Preliminary Report on Source Protection

Nephin Valley Group Water Scheme and Levally Lough

County Mayo

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Executive Summary

Source protection is the protection of raw water quality through measures that limit or eliminate the risk of water contamination. It is an increasingly important strategy for the protection and maintenance of drinking water sources, emphasising prevention rather than cure in relation to raw water quality. The National Source Protection Pilot Project (2005-2009) overseen by the National Centre for Freshwater Studies (now the Centre for Freshwater and Environmental Studies) at Dundalk Institute of Technology represents a model for best practice for the implementation of source protection in Ireland and was designed for replication by group water schemes around the country.

This report provides a physical site description of the Nephin Valley Group Water Scheme (GWS) and Levally Lough catchment (a potential secondary water source for Nephin Valley GWS) and explains the relevance to water quality (Section 4), discusses the potential impact of land use on raw water quality in the Nephin Valley and Levelly Lough catchments (Section 5), evaluates available relevant water quality data for Nephin Valley GWS and Levally Lough (Section 6) and provides recommendations to best manage concerns relating to source protection (Section 7).

The Nephin Valley GWS (53^0 59' 52" N, 9^0 20' 58" W) currently extracts its water from a mountain stream in the south east side of Doonbreedia Mountain which forms part of the Nephin Beg Mountain Range. Within the Nephin Valley GWS, there are some concerns over reduced river flow during droughts, impacting on water availability and reduction in water quality at the mountain river, Lugnamannaun River. As a potential secondary source of water to the Nephin Valley GWS, an assessment of a nearly by lake, Levally Lough (53^0 59' 11" N, 9^0 17' 30" W) is also undertaken in this report.

Nephin Valley mountain stream GWS and Levally Lough Catchment are located in the Western River Basin District, under the geographical sub unit of the Conn Water Management Unit, approximately 5 km from Pontoon and 15 km North of Castlebar. The small mountain stream catchment area of Nephin Valley GWS is 1.1 km^2 and is comprised of a single river that rises in the Doonbreedia Mountain to form the Lugnamannaun River. The maximum elevation of the Nephin Valley mountain stream GWS catchment is 800 m. Levally Lough is located 1.5 km from the Nephin Valley GWS mountain stream catchment, water treatment plant and reservoir. The surface area of the Levally Lough is 0.46 km^2; it is 2 km long from north to south and has an average width of 1 km, with a maximum depth of 9 m and average depth of 6 m. The catchment area of the Levally Lough catchment is 14.3 km^2 and the lake is at an elevation of approximately 29 m. Levally Lough was identified in the Conn Water Management Unit Action Plan as being of 'moderate ecological status' in 2009 and the lake waterbody WFD status in 2010-2012 was 'Good'.

The predominant CORINE land classification of the Nephin Valley GWS mountain stream catchment is moors and heath (44 %), sparsely vegetated areas (48 %) and peat bog (8 %). The bedrock is Nephin Formation with Maan Formation, which is predominantly Quartzite and Schist, with a small pocket of Sandstone located at the south east of the catchment where the water is abstracted for the GWS. There are two aquifer types in the Nephin Valley mountain stream catchment including Poor Aquifer and a small area of Locally Important Aquifer to the south east of the catchment. The soil and subsoil in the catchment is dominated by acid shallow/rocky/peaty mineral and bedrock

outcrops or subcrop respectively. The groundwater vulnerability in this mountain stream catchment is classified as being of E (Rock at/near surface or karst).

Peat bog accounts for a large proportion (63 %) of the land cover in the Levally Lough catchment. The land use in the catchment is agriculture with much of the catchment classified by CORINE as pasture (26 %) and other agriculture (5 %); coniferous forestry cover approximately (6 %) of the land area in the catchment on the in the south and south east of the catchment. The bedrock underlying the Levally Lough catchment is made up of fifteen geological formations, with Allie Limestone Formation, Birreen Formation and Capnagower Formation forming the bedrock surrounding Levally Lough. The aquifers present in the catchment are classified by Regionally Important Aquifers-karstified (conduit), Locally Important Aquifer-bedrock which is moderately productive only in local zones and Poor Aquifer-bedrock which is generally unproductive except in local zones. Subsoils within the Levally Lough catchment are dominated by bedrock outcrops or subcrops and till derived from Devonian Sandstone, whilst the soils in the east and south east of the catchment are mainly acid shallow/rocky/peaty mineral and to the south west of the catchment and surrounding Levally Lough are acid deep, poorly drained mineral. Much of the east and south east of the catchment along the higher slopes is classified as being of E (Rock at/near surface or karst) and Extreme ground water vulnerability. Along the west/south west and surrounding Levally Lough has a groundwater vulnerability of High. This association of poorly draining soils and high groundwater vulnerability may contribute to the Very High and High Risk of nutrients and bacteria contaminating surface waters within the Levally Lough catchment through either surface water or groundwater pathways. This means that care must be taken to ensure that domestic wastewater treatment systems located in the vicinity of the Levally Lough GWS abstraction point are properly installed and maintained.

A range of water quality parameters have been monitored for Nephin Valley GWS by Coffey Group, and other data is also available through Mayo County Council and the EPA. Raw water colour measured by Coffey Group at Nephin Valley water treatment plant exceeded the parametric value of the Surface Water Regulations (1989) for 95 % of sampling occasions. Water colour is likely to be influenced by levels of Total Organic Carbon.

The water quality monitoring undertaken on Levally Lough was conducted by Mayo County Council and the EPA. There was some historical monitoring conducted by the EPA for the Water Framework Directive in 2001 (EPA, 2006). The Conn Water Management Unit Action Plan provides the status of Levally Lough within the WMU from monitored data.

There have been no apparent complaints regarding taste of the Nephin Valley GWS treated water, although it should be noted that Nephin Valley GWS are currently under a boil notice by Mayo County Council. The boil water notice was put in place as a result of as the presence of worms in the treated water supply and low chlorine residuals in the in the network. Mayo County Council have advised the Nephin Valley GWS that the boil water notice will only be lifted under the condition of the installation of a chlorine injection facility within the network to ensure sufficient chlorine residuals in particular in the Lahardaun area.

Given the high values of colour present in the raw water throughout the GWS catchment, the likelihood of Trihalomethane (THM - a bi-product of the chlorination treatment process) being produced during the treatment process is high. The Drinking Water Regulations (2014) parametric

limit for Total THMs (100 THM µg/L) has been exceeded in Nephin Valley GWS and this may cause a risk to consumers, particularly as THM monitoring frequently is typically undertaken outside periods when colour is likely to be highest (from late summer through to early winter) and therefore the probability of the formation of THMs during the treatment process is likely to be greatest. THM samples are taken by Mayo County Council and reported in the annual EPA Drinking Water Reports.

Microbiological contamination (levels of Total Coliforms) within the raw water supply are at levels of significant concern, with Total Coliforms measuring >201 MPN/100ml on 46 % of sampling occasions from the monthly status reports (MSR) from Coffey Group from March 2011 to June 2016. The results from the MSR from Coffey Group indicate that the microbial contamination is being successfully removed by standard treatment processes. However, some management actions have been identified and described later which aim to reduce the microbial contamination of the raw water supply. The UV treatment also undertaken by Nephin Valley water treatment plant can reduce the risk of *Cryptosporidium* contamination of the treated water.

Nephin Valley GWS raw water pH was observed to be below the Surface Water Regulations (1989) parametric range for Class A1 waters on 29 % of sampling occasions resulting in the treatment of the raw water with caustic soda (sodium hydroxide) to bring pH into the range of (6.5-9.5) required by the Drinking Water Regulations (2007 and 2014). Given the naturally low pH of the peaty soils through which the surface waters of the catchment flow, in combination with the naturally low buffering capacity (low alkalinity) of the raw water, there are limited catchment-level source protection management actions available to improve raw water pH prior to treatment.

Nephin Valley GWS treated water measurements at the tap from a number of locations throughout the GWS catchment provided by Mayo County Council, shows spike in water parameters measured on the 15th of September 2015. There was high and excessive peaks in water parameters for example, Manganese (387 µg/L), Aluminium (675 µg/L), Iron (497 µg/L) and Turbidity (1.4 NTU) were observed. The Drinking Water Regulations (2014) set a limit of 50 µg/L for Manganese, of 200 µg/L for Aluminium, and 200 µg/L for Iron. Turbidity levels should not exceed 0.2 NTU to reduce the risk of *Cryptosporidium* presence in drinking water and this value was significantly exceeded in Nephin Valley GWS mountain stream catchment on one occasion over the sampling period (September 2015).

During the initial site visit to Nephin Valley GWS in July 2016, a number of important issues were identified that, if addressed through engagement with Mayo County Council and Coffey Group, the DBO contractor, could lead to an improvement in the raw water quality for Nephin Valley GWS.

- There have been some issues with the presence of worms in the treated water (September 2015 until February 2016) throughout the GWS network. The Health Service Executive (HSE) conducted sampling within the GWS network and concluded a water quality fail. The worms found in the Nephin Valley GWS were 'Doro' worms as identified by the HSE. A water audit was subsequently carried out on the Nephin Valley water treatment plant and no presences of the worms were found in the water treatment works. The chlorine dose at the Nephin Valley GWS was increased to 0.9 mg/L and aggressive scouring within the network was advised to overcome this issue. Since then, three subsequent tests have passed and there are no reported incidences of worms in the scheme. Mayo County Council has requested

that a chlorine injection facility be put in place along the GWS network to ensure sufficient chlorine residuals in particular in the Lahardaun area.

- There are a number of parameters not currently been monitored by Coffey Group on the raw and treated water at the Nephin Valley GWS water treatment plant. These include Manganese, Total Phosphorus, Ammonia, Nitrite, Nitrate, Conductivity and Dissolved Oxygen.
- Coffey Group to specify water colour measurements as True or Apparent.

A number of key issues that should be addressed are recommended in Section 7.0 in order to improve source protection and maintain high quality water supplies from the primary water sources at Nephin Valley. The most urgent recommendations are:

Nephin Valley Mountain Stream Source

1. Put Source Protection on the agenda

Including source protection issues on the agenda of committee meetings increases the profile and awareness of source protection issues within the Nephin Valley GWS catchment and brings into focus the recommendations made within this report. Developing a protocol for dealing with potential pollution incidences would be a good first step for the committee to address.

2. Filling water quality monitoring gaps.

In assessing the water quality monitoring data it is evident that Total Organic Carbon (TOC) should be monitored within the raw water supply and Trihalomethanes (THM) should be monitored in the treated water simultaneously. Monitoring TOC gives an indication of the level of organic matter in the raw water supply that can react with chlorine during the treatment process to produce THM. It is recommended that THM and TOC monitoring is focused over the period from late summer through to early winter as this is when colour values are highest, with additional occasional THM and TOC monitoring undertaken simultaneously throughout the rest of the calendar year. The monitoring of THMs should occur on water after chlorination (the formation of THM occurs within the first ten hours post-chlorination), in/near the GWS storage reservoir and at a representative consumer tap.

3. Engage with Mayo County Council and Coffey Group regarding the management of THMs/Microbial contamination and mitigating measures.

The high, and in some cases excessive, concentrations of THMs of treated waters at the tap is of concern, particularly as THM monitoring has typically been conducted outside of the periods when colour, and subsequently THM concentrations, are usually at their highest (i.e. late summer through to early winter). It is recommended that THM monitoring is focussed during this period, with additional occasional THM monitoring undertaken throughout the rest of the calendar year.

Recent spikes microbial contamination in treated water suggests occasional low chlorine residuals along the network. Mitigation options that aim to reduce THM concentrations in the treated water while at the same time ensuring suitable chlorination residuals along the network should be undertaken to ensure sufficient protection against microbial contamination to the consumer supply should be discussed with both Coffey Group and Mayo County Council.

4. Engage with Mayo County Council and Coffey Group regarding GWS issues and water treatment plant operations.

- Within the Nephin Valley GWS, there are some concerns over reduced river flow during droughts, impacting on water availability and reduction in water quality at the mountain river. This is one of the factors that is driving the GWS to consider Levally Lough as a secondary raw water source for the Nephin Valley mountain stream GWS.
- Current Boil Notice on Nephin Valley GWS under advisement of Mayo County Council to remain until the installation of a chlorine injection facility along the network, in the Lahardaun area.
- Continue to monitor for the presence of worms in the treated water supply throughout the GWS network.
- Current water monitoring gaps in raw and treat water at the Nephin Valley water treatment plant including Manganese, Total Phosphorus, Ammonia, Nitrite, Nitrate, Conductivity and Dissolved Oxygen.
- Clarification regarding whether Coffey Group are measuring Apparent Colour or True Colour since March 2011 (True colour should be monitored to ensure compliance with the Surface Water Regulations (1989) parametric value for colour).

5. Restricting direct sheep access to Lugnamannaun River, water source for the Nephin Valley Group Water Source.

In the vicinity of Lugnamannaun River restricting sheep access assist in reducing potential nutrient and faecal contamination of the raw water source. This action, in combination with the monitoring of faecal coliforms in the raw water, will help to identify further source protection measure required to improve water quality for the GWS and potentially reduce treatment costs in the longer term.

6. Initiate a communications drive

Nephin Valley GWS should undertake a communications initiative to remind scheme members of their legal obligations with regards to nutrient enrichment practices, to recommend Good Agricultural Practices. The location of the treatment works on the hill side of Doonbreedia Mountain presents an opportunity for a community open day when local national schools, members of the local community and GWS members can learn more about the source of their drinking water, be informed about the treatment process, the work that is required to ensure good quality water reaches their taps and the source protection measures that need to be implemented to ensure good raw water quality.

Levally Lough potential secondary raw water source for the Nephin Valley GWS.

1. Filling water quality monitoring gaps in Levally Lough

Monitoring of Total Organic Carbon (TOC) at Levally Lough to gives an indication on the level of organic matter in the raw water. This may provide further information on the use of Levally Lough as a potential secondary water source to Nephin Valley GWS and the potential of the raw water supply from Levally Lough to react with chlorine during the treatment process to produce THMs.

2. Engage with householders within the Levally Catchment with regard to on-site waste treatment systems (septic tanks) maintenance.

Householders within areas of E, Extreme and High ground water vulnerability should be engaged to ensure good septic tanks are maintained and serviced regularly in order to reduce the potential for nutrient and other contaminants entering the surface and ground water bodies.

3. Soil nutrient analysis

Given the unknown nutrient and chlorophyll levels within Levally Lough and its Water Framework Directive Lake Water body score of 'Possibly at risk of not achieving good status', the implementation of soil nutrient analysis for lands bordering Levally Lough would be valuable. Soils with high nutrient status are most likely to result in losses to nearby waterways. Knowledge of soil nutrient status would allow farmers to match fertiliser application to their needs and to save money by not applying fertiliser to fields that do not require it. This analysis would be beneficial to both the GWS and the farmers and therefore the costs could be shared also helping to achieve good ecological status for Levally Lough.

4. Restricting direct livestock access to Levally Lough

It would be important to restrict direct livestock access to water bodies in the vicinity of Levally Lough, if used as a potential secondary water source to the Nephin Valley GWS. This action will assist in reducing potential nutrient and faecal contamination of the raw water source.

5. Initiate a communications drive

Nephin Valley GWS should undertake a communications initiative around Levally Lough as a potential secondary raw water source to the GWS.

1.0 Introduction

Source protection is the protection of raw water quality through measures that limit or eliminate the risk of water contamination. It is an increasingly important strategy for the protection and maintenance of drinking water sources. Source protection should be the first barrier in a multi-barrier approach to providing safe drinking water. In its simplest form, source protection emphasises prevention rather than cure in relation to water quality. A clean water source will help in the long-term provision of safe and cheap potable water. This approach involves managing any pollution in the raw water catchment area.

In Ireland, a limited number of studies have investigated the potential of source protection to improve water quality. The National Source Protection Pilot Project (NSPPP) at Churchill and Oram Group Water Scheme, County Monaghan (2005-2009) was established by the National Rural Water Monitoring Committee and was overseen by the National Centre for Freshwater Studies (now the Centre for Freshwater and Environmental Studies, CFES) at Dundalk Institute of Technology. The objectives of the pilot project were to assess water quality within the Milltown Lake catchment, identify sources of contamination and implement remediation measures to protect and enhance water quality in the lake. The project represents a model for best practice for the implementation of source protection in Ireland and was designed for replication by other group water schemes around the country. It is in the interest of privately-sourced group water schemes to carry out assessments to determine the potential for nutrient enrichment and biological contamination (e.g. *Enterococcus* species, *Escherichia coli, Cryptosporidium* species) of their water supplies, and to meet application conditions for a Water Services Licence under the Water Services Act (2007).

The report provides a physical site description of the Nephin Valley Group Water Scheme (GWS) mountain stream catchment and Levally Lough catchment (a potential secondary water source for Nephin Valley GWS) and explains how this is relevant to water quality. The potential impact of land use is discussed and available raw water quality data from Nephin Valley GWS is evaluated. Finally, major concerns relating to source protection are highlighted and recommendations are made as how best to manage these concerns in the future.

2.0 Methods

2.1 Catchment delineation and description

The outline of the catchment was defined using the available contours on the Map Genie ArcGIS basemaps available from Ordinance Survey Ireland (OSI) and provided under license by the Geological Survey of Ireland (GSI). A number of national digital Geographical Information System Layers (GIS) were available from a number of sources (Table 1), and were clipped to the catchment areas of Nephin Valley and Levally Lough GWS. This allowed detailed descriptions of, for example, land cover using an EU-wide standardised system (CORINE), soils and geology, as well as illustrating the stream and water body network within the catchment.

Table 1: National GIS datasets used to describe the catchment

Dataset	Source	Description
Streams/Lakes/Rivers	EPA Ireland	Location of streams, lakes and rivers
CORINE	EPA Ireland	Image of land cover based on satellite imagery
Bedrock Geology	Geological Survey of Ireland (GSI)	Map (1:100,000 scale) of Irish bedrock geology
Aquifer Bedrock	GSI	Information on the quality of groundwater aquifers
Aquifer Vulnerability	GSI	Information on the connectivity between contaminants and aquifers
Soils	GSI and Teagasc	Information on soil type
Subsoils	GSI and Teagasc	Information on subsoil type

2.2 Water Quality Data

Water quality data for Nephin Valley GWS were collected from a number of sources: Monthly raw and treat water monitoring data is collected by Coffey Group and data from March 2011 until June 2016 was provided by Coffey Group and are presented in this report.

Drinking water monitoring by Mayo County Council and the Environmental Protection Agency (EPA) post treatment at the consumer taps from twenty three sampling locations in the Nephin Valley GWS from November 2010 until May 2016.

Parameters relevant to source protection were extracted from the relevant datasets and analysed and interpreted to highlight possible water quality issues and their potential causes and impacts within the Nephin Valley GWS mountain stream catchment. Also included are details of important parameters that have not been monitored to date. These parameters have been described and it is noted when such parameters have not been monitored for the Nephin Valley GWS catchment.

Water quality monitoring data for Levally Lough (mid-lake) was collected by Mayo County Council and EPA from April 2007 until October 2015 and is presented in this report.

3.0 Overview of Nephin Valley and the Water Framework Directive

Under the Water Framework Directive (WFD, 2000/60/EC), the island of Ireland is divided into eight River Basin Districts (RBDs), two of which are international with boundaries shared by the Republic of Ireland and Northern Ireland. The Nephin Valley GWS mountain stream catchment and Levally Lough catchment lies within the Western River Basin District. Each RBD is subdivided into Water Management Units (WMU), and Nephin Valley GWS mountain stream and Levally Lough catchments are included within the Conn WMU. An action plan for the WMU is available from http://www.westernrbd.ie/.

This action plan presents an overview of water quality, information relating to potential causes of pollution and actions required to improve water quality to 'good' status (the overarching objective of the WFD is to achieve 'good' status for all water bodies) within the Conn WMU. Rivers within the

Conn WMU varied in status but were mostly classed as High (25) or Good (60), 14 rivers at a moderate classification and 5 rivers at a Poor status. There are 13 lakes situated within the WMU and the status is High (6) or Good (1) with 6 at Moderate status classification. Levally Lough was at Moderate Status in 2009.

The Conn WMU Action Plan attributes 80 % of the Total Phosphorus load as diffuse, with agriculture representing the largest source of diffuse nutrients (70 %) and forestry representing (10 %). A total of 9,363 on site water treatment systems (OSWTS) or septic tanks are located within the WMU, with 8,685 OSWTS lie within 104 river water bodies, of which 1,147 OSWTS form a potential risk to 7 water bodies. A summary of the WFD classification for Nephin Valley and Levally Lough catchments is given in Levally Lough has a Lake waterbody WFD status in 2010-2012 as 'GOOD'.

Table 2 and each of the elements monitored through the EPA Water Framework Directive Lakes Water Quality Monitoring Programme (Conn Water Management Unit Action Plan, 2009). The overall Ecological Status is classified as 'Moderate'. No status is given in the WMU Action Plan for Fish, Morphology and Chemical status. Levally Lough has a Lake waterbody WFD status in 2010-2012 as 'GOOD'.

Table 2: Water Framework Directive assigned status for each monitored element for Levally Lough (Adapted from the Conn Water Management Unit Action Plan, 2009).

Name of water body	Biological Elements			Supporting Elements			Status	
	Macrophytes	Chlorophyll	Fish	Morphology	Nutrient Enrichment	Physicochemical	Ecological Status	Chemical Status
Levally Lough	Good	Moderate	No status given	No status given	Good	Good	Moderate	No status given

4.0 Physical Site Description

4.1 Catchment location and outline

Nephin Valley Group Water Scheme is located in County Mayo, approximately 5 km from Pontoon and 15 km North of Castlebar. The scheme extracts its water from a mountain stream in the south east side of Doonbreedia Mountain which forms part of the Nephin Beg Mountain Range (Figure 1). As a potential secondary source of water to the Nephin Valley GWS, an assessment of a nearby lake, Levally Lough is also undertaken in this report (Figure 2).

Nephin Valley GWS has a small catchment area of 1.1 km^2 and is comprised of a single river that rises in the Doonbreedia Mountain to form the Lugnamannaun River. The river waterbody WFD status 2010-2012 for the Lugnammanaun River is 'Good'. Levally Lough (a potential secondary water source to Nephin Valley GWS) is a known pike fishing destination and has a catchment area of 14.3 km^2 (Figure 3). This lake has been classified as having a lake waterbody WFD status of 'good' 2010-2012

and has a waterbody score of “possibly at risk of not achieving good status”. Levally Lough has a ‘Moderate’ status in the Conn WMU action plan. Levally Lough has five inflow points, including two inflowing rivers (Derrinurcher and Pollawarla Rivers) located to the south of the lake. These rivers have been classified as having a river water body WFD status of ‘good’ 2010-2012. There is one main out flowing river, Derrinurcher River which joins the Addergoole River which eventually flows into the west of Lough Conn (Figure 3).

Pressures within the Nephin Valley GWS mountain stream catchment are primarily agricultural, with commonage grazing occurring on the mountain. Peat erosion also threatens water quality within the region. The elevation is greatest at the northern point of the mountain stream catchment at 800m.

Pressures within the Levally Lough catchment are also primarily agricultural, with much of the catchment surrounding Lough and to the west/northwest of the catchment classified by CORINE as pasture and land principle occupied by agriculture. Other pressures within the Levally Lough catchment may include domestic wastewater treatment systems in areas in E and Extreme ground water vulnerability. Elevation is greatest along the east and south of the catchment, reaching a maximum of approximately 340 m in the Cuilmullagh hills to the south of the catchment.

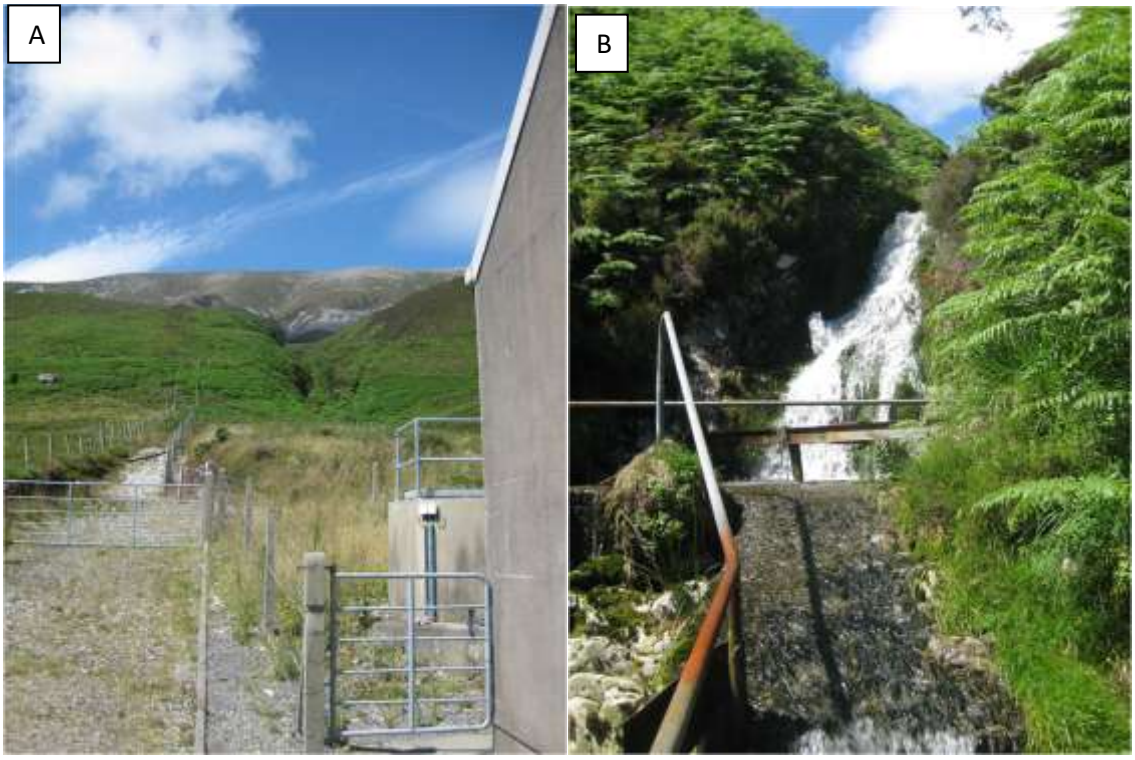

Figure 1: Site Location: Nephin Valley GWS, A) water treatment plant to the right of the photo and the mountain stream abstraction point in the background and B) water abstraction point.

Figure 2: A) Levally Lough (potential abstraction point for secondary water source for Nephin Valley GWS). B) Agricultural pressures along the west of the Levally Lough.

4.2 Bedrock geology

The bedrock underlying the Nephin Valley GWS mountain stream catchment consists of two geological formations and is dominated by Nephin Formation with a small pocket of Maam Formation, dominated by Quartzite and Schist with a small pocket of Sandstone to the south of the catchment near the Nephin Valley water treatment plant (Figure 4).

The bedrock underlying the Levally Lough catchment consists of a number of geological formations, with the geological structure running north east to south west (Figure 5). The bedrock consists of Allie Limestone Formation, which are a dark-fine grained limestone and shale and Rockfleet Bay Limestone Formation, a dark-fine limestone and calcareous shale to the west of the catchment. Birreen Formation, an igneous-clast conglomerate, sandstone and Croghmoyle Formation, a Quartzite clast conglomerate are the domoninate bedrocks to the south of the catchment. Surrounding the majority of Levally Lough, to the north of the catchment there is a Capnagower Formation, grey sandstone and siltstone. The underlying bedrock to the east of Levally Lough is more complex, with numerous geological formations in place including King Hill formation, Glenisland Formation, Leckee Quartzite Formation, Newantrim Member, Meelick Menber, Lower Lismoran Formation, Raheen Barr Volcanic Member, Cashel Member and Slievenagark Member all of which are mainly Quartsite and schist formations.

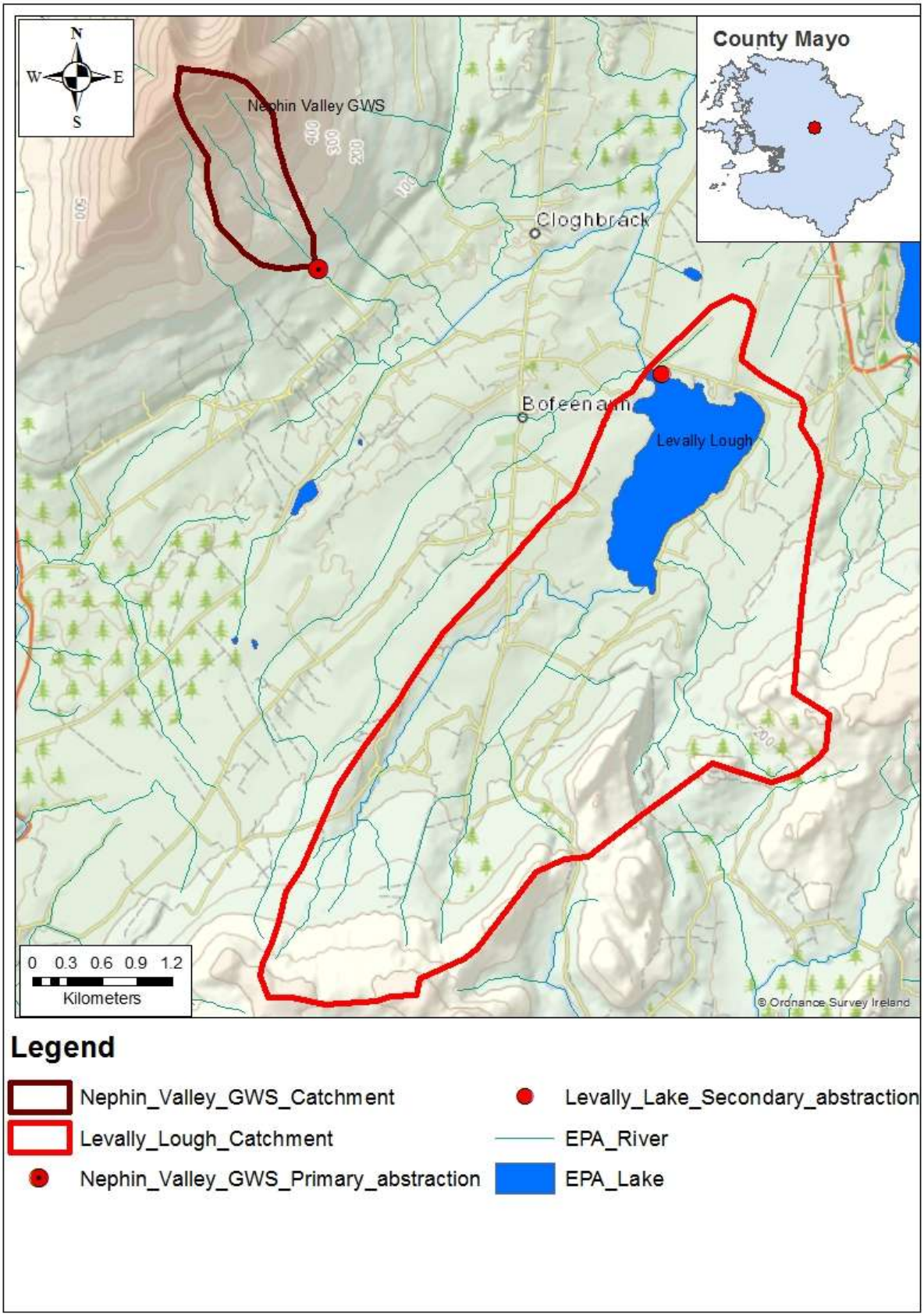

Figure 3: Catchment area and location of Nephin Valley GWS abstraction point and Levally Lough Catchment (a potential secondary water source for Nephin Valley GWS).

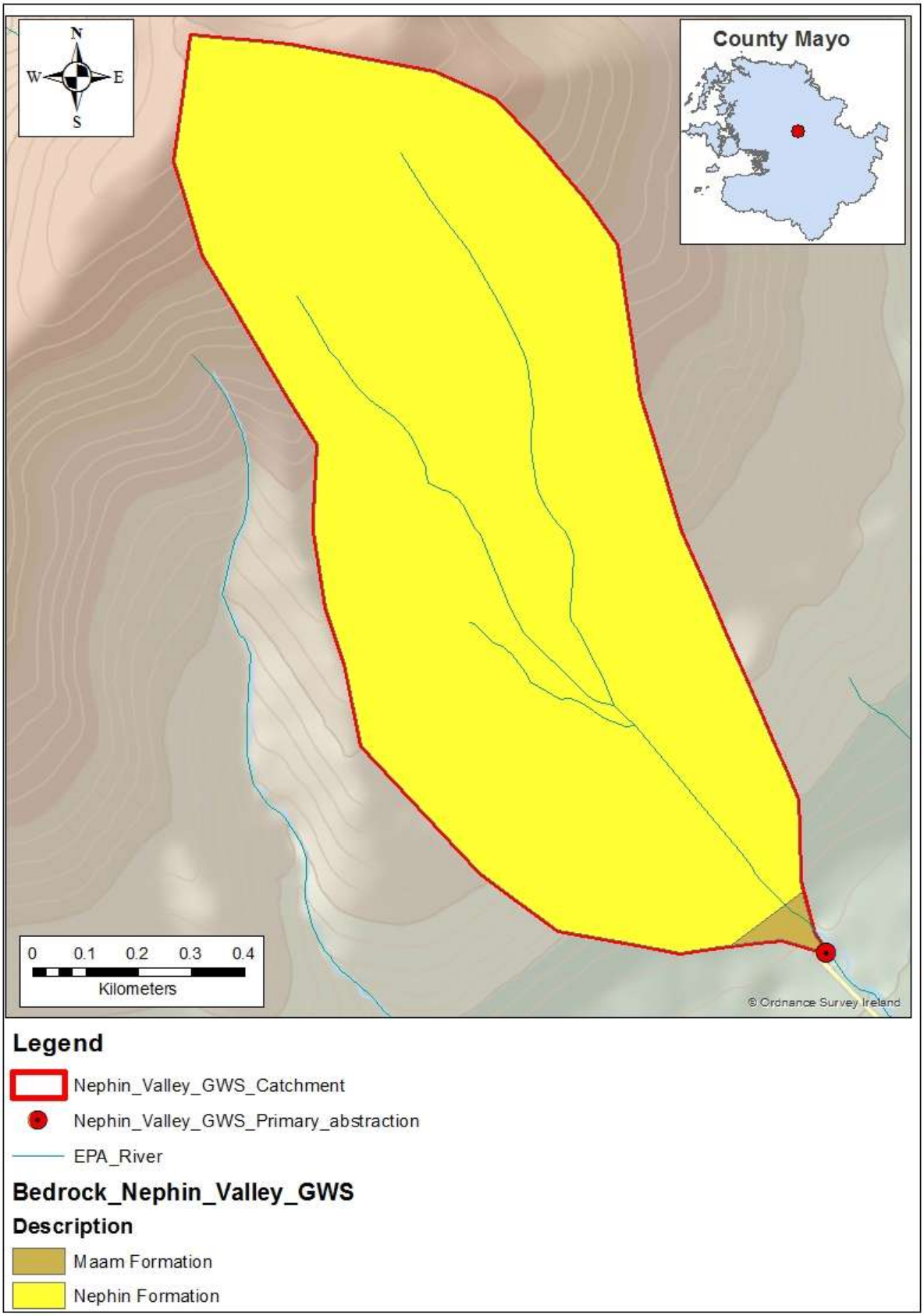

Figure 4: Bedrock geology within the Nephin Valley GWS mountain stream catchment.

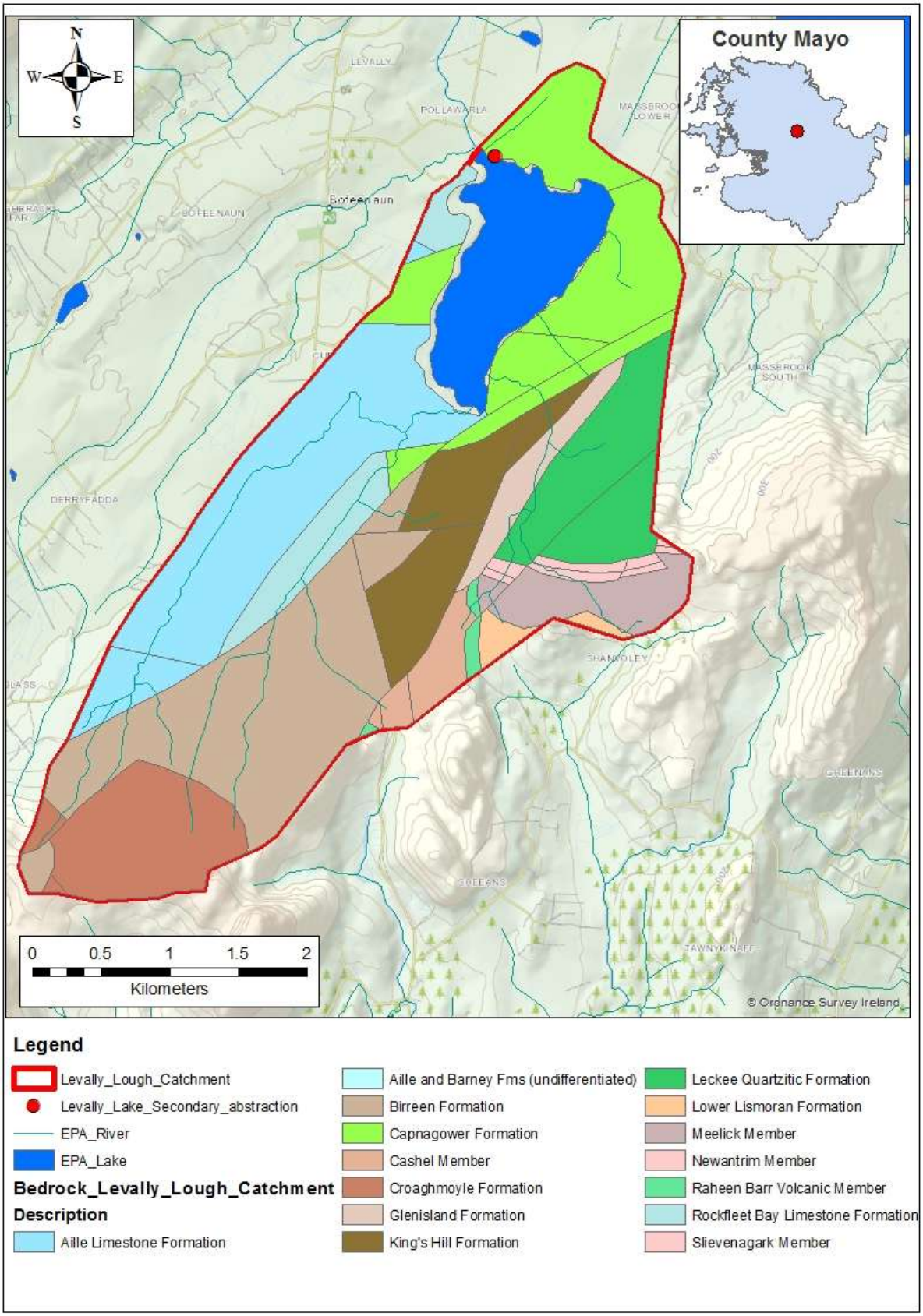

Figure 5: Bedrock geology within the Levally Lough Catchment (potential secondary water source to Nephin Valley GWS catchment).

4.3 Bedrock aquifers

An aquifer is an underground body of permeable rock or sand/gravel that yields water in sufficient quantities for use.

There are two aquifers underlying the Nephin Valley GWS catchment. A 'Poor Aquifer: Bedrock which is generally unproductive except in local zones' predominates the majority of the catchment. Such aquifers are generally considered as unproductive (i.e. grounderwater wells produce low yields), yet are mapped as covering approximately two-thirds of the land area in Ireland. They are not regarded as important sources of water for public water supply, yet are believed to be important with regards to delivering water (and associated pollutants) to rivers and lakes via shallow groundwater pathways (EPA, 2010). There is a small area near the abstraction point which is a 'Locally Important Aquifer: Bedrock which is moderately productive only in local zones' (Figure 6).

The different bedrock types found within Levally Lough catchment (described in section 4.2 above) give rise to various aquifer types (Figure 7). There are three different aquifer types found in the Levally Lough catchment. The dominant aquifer classification in the catchment is 'Poor Aquifer: Bedrock which is generally unproductive except in local zones', which predominates the east and south of the catchment. To the west of the catchment is a 'Regionally Important Aquifer Karstified (conduit). This productive aquifer corresponds with the limestone in the area. The porous nature of the karstified landscape in association with shallow soils/subsoils can reduce the potential for contaminants filtration from surface water as it flows into the groundwater, providing a potential pathway for contamination to quickly enter groundwater. The area surrounding the majority of the lake (with the exception of the south and a small pocket along the west of the lake), to the north of the catchment, the aquifer type is classifies as 'Locally Important Aquifer: Bedrock which is generally moderately productive.

4.4 Groundwater vulnerability

Groundwater vulnerability refers to the likelihood of surface water contaminants reaching the groundwater store. The vulnerability of groundwater is dependent on three components: 1). the time of travel of infiltrating water (and contaminants); 2). the relative quantity of contaminants that can reach the groundwater; and 3). the contaminant attenuation capacity of the geological materials through which the water and contaminants infiltrate.

The groundwater vulnerability of the Nephin Valley GWS mountain stream catchment encompasses two of the highest vulnerability classifications, with E (rock at/near the surface karst) and Extreme, which is not surprising giving the steep slopes and soil/subsoil within the catchment. The groundwater vulnerability E (rock at/near the surface karst) dominates throughout the catchment and a small vein of Extreme grounder water vulnerability located to the south of the catchment (Figure 8).

The groundwater vulnerability of the Levally Lough catchment is complex and is dominated by three of the highest vulnerability classifications. Groundwater vulnerability E (rock at/near the surface karst) and Extreme are mainly located on higher ground to the east and south of the catchment. The groundwater vulnerability of High, surrounds Lough Levally and the west of the catchment. There are small pockets of Moderate and Low vulnerability located in the west and north of the catchment

(Figure 9). The vulnerability of groundwater is affected by the permeability of the overlying subsoils and soils and the interactions with surface water and groundwater.

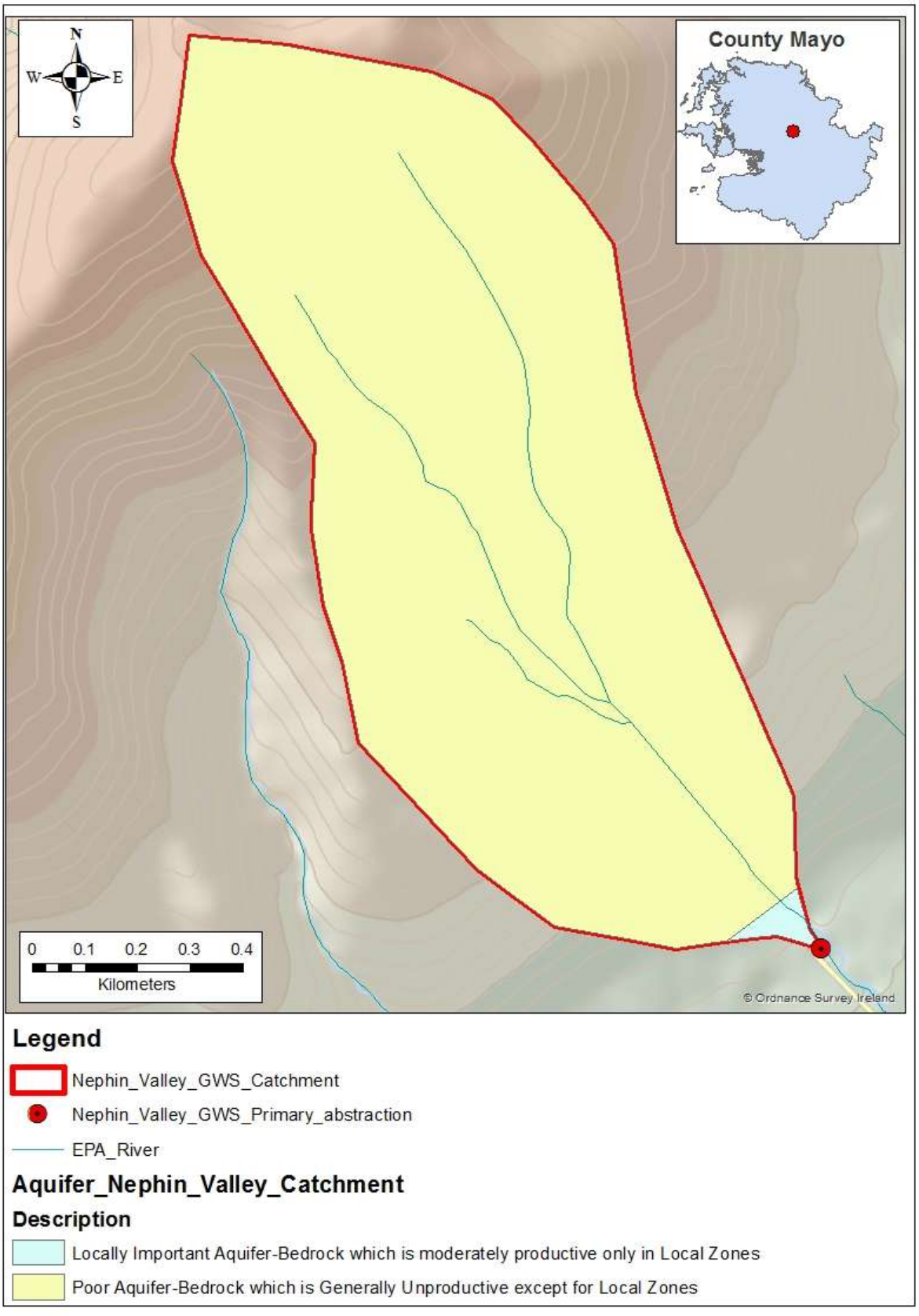

Figure 6: Aquifer types present within the Nephin Valley GWS mountain stream catchment.

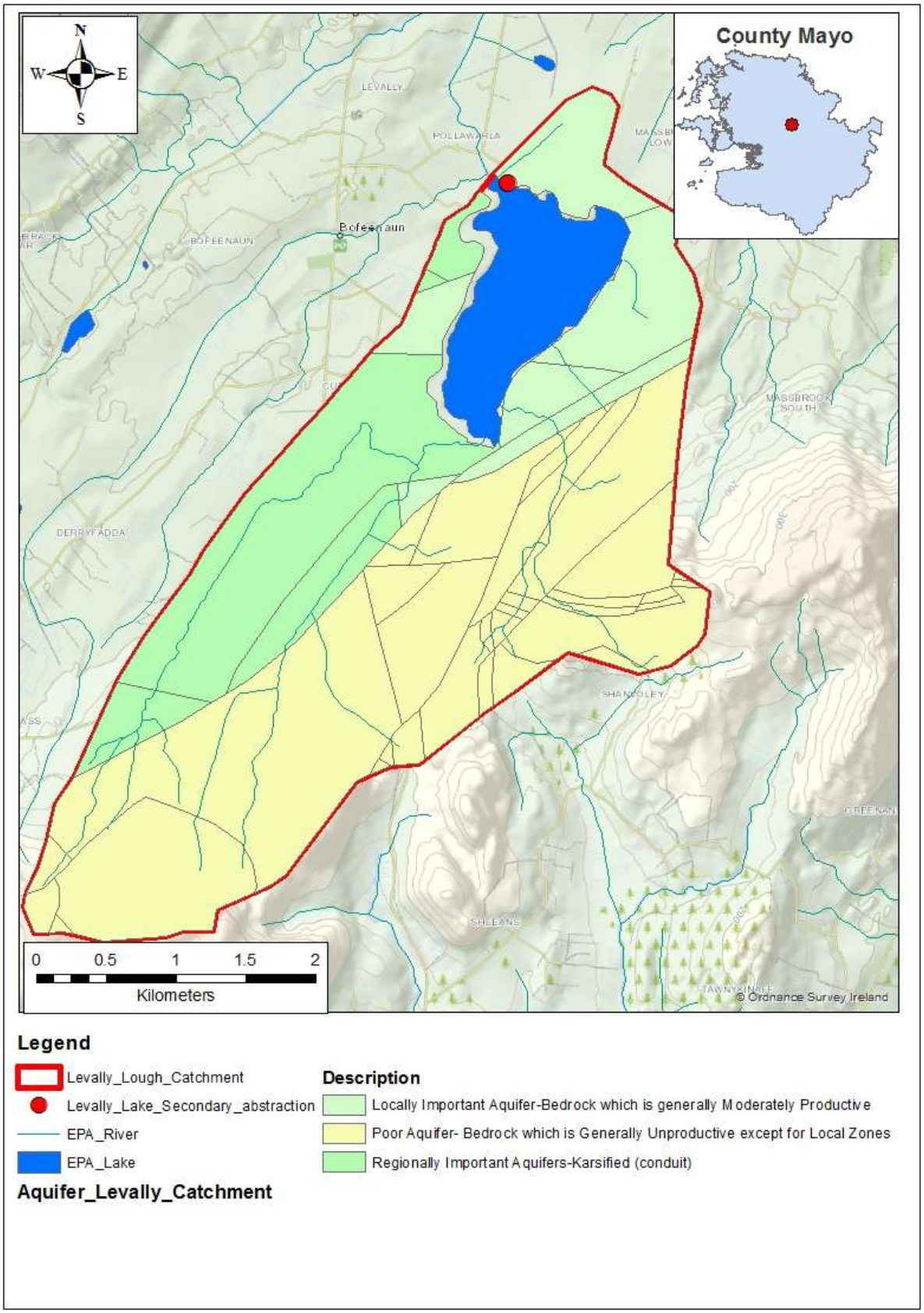

Figure 7: Aquifer types present within the Levally Lough catchment (potential secondary water source to Nephin Valley GWS catchment).

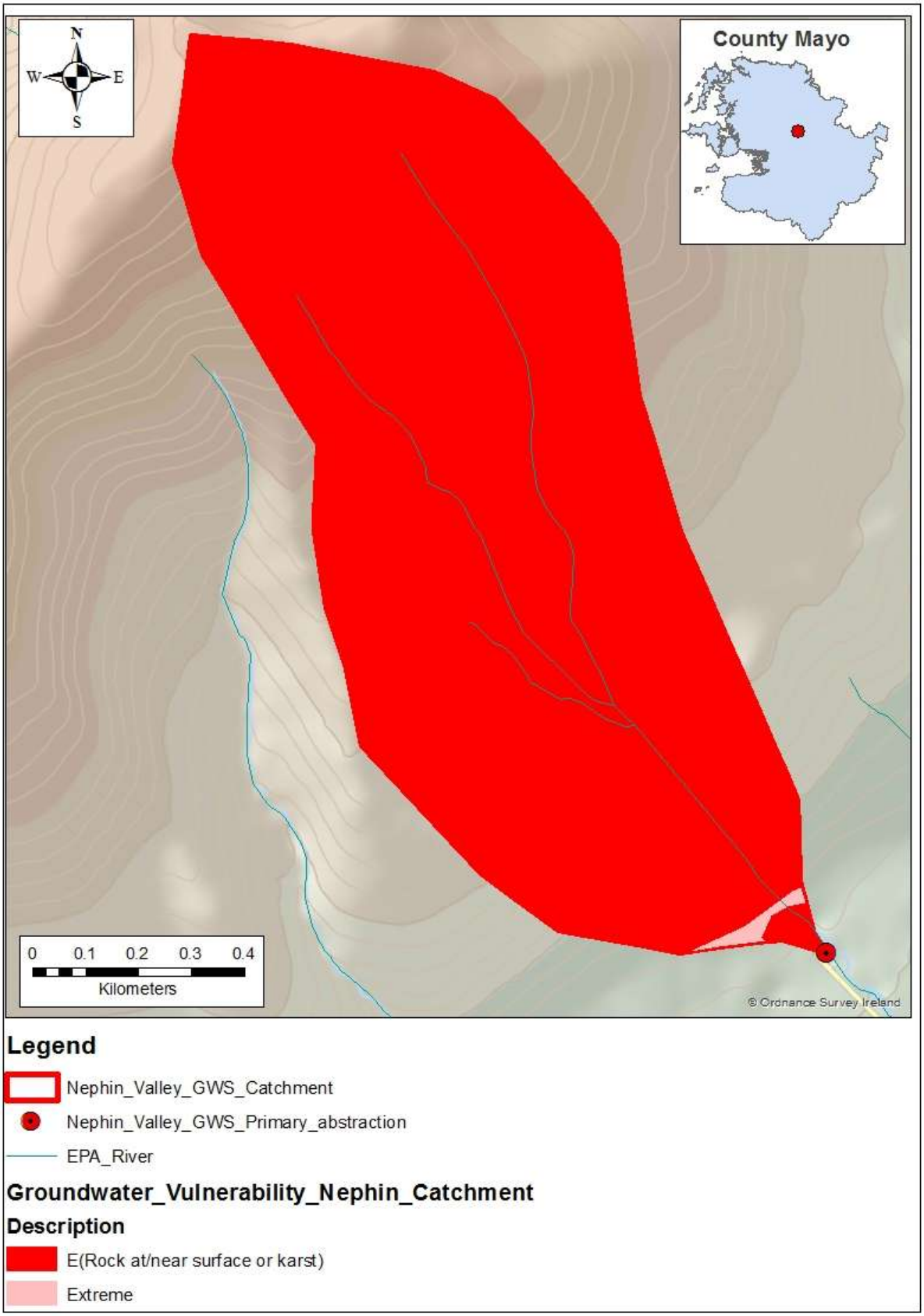

Figure 8: Groundwater vulnerability within the Nephin Valley GWS mountain stream catchment.

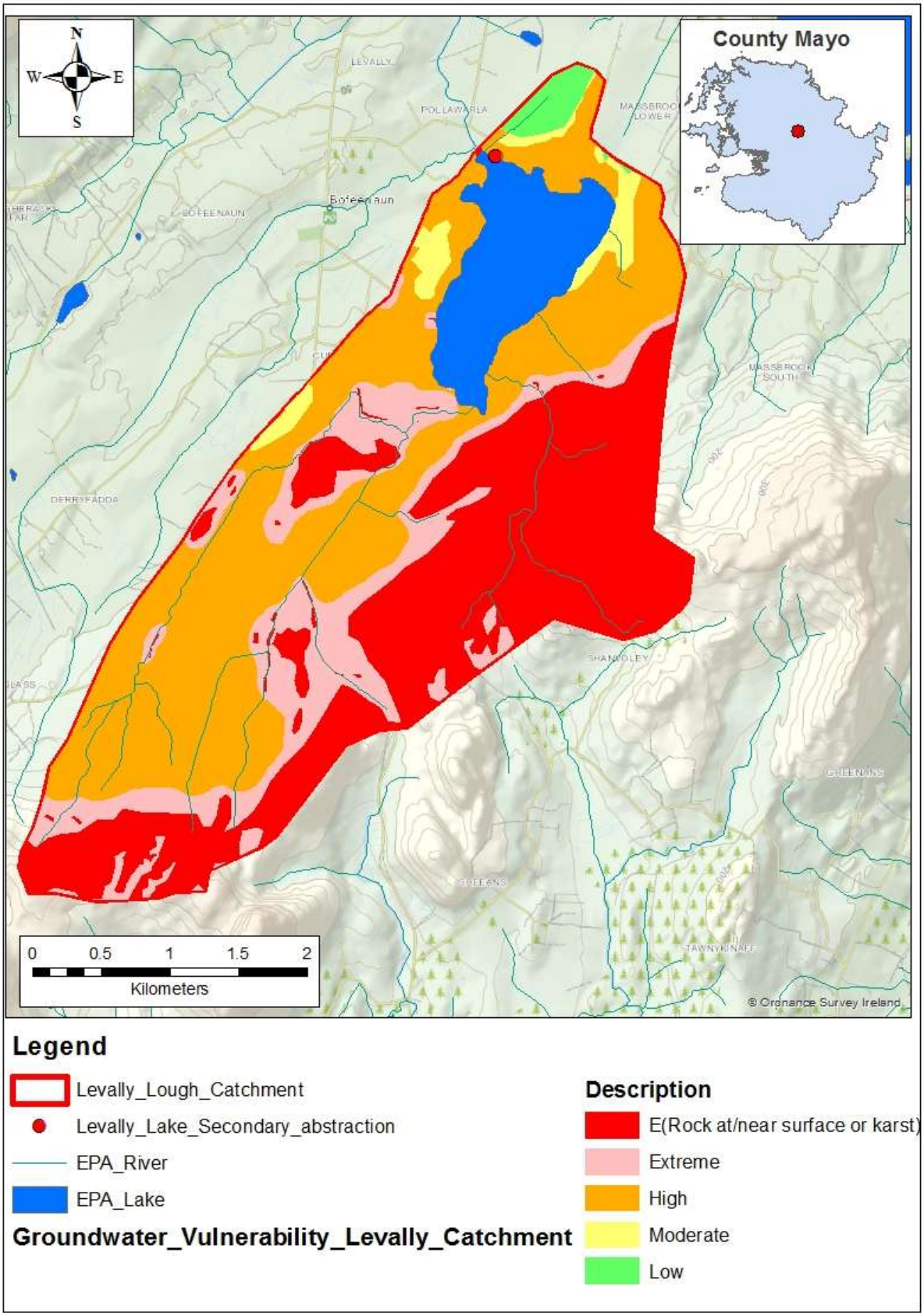

Figure 9: Groundwater vulnerability within Levally Lough catchment (potential secondary water source to Nephin Valley GWS catchment).

4.5 Subsoils

Subsoils lie between the bedrock and soils and are the most important feature in influencing the groundwater vulnerability to pollution as they act as a protective filtering layer, the effectiveness of which depends on their type, permeability and thickness.

There are two subsoil types present within Nephin Valley GWS mountain stream catchment (Figure 10). The majority of the subsoil in the catchment is Bedrock outcrops or subcrops and there is a small vein of Till derived from Devonian and Carboniferous sandstone.

There are eight different subsoil types found in the Levally Lough catchment (Figure 11). A large proportion of the east, south east and south, along higher elevations, the main subsoil are Bedrock outcrops or subcrops. To the north east of the catchment, along the east of Levally Lough there is an area of Till derived from metamorphic rocks and a small pocket can be also found south east of the catchment. In the south west region Till derived from metamorphic rocks are dominates and above that, along the west the subsoil is Till derived from Devonian and Carboniferous sandstones. There are pockets of blanket peat and cutover raised peat scattered throughout the catchment. There is a small area of Alluvium subsoil located at the outflow of Levally Lough and along the west of the catchment and a small compartment of Lacustrine subsoil found at the bottom of Levally Lough.

4.6 Soils

Within the Nephin Valley GWS mountain stream catchment, there are two soil types present, of which Acid shallow/rocky/peat mineral predominated. There is a narrow vein of Acid deep poorly drained mineral located near the abstraction point (Figure 12).

The Levally Lough catchment soils are a mixture of eleven soil types: with the majority of the catchment encompassing a mixture of Acid deep and shallow, poorly and well drained mineral. There are pockets of Basic shallow well and poorly drained mineral, blanket peat, cutover/cutaway peat, mineral Alluvium and Lacustrine found scattered throughout the catchment (Figure 13). The shallow, well drained soils are associated with subsoils classified as having bedrock at or near the surface (Figure 11) and with E or Extreme groundwater vulnerability classes (Figure 9).

4.7 Slope and run-off

The slope of the land leading to a water body is an important determinant of the rate at which water and pollutants move into the lake by overland flows. Slope can affect the quantity of contaminants entering a water body and thus can influence the quality of the water body. Steep slopes are vulnerable to surface water run-off, particularly if combined with poor draining soils. Soil erosion can also be a problem if vegetation cover is sparse, particularly as a result of overgrazing.

The topography of the Nephin Valley GWS mountain stream catchment ranges from 150 m to 800 m in elevation.

The elevation of the Levally Lough catchment is greatest along the east and south of the catchment, reaching a maximum of approximately 340 m in the Cuilmullagh hills to the south of the catchment. The slope of the land greatly reduced around Levally Lough and to the west of the catchment, ranging from between 40 m to 60 m.

The slope of the land also influences groundwater flow directions and water table gradients. Groundwater gradients (the amount of slope of the water table) are determined by the amount of rainfall replenishing the groundwater, and the ability of the aquifer to transmit the groundwater. Poor aquifers tend to have the steepest gradients and regionally important aquifers tend to have the flattest gradients.

The exact impact of the slopes within the Nephin Valley GWS catchment along with those immediately surrounding the Levally Lough basin and catchment could only be assessed in a more detailed study, but the potential interactions between the geology, soils, land use and slope will be discussed in more detail below.

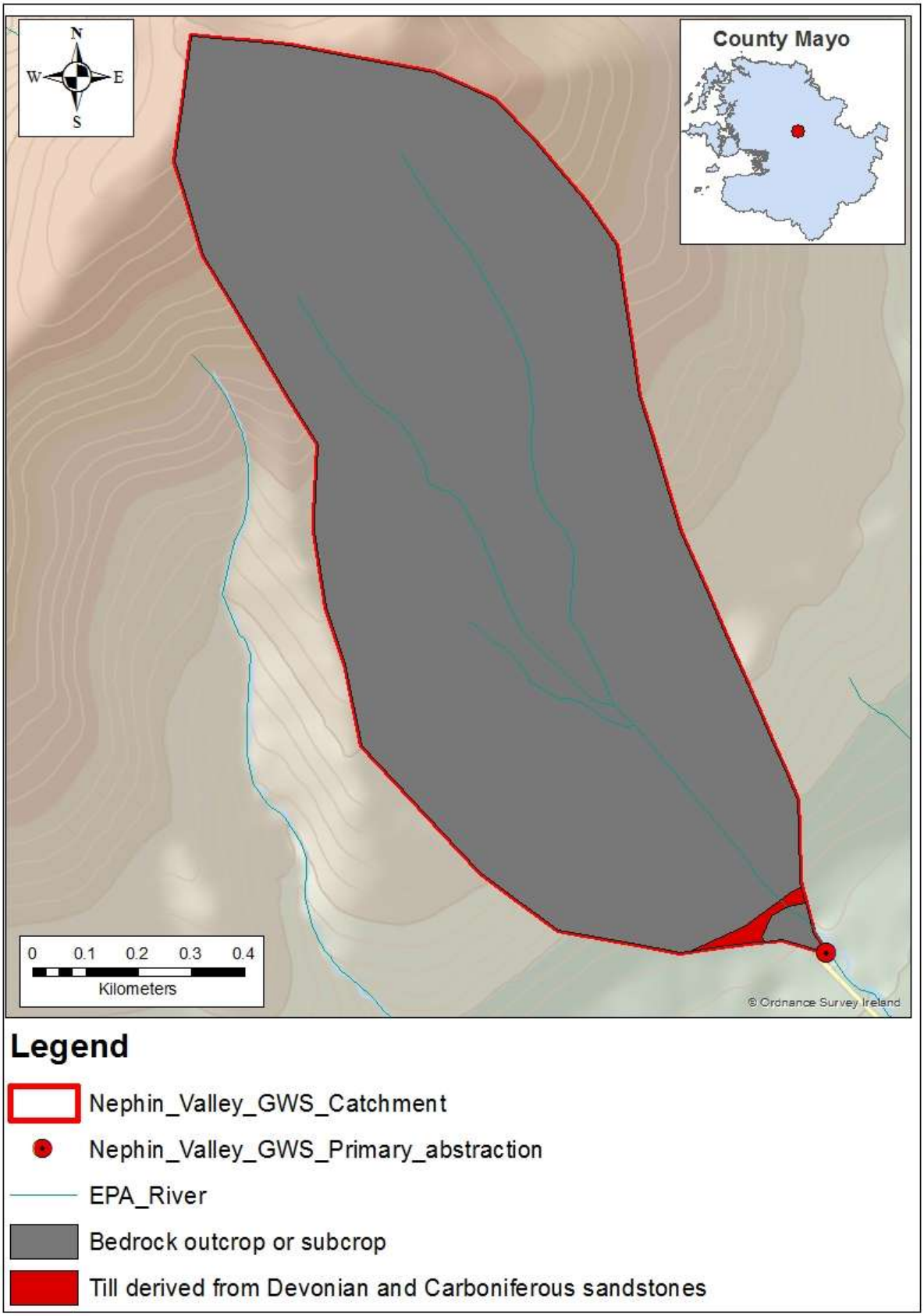

Figure 10: Subsoil deposits within the Nephin Valley GWS mountain stream catchment.

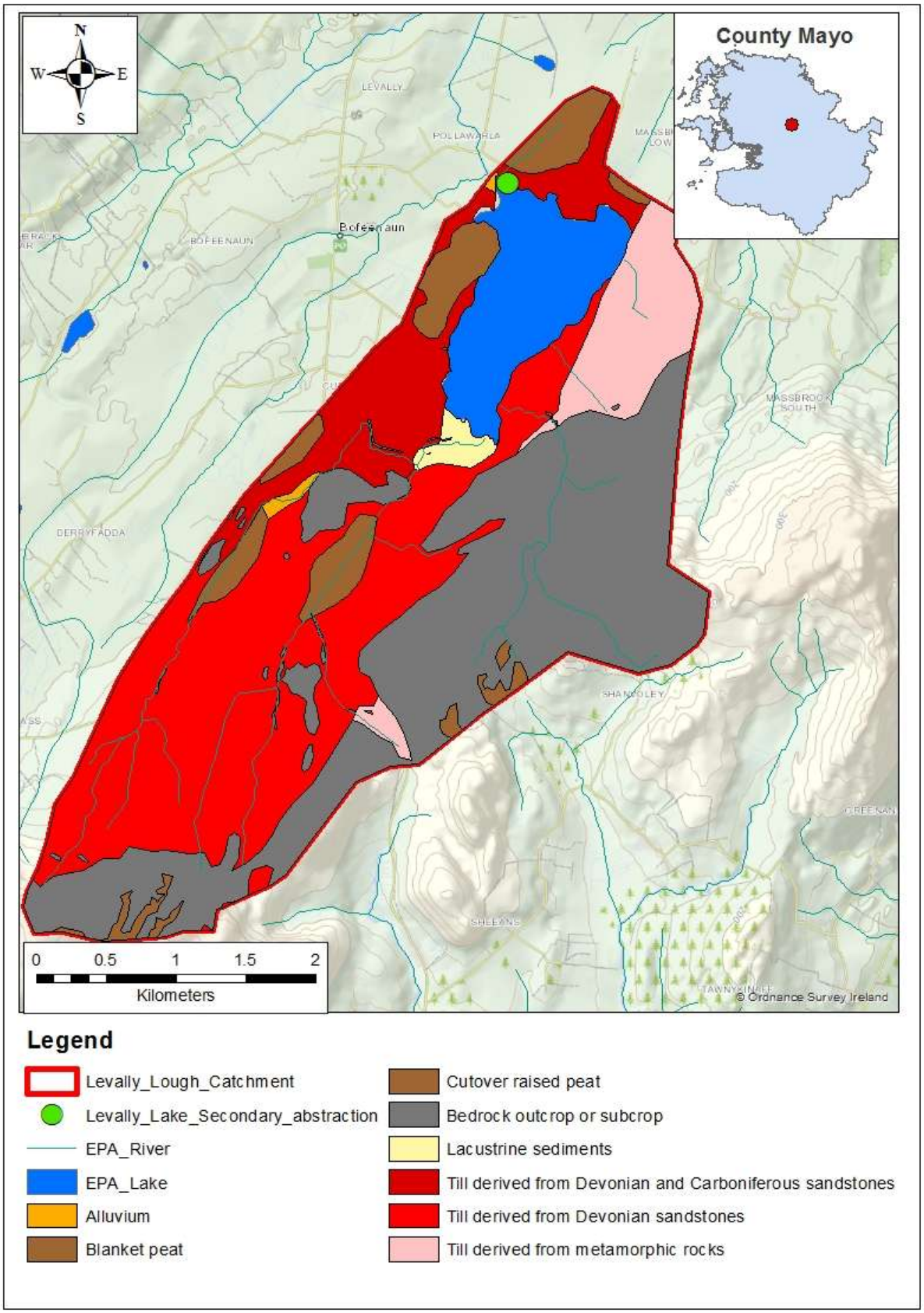

Figure 11: Subsoil within Levally Lough catchment (potential secondary water source to Nephin Valley GWS catchment).

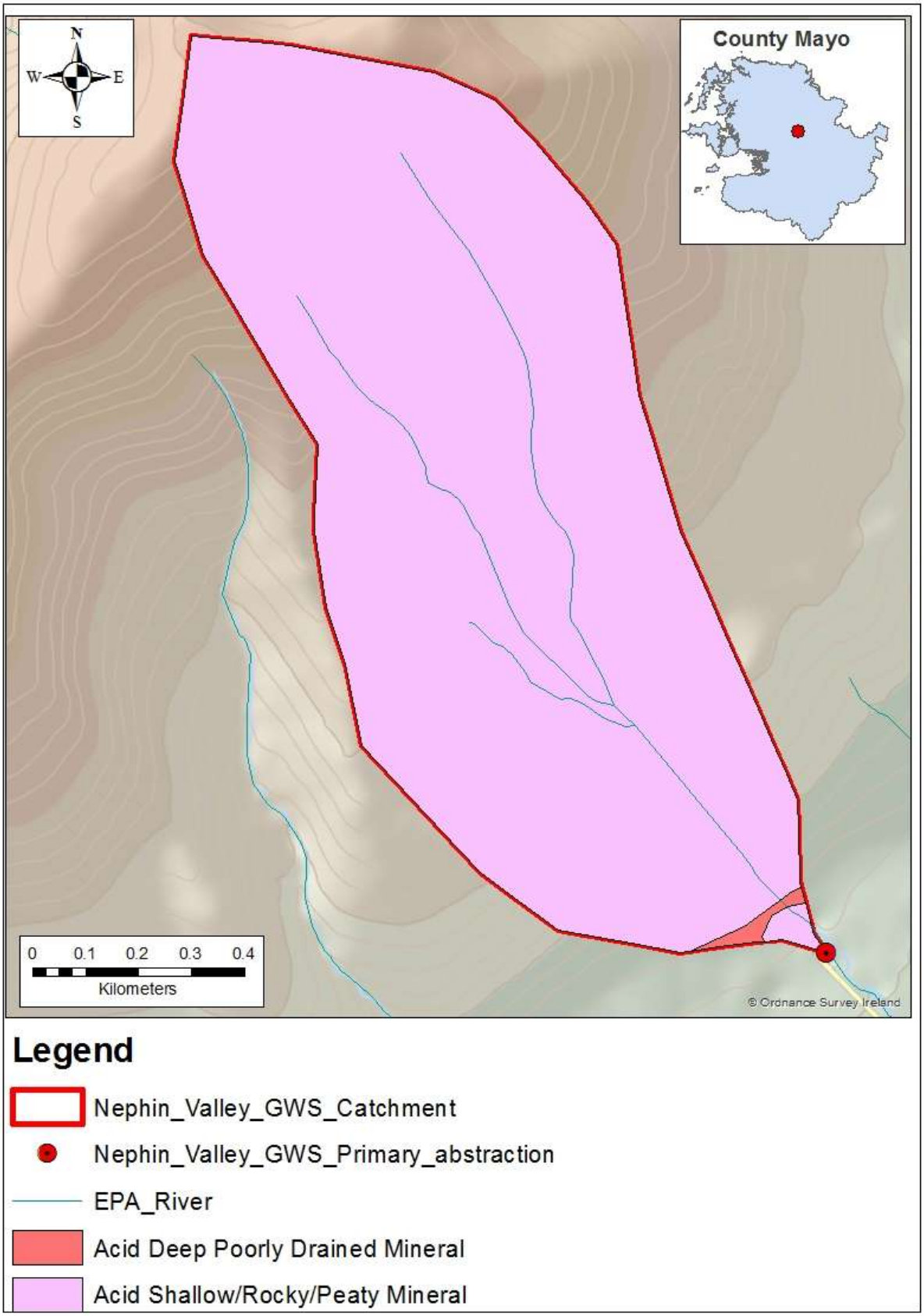

Figure 12: Soil deposits within the Nephin Valley GWS mountain stream catchment.

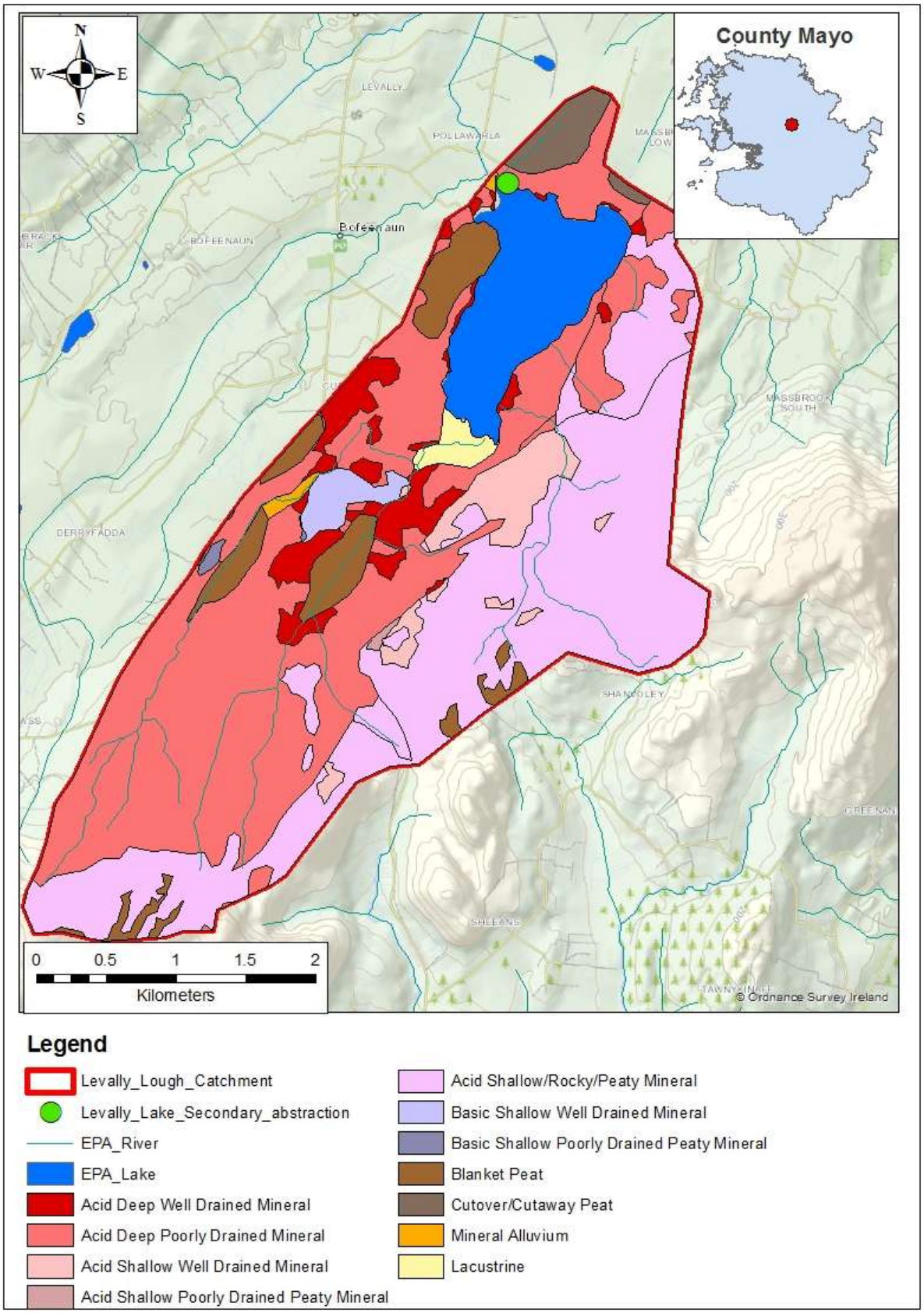

Figure 13: Soil within Levally Lough catchment (potential secondary water source to Nephin Valley GWS catchment).

5.0 Land use within the catchment

5.1 CORINE Land Cover

CORINE land cover is a map of the European environmental landscape based on the interpretation of satellite images (remote sensing). CORINE stands for 'Coordination of Information on the Environment' and the project has resulted in a Europe wide cataloguing of land cover into 44 standard classes. Importantly, land cover is defined as the observed physical cover, as seen from the ground or through remote sensing, including natural or planted vegetation and human constructions (e.g. roads, buildings) which cover the land surface. Therefore water, rock and ice are also included as land cover. Land cover is therefore distinct from land use which is based upon function: the purpose for which the land is being used. CORINE land cover does not include an assessment of land use.

Land cover within the Nephin Valley GWS mountain stream catchment is predominantly Moors and heaths, sparsely vegetated areas and peat bogs (Figure 14). The Nephin Valley GWS catchment forms part of a large area of commonage within the Nephin Beg mountain range.

The land cover within the Levally Lough catchment is pasture, land principally used for agriculture found along the west of the catchment and surrounding Levally Lough, with the exception of the north side of the lake where peat bog is the main land use classification. There are large areas of peat bog with pockets of coniferous forestry found in the east south east and south of the catchment (Figure 15).

The management of the risks associated with each of these land cover classifications will form the basis of this source protection report.

5.2 Forestry

Forestry plantations present threats to the quality of water bodies during the planting and early growing phase of a forest as well as during felling. Water quality can be affected by activities such as ground preparation, fertilisation, thinning, felling and construction of forestry roads. The application of fertilisers to young standing stock to enhance growth can lead to excessive phosphorus availability with the potential to increase phosphorus (P) volumes in the runoff from planted land. During felling, sediment loss, siltation and nutrient release can also occur. In addition, the exposure of un-vegetated soil can lead to the run off of P in soil suspension. The construction of forestry roads and drainage trenches cause disturbance, erosion and compaction of the soil surface resulting in sedimentation and nutrient run-off.

There is no forestry located in the Nephin Valley GWS mountain stream catchment.

Coniferous forestry is present in very small areas to the east and the south of the Levally Lough catchment. Therefore given the small area of commercial forestry within the catchment, the impact of the forestry on raw water quality at the potential abstraction point in the north of Lough Levelly is likely to be limited.

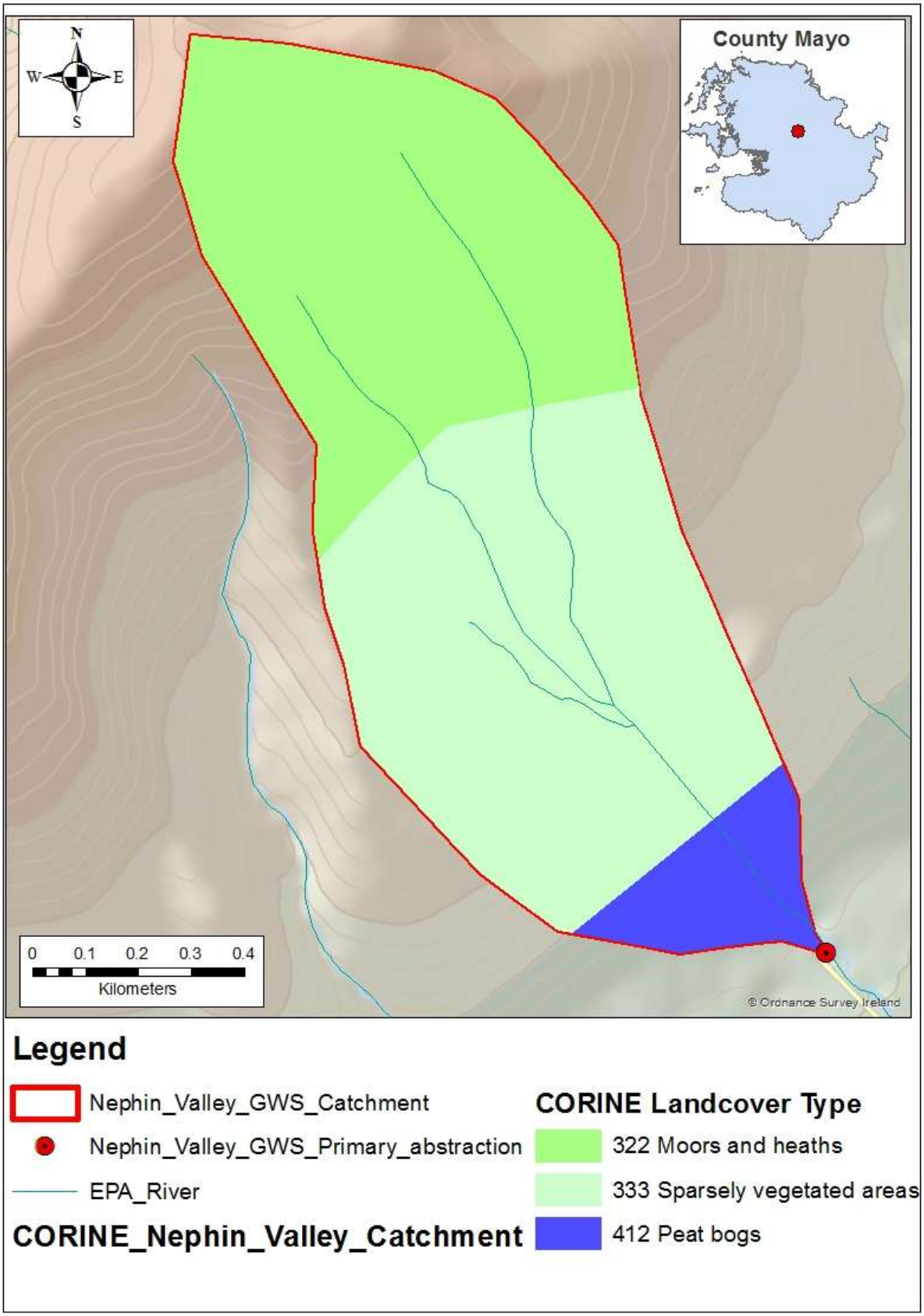

Figure 14: CORINE Land Cover classification within the Nephin Valley GWS mountain stream catchment.

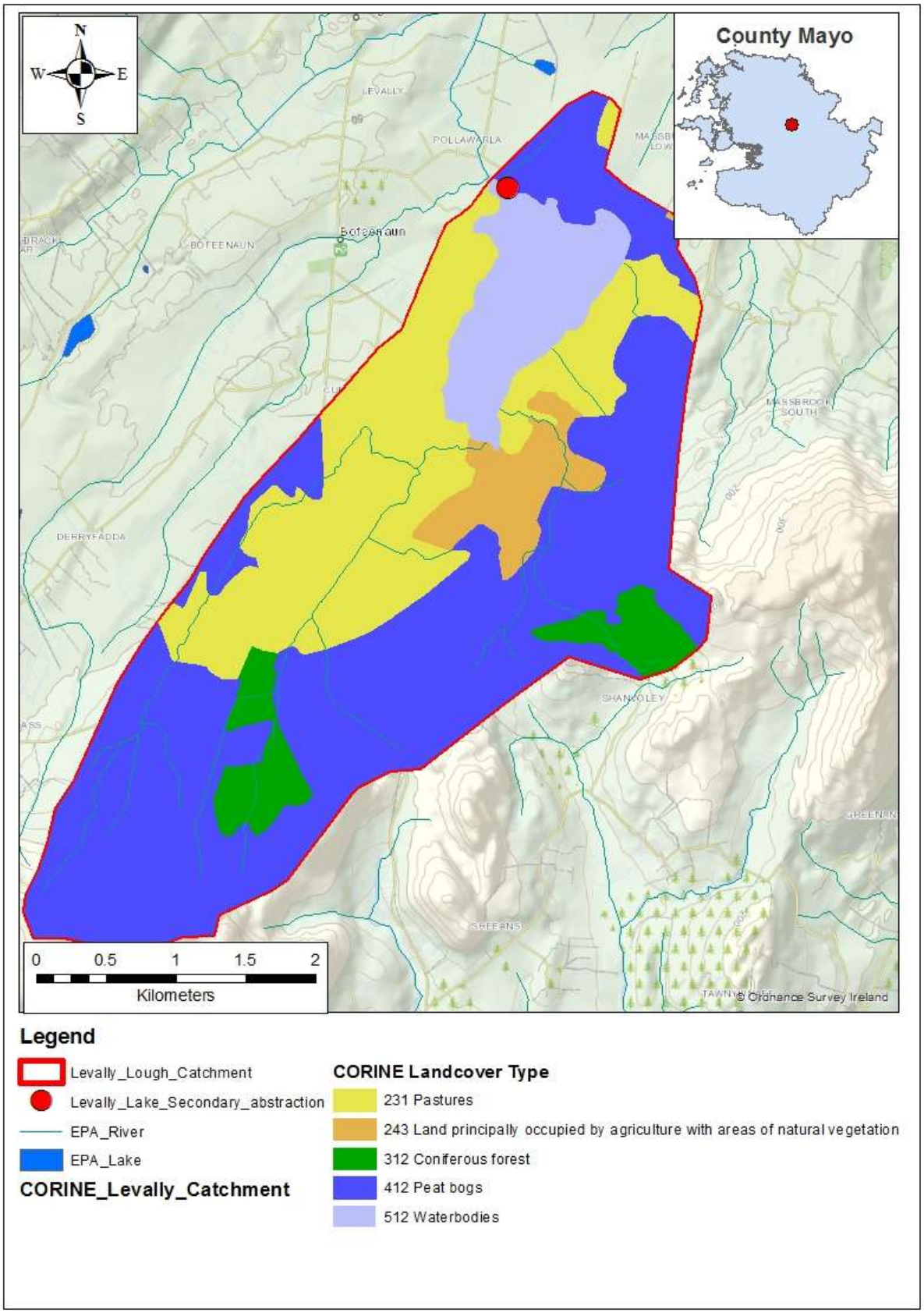

Figure 15: Soil within Levally Lough catchment (potential secondary water source to Nephin Valley GWS catchment).

5.3 EPA licensed facilities – Integrated Pollution Prevention Control (IPPC)

Integrated Pollution Prevention Control (IPPC) is a licensing process under EU Directive 96/61/EC, the enforcement of which is the authority of the EPA. The aim of an IPPC license is to prevent or reduce emissions to air, water and land, to reduce waste and use energy and resources efficiently. An IPPC license must be obtained by certain categories of industry that are subject to thresholds. The EPA is responsible for monitoring emissions and dealing with any infringements on licenses.

There are no IPPC licences within the Nephin Valley mountain stream GWS or Levally Lough catchment.

5.4 Rural housing and on-site wastewater treatment plants

On-site wastewater treatment systems, including septic tanks, can add nutrients, chemicals and pathogenic organisms to water bodies. These risks are particularly elevated when systems are installed in areas of high groundwater vulnerability (i.e. where there is little natural filtration afforded by thin or absent subsoils before effluents enter the bedrock aquifers and the groundwater system and where soil drainage is poor/subsoil permeability are low (i.e. where there is inadequate percolation capacity and effluent backs up and runs overland or is piped to surface water receptors).

There are no on-site wastewater treatment systems within the Nephin Valley GWS mountain stream catchment.

The location of dwellings in the Levally Lough catchment was estimated by viewing the Ordnance Survey map and aerial photography of the area. Whilst dwellings cannot be differentiated from other buildings, some insight into the location of dwellings and associated on-site wastewater treatment plants (usually septic tanks) was gained. The location of dwellings in the Levally Lough catchment within areas of E, and Extreme groundwater vulnerability are presented in Figure 16.

There is data available that identifies the likely risk of contaminants from such treatment systems entering the water bodies within the Levally Lough catchment. In association with the Geological Survey of Ireland, the EPA have undertaken an assessment of domestic wastewater risk, giving a relative ranking that nutrients and bacteria from domestic wastewater treatment systems will contaminate surface waters via either surface water or groundwater pathways (EPA, 2013a and b). There are a number of domestic wastewater risk classifications within the Levally Lough catchment area and these are best viewed online via the EPA's geoportal: http://gis.epa.ie/Envision. There are large areas of Zone 1A - Low Risk in non sensitive areas to the west, south and south east of the Levally Lough catchment. The area east of Lough Levally, northeast of the catchment there are areas of Zone 2A – Low Risk in non sensitive areas. It should be noted that there are limitations related to population densities and scale associated to these maps.

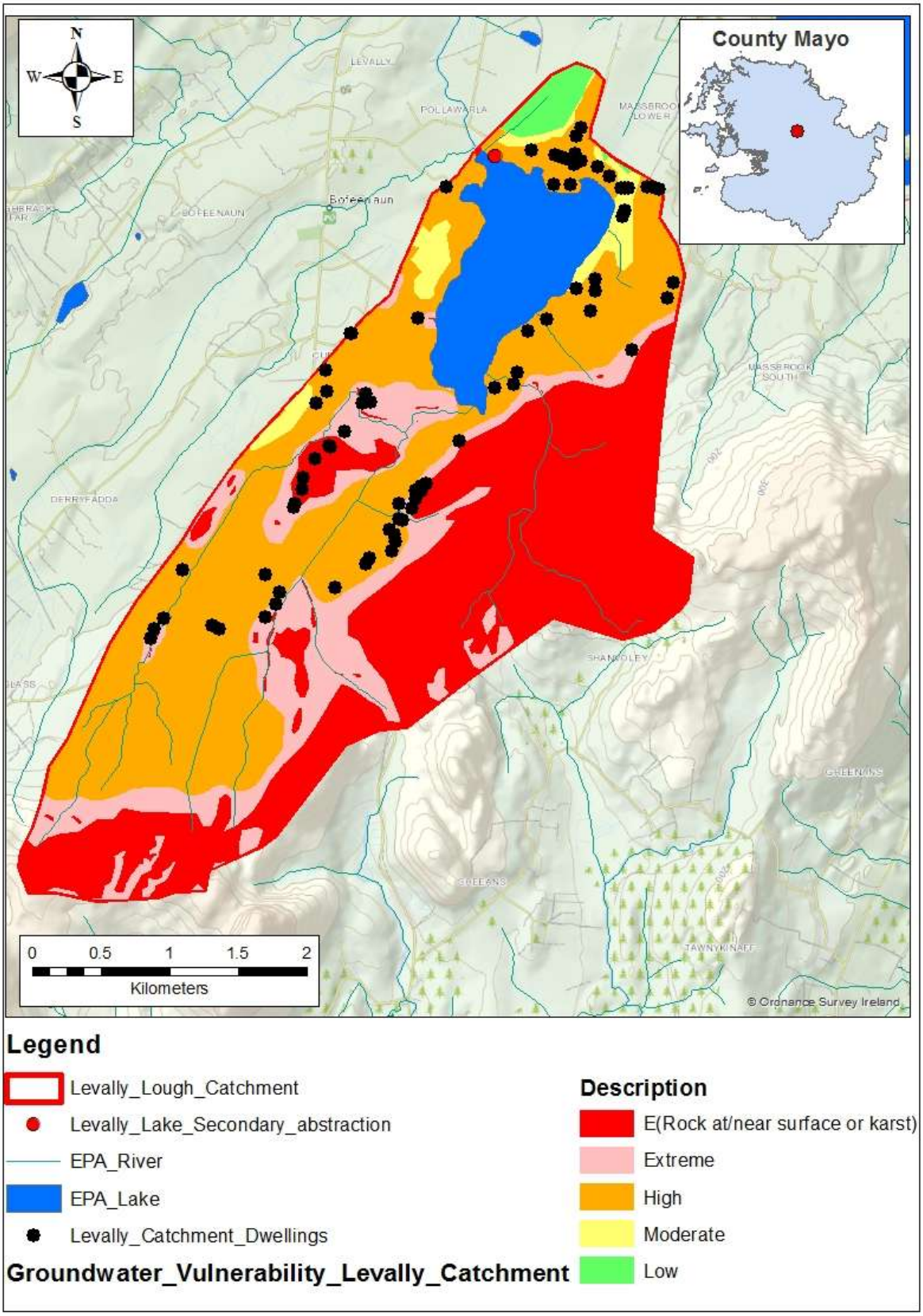

Figure 16: Estimated location of dwellings (black dots) with groundwater vulnerability map for the Levally Lough catchment (potential secondary water source to Nephin Valley GWS catchment).

5.5 Overall interpretation of land use at Nephin Valley GWS and Levally Lough catchments

The Nephin Valley GWS mountain stream catchment has a small catchment area of 1.1 km^2 and is comprised of a single river that rises in the Doonbreedia Mountain to form the Lugnamannaun River. The maximum elevation of the Nephin Valley GWS catchment is of 800 m.

The geology in the Nephin Valley GWS mountain stream catchment is predominantly Nephin Formation, which is a Quartizte and psammitic schist formation. The aquifer underlying the majority of the catchment is Poor Aquifer – Bedrock which is generally unproductive except in local zones. The ground water vulnerability is largely classified as E (rock at or near surface or karst), with a pocket of Extreme ground water vulnerability located near the abstraction location to the south of the catchment. The subsoil mainly consists of Bedrock outcrops or subcrops which is covered with Acid shallow rocky/peaty mineral soils.

Pressures with Nephin Valley GWS mountain stream catchment included open access of sheep to the water course. The fencing of land bordering water courses is important in restricting direct sheep access to the water, thereby reducing the potential for nutrient and faecal contamination of water bodies.

Levally Lough is located 1.5 km from the Nephin Valley GWS catchment water treatment plant and reservoir. The surface area of the Levally Lough is 0.46 km^2 and the catchment area is 14.3 km^2. Levally Lough was identified in the Conn Water Management Unit Action Plan as being of 'moderate ecological status' in 2009 and had a Lake waterbody WFD status 2010-2012 as 'Good'. Water flows into Levally Lough from two main rivers (Derrinurcher and Pollawarla Rivers) and a number of small streams. There is one main out flowing river, Derrinurcher River from the Levally Lough which joins the Addergoole River which eventually flows into the west of Lough Conn.

The geology of the Levally Lough catchment is predominantly a dark-file limestone and shale to the west, Quartzite to the south and a grey sandstone and siltstone surrounding Levally Lough to the north of the catchment. The geology of the east of the catchment consists of schist and Quartzite. The aquifer underlying the catchment is Locally Important Aquifer – bedrock which is generally moderately productive, Poor Aquifer- bedrock which is generally unproductive except for local zones and Regionally Important aquifer-Karstified. The groundwater vulnerability is greatest at the higher elevations, classified as E (rock at or near surface or karst) and Extreme found on the outer edge of the catchment boundary to the east, south east and south of the catchment. The majority of the west, north and the centre of the catchment have High ground water vulnerability. Soils within the catchment are predominantly acid deep and acid shallow, well and poorly drained mineral and blanket peat. This association of acid deep well drained and poorly draining soils and high groundwater vulnerability, especially in the vicinity of water courses within the catchment means that these areas are particularly vulnerable to contaminants being delivered to both surface water and groundwater.

Additional pressures within the Levally Lough catchment are primarily agricultural, much of the west side and centre of the catchment is classed by CORINE land cover as pasture and land principally occupied by agriculture. The dwelling density in the catchment are generally low, there are a number of dwellings in areas of E and Extreme classifications groundwater vulnerability.

These areas of the catchment may be sensitive and contribute to surface water or groundwater contamination with nutrients and bacteria from domestic wastewater treatment systems. These areas, along with cattle yards which are situated within areas of poor soil drainage, high groundwater vulnerability source should be inspected as a priority to ensure that potential risk of contamination from these point sources is reduced. Levally Lough has been classified as having Moderate overall ecological status in the Conn Management Unit Action Plan 2009 and had a Lake waterbody WFD status 2010-2012 as 'Good'. There are risks of nutrient addition through livestock access to the lake and from local on site wastewater treatment systems, which may impact the nutrient status of Levally Lough.

As a potential action that could be undertaken to improve the water quality of Levally Lough if a decision is made to abstract from the lake in the future. Fencing of land bordering the lake would be important to restricting direct livestock access to the water, thereby reducing the potential for nutrient and faecal contamination of water bodies. It would be a recommendation that lands bordering the water bodies in the immediate vicinity of the Nephin Valley GWS potential secondary abstraction point (Figure 3) are surveyed and landowners encouraged to ensure that fencing restricts livestock access to the lake. The installation of vegetation buffer strips may also be feasible around the lake and would have a number of benefits in terms of nutrient attenuation, restriction of direct livestock access to water bodies and provide further diversity of habitat that would help to increase the biodiversity of the area.

An assessment of water quality parameters is provided in Section 6.0.

6.0 Raw Water Quality

Water quality has been assessed at a number of locations throughout the Nephin Valley GWS mountain stream and Levally Lough catchments catchment by Mayo County Council, the EPA and Coffey Group (on behalf of Nephin Valley GWS). Where possible, water quality data collected from the abstraction point by Coffey Group has been analysed and presented along with data collected from monitoring locations throughout the catchments. In order to improve clarity and interpretation, data from the catchments has often been summarised and presented as average (mean) values for each sampling location.

Water quality monitoring was undertaken by Mayo County Council and EPA from April 2007 until October 2015 at Levally Lough and is presented in this report.

6.1 Raw Water Quality

6.1.1 Colour

Natural colour reflects the presence of organic molecules originating from humic matter such as peat, leaves and branches. A coloured water supply does not pose high health risks in itself but the coloured compounds can react with chlorine in the treatment plant to produce Trihalomethanes (THMs), which can be carcinogenic and their removal from drinking water can add significantly to the cost of treatment. For these reasons, high levels of colour should be avoided where possible; however, colour can vary greatly as a parameter, depending on quantities of rain and run off, leading to spikes in results. Results of colour analyses can be presented as apparent colour (from an unfiltered sample) or true colour (from a filtered sample). Irvine *et al*. (2001) reported that colour in Irish lakes ranged between 5 mg/L PtCo to 134 mg/L PtCo. The Surface Water Regulations (1989) recommend a maximum value of 20 mg/L PtCo/Hazen (true colour: PtCo and Hazen are equivalent units) for A1 waters (surface waters that only require simple physical treatment and disinfection to become drinking water).

It should be noted that the water colour data provided by Coffey Group does not specify whether the water colour sample is True colour (Filtered) of Apparent colour (unfiltered). For water colour measurements, due to filtering, true colour values are lower than apparent colour values, therefore comparisons have been made between the data and the surface water regulations (which are for true colour). Mayo County Council measured true water colour (filtered) from November 2010 until September 2014 and switch to measured Apparent water colour (unfiltered) from March 2014 to May 2016 on the treated water supply, but as only true colour data can only be compared against the Surface Water Regulations (1989), the Apparent colour data are not presented here.

Measurements of raw water colour from Nephin Valley GWS were measured at the water treatment plant by Coffey Group from March 2011 to June 2016 (Figure 17). Water colour values for mountain stream raw water ranged from a minimum of 56.5 mg/L PtCo in February 2015 to a maximum of 128 mg/L PtCo in March 2011, with an average of 50.9 mg/L PtCo recorded over the sampling period. The Surface Water Regulations (1989) parametric value of 20 mg/L PtCo for True Colour for Class A1 waters was equalled or exceeded on 59 out of 62 sampling occasions (95 % of occasions). Water colour values were much reduced in the treated water, with the treated water colour ranging from a

minimum of 4 mg/L PtCo in May 2016 to a maximum of 19.9 mg/L PtCo in June 2014, with an average of 9.5 mg/L PtCo.

Mayo County Council measured true water colour from November 2010 until September 2014 on the treated water at the tap from twenty three locations on the Nephin Valley GWS network (Figure 18). The water colour measured at the tap showed a range of water colour from a minimum of 3.2 mg/L PtCo in July 2013 to a maximum of 15.8 mg/L PtCo in August 2011, with an average of 9.3 mg/L PtCo recorded over the sampling period.

Measurements of true water colour from Levally Lough (a potential secondary water source to Nephin Valley GWS catchment) were conducted by Mayo County Council and EPA from April 2007 until October 2015 (Figure 19). True colour values from Levally Lough ranged from a minimum of 15 mg/L PtCo in September 2013 to a maximum of 67 mg/L PtCo, with an average of 35 mg/L PtCo recorded over the sampling period. The Surface Water Regulations (1989) parametric value of 20 mg/L PtCo for True Colour for Class A1 waters was equalled or exceeded on 30 out of 37 sampling occasions (81 % of occasions).

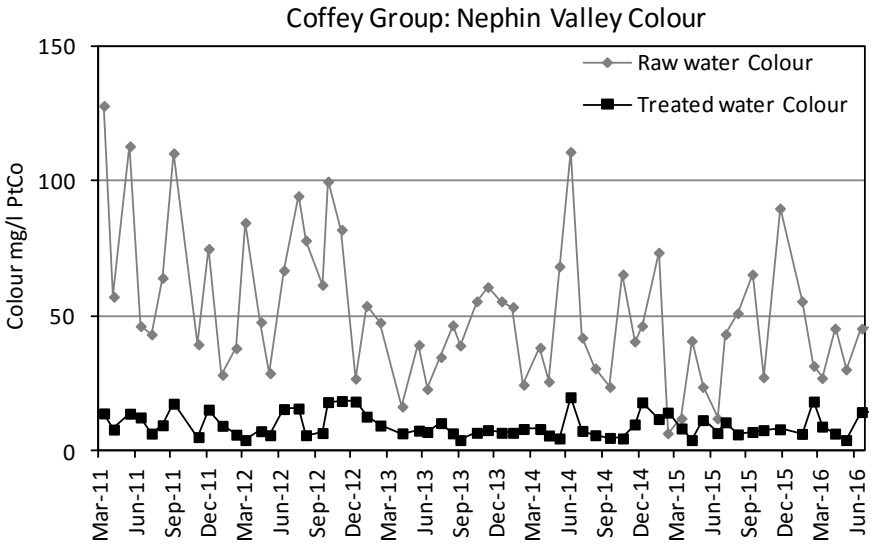

Figure 17: Raw and treated water colour from Nephin Valley GWS water treatment plant from March 2011 until June 2016.

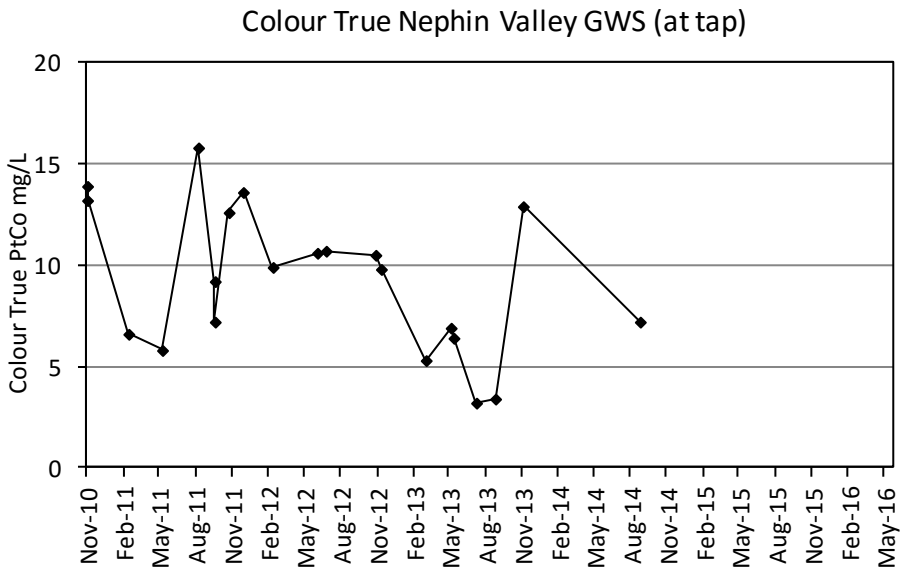

Figure 18: Treated water colour measurements from Nephin Valley GWS from November 2010 until September 2014.

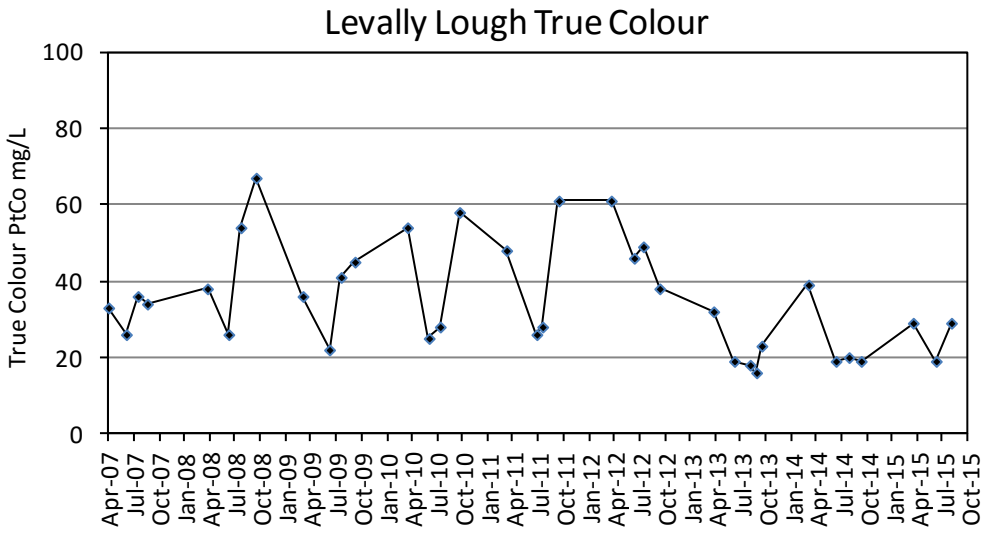

Figure 19: True colour from Levally Lough (potential secondary water source to Nephin Valley GWS catchment) from April 2007 until October 2015.

6.1.1.1 Total Organic Carbon

Natural Organic Matter (NOM) is a complex of organic matter that is found within natural waters which is typically derived from decayed vegetation or microbial decomposition processes. The chlorination of raw water can lead to the production of disinfection by-products such as Trihalomethanes as a result of the reaction of chlorine compounds with the NOM content of the raw water. Total Organic Carbon provides an estimate of the NOM present in a water source and can be used as an assessment of water quality during the treatment process for drinking water. TOC levels within raw water samples from 12 Irish water treatment works were found to range between 3.5 – 14 mg/L (Chua, 1996).

TOC data were provided by Mayo County Council from the treated water for five sampling occasions between December 2011 and April 2015 (Figure 20). Values ranged from a minimum of 1.1 mg/L in July 2013 and a maximum of 4 mg/L in December 2011, with an average of 2.3 mg/L recorded over the seven sampling occasions.

6.1.1.2 Trihalomethane

Trihalomethane data were provided by Mayo County Council for sixteen sampling occasions between September 2010 and May 2016 (Figure 21). Values ranged from a minimum of 15 µg THM/L in February 2015 and a maximum of 120 µg THM/L in July and September 2014, with an average of 67.7 µg THM/L recorded over the sampling occasions. The Drinking Water Regulations (2007 and 2014, limit of 100 µg THM/L) were exceeded on five sampling occasion (November 2012, July, September, September and October 2014) indicating a significant issue with high THM values following the treatment process. It should be also noted that timing of sampling occasions should be focused on periods between late summer and early winter when the possibility of THM formation is likely to be greatest.

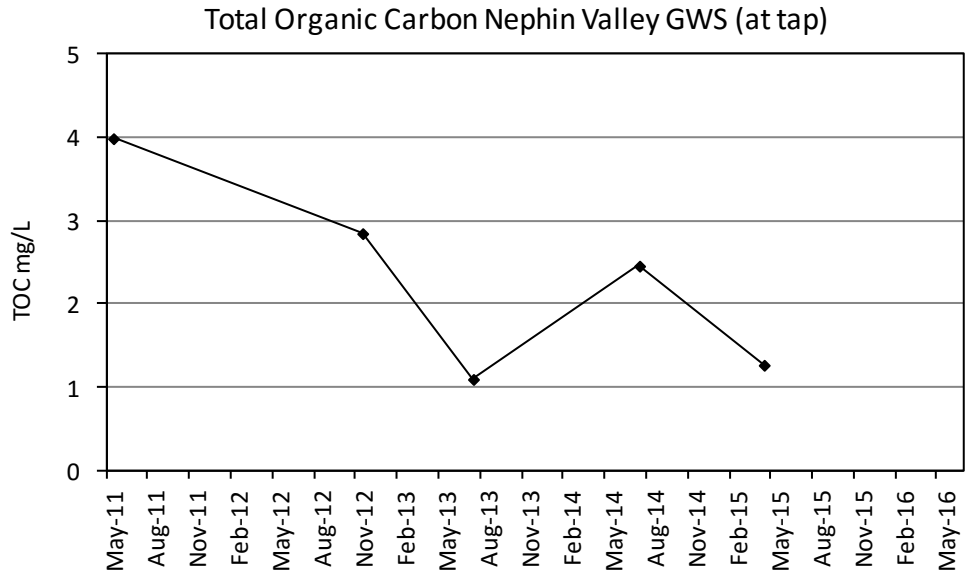

Figure 20: Total Organic Carbon from treated water from Nephin Valley GWS from May 2011 until May 2016.

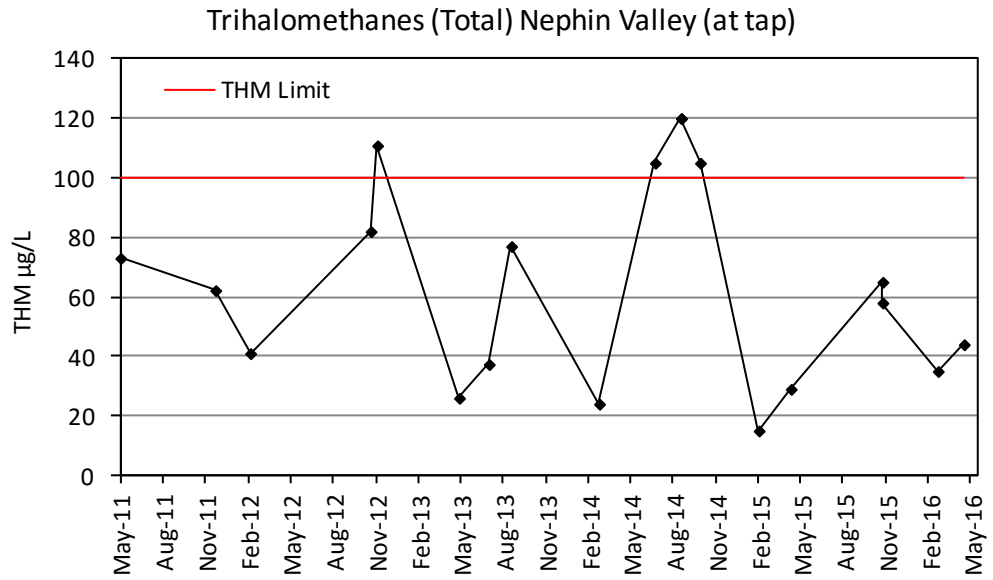

Figure 21: Total Trihalomethanes from treated water from Nephin Valley GWS from May 2011 until May 2016. Red line indicates the Drinking Water Regulation parametric value of 100 µg THM/L.

6.1.1.3 Aluminium

Aluminium is present in drinking water as a direct result of the water treatment process which uses aluminium sulphate (as a coagulant). Aluminium is naturally present in some waters. Historically, there has been some concern about possible links between aluminium in drinking water and Alzheimer's disease. The Drinking Water Regulations (2007 and 2014, limit of 200 µg/L of Aluminium.

Aluminium data were provided by Mayo County Council for November 2010 until May 2016 (Figure 22). Values ranged from a minimum of 44 µg/L in November 2014 and a maximum of 675 µg/L in September 2015, with an average of 112 µg/L recorded over the sampling occasions. The Drinking Water Regulations (2007 and 2014, limit of 200 µg/L for aluminium which was exceeded on one sampling occasion (September 2015).

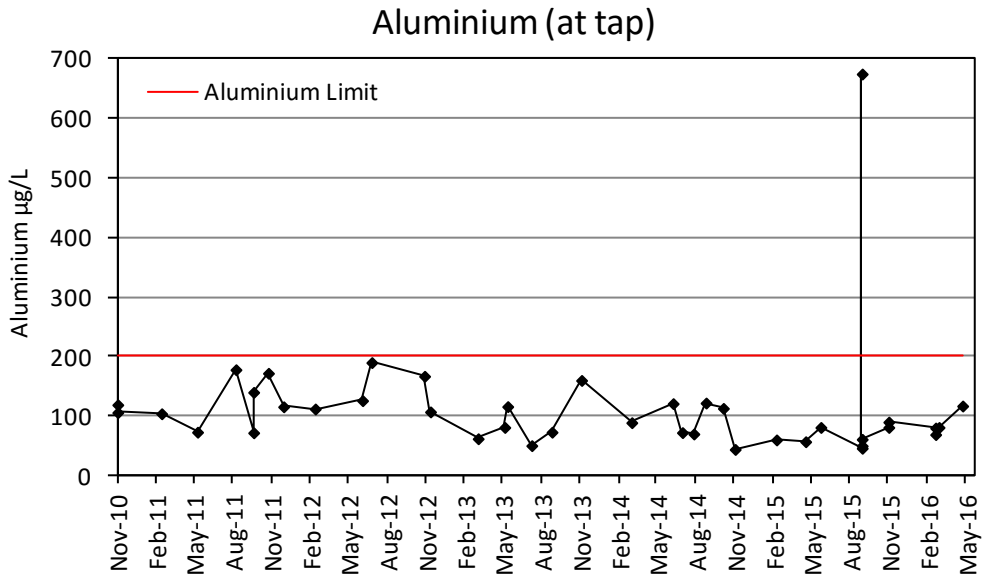

Figure 22: Aluminium from treated water from Nephin Valley GWS from November 2010 until May 2016. Red line indicated the Drinking Water Regulation limit of 200 µg/L.

6.1.2 Turbidity

Turbidity in water consists of very finely divided particles that are too small to be removed through filtration. Their origin may include clay particles, algae, silt, sewage solids and organic or biological sludges. High levels of turbidity in the raw water supply can interfere with the ability of the treatment plant to provide safe drinking water. In groundwater, turbidity can be an indicator that surface waters that potentially carry bacterial pathogens are entering the groundwater system. Turbidity can be represented using the following units: Jackson Turbidity Units (JTU); Formazin Turbidity Units (FTU); and Nephelometric Turbidity Units (NTU). Each of these units can be interpreted to mean the same thing.

Turbidity was monitored at the Nephin Valley water treatment plant on raw and treated water by Coffey Group on behalf of Nephin Valley GWS from March 2011 until June 2016 (Figure 23). The turbidity of raw water ranged from a minimum of 0.2 NTU on a number of occasions to a maximum of 8.6 NTU in October 2014, with an average of 0.9 NTU measured on raw water at the Nephin Valley water treatment plant. The turbidity of treated water ranged from a minimum of 0.2 NTU over the majority of the sampling period and a maximum of 1.5 NTU in October 2012, with an average of 0.3 NTU measured over the sampling period.

Turbidity was also measured by Mayo County Council from November 2010 until May 2016 in the treated water at the tap from a number of locations in Nephin Valley GWS catchment (Figure 24). Results showed the range of turbidity from a minimum of 0.06 NTU in February 2015 to a maximum of 1.4 NTU in September 2015, with an average measurement of 0.5 NTU recorded for the sampling period.

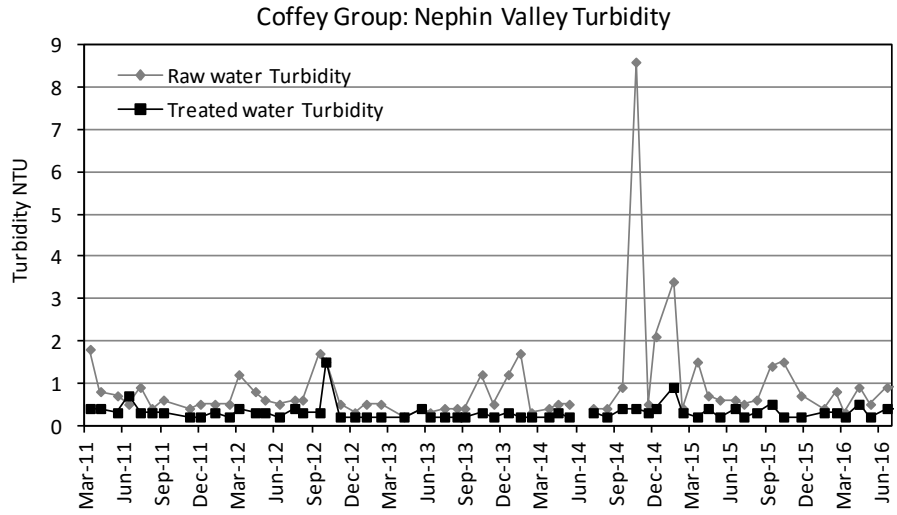

Figure 23: Raw and treated water turbidity from Nephin Valley water treatment plant from March 2011 until June 2016.

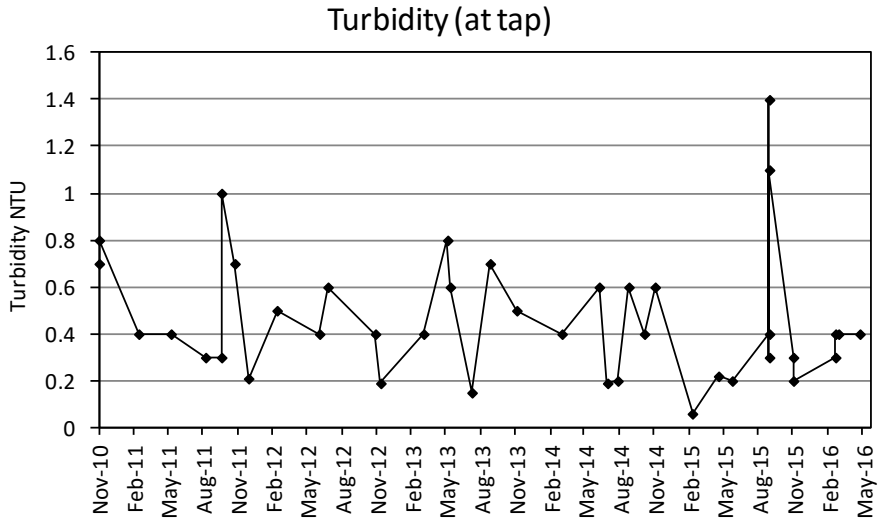

Figure 24: Treated water Turbidity concentrations at the tap from Nephin Valley GWS from November 2010 until May 2016

6.1.3 Iron

Iron (Fe) is present in rocks and soil in an insoluble form but can become soluble when water passes through ground formations containing iron. Large amounts of iron in water are not usually harmful to consumers, but can be aesthetically unpleasing as a result of causing changes in colour or turbidity. This can lead to staining of laundry, discoloration of vegetables following cooking and taste problems. The Surface Water Regulations (1989) recommend concentration of iron in Class A1 waters as 200 µg/L.

The iron concentration of treated water at the tap from a number of locations within the Nephin Valley GWS network was provided by the Mayo County Council from November 2010 until May 2016 (Figure 25). Values ranged from a minimum of 20 µg/L on a number of sampling occasions to a maximum of 497 µg/L in September 2015, with an average (mean) value of 61.4 µg/L recorded over

the sampling period. The Drinking Water Regulations (2014) set a limit of iron in drinking water of 200 µg/L and this was significantly exceeded in Nephin Valley GWS catchment on one occasion over the sampling period (September 2015).

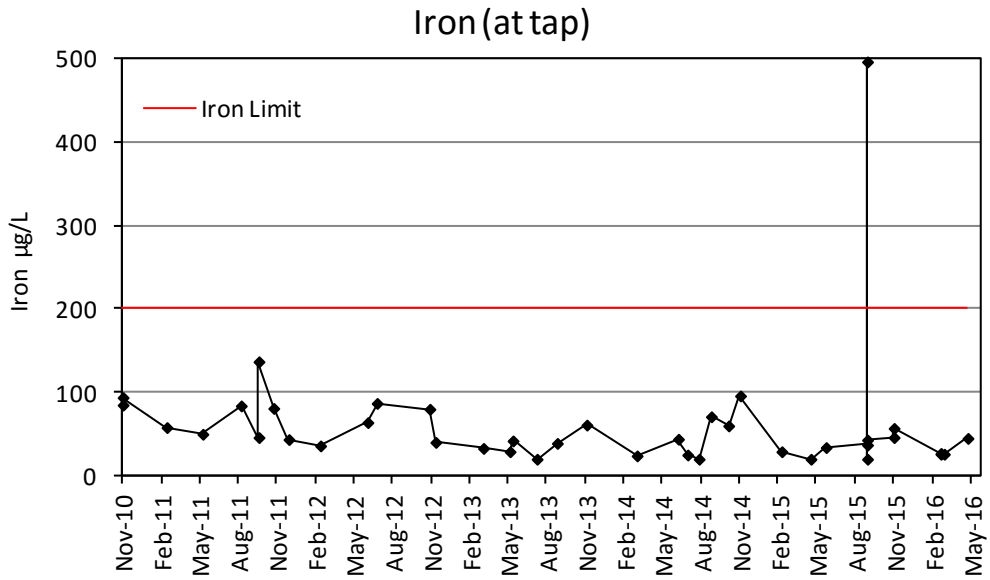

Figure 25: Treated water Iron concentrations at the tap from November 2010 until May 2016.

6.1.4 Manganese

Manganese (Mn) is found in soils and ground waters and is generally not considered harmful to humans unless ingested in significantly elevated concentrations over long periods of time. It can cause more severe staining problems than iron and can adversely affect taste and potentially block pipes in large volumes. The Surface Water Regulations (1989) recommend concentration of manganese in Class A1 waters as 50 µg/L.

Manganese was monitored by Mayo County Council in the treated water within Nephin Valley GWS catchment from November 2010 until May 2016 (Figure 26). Manganese concentration ranged from a minimum of 1 µg/L on a number of sampling occasions to a maximum of 387 µg/L in September 2015, with an average (mean) value of 26.8 µg/L recorded for the sampling period. The Drinking Water Regulations (2014) set a limit of 50 µg/L of manganese in drinking water, and this was significantly exceeded on one sampling occasion (September 2015) over the monitoring period.

Manganese was not monitored by Coffey Group water treatment plant on behalf of Nephin Valley GWS.

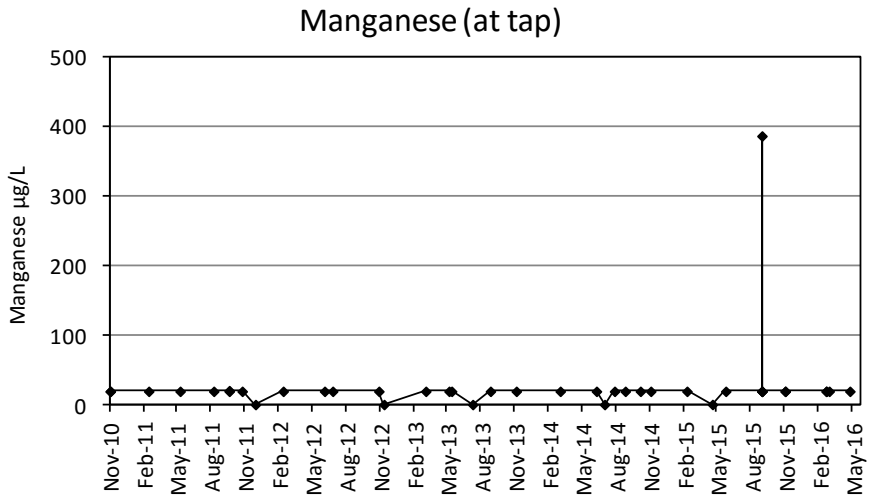

Figure 26: Treated water manganese concentrations at the tap from Nephin Valley GWS from November 2010 until May 2016

6.1.5 pH

The pH of water is generally only of concern if it is extremely low or extremely high indicating acid or alkaline waters respectively. High or low pH values may have consequences for odour or taste, lead to corrosion in distribution systems and affect fish survival. The pH of water generally ranges from 6.5-8.0 and the Surface Water Regulations (1989) recommend a range of 5.5-8.5 for Class A1 waters. The Drinking Water Regulations (2007 and 2014) requires a pH range of 6.5-9.5 for treated water.

pH on raw and treated water has been monitored at the water treatment plant by Coffey Group on behalf of Nephin Valley GWS from March 2011 until June 2016 (Figure 27). The pH values of raw water ranged from a minimum of pH 4.4 in January 2011 to a maximum of pH 7.8 in May 2012. Raw water pH values were below the Surface Water Regulations (1989) of pH 5.5, for Class A1 waters for 29 % of sampling occasions over the monitoring period. pH values of treated water ranged from a minimum of pH 4.7 in February 2015 and a maximum of pH 8.6 in September 2013. Treated water pH was within the range of the Drinking Water Regulations with the excepting of two sampling occasions (March 2011, pH 6.2 and February 2015 pH 4.7), which were below the Drinking Water Regulations (2007 and 2014) that requires a pH range of between 6.5-9.5.

Mayo County Council and the EPA have monitored pH in the treated water a number of sites within the Nephin Valley GWS catchment between November 2011 until May 2016. The pH values were within the range of the Drinking Water Regulations (2007 and 2014) on all sampling occasions.

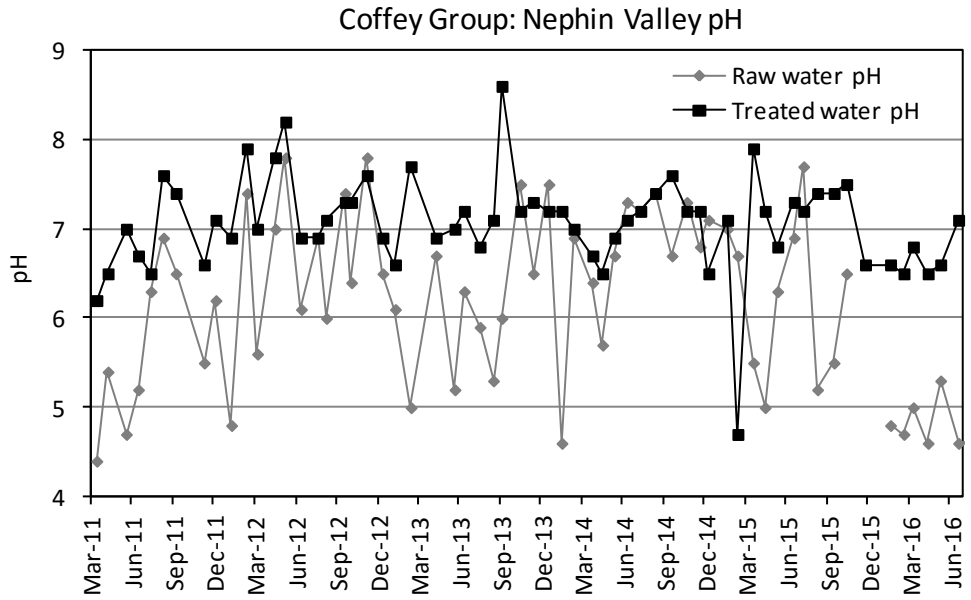

Figure 27: Raw and treated water pH levels for Nephin Valley water treatment plant from March 2011 until June 2016.

6.1.6 Alkalinity

Alkalinity is a measure of water's capacity to neutralise acids, with high alkalinity providing a buffering capacity against pH change. The alkalinity of water is typically associated with bicarbonates in catchment soils. There is little known sanitary significance to alkalinity, however increased levels, although primarily influenced by the soils and rocks over or through which waters flow, can be indicative of eutrophication and photosynthesis.

Alkalinity was measured on treated water at the tap by Mayo County Council from September 2011 until February 2016 (Figure 28). Treated water alkalinity ranged from a minimum of 10 mg/L $CaCO_3$ on a number of sampling occasions to a maximum of 43 mg/L $CaCO_3$ IN September 2015, with an average alkalinity of 19 mg/L $CaCO_3$ measured over the sampling period.

Alkalinity was not monitored by Coffey Group water treatment plant on behalf of Nephin Valley GWS.

Alkalinity was measured mid-lake on Levally Lough by Mayo County Council and EPA from April 2007 until October 2015 (Figure 29). Values ranged from a minimum of 30 mg/L $CaCO_3$ in April 2011 to a maximum of 46 mg/L $CaCO_3$ in October 2015, with an average of 38.2 measured over the sampling period. Levally Lough would be classified as Type 7 - Moderate Alkalinity, deep and small lake (Free *et al.* 2006).

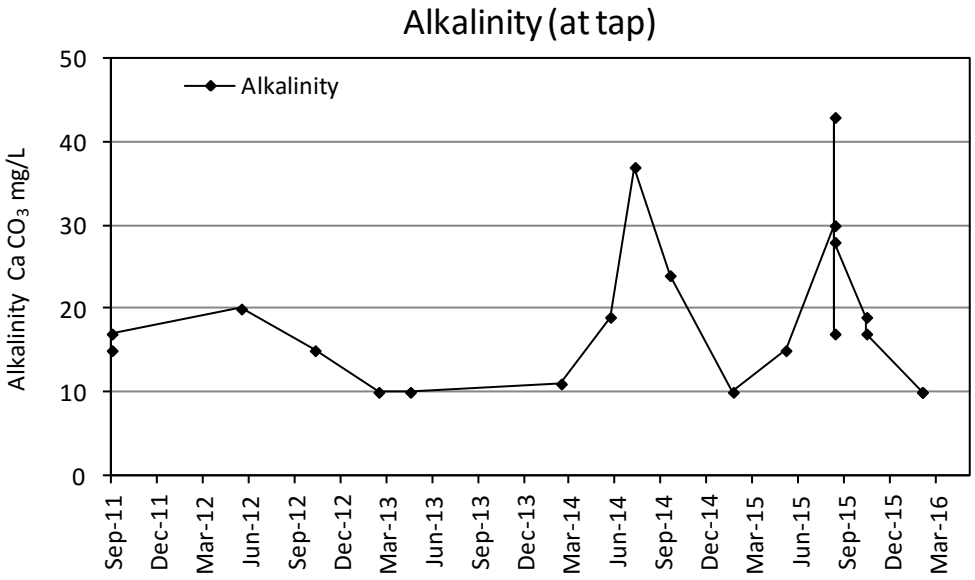

Figure 28: Treated water alkalinity for Nephin Valley GWS from September 2011 until March 2016.

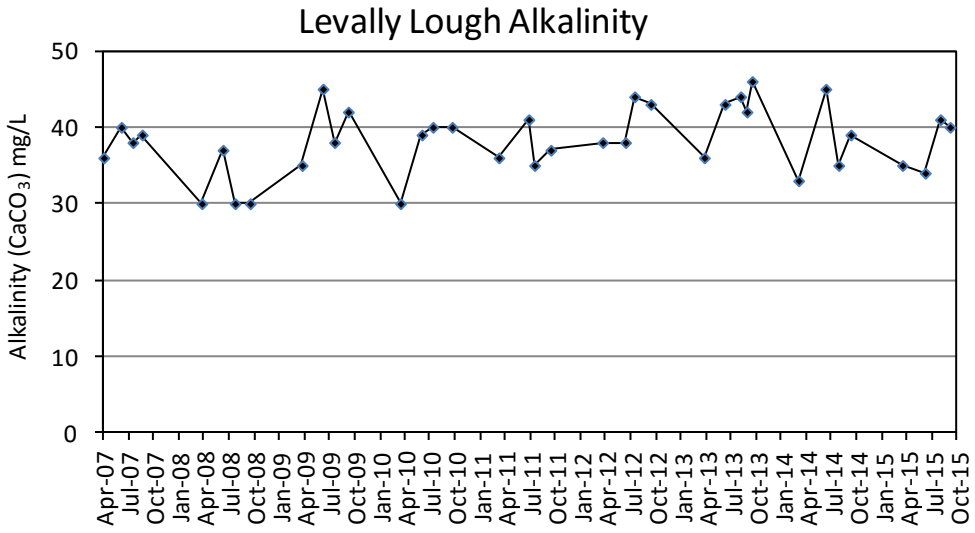

Figure 29: Levally Lough Alkalinity from April 2007 until October 2015.

Eutrophication and Trophic Status (Note)

Eutrophic means well-nourished and eutrophication is the process where water bodies become more eutrophic through the addition of nutrients , primarily nitrogen and phosphorus (N and P). These additional nutrients, often in combination with low flow or still conditions and increased water temperatures, trigger a series of events causing excessive plant and algal growth. The process may culminate in oxygen depletion in waters, fish kills and problems with the treatment of the water for drinking. Waterbodies suffer different degrees of eutrophication, termed trophic status. Lakes are often characterised by their trophic status using the following scale: Oligotrophic (low in nutrients and algal growth); Mesotrophic (moderately productive, less clean than oligotrophic bodies); and Eutrophic (high levels of nutrients and algal growth combined with poor water quality). Lakes suffering from excessive eutrophication can be classed as hypertrophic. Trophic status is typically determined by algal abundance (using Chlorophyll *a* assessments as an indicator of abundance) or total phosphorus concentration (the most important nutrient in the eutrophication process.

6.1.7 Total Phosphorus

Phosphorus (P) occurs widely in nature but much of the phosphorus found in surface waters occurs as a result of anthropogenic activities. Human and animal wastes contain large amounts of phosphorus and therefore agriculture and wastewater treatment plants are large sources of phosphorus and often provide pathways for phosphorus to enter the aquatic environment. Artificial fertilisers used in agriculture and forestry are also primary sources of phosphorus. Phosphorus and, to a lesser extent, nitrogen are the two key drivers of eutrophication events in the aquatic environment (see Eutrophication and Trophic Status note, above) as they are the primary nutrients required by the algae and plants that can flourish during eutrophication events. Eutrophication can lead to a loss of biological diversity (particularly of sensitive and/or desirable species), increased plant growth, the development of algal scum's and a general deterioration in water quality.

Eutrophication is the largest threat to Irish surface water quality and is of great importance to drinking water sources. Increased algal abundance can create problems in treatment plants and decomposing algae can release toxins into the water and cause taste and odour problems. The management of phosphorus levels entering the aquatic environment is central to the long-term viability of many drinking waters sourced from surface water bodies. There is currently no statutory limit for phosphorus in drinking waters.

Total Phosphorus (TP) has not been monitored by Coffey Group at the water treatment plant (on behalf of Nephin Valley GWS) or at the tap within the Nephin Valley GWS network by Mayo County Council.

Total Phosphorus has been monitored within Levally Lough by Mayo County Council and the EPA from April 2007 until October 2015 (Figure 30). The total Phosphorus concentrations values ranged from a minimum of 0.005 mg/L in July 2009 to a maximum of 0.023 mg/L in October 2008. An average phosphorus concentration of 0.013 mg/L was recorded over the sampling period.

6.1.8 Chlorophyll and algae

Chlorophyll is used as an indicator of overall algal abundance within a water source. High levels of chlorophyll can indicate high algal abundance which can have negative implications for the

treatment process and lead to taste and odour problems in treated water. Chlorophyll values are typically greatest in the summer when the water temperatures are warmer and light availability is high.

Chlorophyll data were provided by the EPA from April 2007 until October 2015 within Levally Lough: mid-lake (Figure 31). Chlorophyll concentrations values ranged from a minimum of 1 mg/m^3 in July 2008 to a maximum of 37 mg/m^3 in April 2008, with an average (mean) value of 9.7 mg/m^3 for the sampling period. Chlorophyll *a* values show strong seasonality with highest values typically during summer and early autumn, and lowest values typically during winter months. The peak in Chlorophyll occurs in spring/summer in 2008 and 2015, with the peak in Chlorophyll concentrations occurring in summer/autumn in 2008, 2009, 2011, 2013 and 2014.

The Surface Water Regulations (2009) do not include parametric values for Chlorophyll for Lake Type 7 (the classification given to Levally Lough: Deep (>4 m), Small (< 50 ha) and of moderate alkalinity). The reference and boundary Chlorophyll values for lake type 7 are 3.2 µg/L for reference conditions, 5.8 mg/m^3 for High/Good conditions and 10 mg/m^3 for Good/Moderate conditions. The average Chlorophyll value for Levally Lough was 9.7 mg/m^3 and therefore it is likely that Levally Lough was Good/Moderate condition for the monitoring period. The Water Framework Status for Levally Lough for the period 2007-2009 was Moderate, the Lake water body score for Levally was classified as 'possibly at risk of not achieving good status'. EPA online maps: http://gis.epa.ie/Envision). The Ecological Status given in the Conn WMU Action Plan (2009) was Moderate.

The Water Framework Status for Levally Lough for the period 2010-2012 was Good, although the Lake water body score for Levally Lough was classified as 'at risk of not achieving good status'. (EPA online maps: http://gis.epa.ie/Envision). The Ecological Status given in the Conn WMU Action Plan (2009) was Moderate.

Algal species (in terms of algal counts) have not been monitored within the Levally Lough GWS catchment.

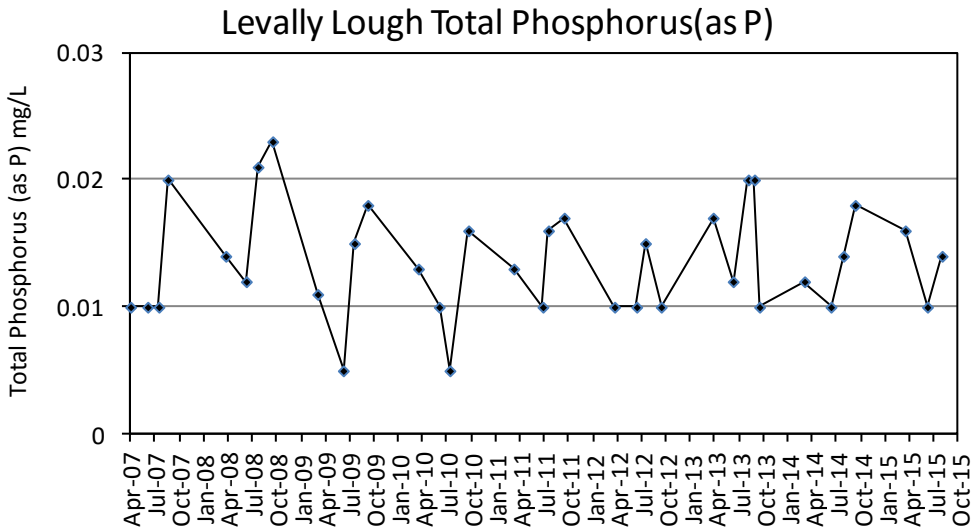

Figure 30: Levally Lough TP from April 2007 until October 2015.

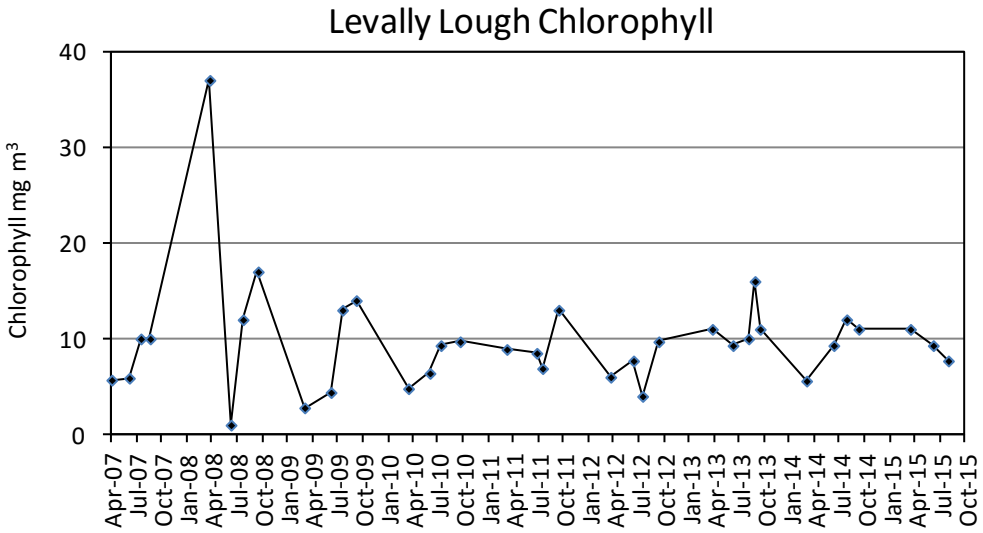

Figure 31: Levally Lough Chlorophyll from April 2007 until October 2015.

6.1.9 Transparency

Transparency can give an indication of the presence of suspended matter within a water body and is measured using a Secchi disk (a coloured disk). The disk is lowered through the water until it can no longer be seen by the naked eye and the distance lowered recorded. The greater the distance, the greater the transparency. The transparency of the water can be used as an overall indicator of quality as algae and/or sediment can reduce transparency. Low transparency levels can effect light penetration and also potentially affect the ability of fish to find prey.

The transparency from mid-lake of Levally Lough was monitored by Mayo County Council and EPA from April 2008 until April 2015 (Figure 32). Values ranged from a minimum of 1.2 m in October 2008 to a maximum of 3.5 m in July 2011, with an average of 2.2 recorded for the sampling period. Results would indicate an increase in water transparency in Levally Lough from 2008 until 2015.

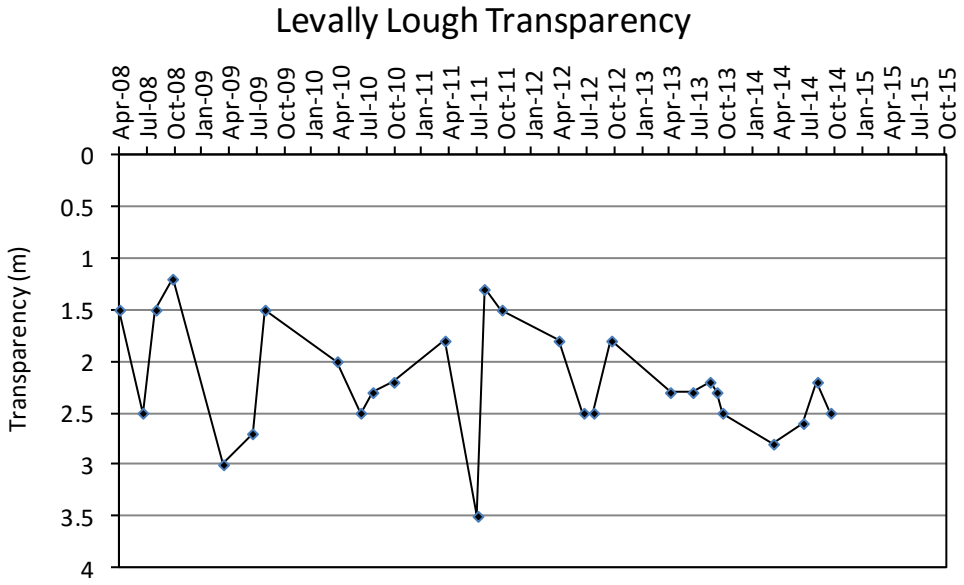

Figure 32: Levally Lough transparency from April 2008 until April 2015.

6.1.10 Nitrogen

Nitrogen (N), together with phosphorus, is central to the development of eutrophication as nitrogen is a key nutrient for plant and algal growth. Although approximately 78% of the earth's atmosphere is made up of nitrogen gas, this form of nitrogen is not available as a nutrient to plants. Instead it is converted to different forms such as ammonium, nitrite and nitrate through the nitrogen cycle. Nitrate is the most common form of nitrogen that exists in aquatic environments and typically originates from human and animal wastes as well as from the application of artificial fertilisers to agricultural lands. Nitrite is an intermediate form between ammonium and nitrate and typically only represents a small proportion of nitrogen in water. Nitrite and nitrate are often presented together and Total Oxidised Nitrogen (TON).

There are specific health implications regarding high nitrate and nitrite levels in drinking water. Methemoglobinemia, or blue baby syndrome, is a condition found especially in infants under 6 months and is a result of the infant's blood not carrying as much oxygen as it should be able to. This is caused by nitrates being converted by bacteria in the baby's stomach to nitrites which are then absorbed into the blood where it is converted to methemoglobin. This methemoglobin does not carry oxygen as efficiently as the usual haemoglobin. Severe cases can result in brain injury and death. Pregnant women and adults with reduced stomach acidity are also susceptible to nitrite-induced methemoglobinemia. Importantly, *nitrates and nitrites cannot be removed from raw water during the standard treatment process*. The Drinking Water Regulations (2014) stipulate maximum acceptable values of 50 mg/L for nitrate and 0.5 mg/L for nitrite.

The source of ammonia in the aquatic environment is most likely from human and animal waste and high concentrations of ammonia can indicate pollution from these sources. Ammonia also arises from peat drainage. In aquatic environments, ammonia (NH_3) is frequently ionised to ammonium (NH_4^+) and equally ammonium can be converted back into ammonia. The pH of the water is the major factor than influences the ionisation of ammonia to ammonium and at the typical pH of most Irish freshwaters; it is ammonium that is the most common form. Although naturally present in small amounts in aquatic environments, values of over 0.1 mg/L N is interpreted as an indication of human waste pollution or industrial contamination. With regards to lake quality classes based on total ammonia levels (NH_4^+ plus NH_3), the Surface Water Regulations (2009) state that bodies must have ≤0.040 mg N/L as a mean for high status (or ≤0.090 95%ile) and ≤0.065 mg N/L as a mean for good status (≤0.140 95%ile). Following treatment, the Drinking Water Regulations (2014) parametric value for ammonium is 0.3 mg/L.

Total Oxidised Nitrogen (TON)

Mayo County Council monitored concentrations of Nitrates and Nitrites in the treated water from a number of locations in Nephin Valley GWS catchment from November 2010 until May 2016 (Figure 33). The maximum nitrate concentration measured was 2.7 mg NO_3-N/L in November 2015. The maximum Nitrite concentration measured was 0.043 mg NO_2-N /L on five sampling occasions (December 2011, November 2012, July 2013, July 2014 and April 2015). These values are well below the 50 mg NO_3-N /L and 0.5 mg NO_2-N /L parametric value stated in the Drinking Water Regulations (2014).

Nitrate and Nitrite has not been monitored by the Coffey Group on behalf Nephin Valley GWS.

The EPA and Mayo County Council have monitored Total Oxidised Nitrogen at Levally Lough from April 2007 until October 2015 (Figure 34). Values ranged from a minimum of 0.1 mg N/L on a number of sampling occasions to a maximum of 0.5 mg N/L in April 2012, with an average TON concentration of 0.18 mg N/L. The surface water Regulations (1989) parametric values were not exceeded on any occasion.

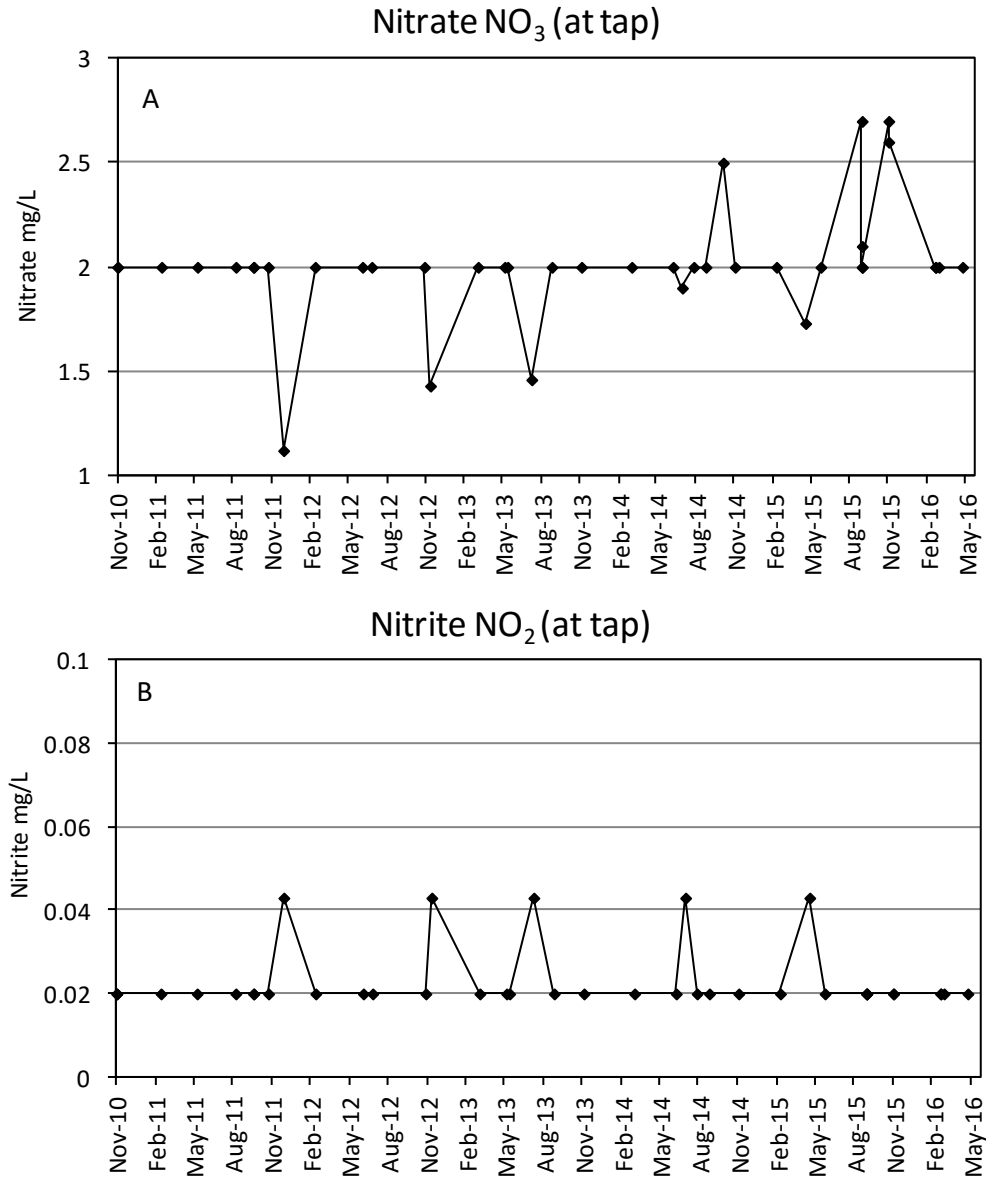

Figure 33: A) Nitrate and B) Nitrite concentrations in the treated water from Nephin Valley GWS November 2010 until May 2016.

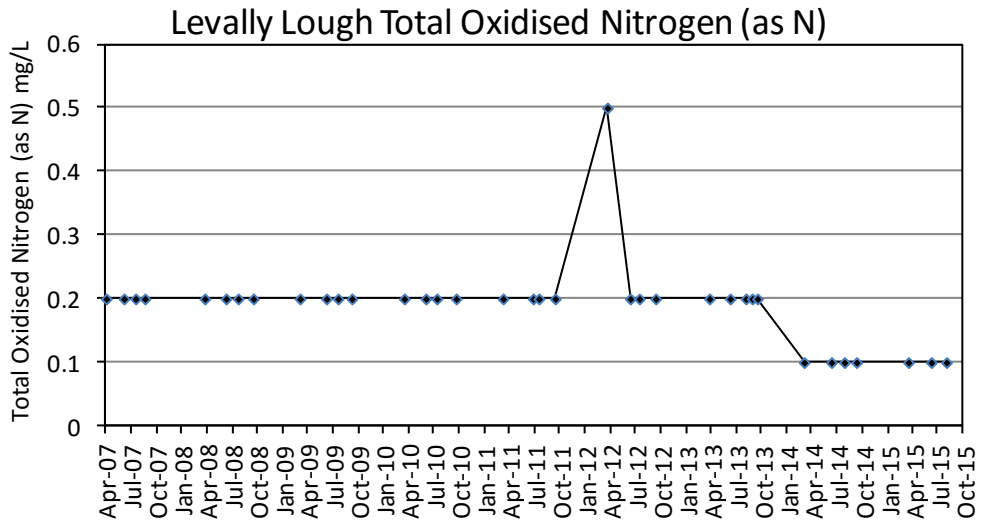

Figure 34: Total Oxidised Nitrogen (nitrate and nitrite combined) for Levally Lough from April 2007 until October 2015.

Ammonium

Mayo County Council monitored Ammonium from November 2010 until May 2016 in the treated water from a number of locations in Nephin Valley GWS network (Figure 35). Values ranged from a minimum of 0.009 mg/L in July 2013 and a maximum of 0.13 mg/L was measured in September 2015 with an average of 0.03 mg/L.

Total Ammonia has not been monitored by Coffey Group in the raw and treated water at the Nephin Valley GWS water treatment plant.

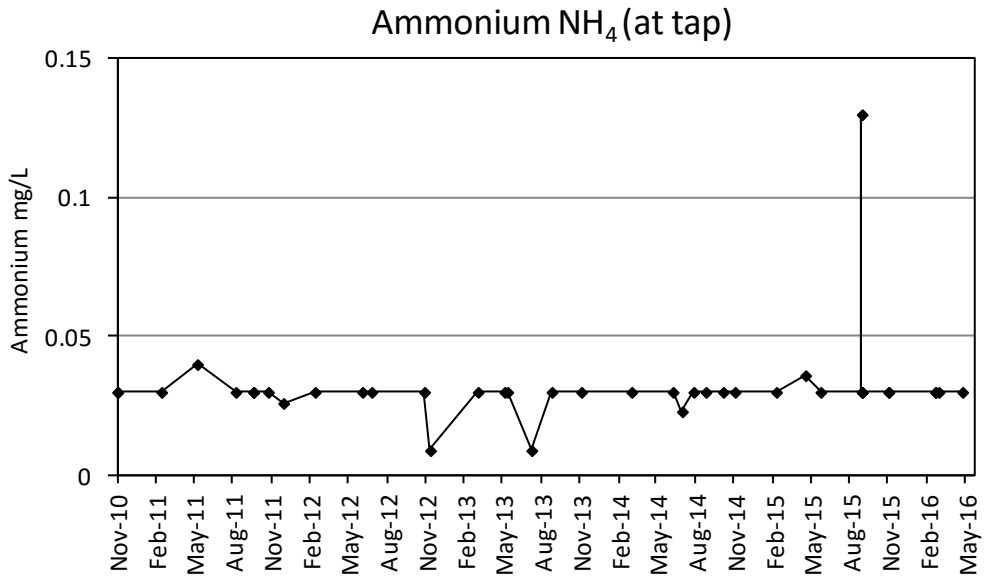

Figure 35: Treated water Ammonium concentrations from Nephin Valley GWS concentration from November 2010 until May 2016.

Mayo County Council and the EPA monitored Ammonia mid-lake from Levally Lough from April 2007 until October 2015 (Figure 36). Ammonia values ranged from 0.10 mg/L to 0.15 mg/L for the

majority of the sampling period, with one exception in April 2014 the Ammonia concentration in Levally Lough was 0.023 mg/L.

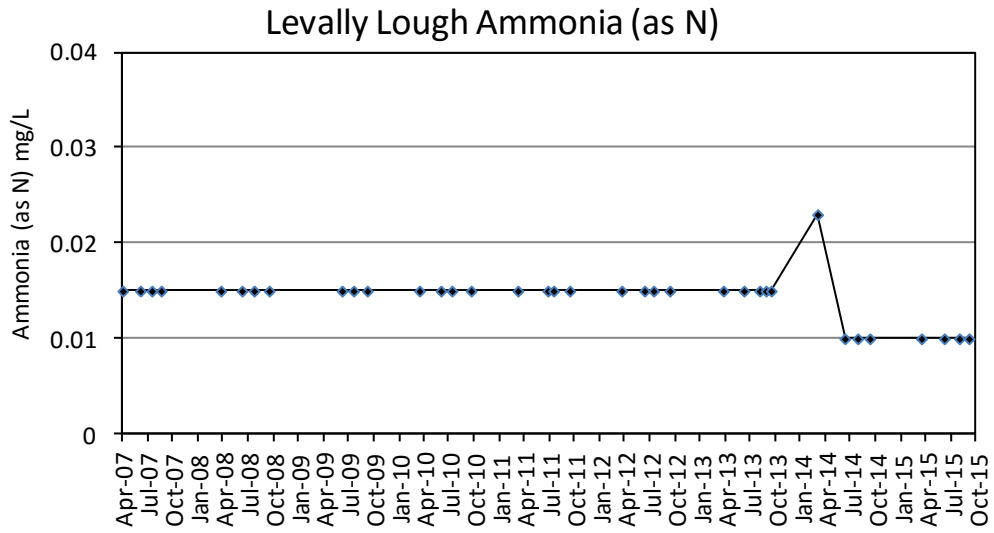

Figure 36: Ammonia concentration from Levally Lough from April 2007 until October 2015.

6.1.11 Conductivity

The ability of water to conduct an electrical current is quantified as the conductivity of water and is an indication of the mineral salt content of the water body. Conductivity itself has no direct health or sanitary significance in freshwater environments, and the Surface Water Regulations (1989) specify a limit of 1000 µS/cm at 20°C for Class A1 waters.

Conductivity was monitored by Mayo County Council from November 2010 until May 2016 in the treated water from a number of locations in Nephin Valley GWS network (Figure 37). The conductivity values ranged from minimums of 70 µS/cm in December 2011 to maximum value of 186 µS/cm in November 2014 with an average of 104 µS/cm. Conductivity values were below the Drinking Water Regulations (2014) of 2500 µS/cm on all sampling occasions.

Conductivity has not been monitored by Coffey Group at the Nephin Valley GWS water treatment plant.

Mayo Country Council and the EPA monitored conductivity from Levally Lough from April 2007 until October 2015. The conductivity values ranged from a minimum of 121 µS/cm in April 2011 to a maximum of 213 µS/cm in August 2009. The conductivity values were well below the Surface Water Regulation (1989) parametric values for Class A1 waters on all occasions during the sampling period.

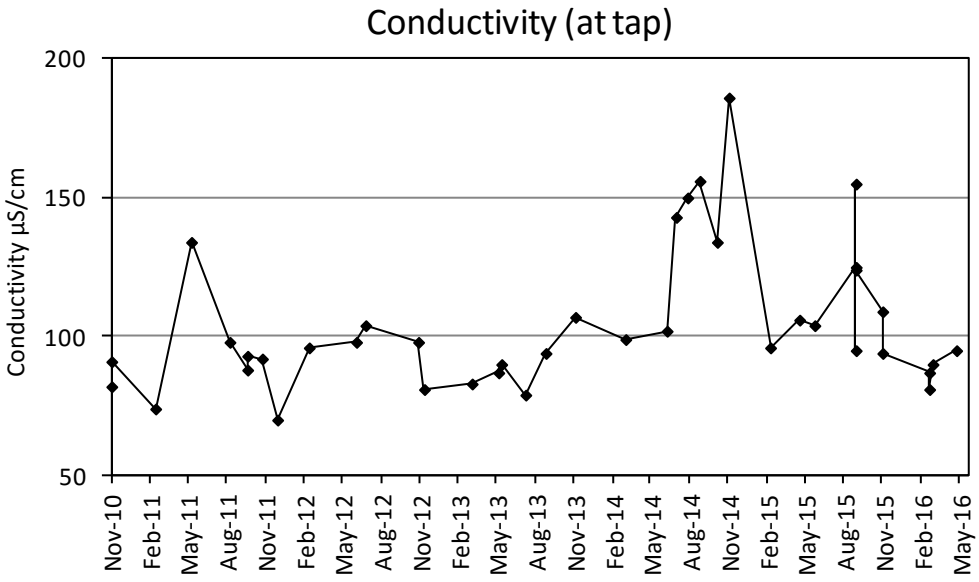

Figure 37: Treated water Conductivity from Nephin Valley GWS from November 2010 until May 2016.

6.1.12 Dissolved Oxygen (DO)

The amount of oxygen dissolved within a water body is important for fish survival. If a water body is suitable for fish survival then it generally meets the quality requirements for most other forms of water consumption.

Dissolved oxygen saturation is dependent on water temperature: warmer waters typically contain less dissolved oxygen then colder waters. Summer temperatures resulting in lower DO levels; in combination with low water levels can leave aquatic environments particularly vulnerable to organic pollution. DO saturation and concentration can also be affected by photosynthesis, with increased eutrophication and photosynthesis leading to high oxygen concentrations during daylight hours, and these high oxygen concentrations can be depleted at night when respiration takes over from photosynthesis.

Dissolved Oxygen has not been monitored by Coffey Group at the Nephin Valley GWS water treatment.

Mayo County Council and the EPA have monitored Dissolved Oxygen in Levally Lough from April 2007 until October 2015 (Figure 38). The values of DO ranged from a minimum of 67 % DO saturation in July 2009 to a maximum of 115 % DO saturation, with an average of 97 % DO saturation recorded over the monitoring period.

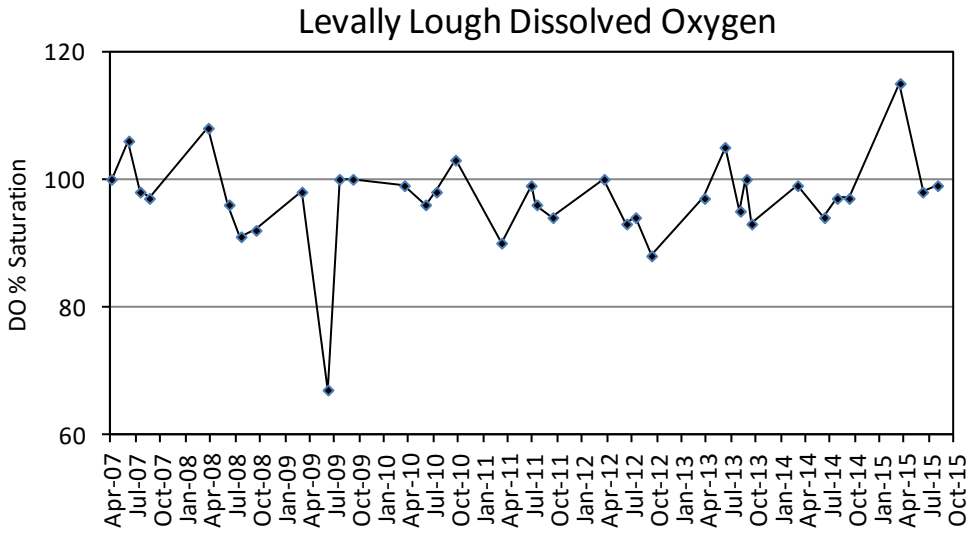

Figure 38: Dissolved Oxygen % saturation for Levally Lough from April 2007 until October 2015.

6.1.13 Biological Oxygen Demand (BOD)

Unpolluted water is typically saturated with dissolved oxygen, but when organic pollution enters a water body, bacteria break it down through a process that uses available oxygen, thus reducing DO levels. The biological oxygen demand (BOD) is a measure of the oxygen demand required to break down organic waste. BOD is the amount of dissolved oxygen taken up by bacteria degrading organic material in the dark at 20 °C over five days. The Surface Water Regulations (1989) require the value for BOD in Class A1 waters to be below 5mg/L O_2.

Biological Oxygen Demand has not been monitored by Coffey Group at the Nephin Valley GWS water treatment plant.

6.1.14 Coliforms

Faecal coliforms such as *E. coli* originate in animal or human wastes. A typical measurement of coliforms is Total Coliforms which include faecal and soil-born coliforms. Total coliforms is used as an indicator of pathogenic organisms within a water body and the Surface Water Regulations (1989) recommend that Class A1 waters should not exceed 5,000 total coliforms per 100 ml, or 1,000 faecal coliforms per 100 ml. Following treatment, the Drinking Water Regulations (2007) state that Total coliforms values above 0 numbers per 100ml are unacceptable.

***Escherichia coli* (*E. coli*)**

Escherichia coli bacteria are present in high numbers in human and animal (including bird) faeces. They are generally not found in waters in the absence of faecal pollution, however, it would be rare to find surface waters that do not contain faecal coliforms. Groundwater's are significantly less susceptible to faecal coliform contamination than surface waters, and frequently do not contain bacteria.

E. coli has been monitored by the Coffey Group in the raw and treated water at the Nephin Valley GWS water treatment plant from March 2011 until June 2016 (Figure 39). For mountain stream raw water the values of *E. coli* ranged from a minimum of 1 MPN/100ml on number of occasions over the sampling period to a maximum of 201 MPN/100ml in June 2013 and August 2013, with an average of 24 MPN/100ml. There was *E. coli* found in the mountain stream raw water supply on 87.4

% of sampling occasions over the monitoring period. In the treated water supply, *E. coli* values were zero over the sampling period, as required by the Drinking Water Regulations (2007 and 2014).

Mayo County Council measured *E. coli* from September 2010 until May 2016 in the treated water from a number of locations in Nephin Valley GWS network. *E. coli* was zero for the majority of sampling occasions with the exception of September 2010 and February 2016 when *E. coli* measured 1 MPN/100ml respectively, exceeding the Drinking Water Regulations (2007 and 2014).

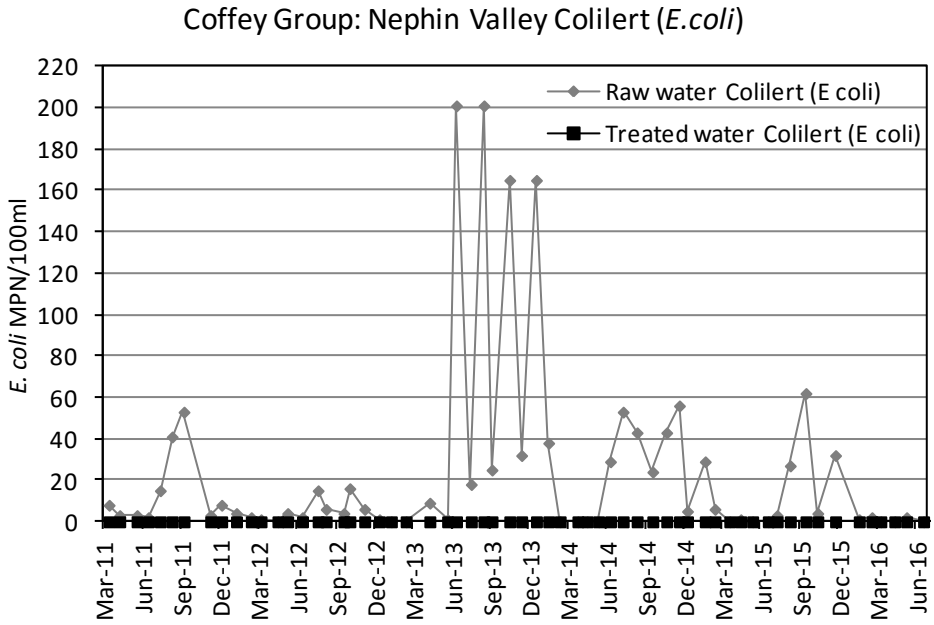

Figure 39: Raw and treated water *E. coli* values at Nephin Valley water treatment plant from March 2011 until June 2016.

Clostridium perfringens

Clostridium perfringens exists as part of the natural bacterial intestinal flora of humans and therefore serves as an indicator of faecal pollution. *Clostridium perfringens* has been monitored by the Coffey Group in the raw and treated water at the Nephin Valley GWS water treatment plant from March 2011 until June 2016 (Figure 40). For mountain stream raw water the values of *Clostridium perfringens* ranged from a minimum of 1 cfu/100ml on number of occasions over the sampling period to a maximum of 20 cfu/100ml in April 2012, with an average of 1.1 cfu/100ml. In the treated water supply, *Clostridium perfringens* values were zero over the sampling period, as required by the Drinking Water Regulations (2007 and 2014).

Mayo County Council measured *Clostridium perfringens* from September 2010 until May 2016 in the treated water from a number of locations in Nephin Valley GWS network (Figure 41) and *Clostridium perfringens* were zero for the majority of sampling occasions with the exception of May 2013, when two exceedances of *Clostridium perfringens* occurred, measured 1 cfu/100ml and 2 cfu/100ml respectively, and in February 2016 when *Clostridium perfringens* measured 23 cfu/100ml, exceeding the Drinking Water Regulations (2007 and 2014).

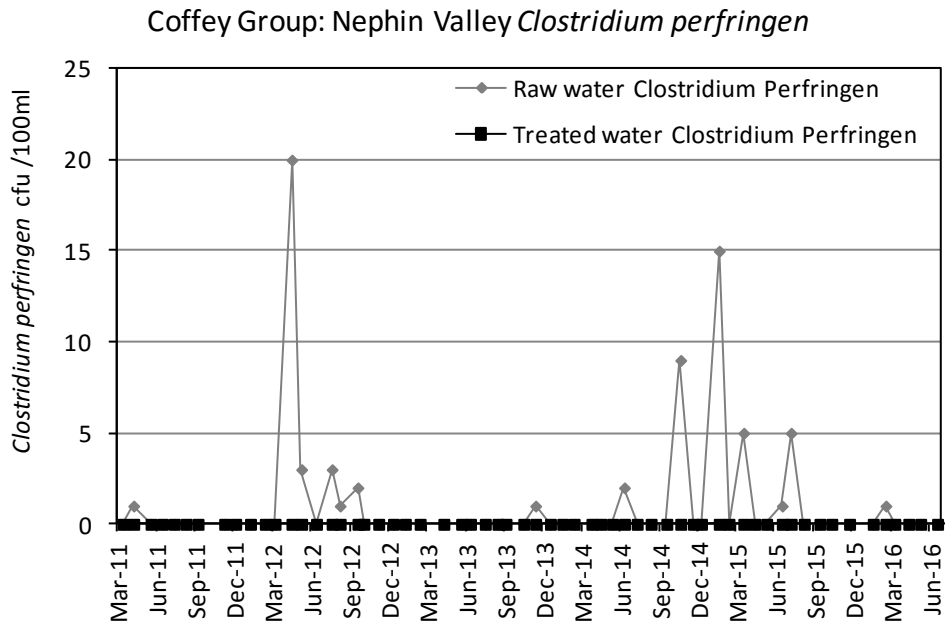

Figure 40: Raw and treated water *Clostridium perfringens* values for Nephin Valley from March 2011 until June 2016.

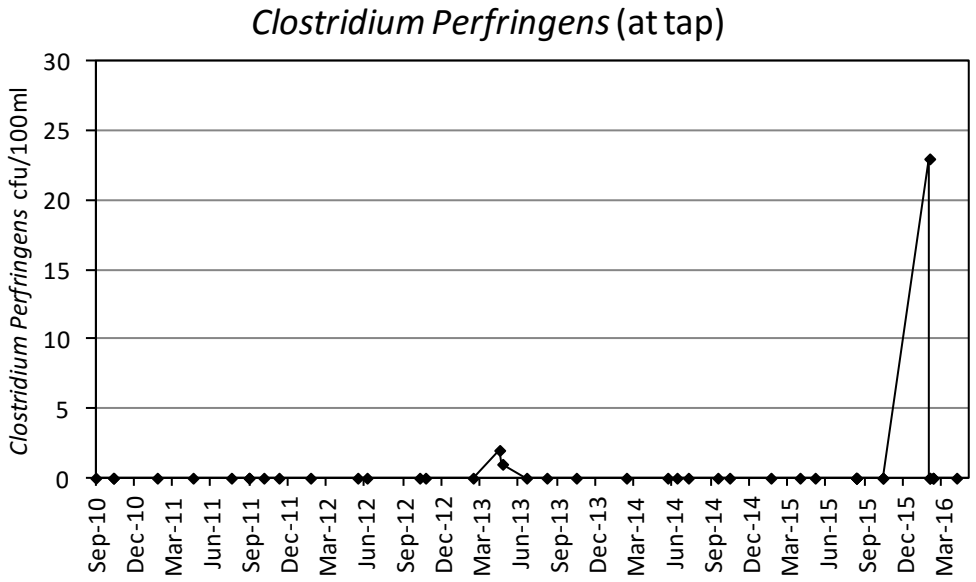

Figure 41: Treated water *Clostridium perfringens* values for Nephin Valley GWS from September 2010 until March 2016.

Total Coliforms

Total Coliforms have been monitored by the Coffey Group in the raw and treated water at the Nephin Valley GWS water treatment plant from March 2011 until June 2016 (Figure 42). For raw water, Total Coliforms ranged from a minimum of 3 MPN/100ml to a maximum of 201 MPN/100ml, with Total Coliforms were found in the raw water supply on 96.8 % of sampling occasions over the monitoring period. The average (mean) Total Coliform measure over the monitoring period was 119.4 MPN/100ml. The Surface Water Regulations (1989) recommend that Class A1 waters should

not exceed 5,000 Total Coliforms per 100 ml. In the treated water supply, Total Coliforms values were zero over the sampling period, as required by the Drinking Water Regulations (2007 and 2014).

Mayo County Council measured Total Coliforms from September 2010 until May 2016 on treated water at the tap from a number of locations in Nephin Valley GWS network (Figure 43). The Total Coliforms were zero for the majority of sampling occasions with the exception of four sampling occasions (September 2010, May 2013, November 2015 and February 2016) when Total Coliforms concentrations ranged from a minimum of 1 MPN/100ml to a maximum of 6 MPN/100ml, exceeding the Drinking Water Regulations (2007 and 2014).

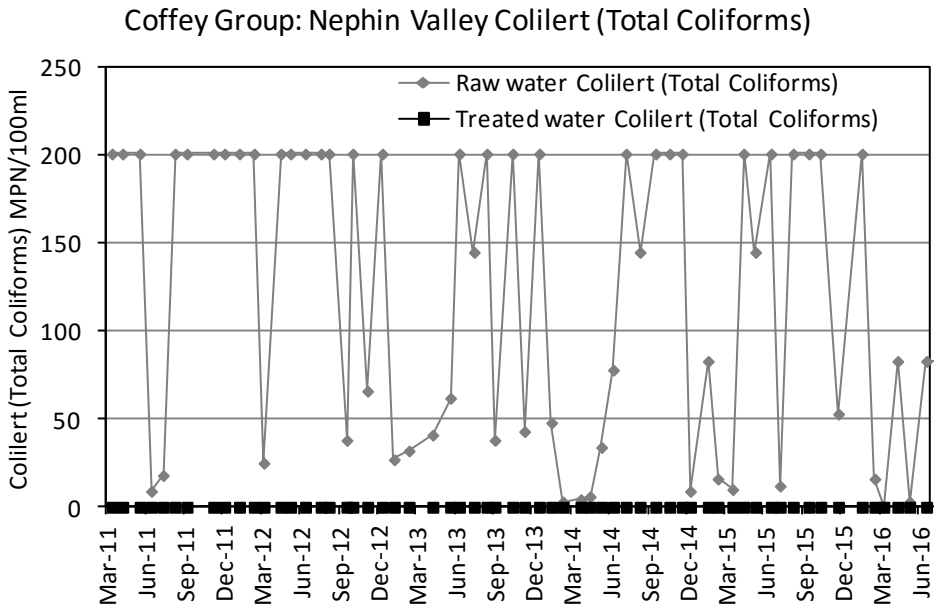

Figure 42: Raw and treated water Total Coliforms from March 2011 until June 2016 for Nephin Valley water treatment plant.

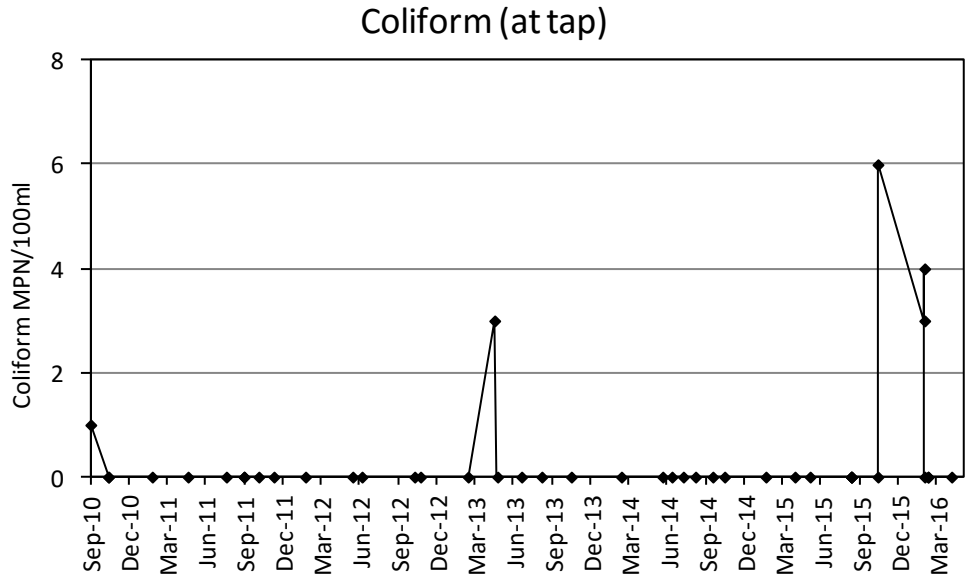

Figure 43: Coliforms in the treated water from September 2010 until May 2016 for Nephin Valley.

6.2 EPA River and Stream Water Quality Monitoring

EPA river and stream water quality monitoring has been presented above for a number of parameters. A brief description of Q-values assessed by the EPA has is provided below.

6.2.1 Biological data

Q values

Clabby *et al.* (2006) state that in the presence of pollution, characteristic and well documented changes are induced in the flora and fauna of rivers and streams. Organic pollution that impacts the aquatic macroinvertebrate communities are particularly well documented, with changes occurring due to varying sensitivities of different species to the stresses caused by pollution.

Macroinvertebrate diversity declines in the presence of pollution and sensitive species are progressively replaced by more tolerant species as pollution increases. The EPA classify benthic aquatic macroinvertebrates into five arbitrary 'indicator groups' based on sensitivity to pollution, with Group A being the most sensitive and Group E being the most tolerant. These groups, in combination with physico-chemical assessment of water quality, are used to produce Quality (Q) Values. The values range from Q1 to Q5, with Q5 waters having the greatest macroinvertebrate diversity (with sensitive species present) and good water quality; and Q1 waters having the little macroinvertebrate diversity (with communities dominated by tolerant species) and poor water quality.

Macroinvertebrates have not been monitored within the Nephin Valley GWS Catchment or the Levally Lough Catchment.

6.3 Overall Interpretation of Water Quality

A range of water quality parameters have been monitored throughout the Nephin Valley GWS catchment by Coffey Group (on behalf of the GWS), Mayo County Council and the EPA. Monitoring in Levally Lough was also undertaken by Mayo County Council and the EPA.

Raw water colour values for Nephin Valley GWS exceeded Surface Water Regulations (1989) parametric value for Class A1 water on 95 % of sampling occasions. For Levally Lough, a potential secondary raw water source to the Nephin Valley GWS, the raw water colour exceeded the Surface Water Regulations (1989) parametric value on 81 % of sampling occasions. As discussed in this report, high levels of colour do not represent a health risk. However, upon treatment with Chlorine, Trihalomethanes (THMs) can be produced when the chlorine reacts with naturally occurring organic matter in the raw water (high colour values can be an indication of high organic matter). Given the high values of water colour present in the raw water from Nephin Valley GWS and Levally Lough, the likelihood of Trihalomethanes (THMs) being produced during the treatment process is high.

THM samples are taken at the tap in a number of locations within Nephin Valley GWS network by Mayo County Council. From these THM results, it clearly shows that THM values significantly exceeded the Drinking Water Regulations (2007 and 2014) on four sampling occasions (November 2012, July, September and October 2014). THM sampling is a requirement of the Drinking Water Regulation and at present there does not appear to be sufficient THM monitoring being undertaken in the treated water supply in Nephin Valley GWS. It should be noted that the timing of THM sampling should be focused on periods between late summer and early winter when the possibility

of THM formation is likely to be greatest. Further details of the proposed monitoring activities are given in Section 7.

Nutrient levels measured in the treated water at the tap (Nitrate and Nitrite and Ammonium) within the Nephin Valley GWS catchment are typically low. Nitrate and Nitrate values are well below the 50 mg NO_3-N /L and 0.5 mg NO_2-N /L parametric value stated in the Drinking Water Regulations (2014). Nitrate, Nitrite, Ammonia and Total Phosphorus has not been monitored within the raw water supply of Nephin Valley GWS.

There were a number of spikes in water parameters measured on the 15th of September 2015 in the treated water at the tap in the Nephin Valley GWS network. This sample had excessive aluminium, iron, manganese, turbidity and ammonium as well as low alkalinity. There may have been a failure of one or more of the treatment processes around the sampling date. It may be advisable for the GWS to check their log books on and prior to this date to see if there were any issues logged that may explain such deterioration in the treated water for this date. If an issue is identified then there can be management actions put in place in order to ensure that such an event does not occur again.

For Nephin Valley mountain stream GWS, levels of Faecal and Total Coliforms within the raw water supply are generally high but should be removed by standard treatment processes. However, there Total Coliforms, *E.coli* and *Clostridium Perfringens* have been present on occasion in the treated water, and this is of concern. An assessment of the chlorination residuals along the network should be undertaken to ensure sufficient protection against microbial contamination to the consumer. The UV treatment undertaken by Nephin Valley mountain stream GWS reduces the risk of *Cryptosporidium* contamination of the treated water although this alone does not provide sufficient protection against microbial contamination along the network.

Levally Lough was identified in the Conn Water Management Unit Action Plan as being of 'moderate ecological status' in 2009 and had a lake waterbody WFD status in 2010-2012 was 'Good'. It would be important to continue to monitor the nutrient status of Levally Lough as a potential raw water supply for the Nephin Valley GWS. Diffuse pollution from agriculture, particularly as the majority of the catchment CORINE land cover is classified as pasture and land principally used for agriculture, is likely to be the primary source of nutrients, with contributions also likely from point sources such as domestic wastewater treatment systems. Recommendations are made in Section 7 with regards to addressing domestic wastewater treatment systems in the locality of Levally Lough catchment.

A number of recommendations are provided in Section 7 based on the assessment of physical properties and raw water quality from within the catchment.

7.0 Recommendations

The Nephin Valley GWS catchment is small at 1.1 km^2 and there are main agricultural grazing pressures acting within the catchment. A number of key issues are recommended to be addressed in order to improve source protection and maintain high quality raw water supplies for the GWS.

Put source protection on the agenda

Within many group water schemes the importance of source protection is often underestimated or neglected. It is recommended that source protection be installed as an item on the agenda at all Nephin Valley GWS meetings (AGM, Committee meetings etc.). This will ensure that important issues within the catchment are discussed and addressed as appropriate. For example, the findings of this report should be discussed as a starting point. Issues around source protection measures and potential pollution within the catchment should also be discussed.

Reporting of potential pollution issues

The Nephin Valley GWS should encourage committee members and people with connections to the scheme to report potential pollution issues. Members should be able to call the scheme staff to report pollution incidents in confidence. The scheme staff can then decide how to proceed with investigation, either dealing with the problem themselves or passing relevant information on to the County Council or the EPA as required.

Develop a protocol for dealing with offenders

The committee should agree a protocol for dealing with potential pollution incidences. From the moment the staff receive knowledge, there should be a procedure in place. The protocol should reflect the seriousness of individual issues with some being dealt with by the scheme and more serious incidences being reported directly to the appropriate authority. Having a protocol in place ensures that all complaints are dealt with in an agreed and equitable manner.

Monitoring Trihalomethanes (THMs) and Total Organic Carbon (TOC)

As discussed in this report, the levels of raw colour that are present in the Nephin Valley GWS raw water supply do not represent health risks. However, upon treatment with chlorine, THMs can be produced when the chlorine reacts with naturally occurring organic matter in the raw water. These THMs have potentially significant health implications, and from the data provided for this report, there does not appear to be sufficient THM monitoring being undertaken in the treated water supply, given the THM values that have been recorded in the current monitoring programme. Monitoring of THMs is a requirement of the Drinking Water Regulations (2007 and 2014). As only limited THM monitoring has been undertaken and because this monitoring has identified high THM issues, the scheme should initiate a monitoring programme for THM and Total Organic Carbon (TOC) in the treated and raw water supply respectively. Monitoring TOC gives an indication on the level of organic matter in the raw water supply that can react with chlorine during the treatment process to produce THMs. It is recommended that THM and TOC monitoring is focused over the period from late summer through to early winter as this is when true colour values are highest, with additional occasional THM monitoring undertaken throughout the rest of the calendar year. Monitoring of TOC and THM should be undertaken simultaneously: TOC should be monitored on raw water and the monitoring of THM should occur on treated water after chlorination (the formation of THM occurs

within the first ten hours post-chlorination), in the GWS storage reservoir and at the consumer tap. The following mitigation methods for raw water are advised by the EPA if THM levels are found to be high in the treated water:

- Improve raw water management; including storage, intake management and monitoring and control (e.g. raw water turbidity monitors or automation of coagulant dosing based on raw water conditions);
- Install automatic shut off when water quality is poor;
- Examine the option for using an alternative raw water source such as groundwater.

For Nephin Valley GWS, it is essential that microbiological contamination of treated water does not exceed the required limit of 0 MPN/100ml under the Drinking Water Regulations (2014). The microbiological contamination along the network of Nephin Valley GWS on occasion is evident and may suggest low level of chlorine residuals along the network. An assessment of chlorine treatment in Nephin Valley GWS is important although the challenge remains between maintaining low THM levels whilst increasing chlorine treatment to remove coliform contamination. It is in this arena where source protection and the catchment-level management actions outline in this report are important. Further information on THMs and their monitoring within Ireland is provided by the Environmental Protection Agency: http://www.epa.ie/pubs/advice/drinkingwater/DrinkingWaterGuide4_v8.pdf.

Agriculture management

Levels of nutrients in Lugnamannaum River the main source for the Nephin Valley GWS are unknown and as there is high to very high risk of nutrient and microbial pathogen contamination throughout the catchment as identified through groundwater vulnerability and water quality monitoring data. The primary sources of nutrient enrichment and microbial contamination of freshwater systems are diffuse agricultural pollution and point source pollution from grazing animals. Therefore the following recommendation may help to address key issues related to these pollution sources:

Fencing of water bodies

Livestock access to Lugnamannaum River can lead to potential contamination issues with regard to nutrient input and faecal coliforms. A survey of fencing and livestock access was not undertaken as part of this report and this is recommended as areas do allow the possibility of direct livestock access to the river. Although it may not be feasible to fence all boundaries to water bodies within Lugnamannaum River, fencing of the main water source to Nephin Valley GWS catchment, could limit livestock access could significantly reduce potential faecal contamination of the GWS water source and remove a potential source of direct nutrient input.

Levally Lough has a catchment area of 14.3 km^2 and agriculture is the main pressure acting within the catchment. A number of key source protection issues are recommended to be addressed in order to help improve Levally Lough as a potential water source for the Nephin Valley GWS.

Monitoring Total Organ Carbon (TOC) in Levally Lough

Monitoring of Total Organic Carbon (TOC) at Levally Lough to gives an indication on the level of organic matter in the raw water (as a potential secondary water source to Nephin Valley GWS).

Agriculture and farmyard management

Levels of nutrients within the Levally Lough are not at levels of concern although it should be noted that there is moderate risk of nutrient and microbial pathogen contamination throughout the catchment as identified through groundwater vulnerability, EPA domestic wastewater risk and water quality monitoring data. The primary sources of nutrient enrichment and microbial contamination of freshwater systems are diffuse agricultural pollution and point source pollution (frequently from domestic wastewater treatment systems). Therefore a number of key issues related to these pollution sources are addressed below:

(a) Fencing of water bodies

Livestock access to Levally Lough can lead to potential contamination issues with regard to nutrient input and faecal coliforms. A survey of fencing and livestock access was not undertaken as part of this report and this is recommended as some areas do allow the possibility of direct livestock access to the lake. There may also be areas of direct livestock access to the inflow streams. Limiting livestock access could significantly reduce potential faecal contamination of the water source and remove a potential source of direct nutrient input.

(b) Nutrient management

Given the dominance of agriculture along the west in the catchment landscape, there are significant aspects of agricultural and farmyard management that have the potential to cause issues within Levally Lough a potential raw water supply to Nephin Valley GWS. Some general recommendations are made below:

(a) Make local landowners aware of potential problems caused by agriculture and the relevant rules and regulations relating to spreading of fertiliser and manure (European Communities (Good Agricultural Practice for Protection of Waters) Regulations 2014).

Some important points include:

- No chemical fertiliser applied within 2 m of surface waters;
- No organic fertiliser/soiled water spread within 20 m of a lake shoreline;
- No organic fertiliser/soiled water spread within 5 m of surface water course UNLESS slope is >10%, then the setback distance is 10 m. The setback distance is 10 m regardless of slope for 2 weeks before and after the closed period.
- For abstractions >100 m^3/d or >500 people, no spreading within 200 m of the abstraction point (surface water, borehole, spring or well).
- For abstractions >10 m^3/d or >50 people, no spreading within 100 m of abstraction point (as above).

Also, fertilisers (including manure) shall not be applied to land when:

- The land is waterlogged;
- The land is flooded or likely to flood;
- The land is frozen or snow-covered;
- Heavy rain is forecast within 48 hours;
- The ground slopes steeply and where – taking into account factors such as proximity to bodies of water, soil condition, ground cover and rainfall – there is significant risk of causing water pollution.

To increase compliance, the scheme should meet with farmers and discuss the use of Levally Lough as a potential secondary source to Nephin Valley GWS.

(b) Some areas within the catchment, including areas surrounding Levally Lough, have the potential to be spread with slurry or manure. Therefore soil nutrient analysis and nutrient management planning is required.

- Farmers should only apply organic and inorganic fertiliser on lands for which nutrient management plans have been completed;
- Nutrient management plans should be completed ever 4-5 years for all farms;
- Field slope should be considered when generating nutrient management places, not just soil nutrient status;
- Issues relating to soil nutrient status should be communicated with farmers both orally and in writing.

Further aspects of nutrient management planning are discussed in Section 7.1 Future Work.

Septic Tanks/Wastewater treatment Systems

Recommendations from the National Source Protection Pilot Project suggest that education should be provided to householders regarding the correct care and maintenance of their on-site wastewater treatment systems (OSWTSs). Good OSWTS management is important within the Levally Lough catchment in order to maintain reduce the potential for nutrients and other contaminants entering surface and ground water bodies.

The Water Services (Amendment) Act (2012) aims to regulate wastewater discharges from all homes that are not connected to the public sewer network. Regulation includes registration and inspection of all OSWTSs. The Environmental Protection Agency has produced a Code of Practice for Wastewater Treatment for Single Houses which is available from the EPA website: https://www.epa.ie/water/wastewater/guidance/cop/.

Nephin Valley GWS should meet with householders within areas of E and Extreme ground water vulnerability in the Levally Lough catchment and provide them with the following advice with regards to ensuring that all wastewater treatment systems within the catchment are functioning properly:

- All wastewater treatment systems should be properly installed by a competent person and a certificate of installation should be obtained upon completion.

- Have the septic tank/wastewater treatment system inspected and de-sludged once a year.
- Only permitted waste contractors should remove the sludge –a list of contractors is available from Mayo County Council.
- If effluent is observed sitting on the ground near the tank/system then the system should be checked for blockages and emptied if required. If this is due to poor drainage then expert advice should be sought by contacting Mayo County Council.

7.1 Future Work

Given the agricultural pressures acting within the Nephin Valley GWS catchment, a number of issues have been identified and recommendations made. The following further work is advised:

Nephin Valley Mountain Stream Source

1. Put Source Protection on the agenda

Including source protection issues on the agenda of committee meetings increases the profile and awareness of source protection issues within the Nephin Valley GWS catchment and brings into focus the recommendations made within this report. Developing a protocol for dealing with potential pollution incidences would be a good first step for the committee to address.

2. Filling water quality monitoring gaps.

In assessing the water quality monitoring data it is evident that Total Organic Carbon (TOC) should be monitored within the raw water supply and Trihalomethane (THM) should be monitored in the treated water simultaneously. Monitoring TOC gives an indication of the level of organic matter in the raw water supply that can react with chlorine during the treatment process to produce THM. It is recommended that THM and TOC monitoring is focused over the period from late summer through to early winter as this is when colour values are highest, with additional occasional THM and TOC monitoring undertaken simultaneously throughout the rest of the calendar year. The monitoring of THM should and THMs should occur on water after chlorination (the formation of THM occurs within the first ten hours post-chlorination), in/near the GWS storage reservoir and at a representative consumer tap.

3. Engage with Mayo County Council and Coffey Group regarding the management and mitigating measures of THMs and Microbial contamination within the distribution network.

- The high, and in some cases excessive, concentrations of THMs of treated waters at the tap is of concern. Mitigation options that aim to reduce THM concentrations in the treated water supply should be discussed with both Coffey Group and Mayo County Council.
- An assessment of the chlorination procedures within the GWS distribution network is essential in order to help reduce the formation of THM while maintaining sufficient chlorine residual levels post reservoirs to eliminate the potential for microbial contamination along the distribution network.

4. Engage with Mayo County Council and Coffey Group regarding GWS issues and water treatment plant operations.

- Within the Nephin Valley GWS, there are some concerns over reduced river flow during droughts, impacting on water availability and reduction in water quality at the mountain river. This is one of the factors that is driving the GWS to consider Levally Lough as a secondary raw water source for the Nephin Valley mountain stream GWS.
- A Boil Notice on Nephin Valley GWS under advisement of Mayo County Council was recently lifted as a result of the installation of a chlorine injection facility along the network, in the Lahardaun area.

- Continue to monitor for the presence of worms in the treated water supply throughout the GWS network.
- Current water monitoring gaps in raw and treat water at the Nephin Valley water treatment plant including Manganese, Total Phosphorus, Ammonia, Nitrite, Nitrate, Conductivity and Dissolved Oxygen.
- Clarification regarding whether Coffey Group are measuring Apparent Colour or True Colour since March 2011 (True colour should be monitored to ensure compliance with the Surface Water Regulations (1989) parametric value for colour).

5. Restrict direct sheep access to Lugnamannaun River, the water source for Nephin Valley Group water scheme.

Restricting direct sheep access to water bodies in the vicinity of Lugnamannaun River will assist in reducing potential nutrient and faecal contamination of the raw water source. This action, in combination with the monitoring of faecal coliforms in the raw water, will help to identify further source protection measure required to improve water quality for the GWS and potentially reduce treatment costs in the longer term.

6. Initiate a communications drive

Nephin Valley GWS should undertake a communications initiative to remind scheme members of their legal obligations with regards to nutrient enrichment practices, to recommend Good Agricultural Practices and to highlight the importance of wastewater treatment system management. Highlighting the importance of Scheme members' actions in regards to improving raw water quality could also raise awareness for facilitating improvements in environmental status of all the water bodies within the Nephin Valley GWS catchment. The location of the treatment works on the hill side presents an opportunity for a community open day when members of the local community and GWS members can learn more about the source of their drinking water, be informed about the treatment process, the work that is required to ensure good quality water reaches their taps and the source protection measures that need to be implemented to ensure good raw water quality.

Consideration should be given to engaging local schools to take an interest in local water resource management issues and to encourage students to undertake projects that can ultimately help raise the profile of Nephin Valley GWS and the source protection measures required to help improve the environmental status of the catchment area whilst also providing cost-savings in the water treatment process.

Levally Lough potential secondary raw water source for the Nephin Valley GWS.

The following further work is advised:

1. Filling water quality monitoring gaps in Levally Lough

Monitoring of Total Organic Carbon (TOC) at Levally Lough to gives an indication on the level of organic matter in the raw water. This may provide further information on the use of Levally Lough as a potential secondary water source to Nephin Valley GWS and the potential of the raw water supply from Levally Lough to react with chlorine during the treatment process to produce THMs.

2. Engage with householders within the Levally Lough Catchment with regard to on-site waste treatment systems (septic tanks) maintenance.

Householders within areas of E, Extreme and High ground water vulnerability should be engaged to ensure good septic tanks are maintained and serviced regularly in order to reduce the potential for nutrient and other contaminants entering the surface and ground water bodies.

3. Soil nutrient analysis

Given the unknown nutrient and chlorophyll levels within Levally Lough and its Water Framework Directive Lake Water body score of 'Possibly at risk of not achieving good status', the implementation of soil nutrient analysis for lands bordering Levally Lough would be valuable. Soils with high nutrient status are most likely to result in losses to nearby waterways. Knowledge of soil nutrient status would allow farmers to match fertiliser application to their needs and to save money by not applying fertiliser to fields that do not require it. This analysis would be beneficial to both the GWS and the farmers and therefore the costs could be shared also helping to achieve good ecological status for Levally Lough.

4. Restrict direct livestock access to Levally Lough.

Restricting direct livestock access to water bodies in the vicinity of Levally Lough will assist in reducing potential nutrient and faecal contamination of the potential secondary water source to Nephin Valley GWS.

5. Initiate a communications drive

Nephin Valley GWS should undertake a communications initiative around Levally Lough as a potential secondary raw water source to the GWS.

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