



6 IRELAND: KILLEGLAN SPRINGS

6.1 Overview

Killeglan spring is actually made up of two springs, the largest of which, Tobermore Spring, is used as a drinking water source for the surrounding region. There are three boreholes located in the spring compound, but it is unclear how much water, if any, is abstracted from the boreholes.

The Killeglan spring and boreholes are situated in the low-lying central plain of Ireland (*Figure 15*). Almost half of the Republic of Ireland is underlain by limestone, over 80% of which lies at an altitude of less than 100 m (*Figure 16*). However, the lowlands are not obviously karstic. Glacial sediments, principally till and peat deposits, overlie the limestones in varying thicknesses. This mantle of Quaternary deposits allows a surface drainage system to exist in places. The Irish karstic lowlands are often characterized by high water levels and severe flooding in winter (Hickey, 2010). Turloughs (seasonal karstic lakes) are abundant in the area. Lowland karsts are probably the most developed and complex karst regions of Ireland, comprising a mixture of re-activated, pre-glacial and inter-glacial karst and Holocene karst.

Much of surface drainage system has been altered by arterial drainage works. Prior to the arterial drainage works, most of the rivers in the western part of this region sank underground. Further east, where Quaternary deposits are thicker, and the limestones are less pure, the surface drainage pattern was largely the same as at present. As with the limestone east of the region (east of the River Shannon), thick subsoils mask much of the bedrock topography, with only isolated exposures of bedrock protruding above the undulating or flat terrain (Drew, 2018). A feature of the study area is the existence of tracts of land (mini-plateaux) with areas of up to tens of square kilometres elevated 20 - 40 m above the surrounding lowland, with no integrated surface water channels and draining to small-medium springs around the periphery. In other areas, the karstic lowlands are also littered with small to medium sized karst springs, often with no obvious catchment area (Hickey, 2008; Drew, 2008; Drew, 2018). The Killeglan spring is one such spring. Exceedances of trihalomethanes and turbidity standards and detections of *Cryptosporidium* and *Clostridium perfringens* in this supply have been notified to the Environmental Protection Agency (EPA) in the past.

The catchment area to the spring has been delineated and encompasses an area of approximately 40 km². The area is sparsely populated with agricultural activity dominating and most of the land used for grassland and grazing. The nearest town is Ballinasloe, located 10 km to the south and outside the catchment. Athlone is located 15 km to the east and also outside of the catchment area. A high density of karst landforms, such as turloughs, intermittent streams and small autogenic sinking streams are mapped in the catchment. A number of houses and farms are present near the spring, some of which are within 500 metres of the source.



Figure 15: The topographical setting for Killeglan spring

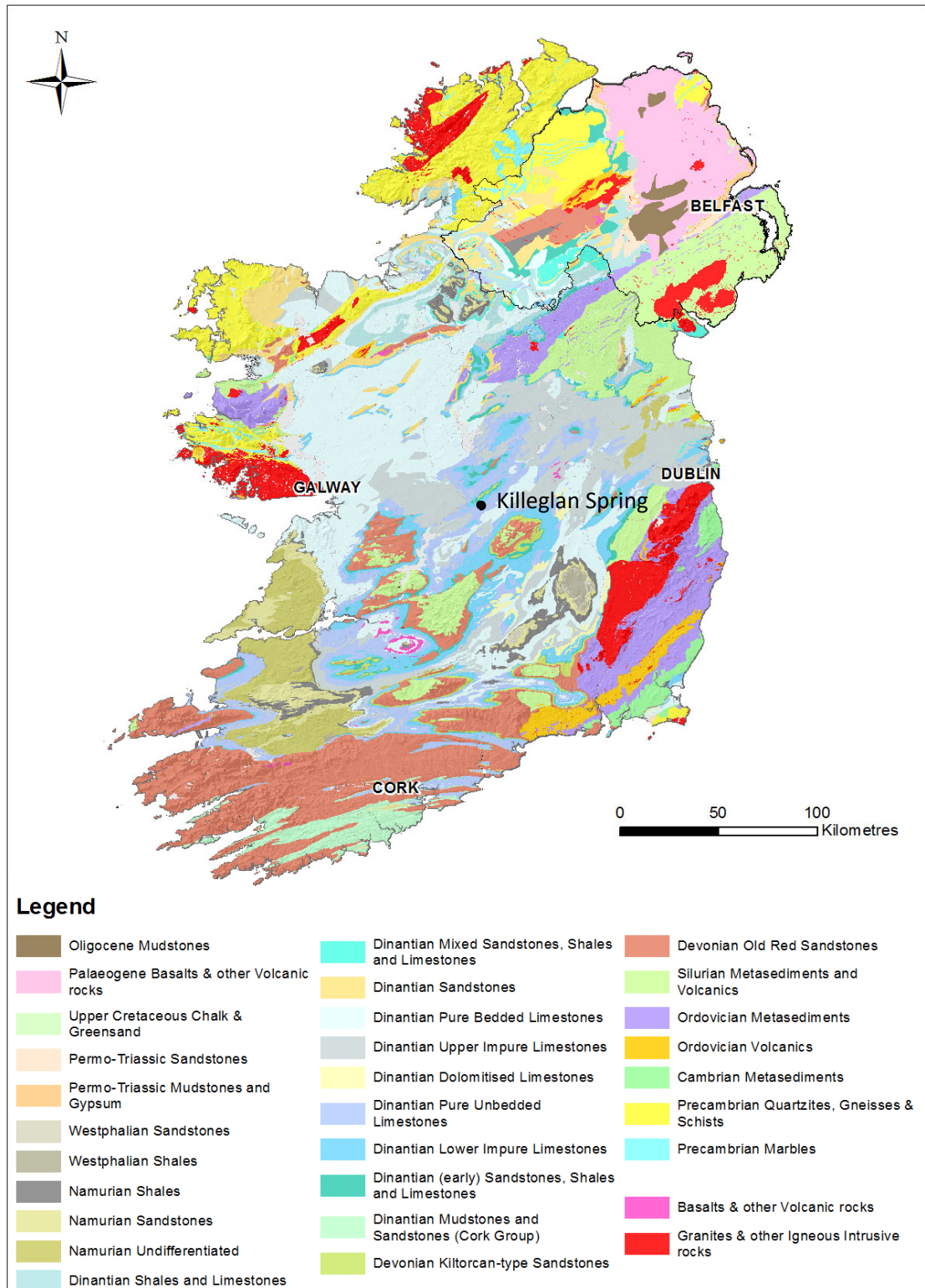


Figure 16: All Ireland Rock Unit Group Map (data from GSI) showing the location of Killeglan Spring

6.2 Geology

6.2.1 Bedrock Geology

The majority of the midlands is underlain by limestone bedrock. In fact, the spring is located in one of the largest continuous areas of limestone in Northwest Europe (almost 20,000 km² in area) (Figure 16). The majority of the pilot area is underlain by Undifferentiated Visean Limestone (Figure 17). These limestones are undifferentiated due to poor exposure but are generally composed of pure, medium- to coarse-grained bedded limestones. A number of small outcrops of the Visean Limestone are noted along the path of the intermittent, seasonal stream, within the catchment. To the south of the Visean Limestone is a thin band of Waulsortian Limestone. The Waulsortian Limestone is a clean, pale grey massive limestone (Morris et al., 2003). The older Ballysteen Limestone is exposed further south and east but outside the catchment area. This limestone is described as a dark grey muddy limestone interbedded with calcareous shales.

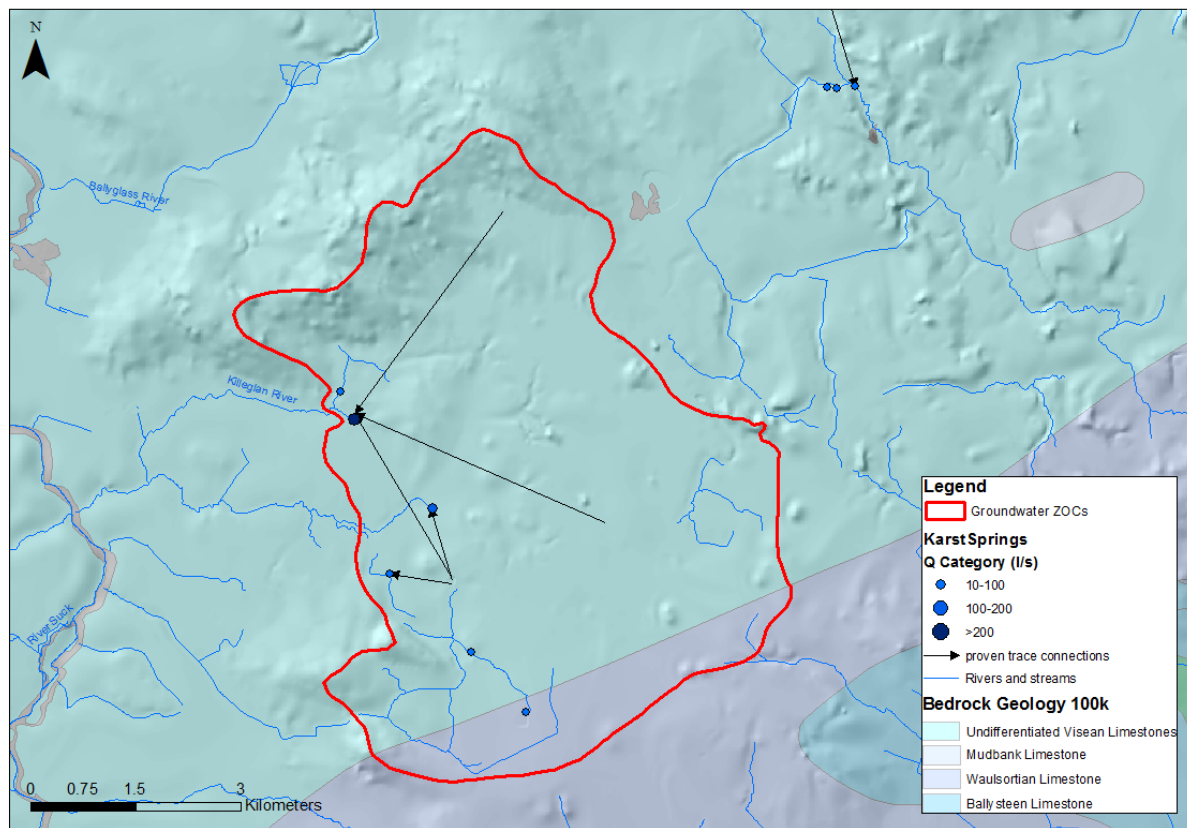


Figure 17: The bedrock geology of the Killeglan spring catchment and surrounding area

6.2.2 Quaternary Geology

The unconsolidated material (subsoil) overlying the bedrock comprises a mixture of coarse and fine-grained materials, namely peat, alluvium, sand/gravels, and tills (Figure 18). Till is the dominant subsoil type in the area and is an unsorted mixture of coarse and fine materials laid down by ice. The gravel-sized fragments ranging up to 10 cm in size are angular to sub-rounded

and are composed of limestone. The matrix is primarily silty SAND (BS 5930) with frequent gravels and clay (Lee & Kelly, 2003). It is classified as being moderately permeable. Peat is located in the low-lying boggy regions of the area, mostly in the southern part. Extensive glaciofluvial sand/gravel deposits are present east and north-east of the springs. A large proportion of the sand/gravel forms a characteristically random, hummocky topography. However long, sinuous, braided ridges of sand/gravel (eskers) have also been deposited (Lee & Kelly, 2003). Lacustrine deposits and lake marl are found around the larger turloughs in the catchment area. Alluvium is deposited in the larger river valleys, such as the Suck River, to the west, and other smaller localised areas within the catchment.

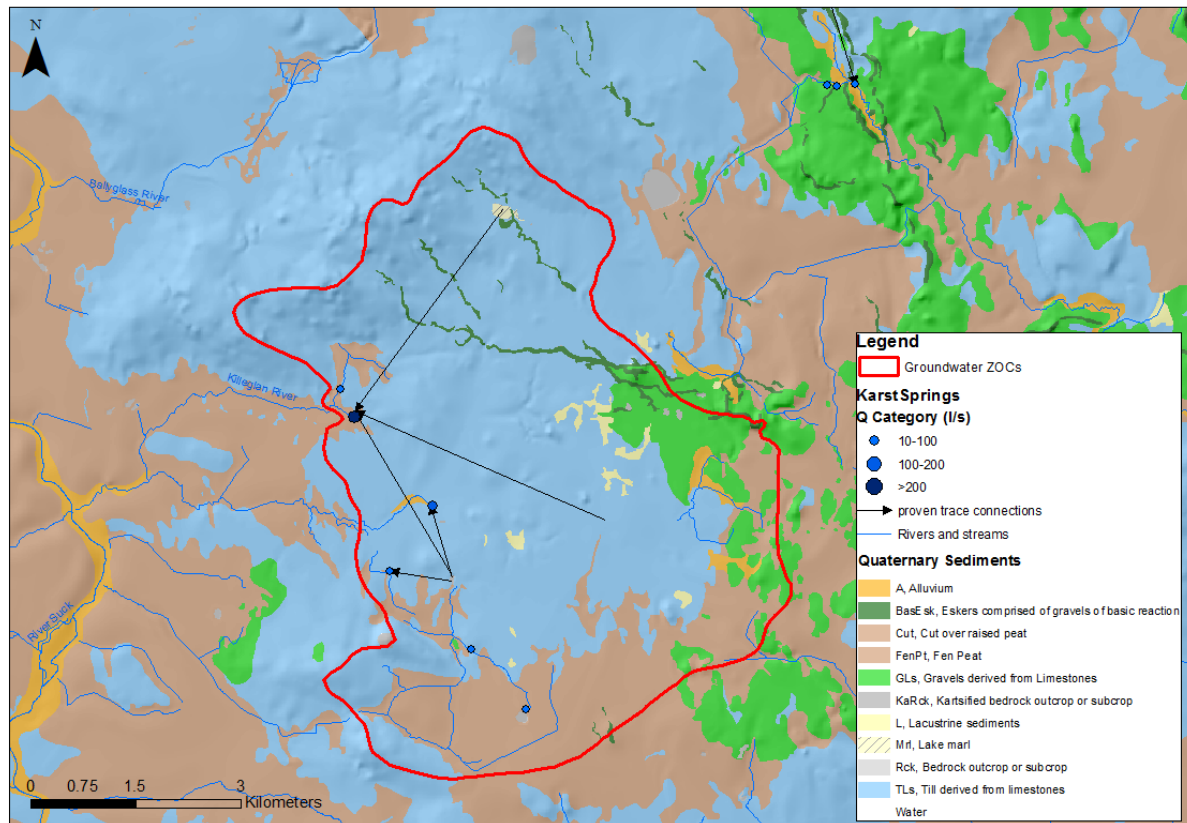


Figure 18: The Quaternary Geology of the Killeglan spring catchment and the surrounding area

6.2.3 Depth to Bedrock

Broad variations in depth to bedrock have been interpreted across the area by using information from the GSI databases, field mapping and air photo interpretation. Data from the drilling programmes indicate that the depth to rock ranges from 2 m to 33 m. In general, the low-lying areas around the spring and towards the central part of the catchment are closer to bedrock. Higher parts of the catchment have greater depths to bedrock.

6.3 Geomorphology

As previously stated, the springs are located in a low-lying region in Ireland, with very little land higher than 100 m above sea level (asl). The spring emerges at 50 m asl. The area immediately around the springs is flat to undulating (Figure 15). However, there is a slight rise to the east

with the land to the east of the springs elevated some 10 m above, with an average height of about 60 m asl. There is also a small elevated ridge to the north of the springs, rising to maximum of 119 m asl.

There is a large river, the River Suck, located 4 km west of the springs, which the springs overflow into (*Figure 18*). This river flows south, eventually joining the River Shannon at Shannonbridge. This river drains the majority of the area shown in the figures. To the east of the springs lies the River Shannon, Ireland's largest river. This river flows south through a series of large lakes and eventually flows out to sea at Limerick via the Shannon Estuary. One of these lakes is Lough Ree, located some 15 km northeast of the springs.

The surface water regime in the catchment is closely interconnected with the groundwater regime. There are several springs, swallow holes and numerous enclosed depressions that are linked to the main surface water bodies in the area (*Figure 19*). Many streams sink a short distance after they rise. An intermittent, seasonal stream is located to the east of the Tobermore spring. Karst landforms are abundant in the catchment, and beyond, with many areas draining into turloughs and subsequently entering the groundwater system in swallow holes as and when the turlough empty.

There are a number of glacial geomorphological features such as eskers ridges, hummocky sand and gravel deposits and ribbed moraines.

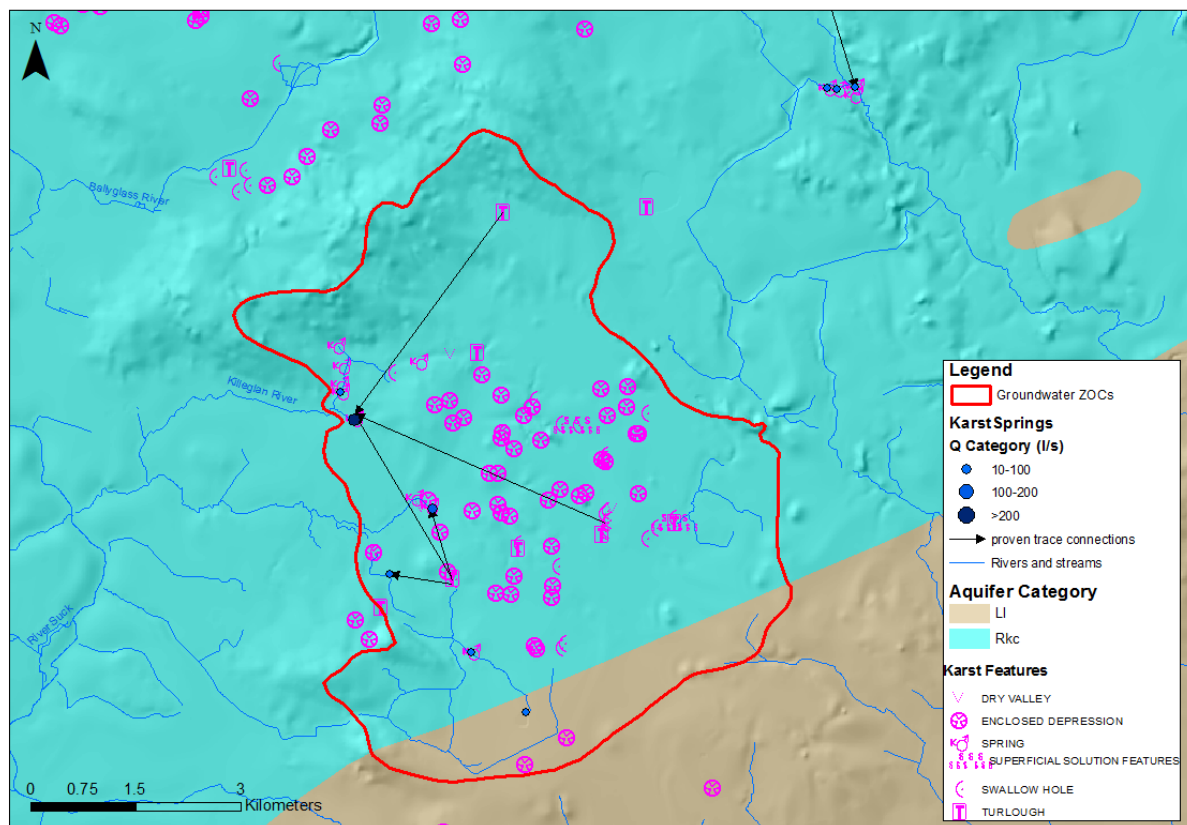


Figure 19: The karst landforms, surface drainage features and aquifer category of the Killeglan spring catchment and the surrounding area



6.4 Climate

Ireland has a temperate maritime climate, which is greatly influenced by the Atlantic Ocean. The climate of Ireland has abundant rainfall and lacks temperature extremes. The mean annual air temperature of Ireland is approximately 10°C, but with an average of 10°C difference between January and July, the weather is more consistent than in other areas at a similar latitude. Average annual rainfall ranges from 750 mm to >3000 mm. The eastern part of the country receives an annual average of 750 to 1,000 mm, while the western part of the Ireland receives an annual average of 1,000 to 1,300 mm of rainfall. Mountainous areas receive greater than 3,000 mm per annum. The average rainfall in the study area is 1,040 mm/yr (Met Eireann 30 year averages, 1981-2010). Major snowstorms are rare in Ireland, with most winters remaining snow free.

6.5 Hydrogeology

Killeglan spring discharge is made up of a cluster of two springs (*Figure 19*). The main spring is called 'Tobermore' as it used as a drinking water supply. There is a smaller spring to the north of this. The overflow from both of these springs combines to form the Killeglan River, which is used for monitoring by the EPA (and used to calculate discharge values for this report). A third smaller spring, called Bellaneeny Spring outflows through Bellaneeny stream, 1.7 km to the south of Tobermore. There are more springs further south of this again. All these springs discharge into the River Suck 4 km to the west.

6.5.1 Surface hydrology

There are four main stream networks in the vicinity of Tobermore Spring. These are as follows:

1. Just north of Taghmaconnell, a stream rises in the townland of Bellaneeny. This stream flows west for approximately 4 km, to join the Killeglan River, which then discharges in the River Suck.
2. A stream network exists to the south of Taghmaconnell, in the townlands of Knock and Sraduff. These streams flow to a turlough in the townland of Glennanea. This turlough appears to take all the flow from the stream network. Another section of stream rises east of this network and then disappears after flowing approximately 1 km to the north-east.
3. An intermittent, seasonal stream is located to the east of the Tobermore Spring. This stream rises in the townland of Carrowduff and Garbally, and travels first north and then east. During wet weather the upper parts of the stream are flowing. Groundwater from the Tobermore Spring and discharge area joins this channel to form the head of the Killeglan River.
4. A small stream network is located in the townland of Esker. This stream network is recorded as having permanent flow but has no apparent surface water outlet. It is therefore likely that this area of surface water feeds into the groundwater system (Lee and Kelly, 2003).

To summarise, the majority of the outflow from this area is via the Killeglan River, which includes the Tobermore Spring discharge. A second smaller outflow is through the stream at Bellaneeny, south of the springs.



6.5.2 Groundwater Levels, Flow Directions and Gradients

The water level at Tobermore Spring is at ground level and the entire flat, low lying area around the spring is saturated and marshy. Tobermore Spring is located in a discharge area that comprises at least three other springs. Other springs also occur along the intermittent, seasonal stream, near the Tobermore Spring. The occurrence of springs and saturated ground in low-lying areas generally indicate a shallow water table. Water level surveying indicates the general features of the water table, such as the level, direction, and gradient. The contours are widely spaced which suggests high permeability. The flow directions interpreted from the map indicate that groundwater flows toward the springs from the south-east, east, north-east and north. The groundwater gradient calculated from the water table map is 0.0015 (Lee and Kelly, 2003).

6.5.3 Karst landforms

A brief karst mapping programme undertaken in the Killeglan area identified a large number of features. As previously mentioned these included enclosed depressions (dolines), swallow holes, sinking streams, springs and turloughs (*Figure 19*). There is also a seasonal stream that runs through the catchment (marked by linear strip of extreme vulnerability in *Figure 20*). Most of the catchment drains into a swallow holes, seasonal or sinking streams or turloughs. So far there are 9 springs, 7 turloughs, 45 enclosed depressions and 26 swallow holes (as well as other karst landforms) mapped within the catchment. The mapping also highlights the density of dolines and swallow holes along the path of the intermittent seasonal stream.

6.5.4 Dye tracing

Tracer testing was undertaken at three different locations within the catchment indicating minimum groundwater velocities of between 70m/hr and 110 m/hr. It also clearly demonstrates the direct and rapid link between most of the catchment and the springs.

6.5.5 Aquifer Category

The Undifferentiated Visean Limestone, which underlies the majority of the area, is classified as a Regionally Important Karstic Aquifer, that is dominated by conduit flow (Rkc). Development potential of the clean Waulsortian Limestone is considered to be limited by its massive nature, and is therefore categorised as a Locally Important Aquifer, that is moderately productive in local zones (LI) (*Figure 19*).

All of the Republic of Ireland's land surface is divided into nine aquifer categories, based on the hydrogeological characteristics and on the value of the groundwater resource. They are as follows:

Regionally Important (R) Aquifers

- Karstified bedrock (**Rk**)
- Fissured bedrock (**Rf**)
- Extensive sand & gravel (**Rg**)

Locally Important (L) Aquifers

- Karstified Bedrock (**Lk**)
- Sand & gravel (**Lg**)
- Bedrock which is Generally Moderately Productive (**Lm**)
- Bedrock which is Moderately Productive only in Local Zones (**LI**)



Poor (P) Aquifers

- Bedrock which is Generally Unproductive except for Local Zones (**PI**)
- Bedrock which is Generally Unproductive (**Pu**)

The Geological Survey's aquifer map distinguishes between limestones with and without a high degree of karstification. All limestone categories, depending on their permeability, storage capacity and areal extent, are categorised into Regionally Important (R); Locally Important (L); and Poor Aquifers (P). Regionally important limestone aquifers are subdivided into three categories. Where karstification is slight, the limestones are hydrogeologically similar to fissured rocks and are classed as Rf, although some karst features may occur. Aquifers in which karst features are more significant are classed as Rk. Within the range represented by Rk, two sub-types are distinguished, termed Rkc and Rkd (GSI, 2006; Hickey, 2018).

Rkc are those aquifers in which the degree of karstification limits the potential to develop groundwater resources. They have rapid flow velocities and a significant proportion of flow is concentrated in conduits focussed on large springs. Storage is low and locating areas of high permeability is difficult; therefore, groundwater development using bored wells can be problematical.

Rkd aquifers are those in which flow is more diffuse, storage is higher, there are many high yielding wells and the development of productive bored wells is less difficult. These areas may also have caves and large springs, but the springs flow regimes are less flashy than those in Rkc aquifers (GSI, 2008; Hickey, 2018).

6.5.6 Groundwater Vulnerability

All of the Republic of Ireland's land surface is divided into five groundwater vulnerability classes. 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/ EPA/GSI 1999). The vulnerability of groundwater depends on:

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 main vulnerability categories: **Extreme**, **High**, **Moderate** and **Low**, based on the geological and hydrogeological characteristics. A further sub-division of Extreme is for rock at or within 1 m of the land surface and around karst landforms (**X**). Further details of the hydrogeological basis for vulnerability assessment can be found in 'Groundwater Protection Schemes' (DELG/EPA/GSI, 1999).

The catchment area for Killeglan spring has a range of groundwater vulnerabilities, as very little bedrock outcrops, and more than 95% of the catchment has depths to bedrock of greater than 5 m and over half has subsoil thicknesses of greater than 10 m (*Figure 20*). Extreme vulnerability is mapped along sinking streams, the entire stream up-gradient of swallow holes, at enclosed depressions and swallow holes and at any area of shallow bedrock. This accounts for only 3-4% of the catchment area. High vulnerability occurs at areas overlain by high permeability subsoils or shallower bedrock. This accounts for over 50% of the catchment area. Moderate vulnerability

occurs at areas of thicker / less permeable subsoil, accounting for 33% of the catchment area, and low groundwater vulnerability occurs in areas overlain by greater than 10 m of low permeability subsoil. This accounts for approximately 8% of the catchment.

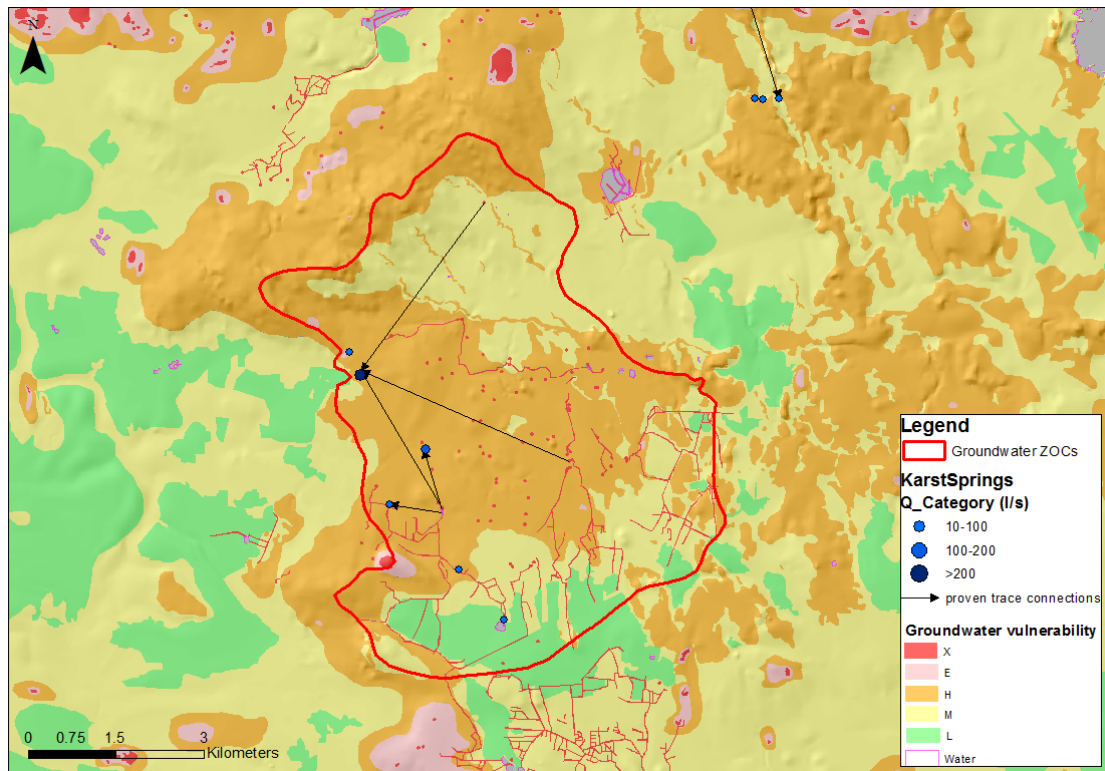


Figure 20: Groundwater Vulnerability for the Killeglan catchment and surrounding area

6.5.7 Groundwater Recharge

Groundwater recharge in the area is a combination of diffuse and point (through swallow holes, sinking streams and turloughs). A groundwater recharge map is available for the Republic of Ireland, which describes diffuse groundwater recharge. The main hydrogeological controls on groundwater recharge include the permeability and thickness of superficial deposits (mainly tills in Ireland), the presence of saturated soils, and the ability of the underlying aquifer to accept percolating waters. Combinations of these factors are assessed, and a 'recharge coefficient' is established for different hydrogeological scenarios. The groundwater recharge map is the result of the recharge coefficients multiplied by the effective rainfall. The recharge map is finally modified to take into account areas where the natural recharge capacity of the underlying aquifer is less than the estimated groundwater recharge potential (Hunter Williams et al., 2013). In karst areas additional point recharge can occur via swallow holes and sinking streams. This is not accounted for in the current groundwater recharge map.

Groundwater recharge in the Killeglan catchment area ranges from as little as 25 mm/yr, in areas of low permeability peat deposits, to over 560 mm/yr in areas where rock is at the surface, around influent karst landforms or areas of high permeability sand and gravel deposits (Figure 21). The majority of the catchment area has groundwater recharge rates of approximately 370 mm/yr. These values do not account for any inflow from sinking streams and influent karst landforms.



Figure 21: Groundwater Recharge in the Killeglan catchment and surrounding area

6.6 Hydrodynamic characteristics of the springs

Killeglan spring occurs in a discharge zone, made up of a cluster of medium sized karst springs. The overflow for Killeglan spring and some smaller springs to the north is monitored by the Environmental Protection Agency (EPA) as part of their long term Hydrometric monitoring network. The average discharge from the springs is approximately $0.5 \text{ m}^3/\text{s}$. The minimum discharge is $0.1 \text{ m}^3/\text{s}$, where the overflow dries up entirely and the maximum discharge is $2.4 \text{ m}^3/\text{s}$, though this is extremely rare (Figure 22). The amount abstracted by the drinking water source is unknown but is thought to be currently around $0.05 \text{ m}^3/\text{s}$. The supply is currently owned by Irish Water, Ireland's National water utility. They took over management of the spring in 2014 and upgraded the water treatment plant (Figure 23). Prior to this the customers on the scheme were on a 'boil water notice' since 2009 due to poor water quality. The drinking water abstraction in the past was approximately $0.1 \text{ m}^3/\text{s}$. It is not yet clear when the abstraction changed and the abstraction regime is not yet fully understood.

It is also not fully understood how much of the discharge comes from Tobermore Spring and how much from the group of smaller springs to the north. There are also four other springs located around the catchment – mostly to the south of Tobermore. There are sporadic discharge records for these springs.

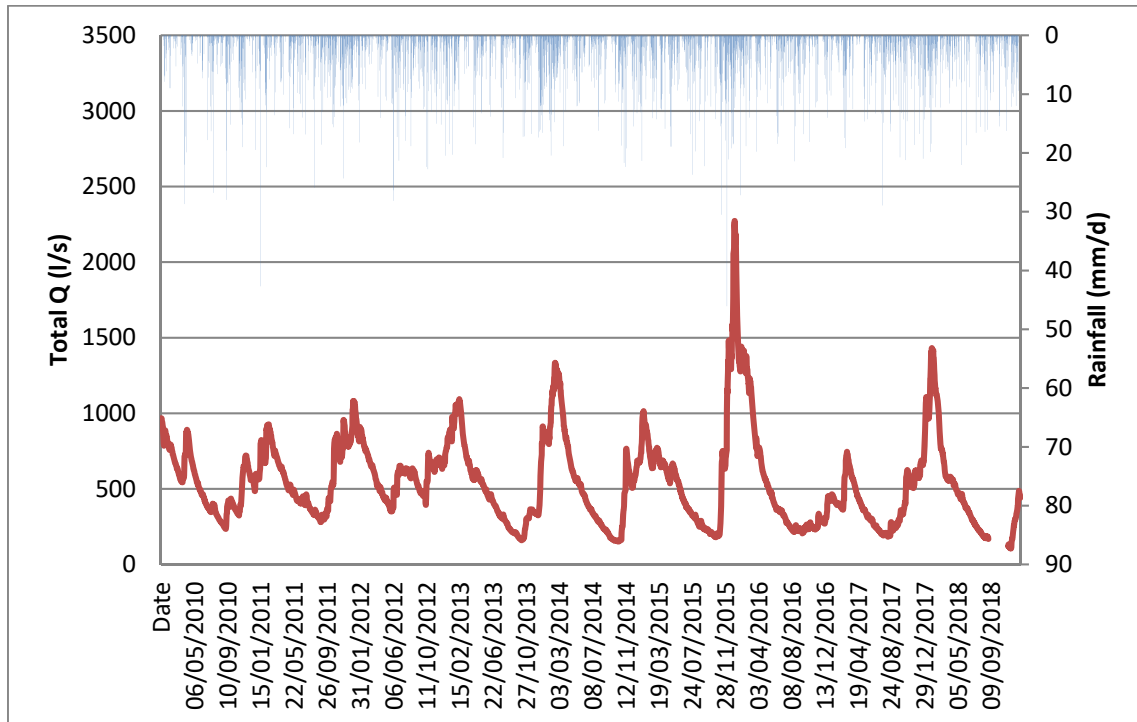


Figure 22: A sample hydrograph for Killeglan Spring plotted against daily rainfall values

As previously mentioned, the spring has had water quality issues and the water was not fit to drink for the 7,000 customers. A 'boil water notice' was in place from 2009 to 2015. The main water quality issues were mostly microbiological with consistent levels of coliforms and spikes of cryptosporidium and *Clostridium perfringens* in the supply. There were also some chemical exceedences. The water treatment was inadequate to deal with gross exceedences in raw water quality. It has since been upgraded with treated water now reaching the required standard (Figure 23).



Figure 23: Aerial view of the upgraded Killeglan Spring and drinking water treatment plant.

6.7 Data available for the project

The data and map layers presented in this report are available for the study area. Datasets such as aquifer classification, groundwater vulnerability, subsoil permeability and type, Quaternary data and recharge data are available at a 1:50,000 scale, bedrock data is available at 1:100,000 scale. Data in the karst landform database and the water tracing database are generally located to 10-50 m.

Spring discharge measurements for Tobermore Spring and the springs to the north, have been recorded since August 2001 and are currently ongoing (*Figure 22*). The readings are taken at 15 minute frequencies. There are some small data gaps in this record. It is monitored as part of the EPA hydrometric network. The EPA currently has 703 active stations, 603 of these have continuous water level monitoring and 20 of these are karst springs. As part of this programme, water quality samples are taken 2-4 times a year. There are only infrequent spot discharge measurements for the remaining, smaller springs in the catchment.

Existing water quality data dates back from November 1995 but these are spot measurements taken a few times a year. The spring was continuously monitored for water quality parameters between October 2009 to April 2012 (*Figure 24*). Temperature, specific conductivity, pH, dissolved oxygen and turbidity were recorded on an hourly basis. There is a question mark over the reliability of some of these data due to instrument drift (Tedd, 2013). More recently, the spring is managed by Glen Aqua for Irish Water. They have continuous hourly readings for EC, temperature, DO, pH and turbidity. They also monitor both the raw and treated water for



various microbiological and chemical parameters. The frequency of this monitoring is not yet understood, but it is at least once a month.

Killeglan Spring: Tobermore Spring and springs to the north			
Data type	Time step	Monitoring period	Time period
Discharge	15 mins	18 year	August 2001 - ongoing
Electrical conductivity	1 hour	6.7+ year (2.7 year and 4+ years)	Oct 2009 – April 2012 2015 - ongoing
Temperature, DO, pH, Turbidity	1 hour	6.7+ year (2.7 year and 4+ years)	Oct 2009 – April 2012 2015 - ongoing
Major anions/cations	2-5 times a year	11 year	June 1995 - 2006
Major anions/cations	12 times a year	4 year	2015 - ongoing
O, H stable isotopes			
TOC	2-5 times a year	9 years	June 1997 - 2006
TOC	12 times a year	4 year	2015 - ongoing

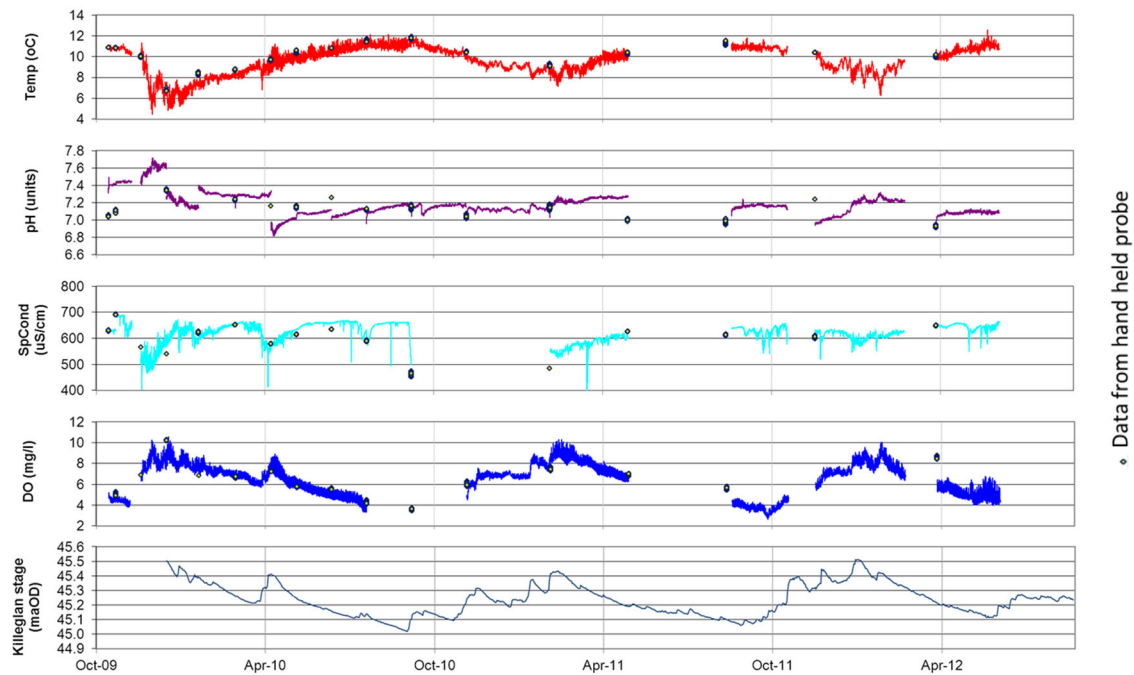


Figure 24 : Killeglan probe parameters plotted with stage (Tedd, 2013)



6.8 Summary

Pilot name	Killeglan Spring		
Country	Ireland	EU-region	Atlantic lowland
Area (km ²)	42	Lithology	Limestone
Short description: The Killeglan spring is situated in the low-lying central plain of Ireland. It is made up of a group of springs; the largest being used a drinking water supply for the region. The spring has had water quality issues due to poor bacteriological water quality and lack of adequate treatment.			
Monitored objects	springs		
Monitored data	Discharge, temperature, electrical conductivity, turbidity, major cation and anions		
Contact person	Caoimhe Hickey (Caoimhe.Hickey@gsi.ie)		

6.9 References

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