# Oliver’s Cross
# Water Supply Scheme

# Groundwater Source Protection Zones

***Prepared by:***
Coran Kelly
Geological Survey of Ireland

***In collaboration with:***
Cork County Council (Northern Division)

**TABLE OF CONTENTS**



List of Tables

# 1 Introduction

The source is a borehole drilled at Oliver's Cross, Mallow, commissioned in 1978. The borehole pumps water to two reservoirs at Ballyviniter (200,000 gallons; 909 $m^3$) and Mountnagle (40,000 gallons; 181 $m^3$). Houses and farms along the 'back' road into Mallow at Keatleysclose and Carrigoon are on direct feed from the production well.

The objectives of the report are as follows:

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

# 2 Location, Site Description and Well Head Protection

The borehole is about 65 m south of Oliver's Cross, a cross-roads that is approximately 3 km outside Mallow, toward Fermoy and Mitchelstown. The borehole is located inside a concrete chamber next to a pumphouse. The chamber is covered by concrete slabs that can be moved easily. The borehole is only 3 m from a busy back road into Mallow.

# 3 Summary of Borehole Details

| | | |
|---|---|---|
| Grid reference | : | W $^1$579 $^0$998 |
| Townland | : | Parkadallane |
| Well type | : | Borehole |
| Owner | : | Cork County Council (Northern Division) |
| Elevation (ground level) | : | 68.4 m OD |
| Depth of borehole | : | 36.6 m (120ft) |
| Diameter of borehole | : | 152.4 mm (6 inches) |
| Depth to rock | : | >12 m |
| Static water level | : | 51.06 m OD. 17.34 m bg on 30/8/2000. |
| Normal consumption | : | 270-300 $m^3$ $d^{-1}$ (60,000 gallons per day) |
| Pumping test summary | : | 11 hour constant rate test carried out by GSI. on 30/8/2000<br>(i) abstraction rate : 855 $m^3$ $d^{-1}$<br>(ii) specific capacity : 157 $m^3$ $d^{-1}m^{-1}$<br>(iii) transmissivity : 280 $m^2$ $d^{-1}$ |

# 4 Methodology

## 4.1 Desk Study

Details about the borehole such as depth, date commissioned and abstraction figures were obtained from 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, subsoil sampling, water sampling and test pumping. 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 source.

## 5 Topography, Surface Hydrology and Land Use

The source is located in a low-lying area 2 km from the Blackwater River. Higher ground surrounds the source to the north, east and southeast. The highest ground occurs to the north of the source, rising to about 150 m in Ballyviniter Upper. To the southeast of the production well the ground rises to about 88 m in the townland of Carrigoon.

There are several small streams to the north of the source, draining the high ground to the north. They join together to become one main stream that flows south toward the source. About 150 m north of the source the stream swings southwest and flows into Spaglen, Mallow, before going on to join the River Blackwater. Immediately south and east of the source there are virtually no surface water features. The main river feature is the River Blackwater, 2 km south of the source, flowing to the east.

The land is primarily used for agriculture: both tillage and pasture. Dairygold have a breeding station about 1 km north of the source. A road haulier, a scrap merchant/garage and several houses are situated with 200 m of the source. There are also several farms within 500 m of the source. A busy byroad passes next to the source. The main Mitchelstown/Fermoy road passes the production well 65 m to the north.

## 6 Geology

### 6.1 Introduction

This section briefly describes the relevant characteristics of the geological materials that underlie the borehole. It 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:

- Bedrock Geology 1:100,000 Map Series, Sheet 21, Kerry-Cork. Geological Survey of Ireland. (Pracht, M., *et al*, 1997).
- The Geology of the area around Mallow, County Cork. Campbell, K.J., 1988, Unpublished MSc thesis, University of Dublin.
- Information from geological mapping in the nineteenth century (on record at the GSI).

Subsoils information was gathered from a drilling programme that was undertaken by GSI personnel to investigate the subsoils of the area.

## 6.2 Bedrock Geology

The rocks are the result of sediments deposited during Carboniferous times; the rocks have subsequently been folded and faulted. Table 1 summarises the bedrock geology in the area. The geology is illustrated in Figure 1.

### 6.2.1 Structure

The succession outlined in Table 1 has been deformed during a 'mountain building event', known as the Variscan Orogeny. The rocks were compressed from north and south to produce an east-west or northeast-southwest trend to the current rock distribution (Pracht, M., *et al,* 1997). The source is located at the western end of the Fermoy Syncline.

Two major fault sets are widespread across the region; east-west or northeast-southwest trending (strike-faults) and north-south trending (cross-faults). The Killarney-Mallow Thrust Fault crosses the area 850 m south of the source. This particular fault is a major fault in the geology of the Kerry-Cork region and is probably associated with the geothermal springs at Spa House in Mallow. There are several north-south faults cutting across the rock units in the area.

Table 1 The Geology of the Oliver's Cross area (after Pracht M., 1997, Campbell, K.J., 1988).

| *Name of Rock Formation* | *Rock Material* | *Occurrence* |
|---|---|---|
| Namurian (undifferentiated) | Black SHALE and SANDSTONE | Occurs in the Ballyviniter and Dromroe areas. |
| Annabella Formation | Interbedded SILTSTONES and SANDSTONES. | Occurs over the high ground around Ballyviniter |
| Caherduggan Formation | Thin well-bedded grey fossiliferous (crinoids) medium to coarse grained LIMESTONE. | Occurs as a narrow band north of the source around Caherduggan. |
| Hazelwood Formation | Pale grey, medium-coarse grained massive reef LIMESTONE. | Occurs beneath the source; sweeps as a band to the north east and east. |
| Waulsortian Formation | Pale grey, massive LIMESTONE. | Underlies the River Blackwater valley bottom. |

## 6.3 Subsoil (Quaternary) Geology

The subsoils comprise a mixture of coarse and fine-grained materials, namely: till. The locations of the auger holes are given in Figure 2 and the logs are given in Appendix 1. The characteristics of the till are described briefly below:

### 6.3.1 Till (Boulder Clay)

Till is the dominant subsoil type in the area. 'Till' is an unsorted mixture of coarse and fine materials laid down by ice. Angular to subrounded purple sandstone and limestone fragments are present in the till. The fragments are gouged and striated. The till is described using BS5930 as being a sandy SILT with clay (with occasional to frequent angular sandstone and limestone fragments, up to 5-7 cm) and CLAY with occasional sandstone and limestone fragments. The till is dense and stiff at all localities seen.

### 6.3.2 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 wells database at the GSI also provided depth to bedrock information at known localities. Immediately around the production well the depth to bedrock is >12 m at all sites that were drilled and is up to 17 or

18 m thick. Throughout the area there are many outcrop localities. Along the streams there is evidence of outcrop. In general, over the higher ground to the north of the source the subsoil thickness is 0-6 m.

# 7 Hydrogeology

## 7.1 Introduction

This section presents our current understanding of groundwater flow in the area of the borehole.

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

- Hydrogeological mapping carried out by GSI.
- 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 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 (data from Met Éireann).
- Annual evapotranspiration losses: 434 mm. Potential evapotranspiration (P.E.) is estimated to be 457 mm $yr.^{-1}$ (based on data from Met Éireann). Actual evapotranspiration (A.E.) is then estimated as 95 % of P.E.
- Potential recharge: 600 mm $yr.^{-1}$. This figure is 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 runoff.
- Annual runoff losses: 180 mm. This estimation is based on the assumption that 50% of the potential recharge will be lost to overland flow and shallow soil quickflow prior to reaching the main groundwater system. The steep slopes indicate that runoff is probably quite high in the catchment with a large proportion of the recharge leaving the catchment via the stream that flows past the borehole.

These calculations are summarised as follows:

| | |
|---|---|
| Average annual rainfall (R) | 1034 mm |
| Estimated A.E. | 434 mm |
| Potential Recharge (R – A.E.) | 600 mm |
| Runoff losses | 300 mm |

| Estimated Actual Recharge | 300 mm |
|---|---|

### 7.3 Groundwater levels, Flow Directions and Gradients

The water table in the area is generally assumed to be a subdued reflection of the topography, with groundwater flowing from the sub-catchment watersheds and discharging into the Blackwater River and its tributaries. As moderately permeability material overlies the bedrock it is assumed that the groundwater is unconfined.

Water levels were measured in the production borehole, an observation well and another well located at Dairygold Breeding station, 750 m northeast of the production well. All the wells measured are located within the Hazelwood Limestone rock unit. The levels are approximately equal, 58-59 m OD for May and June 1999. They indicate a line of equipotential or a very flat water table. There is not enough data around the source, in particular there are no water level data available south of the source except for the water level in the River Blackwater. Water level data exist for wells in the Ballyviniter area, indicating that in general the water table coincides with the top of the bedrock.

It is assumed that the high ground to the north of the source provides the driving head for groundwater flow. As groundwater discharges to the Blackwater and its tributaries it is considered that the flow of groundwater is south-southeast (SSE) toward the Blackwater. However, it can be seen that the main tributary of the Blackwater turns almost at right angles, swinging from a southerly flow to a westerly flow, probably because of the high ground in Carrigoon. Water level measurements at the production well, observation well and the stream across the road from the source, show that the water level in the stream is several metres higher (up to 5 m) than in either the production well or the observation well. It is possible that the groundwater flow directions also swing to a similar direction, parallel to the strike of the rock units. However, it is also possible that the groundwater flow remains steady, maintaining its south-southeasterly (SSE) flow direction. This is because in areas of similar limestone rock types the topography has no control over groundwater movement, because the water table is quite flat in such limestones, not reflecting the topography. In addition, there is a segment of Namurian rocks to the southwest of the production well that would probably inhibit groundwater flow toward the Blackwater along the strike of the beds. Therefore it is assumed that the groundwater flow is south-southeast (SSE).

Groundwater gradients vary over the different bedrock units and with topography. Where the topography is quite steep (north of the main road into Mallow and over the Namurian rocks and the Annabella rock unit) the gradient is steep – 0.01; this figure is estimated from the gradient of the streams and estimated groundwater levels in the wells in the area. Over the Caherduggan, Hazelwood and Waulsortian rock units the gradient is estimated to be 0.001-0.008.

### 7.4 Aquifer Characteristics

The source is located in the Hazelwood rock unit, however, the aquifer characteristics are described for all the rock units in the area. This is because it is likely that there is an input of groundwater from the other rock units upgradient of the source as seen from evidence in previous sections (7.3 and 7.5).

The Annabella Formation and the undifferentiated Namurian rocks are considered to be **locally important aquifers, moderately productive only in local zones** (**Ll**). Permeabilities are likely to be low, about 1 m $d^{-1}$. Groundwater flow in these units is likely to be restricted to the uppermost few metres of bedrock. Groundwater movement is slow and localised, and most of the potential recharge runs off in the upper few metres of rock towards the nearest surface water channel (Deakin et al, 1999). The land is drained by a high frequency of drains and streams, indicating that the rock units have relatively low permeabilities. It is likely that a considerable quantity of the groundwater and surface water leave the catchment via the network of streams. The aquifer characteristics of the sandstones, mudstones and siltstones are generally poorer than the limestones in the area.

The Caherduggan Limestone Formation is considered to be a **regionally important karstified aquifer (Rk)**. On the older edition of the 6″-maps there are a number of swallow holes indicated on the map. It is presumed that these have been filled in as they are not marked on the most recent 6″-maps. It is assumed that this rock unit has similar aquifer properties to the Hazelwood and Waulsortian rock units.

The Hazelwood Limestone Formation is considered to be a **regionally important karstified aquifer (Rk)**. It is similar to the Waulsortian Limestone Formation and has similar hydrogeological properties. The production borehole underwent test pumping on the 30 September 2000. The data is given in Appendices 2 and 3. Analysis of the data indicates that the aquifer has a transmissivity of 280 $m^2$ $d^{-1}$ (using the observation well data). The porosity is 0.025. The permeability is estimated to be about 10 m $d^{-1}$. Velocities are calculated to be about 4 m $d^{-1}$.

The Waulsortian Limestone Formation is considered to be a **regionally important karstified[1] aquifer (Rk)**. Aquifer properties vary widely across the Munster area, generally very productive, recording very high well yields and specific capacities. Test pumping at Downing Bridge and Moorepark suggests transmissivities ranging 15-3400 $m^2$ $d^{-1}$, permeabilities ranging 10-200 m $d^{-1}$. (Motherway, 1999). The porosity is considered to be about 0.025.

Groundwater flow is likely to occur in three main hydrogeological regimes within the limestone aquifer:

- An upper, shallow, highly karstified weathered zone, known as the epikarst, in which groundwater moves quickly, through solutionally enlarged conduits, in rapid response to recharge;
- A deeper zone, where groundwater flows through interconnected, solutionally enlarged conduits and cave systems that are controlled by structural deformation.
- A more dispersed slow groundwater flow component in smaller fractures and joints outside the main conduit systems.

### 7.5 Hydrochemistry and Water Quality

The hydrochemical analyses show that the water is moderately hard to hard, with total hardness values of 266-310 mg $l^{-1}$ (equivalent $CaCO_3$) and electrical conductivity values of 370-641 µS $cm^{-1}$, indicating that the groundwater has a hydrochemical signature of calcium bicarbonate type water. These values are indicative of groundwater from limestone rocks;

[1] Karstification is the process whereby limestones are slowly dissolved away by acidic waters moving through them. This most often occurs in the upper bedrock layers and along some of the pre-existing fissures and fractures in the rocks, which become slowly enlarged. One of the consequences of karstification is the development of an uneven distribution of permeability which results from the enlargement of certain fissures at the expense of others and the concentration of water flow into these high permeability zones (Deakin *et al*, 1998).

however, they are ‘softer’ than analyses for other areas in North Cork, for example at Castletownroche hardness values range from 316-331 mg $l^{-1}$ and at Kildorrery values range 327-344 mg $l^{-1}$. This is probably due to the input of groundwater from the sandstone and siltstone rock units to the north of the borehole. The analyses are given in Appendix 4.

Nitrate concentrations range 11-37 mg $l^{-1}$ (11 samples; 1981-2000), average 27 mg $l^{-1}$. Nitrate concentrations have not exceeded the EU Drinking Water Directive maximum admissible concentration (MAC). Nitrate concentrations appear to have increased throughout the 1980’s and early 1990’s, as illustrated in the graph in Appendix 5. However, the data for the last 4 years indicates a trend whereby the nitrate concentrations appear to be decreasing.

There are 8 samples of untreated water; total coliforms were present in 2 samples (10/2/1997, 11/10/1999) and faecal coliforms were present in the sample taken on the 11/10/99. The borehole water was also sampled for cryptosporidium and giardia, using customised equipment provided by Inniscarra Laboratory. Subsequent analysis by City Analysts found the samples to be negative for both cryptosporidium and giardia.

Iron concentrations were 0.5 mg $l^{-1}$ on 4/9/1996, which exceeds the EU MAC of 0.2 mg $l^{-1}$. The iron content is likely to originate from groundwater that passed through the sandstone and shale rock units to the north of the borehole. Hydrochemical analyses from wells that are located in the sandstones and shales consistently show high levels of iron.

Data exists for wells in Ballyviniter, a townland to the north of the production well that overlies the sandstones and shales. Hardness values are lower than at the production well (66-72 mg $l^{-1}$), conductivity values are also lower (250 $\mu$S $cm^{-1}$). Manganese and iron levels are very high and in most cases exceed the EU MAC. Dissolved solids are high in several instances. The high levels of manganese and iron are likely to originate from the underlying sandstones and shales.

Faecal coliforms, total coliforms and iron are the only parameters to exceed the EU MAC. It is possible that manganese levels occasionally exceed the EU MAC but there are not enough data to determine this.

## 7.6 Conceptual Model

- The production well is located in the Hazelwood Limestone Formation; a **regionally important karstified aquifer (Rk)**. The lower permeability rock units to the north of the borehole are poorer aquifers than the Hazelwood rock unit, but do provide an input to the source.
- The source is overlain by a thick layer of moderately permeable till and is considered to be unconfined.
- The water table follows the topography, sloping toward the River Blackwater. It is steeply dipping over the sandstones and shales and relatively flat within the limestones. Groundwater discharges to streams and to the River Blackwater.
- The groundwater is hard limestone type water with an input of softer groundwater that comes from the sandstones and shales.
- The limestones are important karstified aquifers, with localised high permeability zones that give rise to rapid groundwater velocities. Groundwater flow is probably confined to and controlled by fractures, fissures, joints and bedding planes all of which have been solutionally enlarged due to karstification.
- There are few surface streams occurring over the limestones, indicating the free draining nature of the subsoils and the high permeabilities of the bedrock. In contrast there are frequent springs and streams in the north of the area, located on the Namurian rocks.
- Diffuse recharge is dominant, passing through the permeable till. Swallow holes are noted on the older edition of the 6″-maps, indicating the probability of locations of point recharge. Recharge is

likely to be rapid due to the permeable nature of the subsoils and the limestones; the shallow depth to rock in places; occasional presence of faecal bacteria; the change of conductivity of several hundred $\mu S\ cm^{-1}$ over a short time.

# 8 Delineation of Source Protection Areas

## 8.1 Introduction

This section delineates the areas around the source that are believed to contribute groundwater to it, and that therefore require protection. The areas are delineated based on the conceptualisation of the groundwater flow pattern, and are presented in Figures 2 and 3.

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 borehole.

## 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.

The shape and boundaries of the ZOC were determined using hydrogeological mapping, water balance estimations and the conceptual model and are shown in Figure 1. The ZOC catchment boundaries are discussed as follows:

The **Southern Boundary** is defined using semi-analytical methods. The maximum down gradient extent of the ZOC was estimated using a discharge rate 50% greater than the current abstraction rate, a gradient of 0.002, an effective aquifer thickness of 20 m and a permeability of 20 m $d^{-1}$. It is estimated to be about 500 m downgradient of the well. A conservative gradient was used to account for times of low water levels due to lack of recharge.

The **Eastern Boundary** is defined using topography. A ridge extends from Dromroe Commons through Ballyshehan, past Ballyvorisheen as far as Carrigoon.

The **Western boundary** is defined using topography and is delineated in a similar fashion to the eastern boundary. A ridge extends from Rough Hill (beyond Ballyviniter Upper) through Cloghlucas North and Ballyviniter.
The **Northern Boundary** is defined using topography. A surface watershed exists in Caherduggan South and it assumed that the groundwater divide coincides with the surface watershed due to the relatively impermeable rock units that occupies this area.

The area delineated by the boundaries described is about 7 $km^2$. The area needed to provide water to the source is estimated using a water balance. The water balance uses the average recharge and average abstraction figures + 50% (1282 $m^3\ d^{-1}$) to determine the area. This is calculated to be about 1.6 $km^2$, which is considerably less than the area delineated using the above boundaries. However a considerable proportion (>50%) of the recharge to the northern part of the ZOC is likely discharge from that part of the catchment via the streams that drain the area. As described in sections some groundwater from this part of the ZOC gets to the source, hence this part of the catchment must be considered as part of the entire ZOC.

### 8.3 Inner Protection Area

According to "Groundwater Protection Schemes" (DELG/EPA/GSI, 1999), delineation of an Inner Protection Area is required to protect the source from microbial and viral contamination and it is based on the 100-day time of travel (ToT) to the supply. Estimations of the extent of this area are made by hydrogeological mapping and analytical modelling.

The permeability is estimated to be about 20 m $d^{-1}$ from the test pumping. This would give a velocity of 8 m $d^{-1}$, using a conservative gradient of 0.01 and a porosity of 0.025. Considering the karstification of the limestones there are likely to be zones of higher permeability with extremely high flow velocities, estimated to be as high as 2500 m $d^{-1}$. Therefore groundwater within the limestones that is within the ZOC could reach the production well within several hours. Velocities within the sandstone and shale rock units are about 1 m $d^{-1}$, which gives a 100 day ToT of 100 m. As a result all of the limestone within the ZOC lies within the inner protection zone and a buffer of 100 m extends over the Namurian rock units.

## 9 Groundwater Vulnerability

Vulnerability is a term used to represent the intrinsic geological and hydrogeological characteristics that determine the ease with which groundwater may be contaminated by human activities and depends on the thickness, type and permeability of the subsoils. A detailed description of the vulnerability categories can be found in the Groundwater Protection Schemes document (DELG/EPA/GSI, 1999).

Outcrop, areas of shallow rock, auger holes, and topography are used to give depth to rock contours that are used along with the permeability classifications to develop the vulnerability zones. An average buffer of 100 m is used around areas of outcrop to produce a 3 m depth to bedrock contour, i.e., the limit of the 'Extremely' vulnerable zones. This buffer incorporates topography and known points of depth to bedrock and is based on calculations made by measuring the distance along the ground between outcrops and known points of depth to rock. For areas of 'rock close' an average buffer of 140 m is used.

The distribution of interpreted groundwater vulnerability in the ZOC is presented in Figure 2. There are several outcrops and areas with subsoil thickness <3 m, giving rise to a vulnerability classification of 'Extreme' (E) over parts of the area, most of which are on the high sloping ground.

The subsoils comprise glacial till that has a moderate permeability. This assessment is based on the behavioural characteristics assessed using the British Standard BS5930 in conjunction with the drainage and recharge characteristics. Where the depth to rock <10 m, the vulnerability is 'High' (H) and for areas with depth to rock >10 m and a moderate permeability the category is 'Moderate' (M).

## 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 5 groundwater protection zones present around the borehole as shown in Table 2 and presented in Figure 3.

Table 2 Matrix of Source Protection Zones at Oliver's Cross.

| **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

Land use in the area is described in Section 5. The land around the source is largely tillage and grassland dominated. Agricultural activities, septic tanks, waste petroleum products are the principal hazards in the area. The main potential sources of pollution within the ZOC are farmyards, septic tank systems, hydrocarbon wastes, runoff from the roads, leaky sewers and landspreading of organic fertilisers. The main potential pollutants are faecal bacteria and viruses. Road spillage threatens the water quality at the borehole.

## 12 Conclusions and Recommendations

- The borehole source is located in the Hazelwood Limestone rock unit, which is a **regionally important karstified aquifer (Rk)**.

- Septic tanks, farmyards, landspreading and runoff from the road pose a threat to the water quality at the source.

- The protection zones delineated in the report are 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, geophysics and flow measurements. Geophysics and drilling would also improve the accuracy of the vulnerability boundaries. Drilling would improve considerably the information on the water table, thus delineation of the boundaries could be improved.

- It is recommended that:

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

## 13 References


Campbell, K.J.M., 1988. *The geology of the area around Mallow, County Cork.* Unpublished MSc thesis. University of Dublin.

Deakin, J., Daly, D. and Bloetjes, O. 1999. *County Clare Groundwater Protection Scheme*. Joint GSI/Clare County Council report, Draft, 73 pp.

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

DELG/EPA/GSI, 1999. Department of the Environment and Local Government, Environmental Protection Agency and Geological Survey of Ireland. *Groundwater Protection Schemes*. DELG/EPA/GSI report.

Motherway, K., 1999. *A study of nitrate and vulnerability in the Waulsortian Limestone Aquifer of North Cork, Ireland.* Unpublished MSc thesis. University College London.

Pracht, M. 1997 *A Geological description to accompany the Bedrock Geology 1:100,000 Scale Map Series, Sheet 21, Kerry-Cork,* with contributions by G. Wright (Groundwater), G. Stanley and K. Claringbold (Minerals) and W.P. Warren (Quaternary). Geological Survey of Ireland, 70 pp.

**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. However, in for boreholes OX 2, OX 3 and OX 4 the drill stem could not drill further into the subsoil, and they are minimum depths.

| *Borehole No.* | *Grid Ref.* | *Depth (m)* | *BS5930 Description* | *Permeability* |
|---|---|---|---|---|
| OX1 | W580 994 | 12.5 | Sandy SILT with clay and with frequent stones (1-5 mm) Most of which are sandstone and shale (Till). On the field surface, gouges can be seen on the fragments. Large fragments on the field surface. | Moderate |
| OX2 | W582 995 | 0-7.6 | SILT with frequent stones (1-5 mm) Most of which are sandstone and shale (Till). On the field surface, gouges can be seen on the fragments. Large fragments on the field surface. | Moderate |
| | | 7.6-12.0 | Harder, stiffer. CLAY with frequent angular black small stones. TILL | LOW |
| OX3 | W578 993 | >12.0 | SILT with abundant stones (1-5 mm) Most of which are sandstone and shale (Till). On the field surface, gouges can be seen on the fragments. Large fragments on the field surface. | Moderate |
| OX4 | W577 997 | 8.7 | SILT with abundant stones (1-5 mm) Most of which are sandstone and shale (Till). On the field surface, gouges can be seen on the fragments. Large fragments on the field surface. | Moderate |

# Appendix 2 Test pumping data

PUMPING TEST PUMPING WELL

| | | | | | |
|---|---|---|---|---|---|
| Borehole | Oliver's Cross | Well Depth | 30m | Datum Point | dipping tube |
| Borehole No. | | Well | 15.24cm | Height of Datum | 40cm gl |
| Well Owner | Cork Co. Co. | Pump | 33.5m | Ground Elevation | 68.4 |
| Location | Oliver's Cross, Mallow | Aquifer | hazelwood | Datum Elevation | 68.8 |
| Grid ref. | W 1579 0998 | | | Weather | grand and hot! |
| 6" Sheet No. | 33 | Drilled by Dunnes about 1980 | | Observer | ck & omcalister |

| Date | Time | Elapsed Time | Water level below datum | Drawdown | Discharge | | Discharge | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Mins | (m) | (m) | Meter | Spot | (m3/d) | | |
| 30/08/0 | 6.50a | 0 | 17.74 | 0 | 27031800 | | | | |
| | | 0.5 | 19.1 | 1.36 | | | | | |
| | | 1 | 19.12 | 1.38 | | | | | |
| | | 1.5 | 19.13 | 1.39 | | | | | |
| | | 2 | 19.15 | 1.41 | | | | | |
| | | 8.5 | 19.4 | 1.66 | | | | | |
| | | 9 | 19.6 | 1.86 | | | | | |
| | | 10 | 19.67 | 1.93 | | | | | |
| | | 11 | 19.78 | 2.04 | | | | | |
| | | 11.5 | 19.81 | 2.07 | | | | | |
| | | 12 | 19.84 | 2.1 | | | | | |
| | | 12.5 | 19.89 | 2.15 | | | | | |
| | | 13 | 19.94 | 2.2 | | | | | |
| | | 13.5 | 19.99 | 2.25 | | | | | |
| | | 14 | 20.01 | 2.27 | | | | | |
| | | 14.5 | 20.03 | 2.29 | | | | | |
| | | 15 | 20.07 | 2.33 | 27034100 | | 886 | ~7.05am, not a certain Q | |
| | | 15.5 | 20.1 | 2.36 | | | | | |
| | | 16 | 20.11 | 2.37 | | | | | |
| | | 16.5 | 20.13 | 2.39 | 27034450 | | | | |
| | | 18 | 20.22 | 2.48 | 27034580 | 130 | 851 | | |
| | | 19 | 20.25 | 2.51 | | | | | |
| | | 20 | 20.27 | 2.53 | | 100g/46sec | 854 | | |
| | | 21 | 20.3 | 2.56 | | | | | |
| | | 22 | 20.34 | 2.6 | | | | | |
| | | 23 | 20.4 | 2.66 | | | | | |
| | | 25 | 20.44 | 2.7 | | 100g/46sec | 854 | | |
| | | 26 | 20.48 | 2.74 | | | | | |
| | | 27 | 20.5 | 2.76 | | | | | |
| | | 30 | 20.56 | 2.82 | | | | EC=540; T= 11.2 degs | |
| | | 33 | 20.63 | 2.89 | | | | | |
| | | 36 | 20.65 | 2.91 | | | | | |
| | | 39 | 20.71 | 2.97 | | | | | |
| | | 40 | 20.72 | 2.98 | | | | | |
| | | 45 | 20.78 | 3.04 | | | | | |
| | | 50 | 20.85 | 3.11 | | | | | |
| | | 55 | 20.94 | 3.2 | | | | | |
| | | 60 | 21.01 | 3.27 | | | | | |
| | | 65 | 21.08 | 3.34 | 27040580 | | 884 | | 7.58am |
| | | 70 | 21.14 | 3.4 | | | | | |
| | | 75 | 21.2 | 3.46 | | 132g/min | 864 | | |
| | | 80 | 21.26 | 3.52 | 27042860 | 132g/min | 852 | | 8.15am |
| | | 97 | 21.46 | 3.72 | | | | | |
| | | 110 | 21.6 | 3.86 | | | | EC=545; T= 11.1 degs | |
| | | 120 | 21.7 | 3.96 | | | | | |
| | | 130 | 21.81 | 4.07 | | | | | |
| | | 140 | 21.9 | 4.16 | | 132g/min | 864 | | 9.12am |
| | | 150 | 21.97 | 4.23 | 27050780 | 132g/min | 857 | | 9.15am |
| | | 160 | 22.05 | 4.31 | | | | | |
| | | 170 | 22.11 | 4.37 | | 132g/min | 864 | | 9.44am |
| | | 180 | 22.16 | 4.42 | | 100g/46sec | 854 | | 9.57am |
| | | 195 | 22.24 | 4.5 | | 100g/46sec | 854 | | 9.58am |
| | | 210 | 22.32 | 4.58 | | 132g/min | 864 | | 9.59am |
| | | 220 | 22.34 | 4.6 | 27056600 | | 854 | | 10.0am |
| | | 225 | 22.39 | 4.65 | 27059740 | 132g/min | 864 | | 10.24a |
| | | 240 | 22.43 | 4.69 | 27063140 | | 855 | | 10.50a |
| | | 255 | 22.48 | 4.74 | | | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 270 | 22.52 | 4.78 | | | | | |
| | | 285 | 22.58 | 4.84 | | | | | |
| | | 300 | 22.62 | 4.88 | | | | | |
| | | 330 | 22.7 | 4.96 | | | | | |
| | | 360 | 22.77 | 5.03 | | | | | |
| | | 390 | 22.81 | 5.07 | 27084050 | 132g/min | 864 | | 1.30pm |
| | | 420 | 22.86 | 5.12 | | | | EC=540; T= 11.5 degs | |
| | | 450 | 22.91 | 5.17 | | | | | |
| | | 480 | 22.97 | 5.23 | | | | | |
| | | 510 | 23.02 | 5.28 | | | | | |
| | | 540 | 23.04 | 5.3 | | | | | |
| | | 570 | 23.09 | 5.35 | | | | | |
| | | 600 | 23.12 | 5.38 | | | | | |
| | | 630 | 23.15 | 5.41 | | | | | |
| | 5.50p | 660 | 23.18 | 5.44 | | | | 11 hour test | Sc=855/ |

note on the discharge readings. Discharge is taken to be 855 m3/d
constant but due to '3' methods of measuring there are 3 apparent readings.
1 used the meter readings taken at various stages
2 used a stop watch and the number of gallons taken per minute was measured
3 used a stop watch and it was timed how long it took to pump 100 gallons

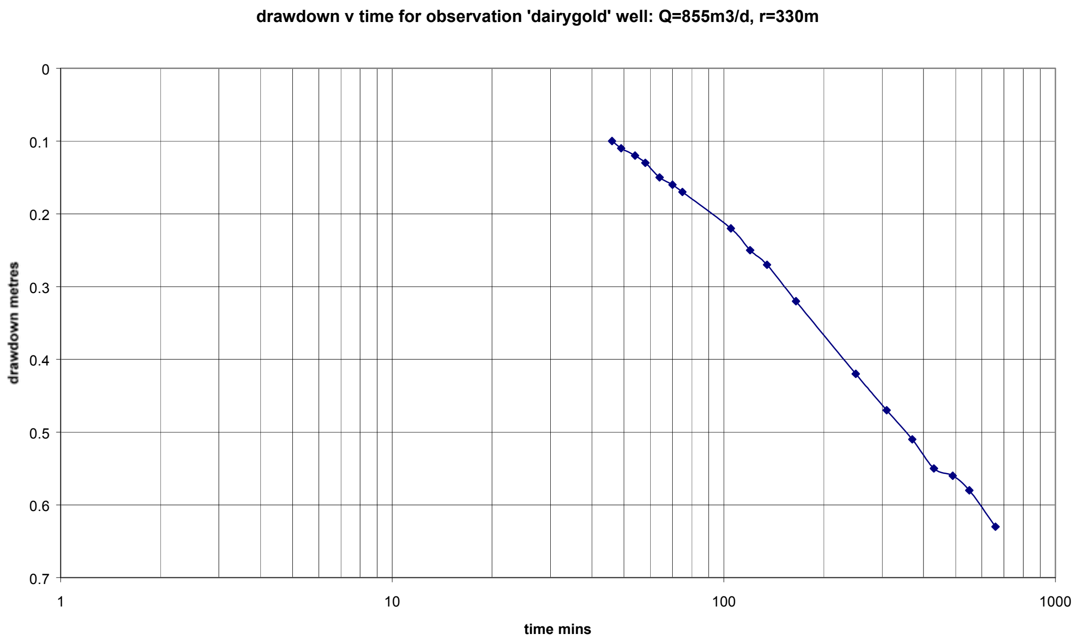
method 2 overestimates as one is looking at the stop watch over the meter and trying to keep an eye on the 60second mark and the hand on the dial; as the hand on the dial is moving fast
Discharge is taken to be 855 m3/d

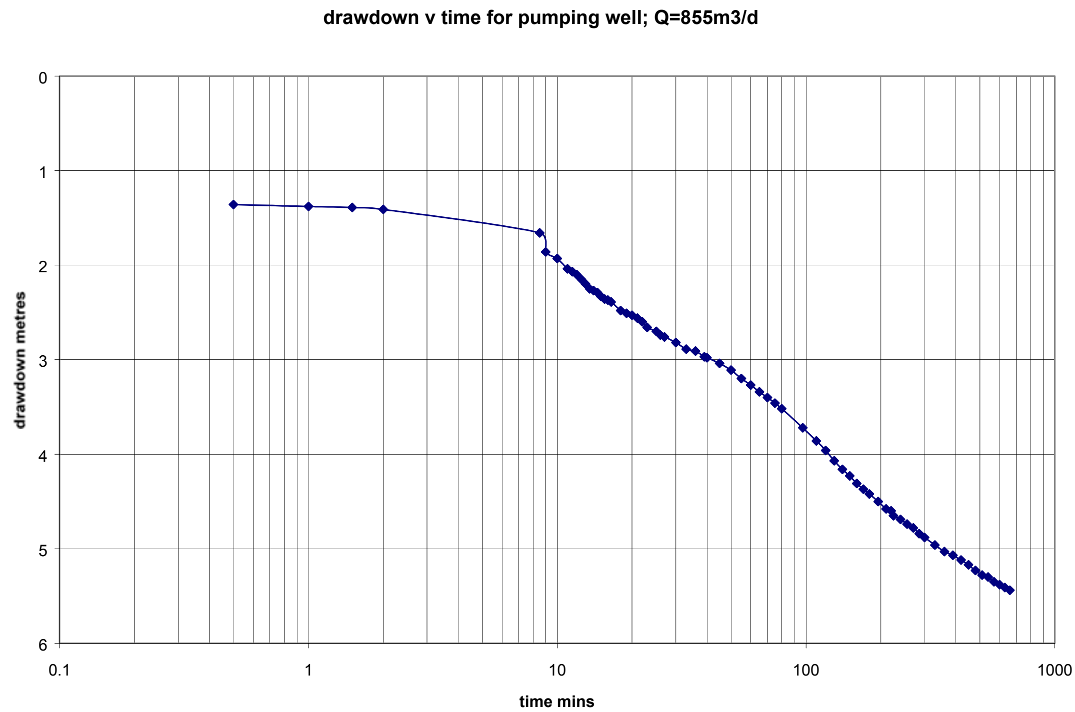
| PUMPING TEST | | | | OBSERVATION WELL | |
|---|---|---|---|---|---|
| **Borehole** | Dairygold Well | **Well Depth** | 90m | **Datum Point** | top of casing |
| **Borehole No.** | | **Well** | 20cm | **Height of Datum** | 30cm above |
| **Well Owner** | Dairygold | **Pump Depth** | | **Ground Elevation** | 70.221m OD |
| **Location** | approx 350m w pump well | **Aquifer** | hazelwood | **Datum Elevation** | 70.521m OD |
| **Grid** | | | | **Weather** | hot and sunny |
| **6" Sheet No.** | 33 | | | **Observer** | ck + orla mc |

| Date | Time | Elapsed Time | Water level below datum | Drawdown | Discharge | | Discharge | |
|---|---|---|---|---|---|---|---|---|
| | | Mins | (m) | (m) | Meter | Spot | (m3/d) | |
| | | 0 | 19.56 | 0 | | | | |
| | | 0.5 | 19.56 | 0 | | | | |
| | | 1 | 19.56 | 0 | | | | |
| | | 10 | 19.56 | 0 | | | | |
| | | 40 | 19.65 | 0.09 | | | | |
| | | 46 | 19.66 | 0.1 | | | | |
| | | 49 | 19.67 | 0.11 | | | | |
| | | 54 | 19.68 | 0.12 | | | | |
| | | 58 | 19.69 | 0.13 | | | | |
| | | 64 | 19.71 | 0.15 | | | | |
| | | 70 | 19.72 | 0.16 | | | | |
| | | 75 | 19.73 | 0.17 | | | | |
| | | 105 | 19.78 | 0.22 | | | | |
| | | 120 | 19.81 | 0.25 | | | | |
| | | 135 | 19.83 | 0.27 | | | | |
| | | 165 | 19.88 | 0.32 | | | | |
| | | 250 | 19.98 | 0.42 | | | | |
| | | 310 | 20.03 | 0.47 | | | | |
| | | 370 | 20.07 | 0.51 | | | | |
| | | 430 | 20.11 | 0.55 | | | | |
| | | 490 | 20.12 | 0.56 | | | | |
| | | 550 | 20.14 | 0.58 | | | | |
| | | 660 | 20.19 | 0.63 | | | | |
| | | | | | | | | |
| | | | | | | | | |

| RECOVERY TEST | | | | PUMPING WELL | | | |
|---|---|---|---|---|---|---|---|
| **Borehole Name** | | | | **Well Depth** | | | **Datum Point** |
| **Borehole No.** | | | | **Well Diameter** | | | **Height of Datum** |
| **Well Owner** | | | | **Pump Depth** | | | **Ground Elev.** |
| **Location** | | | | **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** |
| | **am/pm** | **Mins** | **Mins** | | **(m)** | **(m)** | **(m)** |
| 30/08/2000 | 5.50pm | 660 | | 23.18 | | | |
| | | 662 | 2 | 21.4 | 331 | 3.66 | 1.78 |
| | | 662.5 | 2.5 | 21.05 | 265 | 3.31 | 2.13 |
| | | 665 | 5 | 20.9 | 133 | 3.16 | 2.28 |
| | | 665.5 | 5.5 | 20.75 | 121 | 3.01 | 2.43 |
| | | 666 | 6 | 20.64 | 111 | 2.9 | 2.54 |
| | | 666.5 | 6.5 | 20.55 | 102.53846 | 2.81 | 2.63 |
| | | 667 | 7 | 20.49 | 95.285714 | 2.75 | 2.69 |
| | | 667.5 | 7.5 | 20.43 | 89 | 2.69 | 2.75 |
| | | 668 | 8 | 20.38 | 83.5 | 2.64 | 2.8 |
| | | 668.5 | 8.5 | 20.33 | 78.647059 | 2.59 | 2.85 |
| | | 669 | 9 | 20.24 | 74.333333 | 2.5 | 2.94 |
| | | 670 | 10 | 20.15 | 67 | 2.41 | 3.03 |
| | | 671 | 11 | 20.06 | 61 | 2.32 | 3.12 |
| | | 672 | 12 | 20 | 56 | 2.26 | 3.18 |
| | | 673 | 13 | 19.94 | 51.769231 | 2.2 | 3.24 |
| | | 675 | 15 | 19.82 | 45 | 2.08 | 3.36 |
| | | 677 | 17 | 19.74 | 39.823529 | 2 | 3.44 |
| | | 679 | 19 | 19.67 | 35.736842 | 1.93 | 3.51 |
| | | 681 | 21 | 19.6 | 32.428571 | 1.86 | 3.58 |
| | | 683 | 23 | 19.56 | 29.695652 | 1.82 | 3.62 |
| | | 687 | 27 | 19.43 | 25.444444 | 1.69 | 3.75 |
| | | 682 | 32 | 19.31 | 21.3125 | 1.57 | 3.87 |
| | | 687 | 37 | 19.2 | 18.567568 | 1.46 | 3.98 |
| | | 692 | 42 | 19.13 | 16.47619 | 1.39 | 4.05 |
| | | 697 | 47 | 19.03 | 14.829787 | 1.29 | 4.15 |
| | | 702 | 52 | 18.98 | 13.5 | 1.24 | 4.2 |
| | | 707 | 57 | 18.92 | 12.403509 | 1.18 | 4.26 |
| | | 712 | 62 | 18.88 | 11.483871 | 1.14 | 4.3 |
| | | 722 | 72 | 18.78 | 10.027778 | 1.04 | 4.4 |
| | | 732 | 82 | 18.69 | 8.9268293 | 0.95 | 4.49 |
| | | 742 | 92 | 18.62 | 8.0652174 | 0.88 | 4.56 |
| | | 752 | 102 | 18.57 | 7.372549 | 0.83 | 4.61 |
| | | 762 | 112 | 18.5 | 6.8035714 | 0.76 | 4.68 |
| | | 772 | 122 | 18.45 | 6.3278689 | 0.71 | 4.73 |
| | | 780 | 130 | 18.42 | 6 | 0.68 | 4.76 |

**Appendix 3 Graphs of test pumping data for observation well and pumping well.**



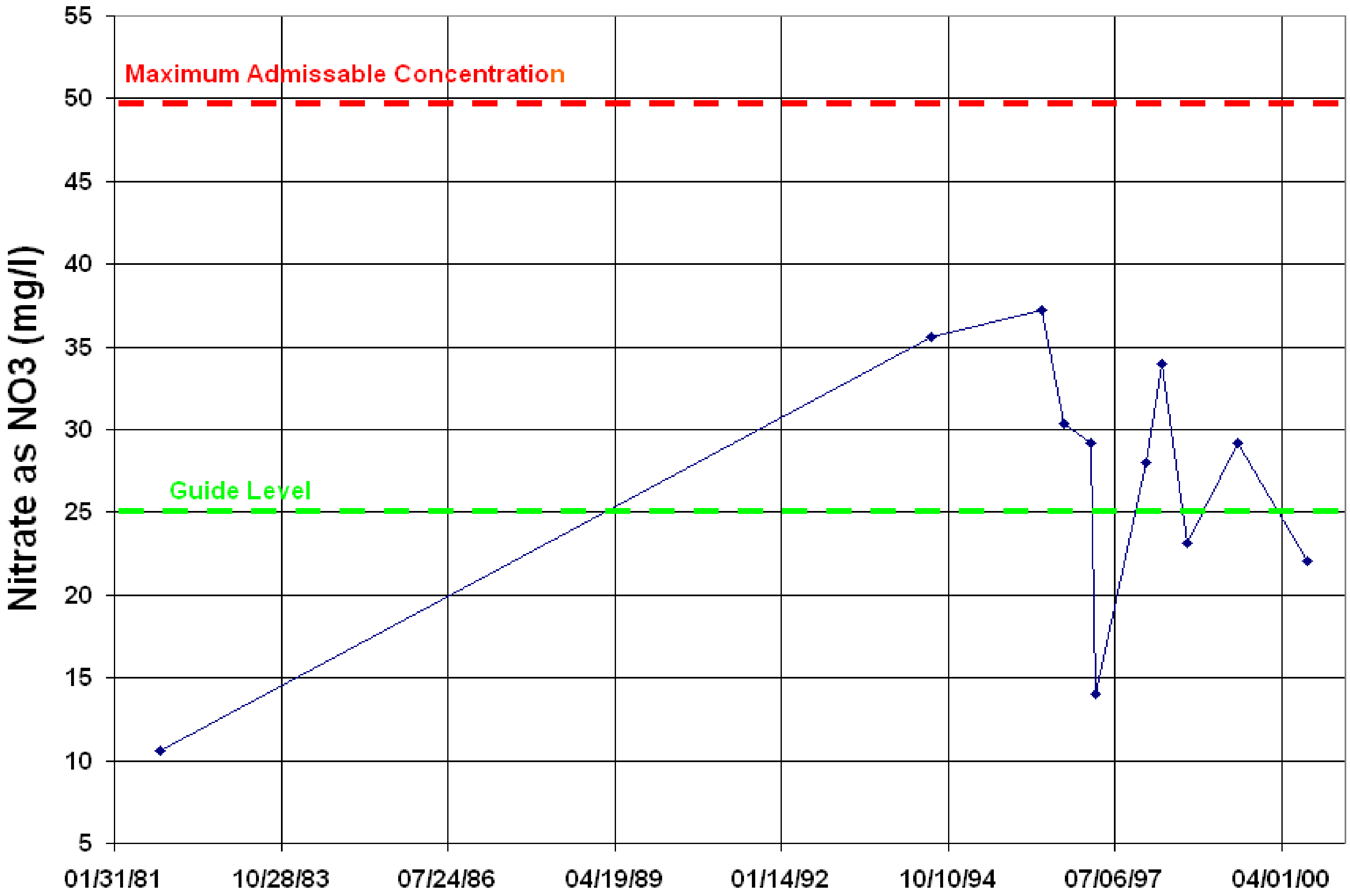
## Appendix 4 Hydrochemical Analyses for Oliver's Cross Borehole.

| **Parameter** | 4/11/1981 | 6/7/1994 | 24/4/1996 | 4/9/1996 | 10/2/1997 | 15/9/1998 | 15/7/1999 | 11/10/99 | 4/9/2000 |
|---|---|---|---|---|---|---|---|---|---|
| Conductivity (µS/cm) | - | 641 | 558 | 535 | 578 | 370 | 571 | 564 | 518 |
| Temperature (°C) | 10 | 14.4 | 10 | 15 | 8.0 | 14 | 11 | 10 | 17.0 |
| pH | 7.2 | 7.1 | 7.2 | 7.2 | 7.3 | 7.2 | 7.2 | 7.4 | 7.7 |
| Total Hardness (mg $l^{-1}$ $CaCO_3$) | 266 | | | | | | 310 | | |
| Total Alkalinity (mg $l^{-1}$ $CaCO_3$) | 250 | | | | | | 266 | | |
| Calcium | | | | | | | 111 | | |
| Magnesium | | | | | | | 8.6 | | |
| Chloride | | | | | | | 23 | | |
| Sulphate | | | | | | | 16.6 | | |
| Sodium | | | | | | | 11.6 | | |
| Potassium | | | | | | | 1.6 | | |
| Aluminium | | | | 0.02 | | | - | | |
| Ammonium | 0.035 | 0.013 | 0.015 | 0.017 | 0.026 | 0.02 | <0.026 | 0.02 | 0.026 |
| Nitrate (as $NO_3$) | 10.6 | 35.6 | 37.19 | 30.39 | 29.15 | 23.13 | 29.2 | | 22.1 |
| Nickel | | | | | | | - | | |
| Cadmium | | | | | | | - | | |
| Chromium | | | | | | | - | | |
| Copper | | | | | | | <0.04 | | |
| Iron | | | | **0.5** | | | <0.1 | | |
| Manganese | | | | | | | <0.05 | | |
| Zinc | | | | | | | <0.05 | | |
| O-PO4-P | | | | | | | 0.016 | | |
| Total Coliforms per 100 ml | | 0 | 0 | 0 | **1** | 0 | 0 | **5** | 0 |
| Faecal Coliforms per 100 ml. | | 0 | 0 | 0 | 0 | 0 | 0 | **4** | 0 |

Additional Nitrate data taken from Cork County Council Nitrate monitoring programme.

| Date | 15/3/1997 | 15/1/1998 | 15/4/1998 |
|---|---|---|---|
| Nitrate (as $NO_3$) | 14 | 28 | 34 |

**Appendix 5 Graph of Nitrate levels at Oliver's Cross Borehole.**



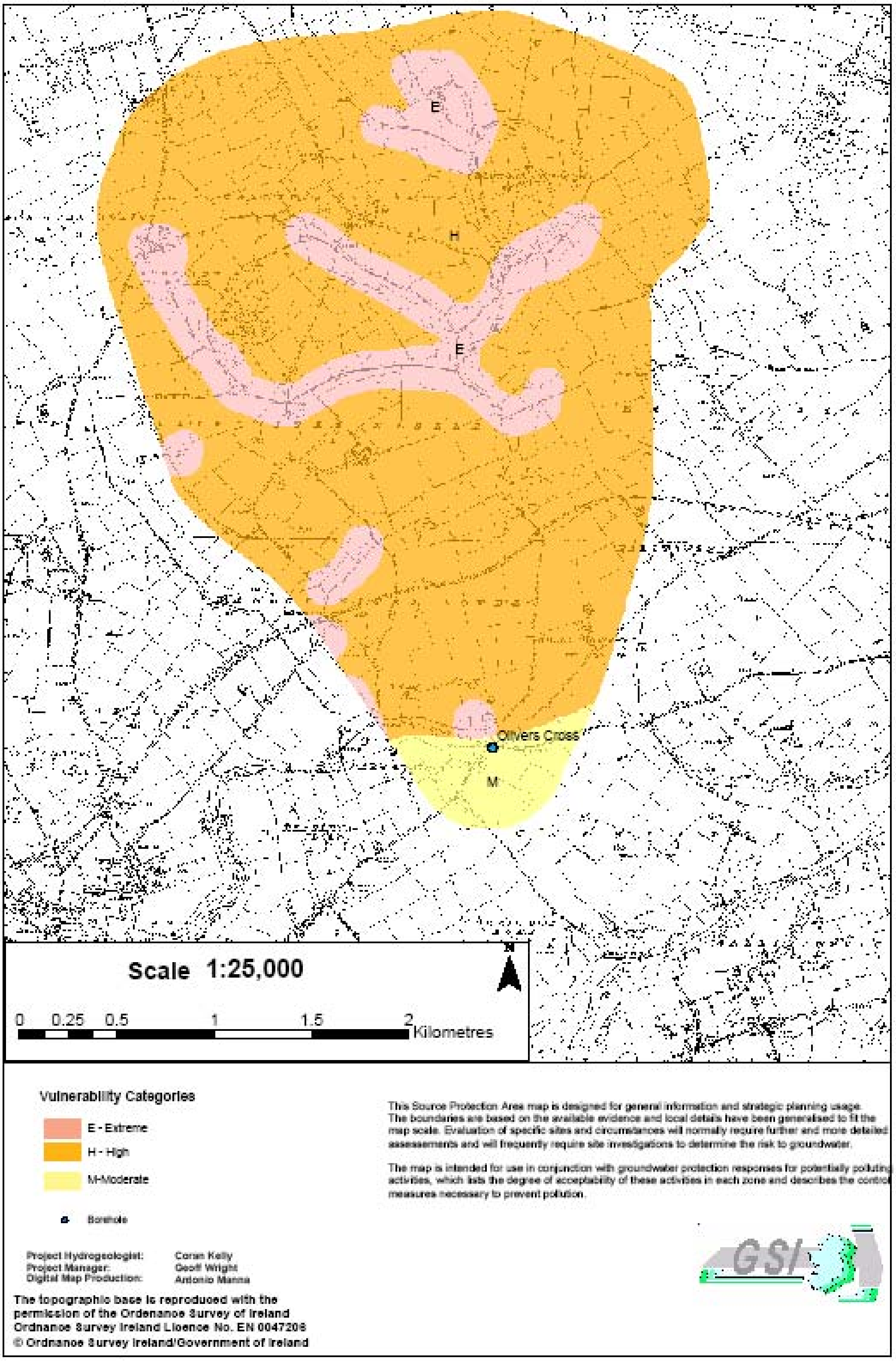



**Figure 1 Groundwater Vulnerability around Oliver’s Cross Borehole**

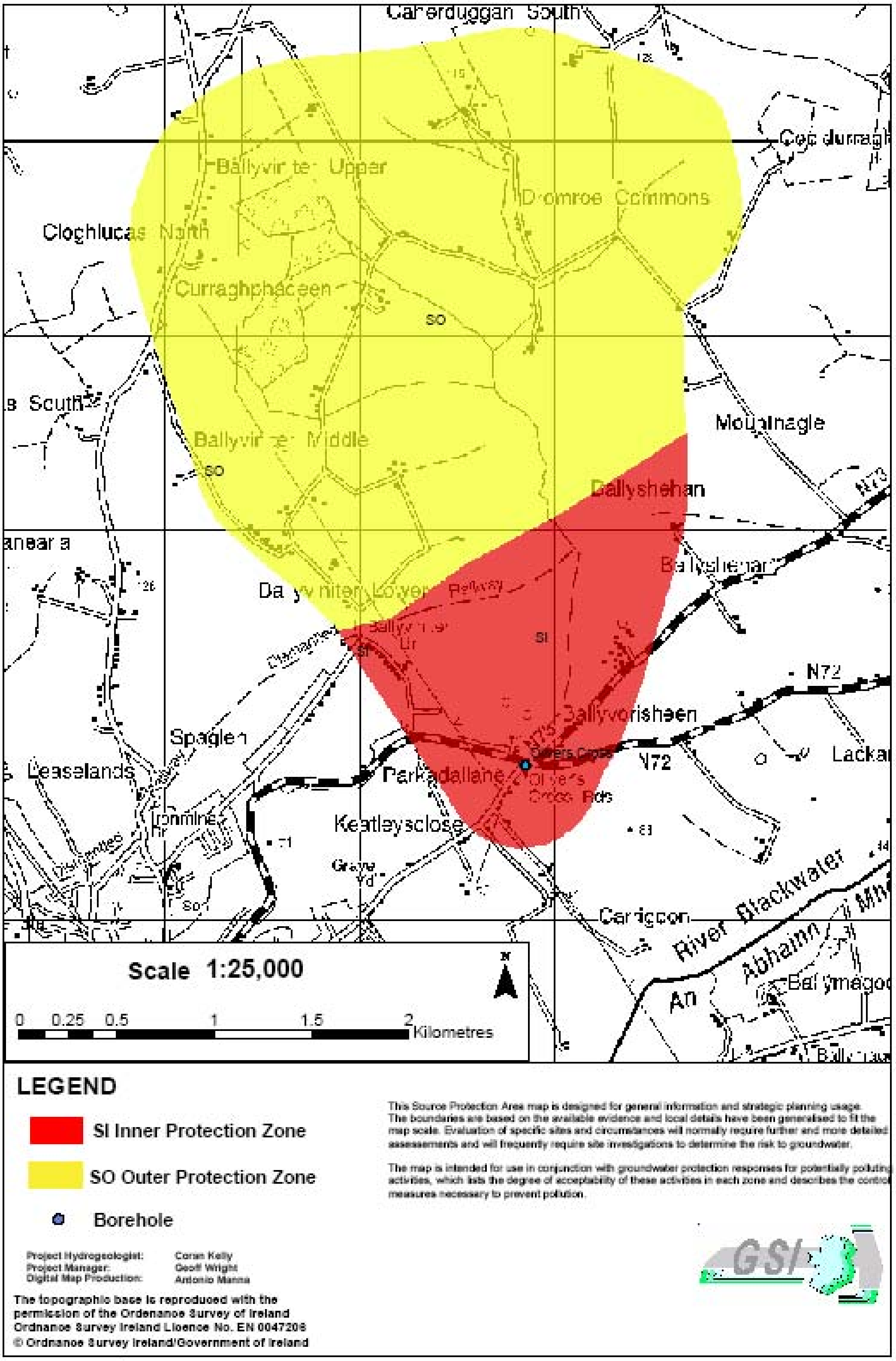



**Figure 2 Groundwater Source Protection Areas for Oliver's Cross Borehole**

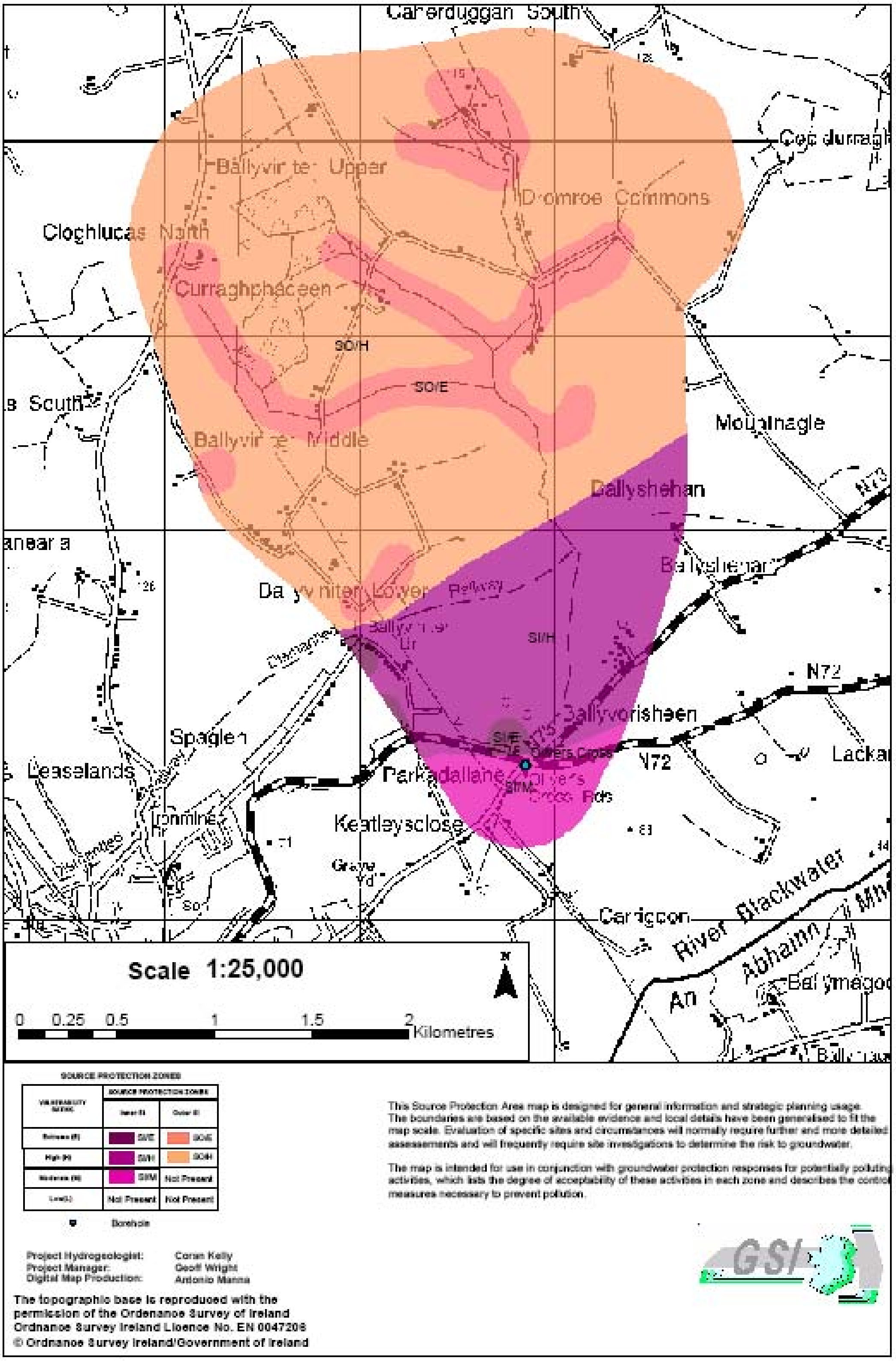



**Figure 3 Groundwater Source Protection Zones for Oliver's Cross Borehole**