Environmental Protection Agency

Establishment of Groundwater Source Protection Zones

Enniscorthy Public Water Supply Scheme

Edermine 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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1. Introduction

Groundwater Source Protection Zones are delineated for the Edermine 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 'Edermine' Borehole is the groundwater source for Enniscorthy Public Water Supply. The borehole supplies approximately 600 m^3/day, primarily to Enniscorthy Town, but also to part of the Sow Regional Water Supply Scheme (RWSS), south of Enniscorthy and to the east of the River Slaney. A second borehole located to the north of Enniscorthy supplies the balance of water to Enniscorthy.

The objectives of the report are as follows:

- To outline the principal hydrogeological characteristics of the Edermine area.
- To delineate source protection zones for the Edermine borehole.
- To assist the Environmental Protection Agency (EPA) and Wexford 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 for this study consisted of data collection, desk studies, site visits and field mapping. Analysis of the information collected during the studies was used to delineate Groundwater Source Protection Zones.

The initial site visit and interview with the caretaker took place on 05/10/2010. Site walk-overs and field mapping of the study area (including measuring the electrical conductivity and temperature of streams in the area) were conducted on 05/10/2010, 12/10/2010 and 13/12/2010.

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 Edermine borehole, operated by the Wexford County Council since 2004, is located at the edge of the floodplain of the River Slaney, 5 km south of Enniscorthy Town (see Figure 1). The site is located along a farm road, which extends off Edermine Road, and is surrounded by agricultural lands. The Dublin to Wexford railway line runs equidistant between the Edermine borehole and the River Slaney.

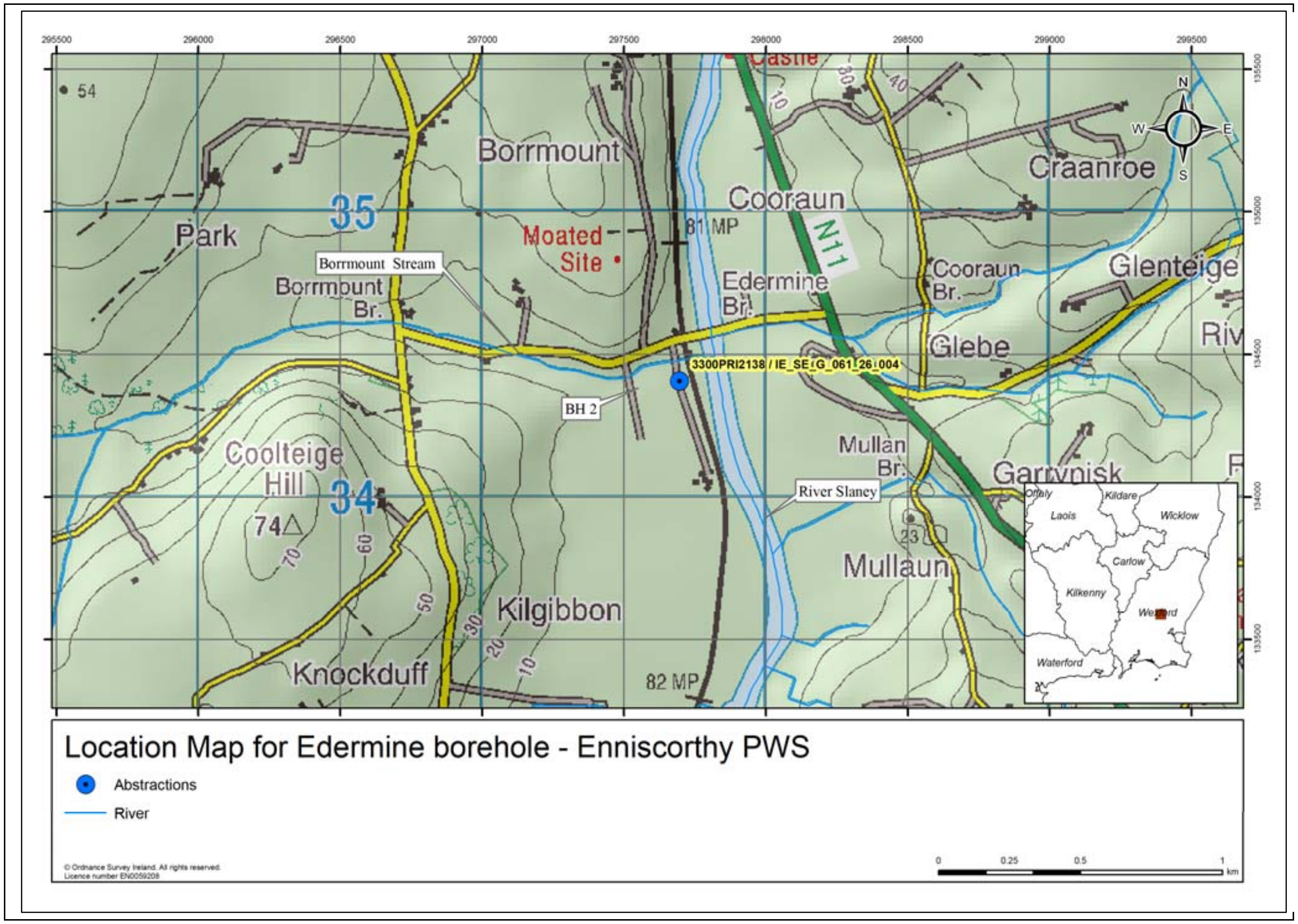

Figure 1 Location map for the area around Edermine borehole

Photograph 1 Housing for Edermine borehole

Photograph 2 Detail of Edermine borehole and rising main

The borehole is located within a secure, locked pump house and the site is fenced (Photo 1). The annulus around the borehole is grouted to 19.7 m bgl according to the borehole log. However, it is unlikely that the borehole is grouted to entire length and is more likely to be grouted from the surface to above the well screen (8 m bgl).

4. Summary of well details

Edermine borehole is a production borehole which was drilled and pump tested in 1979 by Flood Drilling, Clonroche, Co. Wexford. The 200 mm borehole was drilled to a total depth of 19.7 m bgl. The well is screened between 8 m bgl and 15.5 mbgl, in gravels, and is open hole in the underlying volcanic rocks, from 15.5 to 19.7 m bgl.

No information is available on the slot size of the screen, but the borehole is cement grouted from surface to 8 m bgl. A summary borehole log is provided in Appendix I. An additional well BH 2 was also drilled 100 m north of Edermine Borehole, but no log of BH 2 was available at the time of writing. This second borehole is 250 mm in diameter and 72 m deep, and the borehole cover has been removed and is currently open to the elements.

The Edermine borehole was brought into production in 2004 and is pumped on a continuous basis. The initial pumping test achieved an abstraction rate of 2,350 m^3/day; however the borehole was not capable of sustaining this pumping rate continuously during production and now abstracts an average of 600 m^3/day. Table 3.1

Table 3.1 provides a summary of details as currently known. Photograph 1 shows the site compound and cover of the Edermine production borehole.

Table 3.1 Summary Details

	Edermine borehole
EU Reporting Code	IE_SE_G_061_26_004
Grid reference	E 297668 N134400
Townland	Kilgibbon
Source type	Borehole
Drilled	1979 (Not commissioned until 2004)
Owner	Wexford County Council
Elevation (Ground Level)	Approximately 5 m OD
Depth	19.7 m
Depth of casing	Outer casing from 0 m bgl to 8 m bgl Screen from 8 m bgl to 15.5 m bgl 200 mm open hole from 15.5 m bgl to 19.7 m bgl
Diameter	Outer casing 200 mm steel.
Depth to rock	15.5 m
Static water level	1.7 m bgl (1979)
Pumping water level	4.2 m bgl @ 600 m3/day
Consumption (County Council records)	600 m^3/d, pumping 24 hours per day
GSI Productivity Rating	Class I
Specific capacity	192 m^3/day/m (June 1979)
Transmissivity	234 m^2/day (Logan T)

5. Topography, surface hydrology and landuse

Edermine borehole is located on the western flank of the River Slaney Valley (Hydrometric Area 12, see Figure 1). The valley floor is 1.3 km wide in the vicinity of Edermine, and is flanked on either site by moderately steep hills with gradients of 1:10 to 1:25. The topography in the vicinity of the borehole is low-lying and gently undulating, between the River Slaney to the east and for 0.8 km to the west. At this point the land rises steadily in height from 10 m OD to 72 m OD on Coolteige hill. A break in slope is evident between the base of Coolteige hill and the undulating lowland area (Refer to photo 3).

Photo 3 Break in slope marked by broken hedge looking west from BH 2. Note: Rushes in the foreground of photo 3 are a result of previous gravel extraction and redistribution of soil and poaching.

The River Slaney is 100 m east of the source, and is approximately 100 m wide and tidal at this locality. The river flows south towards Wexford Town. A small tributary stream flows eastwards into the Slaney approximately 80 m to the north of Edermine borehole, referred to as the Borrmount stream in this report. The Borrmount stream is also tidal along a 600 m stretch to the north of Edermine borehole.

In general, the natural drainage density around the source is moderate. Drainage ditches are absent to the south and south west of Edermine borehole with ditches becoming common on the lower ground adjacent to the Borrmount stream and the River Slaney. Rushes occur on the lowlying areas adjacent to streams, but are absent elsewhere.

Land use in the area is primarily agricultural, with the majority of the lands used for tillage (*c*. 50%) or set to pasture (*c*. 40%). To the north and east of the borehole, small areas of native riparian woodland, covering approx. 10% of the surrounding area, grow along the banks of the Borrmount stream and the River Slaney. The riparian woodland areas are part of the River Slaney Valley cSAC/pNHA, as are the railway line and borehole.

A number of farmyards have been noted in the area, though no farmyards were identified within 200 m of the borehole. A garden centre/nursery is located 100 m to the north of the pumphouse, on Edermine Road. No major industries or IPPC license premises were identified in the environs of the source.

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:* 1002 mm*. The nearest rainfall gauging station to the Edermine borehole is located at Enniscorthy, where an average annual rainfall of 1002 mm was recorded at the Vocational School gauging station, during the period 1961 to 1990 (Fitzgerald and Forrestal, 1996).

***Annual evapotranspiration losses:* 450 mm.** Potential evapotranspiration (P.E.) is estimated to be 500 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:* 552 mm**. The annual effective rainfall is calculated by subtracting actual evapotranspiration from rainfall. Potential recharge is therefore equivalent to this figure, or 552 mm/year.

7. Geology

7.1. Bedrock geology

This section briefly describes the relevant characteristics of the geological materials that underlie the Edermine 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 South Wexford Sheet 23, 1:100,000 Series (Tiestzsch-Tyler *et al*., 1994).

The Bedrock Geological Map of South Wexford indicates that this area is principally occupied by Lower Palaeozoic Rocks of the Campile Formation (Ordovician Volcanics). The Campile Formation is comprised of pale coloured rhyolitic and felsic volcanics with horizons of grey and interbedded brown shale and slate.

Bedrock exposures of the Campile Formation noted in the field (localities B1 and B2 on the geology map) to the west of Edermine borehole confirm the presence of volcanics and slates. Granitic intrusive rocks form the core of Coolteige Hill approximately 1.5 km west of the borehole. To the south and southeast, Ordovician Metasediments of the Ballyhoge Formation are present. Refer to Figure 2 for the Geology Map of the area.

The Ordovician bedrock has been highly deformed and folded, and a large number of mapped faults occur in the Campile Formation. The majority of these faults generally trend NNW to SSE and represent a complex pattern of lateral displacement of the Campile Formation during the Caledonian Orogeny (410 million years ago). One of these faults is shown on the 1:100,000 geology map to run north/south approximately 150 m to the west of Edermine borehole.

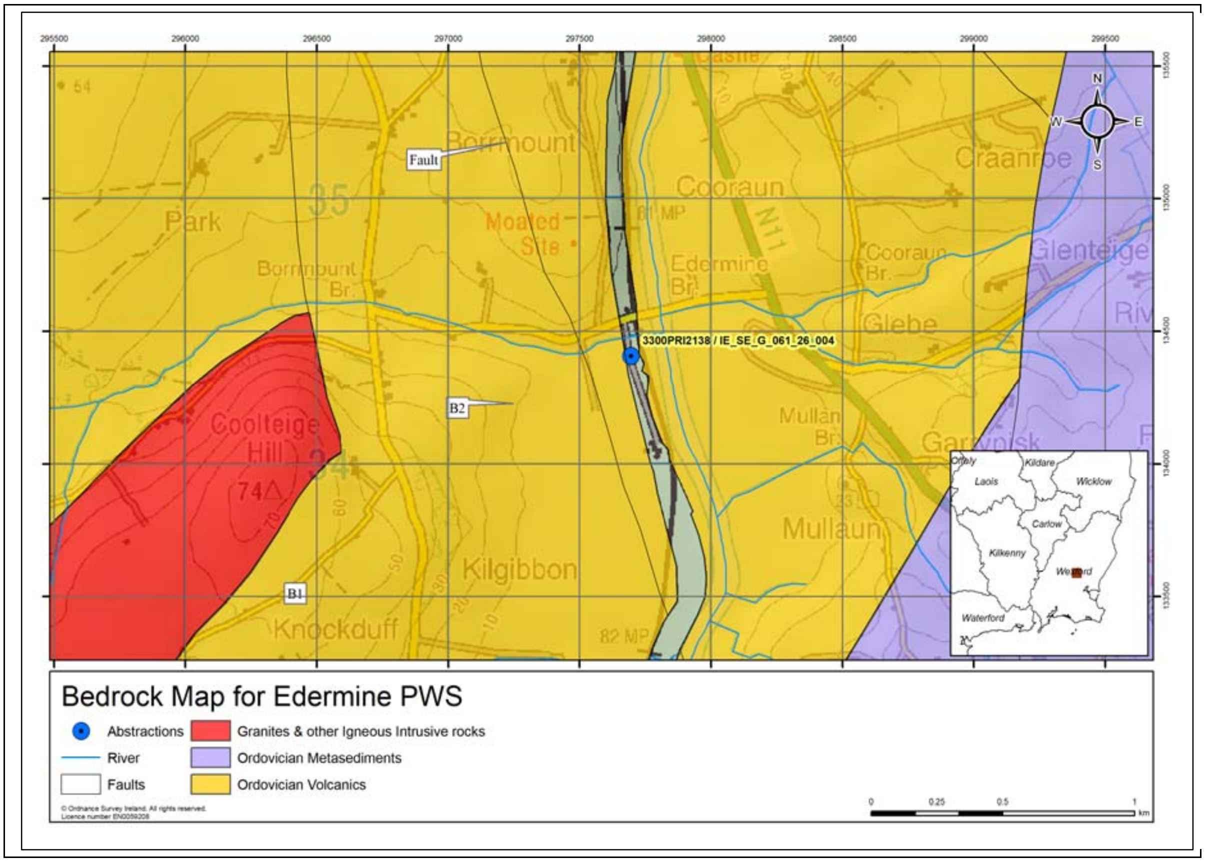

Figure 2 Geology map for the area around Edermine borehole

7.2. Subsoils geology

According to GSI and EPA web mapping, the subsoils of the study area are dominated by sand and gravel deposits derived from Lower Palaeozoic Sandstones and Shales (GLPSsS). The glaciofluvial sands and gravels around the borehole comprise a gently undulating outwash plain flanking both sides of the River Slaney. From examination of an exposure into these deposits adjacent to BH 2, the sands and gravels are comprised of gravelly, medium to course SAND and sandy, fine to medium pebble GRAVELS with occasional cobbles (see Figure 3 below). Small scale gravel extraction is believed to have occurred immediately south of the Edermine Borehole based on the OSI 25" maps, and to the west of BH2.

Extensive alluvial deposits have accumulated from repeated flooding in the low, tidal zones of both the River Slaney and the Borrmount stream. The alluvial deposits are exposed in the banks of the Borrmount stream between S1 and S2 (Figure 4), and consist primarily of laminated, organic silts and clays with occasional beds of sand and gravel, between 0.05 m and 0.35 m thick.

Bedrock is close to surface on the crests and upper slopes of the surrounding hills. On the slopes of the surrounding ridges to the west and north of Borrmount stream, till derived from Lower Palaeozoic shales (TLPS) occurs.

The soils on the sand and gravel areas are predominately well drained shallow soils (AminSW) while the till areas host well drained, deep mineral soils (AminDW) (EPA webmapping).

Figure 3 Sand and gravel deposits at road cutting near BH 2. Grid Ref: E297579 N 134398

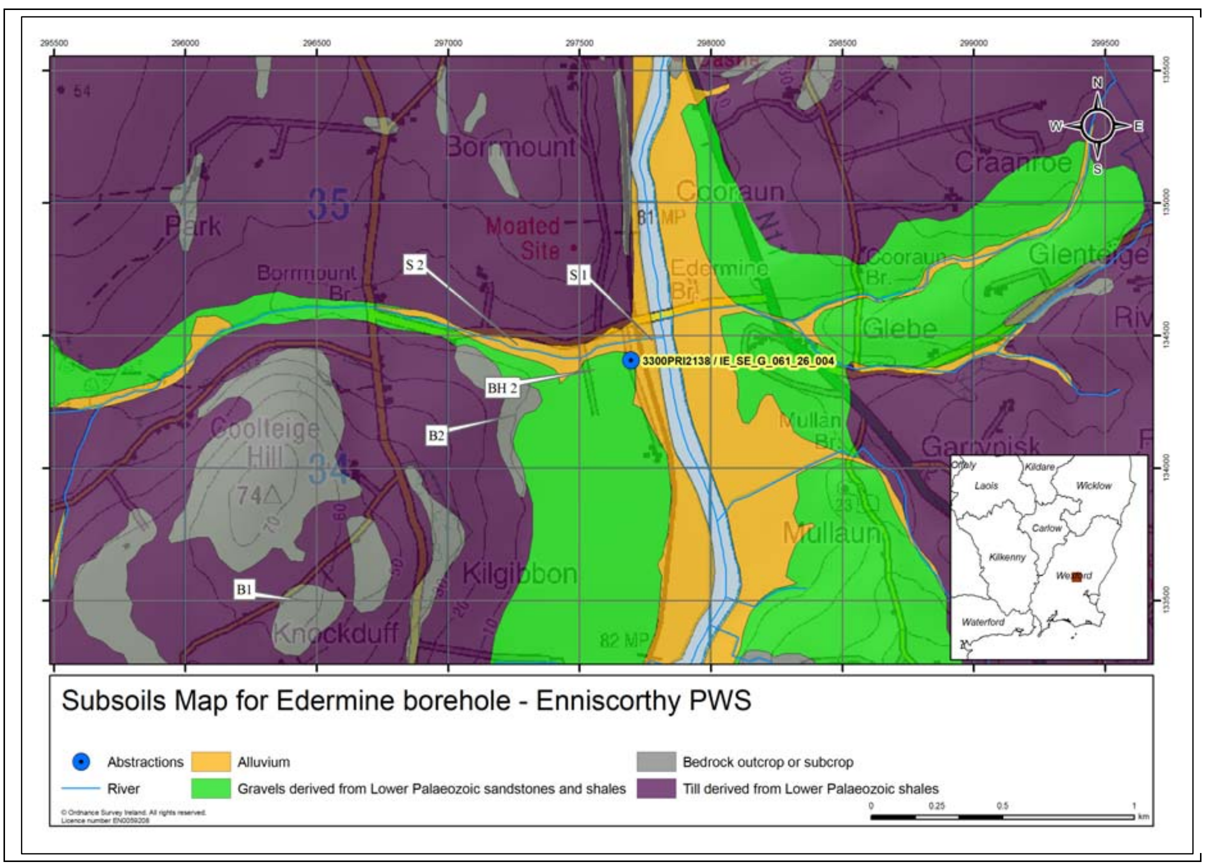

Figure 4 Subsoil Map for the area around Edermine borehole

7.3. Depth to bedrock

Depth to bedrock (DTB) has been interpreted across the study area based on the location of bedrock outcrops mapped by the GSI, the Wexford Groundwater Vulnerability Map (2010), site investigations as part of this SPZ work, bedrock and subsoil outcrops mapped during site visits, areas mapped as extreme groundwater vulnerability under the GSI Groundwater Protection Scheme (GWPS) and borehole information at Edermine.

From the GWPS mapping, DTB is mapped as less than 3 m on the summits and shoulders of the ridges on either side of the River Slaney valley, with shallow bedrock areas being extensive on the hill summits to the north and west of the source. DTB increases towards the base of the valley, and is 15.5 m at Edermine borehole.

The alluvial deposits were probed between S1 and S2 along the Borrmount stream, and along the banks of the River Slaney, using a 3 m long pole. Soft alluvial deposits extend for at least 3 m in the vicinity of the Borrmount stream and the River Slaney.

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 the sand/gravel aquifer, and the permeability and thickness of the subsoil in areas where the sand/gravel aquifer is 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 Groundwater Vulnerability Map (2010) for the region, as mapped by Tobin on behalf of GSI, is dominated by ‘Extreme’ and ‘High’ vulnerability areas and is shown in Figure 5. Most of the summits, shoulders and upper backslopes of the ridges in the area have ‘Extreme’ Vulnerability areas, where depths-to-bedrock are interpreted as less than 3 m. Elsewhere, where till of moderate permeability and depths-to-bedrock of less than 10 m occur, the vulnerability is mapped as ‘High’.

For the purposes of vulnerability mapping in sands and gravels, the “**water table**” is the target. The sand and gravel deposits are mapped as ‘High’ vulnerability, with areas of ‘Extreme’ vulnerability occurring where the water table is within 3 m of ground level.., A small area of ‘Extreme’ vulnerability in the sands and gravels is proposed in the immediate vicinity of Edermine borehole, where the water table is within 3 m of ground level (see Figure 5 and Section 9.2).

On the eastern side of the River Slaney, 1.5 km from the source, relatively deep depths-to-bedrock and tills of ‘Low’ permeability mean ‘Moderate’ and ‘Low’ vulnerability areas are mapped.

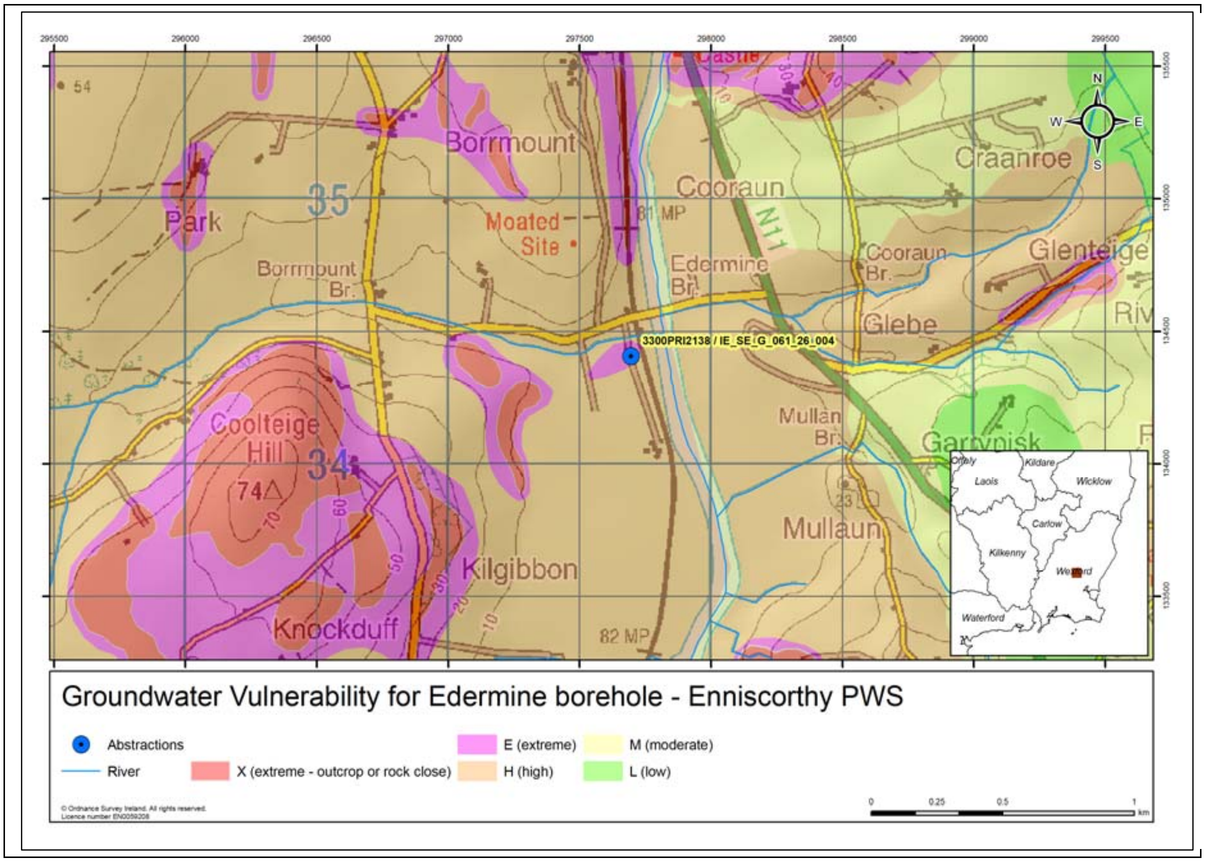

Figure 5 Groundwater Vulnerability for the area around Edermine borehole (GSI)

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;
- Enniscorthy Groundwater Body;
- Local Authority Drinking Water returns; and
- Hydrogeological mapping by TOBIN Consulting Engineers in October 2010.

9.1. Groundwater body and status

The Edermine borehole is located within the Enniscorthy Groundwater Body which has been classified as being of 'Good Status'. 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.

9.2. Groundwater levels, flow directions and gradients

The groundwater flow directions are assumed to radiate from the summits of the surrounding hills and discharge to local streams and the River Slaney. Local groundwater flow within the subsoil and bedrock aquifers at Edermine borehole may however be controlled by the pumping of the well.

A pumping water level of 4.24 m bgl (drawdown of approximately 2 m) was measured on 15th December 2010 in Edermine borehole whilst pumping at 610 m^3/d. The groundwater level in BH 2, 100 m away, at that time was 5.94 m bgl. Previous monitoring of Edermine borehole on 10th October 2010 recorded a water level of 3.7 m bgl whilst pumping at reduced rate of 450 m^3/d.

Preliminary levels were surveyed using a dumpy level and are outlined below in Table 9.2. Levels outlined in Table 9.2 are not tied into the true ordnance datum, but are relative to the top of Edermine borehole, which is estimated to be at approximately 5.0 m OD. Therefore the levels given are approximate OD heights.

Table 9.2 Preliminary Water levels for Edermine Borehole (15/12/2010)

Borehole ID	Relative Elevation to Edermine borehole (m)	Water level during active Pumping (m bgl)	Relative groundwater/surface levels to Edermine borehole (m)
Edermine borehole	5.0	4.24	0.76
BH 2	9.75	5.94	3.81
Borrmount River adjacent BH 2	3.55	-	3.55
Borrmount stream at access bridge – High Tide	4.15	0.6	3.55
Spring location SP 2	4.2	0.6	3.6
Borrmount stream at access bridge – Low Tide	4.15	1.7	2.45

Note: See Figure 12 for locations.

Based on the levels taken on the 15th December 2010, the pumping water level in Edermine borehole is below the water levels in both the Borrmount stream and the River Slaney. A steep (pumping) groundwater gradient of 1:35 exists between BH2 and Edermine borehole but appears to be relatively flat between BH2 and SP 2.

The land adjacent to the River Slaney and Borrmount stream floods at high tide. Due to the effect fo the tides, freshwater backs up at Edermine and regularly flows back up the Borrmount stream and inundates the woodland areas north and east of the borehole. Flooding also occurs in what appears to be a small, lowlying former gravel extraction area, approximately 25 m southeast of Edermine borehole, during high tide. Water appeared to recede slowly after high tide. The flooded area to the south east of Edermine borehole appeared to percolate into the ground and potentially flows to Edermine Borehole. This is conceptually drawn below in Figure 6.

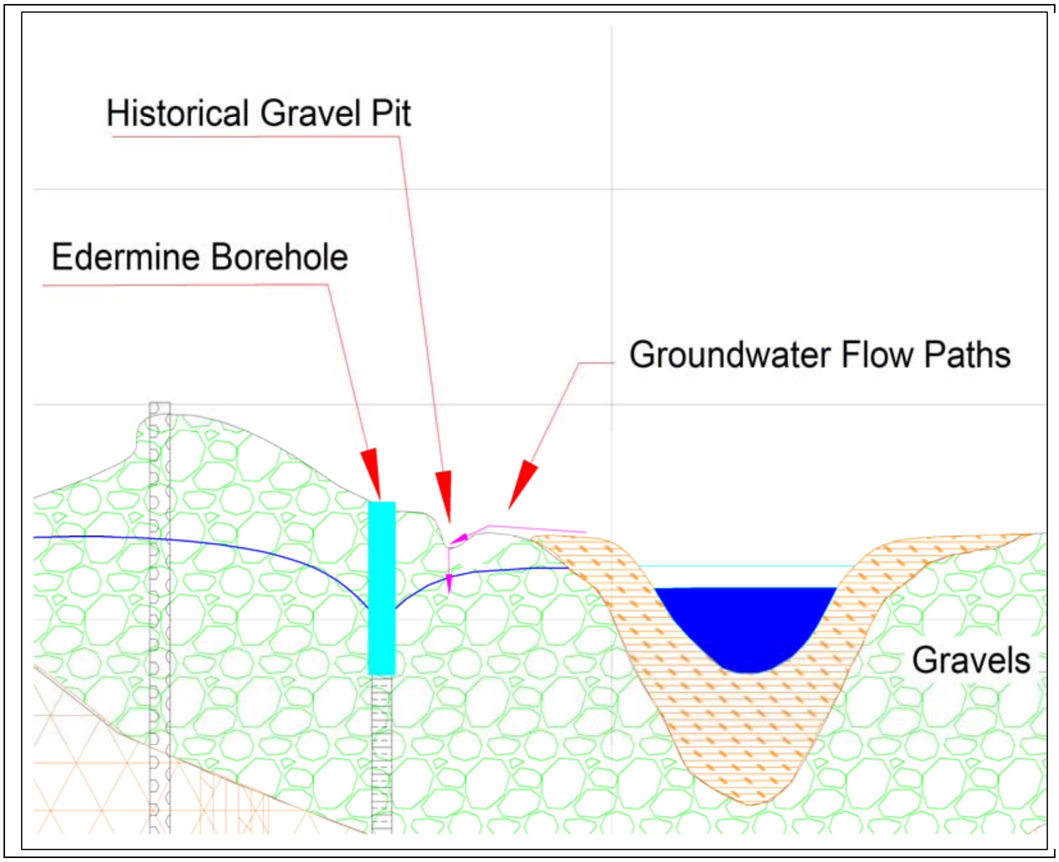

Figure 6 Conceptual flow via historical pit at Edermine

Monitoring of groundwater levels on 10th October 2010 in Edermine borehole indicated a small rise (0.05 m) in response to high tide levels on that day. It is known that the Edermine Road and railway crossing are liable to flooding, and though there is no evidence of flooding at the borehole, high tide levels are approximately 1.5 m below the top of the casing.

A number of springs (SP1 to SP 3) are mapped on the OSI 25" maps adjacent to the Borrmount stream and River Slaney. Groundwater flow was evident at SP 1 and SP 2 during field mapping. A spring marked on the 25" maps (SP 3) approximately 160 m to the south of Edermine borehole, was not visible during field mapping. It is possible that either land drainage works, or pumping at Edermine borehole, may have affected this spring.

The natural groundwater gradient is considered to be relatively low, approximately 0.01, reflecting the high permeability subsoils and weathered zone at the top of bedrock. It is likely to vary, and may even reverse direction, in response to the tide levels along the Borrmount stream and River Slaney. There are no well or water level data available for the bedrock aquifer on the hills to the east and north of the borehole.

9.3. Hydrochemistry and water quality

Conductivity measurements taken from the River Slaney and Edermine borehole on the 10th October 2010 were similar at 180 and 186 µS/cm @ 25^{o}C respectively. Conductivity values in the Borrmount stream were between 180 µS/cm adjacent to the site and 192 µS/cm @ 25^{o}C at SP 2. The conductivity values of groundwater and surface water are similar which may indicate a surface water contribution at Edermine borehole.

Thirty sample analyses taken from Edermine were available from the EPA Groundwater Monitoring Network between 1993 and 2009. The water quality is soft (35 to 95 mg/l $CaCO_3$). Alkalinity ranges from 10 to 90 mg/l $CaCO_3$. The pH ranges appear to be variable, between 6.0 and 7.8. Electrical conductivity ranges from 200 to 261 µS/cm @ 25^{o}C. The water chemistry is variable and may reflect different relative contributions from different source contributions from the stream, bedrock and gravels during meteorological cycles and tide stages. The hydrochemical signature of the Edermine groundwater is magnesium bicarbonate.

The concentrations of nitrates are slightly elevated at Edermine. There is no reported exceedance of the EU Drinking Water Directive maximum admissible concentration of 50 mg/l, but historical mean values slightly exceeded, the groundwater Threshold Value of 37.5 mg/l NO_3 (Groundwater Regulations S.I. No. 9 of 2010) for the period between 1999 and 2005. The River Slaney is moderately eutrophic adjacent to the site (EPA web mapping). The presence of intensive agricultural practices on free draining soils suggests that diffuse agricultural sources are a cause of elevated nitrate concentrations, such as those seen at Edermine. This is a common phenomenon in south east Ireland where a positive correlation between nitrate levels in rivers and the proportions of ploughed land in their catchments has been shown (EPA, 2009). A noticeable downward trend in the nitrate data from July 2007 to present is shown in Figure 7. This is possibly as a result of increased dilution by above average rainfall for the years of 2007 to 2009.

Chloride concentrations range from 20 to 25 mg/l, with a mean of 22 mg/l, which is considered to be above the mean natural background level of 18 mg/l (Baker *et al.,* 2007). Given the proximity of Edermine to the coast (10 km to the south and east) the chloride levels may reflect the elevated chloride levels in coastal rainfall, or may be associated with the increased nitrate. A slight downward trend in chloride concentration is evident in 2008-2009 with an average concentration of 21.6 mg/l.

Faecal coliforms were below detection limits in all water samples analysed. The presence of deep sands and gravels suggests a relatively low likelihood of faecal contamination occurring, due to filtration. Elevated concentrations of total coliforms were detected on five occasions. However, due to the absence of faecal coliforms, such values may be due to sampling or analysis error. The installation of greater wellhead protection may help resolve the total coliform issues at Edermine borehole.

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

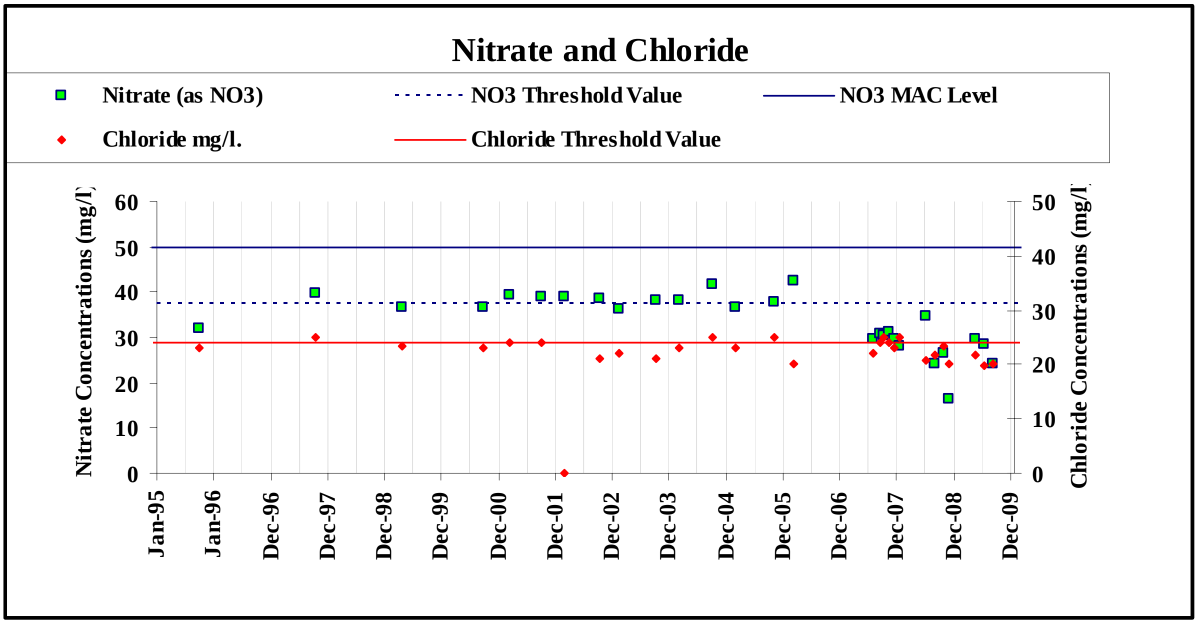

Figure 7 Nitrate and Chloride values at Edermine borehole

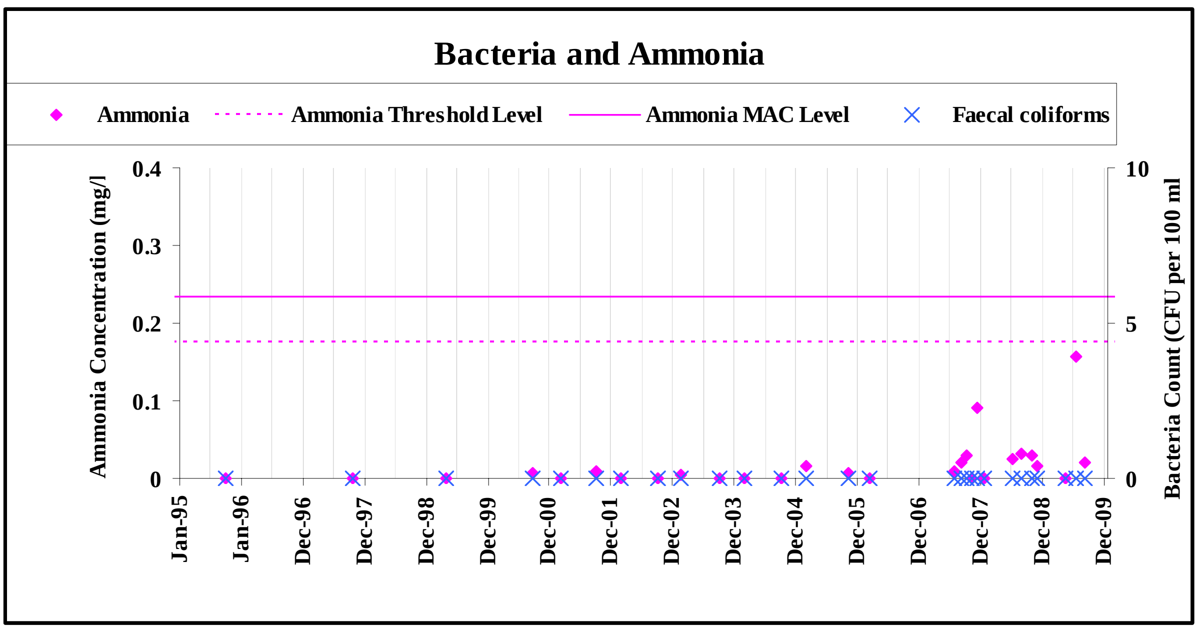

Figure 8 Bacteria and Ammonium concentrations at Edermine Borehole

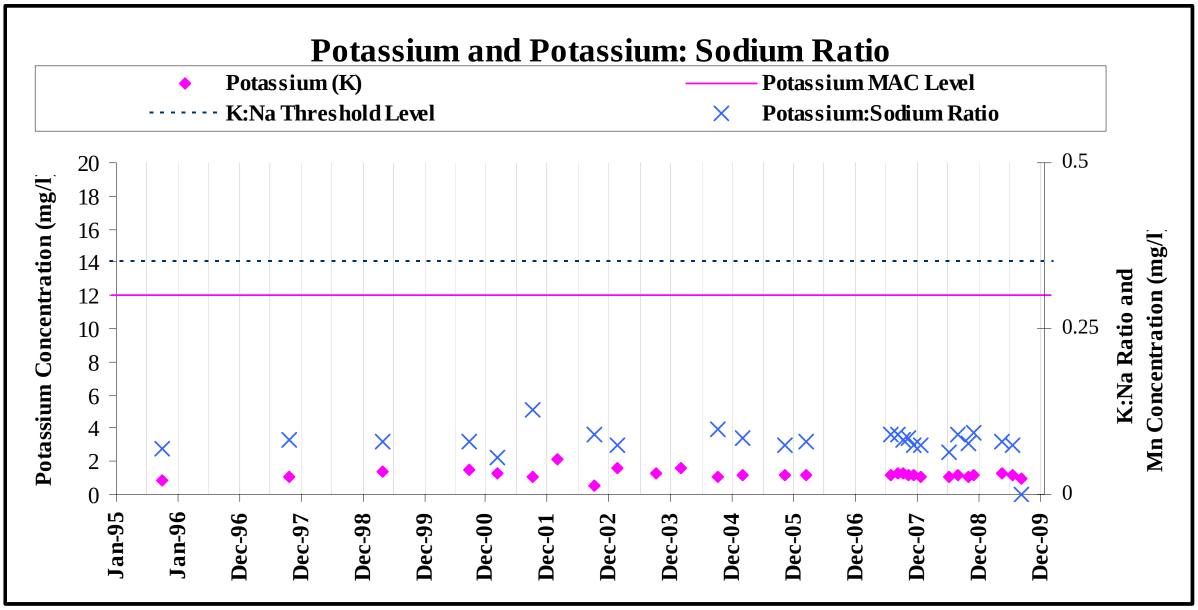

Figure 9 Potassium and K:Na ratios for Edermine borehole

The concentrations of all other trace metals are below groundwater thresholds. The concentrations of all organic compounds are below the detection limit of the laboratory.

In summary, the elevated levels of nitrate are possibly due to either organic or inorganic fertilizer used in the intensive agriculture practises in the area, including tillage. Overall, the current water quality is generally relatively good given the absence of faecal coliforms and low K:Na ratios, and nitrate concentrations appear to have been continually improvement since 2007.

9.4. Aquifer characteristics

The fractured bedrock is thought to be hydraulically connected to the overlying subsoils. Groundwater is assumed to migrate through the subsoils and upper bedrock towards the borehole.

The GSI bedrock aquifer map of the area indicates that the Lower Palaeozoic rocks of the Campile Formation are classified as a ***Regionally Important Fractured Bedrock Aquifer (Rf).*** The Campile Formation consists of interbedded layers of shales and volcanics. During structural deformation the shales tend to fold and warp whereas the volcanic layers tend to shatter and crack. This disruption of the volcanic rocks allows groundwater flow through the connected layers of fractures, while there is relatively little groundwater flow in the shaly areas (WYG, 2010). Groundwater flow within the bedrock as a consequence of folding/faulting is heterogeneous (non-uniform) and assumed to be strongly influenced by the north northwest – south southeast faulting. Groundwater flow in the bedrock at Edermine is likely to preferentially flow along the faults. Folding and faulting of the siliceous crystalline bedrock has resulted in clean open fractured bedrock and groundwater flow paths can be up to several kilometres in length.

It should be noted that granite bedrock is located approximately 1.5 km to the west of Edermine borehole, and forms the core of Coolteige Hill. Groundwater flow within the granite is considered to be limited and it is generally classified as a poor aquifer.

The well is screened in the deep glaciofluvial sand and gravel deposits, which overlie the bedrock aquifer.. Based on the borehole log which indicated a significant depth of sand and gravel (15.5 m) and the areal extent of the mapped sand and gravel subsoils (1 km^2). Given their areal extent the sands and gravels should be classified as a ***Locally important sand and gravel aquifer (Lg).***

A step test, 72 hour pumping test and monitored recovery were completed in June 1979. The pumping rates of the first and second steps were not legible on the pump test sheet, however in the 3rd step, the well was was tested at 2,350 m^3/day for a drawdown of 11 m (see Figure 9). During the 72 hour pump test, the borehole pumping rate was initially started at 2,600 m^3/day, and was cut back to 2,350 m^3/day after a larger than expected drawdown within the well. Water levels appeared to stabilize at 13.9 m bgl after 12 hours of pumping. Recovery within the well was virtually instant: the well had achieved 90% recovery after 1 minute of pump shut down. No information was available on the monitoring of BH 2 during the 1979 pumping test at the time of writing, but it is possible that BH 2 was drilled at a later date than Edermine borehole.

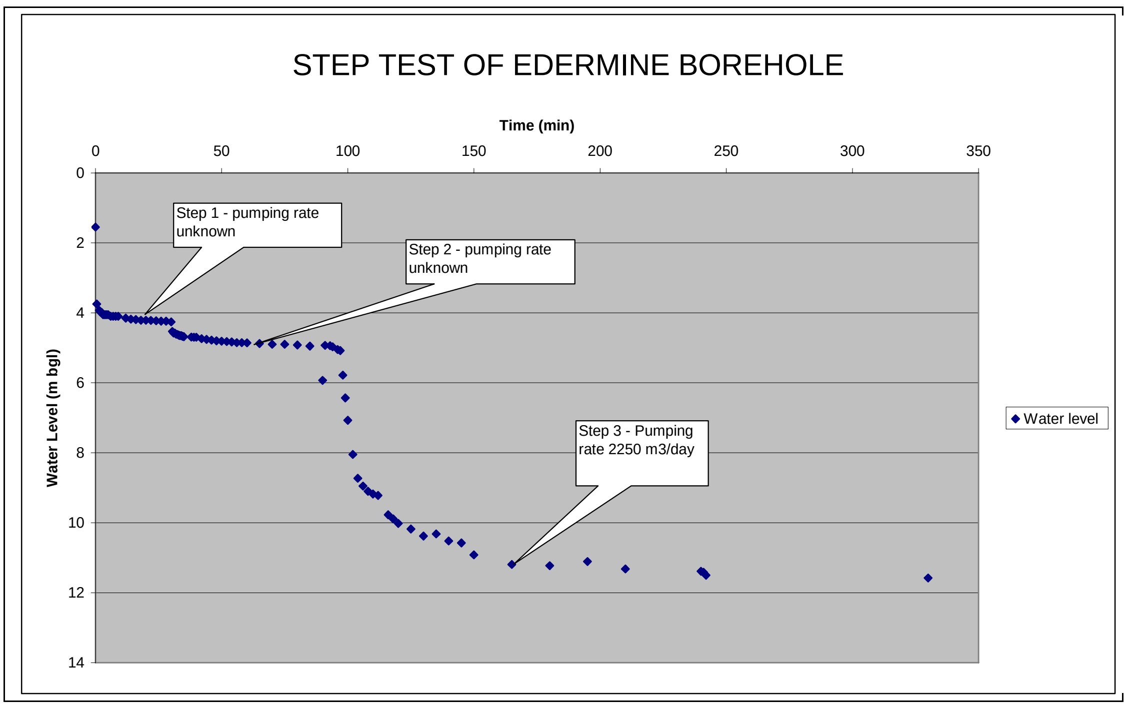

Figure 10 Step test at Edermine borehole in June 1979

Since the well has been brought into production, the test pumping rate of 2,350 m^3/day has not been achieved and the current pumping rate is 600 m^3/day. It is possible that equilibrium conditions may not have been achieved during the 72 hour pumping test. The reduction in yield is also possibly due to well losses owing to clogging of the well screen and aquifer immediately around the screen in the intervening period.
Well losses can also comprise head losses: those resulting from the aquifer becoming plugged with drilling mud that reduce the permeability near the bore hole; head losses in the gravel pack; or head losses in the screen. It is most likely that head losses in the borehole are as a result of clogging of the screen, gravel pack or the area surrounding the gravel pack with fines over time. The percentage well efficiency could be calculated if a step test was completed on Edermine borehole and compared with the step test data from

1979. The recovery test completed in 1979 provides some evidence that well losses were occurring as water levels recovered by 90% within 1 minute of stopping the test. Refer to Figure 10 below.

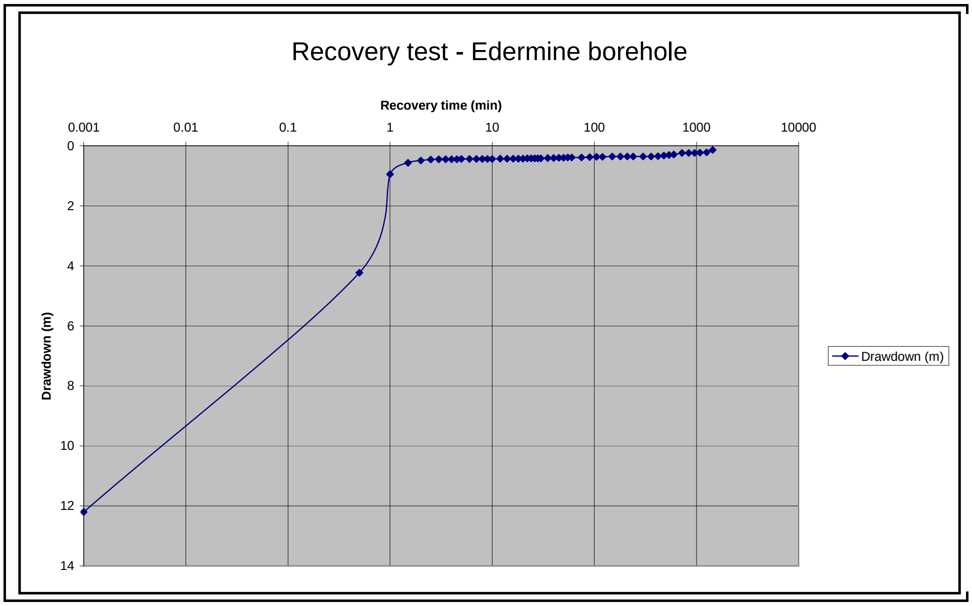

Figure 11 Recovery test Edermine borehole (1979)

No information is available to differentiate what percentage of groundwater flow is contributed from the sand and gravel aquifer or from the underlying bedrock aquifer. As such, the aquifer parameters outlined below are a composite of the locally important sand and gravel aquifer and regionally important bedrock aquifer.

The yield of Edermine borehole is 'excellent', according to GSI classification, and the productivity is Class I. Based on data from June 1979, the specific capacity of Edermine is approximately 192 m^3/day/m (12.22 m drawdown).

Using the Logan transformation of T = Q/s x 1.22 (Misstear, 1998) and a calculated specific capacity (based on pumping test) of 192 m^3/m/day, the transmissivity of the sand and gravel/bedrock aquifer in the vicinity of the borehole is estimated to be of the order of 234 m^2/day.

This analysis is based on limited data and would require further monitoring to validate assumptions. It is believed that a number of monitoring wells were drilled and monitored during the pump test but they could not be located for the purposes of analysis within this report.

Based on the estimated aquifer transmissivity and the aquifer hydraulic gradients, the 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.

Transmissivity is in the order of 234 m^2/day based on a minimum saturated thickness of 20 m, and effective porosity (of the sand and gravel/bedrock aquifer) is assumed to be in the order of 6%. Therefore velocity, assuming a gradient of 0.01, is in the order of 2 m/day.

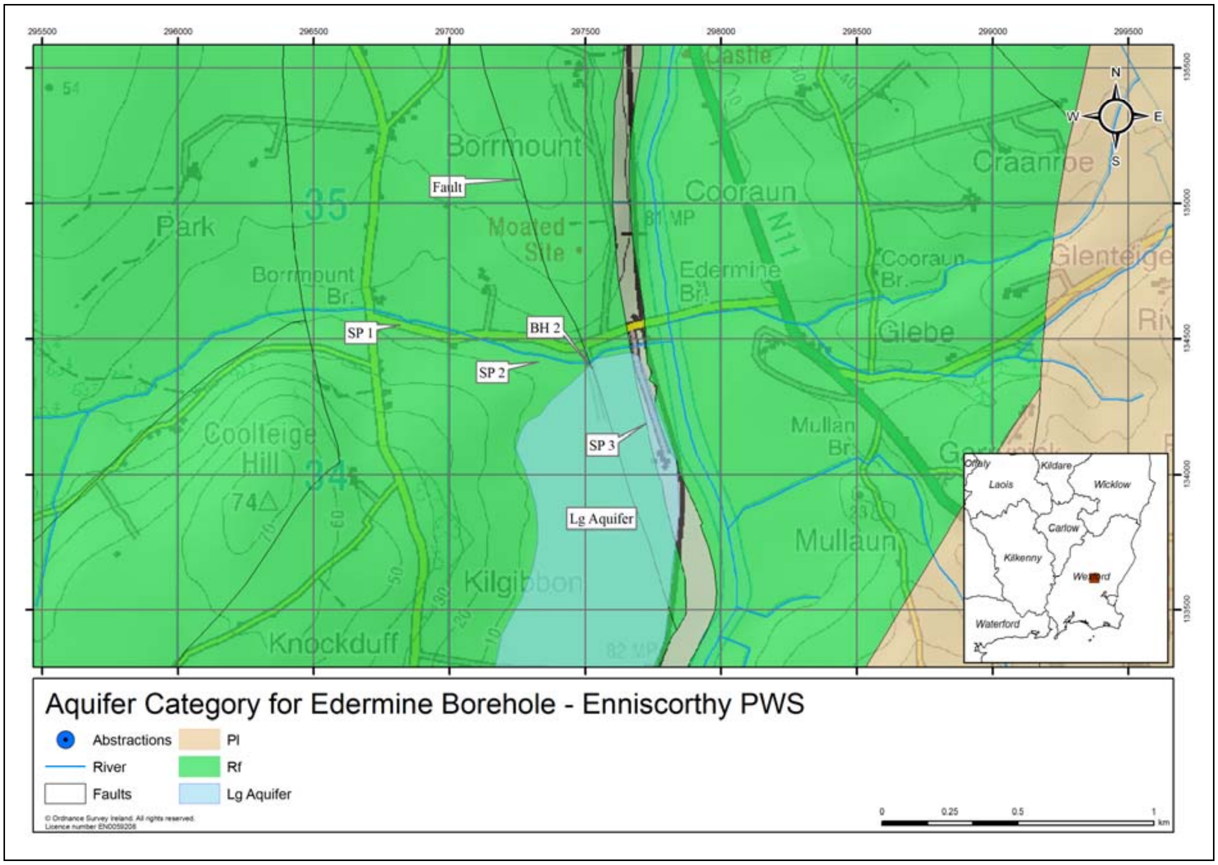

Figure 12 Aquifer map including proposed sand/gravel aquifer

10. 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.

10.1. Conceptual model

Groundwater is interpreted to flow generally in a southeast direction towards the source. The bedrock aquifer is the Ordovician (Campile Formation) which is mapped as a Regionally Important fissured aquifer; (Rf). The overlying sand and gravel deposits are reclassified here as a locally important sand and gravel aquifer (Lg). In this area, the high well yield, high transmissivity, high specific capacity and shallow gradients, all provide evidence that the sands and gravels and underlying the bedrock provide a sustainable source.

The aquifer is unconfined, has Extreme and High vulnerability across the majority of the area around the borehole, and is likely to be recharged locally, through highly permeable, deep sand and gravel subsoils, as well as through the moderately permeable till deposits. This is reflected in the water quality results which show the absence of faecal bacteria in the untreated water.

The River Slaney and Borrmount stream are thought to be in hydraulic connectivity with the source but the extent of this may be limited due to the presence of low permeability alluvial subsoils between the source and the watercourses.

Limitations to the conceptual model mainly lie in our understanding of the complex relationship between the surface water features and Edermine borehole *via* the sand and gravel and the alluvial deposits. The groundwater contours are relatively flat surrounding Edermine borehole and are complicated by the tidal influence of the Borrmount stream and River Slaney. Additionally, limited borehole monitoring locations were available for the compilation of this report.

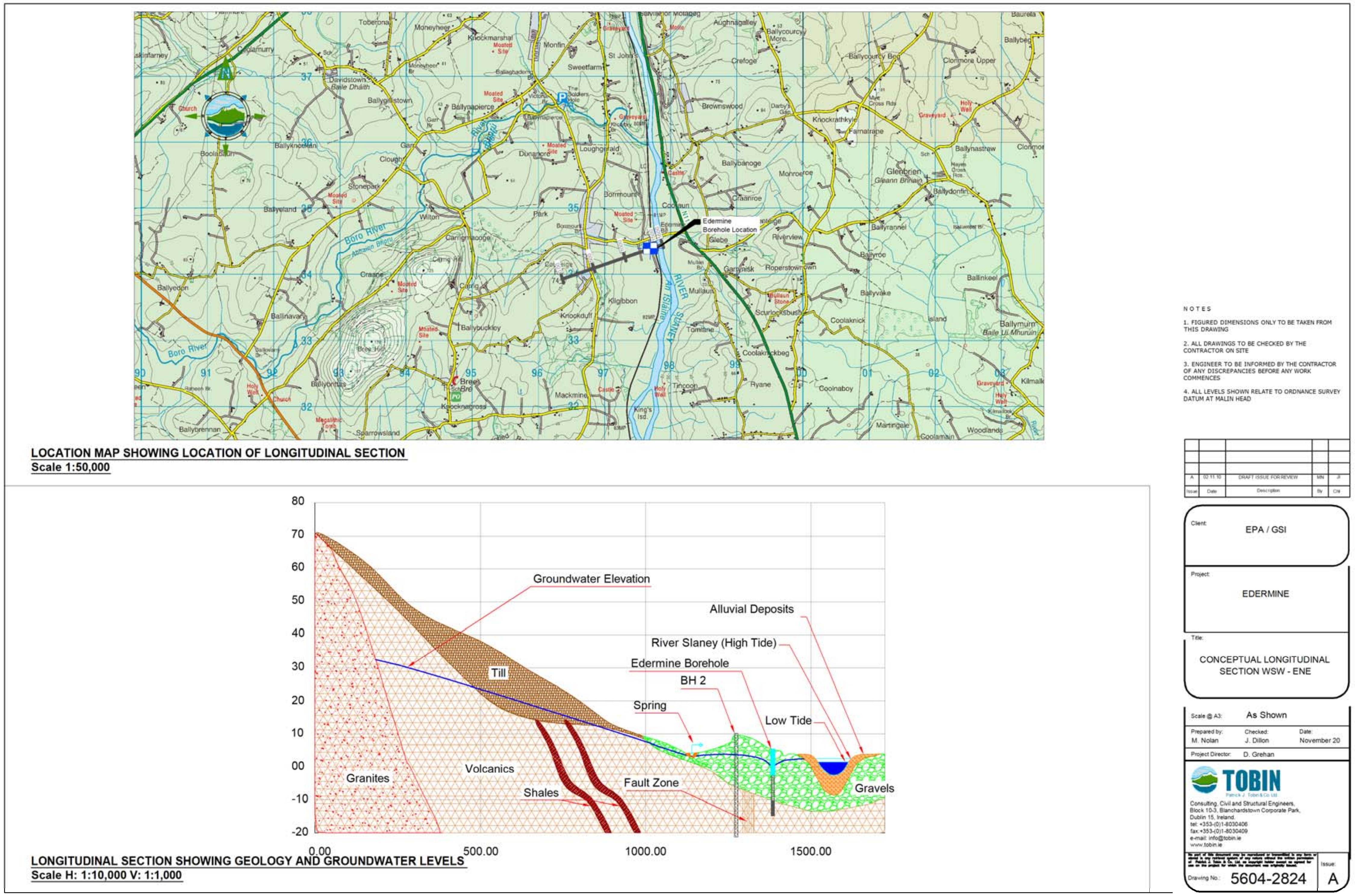

Figure 13 Conceptual model WSW/ENE through Edermine borehole

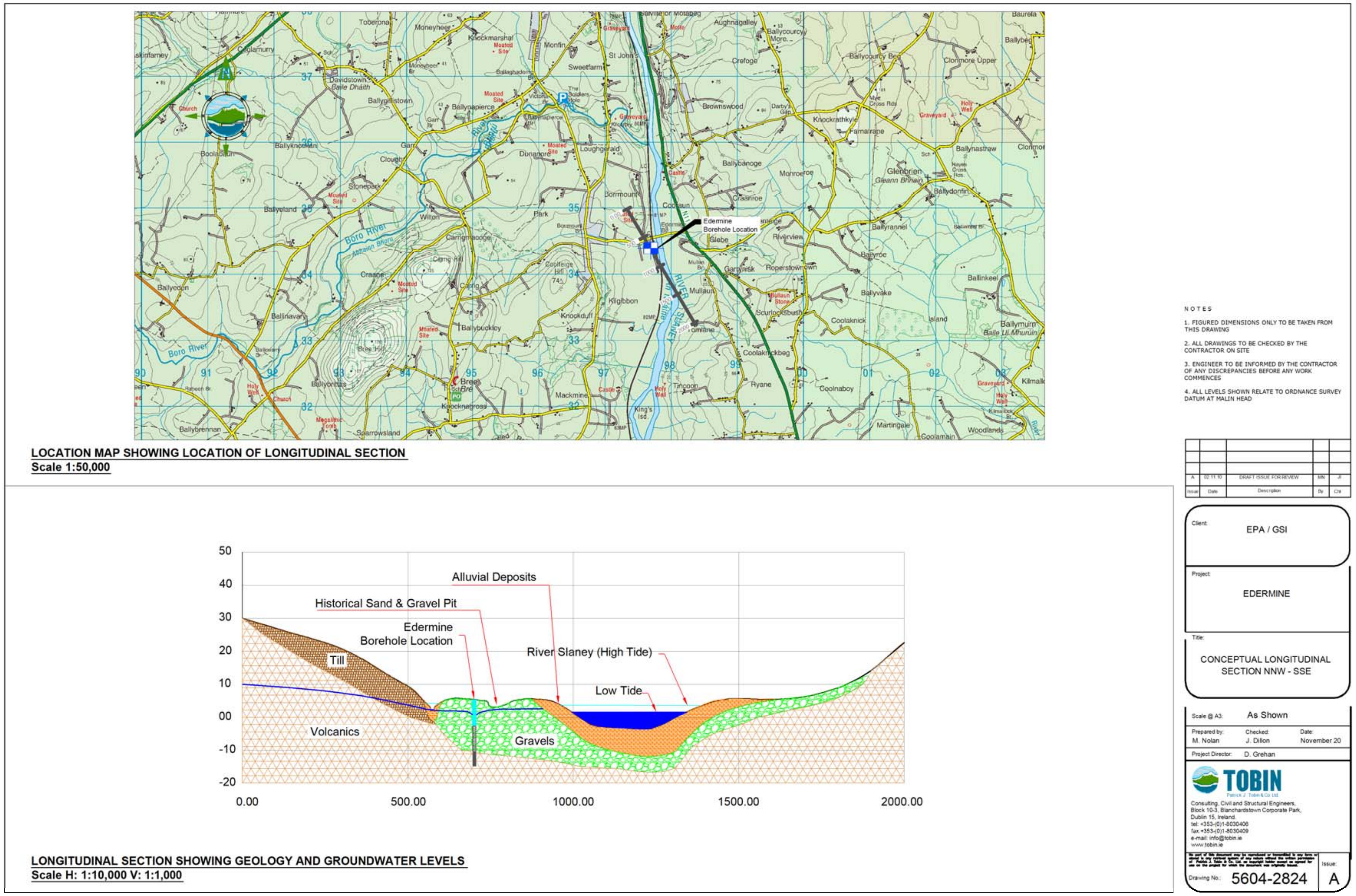

Figure 14 Conceptual model NNE/SSW through Edermine borehole

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 (Figure 13 and Figure 14). 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:

The **Northern Boundary** is primarily based on the conceptual model of flow to the borehole. The ZOC is thought to extend beyond the Borrmount stream as it is assumed that a weak connection exists with the Borrmount stream. Water is only abstracted where a high permeability pathway between the borehole and the stream exists. The connection with the Borrmount stream may vary with different tidal stages. Based on the faulting within the bedrock, groundwater will preferentially flow NNE/SSW to the borehole.

The northern boundary is extended to the topographical high, north of the Borrmount stream. It is unlikely that the ZOC would extend past the topographic high. Groundwater is likely to preferentially flow along the north-northwest orientated faults and fractures in the underlying bedrock.

The **Southern Boundary** is based on a combination of topographic gradients and hydrogeological mapping. A ridge crest is located approximately 250 m to the south and southwest of the borehole. It is thought that this ridge corresponds to a groundwater divide. An area mapped as a spring 160 m to the south on the 25” OSI maps is now dry and therefore included within the ZOC.

The **Eastern Boundary** is defined by the River Slaney. The borehole is 100 m from the river and is 25 m from a sand and gravel area that is regularly inundated with surface water. Additionally, the pumping water level is approximately below the river water level and is potentially drawing water from the river into the gravels. The alluvium deposits, while predominately fine grained, contain sand and gravel lenses and are assumed to be in hydraulic connectivity with the gravels. Given the shallow gradients and the width of the river the borehole is not expected to draw water from the other side of the river.

The **Western Boundary** is difficult to delineate. The western boundary is conservatively extended towards Coolteige hill.

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

Runoff losses: 130 mm. Runoff losses are assumed to be 20% of potential recharge. This value is based on an assumption of *c*. 20% runoff for the area with extreme and high vulnerability, and high to moderate permeability subsoils and soils (Guidance Document GW5, Groundwater Working Group 2005).

The bulk ***recharge coefficient*** for the area is estimated to be 80%.

These calculations are summarised as follows:

Average annual rainfall (R)	1002 mm
Estimated P.E.	500 mm
Estimated A.E. (95% of P.E.)	450 mm
Effective rainfall	552 mm
Potential recharge	552 mm
Runoff losses	20%
Bulk recharge coefficient	80%
Recharge	442 mm

Water balance: The water balance calculation states that the recharge over the area contributing to the source, should equal the discharge at the source. At a recharge of 442 mm/yr, an average yield of 600 m^3/day would require a recharge area of 0.5 km^2.

The ZOC described above is 0.475 km^2 and is based on the current understanding of the hydrogeology and in groundwater flow directions.

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 9.4, the groundwater velocity is 2 m/d, and hence the 100-day time of travel distance is 200 m. The Inner Protection Area is illustrated in Figure 14.

The Outer Protection Area (SO) encompasses the entire zone of contribution to the source *i.e.0.475* km^2*.*

Groundwater protection zones are shown in Figure 16, and are based on an overlay of the groundwater vulnerability on the source protection areas. Therefore the groundwater protection zones are SI/E, SI/H, SO/E and SO/H. The majority of the area is designated SO/H.

Table 10.3 Source Protection Zones

Source Protection Zone	% of total area
SI/Extreme	10%
SI/High	14%
SO/Extreme Rock close	9
SO/Extreme	15%
SO/High	48%

12. Potential pollution sources

The borehole area is currently fenced off and the borehole is grouted. A secure borehole housing is in place.

The majority of land within the Inner Source Protection Area is agricultural grassland and the dominant farm activity in the Outer Source Protection Area is tillage. The main potential pollution sources associated with farming activities are, grazing animals and landspreading of agricultural waste. The possible impacts to the water quality of the public supply associated with the tillage are elevated levels of ammonia, nitrate, phosphate, chloride, potassium, BOD, COD, TOC and pesticides. With the exception of the nitrate levels (average 30 mg/l), these parameters are not generally elevated in the untreated water supply. Moreover, an improvement in water quality has been observed since 2007, with a significant reduction in nitrate. Faecal coliforms have not been detected in the untreated water.

A small number of private dwellings are located within the ZOC, to the north of Edermine borehole. Though these are not a major problem as is, the installation of any new wastewater treatment systems in this area should be well assessed and closely monitored.

A railway line and private home heating fuel tanks are located within the catchment area. The main potential contaminants from these sources are hydrocarbons. Finally, there is a third class road within the ZOC. The main potential contaminants from this source are surface water runoff contaminated with hydrocarbons and metals. However, the low traffic density locally suggests that the risk of such contamination is low.

13. Conclusions

The borehole is a high yielding borehole that abstracts from the sand and gravel deposits, and from the underlying bedrock. The bedrock is overlain by approximately 15.5 m of sand and gravels. Groundwater is thought to infiltrate slowly through the subsoils and upper fractured bedrock towards the borehole.

The River Slaney and Borrmount stream are thought to be in hydraulic connectivity with the source but the extent of this may be variable due to the presence of alluvial subsoils between the source and the watercourses.

The untreated groundwater is currently of good microbial quality. The Outer Source Protection Area or the Zone of Contribution is calculated to extend to 0.475 km^2. The Inner Source Protection Area or the 100-day horizontal travel time is calculated to extend 200 m from the abstraction source.

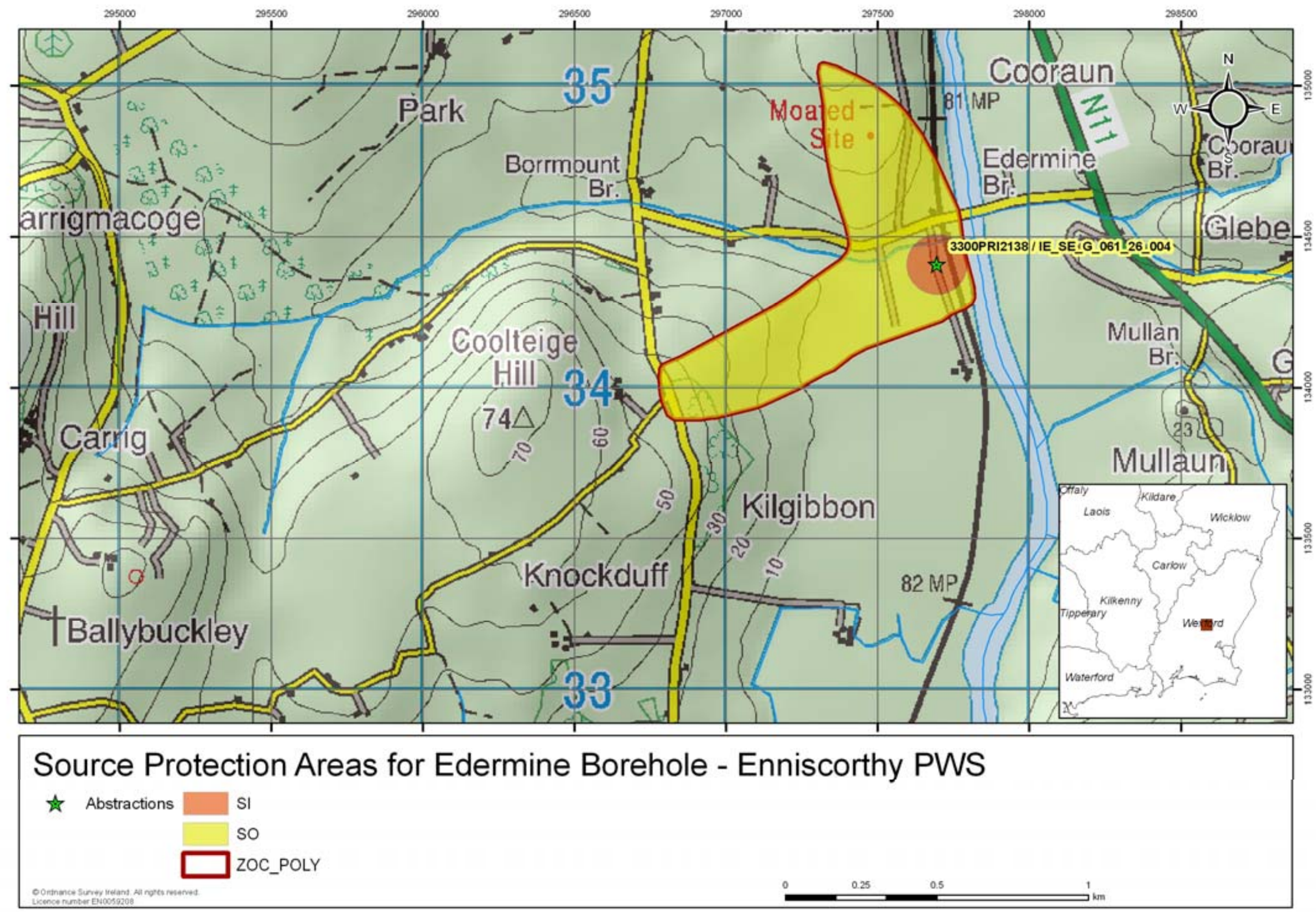

Figure 15 Source Protection Areas around Edermine borehole

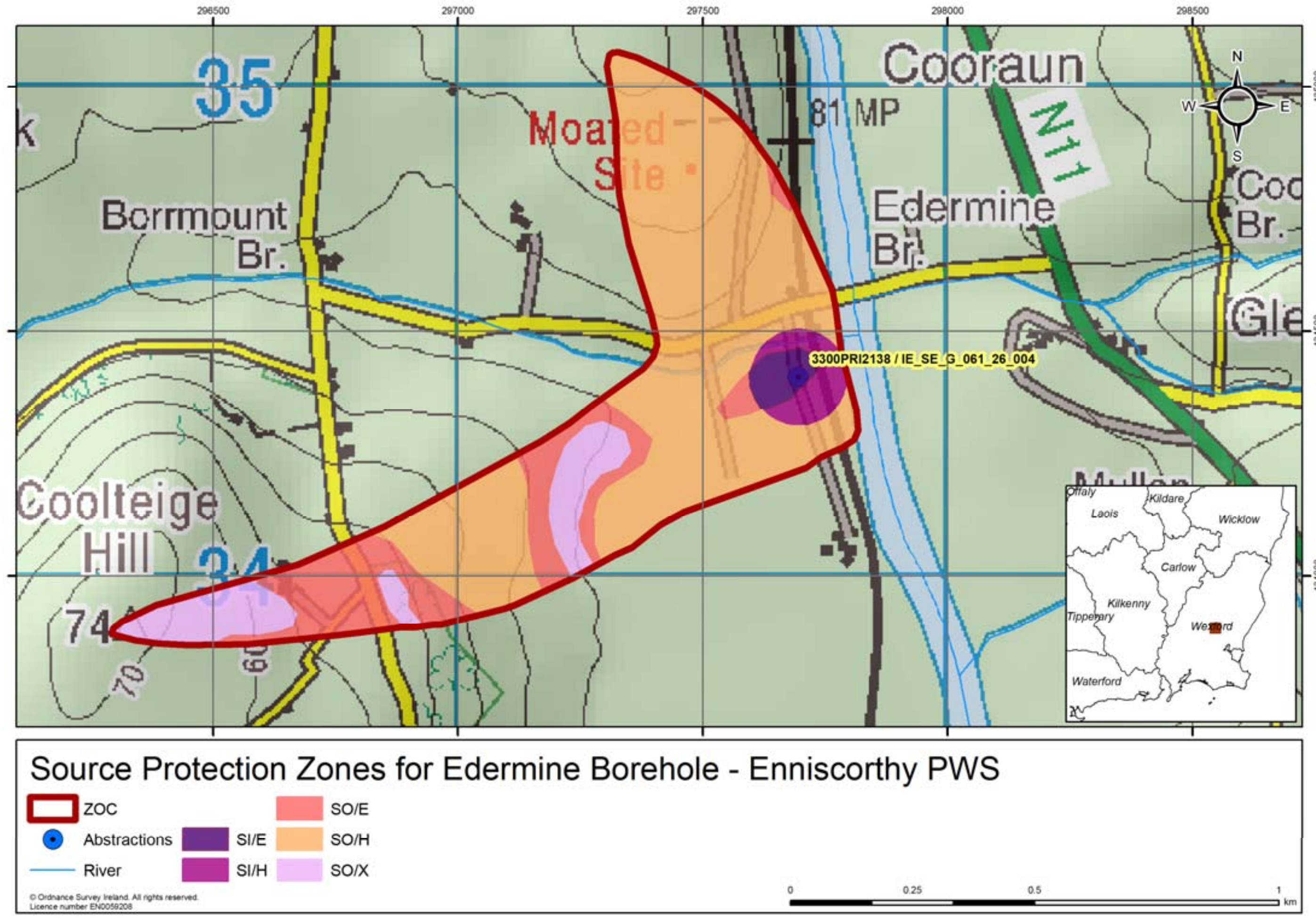

Figure 16 Source Protection Zones around Edermine borehole

14. Recommendations

The protection of the source site involves prevention of access and prevention of activities in the immediate proximity of the abstraction borehole. The cover from BH2 has been removed and the borehole is currently open. A secure cover should be placed on BH2 to ensure the well is not a potential pollution pathway to the underlying aquifer. A cordon should also be placed around BH2 to ensure the well is not damaged by farming activities.

Given the proximity to the tidal River Slaney and Borrmount stream, a preliminary assessment of potential flooding at Edermine borehole should be completed.

A secure cap cover above the borehole should be considered. There should be a small hole (~25 mm) in the cap with a plug to allow access for dipping the well. The rising pipe joint with the casing cap should be protected with a seal (such as rubber, IGI Well Drilling Guidelines, 2007)

To assess the well efficiency, a step test should be completed and compared to the original step test. Appropriate well maintenance can restore and improve the performance of the borehole.

15. References

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White Young Green, 2010. Gorey Regional Water Supply Scheme South Wellfield Project Source Protection Plan March 2010

APPENDIX 1

Borehole Log & Pumping test

Note Kevin Cullen has pump test results for this well
Afm 30/6/81

GENERAL INFORMATION SHEET

Well Location: EDERMINE   Well No: ____________

G.S.I. Ref No: 26/2

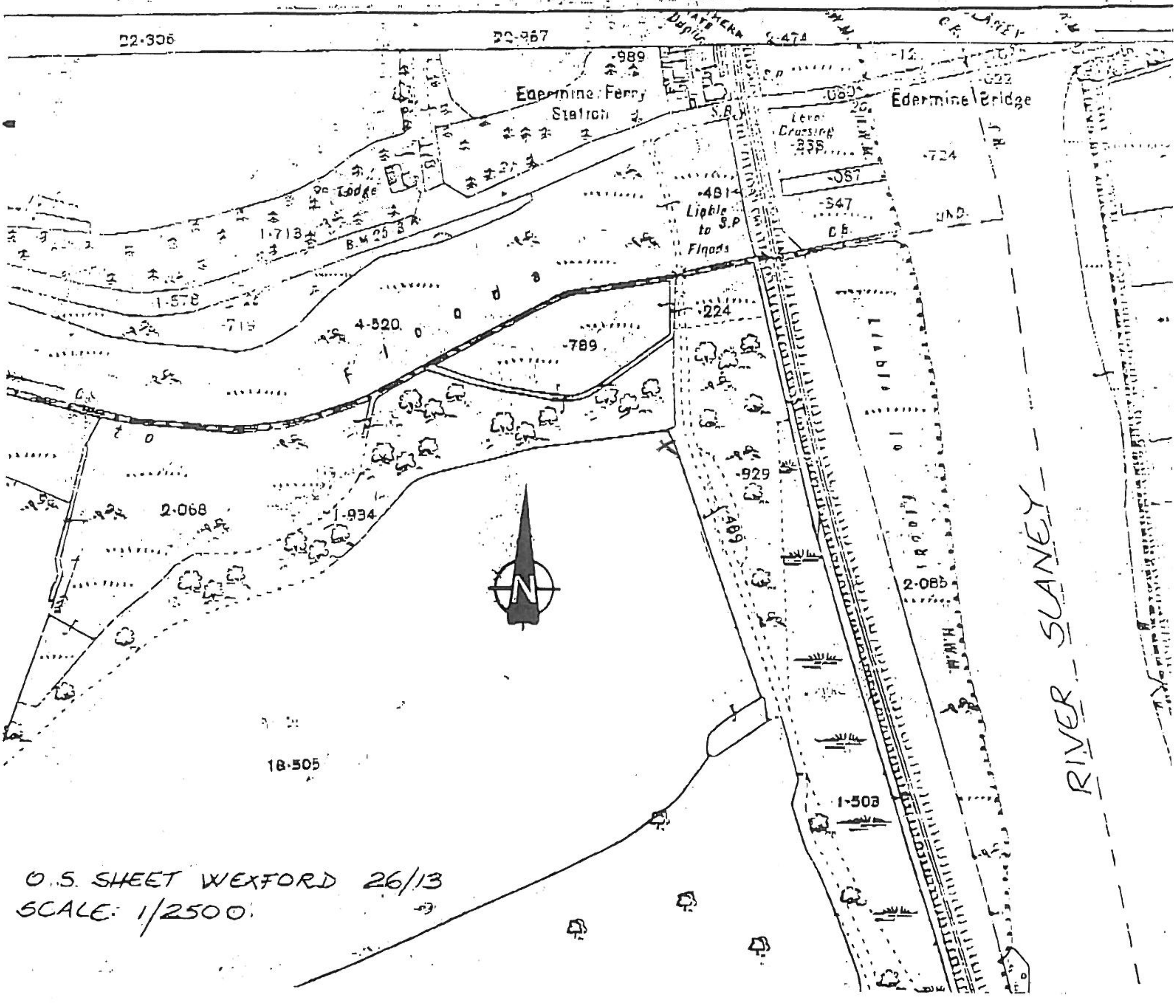
Drilled (Date): JUNE 977   By: S FLOOD

Aquifer: Sands & gravels   Level of Well top: 7.7 m.o.d.

Ground Level: 7.71 m.o.d.   Rest Water Level: 6.15 m.o.d.

Pump Water Level:	~~2~~ 13.8 m (ie − 6.1 mod) m bwt @	2350	m^3/day ~~gph.~~
	m bwt @		m^3/day gph.
	m bwt @		m^3/day gph.

Specific Capacity	192	m^3/day/m	gph/m
Estimated Safe Yield	2000	m^3/day	gph.
Finished Internal Well Diameter	200	mm	in.
Total Depth	19.7	m	ft.



O.S. SHEET WEXFORD 26/13
SCALE: 1/2500

... AND CONSTRUCTION SHEET

page:

WELL NO: 26/2

REMARKS:

WELL CONSTRUCTION

WELL GEOLOGY

DEPTH (METERS)	Grout	Water Levels	Water Entry	Water loss	Casing Diam. 200 mm	Casing Diam. mm	Casing Diam. mm	Casing Diam. mm	Screen Diam. 200 mm	Screen Diam. mm	Open hole Diam. 180 mm	Open hole Diam. mm	STRATA	DEPTH (FEET)
5													0–15.5 SANDS & GRAVELS	
10														
15													ORDOVICION VOLCANICS	
20														
25														
30														
35														
40														
45														
50														

Borehole name EDERMINE No. 26/2 Drawdown ☐ Recovery ☑

County 6" sheet No. 26 Pumping well ☑ Observation well ☐

Date 5th Feb '80 Distance from pumping well

Weather Test conducted by

Time	Elapsed time	Days		Water level	Draw-down	Meter reading	Q	Remarks
~~GMT~~/ BST	Mins/ Hours			M	M			(i.e. pump behaviour water temp, water quality etc)
	0	0.0		13.78				
	½ min	3.47 x 10^{-4}		5.81				
	1	6.95		2.53				
	1½	1.04 x 10^{-3}		2.15				
	2	1.39		2.07				
	2½	1.74		2.04				
	3	2.08		2.03				
	3½	2.43		2.03				
	4	2.78		2.03				
	4½	3.13		2.03				
	5	3.47		2.02				
	6	4.17		2.02				
	7	4.86		2.02				
	8	5.56		2.02				
	9	6.25		2.02				
	10	6.94		2.02				
	12	8.33		2.01				
	14	9.72		2.01				
	16	1.11 x 10^{-2}		2.01				
	18	1.25		2.01				
	20	1.39		2.01				
	22	1.53		2.00				
	24	1.67		2.00				
	26	1.81		2.00				
	28	1.94		2.00				
	30	2.08		2.00				
	35	2.43		1.99				
	40	2.78		1.99				
	45	3.13		1.98				
	50	3.47		1.98				
	55	3.82		1.97				
	1 hour	4.17		1.97				
	1¼	5.21		1.97				
	1½	6.25		1.96				
	1¾	7.29		1.95				
	2	8.83		1.95				
	2½	1.04 x 10^{-1}		1.94				

Borehole name. EDERMINE .... No 26/2.. ~~County~~. DRANDOWN..... 6" sheet no. 2..

Time	Elapsed time	Days		Water level	Draw-down	Meter reading	Q	~~Remarks~~ (i.e. pump behavi.. water temp, wate.. quality etc)
GMT/ BST	Mins/ Hours			M	M			
	3	1·25		12·94				
	3½	1·46		13·07				
	4	1·67		13·08				
	5	2·08		13·22				
	6	2·5		13·24				
	7	2·92		13·29				
	8	3·33		13·36				
	9	3·75		13·36				
	10	4·17		13·78				
	12	5·0		13·83				
	14	5·83		13·90				
	16	6·67		—				
	18	7·5		13·90				
	21	8·75	!	13·80				
	24	1·0 x 10^{0}		13·90				360 GPM
	27	1·125		13·70				(ie 21,600 gph
	30	1·25		13·85				or 518,000 gpd
	36	1·5		13·70				
	42	1·75		13·85				
	48	2·0		13·74				360 GPM
	54	2·25	!	13·90				
	60	2·5		13·90				
	66	2·75		13·80				
	72	3·0						360 GPM.
		3·5						
		4·0						
		4·5						
		5·0						
		6·0						
		7·0						
		8·0						
		9·0						
		10·0						

Other remarks

Borehole name EDERMINE No. 26/2 | Drawdown [✓] | Recovery [ ]

County .... 6" sheet No. 26 | Pumping well [✓] | Observation well [ ]

Date 72 hr TEST | Distance from pumping well ....

Weather .... | Test conducted by ....

Time	Elapsed time	Days		Water level	Draw-down	Meter reading	Q	Remarks (i.e. pump behaviour, water temp, water quality etc)
~~GMT~~/BST	Mins/Hours			M	M			
	0	0.0		1.58				
	½ min	3.47×10^{-4}		11.30				
	1	6.95		—				
	1½	1.04×10^{-3}		8.80				
	2	1.39		9.00				
	2½	1.74		10.13				
	3	2.08		10.54				
	3½	2.43		10.95				
	4	2.78		10.96				
	4½	3.13		10.97				
	5	3.47		11.39				
	6	4.17		—				
	7	4.86		11.40				
	8	5.56		11.74				
	9	6.25		11.91				
	10	6.94		11.99				
	~~12~~	8.33		12.12				
	14	9.72		12.18				
	16	1.11×10^{-2}		12.22				400 G.P.M.
	18	1.25		11.95				REDUCED SPEED
	20	1.39		11.90				
	22	1.53		11.90				
	24	1.67		11.92				
	26	1.81		—				
	28	1.94		11.86				
	30	2.08		11.88				
	35	2.43		11.89				395 GPM
	40	2.78		—				REDUCED SPEED
	45	3.13		12.48				365 G.P.M.
	50	3.47		12.63				
	55	3.82		12.72				
	1 hour	4.17		12.71				
	1¼	5.21		12.88				
	1½	6.25		12.96				
	1¾	7.29		12.98				
	2	8.83		13.02				
	2½	1.04×10^{-1}		13.00				

Borehole name EDERMINE No. 2612 | Drawdown ☑ | Recovery ☐

County ... 6" sheet No. 26 | Pumping well ☑ | Observation well ☐

Date 1st FEB '80 3rd STEP TEST | Distance from pumping well ...

Weather FINE | Test conducted by ...

Time GMT/BST	Elapsed time Mins/Hours	Days		Water level M	Draw-down M	Meter reading	Q	Remarks (i.e. pump behaviour, water temp, water quality etc)
	0	0.0		5.93				
	1/2 min	3.47 x 10^{-4}		—				
	1	6.95		4.93				
	1 1/2	1.04 x 10^{-3}		—				
	2	1.39		—				
	2 1/2	1.74		—				
	3	2.08		4.94				
	3 1/2	2.43		—				
	4	2.78		4.97				
	4 1/2	3.13		—				
	5	3.47		—				
	6	4.17		5.05				
	7	4.86		5.08				
	8	5.56		5.78				
	9	6.25		6.43				
	10	6.94		7.07				
	12	8.33		8.05				
	14	9.72		8.73				360 gpm.
	16	1.11 x 10^{-2}		8.95				
	18	1.25		9.10				
	20	1.39		9.18				
	22	1.53		9.22				
	24	1.67		—				
	26	1.81		9.77				
	28	1.94		9.89				
	30	2.08		10.02				
	35	2.43		10.18				
	40	2.78		10.38				
	45	3.13		10.32				
	50	3.47		10.52				
	55	3.82		10.58				
	1 hour	4.17		10.92				
	1 1/4	5.21		11.19				
	1 1/2	6.25		11.23				
	1 3/4	7.29		11.11				
	2	8.83		11.32				360 gpm
	2 1/2	1.04 x 10^{-1}		11.39				

Borehole name EDERMINE ...... No. 20/2 ~~County~~ STEP TEST .... 6" sheet no....

Time	Elapsed time	Days		Water level	Draw-down	Meter reading	Q	Remarks (i.e. pump behavi water temp, wate quality etc)
GMT/ BST	Mins/ Hours			M	M			
	3	1.25		11.42				
	3½	1.46		11.50				
	4	1.67		11.58				
	5	2.08						
	6	2.5						
	7	2.92						
	8	3.33						
	9	3.75						
	10	4.17						
	12	5.0						
	14	5.83						
	16	6.67						
	18	7.5						
	21	8.75						
	24	1.0×10^{0}						
	27	1.125						
	30	1.25						
	36	1.5						
	42	1.75						
	48	2.0						
	54	2.25						
	60	2.5						
	66	2.75						
	72	3.0						
		3.5						
		4.0						
		4.5						
		5.0						
		6.0						
		7.0						
		8.0						
		9.0						
		10.0						

Other remarks

Borehole name EDERMINE No. 26/2

County 6" sheet No. 26

Date 1st FEB '80 2ND STEP TEST

Weather FINE

Drawdown ☐ Recovery ☐

Pumping well ☐ Observation well ☐

Distance from pumping well

Test conducted by

Time	Elapsed time	Days		Water level	Draw-down	Meter reading	Q	Remarks (i.e. pump behaviour water temp, water quality etc)
~~GMT~~/ BST	Mins / Hours			M	M			
	0	0.0		4.26				
	1/2 min	3.47 X 10^{-4}		4.53				
	1	6.95		4.58				
	1 1/2	1.04 X 10^{-3}		4.58				
	2	1.39		4.61				
	2 1/2	1.74		4.62				
	3	2.08		4.64				
	3 1/2	2.43		4.65				
	4	2.78		4.65				
	4 1/2	3.13		4.67				
	5	3.47		4.68				
	6	4.17		—				
	7	4.86		—				
	8	5.56		4.69				
	9	6.25		4.70				
	10	6.94		4.70				
	[illegible]	8.33		4.74				
	14	9.72		4.76				
	16	1.11 X 10^{-2}		4.78				
	18	1.25		4.80				
	20	1.39		4.81				
	22	1.53		4.82				
	24	1.67		4.83				
	26	1.81		4.85				
	28	1.94		4.85				
	30	2.08		4.86				
	35	2.43		4.88				
	40	2.78		4.90				
	45	3.13		4.90				
	50	3.47		4.92				
	55	3.82		4.95				
	1 hour	4.17						
	1 1/4	5.21						
	1 1/2	6.25						
	1 3/4	7.29						
	2	8.83						
	2 1/2	1.04 X 10^{-1}						

Borehole name EDERMINE No. 26/2

County ...... 6" sheet No. ......

Date 1st FEB '80 1st STEP TEST

Weather ......

Drawdown [ ]

Pumping well [✓]

Recovery [ ]

Observation well [ ]

Distance from pumping well ......

Test conducted by ......

Time GMT/BST	Elapsed time Mins/Hours	Days		Water level M	Draw-down M	Meter reading	Q	Remarks (i.e. pump behaviour water temp, water quality etc)
	0	0.0		1.55				
	1/2 min	3.47 x 10^{-4}		3.75				
	1	6.95		—				
	1 1/2	1.04 x 10^{-3}		3.93				
	2	1.39		3.98				
	2 1/2	1.74		3.99				
	3	2.08		4.05				
	3 1/2	2.43		4.05				
	4	2.78		4.05				
	4 1/2	3.13		4.05				
	5	3.47		4.05				
	6	4.17		4.10				
	7	4.86		4.10				
	8	5.56		4.10				
	9	6.25		4.10				
	10	6.94		—				
	~~12~~	8.33		4.15				
	14	9.72		4.18				
	16	1.11 x 10^{-2}		4.19				
	18	1.25		4.21				
	20	1.39		4.21				
	22	1.53		4.22				
	24	1.67		4.23				
	26	1.81		4.24				
	28	1.94		4.24				
	30	2.08		4.26				
	35	2.43						
	40	2.78						
	45	3.13						
	50	3.47						
	55	3.82						
	1 hour	4.17						
	1 1/4	5.21						
	1 1/2	6.25						
	1 3/4	7.29						
	2	8.83						
	2 1/2	1.04 x 10^{-1}						

Borehole name EDERMINE .... No 26/2... ~~County~~ RECOVERY ...... 6" sheet no..

Time GMT/ BST	Elapsed time Mins/ Hours	Days		Water level M	Draw-down M	Meter reading	Q	Remarks (i.e. pump behav water temp, wat quality etc)
	3	1.25		1.94				
	3½	1.46		1.94				
	4	1.67		1.94				
	5	2.08		1.94				
	6	2.5		1.94				
	7	2.92		1.93				
	8	3.33		1.91				
	9	3.75		1.89				
	10	4.17		1.87				
	12	5.0		1.82				
	14	5.83		1.82				
	16	6.67		1.82				
	18	7.5		1.81				
	21	8.75		1.80				
	24	1.0×10^{0}		1.72				
	27	1.125						
	30	1.25						
	36	1.5						
	42	1.75						
	48	2.0						
	54	2.25						
	60	2.5						
	66	2.75						
	72	3.0						
		3.5						
		4.0						
		4.5						
		5.0						
		6.0						
		7.0						
		8.0						
		9.0						
		10.0						

Other remarks