



Environmental Protection Agency

Establishment of Groundwater Source Protection Zones

Doon Water Supply Scheme

Cooga Spring

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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 Cooga Spring 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 'Cooga Spring' is part of the Doon Public Water Supply. The spring supplies approximately 180 m³/day to Doon Village. Two boreholes at Carrigmore (4 km to the southeast) and Lacka (2.5 km to the east) supply the balance of water to Doon village and surrounding area. Three additional boreholes to the east and south of Doon Village were drilled in the early 2000's but were not brought into supply. A private borehole (BH2) was drilled in 2007 to provide additional supply for a proposed private housing development has not been brought into supply.

The objectives of the report are as follows:

- To outline the principal hydrogeological characteristics of the Doon area, in particular that around Cooga Spring.
- To delineate source protection zones for Cooga Spring.
- To assist the Environmental Protection Agency and Limerick 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 consisted of data collection, desk studies, field mapping, site visits and conductivity/temperature measurements at Cooga Spring. A datalogger was installed in the spring to assist in obtaining information on groundwater levels. Analysis of the information collected during the study was used to delineate Groundwater Source Protection Zones.

The initial site visit and interview with the caretaker took place on 08/10/2010. Site walk-overs and field mapping (including measuring the electrical conductivity and temperature of streams in the area) of the study area were conducted on 08/10/2010, 11/10/2010 and 17/10/2010.

While specific fieldwork was carried out in the development of this report, the maps produced are based largely on the readily available information and mapping techniques using inferences and judgments from experience at other sites. As such, the maps may not 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 spring protection

Cooga Spring, operated by the Limerick County Council since the 1960s, is located 1.3 km west of Doon Village (see Figure 1). The site is located along a farm road access from the R505 and is surrounded by agricultural land. Groundwater is pumped from the spring source to the adjacent treatment works where the

untreated water is chlorinated. A raw water tap is located within the treatment works. Treated water is then pumped to Doon Reservoir, 1 km to the east, for storage and distribution throughout the network.

The spring has a concrete collecting chamber which is covered and locked (Photo 1). The spring chamber is approximately 4.2 m deep and 4.5 m in diameter. The spring and adjacent treatment works are fenced off.



Photograph 1 Cooga Spring

4 Summary of spring details

Cooga Spring provides approximately 40% of the water supply for Doon Village. The groundwater abstraction varies between 140 and 200 m³/day depending on demand.

The water levels at the spring were dipped to establish the depth of the watertable and were recorded to be between 1.4 m below the top of the spring housing (0.6 m below ground level). Levels are known to drop by approximately 1.5 m during dry summers. Table 3.1 provides a summary of the details as currently known. When water levels are high, an overflow from the concrete chamber discharges surplus groundwater to an adjacent drainage ditch. The overflow volume is not measured.

Table 3.1 Summary Details

	Cooga Spring
EU Reporting Code	IE_SH_G_213_13_008
Grid reference	E181870 N150550
Townland	Cooga Lower
Source type	Spring
Owner	Limerick County Council
Elevation (Ground Level)	c. 72 m OD
Depth	4.2 m
Diameter	4.5 m
Depth to rock	-
Static water level	Approximately 0.6 m bgl (October 2010)
Pumping water level	Approximately 0.5 to 1.5 m bgl
Transmissivity	50 m ² /day
Consumption (County Council records)	Average 180 m ³ /d, pumping 24 h/d. Range 140–200 m ³ /d

5 Topography, surface hydrology and landuse

The spring is located along the southern edge of the Silvermines/Slieve Phelim Mountains, approximately 1.3 km west of Doon, in the townland of Cooga Lower. The spring is located on a break in slope between the hummocky and undulating outwash sand and gravels to the north, and a relatively flat peaty area to the south. To the north of the spring, the hummocky ground rises in a north-northeast direction, becoming moderately steep between 100 m and 140 m OD, and steep between 140 m and 418 m OD, on the slopes of Gortnageragh Mountain (See Figure 1). Gradients to the north of the study area increase from 1:50 to 1:5. To the south of the spring, the topography falls gently at a gradient of over 1:100 towards the Dead River.

Cooga Spring is located within the Shannon catchment (Hydrometric Area 25). There are a number of surface water courses in the surrounding area, all of which are tributaries of the Mulkear River. To the west and north, a number of rivers including the Bilboa River and Gortnageragh River flow off the Silvermines/Slieve Phelim mountains. The Dead River drains the lowland peat areas to the south of Cooga Spring and flows in a westerly direction towards the Mulkear River. A number of unnamed tributary streams of the Dead River rise to the south and east of the Cooga Spring. Refer to Figure 1 which shows the location of Cooga Spring and the surrounding surface water features.

The land in the immediate vicinity of the spring, and in the lower lying areas to the south, is generally quite wet and marshy. Numerous man made ditches drain these peaty, lowland areas. Drainage ditches are generally absent from the hummocky sands and gravels in the locality (see section 7.3 following), with ditches becoming common however in the till areas. Rushes occur intermittently on these till slopes, but also on occur in the sand and gravel areas. A number of small ponds occur at the base of hollows in the hummocky topography between 90 m and 95 m OD, to the north of Cooga Spring. These areas appear to be areas where the water table breaks the surface, and have no inflow or outflow features.



Photo 2 Area north of Doon showing hummocky topography and small pond in hollow

Land use in the study area is primarily agricultural, with most of the land set to pasture. A number of one off houses is located along the local roads to the north of Cooga Spring (See Figure 2) which discharge to ground *via* septic tanks and mechanical aeration systems. A number of farmyards have been noted in the area, with one farmyard identified 120 m to the northeast of the source. No major industries or IPPC licenses were identified in the environs of the source.

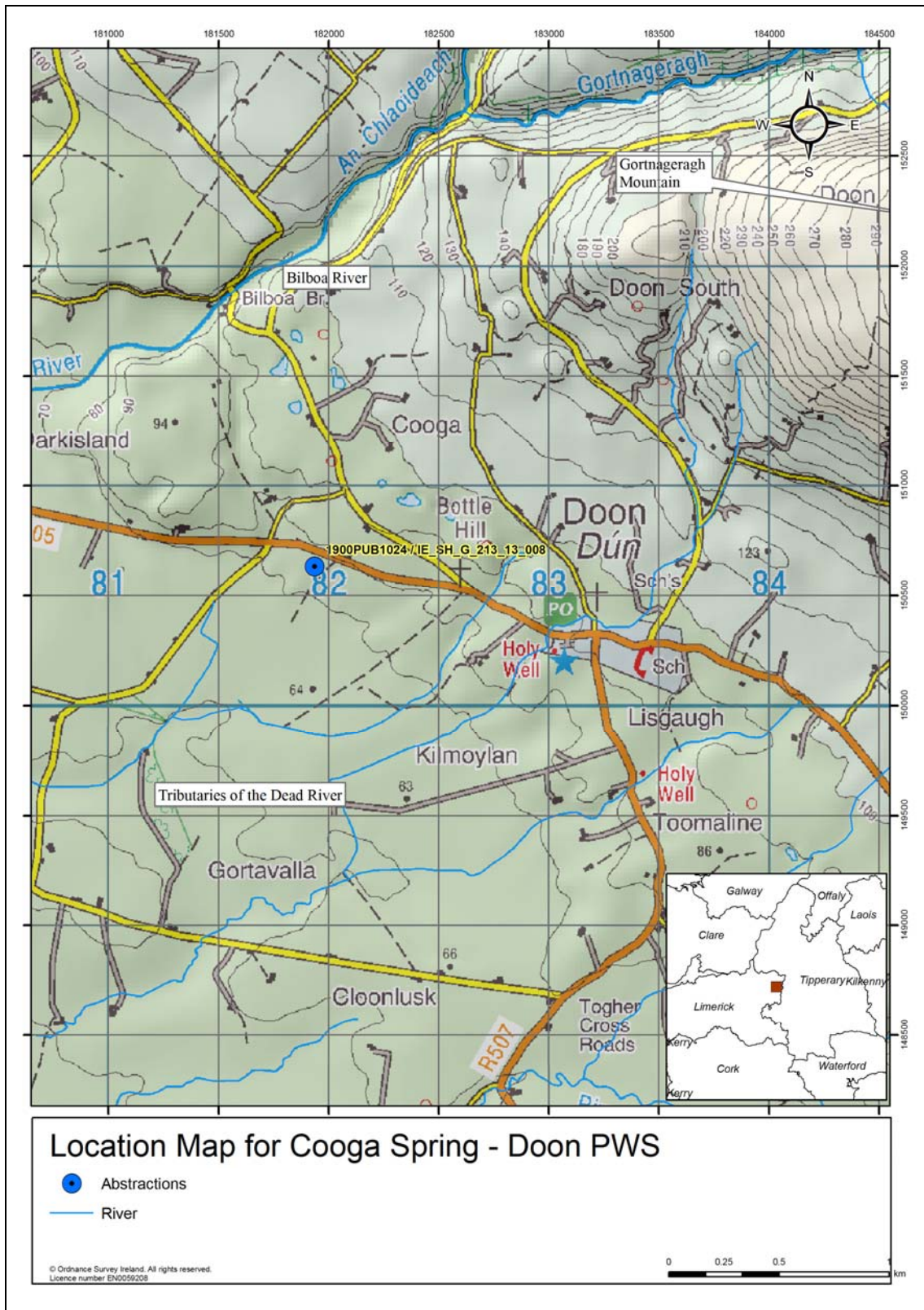


Figure 1 Location Map for the area around Cooga Spring

6 Hydrometeorology

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: 993 mm. Data from the Met Eireann website show that the source is located between the 800 mm and 1000 mm average annual rainfall isohyets. The nearest gauging station to Cooga Spring during the period 1961 to 1990 is located at Oola, 8 km to the south, which recorded an average annual rainfall of 993 mm (Fitzgerald and Forrestal, 1996).

Annual evapotranspiration losses: 427 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: 566 mm. The annual effective rainfall is calculated by subtracting actual evapotranspiration from rainfall. Potential recharge is therefore equivalent to this, or 566 mm/year.

7 Geology

7.1 Introduction

This section briefly describes the relevant characteristics of the geological materials that underlie the site. It provides a framework for the assessment of groundwater flow and delineation of the source protection zones following in later sections.

The desk study data used comprised the following:

- Geology of Tipperary. Bedrock Geology 1 : 100,000 Map series, Sheet 18, Geological Survey of Ireland (Archer, *et al*, 1996)
- County Limerick Groundwater Protection Scheme. Geological Survey of Ireland report to Limerick Co. Co., (Deakin, *et al*, 1998)
- Soils of Co. Limerick (Finch and Ryan, 1966)

7.2 Bedrock geology

The Bedrock Geological Map of Tipperary indicates that the spring is underlain by the Lower Limestone Shales which are comprised of thinly bedded sandstones, mudstones and thin limestones and mark the boundary between the Old Red Sandstones and the Dinantian limestones. There are no exposures of Lower Limestone Shales in the Cooga Spring area due to the thick subsoil cover.

To the north of the spring, the bedrock geology comprises sandstones and conglomerates of the Devonian Old Red Sandstones which is mapped in this area as the Keeper Hill Formation. The rocks are pale and red sandstones, with mudstones and coarse conglomerates. The Dinantian Lower Impure Limestones are located 0.5 km to the south of the spring. Refer to Figure 2 for the Geology Map of the area.

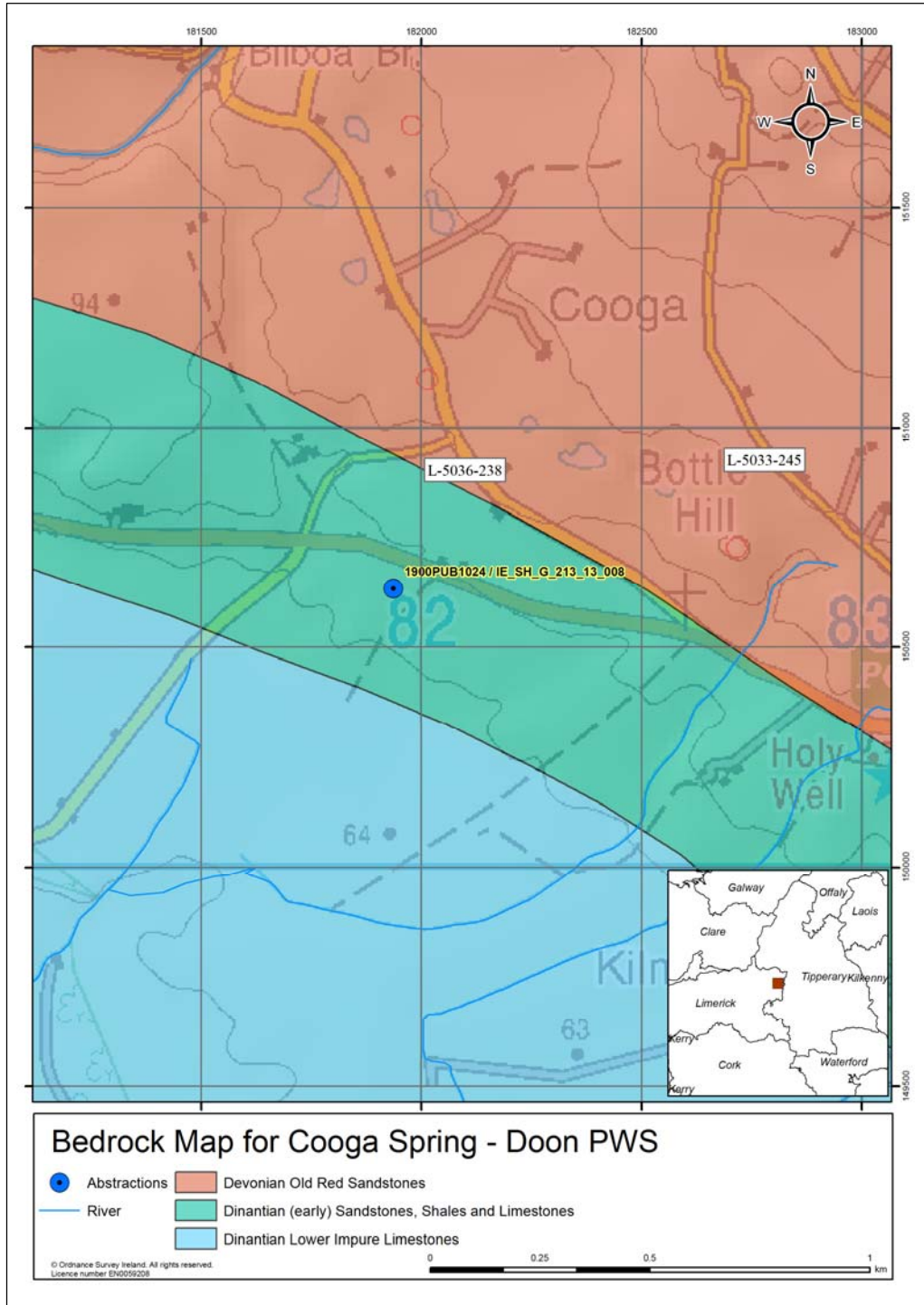


Figure 2 Geology Map for the area around Cooga Spring

7.3 Subsoils geology

According to GSI and EPA web mapping, the subsoils immediately to the north of the source are dominated by sand and gravel deposits derived from Devonian sandstones (GDSs). Surrounding the mapped sand and gravel deposits is an area dominated by till deposits derived from Devonian sandstones (TDSs). Further to the north of the local road L-5033-245 and on the slopes of Gortnageragh Mountain, areas of till derived from Lower Palaeozoic Sandstone and Shales (TLPSs) are mapped. See Figure 3 for details.

The sand and gravel area is composed of sorted sand and gravels, as confirmed by shallow soil augering at a number of locations (S1 and S2) and a 2 m deep subsoil exposure at S3. The deposits at S3 were comprised of slightly silty, fine to medium gravelly SAND with frequently cobbles; which is in keeping with the mapped sands and gravel deposits.



Photo 3 Gravel subsoil exposure at S3

The soils on the sand and gravel areas are predominately well drained shallow soils (AminSW). Small pockets of till are located within the sands and gravels which correspond to areas of rushes and other indicators of low permeability subsoil. The till areas have predominately 'wet' soil types: typically poorly drained deep mineral soils (AminPD) (EPA webmapping). In the immediate vicinity of the spring, the sands and gravels host poorly drained, shallow soils, as they are overlain by a thin unit of till. The sand and gravel area is surrounded by till and till is also thought to underlie the sand and gravel deposits. A number of water filled hollows occur within the sand and gravel deposits between 90 m and 95 m OD, which are underlain by small areas of lacustrine deposits and appear to correspond with the groundwater table.

The subsoils across County Limerick have been classified according to British Standards 5930 in the preparation of the Groundwater Vulnerability map for Meath County Council, by the GSI. The subsoil permeability of the till unit around the source has been classed as '*low permeability*'. Areas of '*high*' permeability sand and gravel deposits are located towards the north of the borehole.

7.4 Depth to bedrock

Depth to bedrock (DTB) has been interpreted across the study area based on bedrock outcrops mapped by the GSI, outcrops mapped during site visits and areas mapped as extreme groundwater vulnerability under the GSI Groundwater Protection Scheme (GWPS), as well as borehole and well data.

From the GWPS mapping, DTB is mapped as less than 3 m on the slopes of Gortnageragh Mountain but increases rapidly towards the till and sand and gravel areas. The depth of sand and gravel varies within the hummocky topography but is believed to be less than 5 m deep on average and underlain by till. Limited data is available on the depth to bedrock at the source and immediately upgradient. Depth to bedrock at Cooga Spring is unknown but is believed to be greater than 4.2 m (total depth of the spring) as bedrock was not encountered in the spring chamber.

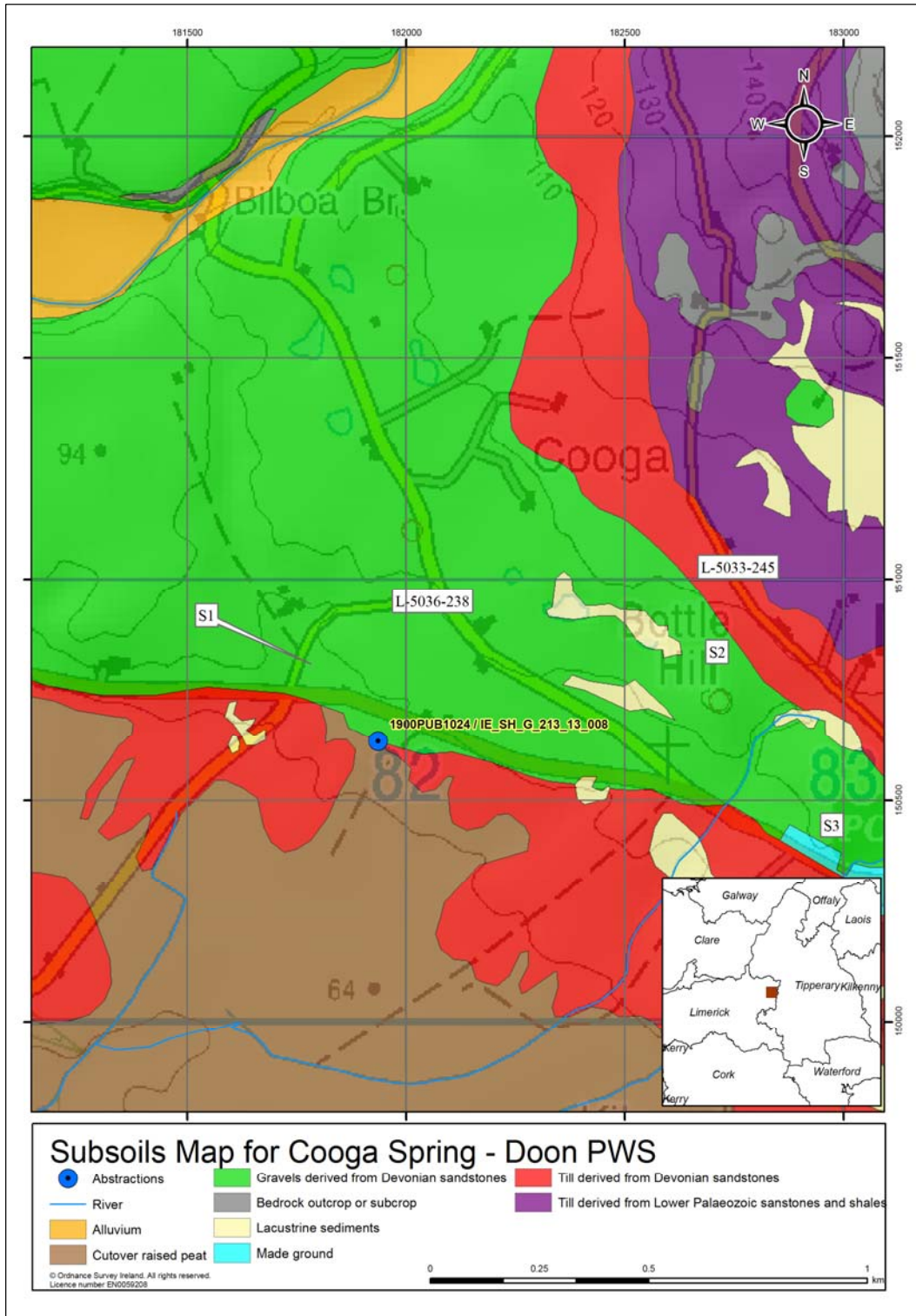


Figure 3 Subsoil Map for the area around Cooga Spring

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 sand and gravel subsoil at Cooga Lower is interpreted as "high" permeability, in keeping with the general subsoil permeability categories. The permeability of the till subsoil is "low", based on the presence of secondary indicators of low subsoil permeability.

For the purposes of vulnerability mapping in the immediate vicinity of the spring, the "**water table**" is the target, as this lies close to the surface in the gravels. This map incorporates a proposed area in the immediate vicinity of the spring where the water table is within 3 m of ground level (see section 9.2) and therefore the vulnerability is interpreted as extreme. It is thought that the underlying low permeability till deposits limit the downward percolation of groundwater and as a consequence, groundwater levels are within 3 m of the surface.

Further to the north, areas of extreme, high and moderate vulnerability occur on the slopes of Gortnageragh Mountain.

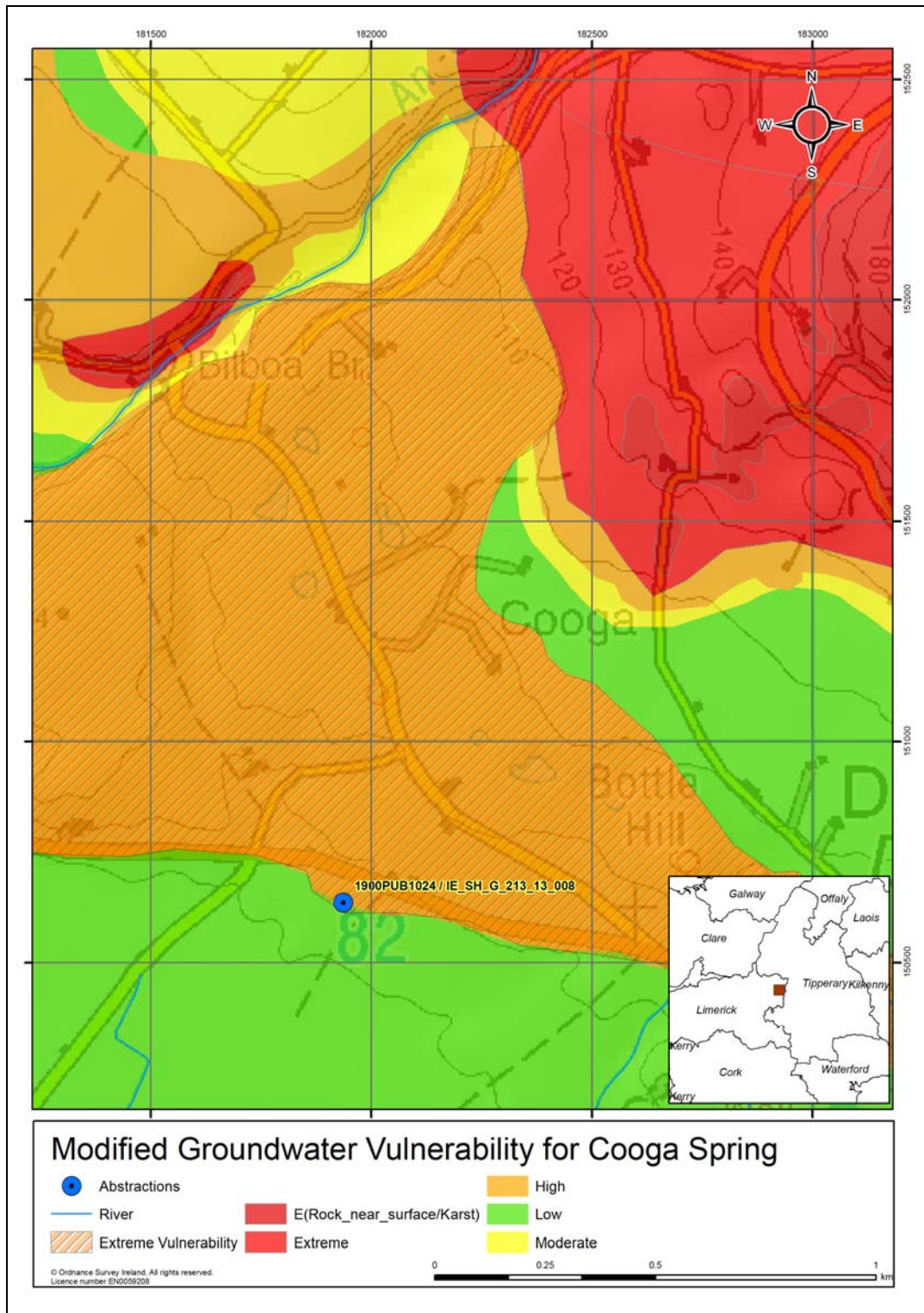


Figure 4 Modified Groundwater Vulnerability for the area around Cooga Spring for source report

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; and
- Hydrogeological mapping by TOBIN Consulting Engineers in October 2010.

9.1 Groundwater body and status

Cooga Spring is located within the Slieve Phelim 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

Groundwater flow to the spring is considered to be primarily from the sand and gravel subsoil. The groundwater flow direction is assumed to follow topography and radiate from the upland areas and discharge locally at the break in slope between the mapped sand and gravel deposits and peat deposits. In the vicinity of the source, groundwater flow is assumed to follow topography and flow south-southeast.

A number of groundwater rises (GR 1 to GR 4) occur in drainage ditches to the east and west of Cooga Spring (see Figure 9). This suggests the diffuse nature of groundwater discharge along the boundary between the sand and gravels and peat. Some groundwater flow within the Old Red Sandstones is likely to rise at this point where it encounters lower permeability horizons of the Lower Limestone Shales which underlie the spring.

A number of small ponds are located between 90 m and 95 m OD, 1 km to the north of Cooga Spring, and are considered to represent the groundwater table at these localities (see Figure 9). Most trial pits excavated for percolation tests for onsite waste water treatment systems to the north of Cooga Spring encountered water levels between 2 m and 3 m below ground level. Groundwater levels in a borehole (BH 1) drilled near Doon village is less than 1 m bgl and artesian during the winter period. Groundwater levels in Cooga Spring vary little between summer and winter periods (0.5 m bgl and 2 m bgl), which is suggestive of the high storage within the sands and gravels. The natural groundwater gradient is considered to be moderately steep, approximately 0.02, reflecting the topographical gradients. The groundwater gradient between the ponds and Cooga Spring is 0.02.

Over a 25 day period in October and November 2010, water levels and temperature within Cooga Spring were measured using a pressure transducer whilst pumping at 130 to 170 m³/d. Water levels, corrected to account for atmospheric pressure, are presented below in Figure 5. Water levels were seen to respond to pumping events during the period of monitoring: they varied by an average of 0.1 m when pumping with a maximum variation of 0.35 m over 25 days of monitoring. The minimal variation in water levels during

pumping seems indicative of the high storage and transmissivity of the sand and gravel deposits. During the monitoring period, water levels were at or near the overflow level. The increased drawdown as seen on the 23/10/2010 to the 26/10/2010 was in response to an increased pumping rate during this period. When compared to rainfall data, no clear response could be recognised. A slight upward trend of 0.02m is a result of data drift.

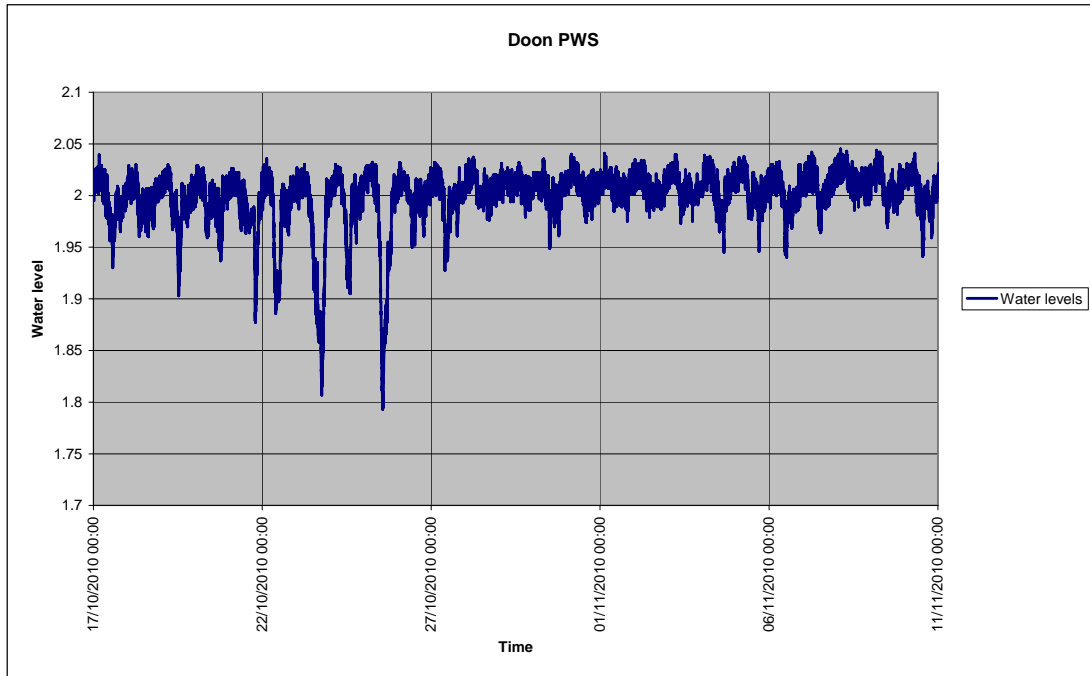


Figure 5 Groundwater levels in Cooga Spring (17/10/2010–11/12/2010)

9.3 Hydrochemistry and water quality

Thirty five sample analyses from Cooga Spring were available from the EPA Groundwater Monitoring Network between 1995 and 2009. The water quality is hard (138 to 486 mg/l CaCO_3). Alkalinity ranges from 112 to 353 mg/l CaCO_3 . The pH ranges between 7.3 and 8.6, which is alkaline. Electrical conductivity ranges from 448 to 543 $\mu\text{S}/\text{cm}$ @ 25°C. The hydrochemical signature of Cooga Spring's groundwater is calcium bicarbonate.

The concentration of nitrate ranges from 12.9 to 43.6 mg/l with a mean of 22.8 mg/l (as NO_3) which is below the Threshold Value (Groundwater Regulations S.I. No. 9 of 2010) of 37.5 mg/l NO_3 . There were no reported exceedances above the EU Drinking Water Directive maximum admissible concentration of 50 mg/l NO_3 . A slight downward trend in the nitrate data has occurred since 2002, with a significant decrease since 2007 to present (Figure 5). This is possibly as a result of improved organic waste management practices in the surrounding farmland and above average rainfall from 2007 to 2009.

Private dwellings to the north of Cooga Spring are served by septic tanks or mechanical aeration systems discharging to ground and agriculture is practiced in the general area. Ammonium concentrations were low in all samples with no exceedance of the Threshold Value.

Chloride is a constituent of organic wastes, sewage discharge and artificial fertilisers, and levels higher than 24 mg l^{-1} (Groundwater Threshold Value, Groundwater Regulations S.I. No. 9 of 2010) may indicate contamination, with levels higher than 30 mg/l usually indicating significant contamination (Daly, 1996). Chloride concentrations range from 14.9 mg/l to 29.9 mg/l , with a mean of 20.4 mg/l which is considered to be above the mean natural background level of 18 mg/l (Baker *et al.*, 2007), but is below the Threshold Value. Similar to nitrate concentrations, a slight downward trend in the chloride concentrations has occurred since 2002, with a significant decrease since 2007 to present, as shown in Figure 5. This is possibly as a result of improved organic waste management practices in the surrounding farmland and above average rainfall from 2007 to 2009.

Low levels of faecal coliforms (1, 2 and 3 cfu/100 ml) were detected in three groundwater samples of the 35 water samples analysed in 2007 to 2009. Elevated concentrations of total coliforms were detected on 18 occasions. The shallow water table and unsaturated zone, as well as the abstraction of shallow groundwater flow, mean that there is potential for faecal contamination of the source.

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 0.2 and never exceeds 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.

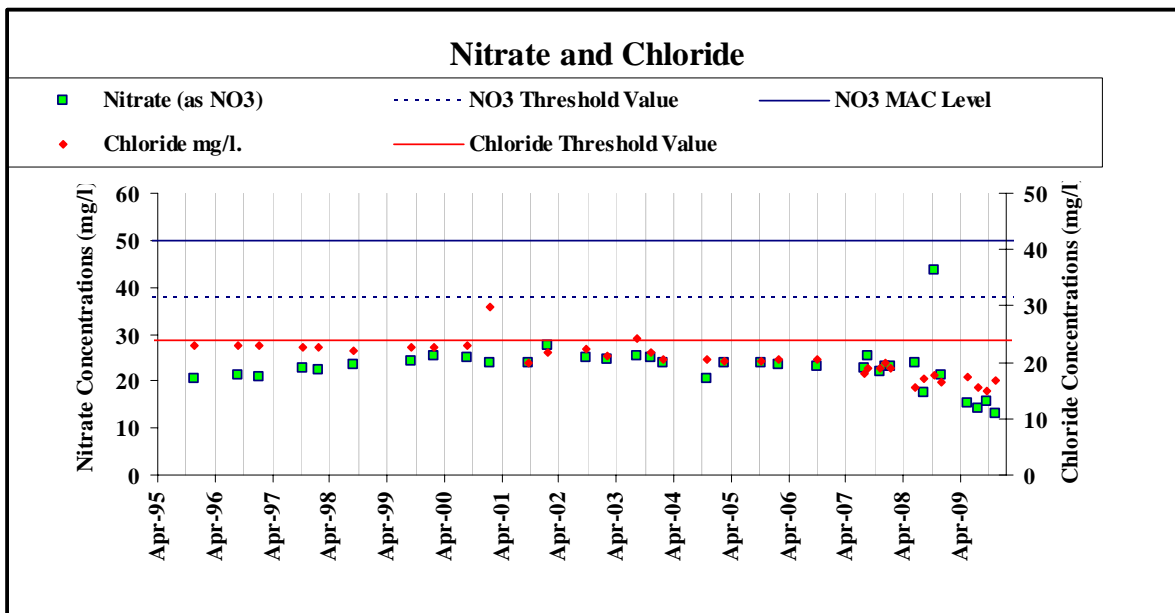


Figure 6 Nitrate and Chloride concentrations at Cooga Spring

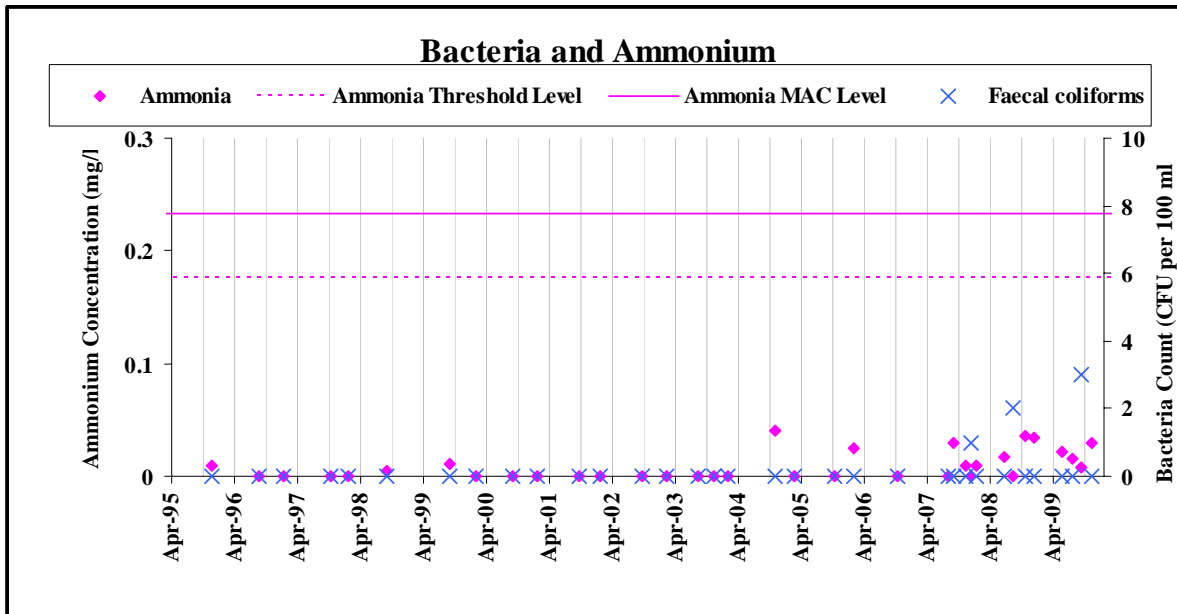


Figure 7 Ammonium and Faecal Coliforms at Cooga Spring

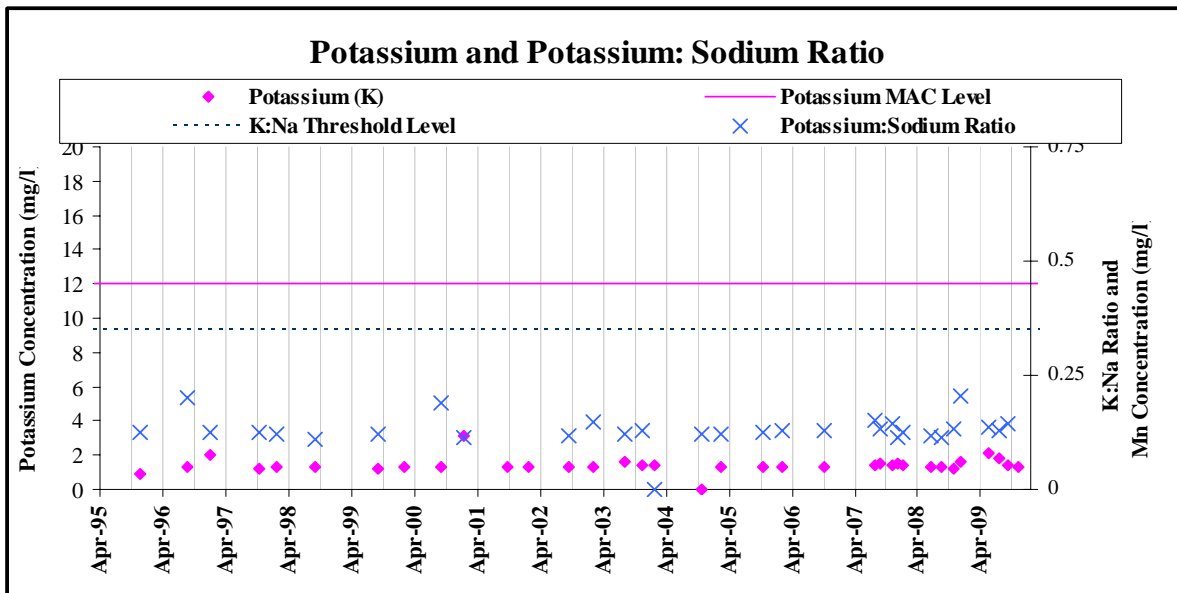


Figure 8 Water Quality Graphs for Cooga Spring

Concentrations of barium are elevated at Cooga Spring, with an average concentration of 435 µg/l and one exceedance of the Drinking Water standard in November 2004 (746 µg/l). It is believed that the elevated concentrations are naturally occurring and reflect the low grade mineralization in the parent bedrock and derived subsoil. Previous exploration work (Natural Resource Consultants, 1990) identified elevated barium in surface water samples. Uneconomic deposits of baryte were identified in quartz veins within the Slieve Phelim Mountains.

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

In summary, the concentrations of nitrate and chloride which are above background levels and are highly variable but are still on average relatively low, the low K:Na ratios, and the infrequent low levels of faecal bacteria, suggest that there are some anthropogenic impacts occurring in the spring catchment but that they are limited. The recent detection of faecal coliforms in the spring requires close monitoring. Overall, the current water quality is generally relatively good and appears to have been continually improving since 2002.

9.4 Aquifer characteristics

The GSI bedrock aquifer map of the area indicates that the Lower Limestone Shales are classified as a Poor Aquifer which is generally unproductive except for local zones (PI). The bedrock aquifers to the north and south of the spring, are classified as Locally Important Aquifers which are moderately productive only in local zones (LI). It is believed that bedrock does not outcrop at Cooga Spring and does not significantly contribute to the groundwater emerging from the source.

The overlying subsoil is therefore considered to provide the main groundwater contribution to the spring; however the sand and gravels do not appear to constitute a locally important aquifer. Groundwater is assumed to slowly migrate through the sand and gravel subsoils towards the spring. Sand and gravel deposits generally have a high porosity and relatively high permeabilities (10 m/d). The effective porosity is expected to be high at approximately 12% (Fetter, 2001). As the unconsolidated deposits are at the surface, groundwater is unconfined. Groundwater gradients are moderately steep at 0.02 based on topography, the high groundwater table and the presence of groundwater fed ponds. While the groundwater gradient is relatively steep, the underlying low permeability subsoil and bedrock prevents the downward migration of groundwater.

Transmissivity is estimated to be in the order of 50 m²/day, and effective porosity of the sand and gravel is assumed to be in the order of 12% (Fetter, 2001). Therefore velocity, assuming a gradient of 0.02, is in the order of 1.7 m/day. This analysis is based on limited data and would require further monitoring to validate assumptions. However, the transmissivity values and porosity values used are conservative. The yield of Cooga Spring is 'good', according to GSI classification.

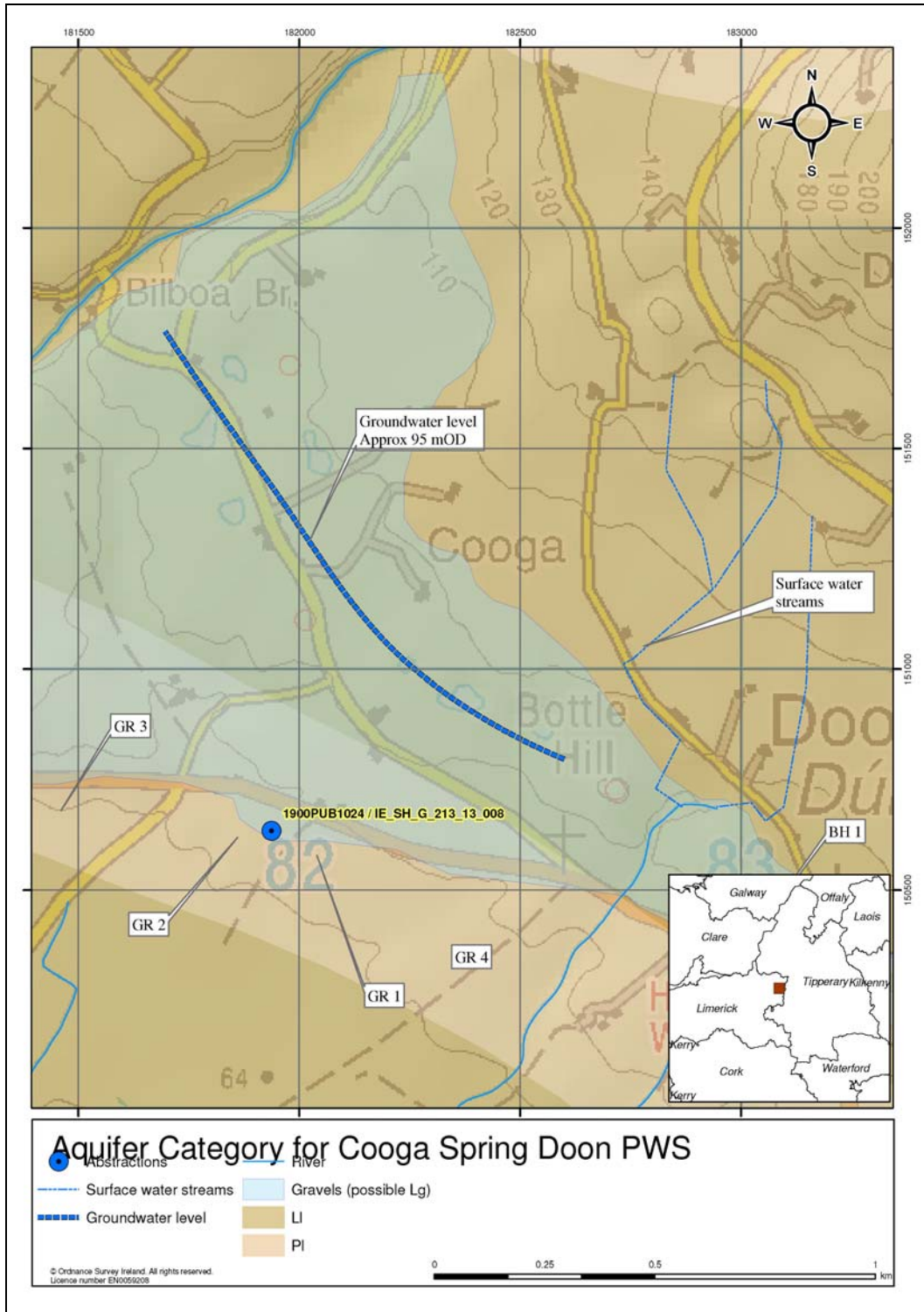


Figure 9 Aquifer Map for the area around Cooga Spring

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

The spring emerges at the edge of the sand and gravel deposit which coincides with a break in slope. Groundwater flows in a south-south easterly direction towards the source. The sand and gravel deposits are considered to provide the main groundwater flow to Cooga Spring. The overlying sand and gravel deposits are relatively shallow (<5 m deep) and considered to be in hydraulic connectivity with the spring. The aquifer is unconfined, has extreme Vulnerability, and is likely to be recharged locally, through high permeable, sand and gravel subsoils.

The groundwater within the bedrock may also provide additional flow to the spring however limited data is available on the depth to bedrock and bedrock permeability/transmissivity of the underlying formations. Additionally surface water runoff from the upgradient tills appears to percolate back to ground and provides additional recharge the sand and gravel deposits.

Limitations to the conceptual model mainly lie with a lack of information on depth of subsoils and depth to bedrock underlying the spring. Additional drilling data is likely to improve our understanding of the complex relationship between the sand and gravel, till and bedrock units.

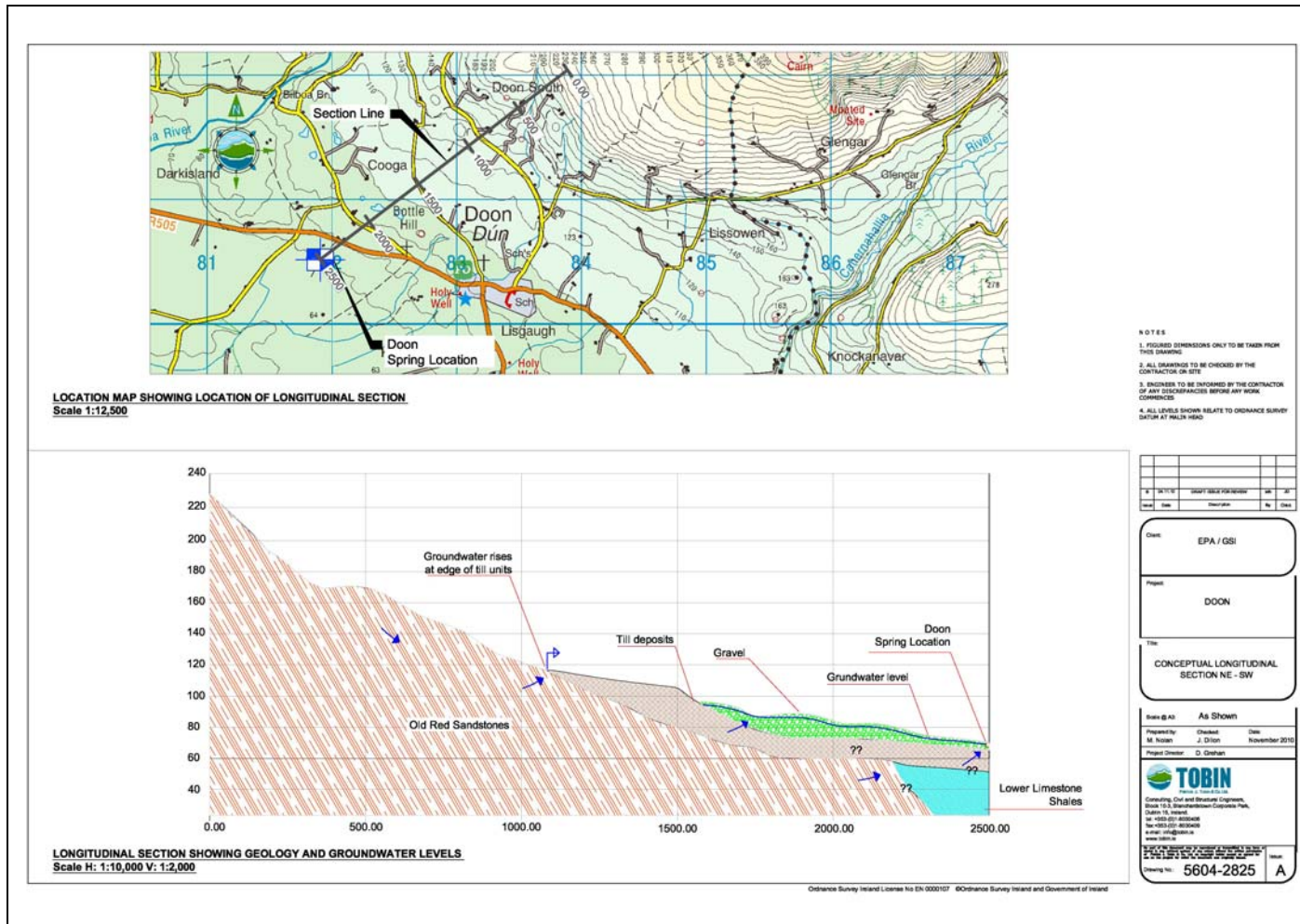


Figure 10 Conceptual model N/S through Cooga Spring

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 10):

For the **Southern Boundary** it is assumed that the water down-gradient of the spring will not flow back to contribute to their discharge. Therefore the boundary delineates the groundwater flow down-gradient of the spring, which will be outside the ZOC. An arbitrary buffer of 30 m downgradient of the spring is incorporated.

The **Northern Boundary** is based on topography. To allow for runoff from the till deposits bounding the sand and gravel deposits the Zone of Contribution is extended beyond the gravels. The boundary is extended up to the surface water catchment to the north of the sand and gravel deposits.

The **Eastern Boundary** and **Western Boundary** are difficult to delineate. The eastern and western boundaries are based on topography, water balance calculations, an estimation of a reasonable 'catchment' for the spring and the assumed quantities of groundwater flow through the sands and gravels.

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

Runoff losses: 111 mm. Runoff losses are assumed to be 20% of potential recharge. This value is based on an assumption of *c.* 15 % runoff for 70% of the area with extreme vulnerability, high permeability subsoils and soils and (Guidance Document GW5, Groundwater Working Group 2005). Runoff losses from the tills (extreme to low vulnerability) is based on the assumption of 40 % runoff for 30 % of the area.

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

These calculations are summarised as follows:

Average annual rainfall (R)	993 mm
Estimated P.E.	450 mm
Estimated A.E. (95% of P.E.)	427 mm
Effective rainfall	566 mm
Potential recharge	566 mm
Runoff losses	20%
Bulk recharge coefficient	80%
Recharge	445 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 445 mm/yr, an average yield of 180 m³/day would require a recharge area of 0.15 km².

The ZOC described above is 0.22km² and is conservative and allows uncertainties in 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 overlay 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 1.7 m/d, and hence the 100-day time of travel distance is 170 m. The Inner Protection Area is illustrated in Figure 11.

The Outer Protection Area (SO) encompasses the entire zone of contribution to the source as described in Section 10.3.

Groundwater protection zones are shown in Figure 9, and are based on an overlay of the source protection areas on the groundwater vulnerability. Therefore the groundwater protection zones are SI/E and SO/E. The majority of the area is designated SO/E (See Figure 12).

Table 10.2 Source Protection Zones

Source Protection Zone	% of total area (0.22km ²)
SI/Extreme	15%
SO/Extreme rock close	1.5%
SO/Extreme	55%
SO/High	3.5%
SO/Moderate	5%
SO/Low	20%

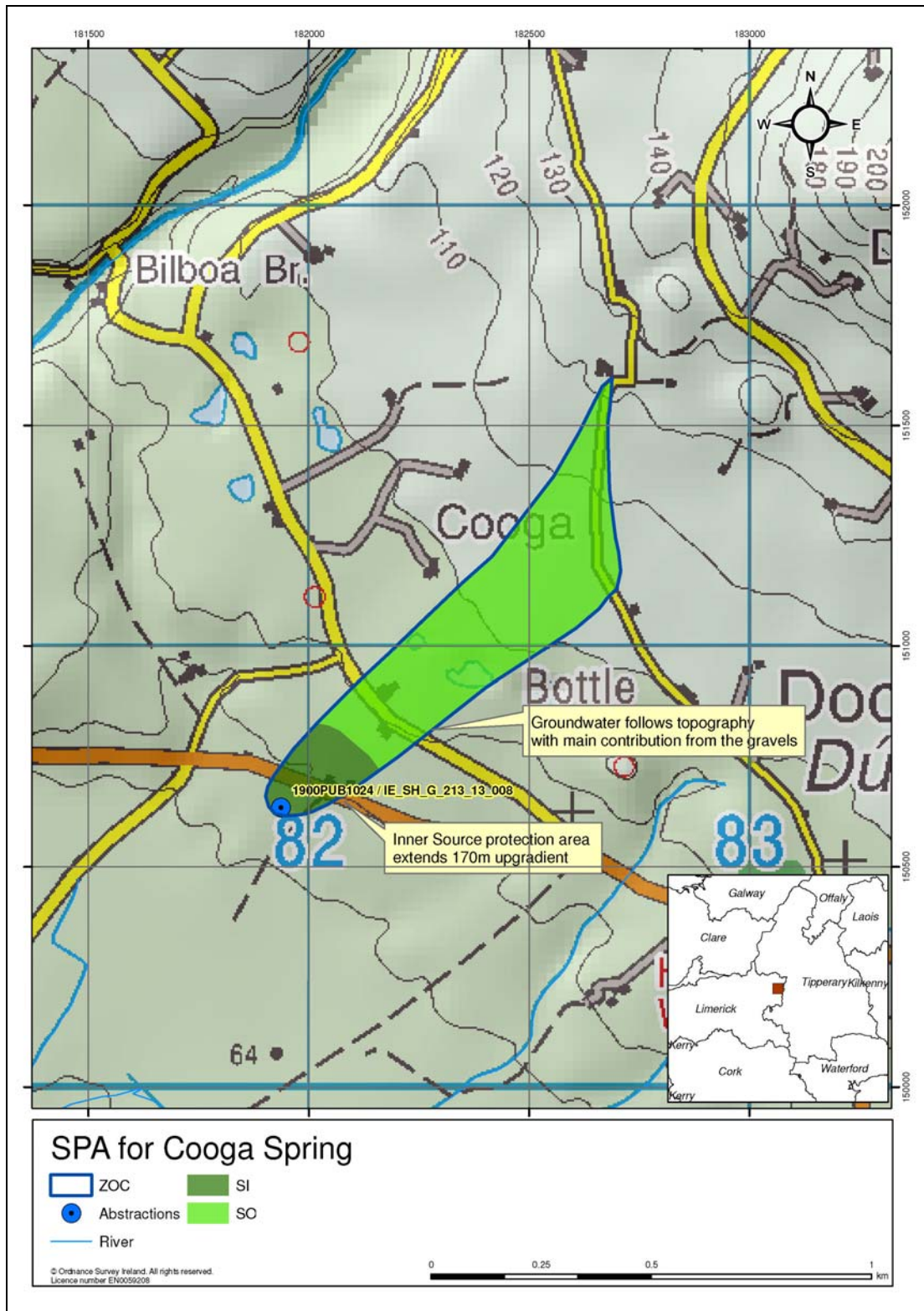


Figure 11 Source Protection Areas around Cooga Spring

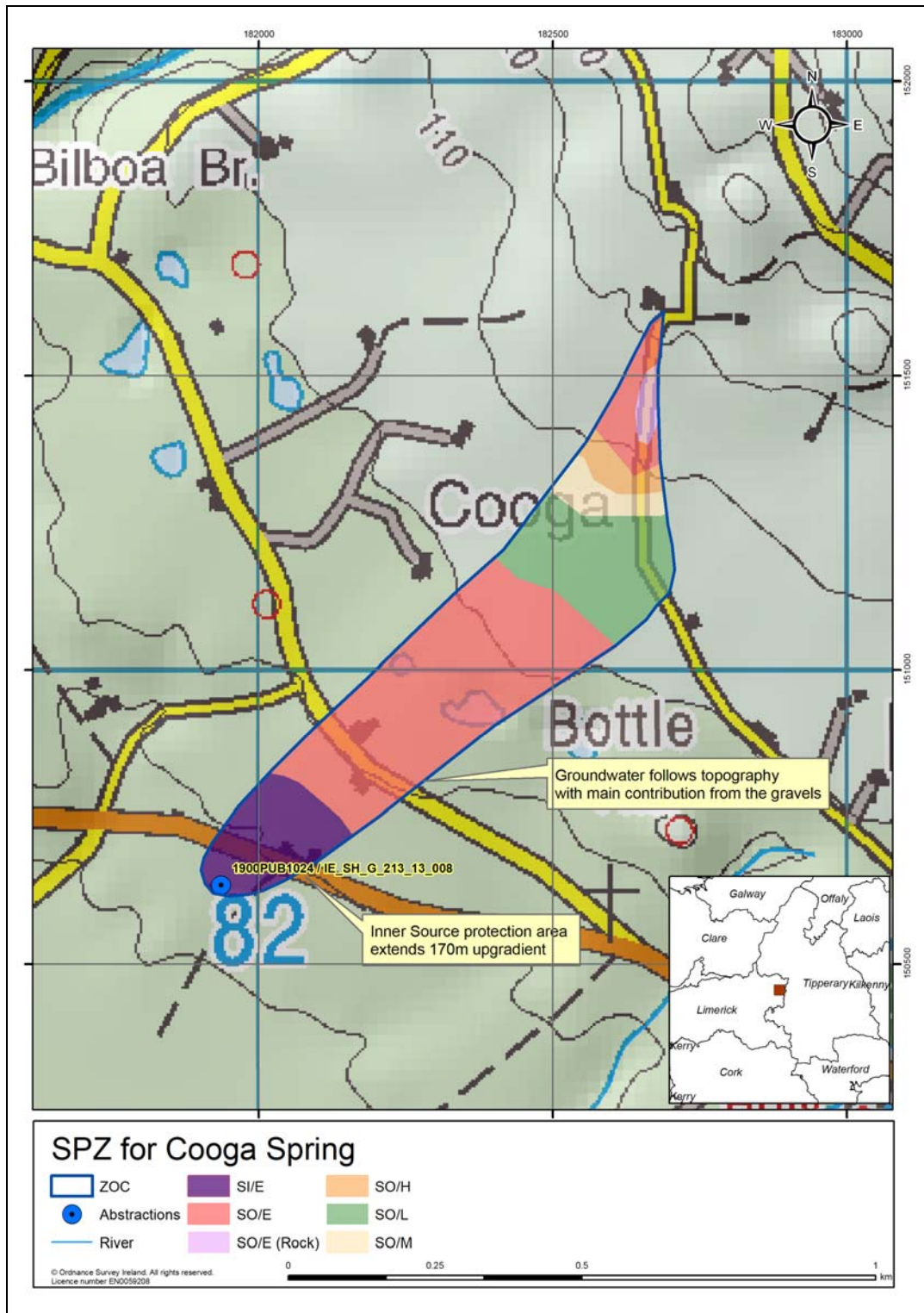


Figure 12 Source Protection Zones around Cooga Spring

12 Potential pollution sources

The spring is contained within a covered concrete chamber which is fenced off from the adjacent farm. The risk of contamination immediately up-gradient of the chamber is moderate to high. The water table at the spring is close to ground surface thus the vulnerability is '**extreme**'. This can be seen in the regular occurrences of total coliforms and occasional faecal coliforms in the untreated water.

The inner protection area encompasses a 170 m buffer around the spring, all of which is 'extremely' vulnerable to contamination. Rainfall landing on the fields and farmyard within 170 m upgradient of the source can get to the spring relatively quickly. The main potential contaminants from these sources are ammonia, nitrates, phosphates, chloride, potassium, pesticides, faecal bacteria, viruses and cryptosporidium.

Across the rest of the outer protection area (SO), the groundwater vulnerability is '**extreme to low**'. There are a number of houses, farms and farm yards directly upgradient of the spring which pose a risk to the source.

Private home heating fuel tanks are located within the catchment area. The main potential contaminants from this source are hydrocarbons. Finally, there are a number of roads present in the ZOC. The main potential contaminants from this source are surface water runoff contaminated with hydrocarbons and metals.

13 Conclusions

The spring is a moderate yielding spring that abstracts from the shallow sand and gravel deposits. Groundwater is thought to infiltrate through the subsoils and discharge at the spring and to adjacent drainage ditches. It is possible that the underlying bedrock also provides a groundwater contribution to the spring however the depth to bedrock is poorly understood due to lack of detailed drilling data at the source.

The Outer Source Protection Area or the Zone of Contribution is calculated to extend to 0.22 km². The Inner Source Protection Area or the 100-day horizontal travel time is calculated to extend 170 m from the abstraction source.

14 Recommendations

The source site is the area immediately around the groundwater abstraction. Protection in this area is paramount to ensure that direct intentional or accidental interference is not caused to the spring.

The protection of the source site involves prevention of access and prevention of activities in the immediate proximity of the abstractions. It is recommended that drilling be undertaken to further inform the conceptual understanding of the hydrogeological relationship between the gravels, till and underlying bedrock.

15 References

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