Geashill Public Supply

Groundwater Source Protection Zones

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1 Introduction

The Groundwater Section, Geological Survey of Ireland, have prepared this report at the request of Offaly County Council.

The objectives of the report are as follows:

- To delineate source protection zones for Geashill spring.
- To outline the principle hydrogeological characteristics of the Geashill area.
- To assist Offaly County Council in protecting the water supply from contamination.

The report does not take account of the proposal by Ballinagar GWS to abstract water from nearby wells.

2 Location, Site Description and Well Head Protection

The source is one kilometre north of Geashill village, in the townland of Dalgan.

Two large sumps collect the water and an overflow discharges to a nearby stream. A gravel fill has been put in around the sumps. The rest of the site is grassed over.

The site is fenced off and the pumphouse is padlocked. One of the sumps is covered, the other is not fully covered and is thus exposed to birds and animals.

3 Summary of Well / Spring Details

GSI no.	:	2321NE W0001
Grid ref. (1:25,000)	:	N 24510 22160
Townland	:	Dalgan
Well type	:	Spring
Owner	:	Offaly County Council
Elevation (ground level)	:	70.7 m OD (232 feet OD)
Depth & Diameter of sump	:	1m x 3m
Depth to rock	:	10.7m
Static water level	:	Close to ground level, overflowing to stream in high flow periods
Normal Abstraction	:	910 $m^3 d^{-1}$ (~200,200 gal d^{-1})
Estimated Total Discharge	:	910 $m^3 d^{-1}$ to 1170 $m^3 d^{-1}$ (~200,200-257,000 gal d^{-1})

4 Methodology

The assessment involved three stages: (a) a desk study; (b) site visits and fieldwork; and (c) analysis of the data.

The desk study was conducted in the Geological Survey: details about the group schemes and springs such as elevation, and abstraction figures were obtained from GSI records and County Council personnel; and hydrogeological information was provided by the Groundwater Protection Scheme (Daly et al, 1998).

The second stage comprised site visits and fieldwork in the Geashill area. This included carrying out spring overflow measurements, depth to rock drilling and subsoil sampling. Field walkovers were also carried out to investigate the subsoil geology, the hydrogeology and vulnerability to contamination.

Analysis of the data utilised field studies and previously collected data to delineate protection zones around the springs.

5 Topography, Surface Hydrology and Land Use

The spring emerges in a low-lying area at about 70.7 m OD (232 ft). The topography surrounding the springs is generally hilly with higher ground to the east, south and west. The highest point lies to the south of the village at 111m OD (363 ft).

The springs emerge beside a northward flowing tributary of the Tullamore river. In the catchment to the springs there are very few surface streams/drains, reflecting the free draining nature of the land in the area.

Agricultural activity dominates the area with most of the land used for grassland. Geashill village and a number of houses and farmyards are present in the vicinity of the springs. A sewage works lies between the village and the springs.

6 Geology

6.1 Introduction

This section briefly describes the relevant characteristics of the geological materials that underlie the Geashill spring source. This provides a framework for the assessment of groundwater flow and source protection zones that will follow in later sections.

Bedrock information was taken from a desk-based survey of available data, which comprised the following:

- County Offaly Groundwater Protection Scheme (Daly *et al*, 1998)
- Information from geological mapping in the nineteenth century (on record at the GSI).

Subsoils information was taken from the Offaly Groundwater Protection Scheme (Daly *et al*, 1998) and gathered from a drilling programme that was undertaken by GSI personnel to investigate the subsoils of the area.

6.2 Bedrock Geology

Limestones occupy the whole area and a brief description of the individual rock units in the vicinity of the source is given in Table 6-1. The boundaries are shown in Figure 1.

The springs appear to occur at or close to the Calp - Allenwood boundary. The units are presented in order of increasing age and all are deposited in Carboniferous times.

Table 6-1 The Bedrock Geology of the Geashill area.

Name of Rock Formation	***Rock Material***	***Occurrence***
Calp	Dark well bedded, fine grained, clayey LIMESTONE with calcareous mudstones	Occurs in the western part of the catchment. Source within this unit.
Allenwood	Pale-grey, poorly bedded, medium to coarse grained LIMESTONE	Occurs as a narrow band underlying Geashill village.
Waulsortion	Fossiliferous, pale- grey, poorly bedded fine grained LIMESTONE	Occurs to the east of Geashill village.

Movements in the earth's crust have caused the rocks to be folded, faulted and jointed. The different rock units have a NE-SW trend or strike and they generally dip either north-westwards or south-eastwards at a low angle. Two major fault sets are present — NE-SW and SE-NW. The joint pattern is likely to have similar orientations. There is one mapped fault which is close to the springs and possibly intersects the zone of contribution and there are probably other faults that haven’t been noted because of the lack of outcrop in the area.

6.3 Subsoil Geology

6.3.1 Introduction

The Groundwater Protection Scheme and a site specific drilling programme carried out by the GSI provided the information on the subsoils. The subsoils comprise a mixture of coarse and fine grained materials, namely; peat, tills with gravels, tills, sand & gravels (eskers) and are directly influenced by the underlying bedrock, which is made up of the Calp, Allenwood and Waulsortion limestones. The muddy, dark nature of the Calp often means that the overlying subsoils will have proportionally higher percentages of fine grained material than subsoils produced over the Allenwood and Waulsortion rock types. The distribution of subsoils is shown in Figure 1, and is based on the Groundwater Protection Scheme (Daly et al, 1998). The geological logs of the auger holes drilled are given in Appendix 1.

The characteristics of each category are described briefly below:

6.3.2 Peat

This material occurs in the low-lying area around the springs themselves. The peat can be seen in stream cuttings next to the springs.

6.3.3 Tills with gravels

This is the dominant subsoil type in the area. The matrix is composed mostly of silty SAND with gravel and/or clay; sandy SILT with clay and clayey SILT with gravels (see appendix 1 for further details). The reconnaissance work in Offaly has shown that many of the sand/gravel units are small and are interbedded with tills. In many places it is not possible to map out separately the sand/gravel units and the till units during a reconnaissance mapping project. This has led to the term "till with gravel" being employed to categorise the sediments over relatively large areas (Daly *et al*, 1998).

6.3.4 Tills

'Till' is an unsorted mixture of coarse and fine materials laid down by ice. Angular limestone fragments are abundant in the tills. A small area in the north east part of the catchment is made up of this subsoil type.

6.3.5 Sand & Gravels

Extensive fluvioglacial sand and gravels are present in County Offaly and occur in the Geashill area in the form of eskers. The sands and gravels making up the eskers are (BS5930: sandy GRAVELS and GRAVELS) normally are generally coarse, poorly sorted but often contain lenses of better sorted material. The boulders and cobbles are limestone in composition.

6.3.6 Depth to Bedrock

The depth to rock is known in certain localities from a drilling programme carried out by the GSI to ascertain the thickness and permeability of the subsoils. The locations of the auger holes are given in Figure 1 and the depth of the holes is given in Appendix 1. The depth to bedrock varies between 5 and 10m. The lower lying areas around the spring has the thickest subsoil cover (8-11m) and the higher ground of the catchment has somewhat thinner subsoil cover (6-8m). There is no outcrop in the area.

7 Hydrogeology

7.1 Introduction

This section presents our current understanding of groundwater flow in the vicinity of the Geashill source. The interpretations and conceptualisations of flow are used to delineate source protection zones around the spring.

Hydrogeological and hydrochemical information for the study was obtained from the following sources:

- Offaly Groundwater Protection Scheme (Daly *et al* 1998).
- An Assessment of the Quality of Public and Group Scheme Groundwater Supplies in County Offaly, (Cronin *et al*, 1999).
- GSI files. Archival Offaly County Council data for the years 1977, 1989, 1991. C1–C2 type parameters.
- Offaly County Council annual drinking water returns 1992–1999 inclusive (C1, C2, C3 and C4 type parameters). Some raw water analyses were also carried out.
- Limited additional fieldwork.

7.2 Meteorology and Recharge

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 generally assumed to consist of an input (i.e. annual rainfall) less water losses 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 (i.e. the outer source protection area).

In areas where point recharge from sinking streams, etc., is discounted, the main parameters involved in recharge rate estimation are annual rainfall, annual evapotranspiration, and annual runoff and are listed as follows:

- Annual rainfall: 825 mm. Rainfall data for the area are taken from a contoured rainfall map of Co. Offaly, which is based on data from Met Éireann.
- Annual evapotranspiration losses: 431 mm. Potential evaporation (P.E.) is estimated to be 454 mm $yr.^{-1}$ (from Met Éireann data). Actual evapotranspiration (A.E.) is then estimated as 95 % of P.E.
- Potential recharge: 394 mm $yr.^{-1}$. This figure is a calculation based on subtracting estimated evapotranspiration losses from average annual rainfall. It represents an estimation of the excess soil moisture available for either vertical downward flow to groundwater, or lateral soil quickflow and overland flow direct to surface water.
- Annual runoff losses: 79 mm. This estimation is based on the assumption that 20% of the potential recharge will be lost to overland flow, stream runoff and shallow soil quickflow prior to reaching the main groundwater system.

These calculations are summarised below:

Average annual rainfall (R)	825 mm
Estimated A.E.	431 mm
Potential Recharge (R – A.E.)	394 mm
Runoff losses	79 mm
Estimated Actual Recharge	315 mm

This is an estimation of recharge which allows for surface water outflow, particularly during periods of heavy rainfall.

7.3 Groundwater Levels, Flow Directions and Gradients

- There is no water level data for the area south of the springs.
- At the springs the water level is at ground level and the entire area around the springs is boggy, marshy, quite flat and low lying.
- The water table in the area is generally assumed to be a subdued reflection of topography; as the topography slopes northwards, the water table slopes northwards toward the springs. The dominant driving head are the hills around Geashill village. The flow directions will be perpendicular to the contour lines. In simple terms, rainfall reaching the water table anywhere in the catchment of the springs will flow in a northerly and north-westerly direction toward the springs.

- The groundwater gradient is assumed to somewhat less than the topographic gradient, i.e. is estimated as 0.015.

7.4 Aquifer Characteristics

The Allenwood limestone has wide range of hydrogeological characteristics; permeability and transmissivity values ranging over several orders of magnitude (Daly et al, 1998). Free draining land overlies the Allenwood in the Geashill area and there are no surface streams, indicating that the Allenwood has good aquifer properties in this area. Permeability and porosity for the Allenwood in this locality are based on evaluation of data for the Allenwood in other areas and of rocks that are generally similar to the Allenwood. Estimates for these parameters are as follows:

Permeability ~ 10 m d^{-1};
Porosity ~ 2 %.

7.5 Aquifer Category

The Allenwood limestone is classed as a **Regionally Important Fissured aquifer (Rf)**. (Daly et al, 1998).

7.6 Hydrochemistry and Water Quality

The hydrochemical analyses show that the Geashill spring water is a hard to a very hard water with alkalinity values of 150-165 mg l^{-1}, total hardness values of 375-412 mg l^{-1} (equivalent $CaCO_3$) and electrical conductivity values of 550-770 µS cm^{-1}, indicating that the groundwater has a hydrochemical signature of calcium bicarbonate type water. These values are typical of groundwater from limestone rocks. Table 7-1 gives summary statistics for electrical conductivity. Electrical Conductivity values are high and the current data set shows a unimodal tendency. The coefficient of variation of conductivity is 8.1% which indicates that diffuse recharge is the type of recharge (Doak, 1995).

Table 7-1 Summary Statistics for Electrical Conductivity (EC).

Parameter	*Value (µS cm^{-1})*
Average	670
Max.	770
Min.	550
Standard Deviation	55
Coefficient of variation of St. Dev. of E. C.	8.1%
Sample Number	14

Nitrate concentrations to date have not exceeded the EU Drinking Water Directive maximum admissible concentrations (MAC); values range between 8.8 to 41 mg l^{-1} with a mean of 25.2 mg l^{-1}. Since 1979, there has been a general increase in nitrate levels with two significant peaks in the data set, (Nov. 1990: 41 mg l^{-1}, March 1998: 37 mg l^{-1}). Throughout the 1990's the levels range between 20 and 30 mg l^{-1}. There is no apparent upward trend in recent years from the current data set.

Chloride levels range from 21-31 mg l^{-1}, with a mean of 25 mg l^{-1}, which are higher than typical background levels (12-15 mg l^{-1}). Chloride is a constituent of organic wastes and levels higher than 25 mg l^{-1} may indicate significant contamination. Concentrations higher than the 30 mg l^{-1} usually indicates significant contamination. In July 1979, the level exceeded 30 mg l^{-1}, but in general are about 25 mg l^{-1}.

Sodium levels range between 7-18 mg l^{-1}. The higher recorded values are slightly above the normal range expected for sodium in uncontaminated groundwater.

Potassium levels range between 2.4-6.1 mg l^{-1}. On two occasions in 1997 (May and June) the levels were 5.8 and 6.1 mg l^{-1}. These values suggest contamination by an organic waste source.

The ratio of potassium to sodium (K:Na) may indicate contamination if the ratio is > 0.4. On three occasions this ratio has been > 0.4, (Sept'97, May'98 and July'98). The high ratios usually indicate contamination from farmyard wastes. However, chlorides, nitrates and ammonia levels on those dates are well inside the range of values for each these parameters respectively.

The water quality analyses show that the only parameters to have exceeded EU Drinking Water Directive maximum admissible concentrations (MAC) is that of faecal coliforms and turbidity. These exceedances occurred October and September 1997. All the drinking water returns analysed are for treated water.

7.7 Spring Discharge

The total discharge at the springs is difficult to measure accurately. There have been several estimates of the total yield and these are summarised in Table 7-2.

Table 7-2 Estimates of spring discharge at Geashill.

Date	*Source*	*Estimate type (m^3 d^{-1})*	*Discharge*
May 1999	GWS	Abstraction	909 m^3 d^{-1}
July 1999	GSI & GWS	Overflow + abstraction (0+909)	909 m^3 d^{-1}
November 1999	GSI	Overflow + abstraction (260 *(overflow figure)* + 909)	1169 m^3 d^{-1}

The differences in these estimates is that in the first estimate does not take account of the overflow; the second estimate recorded no overflow on the date of measurement and the third estimate is a winter flow measurement during higher flows and the overflow was recorded and measured.

7.8 Conceptual Model

- The highest measured discharge was 1170 m^3 d^{-1}; it is probably greater during wetter weather.
- The groundwater regime in the area is complex and the available hydrogeological information does not allow a definitive understanding of the hydrogeology. While there is insufficient drilling data to be conclusive, it is considered that the source of groundwater is largely due to the bedrock and not to the sand/gravel.
- The spring appears to be emerging at or close to the boundary between the Calp and Allenwood limestones. It is thought that it is likely that the boundary is slightly further north than shown on the bedrock geology map of the area. The Calp generally has a lower permeability and transmissivity than the Allenwood, thus causing an impedance of the general groundwater flow. The presence of the esker gravels may also influence the location as it allows discharge of groundwater at that point.
- The esker probably act as a high permeability "drain" which could take shallow groundwater to the spring.
- There are no surface streams in the catchment to the springs indicating the free draining nature of the subsoil and the relatively high permeabilities of the underlying Allenwood limestone.
- Groundwater flow is likely to flow through two mediums:

1) interconnected, possibly solutionally enlarged fracture zones and along fractures and joints outside the main fracture systems. The discharge indicates high velocities at least close to the springs;
2) via the eskers which may act as a drain or a conduit for groundwater flow from direct recharge through to the eskers or from water drawn in from less permeable tills.

8 Delineation Of Source Protection Areas

8.1 Introduction

This section delineates the areas around the well that are believed to contribute groundwater to the well, and that therefore require protection. The areas are delineated on the basis of the conceptualisation of the groundwater flow pattern, as described in Section 7.8 and are presented in Figures 1 and 2.

Two source protection areas are delineated:
- ♦ Inner Protection Area (SI), designed to give protection from microbial pollution;
- ♦ Outer Protection Area (SO), encompassing the zone of contribution (ZOC) of the well.

8.2 Inner Protection Area

The Inner Protection Area (SI) is the area defined by a 100 day time of travel (ToT) to the source and it is delineated to protect against the effects of potentially contaminating activities which may have an immediate influence on water quality at the source, in particular microbial contamination. Estimations of the extent of this area cannot be made by hydrogeological mapping and conceptualisation methods alone. Analytical modelling is also used and by using the aquifer parameters for permeability and hydraulic gradient 100 day ToT estimations are made. From Section 7.4 the parameters used give velocities of 7.5 m d^{-1}, and so it is assumed that for a 100 day time of travel, groundwater would travel 750 m, using a hydraulic gradient of 0.01. Thus the upgradient extent of the SI zone is 750 m. The SI is presented in Figure 2.

8.3 Outer Protection Area

The Outer Protection Area (SO) is bounded by the complete catchment area to the source, i.e. the zone of contribution (ZOC), and is defined as the area required to support an abstraction from long-term recharge. The ZOC is controlled primarily by a) the total discharge, b) the groundwater flow direction and gradient, c) the rock permeability and d) the recharge in the area.

The shape and boundaries of the ZOC were determined using hydrogeological mapping and the conceptual model. The ZOC catchment boundaries are as follows and illustrated in Figures 1, 2 & 3:

1. The **Northern Boundary**: Groundwater to the north of the springs cannot flow to the springs as the groundwater is downgradient on the northern side of the springs. An arbitrary buffer of 30 m is placed on the downgradient side of the springs. No account has been taken of any future development of the source downgradient of the springs for the Ballinagar GWS.

2. The **Eastern Boundary**: This is defined by the topographic divide that runs north-south subparallel to the road into the village. Groundwater east of this watershed flows eastward toward the Tullamore river. On the western side of this ridge groundwater flows toward the source. The slope toward the Tullamore river is gradual and the slope toward the spring is quite steep.

3. The **Southern Boundary** is marked by a topographic high which acts as a watershed dividing water flowing north and south. It could be argued that water may flow north east and discharge at the Tullamore river. However, in view of the quantity discharging at the springs; the general surface water patterns; the north westerly longitudinal direction of the eskers; the dip and stratigraphy of the bedrock geology - it is likely that groundwater in the southern part of the area flows to the springs.

4. The **Western Boundary** is constrained by a subtle topographic divide to the west of the springs and the village. This boundary roughly coincides with a change in rock units (Allenwood to the Calp). Groundwater to the west of the boundary (overlying the Calp) discharges to the stream which flows past the springs. Groundwater discharges to the spring on the east of this boundary. This idea is strengthened by the fact the head at the springs is higher than the head in the stream (water is unlikely to flow underneath the stream to the springs when it is easier to discharge to the stream). Further evidence is that the Electrical Conductance of the stream has a groundwater signature (Nov. 1999: 728 $\mu S\ cm^{-1}$).

These boundaries delineate the physical limits within which the ZOC is likely to occur. The area constrained by the hydrogeological mapping is 1.5 km^2. A water balance was used to estimate the areal extent of the catchment providing the water to the springs and the resulting area is compared to that delineated by mapping. Table 8-1 shows the results of the water balance and the various estimates of the ZOC according to the discharge. A water balance is carried out by using an estimated recharge value and the discharge estimates.

Table 8-1 Water balance calculations at Geashill Spring.

Discharge (m^3 d^{-1})	Recharge (mm yr.$^{-1}$)	Area (ZOC) (km^2)
1169	315	1.35
909	315	1.05

The water balance indicates that the largest estimated discharge requires an area of 1.35 km^2. The results suggest that the boundaries as defined by the hydrogeological mapping and the conceptualisation processes are slightly conservative, however, the largest discharge recorded is an early winter time record and doesn't accurately reflect the discharge during heavy rainfall periods.

9 Vulnerability

The distribution of interpreted groundwater vulnerability in the ZOC is presented in Figure 1. Most of the catchment is under the high vulnerability classification as it is covered by moderately to highly permeable materials with the depth to bedrock between 5 and 10 metres. Around the source itself where the subsoil cover is greater than 10m, there is highly permeable material overlying moderately permeable material. Where the water table is estimated to be within 3m of the ground surface in the esker, an extreme vulnerable area is delineated.

10 Groundwater Protection Zones

The groundwater protection zones are obtained by integrating the two elements of land surface zoning (source protection areas and vulnerability categories) – a possible total of 8 source protection zones (see the matrix in the Table 10-1 below). In practice, the source protection zones are obtained by superimposing the vulnerability map on the source protection area map. Each zone is represented by a code e.g. **SI/H**, which represents an Inner Protection area where the groundwater is highly vulnerable to contamination. There are 3 groundwater protection zones present around the Geashill Source as shown in the matrix below. The final groundwater protection map is presented in Figure 2.

Table 10-1 Matrix of Source Protection Zones at Geashill.

VULNERABILITY RATING	**SOURCE PROTECTION**	
	Inner	***Outer***
Extreme (E)	SI/E	Absent
High (H)	SI/H	SO/H
Moderate (M)	Absent	Absent
Low (L)	Absent	Absent

It is not within the scope of this report to delineate the resource protection zones in the surrounding area and this is dealt with at the regional resource protection scale. For further details refer to Groundwater Protection Scheme for County Offaly (Daly et al, 1998).

11 Potential Pollution Sources

The land in the vicinity of the source is largely grassland-dominated and is primarily used for grazing. Agricultural activities and the village are the principal hazards in the area. The main potential sources of pollution within the ZOC are farmyards, septic tank systems, runoff from the roads, the sewage works, leaky sewers and landspreading of organic fertilisers. The main potential pollutants are faecal bacteria, viruses, cryptosporidium and nitrogen. The sewage works is within the zone of contribution to the springs. Also it lies immediately next to the esker which may act as a "drain" leading to the spring. Therefore, it poses a significant threat to the groundwater quality of the spring.

12 Conclusions and Recommendations

♦ The source at Geashill is an excellent yielding well, which is located at the boundary of the Allenwood and Calp limestones.

♦ The area around the supply is highly vulnerable to contamination.

♦ The sewage works, runoff from the roads, the garages in the village, houses, farmyards and landspreading pose a threat to the water quality in the spring.

♦ It is recommended that:

1) A full chemical and bacteriological analysis of the **raw** water should be carried out on a regular basis at the source.
2) particular care should be taken when assessing the location of any activities or developments which might cause contamination at the springs.
3) the potential hazards in the ZOC should be located and assessed.

♦ The protection zone delineated in the report is based on our current understanding of groundwater conditions and on the available data. Additional data obtained in the future may indicate that amendments to the boundaries are necessary.

♦ A more definitive understanding of the hydrogeology would require a site investigation that would include drilling and geophysics.

13 References

Cronin, C. and Daly, D., 1999. *An Assessment of the Quality of Public and Group Scheme Groundwater Supplies in County Offaly*. Geological Survey Report, 30 pp.

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Doak, M., 1995. *The Vulnerability to pollution and hydrochemical variation of eleven springs (catchments) in the karst lowlands of the west of Ireland*. M Sc. Thesis, Sligo RTC, 52 pp.

Thorn, R., 1994. STRIDE project report, DoE.

Appendix 1 Geological Logs of the auger Boreholes

All borehole depths are maximum depths drilled by the auger. The depths are the depth at which the auger would not go any further. It assumed that the auger has reached bedrock, the evidence being that in most cases floured bedrock is recovered on the teeth of the auger.

Geashill No. 9 National Grid Reference: N 24530 22073

Depth (m)	Subsoil	BS 5930	Permeability
0-1.0	Top soil	SILT	MODERATE
1.0-2.5	Till	sandy SILT with gravels	MODERATE
2.5-4.0	Till	clayey SILT with gravels	MODERATE
4.0-6.0	Till	clayey SILT with frequent gravels	MODERATE
6.0-6.15	Till	sandy CLAY with silt	LOW
6.0-6.30	Till	sandy SILT with clay	MODERATE

Geashill No. 8 National Grid Reference: N 24528 22125

Depth (m)	Subsoil	BS 5930	Permeability
0-1.5	Till	sandy GRAVEL	HIGH
1.5-3.0	Till	sandy SILT with frequent gravels	MODERATE
3.0-5.7	Till	sandy SILT with gravels	MODERATE

Geashill No. 2 National Grid Reference: N 24506 22173

Depth (m)	Subsoil	BS 5930	Permeability
0-4.0	Till/Esker	GRAVELS	HIGH
4.0-10.7	Till	sandy SILT with clay	MODERATE

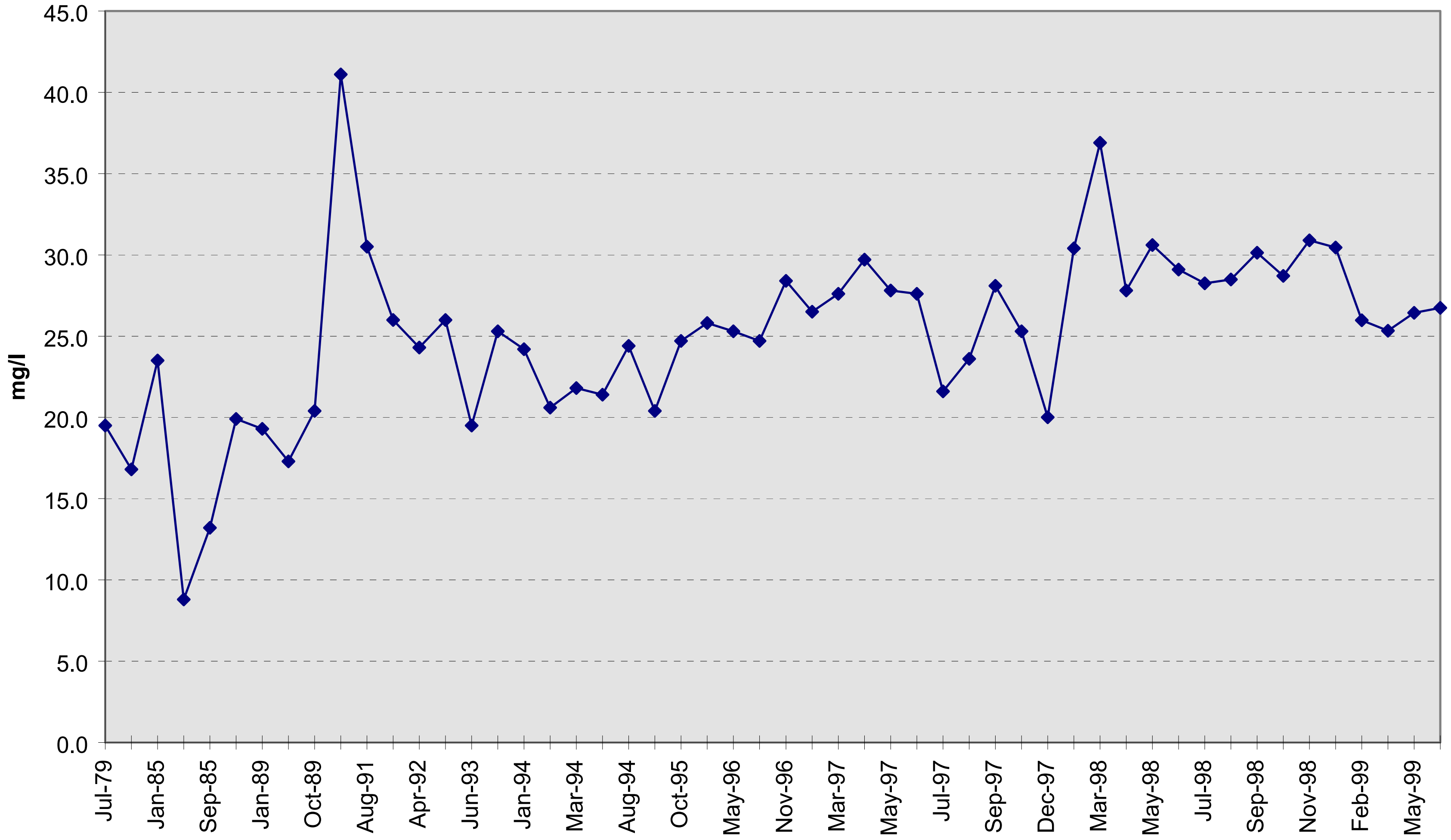
Geashill No. 4 National Grid Reference: N 24513 22162

Depth (m)	Subsoil	BS 5930	Permeability
0-0.8.5	Till/Esker	sandy SILT with clay and abundant gravels	MODERATE

Geashill No. 7 National Grid Reference: N 24557 22132

Depth (m)	Subsoil	BS 5930	Permeability
0-3.5	Till	sandy SILT with gravels	MODERATE
3.5-4.0	Till	sandy SILT with clay	MODERATE
4.0-7.0	Till	clayey SILT with gravels	MODERATE

Appendix 2 Nitrate levels in Geashill Spring



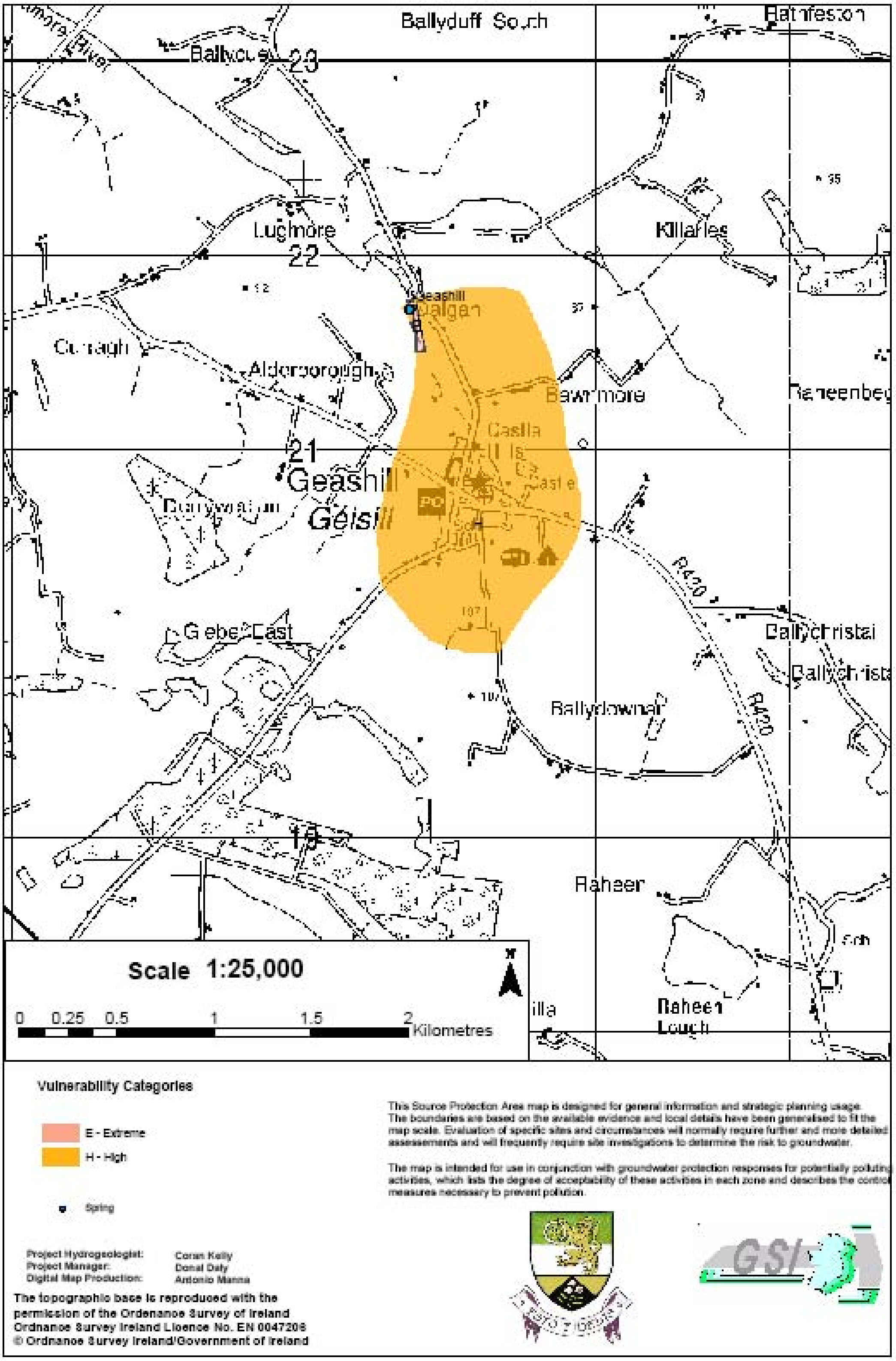


Figure 1 **Groundwater Vulnerability around Geashill**

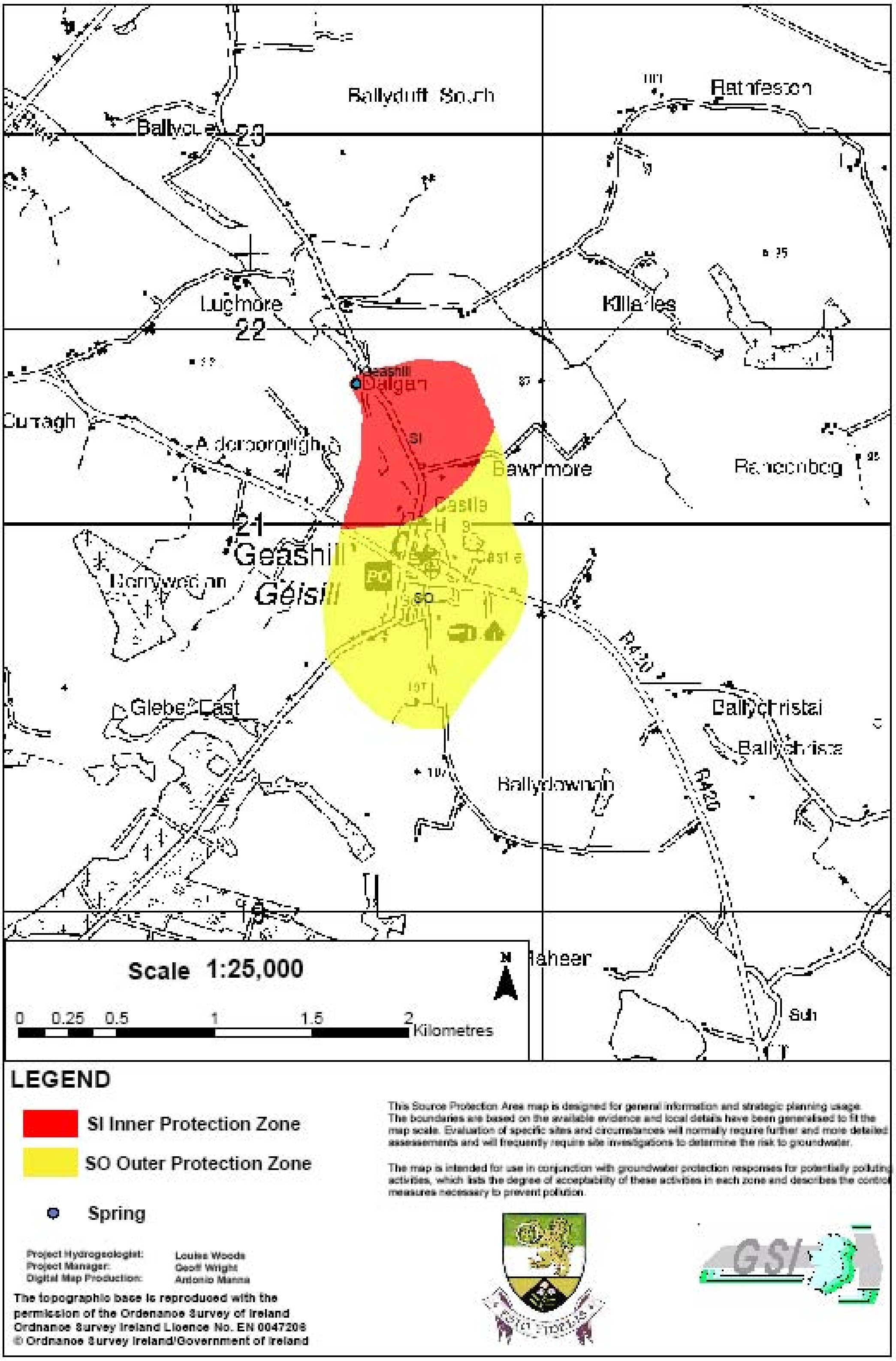


Figure 2 **Groundwater Source Protection Areas for Geashill**

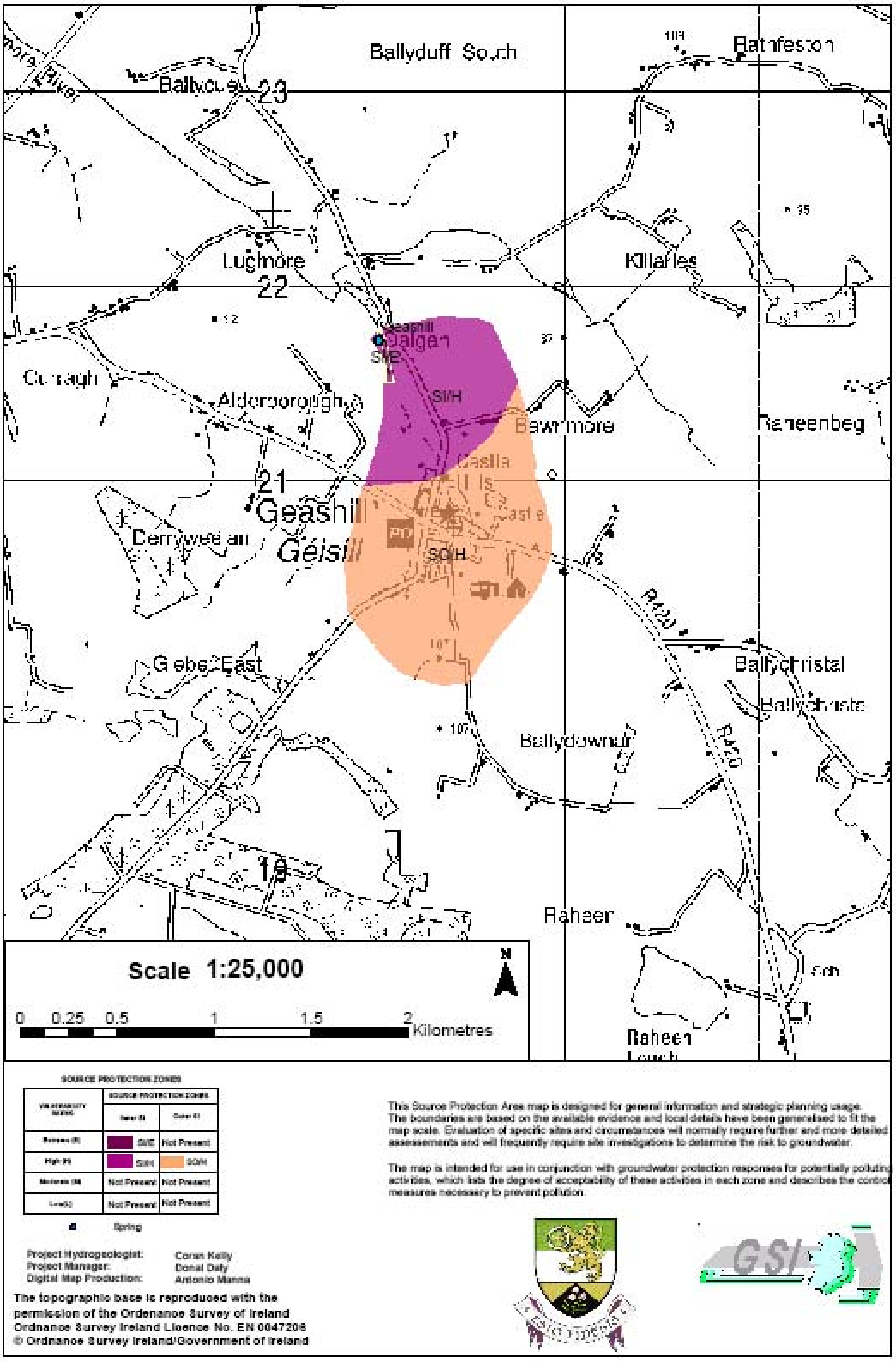


Figure 3 **Groundwater Source Protection Zones for Geashill**