Preliminary Report on Source Protection

Gowlan Group Water Scheme

(Garvagh Lough and Upland Streams)

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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 Gowlan Group Water Scheme (GWS) catchment and explains the relevance to water quality (Section 4), discusses the potential impact of land use on raw water quality (Section 5), evaluates available relevant water quality data (Section 6) and provides recommendations to best manage concerns relating to source protection (Section 7).

Gowlan GWS abstracts water from two locations: the primary source consists of two upland streams/springs located in the Cuilcagh Mountains. During periods when flow from the streams/springs is not sufficient to maintain supply, water is abstracted from Garvagh Lough. The susceptibility of the primary source to faecal contamination by sheep is high and the groundwater vulnerability (the likelihood of surface water contaminants reaching the groundwater store) of this location is classified as extreme. Remedial work to preserve water during low flow periods and to protect the primary sources from potential contamination is required.

As elevation lowers from the primary source towards the secondary source, the blanket bog that surrounds the primary source gives way to more productive sheep and cattle grazing pasture land along with limited areas of forestry. Soils are typically poorly drained, promoting overland water flow. The geology of the catchment also changes with elevation: Shale and sandstone is present at higher elevation whilst karstified limestone surrounds the secondary source of Garvagh Lough. The extreme and high groundwater vulnerability of this karstified limestone environment in combination with high connectivity between surface waters and groundwaters in karst systems means that there is an increased likelihood of contaminants being delivered to Garvagh Lough by both surface and subsurface means.

The small number of private dwellings located within close proximity to Garvagh Lough, all serviced by on site waste water systems, would not normally be expected to provide large pressures on the water body. However due to the poor soil drainage of the area, the karstic environment, the high vulnerability of the groundwater to contaminants and the hydrological linkages between the Lough and surrounding surface waters and groundwaters, there is potential for contaminants to swiftly enter Garvagh Lough via overland and underground water flows. Correct care and maintenance of on-site waste water systems is therefore very important.

The agricultural management of the pasture surrounding Garvagh Lough has the potential to introduce both nutrients and faecal contaminants to the secondary abstraction source, particularly where areas of the Lough are unfenced allowing livestock direct access to the Lough.

A good range of raw water parameters are monitored on a monthly basis, however there are a number of important parameters that have not been monitored within the Gowlan GWS catchment

that would allow for greater insights into required catchment management and source protection. In particular, the availability of total phosphorus data would allow greater interpretation of the effects of surrounding land use and provide linkages with the available algal data. There are potential nutrient issues in Garvagh Lough as indicated by a large value of Total Oxidised Nitrogen observed in August 2011 which exceeded the Drinking Water Regulations (2007 and 2014). A bloom of blue-green algae was observed in September 2013 again indicating potential nutrient issues within Garvagh Lough. Although the low intensity agricultural practices within the catchment makes the likelihood of the Lough being severely impacted by elevated nutrients as low, given the underlying karstic environment surrounding Garvagh Lough, the vulnerability of local groundwater, the poor drainage of the catchment soils, the potential for phosphorus additions to the catchment through forestry management and agricultural practices and the addition of nutrients and contaminants through livestock access to water bodies, local wastewater treatment systems and farmyard slurry storage tanks, the precautionary principle must be taken with regards to potential diffuse and point pollution sources.

Although raw water values for total coliforms did not exceed the Surface Water Regulations (1989) for Class A1 waters, high values were observed on a number of occasions that represent a potential health risk for the Gowlan GWS. There are a number of likely potential pathways for pathogens and faecal coliforms to enter the raw water supply: through faecal contamination of the primary water supply by sheep accessing the mountain streams/springs; through faecal contamination of the secondary water supply through livestock having direct access to Garvagh Lough; through old and poorly maintained domestic waste water treatment systems; and through the intake of sediment at the secondary source intake pipe.

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

1. **Remedial works on the primary abstraction sources (mountain streams/springs)** to (a) preserve the water resource for a short period of time when flows are low; and (b) protect the primary source from potential faecal contamination through livestock access to the source. Implementation of the recommendations made by Jennings O'Donovan (2008) as part of their *Cryptosporidium* risk assessment report is also strongly advised.
2. **Relocation of the abstraction pipeline point at the secondary water source, Garvagh Lough** to reduce issues with filtration, reduce water treatment costs and reduce levels of coliforms entering the abstraction pipe. Clearance of vegetation (floating and fringing) close to the abstraction point would facilitate maintenance access.
3. **Filling water quality monitoring gaps**. Phosphorus and nitrogen are the key nutrients for algal and plant growth. Total phosphorus has not been monitored within the catchment and there are issues with regards to the limits of detection reported by EPS Pumping and Treatment Systems' current nitrate and nitrite monitoring. Total Phosphorus should be monitored at the secondary water source (Garvagh Lough) and consideration should be given to monitoring Total Phosphorus within the Loopagh stream inflow to Garvagh Lough. Clarification on limits of detection for nitrate in particular should be sought from EPS. Monitoring turbidity and dissolved oxygen in Garvagh Lough would also provide further information with regards to potential issues relating to eutrophication and algal blooms.

4. **Facilitating good agricultural practice within the catchment area** in regards to both livestock management and fertiliser application.
5. **Increasing the awareness of source protection in the local community** by putting source protection on the agenda at GWS meetings and communicating the importance of good agricultural practice to Scheme users (particularly those living and working within the catchment area).

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 Gowlan Group Water Scheme (GWS) catchment and explains how this is relevant to water quality. The potential impact of land use is discussed and available raw water quality data 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 and provided under license by the Geological Survey of Ireland. 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 area of Gowlan 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) and Geological Survey of Northern Ireland (GSNI)	Map (1:100,000 scale) of Irish bedrock geology
Aquifer Bedrock	GSI and GSNI	Information on the quality of groundwater aquifers
Aquifer Vulnerability	GSI and GSNI	Information on the connectivity between contaminants and aquifers
Soils	GSI and Teagasc; GSNI	Information on soil type
Subsoils	GSI and Teagasc; GSNI	Information on subsoil type

2.2 Water Quality Data

Water quality data relating to Garvagh Lough and its catchment were collected as part of the raw water monitoring activities undertaken on a monthly basis by EPS Pumping and Treatment Systems between May 2006 and September 2013 (data provided by the National Federation of Group Water Schemes).

There has been no regular water quality monitoring undertaken within the Gowlan GWS catchment by the EPA through the Water Framework Directive monitoring programme.

Parameters relevant to source protection were extracted from the EPS monitoring data and analysed and interpreted to highlight potential water quality issues and their potential causes and impacts within the Gowlan GWS 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 Gowlan Lough catchment.

3.0 Overview of Garvagh Lough (and Upland Streams) and the Water Framework Directive

Under the Water Framework Directive, 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 Gowlan GWS catchment lies within the Shannon International River Basin District. Each RBD is subdivided into Water Management Units, and Garvagh Lough and its catchment are included within the Upper Shannon Water Management Unit. An action plan for the Water Management Unit is available from http://www.shannonrbd.com/draftmanagementplan.htm.

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 Upper Shannon Water Management Unit.

No streams or lakes have been monitored within the Gowlan GWS catchment as part of the Water Framework Directive water quality monitoring programme.

4.0 Physical Site Description

4.1 Catchment location and outline

Gowlan Group Water Scheme extracts its water from two sources: the primary source is from two upland streams/springs located high in the Cuilcagh Mountains; the secondary source is Garvagh Lough, located approximately 7 Km south of Blacklion, County Cavan (Figure 1). Garvagh Lough itself is 8.7 ha in area, with the catchment covering approximately 8.78 km^2. The Lough is situated in a valley within the Cuilcagh Mountains and is hydrologically linked with the Shannon Pot, the traditional source of the River Shannon (Brown, 2005). Garvagh Lough is situated over a major geological fault that runs east to west almost perpendicular to the Cuilcagh Dyke (Brown, 2005: Figure 2). The catchment of the Lake extends to the north, east and southeast, with the land increasing sharply in altitude towards Cuilcagh Mountain to the southeast. The border of the Republic of Ireland and Northern Ireland runs north-south in the eastern section of the catchment. The primary sources of water abstraction (Figure 3) are situated at approximately 410m and 480m above sea level, with the highest part of the catchment being approximately 600m above sea level. Garvagh Lough is situated approximately 160m above sea level (Figure 4).

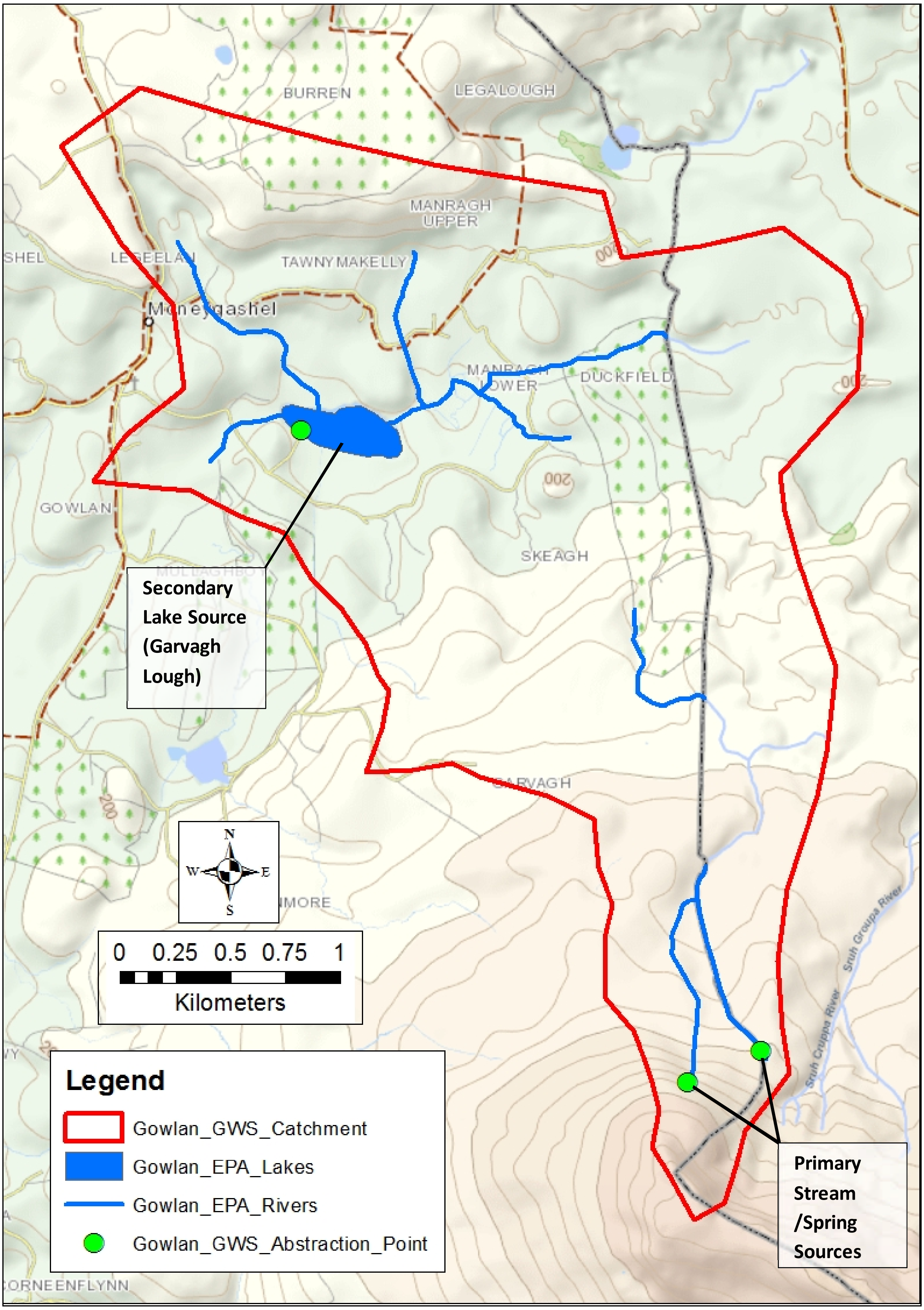

Figure 1: Catchment area and location of the primary and secondary water sources of Gowlan Group Water Scheme.

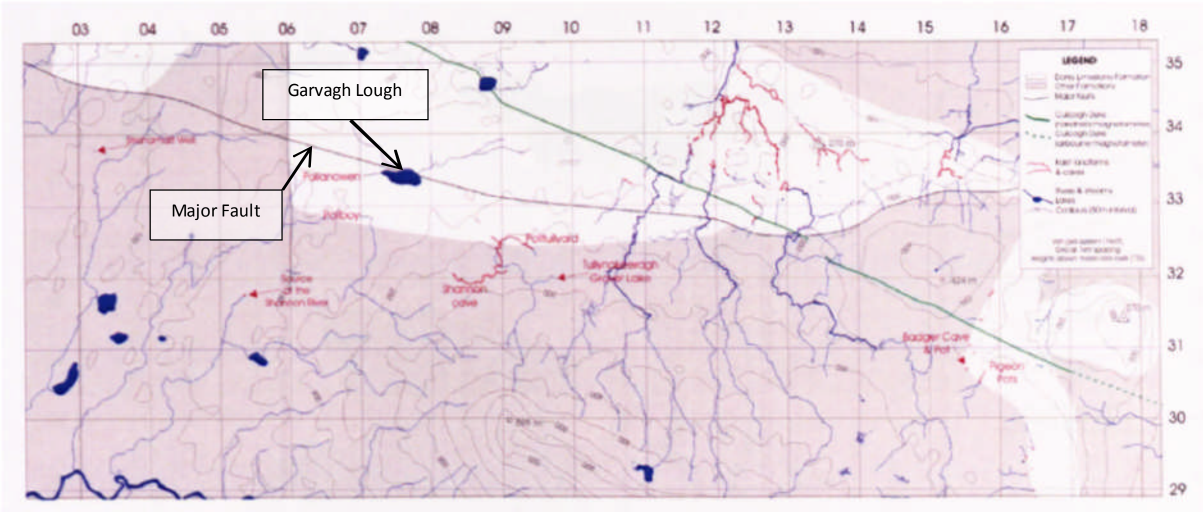

Figure 2: The caves and landforms of the Shannon Karst region showing the location of the major fault line above which lies Garvagh Lough. Figure taken from Brown (2005).

Figure 3: The abstraction points for the primary source of water for Garvagh Lough/Gowlan GWS: The easterly (left) and westerly (right) mountain streams/springs whose locations are shown in Figure 1.

Figure 4: View of Garvagh Lough from the southeast looking northwest with karstic features (e.g. doline) in the foreground.

The two streams/springs that provide the primary source of water are located in the southeast of the catchment. The abstraction point is located close to the spring point at each location. The springs are unable to consistently provide the volume of water required by the GWS, and therefore during periods of low flow, water is extracted from Garvagh Lough.

Water enters Garvagh Lough from a stream to the east of the Lough (Loopagh Stream), and the lough is likely to also be spring fed as a result of the karstic limestone geology of the area (see Section 4.2 below). An outflow stream to the west of Garvagh Lough soon sinks into the landscape and likely flows into the Shannon Pot.

4.2 Bedrock geology

The bedrock geology of the Garvagh Lough/Gowlan GWS catchment is dominated by limestones, sandstones and shales (Figure 5). Garvagh Lough itself is surrounded and underlain by karstic limestone of which sinkholes, disappearing streams, and springs are a common feature. As such, linkages between the surface water and groundwater are an important component of the hydrology of this catchment. Karstic areas that have little soil/subsoil cover can have high infiltration rates into the bedrock aquifer, and high groundwater flow speeds within the aquifer, which can result in a reduced capacity for filtration of water-borne contaminants between surface waters and the groundwater system.

The two major limestone units within the catchment are the Dartry Limestone Formation, a dark, fine-grained limestone formed approximately 335 million years ago; and the Knockmore Limestone Member which frequently overlays or is enclosed by Dartry Limestone Formation. As elevation increases to the south and southeast, the limestone is replaced by shales and sandstone formations. These sedimentary rocks found within the catchment are formed after the deposition and compaction of mineral and organic material. Limestones were formed through the compaction of skeletal remains of marine organisms and consist mainly of calcium carbonate. Shales are formed through the compaction of mud and typically break into thin parallel layers as a result of the parallel

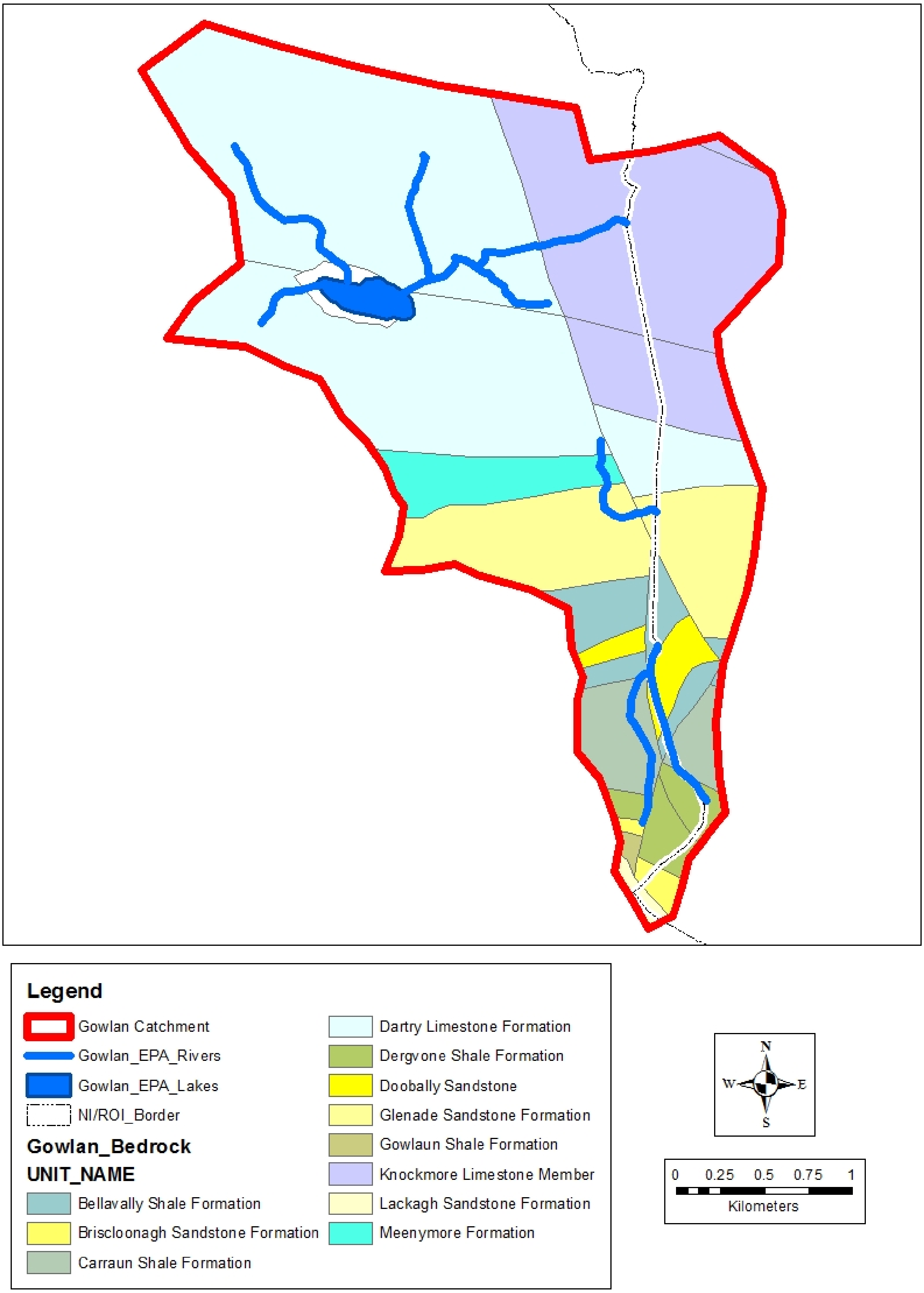

Figure 5: Bedrock geology within the Garvagh Lough/Gowlan GWS catchment

orientation of the clay mineral flakes. Sandstone is comprised of sand-sized grains of mineral, rock or organic material and may contain silt or clay-sized material between the sand grains. In Ireland, these rocks generally do not have any of the original pore spaces remaining and groundwater flows only through fractures in the rocks.

4.3 Bedrock aquifers

An aquifer is an underground body of permeable rock or sand/gravel that yields water in sufficient quantities for use. The different bedrock types found within the Gowlan GWS catchment (described above in Section 4.2) give rise to various aquifer types (Figure 6). The classification of aquifers is different in the Republic of Ireland and Northern Ireland and therefore these differences are highlighted in Figure 6.

A large proportion of the aquifer in Northern Ireland is classed as either high or moderate productivity, with the highly productive area to the east of Garvagh Lough being incorporating a karstic element (Figure 6). The area immediately surrounding Garvagh Lough within the Republic of Ireland is classified as a regionally important aquifer with karstified or a karstified (conduit) element (Rk). These productive aquifers within both the Republic and Northern Ireland correspond with the karstic limestone areas identified in the bedrock of the catchment (Figure 5).

As elevation increases towards the south and southeast, the bedrock aquifers in the Republic of Ireland are classed as locally important which is generally moderately productive (Lm, the sandstones) to locally important productive only in local zones (Ll, the sandstones/shales) (Figure 6). The rocks underlying the highest elevations in the southeast represent the poorest classification of aquifers within the catchment on both sides of the border.

The karstified aquifers present around Garvagh Lough are likely to contain large groundwater stores and springs and swallow holes typical of a karstified environment are present within this locality. However, as mentioned above, the porous nature of the karstified landscape in association with shallow soils/subsoils can reduce the potential for contaminant filtration from surface water as it flows into the groundwater, providing a potential pathway for contaminants to quickly enter groundwater.

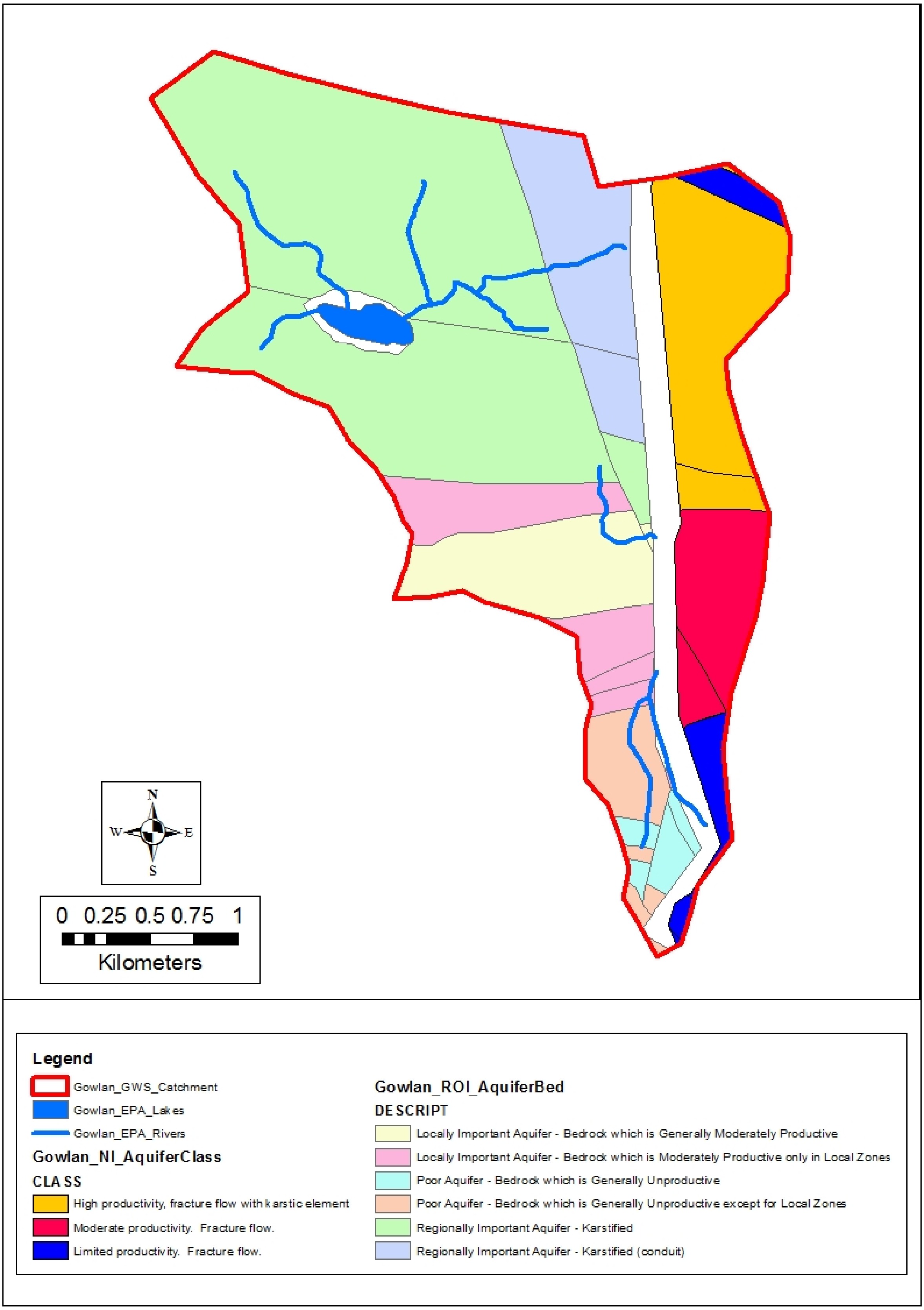

Figure 6: Aquifer types present within the Garvagh Lough/Gowlan GWS catchment.

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 classification systems in Northern Ireland and the Republic of Ireland differ and therefore these differences are highlighted in Figure 7. The majority of the groundwater vulnerability in the catchment lying within Northern Ireland is classified as extreme with low permeability cover (permeability, or hydraulic conductivity, is the ease with which fluids such as water can move through soils, subsoils or rock). For the area of catchment lying within the Republic of Ireland, the situation is more detailed as a result of different assessment and classification methods. The majority of groundwater vulnerability of the catchment in the Republic of Ireland is classified as Extreme or High with some areas classified at the highest vulnerability score of E (rock at or near the surface or karst). An area of moderate vulnerability lies to the north and west of Garvagh Lough.

The generally high to extreme groundwater vulnerability classifications within this catchment mean that there is great potential for contaminants to enter the groundwater. The vulnerability of groundwater is affected by the permeability of the overlying subsoils (called superficial soils in Northern Ireland) and soils and the interactions with surface water and groundwater.

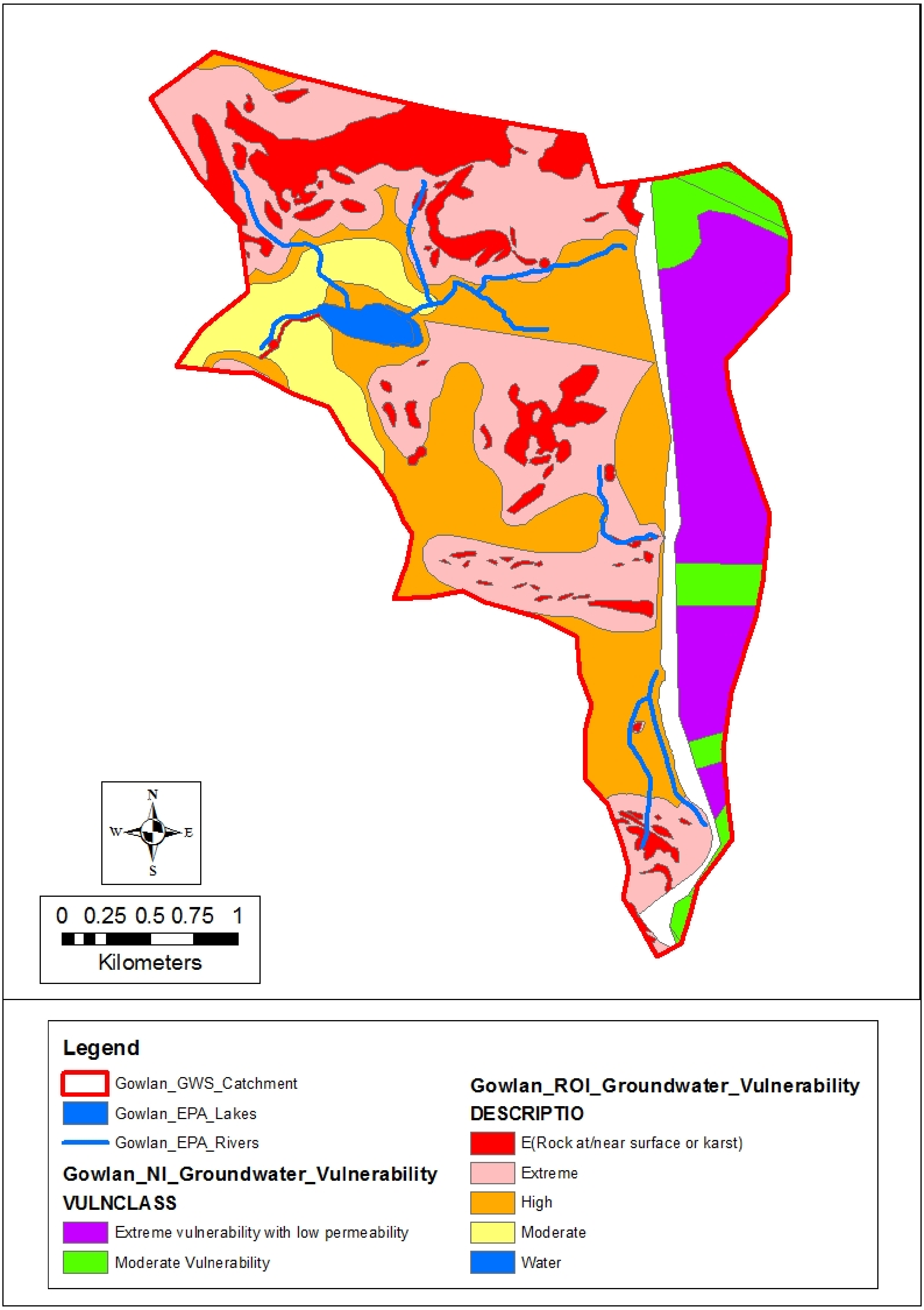

Figure 7: Groundwater vulnerability within the Garvagh Lough/Gowlan GWS catchment.

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. In Northern Ireland, subsoils are known as Superficial Deposits or 'Drift'. The different classifications within the two regions once again results in disparity in the mapping (Figure 8).

The majority of the subsoils/superficial deposits present within the Northern Ireland area of the Garvagh Lough/ Gowlan GWS catchment are derived from peat soils; with some Diamicton Till (a glacial deposit) also present (Figure 8). In the Republic of Ireland, the different classification system results in a more detailed subsoil map in comparison the Northern Ireland area. In the vicinity of Garvagh Lough, a number of subsoil types are present with the dominant type being Till derived from Namurian Shales and Sandstones. Areas of cutover peat subsoils are present surrounding Garvagh Lough and to the east of the lough. A small area of undifferentiated alluvium occurs to the west of Garvagh Lough along the flow path of the outflow stream. Karstified limestone bedrock is present at the surface of the catchment to the north of Garvagh Lough and in small areas to the south. As elevation increases to the south and south east, the subsoils are dominated by blanket peat subsoils interspersed with small areas where the bedrock is at the surface.

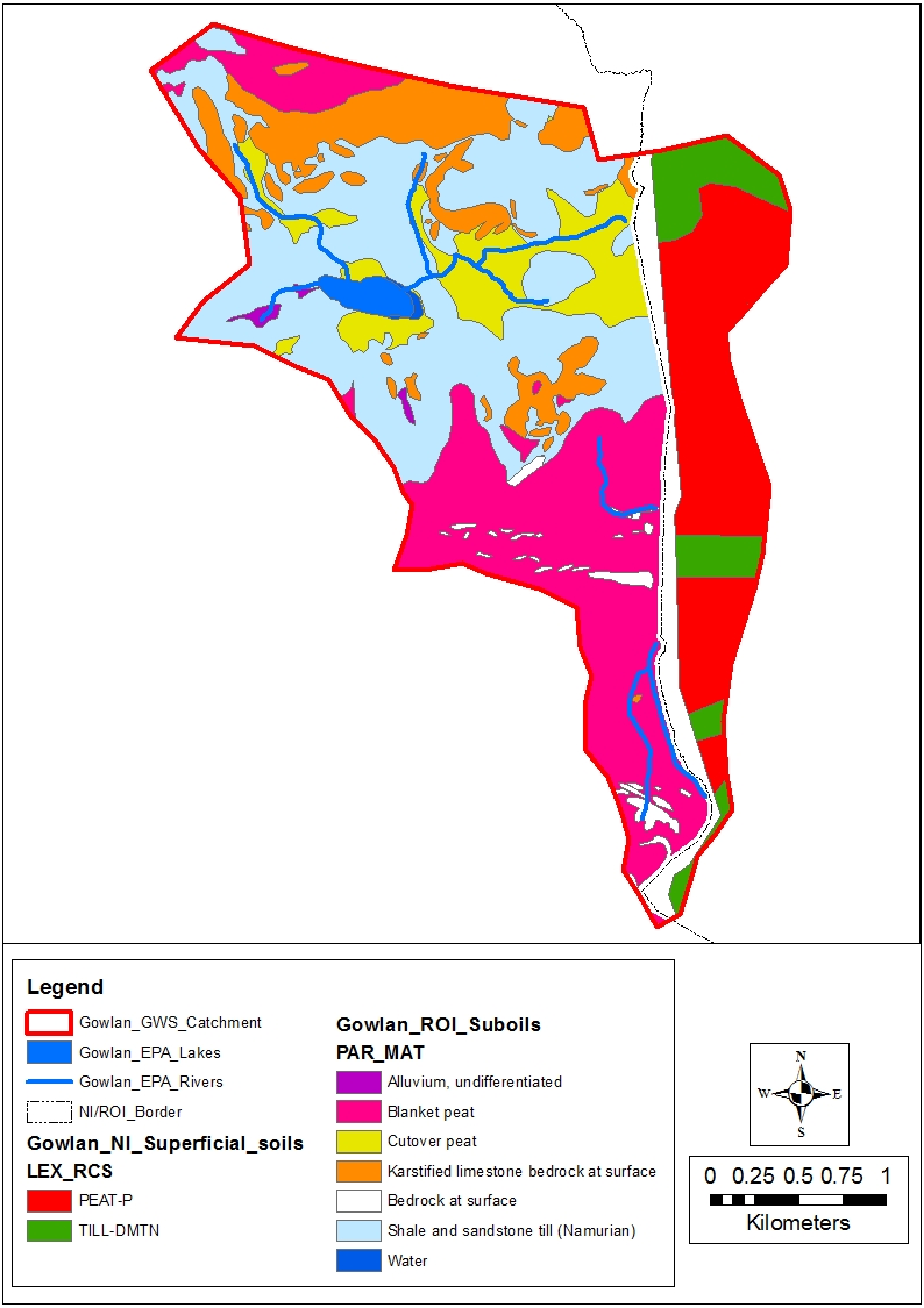

Figure 8: Subsoil (Superficial) deposits within the Garvagh Lough/Gowlan GWS catchment.

4.6 Soils

The differing classification systems present within the Republic of Ireland and Northern Ireland again result in two contrasting soil maps between the two regions (Figure 9). In Northern Ireland, soils in the area to the east of Garvagh Lough are derived from limestone whilst at the higher elevations to the south east of the catchment the soils are derived from peats with a small area of soil derived from Millstone grit at the highest elevation in the catchment. In the Republic of Ireland, the soil map is much more detailed with nine different soil types present and a key to these soil types is presented in Table 2. The majority of the soils within the catchment are poorly drained, with the AminPD category representing shallow gley soils which have impeded drainage and poor physical condition.

Soils derived from cutaway peat and poorly drained mineral soils derived from mainly acidic parent material (AminPD) are located in the vicinity of Garvagh Lough. To the north of the lough, shallow, well drained soils derived from mainly basic (alkaline) parent material occur, along with soils derived from blanket peat. These blanket peat soils dominate the higher elevations to the south and east of the catchment area.

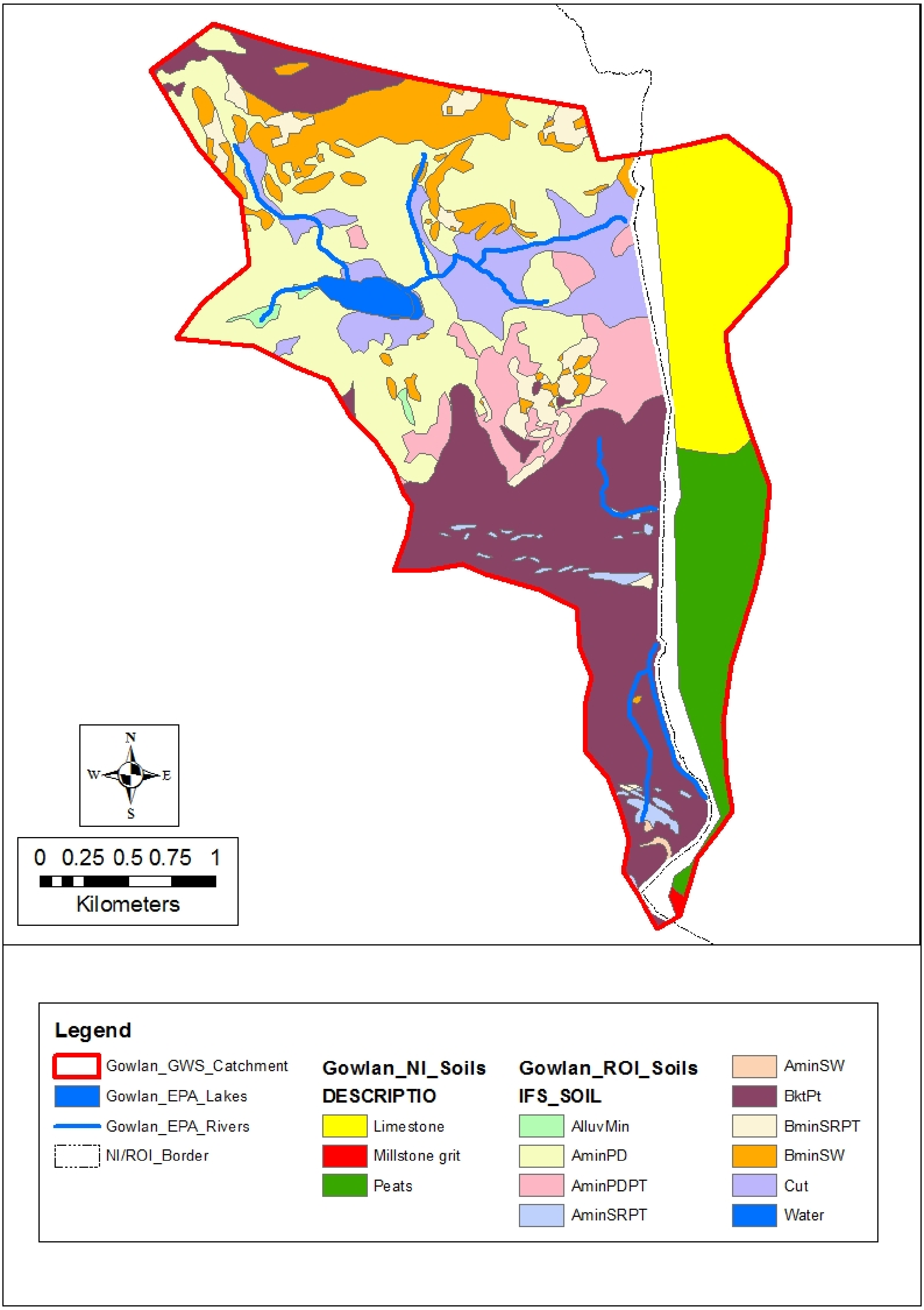

Figure 9: Soil types present within the Garvagh Lough/Gowlan GWS catchment. A key to the soil classifications within the Republic of Ireland is presented in Table 2.

Table 2: A key to the soil classifications in the Republic of Ireland found within the Garvagh Lough/Gowlan GWS catchment (see Figure 9).

Soil Classification	Description	IFS Soil Code
AlluvMIN	Mineral alluvium	51
AminPD	Deep poorly drained mineral soil derived from mainly acidic parent materials	31
AminPDPT	Poorly drained mineral soil with peaty topsoil derived from mainly acidic parent materials	41
AminSRPT	Predominantly shallow mineral soils derived from mainly acidic parent materials with or without a peaty surface horizon	43
AminSW	Shallow well drained mineral soil derived from mainly acidic parent materials	21
BkPt	Blanket Peat	63
BminSRPT	Predominantly shallow mineral soils derived from mainly basic (alkaline) parent materials with or without a peaty surface horizon	46
BminSW	Shallow well drained mineral soils derived from mainly basic (alkaline) parent materials	22
Cut	Cutaway peat	65

4.7 Slope and run-off

The slope of the land leading to a waterbody 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 waterbody and thus can influence the quality of the waterbody. 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 land to the south and southeast of the catchment is particularly steep with a maximum elevation of 600m and dropping approximately 450m to Garvagh Lough within approximately 3.5Km distance (as the crow flies). The blanket bog that occurs in this upland environment in the south and southeast of the catchment has the capacity to retain some volumes of water despite the soils being poorly draining. Landslides have been an issue in this catchment previously and caution must be taken with regard to land management practices to reduce the potential for such events. There are a small number of surface water streams flowing from this part of the catchment and the two streams present in the higher elevations of the catchment are the primary source of water for the Gowlan GWS.

The land to the north of Garvagh Lough is also relatively steep and a forestry plantation is located on this high land (see description in Section 5.2 below). The exact impact of these slopes 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 details below.

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, all other things being equal.

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. Figure 10 shows the CORINE land cover within the Gowlan GWS catchment.

The land cover immediately surrounding Garvagh Lough is classified as being principally occupied by agriculture with areas of natural vegetation. Areas of pasture occur to the northwest of the Lough. Three areas of forestry occur within the catchment, each located on the upper slopes of the hills immediately surrounding the lough. The majority of the catchment is classified as peat bog.

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 forestry 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 run off from planted land. During felling, sediment loss, siltation and nutrient release can also occur. In addition, the exposure of unvegetated 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.

The forestry within this catchment is located at the upper elevations of the hills immediately surrounding Gowlan GWS's secondary water source: Garvagh Lough. The land is relatively steeply sloping (although not as steeply sloping as the land to the south and southeast of the catchment). The three forestries within this catchment are each located on poorly draining peaty or mineral soils which could facilitate the pathway of contaminants entering water bodies that flow to Garvagh Lough.

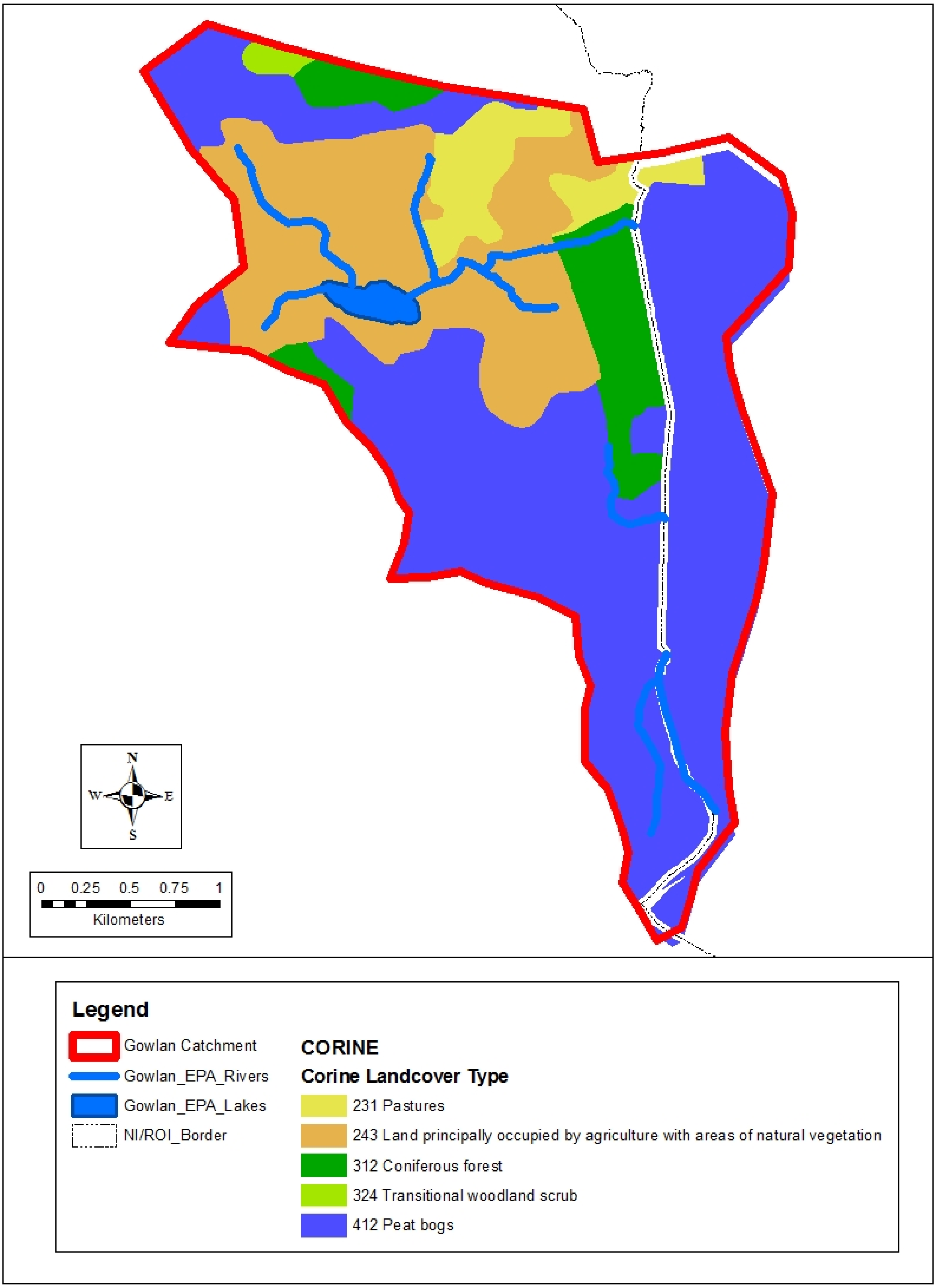

Figure 10: CORINE Land Cover classification within the Garvagh Lough/Gowlan GWS catchment.

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

There are no EPA IPPC licensed facilities within the Garvagh Lough/Gowlan GWS catchment.

5.4 Rural housing and on-site waste water treatment plants

On-site waste water 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 extreme groundwater vulnerability in karst limestone areas (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 the movement of groundwater in the karst conduits can be very rapid), and where soil drainage is poor/subsoil permeabilities are low (i.e. where there is inadequate percolation capacity and effluent backs up and runs overland or is piped to surface water receptors). Much of the area around Garvagh Lough is classified as extreme or high groundwater vulnerability (Figure 7) and soil drainage is poor (Figure 9). The location of dwellings in the Gowlan GWS catchment was estimated by viewing the Ordinance Survey map and aerial photography of the area (Figure 11). Whilst dwellings cannot be differentiated from other buildings, some insight into the location of dwellings and associated on-site waste water treatment plants (usually septic tanks) was gained.

In association with the Geological Survey of Ireland, the EPA have undertaken an assessment of domestic waste water risk, giving a relative ranking that nutrients and bacteria from domestic waste water treatment systems will contaminate surface waters via either surface water or groundwater pathways (EPA, 2013a and b). Domestic waste water risk for the Gowlan GWS catchment is classed as Low risk and a non-sensitive area. This risk ranking is likely due to the low density of domestic waste water treatment systems rather than the pathway elements leading to low contaminant transport risk. The contaminant pathway risk is likely to be high due to the associated poorly drained soils, karst geology and high or extreme groundwater vulnerability in the proximity of Garvagh Lough where the majority of dwellings are located. These risks are particularly high when wastewater treatment systems are not correctly installed or maintained, and the closer the systems are located to surface waters, the greater the risk of contamination. As a result of the karst geology in this region, there is potentially high mobility of contaminants once they are in the groundwater (i.e. they can easily enter groundwater and be dispersed relatively quickly over relatively large distances).

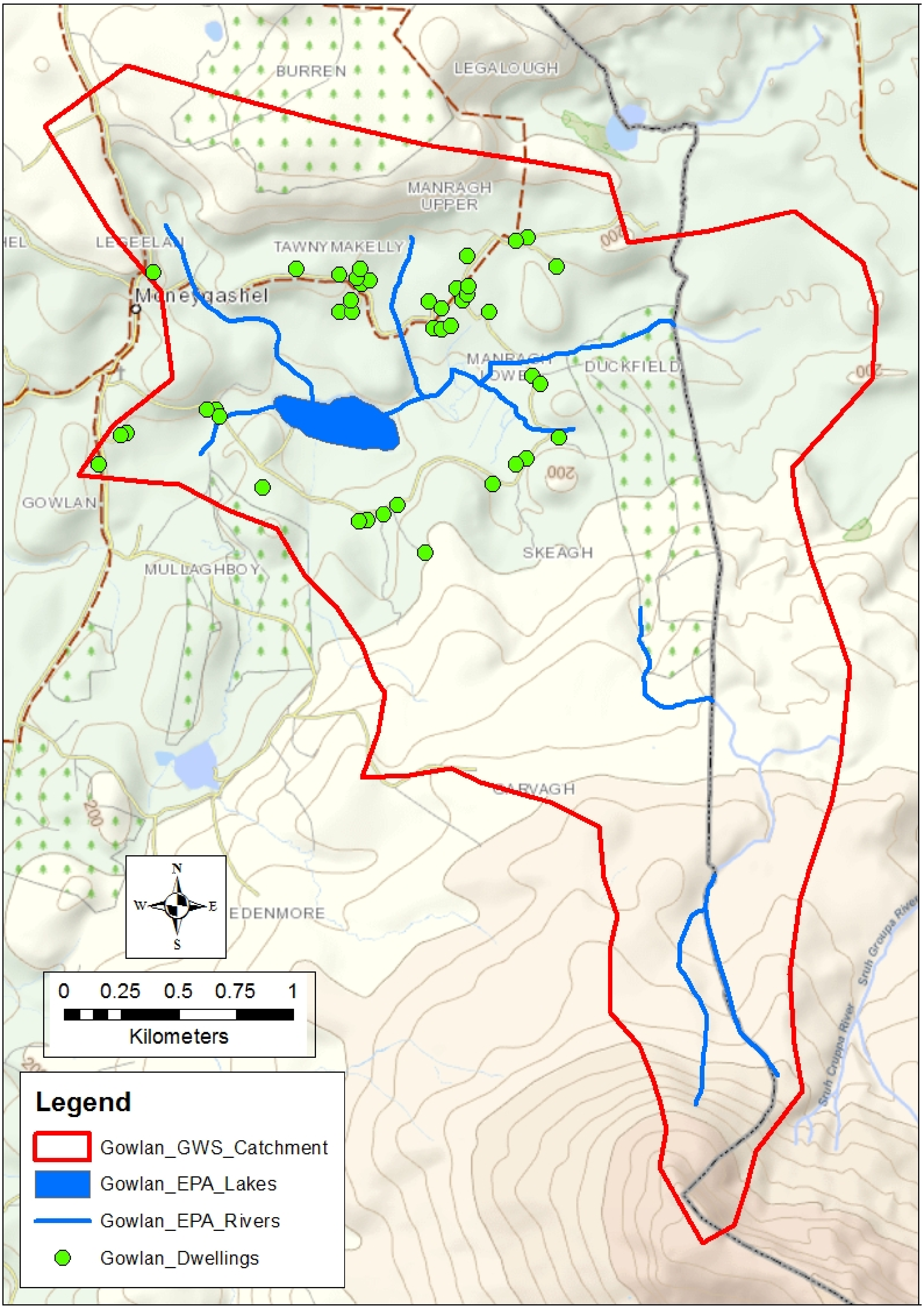

Figure 11: Estimated locations of dwellings (green dots) following examination of Ordinance Survey Map and aerial photography of the Gowlan GWS catchment.

5.5 Overall interpretation of catchment land use

Garvagh Lough is 8.7 ha in area and has a catchment covering approximately 8.78 Km^2 that includes the two mountain streams/springs that are used as Gowlan GWS's primary water source. Water is collected from the streams/springs and gravity fed to the Scheme's reservoir and treatment plant. However during summer and other dry periods, the flows from the streams/springs are frequently not sufficient to consistently provide enough water to the GWS. During these periods water is abstracted from Garvagh Lough and pumped to the Scheme's reservoir and treatment plant.

The primary source springs are located at high elevation in the Cuilcagh Mountains (Figure 3) where the water emerges from the shale and sandstone bedrock aquifer. The point of abstraction lies approximately 150m from the summit of the highest point of elevation within the catchment. Land use surrounding the two streams/springs is blanket bogland which is used for limited upland sheep farming by local land owners. The groundwater vulnerability is classed as extreme (i.e. peat thicknesses are less than 3 m, and frequently bare rock or very thin soils occur). The blanket bog will have some capacity to retain water, but its low permeability promotes overland flow rather than infiltration into the soil following rainfall. As the abstraction point is close to the source of the streams/springs, and given the surrounding land use, the likelihood of contamination of these water sources by pollutants is low. However contamination is possible through direct access to the water sources by sheep, with faecal contamination a possibility along with the potential for a sheep carcass to be present at or close to the abstraction point. Any contamination of shallow groundwater in the catchments to the springs also will reach the springs. The lack of fencing facilitates the open access to these two abstraction points, although some effort has been made to protect the westerly stream/spring with the provision of a concrete cover. However this cover is rudimentary and in need of upgrading. Further recommendations regarding remedial works to protect both the flows and water quality of the two primary sources of abstraction are made in Section 7.0.

The blanket bogs present within the catchment are unlikely to impact adversely on water quality provided they are not being overgrazed or exploited for peat. With often limited vegetation cover surrounding the cutaway areas, there is the potential for peat/soil sediment to enter watercourses. Old peat cuttings were observed on the lower slopes of the mountain in the south of the catchment, but these were limited in size and much of the extraction appeared to be finished.

Bog slides have previously occurred within the upper reaches of the catchment and can result in large volumes of sediments entering water bodies. Management actions should aim to stabilise areas of high risk of bog slides to reduce the potential impact on the local water courses. An online landslide viewer available through the Geological Survey of Ireland (http://spatial.dcenr.gov.ie/GeologicalSurvey/LandslidesViewer/index.html) identifies two undated landslides that occurred close to the locations of the upland streams/springs and may potentially have impacted on surface water quality.

As elevation lowers from the primary source to the secondary source at Garvagh Lough, the blanket bog gives way to more productive sheep and cattle grazing pasture land along with some limited areas of forestry. The soils are typically poorly drained with peats and peaty gleys present. The poor infiltration properties of these soils also promote overland flow; however the underlying geology changes from the shale and sandstone of the higher elevation areas to limestone in the areas surrounding Garvagh Lough. The karstified nature of this limestone provides pathways for the fast flow of groundwater, and also the hydrological linkage of surface water and groundwater. This is evident in the springs, swallow holes and disappearing streams found within the catchment. Groundwater vulnerability is generally classed as extreme or high in the areas surrounding Garvagh Lough, with some karstic areas classified at the highest vulnerability rating of X (extreme, karst or rock close to surface) to the north and southeast of the Lough. There is also an area of moderate groundwater vulnerability to the north and west of Garvagh Lough.

The combination of extreme and high groundwater vulnerability and the karstic environment surrounding Garvagh Lough means that there is likely to be a high connectivity between surface waters and groundwaters resulting in an increased likelihood of contaminants being delivered via the subsurface to Garvagh Lough. The likelihood of the Lough being both surface water fed through stream inflows and overland runoff and being groundwater (spring) fed is high given the surrounding geology.

The land use immediately surrounding Garvagh Lough is agricultural pasture, used for sheep and cattle grazing. A site visit was undertaken on Wednesday 8th January and upon entrance to the Garvagh Lough complex, a herd of cattle were present standing around a feeder. The land within this field was heavily poached from the hillside to the Lough edge, likely facilitating the delivery of nutrients and faecal contaminants down the slope and into the Lough. The Lough was also unfenced in places allowing livestock access to the Lough, again facilitating the delivery of nutrients and faecal contamination to the Lough waters close to the GWS abstraction point. This has consequences for both nutrients entering the Lough and health risks due to microbiological contaminants such as *E. coli* and *Cryptosporidium* spp. In the past, *Cryptosporidium* outbreaks in water supplies have been related to animal defecation, particularly from calves. A *Cryptosporidium* Risk Screening Report (Jennings O'Donovan, 2008) found that the mountain streams/springs and Garvagh Lough were classed in the High and Medium risk categories respectively, with recommendations that a more detailed study of farming practices should be undertaken. Further discussion of recommendations with regards to microbial contamination risk is provided in Section 7.0.

The presence of forestry on the hill crests immediately surrounding Garvagh Lough has the potential to deliver contaminants, in particular phosphorus and sediment, to the Lough at certain points of the forestry management cycle (particularly planting/fertilising and harvesting). These forests should be carefully managed to reduce the potential impact of sediment and nutrients on the Lough.

The small number of private dwellings located within close proximity to Garvagh Lough, which are all serviced by on-site waste water systems, would normally not be expected to provide large pressures on the water body. However due to the poor soil drainage, the karstic environment, the high vulnerability of the groundwater to contaminants and the hydrological linkages between the lough and the surrounding surface waters and groundwaters, there is potential for contaminants to swiftly enter Garvagh Lough via overland and underground water flows. Septic tanks can cause pollution if not correctly installed, sited and maintained. Inspecting high risk tanks will be discussed as a remediation measure later in Section 7.0.

6.0 Raw Water Quality

6.1 Lake 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 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).

Monthly monitoring of colour has been undertaken on behalf of Gowlan GWS by EPS since May 2006 and the results are presented in Figure 12. Values ranged from less than 5 PtCo (the minimum colour value recorded by EPS and shown in the graph as a zero value due to limitations in graphing a value of "<5 PtCo.") to a maximum value of 177 PtCo, with an average value of 37 PtCo for the period May 2006 to September 2013. Although there is variation within the dataset, highest colour values were typically observed in summer when flows from the primary stream/spring source are frequently not sufficient to maintain demand. During such periods, water from the secondary lake source is used to supplement or replace flows from the primary source. High colour values tend to be accompanied by high rainfall events that followed drier periods.

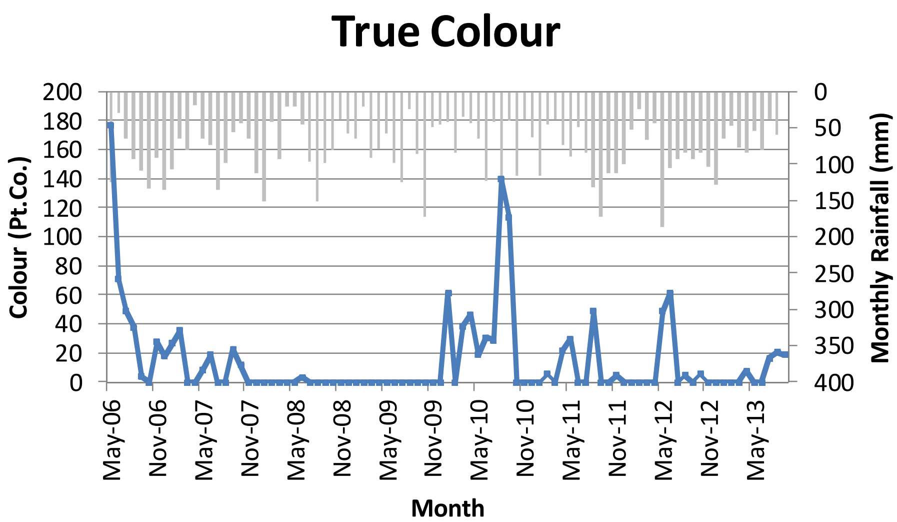

Figure 12: Raw water true colour (primary axis) from May 2006 until September 2013. Monthly rainfall figures compiled from Clones (May 2006-March 2008), Armagh (April 2008-November 2010) and Ballyhaise (November 2010 to September 2013) weather stations are presented on the secondary y-axis.

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 Nephalometric Turbidity Units (NTU). Each of these units can be interpreted to mean the same thing.

The results for the monthly turbidity values are presented in Figure 13. Values ranged from a minimum of less than 0.5 NTU (the minimum value recorded by EPS) to a maximum of 40 NTU with an average value of 2.25 NTU from March 2006 until September 2013. The maximum value of 40 NTU occurred in May 2009 and is the only occasion when turbidity exceeded the next highest value of 7 NTU. There are no obvious reasons outlined in the EPS monitoring report for May 2009 that may explain this large one-off spike in turbidity levels in the raw water supply.

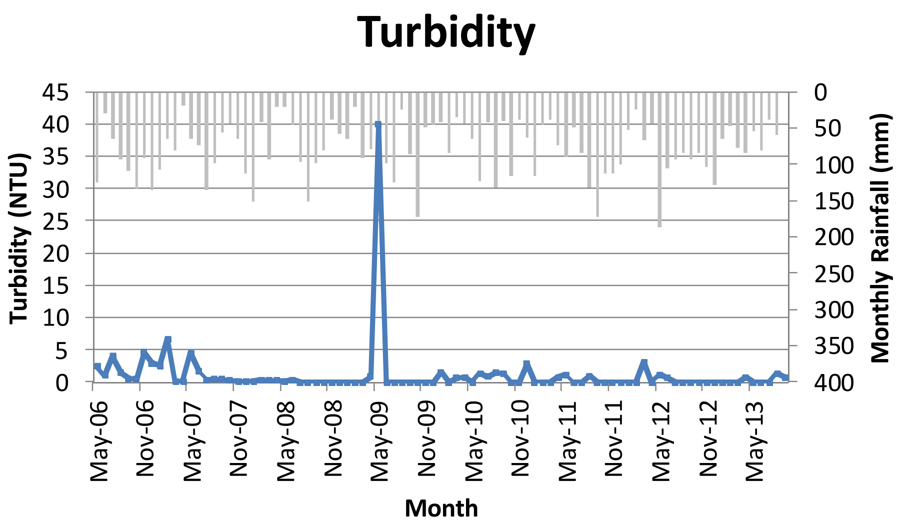

Figure 13: Raw water turbidity levels (primary axis) from May 2006 until September 2013. Monthly rainfall figures compiled from Clones (May 2006-March 2008), Armagh (April 2008-November 2010) and Ballyhaise (November 2010 to September 2013) weather stations are presented on the secondary y-axis.

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 0.2 mg/L.

Results for iron concentration in raw water (Figure 14) ranged from between 0.004mg/L Fe and 0.75 mg/L Fe, with an average of 0.14 mg/L Fe between May 2006 and September 2013. Although this average value falls below the recommended concentration of 0.2 mg/L Fe in class A1 waters (Surface Water Regulations (1989)), this recommended concentration is exceeded on 12 times between 2006 and 2012. There is little correlation between iron concentrations in the raw water and monthly rainfall.

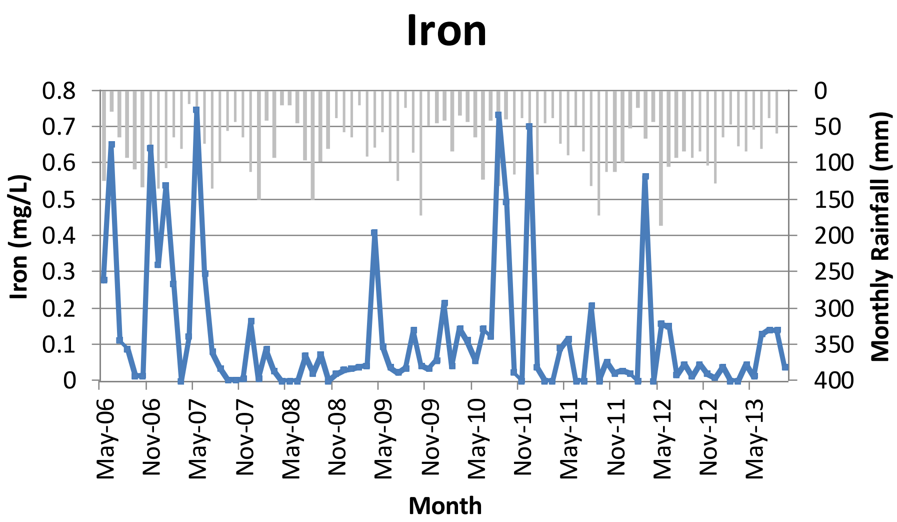

Figure 14: Raw water iron levels (primary axis) from May 2006 until September 2013. Monthly rainfall figures compiled from Clones (May 2006-March 2008), Armagh (April 2008-November 2010) and Ballyhaise (November 2010 to September 2013) weather stations are presented on the secondary y-axis.

6.1.4 Manganese

Manganese is found in soils and groundwaters 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 0.05 mg/L.

Raw water manganese concentrations (Figure 15) ranged from 0.001 mg/L Mn to 0.45 mg/L Mn with an average value of 0.02 mg/L Mn for the period May 2006 to September 2013. However a value of <0.005 mg/L (“<5 µg/L” Mn as recorded in the EPS reports) was recorded on many occasions, particularly between August 2008 and December 2009. This value is presented as a zero value in Figure 15 as it cannot be accurately graphed. The value of “<5 µg/L” Mn is presumably the limit of detection for the analysis at that time, although this is not clarified in any EPS reports.

The recommended concentration of manganese in Class A1 waters (0.05 mg/L) was exceeded in August and December 2010 and March 2012. These high manganese values tend to occur after periods of dry weather.

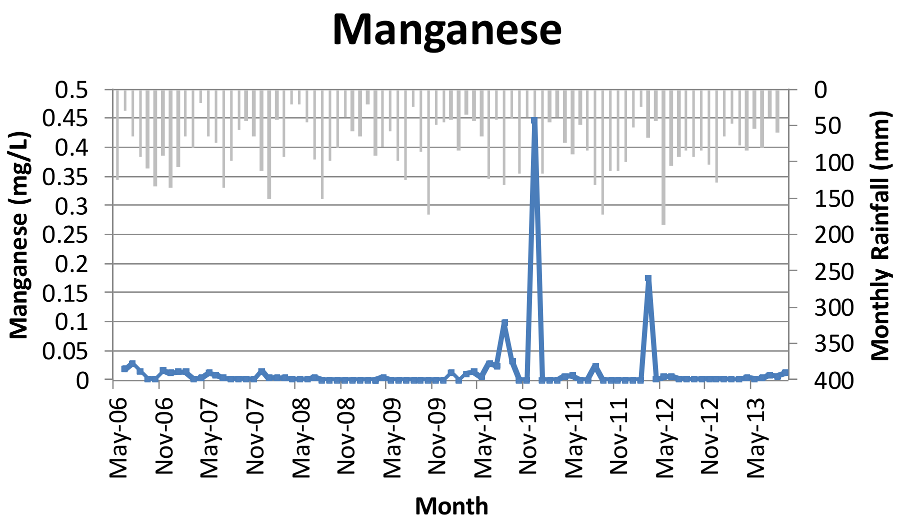

Figure 15: Raw water manganese levels (primary axis) from May 2006 until September 2013. Monthly rainfall figures compiled from Clones (May 2006-March 2008), Armagh (April 2008-November 2010) and Ballyhaise (November 2010 to September 2013) weather stations are presented on the secondary y-axis.

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.

pH ranged from a minimum of 5.40 in December 2006 to a maximum of 8.48 in March 2012. The average value for the period May 2006 to September 2013 was 6.94. The pH was outside of the recommended range (Surface Water Regulations (1989)) on one occasion in March 2012, but only by 0.02 of a pH unit. pH is generally a reflection of catchment geology, and the lower pH values recorded are typically when the source water was extracted from the mountain streams/springs which are located in a blanket bog (acidic) environment. The secondary lake source is situated in a high pH limestone/karst environment and as such, when water was extracted from Garvagh Lough, the pH values of the raw water were higher.

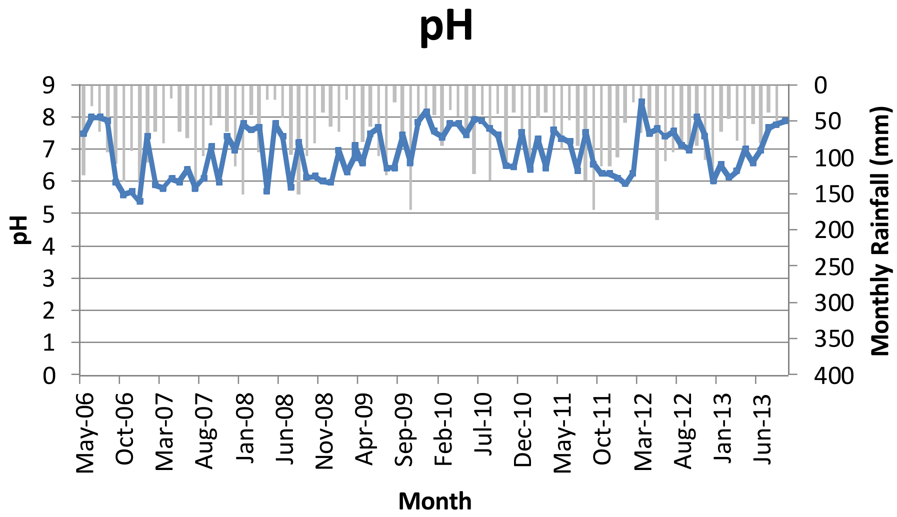

Figure 16: Raw water pH levels (primary axis) from May 2006 until September 2013. Monthly rainfall figures compiled from Clones (May 2006-March 2008), Armagh (April 2008-November 2010) and Ballyhaise (November 2010 to September 2013) weather stations are presented on the secondary y-axis.

6.1.6 Alkalinity

Alkalinity is a measure of a 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 has not been monitored within the Gowlan GWS catchment.

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 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 waste water 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 scums 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 has not been monitored within the Gowlan GWS catchment.

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.

Garvagh Lough was sampled by the EPA on one occasion in 2005 and a Chlorophyll *a* value of 4.0 mg/L was observed. This classified the Lough as Oligotrophic (relatively unproductive lakes with limited nutrient availability) (Clabby *et al.*, 2008).

Algae numbers (recorded as counts of cells per ml) were rarely monitored by EPS between 2006 and 2011 but have been monitored on a monthly basis from 2011 to present (Figure 17). Counts ranged from a maximum of 978 in September 2013 to a minimum of zero (recorded on a number of occasions). The average count for the period May 2006 to September 2013 was 89 cells/ml. The numbers of algae present were low from October 2011 until April 2013 after which point algal counts were typically well above 100 cells/ml except for June 2013.

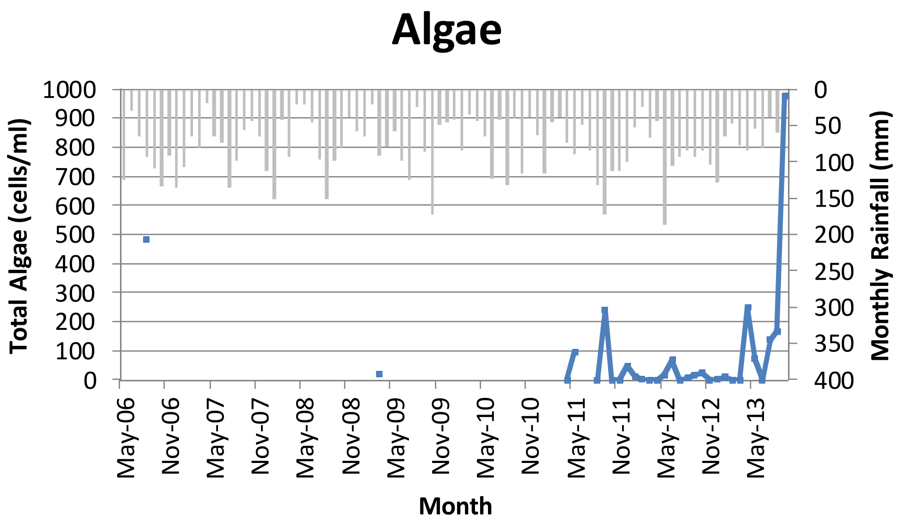

Figure 17: Raw water algal counts (primary axis) from May 2006 until September 2013. Monthly rainfall figures compiled from Clones (May 2006-March 2008), Armagh (April 2008-November 2010) and Ballyhaise (November 2010 to September 2013) weather stations are presented on the secondary y-axis.

In September 2013, the highest value of algal counts was recorded, with numbers being dominated by blue-green algae (representing 96% of the count). Blue-green algae, also known as Cyanobacteria, can be indicators of nutrient enrichment (see Eutrophication and Trophic Status Note, above) and can reproduce quickly in favourable conditions where there is still or slow-flowing water, abundant sunlight and sufficient levels of nitrogen and phosphorus. Algal blooms can occur when suitable conditions persist for several days. The summer of 2013 was notably dry and sunny in comparison to previous years and these conditions would have been favourable for blue-green algae to dominate in Garvagh Lough. The Lough was being used as a water source on the raw water sampling date in September due to insufficient flow from the primary water source as a result of the dry weather experienced during summer 2013. Algal blooms can cause deterioration in water quality (particularly decaying algae can reduce dissolved oxygen in the water) which can impact on fish and other faunal populations in the water body. Toxins can also be produced as a result of blue-green algal blooms which can negatively impact on human health.

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.

Transparency has not been monitored within the Gowlan GWS catchment.

6.1.10 Nitrogen

Nitrogen, 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)

TON is the sum of nitrite and nitrate which were both monitored individually by EPS. Therefore the values for nitrate and nitrite have been combined to show the TON (Figure 18), although nitrite only contributes a very small proportion to the TON value. For the majority of monitoring occasions (67 months out of a total 90 monitored), values were reported as being below what is presumed to be the limit of detection (no limits of detection are stated in the EPS reports). This presumed limit of detection is reported by EPS as a 'less than' value, for example '<8.7 mg/L'. The "less than" values varied for both nitrate and nitrite, ranging between <0.09 mg/L, <8.7mg/L and <8.9mg/L for nitrate and <0.003mg/L, <0.016mg/L, and <0.07mg/L for nitrite. The values of <8.7mg/L and <8.9mg/L are exceptionally high values for limits of detection for nitrate and the validity of these results must be questioned. As a consequence, the interpretation of these TON data is difficult and may not represent the true picture of nitrate concentrations within the Gowlan GWS catchment.

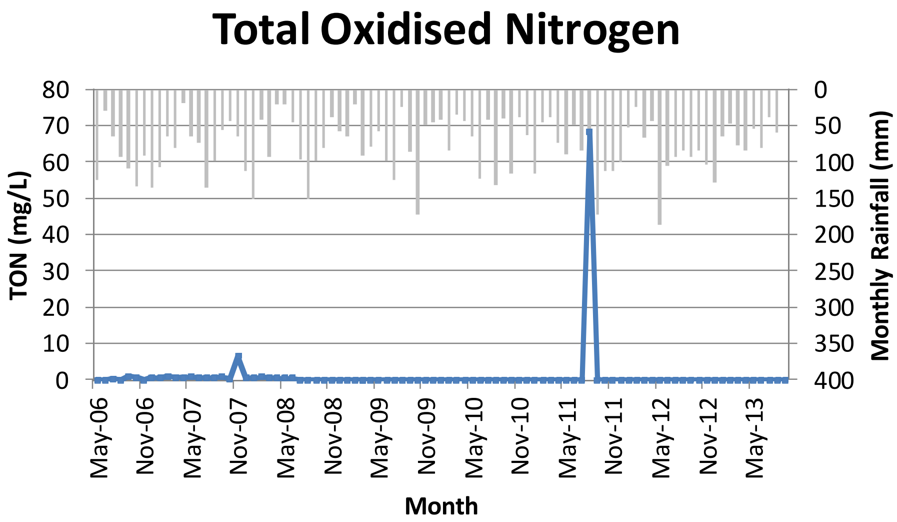

Figure 18: Raw water Total Oxidised Nitrogen (nitrate and nitrite values combined: primary axis) from May 2006 until September 2013. Monthly rainfall figures compiled from Clones (May 2006-March 2008), Armagh (April 2008-November 2010) and Ballyhaise (November 2010 to September 2013) weather stations are presented on the secondary y-axis.

Where values of TON were recorded above the presumed limit of detection, values ranged from a minimum of 0.383mg/L to a maximum of 68.65mg/L. The average value was 3.97mg/L, but this average is heavily influenced by the exceptionally high maximum value which was recorded in August 2011. If this large outlier is removed from the dataset, the recalculated average value is 0.98 mg/L. The Surface Water Regulations (1989) state a limit of 50 mg/L nitrate (as N) for Class A1 waters. As TON comprises mainly of nitrate, given the data provided, this limit was only breached on the one occasion in August 2011. This August 2011 value of 68.65mg/L is comprised of 68.35mg/L Nitrate and 0.3mg/L Nitrate and is therefore in breach of the Drinking Water Regulations (2007).

Ammonia/Ammonium

The Surface Water Regulations (1989) recommend a limit value of 0.155 mg/L (as N) for A1 waters. This was exceeded on three occasions during the period May 2006 to September 2013: in April and May 2009 and May 2010 (0.15, 0.22, and 0.18 mg/L as N respectively). For the vast majority of the sampling occasions, ammonium levels were below the detection limit specified by EPS.

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 values ranged between 32 µS/cm and 275 µS/cm, with an average value of 78 between May 2006 and September 2013. On no occasion did the conductivity value exceed the recommended value for Class A1 waters as set out in the Surface Water Regulations (1989).

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 within the Gowlan GWS catchment.

6.1.13 Biological Oxygen Demand (BOD)

Unpolluted water is typically saturated with dissolved oxygen, but when organic pollution enters a waterbody, 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) requires the value for BOD in Class A1 Waters to be 5mg/L O_2.

BOD has not been monitored within the Gowlan GWS catchment.

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 waterbody 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 coliform values above 0 numbers per 100ml are unacceptable.

E. coli

Escherichia coli bacteria are present in high numbers in human and animal (including bird) faeces. They are not found in waters in the absence of faecal pollution and it would be rare to find surface waters that do not contain faecal coliforms. Groundwaters are significantly less susceptible to faecal coliform contamination than surface waters, and frequently do not contain bacteria. *E. coli* was present in the raw water on a large number of occasions between May 2006 and September 2013 (Figure 19), with particularly high values (a range of 122.3 – 307.6 counts per 100 ml) in May 2007 and June, August and October 2012. The streams/springs were the sole source of water for the scheme in August and October 2012. Maximum values were recorded in August 2012, but since November 2012, values have remained low. On no occasions were the Surface Water Regulations (1989) values for faecal coliforms exceeded for Class A1 waters. Following treatment, on no occasions did the treated water exceed the Drinking Water Regulations (2014) value of 0 counts per 100 ml.

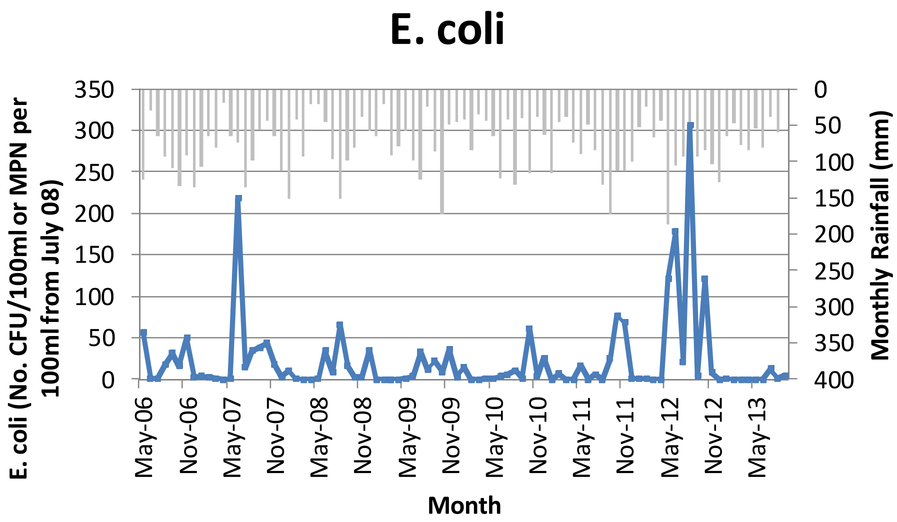

Figure 19: Raw water *E. coli* counts (primary axis) from May 2006 until September 2013. Monthly rainfall figures compiled from Clones (May 2006-March 2008), Armagh (April 2008-November 2010) and Ballyhaise (November 2010 to September 2013) weather stations are presented on the secondary y-axis.

Clostridium perfringens

Clostridium perfringens exists as part of the natural bacterial intestinal flora of humans and therefore serves as an indicator of faecal pollution. *C. perfringens* was detected in the raw water on a number of occasions between May 2006 and September 2013, with maximum levels of 45 CFU/100 ml occurring in December 2010 (Figure 20).

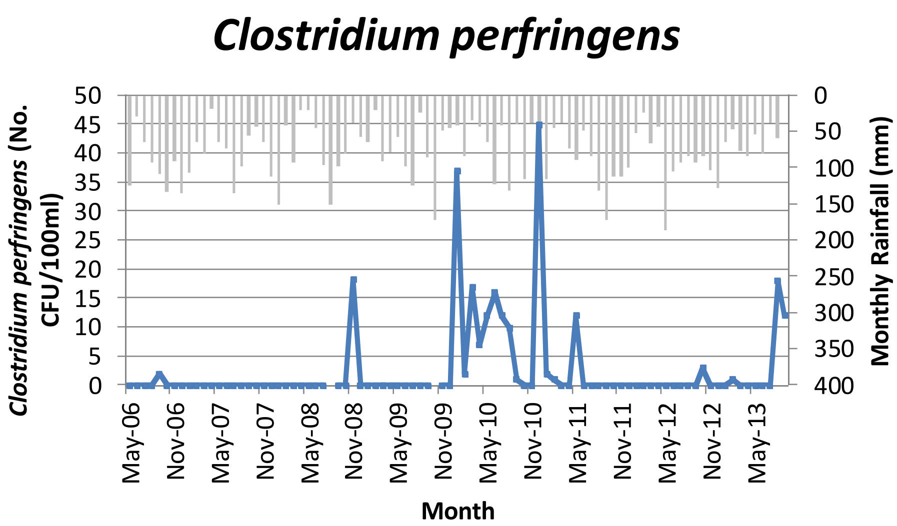

Figure 20: Raw water *Clostridium perfringens* counts (primary axis) from May 2006 until September 2013. Monthly rainfall figures compiled from Clones (May 2006-March 2008), Armagh (April 2008-November 2010) and Ballyhaise (November 2010 to September 2013) weather stations are presented on the secondary y-axis.

Total Coliforms
The Surface Water Regulations (1989) recommend that Class A1 waters should not exceed 5,000 total coliforms per 100 ml. This value was not exceeded in the Gowlan raw water between May 2006 and September 2013, although high values over 2,000 total coliforms per 100 ml were observed in May 2011 and June 2012 (Figure 21). On no occasions were the Surface Water Regulations (1989) values for total coliforms exceeded for Class A1 waters.

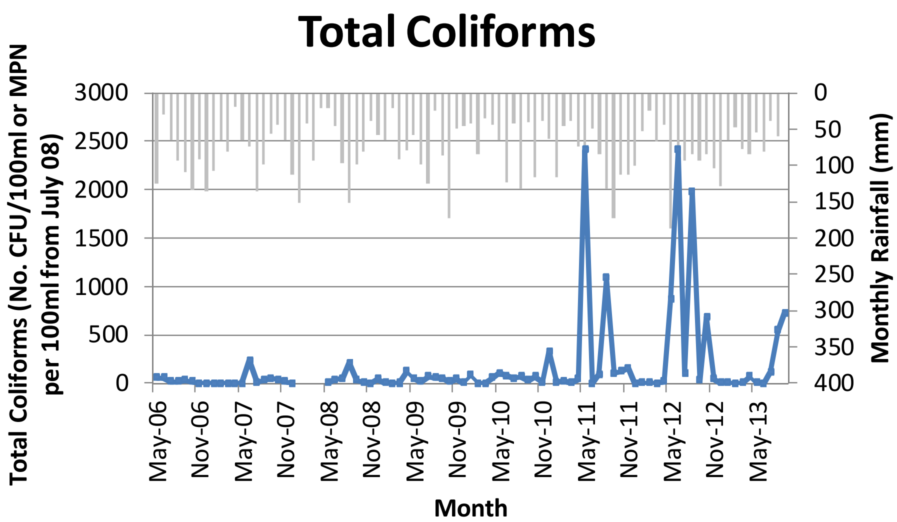

Figure 21: Raw water Total Coliform counts (primary axis) from May 2006 until September 2013. Monthly rainfall figures compiled from Clones (May 2006-March 2008), Armagh (April 2008-November 2010) and Ballyhaise (November 2010 to September 2013) weather stations are presented on the secondary y-axis.

6.2 EPA River and Stream Water Quality Monitoring

No EPA river and stream water quality monitoring has been undertaken within the Gowlan GWS catchment (although stream waters were monitored within the catchment through the Tellus Border Project: See Section 6.3). A brief description of Q-values assessed by the EPA has been included for reference and interpretation of any future monitoring data if undertaken within the catchment.

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.

No EPA Q-value monitoring has been undertaken within the Gowlan GWS catchment.

6.2.2 Chemical data

No EPA hydrochemical monitoring has been undertaken within the Gowlan GWS catchment.

6.3 Tellus Border Soil Geochemistry and Water Chemistry

The Tellus Border Project (www.tellusborder.eu) was an Interreg IVA-funded regional mapping project collecting geo-environmental data on soils, water and rocks across the six border counties of the Republic of Ireland that ran from 2011 until December 2013. As well as using an aircraft to collect information on the physical properties of soils and rocks, the project took approximately 3,500 soil and stream water samples and analysed their chemistry. Data collected by the Tellus Border project is freely available from their website. Figure 22 shows the Tellus Border soil and stream water sample locations within the Gowlan GWS catchment. Soil geochemistry sample location 1, 2 and 3 are within close proximity to Garvagh Lough. Soil geochemistry sample location 4 is on the south-eastern edge of the catchment, but these soils have the potential to influence the mountain stream/spring primary water source of the GWS. The only stream water and stream sediment sample location exists close to where the inflow stream enters Garvagh Lough and will give an indication of the water quality entering the Lough at the point in time from which the sample was taken. However, only the stream waters results are presented here.

Rather than showing a large number of figures depicting the variation of a number of parameters between Tellus Border Sample locations, Table 3 shows the data for a number of key parameters of relevance to source protection compared between each sample location. These values are then compared against ranges and average values across the whole of the six county sampling area of the Tellus Border project.

It is important to note that these Tellus Border values are one-off spot measurements and therefore it is difficult to draw specific conclusions without being able to examine a number of sampling events, particularly for stream water chemistry, to view the range of a certain parameter over the course of time.

6.3.1 Soil Geochemistry

Soil pH throughout the Gowlan GWS catchment is lower than the Tellus Border average pH value, although it is lowest at sample locations three and four, likely reflecting the acidic bogland habitat that these samples were taken from (Table 3). This is also reflected in the high loss on ignition values (a surrogate for carbon content) in samples 3 and, in particular, 4. In general, values within the catchment for the majority of parameters listed in Table 3 are lower than the Tellus Border average value for each parameter. A relatively high value for arsenic was observed at sample location four and there is potential for this to enter the primary source water. However, although higher than the average Tellus Border value for arsenic, the value at location four is below levels of concern.

6.3.2 Stream Waters

For the majority of parameters listed in Table 4, values within the stream flowing into Garvagh Lough are below levels of concern. Given the low intensity agriculture within the catchment, levels of nitrate may be higher than expected. However this may be an indication of groundwater contribution to the catchment rather than an indication of diffuse or point source pollution. The higher than average Calcium and Iron levels are likely a result of the underlying geology within this area of the catchment and may also be an indication of groundwater input into the water body. The values for Phosphorus and Potassium are also low, indicating the low intensity agriculture within the catchment.

The parameters Chloride, Sulphate, Phosphate and Nitrate can be indicators of point source pollution from septic tanks. However the values from these one-off Tellus Border spot measurements do not promote concern over septic tank contamination of this water body. Sampling over a period of time, for example one year, would lead to a greater understanding of the potential contribution of wastewater treatment plants to contaminate this water body.

Arsenic and Lead values are well below levels of concern.

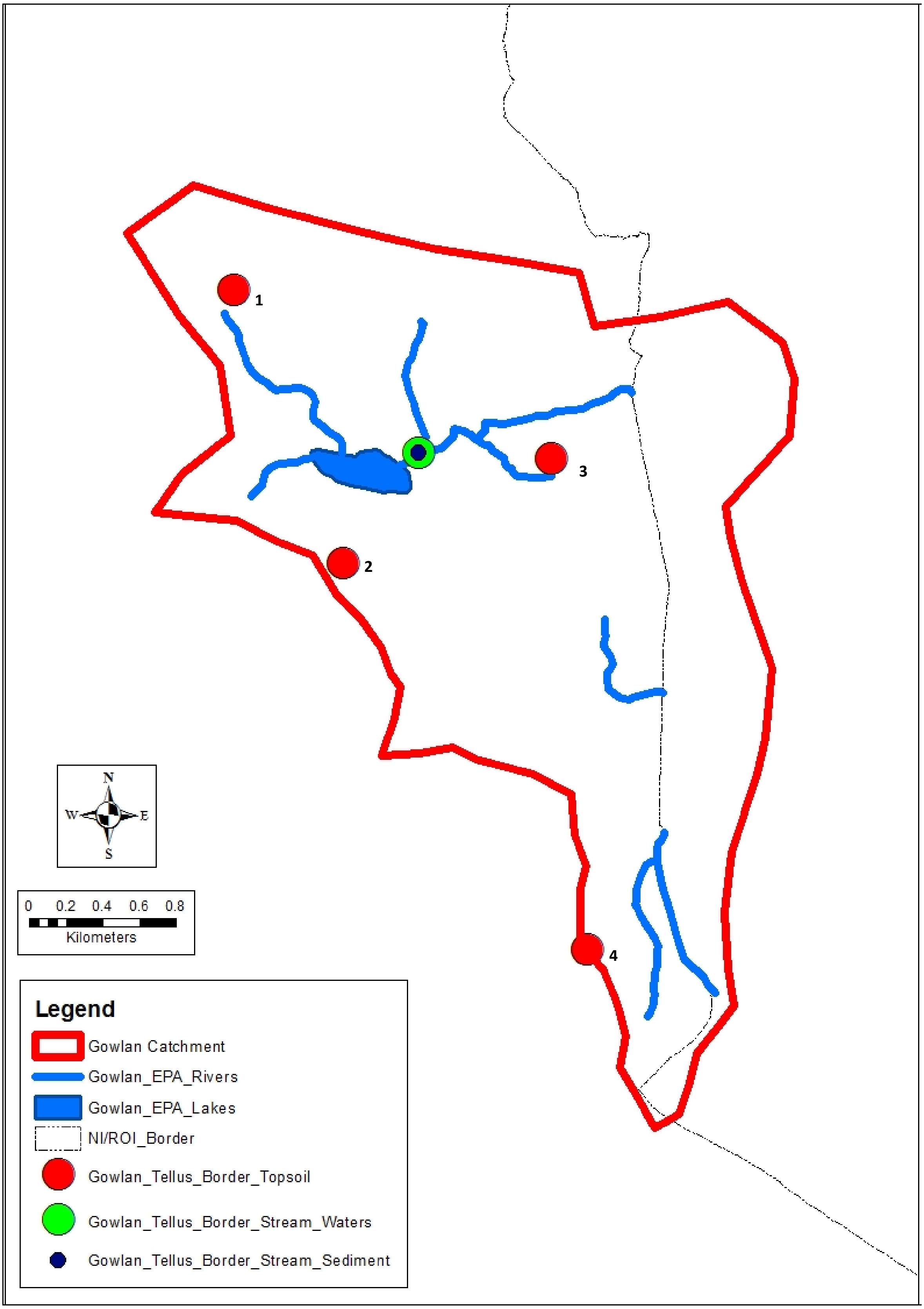

Figure 22: Tellus Border Soil, Stream Water and Stream Sediment sample locations within the Gowlan GWS catchment.

Table 3: Tellus border soil geochemistry parameters across four of sampling locations within the Gowlan GWS catchment (Figure 22). Range values and average values are calculated from the entire Tellus Border dataset.

Sample Location Number (Figure 22)	pH	Loss on Ignition (%)	Aluminium (%)	Calcium (%)	Copper (mg/Kg)	Iron (%)	Manganese (mg/Kg)	Phosphorus (mg/Kg)	Arsenic (mg/Kg)	Mercury (mg/Kg)
Soil Geochemistry										
1	4.02	15.5	1.3	0.2	3.16	0.8	73.8	540	1.1	0.07
2	4.11	14.5	0.7	0.17	16.03	0.77	123.6	580	2.1	0.06
3	3.88	35.5	0.43	0.2	7.31	1.03	85.4	530	4.8	0.13
4	3.61	71	0.51	0.2	13.8	8.59	55.5	850	29.8	0.34
Tellus Border Range Values (Min-Max)	2.55 - 7.78	0.63 - 98.5	0.005 - 3.62	0.005 - 15	0.25 - 413.14	0.05 - 15	1 - 8351.5	25 - 3850	0.5 - 960.8	0.005 - 1.66
Tellus Border Average Value	4.51	35.11	1.06	0.46	22.66	1.94	461.7	805.40	6.50	0.10

Table 4: Tellus border stream water parameters across four of sampling locations within the Gowlan GWS catchment (Figure 22). Range of values and average values are calculated from the entire Tellus Border dataset.

	pH	Conductivity (µS/cm)	Chloride (mg/L)	Sulphate (mg/L)	Nitrate as NO_3 (mg/L)	Nitrite as NO_2 (mg/L)	Phosphate (mg/L)	Aluminium (µg/L)	Phosphorus (mg/L)	Potassium (mg/L)	Calcium (mg/L)	Manganese (µg/L)	Iron (µg/L)	Arsenic (µg/L)	Lead (µg/L)
Stream Water Sample Location	**7.68**	**255**	**11.98**	**2.83**	**1.41**	**0.02**	**0.05**	**39**	**0.016**	**0.715**	**56.77**	**45.81**	**619.3**	**0.32**	**0.07**
Tellus Border Range Values (Min-Max)	**4.07 - 11.75**	**2 – 39,000**	**0.176 - 12,600**	**0.05 - 1662**	**0.025 - 86.43**	**0.005 - 5.042**	**0.05 - 5.29**	**0.5 - 734.4**	**0.005 - 2.04**	**0.01 - 250.39**	**0.15 - 306.03**	**0.1 - 5647.92**	**0.5 - 20234.9**	**0.02 - 8.38**	**0.0005 – 3.72**
Tellus Border Average Value	**7.29**	**219**	**28.77**	**9.71**	**2.31**	**0.02**	**0.07**	**57.16**	**0.03**	**1.74**	**30.82**	**85.57**	**575.67**	**0.44**	**0.12**

6.4 Overall Interpretation of Water Quality

Although a good range of raw water parameters are monitored on a monthly basis, there are a number of important parameters that have not been monitored within the Gowlan GWS catchment that would allow for greater insights into required catchment management and source protection. In particular, the availability of total phosphorus data would allow greater interpretation of the effects of surrounding land use and provide linkages with the algal data available (particularly with regards to the blue-green algal bloom observed in September 2013). The availability of macroinvertebrate data and/or Q-value data would provide an indication on the quality status of the water body with regard to the Water Framework Directive.

Colour values in the raw water varied greatly, with higher values typical during summer months. High colour values may be representative of the peaty and iron-rich soils that are typical of the catchment, and may be influenced by the location of the secondary source inflow pipe being located on the bottom of Garvagh Lough with the potential of collecting sediment in the raw water intake. If colour values are high then it is likely that following treatment, values for trihalomethanes (THMs) will also be high. Trihalomethanes are expensive to monitor and they are not included in the EPS reports.

Iron values frequently exceeded the Surface Water Regulations (1989) recommended values for Class A1 waters, and this is a likely reflection of the iron present in the underlying rocks and soil, particularly in the higher elevation areas of the catchment (as shown in the Tellus Border Soil samples), but also may be indicative of potential groundwater input into both Gowlan Lough and its surface water inflows (as indicated by the Tellus Border Stream Water sample).

Manganese values are typically low in the Tellus Border sampling locations and this is reflected in the few occasions that the Surface Water Regulations (1989) recommended value was breached. Therefore the levels of manganese within the catchment are unlikely to greatly impact on colour and taste and potability of the drinking water.

Eutrophication is the over-enrichment of waters with nutrients, leading to increased algal biomass. Phosphorus is the main limiting nutrient in this process, but unfortunately this parameter has not been monitored sufficiently within the catchment. This, combined with the limited usable data available on Total Oxidised Nitrogen, makes it difficult to draw specific conclusions regarding catchment management and source protection. However there are potential nitrate issues within the catchment as observed by the large value observed in August 2011 which exceeded the Drinking Water Regulations (2007 and 2014). Chlorophyll *a*, a surrogate for algal biomass and used in national and international classification systems for trophic status, has not been monitored within the catchment (specifically Garvagh Lough), save for the sole EPA monitoring occasion in 2005 which classified Garvagh Lough as oligotrophic. However, the periodic monitoring of algal counts and species has enabled a limited understanding of the interactions of nutrient dynamics and this, accompanied by the current low intensity agricultural practices within the catchment makes the likelihood of either the primary or more specifically the secondary source being severely impacted by elevated nutrients as low. However, given the underlying karstic environment surrounding Garvagh Lough, the vulnerability of the local groundwater, the poor drainage of the catchment soils, the potential for phosphorus additions to the catchment through forestry management practices and the addition of other nutrient and contaminants through livestock access to water bodies, local wastewater treatment systems and farmyard slurry storage tanks, the precautionary principle must be taken with regard to potential diffuse and point pollution sources.

Although the values observed in the raw water for total coliforms did not exceed the Surface Water Recommendations (1989) for Class A1 waters, high values of total coliforms were observed on a number of occasions and these represent a potential health risk for the Gowlan GWS. There are two likely potential pathways for pathogens and faecal coliforms to enter the raw water supply:

- Through faecal contamination of the primary water supply by sheep accessing the mountain streams/springs. The free access of sheep to the primary source of water allows for easy contamination of the primary supply. There is also the potential for any stock that may die in the vicinity of the primary source to pose a significant health hazard to the GWS;
- Through the intake of sediment at the secondary source intake pipe. The coliform and bacterial loading of lake sediments are typically greater than that in the water column as a result of coliforms and bacteria attaching to suspended particles that settle to the bottom. The current positioning of the secondary source intake pipe along the bottom of Garvagh Lough represents a potential pathway for sediment to be re-suspended for greater loadings of faecal coliforms and bacteria to enter the raw water supply. The repositioning of the intake pipe into the water column may reduce the potential intake of pathogens into the raw water supply when taken from Garvagh Lough.

7.0 Recommendations

The Gowlan GWS catchment is relatively small at 8.78 Km^2, and due to its upland location there are relatively low levels of agricultural and human population pressures acting within the catchment. However there are a number of key issues that are recommended to be addressed in order to improve source protection and maintain high quality water supplies from both the primary and secondary water sources.

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 Gowlan 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 Gowlan 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.

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.

Relocation of the abstraction pipeline point at the secondary water source, Garvagh Lough

Currently the abstraction pipeline at Garvagh Lough is situated on the lake bed. When this secondary source is contributing to the water supply (during times of low flow from the primary sources), sediment can enter the abstraction pipe, leading to issues with filtration and increasing the cost of water treatment. Faecal coliforms and other contaminants are found in higher levels within sediments compared to water columns. The relocation of the intake pipe to within the water column and away from the lake bed would reduce filtration costs, water treatment costs and reduce the levels of coliforms entering the abstraction pipe. It is therefore recommended that the abstraction pipe be relocated to the water column, with the pipe inlet raised a minimum of 1 meter from the sediment. The clearance of vegetation (floating and fringing) close to the abstraction point would facilitate maintenance access for the proposed works.

Remedial works on the primary abstraction sources

When flows from the primary sources are low, water is taken from the secondary source at Garvagh Lough. At the westerly mountain stream/spring (Figure 1 and Figure 3) rudimentary work has been undertaken in the past in an attempt to preserve the water resource for a short period of time when flows are low. These rudimentary works need upgrading and no preservation work has been undertaken at the easterly mountain stream/spring. It is therefore recommended that remedial works are undertaken at both the primary sources in an attempt to preserve water during periods of low flow. It is also advised that the recommendations made by Jennings O'Donovan (2008) as part of their *Cryptosporidium* risk assessment report be implemented (see Section 7.1 and Appendix 1 for further details).

Agriculture and farmyard management

Although agricultural pressures within the Gowlan GWS catchment are relatively low, there are still some significant aspects that have the potential to cause issues within the raw water supply. These specific issues have been highlighted below, but other general recommendations have also been included that are of importance to source protection.

Specific issues

Fencing of the primary abstraction sources

There is currently no restriction of access by humans or livestock to the primary source of water: the mountain streams/springs. This creates potential contamination issues, particularly with regard to faecal coliforms emanating from livestock accessing the primary sources. It is understood that fencing may attract curiosity from passing individuals; however the remoteness of the location means that numbers of passing individuals would be low. Restricting livestock access to the primary sources is important, particularly as there is currently the possibility of livestock dying and contaminating the primary source resulting in serious health implications for the Scheme. It is recommended that fencing works are undertaken to enclose each of the mountain streams/springs around the abstraction point.

Livestock presence and access at the secondary abstraction source

During the site visit undertaken on 15th January 2014 in advance of the preparation of this report, a number of issues were identified with regard to livestock management in the vicinity of, and access to, Garvagh Lough. Upon entering the enclosed roadway leading to the Garvagh Lough pump house, a number of head of cattle were being kept in the field that leads down to Garvagh Lough. In places, the slope towards to the Lough is steep. The cattle had excessively poached the land, particularly around the feeder which lies at the crest of a slope that runs down towards the Lough (Figure 23 and Figure 24). The weather conditions at this time of year, in association with the excessive poaching, the slope of the land and the poorly drained soil facilitate the overland flow of nutrients and faecal contaminants into the secondary abstraction source, close to the abstraction point. The cattle also have free access to the Lough, significantly increasing the nutrient and faecal contaminant load to the Lough (Figure 25). It is recommended that (1) Cattle are housed during winter periods to reduce the poaching of land and likely overland contaminant run-off into the Lough; and (2) In fields where livestock are grazed, fencing is erected to restrict access to the Lough to reduce direct input of nutrient and contaminants into the secondary abstraction source.

Figure 23: Cattle presence on land sloping down to the secondary abstraction source, Garvagh Lough.

Figure 24: Excessive poaching can be seen around the feeder and was also present throughout the paddock running down towards Garvagh lough.

Figure 25: Faeces and cattle poaching with direct access Garvagh Lough close to the secondary abstraction point. Photograph: Brian MacDomhnaill

General Recommendations

(a) Make scheme members 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 2m of surface waters;
- No organic fertiliser/soiled water spread within 20m 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.
- No organic fertiliser/soiled water spread within 15m of karst features/exposed karst
- For "Extreme Vulnerability Areas on Karst Limestone Aquifers", soiled water shall not be applied to land (a) in quantities which exceed in any period of 42 days a total quantity of 25,000 litres per hectare, or (*b*) by irrigation at a rate exceeding 3 mm per hour unless the land has a consistent minimum thickness of 1m of soil and subsoil combined.
- For abstractions >100 m^3/d or >500 people, no spreading within 200m of the abstraction point (surface water, borehole, spring or well).
- For abstractions >10 m^3/d or >50 people, no spreading within 100m 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 to remind them of their legal obligations and the benefits to the scheme of complying within this code of good agricultural practice.

(b) Although much of the land within the catchment is unlikely to require significant nutrient enrichment, some areas surrounding Garvagh 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.

Forestry

Commercially run forestry is present to the north, east and south of Garvagh Lough. The owners and managers of the forestry should be identified and channels of communication opened to discuss issues around water quality protection. Discussion should focus on two main areas: the harvesting of the current crop without impacting on water quality; and future planting and management at each site.

Source protection measures should include the establishment of buffer zones, the use of sediment traps and nutrient management plans, the potential for phased felling and informing the GWS when any planting or felling actions will be undertaken. Enquiries should be made with regard to current measures in place to reduce potential contamination of water bodies and any plans for future improvements.

Guidelines on buffer zone specifications, cultivation and harvesting operations and fertiliser application are available from the Forestry Service (Department of Agriculture, Food and the Marine). In particular, the following guidelines would be of importance: Forestry and Water Quality Guidelines; Forestry Harvesting and the Environment Guidelines. Both guidelines are available for download at http://www.agriculture.gov.ie/forestservice/publications/.

Septic Tanks/Waste Water 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 waste water treatment systems (OSWTSs). Although there are low housing pressures within the Gowlan

GWS catchment, all dwellings are located within the karst environment with poorly drained soils. Therefore good OSWTS management is vital within the catchment in order to 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 Waste Water Treatment for Single Houses which is available from the EPA website: https://www.epa.ie/water/wastewater/guidance/cop/.

Gowlan GWS should meet with Scheme members within the catchment and provide them with the following advice with regards to ensuring that all waste water 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 Cavan 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 due to poor drainage then expert advice should be sought by contacting Cavan County Council.

7.1 Future Work

As mentioned above, there are relatively limited pressures acting within the Gowlan GWS catchment, but a number of issues have been identified and recommendations made. The following further work is advised:

1. Filling water quality monitoring gaps.

In assessing the water quality monitoring data a key parameter, Total Phosphorus, has not been monitored at all within the catchment. Phosphorus is a key limiting nutrient and the fact that intermittent algal blooms have been observed within the raw water supply, most notably in September 2013, suggest that there is potentially a phosphorus issue within the raw water supply. Total Phosphorus should be monitored at the secondary water source (Garvagh Lough) and consideration should be given to monitoring Total Phosphorus within the Loopagh stream inflow to Garvagh Lough. This would help to identify potential sources of phosphorus input and could highlight areas in need of remediation measures. The monitoring of turbidity and dissolved oxygen in Garvagh Lough would also provide further information with regards to potential issues relating to eutrophication and algal blooms.

2. Remedial Work funding applications

Potential avenues for funding sources for remedial works at both the primary and secondary abstraction points should be identified and applications made as soon as possible.

3. Identification of when the secondary source is switched on and off

The majority of the EPS water quality monitoring reports do not identify the exact dates as to when the secondary source is switched on or off. Rather more generalised comments are made, for example from April 2010: “The lake water was turned off for a period of time when there was sufficient water flowing from the spring source. However due to the dry weather the lake water had to be turned back on.” More precise information would help in identifying whether pollution or contamination events are emanating from either the primary or secondary source.

4. Soil nutrient analysis

Within the Gowlan GWS catchment, due to the current agricultural practices, only land in the vicinity of Garvagh Lough is likely to possibly be enriched with fertiliser application at any point in the future. The implementation of soil nutrient analysis throughout the catchment area surrounding Garvagh 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.

5. Implementation of recommendations of *Cryptosporidium* risk assessment report

If not already implemented, the recommendations made by Jennings O’Donovan (2008) as part of their *Cryptosporidium* risk assessment report should be fully implemented as soon as possible. These recommendations are listed in Appendix 1. The recommendations involving fencing of waterbodies and the remedial works at the primary source are of particular importance for source protection.

6. Undertaking assessments of Zones of Contribution for the primary (stream/spring) sources

As the primary water abstraction points are essentially groundwater dependent (they are reliant on water springing from underground close to the abstraction point), groundwater zones of contribution should be delineated and associated groundwater source protection assessments should be undertaken. Such bodies of work have been completed for other Group Water Schemes that abstract water from groundwater sources and the National Federation of Group Water Schemes should be engaged to provide guidance on how to proceed further with this.

8.0 References

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Appendix One

Recommendations from the Gowlan Group Water Scheme *Cryptosporidium* Risk Assessment Report (Jennings O'Donovan, 2008).

5.3 Recommended Improvements to Reduce Cryptosporidium Risk

5.3.1 Categories 1 – 4: Animals within the Catchment; Agricultural Practices within the Catchment; Discharges to Catchment/Source Protection Area; Catchment/Source Protection Area (SPA) Inspections

The number of animals within the zone of contribution of *Culicagh Springs* and *Garvagh Lough.* may be difficult to reduce, particularly in this predominantly agricultural area. The Groundwater Vulnerability Maps (ref. GSI) included in Appendix 3 show that the groundwater in the catchments of the source is generally vulnerable to contaminants. However it is considered that the recommendations below could reduce the risk of *Cryptosporidium* contamination. In addition a full auditable catchment inspection procedure should be developed and implemented as part of an overall source protection policy.

<u>**General Recommendations**</u>

i. A land/farm survey should be conducted, and farms where activities such as sheep pens/cattle byres, and lambing/calving should be located for both sources. The effect of such activities and facilities to all feader/sinking streams should be evaluated. Where practical the immediate zone of contribution to streams leading into them should be fenced off at winter water table levels.

ii. Sheep pens/cattle byres should be inspected on a monthly basis.

iii. Lambs and calves should be kept away from land immediately adjacent to the springs.

iv. Where practical, fencing should be carried out around all ditches within the catchment of *Garvagh Lough*, to prevent livestock from contaminating the water source. Proper drinking troughs for livestock should be provided.

v. A full survey and assessment of the location and condition of septic tanks in the catchment should be carried out to determine the risk of sewage (and hence *Cryptosporidium*) contaminating the *Garvagh Lough* source.

vi. A full survey of the stormwater pipes/drains in the catchment should be carried out to identify if there are any pipes/drains discharging directly into the sources or swallowholes. Where possible any such drains could be diverted or re-routed.

vii. Regular catchment inspections should be made and procedures put in place to deal with any identified irregularities. Routine catchment inspections should include observations made on land-use practice.

5.3.2 Category 5, 6 & 7: Geology/Hydrogeology; Rapid Bypass of Unsaturated Zones; Water Source Type

This is an inherent risk and therefore it cannot be reduced.

5.3.3 Category 8: Sanitary Protection of Groundwater Supply

Raising the *Culicagh Springs* headworks above natural ground level by at least 200mm and installing completely sealed raised covers to avoid surface water being washed into it during heavy rains would reduce the risk of contamination. This action would also protect the water source from infiltration from surface water run-off.

5.3.4 Category 9: Water Treatment Processes

Consideration must be given to the fact that the scheme is run by a committee on a volunteer basis. The monitoring of catchments, carrying out inspections and influencing farmers to change their agricultural practices may not be realistic or not possible. The most certain means of dealing with Cryptosporidium could be to address the risk at the treatment plant by utilizing the *Garvagh Lough* source which has been evaluated at Moderate Risk.

The treatment processes at Gowlan GWS consists of coagulation, dissolved air filtration, rapid gravity filtration, pH correction and chlorination which is effective in removing *Cryptosporidium* oocysts to below the level of 0.05 in 10 litres of water.

As the *Garvagh Lough* source has a moderate risk score, it is not necessary to recommend further treatment at the water treatment plant to deal with the risk of cryptosporidium.

5.3.5 Category 10: Treatment Works Operation

The Gowlan water treatment plant already has turbidity meter installed on the treated water outlet from the plant. The turbidity meter is linked to a SCADA system that has an alarm facility for elevated turbidity levels, which in turn can highlight the risk of Cryptosporidium outbreak. No reduction in the scoring of risk is gained by installing further turbidity monitors.