

Environmental Protection Agency

Establishment of Groundwater Source Protection Zones

Trim Water Supply Scheme Trim Borehole

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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.

The project "Establishment of Groundwater Source Protection Zones", led by the Environmental Protection Agency (EPA), represents a continuation of the GSI's work. A CDM/TOBIN/OCM project team has been retained by the EPA to establish Groundwater Source Protection Zones at monitoring points in the EPA's National Groundwater Quality Network.

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).



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APPENDIX

Appendix 1 Borehole log

1 Introduction

Groundwater Source Protection Zones are delineated for the Trim Borehole 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 borehole supplies approximately 375 m³/day to the town of Trim, Co. Meath. The borehole is located within the confines of Trim Waterworks in Scurlockstown townland, just outside the town. The borehole is used as a top up for the surface water abstraction from the River Boyne.

The objectives of the report are as follows:

- To outline the principal hydrogeological characteristics of the Scurlockstown area.
- To delineate source protection zones for the Trim Borehole.
- To assist the Environmental Protection Agency and Meath County Council in protecting the water supply from contamination.

The protection zones are intended to provide a guide in the planning and regulation of development and human activities to ensure groundwater quality is protected. More details on protection zones are presented in 'Groundwater Protection Schemes' (DELG/EPA/GSI, 1999).

2 Methodology

The methodology applied to delineate the SPZ consisted of data collection, desk studies, site visits and field mapping and subsequent data analysis and interpretation.

The initial site visit and interview with the caretaker took place on 17/07/2010. Site walk-overs and field mapping (including measuring the electrical conductivity and temperature of streams) of the study area were conducted on 17/07/2010 and 22/07/2010.

While specific fieldwork was carried out in the development of this report, the maps produced are based largely on the readily available information in the area 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.

3 Location, site description and well head protection

The Trim Borehole, operated by Meath County Council since 2005, is located approximately 1 km to the southeast of Trim at Scurlockstown, within the River Boyne catchment (See Figure 1).

The borehole is located to the southeastern boundary of the Trim Waterworks, approximately 0.3 km south of the R154 road. The groundwater is pumped to a reservoir where the untreated water is chlorinated. The annulus around the borehole does not appear to be grouted. The borehole cover and surrounding area is securely covered and locked while the site compound is secured by palisade fencing. Photograph 1 shows

the location of the production borehole. During the site visit in July 2010, the borehole pump had been removed for repairs.



Figure 1 Location map of the area around Trim borehole



Photograph 1 Borehole and adjacent pipeworks

4 Summary of borehole details

A production borehole (PW1) was drilled in December 2004. Drilling, which was carried out by Briodys, encountered 9.1 m of 'boulders and clay' overlying bedrock. The underlying bedrock was fractured/weathered shale and limestone between 9.1 m and 47.9 m bgl, becoming relatively competent with groundwater inflows encountered at 67.1 and 85 m bgl (see Appendix I). The borehole casing was completed towards the top of the weathered bedrock, at 9.1 m bgl.

A 9-day pumping test was initially carried out on PW1 in January 2005. From the pumping test information, pumping at 26.5 m^3 /hour for 9 days resulted in a drawdown of 15 m. Water levels recovered 14 m within 4 hours.

The borehole log is provided in Appendix I. Table 4.1 provides a summary of the well details as currently known.

Table 4.1 Summary details

	Trim Borehole		
EU Reporting Code	IE_EA_G_002_17_011		
Grid reference	E282890 N255970		
Townland	Scurlockstown		
Source type	Borehole		
Drilled	2004		
Owner	Meath Co. Co.		
Elevation (Ground Level)	c. 53.5 mOD		
Depth	85 m		
Depth of casing	Inner Casing 85 m; Outer casing 9.2 m		
Diameter	Inner Casing 0.125 m uPVC. Outer Casing 0.25 m & 0.35 Steel.		
Depth to rock	9.1 m		
Static water level	2.37 m bgl		
Consumption (Co. Co. records)	375 m ³ /d		
Specific capacity	42 m ³ /day/m		
Transmissivity	225 m²/day		

5 Topography, surface hydrology and landuse

Trim Borehole is located 50 m east of the Knightsbrook River within the River Boyne catchment (Hydrometric Area 07). The Knightsbrook River discharges to the River Boyne 450 m downstream and to the north of the source.

The Boycetown River is located 350 m to the east of the Trim Borehole and discharges to the River Boyne downstream of the Knightsbrook – Boyne confluence. A number of smaller, unnamed streams flow into the Knightsbrook River and Boycetown River up-gradient of the source borehole (Refer to Figure 1).

The land rises gently to the south and east of the source. Along the northern banks of the Knightsbrook River a former mill race and buildings are present. While no longer in use, minor water flows were noted in the mill race. The topography along the Knightsbrook River flood plain is relatively flat with a moderate to gentle slope of 1:10 to 1:100 along the southern bank. A steep slope of 1:4 is present on the northern bank at the Mill Race. Drainage/flood relief programmes in the 1980's appear to have deepened the Knightsbrook River with spoil heaps located adjacent to the river. The banks of the Knightsbrook River, which have been modified as a result of drainage works, are near vertical (approximately 2 m in height) in profile in the vicinity of the source.

Land use in the area is primarily agricultural, with lands set to pasture or used for tillage. A number of farmyards have been noted in the area, two of which were identified within 250 m of the borehole. Some land reclamation/raising has taking place to the east of the source between the Boycetown and Knightsbrook Rivers.

The Scurlockstown area has a moderate housing density of one-off houses within 500 m of the source. No major industry was identified in the environs of Trim Borehole. Drainage ditches are generally absent, with well drained soils surrounding the borehole.

6 HYDROMETEROLOGY

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

Annual rainfall: 814 mm. The closest meteorological station to Trim borehole is located 2.5 km to the northwest at Trim gauging station. Data records used (814 mm at Trim gauging station) are based on Met Éireann data for long term annual average rainfall (Fitzgerald and Forrestal, 1996). Data from the Met Eireann website (<u>www.met.ie</u>) also shows that the source is located between the 800 mm and 1000 mm average annual rainfall isohyets.

Annual evapotranspiration losses: 428 mm. Potential evapotranspiration (P.E.) is estimated to be 450 mm/yr (based on data from Collins and Cummins, 1996). Actual evapotranspiration (A.E.) is then estimated as 95% of P.E., to allow for seasonal soil moisture deficits.

Annual Effective Rainfall: **386 mm**. The annual effective rainfall is calculated by subtracting actual evapotranspiration from rainfall. Potential recharge is therefore equivalent to this, or 386 mm/year.

7 Geology

7.1 Bedrock geology

This section briefly describes the relevant characteristics of the geological materials that underlie the Trim Borehole. 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 the Bedrock Geological Map of Meath Sheet 13, 1:100,000 Series (McConnell *et al*, 2001) and the GSI Karst Database.

The Bedrock Geological Map of Meath indicates that this area is principally underlain by Dinantian Upper Impure Limestones (Lucan Formation). Refer to Figure 2 for the geology map of the area. These limestones are overlain, 1.3 km to the northwest, by undifferentiated Namurian Deposits.

Bedrock lithologies recorded while drilling the borehole source (PW1) consisted of dark grey limestones and shales, with some units of highly weathered limestones. Fissures/fractures were encountered at 47.9, 61 and 85 m bgl. Bedrock exposures within the Knightsbrook River show mid to dark-grey, strong, argillaceous limestones with subordinate black to dark grey calcareous shales and minor fissile poorly calcareous shales. Bedrock at this exposure was moderately dipping (10^{0}) to the east. Refer to Figure 2 Bedrock geology map around Trim borehole.



Figure 2 Geology map of the area around Trim borehole

7.2 Subsoils geology

According to GSI and EPA web mapping, the study area is dominated by subsoils comprising sand and gravel deposits derived from limestone (GLs) and till derived from limestone (TLs).

A beaded esker and fan complex is present underlying the Scurlocktown area and is orientated northwest and southeast. Surrounding, and potentially underlying portions of the esker fan complex are till deposits. More recent alluvial and lacustrine deposits have been deposited along the main rivers and streams in the area.

Based on information from the borehole log of PW1, the underlying subsoil at the borehole is comprised of boulders and clay to 9.1 m. The bedrock exposures 50 m to the north, along the Knightsbrook River, indicate that bedrock between S4 and S5 is approximately 2 m bgl. Based on this information it is possible that the borehole may have encountered elements of weathered bedrock within the subsoil in the borehole, between 0 and 9.1 m bgl.

A number of soil and subsoil exposures were noted in the area surrounding the source. Where exposures were noted, they were typically limited at less than 2 m depth. At S1, approximately 300 m north of Trim Borehole, adjacent to the R154, gravel deposits were described using BS5930 as grey, loose, slightly silty sandy GRAVEL. A number of small gravel pits are evident on the OSI 25" maps to the north and east of Trim Borehole and appear to confirm the presence of sand and gravel deposits as mapped on Figure 3. At S2,

approximately 200 m north of the Trim borehole, stiff, slightly gravelly sandy CLAY was evident in the alluvial deposits. Along the banks of the Knightsbrook River, occasional sand and gravel lenses were evident within the alluvial deposits. Refer to Figure 3 for the subsoils map.

The soils on the till and sand and gravel areas are mapped as 'dry' soil types: typically well drained deep mineral soils (BminDW) and well drained shallow soils (BminSW) (EPA webmapping). Areas of alluvial soils are mapped along the course of the Boyne River, Boycetown River, Knightsbrook River and tributary streams and drainage channels.



Figure 3 Subsoil map of the area around Trim borehole

7.3 Depth to bedrock

Based on the geological information acquired from the GSI well database, the depth to bedrock in the Scurlockstown area is in general between 5 m and 10 m. Depth to bedrock at the production borehole PW1 is 9.1 m. Known bedrock outcrops are present along the River Boyne and at the church ruins to the north of Scurlockstown Bridge (S3).

Along the Knightsbrook Stream, a number of previously unknown bedrock outcrops were identified during site visits. Bedrock is exposed along the base of Knightsbrook River between S4 and S5 which was comprised of argillaceous limestones and highly weathered shales. Bedrock at the various exposures were moderately dipping (10⁰) to the east.

Previous drilling within Freffans Little townland, 3 km south of Trim Borehole (BHP, 1999), indicated that the depth to bedrock at this location was 9.1 m.

8 Groundwater vulnerability

Groundwater vulnerability is dictated by the nature and thickness of the material overlying the uppermost groundwater 'target'. This means that vulnerability relates to the thickness of the unsaturated zone in a sand/gravel aquifer, and the permeability and thickness of the subsoil in areas where sand/gravel aquifers are absent. 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 permeability of the till subsoil to the south and east is interpreted to be "moderate", based on the general absence of permanent surface water features or secondary indicators of low subsoil permeability (see Figure 3 for the distribution of subsoils in these areas). In the sands and gravels, the permeability is interpreted as "high".

Additional depth to bedrock data along the Knightsbrook River was indentified as part of the site investigation works, thus, the vulnerability map (Figure 4) has been revised in this report. In particular an area of '*Extreme Vulnerability*' has been delineated along the Knightsbrook River. The vulnerability around the source, as mapped by GSI, is dominated by High Vulnerability and is shown on Figure 4.

'High' Vulnerability sand and gravel deposits are extensive in the surrounding area and are primarily located towards the north, south and east of the borehole. The vulnerability of the till unit has been classed as *'Moderate Vulnerability'* by the GSI (Woods et al, 1998).



Figure 4 Revised groundwater vulnerability in the area based on site observations and GSI data

9 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 Well Database;
- County Council Staff;
- EPA website and Groundwater Monitoring database;
- Local Authority Drinking Water returns;
- Hydrogeological mapping by TOBIN Consulting Engineers in July 2010;
- Briody (2005). Drilling and Testing of a Production Well at Trim, Co. Meath (unpublished report); and
- Woods et al (1998) County Meath Groundwater Protection Scheme.

9.1 Groundwater body and status

The Trim Borehole is located within the Trim Groundwater Body which has been classified as being of Good Status <u>www.wfdireland.ie/maps.html</u>. The groundwater body descriptions are available from the GSI website: <u>www.gsi.ie</u> and the 'status' is obtained from the Water Framework Directive website: <u>www.wfdireland.ie</u>.

9.2 Groundwater levels, flow directions and gradients

Groundwater levels in the area surrounding Trim Borehole are close to the surface. Groundwater flow in the region is considered to be towards the nearest river. Static groundwater levels at PW1 were recorded at 2.37 m bgl on 17/07/2010. Due to the shallow gradients within the surrounding area and the aquifer classification, groundwater levels are likely to be less than 5 m bgl.

Based on the hydrochemistry (see Section 8.4), all streams are interpreted as being groundwater fed. It is anticipated that the groundwater gradient is likely to reflect the surrounding topography with groundwater discharging to the local streams and rivers. Based on the topography and surface water drainage, groundwater infiltrating from the high ground to the south and southeast of the Trim borehole, flows to towards the Knightsbrook River and Boycetown River. The regional groundwater flow direction in the vicinity of the Trim borehole is from the southeast to the northwest, towards the River Boyne.

A topographical high is present between the Boycetown River and Knightsbrook River, approximately 200 m to the east of Trim Borehole which is likely to coincide with a groundwater divide.

Local groundwater flow at PW1 is controlled by the pumping of the well. The natural hydraulic gradient is considered to be relatively low, approximately 0.01, reflecting the gentle topographical gradients in the area.

9.3 Hydrochemistry and water quality

To investigate the relationship of groundwater to surface water, field mapping of surface water features was carried out in July 2010 including measurement of electrical conductivity and temperature. Monitoring of hydrochemistry was undertaken in the mill race, Knightsbrook River, Boycetown River, and some associated streams. Table 8.1 provides the field data from 17th July 2010. Refer to Figure 3 for locations.

SW stream ID	Conductivity (µS/cm @ 25°C)	pН	Dissolved Oxygen (DO) %	Temperature °C	Notes
SW 1	553	7.0	5	12.6	Mill Race
SW2	572	7.1	96	13.7	Knightsbrook River
SW 3	573	7.2	87	14.1	Boycetown River
SW 2A	584	7.1	48	12.1	Trib to Knightsbrook River
SW 3A	601	7.2	50.5	12.3	Trib to Boycetown River

Table 9.1 Field measurements of surface water features surrounding Trim Borehole

As monitoring took place after an extended dry period, the baseflow within all streams is interpreted as being primarily groundwater at this time. The lower temperatures and DO saturation values indicates the streams and mill race (SW1, SW2A and SW3A) have intercepted groundwater discharges. Oxygen levels and temperature are higher in the main streams (SW2 and SW3), principally due to longer flow paths and turbulent flow/oxygenation in the rivers. Electrical conductivity in all rivers/streams is similar.

Seven sample analyses were available for the Trim Borehole from the EPA Groundwater Monitoring Network Sampling Programme between 2008 and 2009. The water quality at the source varies from hard to very hard (278 to 311 mg/l CaCO₃), and alkalinity ranges from 274 to 309 mg/l CaCO₃. The pH ranges between 7.4 and 7.8, which is alkaline. The hydrochemical signature of the water is calcium bicarbonate. The field electrical conductivity ranges from 549 to 709 μ S/cm @25°C but is typically between 550 and 600 μ S/cm @25°C.

The concentration of nitrate ranges from below detection limits to 0.7 mg/l (as NO₃). There is no reported exceedance above the EU Drinking Water Directive maximum admissible concentration (MAC) of 50 mg/l, or the groundwater Threshold Value (S.I. No. 9 of 2010 Groundwater Regulations) of 37.5 mg/l (see Figure 5). Ammonical Nitrogen concentrations however were slightly elevated on one occasion (0.2 mg/l on 15/07/2009) but below the ammonical nitrogen MAC. Nitrite was also elevated in one sample (0.105 mg/l on 19/11/2009) but did not exceed it's MAC. The low concentrations of nitrate and the slightly elevated levels of ammonical nitrogen and nitrate would indicate that reducing conditions are present within the aquifer (probably the bedrock) and that denitrification is occurring.

Chloride concentrations range from 11.3 mg/l to 15.5 mg/l at the source, with a mean of 12.8 mg/l. This is considered to be below the mean natural background level of 18 mg/l for Ireland (O'Callaghan Moran 2007) and the groundwater Threshold Value (S.I. No. 9 of 2010 Groundwater Regulations) of 24 mg/l. Exceedance of the iron and manganese MACs were noted in the majority of samples (see Figure 5 below). High iron and manganese concentrations are known to occur naturally within the impure limestone bedrock in Meath and may also indicate that reducing conditions are prevalent in the aquifer.

There were no faecal coliforms recorded in any of the water samples. Total coliforms were present on six of the seven sampling occasions. However, due to the absence of faecal coliforms, the results may be due to sampling or analysis contamination error.

The concentration of sulphate, potassium, sodium, magnesium and calcium are within normal ranges. The Potassium: Sodium (K:Na) ratio is low, at 0.1 and never exceeding the GSI threshold of 0.35. A low K/Na ratio suggests that organic wastes derived from farmyards or landspreading of agricultural wastes are not a major cause for concern.

The concentrations of all other trace metals are low and/or are below the detection limit of the laboratory. The concentration of all organic compounds and herbicides are also below the detection limits of the laboratory.

In summary, very low concentrations of nitrate, the absence of faecal coliforms, Low K:Na ratios and low chloride concentrations suggest a high quality groundwater source, with minimal anthropogenic impacts. The high quality is likely to be due to the limited area of extreme vulnerability and the general presence of sands and gravels, which can filter out potential contaminants.



Figure 5 Nitrate and Chloride Concentrations at Trim Borehole



Figure 6 Manganese and Iron Concentrations at Trim borehole



Figure 7 Water quality graphs for Trim borehole

9.4 Aquifer characteristics

The GSI bedrock aquifer map of the area indicates that the Dinantian Upper Impure Limestone (Lucan Formation) is classified as a *Locally Important Aquifer which is moderately productive (Lm)*. The bedrock aquifer is not considered to have any primary porosity with groundwater flow occurring predominantly through fractures, fissures and joints in the upper fractured and weathered zone. Storage is low based on the aquifer type and limited primary and/or secondary porosity. While extensive deposits of sand and gravel exist

around the source, the deposits do not meet the criteria for a Sand and Gravel Aquifer (Lg or Rg) as it is anticipated that the depth of saturated sand and gravels are less than 5 m.

Groundwater recharge is primarily through the gravels and till to the underlying bedrock. The overlying deposits are considered to provide a groundwater contribution to PW1, *via* the underlying bedrock aquifer. It is possible that tills may underlie the gravels in this area (R. Meehan pers comm), which may mean that the hydraulic connection between the gravels and bedrock is limited to places where the till layer is present.

The specific capacity of PW1, also derived from the pumping test data, is 42 m³/day/m. The yield of Trim Borehole PW1 is 'excellent' according to GSI classification and the productivity is Class II, according to GSI classification.

The estimated transmissivity of the borehole based on the pumping test at PW1 using the Theis recovery method is **225** m^2/day . Refer to Figure 8 for the pumping test recovery.

Permeability (K) is in the order of 2.64 m/day based on a minimum saturated thickness of 85 m, and a Transmissivity of 225 m/day. Effective porosity is assumed to be in the order of 1%. Velocity is determined using Darcy's law, $v = K(dh/dl)/n_e$.

K is the Hydraulic Conductivity = (Transmissivity of 225 $m^2/d/saturated$ thickness of 85 m)

gradient = 0.01

 n_e is the effective porosity = 0.01

Therefore velocity is in the order of 2.64 m/day.



Figure 8 Recovery data for Trim Borehole



Figure 9 Aquifer map in the vicinity of Trim Borehole



Figure 10 Cross section of the area around Trim borehole

10 ZONE OF CONTRIBUTION

10.1 Conceptual model

The current understanding of the geological and hydrogeological setting at Trim is given as follows:

The borehole log suggests that water inflows principally from the fissures/fractures within the Lucan Limestones. Groundwater recharges through the overlying subsoil to the underlying bedrock and is abstracted at the borehole. Groundwater flow is likely to follow topography and to be from the land to the south and southeast towards the borehole source. This is also the regional flow direction within the groundwater body, towards the River Boyne.

The borehole is drilled into the Dinantian Upper Impure Limestone, classified as a *Locally important aquifer* which is moderately productive (*Lm*). Immediately to the north, east and south of the source, sand and gravel deposits have been mapped which are unproven in their potential. The aquifer is unconfined, the depth to bedrock is shallow and the subsoils are classified as being of 'high' to 'moderate' permeability. Groundwater recharges rapidly through the sand and gravel and till overburden and through the upper zones of the underlying bedrock, towards the borehole.

Due to the proximity of the well to the Knightsbrook River, the presence of fractures in the upper weathered bedrock and the extensive bedrock exposures along the river bed, a hydraulic connection with the Knightsbrook River is likely. During active borehole pumping a reversal of gradients is likely between the borehole and the Knightsbrook River. Groundwater levels during pumping in the boreholes are greater than 10 m below the bed of Knightsbrook River. The potential groundwater pathway is through the fissured/fractured bedrock.

The groundwater is of calcium bicarbonate signature and hard. Nitrate concentrations are low. Manganese and iron concentrations are elevated owing to the reducing conditions which natural prevail in shaly bedrock such as that found underlying the site. The microbial analysis of the water samples indicates that the groundwater does not appear to be significantly impacted by contamination from human or agricultural sources. A zero count for faecal coliforms was recorded in all seven samples.

10.2 Boundaries of the ZOC

The shape and boundaries of the ZOC were determined using hydrogeological mapping, water balance estimations, and conceptual understanding of groundwater flow. The boundaries are described below along with associated uncertainties and limitations. The boundaries of the area contributing to the source are considered to be as follows (Figure 11):

The **Western and Northern Boundary** is based on a combination of hydrogeological mapping, the uniform flow equation and an assumption that in general the River Knightsbrook is in hydraulic connection with groundwater.

The uniform flow equation (Todd, 1980) states that:

 $x_L = Q / (2\pi^* T^* i)$

where: Q is the daily pumping rate T is Transmissivity (taken from aquifer characteristics) i is the background non-pumping gradient.

The uniform flow equation suggests the well could pump from 27 m down gradient (based on an approximate transmissivity of 225 m^2 /day, a pumping rate of 375 m^3 /day and a natural groundwater gradient of 0.01). It is possible however, given the distance and the pumping induced groundwater gradient, that water could be drawn from the Knightsbrook River, which is 50 m away, particularly during dry periods. Given the position of the river 50 m to the west of the borehole source and a degree of uncertainty in relation to gradients, the northern boundary is conservatively extended as far as the Knightsbrook River.

The **Southern Boundary** is based on the up-gradient topographic high, that is assumed to coincide with the local groundwater divide. Groundwater flow directions are to the north and northwest and it is assumed that groundwater flowing in that direction in the limestones can be intercepted by the borehole.

The **Eastern Boundary**, is based on the on the up-gradient topographical high, that is assumed to coincide with the groundwater divide between the Knightsbrook River and the Boycetown River and its tributaries.

10.3 Inner protection area

This area is designed to protect against the effects of human activities that might have an impact on the quality of the groundwater source. The Inner Source Protection Area is the area defined by the horizontal 100 day time of travel from any point below the watertable to the source. The 100-day time of travel is chosen in Ireland as a conservative limit to allow for the heterogeneous nature of Irish aquifers. The 100-day horizontal time of travel to the abstraction boreholes is calculated from the velocity of groundwater flow in the bedrock. This velocity is determined using Darcy's law:

 $v = K(dh/dl)/n_{e}$

where: K = hydraulic conductivity = 2.64 m/day (Transmissivity of 225 m²/d/saturated thickness of 85 m) dh/dl = gradient = 0.01 n_e = effective porosity = 0.01

The velocity of groundwater flow in the subsoil is estimated to be approximately 2.64 m/day. Therefore the 100-day horizontal time of travel, and therefore the Inner Protection Area, is calculated as a radius extending 264 m around the source.

10.4 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 assumed to consist of input (*i.e.* annual rainfall) less 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 it will dictate the size of the zone of contribution to the source (*i.e.* the outer Source Protection Area).

At Trim, the main parameters involved in the estimation of recharge are: annual rainfall; annual evapotranspiration; and a recharge coefficient.

Runoff losses: 77 mm. Runoff losses are assumed to be 20% of potential recharge. This value is based on an assumption of *c*. 15% runoff for 95% of the area (high vulnerability, high permeability subsoil, well drained soils), and 65% runoff over 5% of the area due to moderate vulnerability, moderate permeability subsoil, well drained soils.

The bulk *recharge coefficient* for the area is therefore estimated to be 80% or 308 mm. (Guidance Document GW5, Groundwater Working Group 2005).

	Assumed recharge	308 mm
	Bulk recharge coefficient	80%
	Runoff losses	20%
	Potential recharge	386 mm
	Effective rainfall	386 mm
	Estimated A.E. (95% of P.E.)	427.5 mm
	Estimated P.E.	450 mm
	Average annual rainfall (R)	814 mm
lese calculations are	summanseu as ionows.	

These calculations are summarised as follows:

Since the majority of groundwater flow to the well is from the gravel subsoil and the *Lm* aquifer a recharge cap is not applied in this instance.

Water balance: Based on an abstraction of 375 m³/day, and the estimated recharge of 308 mm/year, a zone of contribution of 0.44 km² in area is required. Hydrogeological field mapping and the conceptual model determined an area of 0.42 km². Current GSI guidance states that ZOC delineation should conservatively account for 150% of the abstraction volume to allow for expansion in dry weather and uncertainties in the aquifer characteristics. The ZOC presented therefore does not meet the extended areal extent. However the Knightsbrook River is thought to be in hydraulic connectivity with the borehole, with the Knightsbrook River acting as a line recharge boundary. Further refinement of the zone of contribution will require further investigation.

11 SOURCE PROTECTION ZONES

The Source Protection Zones 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 the 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, the Inner Protection Area and the Outer Protection Area.

The Inner Protection Area (SI) is designed to protect the source from microbial and viral contamination and it is based on the 100-day time of travel to the supply (DELG/EPA/GSI 1999). Based on the indicative aquifer parameters presented in section 8.5, the groundwater velocity is 2.64 m/d, and hence the 100-day time of travel distance is 264 m. The Inner Protection Area is illustrated in Figure 11.

The Outer Protection Area (SO) encompasses the entire zone of contribution to the source i.e. 0. 42 km².

Source protection zones are shown in Figure 11, and are based on an overlay of the source protection areas on the groundwater vulnerability. Five groundwater protection zones are delineated, and are SI/E, SI/H, SO/E, SO/H and SO/M. The percentages are shown in Table 10.1, with the majority of the area designated SO/H.

Table 11.1 Source protection zones

Source Protection Zone	% of total area
SI/Extreme	0.7%
SI/High	20.4%
SI/M	<0.1%
SO/Extreme	0.5%
SO/High	74.5%
SO/ Moderate	3.8%



Figure 11 Source Protection Zones around Trim borehole

12 Potential pollution sources

Trim Borehole is capped and the site is securely fenced. The inner protection area is 'extremely' or 'highly' vulnerable to contamination. The majority of land within the ZOC is agricultural land, primarily grassland and

there are a number of farming operations present. The main potential contaminants from these sources are ammonia, nitrates, phosphates, chloride, potassium, BOD, COD, TOC, pesticides, faecal bacteria, viruses and cryptosporidium.

A number of one off private residences are located within the ZOC. Private residences within the ZOC are serviced by septic tank systems or mechanical aeration systems discharging to soakholes or percolation areas. The main potential contaminants from this source are ammonia, nitrates, phosphates, chloride, potassium, BOD, COD, TOC, faecal bacteria, viruses and cryptosporidium. As well as this, there are some private home heating fuel tanks located within the catchment area. The main potential contaminants from this source are hydrocarbons. There is currently no evidence of any contamination from hydrocarbons at the source.

Finally, there are a number of roads present in the ZOC. The main potential contaminants from this source are hydrocarbons and metals.

13 Conclusions

The borehole is a moderately yielding borehole that abstracts from an impure bedded limestone. The untreated groundwater is currently of good microbial quality, with no observable impact associated with human activities. However, naturally elevated concentrations of iron and manganese have been detected in the raw groundwater samples, above permissible levels under Potable Water Standards (SI 278 of 2007).

The Outer Source Protection Area or the Zone of Contribution is calculated to extend to 0.42 km². The Inner Source Protection Area or the 100-day horizontal travel time is calculated to extend 264 m from the abstraction source.

14 Recommendations

Continued monitoring of water levels during the operation of the scheme should be collated to develop a real-time database of hydrogeological information.

The source site is the area immediately around the groundwater abstraction borehole. Protection in this area is paramount to ensure that direct intentional or accidental interference is not caused to the borehole, particularly as the borehole is not grouted. The protection of the source site involves prevention of access and prevention of activities in the immediate proximity of the abstraction boreholes.

Further investigations into the nature of the hydraulic connection between the gravels, the underlying limestones and the Knightsbrook River under pumping conditions, would help to better constrain the ZOC.

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APPENDIX 1

Borehole Log

WELL LOG

Meath County Council,	
County Hall,	
Navan,	
Co. Meath.	

Well No. 1: Trim Water Works

150mm DIAMETER WELL

TOTAL DEPTH OF WELL: 85.4 mts

DESCRIPTION		DIAMETER		DEPTH
Drill		250mm		9.2 mts
Supply & Install Steel Casing	5	200mm		9.2 mts
Drill		200mm		9.2 mts - 47.9 mts
Supply & Install Slotted Stee	el Casing	150mm		0 mts - 24.4 mts
Supply & Install Standard St	eel Casing	l Casing 150mm		24.4 mts - 47.9 mts
Drill		150mm		47.9 mts - 85.4 mts
Supply & Install PVC Well C	Casing	125mm		0 mts - 85.4 mts
Well Grouted				Yes
Chlorinate Well				Yes
Type of Subsoil:	0 mts - 9.1 mts 9.1 mts - 47.9 mts		Boulders & Clay Broken Shale & Brown Rock	
Depth to Bedrock:	47.9 mts			
Type of Bedrock:	Black Limestone.			
Supply at time of testing with drilling rig:	Depth		Gallons Per Hour	
	39.6 mts 67.1 mts		3,600 4,500	
	85.4 mts		5,000	
Remarks: Supply & Install Lockable Cap. Airlift well for 5 hours.				