Louth County Council

Establishment of Groundwater Source Protection Zones

Omeath Water Supply Scheme

Esmore Bridge Borehole

July 2014

Revision: D

Prepared by:
Peter Conroy
On behalf of the Geological Survey of Ireland

With contributions from:
Dr. Robert Meehan, Consultant Geologist; Jenny Deakin TCD; Natalya Hunter-Williams, GSI
And with assistance from:
Louth County Council

PROJECT DESCRIPTION

Since the 1980's, the Geological Survey of Ireland (GSI) has undertaken a considerable amount of work developing Groundwater Protection Schemes throughout the country. Groundwater Source Protection Zones are the surface and subsurface areas surrounding a groundwater source, *i.e*. a well, wellfield or spring, in which water and contaminants may enter groundwater and move towards the source. Knowledge of where the water is coming from is critical when trying to interpret water quality data at the groundwater source. The Source Protection Zone also provides an area in which to focus further investigation and is an area where protective measures can be introduced to maintain or improve the quality of groundwater.

Louth County Council contracted GSI to delineate source protection zones for eight groundwater public water supply sources in Co. Louth. The sources comprised Ardee, Cooley (Carlingford and Ardtullybeg), Collon, Greenore, Termonfeckin, Omeath (Esmore Bridge and Lislea), Drybridge and Killineer.

This report documents the delineation of the Omeath – Esmore Bridge source protection zones.

A suite of maps and digital GIS layers accompany this report and the reports and maps are hosted on the EPA and GSI websites (www.epa.ie; www.gsi.ie).

TABLE OF CONTENTS

TABLES, FIGURES & APPENDICES

TABLES

FIGURES

APPENDICES

1. INTRODUCTION

Groundwater Source Protection Zones are delineated for the Esmore Bridge Borehole source according to the principles and methodologies set out in 'Groundwater Protection Schemes' (DELG/EPA/GSI, 1999) and in the GSI/EPA/IGI Training course on Groundwater Source Protection Zone Delineation.

The Esmore Bridge borehole source supplies a portion of the drinking water to the town of Omeath on the Cooley Peninsula in northeast Co. Louth. Omeath Water Supply Scheme also abstracts from another borehole groundwater source at Lislea Cross, approximately 1.5 km west of Omeath town centre. The source at Lislea Cross is dealt with in a separate report.

The objectives of the report are as follows:

- To outline the principal hydrogeological characteristics of the area surrounding the Esmore Bridge borehole source.
- To delineate source protection zones for this borehole.
- To assist Louth County Council in protecting the water supply from contamination.

Groundwater protection zones are delineated to help prioritise the area around the source in terms of pollution risk to groundwater. This prioritisation is intended as a guide in evaluating the likely suitability of an area for a proposed activity prior to site investigations. The delineation and use of groundwater protection zones is further outlined in 'Groundwater Protection Schemes' (DELG/EPA/GSI, 1999).

The maps produced are based largely on the readily available information in the area, a field walkover and on mapping techniques which use inferences and judgements based on experience at other sites. As such, the maps cannot claim to be definitively accurate across the whole area covered, and should not be used as the sole basis for site-specific decisions, which will usually require the collection of additional site-specific data.

2. METHODOLOGY

A desk study of existing data sources relevant to the source was carried out prior to a site visit. Site visits and site walk-overs and field mapping of the study area were conducted on 30/04/2010 and 29 & 30/06/2010. An interview with the source caretaker was carried out on 30/04/2010. Sampling of the untreated source water, the Ryland River and two additional boreholes within the study area was conducted on 29/06/2010. A depth to bedrock drilling programme was carried out by the GSI during May 2007 to investigate the subsoil geology, the depth to bedrock, the hydrogeology and vulnerability to contamination of the groundwater within the study area.

3. LOCATION, SITE DESCRIPTION AND WELL HEAD PROTECTION

The Esmore Bridge borehole is located on the R173 regional road between Omeath and Carlingford, in the townland of Knocknagoran, approximately 1 km south-southeast of Omeath town centre. The borehole is in the southwest corner of an agricultural field adjacent to the north bank of the west-east flowing Ryland River, approximately 160 m upstream of Esmore Bridge. The source location is shown in Figure 1. In this report the source borehole is labelled borehole PWSBH02 as it is one of two wells supplying the Omeath Water Supply Scheme.

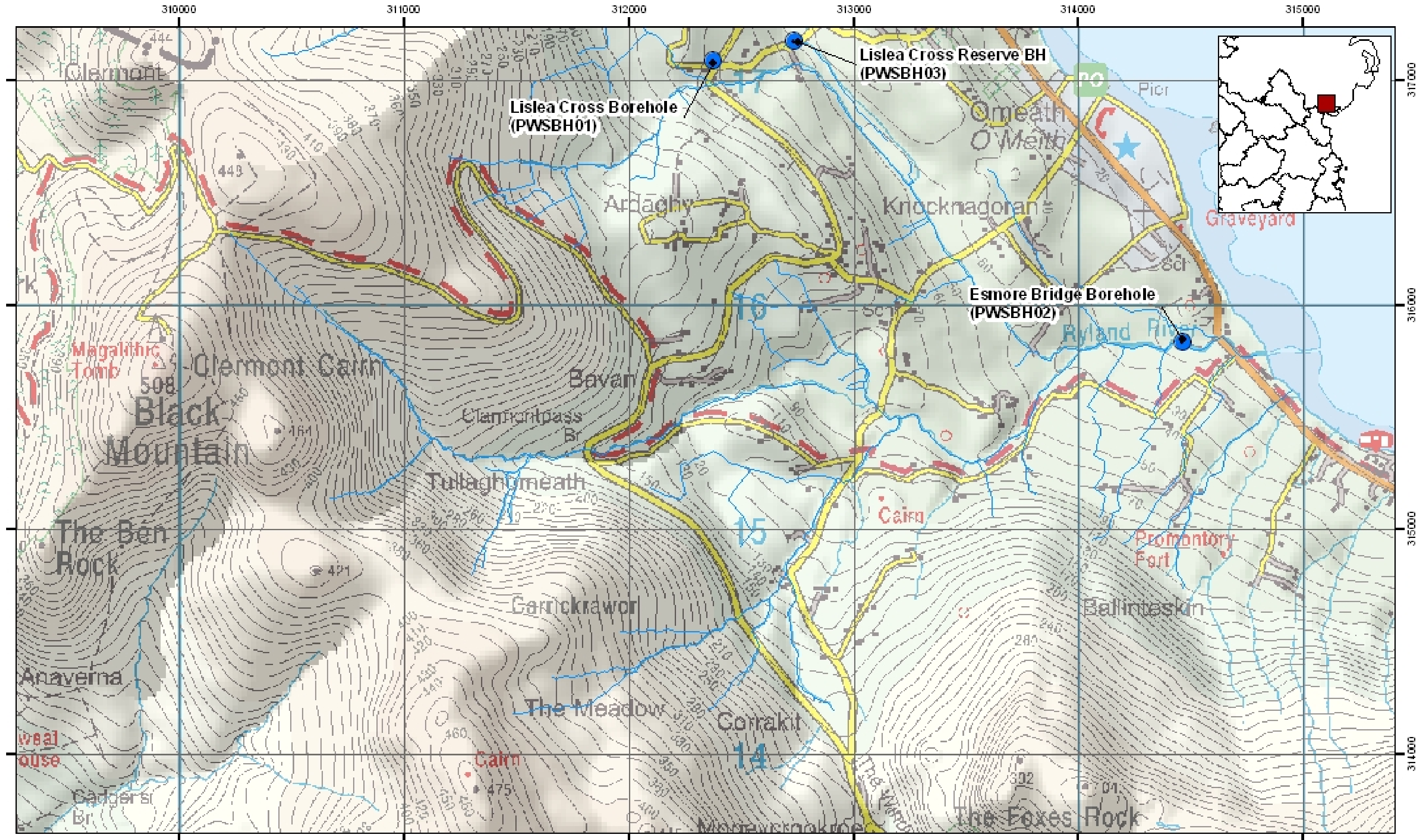


Figure 1 Omeath - Esmore Bridge Site Location Map

PWS Abstraction

Stream

0 0.25 0.5 0.75 km

A 160 m long riverside track leads from the R173 road to the gated entrance to the field, which contains the borehole. The borehole is located just inside the field to the left of the gate. A small kiosk stands beside the borehole and houses the borehole pumping controls, while a larger kiosk is located 3 m west of the borehole and contains the water treatment system. There is no compound separating the borehole from the field, which itself is enclosed by a 1.2 m high concrete post and wire fence. The field is set in grass and is currently used for sheep grazing.

Borehole PWSBH02 is located inside a concrete block built manhole chamber. The chamber is approximately 1 m^2 and covered by a circular cast iron manhole cover. The floor of the chamber lies at 0.5 mbgl. The manhole cover is not lockable and is set in a 1.5 m by 1.5 m square concrete pad which slopes away from the manhole cover. Two service ducts, on the south and west sides of the chamber, provide access to the borehole for cables. The concrete pad and chamber wall are broken out where these ducts enter, particularly on the west side, and allow surface drainage to enter the chamber. The chamber contains the borehole headworks and rising main and an adjacent valve assembly. The site layout and borehole chamber can be seen in the photographs below.

Photograph 1 View of Site Compound from north

Photograph 2 Plan view of borehole PWSBH02

Photograph 3 View Ryland River adjacent to borehole PWSBH02, with borehole treatment kiosk on RHS of photo

Photograph 4 View of field looking west from borehole PWSBH02

The mouth of the borehole is formed by a 150 mm diameter steel casing inside a 250 mm steel casing with a gravel pack installed between the two. The top of the 150 mm steel casing stands 0.13 m above the floor of the manhole chamber, while the top of the 250 mm casing is at 0.1 m above the chamber floor. The floor of the chamber is comprised of native subsoil. The borehole log indicates that the gravel pack extends to the top of the 250 mm casing, and there is no record of a grout seal on the borehole log.

4. SUMMARY OF BOREHOLE DETAILS

A copy of a graphical borehole log for borehole PWSBH02 was provided by Louth County Council and is included in Appendix 1. The borehole was completed on the 14th May 1984. The drilling company and drilling method used are not recorded. The locations of the point features investigated during the site visits and identified during the desk study are shown in Figure 2. A summary table of the point data collected during the site visits and field mapping is provided in Table A1.1a in Appendix 1.

The Esmore Bridge borehole (PWSBH02) was drilled to a depth of 7.32 mbgl. The driller's log records that 3.7 m of boulder clay overlies approximately 2.7 m of saturated sand/gravel. The borehole penetrates bedrock from 6.4 m onwards. The borehole was cased with nominal 250 mm diameter mild steel casing to 7.32 mbgl. A 150 mm diameter steel casing was subsequently used to line the borehole between 0 m and 7.32 mbgl, with 2.9 m of well-screen incorporated between 3.5 m and 6.4 mbgl. A gravel pack was installed between the two casings and the 250 mm casing was subsequently pulled back to 3.66 mbgl and the excess casing cut off. The borehole log records that the gravel pack was of 9.4 mm size. This is assumed to refer to the pack grading D_{90} value, such that 90% of the pack granules are assumed to be less than 9 mm diameter. The gravel pack is intended to prevent entry of fine material into the borehole from the water bearing zone, which is a slightly clayey GRAVEL and SAND, encountered between 3.6 m and 6.4 mbgl.

There are no records of a pumping test being carried out prior to commissioning of the well. The current abstraction rate from the borehole is 113 m^3/day, based on 2009 records. The available abstraction records indicate that a maximum abstraction rate of 150 m^3/day was reached during June 2006. The GSI carried out a short pumping test on the borehole in 2006 using the installed headworks and abstracting at a rate of approximately 150 m^3/day. Drawdown of the borehole water level during the test was not significant.

The water is chlorinated using an electro-chlorination system in the adjacent treatment kiosk. An untreated-water sampling tap is located inside the treatment kiosk. Water quality data indicate that up to April 2010 samples were affected by the electro-chlorination system (see Section 9.3). The sampling tap was moved to a new location on the rising main in June 2010 to rectify this problem.

Table 1 provides a summary of the well details.

Table 1 Summary of Source Details

EPA/WFD Monitoring Code	**n/a**
GSI Well Database Reference No.	2931SEW201
Borehole Name	Esmore Bridge/PWSBH02
Grid reference	E314472 N315831
Townland	Knocknagoran
Source type	Borehole
Drilled	May 1984
Owner	Louth County Council
Elevation (Ground Level)	approx. 7.01 mAOD (i, ii)
Depth	7.32 mbgl (iii)
Depth of casing	7.32 mbgl
Depth of Well Screen	Steel well screen 3.5 m to 6.4 mbgl
Gravel Pack	Gravel pack installed between 250 mm & 150 mm casing from ground level to total depth. 250mm casing pulled back to 3.66 m after installation of gravel pack.
Diameter	250 mm nominal diameter steel casing 0.37 to 3.66 mbgl. 150 mm diameter steel casing 0.4 m to 7.32 mbgl.
Depth to rock	6.4 mbgl
Static water level (SWL)	approximately 0.9 to 1.0mbRef (iv), (v)
Pumping water level (PWL)	1.4 mbRef (29/04/2010 @ approx 15:00) 1.435 mbRef (29/06/2010 @ 12.30)
Drawdown at current pumping rate (vi)	approximately 0.4 to 0.5 m (v)
Depth of pump	approx. 6 m
Consumption (Co.Co. records)	113 m^3/d(vii)
Borehole Yield	Not proven. Max recorded abstraction is 150 m^3/day.
Pumping test summary (viii):	
(i) abstraction rate m^3/d	150 m^3/d
(ii) specific capacity	Negligible drawdown. No records, assume > 150 m^3/d/m @ 150 m^3/day

Note (i): mAOD = metres above ordnance datum;
Note (ii): Elevation taken from EPA 20 m grid spacing Digital Terrain Model for Co. Louth.
Note (iii): mbgl = metres below ground level.
Note (iv): mbRef = metres below PWSBH02 water level measurement reference datum, i.e. PWSBH02 Ref = the top of the 150 mm steel casing, which is 0.4m below the steel rim of the manhole chamber, which is approximately ground level.
Note (v): SWL estimated assuming that natural SWL would be above the level of the adjacent riverbed
Note (vi) Pumping rate at time of PWL measurement = approx 113 m^3/day.
Note (vii): Based on Louth County Council abstraction records for 2009. Borehole caretaker indicated that borehole typically pumped at 4 to 5 m^3/hr for 24 hours per day.
Note (viii): Based on anecdotal evidence from aborted GSI pumping test in 2006.

5. TOPOGRAPHY, SURFACE HYDROLOGY AND LANDUSE

The abstraction borehole (PWSBH02) is located on the narrow flood plain of the Ryland River, on the north side of the river. The flood plain extends approximately 100 m to the north and south of the river in the vicinity of the borehole and approximately 300 m upstream from the borehole. The ground elevation in the flood plain at the borehole is estimated at 7 m AOD, rising gently to approximately 10 m AOD to the north and south and to approximately 15 m AOD to the west. The topographical gradient in the vicinity of the borehole on the north side of the river is towards the river from the north and west and varies between 0.018 and 0.027; on the south side the gradient is approximately 0.075, also towards the river. The Ryland river is incised into the flood plain and in the vicinity of the borehole the riverbed lies approximately 1.45 m below the adjacent ground surface.

To the north and west of the flood plain two parallel, north-northwest to south-southeast trending ridges extend to the northwest for approximately 2 km (Figure 1). The northern ridge is called Knocknagoran ridge in this report[1], while the parallel western ridge[2] is referred to as the Ardaghy ridge. The valley between the ridges is referred to as the Knocknagoran valley. To the west of the Ardaghy ridge the ground rises steeply to the summit of Black Mountain. The eastern slope of the mountain is incised by numerous valleys which carry the headwater tributaries of the Ryland River. To the south of the river and flood plain, the ground rises steeply to the summit of The Foxes Rock Hill. The sea lies about 270 m to the east of the Esmore Bridge borehole.

Drainage is generally to the east or east-northeast, with streams flowing off the eastern slopes of Black Mountain to the sea, with the exception of the Lislea stream, which flows south-southeast along the Knocknagoran valley before turning east around the end of the Knocknagoran ridge, 700 m upstream of borehole PWSBH02. The confluence with the main tributary of the Ryland River is located 200 m downstream of this bend. This tributary flows in a generally easterly direction off Black Mountain, through the townland of Tullaghomeath, and is called the Tullaghomeath stream in this report. Both the Lislea and Tullaghomeath streams receive numerous minor tributaries from the slopes of Black Mountain and the Foxes Rock. Downstream of the confluence the Ryland River accepts further tributaries from the northern slopes of The Foxes Rock as well as from the southern end of the Knocknagoran ridge. On the Foxes Rock Hill, several small streams issue forth from the ground mid-way down the slope of the hill. These risings are considered to be related to the boundary between bedrock outcrop, which covers the upper half of the hill, and the subsoil cover on the lower part of the hill. There is also a break in slope at this level. Excess groundwater flow at the boundary is considered to overwhelm the bedrock-subsoil flow regime and overspill into surface water courses (see Sections 9.5 and 10).

Drainage density is high, in excess of 1 km per 1 km^2. During site visits artificial drainage and indicators of poor drainage conditions, such as rushes, were observed on steeper slopes with shallow subsoils. Further down the catchment, where thicker subsoils occurred, poor drainage indicators were absent.

Landuse in the vicinity of borehole PWSBH02 is primarily agricultural, with extensive sheep and cattle grazing dominating landuse. A caravan park is located on the northern edge of the flood plain approximately 60 m from borehole PWSBH02. To the north of the caravan park the density of domestic residences increases along the R173 road towards Omeath town. To the west of the source there are generally only scattered domestic residences on agricultural holdings. Domestic residences in the town of Omeath are serviced by mains sewerage, however, outside the town, domestic residences and the caravan park are serviced by onsite wastewater treatment systems.

---

[1] Ridge trending through Drummullagh and Knocknagoran townlands near the coast.

[2] Ridge that passes through the townlands of Ardaghy and Lislea.

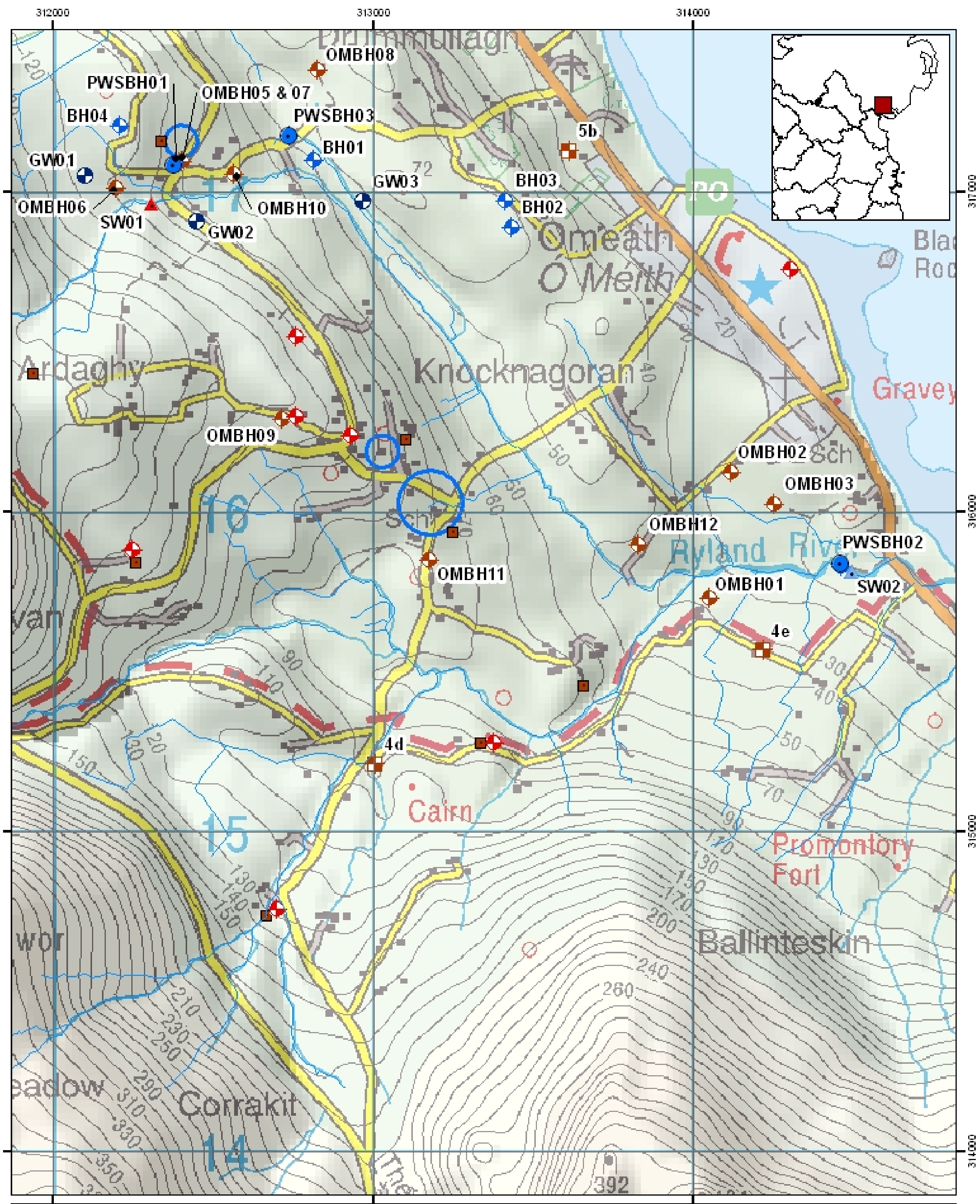


Figure 2 Datapoints in the Vicinity of Esmore Bridge Borehole

PWS Abstraction
Stream
OtherDTB
Groundwater, Borehole
Groundwater, Spring
Surface Water, Abstraction
Surface Water, Monitoring Point
GSI Auger Hole
GSI Exposure
GSI Well Database (0 to 50 m accuracy)
GSI Well Database (50 to 1000 m acc.)

0 0.25 0.5 0.75 km

6. HYDRO-METEROLOGY

Establishing groundwater source protection zones requires an understanding of general meteorological patterns across the area of interest. The data source is Met Éireann.

Annual rainfall: 1102 mm. The contoured data map of rainfall in Ireland (Met Éireann; 1961-1990 dataset) shows that the source is located between the 1,000 mm and 1,200 mm average annual rainfall isohyets. The closest meteorological station to the Esmore Bridge Source is Omeath G.S. in Omeath town centre, 800 m to the north, where the average rainfall between 1961 and 1990 was 1102 mm/yr (Fitzgerald and Forrestal, 1996).

Annual evapotranspiration losses: 451 mm. The closest synoptic weather station to the study area is Clones, situated 64 km west and inland from the source and where average annual rainfall is estimated at 928 mm, and potential evapotranspiration (P.E.) is estimated at 438 mm/yr. The nearest coastal synoptic station is Dublin Airport, 72 km to the south, where annual average rainfall is estimated at 733 mm and potential evapotranspiration is estimated at 560 mm/yr. The contoured mean annual potential evapotranspiration for Ireland shows that Esmore Bridge lies approximately midway between the 450 mm and the 500 mm/yr contours (Collins and Cummins, 1996). Based on the mean annual PE contours and the data for Clones, which has a closer annual rainfall to Omeath than Dublin Airport, annual PE at Omeath is estimated at 475 mm. Actual evapotranspiration (A.E.) is then estimated as 95% of P.E., to allow for seasonal soil moisture deficits, giving an Actual Evapotranspiration of 451 mm.

Annual Effective Rainfall: 651 mm. The annual effective rainfall is calculated by subtracting actual evapotranspiration from rainfall. Potential recharge is therefore equivalent to this, or 651 mm/yr. See Section 11.2, which estimates the proportion of effective rainfall that enters the aquifer.

7. GEOLOGY

This section briefly describes the relevant characteristics of the geological materials that underlie the Esmore Bridge source. It provides a framework for the assessment of groundwater flow and source protection zones that will follow in later sections. The geological information is based on the bedrock geological map of Monaghan - Carlingford, Sheet 8 and part of Sheet 9, 1:100,000 Series (Geraghty, 1996) and accompanying memoir (Geraghty, 1997), historical geological mapping by the GSI at the 6-inch to 1 mile scale, the GSI Well and Borehole Databases, and on bedrock outcrop and subsoil exposures encountered during site visits. The bedrock geology of the area is shown in Figure 3.

7.1 BEDROCK GEOLOGY

The bedrock map indicates that the area surrounding the source and extending to the west of it is underlain by sandstones and minor shales of the Inniskeen rock unit. The Inniskeen rock unit underlies a coastal strip 1 km wide to the north and south of borehole PWSBH02 and extends inland, in a wedge underlying the Tullaghomeath stream, onto the lower slopes of Black Mountain. The Inniskeen rock unit is bounded by much younger volcanic and granitic-type bedrock units.

The different geological formations in the area are described in Table 2 and can be seen in Figure 3. A cross-section of the geology in the vicinity of the source is shown in Figure 4. The line of the cross-section in Figure 4 is shown on Figure 3.

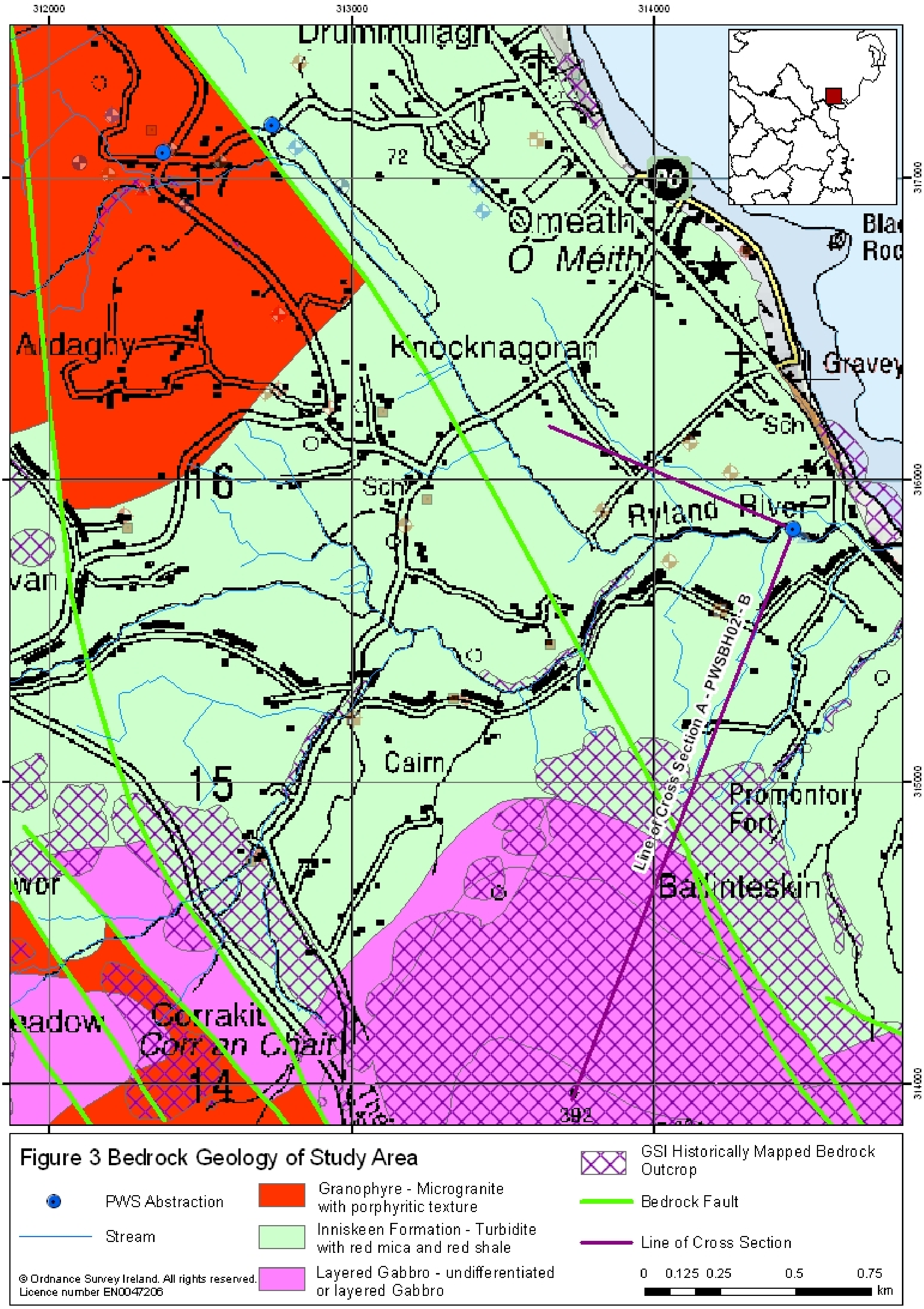


Figure 3 Bedrock Geology of Study Area

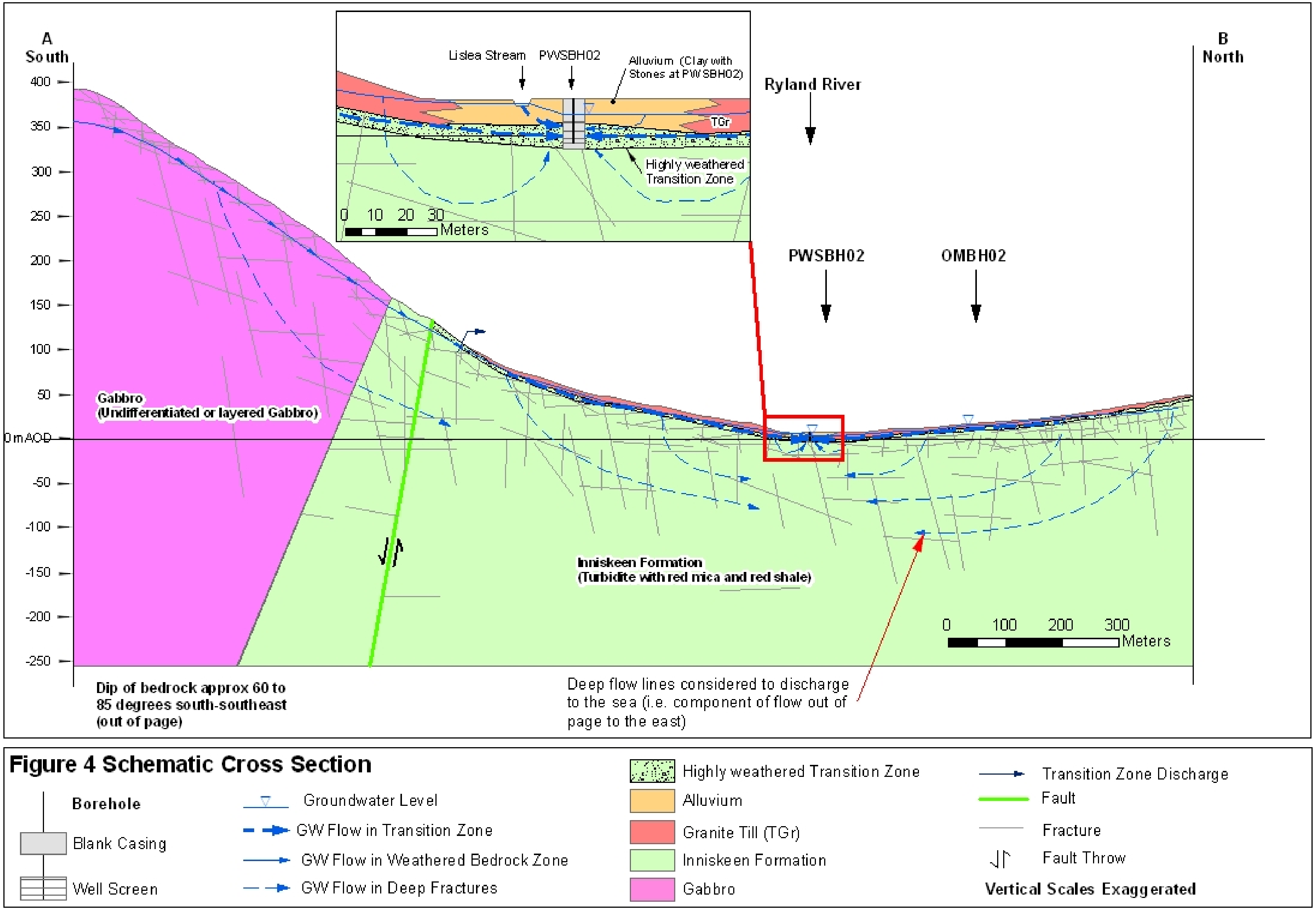


Figure 4 Schematic Cross Section

Table 2 Bedrock Geology and descriptions around Esmore Bridge PWS Boreholes

Bedrock Formation	Geological Description	Geological Age
Granophyre	Microgranite with porphyritic texture (occurs to the northwest and southwest underlying Black Mountain)	Tertiary
Layered Gabbro	Undifferentiated or layered Gabbro (underlying The Foxes Rock Hill)	Tertiary
Inniskeen Formation (IN)	Medium to thick bedded turbiditic greywacke sandstones and minor amounts of shale, with red biotite mica and red shale (around source)	Silurian

Two roughly north to south trending faults are mapped to the west of the source. The westerly fault lies approximately 2.5 km to the west, and is a regional scale feature extending south from north of Newry and along the length of the Cooley peninsula. The other fault is approximately 900 m to the west of borehole PWSBH01, extending from near Carlingford at the south to the point where it abuts the western fault approximately 3.7 km north-northwest of the source. The rock layers between the two faults are down-thrown relative to the rocks on the other sides of the faults. GSI historical mapping indicates that bedrock layers are significantly tilted, and dip very steeply south-southeast at approximately 60 to 85 degrees.

7.2 SOILS AND SUBSOILS

7.2.1 Soils

Teagasc mapping indicate that the soils underlying the source and at the various alluvial flats upgradient of the source comprise mineral alluvial soils. Across the majority of the study area the remainder of the soil is classified as deep, well drained mineral soils (AminDW) derived from mainly non-calcareous parent materials. The soils on the upper slopes of Black Mountain are predominantly comprised of deep poorly drained mineral soils with peaty topsoil and derived from mainly non-calcareous parent materials (AminPDPT) (Teagasc, 2004b). Blanket peat is found along the floor of the Knocknagoran valley.

7.2.2 Subsoil

According to GSI and EPA mapping, a number of different subsoil units underlie the areas around the Esmore Bridge water supply. Drilling and permeability mapping carried out by Tobin Consulting Engineers for the Louth portion of the National Vulnerability Mapping Programme, and by the GSI for this project, provide additional information on the subsoils. The subsoil map of the area is shown in Figure 5.

The subsoils directly underlying the source are mapped as alluvium (A). Alluvium is a post-glacial deposit and may consist of gravel, sand, silt or clay in a variety of mixes and usually includes a high percentage of organic carbon (10%-30%). Alluvium is mapped only on modern day river floodplains. The alluvium is mapped underlying the Ryland river flood plain in the vicinity of the source. It is also mapped at several additional alluvial floodplains along the river and its tributaries on the eastern slopes of Black Mountain. The borehole log for borehole PWSBH02 indicates that the borehole encountered CLAY with boulders between 0 m and 3.7 mbgl. Based on the subsoils map, the CLAY with boulders is interpreted to be an alluvial deposit.

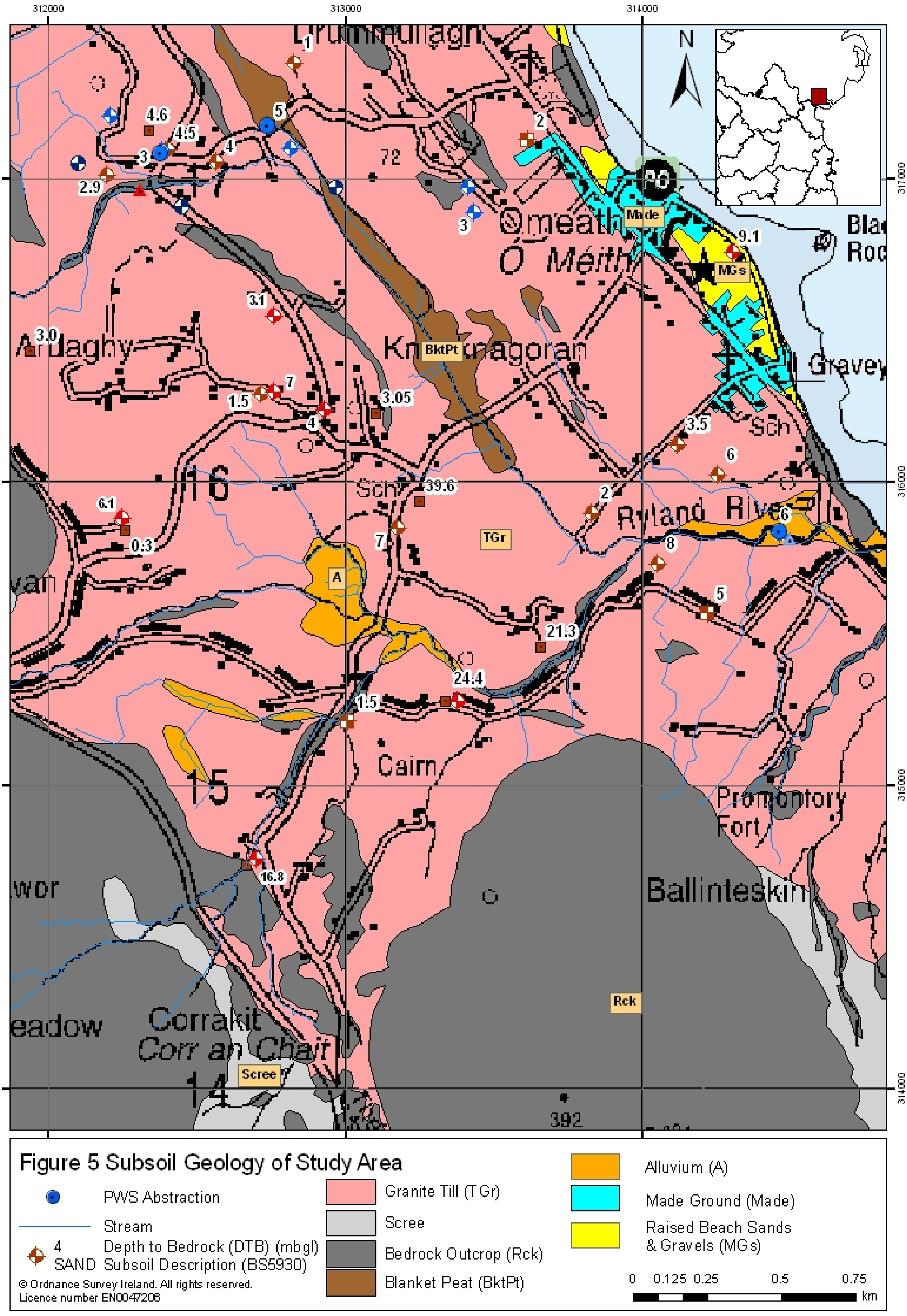


Figure 5 Subsoil Geology of Study Area

The CLAY with boulders deposit at borehole PWSBH02 overlies 2.8 m of slightly clayey, GRAVEL and SAND. Coarse grained, sandy GRAVEL over shallow bedrock was encountered at auger hole OMBH02, which is outside the mapped alluvium in an area mapped as granite till. The coarse grained deposits are water-bearing in each borehole. The presence of water-bearing, coarse-grained material on top of bedrock under different subsoil types across the area suggests an extensive fluvio-glacial deposit, or maybe that the layer of coarse grained material derives from weathering of the bedrock. In this report the material is interpreted as potentially comprising both glacio-fluvial deposits and a highly weathered transition zone at the top of the bedrock. The transition zone is assumed to extend to the south underneath the Ryland River and generally to be present at the top of bedrock across the area underlain by Inniskeen Formation bedrock.

The alluvial subsoils are surrounded by till derived from granite bedrock (TGr). Till is an unsorted mixture of coarse and fine materials laid down by ice. Tills are often over-consolidated, or tightly packed, unsorted, unbedded and possess many different particle and clast (stone) sizes. They commonly have sharp, angular clasts. The till in the vicinity of the source is categorised according to its dominant lithological component.

Blanket peat deposits are present along the floor of the Knocknagoran valley and in places on the upper slopes of Black Mountain. Large parts of the upper slopes of Black Mountain are underlain by scree slopes and bedrock outcrop. Bedrock outcrop is mapped at several places along the Tullaghomeath stream upstream of the confluence with the Ryland River, across large tracts of Black Mountain and The Foxes Rock Hill, along the Knocknagoran ridge and in Ardaghy at a break in slope running roughly along the local road between Ardaghy and Lislea.

7.2.3 Subsoil Permeability

The subsoils across County Louth have been classified with respect to their permeability in the preparation of a Groundwater Vulnerability map for Louth County Council, by the Geological Survey of Ireland. Under the GSI investigations, the permeability of the granite till in the study area has been classed as '***Moderate Permeability'***.

Eleven auger holes were drilled in the granite till deposits in the areas surrounding the Esmore Bridge and Lislea Cross groundwater sources. Subsoil samples from the auger holes were logged in accordance with BS5930. The data from the auger hole drilling are summarised in Table 3. The auger hole locations are shown on Figure 2.

Auger holes OMBH01, 03, 11 and 12 were drilled in the vicinity of borehole PWSBH02. In auger holes OMBH03 and 11, sandy GRAVEL subsoils were recorded which, given the granite till setting of the boreholes, suggests moderate subsoil permeability. The soils in the vicinity of the PWS borehole are well drained, which again suggests moderate bulk permeability. No subsoil record was obtained from auger hole OMBH01, while at auger hole OMBH12 the depth to rock was only 2 m.

Some rushes were observed in the vicinity of auger holes OMBH02 and 03 while drainage ditches were recorded in the vicinity of auger hole OMBH11. These suggestions of poor drainage are likely to be due to localised groundwater discharge in topographic low points, or at breaks in slope in the case of OMBH11.

Table 3 Subsoil data from Auger Drilling samples taken in vicinity of Esmore Bridge Public Supply[3]

Location	Easting	Northing	DTB (m)	BS5930 Result	Subsoil Permeability	Subsoil Unit
OMBH01	314054	315732	8	None	n/a	TGr
OMBH02	314123	316123	3.5	Very dense, coarse grained sandy GRAVEL. Water bearing	Moderate	TGr
OMBH03	314258	316023	6	Very dense becoming soft, very silty GRAVEL.	Moderate	TGr
OMBH05	312397	317094	4.5	Very sandy, GRAVEL.	Moderate	TGr
OMBH06	312196	317014	2.9	Rck Close	n/a	TGr
OMBH07	312403	317096	4.5	Loose, sandy GRAVEL.	Moderate	TGr
OMBH08	312829	317381	1	Rck Close	n/a	TGr
OMBH09	312716	316289	1.5	Rck Close	n/a	TGr
OMBH10	312568	317057	4	Very dense SAND.	Moderate	TGr
OMBH11	313179	315849	7	Sandy, coarse GRAVEL.	Moderate	TGr
OMBH12	313832	315897	2	Rck Close	n/a	TGr

The widespread vegetation indicators of poor drainage on the steep, upper slopes of the study area where subsoils are thin is interpreted to be due to rejected recharge from the low permeability bedrock overwhelming the storage capacity of the shallow subsoils, and resulting in saturated conditions up to the ground surface and overland flow, despite the moderate permeability of the thin, overlying subsoil (Robbie Meehan, pers comm., 2010). Where the subsoils are thicker they have sufficient storage and permeability to transmit the rejected bedrock recharge downgradient, subsurface to surface water courses without giving rise to saturated topsoil conditions, such that plant indicators of poor drainage are largely absent.

7.3 DEPTH TO BEDROCK

Depth to bedrock (DTB) has been interpreted across the study area based on bedrock outcrops mapped by the GSI, outcrops mapped during site visits, areas mapped as extreme groundwater vulnerability under the GSI Groundwater Protection Scheme (GWPS), DTB data from the GSI Well Database and logged evidence from drilling of GSI auger holes in the vicinity of the source.

The subsoil map of Louth indicates that areas of outcropping rock are found on large parts of the upper slopes of Black Mountain and The Foxes Rock Hill, along the Tullaghomeath stream upstream of the source, along the Knocknagoran ridge, and in Ardaghy at a break in slope running roughly along the local road between Ardaghy and Lislea.

Depth to bedrock point data for the area are shown in Figure 5. DTB data from GSI auger holes are shown in Table 3. DTB data from other data sources is shown in Tables A1.1a to A 1.1c in Appendix 1.

The data indicate that in the vicinity of the source, DTB is generally between 5 m and 10 m with the borehole log for borehole PWSBH02 (Esmore Bridge) indicating a depth to (solid) bedrock of 6.4 m. In the granite till subsoils, outside areas mapped as rock close to surface, the DTB is generally between 4.5 m and 8 m. On the south side of the Ardaghy ridge and along the southeastern end of the Knocknagoran valley an area of thicker subsoils with DTB greater than 5 m and up to 39 m has been mapped. This area includes auger hole OMBH11 which has a DTB of 7 m.

[3] Note: There was no auger hole labelled "OMBH04" drilled during the investigation.

7.4 GROUNDWATER VULNERABILITY

Groundwater vulnerability is dictated by the nature and thickness of the material overlying the uppermost groundwater 'target'. In this area the 'target' includes the water-bearing highly weathered transition zone on top of the bedrock. A detailed description of the vulnerability categories can be found in the Groundwater Protection Schemes document (DELG/EPA/GSI, 1999) and in the draft GSI Guidelines for Assessment and Mapping of Groundwater Vulnerability to Contamination (Fitzsimons et al, 2003).

The groundwater vulnerability map (Figure 6) indicates areas of extreme vulnerability on the upper slopes of Black Mountain and The Foxes Rock Hill, and along the areas of outcrop in the Tullaghomeath stream and tributaries upstream of the source. Outcrop areas along the Knocknagoran ridge and in the Ardaghy area are also mapped as extreme vulnerability. A small area of extreme vulnerability has been added to the TOBIN/GSI map for this project in the vicinity of auger hole OMBH12, where the depth to bedrock is recorded as 2 m.

The majority of the remainder of the study area surrounding the source is classified as high vulnerability due to the presence of 3–10 m of moderate permeability subsoils overlying the more permeable subsoil unit. An area of moderate vulnerability has been delineated south and southwest of the Ardaghy ridge where subsoil thickness exceeds 10 m. A small area within this zone in the vicinity of auger hole OMBH11 has been classified as high vulnerability for this project, due to the evidence of DTB equal to 7 m at the auger location.

8. HYDROGEOLOGY

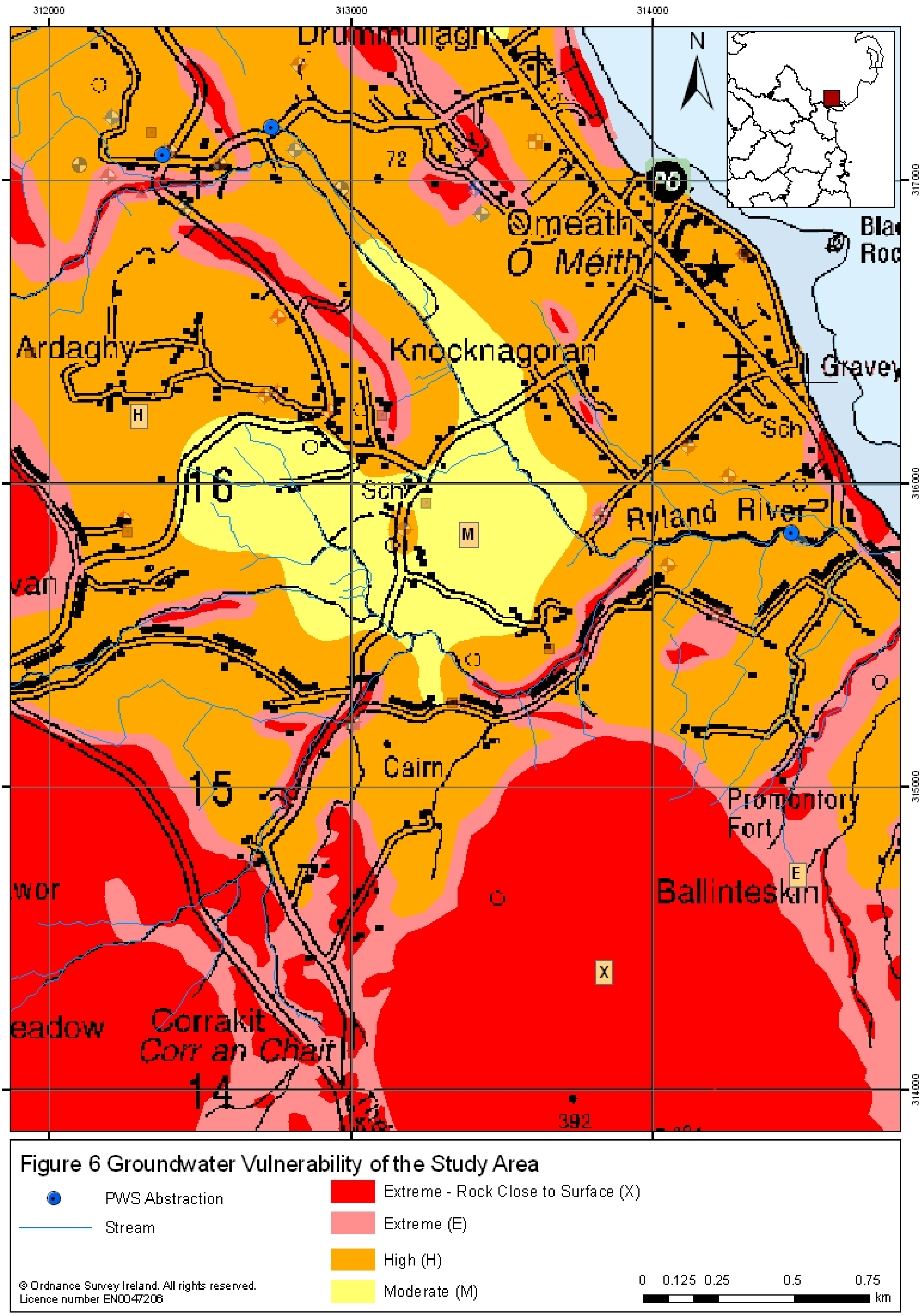
This section describes the current understanding of the hydrogeology in the vicinity of the source. Hydrogeological and hydrochemical information was obtained from the following sources:

- GSI Website and Databases
- County Council Staff
- Local Authority Drinking Water returns and monitoring of untreated groundwater quality,
- Hydrogeological mapping by Peter Conroy and Robert Meehan (April 2010)
- Local hydrogeological mapping carried out by the GSI and Tobin Consulting Engineers as part of the National Vulnerability Mapping Programme;
- Drilling and permeability mapping carried out by GSI in May 2007
- Met Éireann rainfall and evapotranspiration data

8.1 GROUNDWATER BODY AND STATUS

The source and the surrounding area form part of the Louth groundwater body (GWB), which extends across the majority of the Cooley peninsula and Co. Louth and as far west as Castleblaney and Carrickmacross in Co. Monaghan, as well as into parts of northeast Co. Meath.

The Water Framework Directive (WFD) reporting tool WaterMaps indicates that the status of the Louth GWB is "*Good*". The groundwater body descriptions are available from the GSI website: www.gsi.ie and the 'status' is obtained from the Water Framework Directive website: www.wfdireland.ie .


312000
313000
314000
317000
316000
315000
314000
Drummullagh
Omeath
Ó Méith
Knocknagoran
Ardaghy
Ryland River
Sch
Gravey
Cairn
Promontory
Fort
Ballinteskin
Corrakit
Corr an Chait
H
M
E
X
PO
72
392
N
Figure 6 Groundwater Vulnerability of the Study Area
PWS Abstraction
Stream
Extreme - Rock Close to Surface (X)
Extreme (E)
High (H)
Moderate (M)
0 0.125 0.25 0.5 0.75
km
© Ordnance Survey Ireland. All rights reserved.
Licence number EN0047206

8.2 GROUNDWATER LEVELS, FLOW DIRECTIONS AND GRADIENTS

The pumping ground water level in borehole PWSBH02 was measured at 1.435 mbtc on 29th June 2010. The groundwater level at the borehole resides in saturated, slightly clayey GRAVEL and SAND, which is assumed here to be at least partly comprising the highly weathered transition zone on top of the bedrock. Based on the estimated ground level at the borehole in Table 3, this equates to a groundwater elevation of 5.18 mAOD, which is slightly lower than that of the adjacent stream. Full details of the water level data collected in the study area are provided in Table A1.1a in Appendix 1.

No other boreholes allowing further groundwater level measurements were found in the vicinity of borehole PWSBH02. The GSI auger hole OMBH02 encountered groundwater at 1.7 mbgl in coarse grained, sandy GRAVEL (1.8 m above coherent bedrock). The water in this glacio-fluvial/bedrock transition zone unit is likely to be hydraulically continuous with the groundwater in the underlying fractured bedrock. As such the water strike is likely to reflect the bedrock water table at the location and equates to a groundwater elevation of 17.73 mAOD.

Water levels from auger hole OMBH02 and borehole PWSBH02 indicate that the groundwater elevation follows the topographic slope. The hydraulic gradient and groundwater flow direction in the vicinity of borehole PWSBH02 on the north side of the river are therefore expected to be directed approximately southeast from the southeastern end of the Knocknagoran ridge towards the Ryland River and the sea. On the south side of the river on Foxes Rock Hill the gradient and groundwater flow direction are expected to be to the northeast, again towards the river and the sea. The hydraulic gradients in the study area are assumed to closely follow the topographic gradient and are likely to range from 0.018 on the north side to 0.075 on the south side of the river.

Measurement of the Ryland River riverbed level with respect to the ground level at borehole PWSBH02 indicates that the riverbed lies approximately 1.04 m below the top of the PWSBH02 150 mm steel casing. This indicates that the pumping water level in the borehole lies approximately 0.39 m below the adjacent riverbed level.

In the absence of borehole abstraction, the natural groundwater conditions at the site of borehole PWSBH02 would be for groundwater in the bedrock and overlying slightly clayey GRAVEL and SAND (the highly weathered bedrock layer) to discharge to the river. This implies that the rest groundwater level at the borehole should be higher than the river bed level, *i.e*. approximately 0.4 m to 0.5 m higher than the current pumping water level.

8.3 HYDROCHEMISTRY AND WATER QUALITY

Five samples of untreated groundwater have been collected from the Esmore Bridge borehole (PWSBH02) between April 2009 and June 2010. Three of the samples, collected in April, May and November of 2009, were analysed for a limited suite of parameters. The sample from April 2010 was analysed for an extended suite of parameters including major ions, physico-chemical parameters and the parameters listed in the Drinking Water Regulations (SI No. 278 of 2007). The sample from June 2010 was analysed for major ions, pH and electrical conductivity. The first four samples were analysed by the EPA on behalf of Louth County Council. The analysis of the final sample was carried out by STL laboratories in the UK. Three additional groundwater samples were collected from the Ryland River adjacent to borehole PWSBH02 (labelled SW02), borehole PWSBH03 (back up borehole at Lislea Cross) and borehole BH02. These samples were analysed for major ions, pH and electrical conductivity at STL Laboratories in the UK.

The water samples at borehole PWSBH02 are collected from a sampling tap within the water treatment kiosk. The results suggest that between April 2009 and May 2010 the sampling tap was positioned downstream of the water softener and was also affected by the sodium chloride solution used to feed the electro-chlorination unit (see below for discussion). The sampling tap was subsequently moved to an upstream location on the rising main within the kiosk so that in June 2010 a completely untreated sample was collected.

The water quality data from the analyses are presented in Table A1.2 in Appendix 1. Field water quality data (pH, conductivity and temperature) were collected from all sampling locations in June 2010 and are presented in Table A1.3 in Appendix 1.

Data for borehole PWSBH02 showed extremely elevated chloride, electrical conductivity and chemical oxygen demand in samples from April and November 2009. Chloride was also slightly elevated in the sample from April 2010. The sampling times on these dates were compared to high tide times in Carlingford Lough on the same dates to check whether the exceedences might be related to a salt water wedge protruding up the Ryland River. However there was no correlation between the data.

The April 2010 sample show that calcium, magnesium and potassium were below the detection limit while the sodium concentration was elevated. This indicates that the sample was collected from treated water which had passed through a water softener. It is likely that the samples collected in 2009 were also from treated water. The elevated chloride concentration and electrical conductivities detected in some of the samples are also assumed to be related to the treatment system, which uses a concentrated sodium chloride solution to generate chlorine for disinfection of the water supply.

The major ion data for June 2010 are within normal ranges and similar to values from boreholes BH02 and PWSBH03, which indicates that this sample is not affected by the treatment system.

Groundwater from borehole PWSBH02 has a low to moderate level of mineralization as indicated by the electrical conductivity (120 µS/cm), alkalinity (37.6 mg/l as CaCO3) and hardness (121 mg/l as CaCO3). The alkalinity and hardness values are within the ranges predicted by the Louth GWB Initial Characterisation Summary (GSI, 2004a). The groundwater has a calcium-bicarbonate signature, which is likely to be the result of dissolution of calcite in the subsoil deposits. The pH of the groundwater is neutral to slightly acidic with a measured average of 6.98 [range 6.62 to 7.5]. Heavy metal concentrations have generally been low to non-detectable when measured.

The groundwater from borehole PWSBH03 and the private borehole BH02 is derived from the same bedrock aquifer that underlies borehole PWSBH02. These two boreholes are in the upper reaches of the catchment. The electrical conductivity and major ion parameters indicate that the bedrock groundwater at borehole PWSBH03 and the private borehole BH02 is generally more mineralized than the groundwater abstracted from borehole PWSBH02. Conductivity, calcium, magnesium, alkalinity, chloride and sulphate all record higher concentrations in borehole PWSBH03 and in the private borehole BH02. In contrast, the water sample from the Ryland River is less mineralized than the sample from borehole PWSBH02. Electrical conductivity, calcium, magnesium, chloride and alkalinity are all lower in the river water than in borehole PWSBH02.

Given the construction of borehole PWSBH02 with its screened interval in slightly clayey GRAVEL and SAND overlying bedrock and the hydraulic gradient from the river to the borehole, it is likely that the water abstracted from the borehole derives from both groundwater and river water. The hydrochemistry data suggest that this is the case, with the water from borehole PWSBH02 having a composition that is a mixture of the river and background groundwater endpoints.

The relative contributions of groundwater and river water being abstracted from the Esmore Bridge borehole can be estimated applying a mass balance equation to chloride concentrations in each end member in the mixed water abstracted from borehole PWSBH02:

$$x = \frac{Cl_{mix} - Cl_{gw}}{Cl_{riv} - Cl_{gw}},$$

where: Cl_{mix}, Cl_{riv} and Cl_{gw} are the concentrations of chloride in borehole PWSBH02, the Ryland River and the average of boreholes PWSBH03 and BH02 respectively;
x is the proportion of river water in the final mixed water; and,
(1 – x) is the proportion of bedrock groundwater in the final mixed water.

Using chloride data from 30th June 2010 gives Clmix, Clriv and Clgw equal to 11.6, 10.7 and 13.2 mg/l respectively and gives x = 0.64. This indicates that the abstraction from borehole PWSBH02 is derived from the Ryland River and the bedrock aquifer approximately in the ratio of 2:1. This estimate should be considered indicative only and as an upper estimate, because: (i) it is based on only one measurement; (ii) less mineralised waters would be expected in the shallow groundwaters flowing in the transition zone as compared to longer-residence time groundwater abstracted by deeper boreholes (e.g. BH02).

Figure 7a shows the EPA measured concentrations of faecal and total coliforms and ammonia at the source. No coliform bacteria have been detected in the untreated water samples. Ammonia concentrations are not detectable at the borehole.

Figure 7b shows the measured concentrations of nitrate and chloride at the source. The average nitrate concentration over the monitoring period was 3.8 mg/l as NO_3, which is very low and within natural background levels. The measured water quality at the source exceeded the Drinking Water Standard for chloride in April and November 2009 and exceeded EPA threshold levels for chloride in April 2010. The EPA electrical conductivity threshold was also exceeded in April and November 2009. These exceedences are discounted as the result of alteration of the untreated groundwater by the water treatment system at the borehole. Data from June 2010 indicate that natural chloride concentrations are well below the EPA threshold.

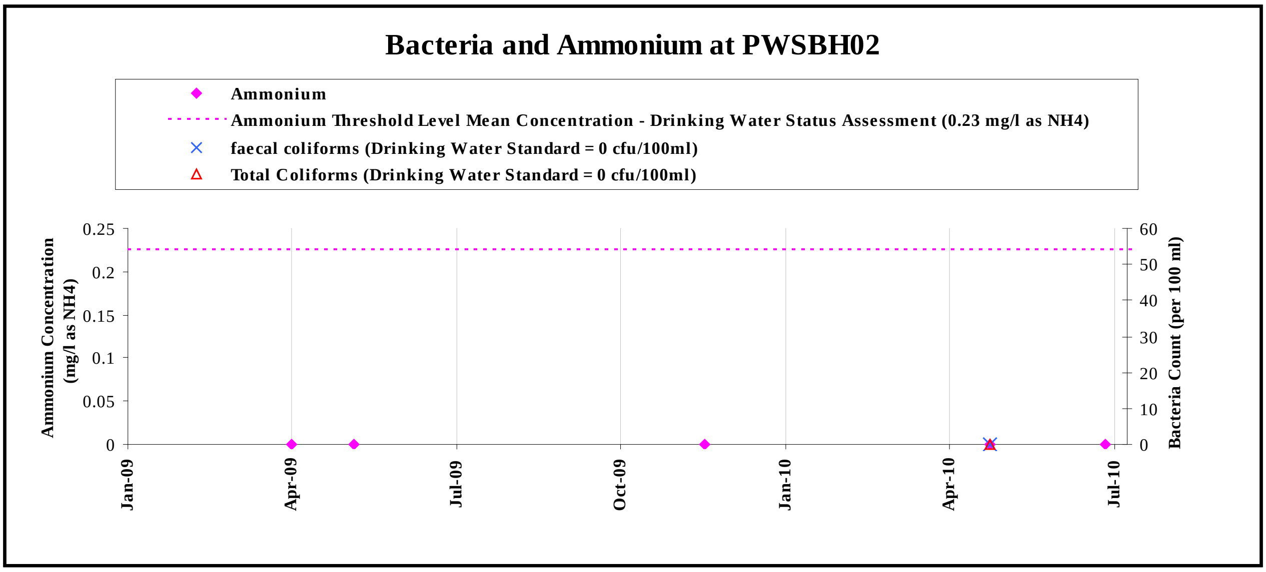


Figure 7a Graph of Bacteria and Ammonia Concentrations at Borehole PWSBH02

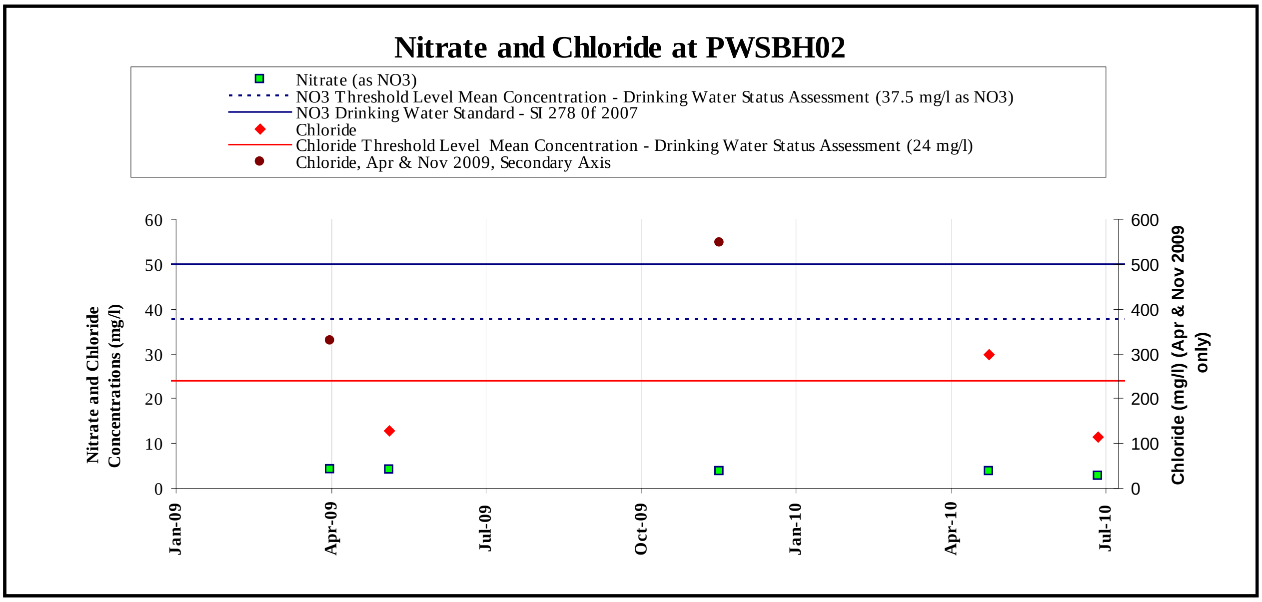


Figure 7b Graph of Nitrate and Chloride Concentrations at Borehole PWSBH02

Figure 7c shows the EPA measured concentrations of manganese and potassium and the Potassium:Sodium ratio at the source. None of these parameters exceeded their respective thresholds. The Na:K ratio at PWSBH03 on 29 June 2010 was 0.11, which is below the threshold of 0.4.

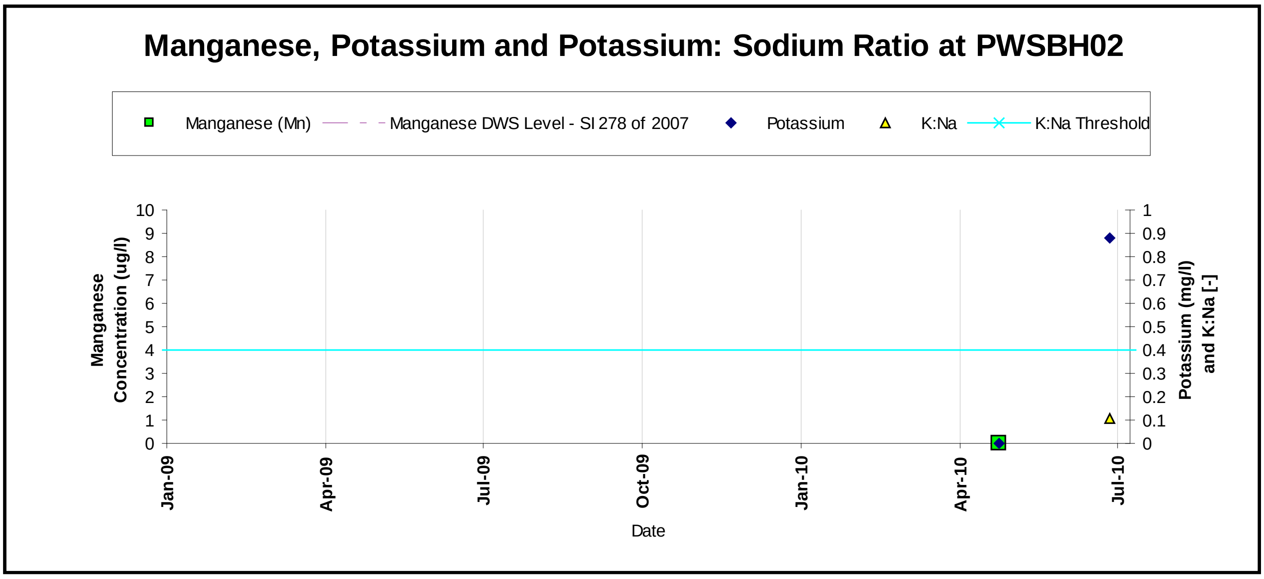


Figure 7c Graph of Manganese, Potassium and Potassium:Sodium Ratio at Borehole PWSBH02

The remaining parameters measured do not exceed their respective drinking water standard and have average concentrations less than their respective EPA thresholds.

In summary, the data indicate that the abstraction from borehole PWSBH02 is unpolluted and is a mix of river water and groundwater. Given the agricultural setting with sheep grazing adjacent and domestic onsite wastewater treatment systems in the vicinity of the source it would be prudent to continue monitor the stream water quality and the untreated water quality from borehole PWSBH02 lest the source be impacted by contamination in the future.

8.4 AQUIFER CHARACTERISTICS

The groundwater source is located in the Louth Groundwater Body. The GSI bedrock aquifer map of the area indicates that the Silurian Metasediments and Volcanics are classified as a *Poor Aquifer – Generally Unproductive Except in Local Zones (Pl).* The regional, 1;100,000 bedrock aquifer map of the area as mapped by the GSI is shown in Figure 8.

Groundwater flow in the catchment is likely to have shallow and deep components (see Sections 7.2 and 8.2). The shallow component of flow is likely to occur in porous material such as the slightly clayey GRAVEL and SAND, and the coarse grained, sandy GRAVEL encountered in borehole PWSBH02 and auger hole OMBH02 respectively. These materials are thought to represent fluvio-glacial deposits and/or highly weathered bedrock in a transition zone on top of the competent bedrock. Associated with this porous layer will be additional flow in a zone of interconnected fissuring approximately 10 m thick below the highly weathered transition zone. The deep component of flow is likely to occur in a zone of isolated poorly connected fissuring, which is typically less than 150 m thick (GSI, 2004). It is probable that much of the groundwater flowing within the fractured bedrock aquifer bypasses the river and borehole and discharges to the sea.

Groundwater flow in the vicinity of borehole PWSBH02 is considered to be concentrated in the sands & gravels/highly weathered transition zone. Under natural conditions, groundwater flowing from the north would be expected to discharge to the Ryland River in the vicinity of borehole PWSBH02. Groundwater flow from the south is driven by a greater hydraulic gradient. As such, some of the flow from this direction is likely to discharge to the river. However, a portion may also pass under the river *via* the transition zone and deeper flow paths to discharge at the coast. It is possible that much of the flow below the highly weathered transition zone bypasses the river and borehole and discharges to the sea. Based on this model of groundwater flow therefore, the abstraction from borehole PWSBH02 is expected to capture groundwater flow in the sands & gravels/transition zone from both the north and south sides of the Ryland River.

A large number of risings occur on Foxes Rock Hill, most of which are related to thickening subsoils (roughly coincident with the boundary of the E(X) groundwater vulnerability areas) and also to breaks in slope. This indicates that the capacity of the subsurface to transmit all available groundwater recharge to the river and sea is exceeded, and results in groundwater discharging to surface water as spring and seeps. Despite this discharge from the groundwater system, it is still possible that a component of recharge to the upper slopes of the hill could reach borehole PWSBH02 *via* the transition zone pathway.

The borehole is located approximately 8 m from the riverbank, giving a lateral hydraulic gradient of 0.048 from the river towards the borehole and indicating that water is likely to flow from the river towards the borehole. Based on the borehole log for borehole PWSBH02, any loss of water from the river to the borehole would have to migrate vertically through 2.21 m of the CLAY with boulders (*i.e.* riverbed incised 1.45 m into 3.66 m of CLAY with boulders) before entering the underlying slightly clayey GRAVEL and SAND layer and flowing laterally to the borehole. The CLAY with boulders is assumed to be an alluvial deposit. There may be preferential flow paths within the alluvium. These pathways would facilitate leakage of water from the riverbed to the borehole. The hydrochemistry data for the area suggests that this leakage occurs (see Section 9.3). The hydraulic conditions which favour leakage from the river may also enhance the flow of groundwater underneath the river to the borehole *via* the transition zone

On the local scale, at borehole PWSBH02 it would appear that drawdown in the borehole induces leakage from the river into the unconsolidated deposits, such that river water accounts for up to two-thirds of the abstracted borehole water, *i.e.* up to approximately 75m^3/day at the current abstraction rate. Under natural, non-pumping conditions groundwater would be expected to discharge to the river as baseflow.

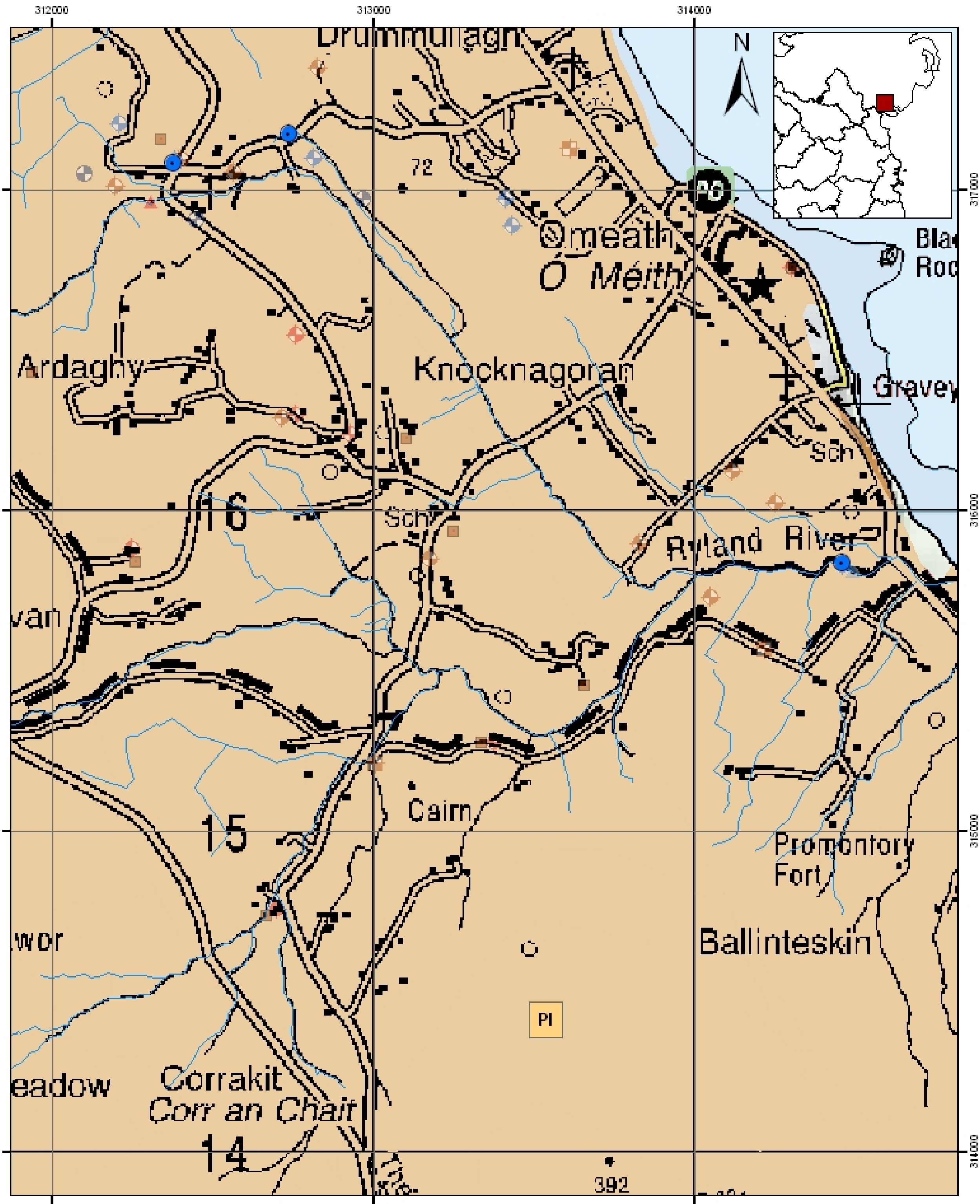


Figure 8 Bedrock Aquifer Map of Study Area

PWS Abstraction

Stream

PI: Poor Aquifer - Bedrock which is Generally Unproductive except for Local Zones

0 0.125 0.25 0.5 0.75 km

Drawdown in borehole PWSBH02 is considered to be approximately 0.5 m based on the assumption that under non-pumping conditions the borehole water level would be above the level of the adjacent riverbed. This indicates an approximate specific capacity for the transition zone materials, in hydraulic continuity with the river and underlying bedrock aquifer, of 226 m^3/day/m.

The Groundwater Body report for the Louth GWB suggests aquifer transmissivity in the Silurian greywacke / shale and granite Pl aquifers is typically low (2 m^2/day) to moderate (20 m^2/day) (GSI 2004). In contrast, the transmissivity of gravels at Ardtully Beg in the nearby Dundalk Gravels GWB has been measured at 1,000 m^2/day. The transmissivity of the transition zone materials in which the borehole is screened is likely to be between these two extremes. The minimal drawdown experienced during the short 2007 pumping test suggests the river-groundwater system exploited by the borehole is highly transmissive. A rough estimate of the transmissivity of the materials can be obtained using Logan's rule:

$$T = 1.22 * S.C$$

where: T = bulk transmissivity of the transition zone materials (m^2/day); and,
S.C. = specific capacity of the borehole (m^3/day/m).

Using Logan's rule the transmissivity of the transition zone materials in the vicinity of the borehole is estimated at 275 m^2/day.

Based on the estimated transmissivity of the sand & gravel/transition zone materials and the hydraulic gradient, average groundwater flow velocity can be estimated based on the equation:

$$v = \frac{T \cdot i}{b \cdot n_e}$$

where: v = average groundwater velocity (m/day);
T = aquifer transmissivity (m^2/day); n_e = effective porosity (dimensionless)
i = hydraulic gradient; and, b = aquifer thickness.

The estimated groundwater velocity range in the sand & gravel/transition zone materials, based on the available data is given in Table 4. Estimates for groundwater flow within the fractured bedrock are given in Table 5.

Table 4 Estimated Groundwater Velocity Range in the Sand & Gravel/Transition Zone Materials

Parameter	Units	Min	Max	Value used	Data Source
T	m^2/d	138	414	275	Estimated T (+/- 50%)
i	[-]	0.018	0.086	0.018 (north) 0.07 (south)	Min from minimum topographic gradient; Max from estimated hydraulic gradient between OMBH02 and PWSBH02. Values used for ZOC north/south of Rylandwater based on land gradient.
b	m	2.8	2.8	3.0	Based on PWSBH02 borehole log
n_e	[-]	0.1	0.3	0.2	Typical effective porosity range for unsorted unconsolidated material
v	m/d	3	127	8.25 (north) 32 (south)	Calculated from groundwater flow equation and parameter values

Table 5 Estimated Groundwater Velocity Range in the fractured bedrock aquifer

Para-meter	Units	Min	Max	Value used	Data Source
T	m^2/d	2	20	5	Groundwater body descriptions
i	[-]	0.018	0.086	0.045 (north) 0.07 (south)	Min from minimum topographic gradient; Max from estimated hydraulic gradient between OMBH02 and PWSBH02. Values used for ZOC north/south of Rylandwater based on land gradient.
b	m	-	-	15	Groundwater body descriptions
n_e	[-]			0.01	Typical effective porosity range for poorly fractured bedrock
v	m/d			1.5 (north) 2.3 (south)	Calculated from groundwater flow equation and parameter values

In the case of migration of river water from the river bed to the borehole, the hydraulic gradient is estimated at 0.048 (Section 8.2). Using this gradient together with the values of T, b and n_e from Table 4 gives a river water migration velocity of 11 m/d to 33 m/d, with an average of 22 m/d. This suggests that river water is likely to migrate across the 8 m distance separating the river and the borehole in less than or equal to one day.

9. ZONE OF CONTRIBUTION

The Zone of Contribution (ZOC) is the complete hydrologic catchment area to the source, or the area required to support an abstraction from long-term recharge. The size and shape of the ZOC is controlled primarily by (a) the total discharge, (b) the groundwater flow direction and gradient, (c) the subsoil and rock permeability and (d) the recharge in the area. This section describes the conceptual model of how groundwater flows to the source, including uncertainties and limitations in the boundaries, and the recharge and water balance calculations which support the hydrogeological mapping techniques used to delineate the ZOC.

9.1 CONCEPTUAL MODEL

A schematic cross section illustrating the conceptual model is shown in Figure 4. The current understanding of the geological and hydrogeological setting is given as follows:

- The water supply source described in this report comprises one borehole (PWSBH02) in the Esmore Bridge area of Omeath, situated in the upper, highly weathered transition zone of the Silurian Metasediments and Volcanic bedrock, classified as a *Poor Aquifer (Pl)*. There is another borehole at Lislea Cross that contributes water to the Omeath Water Supply Source.

- Abstraction rates from borehole PWSBH02 currently average 113 m^3/day. The borehole pumps 24 hours per day at between 4 and 5 m^3/hr.

- Depth to bedrock is considered to be less than 3 m on the upper slopes of Black Mountain, the Foxes Rock Hill, along the Knocknagoran ridge and along the Tullaghomeath stream upstream of the source. In the vicinity of the source, DTB is generally between 5 m and 10 m. In the granite till subsoils, outside areas mapped as rock close to surface, the DTB is generally between 3.5 m and 8 m. On the south side of the Ardaghy ridge and along the southeastern end of the Knocknagoran valley an area of thicker subsoils with DTB greater than 5 m and up to 39 m has been mapped.

- The area in the immediate vicinity of the source along the Ryland River is underlain by alluvial subsoils. The remainder of the study area is underlain by granite till subsoils (TGr). Both subsoil types are considered to have a moderate permeability. A layer of coarse, unconsolidated material is present on top of the bedrock at the source and upgradient to the north. This layer is interpreted as glacio-fluvial deposits and/or highly weathered bedrock forming a transition zone at the top of the bedrock.

- Groundwater vulnerability where DTB is less than 3 m is extreme. The remainder of the study area is mapped as high vulnerability, except for the pocket of thicker subsoils on the southwest side of the Ardaghy ridge, which is mapped as moderately vulnerable.

- The pumping ground water level in borehole PWSBH02 was measured at 1.435 mbtc (approximately 5.18 mAOD) in June 2010. The available groundwater level data for the wider study area indicates that the groundwater levels decrease with the topographic slope, with the water table being a subdued reflection of topography. The elevation of the Ryland River riverbed is estimated to be approximately 0.39m above the pumping water level in the adjacent borehole PWSBH02.

- On the north side of the river, the hydraulic gradient and groundwater flow direction in the vicinity of borehole PWSBH02 are expected to be directed approximately southeast from the southeast end of the Knocknagoran ridge towards the Ryland River and the sea. On the south side of the river the gradient and flow direction are expected to be northeast again towards the river and the sea. Groundwater flow in the vicinity of the source is largely in high permeability fluvial deposits/shallow highly weathered zone. This high permeability zone is considered to pass underneath the river and allows the borehole to capture groundwater flow in the weathered zone from the south side of the river.

- Rainfall replenishes the groundwater system across the study area, with the infiltration amount depending on the nature and thickness of the soil and subsoil cover, and of the ability of the bedrock aquifer to accept the potential recharge.

- A proportion of groundwater flowing in the transition zone in the upper slopes of the Foxes Rock Hill discharges to surface water immediately down-gradient of the break in slope and the limit of the bedrock outcrop on the upper slopes of the hill. The remainder of groundwater recharge over the upper slopes of the hill becomes partially confined beneath the subsoil and could reach borehole PWSBH02.

- Under natural, non-pumping conditions, groundwater in the glacio-fluvial sands & gravels and/or highly weathered transition zone would be expected to have a component of discharge to the Ryland River in the vicinity of borehole PWSBH02 and another component discharging to the sea. Deeper groundwater flow would be expected to discharge to the sea. In the area underlain by alluvial subsoils, bedrock groundwater is likely to discharge to the river from the highly weathered transition zone *via* preferential pathways in the alluvial deposits.

- The hydraulic gradients in the study area are assumed to closely follow the topographic gradient and are likely to range from 0.018 – 0.045 on the north side to 0.07 on the south side of the river.

- The hydraulic gradient between the Ryland River and the pumping borehole is estimated at 0.048 towards the borehole. It is considered likely that water flows from the river to the borehole under this gradient. Leakage from the river to the borehole is likely to take place *via* preferential pathways through the intervening alluvial CLAY with stones layer. The hydraulic conditions which favour leakage from the river may also enhance the flow of groundwater underneath the river to the borehole *via* the transition zone.

- The groundwater has a low to moderate level of mineralisation and is of calcium bicarbonate type. The pH of the groundwater is slightly alkaline. Background groundwater hydrochemistry in the bedrock aquifer is more mineralized than water in the Ryland River. The water abstracted from borehole PWSBH02 lies between the two water types and is likely to be comprised of a mix of the two waters. A chloride mass balance calculation, taking the borehole water to be a mix of the river and background groundwater end-members, suggests that the ratio of river to groundwater in the abstraction is approximately 2:1.

- The transmissivity of the sand & gravel/highly weathered transition zone is expected to be in the order of 276 m^2/day. Borehole PWSBH02 is screened in a layer of 2.8 m of saturated slightly clayey GRAVEL and SAND (possible highly weathered transition zone) overlying, and hydraulically continuous with, the underlying fractured bedrock aquifer. Drawdown in borehole PWSBH02 at the current abstraction rate is estimated at approximately 0.5 m. This indicates a specific capacity of 226 m^3/day/m for the borehole, assuming that the rest water level lies above the adjacent riverbed level.

- Groundwater velocity in the sand & gravel/highly weathered transition zone in the vicinity of borehole PWSBH02 is estimated to range from 3 to 130 m/d. The velocity of water flow from the river to the borehole is estimated to range from 11 to 33 m/d.

9.2 ZOC BOUNDARIES

The ZOC is the area required to support an abstraction from long-term recharge. The ZOC is controlled primarily by (a) the total discharge, (b) the groundwater flow direction and gradient, (c) the subsoil and rock permeability and (d) the recharge in the area. The shape and boundaries of the ZOC were determined using hydrogeological mapping, water balance estimations, and the conceptual understanding of groundwater flow. The boundaries are described below along with associated uncertainties and limitations.

The water balance approach calculates the recharge area footprint required to supply a recharge volume equal to the public water supply abstraction. The current abstraction rate for borehole PWSBH02 is 113 m^3/day, however the maximum recorded abstraction is 150 m^3/day. The conceptual model for the borehole indicates that approximately one third of the borehole abstraction is derived from groundwater, with the remainder coming from leakage from the adjacent Ryland River. This suggests that the maximum groundwater demand on the borehole would be 50 m^3/day, while the maximum surface water demand would be 100 m^3day.

The ZOC water balance concept only applies to the bedrock groundwater component of the abstraction. The surface water component is drawn from the catchment of the Ryland River upstream of the borehole, which is defined by the topography of the catchment. The availability of the surface water component at any moment in time depends on the rainfall input to the catchment. Assessment of the ability of the river to continuously meet the demand of the surface water component of the abstraction is outside the scope of this document. There are no data available with respect to the long term dry weather flow in the river. During field investigations for this report in June 2010, which was a dry period, the flow in the river was estimated to be in excess of 100 l/s (8640 m^3/day), which greatly exceeds the supply's riverine component.

In order to provide a safety margin to account for the possibility that the borehole might capture more than 50 m^3/day, the groundwater zone of contribution has been delineated based on a groundwater abstraction of approximately 100 m^3/day, which is double the maximum recorded groundwater yield from the borehole.

The conceptual model indicates that the borehole is likely to capture groundwater flow in the sand and gravel/highly weathered bedrock transition zone from both the north and south sides of the river. As such, the delineated ZOC has been delineated on both sides of the river.

The recharge area required to supply a groundwater abstraction component of 100 m^3/day to borehole PWSBH02, based on an annual recharge of 100 mm, is 0.37 km^2. The ZOC for the borehole, based on the water balance and constrained by the source conceptual model has been delineated as follows.

The width of the ZOC to the north and south of the river has been determined using the uniform flow equation (Todd, 1980). This gives the maximum upgradient half-width of the ZOC as:

$Y_L = Q / (2 * T * i)$ where

Q is the daily pumping rate +/- X%

T is Transmissivity (based on the aquifer hydraulic characteristics)

i is background non-pumping hydraulic gradient.

Based on the highly weathered bedrock transition zone parameter values in Table 4, Y_L has been estimated at approximately 15 m for borehole PWSBH02. This gives the full width of the ZOC as 30 m. To the north and south of the borehole the ZOC boundaries have been delineated following flow lines along the topographic gradient to give a ZOC of approximately this width. In order to account for possible variation in the groundwater flow direction, the direction of the ZOC longitudinal axes has been varied by +/- 10^O to estimate the possible areal range of the ZOC. The entire area covered by this range has been included in the final ZOC.

On the north side of the river these flow line boundaries extend west and west-northwest from the borehole towards the southern end of the Knocknagoran ridge. On the south side of the river the flow line boundaries extend south and south-southwest. The ZOC boundaries on the south side extend up the side of Foxes Rock Hill to account for the possibility that a component of the recharge to the bedrock outcrop area could reach borehole PWSBH02 via the highly weathered transition zone (see Sections 7.2 and 8.2).

The eastern extremity of the ZOC is on the downstream side of borehole PWSBH02. This is considered to be a downgradient boundary and its location has been estimated using the uniform flow equation. The uniform flow equation gives the downgradient extreme of the ZOC (X_L) as:

$X_L = Q / (2\pi * T * i)$ where

Q is the daily pumping rate +/- X%

T is Transmissivity (based on the aquifer hydraulic characteristics)

i is background non-pumping hydraulic gradient.

Based on the highly weathered bedrock transition zone parameter values in Table 4 suggests that the downgradient extreme of the ZOC boundary lies approximately 13 m east of the borehole along the Ryland River. This value has been doubled to give a safety margin in the positioning of this boundary.

The resulting ZOC is shown in Figure 8, and captures an area of 0.11 km^2. The delineated area is considered to enclose the surface footprint supplying the estimated maximum known groundwater yield from the borehole of 50 m3/day.

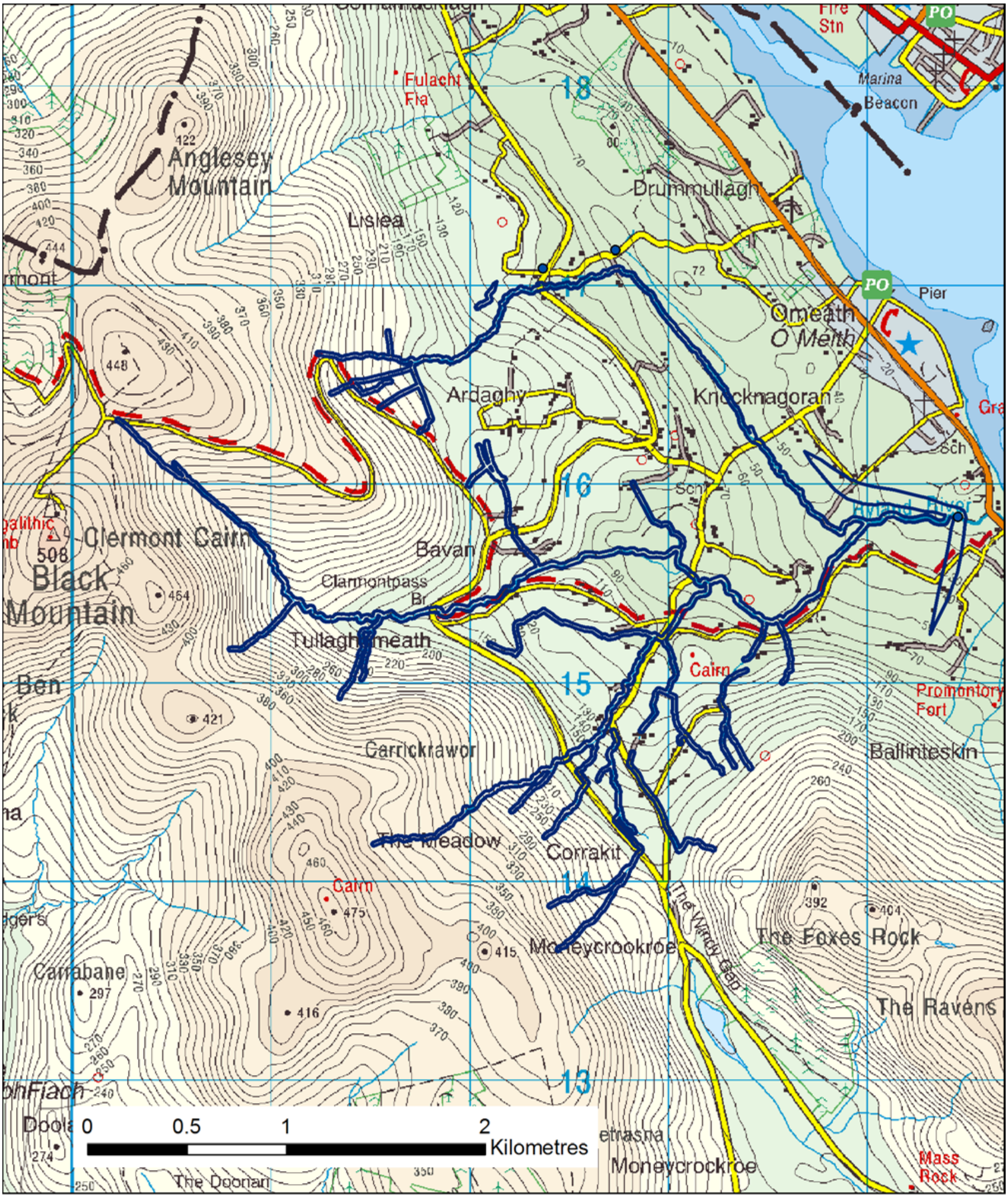


Figure 9 Zone of Contribution

PWSS Abstraction

Zone of Contribution for Esmore Bridge PWSS

9.3 RECHARGE AND WATER BALANCE

The term 'recharge' refers to the amount of water replenishing the groundwater flow system. The recharge rate is generally estimated on an annual basis, and is assumed to consist of the rainfall input (*i.e*. annual rainfall) minus any water loss prior to entry into the groundwater system (*i.e*. annual evapotranspiration and runoff). The estimation of a realistic recharge rate is critical in source protection delineation, as this dictates the size of the groundwater zone of contribution to the source (*i.e*. the outer Source Protection Area).

The hydrochemistry data indicate that only one-third of the abstraction from borehole PWSBH02 (approximately 38 m^3/day) derives from the bedrock aquifer with the remainder coming from leakage from the Ryland River. The river component (approximately 75 m^3/day) may be comprised of water deriving from any part of the surface water catchment upstream of the zone of leakage through the river bed. As such, the entire catchment is considered to be a potential source of the riverine component of the borehole abstraction.

The bedrock component of the abstraction derives from diffuse recharge to the transition zone materials and the underlying bedrock aquifer. The main parameters involved in recharge rate estimation are: annual rainfall; annual evapotranspiration; and a recharge coefficient. The recharge coefficients chosen for the different subsoil settings across the study area, based on Guidance Document GW5 (IWWG, 2005), are detailed in Table A3.1 in Appendix 3. The actual recharge is given by the potential recharge multiplied by the recharge coefficient. The potential recharge for the area is calculated as 651 mm/yr (see Section 6).

For Pl aquifers where the calculated actual recharge exceeds 100 mm/yr the Water Framework Directive Guidance Document GW5 recommends that actual recharge should be capped at 100 mm/yr. This is because Pl aquifers are generally unable to accept, and transmit from recharge area to discharge area, volumes of recharge in excess of the cap. The excess recharge overwhelms the storage capacity of the aquifer such that the aquifer fills up to the brim and the excess effective rainfall runs off to surface water. The Pl cap is also conservatively applied to the transition zone materials. The layer of transition zone materials is thin and therefore has a low storage capacity. As such, these materials are also likely to be overwhelmed by the available potential recharge.

Table A3.1 in Appendix 3 details the area occupied by each recharge setting as a percentage of the total area contributing recharge to the source borehole. In all cases the Pl aquifer recharge cap of 100 mm was applied. An actual recharge value of 100 mm/yr equates to a recharge coefficient of 0.15. After application of the recharge cap, the bulk runoff losses from the total recharge area are estimated at 85% of potential recharge. The bulk ***recharge coefficient*** for the area is therefore estimated to be 0.15. The recharge calculations are summarised in Table 6.

Table 6 Recharge Calculation Summary

Parameter	**Coefficient**	**Rate**
Average rainfall (R)		1102 mm/yr
Estimated P.E.		475 mm/yr
Estimated A.E. (95% of P.E.)		451 mm/yr
Effective rainfall		651 mm/yr
Potential recharge		651 mm/yr
Averaged runoff losses	0.85	585mm/yr
Bulk recharge coefficient	0.15	
Recharge		100 mm/yr

10. SOURCE PROTECTION ZONES

The Source Protection Zones (SPZs) are a landuse planning tool which enables an objective, geoscientific assessment of the risk to groundwater to be made. The zones are based on an amalgamation of source protection areas and the aquifer vulnerability. The source protection areas represent the horizontal groundwater pathway to the source, while the vulnerability reflects the vertical pathway. Two source protection areas have been delineated:

- Inner Protection Area (SI), designed to give protection from microbial pollution.
- Outer Protection Area (SO), encompassing the zone of contribution to the source.

The delineated source protection areas are shown in Figure 10.

10.1 OUTER PROTECTION AREA

The Outer Protection Area (SO) is bounded by the complete catchment area to the source*, i.e.* **the zone of contribution (ZOC)**, as described in Section 9.2.

10.2 INNER PROTECTION AREA

The Inner Source Protection Area (SI) is the area defined by the horizontal 100 day time of travel from any point below the water table to the source (DoELG, EPA, GSI, 1999). The 100-day horizontal time of travel to the source is calculated from the velocity of groundwater flow in the bedrock. The velocity multiplied by the 100 day time period gives the distance travelled by the groundwater during the TOT. This distance gives the lateral extent of the buffer which must be applied around the source to form the SI.

Estimated groundwater velocities in the bedrock and in the sand and gravel/transition zone in the vicinity of borehole PWSBH02 (Tables 4 and 5) indicate that over most of the ZOC, the time of travel of groundwater and any contaminants is less than 100 days. As such, the only part of the ZOC classified as SO is on the northern 'wing' of the groundwater ZOC, near to Knocknagoran Ridge.

It is estimated that water flowing from the river to the borehole will do so in less than 100 days (Section 8.4). As such, the Ryland River and tributaries upstream of the borehole have been included in the SI. A 10 m buffer zone has been applied to either side of the surface water courses to provide a measure of protection for direct runoff into the river. The additional ZOC area added by this step has not been included in the water balance calculation detailed in Section 9.3.

Groundwater protection zones are shown in Figure 11 and are based on an overlay of the source protection areas on the groundwater vulnerability. Because the river water filters through sand and gravel before reaching the borehole, and there is no evidence of bacteriological contamination at the source, the river reach is designated 'High' vulnerability. Therefore the groundwater protection zones are SI/H and SO/H.

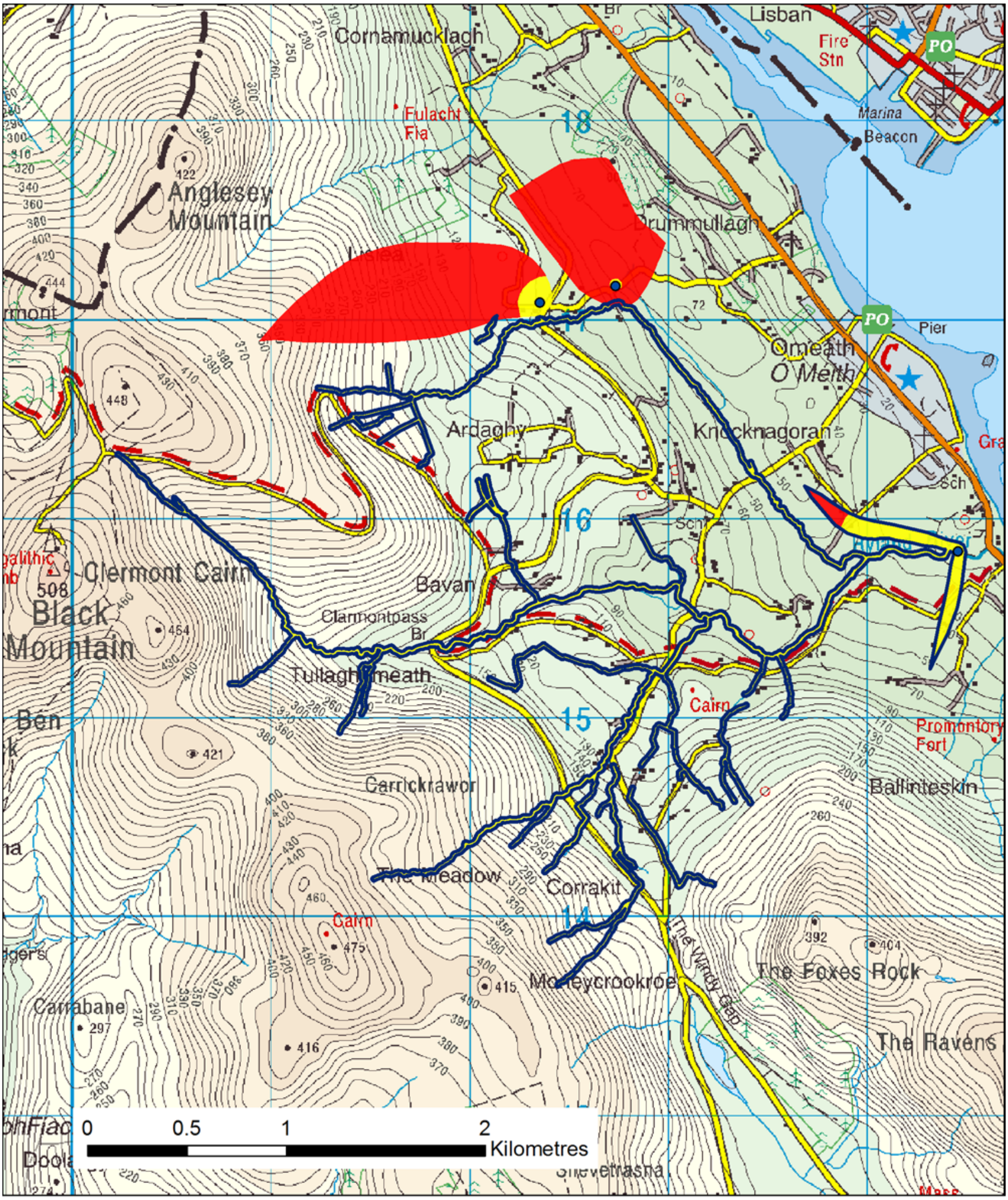


Figure 10 Source Protection Areas

- PWSS Abstraction
- Zone of Contribution for Esmore Bridge PWSS
- Inner Source Protection Zone (SI)
- Outer Source Protection Zone (SO)

NB - also shown are the SPAs for Lislea Cross PWSS

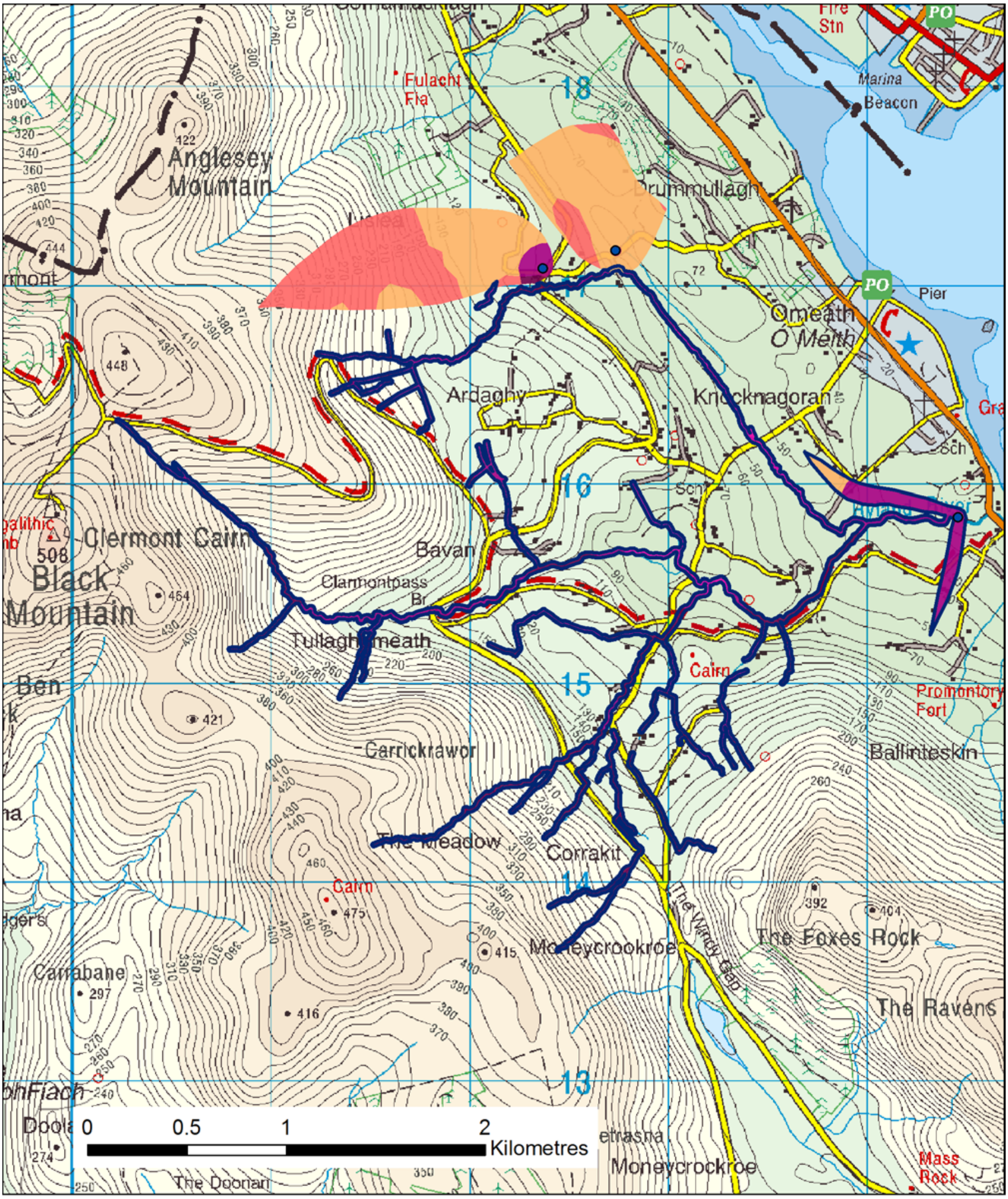


Figure 11 Source Protection Zones

- PWSS Abstraction
- Zone of Contribution for Esmore Bridge PWSS
- SI/H
- SO/H

NB - also shown are the SPZs for Lislea Cross PWSS.
SPZ legend shown only for Esmore Bridge PWSS.

11. POTENTIAL POLLUTION SOURCES

Land use within the valley is predominantly agricultural grassland and rough grazing. The main potential sources of contamination within the ZOC are:

- Direct microbial contamination of the source from surface water runoff into the well head chamber. Surface water is likely to drain into the chamber *via* the roughly broken out concrete around the services ducts. This water may be contaminated by animals and birds. The main potential contaminants from these sources are faecal bacteria, viruses and cryptosporidium.
- Agricultural land use occupies a significant component of the zone of contribution and is dominated by cattle and sheep grazing activities. It is likely that some landspreading of organic matter from agricultural sources (*e.g*. cattle slurry) takes place within the delineated ZOC. Runoff from farmyards may also be contaminated by organic matter. The main potential contaminants from this source are ammonia, nitrates, phosphates, chloride, potassium, BOD, COD, TOC, pesticides, faecal bacteria, viruses and cryptosporidium.
- Effluent discharge to ground from domestic onsite wastewater treatment systems. The main potential contaminants from this source are ammonia, nitrates, phosphates, chloride, potassium, BOD, COD, TOC, faecal bacteria, viruses and cryptosporidium.
- Private home heating fuel tanks are likely to be located within the catchment area. The main potential contaminants from this source are hydrocarbons.
- Roadways are present within the ZOC. The main potential contaminants from this source are hydrocarbons and metals.

12. CONCLUSIONS

The Omeath Esmore Bridge source is supplied by both surface water and groundwater in the estimated ratio of 2:1. A conservative ZOC for the groundwater component has been delineated, extending north and south of the borehole on either side of the Ryland River. The ZOC is based on approximately double the groundwater component from the maximum recorded abstraction rate at the borehole of 150m^3/day. The delineated ZOC is therefore considered to be conservative with respect to the groundwater component of the abstraction. The majority of the ZOC is classified as SI. A buffered zone 10 m wide on either side of the Ryland River upstream of the borehole has also been included in the ZOC and designated SI to protect the surface water derived component of the abstraction.

The pressures on the groundwater and river water are low, with low-density agriculture the main potential risk. The untreated groundwater was unpolluted at the times of measurement.

Particular care should be taken when assessing the location of any activities or developments that might cause contamination of the Esmore Bridge Source, particularly as the entire ZOC lies within the inner source protection zone (SI). Reference should be made to the guidelines contained within the DELG/EPA/GSI “Groundwater Protection Scheme” publication regarding the siting of certain activities, such as septic tanks and landspreading of organic wastes, within source protection areas.

The conclusions and recommendations of the report are based on current understanding of groundwater conditions and bedrock geology as inferred from the available data. The report should not be used as the sole basis for site-specific decisions.

13. RECOMMENDATIONS

- The well head protection measures at borehole PWSBH02 should be improved. Measures should include sealing of the well head chamber to isolate it from surface drainage and surface flooding and erecting a fenced compound around the borehole to provide a sanitary cordon of 5-10 m radius from the borehole on the north side of the Ryland River.
- Monitoring of untreated groundwater quality should continue at boreholes PWSBH02, PWSBH03 and BH02 and in the Ryland River at SWO1 to allow the seasonal range of surface and groundwater components of the abstraction to be determined by chloride mass balance.

14. REFERENCES

BS 5930:1999. Code of practice for site investigations. British Standards Institute - BSI

Collins, J.F. and Cummins, T., 1996. Agroclimatic Atlas of Ireland. Joint Working Group on Agricultural Meteorology, AGMET.

Conroy, P., Deakin, J. and Meehan, R., 2010. Establishment of Groundwater Source Protection Zones, Omeath Water Supply Scheme, Lislea Cross Borehole. Geological Survey of Ireland.

DELG/EPA/GSI, 1999. Groundwater Protection Schemes. Dept. of the Environment & Local Government; Environmental Protection Agency; Geological Survey of Ireland.

EPA website. www.epa.ie

Fitzgerald, D. and F. Forrestal, 1996. Monthly and annual averages of rainfall for Ireland 1961 to 1990. Meteorological Service Climatological Note No. 10. Glasnevin Hill, Dublin 9.

Fitzsimons, V., Daly, D. and Deakin, J., 2003. GSI Guidelines for Assessment and Mapping of Groundwater Vulnerability to Contamination. Draft Report, Geological Survey of Ireland.

Geraghty, M., 1997. Geology of Monaghan – Carlingford. A geological description to accompany the Bedrock Geology 1:100,000 Scale Map Series, Sheet 8/9, Monaghan Carlingford. Geological Survey of Ireland.

GSI website. www.gsi.ie

GSI, 1996. Bedrock Geology 1:100,000 Scale Map, Sheet 8/9. Geological Survey of Ireland.

GSI, 2004. Louth Groundwater Body – Water Framework Directive Initial Characterisation Summary – 1st Draft. Geological Survey of Ireland.

IWWG 2005. Guidance on the Assessment of the Impact of Groundwater Abstractions. Guidance Document No.GW5. Intergovernmental Working Group on Groundwater.

SI No. 278 of 2007. European Communities (Drinking Water) (No.2) Regulations 2007. Stationary Office, Dublin.

Teagasc, 2004a. Subsoils map of County Louth. Map produced as part of EPA Soils and subsoils Mapping Project. Teagasc, Kinsealy, Dublin.

Teagasc, 2004b. Soils map of County Louth. Map produced as part of EPA Soils and subsoils Mapping Project. Teagasc, Kinsealy, Dublin.

Todd, D.K., 1980. Groundwater Hydrology. 2nd Edition New York: John Wiley & Sons.

APPENDIX 1

POINT DATA, WATER QUALITY DATA & BOREHOLE DATA

- Table A1.1a – Point Data from hydrogeological Mapping
- Table A1.1b – GSI Well Database Data
- Table A1.1c – GSI Depth to Bedrock Data
- Table A1.2 – Water Quality Data For Boreholes PWSBH02, PWSBH03, BH02 & SW02
- Table A1.3 – Field Water Quality Data For Boreholes PWSBH02, PWSBH03, BH02 & SW02
- Borehole PWSBH02 Borehole Log

Table A1.1a - Point Data from Desk Study Hydrogeological Mapping - Omeath - Esmore Bridge Public Water Supply

Name	Type	Sub-type	X	Y	Description	GWL mbtc	GWL mbtc	GWL mbtc	GWL mbtc	Total Depth (m)	tc magl	GL mAOD	GWL mAOD	DTB	Exp Interval	Subsoil K
						18/06/1998	Mar-07	29/04/2010	29/06/2010							
PWSBH01	Groundwater	Borehole	312383	317093	Referred to as ' Borehole No.3 Omeath' on Des Meehan BH log. Also known as 'Lislea Cross PWS Borehole'. 'tc' = steel rim of well chamber cover = 0.63 m above top of orange PVC pipe attached to the top of the 6" steel casing. PVC pipe stuck on to keep chamber flooding out of the borehole. Pump depth approx 52m . Drilled by Des Meehan in August 1997 by rotary percussion. 6" Steel casing to 5.19mbgl (stick up approx 10 cm above chamber floor). 115mm ID PVC slotted liner 0 to 110m. Water strikes at 7.6 (13m3/d); 49m (32m3/d); 61m (78m3/d); & 94m (345m3/d). No grout seal. GWL in Mar 07 & Apr 10 = PWL; GWL on 30/6/10 = Rest GWL. GL estimated from EPA 20m grid DTM of Louth.		3.605	6.4	5.99	110	0.15	94.63	88.79	3		
PWSBH02	Groundwater	Borehole	314468	315829	Also known as 'Esmore Bridge PWS Borehole'. Drilled /completed 14/05/1984.10" SC 0 to 3.66m; 6" SC 0 to 7.31m, incorporating a 2.89m long 6" dia steel screen between 3.66 and 6.4m. Water strike in gravels between 3.66 and 6.4m. Well drilled with 10" SC to TD, 6" casing installed inside 10", gravel pack installed between 10" and 6" SC, then 10" SC retracted to 3.66m. 'tc' = top of 6" SC. BH was pumping @ 116m3/d when GWLs measured. Pump depth approx 5.5mbtc.			1.4	1.435	7.31	-0.4	7.01	5.175	6.4		
PWSBH03	Groundwater	Borehole	312741	317177	Referred to as ' Borehole No.1 Omeath' on Des Meehan BH log. Also known as 'Lislea Cross Reserve Borehole'. 'tc' = top of 6" steel casing = 0.3m below steel rim of well cover. Drilled by Des Meehan in August 1997 by rotary percussion. 6" steel casing to 9.14mbgl; No PVC liner. Water Strike @ 29m (19m3/d) & below 75m yield = 32m3/d. No grout seal. GWLs are rest levels. Borehole hydro-fractured on 25/08/1997 with packer set placed in turn at 7.m, 55m & 37m, improved yield from 32m3/d to 106m3/d. GL estimated from EPA 20m grid DTM of Louth.	1.2		0.77	0.81	95	0.23	60.5	59.92	4.87		
BH01	Groundwater	Borehole	312816	317101	Referred to as 'Borehole No.2 Omeath' in Des Meehan borehole records. Abandonned borehole approximately 200m south of PWSBH03. Borehole casing sticks up apporx 0.6m agl and is welded shut with a steel cap. GL estimated from EPA 20m grid DTM of Louth.											
BH02	Groundwater	Borehole	313437	316889	Private borehole. Drilled 05/07/2007. 8" & 6" steel casing & 5" PVC liner visible at GL. Grout seal between 8" & 6" casings, no info on grouting of annulus. 6" casing stick up = 1.44magl, which may indicate artesian GWL during winter (GWL below GL at time of visit). BH not currently in use. Water strikes @ 45m (3m3/d) & 70m (162m3/d). 'tc' = top of 6inch steel casing = 1.44magl (top of 5" PVC liner at same level). GL estimated from EPA 20m grid DTM of Louth.				9.93	79	1.44	61.43	52.94	3.05		
BH03	Groundwater	Borehole	313415	316975	Private borehole adjacent to local road and water treatment building. No borehole construction info available. Proabably drilled since 2005. 'tc' = top of 6" steel casing. BH covered with a square manhole. GL estimated from EPA 20m grid DTM of Louth.				0		0.11	60.01	60.12			
BH04	Groundwater	Borehole	312208	317209	Private Borehole. Recorded by GSI in Mar 2007. Drilled approx 2002 by Dunnes. Assume 'tc' = top of 6" steel casing & = GL		10.35			79	0	112.34	102			
SW01	Surface Water	Abstraction	312308	316964	Lislea Surface Water Abstraction Point											
SW02	Surface Water	Monitoring Point	314474	315829	Surface water quality monitoring point in the Ryland River adjacent to PWSBH02											
GW01	Groundwater	Spring	312103	317052	Spring recorded by the GSI											
GW02	Groundwater	Spring	312450	316908	Spring recorded by the GSI											
GW03	Groundwater	Spring	312970	316975	Area of "numerous springs" recorded on GSI 6-inch geology field map											

GSINAME	ORIGNAME	TYPE	DEPTH_M	DPTH_RCK_M	DTRCONFID	DRILLDATE	EASTING	NORTHING	LOC_ACC	TOWNLAND	TOWN	COUNTY	SIXINSHTNO
2931SEW017	682	Borehole	73.2	3.1	Bedrock Met	23/07/1997	312760	316550	to 50m	ARDAGHY		Louth	5
2931SEW105	NERDO L5/1B	Borehole	42	4	Bedrock Met	00:00:00	312930	316240	to 20m	ARDAGHY		Louth	5
2931SEW106	NERDO L5/1C	Borehole	33	7	Bedrock Met	00:00:00	312760	316300	to 20m	ARDAGHY		Louth	5
2931SEW019	1336	Borehole	94.5	6.1	Bedrock Met	04/06/1998	313030	316190	to 100m	ARDAGHY	oMEATH	Louth	5
2931SEW131		Borehole	91.4	13.7	Bedrock Met	20/08/2002	312400	317160	to 100m	LISLEA		Louth	5
2931SEW063	2021	Borehole	79.3	3.1	Bedrock Met	14/02/2000	313750	317010	to 1km	DRUMMULLAGH	Omeath	Louth	5
2931SEW013	628	Borehole	36.6	6.1	Bedrock Met	03/02/1997	313440	317760	to 200m	DRUMMULLAGH		Louth	2
2931SEW014	626	Borehole	54.9	12	Bedrock Met	28/01/1997	313410	317820	to 200m	DRUMMULLAGH		Louth	2
2931SEW015	627	Borehole	36.6	12	Bedrock Met	29/01/1997	313380	317890	to 200m	DRUMMULLAGH		Louth	2
2931SEW016	629	Borehole	30.5	6.1	Bedrock Met	04/02/1997	312920	317860	to 200m	DRUMMULLAGH		Louth	2
2931SEW033		Borehole	36.6	4.6	Bedrock Met	21/09/1998	313460	317880	to 200m	DRUMMULLAGH		Louth	2
GSINAME	ORIGNAME	SRCNAME	DEPTH_M	DPTH_RCK_M	DTRCONFID	DRILLDATE	EASTING	NORTHING	LOC_ACC	TOWNLAND	TOWN	COUNTY	SIXINSHTNO
2931SEW060	1684		54.9	16.8	Bedrock Met	21/06/1999	312700	314760	to 50m	CORRAKIT		Louth	5
2931SEW061			79.2	24.4	Bedrock Met	00:00:00	313380	315280	to 50m	CORRAKIT		Louth	5
2931SEW124			61	6.1	Bedrock Met	21/11/2002	312250	315880	to 50m	BAVAN		Louth	5
2931SEW130			54.9	9.1	Bedrock Met	19/08/2002	314310	316760	to 50m	KNOCKNAGORAN		Louth	5
2931SEW007			0.9	0.6		00:00:00	313940	314680	to 1km	BALLINTESKIN		Louth	5
2931SEW135	2992		54.9	27.4	Bedrock Met	18/09/2001	313180	316030	to 200m	BAVAN		Louth	5

GSINAME	SOURCEUSE	YLDCLASS	YIELD_M3D	CAS1DIA_MM	WTRSTRK1_M	WTRSTRK2_M	WTRSTRK3_M	WTRSTRK4_M	GENCOMMS	DRILLCOMMS	CASINGCOMS
2931SEW017		Poor	32.7	152	61				Driller Dunnes, Dromiskin		Yield estimated
2931SEW105		Poor	26							INFORMATION FROM THE NERDO REPORT 1981	
2931SEW106		Poor	26							INFORMATION FROM THE NERDO REPORT 1981	SILURIAN STRATA
2931SEW019		Poor	21.8	152	54.9	61	85.3	88.4	Driller Dunnes, Dromiskin		Yield estimated
2931SEW131	Agri & domestic use	Poor	15.3	203					Driller Dunnes, Dromiskin		Y estimated
2931SEW063	Domestic use only	Poor	6.5	203					Drilled by Dunnes, Dundalk		Yield estimated
2931SEW013		Moderate	43.6	152					Driller Dunnes, Dromiskin		Yield estimated
2931SEW014	Domestic use only	Poor	13.1	152	42.7				Driller Dunnes, Dromiskin		Yield estimated
2931SEW015	Domestic use only	Moderate	55	152	24.4				Driller Dunnes, Dromiskin		Yield estimated
2931SEW016		Moderate	76.6	152					Driller Dunnes, Dromiskin		Yield estimated
2931SEW033	Domestic use only	Poor	21.8	152	18.3	30.5			Drilled by Dunnes, Dundalk		Yield estimated
2931SEW060	Domestic use only	Moderate	54.5	152	36.6				Drilled by Dunnes, Dundalk		Yield estimated
2931SEW061	Domestic use only	Poor	27.3	152					Drilled by Dunnes, Dundalk		Yield estimated
2931SEW124	Agri & domestic use	Poor	19.6	203					Driller Dunnes, Dromiskin		Y estimated
2931SEW130	Agri & domestic use	Moderate	54.5	152					Driller Dunnes, Dromiskin		Y estimared
2931SEW007											
2931SEW135	Domestic use only	Good	131	203					Drilled by Dunnes, Dundalk		Yield estimated

GSI Sources

Table A1.1c - Other known GSI Data Points in Study Area - Omeath - Esmore Bridge Public Water Supply

Type	Name	DTB	EASTING	NORTHING	Subsoil_K	SubSL_Desc
Exposure	4d	1.5	313006	315210	Moderate	Firm, sandy SILT with frequent gravels.
Exposure	4e	5	314220	315566	High	gravelly SAND with frequent cobbles.
Exposure	5b	2	313613	317127	High	Soft, gravelly SAND with frequent cobbles.
OMBH	OMBH08	1	312829	317381		
OMBH	OMBH09	1.5	312716	316289		
OMBH	OMBH06	2.9	312196	317014		
OMBH	OMBH02	3.5	314123	316123	High	Very dense, coarse grained sandy GRAVEL.
OMBH	OMBH10	4	312568	317057	High	Very dense SAND.
OMBH	OMBH05	4.5	312397	317094	High	Very sandy, GRAVEL.
OMBH	OMBH07	4.5	312403	317096	High	Loose, sandy GRAVEL.
OMBH	OMBH03	6	314258	316023	High	Very dense becoming soft, very silty GRAVEL.
OMBH	OMBH01	8	314054	315732		
OMBH	OMBH11	7	313179	315849	High	Sandy, coarse GRAVEL.
OMBH	OMBH12	2	313832	315897		
OtherDTB		0.3	312260	315840		
OtherDTB		16.8	312670	314740		
OtherDTB		21.34	313663.4913	315455.3801		
OtherDTB		24.4	313340	315280		
OtherDTB		39.6	313252	315939		
OtherDTB		3.048	311939	316432		
OtherDTB		3.05	313104.8801	316225.8569		
OtherDTB		4.57	312341	317161		
OtherDTB		9.1	314310	316760		

Table A1.2 - Louth County Council EPA Water Quality Data for Omeath PWS Source (Esmore Bridge - PWSBH02)

			mg/l NO3	mg/l Ca	mg/l Mg	mg/l K	mg/l Na	mg/l Cl	mg/l NO2	mg/l SO_4	mg/l $CaCO_3$	mg/l $CaCO_3$	uS/cm	ug/l Al
GSI Name	**Date**		**NO3**	**Ca**	**Mg**	**K**	**Na**	**Cl**	**NO2**	**SO4**	**Alk**	**Hard**	**Cond**	**Al**
	Jan-82	**Threshold**	**37.5**				**150**	**24**	**0.375**	**187.5**			**800**	**150**
	Jan-82	**DWS**	**50**				**200**	**250**	**0.5**	**250**			**2500**	**200**
GSI Name	**Date**		**NO3**	**Ca**	**Mg**	**K**	**Na**	**Cl**	**NO2**	**SO4**	**Alk**	**Hard**	**Cond**	**Al**
PWSBH02 (ESM2900948)	02-Apr-09		4.25					331			60.0		1251	
PWSBH02 (ESM2901247)	07-May-09		4.16					13.0			55.0		161	
PWSBH02 (ESM2904198)	18-Nov-09		3.72					547			79.0		1923	
PWSBH02 (ESM1001140)	26-Apr-10		3.85	<1	<1	<1	45.21	30.0	<0.007	5.60	52.0	<9	214	<10
PWSBH02	29-Jun-10	6.62	2.85	13.0	2.70	0.880	8.30	11.6		5.25	37.6	121	120	
BH02	29-Jun-10	7.99	1.46	29.0	3.50	0.310	11.0	13.0		5.96	82.1		197	
PWSBH03	29-Jun-10	7.01	0.66	51.0	6.40	0.760	14.0	13.3		11.2	148		318	
Ryland River	29-Jun-10	7.80	1.28	9.40	2.50	0.970	8.10	10.7		6.21	30.9		98.0	
	PWSBH02 Average	mg/l	3.77				26.8	187		5.43	56.7		734	
		PWSBH02 on 29/06/2010												
		mmol/l	0.05	0.33	0.11	0.02	0.36	0.33		0.05	0.38	mmol of CaCO3 = mmol of CO3--		
		MW	62.00	40	25.31	39.1	22.99	35.45	47	96.066	100			
		charge	1	2	2	1	1	1	1	2	2			
		meq/l	0.05	0.65	0.21	0.02	0.36	0.33		0.11	0.75	meq of CO3-- = meq of HCO3-		
											0.75	mmol HCO3-		
		meq cations	1.25								45.87	mg/l as HCO3-		
		meq anions	1.23											

Red colour denotes result in excess of Drinking Water Standard (DWS)
Orange Colour denotes result in excess of EPA Threshold

Source: available Louth County Council EPA data.

Table A1.3 - Field Water Quality Data - Omeath - Esmore Bridge Public Water Supply

							degC	uS/cm	degC	mg/l O2	%	degC	mg/lCaCO3	
Name	X	Y		Time	RWL	pH	Tph	EC	Tec	DO	DO	Tdo	Alk	Ref
PWSBH01	312383	317093	30/06/2010	10:20	5.99	6.67	13.1	300	13.2	4.07	40	14	86	steel rim of chamber
PWSBH01	312383	317093	30/06/2010	15:15	5.99	6.78	13	294.2	12.9	5	45	13.8	84	steel rim of chamber
SW01	314474	315829	29/06/2010	11:30	-	8.38	15.1	108.5	15	10.25	103.6	15.4	28	
PWSBH02	314472	315831	29/06/2010	12:00	1.435	6.6	11.4	123.4	11.4	1.83	16.9	12	36.5	top of 6" Steel Casing
BH02	313437	316889	29/06/2010	15:05	9.93	8.25	10.5	207.9	10.7	1.33	12.5	11.9	77	top of 6" Steel Casing
PWSBH03	312741	317177	29/06/2010	16:45	0.81	7.02	10.5	332	10.6	0	0	11.5	133	top of 8" Steel Casing

Table A1.2 - Louth County Council EPA Water Quality Data for Omeath PWS Source (Esmore Bridge - PWSBH02)

		ug/l Fe	ug/l Mn	mg/l NH4	No./100ml	No./100ml	ug/l Ba	mg/l B	mg/l Cd	ug/l Cr	mg/l Cu	mg/l F^-	mg/l Pb	ug/l Hg	ug/l Ni
GSI Name	**Date**	**Fe**	**Mn**	**NH4**	**TC**	**F. coli**	**Ba**	**B**	**Cd**	**Cr**	**Cu**	**F**	**Pb**	**Hg**	**Ni**
	Jan-82			**0.23**				**0.75**	**0.00375**	**37.5**	**1.5**		**0.01875**	**0.75**	**15**
	Jan-82	**200**	**50**	**0.3**	**0**	**0**		**1**	**0.005**	**50**	**2**	**1.5**	**0.025**	**1**	**20**
GSI Name	**Date**	**Fe**	**Mn**	**NH4**	**TC**	**F. coli**	**Ba**	**B**	**Cd**	**Cr**	**Cu**	**F**	**Pb**	**Hg**	**Ni**
PWSBH02 (ESM2900948)	02-Apr-09			< 0.039											
PWSBH02 (ESM2901247)	07-May-09			< 0.039											
PWSBH02 (ESM2904198)	18-Nov-09			< 0.039				B							
PWSBH02 (ESM1001140)	26-Apr-10	<10	<1	<0.039	0	0		<0.01	<0.0001	<1	0.002	<0.15	<0.001	<0.1	<1
PWSBH02	29-Jun-10			<0.009											
BH02	29-Jun-10			<0.009											
PWSBH03	29-Jun-10			0.065											
Ryland River	29-Jun-10			0.015											
PWSBH02 Average					0	0					0.002				

Red colour denotes result in excess of Drinking Water Standard (DWS)

Orange Colour denotes result in excess of EPA Threshold

Source: available Louth County Council EPA data.

Table A1.2 - Louth County Council EPA Water Quality Data for Omeath PWS Source (Esmore Bridge - PWSBH02)

		mg/l P	mg/l P	mg/l Se	mg/l Ag	mg/l Sr
GSI Name	**Date**	**PO4**	**P**	**Se**	**Ag**	**Sr**
	Jan-82	0.035				
	Jan-82			0.01		
GSI Name	**Date**	**PO4**	**P**	**Se**	**Ag**	**Sr**
PWSBH02 (ESM2900948)	02-Apr-09	<0.02				
PWSBH02 (ESM2901247)	07-May-09	<0.02				
PWSBH02 (ESM2904198)	18-Nov-09	<0.02				
PWSBH02 (ESM1001140)	26-Apr-10	<0.02	<0.007	<0.001		
PWSBH02	29-Jun-10					
BH02	29-Jun-10					
PWSBH03	29-Jun-10					
Ryland River	29-Jun-10					
	PWSBH02 Average					

Red colour denotes result in excess of Drinking Water Standard (DWS)
Orange Colour denotes result in excess of EPA Threshold

Source: available Louth County Council EPA data.

Table A1.2 - Louth County Council EPA Water Quality Data for Omeath PWS Source (Esmore Bridge - PWSBH02)

		mg/l Zn	mg/l Sb	mg/l As	[-]	%	deg C	mg/l C	mg/l O2	mg/l O2	mg/l O2	mg/l O_2
GSI Name	**Date**	**Zn**	**Ant**	**As**	**K/Na Ratio (using meq)**	**DO (% Sat)**	**pH**	**Temp**	**TOC**	**COD**	**BOD**	**DO**
	Jan-82			0.0075	0.4							
	Jan-82		0.005	0.001			>6.5 & < 9.5					
GSI Name	**Date**	**Zn**	**Ant**	**As**	**K/Na Ratio**							
PWSBH02 (ESM2900948)	02-Apr-09					64	7.50	9.50	2.3	27	<2.0	
PWSBH02 (ESM2901247)	07-May-09					44	7.00	11.2	2.2	<10	<1.5	
PWSBH02 (ESM2904198)	18-Nov-09					52	7.00	9.60	<3.0	151	<5.0	
PWSBH02 (ESM1001140)	26-Apr-10	<0.001	<0.001	<0.001		74	6.80	14.3	<1.5			
PWSBH02	29-Jun-10				0.11	17	6.62	11.4				1.83
BH02	29-Jun-10				0.03	13	7.99	10.5				1.33
PWSBH03	29-Jun-10				0.05	0	7.01	10.5				0
Ryland River	29-Jun-10				0.12	103	7.80	15.1				10.3
	PWSBH02 Average						6.98	11.2				

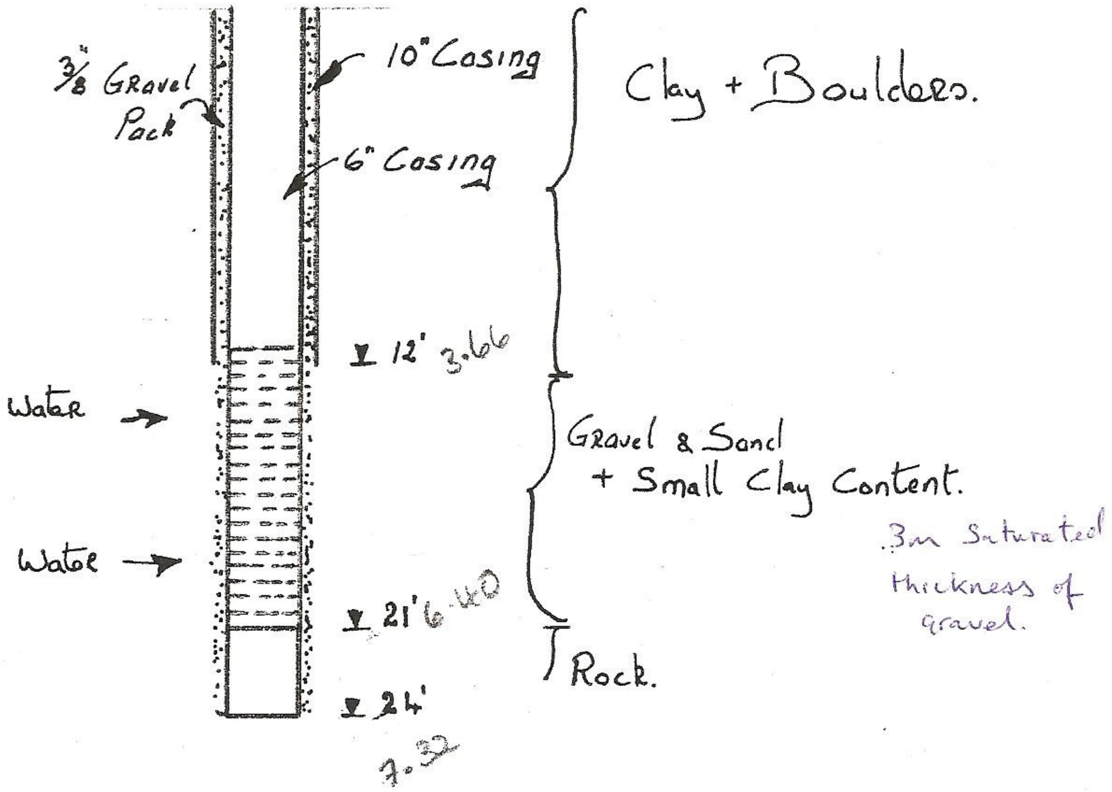
Red colour denotes result in excess of Drinking Water Standard (DWS)

Orange Colour denotes result in excess of EPA Threshold

Source: available Louth County Council EPA data.

(ESMORE BRIDGE) **Borehole at Omeath**

Completed 14/5/84.



The borehole was drill to Rock & Lined with 10" Casing
A 9'6" (2.89m) Screen was welded to 6" Casing & installed as shown above. A gravel pack was placed between the 10" Casing & the 6" Screen. Subsequently the 10" Casing was withdrawn to within 12 ft of the ground level.

APPENDIX 2

Laboratory Water Quality Reports

Note on Laboratory Water Quality Reports:

It is the opinion of the author that the data provided in the laboratory water quality reports for boreholes PWSBH02 and BH02 have been transposed. Field measured pH, EC and Alkalinity data corroborate this, with the field data for borehole PWSBH02 closely matching the laboratory reported data for borehole BH02 and vice versa. The chloride datum reported as belonging to borehole PWSBH02 is almost identical to that for PWSBH03. Conceptually it is more likely for this to be the case for borehole BH02, which agrees with the field data.

This discrepancy was noticed after the laboratory had discarded the samples. The laboratory paperwork supports the final laboratory report.

In this report the laboratory data have been interpreted in line with the field data. Re-sampling of the boreholes would be required to definitively confirm that the interpretation used here is correct.

SEVERN TRENT STL

Ms Clinton
O'Connell Agricultural Consultants
TBD
Enfield Meath

14 July 2010

Test Report: BRD/705544/2010

Dear Ms Clinton

Analysis of your sample(s) submitted on 01 July 2010 is now complete and we have pleasure in enclosing the appropriate test report(s).

An invoice for the analysis carried out is included with this report.

Should you have any queries regarding this report(s) or any part of our service, please contact Customer Services on +44 (0)16 5664 7557 who will be happy to discuss your requirements.

If you would like to arrange any further analysis, please contact Customer Services. To arrange container delivery or sample collection, please call the Couriers Department directly on 024 7685 6562.

Thank you for using STL and we look forward to receiving your next samples.

Yours Sincerely,

Signed:

Name: R. Robins

Title: Team Leader

Report Summary

1314
0897
1229
1510

Ms Ruth Clinton
O'Connell Agricultural Consultants
TBD
Enfield
Meath

Date of Issue: **14 July 2010**

Report Number: **BRD/705544/2010** Issue **1**

Job Description: Water analysis

Number of Samples included in this report **4**

Job Received: **01 July 2010**

Number of Test Results included in this report **44**

Analysis Commenced: **01 July 2010**

Signed: R Robins

Name: **R. Robins** Date: **14 July 2010**

Title: **Team Leader**

STL was not responsible for sampling unless otherwise stated. Sampling is not covered by our UKAS accreditation.

Information on the methods of analysis and performance characteristics are available on request.
Opinions and interpretations expressed herein are outside the scope of UKAS accreditation. The results relate only to the items tested.
Tests marked 'Not UKAS Accredited' in this Report/Certificate are not included in the UKAS Accreditation Schedule for our laboratory.

Certificate of Analysis

1314
0897
1229
1510

SEVERN TRENT STL

Report Number: **BRD/705544/2010** Issue **1**
Laboratory Number: **11842265** Sample **1** of **4**

Sample Source: **O'Connell Agricultural Consultants**
Sample Point Description: **O'Connell Agricultural Consult**
Sample Description: **SW01 Rylond River**
Sample Matrix: **Clean waters**

Sample Date: **29 June 2010** Sample Received **01 July 2010** Analysis Complete: **06 July 2010**

Test Description	Result	Units	Accreditation		Method
Calcium, Filtrate as Ca	9.4	mg/l	Y	Brd	SBC64
Magnesium, Filtrate as Mg	2.5	mg/l	Y	Brd	SBC64
Potassium, filtrate as K	0.97	mg/l	Y	Brd	SBC64
Sodium, Filtrate as Na	8.1	mg/l	Y	Brd	SBC64
Hydrogen ion (pH)	7.80		Y	Brd	SBE17
Conductivity	98	uS/cm	Y	Brd	SBE17/SBE 14
Alkalinity as CaCO3	30.9	mg/l	Y	Brd	SBC51
Ammonium ammonia+ammonium ion	0.015	mg/l	Y	Brd	SBC01
Chloride as Cl	10.7	mg/l	Y	Brd	SBC04
Nitrate as NO3	1.28	mg/l	Y	Brd	SBC39
Sulphate as SO4	6.21	mg/l	Y	Brd	SBC07

Analyst Comments for 11842265: No Analyst Comment

Accreditation Codes: Y = UKAS Accredited, N = Not UKAS Accredited, M = MCERTS.
Analysed at: Brd = STL Bridgend, Cov = STL Coventry, Mid = STL Midlands, Rea = STL Reading, Run = STL Runcorn, S = Subcontracted.
For Microbiological determinands 0 or ND=Not Detected, For Legionella ND=Not Detected in volume of sample filtered. Relating to Legionella volume analysed 1g is approximately equivalent to 1ml.
I/S=Insufficient sample

Certificate of Analysis

1314
0897
1229
1510

Report Number: **BRD/705544/2010** Issue **1**
Laboratory Number: **11842266** Sample **2** of **4**

Sample Source: **O'Connell Agricultural Consultants**
Sample Point Description: **O'Connell Agricultural Consult**
Sample Description: **Esmore Bdg PWS BH02**
Sample Matrix: **Clean waters**

Sample Date: **29 June 2010** Sample Received **01 July 2010** Analysis Complete: **06 July 2010**

Test Description	Result	Units	Accreditation		Method
Calcium, Filtrate as Ca	29	mg/l	Y	Brd	SBC64
Magnesium, Filtrate as Mg	3.5	mg/l	Y	Brd	SBC64
Potassium, filtrate as K	0.31	mg/l	Y	Brd	SBC64
Sodium, Filtrate as Na	11	mg/l	Y	Brd	SBC64
Hydrogen ion (pH)	7.99		Y	Brd	SBE17
Conductivity	197	uS/cm	Y	Brd	SBE17/SBE 14
Alkalinity as CaCO3	82.1	mg/l	Y	Brd	SBC51
Ammonium ammonia+ammonium ion	<0.009	mg/l	Y	Brd	SBC01
Chloride as Cl	13.0	mg/l	Y	Brd	SBC04
Nitrate as NO3	1.46	mg/l	Y	Brd	SBC39
Sulphate as SO4	5.96	mg/l	Y	Brd	SBC07

Analyst Comments for 11842266: No Analyst Comment

Accreditation Codes: Y = UKAS Accredited, N = Not UKAS Accredited, M = MCERTS.
Analysed at: Brd = STL Bridgend, Cov = STL Coventry, Mid = STL Midlands, Rea = STL Reading, Run = STL Runcorn, S = Subcontracted.
For Microbiological determinands 0 or ND=Not Detected, For Legionella ND=Not Detected in volume of sample filtered. Relating to Legionella volume analysed 1g is approximately equivalent to 1ml.
I/S=Insufficient sample

Certificate of Analysis

1314
0897
1229
1510

SEVERN TRENT STL

Report Number: **BRD/705544/2010** Issue **1**
Laboratory Number: **11842267** Sample **3** of **4**

Sample Source: **O'Connell Agricultural Consultants**
Sample Point Description: **O'Connell Agricultural Consult**
Sample Description: **BH02**
Sample Matrix: **Clean waters**

Sample Date: **29 June 2010** Sample Received **01 July 2010** Analysis Complete: **06 July 2010**

Test Description	Result	Units	Accreditation		Method
Calcium, Filtrate as Ca	13	mg/l	Y	Brd	SBC64
Magnesium, Filtrate as Mg	2.7	mg/l	Y	Brd	SBC64
Potassium, filtrate as K	0.88	mg/l	Y	Brd	SBC64
Sodium, Filtrate as Na	8.3	mg/l	Y	Brd	SBC64
Hydrogen ion (pH)	6.62		Y	Brd	SBE17
Conductivity	120	uS/cm	Y	Brd	SBE17/SBE 14
Alkalinity as CaCO3	37.6	mg/l	Y	Brd	SBC51
Ammonium ammonia+ammonium ion	<0.009	mg/l	Y	Brd	SBC01
Chloride as Cl	11.6	mg/l	Y	Brd	SBC04
Nitrate as NO3	2.85	mg/l	Y	Brd	SBC39
Sulphate as SO4	5.25	mg/l	Y	Brd	SBC07

Analyst Comments for 11842267: No Analyst Comment

Accreditation Codes: Y = UKAS Accredited, N = Not UKAS Accredited, M = MCERTS.
Analysed at: Brd = STL Bridgend, Cov = STL Coventry, Mid = STL Midlands, Rea = STL Reading, Run = STL Runcorn, S = Subcontracted.
For Microbiological determinands 0 or ND=Not Detected, For Legionella ND=Not Detected in volume of sample filtered. Relating to Legionella volume analysed 1g is approximately equivalent to 1ml.
I/S=Insufficient sample

Certificate of Analysis

UKAS TESTING
1314
0897
1229
1510

SEVERN TRENT STL

Report Number: **BRD/705544/2010** Issue **1**
Laboratory Number: **11842268** Sample **4** of **4**

Sample Source: **O'Connell Agricultural Consultants**
Sample Point Description: **O'Connell Agricultural Consult**
Sample Description: **Reserve BH**
Sample Matrix: **Clean waters**

Sample Date: **29 June 2010** Sample Received **01 July 2010** Analysis Complete: **06 July 2010**

Test Description	Result	Units	Accreditation		Method
Calcium, Filtrate as Ca	51	mg/l	Y	Brd	SBC64
Magnesium, Filtrate as Mg	6.4	mg/l	Y	Brd	SBC64
Potassium, filtrate as K	0.76	mg/l	Y	Brd	SBC64
Sodium, Filtrate as Na	14	mg/l	Y	Brd	SBC64
Hydrogen ion (pH)	7.01		Y	Brd	SBE17
Conductivity	318	uS/cm	Y	Brd	SBE17/SBE 14
Alkalinity as CaCO3	148	mg/l	Y	Brd	SBC51
Ammonium ammonia+ammonium ion	0.065	mg/l	Y	Brd	SBC01
Chloride as Cl	13.3	mg/l	Y	Brd	SBC04
Nitrate as NO3	0.66	mg/l	Y	Brd	SBC39
Sulphate as SO4	11.2	mg/l	Y	Brd	SBC07

Analyst Comments for 11842268: No Analyst Comment

Accreditation Codes: Y = UKAS Accredited, N = Not UKAS Accredited, M = MCERTS.
Analysed at: Brd = STL Bridgend, Cov = STL Coventry, Mid = STL Midlands, Rea = STL Reading, Run = STL Runcorn, S = Subcontracted.
For Microbiological determinands 0 or ND=Not Detected, For Legionella ND=Not Detected in volume of sample filtered. Relating to Legionella volume analysed 1g is approximately equivalent to 1ml.
I/S=Insufficient sample

Signed: R Robins

Name: **R. Robins** Date: **14 July 2010**
Title: **Team Leader**

APPENDIX 3

Recharge coefficients for the study area

Table A3.1 Recharge coefficients for the study area

Vulnerability	Location in Study Area	Additional Factors	% Area	Recharge Coefficient Guidance		Chosen Recharge Coefficient	Calculated Recharge	Recharge after PI Recharge Cap
				Inner Range	Outer Range		(mm/yr)	(mm/yr)
High	Till subsoils across the study area with well drained soils	Generally moderate slopes underlain by moderate permeability subsoils	48.7	50 - 70%	35 - 80%	0.6	391	100
	Till subsoils across the study area with poorly drained soils	Generally moderate slopes underlain by moderate permeability subsoils	0.7	25 - 40%	15 - 50%	0.35	163	100
Extreme (E)	Till subsoils around outcrop on The Foxes Rock Hill and on Knocknagoran Ridge with well drained soils	Moderate to steep slope	5.0	50 - 70%	45 - 80%	0.6	391	100
	Till subsoils around outcrop on The Foxes Rock Hill with poorly drained soils	Moderate to steep slope	1.1	25 – 40%	15 - 50%	0.35	163	100
Extreme (X)	Bedrock outcrop on The Foxes Rock Hill	Moderate to steep slope	44.5	80 – 90%	60 – 100%	0.7	456	100