Castlerea Water Supply Scheme

Longford Spring and Silver Island Spring

Groundwater Source Protection Zones

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1 Introduction

There are a number of large springs in the vicinity of Castlerea. Longford Spring was developed in 1982 and is used to supply the Castlerea Rural Water Supply Scheme. Silver Island Spring (developed in 1938) supplies the Castlerea Urban Water Supply Scheme. The County Council initially requested a source protection zone report for the Longford Spring however, given the complexity of the geology in this area, these two springs are considered together.

The objectives of the report are as follows:

- To delineate source protection zone for the Longford and Silver Island Springs.
- To outline the principle hydrogeological characteristics of the Castlerea area.
- To assist Roscommon County Council in protecting the water supply from contamination.

2 Location, Site Description and Well Head Protection

The Longford Spring is located approximately 1.5 km south-south-east of Castlerea. It supplies the rural area around the town, extending down towards Ballintober.

The spring emerges from the bedrock and filters through gravel fill to collect in a circular sump (approximately 1 m diameter by 4 m deep). The sump is covered with concrete and is partially beneath the pump-house, from which water is pumped to the distribution system. A drainage channel takes the spring overflow from the spring sump.

The site area is fenced off from the surrounding field, which is used for grazing. The sump and part of the drainage channel are also fenced off within the site area. The drainage channel is frequently overgrown with weeds, as recorded on a number of site visits and reported by EPA personnel.

The Silver Island Spring is c.2 km east of Castlerea and supplies the Castlerea urban area. Like the Longford Spring, this spring also feeds into a concrete sump and then into the distribution system by gravity feed. The overflow from the spring discharges via the sump and ponds behind a concrete 'V'-notch weir. There appears to be a constant discharge over the weir.

The sump and pond areas are closed off from the surrounding grazing area by a fence and locked gate.

3 Summary of Spring Details

	Longford Spring	*Silver Island Spring*
GSI Number	1427SEW019	1727SWW089
Grid Reference (1:50,000)	16913 27832	17006 27973
Townland	Longford	Rathleg
Well Type	Spring	Spring
Owner	Roscommon County Council	Roscommon County Council
Elevation (ground level)	c.67 m	c.82 m
Depth to Rock	c.4 m	–
Sump Dimensions	1.2 m diameter by 4.25 m deep	–
Static Water Level	Ground level	Ground level
Normal Abstraction	2700 – 3200 m^3/d	c.1350 m^3/d
Estimated Total Discharge	5200 – 5700 m^3/d	c.2450 – 4400 m^3/d

4 Methodology

4.1 Desk Study

Details about the springs such as elevation and abstraction figures were obtained from GSI records and County Council personnel. Geological and hydrogeological information was provided by the GSI.

4.2 Site visits and fieldwork

This included depth to rock drilling, subsoil sampling and water quality sampling. Field walkovers were also carried out to investigate the subsoil geology, the hydrogeology and vulnerability to contamination.

4.3 Assessment

The analysis utilised field studies, previously collected data and hydrogeological mapping in order to delineate protection zones around the springs.

5 Topography, Surface Hydrology and Land Use

Castlerea is located in a relatively low-lying area. A number of springs, including the Longford and Silver Island Springs, emerge in this low-lying immediately east of Castlerea. An upland plateau area is situated approximately 3 km east and north-east of Castlerea, trending north-north-east to south-south-west. This area rises to approximately 140 m OD in the Castleteheen townland.

The River Suck flows southwards through Castlerea towards Ballymoe. A large number of tributaries of the Suck are located within the low-lying area, which generally have a north-west to south-east orientation.

Longford Spring discharges into an artificial drainage channel, which first flows south-west and then joins a north-west flowing river to eventually discharges into the River Suck, south of Castlerea. The Silver Island Spring also flows in a drainage channel, in a south-west direction. It then joins the Francis River, which flows north-west into Castlerea and discharges into the River Suck.

Three other springs have been recorded in close proximity to the Longford and Silver Island Springs (Figure 1). These comprise:

- the Poolacurragh Spring, which emerges as two springs in the Ardass townland and flows into the Termon River,
- 'Coran's Spring', situated in the Rathleg townland and discharging into the Termon River downstream of the Poolacurragh Spring, and
- 'New Spring', also located in the Rathleg townland and forming the head of the Francis River.

All five springs are situated along an approximate line trending north-east to south-west.

Approximately 1 km east of the springs the ground level starts to rise up into the plateau area. There is a noted absence of surface drainage in the entire plateau area, although there are two short stretches of permanent stream. One of these is known to disappear into a swallow hole.

Outside the Castlerea urban area, agricultural activity is the dominant land use with most of the land used for grazing. A number of houses and farmyards are located in the general area, and there is at least one small quarry.

6 Geology

An understanding of the geological material underlying the Castlerea area provides a framework for the assessment of groundwater flow and for source protection zones, as discussed in Sections 7 and 8.

6.1 Bedrock Geology

Bedrock information was taken from the Bedrock Geology 1:100,000 scale GSI map series, Sheets 12 (Geraghty et al, 1996) and from unpublished work undertaken by the Bedrock Section, GSI. The bedrock around the springs is shown in Figure 2.

The area to the east of the springs is underlain by Undifferentiated Visean Limestone. In this part of the county, this rock is generally described as pale grey, clean, medium to coarse-grained, bedded limestone.

Faulting has resulted in small areas of Waulsortian and Kilbryan Limestones occurring immediately west of the line of springs. The Waulsortian Limestones is a clean, pale grey massive limestone. The Kilbryan Limestone is described as limestone interbedded with calcareous shales, and strongly muddy limestone.

The line of springs is essentially adjacent the fault line (Figure 2).

Small areas of outcrop are recorded very close to Longford Spring and approximately 1 km east of Coran's Spring. A number of outcrops are also noted in the higher plateau area.

6.1.1 Karst Features

Karst mapping was undertaken in the Castlerea area during the summer 2000. As shown in Figure 2, the mapping identified an unusually large number of features. These included enclosed depressions (dolines), swallow holes, springs, dry valleys and superficial solution features (limestone pavement and karren). The mapping particularly highlights the density of dolines and swallow holes and the alignment of these features i.e. two lines of densely packed dolines and swallow holes are noted as trending north-west to south-east.

6.2 Subsoils

Subsoils mapping was undertaken by Dr. R. Meehan (Teagasc) to produce the Forest Inventory and Planning System – Integrated Forestry Information System (FIPS-IFS) Soils Parent Material Map (Figure 3). This information forms the basis for subsoil permeability assessments for the county (Lee and Daly, 2002). Further data was gathered from GSI drilling programmes (1999 and 2001).

The subsoils comprise a mixture of coarse and fine-grained materials. Peat is recorded in the low-lying area around Longford Spring and there is a sizeable area of alluvium which encompasses the remaining four springs. The alluvial material is deposited in the low-lying area around the Rivers Termon, Francis and Cloonard, which are in close proximity to each other at this location.

'Till' is the dominant subsoil type in the area and is generally described as an unsorted mixture of coarse and fine materials laid down by ice. There are 12 representative till samples within 3 km of the springs. Seven of these samples are described as CLAY (BS 5930), with the remaining five described as SILT (BS 5930). Seven samples have particle size distribution data (PSD), which are shown in Table 1 below.

Table 1. Till Sample Particle Size Distribution Data.

Sample	BS 5930 Description	Fines [i] (%)	Clay (%)	Comments
C1	SILT	42	12	Borderline PSD but BS 5930 test determined SILT.
C2	SILT	32	–	PSD supporting BS 5930 classification
SA029	SILT	31	9	PSD supporting BS 5930 classification.
BH075	CLAY	46	16	PSD supporting BS 5930 classification.
BH057	CLAY	39	15	PSD (especially CLAY content) supporting BS 5930 classification.
BH058	CLAY	40	–	Borderline PSD but BS 5930 test determined CLAY.
BH060	CLAY	42	–	Borderline PSD but BS 5930 test determined CLAY.

[i] The PSD percentages have been standardised where the maximum grain size is 20 mm.

Interestingly, samples SA029 and BH075 were taken at practically the same location although SA029 was taken at approximately 2 m below ground level (b.g.l.) and BH075 at 9.5 m b.g.l. The material from these samples was found to be significantly different, which is reflected in the BS 5930 descriptions and PSD. The shallower sample (SA029) was a reddy brown, very sandy SILT whilst the deeper sample was a very dense, dark grey, sandy CLAY. This change in material was also noted during the drilling of BH075, at approximately 2.5 m b.g.l.

Given the complex glacial history across mid Roscommon, it is likely that layers of till originating from one rock type (e.g. limestone) were subsequently overlain by till derived from a different rock type (e.g. sandstone). Subsequent deposition would also result in the compressing and compacting of the original layers of till, which was evident during drilling.

6.2.1 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.

The available data indicate that the depth to rock ranges from 0 m (outcrop) to approximately 10 m. In general, the low-lying area immediately around the springs appears to be close to bedrock. Moving eastwards, the subsoils become thicker however, as the ground rises up to the plateau area, the subsoils become thinner again. The entire plateau area is considered to have relatively thin subsoil (<3 m).

6.3 Groundwater Vulnerability

The concept of vulnerability is discussed in the Roscommon Groundwater Protection Scheme Main Report (Lee and Daly, 2002). The vulnerability classifications for this region are shown in Figure 4 [1].

The till in this region are either described as CLAY or SILT (BS 5930) with the available grain size distributions generally supporting the descriptions. These materials are categorised as having either a ‘low’ or ‘moderate’ permeability respectively.

At one location, approximately 2 m of more permeable SILT were recorded over at least 8 m of less permeable, dense CLAY (SA029 and BH075; Section 6.2). In this instance the greater thickness of less permeable material will dictate the resultant permeability of the total depth of subsoil. Therefore this material is considered to have an overall ‘low’ permeability.

[1] The permeability estimations and depth to rock interpretations are based on regional-scale evaluations. The mapping is intended only as a guide to land use planning and hazard surveys, and is not a substitute for site investigation for specific developments. Classifications may change as a result of investigations such as trial hole assessments for on-site domestic wastewater treatment systems.

Where subsoil thickness is greater than 3 m, the vulnerability classification ranges from 'moderate' to 'high', depending on the specific combination of permeability and subsoil thickness.

At subsoil thickness of less than 3 m, as indicated by the outcrop, subcrop and drilling data, bulk permeability becomes less relevant in mapping vulnerability across wide areas (as opposed to specific sites). This is because infiltration is more likely to occur through 'bypass flow' mechanisms such as cracks in the subsoil. Based on the general depth to bedrock, a vulnerability classification of 'extreme' has been assigned in areas of shallower subsoil.

Several types of karst feature (e.g. dolines, swallow holes) provide locations of point recharge i.e. surface water can infiltrate directly to the bedrock, by-passing any attenuation capacity of the subsoil. These locations are therefore classified as 'extremely' vulnerable, which includes an arbitrary buffer of 30 m.

7 Hydrogeology

7.1 Introduction

This section presents the current understanding of groundwater flow near the Castlerea Rural and Urban Water Supply Schemes. The interpretations and conceptualisations of flow are used to delineate source protection zones around the Longford and Silver Island Springs.

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

- GSI databases.
- GSI multiple dye tracer testing.
- GSI geophysical investigation.
- Roscommon County Council hydrochemistry data.
- Field work (flow gauging, drilling, subsoil sampling, water quality sampling).

7.2 Meteorology and Recharge

The term 'recharge' refers to the amount of water replenishing the groundwater flow system. The recharge rate is generally estimated on an annual basis, and assumed to consist of input (i.e. annual rainfall) less water losses prior to entry into the groundwater system (i.e. annual evapotranspiration and runoff). The estimation of a realistic recharge rate is important in source protection delineation, as it can be used to estimate the size of the zone of contribution (i.e. the outer source protection area). The calculations are summarised in Table 2 below.

Table 2. Estimate of Recharge.

Parameter	Amount (mm/yr)	Data Source
Annual rainfall	1080	Average annual rainfall 1961 – 1990 (Met Éireann, 1996).
Annual evapotranspiration	388	Potential evapotranspiration (PE) is estimated as 408 mm/yr (Met Éireann data). Actual evapotranspiration (AE) is estimated as 95% of PE.
Potential recharge	692	Rainfall minus AE. Estimation of the excess soil moisture available for either flow to groundwater, or soil quickflow and overland flow to surface water.
Runoff losses	104	Assumed as 15% of potential recharge. Based on: • Negligible runoff over 80% of the area – high proportion of outcrop and subcrop, also shown by the lack of surface streams; • 80% runoff over 20% of the area due to thicker, less permeable subsoil.
Estimated Recharge	588	

7.3 Groundwater Direction and Flow Paths

All five springs emerge in flat, low-lying areas, which are generally marshy. A high density of artificial drainage is required in these areas in order to utilise the land, which is mainly grazed. There is also a high natural drainage density in the low-lying area around Castlerea. The emergence of springs and higher natural and artificial drainage densities generally indicate a shallow water table.

The GSI undertook a multiple tracer testing in the Castlerea area in November 2000. Dye was injected into four swallow holes located in the higher plateau area, east of the Longford and Silver Island Springs. Nine springs, including the Longford and Silver Island Springs, and two rivers (including the River Suck) were sampled (Figure **1**).

The results of the tracer test show that dyes from all of the swallow holes were detected. Figure **1** shows that the groundwater from the Mewlaghmore, Southpark Demesne and Lissalway swallow holes flow in a westerly direction towards the five springs including the Longford and Silver Island Springs. Groundwater from the Knocklegan swallow hole flows in a north-easterly direction and was detected in St. Luke's well and St. Elvia's well.

The established connections between the springs and swallow holes suggest that the direction of groundwater flow is complicated and thus not easy to predict. This is due to the karstic nature of the bedrock, where particular fissures/conduits are likely to locally dictate the flow directions under specific flow conditions.

All of the dyes were detected at the various springs one to two days after injection, indicating minimum groundwater velocities of between 67 m/hr and 107 m/hr (Table 3).

Table 3. Castlerea Multiple Tracer Test Results.

Injection Point (Swallow Hole)			**Detection Location**	**Estimated Groundwater Velocity (m/hr)**
GSI Number	***Townland***	***Grid Reference***		
1727SWK016	Mewlaghmore	17337 27874	Longford Spring	107
			New Spring	93
			Silver Island Spring	94
			Coran's Spring	92
1727SWK073	Southpark Demesne	17266 27948	New Spring	76
			Silver Island Spring	69
			Coran's Spring	67
			Poolacurragh Spring	61
1727SWK145	Lissalway	17397 27956	Silver Island Spring	106
			Coran's Spring	106
			Poolacurragh Spring	94
1727SWK169	Knocklegan East	17573 27805	St Luke's Well	75
			St Elvia's Well	90

Dye was not detected in two of the springs or the rivers monitored. Although these 'negative' results are not conclusive, they do suggest that the swallow holes are not connected to these springs and rivers under the flow conditions at the time of testing.

Further to the multiple tracer test, a geophysical investigation (microgravity survey) was undertaken in the Castlerea area (McGrath, 2001). It was thought that the investigation would help to determine whether groundwater is flowing in solutionally enlarged conduits, as suggested by the rapid groundwater velocities recorded in the tracer test. The investigation focussed on five transects (Figure **1**) and the results are outlined below:

1. ***Longford Spring:*** two large conduits are inferred by the results.
2. ***East of Longford Spring:*** results mainly suggest one large conduit.
3. ***Silver Island Spring:*** results indicate one large, circular conduit.
4. ***Mewlaghmore Swallow Hole:*** results indicate a large deep conduit overlain by smaller conduits.
5. ***North of Mewlaghmore Swallow Hole:*** results are inconclusive.

7.4 Aquifer Characteristics

The Undifferentiated Visean Limestone provides the groundwater to the Longford and Silver Island Springs. Both springs are considered have a high yield and are located in a low-lying discharge area that comprises at least three other springs.

A large karst network probably underlies the source and causes the water to concentrate in the spring and low-lying discharge area. Bedrock is close to the surface near the Longford Spring.

Karstification is an important process in Irish hydrogeology. It involves the enlargement of rock fissures when groundwater dissolves the fissure walls as it flows through them. The process can result in significantly enhanced permeability and groundwater flow rates. It generally occurs in 'cleaner' limestones. The large number of densely packed swallow holes and dolines provide evidence for significant karstification in the Castlerea area. The results of the tracer tests and geophysical investigation also indicate a high degree of karstification.

The tracer tests recorded minimum groundwater velocities of between 67 m/hr and 107 m/hr. These flow rates depend on several factors including topography, rainfall and groundwater levels. However, such high velocities are characteristic of flow in karstified limestone aquifers.

The bedrock in the Castlerea area is likely to be characterised by:

- groundwater flow in solutionally-enlarged bedding plane partings, joints, faults and conduits;
- high groundwater velocities, several orders of magnitude greater than in granular (sand/gravel) aquifers;
- concentration of groundwater flow into zones of high permeability;
- a combination of diffuse and point (through swallow holes, dolines) means of recharge;
- irregular or poorly connected water table;
- often extreme vulnerability to contamination due to point recharge by-passing the potential attenuation capability of the subsoil;
- minimal attenuation of contaminants, except by dilution;
- high turbidity, suspended solids and colour after heavy rain, particularly in the autumn;
- short response times when pollution incidents occur.

7.5 Aquifer Category

The Undifferentiated Visean Limestone, which underlies almost the entire area, is classified as a Regionally Important Karstic Aquifer, which is characterised by conduit flow (**Rk^{c}**).

Although a clean limestone, the development potential of the Waulsortian rock is considered to be limited by its massive nature. The high clay content and shale layers in the Kilbryan Limestone are thought to inhibit groundwater flow. These rocks are therefore categorised as Locally Important Aquifers, which are moderately productive in local zones (**Ll**).

The derivation of these classifications is presented in the County Roscommon Groundwater Protection Scheme Main Report (Lee and Daly, 2002).

7.6 Hydrochemistry and Water Quality

The available water quality data for the Longford and Silver Island Springs are from Roscommon County Council drinking water returns for 1999 to 2001. These samples are collected as part of the Rural Water Quality Monitoring Programme. The EPA biannual data (1997 – 2001) was also included in this assessment as were two sampling rounds undertaken by the GSI (February and September 2001). A summary of the more relevant results (i.e. those which exceed thresholds or reflect the natural water quality) are given in Table 4 below.

Table 4. Summary Water Quality Data

Parameter	Longford Spring				Silver Island Spring			
	No. Samples	*Min*	*Max*	*Ave*	*No. Samples*	*Min*	*Max*	*Ave*
Hardness (mg/l $CaCO_3$)	8	258	384	339	6	328	396	364
Conductivity (µS/cm)	24	511	763	659	19	481	751	632
Faecal Coliforms (counts/100 ml)	25	0	**1190**	**118**	21	**1**	**1560**	**250**
Sodium:Potassium Ratio	8	0.21	**0.38**	0.29	6	0.13	**0.42**	0.31
Nitrates (mg/l)	21	4	12	7	17	4	9	6
Phosphates (mg/l)	23	0.01	**0.08**	**0.03**	19	0.01	**0.05**	**0.03**
Iron (mg/l)	20	0	**0.22**	0.05	16	0	**0.20**	0.05
Turbidity (NTU)	21	0	**6.8**	1.3	18	0	4.1	1.1

The hydrochemical analyses suggest that both of the springs have water with hard to very hard (250 – >350 mg/l $CaCO_3$) calcium-bicarbonate hydrochemical signatures. Both springs have similar conductivity values, which ranges from 480 µS/cm to 765 µS/cm (averaging 647 µS/cm).

Table 4 shows that faecal coliforms are consistently present in the raw water samples from both springs and exceed the EU Drinking Water Directive maximum admissible concentrations (MAC). There are greater than 10 faecal coliforms per 100 ml in 80% of both the Longford the Silver Island raw water samples. This level is considered to be gross contamination (Keegan *et al*., 2002).

The level of iron ranges from 0 – 0.22 mg/l in both springs. The results show that iron exceeds the MAC (0.20 mg/l) once in September 1998 at the Silver Island Spring and once in November 1999 in the Longford Spring. If iron levels are not attributed to the influence of bedrock, as with the Castlerea area, they can indicate effluent from organic wastes.

The sodium potassium ratios (Na:K) range from 0.13 – 0.42 (averaging 0.30) in 14 samples from both springs. One of the eight Longford samples and two of the six Silver Island samples exceed the GSI threshold (0.35). Elevated Na:K ratios suggest that farmyard waste, rather than septic tanks, are likely the source of organic wastes.

Nitrate levels range from 4 mg/l – 12 mg/l. These values are beneath the MAC and GSI threshold and there does not appear to be any obvious seasonal variability, or apparent upward trend in the dataset.

7.7 Discharge Estimates

There are no long-term data for the springs in the Castlerea area. However, the County Council occasionally measured flows from the Longford and Silver Island Springs between 1966 and 1973. Flows from New Spring, Coran's Spring and Poolacurragh Spring were estimated during a karst mapping programme, which was undertaken during 2000 by the GSI. The estimated discharge values, including approximate abstractions, are given below:

Longford Spring:	5200 – 5700 m^3/d
Silver Island Spring:	2450 – 4400 m^3/d
New Spring:	3850 m^3/d
Coran's Spring:	4600 – 6400 m^3/d
Poolacurragh Spring:	2200 m^3/d

7.8 Conceptual Model

- The higher plateau area to the east of Castlerea is underlain by Visean Limestone and has a noted absence of surface streams. The lack of surface drainage suggests that potential recharge readily infiltrates into the groundwater system.
- The clean Visean Limestone in the region has undergone significant karstification, shown by the high number of densely packed dolines, swallow holes, springs and dry valleys. Tracer test results also infer that the karst is well developed.
- The tracer test identified two distinct flow directions: westwards from the swallow holes on the western side of the plateau area (Mewlaghmore, Southpark Demesne and Lissalway) and eastwards from the swallow hole on the eastern side plateau area (Knocklegan). These results indicate that the groundwater divide in the plateau area is topographically controlled.
- With regard to the Castlerea Schemes, the groundwater appears to move from the higher portion of the catchment (plateau area), through the Visean Limestone, to the lowest point in the catchment. At this location, some of the groundwater emerges at the surface as one of five springs, which include the Longford and Silver Island Springs.
- The significantly less permeable Kilbryan and Waulsortian Limestones border the Visean Limestone to the west. This boundary is very close to the line of springs. It is possible that the change in bedrock is part of the reason why the springs emerge at this particular location.
- Given the degree of karstification in the Visean Limestone, groundwater is likely to flow along interconnected, solutionally enlarged fractures and pronounced joints that exist in these rocks. The results of the tracer test and the geophysical investigation possibly reflect some of the larger conduits.
- The precise pathways of groundwater flow are not known. However the established connections identified by the tracer test highlight the complexity of potential flow paths through the limestone.
- Groundwater velocities through the Visean Limestone are high (minimum of 67 m/hr).
- Both diffuse and point recharge occurs in this area. Swallow holes and dolines provide the means for point recharge. The subsoil over 80% of the area are relatively thin (<3 m) and therefore probably allow a high proportion of recharge to occur through them. Subsoil over the remaining area is thicker and is categorised as 'low' permeability. Thus a smaller amount of recharge is likely to be occurring through them.
- The point recharge allows the springs to respond rapidly to rainfall. The tracer test results recorded a response time of one to two days for the various springs.

8 Delineation Of Source Protection Areas

8.1 Introduction

This section delineates the areas around the spring that are believed to be contributing groundwater and that therefore require protection. The delineated areas are based on the conceptualisation of the groundwater flow pattern, as described in Section 7.8 and are presented in Figure **1**.

Two source protection areas are delineated:

- Inner Protection Area (SI), designed to give protection from microbial pollution.
- Outer Protection Area (SO), encompassing the zone of contribution (ZOC) of the source.

8.2 Outer Protection Area

The Outer Protection Area (SO) is bounded by the complete catchment area to the source, i.e. the zone of contribution (ZOC), and is defined as the area required to support an abstraction from long-term recharge. The ZOC is controlled primarily by a) the total discharge, b) the groundwater flow direction and gradient, c) the rock permeability and d) the recharge in the area.

Although relatively good hydrogeological data exists for the Castlerea area, the underlying aquifer is karstified. Groundwater flow through karst areas is extremely complex and difficult to predict. Flow velocities are relatively fast and variable, both spatially and temporally. Catchment areas are often difficult to define and they may change seasonally. Consequently, some uncertainty generally exists when delineating boundaries in karst areas.

The ZOC has been defined for all five springs, which includes the Longford Spring and Silver Island Spring. The reason for this is that the springs share, at least in part, the same catchment area. Given the available data, it is impossible to define the precise zone for each individual spring.

The shape and boundaries of the ZOC were determined using hydrogeological mapping, including tracer testing, and the conceptual model. The boundaries and the uncertainties associated with them are as follows:

1. The **Eastern Boundary** is complicated although is primarily based on the topographic divide on the higher plateau area. The boundary divide includes catchment areas for the Mewlaghmore, Southpark Demesne and Lissalway swallow holes.

   The boundary also includes the catchment area for the densely packed lines of dolines and swallow holes, which extend to the townland of Knocklegan West. These features appear to form a network, which includes the Southpark Demesne swallow hole. Given the likely interconnects between different dolines and swallow holes, it is possible that point recharge occurring through these features is also contributing to the discharge at the springs.

   Two streams are recorded in this area, in the townlands of Castleteheen and Knocklegan East. Both flow eastwards, towards the Castleplunket – Ballintober road and one disappears into the Knocklegan swallow hole. The catchment boundaries for these streams share their western boundary with the ZOC boundary.

2. The **North-Eastern Boundary** is defined as the topographic catchment for the Lissalway swallow hole. It is possible that groundwater could flow to the springs from beyond this boundary. However given the data available, additional groundwater flow directions in this area cannot be determined. Therefore a more accurate north-eastern boundary cannot be delineated.

3. The **Northern Boundary** is determined by a ridge running from the Lissalway townland through Carradooan, and down to the Ardass townlands. Outcrop is recorded through the main part of the ridge between Lissalway and Ballymulrennan, which suggested that the ridge is bedrock cored.

4. The **Southern Boundary** is also defined by a topographic ridge which passes through the townlands of Lisliddy, Carrowmore, Carrowkeel, Listhomasroe and Bohagh. This boundary also represents the northern catchment boundary for the stream to the south.

5. For the **Western Boundary** it is assumed that water down-gradient of the springs will not flow back to contribute to their discharge. Therefore this boundary delineates the groundwater flow down-gradient of the springs, which will be outside the ZOC. It is based on the direction of flow suggested by the tracer tests and the general trend of surface drainage patterns (i.e. south-east to north-west). An arbitrary buffer of 30 m down-gradient of the springs is incorporated into this boundary.

These boundaries delineate the physical limits within which the ZOC is likely to occur. The area constrained by the hydrogeological mapping is approximately 12 km^2.

The available discharge data (Section 7.7) are not comprehensive enough to undertake a water balance and thus accurately estimate the catchment area for the total discharge from the springs. However, an approximation of the averaged discharge data and recharge data (Section 7.2) indicate that the delineated catchment area is large enough to support the discharge from the springs.

8.3 Inner Protection Area

According to the National Groundwater Protection Scheme (DELG/EPA/GSI, 1999), delineation of an Inner Protection Area is required to protect the source from microbial and viral contamination and it is based on the 100 day time of travel to the supply.

The tracer tests carried out by the GSI recorded rapid groundwater velocities in the Visean Limestone (minimum 67 m/hr), which essentially covers the entire ZOC. Given this minimum velocity, the groundwater can possibly reach the spring from any point in the ZOC within 5 days.

It is therefore likely that all groundwater within the delineated catchment could reach the source in less than 100 days. These data suggest that the entire ZOC should be incorporated into the Inner Protection Area.

9 Groundwater Protection Zones

The groundwater protection zones are obtained by integrating the source protection areas and vulnerability categories – giving a possible total of 8 source protection zones (see Table 5). In practice, this is achieved by superimposing the vulnerability map (Figure 4) on the source protection area map. Each zone is represented by a code, e.g. **SI/H**, which represents an <u>Inner Source Protection area</u> where the groundwater is <u>highly</u> vulnerable to contamination. All of the hydrogeological settings represented by the zones may not be present around any given source. Three groundwater protection zones are present around the Longford and Silver Island Springs (Figure 5), as shown in the matrix below.

Table 5. Matrix of Source Protection Zones.

VULNERABILITY	**SOURCE PROTECTION**	
RATING	***Inner***	***Outer***
Extreme (E)	SI/E	na
High (H)	SI/H	na
Moderate (M)	SI/M	na
Low (L)	na	na

10 Potential Pollution Sources

There are a number of houses and farmyards within the ZOC. Some of these are located 750 m immediately up-hill of the Longford and Silver Island Springs. Agriculture in the main land use in the area, which is dominated by pasture. There is also at least one small-scale quarry in the ZOC.

The hydrochemical data mainly highlights consistently elevated levels of total and faecal coliforms in raw water samples. Analysis of the other indicator parameters suggests that at least one of the sources of this contamination is likely to be organic waste, possibly from farmyard wastes.

The main hazards associated within the ZOC are therefore considered to be agricultural (farmyards leakage, landspreading) and domestic, such as on site treatment systems (septic tanks). The location of these activities in any part of the ZOC categorised as 'extremely' vulnerable presents a potential risk, given rapid travel time through the underlying bedrock.

A more specific issue has been noted at the Longford Spring pump house. If there is excessive plant growth in the overflow channel, it impedes flow away from the sump. It was also noted that the gate to the outer field was open on several occasions, thereby allowing any livestock to enter the pump house site area. It is therefore possible that the sump is susceptible to surface contamination via the backed-up overflow re-entering the sump.

Detailed assessments of hazards have not been carried out as part of this study.

11 Conclusions and Recommendations

- The Castlerea Urban (Silver Island Spring) and Rural (Longford Spring) Schemes are located in, and predominantly supplied by, the Undifferentiated Visean Limestone.
- In the Castlerea area the Visean Limestone aquifer is highly karstified, as illustrated by the high number of densely packed karst features, the tracer test results and the geophysical investigation results.
- The ZOC has been delineated for the five springs, including Longford and Silver Island Springs. This approach is necessary due to the complicated nature of groundwater flow in this area of karstified rock, as shown by the available data.
- Due to the rapid groundwater velocities, it is considered that groundwater within any part of the ZOC could potentially reach the spring within 100 days. Therefore the entire ZOC should be classified as the Inner Protection Area.
- There are no recent flow data from the Longford and Silver Island Springs. Flow data from these springs would indicate whether further abstractions could be made, especially during summer months. Additional flow data for the remaining three springs would highlight whether they have consistent discharges throughout the year. These data could also be used in a water balance to accurately determine the area required to supply the springs. This could then be compared to the ZOC delineated by hydrogeological mapping.
- The groundwater in the Protection Area is 'extremely' to 'moderately' vulnerable to contamination.
- At Longford Spring, the sump may be susceptible to surface contamination due to possible access by livestock and the overgrown drainage channel causing the overflow to back up to the sump.
- The protection zones delineated in this chapter are based on our current understanding of groundwater conditions and on the available data. Additional data obtained in the future may indicate that amendments to the boundaries are necessary.

- It is recommended that:
  - the sump and pump house area at Longford Spring be adequately maintained to minimise the risk of inundation by surface contamination at the source. Specifically, the overflow channel needs to be frequently cleared of vegetation to prevent backing up of water to the sump. Also the gate to the pump house area should be closed at all times to prevent livestock gaining access to this area.
  - given the close proximity of farmyards and houses up-hill of both the Silver Island and Longford Springs, all potential hazards in the ZOC should be located and adequately assessed.
  - frequent and consistent flow monitoring be undertaken at the Longford and Silver Island Springs. It would be also be very useful if flow from the remaining three springs (New, Coran's and Poolacurragh) were measured. If appropriate, these flows may have development potential for augmentation purposes.
  - further tracer tests be undertaken within and outside of the ZOC. This would increase our understanding of the groundwater flows in this area. Such information may aid delineation of the specific areas contributing to individual springs.
  - the present chemical and bacteriological analyses of raw water should be continued. The chemical analyses should include all major ions – calcium, magnesium, sodium, potassium, ammonium, bicarbonate, sulphate, chloride, and nitrate.

12 References

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Lee M. and Daly D. (2002). *County Roscommon Groundwater Protection Scheme Main Report*. Geological Survey of Ireland. Unpublished.

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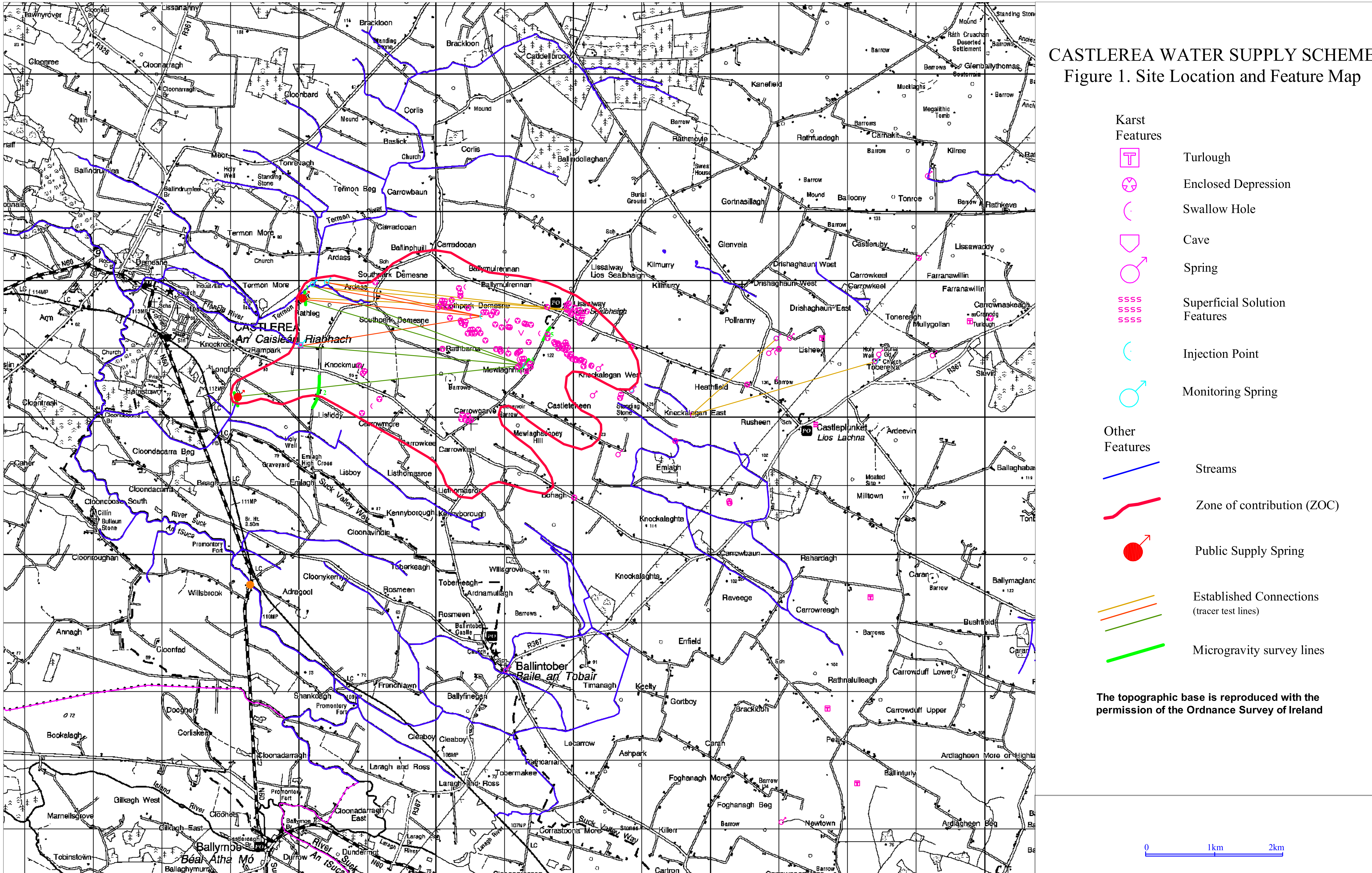
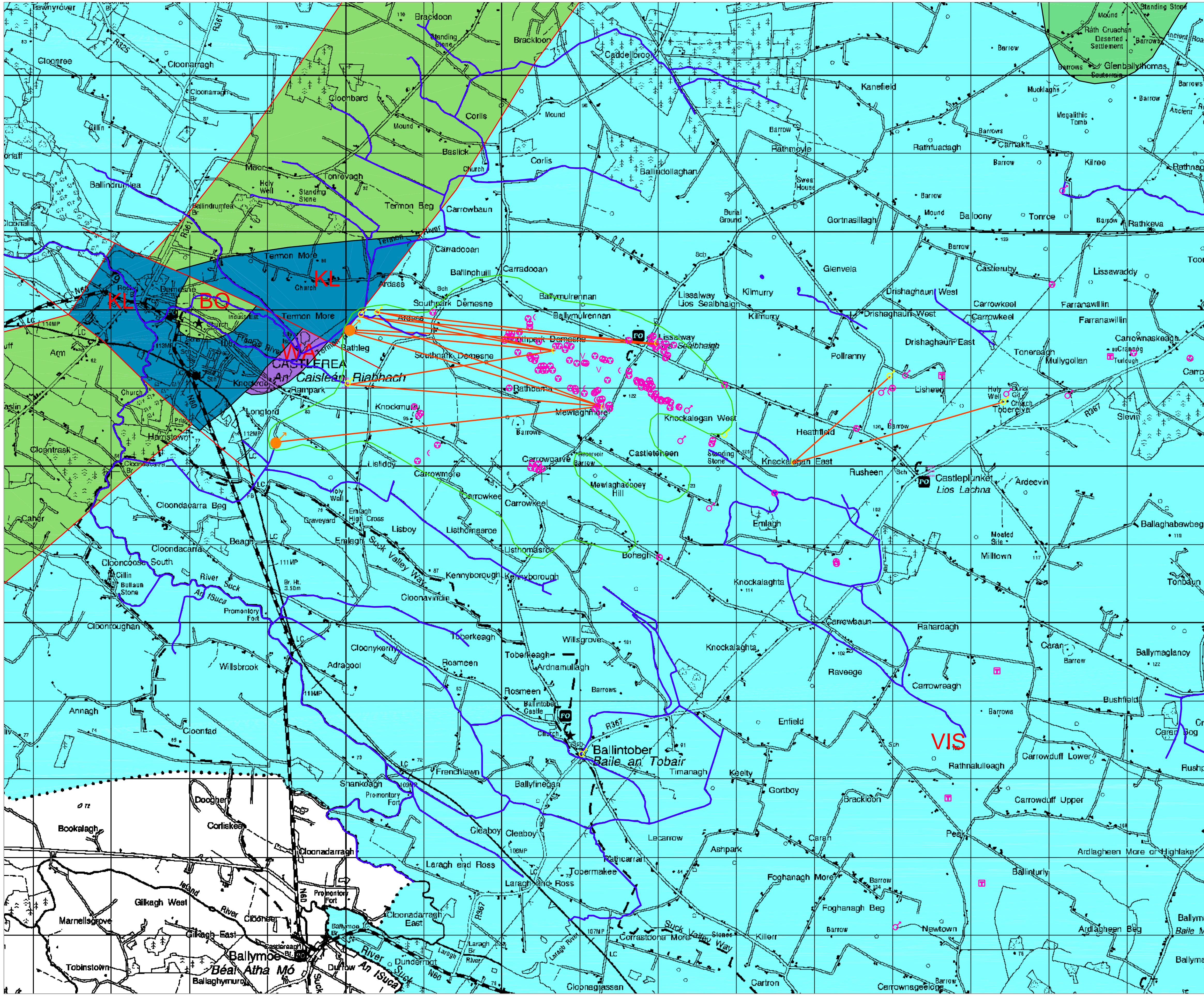


CASTLEREA WATER SUPPLY SCHEME

Figure 1. Site Location and Feature Map



CASTLEREA WATER SUPPLY SCHEME

Figure 2. Geology Map

VIS	Visean Limestone (undifferentiated)	Generally poorly exposed. Likely to comprise units of clean and muddy limestones north of Tulsk. Likely to comprise clean limestone south of Tulsk.
KL	Kilbryan Limestone Formation	Dark nodular calcarenites and shales
BO	Boyle Sandstone Formation	Sandstone and red green conglomerates
WA	Waulsortian Limestones	Massive unbedded Lime-mudstone

Streams

Established Connections
(tracer test lines)

Karst Features

Zone of Contribution

Fault

Public Supply Spring

Geological Contact

This **bedrock map** is designed for general information and strategic planning usage. The boundaries are based on the available evidence and local details have been generalised to fit the map scale. Evaluation of specific sites and circumstances will normally require further and more detailed assessments and will frequently require site investigations.

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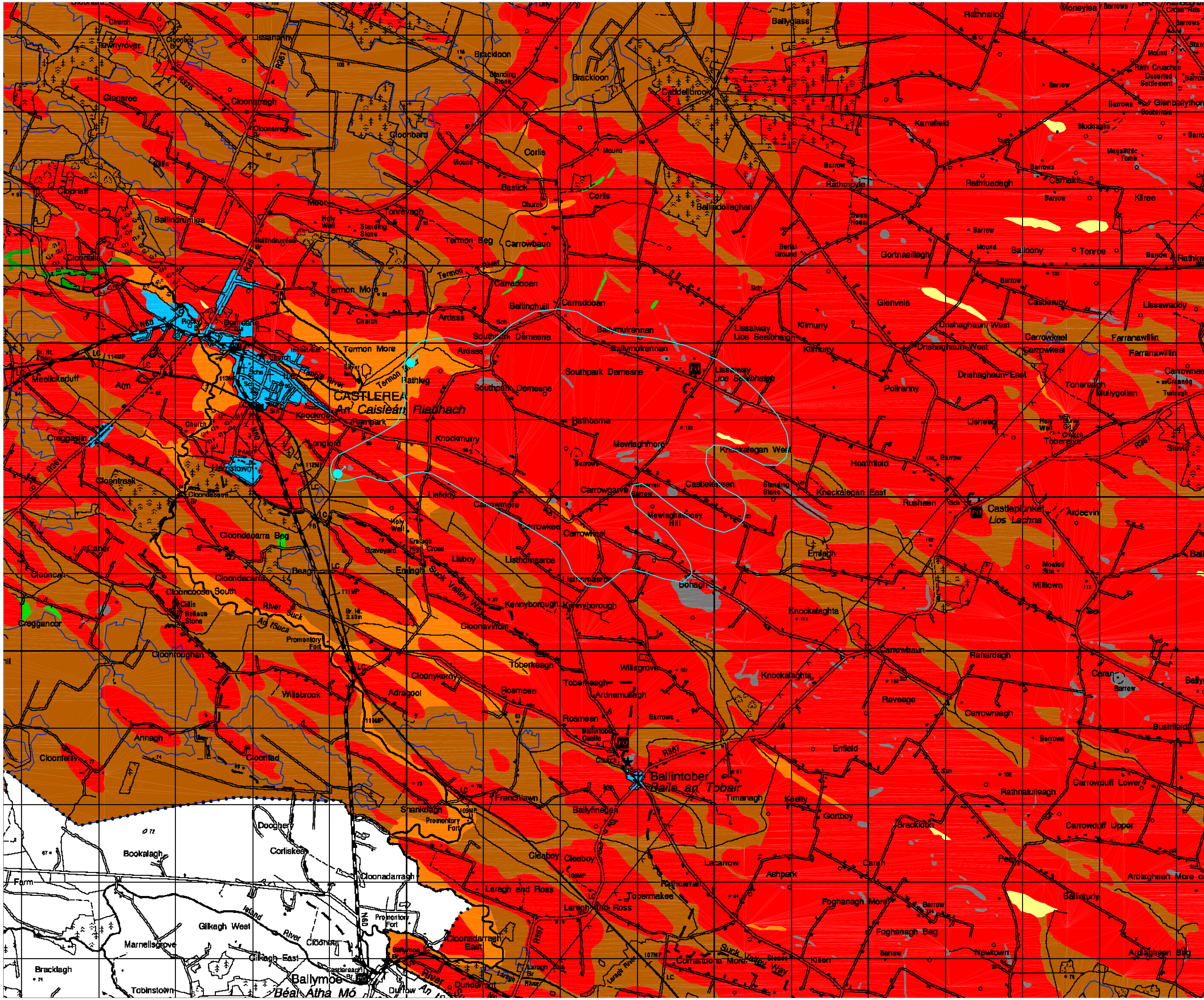
0 1km 2km

CASTLEREA WATER SUPPLY SCHEME

Figure 3. Subsoils Map



	Alluvium undifferentiated
	Peat
	Sands and Gravels
	Lake Sediments
	Lake
	Made or built ground
	Rock outcrop or subcrop
	Tills

Cut peat boundaries used for Vulnerability map

Zone of Contribution

Public Supply Spring

Sources of Information

"FIPS-IFS Soil Parent Material Map" Compiled by R. Meehan (Teagasc).

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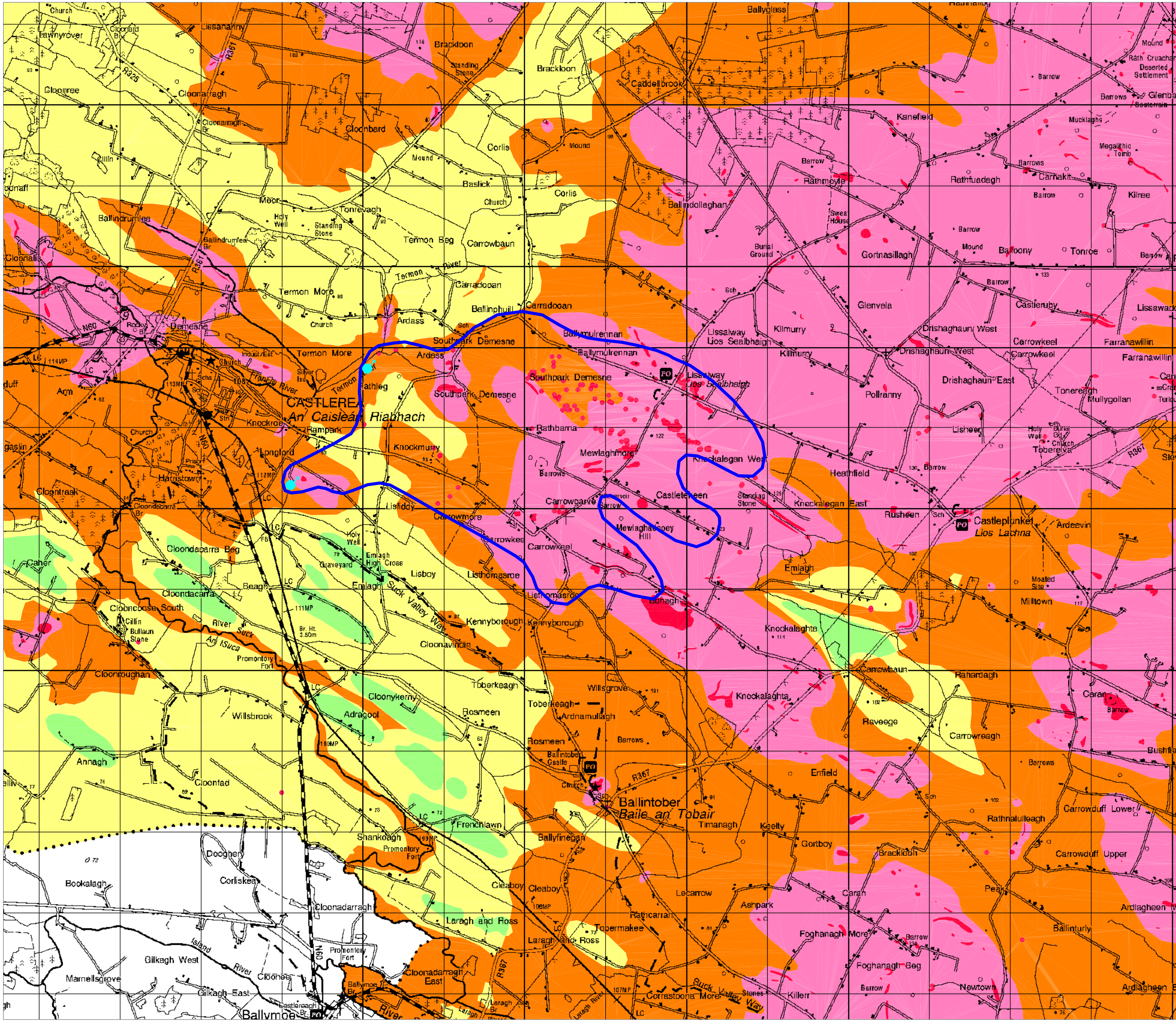
0 1km 2km

CASTLEREA WATER SUPPLY SCHEME

Figure 4. Vulnerability Map



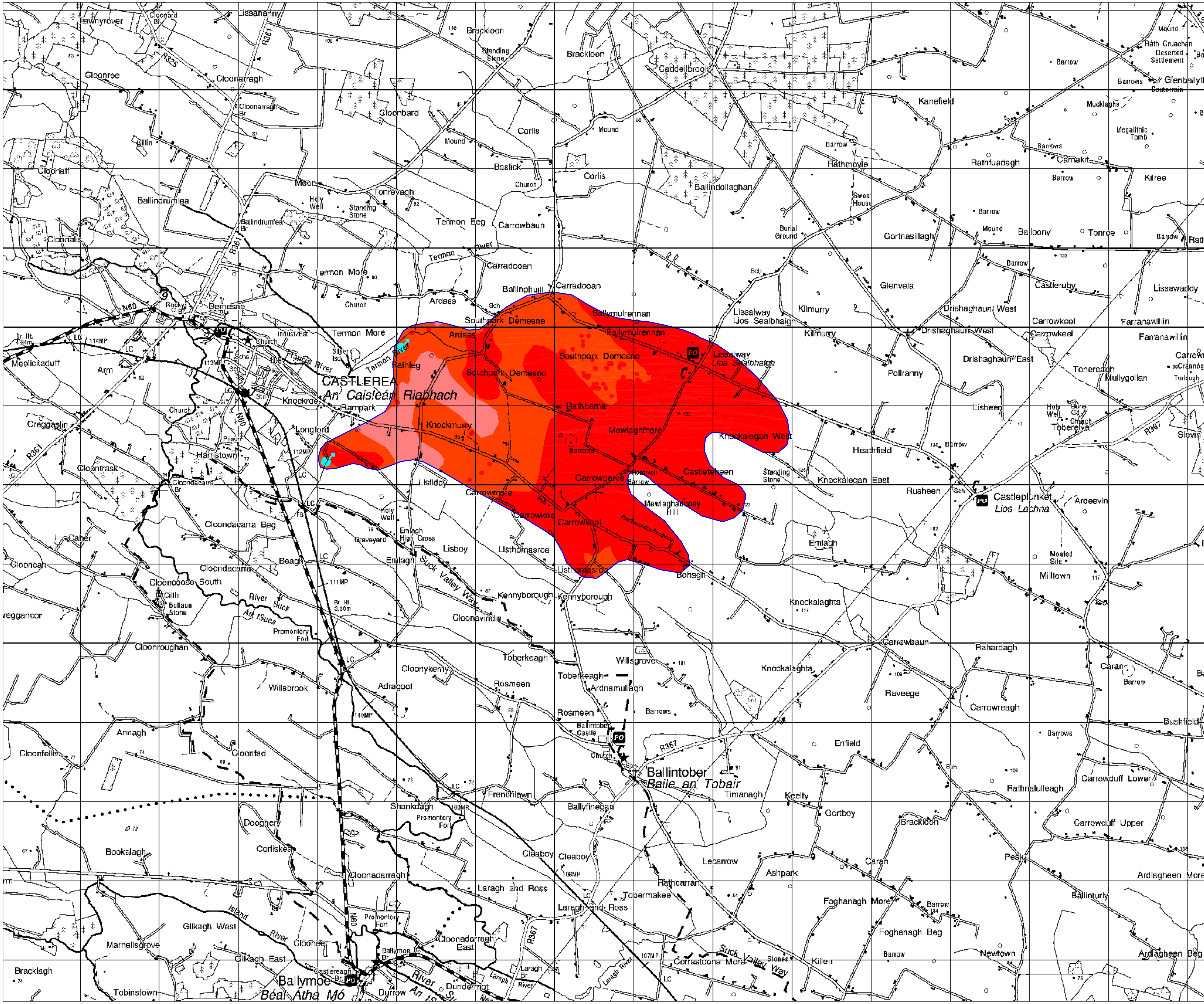
Extreme (E)	
Outcrop/Shallow rock (E)	
High (H)	
Moderate (M)	
Low (L)	
Zone of Contribution to Well	
Public Supply Spring	

Vulnerability is a term used to represent the intrinsic geological and hydrogeological characteristics that determine the ease with which groundwater may be contaminated by human activities.

The map shows the **vulnerability** of the first groundwater encountered (in either sand/gravel aquifers or in bedrock) to contaminants released at depths of 1-2 m below the ground surface. Where contaminants are released at significantly different depths, there will be a need to determine groundwater vulnerability using site-specific data. The characteristics of individual contaminants have not been taken into account.

This **vulnerability** map is designed for general information and strategic planning usage.The boundaries are based on the available evidence and local details have been generalised to fit the map scale. Evaluation of specific sites and circumstances will normally require further and more detailed assessments,and will frequently require site investigations to determine the risk to groundwater.

0 1km 2km



CASTLEREA WATER SUPPLY SCHEME
Figure 5. Source Protection Zones

VULNERABILITY RATING	SOURCE PROTECTION ZONES	
	Inner (SI)	
Extreme (E)		SI/E
High (H)		SI/H
Moderate (M)		SI/M
Low (L)	not present	SI/L

Zone of Contribution to well (SI)

Public Supply Spring

This **Source Protection Zone map** is designed for general information and strategic planning usage. The boundaries are based on the available evidence and local details have been generalised to fit the map scale. Evaluation of specific sites and circumstances will normally require further and more detailed assessements and will frequently require site investigations to determine the risk to groundwater.

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

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0 1km 2km