Appendix 6-5
Aquatic Ecology and Fish Survey Report

Malachy Walsh and Partners
Engineering and Environmental Consultants

Aquatic Ecology and Fish Survey Report
Carrownagowan Wind Farm

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1 INTRODUCTION

Malachy Walsh and Partners (MWP) has been commissioned by *Coillte Cuideachta Ghníomhaíochta Ainmnithe*, hereafter referred to as Coillte, to prepare an Environmental Impact Assessment Report (EIAR) to accompany a planning application to An Bord Pleanála for the Carrownagowan Wind Farm. The EIAR also assess the associated grid connection and works on the haul route in Co. Clare (the proposed project).

This report has been prepared by Malachy Walsh and Partners (MWP) to present baseline information for input to the Biodiversity Chapter of the Environmental Impact Assessment Report (EIAR) and Natura Impact Statement (NIS). This report is based primarily on field studies of watercourses potentially affected by the proposed project. Information collated from desk studies has also been included in this report.

The project also requires the replanting of forestry at three replacement sites. The aquatic baseline conditions at these three replacement sites are described in Appendix 6-11 of the Biodiversity Chapter (Chapter 6) of the EIAR.

The study area includes the rivers and streams draining the proposed project. The study area is located in Water Framework Directive (WFD) catchments/Hydrometric Areas 25 and 27, within the Shannon River Basin District (ShRBD). The water features in the study area are illustrated in **Figure 1**.

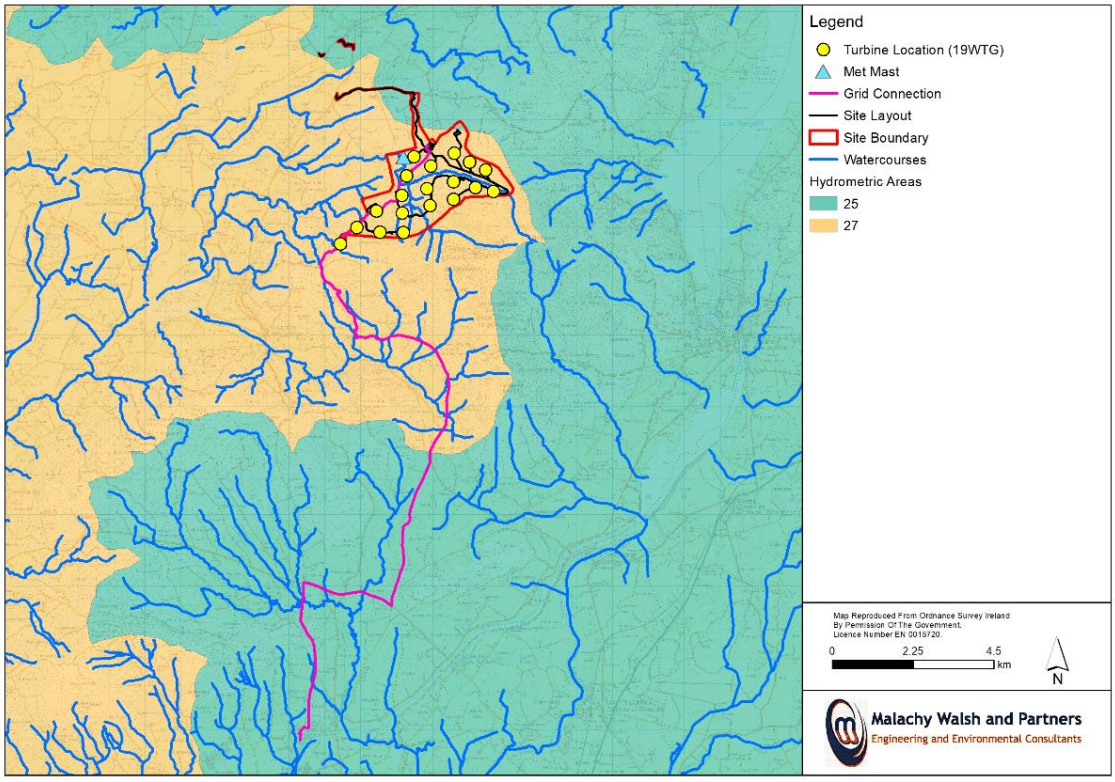

Figure 1. Water features draining the study area

1.1 DESCRIPTION OF WATERCOURSES IN THE STUDY AREA

The proposed wind farm site is mainly situated within Coillte Forestry, and is drained largely by the Owengarney River in Hydrometric Area 27. The upper catchment of the Owengarney River drains an elevated area of peat overburden, much which has been planted with commercial coniferous forestry. The proposed haul route has a stream crossing draining to the Coolreagh Beg, in Hydrometric Area 25. The grid route lies mainly within the Broadford (Hydrometric Area 27) and Blackwater River (Hydrometric Area 25) catchments.

The Owengarney River (also referred to as the Owenogarney) rises on the western slope of Moylussa. As it flows west on its course of ca. 2.5km towards the proposed wind farm site, it is fed by two 1st order streams which drain the western and northern sides of Slieve Bernagh. The Owengarney River flows for ca. 3.5km northwest through the proposed wind farm site, draining the central part of the site. Along this reach, it is fed from the southwest by the 1st order Killokennedy Stream which rises within the site, with a channel length of ca. 1.3km. The Coumnagun Stream is a 1st order watercourse of ca. 5km and joins the Owengarney from the east within the site. The Coumnagun Stream rises on the western slope of Moylussa and enters the site ca. 1.3km from source.

Approximately 3.2km downstream of the wind farm site, the 2nd order Owengarney River flows west under the R465 at Ballymacdonnell Bridge. The upper Owengarney River is also called the Ballymacdonnell River. A further 3.8km downstream, the Owengarney River is fed by the 3rd order Killuran River. The Killuran River drains the western most aspect of the site. The Killuran River rises at Poulalougha, a minor lough ca. 600m upstream, and to the south east of the proposed wind farm site. The Killuran River flows along the southern boundary, within the proposed wind farm site for ca. 1.3km and met from the south by the 1st order Ballynabrone Stream ca. 250m downstream, to the west of the site. After its confluence with the Ballynabrone Stream, the Killuran River flows northwest for ca. 1km before its junction with the 2nd order Killuran More Stream from the east. The Killuran More Stream rises within the proposed wind farm site and has a length of ca. 2.8km. It has four 1st order tributaries that rise and/or flow thorough the site, including the Inchalughoge and Gortatrassa Streams. After its confluence with the Killuran More Stream, the Killuran River generally flows in a westerly direction over a course of ca. 1km to Turner's Bridge on the R465. It continues on a broadly westerly course for ca. 3.2km before discharging to the Owengraney River. After its confluence with the Killuran River, the Owengarney River flows south for ca. 2km before feeding Doon Lough. From the western shore of Doon Lough, the 3rd order Owengarney River flows less than 1km to an Duin Lough. The 3rd order Broadford River also flows into Duin Lough. Downsream of Duin Lough, the Owengarney River generally flows in a south-westerly direction over a course of ca. 21km before meeting the transitional waters of the Shannon Estuary at Bunratty. Along this reach, the Broadford River flows through Ballymulcashel and Castle lakes as well as Siximilebridge village. The main tributaries along this reach are the 3rd order Derrymore East, Clashduff and Gourna Rivers.

Plate 1: Stretch of the Owengarney at the R465 to the west of the proposed project in August 2018 (left). The Broadford River at Broadford downstream of the grid route crossings (right).

The proposed haul route leading up to the site crosses a culvert of an unmapped stream, which generally drains to the northwest, and enters the Coolreagh Beg, c. 1 linear km to the northeast.

The northern proportion of the grid route lies within the Broadford River catchment. The Broadford River has numerous tributaries including the Cloongaheen West, Cloongaheen East, Kilbane, Cloonaconry, Ballyquin Beg and Glenomra Wood Streams, all of which are crossed by the grid connection. The southern extent of the grid route occurs within the Blackwater (Clare) River catchment. This river drains an area between Broadford and Ardnacrusha, where gradient is generally of a south-westerly aspect. It has several tributaries from the north including the 3rd order Snaty River, the 2nd order O'Neill's Stream and the 3rd order Mountrice River. The largest tributary of the Blackwater River is the 3rd order Glenomra Wood Stream which joins the Blackwater River from the north. The Glenomra Wood Stream is crossed by the grid route ca. 1km upstream of the Blackwater River confluence. After the Glenomra River confluence, the Blackwater River flows south for ca. 4km as a 4th order watercourse before intersecting with the headrace of the Ardnacrusha Hydro-scheme. The headrace is classified as a canal, owing to its artificial character. The Blackwater River flows under the headrace through a culvert. At the upper (northern) end of this culvert, the Blackwater River falls steeply over a sloped concrete sill. This is considered a significant barrier to fish migration as flows are fast and would be impassable in the upstream direction for most fish species. After flowing under the headrace, the Blackwater River flows south for ca. 4.5km to meet the 7th order River Shannon at Plassey.

Plate 2: The intersection of the Blackwater River and the headrace of Ardnacrusha Hydro-scheme (left). Upper end of the culvert for the Blackwater River under the headrace of Ardnacrusha Hydro-scheme (right).

1.2 GUIDANCE AND LEGISLATION

The assessment has regard to the following legislation:

- European Communities Environmental Objectives (Surface Waters) Regulations 2009 (S.I. 272 of 2009) and (Amendment) Regulations 2012 and 2015;
- Birds and Natural Habitats Regulations 2011 as amended; and
- Wildlife Act 1976 as amended.

The European Communities Environmental Objectives (Surface Waters) Regulations 2009 (S.I. 272 of 2009) and (Amendment) Regulations 2012 and 2015 establish legally binding quality objectives for all surface waters and environmental quality standards for pollutants for purposes of implementing provisions of E.U. legislation on protection of surface waters. These regulations clarify the role of public authorities in the protection of surface waters also concern the protection of designated habitats.

Relevant guidance published by the National Roads Authority (NRA), and applicable to assessing watercourses in Ireland were also followed, including 'Guidelines for the Crossing of Watercourses during the Construction of National Road Schemes' (NRA, 2005). IFI (2016) 'Guidelines on Protection of Fisheries during Construction Works in and Adjacent to Waters' was also consulted in relation to necessary mitigation.

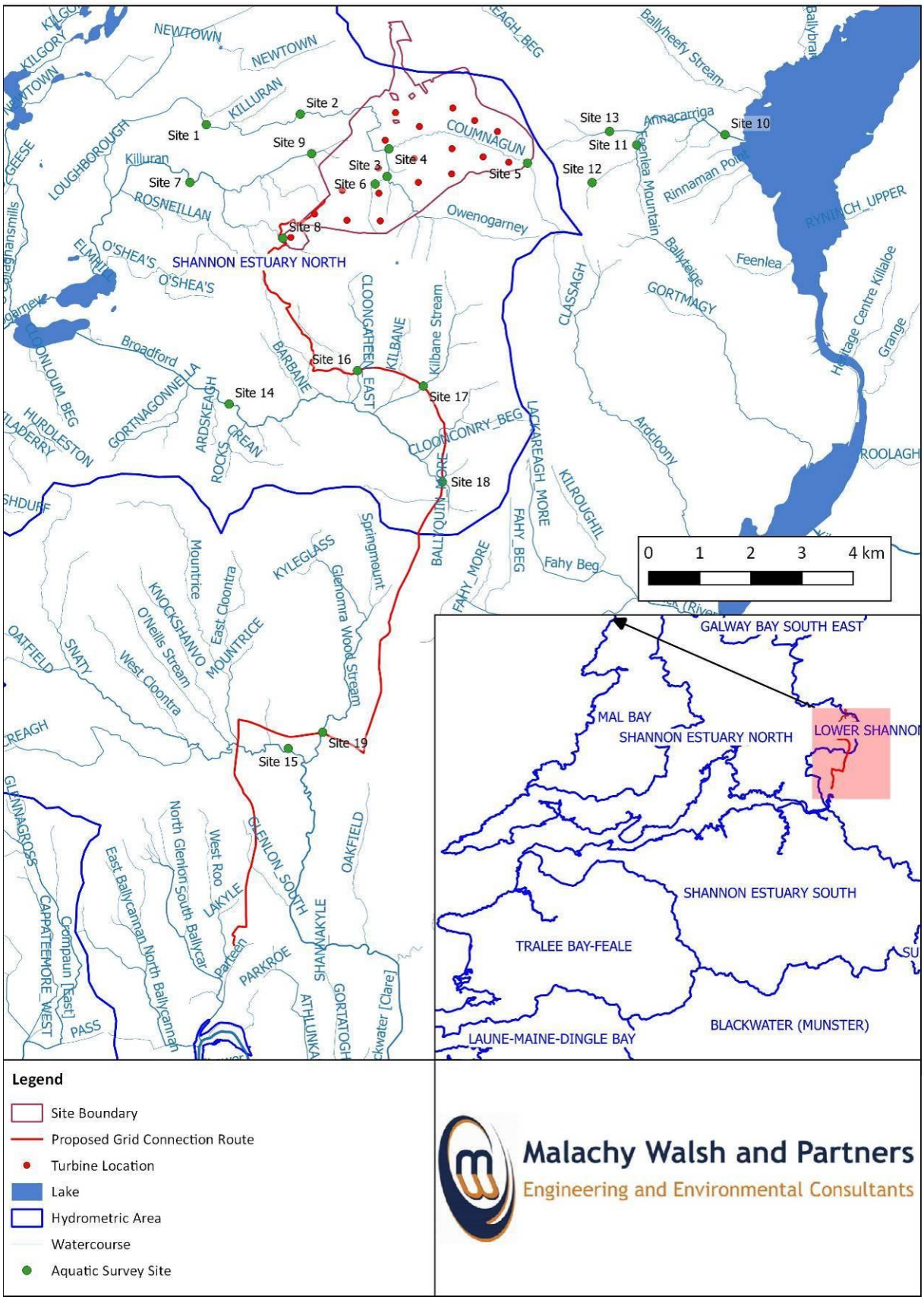

Figure 2: Watercourses and survey sites examined as part of the aquatic ecology studies for the proposed project.

1.3 CONSULTATION

Consultation with Inland Fisheries Ireland (IFI) was undertaken via email to Limerick@fisheriesireland.ie on the 5th June 2018. Michael Fitzsimons (Senior Fisheries Environment Officer) replied on the 26th July 2018 as follows:

"This development is entirely in the lower Shannon catchment area and the watercourses in the area are considered important fisheries. The Owengarney River and its tributaries are considered by IFI to be important for both salmon and trout spawning. The Annacarriga River is considered to be more important as a trout spawning River. Please be aware that peat stability in this catchment has posed problematic in the past and a significant peat slip took place in the 1980s causing significant water quality problems and a fish kill. Arising from the above I would be in a position to respond in a more detailed manner in the next couple of days."

2 METHODOLOGY

2.1 DESK STUDY

A desktop review was carried out to collate information on fish and to identify features of aquatic ecological importance within the study area. Records of protected species in the environs of the proposed project were identified. This information was obtained by accessing the website of the National Parks & Wildlife Service (NPWS)[1] and Inland Fisheries Ireland (IFI)[2]. The database of the National Biodiversity Data Centre (NBDC)[3] was consulted to assess the presence of aquatic faunal species and records of protected species from records of the study area. The document '*Quantification of the freshwater salmon habitat asset in Ireland*' by McGinnity *et al.* (2003) was also reviewed to classify the salmonid habitats in the study area.

2.2 FIELD STUDY

The survey comprised an evaluation of aquatic habitats, a fish survey, a biotic assessment using aquatic macroinvertebrates and water sampling for analysis of physico-chemical water quality parameters.

Representative locations on watercourses draining the proposed project were surveyed. A total of 19 sites were selected within the study area, on watercourses shown on Environmental Protection Agency / Ordnance Survey Ireland mapping. It is noted that the sites to the east, in the Annacarriga catchment do not drain the proposed project. These sites were selected based on a preliminary layout which extended into the Annacarriga Catchment Area. The study area was defined as surface waters potentially affected by the proposed project, including fluvial habitats (watercourses) within the proposed project site, and those downstream. While survey locations down-gradient of the proposed project area are influenced by factors outside of the site boundary, downstream biota are nonetheless receptors for the proposed project, and acquisition of baseline information at these locations is deemed important in a complete understanding of aquatic sensitivities. Indeed, the

[1] https://www.npws.ie/maps-and-data
[2] https://www.fisheriesireland.ie/
[3] http://www.biodiversityireland.ie/

larger size of watercourses downstream of the proposed project provide more habitat and are considered more suitable for salmonids than reaches inside the proposed project site boundary.

The list of survey sites are given in **Table 1,** where the aquatic surveys carried out at each location are indicated. A map of the entire study area is shown on **Figure 1**. **Figure 2** - **Figure 5** illustrates the survey locations at the north-western, north-eastern and southern extents of the study area respectively. Sites were accessed using public roadways and forest tracks. In this report, 1st and 2nd order watercourses have been referred to as streams. Watercourses of 3rd order and larger are referred to as rivers.

Field work pertaining to habitats and macroinvertebrates at Site 1 – Site 15 was carried out on the 1st, 2nd, 3rd, 28th, 29th and 30th August 2018. Macroinvertebrate sampling at Site 16 – Site 19 was carried out on 31st October 2019. The fish surveys were carried out on the 25th, 26th and 27th September 2018. In cognisance of the risk of spread of non-native invasive alien species, the Inland Fisheries Ireland (IFI) document 'Biosecurity Protocol for Field Survey Work (IFI, 2010) was followed at all stages of field work. All equipment (including waders etc.) was disinfected with spray bleach disinfectant after use, washed, dried out and put in storage.

The macroinvertebrate assessment included a freshwater pearl mussel (FPM) *Margaritifera margaritifera* survey. The FPM survey was carried out on selected watercourses identified within 'freshwater pearl mussel sensitive' catchments (see section 2.2.5). The extent of freshwater pearl mussel surveys carried out on selected watercourses identified within FPM sensitive catchments are presented in **Figure 6**.

Plate 3: Site 1 on the Owengarney River (left). This watercourse supports Salmon, Brown trout and European eel. Site 2 on the Owengarney River (right). Heterogenous fluvial habitat here provides ideal rearing conditions for salmonids.

Plate 4: Site 3 on the Owengarney River in the townland of Carrownagowan (left). This reach of river is within the proposed project site. Site 4 on the Coumnagun Stream, a tributary of the Owengarney – this watercourse flows through the proposed project site (right).

Plate 5: Site 5 on the Coumnagun Stream. Brown trout were the only fish species recorded here (left). Site 6 on the Killokennedy (27K70) Stream (right). This stream is considered prone to drying out during long dry spells.

Plate 6: Site 7 on the Killuran Stream in August 2018 (left). Site 8 on the Killuran Stream (right).

Plate 7: Site 9 on the Killuran More Stream (left). Substrates were compacted at this location, which result in suboptimal spawning grounds for salmonids. Site 10 on the Anacarriga River (right).

Plate 8: Site 11 on the Annacarriga River (left). A series of falls and rapids downstream of Site 11 on the Annacarriga are considered an obstacle for upstream migrating salmon (right).

Plate 9: Site 12 on the Carrownakilly Stream - upper Annacarriga River catchment (left). Site 13 on an un-named tributary of the Annacarriga River (right).

Plate 10: Site 14 on the 3rd order Broadford River ca. 1km upstream of Broadford (left). Site 18 on the 2nd order Broadford River (right).

Plate 11: Site 15 on the Blackwater River (Clare) at the R465 Bridge (left). Site 16 on the Cloongaheen East Stream (right).

Plate 12: Site 17 on the Kilbane Stream (right). Site 19 on the Glenomra Wood Stream.

Water quality affects the viability and quality of salmonid habitat so is useful in assessing habitats for trout and salmon. To this end biological sampling and water quality indices as well as macroinvertebrate functional feeding group analysis were used to classify watercourses at selected locations.

Table 1: Aquatic ecology and fish survey locations on watercourses draining the proposed project.

Hydrometric Area/River Basin	River Catchment	Waterbody / EPA Code	Tributary - Sub-tributary / EPA Code	Order	Location	EPA River Segment code	Site No.	Co-ordinate		Survey			
								X	Y	Fish habitat	Fish survey	Biological	Physico-chemical
27 / Coastal	Owengarney	Owengarney / 27O01	Owengarney (Ballymacdonnell) / 27O01	2	Ballymacdonnel Bridge, R465	27_44	1	-8.6275	52.8493	✓	✓	✓	✓
			Owengarney (Ballymacdonnell) / 27O01	2	Inchalughoge	27_356	2	-8.6001	52.8512	✓	✓	✓	✓
			Owengarney (Ballymacdonnell) / 27O01	2	Carrownagowan	27_386	3	-8.5747	52.8406	✓	✓	✓	✓
			Coumnagun / 27C97	1	Carrownagowan	27_341	4	-8.5749	52.8451	✓	✓	✓	✓
				1	Carrownagowan	27_341	5	-8.5340	52.8428	✓	✓	✓	✓
			Killokennedy / 27K70	1	Carrownagowan	27_808	6	-8.5784	52.8390	✓		✓	✓
			Killuran / 27K01	3	Turner's Bridge, R465	27_871	7	-8.6319	52.8391	✓	✓	✓	✓
				1	Killokennedy	27_946	8	-8.6040	52.8287	✓	✓	✓	✓
			Killuran / 27K01 - Killuran More / 27K15	1	Inchalughoge	27_1225	9	-8.5969	52.8442	✓	✓	✓	✓
			Broadford / 27B02	3	Track crossing ca. 1km upstream of Broadford, adjacent to R466	25_481	14	-8.6223	52.8005	✓	✓	✓	✓
			Broadford / 27B02 – Cloongaheen East 27C18	2	Ballymoloney – Cloongaheen Road	27_744	16	-8.5830	52.8063	✓		✓	
			Broadford / 27B02 -	2	Ballymoloney –	27_849	17	-8.5830	52.8061	✓		✓	

Hydrometric Area/River Basin	River Catchment	Waterbody / EPA Code	Tributary - Sub-tributary / EPA Code	Order	Location	EPA River Segment code	Site No.	Co-ordinate		Survey			
								X	Y	Fish habitat	Fish survey	Biological	Physico-chemical
			Kilbane Stream 27K05		Cloongaheen Road								
			Broadford / 27B02	2	Ballymoloney – Cloongaheen Road	27_1315	18	-8.5638	52.8035	✓		✓	
15 / Shannon Lower	Shannon	Lough Derg / 250155b 0450	Annacarriga / 25A05	3	First Bridge u/s Lough Derg, R463	25_1514	10	-8.4765	52.8482	✓	✓	✓	✓
				2	Carrownakilly	25_2385	11	-8.5024	52.8452	✓	✓	✓	✓
				1	Carrownakilly	25_2284	12	-8.5149	52.8395	✓	✓	✓	✓
			Un-named	1	Carrowbaun	27_742	13	-8.5101	52.8487	✓	✓	✓	✓
		Blackwater (Clare) / 25B06	Blackwater (Clare) / 25B06	3	R465 Bridge, Br. d/s Killaly's Br.	25_3209	15	-8.6024	52.7398	✓	✓	✓	✓
			Glenomra Wood Stream / 25G12	3	R471 Bridge	25_3221	19	-8.5923	52.7427	✓		✓	

2.2.1 Habitats

Physical characteristics of all survey sites were recorded on-site in cognisance that fluvial and riparian habitats have a key influence on instream faunal communities. All sites were evaluated with reference to '*River Habitat Survey in Britain and Ireland Field Survey Guidance Manual: 2003 Version*' published by the Environment Agency (EA, 2003). At each survey location, the watercourse was assessed in terms of:

- Stream width and depth and other physical characteristics;
- Substrate type, listing substrate fractions in order of dominance, i.e. large rocks, cobble, gravel, sand, mud etc;
- Flow type, listing percentage of riffle, glide and pool in the sampling area;
- Instream vegetation, listing plant species occurring and their percentage coverage of the stream bottom at the sampling site (as applicable) and on the bankside;
- Estimated cover by bankside vegetation, giving percentage shade of the sampling site.

2.2.1.1 Fish

The results of the stream habitat surveys were used in conjunction with the leaflet '*The Evaluation of habitat for Salmon and Trout*' (DANI, 1995) to assess habitat suitability for salmonids at selected representative sites. This leaflet (Advisory leaflet No. 1) was produced by the Department of Agriculture for Northern Ireland Fisheries Division and was designed for use in the EU salmonid enhancement programme.

An evaluation of lamprey nursery habitat was also carried out based on the habitat requirements of juvenile lampreys as outlined in Maitland (2003). Searches for juvenile lampreys were carried out using agitation sampling where suitable nursery habitat occurred.

Any fish captured were identified with reference to the Freshwater Biological Association's publication *'Key to British Freshwater Fish with notes on their ecology and distribution*' (Maitland, 2004) and other referenced sources. Lampreys were identified using the document 'Identifying Lamprey - A field key for Sea, River and Brook Lamprey' by Gardiner (2003). Any fish captured during biological sampling were recorded.

Watercourses were photographed at survey site locations throughout the study area. Anthropogenic and livestock influences on fluvial and riparian habitats were noted along the surveyed stretches.

2.2.1.2 Macroinvertebrates

Habitat has a key influence on the macroinvertebrate communities, which occur in rivers and streams. The physical habitats of study sites were assessed in relation to macroinvertebrates using a method given by Barbour and Stribling (1991). A table showing how habitats are assessed using this method is provided in **Appendix 1**. This method assesses habitat parameters and rates each parameter as optimal, sub-optimal, marginal or poor (scores 5, 10, 15 and 20 respectively). The scores for each parameter are then added up to give an overall habitat score.

2.2.2 Fish stock assessment

Electrical fishing assessments were carried out at selected sites under authorisation from the Department of Communication, Energy and Natural Resources under Section 14 of the Fisheries Act

(1980). The purpose of this survey was to assess fish populations present at selected sites on watercourses draining the proposed project. Sites were surveyed following the methodology outlined in the CFB guidance 'Methods for the Water Framework Directive - Electric fishing in wadeable reaches' (CFB, 2008). A portable electrical fishing unit was used during the assessment.

Quantitative/depletion electrical fishing was carried out at Site 1 (Owengarney River) using stops nets at the upper and lower extent of the surveyed area. This area was fished a total of three times: three passes. Records were taken of fish captured from each pass immediately after each pass. A qualitative electrofishing survey was conducted on a $1m^2$ area at Site 14 and at Site 15. At other locations, electrical fishing was carried out continuously for over a certain time. The time spent at each location was recorded.

Plate 13: Electrofishing was carried out using standard gear including a battery powered electric fishing unit, dip nets and containers (left). Portable meters were used to measure certain water quality parameters and biological sampling kit required for determining macroinvertebrate community structure (right).

Captured fish were collected into a container of river water and were then anaesthetised using a solution of clove oil. Fish were measured to the nearest mm using a measuring board. Subsequent to this the fish were allowed to recover in a container of river water. All fish were released alive and spread evenly over the sampling area. Following completion of the fishing the dimensions and physical habitat characteristics of each site were recorded. Results of the investigations are presented using two Catch per Unit Effort (CPUE) indices; fish number/m^2 and fish number/minute.

2.2.3 Biological Sampling

Semi-quantitative sampling of benthic macroinvertebrates was undertaken at selected locations using kick or sweep sampling (Toner *et al*, 2005). Sampling was undertaken on the 18th and 19th of July 2017. The biological sampling procedure followed at each site involved the use of a 'D' shaped hand net (mesh size 0.5 mm; 350 mm diameter) which was submerged on the river bed with its mouth directed upstream. The substrate upstream of the net was then kicked for one minute dislodge invertebrates, which were subsequently caught in the net. This procedure was undertaken at three points along/across the watercourse. Stone washings and vegetation sweeps were also undertaken over a further 1-minute period to ensure a representative sample of the fauna present at each site was collected.

Plate 14: Biological sampling was undertaken at selected representative watercourses in the study area (left). Macroinvertebrates captured during kick sampling were live sorted for 20 minutes at each site using a forceps and a white background. Identification was assisted by using a lens (right).

All three samples of invertebrates from each substation were combined and live sorted on the river bank for 20 minutes with the assistance of a headband magnifier. Specimens were fixed in an alcohol solution. Identification was undertaken in the laboratory using high-power and low-power binocular microscopes. Macroinvertebrate samples were taken in accordance with I.S. EN ISO 5667-3:2004: *Water Quality – Sampling – Part 3: Guidance on the Preservation and Handling of Water Samples and ISO 7828: Water Quality – Methods of biological sampling – Guidance on Hand net sampling of aquatic benthic macro-invertebrates*. Macroinvertebrates were identified using keys listed in the references section.

2.2.4 Water quality

2.2.4.1 Biotic Indices

The Quality Rating (Q) System (Toner *et al*, 2005), BMWP (Walley and Hawkes, 1997) and EPT index (Lenat, 1988) were used to assess biological water quality at each site. Additional details of biotic indices can be found in **Appendix 2**.

The Quality Rating (Q) System (Toner *et al*, 2005) is the standard biotic index which is used by the EPA. The Q-index is a quality measurement ranging from Q1-Q5 with Q1 being of the poorest quality and Q5 being pristine / unpolluted. The Quality Rating System has been shown to be a robust and sensitive measure of riverine water quality and has been linked with both chemical status and land-use pressures in catchments (Donohue *et al*., 2006). The system facilitates rapid and effective assessment of the water quality of rivers and streams. There are nine Q-value scores, ranging from 1 to 5 (intermediate scores such as Q4–5 are also possible). High ecological quality is indicated by Q5, Q4–5 while Q1 indicates bad quality.

The other main biotic index used was the BMWP score. In the revised BMWP scheme (Walley and Hawkes, 1997) biotic index of water quality, each family recorded in the sample is assigned a habitat specific score. This score depends on the pollution sensitivity of the invertebrate family together with the characteristics of the site where the invertebrates were found. A site is classed as one of the following depending on substrate type: riffle (>= 70% boulders and pebbles), pool (>= 70% sand and silt) or riffle/pool (the remainder). The BMWP score is the sum of the individual scores of the families recorded at each site - a family scores if present. A higher BMWP score is considered to

reflect a better water quality and a score over 100 is indicative of very good water quality. Appendix 1 shows revised BMWP scores for riffled locations and the BMWP scoring system. Each site was assigned a biological status on a scale of High-Good-Moderate-Poor-Bad.

Each site was allocated an Average Score Per Taxa (ASPT). A weakness of the BMWP system, in common with many other score systems, is the effect of sampling effort. A prolonged sampling period can be expected, under most circumstance, to produce a higher final score than a sample taken quickly. To overcome this inherent weakness of the BMWP system, it became common practice to calculate the ASPT. The ASPT index calculation is based on the average value of each taxa (families) sampled is calculated by summing up the indicator values and their division by numbers of taxa (families) sampled and ranges from 0 to 10. A high ASPT index values indicates thus high ecological status and low values indicate bad/degraded ecological status. In general, the higher the number of taxa present, the better the biological quality of the reach, especially where the ASPT values are high (greater than 5.5).

Biological water quality was also assessed using the EPT index. The EPT index (Lenat, 1988) uses three orders of aquatic insects that are easily sorted and identified: Ephemeroptera (mayflies), Plecoptera (stoneflies and Trichoptera (caddisflies), and is commonly used as an indicator of water quality. The EPT index is calculated by summing the number of taxa represented by these 3 insect orders. The EPT Index is based on the premise that high-quality streams usually have the greatest species richness. Many aquatic insect species are intolerant of pollutants and will not be found in polluted waters. The greater the pollution, the lower the species richness expected.

2.2.4.2 Physico-chemical water quality

Chemical water quality samples were taken at all sites on 13th November 2018. Samples were taken from each site using aseptic techniques. Samples were stored in cooler boxes and delivered to Southern Scientific within 24hrs of sampling. The following physico-chemical parameters/ determinands were assessed: pH, Conductivity, Nitrate, Sulphate, Phosphate, Biological Oxygen Demand (5 day), Total Petroleum Hydrocarbons (TPH), Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), Total Hardness, Potassium, Total Organic Carbon (TOC), Total Organic Nitrogen (TON), Total Ammonia, Phosphorus, Orthophosphate (MRP) and Iron.

On-site measurements of Dissolved Oxygen, Electrical Conductivity, Turbidity, pH, Total Dissolved Solids and water temperature were also taken using calibrated portable meters.

Each site was assigned a chemical status on a scale of High-Good-Moderate-Poor-Bad based on water quality standards given in Surface Water Regulations (DoEHLG, 2009), the Freshwater Fish Directive (78/659/EEC) and the Salmonid Water Regulations (1998). **Table 2** gives chemical parameter thresholds for achievement of Water Framework Directive 'High' and 'Good' Status.

Table 2: Chemical parameter thresholds for achievement of Water Framework Directive 'High' and 'Good' Status. From the Surface Water Regulations (SWR, 2009 and as emended)

Parameter	High Status	Good Status
BOD	≤1.3 (mean(1)) or ≤2.2 (95%ile)	≤1.5 (mean(1)) or ≤2.6 95%ile
Total Ammonia	≤0.040 (mean) or ≤0.090 (95%ile)	≤0.065 (mean) or ≤0.140 (95%ile)
Orthophosphate	≤0.025 (mean) or ≤0.045 (95%ile)	≤0.035 (mean) or ≤0.075 (95%ile)

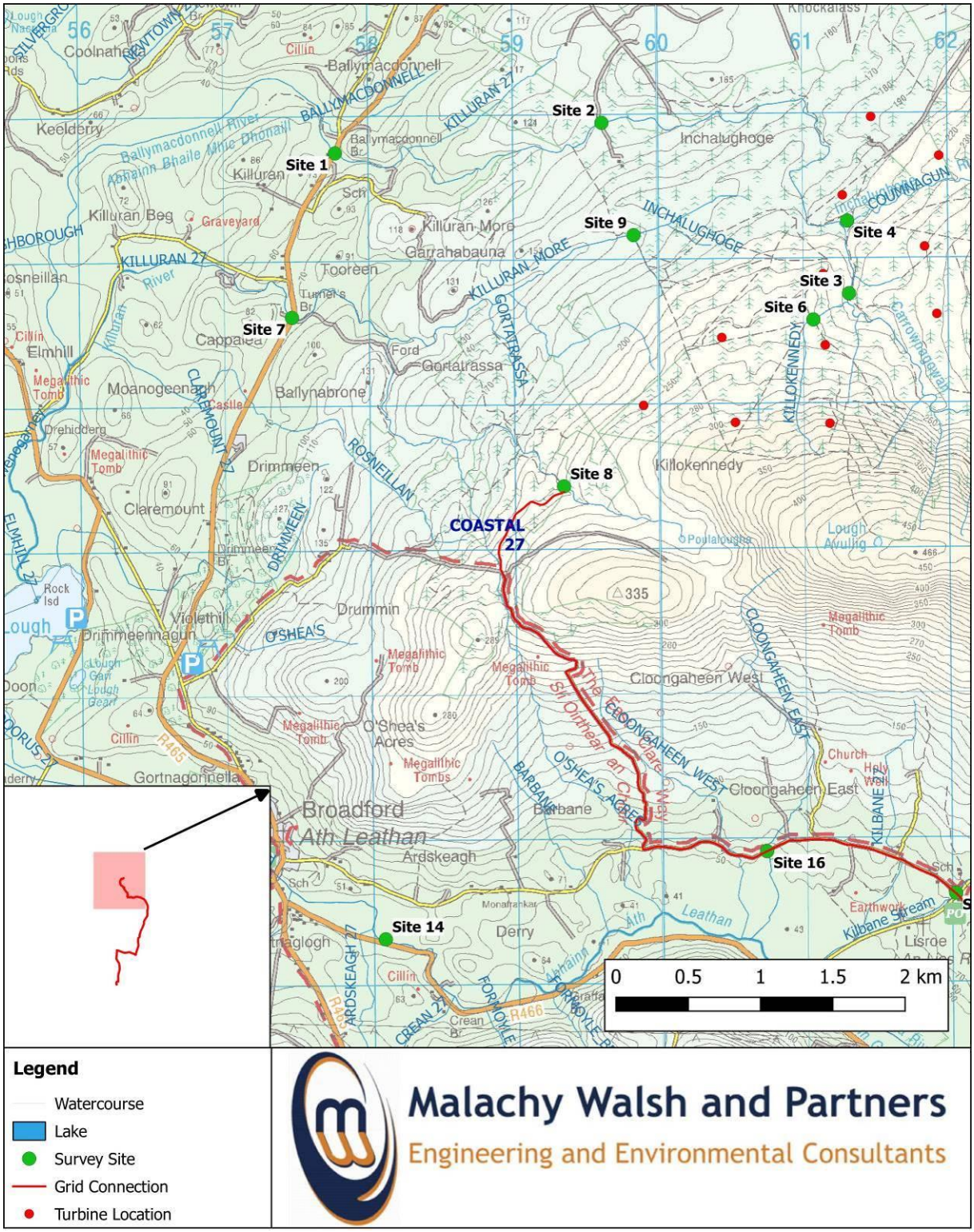

Figure 3. Aquatic survey sites at the north-western extent of the proposed project

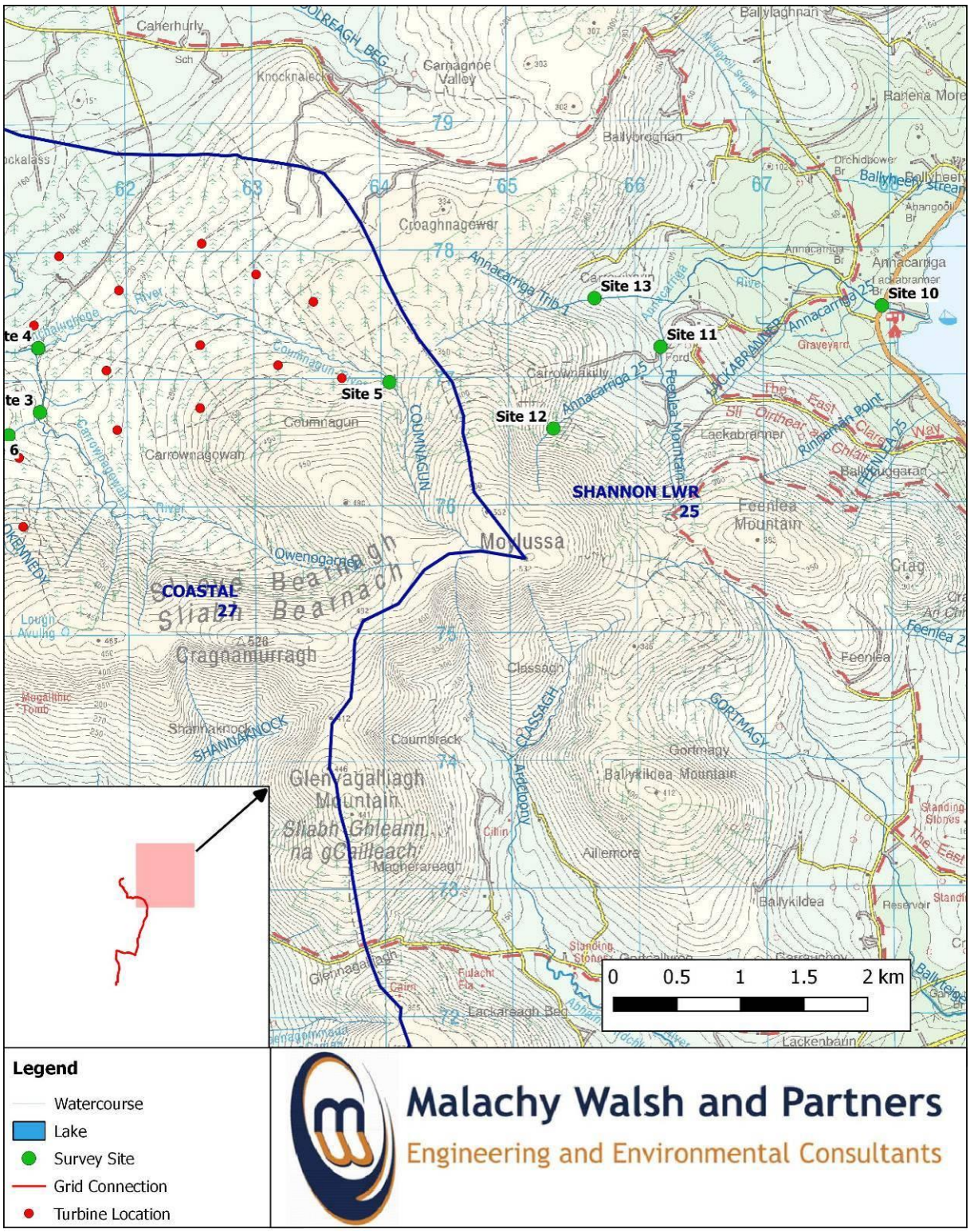

Figure 4: Aquatic survey sites at the north-eastern extent of the proposed project

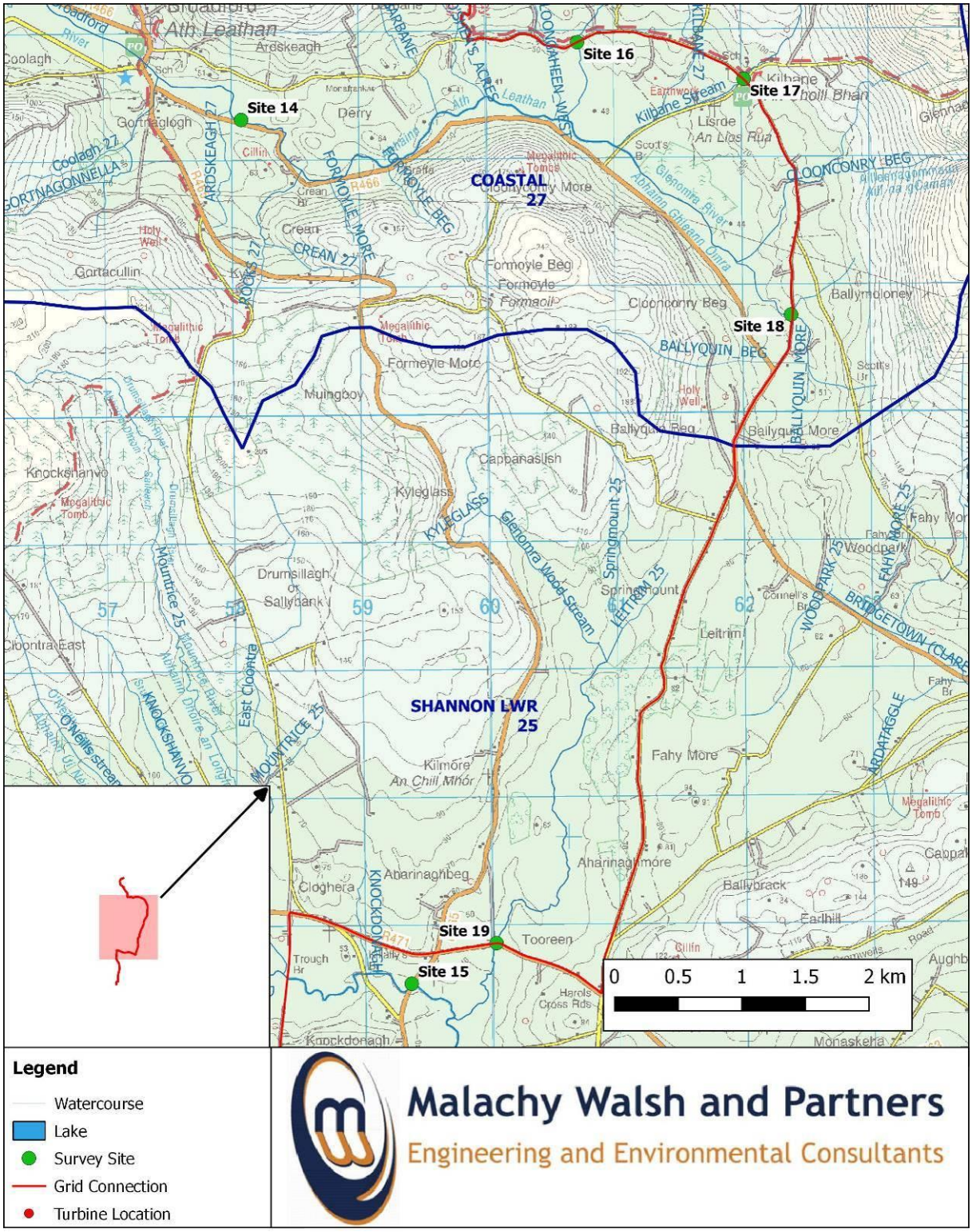

Figure 5: Aquatic survey sites at the southern extent of the proposed project

2.2.5 Freshwater pearl mussel

MWP applied for and were issued a licence (No. C115/2017) from NPWS to undertake freshwater pearl mussel (FPM) *Margaritifera margaritifera* survey at the study area. The survey was carried out on 1st and 2nd August. During this time, water levels were low, sunshine dominated, and underwater visibility was suitable for FPM detection.

Areas surveyed were within a catchment listed in the NPWS *Margaritifera* Sensitive Areas Map[4]. The Shannon - Graney / Scariff is the only such catchment potentially affected by the proposed project and occurs to the north. This catchment is identified having 'Previous records of *Margaritifera*, but current status unknown'. The Graney River and Coolreagh Beg (Annamullaghaun) River within this catchment were surveyed, downstream and upstream of O'Grady Lough respectively. The entire river sections listed in **Table 3** and illustrated in **Figure 6** were surveyed.

Surveying for FPM was carried out following the NPWS guidance '*Margaritifera margaritifera* Stage 1 and Stage 2 survey guidelines, Irish Wildlife Manuals, No. 12' (Anon, 2004). The watercourse reaches examined were subject to a presence/absence survey which involved wading in the river while viewing the substrate and looking for FPM with the aid of a bathyscope and polarised sunglasses. Instream movements were from downstream to upstream. The survey also involved checked for the presence of dead shells, particularly in depositing areas.

Plate 15: Plate Stretch of the Scariff/Graney River surveyed for freshwater pearl mussel *Margaritifera margaritifera* upstream of Scariff (left). This reach of the river has been drained. A reach of ca. 900m of this river was surveyed in the environs of the R352 Bridge (right).

The river condition and habitat features at each survey stretch were noted. The potential for FPM to occur along each stretch was assessed with reference to Conserving Natura 2000 Rivers Ecology Series No. 2 *'Ecology of the Freshwater Pearl Mussel*' (Skinner *et al.* (2003). The habitat was evaluated with reference to Environmental Quality Objectives (EQOs) as specified in Schedule 4 of the '*European Communities Environmental Objectives (Freshwater Pearl Mussel) Regulations'*, S.I. 296 of 2009 (See **Table 4**).

[4] https://www.npws.ie/maps-and-data/habitat-and-species-data

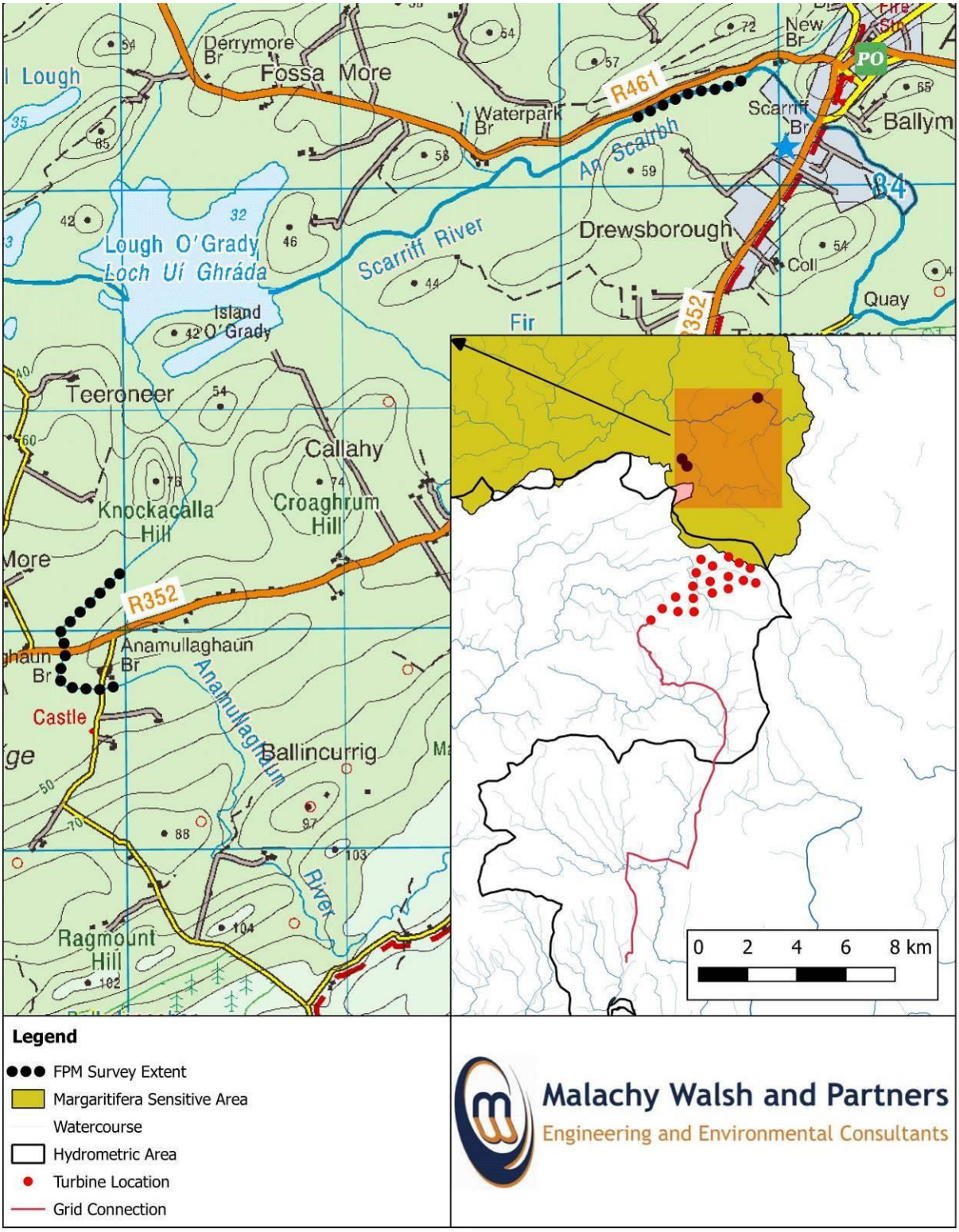

Figure 6: Stretches of watercourses examined during the freshwater pearl mussel survey in the Greaney Scariff sub-catchment during August 2018

Table 3: Watercourses reaches surveyed for FPM during August 2018.

Watercourse	Location	Survey stretch (Long, Lat)		Approx. length of channel surveyed (m)	Survey method
		Start	Finish		
Graney	Reach upstream of Scarriff, adjacent to the public park	-8.5384, 52.9103	-8.5456, 52.9087	520	Wading/ bathyscope
Coolreagh Beg (Annamullaghaun)	Environs of the R352 Bridge	-8.5810, 52.8855	-8.5802, 52.8903	900	Wading/ bathyscope

Table 4: Ecological Quality Objectives for Freshwater pearl mussel habitat.

Element	Objective	Notes
Filamentous algae (Macroalgae)	Absent or Trace (<5%)	Any filamentous algae should be wispy and ephemeral and never form mats
Phytobenthos (Diatoms)	EQR 0.93	High status
Macrophytes - Rooted higher plants	Absent or Trace (<5%)	Rooted macrophytes should be absent or rare within the mussel habitat
Siltation	No artificially elevated levels of siltation	No plumes of silt when substratum is disturbed

from S.I. No. 296 of 2009

3 RESULTS

This section provides a description of the aquatic habitats, fish and macroinvertebrates in the study area, based on the 15 survey sites examed. The watercourses draining the proposed project comprise mainly the Annacarriga River to the east and Owengarney River to the west. The grid route crosses the Broadford River and the Black River along with tributaries of these channels. The physical characteristics of the aquatic study sites have been documented and are given in **Table 5**.

3.1 FISH

3.1.1 Existing information

The Annacarriga River and its tributaries are located upstream of the hydroelectric station at Ardnacrusha. In McGinnity *et al.* (2003)[5], these waterbodies are shown on maps for the Shannon district and are classified as 'Non self-sustaining Salmon' watercourses. According to McGinnity *et al.* (2003), the watercourses in the Owengarney and Blackwater catchments are producers of Salmon and Sea Trout. Atlantic salmon are listed under Annex II of the EU Habitats Directive.

As part of fish samping for the National Research Survey Programme, Inland Fisheries Ireland (IFI) surveyed six sites in the Graney catchment in September 2016 (Kelly *et al.* 2017a)[6]. One site was located on the Coolreagh Beg (Anamullaghaun) River at Anamullaghaun Bridge. Two locations were surveyed on the Scariff/Graney River. Seven fish species were recorded in the Scariff River: Brown trout *Salmo trutta,* European eel *Anguilla anguilla*, Gudgeon *Gobio gobio*, Perch *Perca fluvialitis*,

[5] https://www.fisheriesireland.ie/salmon-management-sp-942452909/quantification-of-the-freshwater-salmon-habitat-asset-in-ireland/file.html

[6] http://wfdfish.ie/wp-content/uploads/2017/11/Rivers-Report-2016_v2.pdf

Roach *Rutilus rutilus*, Stone loach *Barbatula barbatula* and Three-spined stickleback *Gasterosteus aculeatus*.

Table 5: Physical characteristics of the study sites.

Site	Watercourse	Physical characteristic																
		Wetted Width (m)	Mn Depth (cm)	Mx Depth (cm)	Rock (%)	Cobble (%)	Gravel (%)	Fine (%)	Riffle (%)	Glide (%)	Pool (%)	Instream vegetation* (%)	Bank Height (cm)	Bank slope (°)	Bank cover (%)	Shade (%)	Silt	Algae
1	Owengarney	3.5	20	70	30	40	20	10	60	35	5	0	40	40	85	80	light	not excessive
2	Owengarney	4.5	15	55	10	65	20	5	40	30	30	0	35	90	85	80	light	not excessive
3	Owengarney	2.6	15	50	15	20	65	10	60	30	10	10	70	90	90	50	light	not excessive
4	Coumnagun	2.9	20	60	10	60	25	5	50	25	25	15	100	45	80	85	light	not excessive
5	Coumnagun	1.8	10	30	25	35	35	5	65	25	10	20	70	70	95	10	free	none apparent
6	Killokennedy	0.9	10	25	15	55	25	5	60	20	20	20	30	60	90	50	free	none apparent
7	Killuran	3	15	50	20	50	25	5	60	30	10	5	100	50	95	15	light	luxuriant[1]
8	Killuran	1.2	15	45	40	30	15	5	40	20	40	10	50	90	85	60	considerable	not excessive
9	Killuran More	1.2	15	25	25	50	25	25	45	30	25	5	25	75	80	90	light	not excessive
10	Annacarriga	3	20	50	20	45	20	15	50	40	10	5	30	45	95	85	light	not excessive
11	Carrownakilly	1.5	10	45	80	20	5	5	60	5	35	0	20	45	80	75	light	none apparent
12	Carrownakilly	0.9	10	20	25	30	25	20	30	30	30	0	50	35	90	90	light	none apparent
13	Un-named	3	25	55	10	40	40	10	10	85	5	0	120	80	95	5	considerable	none apparent
14	Broadford	4.5	25	60	10	50	35	15	40	40	20	5	150	60	95	80	considerable	luxuriant
15	Blackwater	4	20	80	5	50	30	15	30	40	30	5	100	75	75	70	considerable	not excessive
16	Cloongaheen East	1.1	10	25	55	30	10	5	85	5	10	0	85	45	85	100	no silt	none apparent
17	Kilbane Stream	2.5	15	40	20	10	55	15	80	10	10	0	200	75	95	80	no silt	none apparent
18	Broadford	1.2	10	30	5	15	65	15	40	30	30	15	25	30	85	90	light	none apparent
19	Glenomra Wood Stream	2.6	25	40	25	40	25	10	75	20	5	0	65	90	90	50	light	none apparent

* instream vegetation related primarily to bryophytes

[1]when examined in August, not excessive in September

A total of eight fish species and one type of hybrid were recorded on Lough Derg in June 2016 (Kelly *et al.* 2017b)[7]. Roach was the most common fish species recorded, followed by perch, roach x bream hybrids, Brown trout, pike, eel, bream, pollan, and tench. During the previous surveys in 2009 and 2012 the same species composition was recorded, with the exception of pollan, which were not captured in the 2009 survey and tench, which were not captured in 2012.

Two sites were electric fished on the Broadford River as part of the Water Framework Directive (WFD) surveillance monitoring programme in rivers 2013 (Kelly *et al.* 2014)[8]; these sites were located ca. 600m upstream of Doon Lough and at Broadford village. Six fish species were recorded in the Broadford River (Doon Lough) site. Gudgeon was the most abundant species recorded, followed by salmon *Salmo salar*, perch, Brown trout, three-spined stickleback and minnow. Salmon captured during the 2013 survey ranged in length from 8.6cm to 12.1cm (mean = 10.6cm) - only one age class (1+) was present. Salmon captured during the 2009 survey ranged in length from 5.1cm to 12.6cm (mean = 8.6cm). Two age classes were present (0+ and 1+), accounting for 55% and 45% of the salmon catch respectively. Three fish species were recorded in Broadford River (Broadford Village) site during the 2013 survey. Brown trout was the most abundant species recorded, followed by salmon and European eel. Salmon captured during the 2013 survey ranged in length from 4.1cm to 11.2cm (mean = 8.0cm). Two age classes (0+ and 1+) were present, accounting for 39% and 61% of the total salmon catch respectively.

3.1.2 Fish habitats

The watercourses in the study area are generally fast flowing of spate nature i.e fast repsonse to rainfall. They are categorised as eroding/upland rivers with reference to Fossitt (2000). The watercourses draining the proposed project are typically medium-high gradient channels over siliceous geology. The watercourses within the site boundary are elevated and drain predominantly peaty soils.

Due to the elevation of the proposed wind farm site, and its location in the environs of the Ownegarney watershed, the watercourses within the site are no larger than 2nd order. The reach of the Owengarney within the site is considered large for a 2nd order stream however, with a wetted width of ca. 4.5m at Site 2. Drainage associated with afforestation and commercial forestry in the catchments may be affecting the flow regime of the study watercourses. For example, low flows during the summer could have been exacerbated by drainage of peat habitats, where potential water reserves in peat are released faster than natural processes by lowering the water table. The development of large area of commercial forestry can also limit precipitation reaching the soil and therefore reduce surface water flow.

Table 6 gives the habitat rating of the watercourses examined with reference to salmonid habitats. The stream substrates comprise mainly of cobble and gravel with little/no silt deposits. Bedrock is the main component of the streambed along some high gradient reaches (e.g. the Killuran Stream upstream of Site 7 and the Annacarriga River downstream of Site 11). The subject watercourses are generally characterised by riffle-glide-pool sequences. They are generally shallow with a mean summer s depth of 15cm-20cm.

[7] http://wfdfish.ie/wp-content/uploads/2017/10/Derg_2016-1.pdf
[8] http://wfdfish.ie/wp-content/uploads/2013/08/SHIRBD_rivers_report_2013.pdf

Within the streams surveyed, a relatively small proportion of the riverine habitat was classified as suitable for salmonid spawning. Such habitats are the transitional area between pool and riffle where flow was accelerating and depth decreasing over gravel beds. These areas typically occur at the end of pools, for example at Site 4 on the Coumnagun Stream which flows through the proposed wind farm site.

Table 6: Habitat rating at the sites examined on watercourses potentially affected by the proposed project.

Sub-catchment	Site	Watercourse	Spawning		Nursery		Holding	
			Habitat grade[1]	fluvial cover[2] (≈%)	Habitat grade[1]	fluvial cover[2] (≈%)	Habitat grade[1]	fluvial cover[2] (≈%)
Owengarney	1	Owengarney	2	15	1	70	2-3	15
	2	Owengarney	1	15	1-2	85	2-3	15
	3	Owengarney	2	20	1	80	3-4	10
	4	Coumnagun	1	15	1-2	75	3	10
	5	Coumnagun	2-3	25	1	80	4	5
	6	Killokennedy	4	5	3-4	50	0	n/a
	7	Killuran	2-3	10	2-3	80	3	10
	8	Killuran	3	10	1-2	90	4	10
	9	Killuran More	3	15	2	60	0	n/a
	14	Broadford	2	15	1-2	85	3	15
	16	Cloongaheen East	3	10	3	20	4	10
	17	Kilbane Stream	2-3	15	2	60	3-4	25
	18	Broadford	2-3	20	2-3	45	3-4	30
	19	Glenomra Wood Stream	1-2	15	2	50	3	20
Annacarriga	10	Annacarriga	1	20	1-2	85	3	20
	11	Carrownakilly	2	5	1-2	75	3-4	10
	12	Carrownakilly	4	5	2	20	4	5
	13	Un-named	2-3	25	2-3	50	0	n/a
	15	Blackwater	1	10	1-2	60	2-3	25

Following DCAL's advisory leaflet '*The Evaluation of habitat for Salmon and Trout*'

[1] *Grade 1 is optimal habitat and habitat quality reduces with increases in Grade (Grade 4 = poor)*

[2] *Fluvial cover relates to river substrate under water and available to fish*

The abundance of riffle (broken water), instream rocks and overhanging banks and dappled shade, or combinations thereof, provide good salmonid nursery habitat in the watercourses surveyed. Based on the habitats present at the sites surveyed, as well as favourable water quality, the watercourses draining the site are considered optimal for the early life stages of salmonids. At Site 2 on the Owengarney River for example, heterogenous fluvial habitat provides ideal rearing conditions for salmonids. At Site 11 on the Coumnagun Stream, ideal substrate conditions for the early life stages of salmonids were apparent. Substrate siltation was noted however at some locations, for example at Site 7 on the on the Killuran Stream during August. Silt clogs the interstices at the surface of the riverbed. This can prevent or disrupt alevin emergence and reduce the fitness of the fry and

parr, and hence their ability to cope with the natural pressures faced within the riverine environment.

Some of streams within the proposed project site are considered to be used as trout spawning and nursery areas but are of limited value due to small size and steep gradient. For example, the Killokennedy Stream within the site, a tributary of the Owengarney River, is considered prone to drying out during long dry spells. This watercourse is a marginal habitat for trout.

Despite the agility and persistence of Salmon in leaping obstacles, falls and rapids on certain reaches of watercourses are considered barriers for upstream migrating Salmon, and perhaps European eel also. Other barriers to migration include bridge aprons and perched culverts. For instance, there are two perched pipes on the Killuran Stream under the existing internal track at Site 8, and a perched bridge foundation on the crossing the Coumnagun Stream at Site 4, both of these locations within the proposed wind farm site. Most of the roadways within the proposed wind farm site feature culverts that are perched in some fashion or other at their downstream end. Downstream of the site, a bridge plinth on the Killuran Stream at Site 7 represents an upstream migration barrier for some species including lamprey and perhaps European eel.

Plate 16: Bridge plinth on the Killuran Stream at Site 7 represents an upstream migration barrier for some species including lamprey and perhaps European eel (left). Waterfall on the Killuran River upstream of Site 7 (right). Sudden river profile changes such as this limit upstream migration of fish into the proposed project site.

Fish were not detected in some stream reaches above significant falls, so some upper reaches of watercourses within and downstream of the proposed wind farm site are considered not utilised by fish. No fish were recorded upstream of a waterfall on the Killuran River, upstream of Site 7 with the waterfall a lilely obstalce to upstream fish movement. Flows in watercourses within the wind farm site may be insufficient to draw adult fish into these stretches, or to provide plunge pools of sufficient depth beneath obstacles to allow adult salmon to pass. The maximum depth of the watercourses at the study sites ranged from 20cm to 80cm (based on low/normal) flow.

All watercourses in the study area have the potential to support European eel. Suitable habitat for this species occurs in the smallest of watercourses affected by the proposed development, namely rocky substrates.

The only location where suitable juvenile lamprey habitat was recorded was in the Blackwater and Broadford Rivers. The fast-flowing high gradient nature of watercourses in the study area provides unsuitable conditions for lamprey larvae, which require soft substrates into which they can burrow.

Three-spined stickleback is likely to occur in most of the watercourses affected by the proposed development, particularly in the lower gradient reaches of these watercourses.

3.1.3 Survey Results

Electrical fishing site characteristics at aquatic survey sites examined for the proposed Carrownagowan Wind Farm are provided in **Table 7**. Salmonidae were the most frequent and widely distributed group recorded within the study area. A total of seven fish species fish species were recorded during the surveys: Brown trout (n=196); Atlantic salmon (n=70); river/brook lamprey (n=16); Three-spined stickleback (n=6); stone loach (n=5); European eel (n=3) and minnow (n=3). The lengths of the fish caught during electrical fishing can be seen in **Appendix 3. Table 8** gives length descriptive statistics for fish captured during survey. Catch Per Unit Effort (CPUE) indices for salmonids, and fish other than Salmonids are presented in **Table 9** and **Table 10** respectively. **Figure 6** illustrates the fish found at each site.

Table 7: Electrical fishing site characteristics at aquatic survey sites examined for the proposed Carrownagowan Wind Farm.

Site	Watercourse	Width fished (m)	Length fished (m)	Area fished (m^2)	Time fished (mins)	Passes
1	Owengarney	3.5	28	98	n/a[1]	3
2	Owengarney	4.5	26	117	10	1
3	Owengarney	2.6	22	57.2	5	1
4	Coumnagun	2.9	14	40.6	5	1
5	Coumnagun	1.8	26	46.8	5	1
6	Killokennedy	0.9	15	13.5	5	1
7	Killuran	3	27	81	10	1
8	Killuran	1.2	15	18	5	1
9	Killuran More	1.2	18	21.6	5	1
14	Broadford	4.5	34	153	20	1
		1[2]	1	1	n/a	1
10	Annacarriga	3	26	78	10	1
11	Carrownakilly	1.5	67	100.5	10	1
12	Carrownakilly	0.9	19	17.1		1
13	Un-named	3	34	102	5	1
15	Blackwater	4	35	140	20	1
		1[2]	1	1	n/a	1

[1] *Quantitative electrical fishing*

[2] *survey aimed at lampreys*

Juvenile salmon were recorded at the lowermost site on the Owengarney (Site 1, n=5) and in the Broadford River (Site 14, n=55), a tributary of the Owengarney. Salmon were not recorded any further upstream in the Owengarney catchment. Salmon were also present at the lowermost site in the Blackwater River (Site 15, n=7) and in the Annacarriga River (Site 10, n=3). It is noted that the Annacarriga River flows into the River Shannon upstream of Parteen Weir, while the Blackwater River flows under the headrace of Ardnacrusha Dam before joining the River Shannon at Plassey. The minimum, average and maximum length of Salmon was 5.1cm, 7.6cm and 13.1cm, respectively. **Figure 7** shows the Length - Frequency distribution of Salmon captured during the entire survey. Two

age cohorts are apparent in this young population: 0+ and 1+ fish. These represnt the juvenile fish that are the progeny of adults that spawned in these watercourses in the 2017-18 and 2016-17 winter seasons. The less frequent 1+ age class could be attributed to a number of factors including lower spawning activity in the earlier 2016-17 season but more likely predation and natural mortalities.

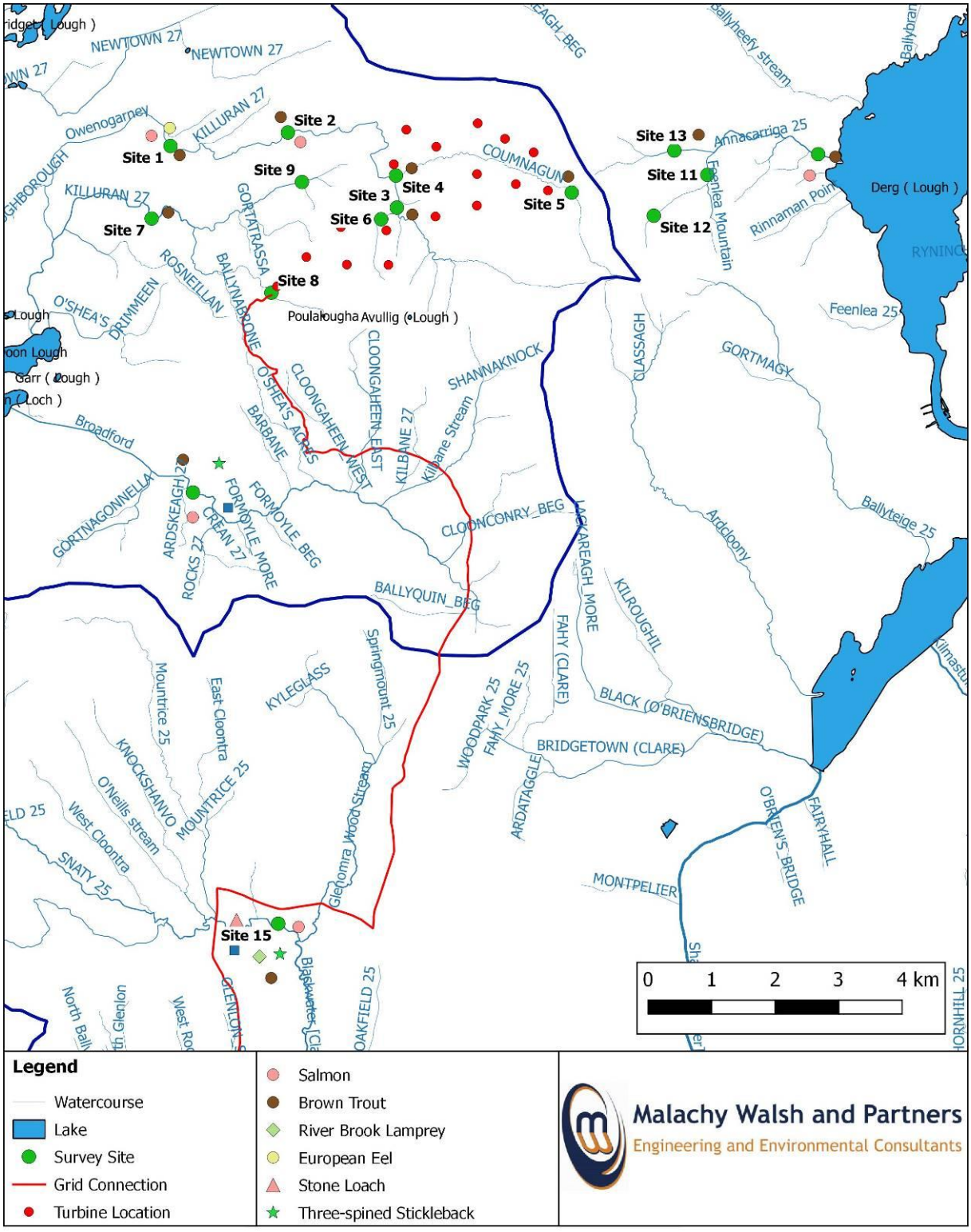

Figure 7: Fish Survey results at the aquatic sites investigated for the proposed Carrownagowan Wind Farm in September 2018.

Table 8: Length descriptive statistics for fish species captured during the 2018 electrofishing survey of watercourses draining the proposed Carrownagowan Wind Farm

Site	Watercourse	Fish Species	Scientific Name	N	Length (cm)			
					Mean	Min	Max	St. Dev.
1	Owengarney	Brown trout	*Salmo trutta*	59	9.4	5.9	15.7	3.6
		Salmon	*Salmo salar*	5	10.1	8.2	11.9	1.7
		European eel	*Anguilla anguilla*	3	27	19.3	31.5	6.7
2	Owengarney	Brown trout	*Salmo trutta*	21	9.4	6.1	19	3.8
3	Owengarney	Brown trout	*Salmo trutta*	14	8.6	6.3	14	2.8
4	Coumnagun	Brown trout	*Salmo trutta*	17	8.6	5.9	12.9	2.6
5	Coumnagun	Brown trout	*Salmo trutta*	5	10.7	8.8	16	3.1
6	Killokennedy	No fish	-	0	-	-	-	-
7	Killuran	Brown trout	*Salmo trutta*	26	11.4	6.7	19.5	3.7
8	Killuran	No fish	-	0	-	-	-	-
9	Killuran More	No fish	-	0	-	-	-	-
14	Broadford	Brown trout	*Salmo trutta*	14	9.6	5.5	15.2	3.1
		Salmon	*Salmo salar*	55	6.8	5.1	11.9	1.9
		Three-spined stickleback	*Gasterosteus aculeatus*	1	3.7	3.7	3.7	0
		minnow	*Phoxinus phoxinus*	1	4.5	4.5	4.5	0
10	Annacarriga	Brown trout	*Salmo trutta*	15	10.3	6	15	3.1
		Salmon	*Salmo salar*	3	11.7	11.1	12.4	0.7
11	Carrownakilly	No fish	-	0	-	-	-	-
12	Carrownakilly	No fish	-	0	-	-	-	-
13	Un-named	Brown trout	*Salmo trutta*	6	5.6	5.4	6.4	0.4
15	Blackwater	Brown trout	*Salmo trutta*	19	14.7	7	16.5	4.9
		Salmon	*Salmo salar*	7	10.8	6.6	13.1	2.7
		stone loach	*Barbatula barbatula*	5	7.2	6.2	8.5	1
		Three-spined stickleback	*Gasterosteus aculeatus*	5	2.6	2.1	3	0.3
		minnow	*Phoxinus phoxinus*	2	2.6	2	3.2	0.8
		Brook Lamprey	*Lampetra planeri*	17	3.7	3.1	4.3	0.6

The most common fish in the study area is Brown trout. A total of 196 Brown trout were captured during the investigations. The minimum, average and maximum length of these fish was 5.4cm, 10.1cm and 24.1cm, in that order. **Figure 8** shows the Length - Frequency distribution of brown trout captured during the entire survey. Brown trout in the length range 5.5cm – 7cm are considered 0+ fish, 7.5cm - 9cm are deemed 1+ fish, while those in the 9cm – 12cm division are probably 2+ group juveniles.

Figure 9 shows the Length-Frequency distribution of brown trout captured on the Owengarney River at Site 1. **Table 11** shows the results of the depletion electrical fishing survey on the Owengarney (Site 1), which involved three passes. A depletion line for the numbers of trout captured during the quantitative electrical fishing investigation on the Owengarney River at Site 1 is illustrated in **Figure 10**. The quantitative electrical fishing carried out here indicates a brown trout pollution density of 0.6/m^2. Qualitative investigations were carried out at all other locations.

Table 9: Per Unit Effort (CPUE) indices for salmonids (family Salmonidae) captured during the 2018 electrofishing survey of watercourses draining the proposed Carrownagowan Wind Farm.

Site	Watercourse	Area fished	Time fished	Brown trout	Atlantic salmon CPUE

		(m^2)	(mins)	N	CPUE		N	CPUE	
					Fish/m^2	Fish/min		Fish/m^2	Fish/min
1	Owengarney	98	20	59	0.6	n/a	5	0.05	n/a
2	Owengarney	117	10	21	0.18	2.1	0	0	0
3	Owengarney	57.2	5	14	0.24	2.8	0	0	0
4	Coumnagun	40.6	5	17	0.42	3.4	0	0	0
5	Coumnagun	46.8	5	5	0.11	1	0	0	0
6	Killokennedy	13.5	5	0	0.00	0	0	0	0
7	Killuran	81	10	26	0.32	2.6	0	0	0
8	Killuran	18	5	0	0	0	0	0	0
9	Killuran More	21.6	5	0	0	0	0	0	0
14	Broadford	153	20	14	0.09	0.7	55	0.36	2.75
10	Annacarriga	78	10	15	0.19	1.5	3	0.04	0.3
11	Carrownakilly	100.5	10	0	0	0	0	0	0
12	Carrownakilly	17.1	5	0	0	0	0	0	0
13	Un-named	102	5	6	0.06	1.2	0	0	0
15	Blackwater	140	20	19	0.14	0.95	7	0.05	0.35

Table 10: Catch Per Unit Effort (CPUE) indices for fish other than Salmonidae captured during the 2018 electrofishing survey of watercourses draining the proposed Carrownagowan Wind Farm

Site				1	14		15	
Watercourse				Owengarney	Broadford		Blackwater	
Area fished (m^2)				98	153	1*	140	1*
Time fished (mins)				20	20	n/a	20	n/a
Petromzonidae	Brook Lamprey	N		0	0	0	0	16
		CPUE	Fish/m^2	0	0	0	0	16
			Fish/min	0	0	0	0	n/a
Gasterosteidae	Three-spined stickleback	N		0	1	0	4	1
		CPUE	Fish/m^2	0	0.01	0	0.03	1
			Fish/min	0	0.05	0	0.2	n/a
Cyprinidae	minnow	N		0	1	0	2	0
		CPUE	Fish/m^2	0	0.01	0	0.01	0
			Fish/min	0	0.05	0	0.1	0
Anguillidae	European eel	N		3	0	0	0	0
		CPUE	Fish/m^2	0.03	0	0	0	0
			Fish/min	0.15	0	0	0	0
Cobitidae	Stone Loach	N		0	0	0	5	0
		CPUE	Fish/m^2	0	0	0	0.04	0
			Fish/min	0	0	0	0.25	0

**pertains to 1m^2 examined specifically for lampreys*

Only Brown trout were recorded in the Killuran Stream at Site 7 (n=26). This watercourse is a tributary of the Owengarney River, so it is probable that Salmon movement is impeded downstream of the lower survey site on this channel. Fish were not detected at Site 8 and Site 9 on the Killuran Stream sub-catchment. These locations are within and in close proximity to the proposed development site, respectively. A steep gradient of this watercourse ca. 0.6km upstream of Site 7 identified as a potentail barrier for fish could represent the upstream limit of fish in this part of the Owengarney catchment. Brown trout were recorded at all loations within the Owengarney River usptream of Site 1, with the exception of Site 6 on the Killokennedy Stream (Site 6) within the proposed development site boundary. Brown trout were recorded at Site 10 (n=15) and Site 13 (n=6) in the Annacarriga sub-catchment. Fish were not recorded at Site 11 and Site 12. These sites are located above a series of rapids, which are considered to represent the upstream limit of fish in this

part of the Annacarriga system. **Figure 11** shows the Length - Frequency distribution of brown trout captured at Site 2. **Figure 12** and **Figure 13** show the Length - Frequency distribution of salmon captured at Site 14, and trout at Site 7, respectively.

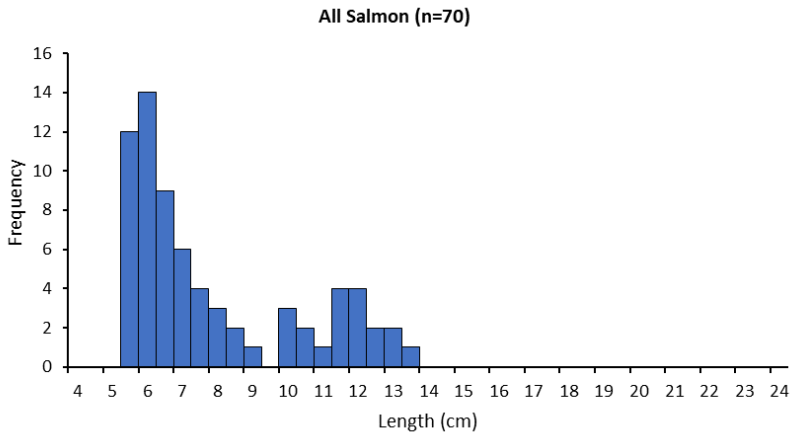

Figure 8: Length-Frequency distribution of salmon captured during the entire survey.

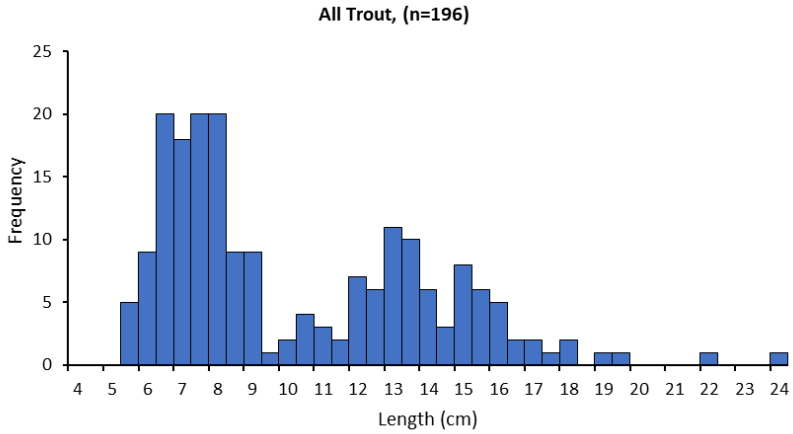

Figure 9: Length-Frequency distribution of trout captured during the entire survey.

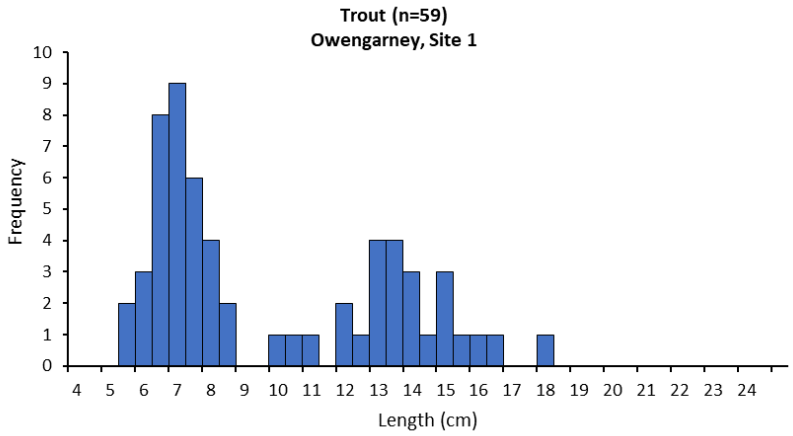

Figure 10: Length-Frequency distribution of brown trout captured on the Owengarney River - Site 1.

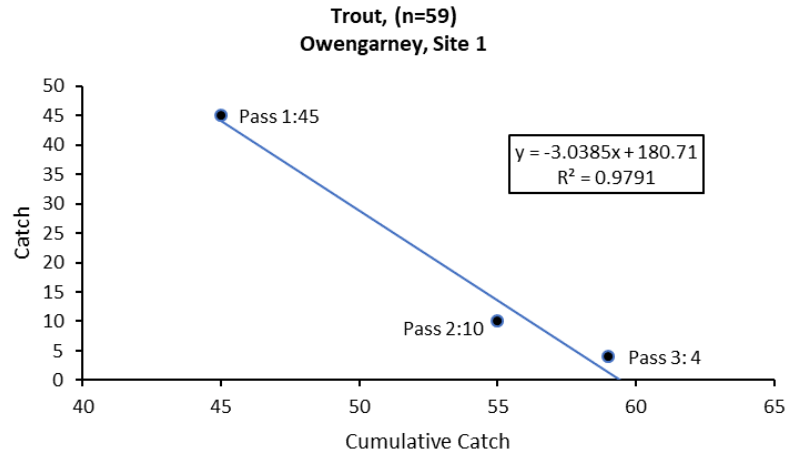

Figure 11: Depletion lines, Leslie-Davies method, for the numbers of trout captured during the quantitative electrical fishing investigation on the Owengarney River at Site 1.

Table 11: Results of the depletion electrical fishing survey on the Owengarney (Site 1).

	Trout	Salmon
Pass 1	45	5
Pass 2	10	0
Pass 3	4	0
Total	59	5

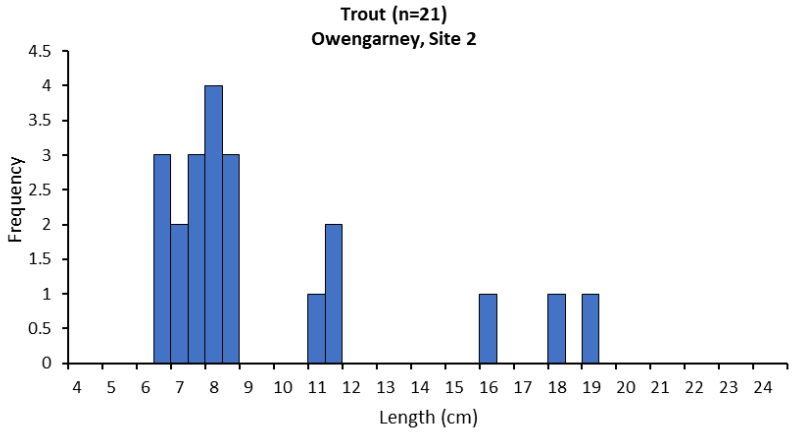

Figure 12: Length-Frequency distribution of brown trout captured on the Owengarney River - Site 2.

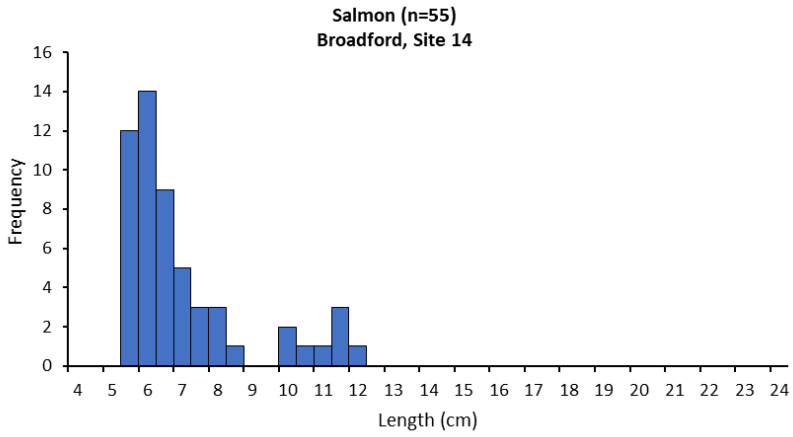

Figure 13: Length-Frequency distribution of salmon captured on the Broadford River - Site 14.

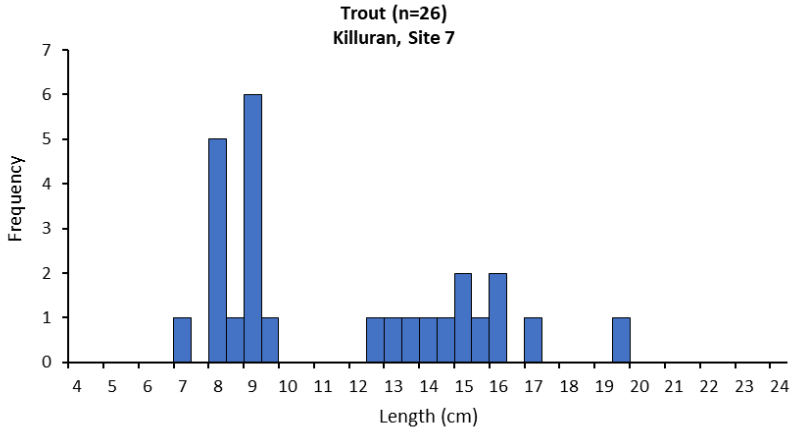

Figure 14: Length-Frequency distribution of brown trout captured on the Killuran River - Site 7.

European eel was recorded at only one location, Site 1 on the Owengarney River (n=3). These fish were found in rocky substrate in the environs of the bridge. It is noted that two of the three Eels were recorded during the 2nd pass. The minimum and maximum length of these fish was 19.3cm and 31.5cm. Three-spined stickleback were recorded in the Broadford River at Site 14 (n=1) and in the Blackwater River at Site 15 (n=5). Three-spined stickleback is one of the most widely distributed fish in the British Isles (Maitland and Campbell, 1992). Minnow were recorded in the Broadford River at Site 14 (n=1) and in the Blackwater River at Site 15 (n=2). Stone loach, a member of family Cobitidae was recorded at one location only: Site 15 on the Blackwater River (n=5). The mean length of stone loach captured during the survey was 7.2cm.

An area of $1m^2$ was surveyed for lampreys in the Blackwater River at Site 15 and in the Broadford River at Site 14. Lampreys were not detected in the Broadford River. A total of 16 Brook / River Lampreys were recorded in the Blackwater River. This included one Brook Lamprey *Lampetra planeri* transformer. **Figure 14** shows the Length - Frequency distribution of Brook Lamprey captured on the Blackwater River at Site 15. The variety of age groups indicates ongoing recruitment in this reach of the river. Brook lampreys were recorded in the Blackwater River only. It is considered that if lampreys occur in other watercourses in the study area, densities are low.

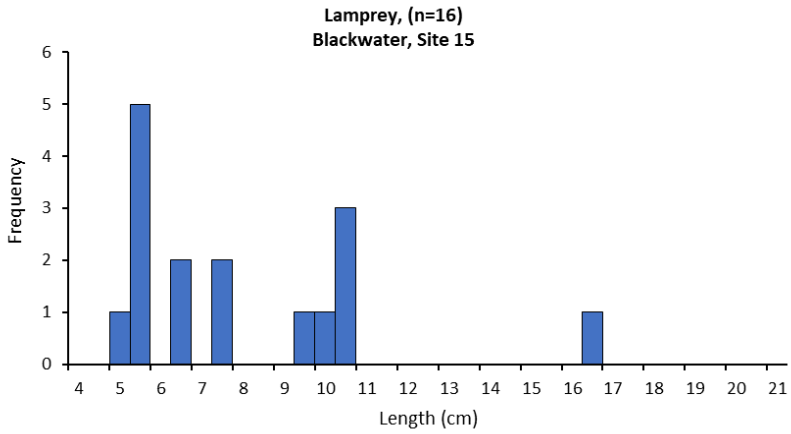

Figure 15: Length - Frequency distribution of brook lamprey captured on the Blackwater River - Site 15.

Plate 17: Juvenile salmonids captured at Site 1 on the Owengarney River (left). Juvenile salmon (bottom) can normally be distinguished from young Brown trout by the more streamlined shape, deeply forked tail, longer pectoral fin, lack of orange on adipose fin, smaller mouth, sharper snout, only 1-4 spots on gill cover (often one large spot), well defined parr marks[9]. Salmon from two different age cohorts captured during electrical fishing at Site 10 on the Annacarriga River (right).

Plate 18: Brown trout captured during the survey at Site 15 on the Blackwater River (right). Brown trout recovering from anaesthetic in a the Coumnagun River at Site 5 (right).

[9] http://www.atlanticsalmontrust.org/salmon-and-trout-recognition/

Plate 19: European eel in the Owengarney River at Site 1. European eel is listed as 'Critically endangered' and is now 'Red Listed'. Stone loach *Barbatula barbatula* occur in the Blackwater River.

Plate 20: Three-spined stickleback *Gasterosteus aculeatus* were found in the Blackwater and Broadford Rivers (left). Three-spined stickleback is likely to occur in most of the watercourses affected by the proposed development. Minnow *Phoxinus phoxinus* were recorded in the Blackwater and Broadford Rivers during August 2018 (right).

Plate 21: Juvenile lamprey are blind and are also known as larvae or ammocoetes Multiple age cohorts indicate ongoing recruitment. The largest lamprey (transformer) was undergoing metamorphosis to adulthood (left). Juvenile lamprey released to the Black River following identification. Deposited sand/silt is a suitable habitat for juvenile lampreys (right).

3.2 MACROINVERTEBRATES

This section provides information on aquatic macro-invertebrates other than freshwater pearl mussel (FPM). FPM is discussed in Section 3.3.

3.2.1 Existing information

The proposed development and the watercourses examined during the current assessment occur largely in the 10km grid squares R57, R58 an R67. National Biodiversity Data Centre (NBDC) records indicate the presence of numerous groups of aquatic insects in this area. Water beetles (Coeloptera) previously recorded include *Agabus affinis, A. Bipustulatus, Hydrobius fuscipes, H. Inaequalis, Ilybius fuliginosus, I. ater* as well as *Hydroporus scalesianus* and *Donacia marginata*, listed as near threatened in Foster *et al,* (2009). Aquatic Molluscan records in the study area include *Lymnaea stagnalis, Sphaerium corneum, Potamopyrgus antipodarum, Valvata piscinalis* and the highly invasive Zebra Mussel *Dreissena polymorpha*.

Dragonflies known to occur comprise species such as *Coenagrion puella, Calopteryx splendens, Ischnura elegans, Aeshna grandis, Sympetrum striolatum* and *Pyrrhosoma nymphula.* Aquatic Bugs (Heteroptera) recorded include *Gerris lacustris, Notonecta glauca, Aphelocheirus aestivalis, Hydrometra stagnorum* and *Nepa cinerea*. The habitats of these Odonates and Hemipterans are slow flowing waterbodes and lakes.

Caddisfly (Trichoptera) records are diverse with records including the cased *Limnephilus marmoratus, L. lunatus, L. stigma, Agrypnia varia, A. obsoleta and Holocentropus picicornis,* along with caseless *Plectrocnemia conspersa*, *Polycentropus irroratus, P. kingi* and *Tinodes waeneri.* Mayfly records in the study area are *Baetis rhodani, Caenis horaria, C. luctuosa, Centroptilum luteolum, Serratella ignita* and *Ephemera danica.* There are a variety of Stoneflies (Plecoptera) in the study area. These include *Protonemura meyeri, Amphinemura sulcicollis, Brachyptera risi, Dinocras cephalotes, Perla bipunctata, Leuctra hippopus* and *L. fusca.* An abudanec of True flies have been documented including mostly Chironomidae (e.g. *Chironomus tentans, Sericomyia silentis*) and Hoverflies (Syrphidae).

Crustacean diversity in the study area is low, with a record of *Asellus aquaticus* and *Niphargus kochianus* subsp*. Irlandicus* in R57 and R58 respectively. *Crangonyx pseudogracilis* and *Hemimysis anomala* have been found in R67, the latter an invasive shrimp-like Mysid, native to the Ponto-Caspian region, which has been spreading across Europe since the 1950s. There are no records of White-clawed Crayfish *Austropotamobius pallipes* in the study area. The current distribution and range of this species is given in NPWS (2013), which excludes the four 10km grid squares encompassing/surrounding the proposed development (i.e. R57, R58, R67 and R68). In most of its range, White-clawed Crayfish is found most commonly in first-order streams, but in Ireland it has a much wider habitat range occurring in small and medium-sized lakes, large rivers, streams and drains wherever there is sufficient lime (Lucey and McGarrigle 1987). White-clawed Crayfish has been recorded in the River Shannon at Plassey, Limerick but abundance is low (record by G Hayes, MWP). This species is not expected to occur in the other watercourses draining the proposed development, considering the siliceous underlying geology.

3.2.2 Macroinvertebrate habitats

The physical habitat suitability assessment of the survey sites for macroinvertebrate production is provided in **Table 12.** Based on the physical attributes of the study site and assessment criteria, the sites are generally rated suboptimal. This rating was applied to all the sites in the Owengarney catchment (save Site 6) and the sites on smaller watercourse in the Annacarriga catchment (Site 12 and 13). This was due to the domination of substrates by one size class (rock/cobble) owing to their high gradient, suboptimal habitat complexity, coupled with mainly marginal pool quality (<1m deep) and canopy conditions (usually heavily shaded). Site 6 was rated marginal primarily due to stream size. Habitat for macroinvertebrate production was rated optimal at the sites on the Annacarriga River (Site 10), Carrownakilly Stream (Site 11), Broadford River (Site 14) and Blackwater River (Site 15). The variety of flow features and bottom substrates at these locations, along with generally dappled shade and bank characteristics provide various ecological niches for infauna.

Table 12: Physical habitat assessment of the survey sites regards suitability for macroinvertebrate production (adapted from Barbour and Stribling, 1991).

Sub-catchment	Site	Watercourse	Bottom substrate	Habitat complexity	Pool quality	Bank stability	Bank protection	Canopy	Score	Overall Assessment[1]
Owengarney	1	Owengarney	15	15	10	15	20	15	90	suboptimal
	2	Owengarney	15	15	5	20	20	15	90	suboptimal
	3	Owengarney	15	15	5	15	15	20	85	suboptimal
	4	Coumnagun	15	15	10	15	15	10	80	suboptimal
	5	Coumnagun	20	15	5	20	15	10	85	suboptimal
	6	Killokennedy	10	10	5	15	15	5	60	marginal
	7	Killuran	15	10	10	15	15	10	75	suboptimal
	8	Killuran	15	15	5	15	15	5	70	suboptimal
	9	Killuran More	15	10	5	20	15	5	70	suboptimal
	14	Broadford	20	15	20	20	15	15	105	optimal
	16	Cloongaheen East	15	5	0	10	15	10	55	suboptimal
	17	Kilbane Stream	15	15	5	15	10	10	70	suboptimal
	18	Broadford	10	15	5	10	10	10	60	suboptimal
	19	Glenomra Wood Stream	20	15	10	15	15	10	85	suboptimal
Annacarriga	10	Annacarriga	20	20	15	20	20	20	115	optimal
	11	Carrownakilly	15	20	15	20	20	15	105	optimal
	12	Carrownakilly	10	15	5	20	15	10	75	suboptimal
	13	Un-named	15	15	5	15	15	10	75	suboptimal
	15	Blackwater	20	20	20	15	15	20	110	optimal

[1] *scale: poor - marginal – suboptimal - optimal*

3.2.3 Macroinvertebrate diversity and abundance

The macroinvertebrate communities recorded at study sites comprised a wide range of macroinvertebrate taxa. The major groups including *Ephemeroptera*, *Plecoptera* and *Trichoptera*

were well represented at most locations (larval stage). The results of the macroinvertebrate surveys are presented in **Table 13**, where a species list of macroinvertebrates recorded at each survey location has been given.

The mayfly assemblage was dominated by *Baetis rhodani* which is classified as a pollution tolerant (Group C) indicator by the EPA. The larger watercourses/ those at lower elevations generally supported several other mayfly species, namely *Heptagenia sulphurea, Rhithrogena semicolorata*, *Ecdyonurus* sp. and *Seratella ignita*. These species ranged from 'present' to 'fair numbers' at site where they occurred. These taxa are all classified as pollution sensitive (Group A) by the EPA, with the exception of *S. ignita* (Group C).

A wide range of stonefly larvae were recorded, including pollution sensitive larvae of *Isoperla grammatica* which was absent or scarce at the sites in the Owengarney sub-catchment, but more widespread and abundant in the Annacarriga sub-catchment (e.g. 'common' at Site 13). Larvae of *Perla bipunctata* (Sites 1, 2 and 15)*, Dinocras cephalotes* (Sites 3, 5, 10, 11 and 13) and *Chloroperla (Siphonoperla) torrentium* were generally scarce. Larvae of the brown stoneflies *Protonemura sp.* were mainly found in 'fair numbers' at sites in the Owengarney sub-catchment but less widespread in the Annacarriga sub-catchment. *Nemoura* sp. were scarce at Sites 6 and 9. Larvae of 'less sensitive' *Leuctra* sp. generally occurred in 'small numbers' at locations other than Sites 4, 6 and 9.

The Trichopterans were well a represented group with seven cased (Group B) taxa and four caseless (Group C) taxa recorded. Cased caddisfly larvae had patchy distribution and generally 'scarce' to 'fair numbers' in relative abundance. The other cased caddisfly larvae recorded were *Agapetus fuscipes Athripsodes* sp., *Glossosoma* sp., *Odontocerum albicorne, Sericostoma personatum* and the Goeridae. The most prevalent caseless caddisflies were *Hydropsyche* sp. (generally 'small numbers') and *Polycentropus* sp. (generally 'scarce'). Philopomatidae and *Rhyacophila dorsalis* were also recorded within the study area.

Dipteran larvae accounted for a significant proportion of the macroinvertebrate community at the study sites. The most common true fly larvae were pollution tolerant Simulidae ('present' to 'common') and green chironomids ('scarce' to 'fair numbers').

Beetles in six different families were recorded: Dytiscidae, Elmidae, Haliplidae, Hydraenidae, Gyrinidae and Helodidae. The most common beetles were *Elmis* sp. (generally 'fair numbers') and *Hydraena* sp. (generally 'small numbers') these small animals adapted to living in fast water and instream moss, as well as Helodidae (generally 'small numbers').

The crustacean *Gammarus deubeni* was the sole member of Order Crustacea recorded during the current study. This species was widespread but its relative abundance was 'scarce'. The only molluscs recorded were *Ancylus fluviatilis* (Sites 3, 13 and 15) and *Lymnaea peregra* (Sites 14 and 15).

Table 13: Macroinvertebrates recorded during biological sampling on watercourses draining the proposed Carrownagowan Wind Farm development during August 2018. Note: **PSG** = Pollution Sensitivity Group.

Taxa/Species	PSG	Site																	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
MAYFLIES (Uniramia, Ephemeroptera)																				
Family Heptagenidae																				
Autumn dun *Ecdyonurus* sp.	A	***	***		****	***		****									****	**		**
Yellow may dun *Heptagenia sulphurea*	A	****	**	***							****	****		**		*	*			***
Rhithrogena semicolorata	A	****	****		**											****	****	*		*
Spiny crawler mayflies (Seratellidae)																				
Blue-winged olive *Seratella ignita*	C	*	**	**	**	**		**			**				**					
Baetidae																				
Large dark olive *Baetis rhodani*	C	******	******	*******	******	******		******	******	******	******	******	*****	******	*****	******	*****	******	*******	*****
STONEFLIES (Order Plecoptera)																				
Perlodid stoneflies (Perlodidae)																				
Common yellow sally *Isoperla grammatica*	A	**	**			**					*	**	****	*****		****				*
Golden stoneflies (Perlidae)																				
Large pale stonefly *Perla bipunctata*	A	*	*													*				
Dinocras cephalotes	A			**		*					*	****		**				*		
Brown stoneflies (Nemouridae)																				
Protonemura sp.	A	**	******	***	***	***	****	**	****	***	****	**			**			*****		*

Taxa/Species	PSG	Site																	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Nemoura sp.	A						**			**								**		
Little yellows and little greens (Chloroperlidae)																				
Chloroperla torrentium	A				*	**						*		****		***		****		**
Needleflies (Leuctridae)																				
Leuctra sp.	B	**	**	***		****		**	**** *		****	***	****	***	****	****	**	**	*	*
CASED CADDIS FLIES (Tricoptera)																				
Northern caddisflies (Limnephilidae)	B	**	**	**	**	*			**	**	**	***		****		****				*
Long horned caddisflies (Leptoceridae)																				
Athripsodes sp.	B						***													
Glossosomatidae																				
Little black caddisfly *Agapetus fuscipes*	B										**			*						
Little black short- horned sedge *Glossosoma* sp.	B										*									
Primitive caddisflies (Sericostomatidae)																				
Black caperer *Sericostoma personatum*	B		*			*					*	**		*	**	**	*		*	*
Odontoceridae																				
Odontocerum albicorne	B			**				*				*			****			*		*
Family Goeridae	B	*	**	***	***			***						*						*
CASELESS CADDIS FLIES (Trichoptera)																				

Taxa/Species	PSG	Site																	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Grey flags (Hydropsychidae)																				
Hydropsyche sp.	C	***	****		****			*	**	**	*	**	*	***		***		**		*
Finger-net caddisflies (Philopomatidae)	C	*		***	**					*		*	****	***				**		
Green sedges (Rhyacophilidae)																				
The sandfly *Rhyacophila dorsalis*	C	*	*	*	*			*			*	**		**		*				
Trumpet-net caddisflies (Polycentropodidae)																				
Polycentropus sp.	C	**				*		*	**	**		**	**	***	**	***				
TRUE FLIES (Diptera)																				
Blackfly (Simulidae)																				
Simulium sp.	C	***	****	***	****	**** **		***	**** *	**** *	**** *	*	****	**	****	***	****	****	***	***
Craneflies (Tipulidae)	C																			
Tipula sp.						*	**													
Dicranota sp.	C		*	*		*	**	*	*		*			*		*			*	
Solitary Midges (Thaumaleidae)	C	***	**				****		**	**										
Family Chironomidae																				
Bloodworm *Chironomous sp*.	E			**				**						*						
Green chironomid	C		**	*	**			**	***	***	****	*			***	**		*	***	**
House/Stable flies (Muscidae)																				
Limnophora sp.	C										*									
Biting Midge (Ceratopogonidae)	C													*		**				
Dixidae	C				*	**						*		***		*				

Taxa/Species	PSG	Site																	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
BEETLES (Coleoptera)																				
Whirligig beetle larvae (Gyrinidae)	C																			
Whirligig beetle *Gyrinus substriatus*	C															*				
Diving beetles (Dytiscidae)				*	**	**										**				
Sub family Colymbetinae	C				*	*						***			*					
Crawling water beetles (Haliplidae)																				
Brychius elevatus	C				*											***				
Riffle Beetle (Elmidae)																				
Elmis sp.	C	*	****	**	****	***		****	****		***	**** *		****	**	****				
Limnius sp.	C	*													*					
Minute moss beetles (Hydraenidae)																				
Hydraena sp.	C	**	**	**	***		**	*	****		*	***		***	*	****				****
Marsh beetles (Helodidae)	C			*	*	**	***	*	****	***	*	*	*	*			*		**	
SNAILS (Mollusca, Gastropoda)																				
Family Lymnaeidae																				
Wandering snail *Lymnaea peregra*	D														*	*			*	
Family Ancylidae																				
River limpet *Ancylus fluviatilis*	C			*										*		***				
CRUSTACEANS (Crustacea)																				
Amphipods (Gammaridae)																				
Freshwater shrimp	C	*	**	**	**	**	****	**	**	****	****	*	****	*	***	****	*	*	****	**

Taxa/Species	PSG	Site																	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Gammarus duebeni							*			*						*				
LEECHES (Hirudinae)																				
Erpobdellidae																				
Erpobdella sp.	D														*					*
Piscicolidae																				
Piscicola geometra	C														*	*				
BUGS (Hemiptera)																				
Broad shouldered water striders (Veliidae)																				
Velia sp.	C				*	*			**							*				
Broad shouldered water skaters (Gerridae)																				
Gerris sp.	C				**						*					**				
Water Measurer (Hydrometridae)	C								*							**				

**Present (1 or 2 individuals), **Scarce/Few (<1%), ***Small Numbers (<5%), ****Fair Numbers (5-10%), *****Common (10-20%), ******Numerous (25-50%), *******Dominant (50-75%), ********Excessive (>75%).*

Plate 22: Larva of the Ephemeroptera / mayfly *Ecdyonurus* sp. and *Rhithrogena semicolorata* recorded at Site 1 on the Owengarney River (left). Larvae of the Larva of the pollution sensitive Plecoptera / stonefly *Dinocras cephalotes* recorded at Site 4 on the Coumnagun Stream (centre). This species is classified as a Group A pollution sensitive indicator by the EPA. Caseless Trichoptera / caddisfly larvae of Philopotamidae, Rhyacophilidae, Hydropsychidae and Polycentropodidae recorded in the study area (right).

3.3 WATER QUALITY

3.3.1 Existing information

The EPA carries out biological monitoring at various locations on the watercourses draining the propose development. The most recent EPA biological water quality results at EPA biological monitoring stations in the study areas of the Owengarney, Broadford and Blackwater (Clare) River catchments can been seen in **Table 14**.

During the most recent (2016) assessment, Good or high ecological quality was recorded at all Owengarney sites in 2016, with no change compared with 2013[10]. In the Broadford River, Station 0500 (Scott's Bridge) continued to be of Poor ecological quality. This river continued satisfactory at the lower two sites, but with a deterioration from high to good ecological quality at Station 0600 (near Graffa Bridge). There has been no EPA biological assessment of the Killuran River (27K01) since 1991. The Annacarriga River has not been biologically assessed by the EPA since 1998 when it was rated Q4-5 at the first Bridge u/s Lough Derg (RS25A050100). During the most recent (2017) assessment of the Blackwater River, station 0120 improved slightly to High ecological conditions while, good ecological conditions remained at station 0250[11]. Based on the August 2017 assessment, the EPA noted that the Glenomra Wood Stream improved to high ecological conditions.

Table 14: Most recent EPA biological quality ratings (Q-values) for stations on the upper Owengarney (27O01), Broadford (27B02) and Blackwater (25B06) River catchments.

River	Station code	Station name	2013	2014	2016	2017
Owengarney	RS27O010100	Br u/s Ballymacdonnell Br	4-5	-	4-5	-
	RS27O010300	Bridge u/s Doon Lough	4-5	-	4-5	-
	RS27O010600	Agouleen Bridge	4-5	-	4-5	-
Broadford	RS27B020500	Scott's Bridge	2-3	-	3	-
	RS27B020600	Near Graffa Bridge	4-5	-	4	-
	RS27B020800	Bridge u/s Doon Lough	4-5	-	4-5	-
Blackwater	RS25B060120	Br d/s Killaly's Br	-	4*	-	4-5
	RS25B060250	Br SW of Mt St Catherine	-	4	-	4
Glenomra Wood Stream	RS25G120100	Br u/s Blackwater R confl	-	4	-	4-5

**siltation*

3.3.2 Current Survey Results

3.3.2.1 Biological water quality

The current survey results indicate that biological water quality in the watercourses draining the proposed development is generally very good. The watercourses provide water of a quality adequate to support a range of pollution sensitive mayfly and stonefly larvae, as well as salmonids. The Q-ratings, BMWP scores and EPT indices derived from the diversity and relative abundance of the macroinvertebrates at detailed study sites are given in **Table 15**.

[10] http://www.epa.ie/QValue/webusers/PDFS/HA27.pdf?Submit=Get+Results

[11] http://www.epa.ie/QValue/webusers/PDFS/HA25.pdf?Submit=Get+Results

With the exception of the Broadford River, biological water quality at all locations was rated either 'Unpolluted (Q4)', equivalent to Water Framework Directive (WFD) 'Good status', or Q4-5, equivalent to WFD 'High status'. Biological water quality at Site 14 on the Broadford River was rated 'Slightly polluted (Q3-4)', equivalent to WFD 'Moderate status' due the paucity of pollution sensitive taxa, as well as the degree of siltation (considerable) and algal growth (luxuriant). The macroinvertebrate taxa recorded at Site 8 on the upper Killuran Stream demanded a rating of Q3-4 but this was raised to Q4 due to habitat and stream size, in addition to the cleanliness of the substrate.

Plate 23: Underwater view of the substrate at Site 7 on the on the Killuran Stream during August 2018 (left). The settling of particles under the low flow conditions caused external colmation: this can lead to the clogging of the top layer of channel sediments. Filamentous algal growth and silt at Site 14 on the Broadford River signifies water quality problems (right).

Plate 24: Underwater view of the substrate at Site 11 on the Coumnagun Stream (left). This substrate signifies pristine water quality (left). Peat silt deposited in a drain less than 30m west of the Coumnagun Stream (right).

The generally high BMWP scores are a reflection of the good biological diversity recorded. Most sites scored >100, so biological water quality is rated 'Very good' using the BMWP water quality categories, interpreted as 'Unpolluted, unimpacted'. All sites were >5.5 for the ASPT, above which water quality is regarded as good. The EPT *(Ephemeroptera*, *Plecoptera*, *Trichoptera*) index of water quality indicates good water quality and biological stability in the watercourses assessed, ranging from 12-15 in the larger watercourses.

All feeding groups of macroinvertebrates were present at most study sites i.e. shredders, collectors, grazers and predators. This suggests that watercourses in the study area are reasonably healthy, as stream impairment may be indicated when one or more feeding groups are missing from a stream.

3.3.2.2 Physico-chemical water quality

Table 16 gives results of the on-site physico-chemical measurements at study sites. The results of the laboratory physico-chemical analysis are provided in **Table 17**. It is noted that the surveyed watercourses were in spate two-three days prior to the survey and that this is likely to have influenced the current results, especially Suspended Solids. Where a parameter was measures in both field and laboratory, the laboratory result was used in the discussion below.

Oxygenation

Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) are important water quality parameters pertaining to Oxygen. The Dissolved Oxygen (D.O.) concentration at all locations was within the range expected of good quality (Q4) with reference to Toner *et al.* (2005) i.e. DO ranging from 80 to 120%. BOD concentrations were below the Level of Detection (LOD) at most locations and corresponded to High Status with reference to the Environmental Quality Standard (EQS) in the SWR (2009) i.e. ≤1.3 mg/l (mean). COD was below the LOD at Sites 10, 11 and 12 (Annacarriga catchment) and at Site 5 (Coumangun Stream). COD at the remainder of locations varied between 10mg/l (Site 14) and 87mg/l (Site 6).

Nutrients

Concentrations of Orthophosphate (Molybdate-Reactive Phosphate, MRP) were generally low across the study area. Using this key parameter to classify water quality, only three of the fifteen locations (Site 6, Site 9 and Site 10) could not be assigned WFD 'High Status' using the EQS of ≤0.025mg/l (mean value). Orthophosphate concentration at Site 6, Site 9 and Site 10 was 0.15mg/l, 0.03mg/l and 0.04mg/l respectively. These values are within the limits for assigning a surface waterbody WFD 'Good Status' based on the ≤0.075mg/l threshold (95%ile). The level of Total Phosphorus (P) ranged from <0.04mg/l (Site 7, Site 8 and Site 11 to Site 15) to 0.19mg/l (Site 6). In the Freshwater Fish Directive [78/659/EEC], limit values of 0.062mg/l P for salmonid waters may be regarded as indicative in order to reduce eutrophication. All P values were below the level of 0.062mg/l with the exception of Site 6 on the Killokennedy Stream.

Nitrate levels were below the level of detection of 0.25mg/l at Site 1 – Site 4, Site 7 – Site 9, Site 11 and Site 12. Elsewhere, Nitrate levels ranged from 0.27mg/l (Site 6) to 1.16 (Site 14). Nitrite was below the LOD of 0.005mg/l at all locations with the exception of Site 10 (0.01mg/l). Total Ammonia concentrations were ≤0.02mg/l at all locations except Site 6 (0.22mg/l), Site 14 (0.03mg/l) and Site 15 (0.05mg/l). The concentrations at Site 6 and Site 14 are within the limits for assigning a surface waterbody WFD 'Good Status' based on mean value of ≤0.040mg/l. The value at Site 15 is below the maximum allowable concentration for assigning High Status in a river (based on mean values). Nitrate + Nitrite is referred to as Total Oxidised Nitrogen (EPA, 2013). TON levels were below the level of detection of 0.2mg/l at Site 1 – Site 4 and Site 7 – Site 9, Site 8 and Site 9. Potassium (K) concentrations were less than 1mg/l except at Site 14 (1.2mg/l) and Site 15 (1.6mg/l).

Suspended Solids, Total Dissolved Solids, Conductivity, Total Hardness and pH

Suspended Solids levels at all locations were less than 4mg/l, with the exception of 7.2mg/l at Site 14. Total Dissolved Solids (TDS) ranged from 76mg/l at Site 6 to 134mg/l at Site 11. Conductivity

levels were low across the study area, with a minimum of 73µS/cm (Site 9) to a maximum of 149µS/cm (Site 14). Conversely, the maximum Hardness level was at Site 14 (59.1mg/l), and the minimum was at Site 9 (17.6mg/l). pH values ranged from 6.2 at Site 9 to 7.7 at Site 4. A pH below 7 is acidic and a pH above 7 (to a maximum of 14) is basic. pH varies depends primarily on the geology of the river catchment and on river flow. The slightly acidic nature of the waters in the study area is a reflection of the siliceous catchment geology.

Total Organic Carbon

Total Organic Carbon (TOC) is a measure of the dissolved and particulate organic carbon in water. TOC varied from 4.9mg/l at Site 11 to 40.8 at Site 6.

Minerals

Iron levels ranged from 46µg/L at Site 11 to 578µg/L at Site 8. The lowest levels were in the Annacarriga catchment at Site 10 – Site 12. Sulphate levels were blow the LOD at Site 1, Site 2, Site 4, Site 6, and Site 13. The highest Sulphate concentration was at Site 10 (7.22mg/l).

Table 15: Biological water quality results and interpretations at study sites on watercourses potentially affected by the proposed Carrownagowan Wind Farm

Site	Watercourse	Q-rating	Quality Status	Corresponding WFD Status	BMWP Score	BMWP Category	BMWP Interpretation	ASPT	EPT
1	Owengarney	4-5	Unpolluted	High	133.2	Very good	Unpolluted, unimpacted	8.3	15
2	Owengarney	4-5	Unpolluted	High	128.6	Very good	Unpolluted, unimpacted	8.0	14
3	Owengarney	4	Unpolluted	Good	145.3	Very good	Unpolluted, unimpacted	7.6	11
4	Coumnagun	4	Unpolluted	Good	128.4	Very good	Unpolluted, unimpacted	7.1	11
5	Coumnagun	4	Unpolluted	Good	141.3	Very good	Unpolluted, unimpacted	7.9	11
6	Killokennedy	4	Unpolluted	Good	34.2	Poor	Polluted or impacted	6.8	3
7	Killuran	4-5	Unpolluted	High	115.4	Very good	Unpolluted, unimpacted	7.7	9
8	Killuran	4	Unpolluted	Good	81.4	Good	Clean but slightly impacted	6.8	6
9	Killuran More	4	Unpolluted	Good	65.2	Moderate	Moderately impacted	7.2	7
10	Annacarriga	4	Unpolluted	Good	130.2	Very good	Unpolluted, unimpacted	7.7	13
11	Carrownakilly	4-5	Unpolluted	High	160.3	Very good	Unpolluted, unimpacted	8.4	14
12	Carrownakilly	4	Unpolluted	Good	69.5	Moderate	Moderately impacted	7.7	6
13	Un-named	4-5	Unpolluted	High	157	Very good	Unpolluted, unimpacted	8.3	14
14	Broadford	3-4	Slightly Polluted	Moderate	103.1	Very good	Unpolluted, unimpacted	6.9	7
15	Blackwater	4-5	Unpolluted	High	149.1	Very good	Unpolluted, unimpacted	6.8	12
16	Cloongaheen East	4	Unpolluted	Good	51.6	Moderate	Moderately impacted	7.4	6
17	Kilbane Stream	4-5	Unpolluted	High	106	Very good	Unpolluted, unimpacted	8.2	11
18	Broadford	3	Moderately Polluted	Moderate	54.8	Moderate	Moderately impacted	6.1	3
19	Glenomra Wood Stream	4	Unpolluted	Good	105.9	Very good	Unpolluted, unimpacted	7.6	13

Table 16: Results of the on-site physico-chemical measurements at study sites on watercourses potentially affected by the Carrownagowan Wind Farm

Site	Watercourse	D.O. (%)	D.O. (ppm)	Conductivity (µS/cm)	TDS (mg/l)	Temp (°C)	pH	Turbidity (FNU), mean of three
1	Owengarney	98	10.82	181	117	11.3	6.56	2.19
2	Owengarney	93.9	10.3	177	115	12.43	6.45	2.46
3	Owengarney	97.8	10.34	176	115	12.3	6.48	1.79
4	Coumnagun	98.5	10.45	198	128	10.1	6.47	1.66
5	Coumnagun	98.9	10.62	190	122	11.4	6.76	0.62
6	Killokennedy	94.9	10.38	118	76	10.75	5.95	1.83
7	Killuran	99.1	10.73	183	118	12	6.09	1.81
8	Killuran	98.2	10.35	186	120	11.2	6.34	3.83
9	Killuran More	96.4	10.29	126	95	11.0	6.42	2.92
10	Annacarriga	95.8	10.19	225	146	12.3	6.78	1.50
11	Carrownakilly	94.9	10.15	208	134	11.75	6.53	2.15
12	Carrownakilly	96.9	10.52	175	125	11.6	6.54	2.02
13	Un-named	85.8	8.9	188	122	12	6.67	2.64
14	Broadford	86.6	8.92	210	129	11.9	6.50	2.21
15	Blackwater	92.8	10.27	234	115	11.95	6.05	1.68

Table 17: Laboratory water quality results for site surveyed on watercourses potentially affected by the Carrownagowan Wind Farm.

Parameter	Unit	Site														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
COD	mg/L	51	53	33	54	<10	87	43	31	52	<10	<10	<10	38	10	25
BOD	mg/L	1.2	1.3	<1.0	1.2	<1.0	<1.0	<1.0	1.2	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Total Ammonia	mg/L N	0.02	0.02	0.02	0.02	<0.02	0.22	0.02	0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.03	0.05
Total Phosphorous	mg/L	0.1	0.07	0.07	0.07	0.06	0.19	<0.04	<0.04	0.09	0.07	<0.04	<0.04	<0.04	<0.04	<0.04
Orthophosphate	mg/L P	0.02	0.02	0.02	0.02	0.01	0.15	0.01	0.01	0.03	0.01	0.01	<0.01	0.01	0.01	0.02
Suspended Solids	mg/L	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	7.2	<4
Sulphate	mg/L	<0.5	<0.5	0.92	<0.5	0.94	<0.5	4.22	<0.5	5.32	7.22	4.38	1.24	<0.5	8.77	14
pH	pH unit	7.5	7.4	7.4	7.7	7.4	6.6	6.8	7.1	6.2	7.5	7.7	7.7	7.7	7.5	7
Conductivity	µS/cm	84	83	96	93	95	66	83	79	73	157	134	89	100	149	137
Nitrite	mg/L N	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.01	<0.005	<0.005	<0.005	<0.005	<0.005
Nitrate	mg/L N	<0.25	<0.25	<0.25	<0.25	0.69	0.27	<0.25	<0.25	<0.25	0.58	0.52	<0.25	<0.25	1.16	0.97
Total Hardness	mg/L	27.8	28.3	35.8	29.1	37.5	20.2	24.5	28.5	17.6	72.7	64.3	34.3	35.9	59.1	45.4
Potassium	mg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	1.2	1.6
TOC	mg/L	25.6	25.8	16.3	27.3	8.5	40.8	22.8	19.4	26.4	7.2	4.9	6.4	16	7.5	14.3
TON	mg/L N	<0.2	<0.2	<0.2	<0.2	0.69	0.27	<0.2	<0.2	<0.2	0.58	0.52	0.13	0.12	1.16	0.98
MRP	mg/L P	0.02	0.02	0.02	0.02	0.02	0.15	0.01	<0.01	0.03	0.04	<0.01	<0.01	0.01	0.01	0.02
Iron	µg/L	558	570	347	500	120	400	496	578	529	72	46	68	200	354	317
TPH	µg/L	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	14

3.4 FRESHWATER PEARL MUSSEL

There is a freshwater pearl mussel (FPM) sensitive area in the Graney/Scariff catchment to the north of the proposed development. This designation has been attributed to this area due to pre-1970 live records. The Graney and Coolreagh Beg (Annamullaghaun) Rivers to the north and down-slope of a of a single stream crossing are located within this FPM sensitive area.

During the current survey of the Graney and Coolreagh Beg (Annamullaghaun) Rivers, water clarity was good and water levels were suitable for FPM surveying. FPM was not found in the surveyed stretch of ca. 900m in the Coolreagh Beg River or in the stretch of ca. 520m examined in the Graney River. **Table 18** gives an evaluation of FPM survey locations with respect to ecological quality objectives for FPM habitat. The findings at the survey sections are described below.

Table 18: Evaluation of FPM survey locations with respect to ecological quality objectives for FPM habitat (with reference to DoEHLG, 2009).

	Ecological quality element			
	Macro-invertebrates	Filamentous algae (macroalgae)	Macrophytes (rooted higher plants)	Siltation
Objective	EQR ≥ 0.90	Absent or Trace (<5%)	Absent or Trace (<5%)	No artificially elevated levels of siltation
Notes	High status	Any filamentous algae should be wispy and ephemeral and never form mats	Rooted macrophytes should be absent or rare within the mussel habitat	No plumes of silt when substratum is disturbed
Coolreaagh Beg/Annamullaghaun River	Based on substrate siltation and oxygenation conditions, biological water quality fails.	Mats in pools: Fail	Absent: Pass	Considerable: Fail
Scariff/Graney River	Upstream of Scariff, this watercourse was rated Q3-4 (Moderate status) by EPA in 2014: Fail	Mats in some areas: Fail	Absent: Pass	Considerable: Fail

3.4.1 Coolreagh Beg (Annamullaghaun) River

A stretch of ca. 900m of the Coolreagh Beg River was surveyed in the environs of the R352 Bridge, ca. 1.7km upstream of O'Grady Lough. This survey involved a detailed examination the entire stretch of this 2nd order stream. FPM were not detected.

This reach of the river had a wetted width of ca. 3m. It flows through agricultural lands. The substrate consisted mostly of cobble and gravel. The banks were either fully lined with trees, as in the upper and lower stretches, or fully exposed to sunshine as in the middle section. The gradient of this part of the river low/medium, with flow typically glide/pool. A section of the Coolreagh Beg has been drained as obvious from the raised bank along the channel. This anthropogenic induced morphological character is a negative indicator for FPM, as FPM can be removed from a channel during such practice. Additionally, interference with stream substrates results in secondary effects on FPM downstream due to siltation. Water quality of the surveyed stretch was considered

unsatisfactory due to the degree of siltation and eutrophication, the latter manifested in mats of algae.

Regarding the ecological quality objectives for FPM habitat, the surveyed channel of the Coolreagh Beg River fails on the following elements: macroinvertebrates, macroalgae and siltation.

Plate 25: Underwater view of the substrate on the Coolreagh Beg/Annamullaghaun River during August 2018. Signs of siltaton, eutrophication and oxygen supersaturation are evident here (left). Section of the Coolreaagh Beg/Annamullaghaun River (upstream of O'Grady Lough) has been drained as obvious from the raised bank along the channel (right). These anthropogenic morphological impacts are a negative indicator for FPM. Interference with stream substrates results in direct impacts on any FPM present, and secondary effects include downstream siltation.

3.4.2 Scariff (Graney) River

A stretch of ca. 520m of the Scariff River was surveyed between Scariff and O'Grady Lough. FPM were not detected in this 5th order reach of the river.

The substrate of this reach of the river was a combination of limestone bedrock, fractured rock, sand and silt. Flow was over an even low gradient stretch characterised by glide. This reach of the river has been modified in the past by deepening, where bedrock has been broken and extracted from the river. Due to flow, modified nature and apparently unsatisfactory water quality conditions, habitat along this reach of river was deemed suboptimal for FPM. Biological water quality of this watercourse ca. 400 m downstream of Scariff Bridege (station code 25G040400) was rated Q3 (Poor status) by EPA in 2014. This rating is based on macroinvertebrate abundance and diversity.

With regard to the ecological quality objectives for FPM habitat, this section of the Scariff River channel fails on the following elements: macroinvertebrates, filamentous algae and siltation, passing only the macrophytes element.

4 CONCLUSIONS

4.1 FISH AND FISH HABITATS

The upper reaches of the watercourses in the catchments affected by the proposed development are good habitats for the early life stages of salmonids. This is due to their generally shallow nature, riffled features, substrate composition and good water quality. The distribution of fish in the study area is apparently affected by migration obstacles such as high gradient reaches and may also be

affected by artificial structures such as bridge foundation aprons and culverts. As documented by IFI, having undertaken surveys on some of the subject waterbodies (lakes and rivers), and greater fish diversity occurs in the lower gradient reaches of the watercourse draining the proposed development. The low gradient reaches of many watercourses in Co. Clare have been deepened for conveyance purposes, including the Graney and the Annacarriga. Such departures from natural morphological conditions usually decrease the habitat value for fish. Most of the roadways within the proposed development site feature concrete pipe culverts that are perched in some fashion or other at their downstream end. Such features can limit the distribution of salmonids and eel as they can prevent upstream passage. In the case of the current road network within the site, these possible barriers to migration occurred on the Killuran Stream and Killuran More Stream, where natural barriers to upstream movement exist further downstream.

Plate 26: Site 8 on the Killuran Stream (left). This perched culvert represents an impassable barrier to upstream fish migration. Existing internal track crossing of the Coumnagun Stream (right). Brown Trout occur upstream of this location.

Salmon were recorded only in the larger waterbodies at locations downstream of the proposed development site. Salmon were not recorded in the Killuran Stream, though likely to occur in the lower reach of this watercourse upstream of the Owengarney confluence. The upstream limit of Salmon in the Owengarney River is considered close to the proposed development site boundary (recorded ca. 1km downstream). The Broadford River is an important watercourse for salmon. The lower reaches of tributaries of the Broadford River are also considered important salmon spawning and nursery areas. The Salmon encountered in the Blackwater River are considered to be the progeny of adults that spawned in this watercourse, with reference to McGinnity *et al.* (2003) which indicates the larger watercourses in this catchment as producers of salmon. It is deduced therefore that Salmon can negotiate the culvert under the headrace of the Ardnacrusha Dam and access the upper reaches of this system. Salmon can be expected to occur naturally in all watercourse reaches accessible from the sea.

The watercourse reaches examined and considered in this report are largely sub-optimal for holding adult salmon due to their small size. In general, adult salmon are deemed to enter these areas only during the salmonid spawning season, as pools are insufficiently deep.

Most of the main stem of the Annacarriga River is expected to/can potentially support Salmon, as adult fish are likely to have access to all fluvial habitat from its mouth at Lough Derg to ca. 2.5km upstream, where the river falls rapidly. Lough Derg is upstream of Parteen Weir and Ardnacrusha

Dam on the River Shannon. The status of salmon stocks above rivers impounded for hydro-electric schemes is given in the 'The Status of Irish Salmon Stocks in 2017 with Catch Advice for 2018, a report of the Technical Expert Group on Salmon to Inland Fisheries Ireland (IFI)[12]. The conservation limit (CL) applied by the Technical Expert Group on Salmon (TEGOS) to establish the status of individual stocks is the "maximum sustainable yield" (MSY) also known as the stock level that maximises the long-term average surplus, as defined and used by the International Council for the Exploration of the Sea (ICES) and the North Atlantic salmon Conservation Organisation (NASCO). The CL for Salmon on the River Shannon is 49,638. The average 2013 – 2017 Salmon count (partial) was 990, so the proportion of CL achieved was 2%. It is noted that migration of Salmon in the River Shannon is impeded by the Ardnacrusha Hydro-scheme, so any salmon encountered during the current survey are most likely to have been introduced by the ESB, and probably originated in the Parteen hatchery. Stocking and rearing salmonids is an established technique for artificially increasing salmonid productivity with the objective being to increase the adult numbers available to the system. The role of maintenance and preservation of the entire fishery resources on the River Shannon is undertaken by ESB Fisheries Conservation[13].

Plate 27: The lower reaches of the Annacarriga River have been drained downstream of Site 10 (left). The headrace to the Ardnacrusha hydro-scheme (right). The passage of the Blackwater River through a culvert under this structure is deemed a barrier to several fish species, including lamprey and eel.

Brown trout are typically the dominant species in these upland reaches, and the only fish species occurring within the proposed development site. With the exception of the Coumnagun Stream, the 1st order streams within the proposed development are small of limited value to salmonids, due to their small size/inaccessible reaches. Fish were not detected in the upper Killuran River, the Killuran More Stream or Killokennedy Stream in the Owengarney catchment or in the upper Annacarriga system. A proportion of the Brown trout in the Owengarney (including the Broadford River) and Blackwater Rivers are likely to out migrate to the Shannon Estuary / sea and return as adults to spawn, considering that these catchments have been classified as sea trout systems by McGinnity *et al*. (2003).

European eel was recorded at only in the Owengarney River. The European eel is subject to European Council Regulation 1100/2007 'Establishing measures for the recovery of the stock of

[12] https://www.fisheriesireland.ie/extranet/fisheries-management-1/salmon/1496-the-status-of-irish-salmon-stocks-in-2017-with-catch-advice-for-2018/file.html

[13] https://www.esb.ie/acting-responsibly/fisheries-2/the-river-shannon

European eel'. European eel is listed as 'Critically endangered' and is now 'Red Listed' according to 'Red List No. 5: Amphibians, Reptiles & Freshwater Fish' (King *et al*., 2011).

Lampreys have similar habitat requirements for spawning to trout. There is adequate lamprey spawning habitat in the watercourses draining the proposed development, but there is a general lack of sand/silt deposits, a requirement for lamprey larvae. Lamprey may occur in low densities in the mid upper reaches of the rivers assessed, where flows are sufficiently slow to allow accumulation of fine substrates. All lamprey recorded in the Blackwater River are considered Brook Lamprey. This assertion takes account of the poor swimming ability of lampreys (Reinhardt *et al.* 2009) and the presence of a steep incline on the lower reach of the Blackwater River as if flows through the culvert under the headrace of the Ardnacrusha Hydro-scheme.

4.2 MACROINVERTEBRATES

The habitats for macroinvertebrates in the watercourses draining the proposed development are generally suboptimal for macroinvertebrate production. This is a function of their erosive nature (beds dominated by larger sized substrates) and small pool size. The macroinvertebrates recorded were previously recorded in the study area, with reference to NBDC records.

Macroinvertebrate assemblages characteristic of unpolluted upland oligotrophic streams were recorded. Based on the relative abundance of macroinvertebrates that specialize in shredding (*Plecoptera*) and collecting (*Trichoptera*) as a feeding strategy, it is concluded that the aquatic ecosystems at the study sites are driven primarily by energy sources derived outside of the aquatic zone. The macroinvertebrate compositions are indicative of watercourses that require an external supply of organic matter (allochthonous organic matter) for biological sustenance. The naturally low nutrient concentrations of surface waters in the study area, coupled in some instances with their peaty nature mean that benthic life and therefore higher organisms are highly dependent on terrestrial energy sources for survival, rather than primary production instream. For example, leaf litter and aerial insects are likely important food sources for macroinvertebrates and fish, respectively. Low Crustacean diversity and abundance reflects the siliceous nature of the study area. NPWS (2013) lists the pressures on FPM (European code 1029) in the Irish context. High ranking threats include 'modification of hydrographic functioning (J02.05)', 'diffuse pollution to surface waters due to agricultural and forestry activities (H01.05)' and 'restructuring agricultural landholding (A10)'. During the current field surveys, these threats were noted in the Graney/Scariff catchment, a FPM sensitive area which lies to the north of the proposed development. For example, drainage of a reaches of the both the Coolreagh Beg and Scariff River has taken place in the past, representing an interference with hydrographic functioning. Current biological water quality degradation in the case of the Scariff River is likely attributable at least in part, to agricultural activities. Evidence of land drainage, including instream modifications, reseeding and fertilisation recorded in the study area of the Coolreagh Beg catchment relate to the FPM threats J02.05 and H01.05.

4.3 WATER QUALITY

4.3.1 Biological

During the latest EPA biological monitoring of watercourses in the study area, water quality was generally satisfactory as indicated by the latest EPA Q-ratings. The biotic indices derived at the study sites during the current surveys also indicate largely unpolluted waters, with high family richness (>10) recorded at most locations. This was due to the generally high macroinvertebrate diversity recorded, in combination with generally low levels of siltation and algal growths, and Dissolved

Oxygen concentrations close to 100%. Macroinvertebrate diversity corresponded with habitat suitability, with greater diversity recorded in areas of better habitat. In the Irish context, biological water quality in the study area is considered very good, considering the range of pressures on surface waters at a national level, such as nutrient, organic, chemical, and sediment pollution.

Inland Fisheries Ireland and EPA have identified significant pressures for waterbodies that are at risk of not meeting their water quality objectives under the water framework directive by incorporating over 140 datasets, a suite of modelling tools, and local knowledge from field and enforcement staff from the local authorities. While there are a multitude of pressures in every waterbody, the significant pressures are those pressures which need to be addressed in order to improve water quality. A robust scientific assessment process has been carried out to determine which pressures are the significant pressures. The Blackwater River and most of its tributaries to the R465 Bridge are categorised as watercourses under significant pressure from forestry, while the reaches downstream of this location are under pressures from industry[14]. The Graney River is also classified as waterbody under significant pressure from forestry. There are no significant pressures identified for the remainder of the watercourses assessed in this report.

4.3.2 Physico-chemical

The notion of “water quality” comprises consideration of many different factors. Commonly quoted determinands include physical characteristics such as temperature and colour as well as chemical characteristics such as acidity, hardness, and the concentrations of various constituents including nitrates, sulphates and dissolved oxygen (Ward and Robinson, 2005). The loss of nutrients from the terrestrial zone contributes to pollutant loads in surface waters, with anthropogenic activities the primary driver of ecological change in aquatic ecosystems. In the current study area, peat erosion, afforestation and deforestation (clear-felling) are identified as the primary concerns in relation to water quality and dependent biota.

Silt is probably the most significant risk to aquatic fauna in watercourses draining the proposed development. The greatest siltation risk in the watercourses draining the proposed development site is from land drainage associated with commercial coniferous forestry. Soil upheaval, exposure and weathering, associated with recent clear-felling of conifer plantation, for example in the Killokennedy Stream catchment (Site 6) is considered to represent the greatest water quality pressure within the proposed development site. Drainage networks and roads within the site represent a delivery mechanism of sediment from source to watercourse. The effects of peat and soil drainage were apparent at some newly planted areas within the proposed development site during the current surveys: a large accumulation of peat silt was observed close to the Coumnagun Stream, presumably following heavy rainfall and erosion of drains; sand deposits were recorded downslope of another area where peat had been removed to bedrock level.

Substrate siltation was recorded at some of the study sites, most notably in the Broadford River and the Killuran Stream. At Site 7 on the on the Killuran Stream during August 2018, sediment particles had settled under the low flow conditions causing a phenomenon known as external colmation, this can lead to the clogging of the top layer of channel sediments. Problems in watercourses arise primarily with the smothering of coarse patches of sediment with fine particles that ingress into the

[14] https://www.catchments.ie/maps/

coarse sediment and deplete oxygen levels by reducing through-flow within the sediment[15]. The negative impacts of high and persistent sediment loads affect invertebrate assemblages and abundances, with Ephemeroptera, Plecoptera, Trichoptera (EPT) taxa exhibiting the greatest negative response to increased sediment[16]. From examining physico-chemical results in the Owengarney catchment, it is clear that the greatest deviation from natural conditions was at Site 6 (Killokennedy Stream), with more favourable water quality at Site 5 (Coumnagun Stream). Though these watercourses are at comparable elevations and drain similar soils, there is a marked difference in physico-chemical water quality in these minor sub-catchments. This difference is attributed to the contrasting characteristics of the Coumnagun sub-catchment (Site 5), where disturbance, exposure and decomposition of soils and plant matter in the Killokennedy Stream sub-catchment (Site 6) is likely contributing to a decline in water chemistry. Forestry activities in the Killokennedy Stream sub-catchment are considered to have degraded carbon/nutrient banks with consequent leaching of nutrients via overland flows and throughflow. Relatively stable ground conditions feature in the Coumnagun sub-catchment, where there is good floral ground cover. The focus of the discussion of water quality parameters below is on the disparity of results between the Coumnagun and Killokennedy Stream sub-catchments.

Suspended Solids levels at all locations well below the annual average of 25mg/l stipulated in European Communities (Quality of Salmonid Waters) Regulations (S.I. No. 293/1988). It is important to note however that sampling was undertaken a few days after significant rainfall, and when after peak flows in the surveyed channels, when rivers were running relatively clear.

The determination of orthophosphate is of great use in highlighting the presence of one of the most important nutrients. Excessive presence promotes the growth of algae which in overabundance cause serious environmental problems (EPA, 2001). The disparity in orthophosphate concentrations between Site 5 (0.02mg/l) and Site 6 (0.15mg/l) is significant, in fact by a factor of >7. Orthophosphate is the most readily available form for uptake during photosynthesis. High concentrations generally occur in conjunction with algal blooms (EPA, 2013). Orthophosphate is the most readily available form for uptake during photosynthesis and is generally considered to be the limiting nutrient for plant growth in freshwater. Phosphorus (P) is generally considered to be the limiting nutrient for plant growth in freshwater with small quantities occurring naturally mainly from geological sources (EPA, 2013). P levels at Site 6 (0.19mg/l) were > three times higher than at Site 5 (0.06mg/l).

Ammonia occurs naturally in water bodies arising from the microbiological decomposition of nitrogenous compounds in organic matter. Fish and other aquatic organisms also excrete ammonia. Natural (unpolluted) waters contain relatively small amounts of ammonia, usually <0.02mg/l as N (EPA, 2013). Comparing Total Ammonia concentrations at Site 5 (<0.02mg/l) and Site 6 (0.22mg/l), there was a difference in the order of 10. Ammonia exists in aqueous solutions in two forms, ionised (NH_4^+) and un-ionised (NH_3) and the un-ionised fraction is toxic to freshwater fish at very low concentration (EPA, 2013). Arising from the complex relationship between total ammonia concentration, pH and temperature there emerges a level for total ammonia of around 0.3 mg/l NH_3 which is considered to be that which would contain the limiting amount of un-ionised ammonia

[15] https://www.epa.ie/pubs/reports/water/rivers/EPA_River_Sediment_Studies.pdf

[16] https://www.salmon-trout.org/wp-content/uploads/2017/09/STC-The-impact-of-excess-fine-sediment-on-invertebrates-and-fish-in-riverine-systems.pdf

(EPA, 2001). While the Ammonia level in the Killokennedy is below the critical value, the result highlights potential problems with land activities in the area. In unpolluted waters, nitrite levels are generally low i.e. <0.01mg/l (EPA, 2013). With the exception of Site 10 (0.01mg/l) all other sites had nitrite levels below <0.005mg/l. Total Oxidized Nitrogen (TON) is the sum of nitrate and nitrite. This determinand was higher at Site 5 (0.69mg/l) than at Site 6 (0.27mg/l).

Total Organic Carbon (TOC) is a measure of the dissolved and particulate organic carbon in water. The bulk of organic carbon in water is composed of humic substances and partly degraded plant and animal materials (EPA, 2013). The highest TOC level was at Site 6 (40.5mg/l), representing a concentration almost 5 times greater than at Site 5.

Iron is quite harmful to aquatic life, as evidenced by laboratory studies, but in nature the degree of toxicity may be lessened by the interaction of the iron with other constituents of a water. Should the metal be converted to an insoluble form then the iron deposits will interfere with fish food and with spawning (EPA, 2001). The Iron concentration at Site 5 and Site 6 was 120mg/l and 400mg/l respectively. The levels at Site 6 are greater than three times the concentration at Site 5.

The results above highlight the difference in physico-chemical water quality conditions across two streams in adjacent sub-catchments in the Owengarney catchment, one draining an area that has been recently disturbed (Site 6) and another that has not been recently disturbed (albeit clear-felling has taken place there in the past).

Plate 28: Denuded peat soil within the site (left) is a potential source of sediment in watercourses downstream. As runoff flows, it concentrates in rivulets, cutting grooves called rills into the soil surface. Sedimentation of eroded soils had taken place ca. 100m downslope (right) i.e. the settling out of soil particles transported by water.

4.4 FRESHWATER PEARL MUSSEL

A small proportion of the proposed development occurs upslope of a Freshwater pearl mussel sensitive area, namely the Scariff / Graney. This catchment is identified having 'Previous records of *Margaritifera*, but current status unknown'. Representative stretches of the Graney River and Coolreagh Beg (Annamullaghaun) River within this catchment were surveyed for FPM in 2018. FPM were not detected and the riverine habitats in the surveyed reaches of these channels were unsuitable for FPM, both river stretches failing ecological quality objectives for FPM habitat, with reference to the European Communities Environmental Objectives (Freshwater Pearl Mussel) Regulations 2009. Based on the morphologically impacted condition of these rivers and water quality

problems, it is concluded that the presence of FPM in the watercourses in the Graney / Scariff catchment downstream of the proposed development is highly unlikely.

5 RECOMMENDATIONS

The European Communities Environmental Objectives (Surface Waters) Regulations 2009 (S.I. 272 of 2009) and as amended, establish legally binding quality objectives for all surface waters and environmental quality standards for pollutants for purposes of implementing provisions of E.U. legislation on protection of surface waters. These regulations clarify the role of public authorities in the protection of surface waters and also concern the protection of designated habitats. The 2009 Irish Red list of non-marine molluscs identified the following as major threats to FPM: reduction in water quality; increases in siltation and physical interference with habitat (Byrne *et al.* 2009). These threats decrease macroinvertebrate and fish habitat quality in general.

Ina recent and detailed study carried out by Davis *et al.* (2018), sediment, phosphorus and nitrogen were manipulated simultaneously. Davis *et al.* (2018) concluded that

- sediment was the most pervasive stressor particularly at high cover levels
- improving river ecological quality requires improved management of sediment inputs.

The adoption of incorrect procedures will lead to excessive runoff of nutrients and organic matter in times of heavy rainfall. A Surface Water Management Plan (SWMP) should therefore be produced in advance of any works taking place. The SWMP should detail method statement(s) for protecting water quality in the watercourses affected. The SWMP should be distributed and discussed with all parties involved in construction (including any sub-contractors) to protect aquatic conservation interests within the study area. The SWMP should set out measures to avoid siltation, erosion, surface water run-off and accidental pollution events which all have the potential to adversely affect water quality within the site during the construction phase. Any new development at watercourse crossings (upgrading/new tracks) should consider fish passage. Any works involving stream crossings should maintain or improve faunal connectivity upstream and downstream of works. The proposed development will be constructed in cognisance of the following guidelines to achieve the above:

- *'Guidelines for the Crossing of Watercourses during the Construction of National Road Schemes'* (NRA, 2008)
- '*River Crossings and Migratory Fish: Design Guidance'* (Scottish Executive, 2000)
- '*Guidelines on Protection of Fisheries during Construction Works in and Adjacent to Waters*' (IFI, 2016)
- '*Control of water pollution from construction sites - Guidance for consultants and contractors*' (Masters-Williams *et al*. 2001)
- '*Control of water pollution from linear construction projects*' (Murnane *et al.* 2006).

Silt control will be a primary concern during construction stage, as peat silt has been identified a sediment source for downstream areas. The use of conifer brash should be considered in designing erosion control and silt control measures. This is a plentiful resource at the site. It could be used to

check flows, feature as an attenuation component in silt traps and protect denuded areas by laying compacted brash on soils prone to erosion.

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Appendix 1 Biotic indices

Table A1.1 Biological River Quality Classification (Q-Values)

'Q' value	Community Diversity	Water Quality	Condition*	Status	Quality
Q5	High	Good	Satisfactory	Unpolluted	Class A
Q4	Reduced	Fair	Satisfactory	Unpolluted	Class A
Q3	Much Reduced	Doubtful	Unsatisfactory	Slightly Polluted	Class B
Q2	Low	Poor	Unsatisfactory	Moderately Polluted	Class C
Q1	Very Low	Bad	Unsatisfactory	Seriously Polluted	Class D

* *'Condition' refers to the likelihood of interference with beneficial or potential beneficial use.*

The connection between the Q-rating system and the European Communities Environmental Objectives (Surface Waters) Regulations 2009 (S.I. 272 of 2009) is given in **Table A1.2** below.

Table A1.2 Water Framework Directive (WFD) ecological status classification and corresponding Q-rating

Ecological status classification	Corresponding Q-rating
High	Q5, Q4-5
Good	Q4
Moderate	Q3-4
Poor	Q3, Q2-3
Bad	Q2, Q1

Table A1.3 BMWP Scoring System.

BMWP score	Category	Interpretation
0-10	Very poor	Heavily polluted
11-40	Poor	Polluted or impacted
41-70	Moderate	Moderately impacted
71-100	Good	Clean but slightly impacted
>100	Very good	Unpolluted, unimpacted

Appendix 2 Macroinvertebrate physical habitat suitability

Table A2.1 Physical habitat assessment of streams for their suitability for macroinvertebrate production (adapted from Barbour and Stribling, 1991).

	Optimal	Suboptimal	Marginal	Poor
Score	**20**	**15**	**10**	**5**
Bottom substrate	More than 60% of bottom is gravel, cobble, and boulders. Even mix of substratum size classes.	30-60% of bottom is cobble or boulder substrata. Substrate may be dominated by one size class.	10-30% of substrata consists of large materials. Silt or sand accounts for 70-90% of bottom.	Substrate dominated by silt and sand. Gravel, cobble and larger substrate sizes <10%.
Habitat complexity	A variety of types and sizes of material form a diverse habitat.	Structural types or sizes of material are less than optimum but adequate cover still provided.	Habitat dominated by only one or two structural components. Amount of cover is limited.	Monotonous habitat with little diversity. Silt and sand dominate and reduce habitat diversity and complexity.
Pool quality	25% of the pools are as wide or wider than the mean stream width and area >1m deep.	<5% of the pools are >1m deep and wider than the mean stream width.	<1% of the pools are >1m deep and wider than the mean stream width. Pools present may be very deep or very shallow. Variety of pools or quality is fair.	Majority of pools are small and shallow. Pools may be absent.
Bank stability	Little evidence of past bank failure and little potential for future mass wasting into channel.	Infrequent or very small slides. Low future potential of slides.	Mass wasting moderate in frequency and size. Raw spots eroded during high floods.	Frequent or large slides. Banks unstable and contributing sediment to the stream.
Bank protection	Over 80% of streambank surfaces are covered by vegetation, boulders, bedrock, or other stable materials.	50-80% of the streambanks covered with vegetation, cobble, or larger material.	25-50% of the streambank is covered by vegetation.	<25% of the streambank is covered by vegetation or stable materials.
Canopy	Vegetation of various heights provides a mix of shade and filtering light to water surface.	Discontinuous vegetation provides areas of shade alternating with areas of full exposure. Or filtering shade occurs <6h/day.	Shading is complete and dense. Or filtering shade occurs <3h/day.	Water surface is exposed to full sun nearly all day long.

Appendix 3 Electrical fishing data

Site	Species	Fish Length (cm)	Pass	Length fished (m)	Width fished (m)	Time (mins)
1	Brown trout	14.6	1	28	4.5	n/a
1	Brown trout	16.2	1	28	4.5	n/a
1	Brown trout	17.6	1	28	4.5	n/a
1	Brown trout	15.7	1	28	4.5	n/a
1	Brown trout	12.9	1	28	4.5	n/a
1	Brown trout	13.5	1	28	4.5	n/a
1	Brown trout	13.5	1	28	4.5	n/a
1	Brown trout	13.8	1	28	4.5	n/a
1	Brown trout	13	1	28	4.5	n/a
1	Brown trout	13.4	1	28	4.5	n/a
1	Brown trout	13	1	28	4.5	n/a
1	Brown trout	13.9	1	28	4.5	n/a
1	Brown trout	15.1	1	28	4.5	n/a
1	Brown trout	11.6	1	28	4.5	n/a
1	Brown trout	12.4	1	28	4.5	n/a
1	Brown trout	14.5	1	28	4.5	n/a
1	Brown trout	7.5	1	28	4.5	n/a
1	Brown trout	7.4	1	28	4.5	n/a
1	Brown trout	13	1	28	4.5	n/a
1	Brown trout	10.3	1	28	4.5	n/a
1	Brown trout	7.8	1	28	4.5	n/a
1	Brown trout	11.8	1	28	4.5	n/a
1	Brown trout	10	1	28	4.5	n/a
1	Brown trout	6.5	1	28	4.5	n/a
1	Brown trout	7.2	1	28	4.5	n/a
1	Brown trout	11	1	28	4.5	n/a
1	Brown trout	5.5	1	28	4.5	n/a
1	Brown trout	7.3	1	28	4.5	n/a
1	Brown trout	7.7	1	28	4.5	n/a
1	Brown trout	6.9	1	28	4.5	n/a
1	Brown trout	6.4	1	28	4.5	n/a
1	Brown trout	6.3	1	28	4.5	n/a
1	Brown trout	6.9	1	28	4.5	n/a
1	Brown trout	7.6	1	28	4.5	n/a
1	Brown trout	7.6	1	28	4.5	n/a
1	Brown trout	6.7	1	28	4.5	n/a
1	Brown trout	6.5	1	28	4.5	n/a
1	Brown trout	6.6	1	28	4.5	n/a
1	Brown trout	6.8	1	28	4.5	n/a
1	Brown trout	7.4	1	28	4.5	n/a
1	Brown trout	6.4	1	28	4.5	n/a
1	Brown trout	6.5	1	28	4.5	n/a
1	Brown trout	5.5	1	28	4.5	n/a
1	Brown trout	7.1	1	28	4.5	n/a
1	Brown trout	6.8	1	28	4.5	n/a
1	Brown trout	14.8	2	28	4.5	n/a
1	Brown trout	14.6	2	28	4.5	n/a
1	Brown trout	8.1	2	28	4.5	n/a
1	Brown trout	8.2	2	28	4.5	n/a
1	Brown trout	5.7	2	28	4.5	n/a
1	Brown trout	13.9	2	28	4.5	n/a
1	Brown trout	6.6	2	28	4.5	n/a
1	Brown trout	7	2	28	4.5	n/a

Site	Species	Fish Length (cm)	Pass	Length fished (m)	Width fished (m)	Time (mins)
1	Brown trout	6.4	2	28	4.5	n/a
1	Brown trout	5.9	2	28	4.5	n/a
1	Brown trout	6	3	28	4.5	n/a
1	Brown trout	6.5	3	28	4.5	n/a
1	Brown trout	13.5	3	28	4.5	n/a
1	Brown trout	6.6	3	28	4.5	n/a
1	European eel	31.5	1	28	4.5	n/a
1	European eel	19.3	2	28	4.5	n/a
1	European eel	30.2	2	28	4.5	n/a
1	salmon	11.8	1	28	4.5	n/a
1	salmon	11.9	1	28	4.5	n/a
1	salmon	9.8	1	28	4.5	n/a
1	salmon	8.2	1	28	4.5	n/a
1	salmon	9	1	28	4.5	n/a
2	Brown trout	16	1	28	4.5	20
2	Brown trout	11.5	1	28	4.2	10
2	Brown trout	7.7	1	28	4.2	10
2	Brown trout	6.8	1	28	4.2	10
2	Brown trout	7.5	1	28	4.2	10
2	Brown trout	8.1	1	28	4.2	10
2	Brown trout	8.2	1	28	4.2	10
2	Brown trout	10.9	1	28	4.2	10
2	Brown trout	17.8	1	28	4.2	10
2	Brown trout	19	1	28	4.2	10
2	Brown trout	8	1	28	4.2	10
2	Brown trout	11.4	1	28	4.2	10
2	Brown trout	8	1	28	4.2	10
2	Brown trout	8.1	1	28	4.2	10
2	Brown trout	8	1	28	4.2	10
2	Brown trout	6.8	1	28	4.2	10
2	Brown trout	6.5	1	28	4.2	10
2	Brown trout	7.1	1	28	4.2	10
2	Brown trout	6.4	1	28	4.2	10
2	Brown trout	7.2	1	28	4.2	10
2	Brown trout	6.1	1	28	4.2	10
3	Brown trout	12.5	1	22	2.6	5
3	Brown trout	14	1	22	2.6	5
3	Brown trout	13.2	1	22	2.6	5
3	Brown trout	11.6	1	22	2.6	5
3	Brown trout	7.2	1	22	2.6	5
3	Brown trout	7.3	1	22	2.6	5
3	Brown trout	6.5	1	22	2.6	5
3	Brown trout	7.5	1	22	2.6	5
3	Brown trout	6.3	1	22	2.6	5
3	Brown trout	7.1	1	22	2.6	5
3	Brown trout	7.2	1	22	2.6	5
3	Brown trout	7.2	1	22	2.6	5
3	Brown trout	6.3	1	22	2.6	5
3	Brown trout	6.7	1	22	2.6	5
4	Brown trout	12.2	1	14	2.9	5
4	Brown trout	6.6	1	14	2.9	5
4	Brown trout	12.9	1	14	2.9	5
4	Brown trout	12.1	1	14	2.9	5
4	Brown trout	12.4	1	14	2.9	5

Site	Species	Fish Length (cm)	Pass	Length fished (m)	Width fished (m)	Time (mins)
4	Brown trout	10	1	14	2.9	5
4	Brown trout	7	1	14	2.9	5
4	Brown trout	7.5	1	14	2.9	5
4	Brown trout	6.3	1	14	2.9	5
4	Brown trout	5.9	1	14	2.9	5
4	Brown trout	11.7	1	14	2.9	5
4	Brown trout	7.2	1	14	2.9	5
4	Brown trout	6.5	1	14	2.9	5
4	Brown trout	6.6	1	14	2.9	5
4	Brown trout	6.5	1	14	2.9	5
4	Brown trout	7	1	14	2.9	5
4	Brown trout	8	1	14	2.9	5
5	Brown trout	16	1	26	1.8	5
5	Brown trout	10.6	1	26	1.8	5
5	Brown trout	8.8	1	26	1.8	5
5	Brown trout	9	1	26	1.8	5
5	Brown trout	8.9	1	26	1.8	5
7	Brown trout	16	1	27	3	10
7	Brown trout	16.7	1	27	3	10
7	Brown trout	15.4	1	27	3	10
7	Brown trout	13.9	1	27	3	10
7	Brown trout	12.9	1	27	3	10
7	Brown trout	16	1	27	3	10
7	Brown trout	13.4	1	27	3	10
7	Brown trout	19.5	1	27	3	10
7	Brown trout	14.9	1	27	3	10
7	Brown trout	14.4	1	27	3	10
7	Brown trout	14.6	1	27	3	10
7	Brown trout	12.4	1	27	3	10
7	Brown trout	8.8	1	27	3	10
7	Brown trout	8.7	1	27	3	10
7	Brown trout	7.7	1	27	3	10
7	Brown trout	8.8	1	27	3	10
7	Brown trout	9	1	27	3	10
7	Brown trout	7.9	1	27	3	10
7	Brown trout	8	1	27	3	10
7	Brown trout	8.9	1	27	3	10
7	Brown trout	8.7	1	27	3	10
7	Brown trout	7.7	1	27	3	10
7	Brown trout	8.1	1	27	3	10
7	Brown trout	9.1	1	27	3	10
7	Brown trout	7.6	1	27	3	10
7	Brown trout	6.7	1	27	3	10
9	no fish		1	15	1.2	5
10	Brown trout	15	1	26	3	10
10	salmon	12.4	1	26	3	10
10	salmon	11.1	1	26	3	10
10	salmon	11.6	1	26	3	10
10	Brown trout	14.4	1	26	3	10
10	Brown trout	7.5	1	26	3	10
10	Brown trout	12.7	1	26	3	10
10	Brown trout	11.7	1	26	3	10
10	Brown trout	12.8	1	26	3	10
10	Brown trout	10.2	1	26	3	10

Site	Species	Fish Length (cm)	Pass	Length fished (m)	Width fished (m)	Time (mins)
10	Brown trout	8.4	1	26	3	10
10	Brown trout	7.8	1	26	3	10
10	Brown trout	10.4	1	26	3	10
10	Brown trout	6	1	26	3	10
10	Brown trout	6.1	1	26	3	10
10	Brown trout	12.6	1	26	3	10
10	Brown trout	12.7	1	26	3	10
10	Brown trout	6	1	26	3	10
11	no fish us ford	-	1	35	1.5	5
11	no fish no fish ds ford	-	1	32	1.5	5
13	Brown trout	6.2	1	34	1.2	5
13	Brown trout	5.4	1	34	1.2	5
13	Brown trout	6.4	1	34	1.2	5
13	Brown trout	5.6	1	34	1.2	5
13	Brown trout	6	1	34	1.2	5
13	Brown trout	5.5	1	34	1.2	5
14	Brown trout	15.2	1	34	3	20
14	Brown trout	14	1	34	3	20
14	salmon	11	1	34	3	20
14	salmon	11.9	1	34	3	20
14	salmon	10.4	1	34	3	20
14	Brown trout	11.9	1	34	3	20
14	salmon	11.5	1	34	3	20
14	Brown trout	13.4	1	34	3	20
14	salmon	11.2	1	34	3	20
14	Brown trout	8.1	1	34	3	20
14	salmon	6.9	1	34	3	20
14	Brown trout	10.3	1	34	3	20
14	salmon	11.3	1	34	3	20
14	Brown trout	11.6	1	34	3	20
14	Brown trout	5.8	1	34	3	20
14	salmon	5.7	1	34	3	20
14	salmon	9.9	1	34	3	20
14	salmon	10	1	34	3	20
14	Brown trout	7.7	1	34	3	20
14	Brown trout	8	1	34	3	20
14	salmon	6.5	1	34	3	20
14	Brown trout	7.9	1	34	3	20
14	salmon	6.4	1	34	3	20
14	salmon	6.6	1	34	3	20
14	salmon	5.3	1	34	3	20
14	salmon	5.3	1	34	3	20
14	salmon	5.7	1	34	3	20
14	salmon	5.7	1	34	3	20
14	salmon	6.6	1	34	3	20
14	salmon	5.6	1	34	3	20
14	Brown trout	7.8	1	34	3	20
14	salmon	8	1	34	3	20
14	Brown trout	5.5	1	34	3	20
14	salmon	7.3	1	34	3	20
14	Brown trout	7.2	1	34	3	20
14	salmon	7.1	1	34	3	20
14	salmon	5.3	1	34	3	20
14	salmon	6.5	1	34	3	20

Site	Species	Fish Length (cm)	Pass	Length fished (m)	Width fished (m)	Time (mins)
14	salmon	6.2	1	34	3	20
14	salmon	6.4	1	34	3	20
14	salmon	8.2	1	34	3	20
14	salmon	7.7	1	34	3	20
14	salmon	5.5	1	34	3	20
14	salmon	5.4	1	34	3	20
14	salmon	5.9	1	34	3	20
14	salmon	6.5	1	34	3	20
14	minnow	4.5	1	34	3	20
14	salmon	5.3	1	34	3	20
14	salmon	6.6	1	34	3	20
14	salmon	5.7	1	34	3	20
14	salmon	7.5	1	34	3	20
14	salmon	6.4	1	34	3	20
14	salmon	8	1	34	3	20
14	salmon	5.6	1	34	3	20
14	salmon	5.6	1	34	3	20
14	salmon	6.6	1	34	3	20
14	salmon	6.4	1	34	3	20
14	salmon	5.3	1	34	3	20
14	salmon	6.1	1	34	3	20
14	salmon	5.6	1	34	3	20
14	salmon	6	1	34	3	20
14	salmon	5.6	1	34	3	20
14	salmon	5.4	1	34	3	20
14	salmon	5.4	1	34	3	20
14	salmon	5.8	1	34	3	20
14	salmon	5.1	1	34	3	20
14	salmon	5.7	1	34	3	20
14	salmon	5.7	1	34	3	20
14	salmon	5.1	1	34	3	20
14	salmon	5.1	1	34	3	20
14	three-spined stickleback	3.7	1	34	3	20
15	Brown trout	24.1	1	35	4	20
15	Brown trout	21.8	1	35	4	20
15	Brown trout	23.8	1	35	4	20
15	Brown trout	17.2	1	35	4	20
15	Brown trout	17	1	35	4	20
15	Brown trout	13.5	1	35	4	20
15	Brown trout	13	1	35	4	20
15	Brown trout	15.2	1	35	4	20
15	Brown trout	13.4	1	35	4	20
15	Brown trout	7.8	1	35	4	20
15	Brown trout	8.3	1	35	4	20
15	Brown trout	7.5	1	35	4	20
15	salmon	13.1	1	35	4	20
15	salmon	12.8	1	35	4	20
15	salmon	12.1	1	35	4	20
15	stone loach	8.5	1	35	4	20
15	stone loach	6.2	1	35	4	20
15	three-spined stickleback	2.8	1	35	4	20
15	three-spined stickleback	2.4	1	35	4	20
15	three-spined stickleback	3	1	35	4	20
15	three-spined stickleback	2.1	1	35	4	20

Site	Species	Fish Length (cm)	Pass	Length fished (m)	Width fished (m)	Time (mins)
15	salmon	7.4	1	34	3	20
15	salmon	10.5	1	34	3	20
15	Brown trout	15.4	1	34	3	20
15	Brown trout	15.1	1	34	3	20
15	Brown trout	15	1	34	3	20
15	Brown trout	16.5	1	34	3	20
15	Brown trout	14.8	1	34	3	20
15	salmon	13	1	34	3	20
15	Brown trout	13.2	1	34	3	20
15	Brown trout	7	1	34	3	20
15	stone loach	6.5	1	34	3	20
15	stone loach	7.8	1	34	3	20
15	stone loach	6.9	1	34	3	20
15	salmon	6.6	1	34	3	20
15	three-spined stickleback	2.6	$1m^2$	35	4	n/a
15	river/brook lamprey transformer	14.3	$1m^2$	34	3	n/a
15	river/brook lamprey	3.2	$1m^2$	34	3	n/a
15	river/brook lamprey	5.1	$1m^2$	34	3	n/a
15	river/brook lamprey	7.9	$1m^2$	34	3	n/a
15	river/brook lamprey	3.3	$1m^2$	34	3	n/a
15	river/brook lamprey	8.3	$1m^2$	34	3	n/a
15	river/brook lamprey	8.3	$1m^2$	34	3	n/a
15	river/brook lamprey	5.3	$1m^2$	34	3	n/a
15	river/brook lamprey	8.1	$1m^2$	34	3	n/a
15	river/brook lamprey	7.5	$1m^2$	34	3	n/a
15	river/brook lamprey	3.5	$1m^2$	34	3	n/a
15	river/brook lamprey	3	$1m^2$	34	3	n/a
15	river/brook lamprey	3.1	$1m^2$	34	3	n/a
15	river/brook lamprey	4.1	$1m^2$	34	3	n/a
15	river/brook lamprey	4.3	$1m^2$	34	3	n/a
15	river/brook lamprey	3.4	$1m^2$	34	3	n/a
15	minnow	3.2	$1m^2$	34	3	n/a
15	minnow	2	$1m^2$	34	3	n/a