Lisduff - Dunkerrin Water Scheme

Guilfoyles Well

Groundwater Source Protection Zones

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TABLE OF CONTENTS

1	INTRODUCTION	. 1				
2	LOCATION, SITE DESCRIPTION AND WELL HEAD PROTECTION					
3	SUMMARY OF WELL / SPRING DETAILS					
4	METHODOLOGY	. I				
5	TOPOGRAPHY, SURFACE HYDROLOGY AND LAND USE	. 2				
6	GEOLOGY	. 2				
	6.1 INTRODUCTION	. 2				
	6.2 BEDROCK GEOLOGY	. 2				
	6.3 SUBSOIL (QUATERNARY) GEOLOGY	. 3				
	6.3.2 Till	. 5 3				
	6.3.3 Till with gravel	. 3				
	6.3.4 Sand/Gravel	. 3				
	6.3.5 Depth to Bedrock	. 4				
7	HYDROGEOLOGY	. 4				
	7.1 INTRODUCTION	. 4				
	7.2 METEOROLOGY AND RECHARGE	. 4				
	7.3 GROUNDWATER LEVELS, FLOW DIRECTIONS AND GRADIENTS	. 5				
	7.4 AQUIFER CHARACTERISTICS	. 5				
	7.5 AQUIFER CATEGORY	. 0				
	7.0 THEROCHEMISTRY AND WATER QUALITY	.07				
	7.8 CONCEPTUAL MODEL	. 7				
8	DELINEATION OF SOURCE PROTECTION AREAS	. 7				
	8.1 INTRODUCTION	8				
	8.2 OUTER PROTECTION AREA	. 8				
	8.3 INNER PROTECTION AREA	. 9				
9	VULNERABILITY	. 9				
10) GROUNDWATER PROTECTION ZONES	9				
10		• /				
11	11 POTENTIAL POLLUTION SOURCES					
12	2 CONCLUSIONS AND RECOMMENDATIONS	10				
13	13 REFERENCES					
-						
L	ist of Figures (maps are enclosed at the back of the report)					
Fi	gure 1 Aquifer map for the area around Guilfovles well.					
Fi	gure 2 Map illustrating zone of contribution, vulnerability zones, borehole location Guilfoyles well and streams	18,				

- Guilfoyles well and streams. Groundwater Source Protection Zones Map. Graph of Nitrates for Guilfoyles well
- Figure 3 Figure 4

List of Tables

1 Introduction

Guilfoyles Well provides 30-40 % of the water for the Lisduff - Dunkerrin Water Scheme. Lisduff Well and Dunkerrin Village well provide the rest of the water for the scheme. A separate report describes Lisduff Springs (Gately and Kelly, 2000).

The objectives of the report are as follows:

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

2 Location, Site Description and Well Head Protection

Guilfoyles Well is located 1 km west of Moneygall village, in the townland of Cullenwaine. The source is located close to the County Tipperary (North Riding) boundary. The main Dublin - Limerick road passes within 500 m of the source.

Guilfoyles Well comprises a cylindrical sump, of approximately 1 m in diameter, collecting water that emerges at the bottom of the sump. This source originally had been a spring, which Offaly County Council then dug out and deepened.

The site area is closed off with a fence. The sump is covered with a metal cover, which has manhole covers that allow access to the sump itself. There is a pump house on-site, which contains the control panels for the pump and allows for the automatic chlorination of the water. There is a second sunken chamber along side the main sump chamber, in which the pipe taking the water to the treatment house can be accessed. There is a discharge meter attached to the pipe here. There is a metal cover also in place over this chamber with an access manhole. There is a small derelict weir in the source overflow channel. There has been no discharge from the spring in recent years. The rest of the site is grassed over.

3 Summary of Well / Spring Details

GSI no.	:	2017NWW004
Grid ref. (1:50,000)	:	S 20158 18117
Townland	:	Cullenwaine
Well type	:	Spring / Dug well
Owner	:	Offaly County Council
Elevation (ground level)	:	~ 118 m
Depth & Diameter of sump	:	3 x 1 m
Depth to rock	:	5m
Static water level	:	1 m bgl.
Average Abstraction	:	$500 \text{ m}^{3}/\text{d}$
Range in Abstraction	:	250 - 720 m ³ /d

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 spring such as elevation, and abstraction figures were obtained from GSI records and County Council personnel; geological and hydrogeological information was provided by the Offaly Groundwater Protection Scheme (Daly et al, 1998).

The second stage comprised site visits and fieldwork in the Moneygall area. This included carrying out on-site water analysis, 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 spring.

5 Topography, Surface Hydrology and Land Use

Guilfoyles Well emerges at approximately 118 m OD, close to the bottom of a hill, the highest point of which is 248 m OD, known as Armyhill. In general, the area immediately around the well is flat to undulating. To the south and west of the spring the land is hummocky. Further to the south, across the main road the land rises steeply past Laughton House to the townland of Rathmoyle.

The only surface stream near the spring originates approximately 30 m to the east of the source itself. There is another surface stream approximately 700 m to the west of the spring and it flows away to the west. The lack of surface drainage coming off Armyhill implies that the soils and subsoils in that area are free draining.

Agricultural activity dominates the area close to the source, with most of the land used for grassland and tillage. Some of the land around Laughton House is covered with deciduous trees.

There are a number of houses and farmyards within 500 m of the well and Moneygall village lies 1 km to the east of the source.

6 Geology

6.1 Introduction

This section briefly describes the relevant characteristics of the geological materials that underlie Guilfoyles Well. 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:

- County Offaly Groundwater Protection Scheme (Daly et al, 1998)
- Information from geological mapping in the nineteenth century (on record at the GSI).
- Bedrock Sheet 18 (Archer *et al*, 1996)
- Information from exploration drilling carried out by Dresser Minerals (1980 –1982) in the vicinity of the source.

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. Subsoils information was also provided by the exploration carried out by Dresser Minerals.

6.2 Bedrock Geology

There are several bedrock types within the zone of contribution of the source (see figure 1). The area directly beneath the spring is underlain by Lower Limestone Shale (LLS), which is comprised of mudstones, sandstones and thin limestones. To the south of the Lower Limestone Shale lies the

Cadamstown Formation (CW), which is a pale and red sandstone, grit and claystone. The contact between these two formations is faulted. To the south of the Cadamstown Formation, the Hollyford Formation (HF) can be found, which is composed of greywacke, siltstone and grit. The contact between these two formations is an angular unconformity. To the north of the source lies the Ballysteen Formation (BA) which is comprised of fossiliferous dark-grey muddy limestone.

Movements in the earth's crust have caused the rocks to be folded, faulted and jointed. There are two major fault sets present in the area, NW-SE and NE-SW. The joint pattern is likely to have similar orientations. There is a fault to the south of the source, which runs sub-parallel to the main road, on the southern side. This fault was located through a drilling programme carried out by the Dresser Mineral Company (1980-1982). There may be other faults that haven't been noted because of the lack of outcrop in the area.

6.3 Subsoil (Quaternary) Geology

6.3.1 Introduction

The subsoils in the area comprise a mixture of coarse and fine-grained materials, namely; till, till with gravel and sand/gravel (see Figure 1). The logs of the auger holes drilled are given in Appendix 1 and their locations are given in Figure 2. The subsoil boundaries as shown in Figure 1 differ somewhat from the boundaries shown on the regional groundwater protection scheme maps (Daly et al, 1995). This is because new evidence acquired during the project allowed boundaries to be drawn more accurately.

The characteristics of each category are described briefly below:

6.3.2 Till

'Till' is an unsorted mixture of coarse and fine materials laid down by ice. Angular limestone fragments are present in the till near to the source. This till is comprised of SILT (classified using the subsoil description and classification method, adapted from BS 5930) with a moderate amount of gravel. Till deposits are also found to the north-west, north and south of the source. The till found on the lower and middle slopes of Armyhill is classified as silty GRAVEL. The till to the north and northwest of the source is classified as a 'limestone till', that is a till within which the predominant clast type is limestone. This classification is sourced from the County Offaly Groundwater Protection Scheme.

6.3.3 Till with gravel

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). The matrix of the till component of the till with gravel in this area is composed of silty SAND with some clay and abundant gravel. Obviously with the nature of the deposit, layers of more sandy, more clayey or gravelly material can be found within the till with gravel unit.

Exposures of these deposits are found to the east of the source and can be inspected easily along the banks of the stream that rises close to the source.

6.3.4 Sand/Gravel

Sand/gravel dominate the subsoils near the source, and this is evident from the trial pits that have been dug in the ridge approximately 150 m to the south of the spring. Poorly sorted sand/gravel with well rounded to subrounded clasts of various sizes can be seen in these trial pits. Limestone is the most common constitute of this sand/gravel. The topography to the west and south of the spring is

hummocky, indicating the presence of sand/gravel. Exposures of sand/gravel were found approximately 400 m to the west of the source and GSI Borehole 3 recovered over 8 m of gravel on the south side of the main road near to the entrance of Laughton House.

6.3.5 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. Boreholes drilled by the Dresser Minerals Company revealed subsoil thickness of over 18 m in the area. These borehole locations are given in Figure 2. The depth to bedrock varies between 3 and 18 m.

7 Hydrogeology

7.1 Introduction

This section presents our current understanding of groundwater flow in the vicinity of the Guilfoyles 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).
- Offaly County Council annual drinking water returns 1996 2000 inclusive (C3 and C4 type parameters). Some raw water analyses were also included.
- Limited data collected by GSI staff.

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: 1032 mm (Moneygall). Rainfall data for the area are taken from the Monthly and Annual Averages of Rainfall for Ireland (1961-1990); published by Met Éireann.
- Annual evapotranspiration losses: 451 mm. Potential evaporation (P.E.) is estimated to be 475 mm yr.⁻¹ (from Met Éireann data). Actual evapotranspiration (A.E.) is then estimated as 95 % of P.E.
- Potential recharge: 581 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: 58 mm. This estimation is based on the assumption that 10% 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)	1032 mm
Estimated A.E.	451 mm
Potential Recharge (R – A.E.)	581 mm
Runoff losses	58 mm
Estimated Actual Recharge	523 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 around the spring.
- At the source the water level is approximately 1 m below ground level and the area immediately around the source is flat. However, the area to the south and west of the source is hummocky and then rises steeply behind these hummocks to the south to Armyhill.
- 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 spring. The dominant driving head is Army Hill. The groundwater flow direction will be perpendicular to the contour lines. In simple terms, rainfall reaching the water table anywhere in the catchment of the source will flow in a northerly, north-easterly or north-westerly direction toward the source.
- The groundwater gradient in the bedrock is assumed to somewhat less than the topographic gradient, i.e. is estimated as 0.01 in the Lower Limestone Shale and 0.05 in the Cadamstown and Hollyford Formations. It is assumed that the groundwater gradient in the sand and gravels is close to zero owing mainly to the high porosity of these sediments and a value of 0.02 is estimated.

7.4 Aquifer Characteristics

There is a considerable sand and gravel deposit overlying the bedrock in this area, which has proven thicknesses of greater than 9 m. This sand/gravel deposit is considered to provide the main source of groundwater to the Guilfoyles source. The location of the source is near to where the contact of the till and the sand/gravel is and it is likely that the spring rises where it does because of this. The contact between the two subsoil deposits is unlikely to be sharply defined but an amount of interfingering and intermingling has certainly occurred. A lower permeability deposit, SILT, is found at the source and it is likely that the groundwater in the sand/gravel is forced to rise once it meets this barrier. The water level at the source does not vary much throughout the year owing to the high storage capacity of the sand/gravel.

Although there is no specific information available on the sand/gravel aquifer at Guilfoyles, it is likely that it would have similar characteristics to other sand/gravel aquifers in the country. Sand/gravel aquifers in other parts of the country, Offaly, Kildare etc., have permeabilities of around 5 x 10^{-4} m/s (50 m/d). It was also assumed that the sand/gravel has a porosity of 0.1.

While the gravels are the main aquifer supplying Guilfoyles well, groundwater in the bedrock, both north and south of the well contribute to the gravel aquifer. Brief details on the bedrock units in the area are given below.

• The Hollyford Formation is Silurian in age and rarely produces enough water for high yielding wells. Bedrock aquifers of Silurian age in Co. Offaly generally have low permeabilities (<10⁻² m/d) apart from the upper few metres. Therefore, most groundwater flow is likely to be in the

upper metres.

- The Cadamstown Sandstone is Devonian in age and has a relatively high fissure permeability and in areas where the sandstone is friable, due to weathering, it may have an intergranular permeability. Faulting is common in this unit and is likely to be the cause of higher transmissivities, specific capacities and yields for some wells.
- The Lower Limestone Shale is Carboniferous in age and generally has a low permeability (10⁻² m/d) and acts as a confining layer. The Ballysteen Formation is also Carboniferous in age. However, the muddy nature of this bedrock unit means that it has a relatively low permeability, with the possible exception of areas near faults. Generally wells developed in this unit have low yields (20-63 m³/d).

In the catchment area of the source there are no surface streams/drains, reflecting the free draining nature of the soils and subsoils in the area.

7.5 Aquifer Category

In order to have sufficient potential to be classed as an aquifer, a sand/gravel deposit must have a minimum saturated thickness and area. In classifying sand/gravel aquifers, the GSI requires (a) that regionally important sand/gravel (**Rg**) aquifers should be more than 10 km^2 in size and (b) that locally important (**Lg**) aquifers should greater than 1 km^2 in extent and have a saturated thickness greater than 5 m. These figures are somewhat arbitrary and can be changed depending on local circumstances. In many counties, there is little information on the saturated thickness of sand/gravel aquifers; consequently potential aquifers are identified on the basis of areal extent and limited data from existing public and group scheme sources in sand/gravel. This sand/gravel deposit is classified as a **locally important (Lg) aquifer**.

7.6 Hydrochemistry and Water Quality

The hydrochemical analyses show that the Guilfoyles well water is hard to a very hard with total hardness values of $347-430 \text{ mg} \text{ l}^{-1} \text{ CaCO}_3$ and electrical conductivity values of $666-760 \,\mu\text{S} \,\text{cm}^{-1}$, indicating that the groundwater has a hydrochemical signature of a calcium bicarbonate type water. These values are typical of groundwater from a limestone source.

Nitrate is one of the most common contaminants identified in groundwater. The nitrate ion is not adsorbed on clay or organic matter. It is highly mobile and under wet conditions is easily leached out of the rooting zone and through soil and permeable subsoil. It poses a potential health hazard to babies.

Nitrate concentrations have generally exceeded the threshold value of 25 mg/l NO_3 since 1984 (earliest records available) and have regularly exceeded the EU Drinking Water Directive maximum admissible concentration (MAC) of 50 mg/l; values range between 22.71 to 78 mg l⁻¹ with a mean of 44.6 mg l⁻¹ (see Figure 4). From 1984 to 1998 there was a general increase of nitrate values from 29.2 mg/l to a maximum of 78mg/l in July 1998. From July 1998 there was a general decrease in nitrate concentrations and currently values lie in around 34mg/l, which is still above the threshold level, and show a slight upward trend.

Offaly Council was concerned about the high level of nitrates in the water from this source. At the end of 1998, the council asked the farmer who worked the land in the catchment area of the source to stop spreading pig slurry, which he did. The improvement in groundwater quality can most likely be

attributed to the cessation of the slurry spreading.

Chloride levels range from 19-33 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 30 mg l^{-1} may indicate contamination from point sources. In July, August and September 1997, the level exceeded 30 mg l^{-1} .

Sodium levels range between 8.4 - 11.2 mg l^{-1} . The higher recorded values are slightly above the normal range expected for sodium in uncontaminated groundwaters.

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, in the same month, this ratio has been > 0.4, (June 1998). 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.

There have been only two instances of faecal and total coliforms contamination at the well at Guilfoyles. They both occurred in October 1998. Records are available for the years 1997 to 1999 inclusive.

The water quality analyses show that the only parameters to have exceeded the EU Drinking Water Directive maximum admissible concentrations (MAC) are nitrates and faecal and total coliforms. Overall, many of the chemical parameters, such as chloride and sodium, are elevated above background levels and nitrate levels are greatly elevated.

7.7 Spring Discharge

There are no overflow records for the dug well at Guilfoyles. There is however a derelict weir in what was presumably the overflow channel from the well. Presumably in the past less water was abstracted from the well and so there was an overflow. On average, $500 \text{ m}^3/\text{d}$ are abstracted from the source, over a range of 247 m³/d (March 2000) to 720 m³/d (May 2000).

7.8 Conceptual Model

Offaly County Council abstracts approximately $500 \text{ m}^3/\text{d}$ from the dug well at Guilfoyles. The sand/gravel in the area is considered to be the main source of groundwater to the well. The groundwater is a hard to very hard water, which would indicate that the gravel through which the groundwater moves is composed mainly of limestone clasts.

The main driving head in the catchment area of the source is Army Hill. Groundwater flows in a northerly direction towards the source from Army Hill and also from the hill to the northwest of the source, initially through the till and/or bedrock and then through the sand/gravel. Groundwater moves through the sand/gravel towards the source in a northerly, north-easterly, north-westerly and south-easterly direction. The groundwater within the sand/gravel then rises to the surface in a spring approximately 100m inside the till with gravel area. It rises here as it probably encounters a lower permeability till layer.

8 Delineation Of Source Protection Areas

8.1 Introduction

This section delineates the areas around the spring that are believed to contribute groundwater to the source, 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 Figure 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 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), 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.

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

- 1. The **North-eastern Boundary** is constrained by the position of the source itself and by the topography of the hill to the northwest of the source. Groundwater to the northeast of the spring cannot flow to the source, as the groundwater is downgradient and at a lower level. An arbitrary buffer of 30 m is placed on the downgradient side of the source. Groundwater flows from the surface water divide on the hill to the north-west towards the source.
- 2. The **Eastern Boundary** is defined by topography and the fact that groundwater is assumed to flow perpendicular to topographic contour lines towards an area of lower groundwater head.
- 3. The **Southern Boundary** is constrained by the topographic high (near the 200 m contour line) from which groundwater moving through the subsoils and bedrock on Army Hill is assumed to reach the source.
- 4. The **Western Boundary** is defined by the surface water divide on and between the hill to the north-west of the source and Armyhill. Groundwater is assumed to flow towards the source from the eastern side of this surface water divide.

These boundaries delineate the physical limits within which the ZOC is likely to occur. The area constrained by the hydrogeological mapping is approximately 0.74 km^2 .

A water balance was 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. This water balance uses the estimated recharge value of 523 mm (see section 7.2) and the highest discharge value of 720 m³/d. This abstraction value is taken so that the area required for the largest abstraction can be calculated. The water balance indicates that this abstraction requires a ZOC area of 0.5 km². The ZOC constrained by hydrogeological mapping is greater than the area required by the water balance. However, the area obtained using average annual data does not allow for expansion of the ZOC during dry weather. Therefore, an area of 0.74 km² is justifiable.

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 estimated aquifer parameters for permeability and hydraulic gradient, 100-day ToT estimations are made and give a velocity of approximately 1 m/d. The boundary is therefore 100m from the source on the upgradient side. The SI area is presented in Figure 3.

It should be noted that permeability and porosity values, used to calculate the velocity, were not determined at this site, but are estimations based on our experience in other areas.

9 Vulnerability

The distribution of interpreted groundwater vulnerability in the ZOC is presented in Figure 2. The subsoils in the ZOC are of high and moderate permeability. The subsoils range in thickness from 0 m to 18 m thick in the ZOC as described in Section 6.3.5.

In the immediate vicinity of the source, the subsoils have a moderate permeability and are approximately 5 m thick. However, as the unsaturated zone is <3 m in this area, a zone was defined around the source within which the depth to the water table is estimated to be <3 m. This area is defined as having an "Extreme" (E) vulnerability rating. The limits of this zone were drawn using the estimated groundwater gradient (0.002) and the surface topographical gradient from various points to the source. So for instance, the limit of this zone was 40 m from the source to the gravel ridge but was 140 m in the direction of the valley between the ridge and the hill to the north-west. The remainder of the sand/gravel area is classified as having a "High" (H) vulnerability rating. The till on Armyhill has a high permeability and it has a thickness of between 0 m and 3 m in the area contained within the ZOC and so has an "Extreme" (E) vulnerability classification. The till to the north-west of the source is classed as a 'limestone till' and so has a moderate permeability and has a thickness of between 3 m and 10 m. Therefore this till has a 'High' vulnerability (H).

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 <u>Inner Protection area</u> where the groundwater is <u>highly</u> vulnerable to contamination. Four groundwater protection zones are present around the source as shown in Table 1. The final groundwater protection map is presented in Figure 3.

Table 1 Wattix of Source Trotection Zones for Guinoyles			
VULNERABILITY	SOURCE PROTECTION		
RATING	Inner	Outer	
Extreme (E)	SI/E	SO/E	
High (H)	SI/H	SO/H	

 Table 1 Matrix of Source Protection Zones for Guilfoyles

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 are the principal hazards in the area. The main potential sources of pollution within the ZOC are farmyards, septic tank systems, and landspreading of organic fertilisers. The main potential pollutants are nitrogen, faecal bacteria, viruses and cryptosporidium.

12 Conclusions and Recommendations

- The source at Guilfoyles is an excellent yielding dug well, which is located in a predominantly sand/gravel aquifer.
- The area around the supply is 'extremely' to 'highly' vulnerable to contamination.
- Septic tank systems, landspreading and farmyards pose a threat to the water quality in the well.
- Nitrates (NO₃) are elevated above the EC threshold level and generally have been since records are available. Nitrate trends should be monitored and measures taken to ensure that the downward trend continues.

It is recommended that:

- A chemical and bacteriological raw water analysis should be carried out on a regular basis at the source.
- Particular care should be taken when assessing the location of any activities or developments that might cause contamination at the source.
- The potential hazards in the ZOC should be located and assessed.
- A nutrient management plan be put in place to reduce nitrate levels in the catchment.
- 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 comprehensive site investigation that would include drilling, geophysics, spring flow measurements and permeability measurements.
- The map is intended for use in conjunction with groundwater protection responses for potentially polluting activities, which lists the degree of acceptability of these activities in each zone and describes the control measures necessary to prevent pollution.

13 References

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Figure 4 Nitrate trends at Guilfoyles

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.

Auger Hole		Grid	Depth of	Subsoil Type	Permeability
Number		Reference	borehole		Rating
Guilfoyles	GSI 010	S 028 805	0-3	SILT (Till)	MODERATE
No.1					
			3-9	silty GRAVEL	HIGH
				(Till)	
Guilfoyles	GSI 011	S 024 801	0-3	silty GRAVEL	HIGH
No.2				(Till)	
Guilfoyles	GSI 012	S 015 807	0-8.7	GRAVEL	HIGH
No.3				(Fluvioglacial)	
Guilfoyles	GSI 013	S 015 812	010	Peat	LOW
No.4					
			0.10-5	SILT with	MODERATE
				gravel (Till)	

Geological Logs of the boreholes drilled by Dresser Minerals

	m O.D.	Overburden thickness	Bedrock Type
EC 39	127	18	Lower Limestone Shale
EC 40	125	12.2	Sandstone
EC 41	122	12	Melon House Formation / Lower Limestone Shale
EC 42	122	7	Breccia / ORS / Silurian





Figure 2. Groundwater Vulnerability Zones for Guilfoyles Water Supply Scheme





Figure 3.

The boundaries are based on the available evidence and the resulting conceptualisation of groundwater flow, which is described in the accompanying report. Evaluation of specific sites and circumstances will normally require further and more detailed assessments and will frequently require site investigations to determine the risk to groundwater.

The map is intended for use in conjunction with groundwater protection responses for potentially polluting activities, which lists the degree of acceptability of these activities in each zone and describes the control measures necessary to prevent pollution.

Compilation: Cecilia Gately Digital Map: David Chew