Kildorrery Water Supply Scheme

Glenavuddig Bridge

Groundwater Source Protection Zones

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1 Introduction

The borehole at Glenavuddig Bridge is used to supply Kildorrery Water Supply Scheme.

The objectives of the report are as follows:

- To delineate source protection zones for Kildorrery borehole.
- To outline the principal hydrogeological characteristics of the Kildorrery area.
- To assist Cork County Council (Northern Division) in protecting the water supply from contamination.

2. Location, Site Description and Well Head Protection

Kildorrery borehole is located at Glenavuddig Bridge, about 1 km east of Kildorrery village and is one of two sources that supplies the people of Kildorrery. The two sources supply about 800 people and the borehole serves 75 % of the total demand. The spring is located in the townland of Redchard, 4 km north of Kildorrery. A reservoir is located in the village.

It was constructed in 1978 and put into operation in 1984. It is lined with steel casing to bedrock and it is then unlined to the bottom of the hole. The borehole is situated in a lay-by which is a designated picnic area. There are concrete slabs covering the borehole that can be moved easily. A storm drain runs along side the road next to the borehole, the top of which is only 25 cm above ground level.

3. Summary of Well Details

Grid ref. (1:25,000)	:	R 723 108
Townland	:	Kildorrery
Well type	:	Borehole
Owner	:	Cork County Council (Northern Division)
Elevation (ground level)	:	~ 60.25 m OD (~ 198 ft)
Depth of borehole	:	18.2 m (60 ft)
Diameter of borehole	:	30 cm (12 inches)
Depth to rock	:	6 m
Static water level	:	56.99 m OD (187 ft) 3.26 m bg on 5/8/99.
Pumping water level	:	56.35 m OD (185 ft) 3.90 m bg on 5/8/99.
Normal consumption	:	200 $m^3 d^{-1}$ - 300 $m^3 d^{-1}$
Pumping test summary:		(i) Abstraction rate : 550 $m^3 d^{-1}$
		(ii) Drawdown : 64 cm
		(ii) Transmissivity : 1000 to 2000 $m^2 d^{-1}$

Note: since the test pumping carried out in July 1999 a new pump has been installed, capable of 720 $m^3 d^{-1}$.

4. Methodology

4.1 Desk Study

Details about the borehole such as elevation, and abstraction figures were obtained from GSI records and County Council personnel; geological and hydrogeological information was provided by the GSI.

4.2 Site visits and fieldwork

This included carrying out depth to rock drilling, test pumping and subsoil sampling. Field walkovers were also carried out to investigate the subsoil geology, the hydrogeology and vulnerability to contamination.

4.3 Assessment

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

5. Topography, Surface Hydrology and Land Use

The borehole is situated at the bottom of the Funshion River valley. The land rises steeply to the west of the borehole and rises to the north. The highest point in the area is in Kildorrery village at 120 m OD.

The River Funshion is the main surface water feature in the area, flowing southwards. There are two tributary streams flowing from the rising land to the north that meet the Funshion just north of the borehole.

Agriculture and the village are the main activities in the area. There is a sewage treatment works 700 m to the west of the borehole uphill toward the village. There are number of farmyards and houses outside the village which are all within 500 m of the borehole, mostly between the borehole and the village. The main road from Mitchelstown to Mallow passes alongside the borehole. The Funshion is a good fishing river. The main gauging station for the Funshion is 20 km downstream at Downing Bridge, Kilworth.

6. Geology

6.1 Introduction

This section briefly describes the relevant characteristics of the geological materials that underlie the Kildorrery area. 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 geological mapping in the nineteenth century (on record at the GSI) and from a GSI publication on the bedrock geology of the region (Sleeman *et al*, 1996).

Subsoils information was gathered from a drilling programme undertaken by GSI personnel in 1999.

6.2 Bedrock Geology

Limestones underlie the entire area and a brief description of the individual rock units near the source is given in Table 1. The geological boundaries are shown in Figure 1.
The units are presented in order of increasing age and all were deposited in Lower Carboniferous (Dinantian) times.

The rock units in Table 1 (apart from those of the "undifferentiated" Dinantian) belong to the Mitchelstown Succession. Those rocks of the "Undifferentiated" Dinantian are rocks that have not been mapped in detail, probably comprise similar rock types to those in the Mitchelstown Succession. Movements in the earth's crust have caused the rocks to be intensely folded and faulted in the Kildorrery - Mitchelstown area. The different rock units have a NE-SW trend or strike and they generally dip either north-westwards or south-eastwards at steep angles.

These rocks form a folded synclinal structure with the youngest rocks in the centre (a trough-like feature). The axis of the syncline runs parallel to a line from Kildorrery to Mitchelstown. Secondary intense tight folding has caused the rock units near Glenavuddig Bridge to have a narrow outcrop pattern.

Two major fault sets are present: the first trends 10-30 degrees west of North; and the second trends NE-SW. Of the first fault set, one major fault intersects the position of the borehole at Glenavuddig Bridge. This 'cross' fault occurs between the Mitchelstown Succession and the undifferentiated Dinantian limestones that underlie Kildorrery village and is shown in Figure 1. Of the second fault set, one major fault intersects the first fault set close to the borehole. This fault is named as the Tullaghorton Fault and is shown in Figure 1.

Table 1 The Bedrock Geology of the Kildorrery area.

Name of Rock Formation	***Rock Material***	***Occurrence***
Undifferentiated	Light grey, compact, massive, fine grained LIMESTONE	Underlies Kildorrery village, and most of the topographical catchment.
O' Mahony's Formation	Irregularly bedded (wavy), Fossiliferous, grey, fine grained, finely crystalline LIMESTONE	Occupies a narrow area to the east of the borehole
Rathronan Formation	Pale grey, massive, muddy LIMESTONE	Occurs to the north and south of the borehole in narrow bands
Croane Formation	Dark, shaly, fine grained, regularly bedded LIMESTONE	Occurs as a narrow band to the east of the borehole
Kilsheelan Formation	Clean, grey, massive, cherty LIMESTONE	Occurs as a narrow band to the north of the borehole
Waulsortian Formation	Massive, unbedded, recrystallised LIMESTONE	Occurs to the north and south of the borehole
Ballysteen Formation	Dark grey, muddy, fossiliferous LIMESTONE	Occupies a narrow band to the north of the borehole

6.3 Subsoil Geology

6.3.1 Introduction

A drilling programme carried out by the GSI provided information on the subsoils. The subsoils comprise a mixture of coarse and fine grained materials, namely alluvium and tills and are directly influenced by the underlying bedrock. Geological logs of the auger holes are given in Appendix 1. The characteristics of each category are described briefly below:

6.3.2 Alluvium
This material occupies the flood plain along the Funshion river. The drilling programme indicates that it is about 2 m thick near the borehole. The alluvium is a fine grained, blue - black, smooth CLAY. The alluvium overlies the till.

6.3.3 Till (Boulder Clay)
'Till' is an unsorted mixture of coarse and fine materials laid down by ice. Till is the dominant subsoil type in the locality. It is composed of sandy SILT with clays and gravels, sandy CLAY with frequent gravels and clayey SAND with frequent gravels. The gravel sized fragments are usually subangular black limestone fragments ranging from 0.5 cm to 3 cm. Sandstone fragments also occur but are far less frequent and are of similar size and shape.

6.3.4 Depth to Bedrock
A drilling programme was carried out to ascertain the depth, thickness and permeability of the subsoils. Using this information and knowledge of sites that have rock cropping out, the depth to rock is estimated across the area. The borehole locations are given in Figure 2. The depth to bedrock varies between 1.4 and 9.5 metres.

7. Hydrogeology

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

Hydrogeological and hydrochemical information for the study was obtained from the following sources:
- Test pumping of the aquifer on 5/8/99 by GSI personnel.
- A local, one-day hydrogeological mapping survey.
- A drilling programme carried out by GSI to ascertain depth to bedrock and subsoil permeability.
- GSI files and archival Cork County Council data.
- Cork County Council annual drinking water returns.

7.2 Rainfall, Evaporation 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 to the source.

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: 1034 mm. Rainfall data for the area are taken from Met Éireann.
- Annual evapotranspiration losses: 434 mm. Potential evaporation (P.E.) is estimated to be 457 mm $yr.^{-1}$ (from Met Éireann data). Actual evapotranspiration (A.E.) is then estimated as 95 % of P.E.
- Potential recharge: 575 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: 145 mm. This estimation is based on the assumption that 25% of the potential recharge will be lost to overland flow and shallow soil quickflow prior to reaching the main groundwater system.

These calculations are summarised below:

Average annual rainfall (R)	1034 mm
Estimated A.E.	434 mm
Potential Recharge (R – A.E.)	600 mm
Runoff losses	145 mm
Estimated Actual Recharge	455 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 are three boreholes about 300 m and 500 m to the north of the source. These wells have limited space between the borehole casing and the rising main and the water levels were not measured. Apart from these wells there are no others in the vicinity which give information on ground water levels. However the water levels in the streams and the River Funshion are significant and the water level in the River Funshion was measured at Glenavuddig Bridge on 5/8/99.

The water table in the area is generally assumed to be a subdued reflection of topography. The topography slopes toward the River Funshion and the borehole and it is assumed that the water table too slopes toward the river and the borehole. The hill on which Kildorrery village lies and the higher ground to the north of the borehole drive groundwater toward the borehole and river Funshion. The flow directions are assumed to be perpendicular to the contour lines. In simple terms, rainfall reaching the water table anywhere in the catchment will flow toward the borehole and river.

The groundwater gradient is assumed to be somewhat less than the topographic gradient, i.e. is estimated as 0.02.

7.4 Aquifer Characteristics

All of the limestones are fine grained, most are massive and recrystallised, and only the Croane unit shows regular bedding. The rocks in the area are fractured. Permeability in these rocks depends largely on fracturing and further enhancement by enlargement of the fractures by chemical solution (karstification). There is evidence on the outcrops around the hill of

Kildorrery to indicate that the bedrock has undergone karstification.

The data used in this section are based on test pumping undertaken by GSI in August 1999 and from information on yields in the wells close to the borehole.

A constant discharge test in August 1999 was run at 550 $m^3 d^{-1}$ for 10 hours, with a final drawdown of 0.64m. This gives a specific capacity of 860 $m^3 d^{-1} m^{-1}$. Analysis of the test pumping data (pumping and recovery data) from this specific 10 hour test gives transmissivity estimates of 1700-2000 $m^2 d^{-1}$. The test pumping data are given in Appendix 3.

The borehole's location coincides with the southern end of a large north south 'cross' fault, shown in Figure 1. The test pumping results suggest that the borehole taps the fault zone. As such, it is probable that the results of the test pumping reflect the permeabilities and transmissivities along the fault zone, rather than in the surrounding aquifers. Maps and aerial photographs indicate that this fault manifests itself in the topography as incisions into the background topography.

These figures cannot be taken as definitive values for the aquifer itself, but they indicate that the transmissivity and permeability of the fault zone in the immediate vicinity of the borehole must both be 'high'.

For boreholes a, b, and c, shown in Figure 1, the yields are between 40 and 60 $m^3 d^{-1}$ and each can only sustain this yield for a number of hours at most. These values give approximate tranmissivities of about 1-10 $m^2 d^{-1}$, which are considerably lower than for the pumping well. Borehole 'c' never met water although it was drilled to over 90 m. It would appear that none of these boreholes intersected the major fault zone, nor even any smaller fault zone.

As the groundwater flows primarily through the fractures in the karstified rock and the gradients are relatively high, the groundwater velocities in the fractures are also likely to be quite high. All of the limestones are fine grained and many are recrystallised, particularly near the borehole, but are quite 'clean' and light in colour. This would indicate the porosity of the limestones is low. The velocities are likely to vary over several orders of magnitude due to the variable, karstic nature of flow in the aquifer. Assuming a permeability of 5 m d^{-1} (based on values for similar rock types in Limerick and Waterford), a porosity of 0.02 and a hydraulic gradient of 0.02, the resulting velocity is 5 m d^{-1}.

7.5 Aquifer Category

Hydrogeological data for the rock units in the Kildorrery region are poor, consequently their aquifer classification is taken from the Tipperary S.R. Groundwater protection Scheme (Daly, Keegan and Wright, 1998) and the Limerick Groundwater Protection Scheme (Deakin *et al*, 1998).

While the information in Tipperary is also poor, the Rathronan, Kilsheelan and Croane Limestones are tentatively classed as **regionally important karstified aquifers** with a good development potential **(Rk^d)**. Evidence from Tipperary suggests that the Rathronan and Kilsheelan Limestones are cleaner, more karstified and therefore more permeable than the Croane Limestone. There is no hydrogeological data for the O' Mahony's formation, however, the lithology is roughly similar to the rocks mentioned above and so is tentatively classed as a **regionally important karstified aquifer** with a good development potential **(Rk^d)**.

The Ballysteen Limestone is classed as a **locally important aquifer, which is moderately productive only in local, zones** (**Ll**).

The Waulsortian Limestone is classed as a **regionally important fissured aquifer** (**Rf**).

7.6 Hydrochemistry and Water Quality

There is only one full dataset available for analysis for the Glenavuddig Bridge borehole. Other datasets only have data for bacteria and nitrates. Hydrochemical analyses exist for 'mixed' samples, taken from the village. These represent both the spring and the borehole. These are used in conjunction with the analysis for the borehole. Hydrochemical data for the source is presented in Appendix 2.
The hydrochemical analysis shows that the Kildorrery water is hard with total hardness values of 327-344 mg l^{-1} $CaCO_3$.

Electrical Conductivities range from 630-844 µS/cm.

Nitrate levels range from 36-73 mg l^{-1}. The dataset for the source only covers 2 years. The values are quite high and there are 5 exceedances of the EU Maximum Admissable Concentrations (MAC) for nitrates, which is 50 mg l^{-1}. Peaks in the dataset correspond to the first few months of the year (Jan - April). The 'mixed' dataset indicates that there is a trend of increasing levels of nitrates and the peaks correspond to the first few months of the year.

There is only one data value for chlorides (34.0 mg l^{-1}, July 1999). This is 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 in this region higher than 30 mg l^{-1} usually indicates significant contamination.

Sodium (Na): Potassium (K) ratio for July 1999 is 0.17, which is a relatively low ratio. High Na: K ratios (>0.3) usually indicate contamination from farmyard wastes.

There are no faecal bacteria recorded at the source. There is no chlorination carried out at this source. The source was also tested for cryptosporidium and giardia, using customised equipment provided by Inniscarra Water Works; none was found in the sample (July 1999).

7.7 Conceptual Model

- The borehole at Glenavuddig Bridge abstracts up to 300 m^3 d^{-1}, and is capable of abstracting up to 720 m^3 d^{-1}.

- The groundwater regime in the area is complex due to the structural history that the rocks have undergone and the available hydrogeological information does not allow a definitive understanding of the hydrogeology.

- The area lies in a faulted synclinal valley comprised of limestones.

- The borehole's location coincides with the southern end of a large north-south 'cross' fault. The test pumping results indicate that the borehole taps the fault zone. As such, it is probable that the results of the test pumping indicate the permeabilities and transmissivities along the fault zone, rather than the surrounding aquifer.

- Groundwater flow is primarily controlled by fractures in the bedrock and velocities are likely to be quite high. It is likely that the limestones on either side of the fault line provide the groundwater to the fault zone via fractures and the planar discontinuities between the rock units. Karstification has probably enhanced these pathways.

- The gradients to the west and north of the borehole are greater than the gradients to the east of the borehole.

- The test pumping results appear to indicate that there is no hydraulic connection between the borehole and the river. However, greater discharge rates may indicate otherwise.

- It is possible that groundwater from the eastern side of the river at Glenavuddig Bridge gets to the borehole. However, this is unlikely as the higher gradients along the fault zone and to the east of the borehole probably prevent this from happening. Also the regional groundwater flow is probably north to south which would indicate that groundwater to the east of the river at Glenavuddig Bridge would flow south westwards, discharging to the fault and river south of the borehole. It is assumed therefore, that groundwater to the east of the River Funshion does not reach the borehole.

8. Delineation of Source Protection Areas

8.1 Introduction

This section delineates the areas around the borehole that are believed to contribute groundwater to the borehole, and that therefore require protection. The areas are delineated based on the conceptualisation of the groundwater flow pattern, as described in Section 7.7, are presented in Figures 1 and 2. The zones are drawn using the maximum possible abstraction from the newly installed pump.

Two source protection areas are delineated:

- ♦ Inner Protection Area (SI), designed to give protection from microbial pollution;
- ♦ Outer Protection Area (SO), encompassing the remainder of the zone of contribution (ZOC) of the well.

8.2 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), which 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.

Two methods were used to delineate the ZOC and are as follows:

- Hydrogeological mapping and
- Water balance estimations.

The shape and boundaries of the ZOC were determined using hydrogeological mapping and the conceptual model. The ZOC catchment boundaries are as follows:

1. The **Northern Boundary** is defined by a topographic ridge that swings in a northeasterly to westerly to a northwesterly arc. The ridge stops where it meets the tributary of the River Funshion, however, this final section of boundary is adjusted to include the fault zone. The location of this fault can be constrained to the gorge like incisions that occur in the topography. The fault on the geological maps continues outside the ZOC, but is assumed to be reasonable to draw the adjusted ZOC around the fault where it manifests itself on the topographic maps and the aerial photographs. Although there is no direct evidence, it is assumed that this highly permeable pathway can draw water in from the surrounding bedrock and then transmit it rapidly to the borehole. An arbitrary buffer with a width of 100m each side of the gorge is added as a precautionary measure. This is shown in Figure 1. There is a degree of uncertainty with the delineation of this boundary.

2. The **Eastern Boundary** is defined by the River Funshion. It is assumed that groundwater does not travel to the well under the river. However, an arbitrary buffer of 30 m is placed on the eastern side of the borehole.

3. The **Southern Boundary** is similar to the northern boundary, a topographic ridge runs in an arc-like form from the village to the well.

4. The **Western Boundary** is defined by the uppermost limit of the hill in the middle of Kildorrery village. It is assumed that groundwater to the west of the village does not flow to the borehole.

These boundaries delineate the physical limits within which the ZOC is likely to occur. The area constrained by the hydrogeological mapping is approximately 1 km^2. A water balance is then carried out to estimate the areal extent of the catchment providing the water to the source and the resulting area is compared to that delineated by mapping. A water balance is carried out by using an estimated recharge value and the discharge estimates (maximum provided by the new pump - 720 $m^3\ d^{-1}$). The water balance indicates that the largest estimated discharge requires an area of 0.6 km^2. The area constrained by hydrogeological mapping is greater than the area required by the water balance.

8.3 Inner Protection Area

The Inner Protection Area (SI) is the area defined by a 100-day time of travel (ToT) to the source. It is delineated to protect against the effects of potentially contaminating activities that 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 5 m d^{-1}, and so it is assumed that for a 100 day time of travel, groundwater could travel 500 m, assuming a hydraulic gradient of 0.02. Thus, the upgradient extent of the SI zone is 500 m. The SI is presented in Figure 2.

The fault zone complicates the delineation of the inner protection area. From the high transmissivities of the fault zone, it is likely that water getting into the fault zone can reach the borehole relatively quickly i.e. far less than the 100 day ToT. Although there is no direct evidence, it is assumed that this highly permeable pathway can draw water in from the surrounding bedrock and then transmit it rapidly to the borehole. The precise location of this pathway can be probably be constrained to the centre of the gorge-like incisions that occur in the topography that mark the location of the fault. The whole of the gorge is included in the inner protection zone as a precautionary measure. There is a buffer of 50 m to either side of the fault.

9. Groundwater Vulnerability

The distribution of interpreted groundwater vulnerability in the ZOC is presented in Figure 2. The subsoils in the ZOC are of low to high permeability. They are generally 1.4 m to 10 m thick in the ZOC as described in Section 6.3.4. Therefore, most of the land in the ZOC is classified as 'extremely' vulnerable to contamination. In the immediate vicinity of the well, the subsoils have a low permeability category but are less than 10 m thick and so have a 'moderate' vulnerability rating. The rest of the catchment has either a 'high' or 'moderate' vulnerability rating.

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. 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 five groundwater protection zones present around the Kildorrery borehole presented in Figure 2.

Table 2 Matrix of Source Protection Zones for the Glenavuddig Borehole, Kildorrery.

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

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, garages, runoff from the roads, road spillage, the sewage treatment works, leaky sewers and landspreading of organic fertilisers. The main potential pollutants are faecal bacteria, viruses, cryptosporidium, and nitrogen. The sewage treatment works is within the zone of contribution to the borehole.

12. Conclusions and Recommendations

♦ The source at Glenavuddig Bridge is an excellent yielding well, which is located in a karstic limestone aquifer. The test pumping indicates that the present normal abstraction rate of the well could be increased.

♦ The area around the supply is 'moderately to 'extremely' vulnerable to contamination.

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

♦ It is recommended that:
1) A full chemical and bacteriological **raw** water analysis 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 that might cause contamination at the borehole.
3) The potential hazards in the ZOC should be located and assessed.

♦ The protection zones delineated in the report are based on our current understanding of groundwater conditions and on the available data. Due to the hydrogeological complexity of the area, there is uncertainty regarding some of the boundaries. 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. These techniques could be used to provide more information on the location of the fault zone.

13. References

Deakin, J., Daly, D. and Coxon, C. 1998. *County Limerick Groundwater Protection Scheme*. Geological Survey of Ireland, 61 pp.

Daly, D., Keegan, M. and Wright, G.R. 1998. *Groundwater Protection in County Tipperary (S.R.).* Geological Survey of Ireland.

Sleeman, A. G., Mc Connell, B., Claringbold, K., O' Connor, P., Warren, W.P. and Wright, G. 1995. *'A Geological description of East Cork, Waterford and adjoining parts of Tipperary and Limerick to accompany the bedrock geology 1:100,000 scale map series, Sheet 22, East Cork-Waterford'*. Geological Survey of Ireland, 66 pp.

Appendix 1 Geological logs of the auger holes

All borehole depths are maximum depths drilled by the auger, beyond 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. In the case of borehole No. 4, the auger simply refused to go beyond 8 metres. It is likely that the depth to rock in this instance is similar to that of the pumping borehole, which is only about 20 m away and its reported depth to rock is 6 m.

Borehole	Grid Reference	Depth (m)	Subsoil	BS 5930 Description	Permeability Category
Kildorrery 1	R715 1070	0-0.30	Topsoil	SILT	MODERATE
		0.30-3.0	Till	clayey SAND with frequent gravel	MODERATE
		3.0-3.5	Till	sandy CLAY with gravel	LOW
Kildorrery 2	R 716 1075	0-0.20	Topsoil	SILT	MODERATE
		0-1.40	Till (broken bedrock)	GRAVEL	HIGH
Kildorrery 3	R 720 1077	0-.020	Topsoil	SILT	MODERATE
		0.20-5.5	Till	sandy SILT with gravel	MODERATE
		5.5-7.0	Till	sandy SILT with clay and gravel	MODERATE
		7.0-9.0	Till	GRAVEL with clay	HIGH
		9.0-9.5	Till	Clay with gravel	LOW
Kildorrery 4	R 722 1080	0-2.0	Alluvium	CLAY	LOW
		2.0-8.0 no returns after 7.5m	Till	sandy CLAY with frequent gravel	LOW
Borehole 'a'	R 722 111	6			
Borehole 'b'	R 7221 112	3.7			
Borehole 'c'	R 725 115	6.1			

Appendix 2 Hydrochemical Data

Parameter	15/7/99	9/6/98
Conductivity (µS/cm)	632	712
Temperature (°C)	-	
pH	7.3	7.1
Total Hardness	327	344
Total Alkalinity (mg/l)	274	276
Calcium	126	
Magnesium	7.9	
Chloride	34.0	
Sulphate	15.2	
Sodium	7.9	
Potassium	2.7	
Iron	<0.1	
E. coli count per 100 ml.	0	
Total Coliforms per 100ml	6	

Nitrate Monitoring data:

Date	Mg/L
28-Jan-97	56
01-Mar-97	73
02-Apr-97	47
29-Apr-97	46
15-May-97	40
11-Jun-97	36
16-Nov-97	38
10-Dec-97	46
13-Jan-98	49
09-Feb-98	54
25-Mar-98	60
01-Jun-98	54.9
15-Jul-99	37.5
Average	49.0

Hydrochemical Data for Mixed Samples at Kildorrery village.

Date	Colour	Turb.	Temp.	Cond.	pH	NO3	NO2	NH4	Total C.	Faecal.
23/05/1991		0	13	382	7.3	20.03	0.002	0.03	0	0
13/12/1991		0		429	7.3	32.4	0.002	0.01	0	0
27/05/1992		0	9.5	512	7.5	32.9	0.002	0.02	0	0
06/08/1992		0		509	7.3	30.5	0.002	0.02	0	0
30/03/1993		0		402	7.5	37.07	0.002	0.02	0	0
20/06/1994		0	15	670	7.5	42.97	0.003	0.013	0	0
06/09/1994	5	0	17	516	7.4	26.38	0.15	0.02	62	45
07/11/1994		0	12	533	7.4	22.11	0.003	0.022	0	0
07/03/1995	5	1	7	446	7.3	27.52	0.003	0.01	0	0
24/05/1995		0	13.5	608	7.4	37.58	0.003	0.012	0	0
06/11/1995		1	14	576	7.5	19.29	0.002	0.001	0	0
05/02/1996		1	8.5	515	7.3	33.87	0.01	0.01	0	0
15/04/1996	5	1	10	549	7.3	44.36	0	0.013	1	0
24/06/1996		0	14.5	615	7.5	47.98	0.016	0.013	0	0

Appendix 3 Test pumping data

Drawdown data

SITE Kildorrery, North Cork **DATE** 05/08/99

Groundwater Section
Geological Survey of Ireland **PUMPING TEST** **PUMPING WELL**

Project Title **source protection**
Page No. **1**

Borehole Name	Glenavuddig Bridge	**Well Depth**	**18.2 m**	**Datum Point**	**top of casing**
Borehole No.		**Well Diameter**	**30 cm**	**Height of Datum**	**60.5**
Well Owner	Cork County Council	**Pump Depth**	**unknown**	**Ground Elevation**	60.25 m
Location	Glenavuddig Bridge, Kildorrery	**Aquifer**	**Dinantian limestones**	**Datum Elevation**	
Grid ref.	R 723 108			**Weather**	Dry, mild, occassionally sunny
6" Sheet No.	18			**Observer**	Coran Kelly and Sophie O' Connor

Date	Time	Elapsed Time	Water level below datum	Drawdown	Discharge		Discharge	Remarks	
05/08/99		Mins	(m)	(m)	Meter	Spot	(m3/d)	EC & T of groundwater	EC & T of river water
	7.00 am	0	3.51	0	0		0	micros siemens & degs Centigrade	
		0.5	4.08	0.57	84g/min		550		
		1	4.08	0.57					
		2	4.09	0.58					
		3	4.09	0.58					
		4	4.09	0.58					
		5	4.1	0.59					
		6	4.1	0.59					
		7	4.1	0.59					
		8	4.1	0.59					
		9	4.1	0.59					
		10	4.1	0.59					
		11	4.1	0.59	84 g/min		550		
		17	4.11	0.6					
		20	4.11	0.6					
		30	4.11	0.6					
		40	4.11	0.6			550	EC 630 T 12.2	
		50	4.11	0.6					
		60	4.11	0.6					
		70	4.12	0.61			550		730 / 15.2
		80	4.12	0.61					
		90	4.12	0.61			536	638 / 12.1	731 / 15.0
		100	4.13	0.62					
		120	4.13	0.62			543		
		140	4.13	0.62					
		160	4.13	0.62					
		180	4.13	0.62					
		200	4.13	0.62			550	640 / 12.1	
		220	4.14	0.63			550		
		240	4.14	0.63			536		
		260	4.14	0.63			543		
		280	4.14	0.63			543	640 / 12.0	730 / 15.2
		300	4.14	0.63			550		
		320	4.15	0.64			550	640 / 12.1	640 / 15.1
		340	4.15	0.64			550		
		360	4.15	0.64			550	640 / 12.1	530 / 15.2
		400	4.15	0.64			543		
		500	4.15	0.64			550	640 / 12.1	519 / 16.5
		600	4.15	0.64			550	642 / 12.0	535 / 16.6

Recovery Data

SITE	Kildorrery, North Cork			DATE	05/08/99
Groundwater Section				Project Title	source protect.
Geological Survey of Ireland	RECOVERY TEST	OBSERVATION WELL		Page No.	1

Borehole Name	Glenavuddig Bridge	**Well Depth**	details as on pumping	**Datum Point**	
Borehole No.		**Well Diameter**	test sheet.	**Height of Datum**	
Well Owner	Cork County Council	**Pump Depth**		**Ground Elev.**	
Location	Glenavuddig Bridge, Kildorrery	**Duration of Pumping**		**Datum Elev.**	
Grid ref.		**Average Discharge**		**Weather**	
6" Sheet No.		**Aquifer**		**Observer**	

Date	Time	Time since Pumping Began (t)	Time since Pumping Ended (t')	Water level below datum	t/t'	Residual Drawdown	Recovery	Remarks
	am/pm	Mins	Mins		(m)	(m)	(m)	
		600.5	0.5		1201	0.14		
		601	1		601	0.09		
		601.5	1.5		401	0.08		
		602	2		301	0.07		
		602.5	2.5		241	0.06		
		603	3		201	0.06		
		603.5	3.5		172.429	0.06		
		604	4		151	0.05		
		605	5		121	0.05		
		607	7		86.7143	0.04		
		610	10		61	0.04		
		612	12		51	0.03		
		620	20		31	0.02		
		630	30		21	0.01		
		650	50		13	0		
		660	60		11	0		

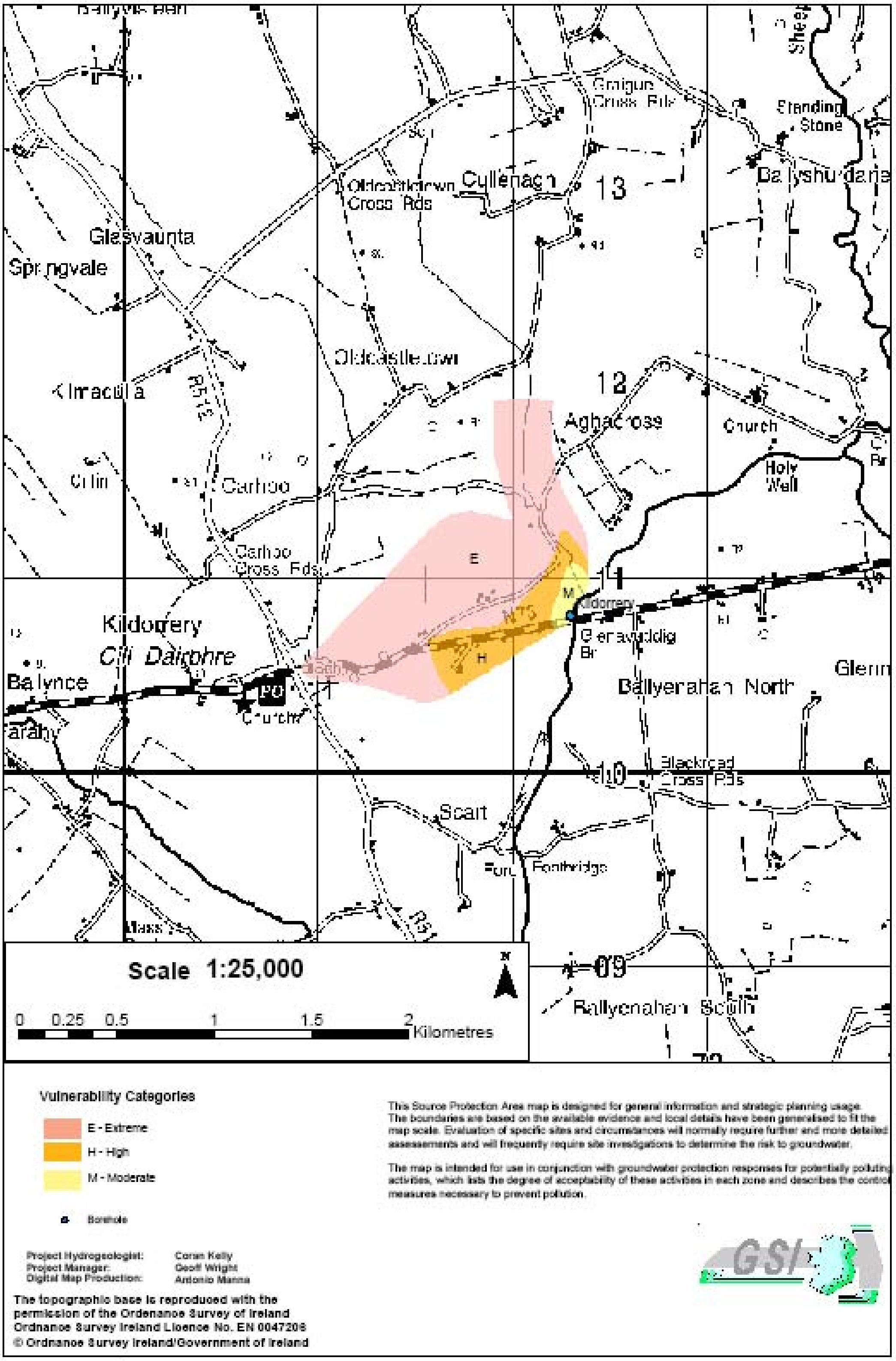

Figure 1 Groundwater Vulnerability around Kildorrery

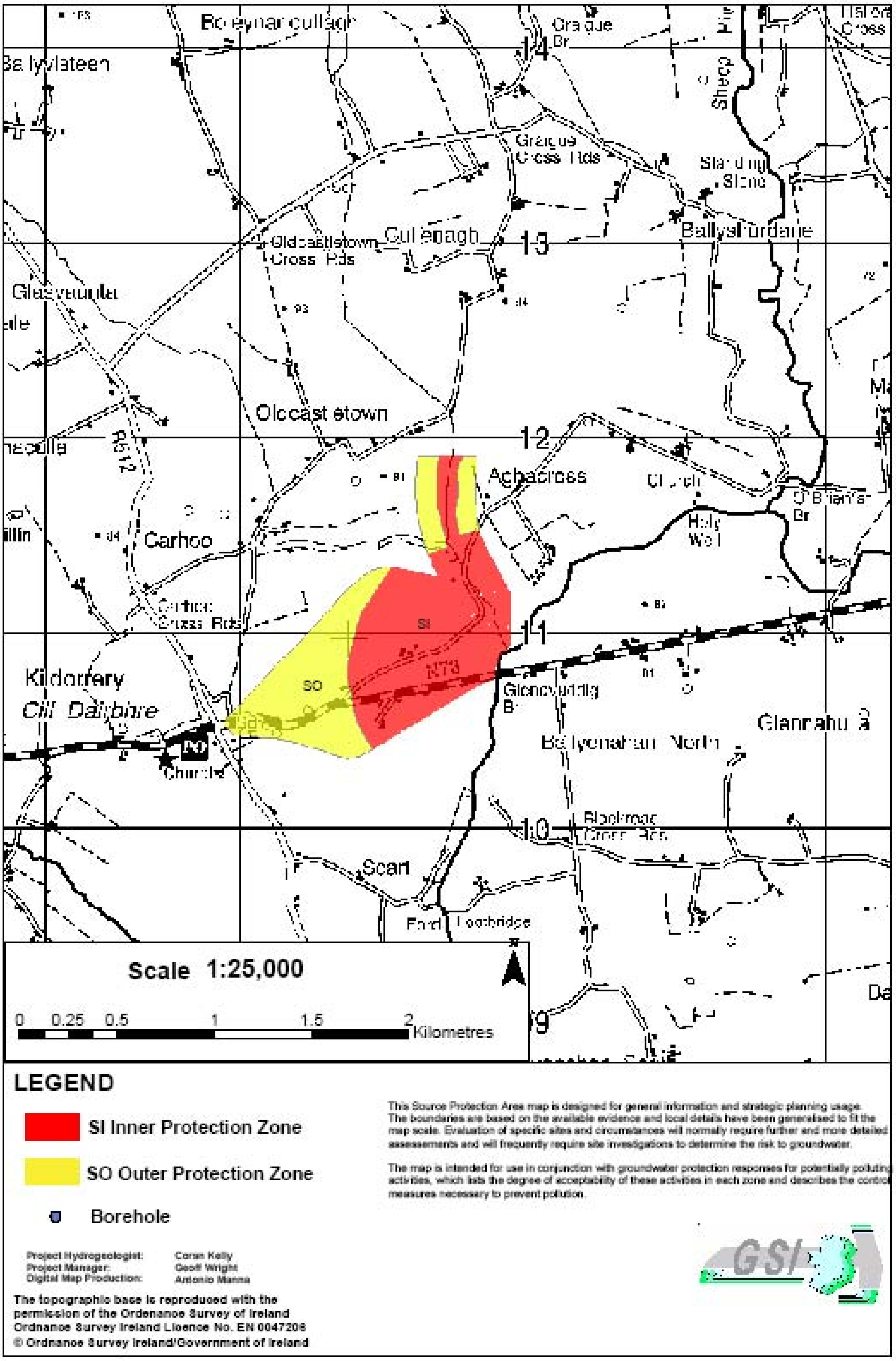

Figure 2 Groundwater Source Protection Areas for Kildorrery

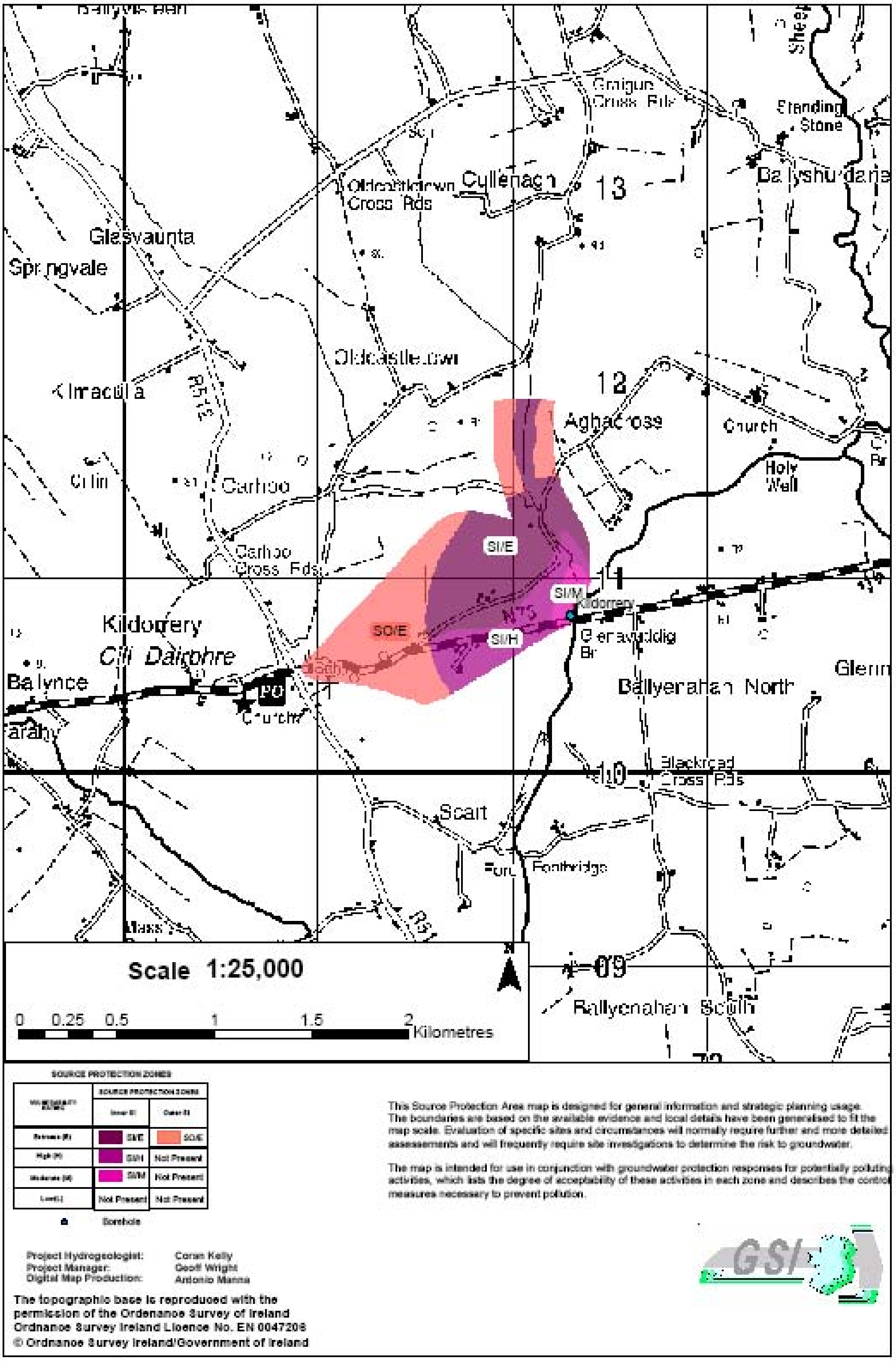

Figure 3 Groundwater Source Protection Zones for Kildorrery