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## Kilcoona/Caherlistrane Group Water Scheme Co-Operative Society Ltd.

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13<sup>th</sup> November 2025

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Re: Planning application made by RWE for the Shancloon Windfarm case no 323699

To whom it may concern.

The Board of Kilcoona Caherlistrane Group Water Scheme Co-operative Society limited would like to make an observation on the planning application case number 323699 highlighting the following in relation to the above proposed windfarm.

The Kilcoona Caherlistrane Group Water Scheme Co-operative Society limited is a community owned Group Water Scheme (GWS) that provides potable water to over 1350 houses and farms, schools and creches. The source of water from the scheme is taken from a spring at Luimnagh on Lough Corrib located close to the area of the proposed development.

- **Impact on Water and Water Safety** – We all rely on ground water from the group water scheme. Many of the proposed turbines are along the Togher River, a tributary of the Black River that feeds into the Corrib. Each turbine includes 16 piles drilled up to 17m deep, filled with steel and 800m<sup>3</sup> of concrete, with another 800m<sup>3</sup> of concrete for the base, posing a big risk of pollution into our drinking water.

Landslides, or land subsidence or peat slippage (which is the acidic and harmful to freshwater life) into the Togher are a strong possibility. In 2003, a landslide of a bog at the Derrybrien Windfarm in South Co Galway had major impacts on the area.

<https://www.independent.ie/irish-news/there-was-no-discussion-about-whether-its-the-best-thing-to-do-derrybrien-wind-farm-seeks-to-pack-up-leaving-70-turbine-foundations-behind/a2073665899.html>

Caherlistrane is surrounded by turloughs, which are EU priority habitats under the EU Habitats Directive. They are listed as a priority habitat of community concern due to their unique nature and conservation importance, which includes supporting terrestrial and aquatic communities.

The scale of the turbines and their construction also pose a threat to underground waterflows, we live in a karst limestone landscape, and the proposal has the potential of water displacement and flooding. This point is of major concern to our GWS, as it is not known, how such major construction work underground, may disturb and effect underground water

flows, as all underground water flows in the Kilcoona Caherlistrane area flow into Lough Corrib

*Please find enclosed a copy of the Zone of Contribution report that was completed by the GWS in 2015 .*

*The board would like to reiterate that its spring and infrastructure provide vital services to the local community in the area and it is crucial that the sources, infrastructure and services provided by the scheme are not negatively impacted as a result of the proposed development during construction and long term.*

*If you require any further information, please contact me.*

*Yours Sincerely  
Enda Monaghan  
GWS Chairman*

# Establishment of Groundwater Zones of Contribution

## Kilcoona-Caherlistrane Group Water Scheme

April 2015

***Prepared by:***

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and

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***And with assistance from:***

Kilcoona-Caherlistrane GWS

The National Federation of Group Water Schemes



ENVIROLOGIC



**Acknowledgements:**

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Karen Carney (NFGWS)

**Document control information**

Revision	Date	Author	Checked	Approved
A	30/11/14	Colin O'Reilly	NHW	15/04/15
B	23/04/15	Colin O'Reilly	NHW	27/04/15

## Project description

Since the 1980s, the Geological Survey of Ireland (GSI) has undertaken a considerable amount of work developing Groundwater Protection Schemes throughout the country. Groundwater Source Protection Zones are the surface and subsurface areas surrounding a groundwater source, i.e. a well, wellfield or spring, in which water and contaminants may enter groundwater and move towards the source. Knowledge of where the water is coming from is critical when trying to interpret water quality data at the groundwater source. The 'Zone of Contribution' also provides an area in which to focus further investigation and is an area where protective measures can be introduced to maintain or improve the quality of groundwater.

This report has been prepared for Kilcoona-Caherlistrane Group Water Scheme as part of the Rural Water Programme funding initiative of grants towards specific source protection works on Group Water Schemes (DECLG Circular L5/13 and Explanatory Memorandum).

The report has been prepared in the format developed during an earlier pilot project 'Establishment of Zones of Contribution' which was undertaken by the Geological Survey of Ireland (GSI), in collaboration with the National Federation of Group Water Schemes (NFGWS), and with support from the National Rural Water Services Committee (NRWSC).

The methodology undertaken by the GSI included: liaising with the GWS and NFGWS to facilitate data collection, a desk study, a site visit to inspect the supply, the local area, and to record groundwater level(s). The data was then analysed and interpreted in order to delineate the ZOC.

The maps produced are based largely on the readily available information in the area, a field walkover survey, and on mapping techniques that use inferences and judgements based on experience at other sites. As such, the maps cannot claim to be definitively accurate across the whole area 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.

The report and maps are hosted on the GSI website ([www.gsi.ie](http://www.gsi.ie)).

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## 1 Overview: Groundwater, Groundwater Protection and Groundwater Supplies

Groundwater is an important natural resource in Ireland. It originates from rainfall that soaks into the ground. If the ground is permeable, the rainfall will filter down until it reaches the main body of groundwater, which is usually within either the bedrock, or a sand/gravel deposit. If the bedrock or sand/gravel deposit can hold enough groundwater and allow enough flow to supply a useful abstraction, it is referred to as an aquifer.

In Irish bedrock aquifers, groundwater predominantly flows through interconnected fractures, fissures, joints and bedding planes, which can be envisaged as a 'pipe network', of various sizes, with varying degrees of interconnectivity. The speed of flow through this network is relatively fast, delivering groundwater, and a large proportion of the contaminants present in the groundwater, to its destination e.g. borehole, spring, river and sea.

In sand/gravel aquifers, the groundwater flows in the interconnected pore spaces between the sand/gravel grains. Generally, this is equivalent to a filter system that may physically filter out contaminants to varying degrees, depending on the nature of the spaces and grains. It also slows down the speed of flow giving more time for pathogens to die off before they reach their destination e.g. borehole, spring, river and sea.

Further filtration of contaminants may occur where the aquifers are protected by overlying soil and subsoil; thick, impermeable clay soil and subsoil provide good protection while thin, very permeable gravel will provide limited protection. Therefore, variations in subsoil type and thickness are important when characterising the 'vulnerability' of groundwater to contamination.

The karst limestone aquifers provide significant and important groundwater supplies in Ireland. Karst landscapes develop in rocks that are readily dissolved by water e.g. limestone (composed of calcium carbonate). Consequently, conduit, fissure and cave systems develop underground<sup>1</sup>. Groundwater typically travels very fast in karst aquifers, which has a significant impact on the water quality; neither filtration nor pathogen die-off are associated with these aquifers.

The interaction between abstraction and geology is shown in **Diagram 1**. In this scenario, a borehole is pumping groundwater from the bedrock aquifer. As the water is abstracted through the well, the original water table (a), is drawn down to level (b), where it induces a drawdown curve of the natural water table (c). The shape of this curve depends on the properties of the aquifer, for example, if the borehole is intersecting an aquifer with few fractures that are poorly interconnected, the groundwater from that system will soon be exhausted, and therefore the pumping will have to pull from deeper depths to maintain supply, which results in the steep, deep drawdown curve. Alternatively, if the borehole is intersecting an aquifer with a large number of well-connected groundwater-filled fractures, the abstraction will be met by pulling water from farther away, at a shallower depth, resulting in a shallow, wide drawdown curve.

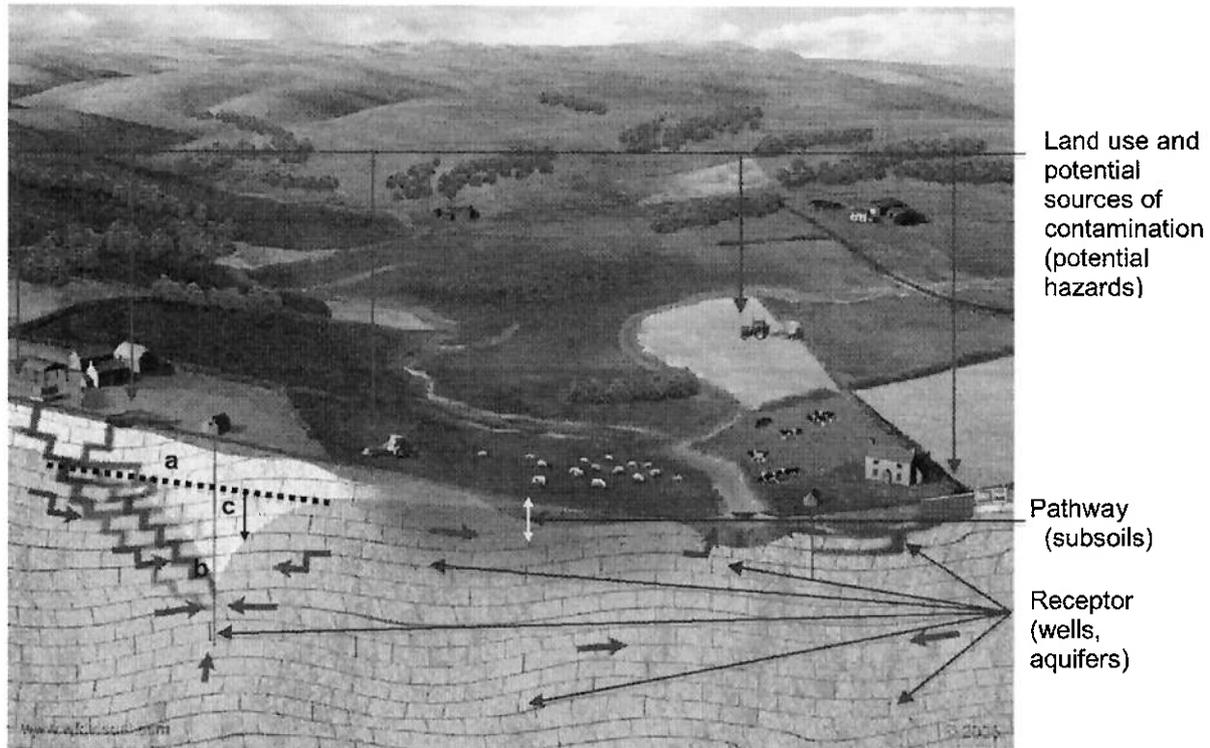
By knowing the rate of abstraction (output), how much rainfall there is (input), and by assessing the geological elements outlined above (nature of the bedrock fractures or sand/gravel deposit; how permeable the soil and subsoil are) to determine what happens in between input and output, the catchment area, or 'Zone of Contribution' (ZOC), to any groundwater water supply can be determined.

**Kilcoona-Caherlistrane GWS is supplied from a mixture of spring discharge from a regionally important aquifer with karstified conduit flow ( $Rk_c$ ) and surface water from Lough Corrib. The current scheme demand is 1000 m<sup>3</sup>/d.**

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<sup>1</sup> Geological Survey of Ireland, 1999.

**Diagram 1. Rural Landscape Highlighting Interaction between Surface Water, Groundwater and Potential Land Use Hazards.**



## 2 Location, Site Description, Well Head Protection and Summary of Borehole Details

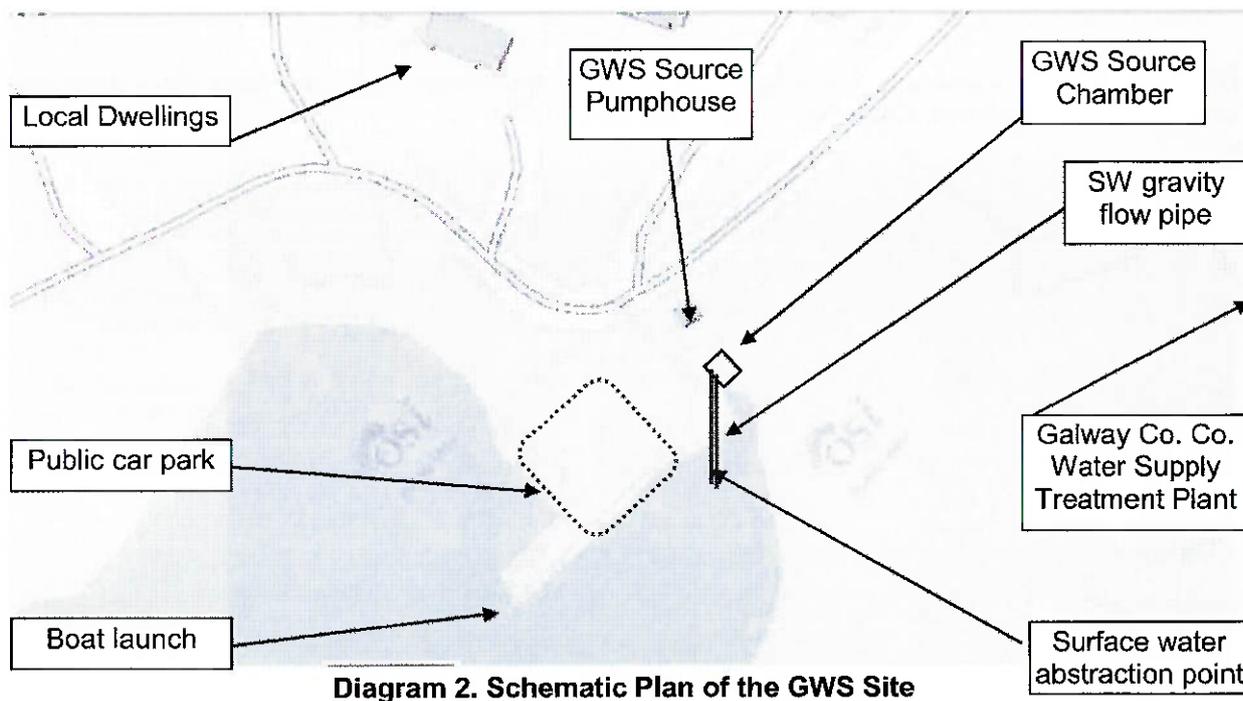
The Kilcoona-Caherlistrane Group Water Scheme (GWS) is supplied from a subsurface chamber in the townland of Luimnagh in County Galway (**Figure 1**). The chamber receives two discrete inflows from (i) groundwater and (ii) surface water from Lough Corrib via a gravity flow pipe. The current scheme demand is 1000 m<sup>3</sup>/d, which provides water to 2,000 connections, of which 1,000 are domestic houses. Users are metered at point of supply. The GWS has been operated as a DBO by Coffey Group since 2005.

The GWS source is located in central Galway: 6.7 km south of Headford and 16 km north of Galway city centre. The chamber is located on the eastern side of a gravel car park at Luimnagh Pier, which provides access to a small inlet on the eastern shore of Lough Corrib (**Diagram 2**). A local road connects Luimnagh Pier with the N84, 1.2 km to the north.

The chamber is a subsurface structure with block-built, rendered walls, and a footprint of 4 m by 3 m. The chamber floor is 3.72 m below ground level and is broken bedrock. This was previously blasted to increase yield. In this sense it could be considered a shallow wide diameter well. Inflow from Lough Corrib is via two 200 mm diameter pipes.

A pumphouse next to the chamber transfers water to a treatment plant at Bohercuil, 6.4 km to the north, which incorporates pressure (sand) filtration, ultra-violet and chlorination. Treatment capacity is 2,459 m<sup>3</sup>/d. Treated water is subsequently transferred to reservoirs on elevated ground (85 mOD) at Kildrum, 8 km to the north.

The chamber is covered with two concrete slabs, each of which includes an access manhole. The chamber and pumphouse are contained within a 10 m by 10 m perimeter fence.



Photos of the chamber can be seen in **Photos 1 to 4** below. **Table 1** provides a summary of existing information relating to the chamber.



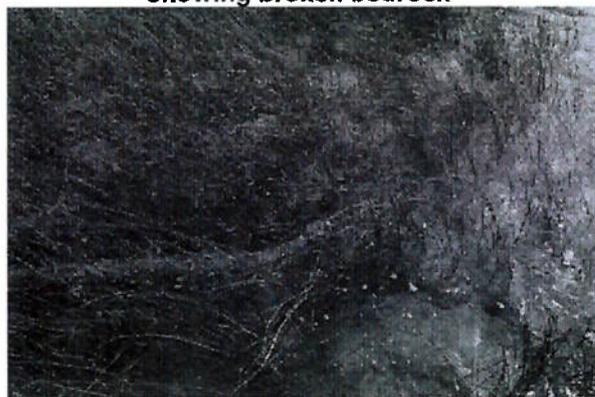
**Photo 1: Chamber cover showing access manholes**



**Photo 2: Rising main and chamber base showing broken bedrock**



**Photo 3: Surface water inlet pipes on internal southeastern chamber wall**



**Photo 4: Surface water intake pipe in Lough Corrib**

**Table 1. Supply Details**

Kilcoona-Caherlistrane GWS Chamber	
Grid reference	129,618 m Easting; 241,217 m Northing
Townland	Luimnagh
Source type	Combination of shallow groundwater supply and surface water from Lough Corrib
Drilled	Chamber constructed in 1980. Upgrade works in 1997 and 2005
Drilling Contractor	Spring chamber constructed by GWS
Owner	Kilcoona-Caherlistrane GWS
Elevation	ground elevation = 7.89 mOD Malin base of chamber = 4.17 mOD base of surface water inlet on internal southeastern wall = 5.12 mOD
Total depth (m)	3.72 m
Construction details	Chamber walls constructed using 100 mm block on the flat and finished with sand/cement render. Roofed with two concrete slabs, each incorporating a steel manhole. Fixed steel ladder provides access for inspection and maintenance. Lengths of timber span the length of the chamber, 1.2 m above base, and are covered with 100 mm blocks to provide an internal walkway above normal water level. Two 150 mm steel rising mains for abstraction fixed from top of chamber. Base is broken bedrock.
Depth to rock (m bgl)	Observed bedrock 2.82 mbgl (5.07 mOD), although the walls may obscure bedrock, meaning top of bedrock may be slightly higher.
Static water level (SWL)	Unconfirmed On 19/08/14, during pumping, w.l. = 5.37 mOD Lough Corrib w.l. = 5.70 mOD High water mark on the chamber wall = 0.33 m above observed water level, i.e. equivalent to lake level. This suggests that during non-pumping the chamber water level equalises with that of the lake water level.
Pump intake depth (m bgl)	2.82 m bgl (5.07 mOD)
Current abstraction rate (GWS)	Total daily abstraction = 1000 m <sup>3</sup> /d The caretaker reports majority of pumping to the reservoirs takes place at night. Caretaker estimates contribution is typically 60% spring vs 40% lake, and that contribution from spring is higher during winter months. No way of verifying this. Inflow from lake is limited by the head differential and conveyance capacity of surface water inlet pipes.
Reported yield (m <sup>3</sup> /d)	Current or maximum yield from groundwater is unknown. A flowmeter on the surface water inflow pipes, and a flowmeter on the total abstraction would allow estimation of groundwater flow, by difference. Given the surface water aspect of the scheme, the yield is limited by the cross sectional area of the two surface water inlet pipes, providing they are covered by lake water.

### 3 Physical Characteristics and Hydrogeological Considerations

#### 3.1 Physical Characteristics of the Area

**Table 2. Physical Characteristics of the Area of Interest**

		Description/Comments
Annual Rainfall (mm)	1178	Met Éireann average annual rainfall data 1981-2010
Annual Evapotranspiration Losses (mm)	463	487.5 mm PE (average annual potential evapotranspiration data, Galway SWS, 1961-1990). 463 AE (Actual Evapotranspiration, assumed to be 95% of PE).
Annual Effective Rainfall (mm)	715	Annual rainfall less annual evapotranspiration losses
Topography (Figure 1)		Lands to the east of Bunatober are generally flat and featureless. Along a southeast-northwest line, 3.5 km east of the GWS, is a trend of raised hummocks and hollows, passing through Turloughgarve (24 mOD), Bunatober (27 mOD) and Kilcoona (31 mOD). 6.5 km north of the site there appears to be a minor northeast-southwest belt of raised ground, passing through Headford. Between these two minor belts of raised ground, topography is depressed, from Turloughcor to Liss. West of the N84, in the vicinity of the GWS, topography falls gently toward the shoreline of Lough Corrib, interrupted only by minor hummocks.
Land use		Land in the area is predominantly used for moderate intensity agriculture. Much of this land has been improved, having originally had significant bedrock at surface. The GWS source is situated on the edge of a gravel car park that services the amenity of Luimnagh Pier (used primarily by fishermen as a boat launch). A perimeter fence separates the source from the car park. The pumphouse is fronted by the local road. Lands to the rear of the GWS (east) are not farmed and contain scrub overgrowth. A linear ribbon development of one-off housing occupies the northern side of the local road. It is assumed that these are serviced by individual septic tanks. Luimnagh Water Treatment Plant, operated by Galway County Council, is located 200 m east of the site. This abstracts up to 48,000 m <sup>3</sup> /d from Lough Corrib and provides water from Tuam to Galway City. This is entirely separate to Kilcoona-Caherlistrane GWS.
Surface Hydrology (Figure 2)		A series of springs emerge on a northwest-southeast plane, 3 km to the east of the site, coinciding with a trough like topographical feature. Some of the springs have significant discharges and these form the headwaters of a series of streams which join and ultimately enter Lough Corrib 1.3 km southeast of the site. A large turlough (Turloughcor) occupies a flat topographical depression 2.8 km north of the site. The turlough receives surface inflows from the south and the northeast, and a channel from the northwest side of the turlough provides an outlet to the sea. A local farmer reported that the turlough was at its lowest ever at the time of the site visit. Lands upgradient of the GWS within a radius of 2 km are devoid of any mapped surface watercourses.
Topsoil		The area to the north is dominated by deep, well-drained basic mineral soils, which become thinner on elevated ground and where bedrock outcrops at surface. Lacustrine material, indicative of a higher lake level in the past, lines the shoreline of the bay to the east of the site, and a small depressed inlet 800 m to the west. Turloughcor and surrounds are mapped as being underlain by lacustrine deposits.
Subsoil (Figure 3)		Limestone till ('boulder clay'). Subsoils may not be present where bedrock is close to surface. Aerial photography shows bedrock is exposed on hilltops.
Groundwater Vulnerability (Figure 4 and Appendix 1)		In general the area is dominated by Extreme (E) vulnerability (bedrock within 3 m of surface), and Extreme (X) where bedrock is exposed. Lacustrine deposits provide some protective cover to groundwater, and vulnerability of groundwater beneath this material is classified as High (H). An area between the site, and the local hummock at Kilgarraff, 1.5 km to the north, is also assigned High (H) vulnerability, indicating over 3 m of overburden on top of bedrock.

Geology Formation: Rock Unit Group (Figure 5)	The GWS source and wider area are underlain by the rock unit group Dinantian Pure Bedded Limestones. To the north of the site, thick-bedded pure limestones are exposed. The dividing line separating the units on the map is nominal, and may not be observed at the surface.  Rock layers generally dip gently south-southeast at around 3°. There are no mapped faults in the area. GSI 6" field sheets indicate outcrops are weathered and jointed. Regionally, north-south and east-west joint sets are expected to occur (Gatley et al., 2006).	
Aquifer (Figure 6)	The limestones are classified by the GSI as a Regionally Important Karstified Bedrock Aquifer, dominated by conduit flow (Rkc). Known surface karst features in the area are shown in Figure 6.	
Groundwater Body	Clare-Corrib GWB (GSI, 2004) Categorised as having a 'poor' status. <a href="http://www.gsi.ie/Programmes/Groundwater/Projects/Groundwater+Body+Descriptions.htm">http://www.gsi.ie/Programmes/Groundwater/Projects/Groundwater+Body+Descriptions.htm</a>	
Recharge Coefficient (Appendix 2)	80 %	Low drainage density, well-drained soils, moderate permeability subsoils, and extreme vulnerability, plus point recharge via karst features give a high recharge coefficient.
Recharge (mm)	572	

### 3.2 Hydrochemistry and water quality

Untreated water samples were collected for the Kilcoona-Caherlistrane GWS on 11/09/2013 and 24/07/14, and analysed by CLS, Ros Muc, Co. Galway (Appendix 3). A dataset containing results taken at various points of supply between 2008 and 2011 was referred to.

Existing laboratory results have been compared to the drinking water limits from the Drinking Water Regulations (SI No. 122 of 2014) and, where relevant, average values have been compared to the Threshold Levels in the European Communities Environmental Objectives (Groundwater) Regulations 2010 adopted in Ireland (S.I. No. 9 of 2010).

Field measurements of conductivity, temperature and pH were made on 19/08/14. In the chamber, electrical conductivity was 353 µS/cm; pH was 7.02; temperature was 15.5 °C. In the lake, electrical conductivity was 272 µS/cm; pH was 7.4; temperature was 15.6 °C. Field measurements on 11/09/13 indicate that the water in the chamber is predominantly groundwater, whilst that taken on 24/07/14 is predominantly surface water.

The water is hard. Lake water is significantly more alkaline than spring water, a signature of limestone bedrock. The hydrochemistry suggests that the groundwater is probably shallow (Drew and Daly (1993) indicate that, in this area, shallow groundwater is characterised by high suspended solids and relatively low electrical conductivities (300-400 µS/cm).

Nitrate concentrations are relatively low which is consistent with the low to moderate intensity farming in the area. Concentrations of the other dissolved minerals in the water that were analysed in the full sample suite were all below drinking water limits and are present in low quantities.

Water quality data as part of continuous monthly monitoring by Coffey Group was also made available. This includes daily discharge flows, and various hydrochemical analyses of raw and treated water. Ongoing analyses show that the raw water supply is consistently contaminated with faecal coliforms. There is no clear relationship between pH and coliform levels, from which might otherwise connect contamination sources to lake water or groundwater. Faecal coliform numbers appear to be higher in summer months. Microbial contamination seems to be sourced from surface water, with the groundwater regime being largely free of bacteria. However, separate testing of each water type would be needed to confirm this.

No microbial contamination was detected at various points of supply, indicating that treatment is adequate.

**Table 3: Water Quality Data**

Parameter	Untreated Water		Treated Water 2007-2011		Parametric Value
	11/09/13	24/07/14	Number of Values	Mean	
pH (lab.)	7.1	7.8	7.5	20	6.5 < pH < 9
Electrical Conductivity (lab.) (uS/cm)	437	219	493	20	800
Colour (PtCo units)	8.9	16.3	13	3.9	acceptable to consumers and no abnormal change
Turbidity (NTU)	0.5	1.0	18	0.48	
Nitrate (mg NO <sub>3</sub> /l)	4.43	< 0.44	16	5.23	37.5
Nitrite (mg NO <sub>2</sub> /l)	< 0.017	< 0.017	10	0.01	0.375
Hardness (mg/l as CaCO <sub>3</sub> )	252	105	0		
Ammonium (mg NH <sub>4</sub> /l)	0.037	0.022	13	0.03	0.3 (SI 122 of 2014)
Iron (ug Fe/l)	13	18	11	31.7	200 (SI 122 of 2014)
Manganese (ug Mn/l)	< 5	< 5	10	16.2	50 (SI 122 of 2014)
Aluminium (ug Al/l)	5	15	13	14	200 (SI 122 of 2014)
E.coli (cfu/100 ml)	0	15	20	0.0	0 / 100 ml
Total coliforms (cfu/100 ml)	0	15	20	0.0	0 / 100 ml

**Table 4 – Monthly Raw Water Monitoring (Coffey Group) 14/03/07 – 05/03/14**

Parameter	Clostridium perfringens (cfu/100 ml)	e. coli (MPN/100 ml)	Total coliforms (MPN/100 ml)	pH
Minimum	0	0	2	6.9
Average	5.8	11	77	7.2
Maximum	> 100	165	435	7.7
Number of samples = 85				

## 4 Zone of Contribution

### 4.1 Conceptual model

The current understanding of the geological and hydrogeological setting is presented on a vertical cross-section in **Diagram 3**. The description below describes how groundwater is replenished by rainfall and flows towards the spring/dug well

A large proportion (80%) of the effective rainfall within the ZOC is assumed to infiltrate to groundwater as recharge, either diffusely by percolating through the soils, subsoils or cracks in the rock, or via point recharge at surface karst features.

Water, and potentially contaminants, is thought to reach the spring/dug well via different interconnected pathways:

1. Recharge into the epikarst layer (topmost highly weathered layer of bedrock) may flow laterally in the upper few metres of bedrock and enter the spring chamber. The rainfall may percolate diffusely into the ground or enter at specific points (such as swallow holes or enclosed depressions (dolines));
2. Groundwater that flows horizontally to the spring/dug well through the fractured zone in the top 20-30 m of the bedrock that has been replenished by rain infiltrating diffusely through the rock surface, thin soils and subsoils or at specific points;
3. Groundwater that has originated as recharge entering the groundwater system at discrete points at the surface such as swallow holes, and also by diffusely percolating through soils/subsoils, may also flow within enlarged conduits.

The GWS source is considered to be a groundwater spring accessed through a wide diameter, shallow well. Shallow groundwater flowing through a network of fractures and fissures to the lake is intercepted at the spring/dug well. Kilcoona-Caherlistrane is not thought to be a surface outlet of a discrete karst conduit (e.g. as at Bunatober). The high density of fractures, as well as dissolution of limestone bedrock along the fissures means that high yields are possible when intercepting this shallow groundwater. The yield of the spring/dug well was enhanced by blasting the bedrock to increase fracturing.

It is assumed that groundwater flows towards Lough Corrib. This, combined with the presence of topographical features in the area, means that the potential ZOC to the GWS is quite localised, and may be slightly better defined when compared to other karst springs in the area. The direction of flow in the upper groundwater regime (i.e. epikarst and jointing) is likely to reflect the local topography. Groundwater flow direction in the epikarst and shallow fractured and fissured zone is generally from north to south. The deeper groundwater conduit system is not considered to significantly affect the inflows at Kilcoona-Caherlistrane.

Consideration was given at first to the ZOC extending to the northwest, including the relatively flat lands between the source and the Clare River. However, it is apparent that most if not all of this groundwater emerges via a series of springs along a southeast-northwest axis from Turloughgarve to Kilcoona, including Bunatober and Balrobuckbeg. There are likely to be deeper flows that bypass these springs. However, it is likely that such groundwater will flow directly into Lough Corrib.

Artificial drainage has altered flows in the depressed area surrounding Turloughcor. This area is underlain by lacustrine deposits, suggesting it was submerged and in continuity with Lough Corrib when water levels were historically higher. As lake water levels fell, this area became disconnected from the lake, but remained inundated. An artificial channel was excavated to re-connect the turlough and surrounding area to Lough Corrib. This channel drains from the northwestern end of the turlough. The low permeability lacustrine material means that Turloughcor exhibits characteristics of an inland lake, and is excluded from the ZOC.

Surface water flows also enter the well via a gravity feed. The surface water catchment to the site is very large, incorporating Lough Corrib and Lough Mask, and all inflows to these waterbodies.

## 4.2 Boundaries

The boundaries of the area contributing to the source are considered to be as follows (**Figure 7**):

The **northern boundary** is the upslope boundary. It extends to a distance of 1,660 m from the source towards a local hummock at Kilgarraff. To the north of Kilgarraff, the turlough at Turloughcor is likely to act as a drain for shallow groundwater in its vicinity. This intercepted water is dispatched to Lough Corrib via a channel that travels through Cloneen.

South of Kilgarraff, shallow groundwater flowing in the epikarst and the upper fractured and jointed bedrock flows south towards Lough Corrib and may be intercepted by the spring/dug well. The distance from the source to the upgradient boundary exceeds the water balance requirements for the GWS abstraction rate of 1,000 m<sup>3</sup>/d. Groundwater enters the spring chamber through the base and sides of the dug well.

The **western and eastern boundaries** are groundwater flow line boundaries. The flow lines are the groundwater flow direction, which is inferred from topography. The **southeastern boundary** is limited by lacustrine deposits surrounding the shoreline of Lough Corrib.

The surface watercourse between Kilcoona and the discharge point to Lough Corrib at Grange is likely to form a hydraulic boundary, although some groundwater is likely to flow underground in karst conduits beneath this watercourse, in a southwestern direction. The ZOC may potentially extend towards this water course and the bundle of hillocks at Mausrevagh.

The **southern boundary** extends downhill of the borehole. Lough Corrib is taken to be the boundary.

Inside the boundaries, precipitation is expected to infiltrate the ground and reach the pumped spring chamber/dug well. Outside the boundaries, groundwater flows towards Lough Corrib.

## 4.3 Recharge and water balance

The current demand for the Kilcoona-Caherlistrane GWS is 1,000 m<sup>3</sup>/d. This demand is met by a mixture of surface water and groundwater. The relative proportion of each is not known, but estimated to be 60% spring versus 40% lake. The basis of this estimation is not clear. It is unclear if the spring was commissioned to supplement a surface water supply, or vice versa, i.e. the surface water supply was added to an original groundwater supply. Hence the maximum potential yield of the groundwater supply is not known.

It is assumed that the groundwater supply is not capable of meeting the 1,000 m<sup>3</sup>/d on its own. However, for the purposes of delineating a ZOC, it is assumed that the demand is met solely from the groundwater source.

Recharge to the ZOC is estimated as 572 mm/yr (see **Table 2**). At a recharge rate of 572 mm/yr, the existing 1,000 m<sup>3</sup>/d abstraction rate requires a ZOC of 0.638 km<sup>2</sup> (63.8 ha; about 158 acres) to capture the required volume of rainfall to balance this abstraction.

The ZOC presented in **Figure 7** has an area of 1.29 km<sup>2</sup>.

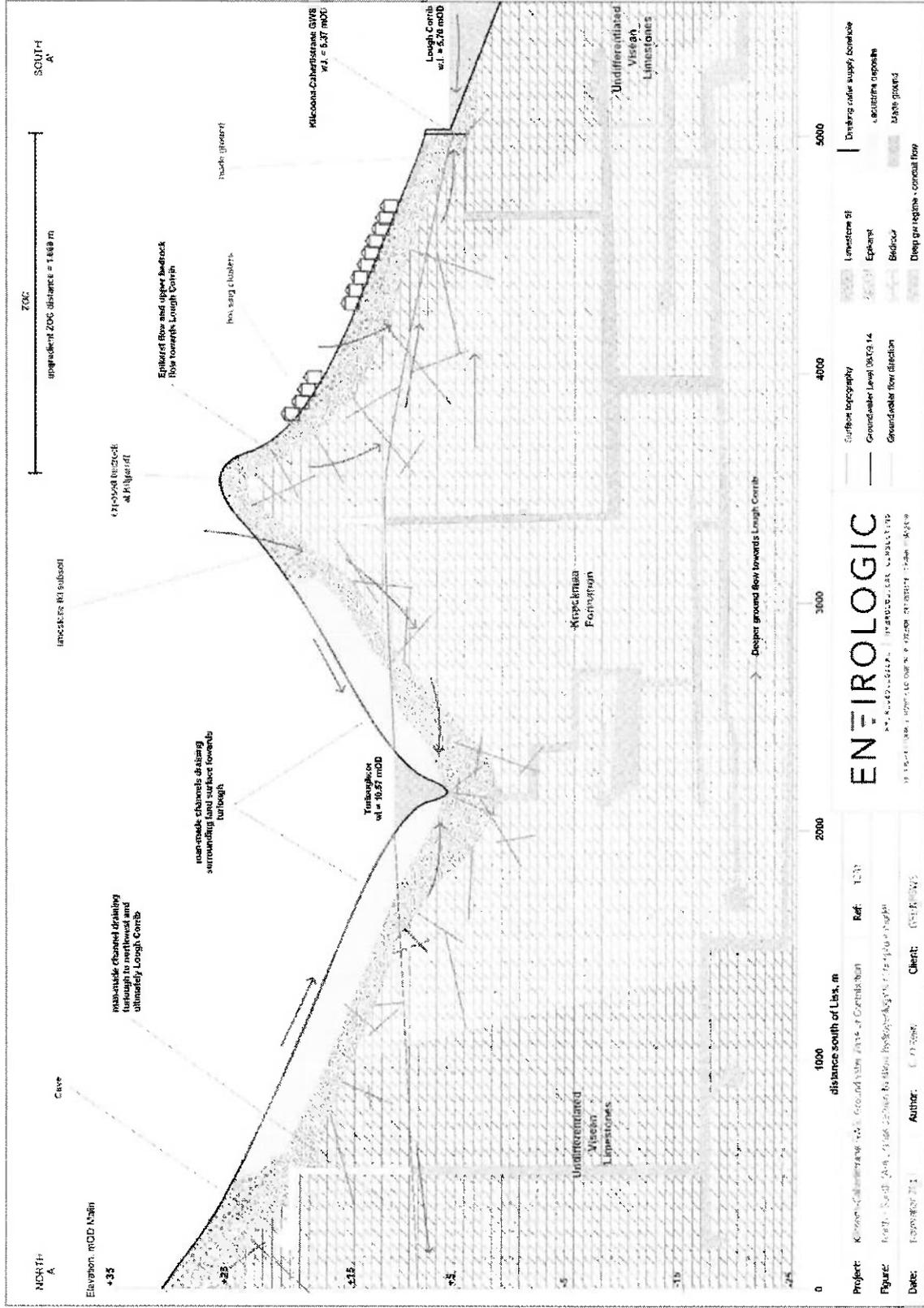


Diagram 3: Schematic Cross Section and Conceptual Model of groundwater flow

## 5 Conclusions

The current abstraction for the Kilcoona-Caherlistrane GWS is 1,000 m<sup>3</sup>/d. Kilcoona-Caherlistrane GWS is a spring that has been enhanced by digging a wide-diameter well and blasting the bedrock to increase groundwater flows.

The spring chamber receives inflows from groundwater and from surface water piped from Lough Corrib under gravity. The relative contribution from each are not known, but estimated as being roughly equal, with groundwater about 60% of total abstraction.

The ZOC delineation is based on hydrogeological mapping techniques, and is the topographical catchment to the spring/dug well. For a daily abstraction rate of 1,000 m<sup>3</sup>/d (i.e. which assumes the entire contribution is from groundwater, the estimated ZOC covers an area of 1.29 km<sup>2</sup>. It is thought that this ZOC is large enough to encompass the area contributing water to the spring, and accounts for uncertainties in groundwater flow direction.

Groundwater inflows to the chamber are likely to be sourced from the upper epikarst and upper set of fractures and joints. The karst conduit system transporting regional groundwater flows is not considered to provide flows directly to the well.

The groundwater vulnerability within the ZOC is mapped mainly as Extreme (E and X). This categorisation means that virtually the entire catchment is at risk of contamination if a source of pollution is present. The highest risk areas are 'X'. The GWS will be able to prioritise areas of risk when auditing or mapping potential hazards, or areas to investigate if a pollution incident does occur.

The mixed nature of the supply makes it difficult to draw any firm conclusions regarding groundwater quality. Hydrochemistry and microbiology results indicate that the combined raw water supply is consistently contaminated with faecal coliforms, and that the lake is the more likely source. Lower level bacterial contamination of groundwater cannot be ruled out, however, and would not be surprising in an Extreme vulnerability setting.

Based on the collection and analysis of the available data for this project, it is recognised that this scale of study (i.e. predominantly desk study) cannot delineate a definitive ZOC for the Kilcoona-Caherlistrane GWS source with a high degree of confidence, due to the complicated nature of the karst aquifer in this region. Therefore, the analysis has been used to identify an area that is highly likely to be supplying the spring. It is possible that additional areas are also contributing to the borehole (depending on the flow regime in operation) so the GWS may want to consider further hydrogeological work/ measures if water quality issues persist, which will provide supporting evidence as to the most likely areas that should be included within the ZOC.

## 6 Recommendations

### Essential:

- Ongoing monitoring of the raw and treated water supply is recommended to ensure treatment is effective at removing the persistent bacterial contamination. The basic untreated groundwater analytical suite should be extended to include VTECs, plus the major ions calcium, magnesium and sulphate.
- Raw water sampling should be undertaken separately on the groundwater and surface water inflows into the chamber. This would provide a sound basis for assessing relative raw water qualities, especially bacteriological loading, and for isolating one or other of the raw water sources in case of a contamination event.
- A sluice valve should be installed on the surface water inflow pipes to facilitate isolation from the lake supply when groundwater inflows are sufficient, and in the event of contamination. The surface water intakes should be grilled to prevent rodent access to the spring chamber.

### Desirable:

- A digital flowmeter displaying flowrate and cumulative flow volumes should be fitted on to the surface water inflow pipes from Lough Corrib, and the total discharge leaving the pumphouse. Groundwater inflows can be determined by difference. This will clarify the contribution of groundwater to the source, and allow more accurate delineation of the ZOC.
- The abstraction should be measured on a cumulative metric flowmeter inside the pumphouse and continue to be monitored on a daily/weekly basis. This is to ensure that the delineated ZOC remains appropriate.
- Comprehensive hazard mapping within the delineated ZOC should be undertaken. Within the ZOC to Kilcoona-Caherlistrane GWS are (i) Galway County Council Water Treatment Plant; (ii) permeable paving car park serving Luimnagh Pier; (iii) 7 dwellings within 250 m; (iv) 35+ houses within remainder of ZOC; (v) limestone quarry; (vi) 3 farmyards.
- The density of housing reduces the ability of upgradient groundwater to assimilate treated effluent completely by dilution. Kilcoona-Caherlistrane GWS should consider liaising with local farmyards to ensure risk from underground slurry storage tanks, silage clamps, and septic tanks is minimised.
- Application of inorganic and organic fertilisers should be restricted where possible where bedrock is at surface.
- The GWS should liaise with NFGWS regarding the completion of a cryptosporidium risk assessment.

### Other:

- The following EPA guidelines may serve as future useful reference documents for the GWS:
  - EPA Drinking Water Advice Note No. 7: Source Protection and Catchment Management to Protect Groundwater Sources. Of particular interest would be Section 4.1 – Step 2 – Hazard Mapping<sup>2</sup>.

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<sup>2</sup>[http://www.epa.ie/pubs/advice/drinkingwater/epadrinkingwateradvicenote-advicenoteno7.html#UpNP\\_eJ9KEp](http://www.epa.ie/pubs/advice/drinkingwater/epadrinkingwateradvicenote-advicenoteno7.html#UpNP_eJ9KEp)

- EPA Drinking Water Advice Note No. 8: Developing Drinking Water Safety Plans. This document contains checklists for hazards which would assist in hazard mapping within the ZOC<sup>3</sup>.
- EPA Drinking Water Advice Note No. 14. Borehole Construction and Wellhead Protection<sup>4</sup>.
- European Union (Good Agricultural Practice for the Protection of Waters) Regulations 2014<sup>5</sup>

## 7 References

DELG/EPA/GSI, 1999. Groundwater Protection Schemes. Dept. of the Environment & Local Government; Environmental Protection Agency; Geological Survey of Ireland.

EPA, 2009. Code of Practice – Wastewater Treatment and disposal systems serving single houses (PE <10). Environment Protection Agency, Ireland.

European Communities (Drinking Water) Regulations, 2007. S.I. No. 278 of 2007.

European Communities Environmental Objectives (Groundwater) Regulations, 2010. S.I. No. 9 of 2010.

Fitzsimons, V., Daly, D., Deakin, J., 2003. GSI Guidelines for Assessment and Mapping of Groundwater Vulnerability to Contamination. Geological Survey of Ireland.

Gardiner, M.J., Radford, T., 1980. Soil associations of Ireland and their land use potential. National Soil Survey of Ireland.

Gatley, S., Somerville, I.D., Morris, J.H., Sleeman, A.G. and Emo, G., 2005. Geology of Galway-Offaly and adjacent parts of Westmeath, Galway, Laois, Clare and Roscommon. A geological description to accompany the bedrock geology 1:100,000 scale map series, Sheet 15. Geological Survey of Ireland.

Geological Survey of Ireland, 1999. Groundwater Protection Schemes. Dept. of the Environment and Local Government; Environmental Protection Agency; Geological Survey of Ireland.

Geological Survey of Ireland, 2004. Clare-Corrib Groundwater Body – Water Framework Directive Initial Characterisation Summary: 1<sup>st</sup> Draft.

GSI website. [www.gsi.ie](http://www.gsi.ie)

Hunter Williams, N.H., Misstear, B. D. R., Daly, D., and Lee, M. Development of a national groundwater recharge map for the Republic of Ireland. Quarterly Journal of Engineering Geology & Hydrogeology. 46(4):493-506.

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<sup>3</sup> <http://www.epa.ie/pubs/advice/drinkingwater/epadrinkingwateradvisenote-advisenoteno8.html#UpNQf-J9KEo>

<sup>4</sup> <http://www.epa.ie/pubs/advice/drinkingwater/advisenote14.html#UpNR8eJ9KEo>

<sup>5</sup> <http://www.irishstatutebook.ie/pdf/2014/en.si.2014.0031.pdf>

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## 8 Acronyms and glossary of terms

BGL	Below Ground Level
EPA	Environmental Protection Agency
DEHLG	Department of Environment Heritage and Local Government
EQS	Environmental Quality Standard
EU	European Union
GPZ	Groundwater Protection Zone
GSI	Geological Survey of Ireland
GWB	Groundwater Body
GWD	Groundwater Directive (European Union)
GWS	Group Water Scheme
IGI	Institute of Geologist of Ireland
MOD	Metres Ordnance Datum
MRP	Molybdate-Reactive Phosphorus
NRG	National Grid Reference
NRWMC	National Rural Water Monitoring Committee
PVC	Polyvinyl Chloride
SPZ	Source Protection Zones
TOT	Time of Travel
TVs	Threshold Values
UV	Ultra-Violet
ZOC	Zone of Contribution
WFD	Water Framework Directive (European Union)

## Glossary of Terms

### ***Aquifer***

A subsurface layer or layers of rock, or other geological strata, of sufficient porosity and permeability to allow either a significant flow of groundwater or the abstraction of significant quantities of groundwater (Groundwater Regulations, 2010).

### ***Attenuation***

A decrease in pollutant concentrations, flux, or toxicity as a function of physical, chemical and/or biological processes, individually or in combination, in the subsurface environment.

### ***Borehole***

A particular type of well - a narrow hole in the ground constructed by a drilling machine in order to gain access to the groundwater system.

### ***Conceptual Hydrogeological Model***

A simplified representation or working description of how a real hydrogeological system is believed to behave on the basis of qualitative analysis of desk study information, field observations and field data.

### ***Confined Aquifer***

A confined aquifer occurs where the aquifer is overlain by low permeability "confining" material. Once all the void space in the aquifer is full of water up to the confining layer, the addition of more water to the aquifer causes the stored water to become pressurised and, the additional water is stored by compression, sealed in by the overlying confining layer (the water is added upgradient where the confining layer is absent). Where a borehole punctures the confining layer, the water will rise up into the borehole to equalise the confining pressure.

### ***Diffuse Sources***

Diffuse sources of pollution are spread over wider geographical areas rather than at individual point locations. Diffuse sources include general land use activities and landspreading of industrial, municipal wastes and agricultural organic and inorganic fertilisers.

### ***Direct Input***

An input to groundwater that bypasses the unsaturated zone (e.g. direct injection through a borehole) or is directly in contact with the groundwater table in an aquifer either year round or seasonally.

### ***Doline***

Or enclosed depressions are relatively shallow bowl or funnel shaped depressions that form in karst landscapes, and serve to funnel or concentrate recharge underground. Their presence indicates that subterranean drainage is in operation.

### ***Dolomitisation***

Is a process, whereby the calcite crystals in limestone is replaced by magnesium. This results in an increase in the porosity and permeability of the rock. Dolomitised rocks are a highly weathered, yellow/orange/brown colour and are usually evident in boreholes as loose yellow-brown sand with significant void space and poor core recovery. Dolomitisation often occurs preferentially in both fault zones and purer limestones.

### ***Down-gradient***

The direction of decreasing groundwater levels, i.e. flow direction. Opposite of upgradient.

### ***Dry Weather Flow (Receiving Water)***

The minimum flow likely to occur in a surface water course during a prolonged drought.

### ***Environmental Quality Standard (EQS)***

The concentration of a particular pollutant or group of pollutants in a receiving water which should not be exceeded in order to protect human health and the environment.

### ***Enclosed Depression***

See doline

### ***Fissure***

A natural crack in rock which allows rapid water movement.

### ***Good Groundwater Status***

Achieved when both the quantitative and chemical status of a groundwater body are good and meet all the conditions for good status set out in Groundwater Regulations 2010, regulations 39 to 43.

### ***Groundwater***

All water which is below the surface of the ground in the saturation zone and in direct contact with the ground or subsoil (Groundwater Regulations, 2010).

### ***Groundwater Body (GWB)***

A volume of groundwater defined as a groundwater management unit for the purposes of reporting to the European Commission under the Water Framework Directive. Groundwater bodies are defined by aquifers capable of providing more than 10 m<sup>3</sup>/d, on average, or serving more than 50 persons.

### ***Groundwater Protection Scheme (GWPS)***

A scheme comprising two principal components: a land surface zoning map which encompasses the hydrogeological elements of risk (of pollution); and a groundwater protection response matrix for different potentially polluting activities (DELG/EPA/GSI, 1999).

### ***Groundwater Protection Responses (GWPR)***

Control measures, conditions or precautions recommended as a response to the acceptability of an activity within a groundwater protection zone.

### ***Groundwater Protection Zone (GPZ)***

A zone delineated by integrating aquifer categories or source protection areas and associated vulnerability ratings. The zones are shown on a map, each zone being identified by a code, e.g. SO/H (outer source area with a high vulnerability) or Rk/E (regionally important karstified aquifer with an extreme vulnerability). Groundwater protection responses are assigned to these zones for different potentially polluting activities.

### ***Groundwater Recharge***

Two definitions: a) the process of rainwater or surface water infiltrating to the groundwater table; b) the volume (amount) of water added to a groundwater system.

### ***Groundwater Resource***

An aquifer capable of providing a groundwater supply of more than 10 m<sup>3</sup>/d as an average or serving more than 50 persons.

### ***Hydraulic Conductivity***

The rate at which water can move through a unit volume of geological medium under a potential unit hydraulic gradient. The hydraulic conductivity can be influenced by the properties of the fluid, including its density, viscosity and temperature, as well as by the properties of the soil or rock.

### ***Hydraulic Gradient***

The change in total head of water with distance; the slope of the groundwater table or the piezometric surface.

### ***Igneous***

Igneous rock is formed through the cooling and solidification of magma or lava.

### ***Indirect Input***

An input to groundwater where the pollutants infiltrate through soil, subsoil and/or bedrock to the groundwater table.

### ***Input***

The direct or indirect introduction of pollutants into groundwater as a result of human activity.

### **Karst**

A distinctive landform characterised by features such as surface collapses, sinking streams, swallow holes, caves, turloughs and dry valleys, and a distinctive groundwater flow regime where drainage is largely underground in solutionally enlarged fissures and conduits.

### **Karstification**

Karstification is the process whereby limestones are slowly dissolved by acidic waters moving through them. This results in the development of an uneven distribution of permeability with the enlargement of certain fissures at the expense of others and the concentration of water flow into these high permeability zones. Karstification results in the progressive development of distinctive karst landforms such as caves, swallow holes, sinking streams, turloughs and dry valleys, and a distinctive groundwater flow regime. It is an important feature of Irish hydrogeology.

### **Pathway**

The route which a particle of water and/or chemical or biological substance takes through the environment from a source to a receptor location. Pathways are determined by natural hydrogeological characteristics and the nature of the contaminant, but can also be influenced by the presence of features resulting from human activities (e.g., abandoned ungrouted boreholes which can direct surface water and associated pollutants preferentially to groundwater).

### **Permeability**

A measure of a soil or rock's ability or capacity to transmit water under a potential hydraulic gradient (synonymous with hydraulic conductivity).

### **Point Source**

Any discernible, confined or discrete conveyance from which pollutants are or may be discharged. These may exist in the form of pipes, ditches, channels, tunnels, conduits, containers, and sheds, or may exist as distinct percolation areas, integrated constructed wetlands, or other surface application of pollutants at individual locations. Examples are discharges from waste water works and effluent discharges from industry.

### **Pollution**

The direct or indirect introduction, as a result of human activity, of substances or heat into the air, water or land which may be harmful to human health or the quality of aquatic ecosystems or terrestrial ecosystems directly depending on aquatic ecosystems which result in damage to material property, or which impair or interfere with amenities and other legitimate uses of the environment (Groundwater Regulations, 2010).

### **Poorly Productive Aquifers (PPAs)**

Low-yielding bedrock aquifers that are generally not regarded as important sources of water for public water supply but that nonetheless may be important in terms of providing domestic and small community water supplies and of delivering water and associated pollutants to rivers and lakes via shallow groundwater pathways.

### **Preferential Flow**

A generic term used to describe water movement along favoured pathways through a geological medium, bypassing other parts of the medium. Examples include pores formed by soil fauna, plant root channels, weathering cracks, fissures and/or fractures.

### **Saturated Zone**

The zone below the water table in an aquifer in which all pores and fissures and fractures are filled with water at a pressure that is greater than atmospheric.

### **Soil (topsoil)**

The uppermost layer of soil in which plants grow.

### **Source Protection Area**

The catchment area around a groundwater source which contributes water to that source (Zone of Contribution), divided into two areas; the Inner Protection Area (SI) and the Outer Protection Area (SO). The SI is designed to protect the source against the effects of human activities that may have an immediate effect on the source, particularly in relation to microbiological pollution. It is defined by a 100-day time of travel (TOT) from any point below the water table to the source. The SO covers the remainder of the zone of contribution of the groundwater source.

### ***Specific Yield***

The specific yield is the volume of water that an unconfined aquifer releases from storage per unit surface area of aquifer per unit decline of the water table.

### ***Spring***

A spring is a natural feature where groundwater emerges at the surface. Springs usually occur where the rate of flow of groundwater is too great to remain underground. The position of a springs usually reflects a change in soil or rocktype or a change in slope.

### ***Subsoil***

Unlithified (uncemented) geological strata or materials beneath the topsoil and above bedrock.

### ***Surface Water***

An element of water on the land's surface such as a lake, reservoir, stream, river or canal. Can also be part of transitional or coastal waters. (Surface Waters Regulations, 2009.).

### ***Swallow Hole***

The point where concentrated inflows of water sink underground. They are found in karst environments.

### ***Threshold Values (TVs)***

Chemical concentration values for substances listed in Schedule 5 of the Groundwater Regulations (2010), which are used for the purpose of chemical status classification of groundwater bodies.

### ***Till***

Unsorted glacial Sediment deposited directly by the glacier. It is the most common Quaternary deposit in Ireland. Its components may vary from gravel, sands and clays.

### ***Transmissivity***

Transmissivity is the product of the average hydraulic conductivity of the aquifer and the saturated thickness of the aquifer.

### ***Unsaturated Zone***

The zone between the land surface and the water table, in which pores, fractures and fissures are only partially filled with water. Also known as the vadose zone.

### ***Vulnerability***

The intrinsic geological and hydrogeological characteristics that determine the ease with which groundwater may be contaminated by human activities (Fitzsimmons et al, 2003).

### ***Water Table***

The uppermost level of saturation in an aquifer at which the pressure is atmospheric.

### ***Weathering***

The breakdown of rocks and minerals at the earth's surface by chemical and physical processes.

### ***Zone of Contribution (ZOC)***

The area surrounding a pumped well or spring that encompasses all areas or features that supply groundwater to the well or spring. It is defined as the area required to support an abstraction and/or overflow (in the case of springs) from long-term groundwater recharge.

## Figures

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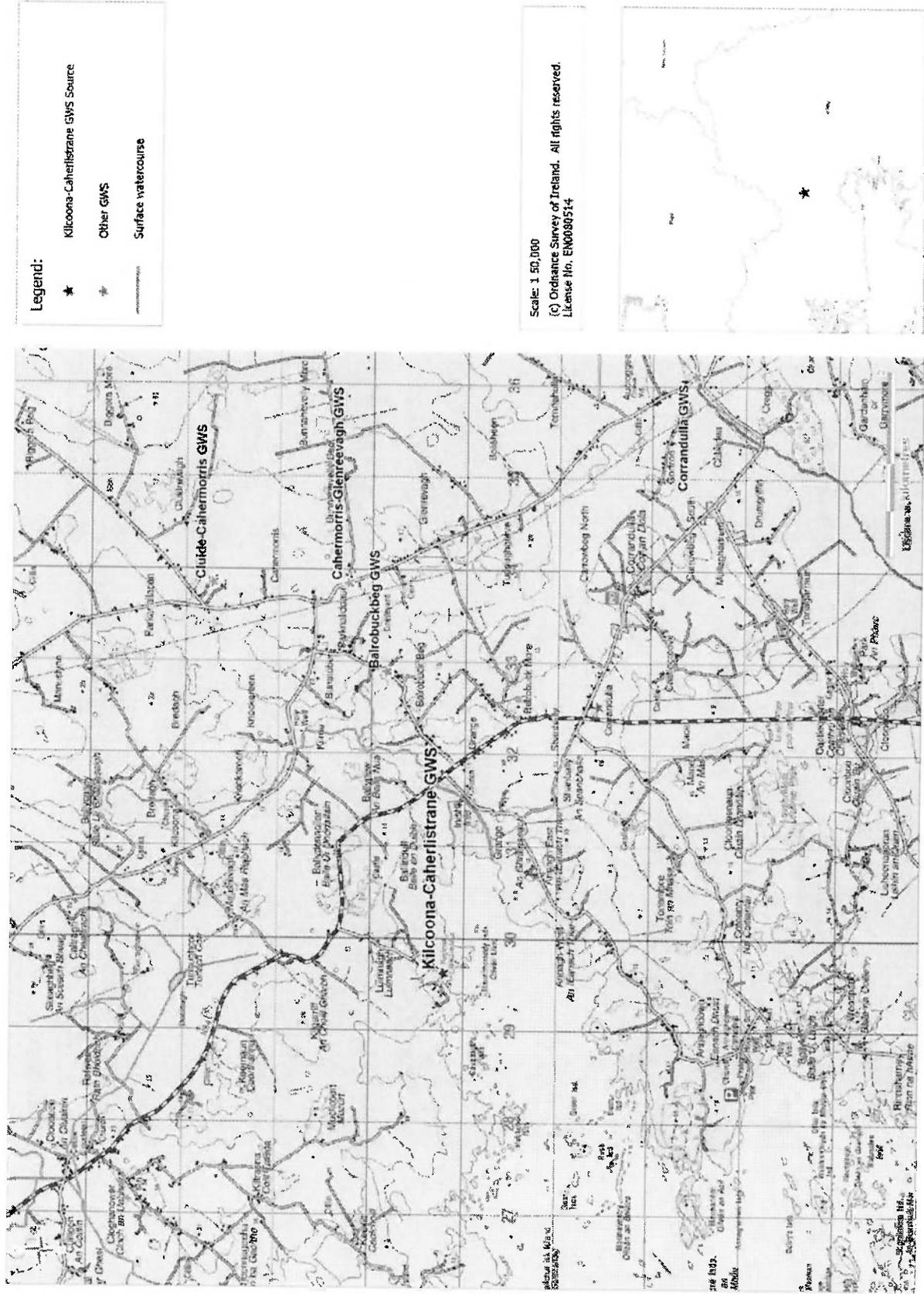


Figure 1: Location Map (OSI Discovery Map Series Map. 1: 50,000 scale)



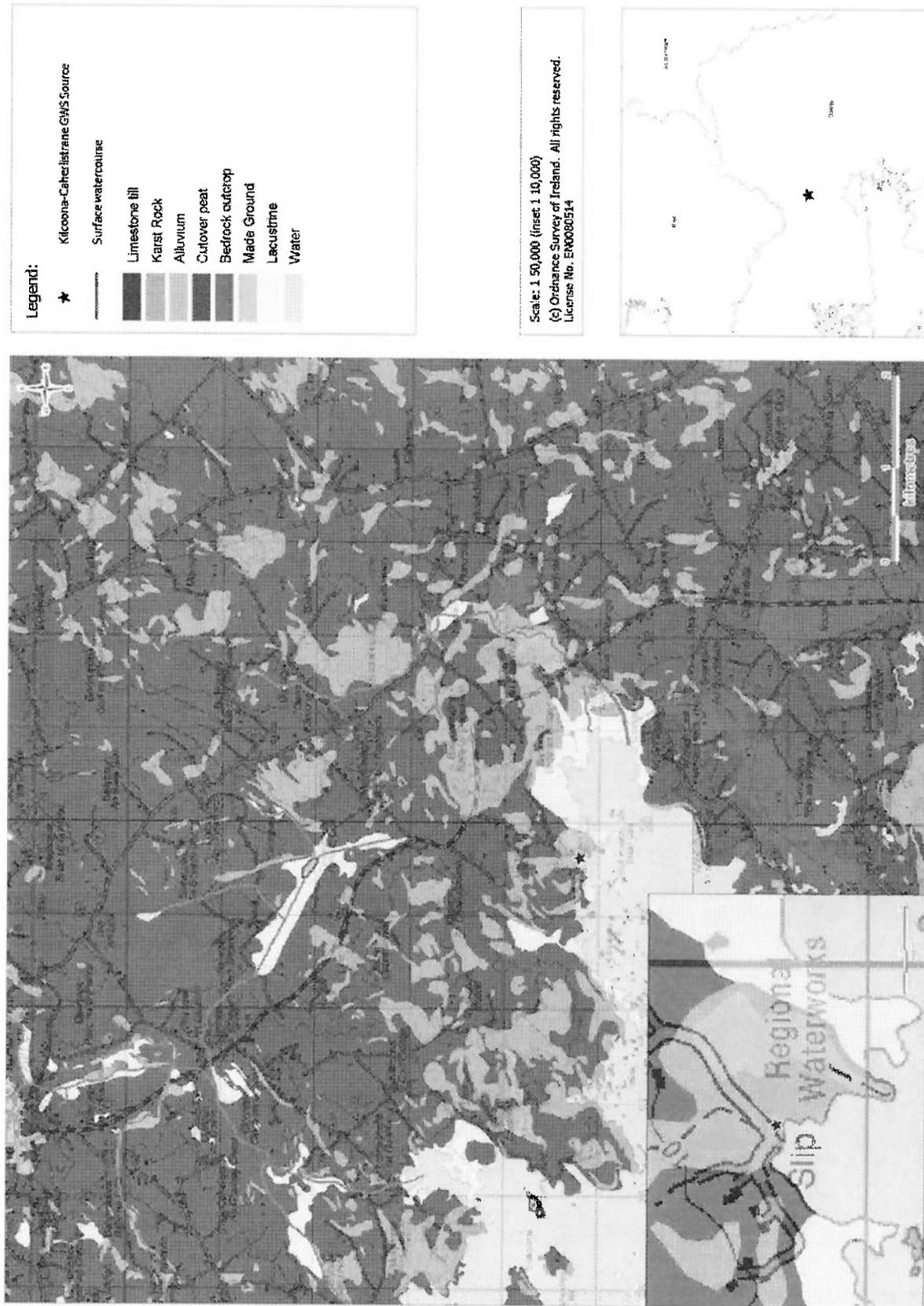


Figure 3: Subsoils Map

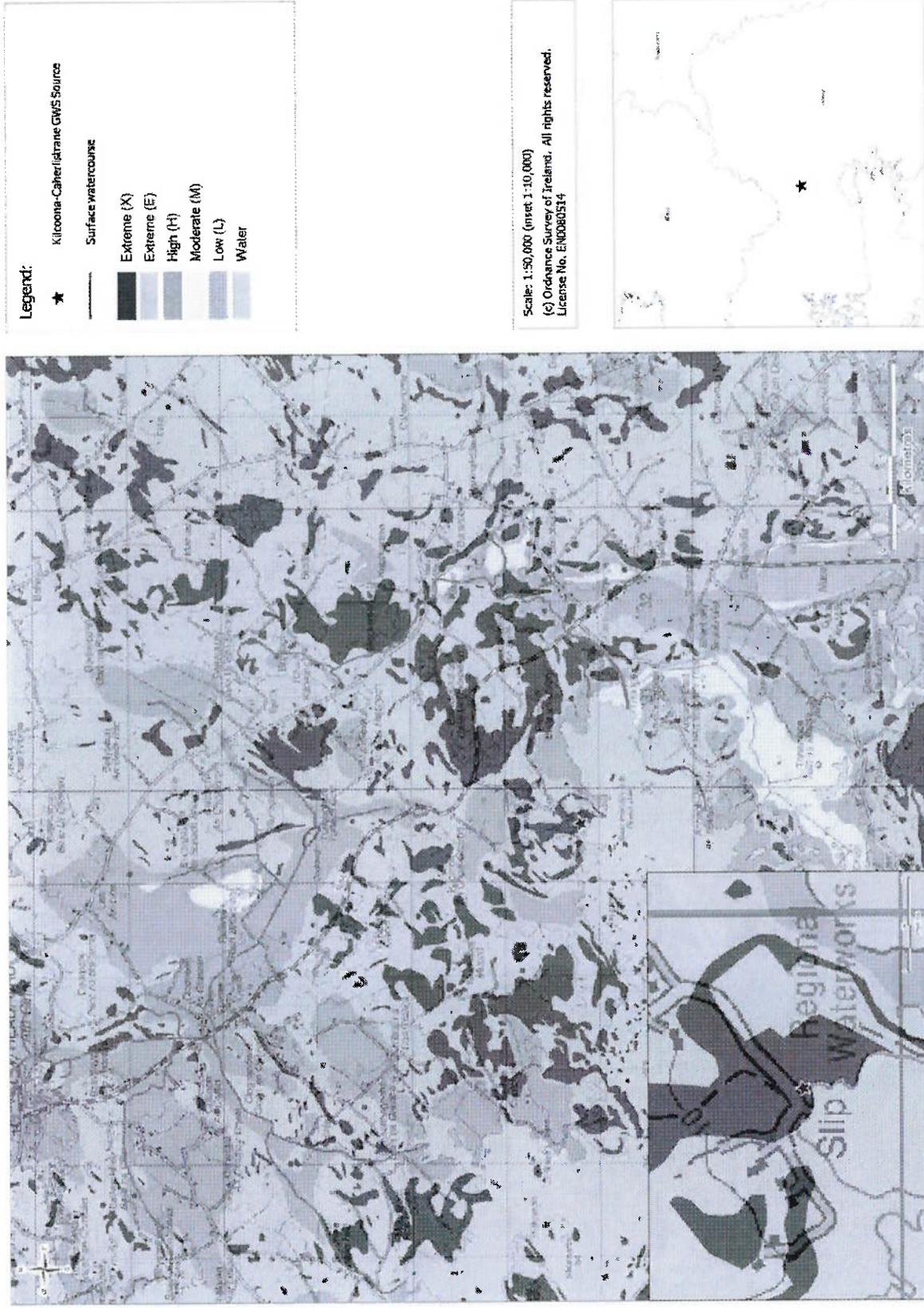


Figure 4: Groundwater Vulnerability Map

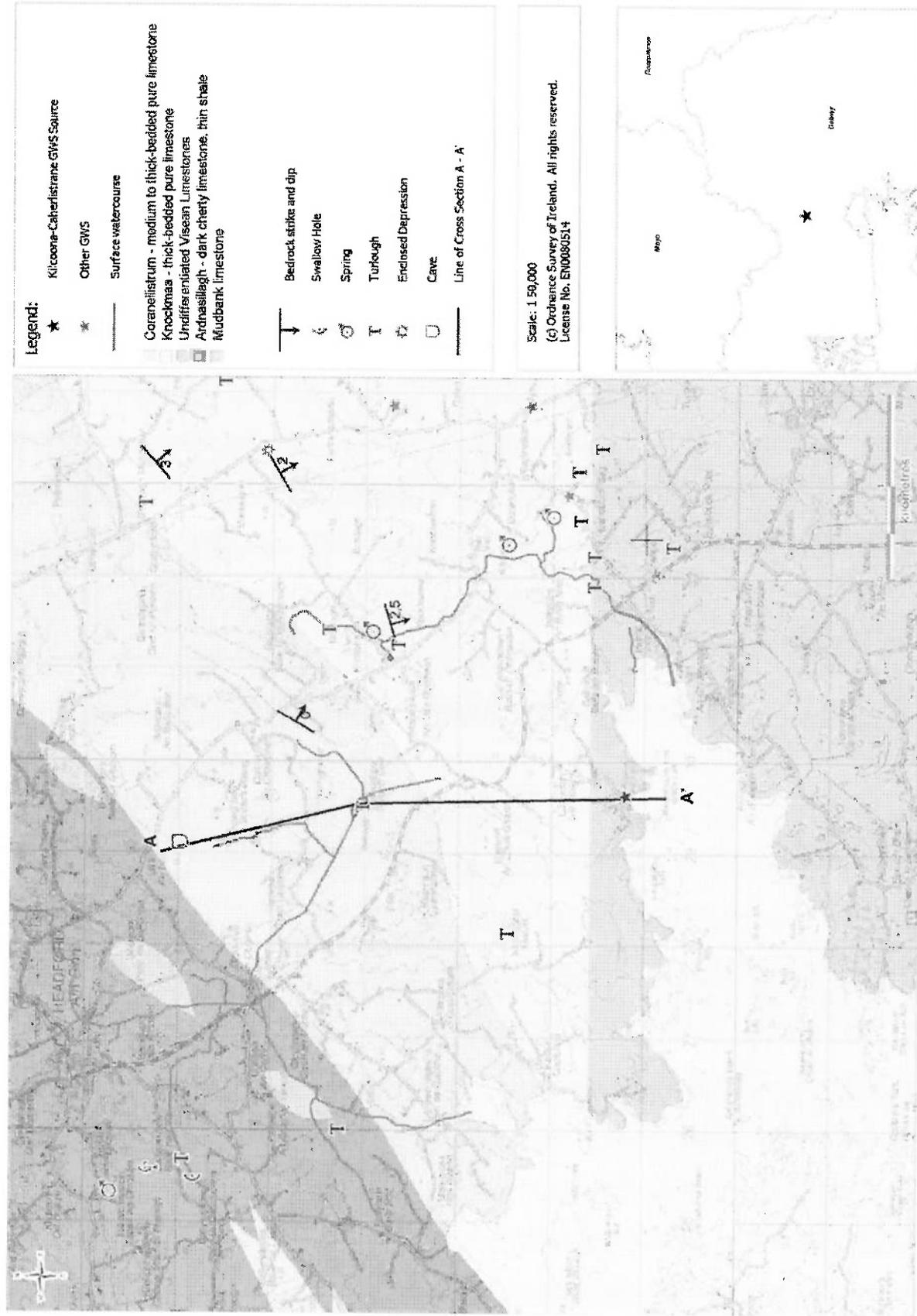


Figure 5: Bedrock Map

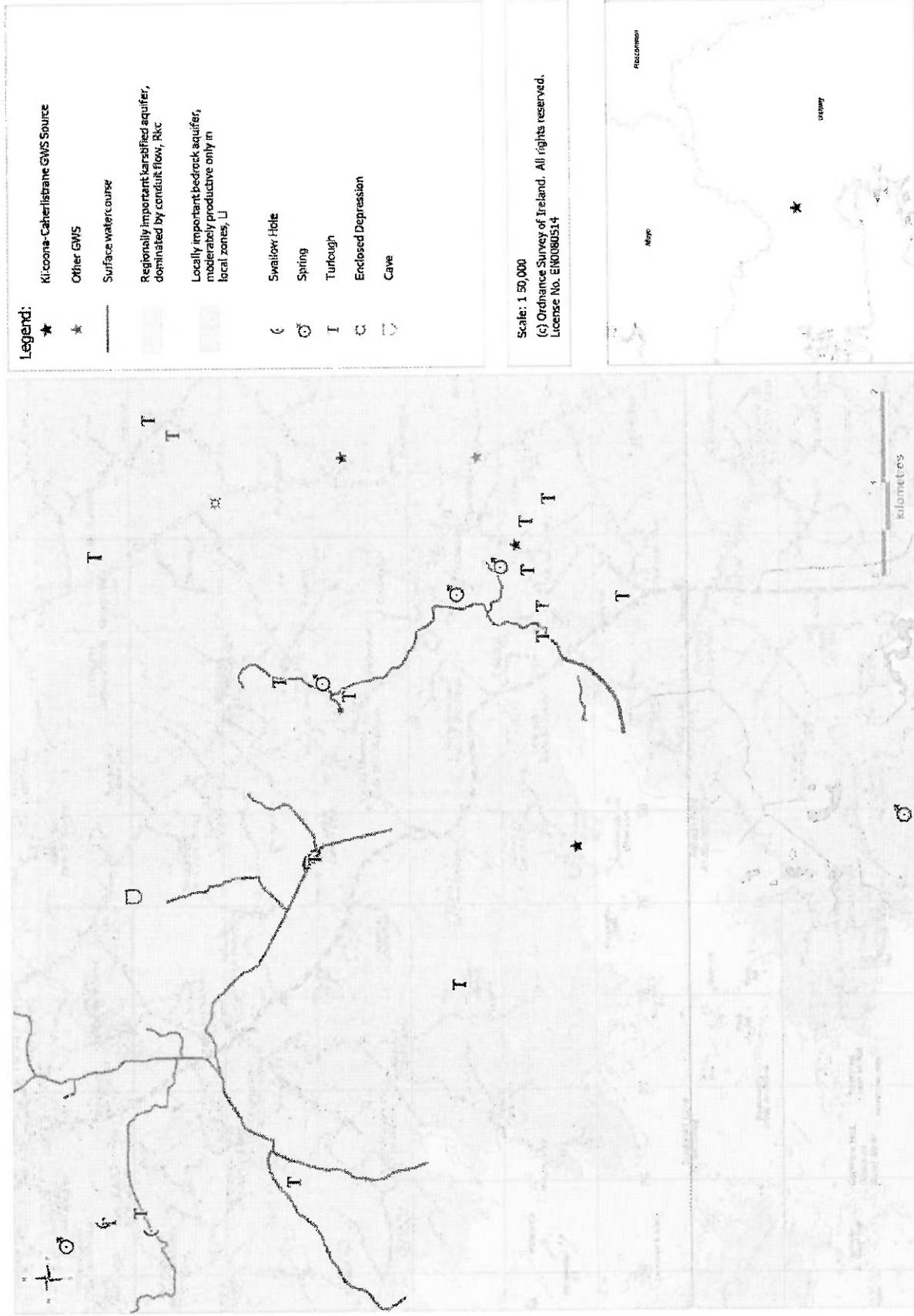


Figure 6: Aquifer Map

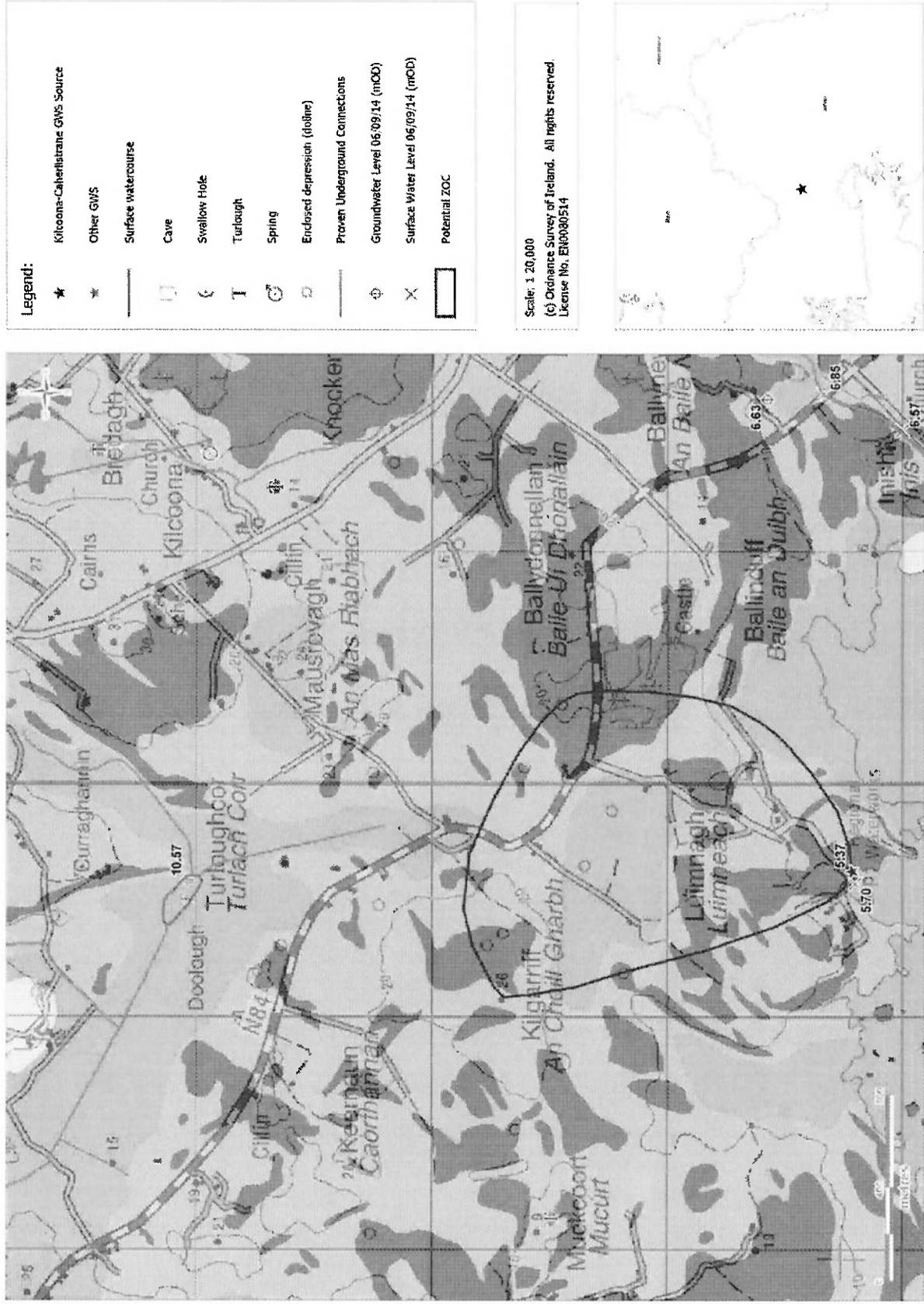


Figure 7: ZOC Boundary

# APPENDIX 1

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## Groundwater Vulnerability

## Introduction

The term 'vulnerability' is used to represent the intrinsic geological and hydrogeological characteristics that determine the ease with which groundwater may be contaminated by human activities (DELG *et al.*, 1999). The vulnerability of groundwater depends on:

- the time of travel of infiltrating water (and contaminants)
- the relative quantity of contaminants that can reach the groundwater
- the contaminant attenuation capacity of the geological materials through which the water and contaminants infiltrate.

All groundwater is hydrologically connected to the land surface; the effectiveness of this connection determines the relative vulnerability to contamination. Groundwater that readily and quickly receives water (and contaminants) from the land surface is more vulnerable than groundwater that receives water (and contaminants) more slowly and in lower quantities. The travel time, attenuation capacity and quantity of contaminants are a function of the following natural geological and hydrogeological attributes of any area:

- the type and permeability of the subsoils that overlie the groundwater
- the thickness of the unsaturated zone through which the contaminant moves
- the recharge type – whether point or diffuse.

In other words, vulnerability is based on evaluating the relevant hydrogeological characteristics of the protecting geological layers along the pathway, and the possibility of bypassing these layers. In summary, the entire land surface is divided into four vulnerability categories: **Extreme**, **High**, **Moderate** and **Low**, based on the geological and hydrogeological characteristics. Further details of the hydrogeological basis for vulnerability assessment can be found in 'Groundwater Protection Schemes' (DELG *et al.*, 1999).

The Groundwater Vulnerability Map shows the vulnerability of the first groundwater encountered, in either sand/gravel or bedrock aquifers, by contaminants released at depths of 1-2 m below the ground surface. Where the water-table in bedrock aquifers is below the top of the bedrock, the target needing protection is the water-table. However, where the aquifer is fully saturated, the target is the top of the bedrock. The vulnerability map aims to be a guide to the likelihood of groundwater contamination, if a pollution event were to occur. It does not replace the need for site investigation. Note also that the characteristics of individual contaminants are not considered.

Except where point recharge occurs (*e.g.* at swallow holes), the groundwater vulnerability depends on the type, permeability and thickness of the subsoil. The groundwater vulnerability map is derived by combining the permeability and depth to bedrock maps, using the three subsoil permeability categories: high, moderate and low; and four depths to rock categories: <3m, 3–5m, 5–10m and >10m. The resulting vulnerability classifications are shown in Table 1.

**Table 1 Vulnerability mapping guidelines (adapted from DELG *et al.*, 1999)**

Thickness of Overlying Subsoils	Hydrogeological Requirements for Vulnerability Categories				
	Diffuse Recharge			Point Recharge	Unsaturated Zone
	Subsoil permeability and type				
	High permeability (sand/gravel)	moderate permeability (sandy subsoil)	low permeability (clayey subsoil, clay, peat)	(swallow holes, losing streams)	(sand & gravel aquifers <u>only</u> )
0–3 m	<b>Extreme</b>	<b>Extreme</b>	<b>Extreme</b>	<b>Extreme</b> (30 m radius)	<b>Extreme</b>
3–5 m	<b>High</b>	<b>High</b>	<b>High</b>	N/A	<b>High</b>
5–10 m	<b>High</b>	<b>High</b>	<b>Moderate</b>	N/A	<b>High</b>
>10 m	<b>High</b>	<b>Moderate</b>	<b>Low</b>	N/A	<b>High</b>

Notes: (i) N/A = not applicable.  
 (ii) Release point of contaminants is assumed to be 1–2 m below ground surface.  
 (iii) Permeability classifications relate to the engineering behaviour as described by BS5930.  
 (iv) Outcrop and shallow subsoil (i.e. generally <1.0 m) areas are shown as a sub-category of extreme vulnerability (amended from Deakin and Daly (1999) and DELG/EPA/GSIa (1999))

### Sources of Vulnerability Data

Specific vulnerability field mapping and assessment of previously collected data were carried out as part of this project. Fieldwork focused on assessing the permeability of the different subsoil deposit types (Figure 3), so that they could be subdivided into the three permeability categories. This involved:

- Describing selected exposures/sections according to the British Standard Institute *Code of Practice for Site Investigations* (BS 5930:1999).
- Collection of subsoil samples for laboratory particle size analyses
- Assessing the recharge characteristics of selected sites using natural and artificial drainage, vegetation and other recharge indicators.

The following additional sources of data were used to assess the vulnerability and produce the map:

- Subsoils Map (EPA/Teagasc Subsoil Map, 2006), which is the basis for the main permeability boundaries. 'Clean' sands and gravels are usually high permeability. Alluvium deposits are either moderate or low permeability.
- Depth to bedrock map, compiled by the mapping team for the current project in the Geological Survey of Ireland, using data compiled from GSI, consultant and county council reports, along with purpose-drilled auger holes
- Geological Survey of Ireland Bedrock Geology Map
- Geological Survey of Ireland well and karst database, which supplied information on well yields and depth to bedrock, as well as locations of point recharge.
- General Soils Map of Ireland (Gardiner and Radford, 1980). This gives additional, indirect information on subsoil permeability in the areas mapped by Teagasc as 'till'.

### Thickness of the Unsaturated Zone

The thickness of the unsaturated zone, or the depth of ground free of intermittent or permanent saturation, is only relevant in vulnerability mapping over unconfined sand and gravel aquifers. As described in Table 6.1, the critical unsaturated zone thickness is 3m; unconfined gravels with unsaturated zones thicker than 3m are classed as having a 'high' vulnerability, while those with unsaturated zones thinner than 3m are classed as having an 'extreme' vulnerability.

## **APPENDIX 2**

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### **Groundwater Recharge**

## Introduction

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 is assumed to consist of the rainfall input (i.e. annual rainfall) minus water loss 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 this dictates the size of the zone of contribution to the source (i.e. the outer Source Protection Area).

The main parameters involved in the estimation of recharge are: annual rainfall; annual evapotranspiration; and a recharge coefficient (Table 1). The recharge coefficient is estimated using Hunter Williams et al (2013), which is based on Guidance Document GW5 (Groundwater Working Group 2005).

**Table 1. Recharge coefficients for different hydrogeological settings.**

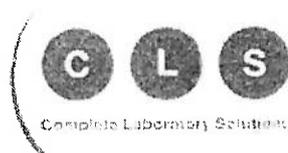
Groundwater vulnerability category	Hydrogeological setting	Recharge coefficient (RC)		
		Min (%)	Inner Range	Max (%)
Extreme (X or E)	1.i	30	80-90	100
	1.ii	50	80-90	100
	1.iii	15	35-50	70
	1.iv	45	50-70	80
	1.v	5	15-30	50
	1.vi	50	80-90	100
	1.vii	1	15-30	50
High (H)	2.i	50	80-90	100
	2.ii	50	80-90	100
	2.iii	15	35-50	70
	2.iv	15	35-50	70
	2.v	35	50-70	80
	2.vi	10	15-30	50
	2.vii	1	20-30	40
	2.viii	1	5-15	20
Moderate (M)	3.i	35	50-70	80
	3.ii	10	15-30	50
	3.iii	1	10-20	30
	3.iv	1	3-5	10
Low (L)	4.i	1	5-10	20
	4.ii	1	3-5	10

The recharge coefficients in this table are summarised in a paper by Hunter Williams et al. (2013) in the Quarterly Journal of Engineering Geology and Hydrogeology. Aquifer recharge acceptance capacity is generally limited in L1 aquifers (200 mm/yr) and P1 and P2 aquifers (100 mm/yr). Made ground has recharge coefficient of 20%.

## **APPENDIX 3**

### **Laboratory Certificate of Analysis**

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Complete Laboratory Solutions  
 Ros Muc, Co. Galway.  
 [Tel] 091 574356  
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 [Email]  
 [web]

Client	Claire McHugh Kilcoona, Caherlistrane GWS Ballybane Headford Co. Galway	Report No.	: 205671
		Date of Receipt	: 11/09/2013
		Start Date of Analysis	: 11/09/2013
		Date of Report	: 20/09/2013
		Order Number	:
		Sample taken by	: CLS

**CERTIFICATE OF ANALYSIS**

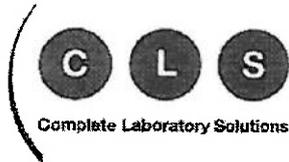
Lab No	Sample Description	Test	Result	Units
468713	Borehole Raw Water Sample 11/09/13	E coli (Filtration)	0	cfu/100ml
		Total Coliforms (Filtration)	0	cfu/100ml
		Colour	8.9	mg/l Pt Co
		Turbidity	0.5	N.T.U
		pH	7.1	pH Units
		Conductivity @20C	477	µS/cm
		Ammonium as NH4	3.057	mg/l
		Nitrate as NO3	4.43	mg/l
		Nitrite as NO2	<0.017	mg/l
		Iron, total	13	µg/l
		Total Hardness (Kone)	252	mg/l CaCO3
		Manganese, Total	<5	µg/l
		Aluminium, Total	5	µg/l
		Enterococci (Environmental Water)- Incubated at 37°C and 44 °C)	0	cfu/100ml



Approved by:

**Rita McGrath**  
 Environmental Scientist

See also IWA test specification on IWA's Portal Page  
 This report only becomes valid once a signed certificate is received in full with the possession of  
 the sample in question.



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Client	: Noel Higgins	Report No.	: 234474
	Kilcoona, Caherlistrane GWS	Date of Receipt	: 24/07/2014
	Ballybane	Start Date of Analysis	: 24/07/2014
	Headford	Date of Report	: 18/08/2014
	Co. Galway	Order Number	:
		Sample taken by	: CLS

**CERTIFICATE OF ANALYSIS**

Lab No	Sample Description	Test	Result	Units
531945	Kilcoona Caherlistrane GWS. 24/07/14	BOD	<1	mg/l
		COD	<10	mg/l
		Turbidity	1.01.0	N.T.U.
		pH	7.8	pH Units
		Conductivity @20C	219	uS/cm
		Alkalinity, total	91	mg/l CaCO3
		Sodium, total	15	mg/l
		Chloride	19.4	mg/l
		Ammonium as NH4	0.022	mg/l
		Nitrate as NO3	<0.44	mg/l
		Nitrite as NO2	<0.017	mg/l
		Dissolved Oxygen (%)	116	%Sat
		Potassium, total	5	mg/l
		Total Hardness (Kone)	105	mg/l CaCO3
		Magnesium, total	6	mg/l
		Colour, apparent	16.3	mg/l Pt Co
		Sulphate	5.19	mg/l
		Orthophosphate as PO4-P	0.018	mg/l
		Calcium, total	30	mg/l
		Aluminium, dissolved	15	ug/l
		Iron, dissolved	18	ug/l
		Manganese, dissolved	<5	ug/l
		Copper, dissolved	<1	ug/l
		Lead, dissolved	<0.5	ug/l
		Chromium, dissolved	<0.5	ug/l
		Nickel, dissolved	0.5	ug/l
		Cadmium, dissolved	<0.5	ug/l
		Arsenic, dissolved	<0.5	ug/l
		Zinc, dissolved	5	ug/l
		Silica	1.12	mg/l
		Barium, dissolved	21	ug/l
		TOC	5.37	mg/L
		Clostridium Perfringens in Water	8	cfu/100ml
		Strontium, dissolved	172	ug/l
		E coli (Filtration) (Environmental Waters)	15	cfu/100ml
		Total Coliforms (Filtration) (Environmental Waters)	15	cfu/100ml
		Fluoride by ISE	0.2	mg/l



Approved by: *Barbara Lee*  
Barbara Lee  
Environmental Scientist

See page 2 for test specifications and accreditation status  
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