12 Kilkea Public Water Supply

12.1 Introduction

The objectives of the report are as follows:

- To delineate source protection zones for the borehole.
- To outline the principal hydrogeological characteristics of the Kilkea area.
- To assist Kildare County Council in protecting the water supply from contamination.

The protection zones are delineated to help prioritise certain areas around the source in terms of pollution risk to the well. This prioritisation is intended to provide a guide in the planning and regulation of development and human activities. The implications of these protection zones are further outlined in 'Groundwater Protection Schemes' (DELG/EPA/GSI, 1999).

The report forms part of the groundwater protection scheme for the county. The maps produced for the scheme are based largely on mapping techniques which use inferences and judgements based on experience at other sites. As such, the maps cannot claim to be definitively accurate across the whole county covered, and should not be used as the sole basis for site-specific decisions, which will usually require the collection of additional site-specific data.

12.2 Borehole Location & Site Description

The source is located on the main Athy - Castledermot road (R418) approximately 600 m north of Kilkea. The source comprises a single borehole that pumps water directly into the distribution system. The system provides water for about 200 people. A manhole cover sits over the borehole which is located next to a small pump house that houses the treatment system and a surge tank. Both the pump house and borehole are located at the roadside. The top of the borehole is below road level (0.48 m). However, the caretaker reports that flooding has never been an issue at the borehole, and that this is due to the location of the manhole cover at the top of small rise in the land surface. In addition, the manhole chamber is lined preventing water from entering the top of the borehole. The risk of runoff from the River Greese is low.

12.3 Summary of Borehole Details

GSI No.	2617NWW267
Grid reference	S ^{2}7419 ^{1}8964
Townland	Kilkea Lodge Farm
Owner	Kildare County Council
Well Type	Borehole
Depth	48.8
Elevation (ground level)	76.9 m OD (Malin Head). Top of borehole is 48 cm lower (76.43 m OD) (measured by GSI staff on 10/5/2002).
Static water level	10.22 m (measured by GSI staff on 13/5/2002)
Normal consumption/abstraction	~45 m^3d^{-1}. (Caretaker's figures 2002)
Hours Pumping	5-10 hours per day
Yield	163 m^3d^{-1} (1500 gallons per hour) from 72 hour initial test pump test
Depth-to-rock	~10 m
Diameter	6 inch
Treatment	Chlorine. raw water tap available
System	Live to mains / No reservoir / submersible pump

12.4 Methodology

12.4.1 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.

12.4.2 Site visits and fieldwork

This included the following;

- Water sampling on July 2002.
- Interview with the caretaker 13/5/02.
- Levelling in the borehole 13/5/02.
- Drilling of depth to bedrock holes during May 2002.
- Field mapping walkovers to further investigate the subsoil geology, the hydrogeology and vulnerability to contamination.

12.4.3 Assessment

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

12.5 Topography, Surface Hydrology and Land Use

The topography in the vicinity of the source is flat or undulating with an altitude lying between 70 and 80 m O.D. The general lie of the landscape is a gentle dip toward the River Barrow. There are small hillocks within a few hundred metres to the west in Kilkea Lodge Farm but the highest point near the source is Mullaghreelan which stands at 140 m O.D. It is about 3 km to the south east of the borehole. The lowest point in the area is the Barrow river which is about 4 km to the west at an elevation of approximately 51 m OD. Overall topographic gradients are in the order of 0.005 to the south west.

There are three main surface water features in the area, namely the River Barrow and its tributaries the River Greese and the Glasna Stream. The land appears to free draining with few field drains or ditches. The Greese is located 500 m due east of the borehole flowing south toward the Barrow. The Glasna stream is located about 1 km to the west of the borehole flowing southwest toward the Barrow. The Barrow flows in a southerly direction.

Land use around the source is generally tillage with corn being the principal crop grown. Large fields occupy the land in the area and the frequency of drainage ditches appears to be low. To the south of Kilkea the land use is pasture with cattle and sheep. There are also several sand/gravel pits in the locality (some disused).

12.6 Geology

12.6.1 Introduction

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

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

- Bedrock Geology 1:100,000 Map Series, Sheet 16, Kildare-Wicklow. Geological Survey of Ireland. (Mc Connell *et al*, 1994)
- Information from geological mapping in the nineteenth century (on record at the GSI).

- Glanville (1997) The quaternary geology of Co. Kildare, map descriptions for relevant 1:25,000 sheets. GSI report.

12.6.2 Bedrock Geology

The Feighcullen Limestone Formation occupies the area around the source (refer to Map 1). The borehole sits approximately 300 m east of the geological boundary with the Ballysteen Formation. Both rock types are largely similar. They primarily comprise fine grained, muddy, fossiliferous limestones. Both these formations do show evidence of dolomitisation but the extent of this is unclear. A borehole drilled into the Ballysteen Formation by KT Cullen 300 m west of the site (GSI well number 2617NWW252) indicates 17.5 m of grey fine-grained dolomite in the upper part of the log. However, three other boreholes drilled into the Feighcullen Formation in the vicinity of the source (GSI well numbers: 2617NWW250, 2617NWW251 and 2617NWW253) do not show evidence of dolomite. This indicates the unpredictability of dolomitisation and also indicates the difficulty in pinpointing dolomitised zones.

12.6.3 Subsoil (Quaternary) Geology

The main subsoil categories in the vicinity of the source are till ('boulder clay'), sand/gravel and alluvium. The characteristics of each category are described briefly below:

- 'Till' or 'Boulder clay' is an unsorted mixture of coarse and fine materials laid down by ice. The mapped till bodies around the source appear to be intermixed with sand/gravel. This is indicated by the subsoils map and borehole logs. A mixture of till and sand/gravel is reported in the majority of the boreholes around the source. Till is generally found to be overlying the sand/gravel component. There are two sand/gravel pits mapped within the till areas. The two closest boreholes to the source report 18 m (2617NWW253) of sand/gravelly SILT and 9 m (2617NWW252) of sand/gravel.
- Sand/gravel is widespread in south Kildare. Several quarries (some disused) are mapped in the vicinity of the source. Several eskers are also mapped nearby to the source. All the borehole logs in the vicinity of the source indicate sand/gravel present. Generally the sand/gravel is located beneath the till where there is till present. It appears from the logs to increase in thickness further south toward Kilkea. Wells 2617NWW251 and 2617NWW250 which are about 650 m to the south of the source have 27 m and 24 m of sand/gravel described in the borehole logs. A sand/gravel aquifer is mapped in this area just to the south of the source.
- Alluvium is mapped along the path of the River Greese. It can be seen along the banks of the river and is approximately one metre thick.
- A depth to bedrock drilling programme was carried out to ascertain the subsoil thicknesses. The thicknesses vary considerably from 0 m at Mullaghreelan hill (rock outcrop) to >20 m in the vicinity to the source in Kilkea Lodge Farm. Two boreholes drilled within 300 m of the source (GSI well numbers 2617NWW252 and 2617NWW253) have recorded depth to bedrock of 9 m and 18 m respectively. Generally, depth to bedrock is >10 m.

12.7 Groundwater Vulnerability

Groundwater vulnerability is dictated by the nature and thickness of the material overlying the uppermost groundwater 'target'.

Areas where the bedrock aquifer is the uppermost target: These areas occur to the north and east of the Kilkea source. Considerations of groundwater vulnerability in this area concern the permeability of the whole subsoil profile and the depth to bedrock. The subsoils are thought to be moderate-highly permeable (refer to Section 5 of Volume I) and are generally greater than 10 m in thickness. Thus the vulnerability is classed as generally 'moderate' (refer to Maps 6 and 8).

Areas where a sand/gravel aquifer is mapped: A small sand/gravel aquifer has been delineated toward Kilkea Demesne. The till covering this aquifer is less than a few metres in thickness and considerations of groundwater vulnerability in this area therefore concern the thickness of the unsaturated zone. The water levels in nearby wells are greater than 3 m and are typically in the order of 4m to 5m below ground. The vulnerability is therefore mapped as being generally 'high'.

The vulnerability mapping provided will not be able to anticipate all the natural variation that occurs in an area. The mapping is intended only as a guide to land use planning and hazard surveys, and is not a substitute for site investigation for specific developments. Classifications may change as a result of investigations such as trial hole assessments for on-site domestic wastewater treatment systems. The potential for discrepancies between large scale vulnerability mapping and site-specific data has been anticipated and addressed in the development of groundwater protection responses (site suitability guidelines) for specific hazards. More detail can be found in 'Groundwater Protection Schemes' (DELG/EPA/GSI, 1999).

12.8 Hydrogeology

12.8.1 Introduction

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

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

- GSI files and archival Kildare County Council data.
- Kildare County Council drinking water returns.
- Hydrogeological mapping carried out by GSI.
- A drilling programme carried out by GSI to ascertain depth to bedrock and subsoil permeability.
- Logs provided by K.T. Cullen & Co.

12.8.2 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:* 750 mm.
  Rainfall data for gauging stations around Kilkea (from Fitzgerald, D., Forrestal., F., 1996).

Gauging Stations	Grid reference	Elevation OD (m)	Approximate distance & direction from source	Annual ppt 1961-1990
Athy (Voc.Sh)	S656933	61	7.5 km north west	746 mm
Castledermot G.S.	S775848	82	6 km south	752 mm

  The contour maps of precipitation presented in the "Agroclimatic Atlas of Ireland" (Collins and Cummins, 1996) and the Monthly and annual averages of rainfall for Ireland (Fitzgerald, D., Forrestal., F., 1996) indicate that the precipitation is about 750 mm annually.

- *Annual evapotranspiration losses:* 400 mm. Potential evapotranspiration (P.E.) is estimated to be 425 mm $yr.^{-1}$ (based on data from Met Éireann). Actual evapotranspiration (A.E.) is then estimated as 95 % of P.E., to allow for seasonal soil moisture deficits. This figure ('actual evapotranspiration') was calculated using an adaptation of the country-wide potential evapotranspiration data presented in the "Agroclimatic Atlas of Ireland" (Collins and Cummins, 1996). More local measurements of evapotranspiration are not available.

- *Potential recharge:* 350 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 and is commonly referred to as "Effective Rainfall" (E.R.).

- *Annual runoff losses:* ~35 mm. The slopes and the nature of the deposits around the source need to be considered in order to give a representative value for the runoff during rainfall events. The subsoils are a mixture of till and sand/gravel and are generally moderate to high permeability. Due to the free draining, flat nature of the land, a representative value for the proportion of runoff is estimated to be in the order to 10%.

These calculations are summarised as follows:

Average annual rainfall (R)	750 mm
Estimated P.E.	425 mm
Estimated A.E. (95% of P.E.)	400 mm
Potential Recharge (R – A.E.)	350 mm
Runoff losses (10% of recharge)	35 mm
Estimated Actual Recharge	**315 mm**

12.8.3 Groundwater levels, Flow Directions and Gradients

Data is available from work done by KT Cullen hydrogeological consultants and from a GSI well survey in the 1960's and 1970's. Additional water level information for the streams & rivers is available on the original GSI archive 1:10560 scale maps. The hydrogeological data shows that the water levels are generally 4-5 m below ground level. The data suggests that the regional groundwater flow direction is to the south west. This would support an assumption that the regional flow patterns were south westerly toward the River Barrow. Groundwater gradients are estimated to in the region of 0.003-0.007.

Due to the predominance of coarse-grained material along the course of the River Greese, the river is assumed to be in hydraulic connection with groundwater. The River Greese is a tributary of the River Barrow. It is also assumed that the Glasna Stream is in hydraulic connection with the groundwater table. No water level data are available in close proximity to the Greese and Glasna, but it is likely that shallow groundwaters within a few hundred metres of these rivers will discharge into them. Thus, there is thought to be a difference between regional and local shallow groundwater flow directions. As a consequence of this difference, a minor watershed is thought to occur between the Kilkea source and the Greese River. To the east of this watershed, shallow groundwater flows will probably occur towards the Greese, while shallow flows to the west will occur towards the Kilkea source and the Glasna and Barrow Rivers.

It is also likely that river flows in the Greese and Glasna Rivers can be induced to recharge shallow groundwater at times of low water levels or in localities where abstraction has had an influence on groundwater levels close to the rivers.

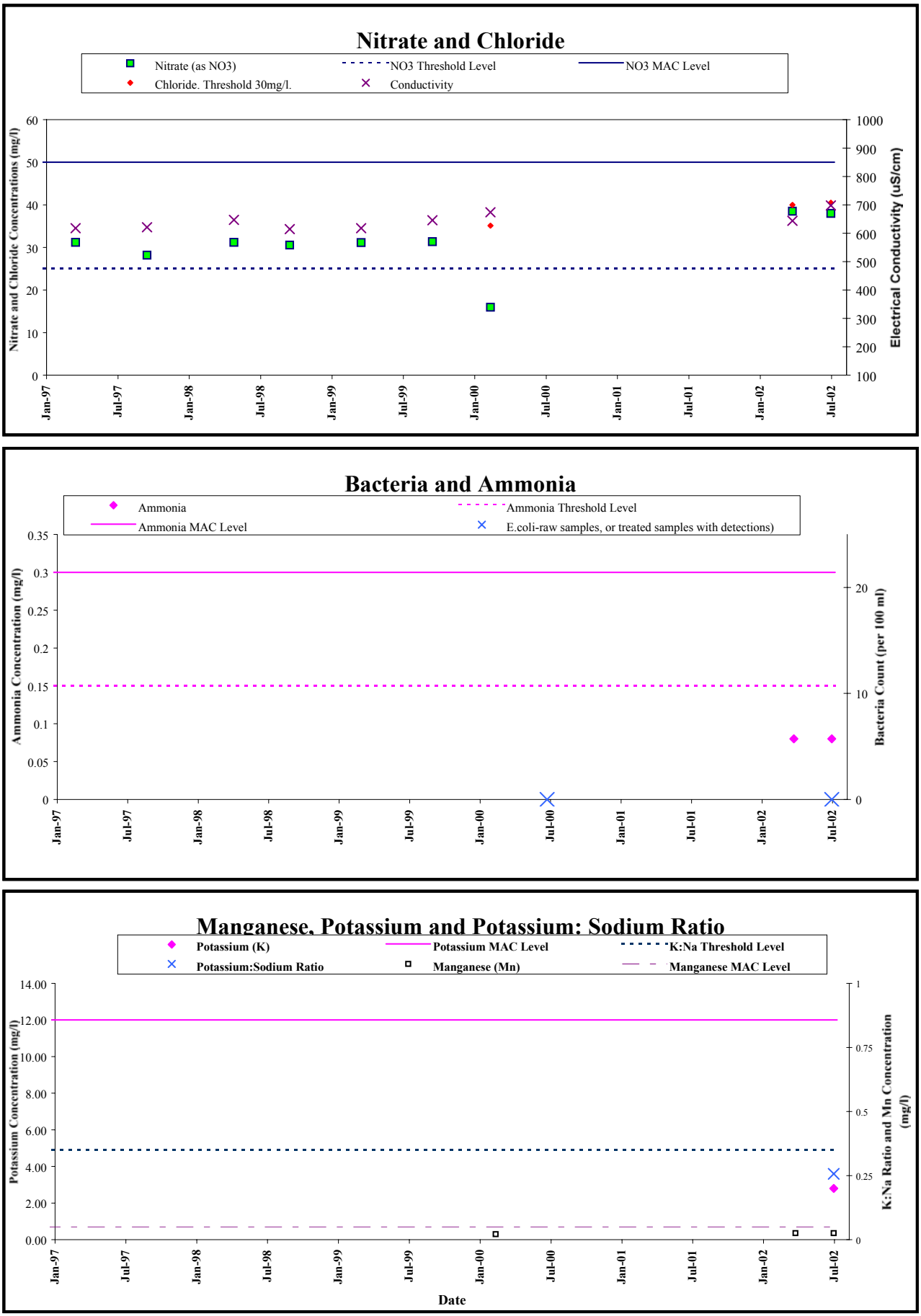
12.8.4 Hydrochemistry and Water Quality

The available data is summarised in Figure 12-1 and the following key points are identified:

- The hydrochemical analyses suggest that the water is very hard, with a total hardness value of 370 mg l^{-1} (as $CaCO_3$) and electrical conductivity values of 608-674 µS cm^{-1}.
- Nitrate concentrations from the nine available analyses over the last five years are typically 30-40 mg l^{-1}. There is some evidence of a slight increase in concentrations.
- Chloride levels from three available analyses are also elevated (30-40 mg l^{-1}). Council staff have indicated that no salt softener is used at Kilkea.
- There are only two raw water analyses of *E.coli* available to GSI. No detections were recorded in either sample.

- The elevated nitrates and chlorides data suggest that organic and possibly inorganic wastes are influencing water quality at the source. Given that no areas of extreme vulnerability are mapped near the source, and given that no significant detections of faecal coliforms and ammonia are apparent, considerations of water quality and groundwater vulnerability cannot be used to distinguish point from diffuse hazards at this source. However, given the obviously intensive agriculture which is practiced in the area, it is likely that diffuse hazards (e.g. tillage practices) are influencing (at least partially) the reported nitrate levels.

Figure 12-1Kilkea - Key indicators of agricultural and domestic contamination at Kilkea PWS



12.8.5 Aquifer Characteristics

The bedrock and the sand/gravel deposits are the main aquifers supplying the borehole. The bedrock is classed as a **locally important** aquifer which is **moderately productive** only in **local zones** (**Ll**). Table 12 provides estimates for the aquifer parameters. The sand/gravel is classed as a locally important sand/gravel aquifer (Lg). It is likely that flows to the borehole occur in bedrock but that the sand/gravel provide extra storage capacity (particularly in summer), with vertical infiltration from sand/gravel into the bedrock. As flow to the well is primarily through the rock, the parameters for bedrock are of more concern in delineating the source protection zones. Flow in the rock is likely to occur in an upper shallow weathered zone and in faults, fractures and joints.

Table 12 Estimated Aquifer parameters for the rock units in Kilkea.

Parameter	*Source of data*	*Feighcullen*
Transmissivity (m^2 $d^{-1)}$	Local	5-15
Permeability (m d^{-1})	Local	0.5-2
Porosity	Assumed	0.01

The permeability of the bedrock has been estimated, from the transmissivity data and from estimates of the thickness of the weathered bedrock, to be in the order of 0.5-2 m d^{-1}. Porosity is assumed to be in the order of 1%.

12.9 Conceptual Model

- The Kilkea Public Water Supply borehole is fed by the Feighcullen Limestone Formation which is classed as a **locally important aquifer** which is **moderately productive** only in **local zones** (**Ll**). Small sand/gravel bodies are common in the area and these are likely to provide additional groundwater storage for the bedrock aquifer.
- The transmissivity in this aquifer is generally low but can increase in local zones depending on dolomitisation, the development of faults, fissures and fractures. Groundwater flow is probably confined to fractures, fissures, joints, bedding planes and the uppermost part of the bedrock as indicated by a series of inflows in the borehole logs.
- The bedrock aquifer is unconfined as it is overlain by moderately permeable till and highly permeable sand/gravel.
- There are few artificial drains and the subsoils are thought to be moderately to highly permeable, depending on the location of sand/gravel pockets.
- The River Greese and Glasna Stream are thought to be in close hydraulic connection with the groundwater. The Greese and Glasna Rivers are thought to form a local groundwater discharge zone. It is expected that shallow groundwater within a few hundred metres of these rivers will discharge into the rivers. Regionally, however, most groundwater will flow to the west and south west and discharge to the River Barrow. As a consequence of the difference between the local and regional flow directions, a minor watershed is thought to occur between the Kilkea source and the Greese River. To the east of this watershed, shallow groundwater flows will probably occur towards the Greese, while shallow flows to the west will occur towards the Kilkea source and the Glasna and Barrow Rivers. It is also likely that river flows in the Greese and Glasna Rivers can be induced to recharge shallow groundwater at times of low water levels or in localities where abstraction has had an influence on groundwater levels close to the rivers.
- Diffuse recharge occurs over most of the land surface through the sands & sand/gravel and the permeable till. Estimates are in the order of 315 mm yr^{-1}.

12.10 Delineation of Source Protection Areas

12.10.1 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 Map 8.

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) to the borehole.

12.10.2 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 pumping rate, (b) the groundwater flow direction and gradient, (c) the subsoil and rock permeability and (d) the recharge in the area. The ZOC is delineated using both analytical modelling and the results of hydrogeological mapping and conceptualisation. Given the limited amount of calibration data available, a full groundwater numerical model was not undertaken. The resulting boundaries are presented in Map 8 and are described as follows:

The **western boundary** is defined by the downgradient limit of the well. This is calculated from semi-analytical equations and is about 100 m. This estimate means that it is anticipated that the well can pull water into the well from up to 100 m downgradient of the well.

The **eastern boundary** is delimited by the Greese River. Under normal conditions, it is expected that most shallow groundwater near the river will not flow towards the well, but will discharge into the river (refer to Section 12.8.3). However, it is possible that, during periods of low water levels, flow directions will change and recharge will be induced from the river to the well. Consequently, the eastern boundary of the ZOC has been extended to meet the Greese River.

The **northern and southern boundaries** are more difficult to establish as there are no obvious topographical or hydrological controls. They have been estimated by varying the main groundwater flow direction between the eastern boundary and the well by +/-20º to form a wedge shape that is at no point any less than 100m from the well.

Note that the total area required to provide sufficient diffuse recharge to meet the demands of abstraction at the Kilkea source is approximately 0.08 km^2. This area is less than that delineated by the above boundaries and was derived using the recharge estimates from Section 12.8.2, and the abstraction figures from Section 12.3. The abstraction rate was increased by a safety factor of 50% to allow for daily variations in abstraction and also to allow for an expansion of the ZOC during dry weather.

12.10.3 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 cannot be made by hydrogeological mapping and conceptualisation methods alone. Analytical modelling was therefore used to estimate the extent of this zone upgradient of the well.

Bedrock Aquifer: Using Darcy's Law, a permeability value of 2 m d^{-1}, porosity of 0.01 and gradients of 0.005, the 100 day ToT is estimated be approximately 100 m.

12.11 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. The final groundwater protection zones are shown in Map 8 and are presented in Table 13.

Table 13 Matrix of Source Protection Zones at Kilkea PWS.

VULNERABILITY RATING	SOURCE PROTECTION	
	Inner	***Outer***
Extreme (E)	Not present	Not present
High (H)	Not present	**SO/H**
Moderate (M)	**SI/M**	**SO/M**
Low (L)	Not present	Not present

12.12 Potential Pollution Sources

Land use in the area is described in Section 12.5. The land around the source is grassland dominated, used for cattle and sheep. Agricultural activities and septic tanks are the principal hazards to the water quality in the area. The main potential sources of pollution within the ZOC are landspreading of organic and inorganic fertilisers, roadway spillages and accidents near the source, farmyards, and septic tank systems.

Note that the source is beside a road, and the well head lies below road level within a manhole chamber. Though the manhole chamber is reported to be sealed, there may be some potential for the direct inundation of contaminants; particularly in relation to accidents close to the source involving tankers. There may also be an issue in relation to herbicides if they are used to maintain the road verges.

12.13 Conclusions and Recommendations

- The source is a relatively small production borehole abstracting about 45 $m^3 d^{-1}$. It is located in a locally important limestone aquifer which is moderately productive only in local zones (Ll). Yields are thought to be supported by vertical flows from a locally important sand/gravel aquifer (Lg).

- Groundwaters supplying the source are thought to be moderately to highly vulnerable to contamination.

- Landspreading of organic and inorganic wastes are the main potential hazards in the area, along with road spillages and accidents near the source, farmyards and septic tank systems.

- 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.

- It is recommended that:
  1. A full scale pumping test be carried out to estimate the yield of the well and to improve the hydrogeological understanding of the area.
  2. A full chemical and bacteriological analysis of the **raw** water is carried out on a regular basis. The normal range of parameters might be expanded to incorporate contaminants associated with roadway spillages and roadway maintenance (e.g. herbicides and hydrocarbons).

3. Particular care should be taken when assessing the location of any activities or developments which might cause contamination at the well, particularly in relation to nitrates.
4. The potential hazards in the ZOC should be located and assessed.