sites.

8.2.1 Construction

Any new infrastructure associated with this sector should attempt to comply with the following:

1) Avoid in stream works;
2) Avoid peat or other highly erodible soil types;
3) Avoid construction works which will lead to the direct removal of bank side vegetation or the associated riparian zone;
4) Avoid new drainage or drain maintenance in sensitive areas;
5) Avoid in-combination impacts of land uses that make use of parts of land that may be contributing to drainage, sediment and / or nutrient pressures;
6) Avoid impacts associated with new road building by carefully siting any roads in areas remote from sensitive areas, ensuring no pathways for impact exist;
7) Avoid any requirement to cross aquatic zones such as rivers, streams and large drains. Unless adequately clear spanned, crossings can lead to bed scour and bank erosion with consequences for movement of fine sediment downstream. Any crossings in a location where there are sensitive aquatic species, or immediately upstream of their suitable habitat, should be completely avoided.
8) Avoid siting of machinery on the river bank where it can lead to compaction, bank erosion and continued release of silt to the river channel.
9) Construction associated mitigation measures should demonstrate that fine sediment will not reach the aquatic environment, e.g. through terrestrial silt fences;

10) Consultation between the contractors responsible for any on-site works and a qualified ecologist should be undertaken in the planning phase prior to the commencement of any works, and continue through the duration of the works and their associated monitoring.

All construction related elements of any project should be appropriately assessed as part of the overall Habitats Directive Assessment or equivalent if located in, or potentially impacting upon, a Natura 2000 site.

8.2.2 Sediment and Nutrient Release

Once sediment and nutrients reach an aquatic area, either a drain, watercourse, or aquatic zone, the risk of damage is very high and efforts at containment are unlikely to be effective. Buffer zones along waterways can provide mitigation during construction activities. Buffer zones must be of adequate dimensions and impede all free flow to waterways. Heavy machinery and site traffic should be excluded from these areas.

During construction and site establishment operations, silt fencing should be used to prevent disturbed soils reaching the aquatic zone. These measures should be applied close to the pressure source in dry terrestrial conditions. Triple silt fencing should be used in the areas of highest risk, and single or double silt fencing at frequent intervals along pathways towards aquatic zones. The silt fencing should be removed only when bare soil is revegetated and sediment movement is no longer a risk. Monitoring of silt fences is essential to ensure their upkeep, and the very regular maintenance required means that appropriate manpower must be on site until such time as vegetation regrowth has occurred and the risk of sediment movement is past.

8.2.3 Hydrological and associated impacts within the catchment

To prevent significant changes in catchment hydrology that can change the flow regime, and to avoid movement of sediment and nutrient along pathways to the aquatic zone, projects should comply with similar protocol as to that outlined previously.

8.3 OPERATION

Following the initial construction and commissioning of transmission infrastructure, very little is required in terms of operational labour. Occasional maintenance may be required but this is rarely intensive and sites are accessed by low impact 4 x 4 vehicles using existing access routes.

In the event that more intensive maintenance is necessary with the potential requirement for heavy duty mechanical plant, appropriate mitigation should be implemented with regard to fuel contamination, hydrocarbons and other pollutants.

8.4 RESTORATION

Restoration is a process of repairing the environmental impacts of aggregate workings. At a basic level it can entail “restoration” which is simply making a site safe and physically stable, usually by covering in subsoil, topsoil or soil-making materials. However usually “aftercare” is also involved which involves full site restoration to a defined after-use, including ongoing management and maintenance of the site to ensure restoration success.

Throughout this study instances have been identified where bank stability has been compromised. These sites would require such restoration measures to limit the long-term impact of works on the waterbody, and as a result restore its ability to achieve high morphological status, and in turn, high ecological status.

8.5 MONITORING

As planned in the methodology, the water quality monitoring programme was informed by the EU Water Framework Directive Monitoring Programme, developed by the EPA (EPA, 2006) which recommends a minimum of 4 samples for physico-chemical monitoring. In order to increase confidence in the data, it was proposed to undertake 6 rounds of sampling for both pre- and post-construction phases, but in many instances this was not feasible. This was largely down to the variability of the planned construction programmes which were subject to external factors such as land access issues and inclement weather conditions.

In relation to all works, effective supervision, informed by engagement with an ecologist, is an essential mitigation measure to prevent impact to water quality. It allows control and mitigation of all activity and assessment of any changes in baseline conditions that may result.

Visual monitoring and clear record keeping, including a photographic record should be an intrinsic part of construction and site establishment activities. The aim of this monitoring is to demonstrate that the mitigation measures undertaken, including weather triggers to stop and start work operations, have prevented any negative effect on water quality.

Monitoring needs to take place for a timescale that reflects the risk period. This includes site preparation, the full construction and site establishment period, during operational phases if a risk to water quality or aquatic ecology is possible, and the duration of any site regeneration works required to return the site to its original state if morphologically altered during the project.

Turbidity should be recorded in drains and streams upstream and downstream of the works area throughout the construction phase by staff on site using a handheld probe. This would allow immediate response in the event that levels were noted to rise.

Other water quality parameters as listed in this study should also be monitored in drains and streams upstream and downstream of works. Monitoring should continue throughout the period of operation and for post operational risk periods as discussed above.

As aquatic sites are recognised as most at risk from anthropogenic pressures, there is now a need for a concerted effort to install an effective policy framework for management and protection of our waters (Irvine & Ní Chuanigh, 2010). Any new policy guidelines put in place as a result of future planning in terms of management and protection of waterbodies should also be taken into consideration.

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