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Water Quality Assessment

Cummeennabuddoge Wind Farm

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MAPPING

CONTENTS

LIST OF TABLES

LIST OF FIGURES

ANNEXES

1 INTRODUCTION

1.1 Terms of Reference

This Water Quality (WQ) assessment was commissioned by FuturEnergy Ireland via their lead consultant to inform development proposals and support a planning application for the proposed Cummeennabuddoge Wind Farm development (hereafter referred to as the 'Proposed Development').

1.2 Purpose

The Proposed Development site is hydrologically linked to sensitive environmental receptors. Potentially significant effects have been identified in EIA screening in relation to nutrient loss from the site affecting water quality in Lough Leane, and suspended sediment in runoff from the Proposed Development causing an adverse effect to water quality in the Clydagh River and qualifying features in the Killarney National Park, Macgillycuddy's Reeks and Caragh River Catchment Special Area of Protection (SAC).

The purpose of the assessment is to **quantitatively assess** the effect of runoff from the Proposed Development to those receptors.

1.3 Statement of Authority

This assessment and report have been prepared and reviewed by qualified professional civil engineers specialising in the fields of hydrology, water quality and flood risk. The key staff members involved in this project are as follows:

- Anna Phoenix BEng (Hons), PhD, MIEI – Senior Project Engineer with experience in the fields of dispersion modelling, water quality assessment, flood modelling, drainage and surface water management design; and
- Kyle Somerville BEng (Hons) CEng MIEI – Director and Chartered Engineer specialising in the fields of applied and engineering hydrology, hydraulic modelling and river hydraulics, with particular experience in flood risk assessment, surface water management and environmental assessment.

1.4 Approach to the Assessment

An initial assessment was carried out which informed the scope of the water quality assessment. This involved:

- Data collation to characterise the study area including identification of key receptors, hydrological characteristics and WFD water body status; and
- Undertaking a screening assessment to determine the relevant water quality parameters and legislation enacted within the study area.

The detailed water quality assessment was then undertaken in two distinct assessments, as follows:

1.4.1 Assessment of Nutrients at Lough Leane

The quality of surface water discharging from the Proposed Development site in terms of potential nutrient release associated with felling operations (required as part of construction phase enabling works) and the potential effects on specific environmental receptors at Lough Leane was assessed.

The assessment determined compliance of the discharges from the Proposed Development site during the felling work with Environmental Quality Standards (EQS) as defined in the relevant European Union (EU) water quality regulations, and determined the effect relative to the long term pre-construction baseline. A detailed and conservative assessment of the impact on the receiving waters based on a proposed clear-fell of trees across the Proposed Development site has been undertaken and the suitability of the proposals in relation to water quality has been assessed.

It should be noted at the outset that due to on-going commercial forestry operations, approximately 40% of the proposed felling area considered in this assessment has already been felled; therefore, assumptions made in this report, and results presented, are considered to be highly precautionary / conservative.

The assessment of nutrients at Lough Leane involved the following:

- A 1D modelling study was conducted to assess the concentration of relevant nutrients at Lough Leane into which the River Clydagh / River Flesk ultimately discharges; and
- Compliance of the modelled water quality parameters in line with the Environmental Quality Standards (EQS) at points of interest relevant to the Proposed Development site was then determined; and the effect of the Proposed Development relative to the pre-construction baseline determined.

1.4.2 Assessment of Total Suspended Solids in the River Clydagh

The assessment of total suspended solids (TSS) in the River Clydagh involved the following:

- A 2D dispersion modelling study was carried out to evaluate discharge of sediments into the River Clydagh (part of the River Flesk catchment), including the adjacent 'Killarney National Park, Macgillycuddy's Reeks and Caragh River Catchment Special Area of Protection (SAC)' under storm events;
- Compliance of the modelled water quality parameters in line with the Environmental Quality Standards (EQS) at points of interest relevant to the Proposed Development site was then determined; and
- The assessment considered various scenarios and a sensitivity analysis.

For the purpose of this study, the following have been considered:

- European Union / domestic water quality regulations relevant at the Proposed Development site;
- Available water quality information at, and downstream of, the Proposed Development site;
- Site level information based on a combination of 1m and 2m DTM height data, 10m LiDAR and 25m DTM height data;
- Site observations based on inspections undertaken in January 2021, April 2021, and July 2022; and
- Detailed assessment (by dispersion modelling) of compliance of surface water discharge with Environmental Quality Standards.

2 SITE INFORMATION

2.1 Application Site

The Proposed Development site is located approximately 20 km east / south-east of Killarney in County Kerry (ITM coordinates 520500, 583500). Parts of the north, east, and south of the Proposed Development site extents (hereafter referred to as the 'Site Boundary') are along the Kerry / Cork County boundary.

Context and location are shown Figure 2.1 and Figure 2.2, respectively, and on the drawings submitted in support of the application.

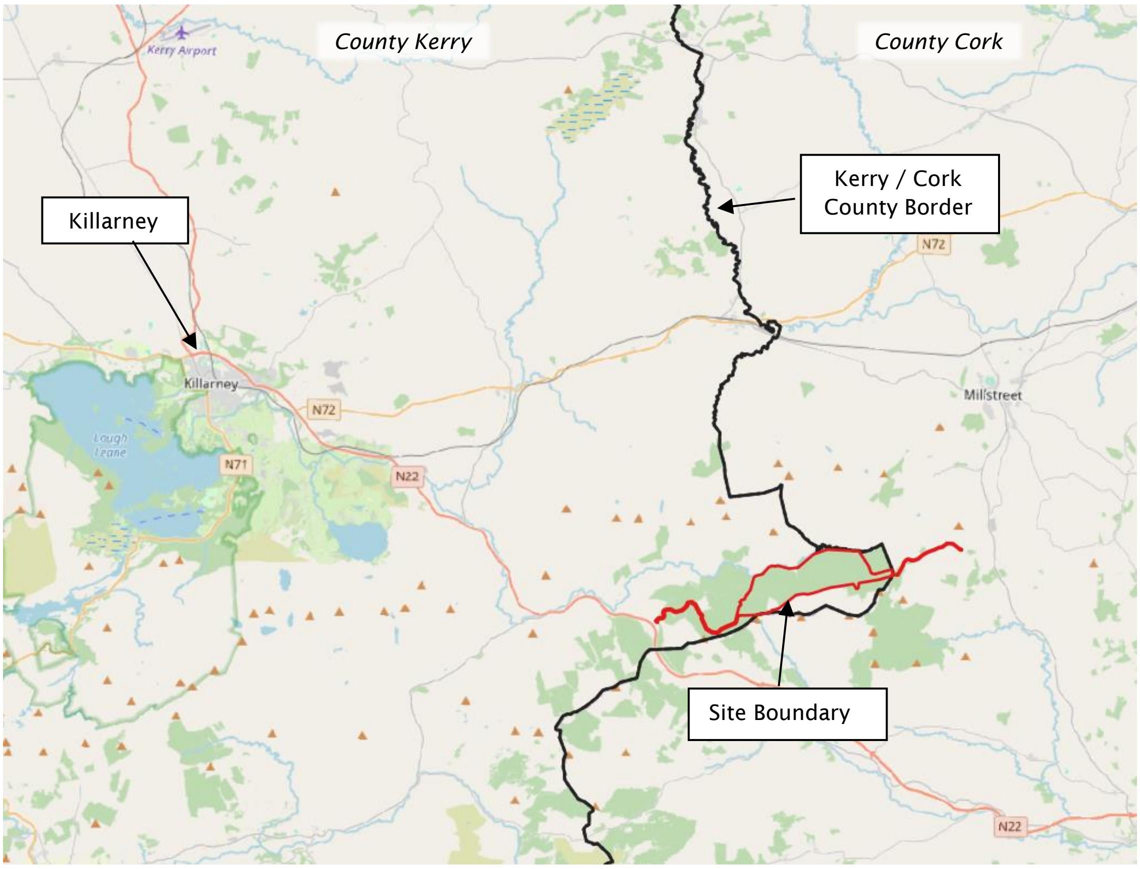


Figure 2.1 Location Context

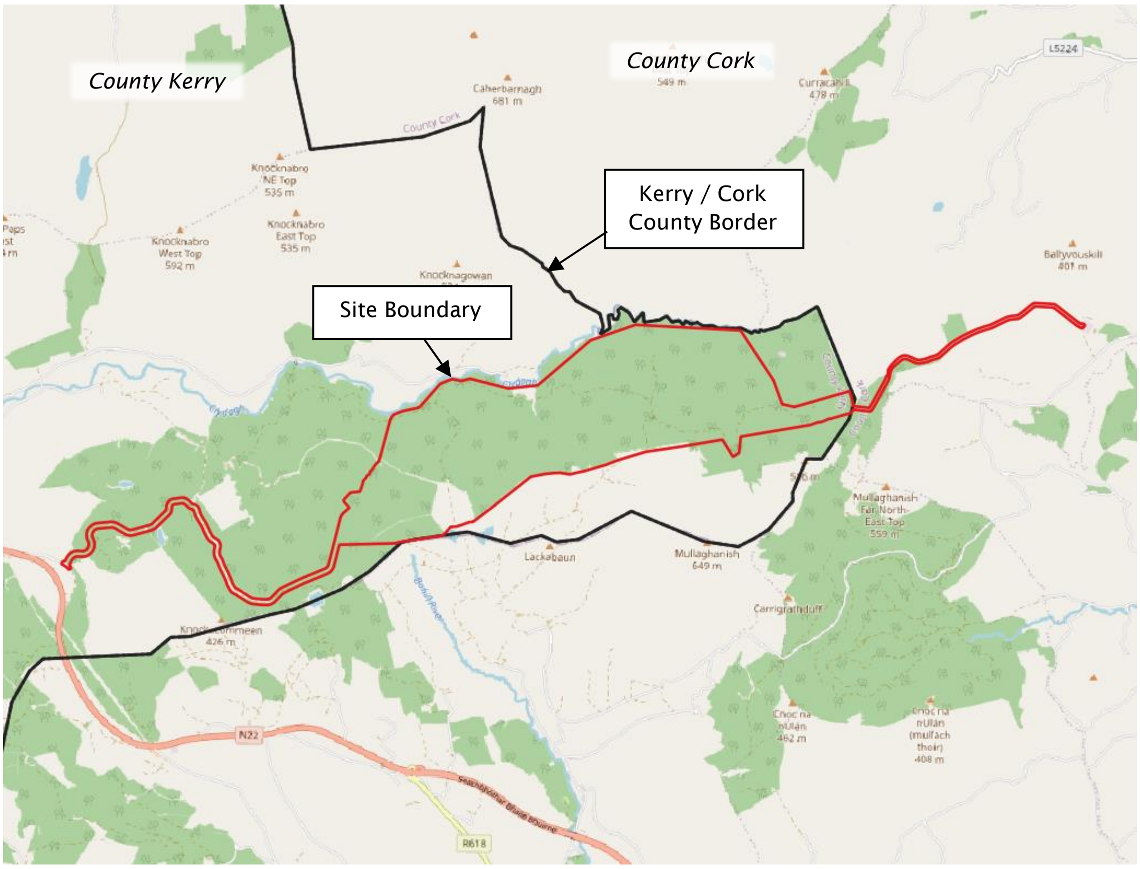


Figure 2.2: Site Location

2.1.1 Existing Land Use

The Proposed Development site lies within an existing forestry plantation owned and operated by Coillte. Site access is via an existing entrance in the west of the site, off a local road that is accessed from the N22 National Road. The existing entrance is currently used for the forestry operations.

2.1.2 Proposed Development

The Proposed Development is detailed in the accompanying Environmental Impact Assessment Report (EIAR) Chapter 4: Description of Development, but in summary comprises; the construction of 17 no. wind turbines and associated hardstand areas, an electrical substation, control building, electrical connections, met mast, upgraded tracks, permanent drainage features, and borrow pits.

Felling of existing commercial forestry and additional temporary / enabling works will be required in advance of the construction of the wind farm. A schematic showing the proposed felling plan considered within this assessment (hereafter referred to as the 'felling plan') is shown in Figure 2-3.

Scoping of the EIA for the Proposed Development has identified that the proposal may result in nutrient and sediment runoff resulting in potential adverse effects on water quality at downstream receptors including Lough Leane. Both the River Clydagh and Lough Leane are designated as part of the 'Killarney National Park, Macgillycuddy's Reeks and Caragh River Catchment' SAC (refer to section 2.3.3.2).

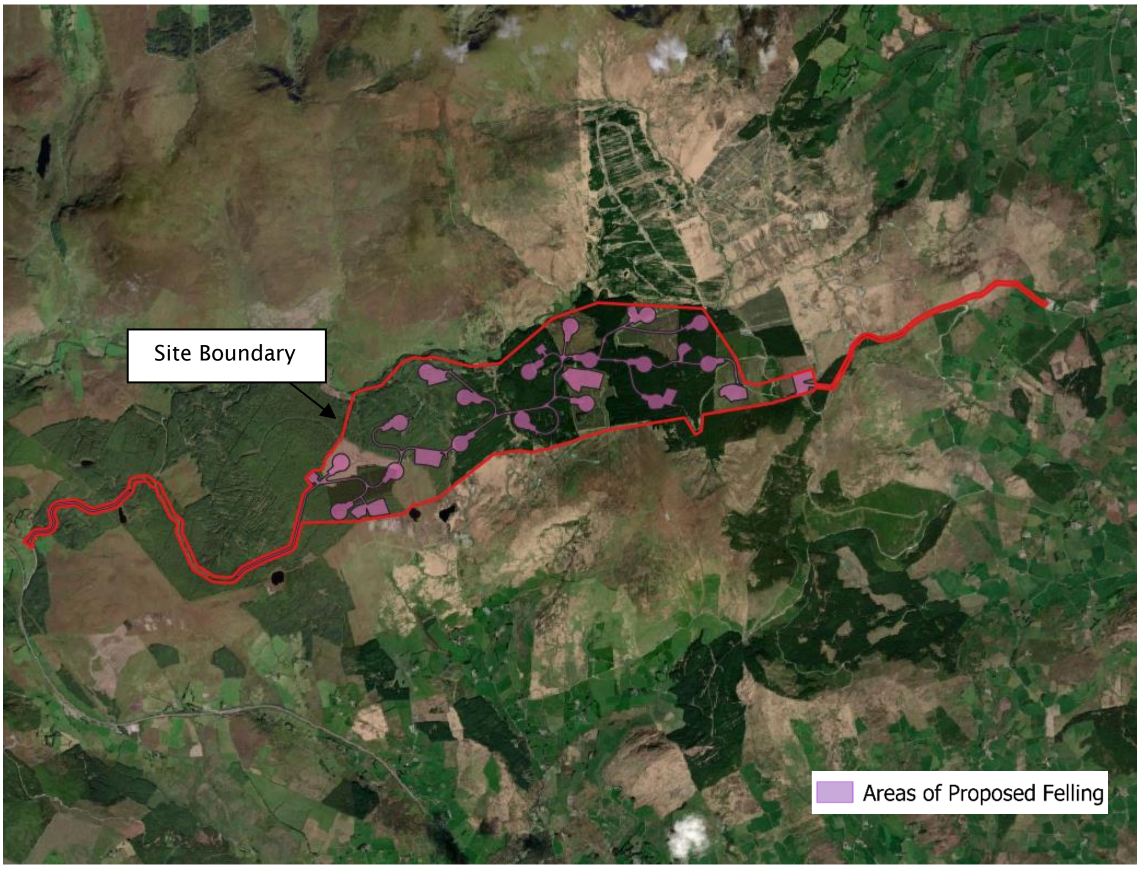


Figure 2-3 - Proposed Felling Plan

2.2 Site Topography

The topography within the Site Boundary typically slopes down from the southern boundary (maximum approximately 520 m OD) to the northern boundary (at approximately 300 m OD) with the Lackabaun and Mullaghanish mountain peaks located to the south of the site.

The majority of the central section of the site is located between 300-400 m OD, and the watercourses crossing the site have created a ridge and shallow valley system. Lower elevations are observed in the west of the site where the access track join from the N22, which is at approximately 270 m OD. The tracks within 1.5 km of the N22 are steep, climbing from an elevation of 270 m OD to approximately 380 m OD as shown in Figure 2-4 below.

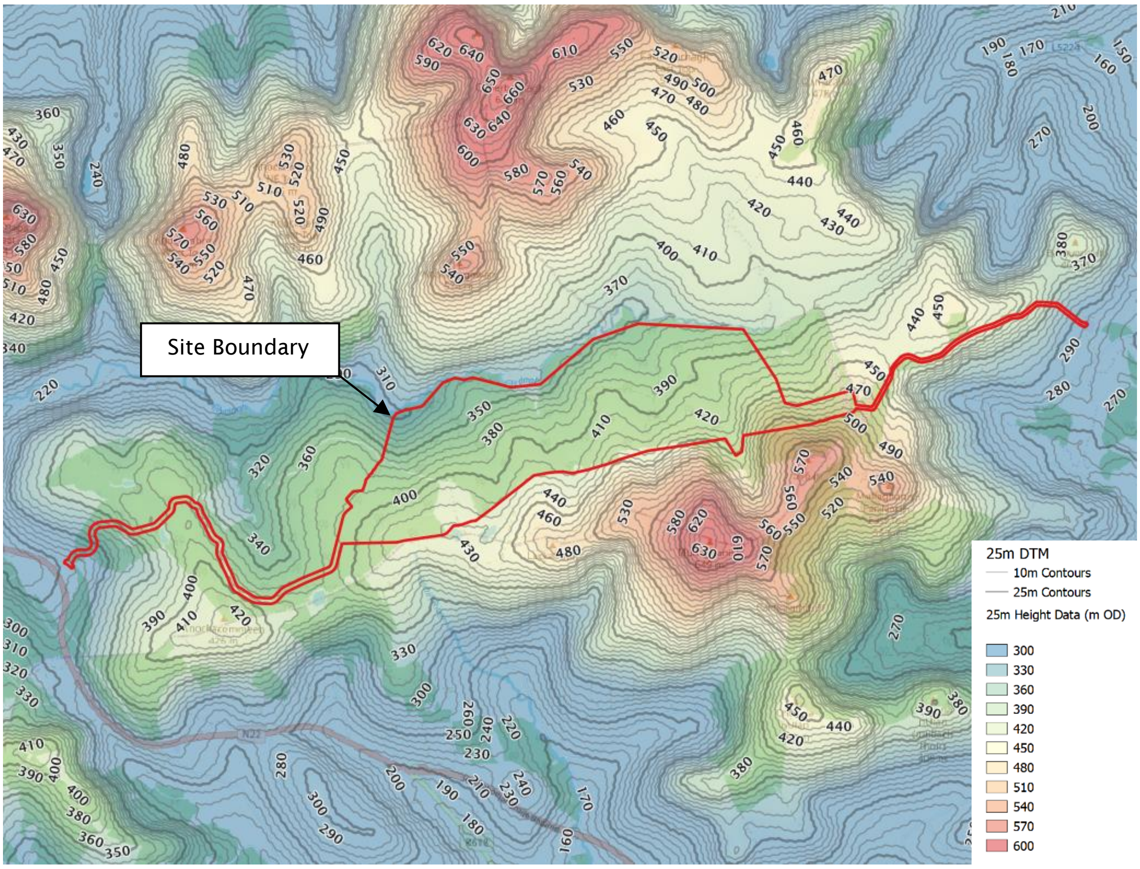


Figure 2-4 - Site Topography

2.3 Water Environment Site Setting

2.3.1 Hydrological Study Area

2.3.1.1 Lough Leane

The hydrological setting for the assessment of Lough Leane comprises the full extent of the River Clydagh and River Flesk, as far downstream as Lough Leane.

Lough Leane has been subject to historic eutrophication due to excessive nutrient-loading (refer to EIA Chapter 11 for further detail). As a result, the potential effects of the proposed felling activities on the lough (i.e., mobilisation and release of fertiliser nutrients such as phosphorous and nitrogen) were assessed. The watercourses within the Lough Leane study area and the Flood Studies Update (FSU) catchment to the Lough are shown in Figure 2-5.

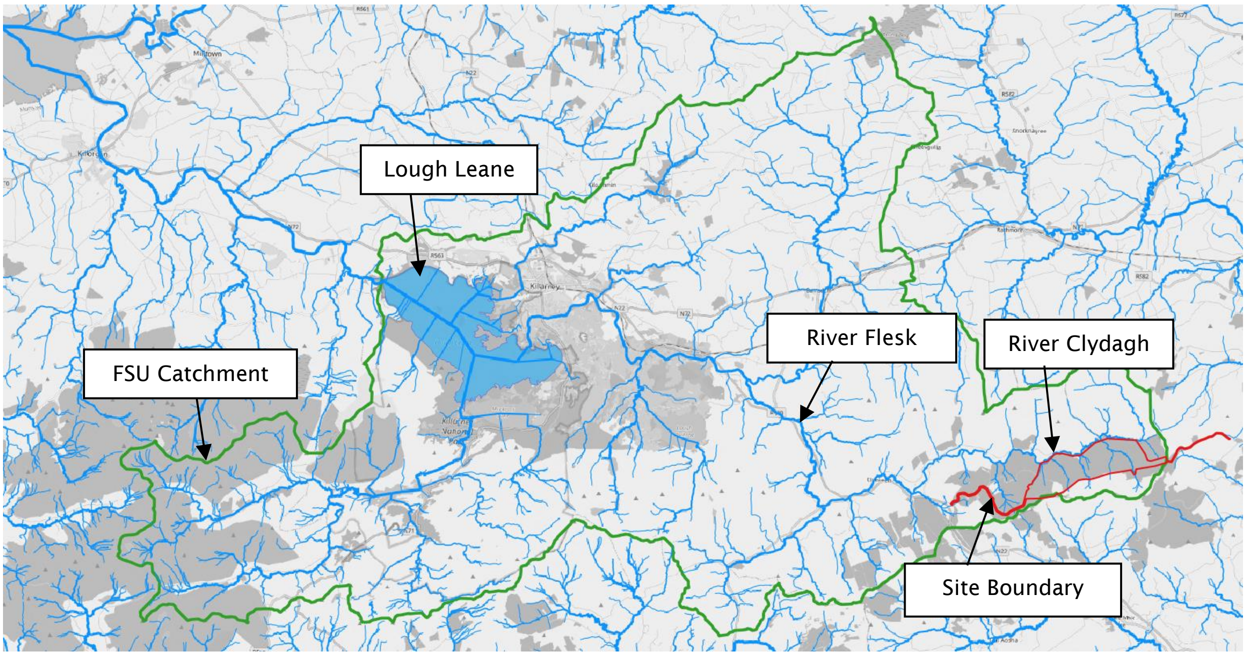


Figure 2-5 – Watercourses (Lough Leane Hydrological Study Area)

2.3.1.2 River Clydagh

A review of Environmental Protection Agency (EPA) Rivers and Lakes has indicated that the River Clydagh flows in a westerly direction along the northern site boundary. Several of its tributaries, including the Clydaghroe and Mullaghanish streams, flow through the Proposed Development site. Given the steeply sloped nature of the site, these watercourses would tend to have steep gradients characteristic of upland streams.

The hydrological setting for the study area relating to assessment of sediments in the SAC comprises a c. 2.4 km stretch of the River Clydagh from the head of the reach, to a point c. 0.65 km downstream of the Site Boundary. This reach of the river includes multiple tributaries which will influence the hydraulics of the watercourse.

The rationale for the selected study area for the Clydagh catchment TSS assessment is that any dispersion effect extending beyond this stretch of the waterbody would be unacceptable in principle based on the River Clydagh designation as an SAC. There is, therefore, no additional value in investigating further downstream effects on sediments.

The named watercourses within the Site Boundary vicinity are shown in Figure 2-6. Further details on unnamed watercourses at, and downstream of, the Proposed Development site are described in EIAR Chapter 11: Hydrology, Water Quality and Flood Risk.

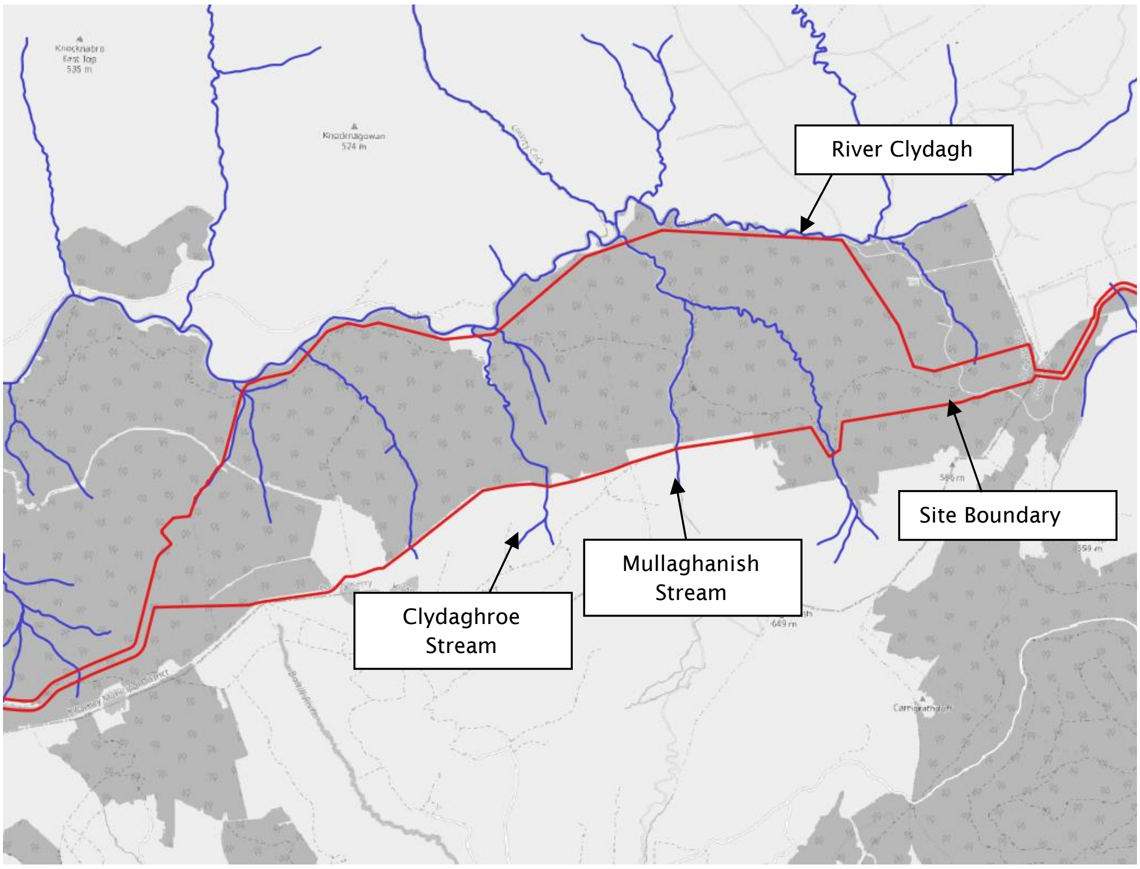


Figure 2-6 –Watercourses (Hydrological Study Area – SAC Within and Immediately Downstream of Site Boundary)

2.3.2 Existing Discharges

A review of existing wastewater and industrial discharges in the vicinity of the Proposed Development site indicated that there are a number of existing discharges to the River Clydagh / River Flesk, downstream of the Site Boundary, as shown in Figure 2-7.

The Killarney Wastewater Treatment Plant (WwTP) is located within the vicinity of the study area. The primary effluent discharge is to the Folies Stream, with two storm water overflow discharges located downstream on the River Flesk. The Barraduff WwTP discharges to the Owneykeagh Stream, which is a tributary of the River Flesk. A number of Section 4 discharges and one licenced waste facility currently discharge to tributaries of the River Clydagh / Flesk.

Ambient pollutant concentrations in the river used in this assessment have been taken from water quality sampling carried out along the watercourse, including at monitoring locations downstream of these existing discharges. The influence of the existing discharges on water quality of the River Clydagh / River Flesk will, therefore, be accounted for in the model.

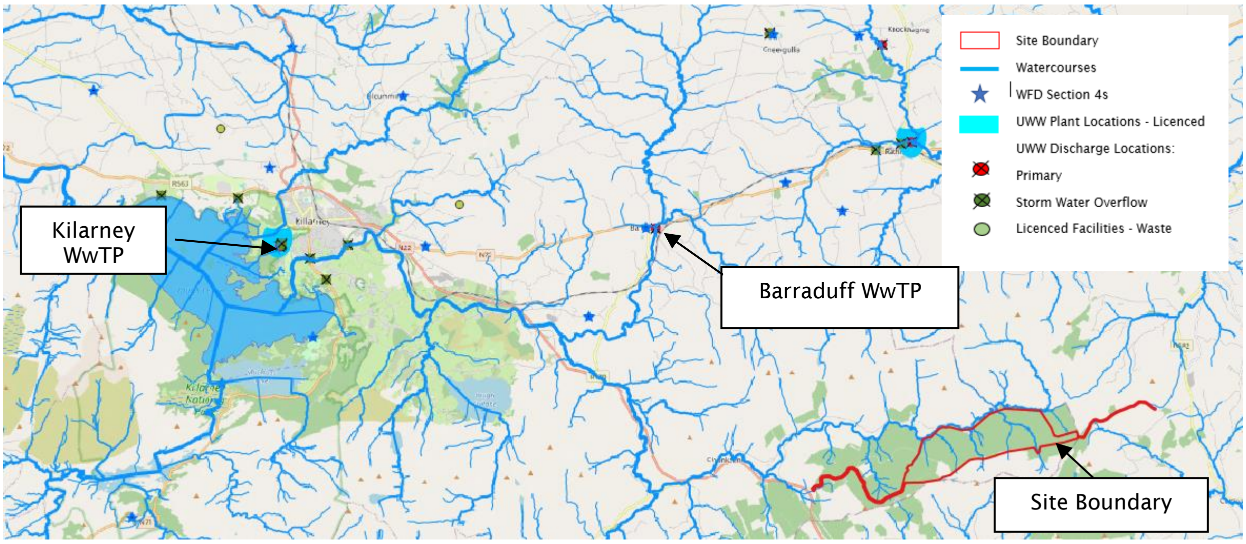


Figure 2-7 – Existing Outfalls

2.3.3 Environmental Receptors

A review of the EPA database has been carried out to identify key environmental receptors relevant to the study area. The receptors identified are presented in the following table.

Table 2-1: Key Environmental Receptors in Study Area

Key Receptors	Regulatory Framework Body / Document
Special Area of Conservation (SAC)	Council Directive 92/43/EEC on the Conservation of Natural Habitats and of Wild Fauna and Flora (Habitats Directive) European Communities (Natural Habitats) Regulations, 1997
Special Protected Area (SPA)	EU Birds Directive (79/409/EEC)
Natural Heritage Area (NHA)	National Parks and Wildlife Service
Salmonid river	European Communities (Quality of Salmonid Waters) Regulations, 1988
Nutrient sensitive area – Lakes & Estuaries	Urban Wastewater Treatment (UWWT) Directive 91/271/EEC Urban Wastewater Treatment (Amendment) Regulations, 2004 & 2010
Drinking water river / groundwater	European Communities (Quality of Surface Water Intended for The Abstraction of Drinking Water) Regulations, 1989 Article 7 - waters used for the abstraction of drinking water (DIRECTIVE 98/83/EC)

Key Receptors	Regulatory Framework Body / Document
WFD river waterbody	Water Framework Directive
WFD lake waterbody	Water Framework Directive
WFD groundwater waterbody	Water Framework Directive

These key receptors along with the WFD status of the relevant waterbodies are discussed in further detail below.

2.3.3.1 Water Framework Directive Waterbodies

Waterbodies within the hydrological study area have been identified per EPA WFD data. Surface water bodies (rivers and lakes) and groundwater bodies defined by WFD are shown in Figure 2-8 and Figure 2-9, respectively.

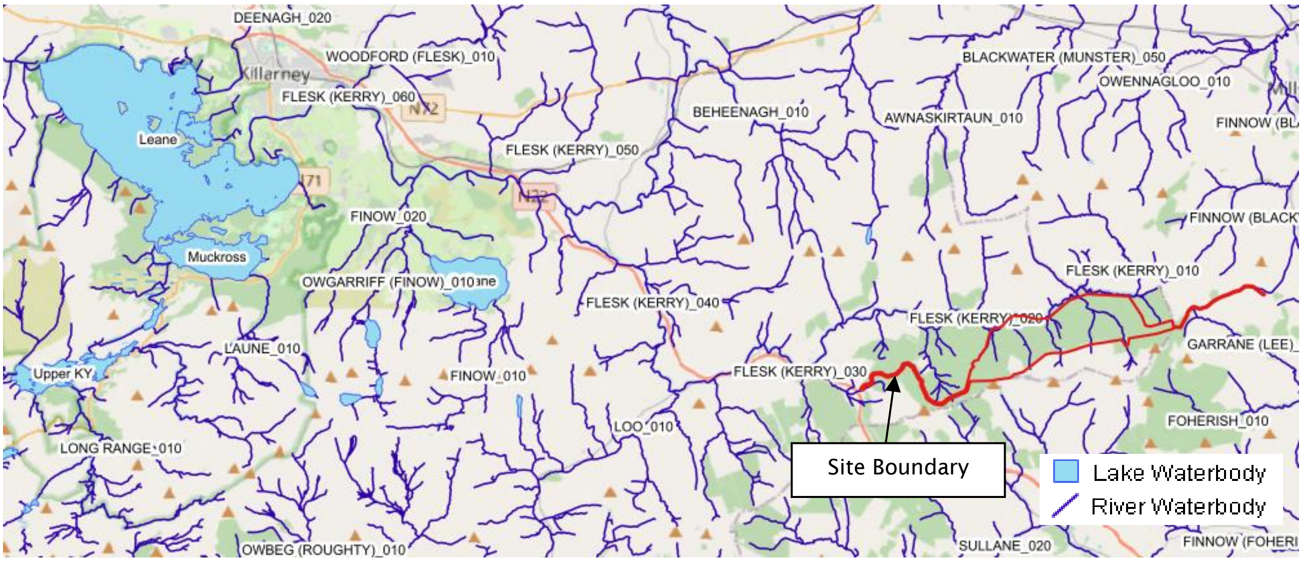


Figure 2-8 – WFD Surface Water Bodies

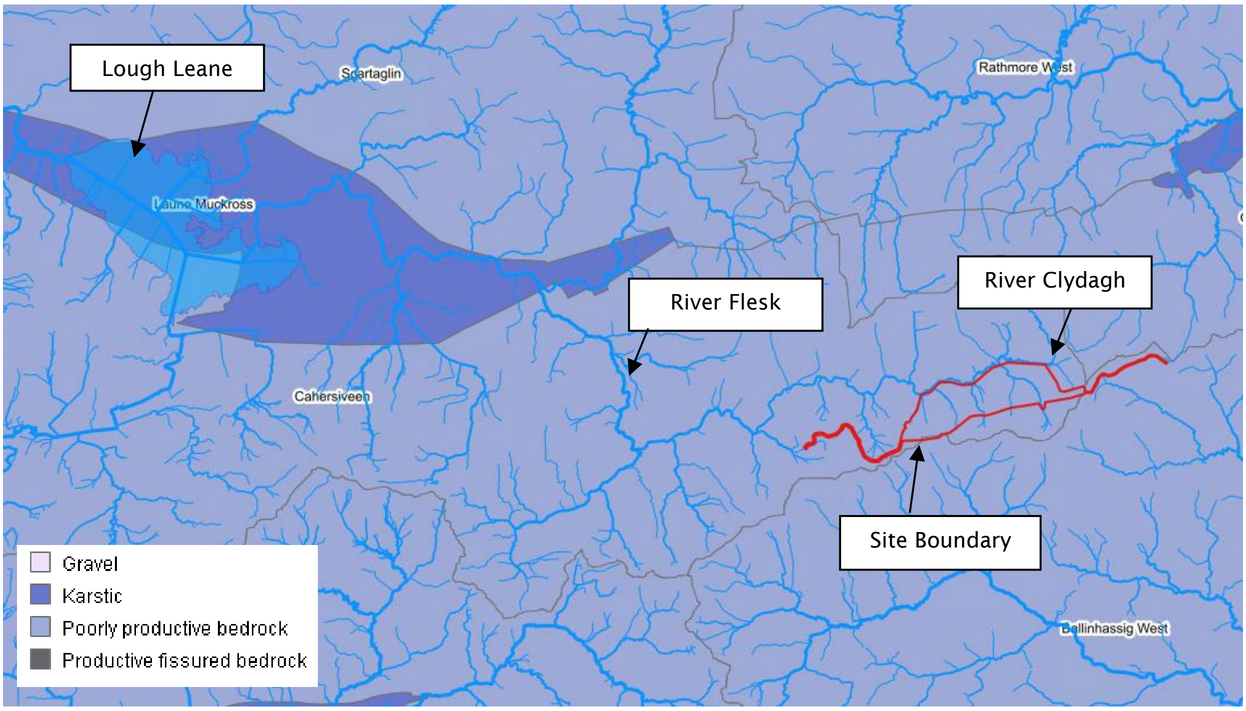


Figure 2-9 – WFD Groundwater Bodies

The WFD status of the water bodies in the study area is shown in Figure 2-10. The River Clydagh and River Flesk are primarily specified as having a 'High' to 'Good' status throughout their sub-basins. The lower reach of the River Flesk immediately upstream of Lough Leane is shown as having a 'Poor' status. Lough Leane itself has a 'Good' WFD status and the surrounding groundwater waterbody is designated as 'Good'.

As part of the WFD monitoring programme, rivers are scored on a five-point system called the Biological Q Rating system. Nine points are located on the River Clydagh / River Flesk within the study area (the locations are shown in Figure 2-10). The first upstream point, located along the northern extent of the Site Boundary has a Q4 value, equating to a 'Good' status. Further downstream monitoring values range between Q4 'Good' status and Q5 'High' status.

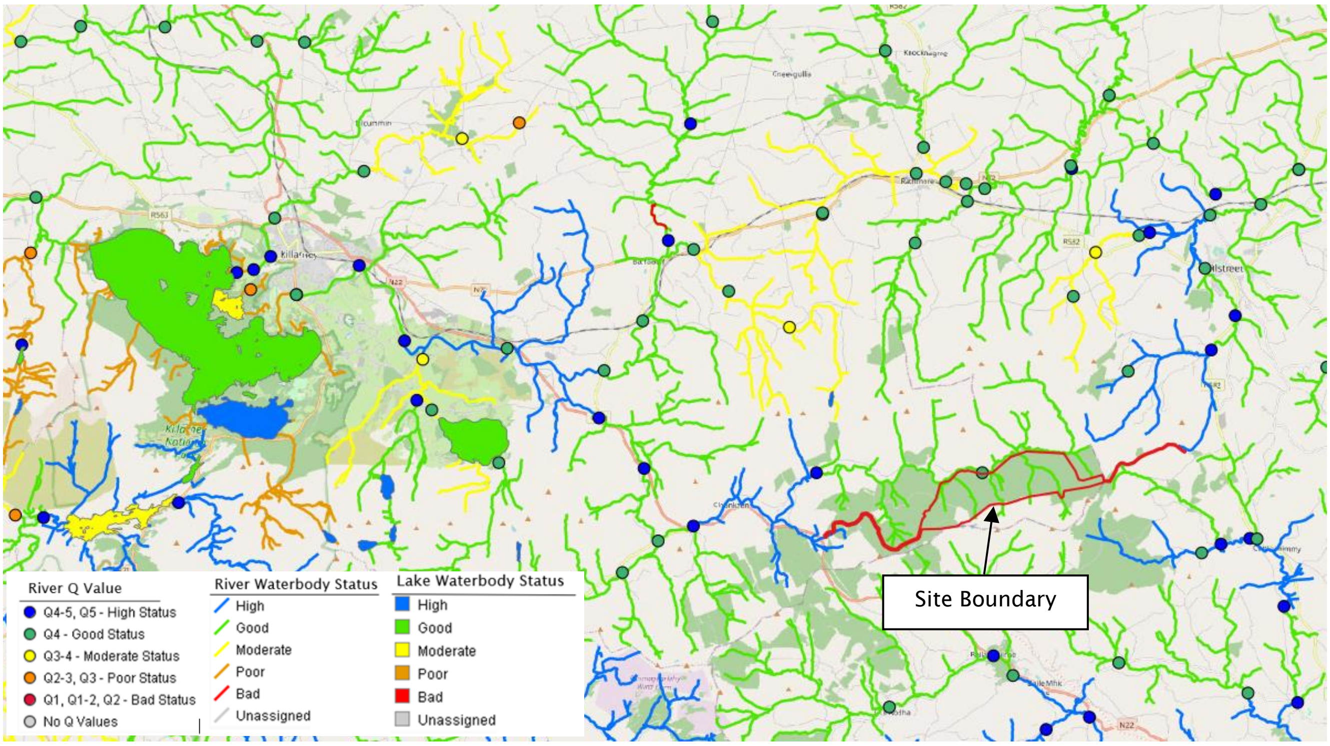


Figure 2-10 – WFD Waterbody Status (2016 - 2021) in Study Area

The WFD waterbody status results are recorded in accordance with the European Communities (Water Policy) Regulations, 2003[1]. The regulation objectives include attaining a 'Good' or 'High' status in all waterbodies. EPA mapping indicates that sections of the River Clydagh / River Flesk, including a reach adjacent to the Site Boundary, are currently 'at risk' of failing to achieve the WFD objectives.

Between the Site Boundary and Lough Leane, the are another two sub-basins within the River Flesk catchment noted to be 'at risk' and one 'under review'. Lough Leane is classified as 'not at risk' of failing to meet the WFD objectives.

The 'at risk' status allocated to portions of the River Clydagh / River Flesk indicate that there are significant pressures on the catchment. As a result, approval of any nutrient or sediment runoff associated with the proposed felling / construction activities will require demonstration that there will be a negligible impact on the water quality of the receiving water environment. Further detail on WFD status, significant pressures, and 'at risk' status, is provided in EIA Chapter 11.

[1] Irish Statutory Instruments, SI No. 722 of 2003. European Communities (Water Policy) Regulations, 2003.

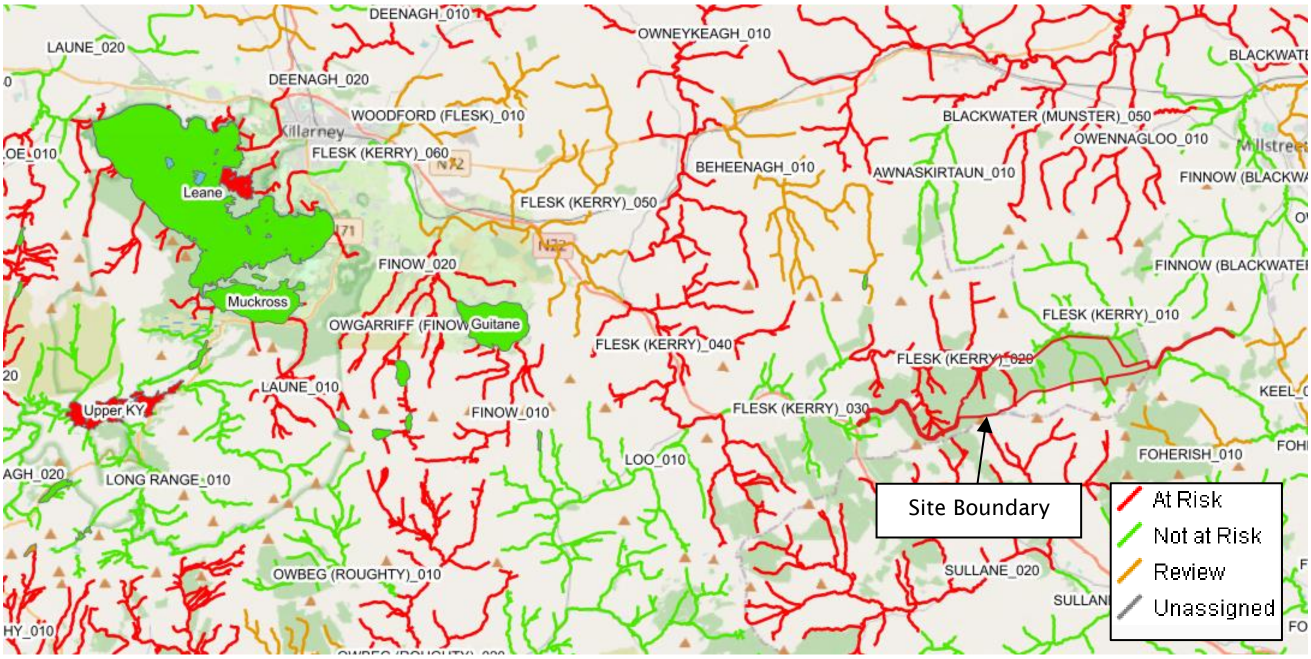


Figure 2-11 – Waterbody Risk Status in Study Area

2.3.3.2 Special Areas of Conservation

The River Clydagh, River Flesk, and Lough Leane are designated as part of the Killarney National Park, Macgillycuddy's Reeks And Caragh River Catchment Special Area of Conservation (SAC) (Site Code: 000365). The locations of the Site Boundary, River Clydagh, River Flesk, and Lough Leane within the SAC are shown in Figure 2-12.

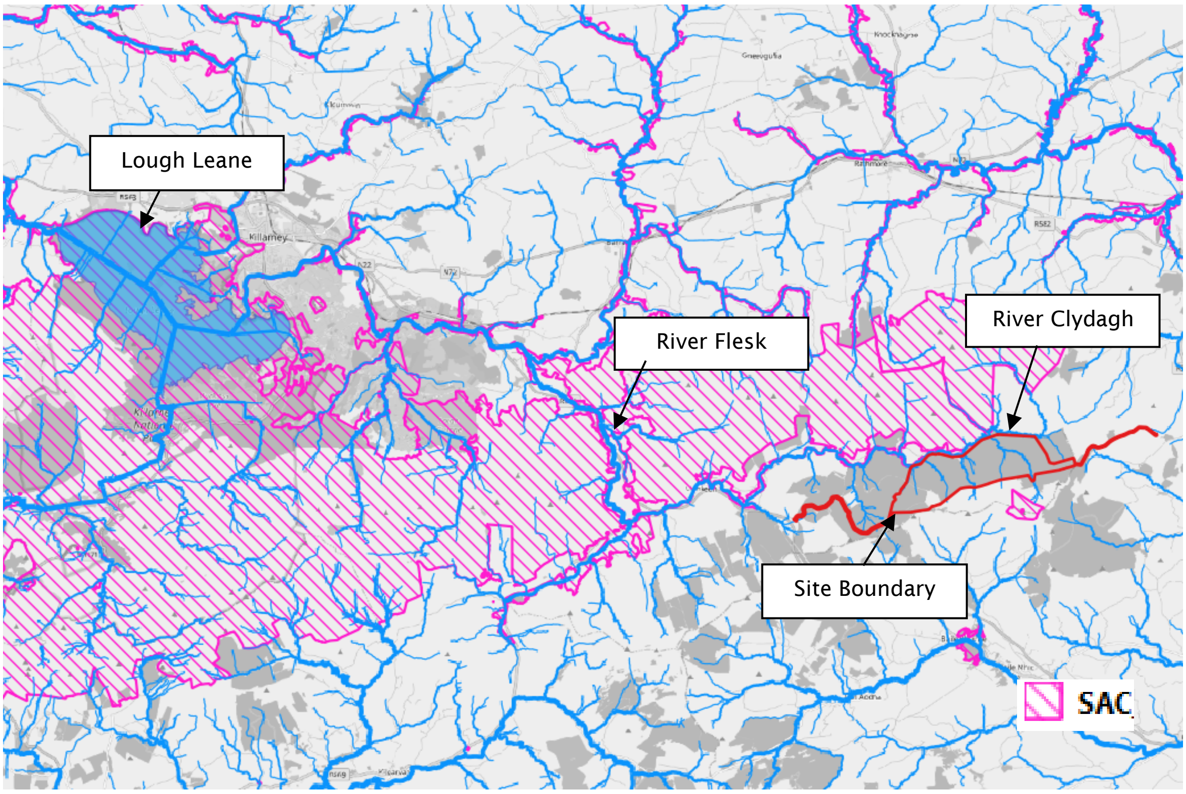


Figure 2-12 – Special Area of Conservation

SACs are designated under the EU Habitats Directive which lists habitats and species within their boundaries that must be protected. The National Parks and Wildlife Service (NPWS) have set out conservation objectives for the Killarney National Park, Macgillycuddy's Reeks And Caragh River Catchment SAC and classify the site as qualifying as an SAC due to the presence of the following habitats and/or species listed on Annex I/II of the EU Habitats Directive (* = priority under the Habitats Directive):

- Oligotrophic waters containing very few minerals of sandy plains (Littorelletalia uniflorae)
- Oligotrophic to mesotrophic standing waters with vegetation of the Littorelletea uniflorae and/or Isoeto-Nanojuncetea
- Water courses of plain to montane levels with the Ranunculion fluitantis and Callitricho-Batrachion vegetation
- Northern Atlantic wet heaths with Erica tetralix
- European dry heaths
- Alpine and Boreal heaths
- Juniperus communis formations on heaths or calcareous grasslands
- Calaminarian grasslands of the Violetalia calaminariae
- Molinia meadows on calcareous, peaty or clayey-silt-laden soils (Molinion caeruleae)
- Blanket bogs (* if active bog)
- Depressions on peat substrates of the Rhynchosporion
- Old sessile oak woods with Ilex and Blechnum in the British Isles
- Alluvial forests with Alnus glutinosa and Fraxinus excelsior (Alno-Padion, Alnion incanae, Salicion albae)
- Taxus baccata woods of the British Isles
- Geomalacus maculosus (Kerry Slug)
- Margaritifera (Freshwater Pearl Mussel)
- Euphydryas aurinia (Marsh Fritillary)
- Petromyzon marinus (Sea Lamprey)
- Lampetra planeri (Brook Lamprey)
- Lampetra fluviatilis (River Lamprey)
- Salmo salar (Salmon)
- Rhinolophus hipposideros (Lesser Horseshoe Bat)
- Lutra (Otter)
- Trichomanes speciosum (Killarney Fern)
- Najas flexilis (Slender Naiad)
- Alosa fallax killarnensis (Killarney Shad)

The SAC designation and qualifying interests specific to the study area were identified by further review of the SAC site synopsis and conservation objectives. These state that Lough Leane is a site for wintering wildfowl and identify the Lough as having an important fish community, containing a freshwater population of Killarney shad (which is unique to Lough Leane) and Arctic charr. The site synopsis also notes that Lough Leane has previously been subject to eutrophication and failed to meet the 'good' nutrient status of the WFD in 2007-09 and 2010-12.

The conservation objectives note the presence of Sea Lamprey and Salmon within the River Clydagh / River Flesk. An aquatic survey (refer to **Appendix 8-3**) indicated the presence of freshwater pearl mussel (FWPM) with the River Flesk, which is also a qualifying interest of the SAC.

Discharge of surface run water including reduced quality runoff will discharge to tributaries shortly upstream of the SAC boundary and would therefore likely impact on water quality in the area. The scope of this assessment study will include assessment of the resulting water quality in this area to comply with

Habitats Directive on the Conservation of Natural Habitats and of Wild Fauna and Flora (92/43/EEC). The river has not been designated by the EPA as a salmonid river, however, as the presence of salmon is identified in the SAC site synopsis, the scope of this study will also include assessment of the resulting water quality to comply with the Salmonid Water Regulations, 1988.

2.3.3.3 Special Protected Area

Lough Leane is part of the Killarney National Park designated Special Protection Area (SPA) (Site Code: 004038). The locations of the Site Boundary, River Clydagh, River Flesk, and Lough Leane within the SPA are shown in Figure 2-13.

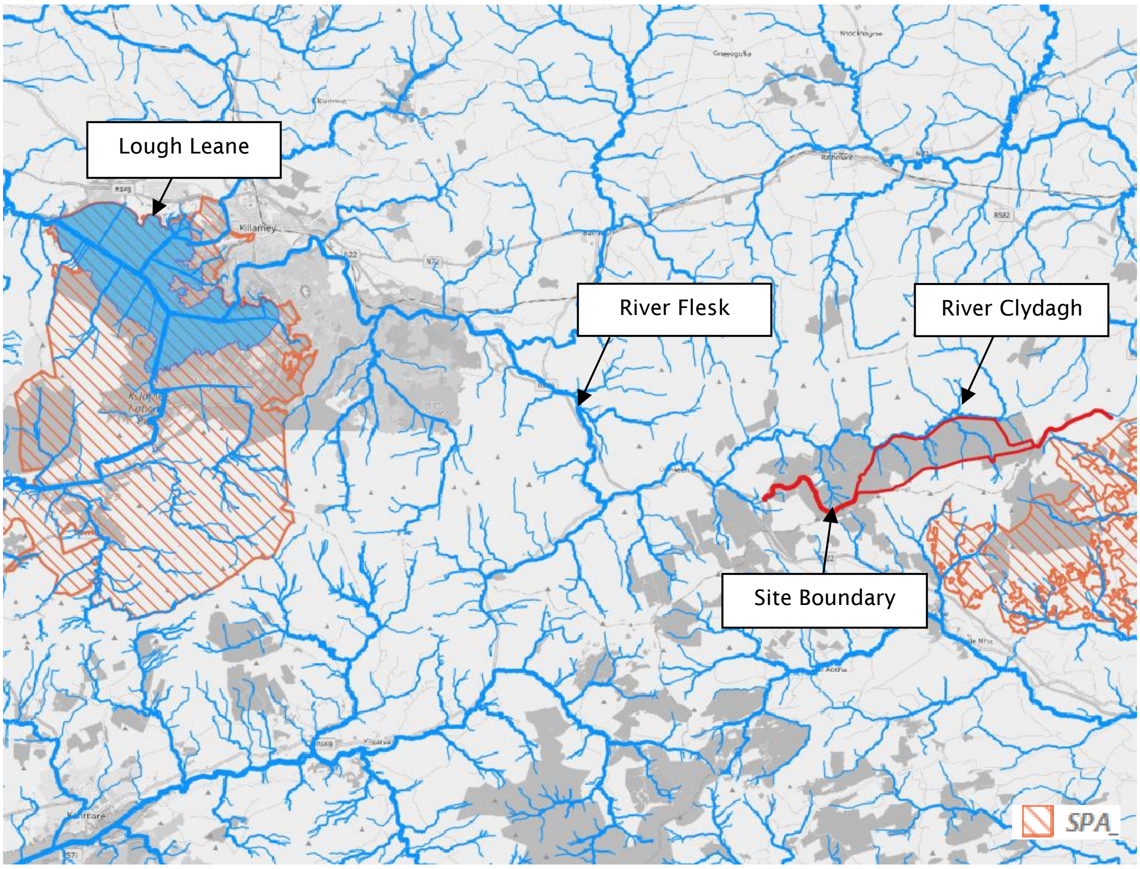


Figure 2-13 – Special Protection Area

SPAs are designated under the EU Birds Directive (79/409/EEC) which lists rare and vulnerable species within SPAs that must be protected. The lough qualifies as an SPA under the EU Birds Directive of special conservation interest due to the presence of Merlin (*Falco columbarius*) and Greenland White-fronted Goose (*Anser albifrons flavirostris*) species as listed on Annex I of the EU Birds Directive. Lough Leane also supports a variety of wintering waterfowl species, including Mute Swan, Teal, Mallard, Pochard, Tufted Duck, Goldeneye, Little Grebe, Cormorant, Coot and Black-headed Gull. It is classed as a mesotrophic system, indicating it consists of medium nutrient levels and intermediate levels of productivity.

2.3.3.4 Nutrient Sensitive Areas – Lakes

Lough Leane is listed as a nutrient sensitive area in accordance with the Urban Wastewater Treatment (UWWT) Directive 91/271/EEC and the Urban Wastewater Treatment (Amendment) Regulations, 2004 & 2010. The scope of this study will therefore include assessment of the resulting water quality in this area to comply with these regulations.

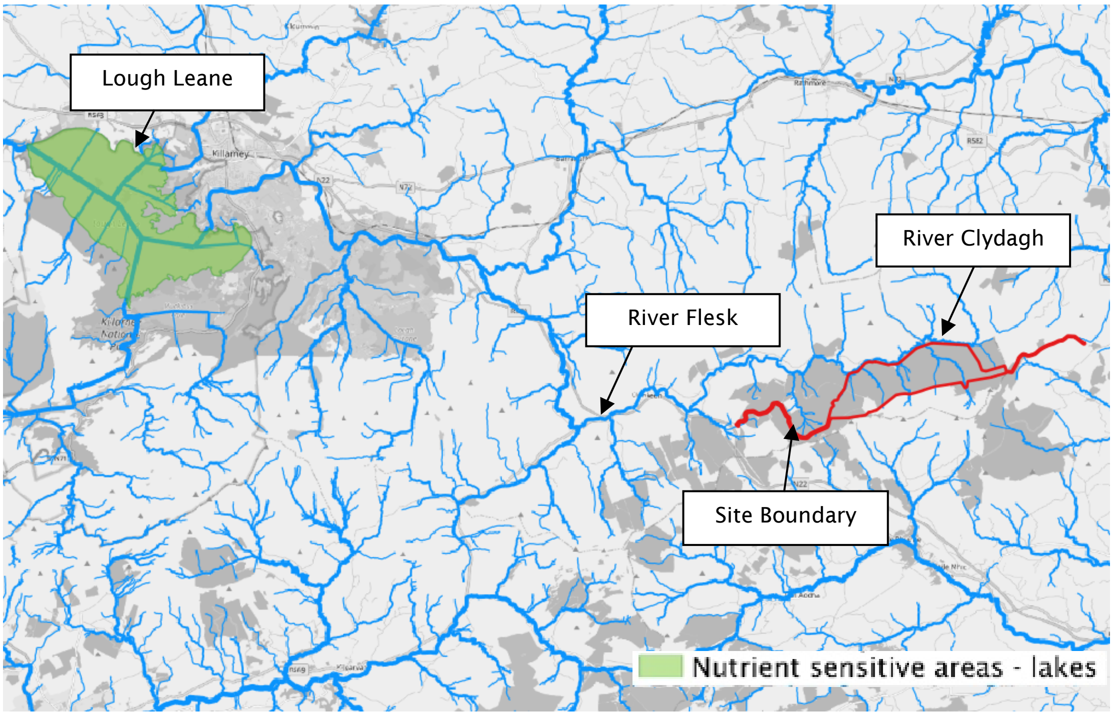


Figure 2-14 – Nutrient Sensitive Areas - Lakes

2.3.3.5 Drinking Water River / Groundwater

A sub-basin within the River Clydagh / River Flesk catchment is used as a source for drinking water, with part of the river reach classified as a Drinking Water River under Article 7 of the Abstraction for Drinking Water Regulations, 1989. Groundwater bodies in the surrounding land are classified as Drinking Water Groundwater under the same regulations.

The nearest abstraction point for public drinking water lies c. 10 km downstream of the Proposed Development site and falls within the model extent. As a result, drinking water legislation has been reviewed as part of the screening assessment.

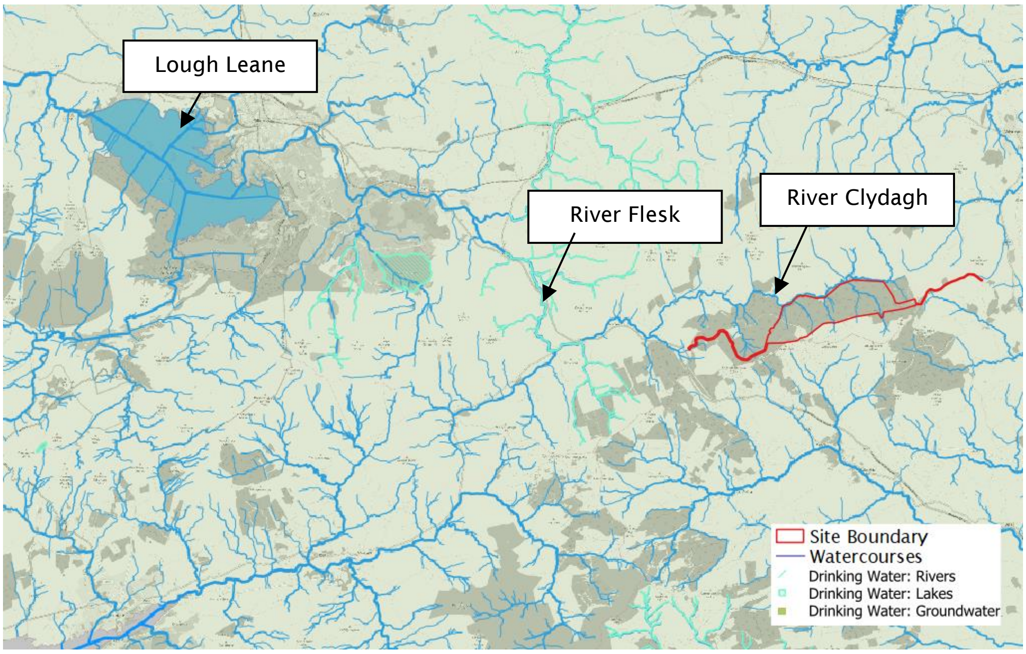


Figure 2-15 – Drinking Water River / Groundwater

3 SCREENING ASSESSMENT

A screening assessment has been undertaken to determine the relevant water quality legislation enacted and applicable at the Proposed Development site. From this, WQ parameters that require assessment at the site to demonstrate compliance with the relevant legislation can be determined.

The relevant regulatory framework directives are as follows:

- Urban Wastewater Treatment (Amendment) Regulations, 2004[2]
- Urban Wastewater Treatment (Amendment) Regulations, 2010[3]
- Urban Wastewater Treatment (UWWT) Directive 91/271/EEC[4]
- The European Union (drinking water) Regulations, 2014[5]
- Surface Water (intended for the abstraction of drinking water) Regulations, 1989[6]
- Surface Water Regulations, 2009[7]
- Surface Water (Amendment) Regulations, 2019[8]
- The European Union Habitats Directive, 92/43/EEC[9]
- Salmonid Water Regulations, 1988[10]
- Freshwater Fish Directive (78/659 EEC) for salmonid waters[11]
- Freshwater Fish Directive (06/55 EEC) for salmonid waters[12]

The relevant WQ parameters identified by the screening assessment, along with the corresponding legislation and EQS threshold levels, are presented in Table 3-1.

Felling and construction operations associated with the Proposed Development have the potential to release nutrients and sediments via surface water discharge into the River Clydagh (a tributary of the River Flesk), which are both classified under the Water Framework Directive as 'river' waterbodies. The River Flesk ultimately discharges to Lough Leane, which is designated under the Water Framework Directive as a 'lake' waterbody. The EQS targets presented in the table are reflective of this.

Table 3-1 - EQS Threshold Levels for Relevant WQ Parameters

Parameter	WQ Directive	Target Level
Total Phosphorous (TP) (mg/l P)	Freshwater Fish Directive (78/659 EEC) for salmonid waters	0.2
Molybdate Reactive Phosphorous (MRP) (mg/l P)	Surface Water (Amendment) Regulations, 2019	0.025 (mean)

2 Irish Statutory Instruments, SI No. 440 of 2004. Urban Wastewater Treatment (Amendment) Regulations, 2004

3 Irish Statutory Instruments, SI No. 48 of 2010. Urban Wastewater Treatment (Amendment) Regulations, 2010

4 European Union, Council Directive 91/271/EEC of 21 May 1991 concerning Urban Wastewater Treatment

5 European Union, SI No. 122 of 2014. European Union (Drinking Water) Regulations, 2014.

6 Irish Statutory Instruments, SI No. 294 of 1989. European Communities (Quality of Surface Water Intended for the Abstraction of Drinking Water) Regulations, 1989.

7 Irish Statutory Instruments, SI No. 272 of 2009. European Communities Environmental Objectives (Surface Waters) Regulations, 2009.

8 Irish Statutory Instruments, SI No. 77 of 2019. European Union Environmental Objectives (Surface Waters) (Amendment) Regulations, 2019.

9 European Union, Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats of wild fauna and flora, 1992

10 Irish Statutory Instruments, SI No. 293 of 1998. European Communities (Quality of Salmonid Waters) Regulations, 1988.

11 EC Directive 78/659/EEC, "The Quality of Fresh Waters Needing Protection or Improvement in order to Support Fish Life", 1978.

12 EU Directive 2006/55/EC, "The Quality of Fresh Waters Needing Protection or Improvement in order to Support Fish Life", 2006.

Parameter	WQ Directive	Target Level
Total Ammonium (mg/l NH_4) / Ammonium nitrogen (mg/l NH_4-N)	Freshwater Fish Directive for salmonid waters, 1978	0.04
Total Suspended Solids (TSS) (mg/l)	Salmonid Water Regulations, 1988	25
Nitrogen (mg/l N)	Surface Water Regulations, 1989	3
Nitrate (mg/l NO_3) Nitrate (mg/l N)	Surface Water Regulations, 1989	50 11.3
Nitrate (mg/l NO_3) Nitrate (mg/l N)	Surrogate Nitrate EQS for 'high' WFD status as defined by EPA	4 0.9
Nitrite (mg/l NO_2) Nitrite (mg/l N)	Directive 2006/44/EC on the quality of fresh waters needing protection or improvement in order to support fish life, 2006	0.01 0.003
Total Oxidised Nitrogen TON (mg/l N)	-	0.9

There is no critical limit for Ammonium-nitrogen for river waterbodies in Ireland. The EQS limit for total ammonium has therefore been adopted as a proxy value.

The critical limit for nitrate is specified under the Surface Water Regulations, 1989 as 11.3 mg/l N (or 50mg/l NO_3). However, the EPA has defined a surrogate nitrate EQS limit to achieve 'High' WFD status in Irish river waterbodies as 0.9 mg/l N (or 4mg/l NO_3) [13]. As 0.9 mg/l N is the more conservative value, it has been adopted as the critical limit for nitrate in this assessment. It should be noted that as ambient monitoring data for nitrate has been provided in mg/l N, the target level adopted will also be per mg/l N.

Oxidised forms of nitrogen include nitrite (in mg/l N) and nitrate (in mg/l N). In water or wastewater applications, total oxidised nitrogen can be adopted as the sum of nitrate and nitrite. Nitrite levels are generally lower than nitrate levels and the target level specified by the European Parliament Directive 2006/44/EC for salmonid waters is 0.01 mg/l NO2 (0.003 mg/l N) which is considerably lower than the 0.9mg/l N limit for nitrate. Therefore, for the purposes of this assessment, a conservative approach has been adopted and the critical limit for nitrate has also been applied to total oxidised nitrogen.

[13] EPA, "Integrated Water Quality Assessment, 2013. North Western & Neagh Bann River Basin.", 2014.

4 ASSESSMENT OF NUTRIENTS AT LOUGH LEANE

4.1 Preamble

Lough Leane has been subject to historic eutrophication and excessive nutrient-loading resulting in the formation of toxic algal blooms. Felling activities associated with the proposed development will result in the release of phosphorous and nitrogen into the downstream catchment. This assessment has, therefore, assessed the water quality parameters primarily responsible for eutrophication (i.e., phosphorous and nitrogen) and their concentrations when runoff reaches Lough Leane. Predicted concentrations were compared against EQS thresholds set out in EU Water Quality Directives to determine compliance of nutrient runoff due to proposed felling operations.

A screening assessment (see Section 3) and review of environmental receptors in the study area (see Section 2.3.3) identified water quality legislation and nutrient parameters relevant to the site catchment. A review of EPA recommended literature further clarified specific pollutants associated with clear felling. Based on this, the following water quality parameters have been included in the nutrient assessment of the Lough Leane:

- Molybdate Reactive Phosphorous (MRP)
- Total Oxidised Nitrogen (TON)
- Ammonium Nitrogen (NH_4-N)
- Total Phosphorous (TP)

To assess compliance of phosphorous and nitrogen parameters at Lough Leane, far field dispersion modelling has been carried out. A sufficiently detailed Infoworks ICM 1D hydrodynamic river model has been developed to model the River Clydagh / River Flesk from immediately downstream of the Site Boundary to its confluence with Lough Leane, allowing accurate determination of pollutant concentrations along the reach and into the lough.

The 1D modelling assessment was based on a felled area of 241 ha. This represents an unrealistic scenario in which the area of clear felling is considerably greater than the proposed felling area of 144 ha. Adopting this approach ensured conservative results as exaggerated nutrient concentrations were modelled as discharging to the watercourse and downstream into Lough Leane.

The hydrology scenario considered is the 50%ile mean flow. Further details of the hydrology assessment are given in Section 4.2. Background water quality was determined based on monitoring undertaken along the river, as described in Section 4.3.1 and proposed nutrient discharge was determined based on a detailed literature review and assessment of the upper reaches of the River Clydagh, as discussed in Section 4.3.2.

4.2 Hydrological Assessment

4.2.1 Catchment Extent

The downstream catchment boundary for the River Clydagh / River Flesk was determined based on GIS-based flow raster accumulation analysis of 25 m DTM height data, which was deemed suitable for representation of the catchment flows to the river and its tributaries. The resulting catchment extent, which has an area of 378 km^2, is shown in Figure 4-1.

The catchment boundary was validated by undertaking a review of watercourse mapping which confirm the contributing flows to the catchment.

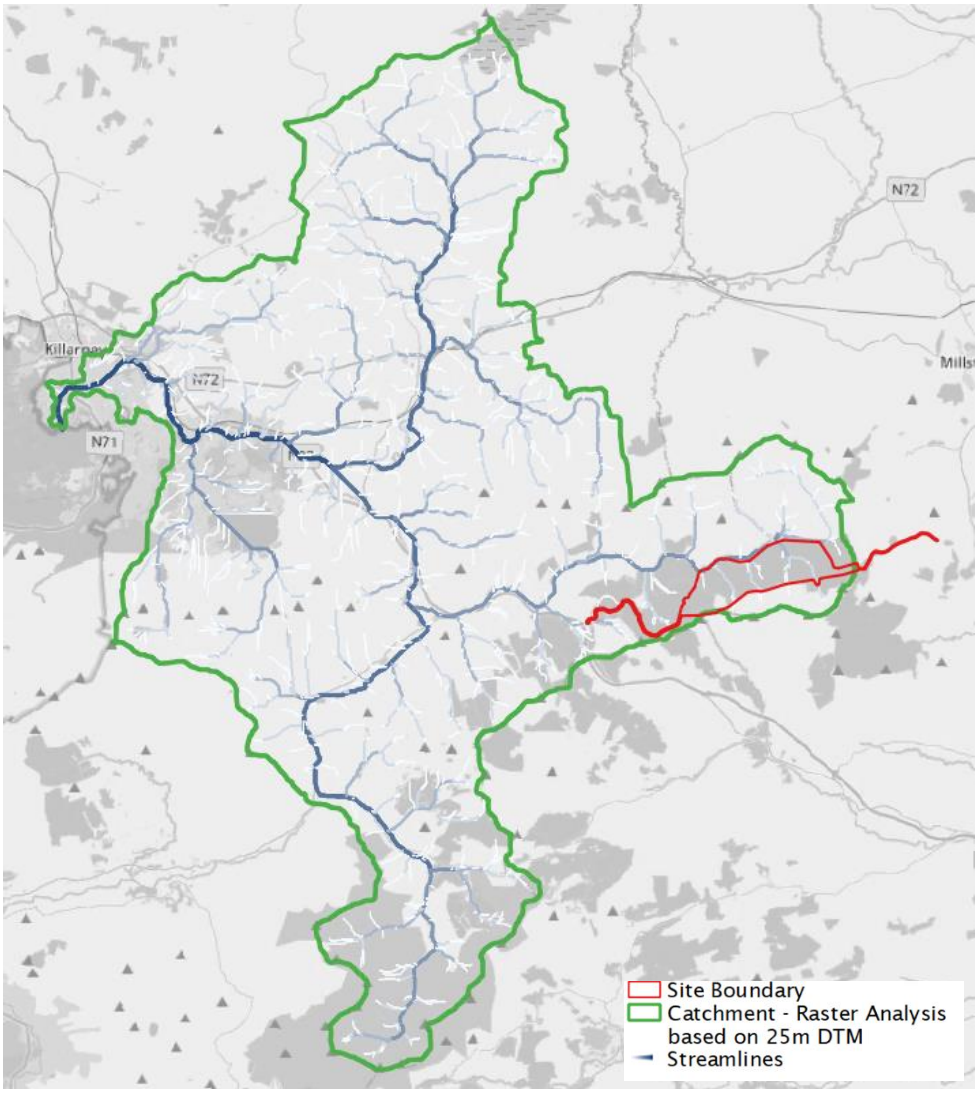


Figure 4-1 Downstream Catchment

4.2.2 Mean Flow Estimation

Hydrological analysis of the catchment was required to determine Q50 (50%-ile) flow rates, which are critical to the nutrient water quality assessment. Q50 flow conditions represent the mean annual scenario, in which fluvial inflows are long-term and continuous.

A hydrometric gauge is located c. 2 km upstream of where the river discharges to Lough Leane at Flesk Bridge (Station number 22006). The gauge has a well-established record of flow spanning 75 years. 50%ile mean flow rates were calculated from the gauge's flow record. The resulting flows were scaled to account for differences in the catchment area at the gauge and at the downstream catchment extent. Detailed calculations for the determination of the mean flow value are included in Annex B.

The resulting 50%ile flow for the River Clydagh is 10.11 m^3/s.

Application of the hydrology used in the 1D modelling study is described below.

4.2.3 Application to 1D Model

Application of calculated hydrology to the model via lateral and point inflows was based on contributing area and applied in such a manner to reflect dispersion along the reach. Application of the hydrology with flow estimation calculated downstream of the Proposed Development site, but flow applied upstream of the site, is a conservative approach. Application of hydrology to the 1D model is shown in Figure **4-2** and the flows applied along the reach are presented in Table 4-1.

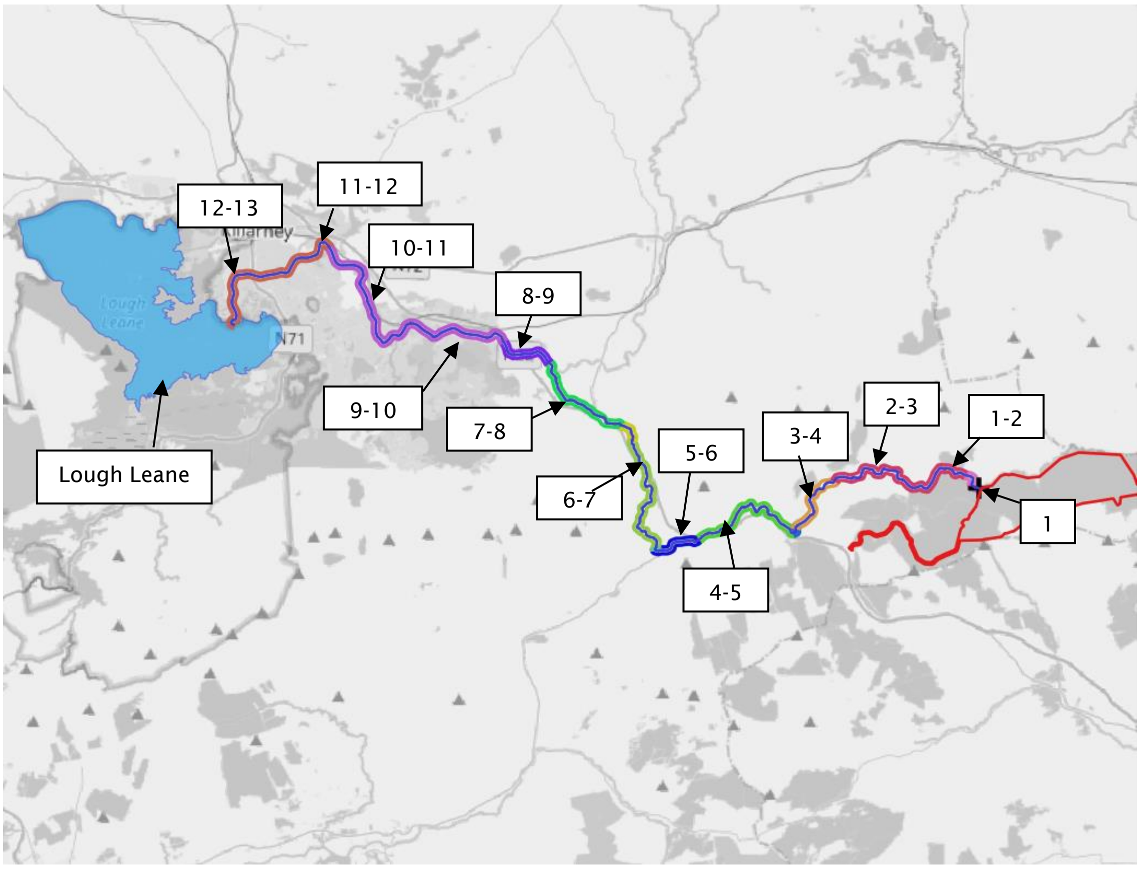


Figure 4-2 Application of Hydrology to the 1D Model

Table 4-1 – Hydrology Applied to the 1D Model

Location	Application	Contributing Area (km²)	Percentage of Total 50%ile Mean Flow (%)
1	Point Inflow	2.41	0.64
1-2	Lateral Inflow	21.42	5.67
2-3	Lateral Inflow	4.73	1.25
3-4	Lateral Inflow	13.60	3.60
4-5	Lateral Inflow	9.29	2.46
5-6	Lateral Inflow	3.48	0.92
6-7	Lateral Inflow	13.80	3.65
7-8	Lateral Inflow	0.70	0.19
8-9	Lateral Inflow	99.70	26.37
9-10	Lateral Inflow	6.08	1.61
10-11	Lateral Inflow	115.50	30.55
11-12	Lateral Inflow	15.32	4.05
12-13	Lateral Inflow	72.01	19.05

4.3 Water Quality Concentrations

4.3.1 Ambient and Storm Concentrations

Project-specific water quality monitoring was commissioned by the Applicant to establish baseline conditions at, and downstream of, the Proposed Development site to inform this assessment. Ambient background concentrations were recorded at monitoring locations positioned at strategic points on watercourses that will receive runoff from the Proposed Development.

Samples were collected between February 2021 and October 2021, including over periods of two known storm events (summer and winter). The monitoring sample locations are shown in Figure 4-3 and the recorded data is included in Annex A.

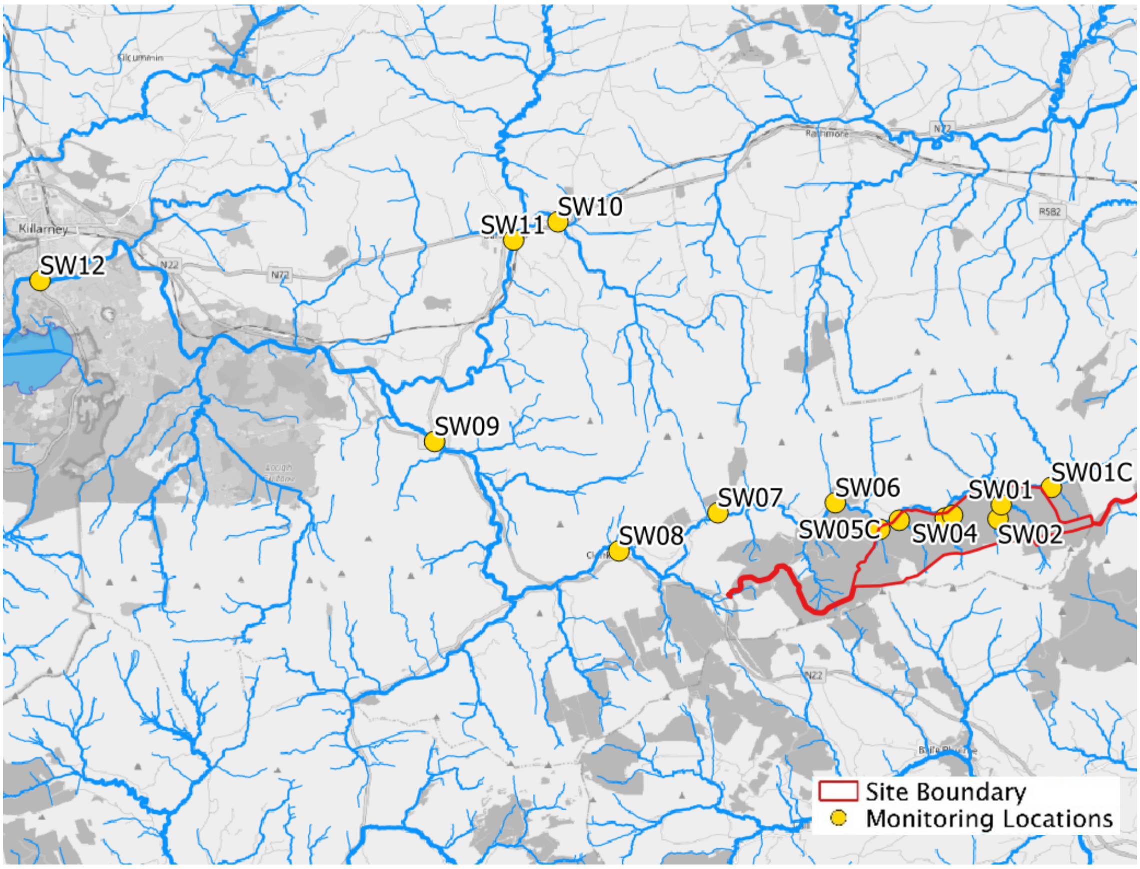


Figure 4-3 WQ Monitoring Locations Along River Clydagh / River Flesk and Tributaries

Background concentrations of the WQ parameters obtained during ambient and storm conditions are accounted for in the assessment. The following data has been used to inform WQ concentrations for the assessment of phosphorous and nitrogen along the River Clydagh / Flesk and into Lough Leane.

- All monitored water quality values obtained from stations SW06, SW07, SW08-01, SW08-02 (located on the River Clydagh), and SW09 and SW12 (located on the River Flesk). All these stations are located downstream of the Proposed Development site. The available chemistry data was recorded on 03/02/21, 14/04/21, 27/07/21, and 18/10/21 and on two storm events; 02/02/21 and 13/08/21. The maximum value for each parameter was selected as the ambient concentration in the river.

A review of the available monitoring data was undertaken to assess the suitability of its use in the assessment. The review, which is detailed in Annex A, showed no significant outliers in the phosphorous or nitrogen data. The full dataset was therefore deemed suitable for use to determine ambient conditions.

The review also highlighted the influence of seasonality on the background concentrations, with higher concentrations recorded over winter months for the pollutants at the majority of the monitoring locations. This tends to suggest that existing concentrations are influenced by reduced quality runoff entrained in seasonal rainfall runoff, rather than rainfall runoff offering improved dilution of particular sources of pollution. Adopting a maximum concentration incorporates the slight bias effect of higher winter concentrations. For a mean annual flow scenario, adopting higher winter values to represent ambient conditions is a conservative approach.

A review of EPA data confirmed that there are a number of discharges and other pollutant sources located downstream of the Proposed Development site. However, the influence of any existing discharges on ambient water quality in the river will be accounted for in the downstream monitoring.

Table 4-2 below presents the ambient WQ concentrations for each parameter included in the 1D modelling assessment of nutrients along the River Clydagh / River Flesk and into Lough Leane. It should be noted tributaries of the river were not included in the 1D model extent, therefore, no background concentrations for the tributaries were required. Any influence of tributary watercourses on ambient conditions in the river will be captured in the downstream monitoring data.

Application of the ambient concentrations to the model is discussed in Section 4.4.5.

Table 4-2 – Background Concentrations of Nutrients Along the River Clydagh / River Flesk

Parameter	Background River Clydagh Concentration
Molybdate Reactive Phosphorous (MRP) (mg/l PO_4-P)	0.013
Total Phosphorous (mg/l P)	0.033
Total Ammonium (mg/l NH_4) / Ammonium nitrogen (mg/l NH_4-N)	0.028
Total Oxidised Nitrogen (mg/l N)	0.393

4.3.2 Discharge Concentrations to Outfall

Nutrient discharges released from the Proposed Development site were determined based on a calculation which determined maximum and average concentrations of nutrient runoff to the downstream site catchment under mean annual flow (Q50) conditions based on an exaggerated felled area of 241 ha.

The calculation considered both the ambient concentrations in the river (presented in Table 4-2) and the nutrient concentrations released during clear-felling. Nutrient discharges associated with clear-felling of the site are based on findings of a detailed literature review and consultation with the EPA. The EPA, in a meeting held on 14/11/22, recommended the EPA-funded Hydrofor project[14] as an appropriate study to use to determine phosphorous and nitrate concentrations resulting from felling operations.

The Hydrofor project identified a study based in County Mayo which investigated and quantified the impact of peatland forest harvesting operations on nutrient discharge to the Gleannamong River. The study considered a control catchment (in which no clear-felling occurred) and a study catchment (in which clear-felling of the catchment took place). Conditions in both catchments were monitored for a year prior to the clear-felling and for 15 months afterwards with the aim of assessing the mobilisation of nutrients due to clear-felling operations and to quantify the effects of implementation of best management practises for forestry harvesting. The peer-reviewed paper by J. Finnegan et., al[15] was reviewed and the findings determined as suitable for use in this assessment. That study determined flow-weighted mean

[14] Kelly-Quinn, M., Bruen, M., Harrison, S., Healy, M., Clarke, J., Feeley, H.B., Blacklocke, S., 2014. HYDROFOR Project Synthesis Report: Assessment of the Impacts of Forest Operations on the Ecological Quality of Water (2007-WQ-CD-2-S1), EPA Research Report.

[15] J. Finnegan, J.T. Regan, M. O'Connor, P. Wilson, M.G. Healy. Implications of applied best management practise for peatland forest harvesting. Journal of Ecological Engineering 63 (2014) 12-26. 2014.

concentrations (FWMC) of specific nutrients by comparing the resulting concentrations in the river from a control catchment (in which no clear-felling occurred) and from a study catchment (in which clear-felling of the catchment took place). The nutrients assessed were ammonium nitrogen, total oxidised nitrogen, molybdate reactive phosphorous and total phosphorous. Utilising the flow-weighted mean concentration allowed a comparison of results from the catchments to be conducted, independent of flow.

In discussions with the EPA on the most suitable methodology for this water quality assessment of the Proposed Development, it was advised to determine discharge concentrations based on flow-weighted mean concentrations.

Nutrient concentrations discharging to the catchment as a result of proposed tree felling were estimated based on the findings of Finnegan et., al. The maximum and averaged flow-weighted mean concentrations for each parameter as determined by Finnegan et., al, were scaled pro-rata to the proposed felling site, based on an exaggerated felled area of 241 ha. The discharge concentrations adopted are highly conservative and are not representative of concentrations observed at and shortly downstream of the site while clear-felling in the Clydagh catchment has been ongoing. For example, monitoring data measured throughout the site during felling operations recorded maximum levels of total phosphorous and molybdate reactive phosphorous of 0.084mg/l and 0.057mg/l, respectively. These recorded concentrations are lower than the maximum discharge concentrations adopted for input into the hydraulic model (see Table 4-3). No catchment-specific monitoring data was available for ammonium nitrogen and total oxidised nitrogen.

The maximum and average nutrient concentrations at the downstream point of the upper Clydagh Reach were estimated and applied as input pollutographs to the hydraulic model. The concentrations are presented below, and the nutrient discharge calculations are provided in Annex C. Application of the discharge concentrations to the model is discussed in Section 4.4.5.

Table 4-3 – Nutrient Discharge Concentrations Used in the 1D Model

Maximum FMWC	
Parameter	Discharge Concentration (mg/l)
Total Phosphorous (mg/l P)	0.32
Molybdate Reactive Phosphorous (mg/l P)	0.07
Ammonium nitrogen (mg/l NH_4-N)	0.41
Total Oxidised Nitrogen (mg/l N)	0.80
Average FMWC	
Parameter	Discharge Concentration (mg/l)
Total Phosphorous (mg/l P)	0.15
Molybdate Reactive Phosphorous (mg/l P)	0.04
Ammonium nitrogen (mg/l NH_4-N)	0.19
Total Oxidised Nitrogen (mg/l N)	0.51

4.4 Hydraulic and Water Quality Model Simulation: 1D Model

Far field dispersion modelling has been carried out to simulate the transport and dispersal of the relevant WQ parameters presented in Section 3 of this report. The aim of the 1D far field study is to assess compliance of the phosphorous and nitrogen parameters at Lough Leane with EQS threshold levels and adherence with the relevant EU Water Quality Directives.

A sufficiently detailed Infoworks ICM 1D hydrodynamic model of the River Clydagh / River Flesk has been developed as part of this study. The model consists of both a hydrodynamic component and a water quality component which are dynamically coupled and run together as a single model. Both the hydraulic and water quality components of the model simulation are discussed in the following sections.

Due to the complexity of the calculations required to determine the mechanisms of dispersal and mixing within the c. 28 km long river reach, and the resulting model simulation time, it was determined that a 1D model would be most suitable for the assessment. No out of bank flows occur under Q50 flow rates therefore, a 2D model component was not required to capture overland flows.

The primary mechanisms by which dispersion of contaminants occurs is the downstream flow of the river and natural dispersal along the reach. The 1D model simulates this via continuity equations and, therefore, captures the primary mechanism by which pollutants are advected and dispersed.

The modelled scenario is an exaggerated proposed case, in which nutrient runoff resulting from felling of 241 ha discharges into the River Clydagh under 50%ile annual mean flows.

4.4.1 Hydraulic Model Simulation

The river reach has been modelled using unsteady state techniques using ICM v 2021.2 software with the most conservative Q50 mean flows predicted for the purpose of the Lough Leane water quality assessment in accordance with the precautionary principal.

The river channel has been modelled in the 1D. Model extents were informed through a site walkover which investigated both the river channel, lough and surrounding area.

Figure 4-4 details the model extents and the model elements incorporated in the 1D model build process. Each of the elements has been detailed further in the subsequent sections of this report with information provided regarding the source of the data and justification of the parameters selected.

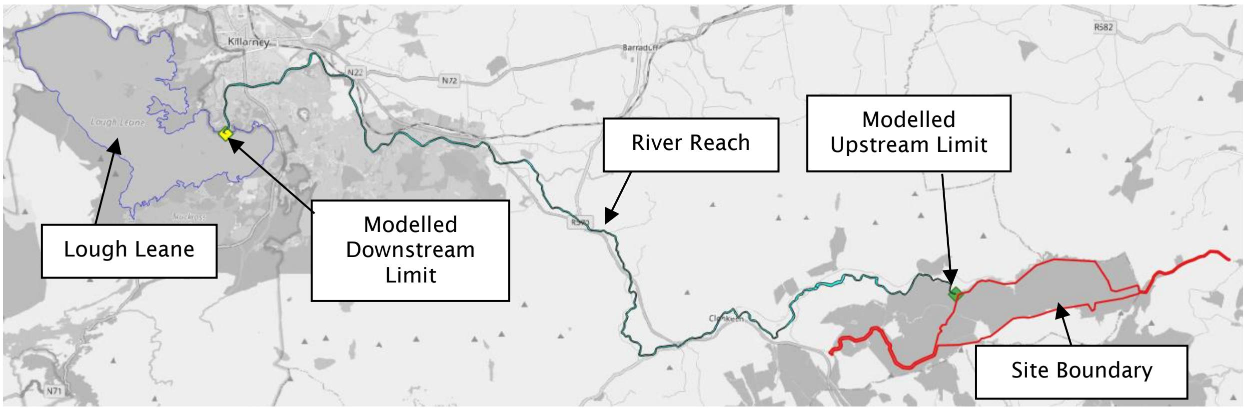


Figure 4-4 1-D Model Geometry

4.4.2 1-Dimensional River Reaches

The geometry of natural channels is irregular and cannot be characterised using simple mathematical relationships. Therefore, representation in mathematical models requires that the stream geometry, in the form of discrete cross sections, be taken transversely at key locations in the watercourse.

Invert levels and bank levels of the River Clydagh / River Flesk watercourses in the vicinity of the Proposed Development site were provided in a high-resolution topographic survey of the site completed by a third-party surveyor.

The positions of the model cross sections were based primarily on the location of significant changes in channel and bank geometry. Detail from the topographic survey determined the channel geometry.

The roughness of the river reach is represented by applying Manning's n roughness values to the river sections for the river channel. A conservative roughness value of 0.035 was used, representing a clean, straight reach with some stones and weeds.

4.4.2.1 Boundary Condition

The downstream 1D boundary condition is set to a normal depth estimated for the watercourse gradient at that point.

4.4.3 Model Inflows

Fluvial inflows were applied as detailed in Section 4.2.3. The River Clydagh is also included as a source of ambient pollutant loadings, this is discussed further in Section 4.4.5.

Discharge nutrient runoff resulting from felling activities is also included in the model. Discharges were applied based on Q50 flow conditions scaled to a felled area of 241 ha via a lateral inflow at the upstream model limit. The upstream modelled limit corresponds to the downstream extent of the Site Boundary. The concentrations of the various pollutants assessed, along with their application to the model are discussed in Section 4.4.5 below.

The location of both the fluvial inflow along with the proposed felling plan within the site is shown in the figure below.

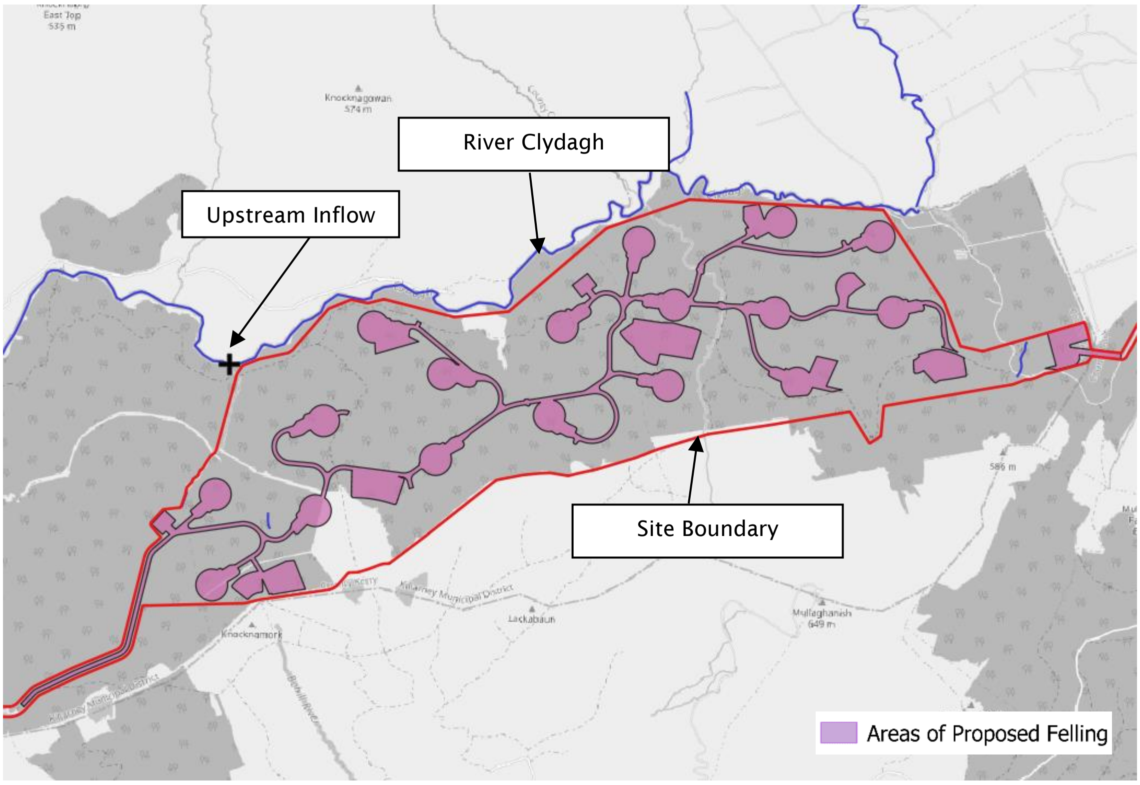


Figure 4-5 Upstream 1D Model Inflow Location

4.4.4 Water Quality Model Simulation

The water quality component of the model is linked directly to the hydraulic model described in the previous section. The combined model represents advection and dispersion of pollutants in the 1D domain.

Each of the elements of the water quality model component are detailed in the subsequent sections of this report with information provided regarding the source of the data and justification of the parameters selected.

4.4.4.1 Dispersion Coefficient

The dispersion coefficient is a key parameter of the water quality model and needs to be specified as part of the 1D model build. The specification of the dispersion coefficient in the model is based on best practice within the industry, an extensive review of relevant literature and previous experience in developing water quality models.

The transport and dispersion of pollutants within ICM is represented via the effective longitudinal dispersion which is governed within the model by the longitudinal dispersion coefficient, D_L. For the purpose of this assessment, the dispersion coefficient is calculated according to river conditions, meaning the diffusion is related to the shear velocity.

The value for the longitudinal dispersion coefficient has been calculated based on the following equation, taken from the works of Fischer et al. (1979)16 :

$$D_L = 0.011\ x\ \frac{U^2W^2}{d\sqrt{gdS}}$$

where;

D_L is the longitudinal dispersion coefficient,

U is the mean stream velocity,

W is the channel width,

d is the channel depth,

g is gravity and

S is the channel slope.

A hydraulic only model run was simulated for the Q50 flow scenario (excluding any WQ parameters) and the mean stream velocity and channel depth extracted from the results. The channel width and slope were taken from river survey data. The parameters were then used to calculate the diffusion coefficient for that scenario and the model re-simulated to include the water quality assessment.

To capture the varying hydrological conditions along the 28 km stretch of river, the modelled river reach was broken down into 11 sections. Diffusion coefficients were calculated and applied along each section. The reach sections are shown in Figure 4-6 and the resulting diffusion coefficients applied to the model are presented in the table below.

[16] Fischer, Hugo B et al., Mixing in inland and coastal waters, Academic Press New York (1979).

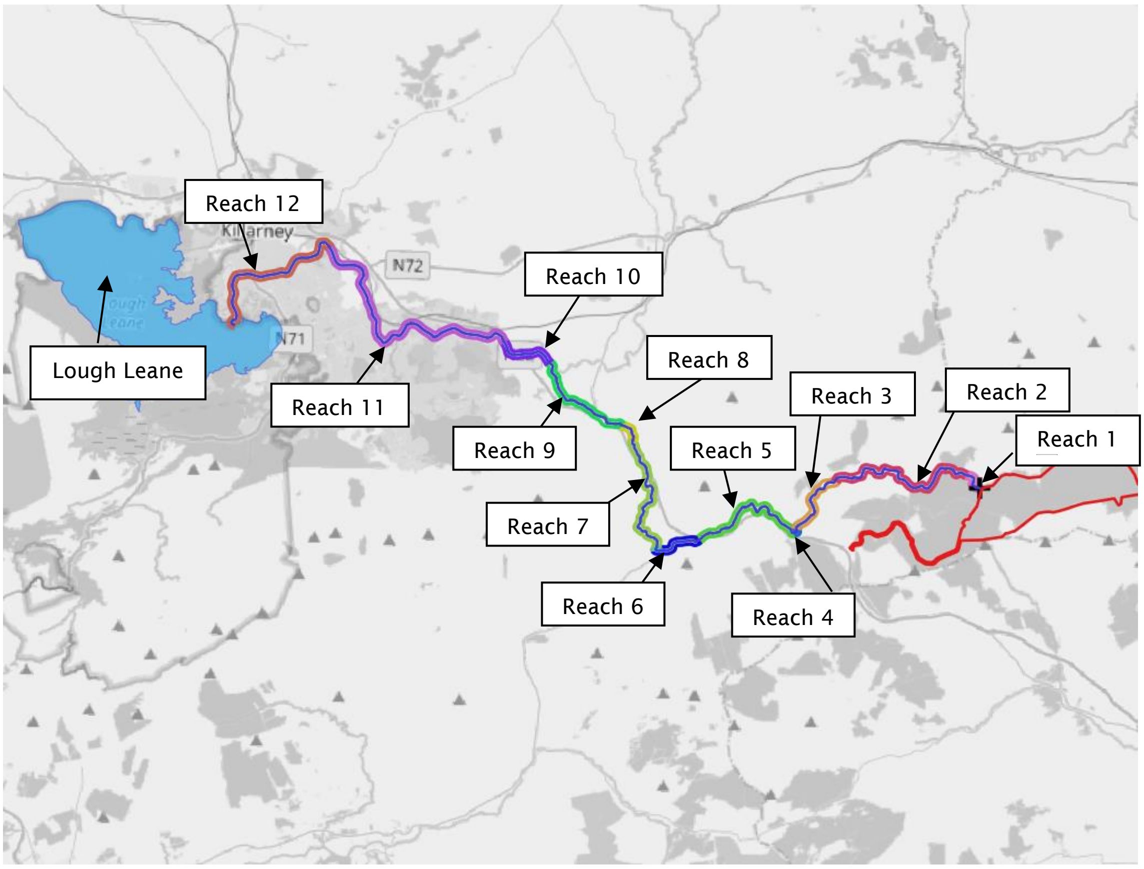


Figure 4-6 Model River Reaches

Table 4-4 Diffusion Coefficients Specified in the Model

Reach #	Diffusion Coefficient	Reach #	Diffusion Coefficient
1	56.26	7	11.27
2	88.21	8	11.44
3	54.90	9	22.77
4	229.63	10	10.30
5	111.62	11	51.89
6	114.38	12	195.22

4.4.5 Discharges and Ambient Concentrations

The background concentrations of the modelled WQ parameters have been accounted for in the model by including pollutant discharges from two separate sources:

- Nutrient runoff due to proposed felling operations; and
- The River Clydagh.

The felling runoff and river sources are characterised by two separate values, namely:

- Flow rate (in m^3/s); and

- Concentration of the relevant WQ parameter (in mg/l).

The product of these two values gives the total flux of the pollutant from the felling runoff / river (in g/m³).

The flow rates and concentrations for all discharges included in the model are presented in Table 4-5.

Table 4-5 Discharge Information

Source	Scenario	Flow rate applied at upstream inflow point (m^3/s)	WQ Parameter Concentration (mg/l)			
			Ammonium-Nitrogen (NH_4-N)	Total Oxidised Nitrogen (N)	Molybdate Reactive Phosphorus (P)	Total Phosphorous (P)
River Clydagh	50%ile mean flow	0.573	0.028	0.393	0.013	0.033
Felling Runoff	50%ile mean flow – Average Scenario	0.064	0.08	0.42	0.022	0.07
Felling Runoff	50%ile mean flow – Maximum Scenario	0.064	0.14	0.50	0.031	0.12

Water quality parameters are represented in the model using pollutographs which are used in conjunction with model inflows. Fluvial concentrations are specified at the upstream point inflow node and felling concentrations are specified at the lateral inflow node located at the upstream model inflow point. The upstream inflow location is shown in Figure 4-5.

The WQ concentrations are defined in the pollutograph, and the corresponding inflow file defines flow rates, together defining the pollutant flux.

4.4.5.1 Decay Rates

The impact of decay cycles of the modelled pollutants was excluded from the assessment. Not specifying decay constants for the WQ parameters is a conservative approach, in which assessment of the change in WQ concentrations is based solely on turbulent mixing and longitudinal dispersion.

4.4.6 Overview of Model Runs

The following scenarios have been simulated as part of this assessment:

- 50%ile low flow – ambient model scenario
- 50%ile low flow – proposed model scenario

The ambient model run was simulated for a 2-day period, to ensure equilibrium of the initial water levels and ambient nutrient concentrations was reached. No felling discharges were applied to the ambient scenario. The results of the ambient simulation were used to set initial conditions for the proposed model.

The proposed model run was simulated for a 24-hour period to ensure equilibrium of modelled nutrient concentrations was reached.

4.4.7 Assumptions and Limitations of Modelling

The representation of any complex system by a model requires a number of assumptions to be made. In the case of the hydraulic model developed for the purposes of the study it is assumed that:

- The estimated Q50 flows are an accurate representation of mean annual flow conditions for the site;
- Roughness does not vary with time; and
- Diffusion coefficient does not vary with time.

The primary limitations of the study are noted as follows:

- No allowance for pollutant decay has been made within the model; and
- Dispersal within the model is calculated based on simple continuity equations only.

4.5 Surface Water Quality Assessment

Modelled concentrations for each of the modelled WQ parameters were extracted at the upstream extent of each of the modelled river reach sections shown in Figure 4-6 and at the last modelled 1D cross section before the river discharges into Lough Leane (location 13 in the tables below).

The maximum and average concentrations predicted at each point are presented in Table 4-6 and Table 4-7, respectively. The existing river concentrations, proposed discharge concentrations and EQS target levels for the relevant nutrients are also presented in the tables. The existing river concentration represents the maximum value recorded across all monitoring points on the River Clydagh/ Flesk, upstream of Lough Leane, as described in Section 4.3.1. The proposed discharge concentration has been determined based on EPA recommended literature as described in Section 4.3.2.

Model results show nutrient concentrations decrease as flow travels downstream along the river. For all nutrients assessed, concentrations return to baseline (**i.e. no measurable change**) at a point upstream of Lough Leane. Model results show concentrations of ammonium nitrogen, total oxidised nitrogen and total phosphorous return to existing river levels after 17.621 km downstream of the model discharge point whilst molybdate reactive phosphorous concentrations return to baseline levels after 7.87 km downstream. As levels of all nutrients assessed return to existing river conditions before discharging into Lough Leane, it can be concluded that nutrient release due to proposed clear-felling will have **no measurable effect on water quality in the Lough.**

The concentrations of all pollutants assessed are also shown to be below relevant EQS targets upstream of the discharge point into Lough Leane, indicating compliance with relevant water quality legislation and EQS standards.

Table 4-6 Pollutant Concentrations Based on Maximum FWMC

Parameter		Ammonium nitrogen (mg/l NH4-N)	Total Oxidised Nitrogen (mg/l N)	Molybdate Reactive Phosphorous (MRP) (mg/l PO4-P)	Total Phosphorous (mg/l P)
Maximum Existing River Concentration recorded Upstream of Lough Leane (mg/l)		0.028	0.393	0.013	0.033
Proposed Discharge Concentration		0.41	0.8	0.07	0.32
EQS Target Level		0.04	0.9	0.025	0.2
Location – US extent of reach # Moving Downstream	1	3.82	4.41	0.62	2.85
	2	0.222	0.598	0.044	0.177
	3	0.037	0.402	0.014	0.039
	4	0.03	0.396	0.013	0.035
	5	0.03	0.395	0.013	0.035
	6	0.029	0.394	0.013	0.034
	7	0.029	0.394	0.013	0.034
	8	0.028	0.393	0.013	0.033
	9	0.028	0.393	0.013	0.033
	10	0.028	0.393	0.013	0.033
	11	0.028	0.393	0.013	0.033
	12	0.028	0.393	0.013	0.033
	13	0.028	0.393	0.013	0.033
Distance (m) from site at which Concentration = Existing River Concentration		17621	7871	17621	17621
Distance (m) from site at which Concentration < EQS Threshold		5699	563	5699	713

	Green shading indicates = Existing River Concentration

Table 4-7 Pollutant Concentrations Based on Average FWMC

Parameter		Ammonium nitrogen (mg/l NH4-N)	Total Oxidised Nitrogen (mg/l N)	Molybdate Reactive Phosphorous (MRP) (mg/l PO4-P)	Total Phosphorous (mg/l P)
Maximum Existing River Concentration recorded Upstream of Lough Leane (mg/l)		0.028	0.393	0.013	0.033
Proposed Discharge Concentration		0.19	0.51	0.04	0.15
EQS Target Level		0.04	0.9	0.025	0.2
Location - US extent of reach # Moving Downstream	1	1.62	1.54	0.31	1.23
	2	0.109	0.452	0.028	0.094
	3	0.032	0.396	0.014	0.036
	4	0.029	0.394	0.013	0.034
	5	0.029	0.394	0.013	0.034
	6	0.028	0.393	0.013	0.033
	7	0.028	0.393	0.013	0.033
	8	0.028	0.393	0.013	0.033
	9	0.028	0.393	0.013	0.033
	10	0.028	0.393	0.013	0.033
	11	0.028	0.393	0.013	0.033
	12	0.028	0.393	0.013	0.033
	13	0.028	0.393	0.013	0.033
Distance (m) from site at which Concentration = Existing River Concentration		17621	7871	17621	17621
Distance (m) from site at which Concentration < EQS Threshold		5699	234	5699	563

	Green shading indicates = Existing River Concentration

5 ASSESSMENT OF TOTAL SUSPENDED SOLIDS IN THE RIVER CLYDAGH

5.1 Preamble

Construction and operation of the Proposed Development at the site is likely to result in reduced quality runoff from the site. A comprehensive drainage plan is proposed to capture and treat runoff to the best possible standard achievable using settlement features, where flocculant dosing or similar is not permitted due to potentially toxic effects affecting fish life.

A quantitative assessment has been undertaken to determine the capacity of the Clydagh River and tributaries on the site to receive runoff from the proposed development under critical (construction phase) conditions, where the construction phase poses the greatest risk to the water environment in terms of mobilisation of sediments and silt.

A far field dispersion modelling assessment has been carried out to simulate the transport and dispersal of total suspended solids (TSS) within the upper reaches of the Clydagh River and tributaries within the application site to assess compliance of TSS in the Killarney National Park, Macgillycuddy's Reeks and Caragh River Catchment SAC in the vicinity and immediately downstream of the Proposed Development site with EQS threshold levels and to determine adherence with the relevant EU Water Quality Directives to protect qualifying interests in the reach of the River Clydagh adjacent to the site

The River Clydagh and tributary network within the site has been modelled in the vicinity of the Proposed Development site. A sufficiently detailed Infoworks ICM 2D hydrodynamic river model has been developed, allowing accurate determination of TSS pollutant concentrations in the SAC in the vicinity and immediately downstream of the Proposed Development site.

The critical hydrological scenario considered for the SAC assessment is low flow conditions coupled with a storm burst event. This scenario is critical as it will result in maximum concentrations of nutrient runoff from the site into the Clydagh catchment where fluvial flows available for dilution and dispersion are at their minimum.

A rainfall model was created to determine surface water draining to the site under varying storm burst conditions. From this, a critical storm duration was determined which was applied along with low flow fluvial hydrology to the baseline and proposed modelled scenarios.

The baseline model represents an existing critical storm scenario, in which the background storm concentrations are applied with fluvial 95%ile low flows and a critical rainfall event.

The proposed model represents a scenario in which runoff of total suspended sediment resulting from the proposed discharges into the River Clydagh, under fluvial 95%ile low flows in the river and a critical rainfall event applied over the catchment.

Sensitivity testing of the proposed scenario was also undertaken, this is discussed in Section 5.6.

5.2 Hydrological Assessment

5.2.1 Catchment Extent

The catchment boundary for the River Clydagh corresponding to the downstream extents of the rainfall and baseline/proposed 2D models was determined based on GIS-based flow raster accumulation analysis of 25 m DTM height data. The 25 m DTM dataset was deemed suitable for representation of the entire surface water catchment draining to the site for the rainfall model and for representing catchment flows to the river and its tributaries for the baseline and proposed models. The resulting catchment extent has an area of 55.79 km^2 and is shown in Figure 5-1.

The catchment boundary was validated by undertaking a review of watercourse mapping which confirmed the contributing flows to the catchment.

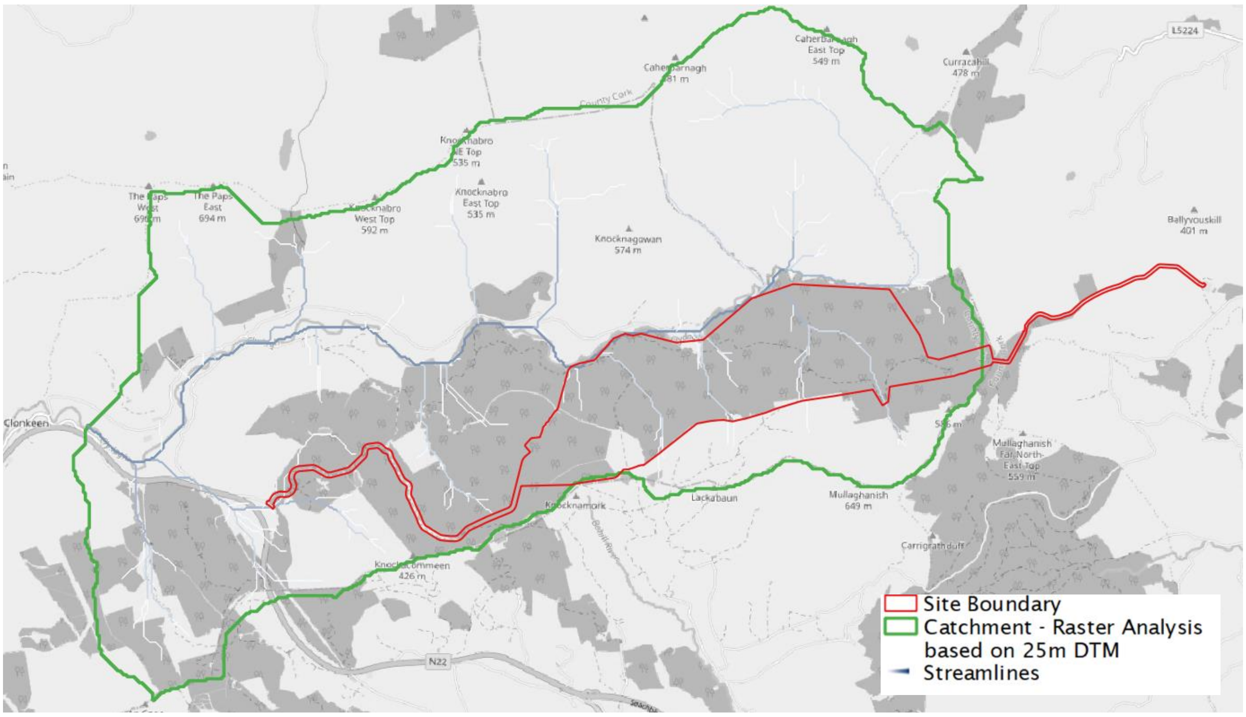


Figure 5-1 2D Model Catchment

5.2.2 Rainfall Estimation

Hydrological analysis of the surface water catchment was undertaken to determine varying rainfall events, including the critical duration scenario.

Flood Studies Update (FSU) rainfall data for the catchment was used to generate rainfall hyetographs for application to the rainfall model. FSU rainfall catchment descriptors were derived for the catchment and used to create hyetographs for 2-year and 10-year return periods at 1-, 6- and 12-hour durations. Model testing identified the 6-hour duration to be critical and it was, therefore, selected as the critical duration storm event for the baseline and proposed model simulations.

Rainfall profile calculations are included in Annex B.

5.2.2.1 Application of Rainfall to the Model

The derived hyetographs were applied directly to the entire 2D zone of the rainfall model (see Figure 5-4). The 2D zone was set up to ensure the entire catchment, with all overland flow routes contributing to surface water flooding, within the study area was covered. The rainfall events were applied with no infiltration specified.

Simulations for the 2-year and 10-year return periods were ran with the 1-, 6- and 12-hour durations. Results indicated well defined flow routes along tributaries and into the River Clydagh. The resulting hydrographs were extracted from the rainfall model simulations at the upstream extents of these flow routes, including at the upstream point of the River Clydagh. To ensure no catchment flows were lost elsewhere, the extracted rainfall hydrographs were scaled to match the 2-year and 10-year flows determined by an FSU assessment. This ensured a conservative approach. The hydrographs were then combined with calculated 95%ile low flows and applied to the baseline and proposed models via 2D line inflows. Calculation of low flows and model application is discussed further in Section 5.2.3. The baseline and proposed model scenarios were simulated with the same rainfall files to ensure consistency in the hydrology applied to the models.

5.2.3 Low Flow Estimation

Hydrological analysis of the catchment was required to determine low flow rates, which are critical to the water quality assessment. Low flow conditions coupled with a critical storm event represent the worst-case scenario, in which fluvial inflows are minimal and runoff discharges are at a maximum. They therefore reflect the most conservative scenario and are the primary focus of the 2D study.

The long-term flow record from the Flesk Bridge hydrometric gauge was used to calculate 95%ile low flow rates. The resulting flows were scaled to account for differences in the catchment area at the gauge and at the downstream model extent. Detailed calculations for the determination of the low flow value are included in Annex B.

The resulting 95%ile low flow for the River Clydagh is 0.45 m^3/s.

5.2.3.1 Application of Low Flows to the Model

Application of calculated hydrology to the model via 2D line inflows, was based on contributing area and applied in such a manner to reflect all catchment flows to the River Clydagh. Constant 95%ile flow rates were combined with derived rainfall hydrographs and applied at the upstream extents of the River Clydagh and its primary tributaries.

Application of the hydrology with flow estimation downstream of the site, but the flow applied upstream of the site, is a conservative approach. Application of hydrology to the 2D model is shown in Figure 5-2.

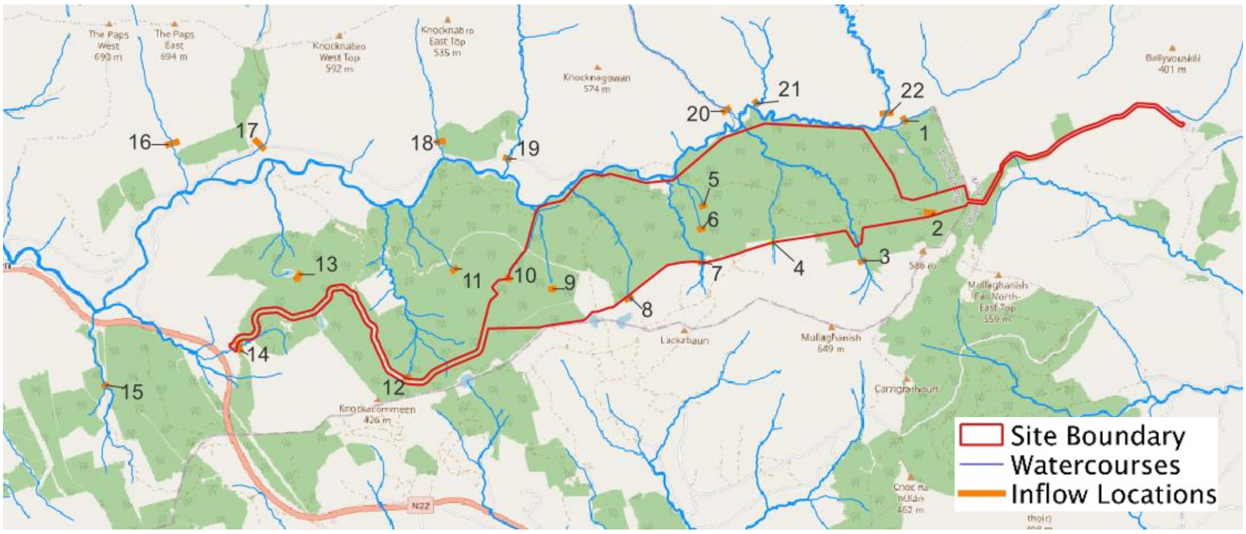


Figure 5-2 Application of Hydrology to the 2D Model

Table 5-1 – Hydrology Applied to the 2D Model

Inflow Location	Contributing Area (km^2)	Percentage of Total 95%ile Low Flow (%)	Percentage of Total Rainfall – 6hr 2-year Critical Storm (%)
1	16.13	28.91	0.516
2	0.75	1.35	3.287
3	2.397	4.30	7.779
4	1.238	2.22	3.370
5	0.232	0.42	0.183
6	0.298	0.53	0.976

Inflow Location	Contributing Area (km²)	Percentage of Total 95%ile Low Flow (%)	Percentage of Total Rainfall – 6hr 2-year Critical Storm (%)
7	1.099	1.97	3.846
8	1.402	2.51	2.391
9	0.362	0.65	5.657
10	0.328	0.59	1.658
11	0.506	0.91	1.113
12	3.02	5.41	9.847
13	0.368	0.66	0.606
14	5.315	9.53	5.737
15	3.273	5.87	8.298
16	1.283	2.30	2.180
17	2.149	3.85	4.376
18	1.893	3.39	11.574
19	4.443	7.96	8.063
20	1.634	2.93	3.254
21	2.089	3.74	4.421
22	5.585	10.01	10.869

5.2.4 Effects of Climate Change

Consideration has been given to the effects of reduced future river summer flows resulting from the effects of climate change. Reduced flows due to climate change are projected to occur throughout Ireland and the River Clydagh experienced drought conditions in the summers of 2010 and 2018.

The EPA was consulted on the most suitable approach to incorporate the potential impact of climate change on river flows. Whilst at present there is no fixed guidance on the topic, EPA's research in the area is ongoing. In 2020, a report[17] commissioned by Irish Water (now Uisce Éireann) was published which assessed the sensitivity of 206 river catchments to low flows caused by climate change. The work produced a table of allowances for climate change related reductions in 95%ile low flows for various river catchments and recommended a reduction of 60% for the River Clydagh, leading to a low flow value of 0.18 m³/s.

[17] Identification of climate sensitive catchments: water resources and climate change adaption, Dr C. Broderick & D. C Murphy, Irish Water, 2020.

As the River Clydagh experienced extreme low flows in 2010 and 2018, low flows from the Flesk Bridge gauge were reviewed. The recorded low flow value for 2010, scaled to the 2D model catchment area is 0.29 m^3/s which is less extreme than the 60% reduction. The EPA recommended 60% reduced flow was, therefore, adopted for use in the assessment and the scenario was included in a sensitivity analysis. This is discussed in greater detail in Section 5.6.2.

Climate change will also result in increased storminess and higher intensity rainfall. A sensitivity analysis has been undertaken to assess the influence of climate change on TSS concentrations for the proposed scenario. For this model scenario, the extreme low fluvial flow of 0.18 m3/s is applied along with the baseline 6 hour-2 year critical storm event. This is a conservative approach as it applied extreme low flows in the river but does not account for increased water in the catchment due to higher intensity rainfall.

Climate change flows were applied to the model as per the low flow hydrology (see Section 5.2.3.1).

5.2.5 Proposed Drainage Catchments

Proposed drainage catchments were determined based on drainage design information developed as part of the planning-stage drainage plan developed in support of the planning application. Proposed discharge rates were calculated based on contributing area of the drainage catchments, including for the effect of surface water attenuation and limited discharge rates, and applied in such a manner to ensure all runoff was accounted for.

The drainage infrastructure is shown in Figure 5-3 and associated discharges are shown in the table below.

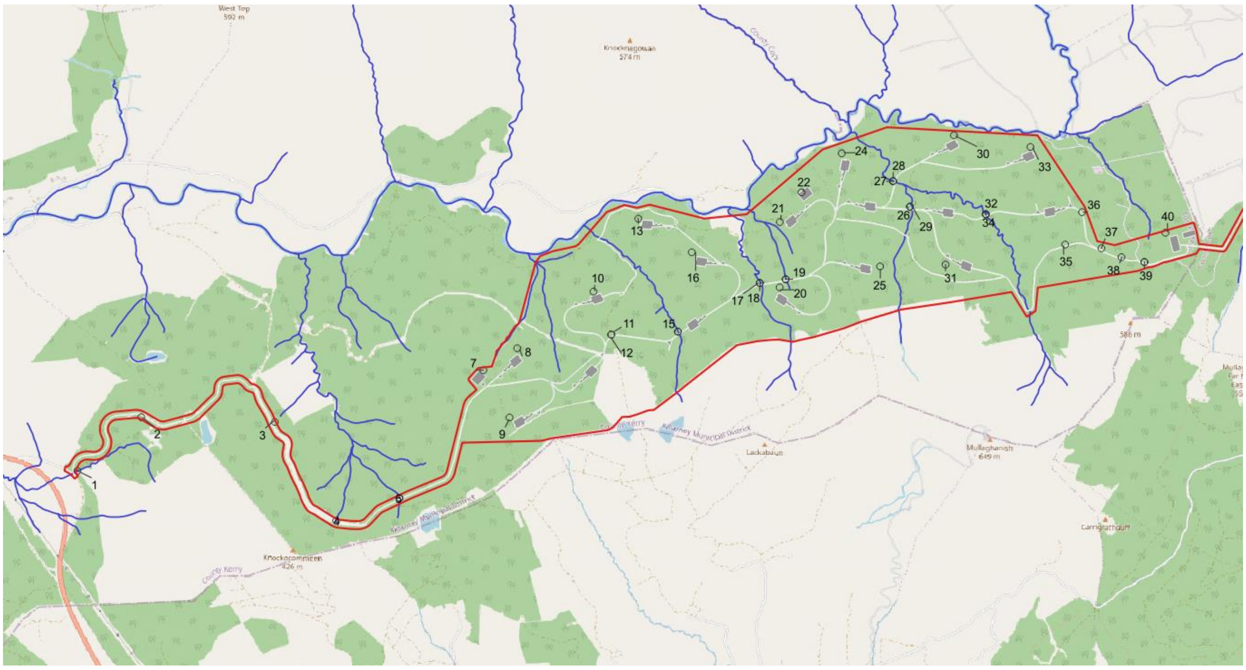


Figure 5-3 – Proposed Drainage Outfall Points

Table 5-2 – Treated TSS Discharge Rate per Drainage Catchment

Catchment ID	Discharge Rate m^3/s		Catchment ID	Discharge Rate m^3/s
1	0.0197		21	0.037
2	0.0173		22	0.048
3	0.0306		23	0.026
4	0.0073		24	0.045
5	0.0078		25	0.039
6	0.0211		26	0.051
7	0.0281		27	0.006
8	0.0758		28	0.020
9	0.0473		29	0.057
10	0.0566		30	0.042
11	0.0453		31	0.043
12	0.0080		32	0.003
13	0.0518		33	0.044
14	0.0060		34	0.057
15	0.0414		35	0.004
16	0.0479		36	0.009
17	0.0099		37	0.004
18	0.0015		38	0.001
19	0.0028		39	0.007
20	0.0465		40	0.052

5.2.6 Application of Proposed Discharge Rates to the Model

Application of calculated proposed hydrology to the model via point inflows, was based on contributing area and applied in such a manner to reflect surface water flow paths into tributaries and the River Clydagh. Proposed outfall discharges were applied to the model via point inflows, where outfalls were located adjacent to but outside of a watercourse they were applied in to model to the nearest tributary.

5.3 Water Quality Concentrations

5.3.1 Ambient and Storm Concentrations

Site specific water quality monitoring data detailed in Section 4.3.1 was used to determine background concentrations of TSS along the River Clydagh and into the downstream catchment for use in the 2D modelling study.

Concentrations of TSS obtained during ambient and storm conditions are accounted for in the assessment. The following data has been used to inform WQ concentrations for the assessment of TSS in the SAC adjacent to the Proposed Development:

- For the River Clydagh, monitored TSS water quality values have been obtained from station SW01 (see Figure 4-3). The station is located at the upstream head of the river. The available chemistry data was recorded on 03/02/21, 14/04/21, 27/07/21, and 18/10/21 and on two storm events; 02/02/21 and 13/08/21. The maximum TSS value recorded during both ambient and storm conditions was selected as the background concentration in the river.
- For the tributaries, monitored TSS water quality values have been obtained from stations SW06, SW07 and SW08-01 (see Figure 4-3). All three stations are located on the River Clydagh, downstream of the Proposed Development site. The available chemistry data was recorded on 03/02/21, 14/04/21, 27/07/21, and 18/10/21 and on two storm events; 02/02/21 and 13/08/21. The maximum TSS value across the three stations during both ambient and storm conditions was selected as the background concentration in the tributaries. TSS concentrations were also recorded on the tributaries at locations SW01-SW05C (see Figure 4-3) during the two storm events. However, the monitored levels were lower than those recorded on the River Clydagh (i.e., at stations SW06, SW07 and SW08-01). Using concentrations recorded along the River Clydagh, downstream of the tributaries located within the vicinity of the Proposed Development site, accounts for all TSS concentrations discharging from the tributaries and into the River Clydagh and is, therefore, a conservative approach.

A review of the available monitoring data was undertaken to assess the suitability of its use in the assessment. The review, which is detailed in Annex A, showed an outlying value in the recorded TSS concentrations which was excluded from the dataset. No other significant outliers were identified in the data.

The qualifying interests of the Killarney National Park, Macgillycuddy's Reeks and Caragh River Catchment SAC immediately downstream of the Proposed Development will be more responsive to low flow conditions coupled with a storm burst event (i.e., a period of intense rainfall). The available monitoring data was analysed to assess the requirement for including MRP, TP, NO3, NO2 and TON in the TSS assessment. The review indicated that the nutrients are not influenced by storm events, with no elevated concentrations recorded during the storm periods. As a result, it was deemed suitable to exclude them from the 2D modelling study.

The review also highlighted the influence of seasonality on the background concentrations, with higher TSS concentrations recorded over winter months at the majority of the monitoring locations. This tends to suggest that existing concentrations are influenced by reduced quality runoff entrained in seasonal rainfall runoff, rather than rainfall runoff offering improved dilution of particular sources of pollution. Adopting a maximum concentration incorporates the slight bias effect of higher winter concentrations. For a low flow scenario (which is the critical scenario to be determined), winter background conditions will not be realised, and, therefore, using them to inform the maximum ambient concentrations is a precautionary and conservative approach. During the storm scenario, adopting the higher winter concentrations is the most appropriate to capture any increased elevations of TSS.

A review of EPA data confirmed that there are a number of discharges and other pollutant sources located downstream of the Proposed Development site. However, none are located within the model extent for the TSS assessment.

Table 5-3 below presents the ambient and storm TSS concentrations included in the 2D modelling assessment. As tributaries of the River Clydagh are included in the 2D model, background concentrations for the tributaries have also been included. Application of the background TSS concentrations to the model is discussed in Section 5.4.5.

Table 5-3 Background concentrations of TSS in the River Clydagh and tributaries

Parameter	Background River Clydagh Concentration	Background Tributary Concentration
Total Suspended Solids (TSS) (mg/l) – Storm Conditions	5.5	7.0
Total Suspended Solids (TSS) (mg/l) – Ambient Conditions	5.5	4.7

5.3.2 Proposed Discharge Concentrations to Outfall

The modelling study assesses 'treated levels' of TSS in runoff at the site utilising treatment efficiencies of surface water management features (temporary SuDS). The rationale to using treated levels of runoff in the assessment is based on the requirement that temporary surface water management measures be included as part of the Proposed Development as standard. Measures such as settlement ponds and swales are common industry practice and considered as primary mitigation in EIA terms.

TSS concentrations resulting from the treated runoff are based on information provided by the proposed drainage plan and predicted settlement pond outflow concentrations. Details on the sediment parameters used in the model, including the proposed discharge concentration, are given in Table 5-4. The settling velocity for the 6 µm and 2 µm particles was set at 0.0092 m^3/s and 0.083 m^3/s, respectively. The 6 µm and 2 µm particles were used in the proposed model to represent a 'best case' scenario. Application of the discharge concentrations to the model is discussed in Section 5.4.5.

Table 5-4 – TSS Effluent Details and Discharge Concentrations Used in the 2D model – Proposed Scenario

Catchment ID	Particle Size (µm)	Discharge Concentration (mg/l TSS)
1	2	19.74
	6	52.91
2	2	19.74
	6	52.91
3	2	19.80
	6	54.58
4	2	19.74
	6	52.91
5	2	19.74
	6	52.91
6	2	19.74
	6	52.91
7	2	19.74
	6	52.91
8	2	19.80
	6	54.58
9	2	19.80
	6	54.58
10	2	19.80
	6	54.58
11	2	19.80
	6	54.58
12	2	19.74
	6	52.91
13	2	19.80
	6	54.58
14	2	19.74
	6	52.91

Catchment ID	Particle Size (µm)	Discharge Concentration (mg/l TSS)
15	2	19.80
	6	54.58
16	2	19.80
	6	54.58
17	2	19.74
	6	52.91
18	2	19.15
	6	37.01
19	2	19.54
	6	47.44
20	2	19.80
	6	54.58
21	2	19.80
	6	54.58
22	2	19.80
	6	54.58
23	2	19.74
	6	52.91
24	2	19.80
	6	54.58
25	2	19.80
	6	54.58
26	2	19.80
	6	54.58
27	2	19.74
	6	52.91
28	2	19.74
	6	52.91
29	2	19.80
	6	54.58
30	2	19.80
	6	54.58
31	2	19.80
	6	54.58
32	2	19.52
	6	46.85
33	2	19.80
	6	54.58
34	2	19.80
	6	54.58
35	2	19.65

Catchment ID	Particle Size (μm)	Discharge Concentration (mg/l TSS)
	6	50.40
36	2	19.74
	6	52.91
37	2	19.66
	6	50.67
38	2	19.14
	6	36.74
39	2	19.74
	6	52.91
40	2	19.80
	6	54.58

5.4 Hydraulic and Water Quality Model Simulation: 2D Model

A sufficiently detailed high resolution numerical 2D model of the River Clydagh has been developed as part of this study. The model consists of both a hydrodynamic component and a water quality component which are dynamically coupled and run together as a single model.

Due to the complexity of the watercourses and the mechanisms of dispersal and mixing within the river reach and its tributaries, it was determined that a detailed 2D model would be most suitable for the TSS assessment. The primary mechanisms by which dispersion of contaminants occurs is the downstream flow from the river and overland flow paths and mixing with the sediment runoff. The 2D model simulates this and, therefore, captures the primary mechanism by which suspended sediment is advected and dispersed.

Both the hydraulic and water quality components of the model simulation are discussed below.

5.4.1 Hydraulic Model Simulation

The river reach has been modelled using unsteady state techniques using ICM v 2021.2 software with the most conservative low flows and critical storm profiles predicted for the purpose of the water quality assessment in accordance with the precautionary principal.

Due to the complexity of the overland flows through which sediment will be transported into the river, along with the requirement to simulate rainfall bursts, a full detailed 2D model of the river reach was selected as the most suitable for the TSS assessment. The 2D model will facilitate accurate representation of the varying overland flow paths and runoff catchments for both the rainfall and suspended sediment releases, which would not be represented in a simple 1D approach.

Three separate 2D model scenarios were developed. The first, a surface water model, was developed to simulate varying rainfall events across the catchment. Model extents were set up to ensure the full surface water catchment and therefore, all overland flows draining to the site, were captured. A baseline model scenario was then developed to simulate 95%ile low flows combined with storm scenarios. The proposed scenario was created from the baseline model with proposed TSS discharges applied. Model extents for the baseline and proposed scenarios were informed through a site walkover which investigated both the river channel and surrounding area in proximity to the proposed discharge locations.

Figure 5-4 through Figure 5-6 detail the model extents and the elements incorporated in the model build process for the rainfall, baseline and proposed scenarios. Each of the elements has been detailed further in the subsequent sections of this report with information provided regarding the source of the data and justification of the parameters selected.

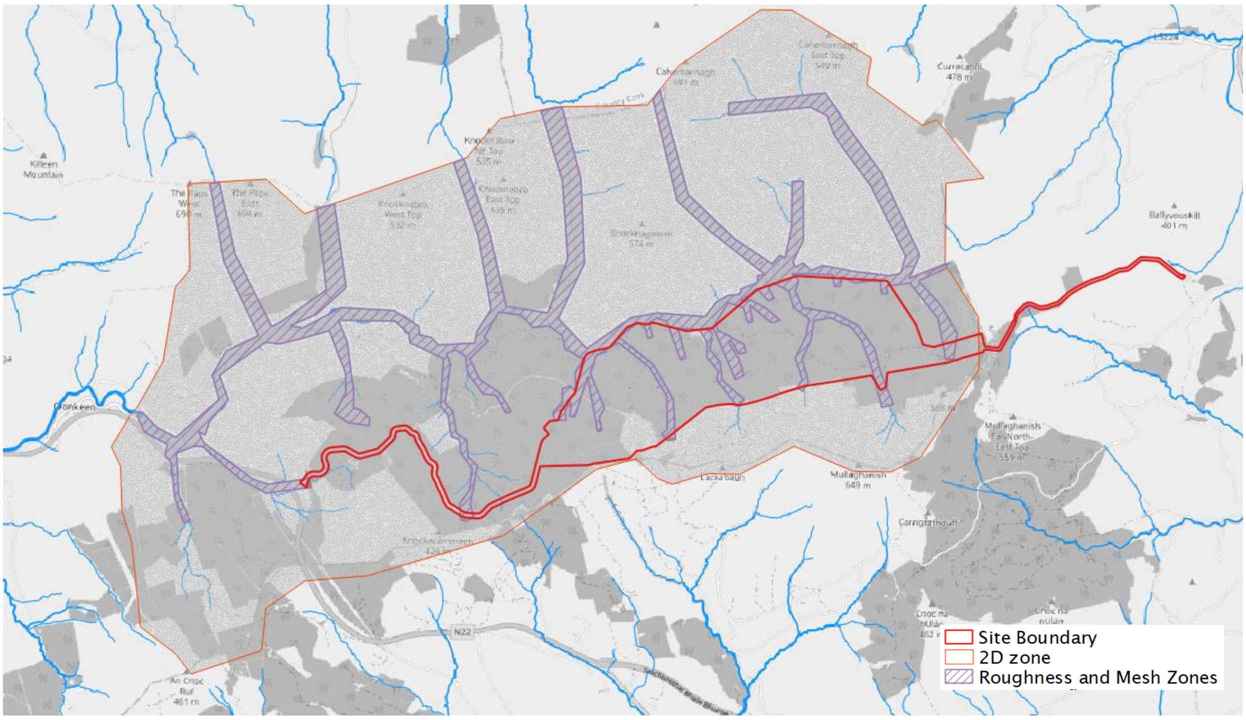


Figure 5-4 2D Model Geometry – Rainfall Model

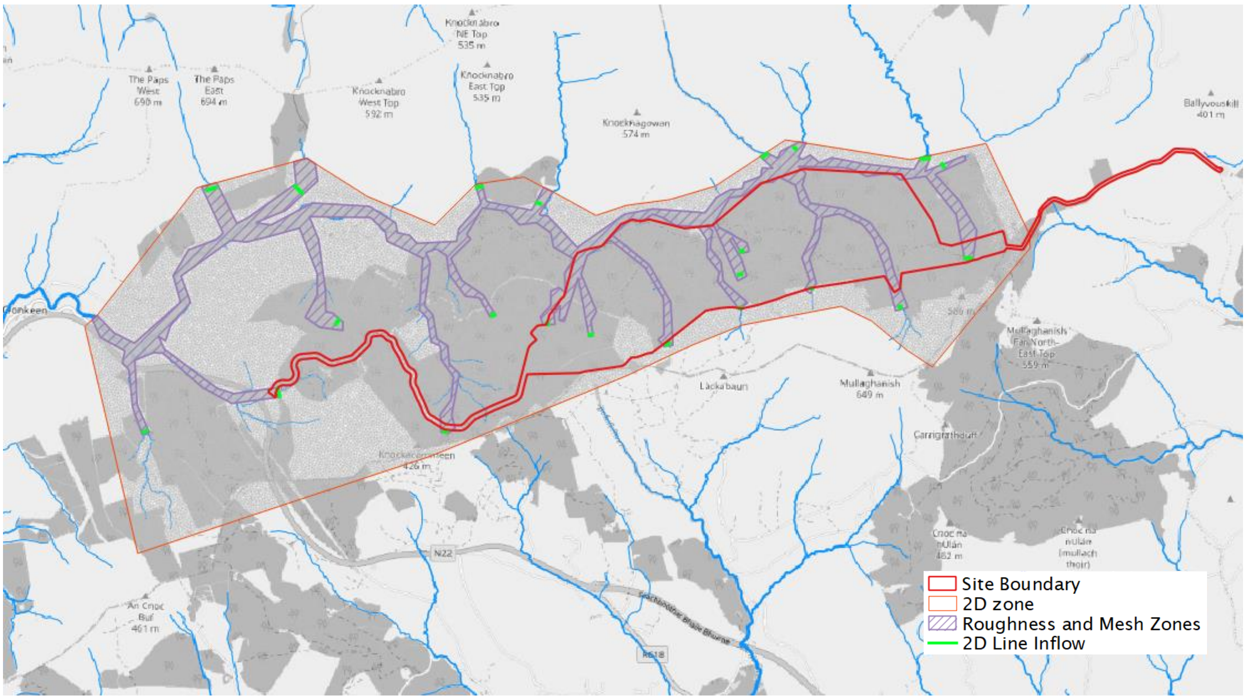


Figure 5-5 2D Model Geometry – Baseline Model

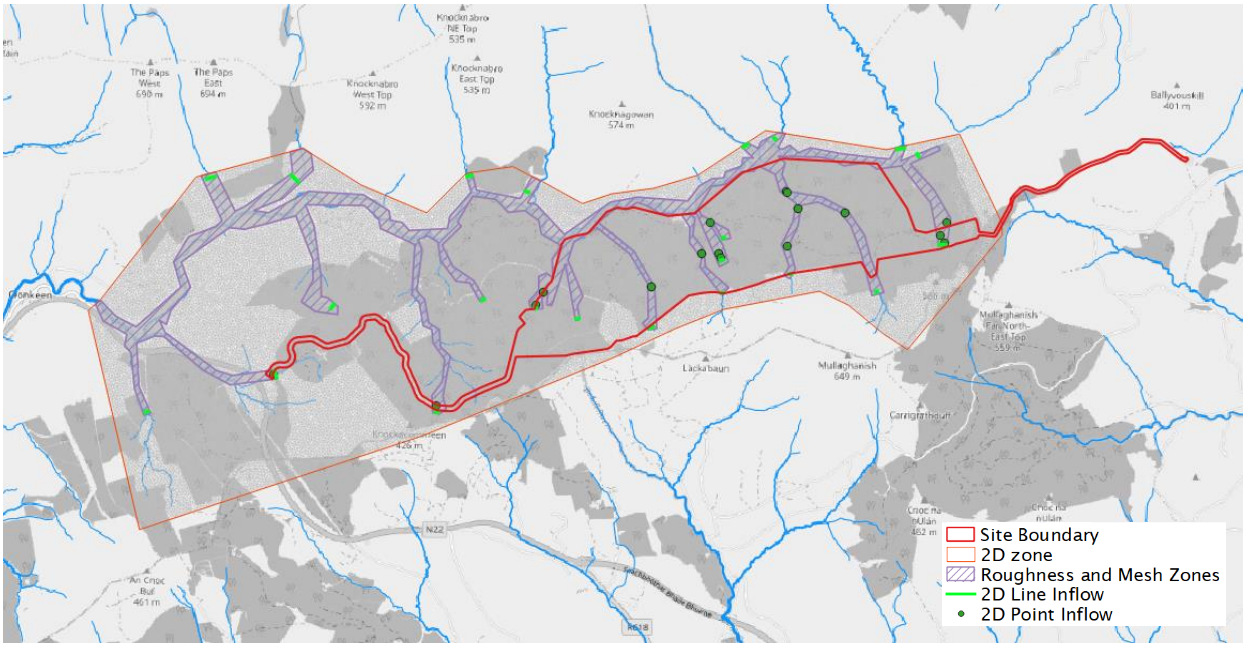


Figure 5-6 2D Model Geometry – Proposed Model

5.4.2 2-Dimensional Surface Model Areas

5.4.2.1 Topography

Out of bank topography was based on a combination of best available 1 m and 2 m resolution LiDAR data and 10 m resolution DTM data. The DTM data was merged to create a combined terrain model which provided improved definition in the area of interest.

5.4.2.2 2D Zone

The terrain model was loaded into InfoWorks ICM as a ground model, and subsequently converted into 2D mesh elements (the surface used to simulate flows across the topography within the model). The 2D zone has a maximum triangle size of 1000 m², reducing to a minimum size of 500 m² in the area of interest with terrain sensitive meshing selected providing a maximum height variation of 2 m.

A mesh zone was applied to the model to increase detail in the vicinity of the watercourses. This increased the resolution of the model to a maximum triangle area of 200 m² and a minimum area of 100 m².

The 2D zone was designed to allow the capturing of any tributaries and minor watercourses along with any areas of significant floodplains / storage in depressions in the vicinity of the site.

The 2D zone extent was increased for the rainfall model to ensure all surface water draining to the site was captured. The mesh zone extent was also increased for the rainfall model, allowing increased detail in the upper reaches of the watercourses located within the larger 2D zone. The mesh density for the rainfall model was unchanged from the baseline/proposed model 2D zone. Rainfall events were applied directly to the entire 2D zone, which converts the direct rainfall applied to the mesh into a runoff volume.

5.4.2.3 Surface Roughness

A Manning's n Roughness value of 0.1 has been applied to the whole 2D zone to represent the area over which water would flow which predominantly is comprised of medium to dense brush and trees.

5.4.2.4 Roughness Zone

Roughness zones were added to the model at locations where watercourses are present to represent roughness values along the river reaches differing to that of the base 2D roughness. A roughness value of 0.035 was applied at each roughness zone representing a clean, straight reach with some stones and weeds.

5.4.2.5 *Boundary Conditions*

A normal depth boundary condition was applied to the 2D zone. This prevents flows from glass walling at the model boundaries. The 2D zone has been sufficiently sized to ensure the boundary is sited a sufficient distance from the study area to limit the possibility of hydrodynamics and water quality concentrations being artificially influenced by the boundary condition.

5.4.2.6 *2D Points and Lines*

Model hydrology was applied via 2D line sources and proposed discharges were applied to the model via 2D point sources. This is discussed further in Section 5.4.3 below.

5.4.3 Model Inflows

Rainfall profiles were applied as detailed in Section 5.2.2 and rainfall hydrographs combined with 95%ile low flows were applied as fluvial inflows as described in Section 5.2.3. Pollutant loadings are also applied to the model and application of the proposed outfall discharge rates is outlined in Section 5.2.5.

Application of background and pollutant concentrations is discussed further in Section 5.4.5.

The location of the fluvial inflows (2D lines) and proposed outfall locations (2D points) are shown in Figure 5-6.

5.4.4 Water Quality Model Simulation

The water quality component of the model is linked directly to the hydraulic model described in the previous section. The combined model represents advection and dispersion of TSS in the 2D domain.

Each of the elements of the water quality model component are detailed in the subsequent sections of this report with information provided regarding the source of the data and justification of the parameters selected.

5.4.4.1 *Advection and Dispersion*

Advection and dispersion are key elements of the water quality model and are incorporated into the ICM 2D model. The 2D module first solves advection of the specified water quality parameters and then performs the diffusion step. In both cases, calculations are performed in each face between the 2D elements within the 2D zone.

5.4.5 Discharges and Ambient Concentrations

TSS background concentrations have been accounted for in the model by including pollutant discharges from two separate sources:

- The River Clydagh; and
- Tributaries / Overland flow routes during storm events.

Discharge concentrations of the modelled WQ parameters have been accounted for in the model by including pollutant discharges from:

- Proposed outfall locations.

The outfall and river sources are characterised by two separate values, namely:

- Flow rate (in m^3/s); and
- Concentration of the relevant WQ parameter (in mg/l).

The product of these two values gives the total flux of the pollutant from the outfall / river (in g/m^3).

The flow rates and concentrations for all discharges included in the model are presented in Table 5-5.

Table 5-5 Discharge Information

Source	Scenario	WQ Parameter Concentration (mg/l)	
		TSS (6 µm particle)	TSS (2 µm particle)
River Clydagh	95%ile low flow	5.5	5.5
Tributaries	95%ile low flow	4.7	4.7
River Clydagh	95%ile low flow & Critical Storm	5.5	5.5
Tributaries	95%ile low flow & Critical Storm	7.0	7.0
River Clydagh	Extreme Climate Change Low Flow & Critical Storm	5.5	5.5
Tributaries	Extreme Climate Change Low Flow & Critical Storm	7.0	7.0
Proposed Outfalls	Maximum Discharge	54.6	19.8

Water quality parameters are represented in the model using pollutographs which are used in conjunction with model inflows. Fluvial concentrations are specified at the upstream 2D line inflow node and outfall concentrations are specified at the 2D point node located along the nearest tributary to the discharge point. The locations are shown in Figure 5-6.

The TSS concentrations are defined in the pollutograph, and the corresponding inflow file defines flow rates, together defining the pollutant flux.

5.4.6 Overview of Model Runs

The following scenarios have been simulated as part of this assessment:

For the rainfall model:

- 1 hour, 2-year storm
- 6 hour, 2-year storm
- 12 hour, 2-year storm
- 1 hour, 10-year storm
- 6 hour, 10-year storm
- 12 hour, 10-year storm

The rainfall model runs were simulated for a 12-hour period, to ensure the full duration of the longest storm event modelled was realised.

Results from the above simulations were used to inform rainfall profiles which could be combined with low flow hydrology and applied as fluvial inflows to the baseline and proposed models. It should be noted that fluvial inflows are required by the ICM water quality model in order to apply pollutographs.

For the ambient model scenario:

- 95%ile low flow

The ambient model run was simulated for a 16-day period, to ensure equilibrium of the initial water levels and TSS concentrations was reached. No storm event was applied to the ambient scenario.

The ambient model scenario was used to determine initial conditions for the subsequent baseline and proposed storm model simulations. This enabled initial water levels and background ambient conditions to be defined along the watercourses.

For the baseline storm model scenario:

- 95%ile low flow + 1 hour, 2-year storm
- 95%ile low flow + 6 hour, 2-year storm
- 95%ile low flow + 12 hour, 2-year storm
- 95%ile low flow + 1 hour, 10-year storm
- 95%ile low flow + 6 hour, 10-year storm
- 95%ile low flow + 12 hour, 10-year storm

Results from the simulations outlined above identified the 6-hour duration as the critical storm event and the 2-year storm was adopted as the design scenario. The 6-hour, 2-year storm event was, therefore, utilised in the final baseline and proposed model runs.

For the proposed storm model scenario:

- 95%ile low flow + 6 hour, 2-year storm + outfall discharges
- River flow sensitivity scenario (detailed further in Section 5.6.2)

The baseline and proposed model runs were simulated for a 12-hour period to ensure peak elevations were reached.

5.4.7 Modelling of Total Suspended Solids

To model the concentrations of total suspended solids in the vicinity of the outfall and along the River Clydagh, the sediment parameters defined in Table 5-4 were applied to the water quality and sediment parameter properties within the model. The 6 μm and 2 μm particles were modelled separately and the resulting concentrations across each element of the 2D zone combined to give the total TSS concentration.

5.4.8 Assumptions and Limitations of Modelling

The representation of any complex system by a model requires a number of assumptions to be made. In the case of the hydraulic model developed for the purposes of the study it is assumed that:

- The terrain model (based on 2m DTM and 10m grid DTM supplemented by 1m resolution topographic survey data across the site) accurately represents the surface topography and associated flow paths;
- The estimated low flows are an accurate representation of low flow conditions for the site;
- The design rainfall is an accurate representation of rainfall for a given return period;
- Application of the rainfall profiles via inflow hydrographs is representative of storm conditions; and
- Roughness does not vary with time.

The primary limitations of the study are noted as follows:

- The model does not represent any topographic features smaller than the minimum resolution of the underlying terrain model derived for the site; and
- No allowance for pollutant decay has been made within the model.

5.5 Surface Water Quality Assessment

Modelled TSS concentrations for the proposed scenario are presented in the spatially varying pollutant concentration plots included in Annex D.

For the figure presented in Annex D, 2 main plots are shown. The EQS Mixing Zone Map shows the modelled concentrations of TSS in relation to the relevant EQS threshold level, whilst the Dispersion Mixing Zone Map shows the variance between the maximum and minimum modelled TSS concentrations throughout the river reach and tributaries.

Results show that in low flow conditions coupled with the critical storm event, upon effluent discharge, the large volume and flow rate of the watercourses disperses and mixes TSS within the waterbodies.

For the baseline scenario, where no outfall discharges are modelled, concentrations are reflective of the ambient storm conditions specified in the model.

For the proposed scenario, where runoff discharges are modelled, resulting TSS concentrations vary across the tributaries and Clydagh river reach. Highest concentrations are noted at the proposed outfall locations, with higher trends in tributaries into which multiple outfalls discharge. Concentrations along the River Clydagh increase gradually downstream due to contaminant input from the tributaries but do not reach the higher levels observed at the outfalls and along the tributaries.

EQS threshold levels are not exceeded within the designated SAC at the River Clydagh or along the majority of the tributaries. One exception is along a small section of a tributary that feeds into the River Clydagh from the south, downstream of outfall location 40 (see Figure 5-3). EQS levels are found to exceed target levels for a 140 m stretch of this tributary. However, this is reflective of the steep gradient of the channel at this reach which results in shallow water levels ranging from 0.09 - 0.02 m. Downstream of this reach, TSS concentrations fall below threshold levels and reduce further still when the watercourse discharges into and mixed with the River Clydagh.

5.6 Model Sensitivity

5.6.1 Overview

Sensitivity analysis was undertaken to assess model sensitivity to changes in flow in the River Clydagh and its tributaries due to the effects of climate change. The flow sensitivity analysis was based on a minimum flow of 0.18 m^3/s, determined based on an EPA recommended 60% reduction in low flows coupled with the critical rainfall event, as discussed in Section 5.2.4.

5.6.2 River Flow Sensitivity

Modelled results are shown to not be sensitive to changes in climate change flow conditions. This is due to the hydrology scenario considered, which is an extreme low flow in the river coupled with a critical storm burst event. The dilution and mixing of pollutants along the watercourses due to the volume of water introduced during peak storm flows is such that a reduction in the low river flow rate will not result in higher levels of pollutant concentrations in the watercourse. As discharges only occur under rainfall events, there will be no measurable effect.

6 SUMMARY OF FINDINGS AND RECOMMENDATIONS

6.1 Summary of Findings

6.1.1 Assessment of Nutrients at Lough Leane

The environmentally sensitive Lough Leane has previously been subject to historic eutrophication and excessive nutrient-loading. An assessment of the water quality parameters primarily responsible for eutrophication (i.e., phosphorous and nitrogen) downstream of the Proposed Development site and into Lough Leane has, therefore, been undertaken. Far field dispersion modelling was carried out to assess the effects of nutrient release associated with felling operations conducted as part of the construction phase of the Proposed Development. A screening assessment identified the pollutants relevant to the assessment as ammonium nitrogen, total oxidised nitrogen, molybdate reactive phosphorous and total phosphorous.

A detailed 1D ICM water quality model of the River Clydagh / River Flesk has been developed to model the watercourse from immediately downstream of the Site Boundary to its confluence with Lough Leane.

The model scenario is under mean annual flow conditions, in which fluvial inflows are long-term and continuous.

The scenario modelled is unrealistically precautious as the proposed discharge concentrations adopted as inputs to the hydraulic model are demonstrably overly conservative compared to nutrient levels captured in the catchment-specific monitoring undertaken during ongoing felling operations at the site. As a result, the modelling study is highly conservative.

Model results show, that for each of the nutrients modelled, downstream dispersion is such that concentrations return to baseline conditions at a point upstream of Lough Leane. Results demonstrate that there is **no measurable effect** to concentrations discharging into Lough Leane and, therefore, no predicted environmental effect with regards to nutrient enrichment.

6.1.2 Assessment of Total Suspended Solids in the Clydagh River

A high resolution 2D ICM water quality model of the upper reaches of the River Clydagh has been developed to determine the concentrations of total suspended solids within the watercourse due discharge of surface water runoff from the Proposed Development.

The critical model scenario is under low flow conditions coupled with a critical 6 hour-2 year storm event.

The results of the model show that for the proposed scenario, TSS concentrations do not exceed EQS threshold levels along the River Clydagh or its tributaries. An exception to this is along a short stretch of a tributary, downstream of outfall catchment 40, in which EQS targets are exceeded due to the underlying topography, with shallow depths leading to reduced mixing in the area. However, after a short distance downstream, these high concentrations are dispersed to below EQS targets. Recommended limits are not exceeded at any point within the Killarney National Park, Macgillycuddy's Reeks and Caragh River Catchment SAC.

To facilitate assessment of the impact of climate change on future summer flows, an extreme low flow scenario was modelled based on an EPA recommended 60% reduction in 95%ile low flows. The model was found to not be sensitive to the reduction in flow, with pollutant concentrations unchanged from the baseline proposed scenario. This is due to influence of the critical storm hydrology applied on dispersal of sediments within the watercourse.

Where EQS targets are not exceeded, there **are no predicted adverse effects to the qualifying interests in the SAC** or the reach of the River Clydagh adjacent to the site. As a result, there will be no adverse effects further downstream due to TSS discharge from the proposed development.

7 RECOMMENDATIONS

Notwithstanding the findings of this assessment which are unambiguous and conclude that there is no predicted adverse effect to Lough Leane or the River Clydagh, likely stakeholder concerns are acknowledged and residual risks are, therefore, proposed to be managed by a robust water quality monitoring and response plan.

Monitoring during the construction phase (including felling phase) will include continuous monitoring using deployed autonomous sondes equipped with telemetry and cloud-upload capabilities.

The Environmental Consultant / ECoW shall monitor trends in specified water quality parameters and be responsible for initiating the response plan (i.e., cessation of works) in the event that water quality threshold levels are exceeded (‘trigger levels’).

Refer to **Appendix 11-3: Water Quality Monitoring and Response Plan** for further details.

Annex A

Review of Monitoring Data

Project	Cummeennabuddoge Wind Farm - Mixing Zone Modelling
Ref	M01944-02
Watercourse	River Clydagh
Date	05/01/2023

Purpose

To assess the influence of storm events on monitoring data

Site	SW01C		SW06		SW07		SW08-01	
Parameter	Max Conc (mg/l)	Date of Max Conc	/lax Conc (mg/l	Date of Max Conc	/lax Conc (mg/l	Date of Max Conc	/lax Conc (mg/l	Date of Max Conc
MRP (mg/l P)	0.048	18/10/2021	0.009	12/10/2021	0.006	03/02/2021	0.009	02/02/2021
Total Phosphorus (mg/l P)	0.101	18/10/2021	0.032	12/10/2021	0.03	12/10/2021	0.033	12/10/2021
Nitrate (mg/l N)	0.097	03/02/2021	0.061	03/02/2021	0.066	03/02/2021	0.092	03/02/2021
Nitrite (mg/l N)	0.012	18/10/2021	0.061	03/02/2021	0.007	12/10/2021	0.006	12/10/2021
Total Oxidized Nitrogen (mg/l N)	0.1	03/02/2021	0.064	03/02/2021	0.069	03/02/2021	0.095	03/02/2021

Monitoring data shows that MRP, TP, N, Ni and TON are not influenced by storm events.
They can therefore be excluded from the analysis of TSS in the River Clydagh.

Project	Cummeennabuddoge Wind Farm - Mixing Zone Modelling
Ref	M01944-02
Watercourse	River Clydagh/Flesk
Date	05/01/2023

Purpose

To assess the influence of seasonality on monitoring data

Site	SW01C	SW06	SW07	SW08-01	SW08-02	SW09	SW12
Parameter	Max Concentration Recorded During:						
MRP (mg/l P)	Winter	Winter	Winter	Winter	Winter	Winter	Winter
Total Phosphorus (mg/l P)	Winter	Winter	Winter	Winter	Winter	Winter	Summer
Ammonia (mg/l NH4)	Summer	Winter	Winter	Summer	Winter	Summer	Winter
Total Suspended Solids (mg/l)	Winter	Winter	Winter	Winter	Winter	Winter	Summer
Nitrate (mg/l N)	Winter	Winter	Winter	Winter	Winter	Winter	Summer
Nitrite (mg/l N)	Winter	Winter	Winter	Winter	Winter	Winter	Winter
Total Oxidized Nitrogen (mg/l N)	Winter	Winter	Winter	Winter	Winter	Winter	Summer

Monitoring data shows the influence of seasonality, with maximum concentrations generally recorded over winter months

Annex B

Hydrological Calculations

Project	Cummeennabuddoge Wind Farm - Mixing Zone Modelling
Ref	M01944-02
Watercourse	River Clydagh
Date	05/01/2023

Purpose

To estimate the 95%ile low flow value for the River Clydagh catchment

95%ile low flows were calculated based on Flesk Bridge gauged flows

95%ile annual gauged flow	2.67	m^3/s	From Flesk Bridge Gauge (Station No. 22006)

HEP	FSU Catchment Area (km^2)	95%ile flow	
Flesk Bridge	328.81	2.67	m^3/s
DS 2D model extent	55.79	**0.45**	m^3/s

Project	Cummeennabuddoge Wind Farm - Mixing Zone Modelling
Ref	M01944-02
Watercourse	River Clydagh
Date	05/01/2023

Purpose

To estimate the 50%ile mean flow value for the River Clydagh catchment

50%ile low flows were calculated based on Flesk Bridge gauged flows

50%ile annual gauged flow	8.79	m^3/s	From Flesk Bridge Gauge (Station No. 22006)

HEP	FSU Catchment Area (km^2)	50%ile flow	
Flesk Bridge	328.81	8.79	m^3/s
DS 1D model extent	378.04	**10.11**	m^3/s

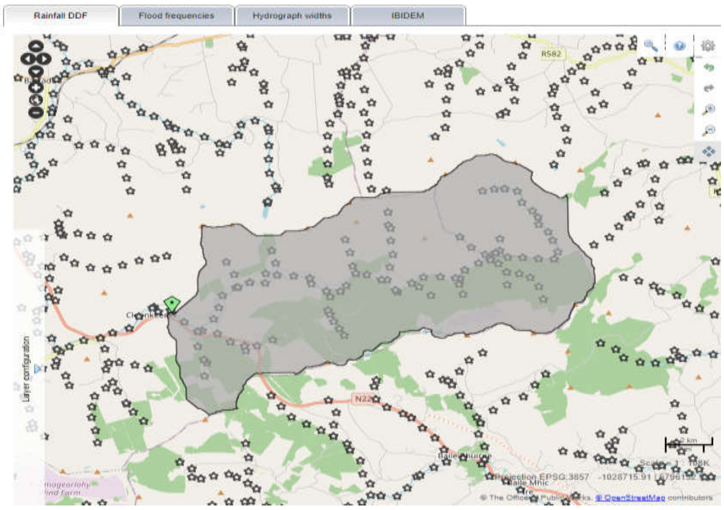
Project	Cummeennabuddoge Wind Farm - Mixing Zone Modelling
Ref	M01944-02
Watercourse	River Clydagh
Date	05/01/2023

Purpose

To estimate the design rainfall depths for various storm events for the River Clydagh catchment

Rainfall depths were calculated based on an ungauged catchment location corresponding to the downstream extent of the 2D model

FSU ungauged catchment at downstream 2D model extent



Resulting Depth (mm) Duration (h) Frequency (yrs) Table

	Rainfall Return Period (yrs)		
Duration	2	10	
1 hour	11.9	17.3	mm
6 hours	29.7	42.5	mm
12 hours	41.6	59.3	mm

Annex C

Nutrient Discharge Calculations

Project	Cummeennabuddoge Wind Farm - Mixing Zone Modelling
Ref	M01944-02
Watercourse	River Clydagh/Flesk
Date	05/01/2023

Purpose

To determine nutrient discharge from clear felling at the proposed development site

Maximum Flow-weighted Mean Concentrations

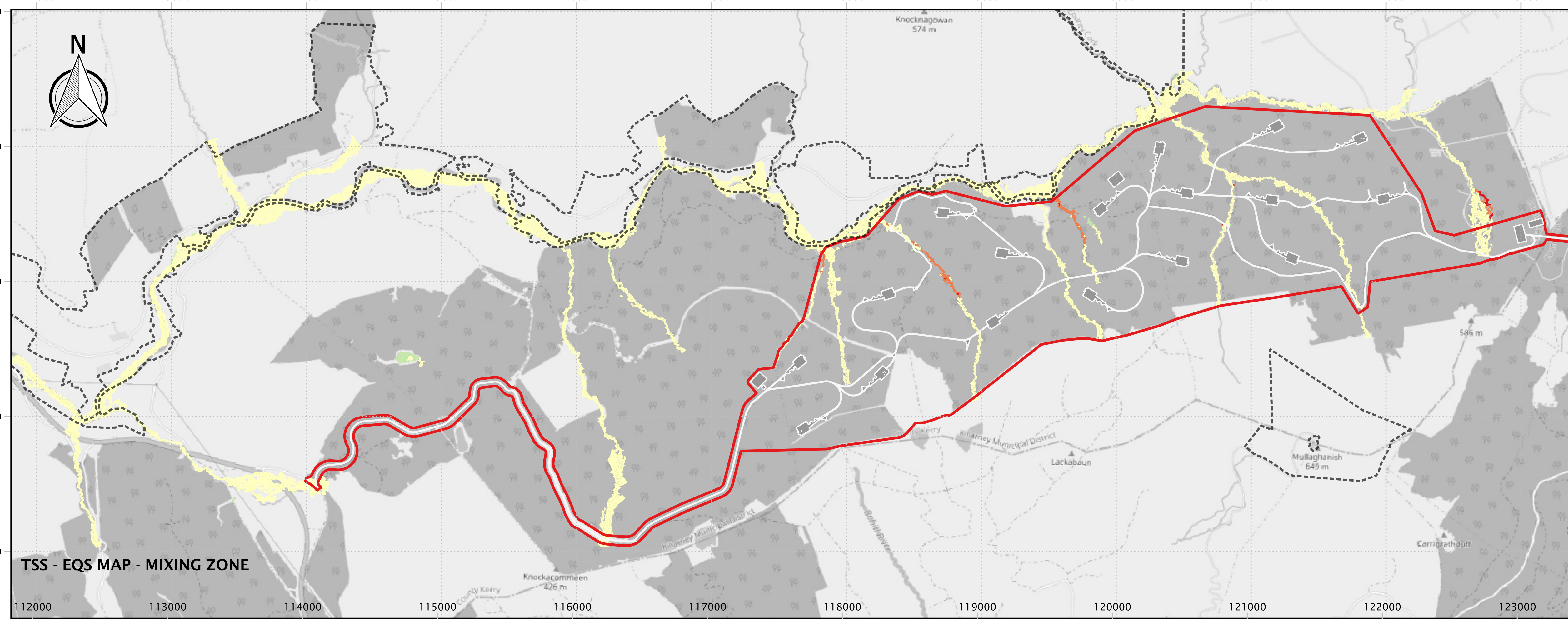
Parameter	Discharge due to clear felling / ha (mg/l/ha) Data Source: Finnegan et., al (2014)	Discharge concentrations due to clear felling of 241ha of development site (mg/l)	Discharge Concentrations at downstream site catchment (mg/l)
Ammonia (mg/l NH4)	0.016	3.820	0.412
Total Oxidized Nitrogen (mg/l N)	0.018	4.410	0.799
MRP (mg/l P)	0.003	0.615	0.074
Total Phosphorus (mg/l P)	0.012	2.846	0.317

Average Flow-weighted Mean Concentrations

Parameter	Discharge due to clear felling / ha (mg/l/ha) Data Source: Finnegan et., al (2014)	Discharge concentrations due to clear felling of 241ha of development site (mg/l)	Discharge Concentrations at downstream site catchment (mg/l)
Ammonia (mg/l NH4)	0.007	1.615	0.189
Total Oxidized Nitrogen (mg/l N)	0.006	1.538	0.509
MRP (mg/l P)	0.001	0.308	0.043
Total Phosphorus (mg/l P)	0.005	1.231	0.154

Annex D

River Clydagh Pollutant Concentration Plots



LEGEND

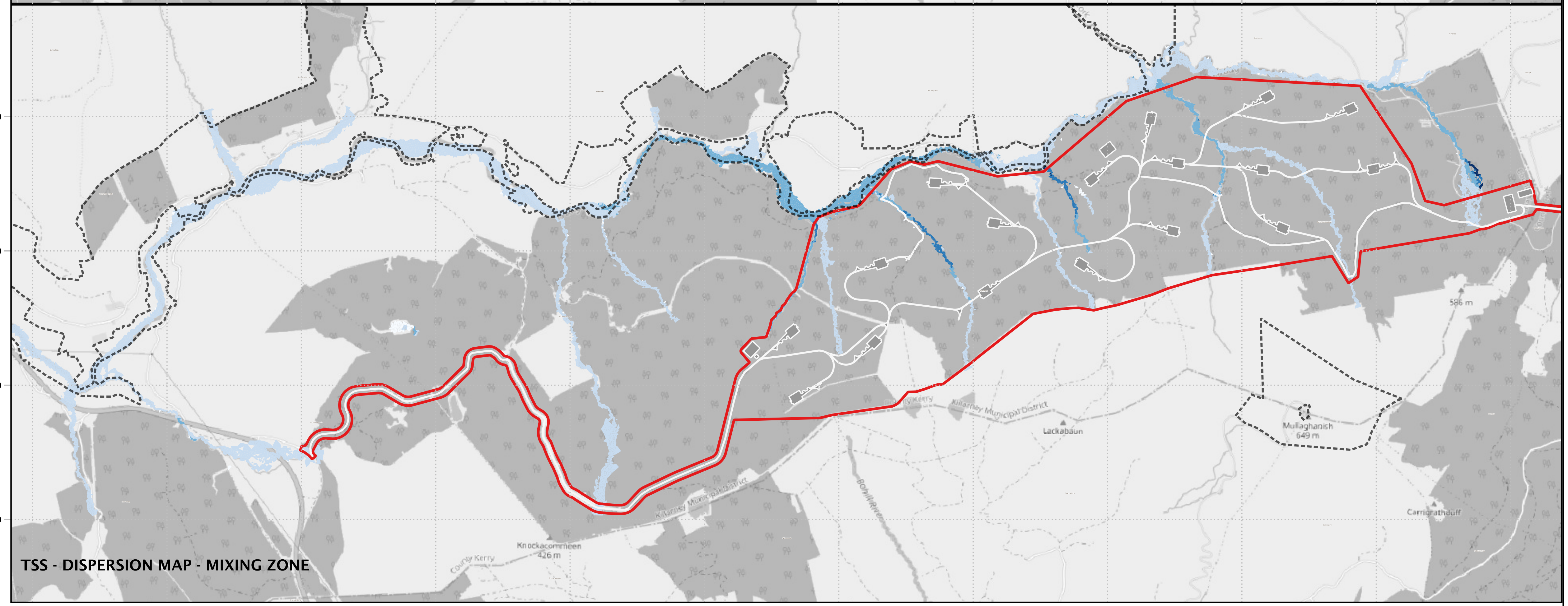
LEGEND - EQS MAP

- SIte Boundary
- Wind Farm Infrastructure
- SAC

Legend

TSS (EQS) - mg/l

- 5 - 10
- 10 - 20
- 20 - 25
- > 25 EQS THRESHOLD



LEGEND - DISPERSION / PLUME MAP

- SIte Boundary
- Wind Farm Infrastructure
- SAC

Legend

TSS (Dispersion) - mg/l

- 7 - 10
- 10 - 15
- 15 - 20
- 20 - 25
- > 25 (EQS THRESHOLD)

Reference Scale - Main Maps

0 500 1,000 1,500 2,000 m

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PROJECT	CUMMEENNABUDDOGE WIND FARM	HYDROLOGY SCENARIO	95%-ile Lowflow, 6hr,2yr Rainfall	SCALE: AS SHOWN	ORIGINAL SIZE: A3
MAP TYPE	EFFLUENT DISPERSION TRACING	PARAMETER SCENARIO	TOTAL SUSPENDED SOLIDS	DRAWN BY: EQ	APPROVED BY: AP
GRID SYSTEM: ITM	FIGURE NUMBER: M01944-02	FIGURE NUMBER	WQ01	REVISION: 0	DATE: 13/03/2024