GRENAGH WATER SUPPLY SCHEME

GROUNDWATER SOURCE PROTECTION ZONES

Draft

Prepared by:

Denise Kelly & Geoff Wright
Geological Survey of Ireland

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1. Introduction

The objectives of this report are as follows:

- To delineate source protection zones for the Grenagh Water Supply Scheme(WSS).
- To outline the principal hydrogeological characteristics of the Grenagh area.
- To assist Cork (South) County Council in protecting the water supply from contamination.

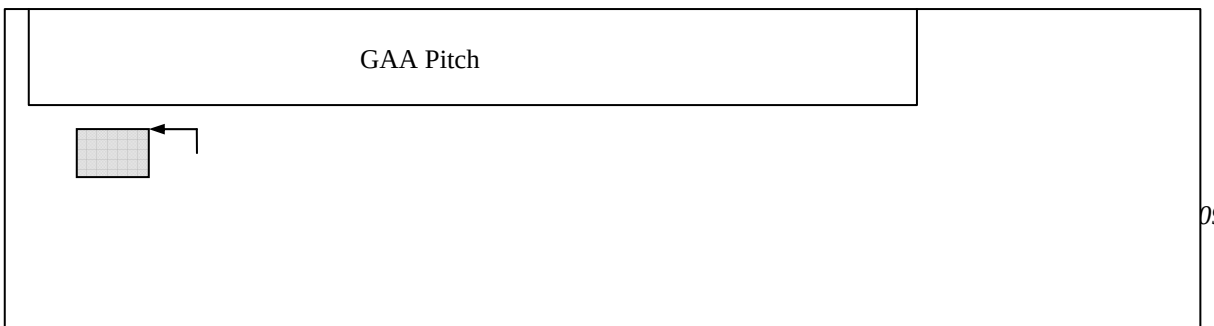
2. Location and site description

The Grenagh Water Supply is spread across the townlands of Grenagh North (in the village) and Grenagh South (at Quarryhall Cross, which is located approximately 1 km south of Grenagh village). The water supply comprises 2 bored wells in the village, located at the edge of a green field area beside the council houses (one borehole in the pumphouse and the other approximately 25 m away, outside) and the bored well at Quarryhall Cross. The "old" well in the village (PW1) is inside the pumphouse while the new well outside (PW2) is protected by a manhole cover. The well in Quarryhall Cross is outside of its pumphouse but is protected by a concrete chamber with a steel cover which is padlocked.

3. Summary of well details

GSI no.	1407NEW123 ("old" well in pumphouse) (PW1)
Grid ref. (1:25,000)	15795 08447
Townland	Grenagh North
Owner	Cork (South) County Council
Well type	Bored well
Elevation (top of casing)	approx. 164 m OD
Depth	approx. 50 - 55 m
Diameter	0.15 m (6")
Depth-to-rock	unknown but approx 3.0 m in "new" well nearby
Static water level	unknown but P.W.L in mid-cycle is 36.2 m b.g.l.
Drawdown	unknown
Current Abstraction	900 - 1500 gals/hr (24 hrs a day)
Pumping test summary	(i) Abstraction rate: n/a (ii) Transmissivity: n/a

GSI no.	1407NEW122 ("new" well outside) (PW2)
Grid ref. (1:25,000)	15795 08441
Townland	Grenagh North
Owner	Cork (South) County Council
Well type	Bored well
Elevation (top of casing)	approx. 163 m OD
Depth	approx. 77 m
Diameter	0.15 m (6")
Depth-to-rock	3.04 m (information from driller)
Static water level	unknown but P.W.L in mid-cycle is 18.4 m b.g.l.
Drawdown	unknown
Current Abstraction	900 - 1200 gals/hr (intermittently) (Not reliable information)
Pumping test summary	(i) Abstraction rate: n/a (ii) Transmissivity: n/a



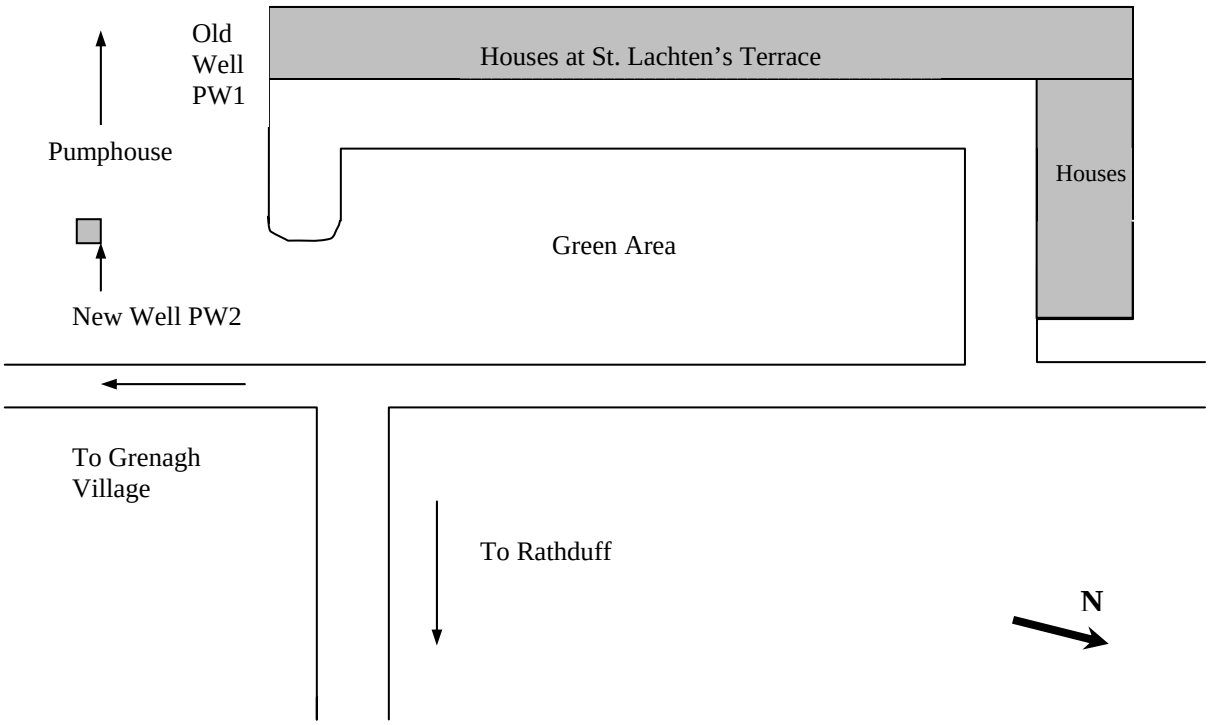


Figure 1 Sketch Map of the area around the Village Wells

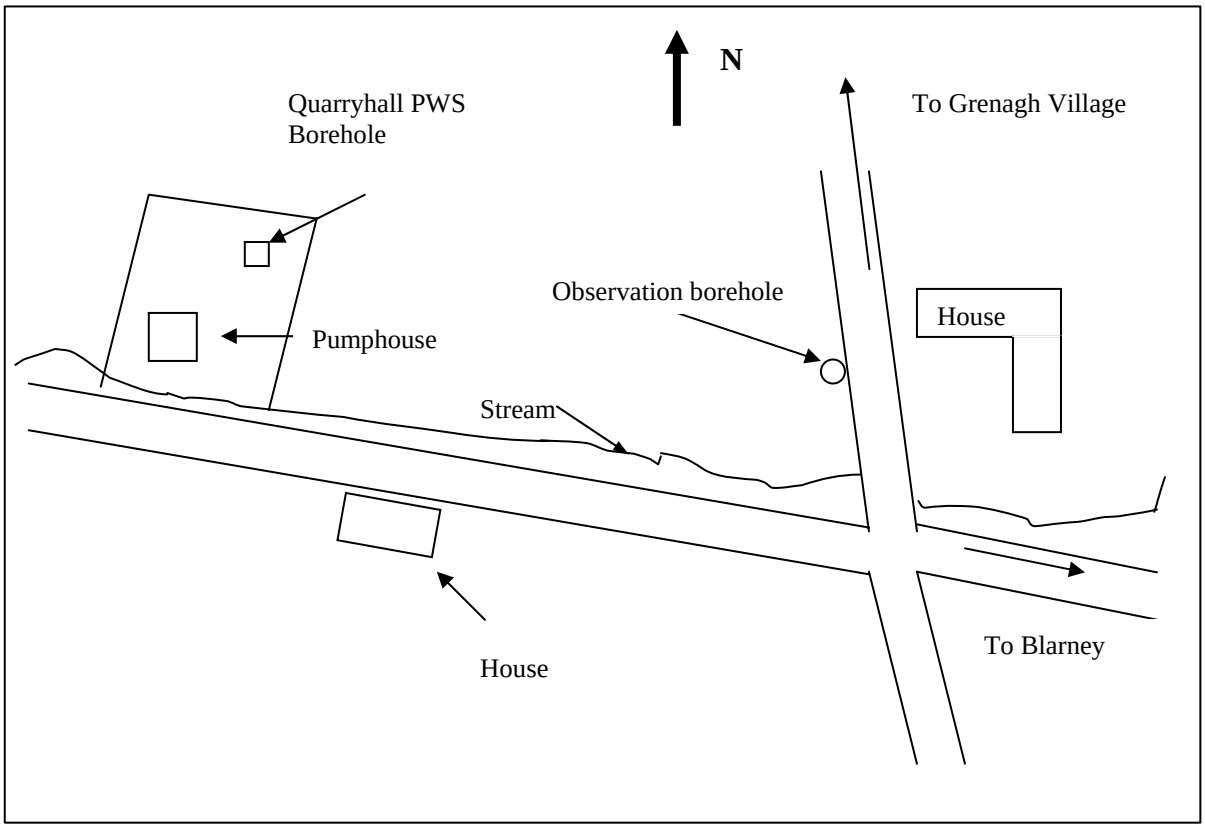


Figure 2 Sketch Map of the area around the Quarryhall Borehole, south of Grenagh

GSI no.	1407NEW124 (Quarryhall Cross borehole)
Grid ref. (1:25,000)	15795 0844
Townland	Grenagh South
Owner	Cork (South) County Council
Well type	Bored well
Elevation (top of casing)	134.3 m OD
Depth	approx. 23 m
Diameter	0.15 m (6")
Depth-to-rock	unknown but approx. < 4.3 m in observation hole nearby
Static water level	10.85 m b.g.l. (on 26/5/99 before pumping test)
Drawdown	7.125 m
Current Abstraction	65.4 m^3/d (pumping 17 hrs a day)
Pumping test summary	(i) Abstraction rate: 57.37 m^3/d (ii) Transmissivity: approx. 2-3 m^2/d

4. Methodology

4.1 Desk Study

Bedrock geology information was compiled from the GSI report and map of Sheet 25, (Sleeman & Pracht, 1994). This map was compiled at the 1:100,000 scale. Subsoils / soils were compiled from information available from Teagasc's draft mapping of soils in County Cork. Basic well details such as borehole depth, elevation, abstraction and pumping test data were obtained from GSI records and County Council personnel.

4.2 Site visits and fieldwork

Site visits and fieldwork in the area included a walkover survey to look at the geology and subsoils of the catchments in order to further investigate the hydrogeology and groundwater vulnerability. Augering of some depth-to-bedrock holes also helped in collecting subsoil samples for later analysis, and in obtaining better knowledge of the thickness of subsoils. Well surveys and a pumping test were also carried out to aid in the conceptualisation of the hydrogeology.

4.3 Data analysis

Analytical equations and hydrogeological mapping were utilised to delineate protection zones around the public supply wells. The subsoils samples taken during fieldwork were analysed using a geotechnical engineering method, BS 5930. This aided in the determination of the groundwater vulnerability of the area.

5. Topography & surface hydrology

The wells in Grenagh village are located beside the council houses at a ground level elevation of approximately 160-165 m. above O.D. (Malin Head). The land slopes gently upwards to the west behind the wells, to a height of 185 m. about 1.5 km away. There is a somewhat steeper gradient downslope of the wells. This land is well drained, and there are very few drainage ditches, with only two streams to the north and south, both about a kilometre away.

The well at Quarryhall Cross, about a kilometre away from the wells in the village, is at an elevation of approximately 134 m. The land here slopes gently upwards to the northwest but quite steeply to the north. It is well drained as evidenced by the vegetation (grassland and pasture) and only one small stream running towards the southeast, just 5 m away from the well, which seems to be the only active drainage in the area. The slope of the land immediately upgradient is quite steep. Land upgradient of the well is pasture used for keeping horses.

6. Geology

6.1 Bedrock Geology

The bedrock geology of the Grenagh area comprises sediments of Middle and Upper Devonian age (over 360 million years old) which were subsequently folded. The rock units of the area, which are shown in Map 1, are summarised below.

Age		Formation
Devonian	Upper	Ballytrasna Fm.
	Middle	Gortanimill Fm.

6.1.1 Gortanimill Formation

The Gortanimill Formation consists of green fine grained sandstone and siltstone. There may also be some red siltstones in evidence. It is part of the Old Red Sandstone succession in the west of what was the Munster Basin and represents a fluvial distributary system. It has some small scale sedimentary structures. All three Council sources are located within this rock unit.

6.1.2 Ballytrasna Formation

Although the Council supplies are not located within this unit, the Ballytrasna Formation does occur about 0.5 km north of the wells in the village. The rocks in this unit are described, by Sleeman & Pracht (1994), as dusky-red to purple mudstones, with subordinate pale-red sandstones. The sandstones are occasionally cross laminated with planar or irregular lower surfaces.

6.1.3 Structure

The geology around Grenagh, particularly around the village, has been influenced by episodes of folding and faulting during the Variscan Orogeny, 300 million years ago. The trend of the folds in the area are east-northeast to west-southwest. Relatively steep dips are recorded in the area ranging from 45^{o} - 65^{o} in rocks dipping south-southeast (towards a syncline in the south), and up to 70^{o} north, just northeast of Grenagh village as the rocks dip northwards from the crest of a small anticline to the centre of another syncline, just 250 m north, as shown on Map 1.

6.2 Subsoil Geology

6.2.1 Tills

The subsoils in this area seem to consist of a very uniform blanket of sandstone tills (based on mapping from digital aerial photography by Teagasc, which is still in draft form). These tills are thought to have been derived from the underlying sandstone and siltstone rocks. There are some areas of rock and rock close to surface, but most of the area around the village seems to be covered by very good pasture land indicating a well drained subsoil. The texture of these subsoils has been confirmed to be a silty sand by analysis of hand samples (by BS 5930 method) from a trial pit close to the Quarryhall public water supply. Further samples from an augered borehole near the observation well in Quarryhall confirm sandy deposits. There are also small areas of alluvial deposits along the streams in the area, notably the River Martin, which flows from north to south, east of Grenagh village, around Rathduff. There is one small occurrence of blanket peat near the source of Lyradane stream, west of the village.

6.2.2 Depth to Bedrock

Accurate information on depth to bedrock is based on outcrop information, well records, subsoil sections and drilling. Subsoil depths for the Grenagh area are fairly shallow. Actual depth to bedrock

at the Quarryhall Cross bore can be estimated at less than 4.3 m, from an observation borehole drilled within 100 m of the Council well. A trial pit in a field just west of the Council well (and within 200 m of it) suggests rock is possibly even closer to the surface, as broken rock can be seen at a depth of approximately 1.25 m. Shallow subsoil is also in evidence around the Council wells in the village. Depth to bedrock estimation was difficult owing to the scarcity of data in the area. However digital aerial photography from Teagasc helped to identify areas of shallow subsoils and areas where the depth to rock was 3 m or less. Over most of the rest of the area, it seems that subsoils are generally between 3 and 5 m in thickness, but this is very hard to prove without more borehole data. There may be areas where rock is between 5 and 10 m from the surface (as is indicated by wells around the Rathduff area).

7. Hydrogeology

7.1 Data availability

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

- Well records and outcrop data were obtained from the G.S.I. archives and databases.
- Water levels taken from well surveys carried out in the area in July 1999.
- A 14 hour pumping test carried out by the GSI in May 1999, on the Quarryhall Cross well.
- Drilling and augering of depth-to-bedrock holes in the area, and subsequent analyses of subsoil samples using BS 5930.
- Subsoils and soils mapping of the area by Teagasc, from digital aerial photographs (draft maps).
- The South Cork Groundwater Protection Scheme, currently in progress at the G.S.I.

7.2 Rainfall and Meteorology

Rainfall data for the area are taken from a contoured rainfall map of Co. Cork (South), which is based on data from Met Éireann. For 1961-1990, the mean annual rainfall (R) for the area was 1202 mm. Potential evaporation (P.E.) is estimated at 480 mm/yr (Met Éireann data). Actual evapotranspiration (A.E) is then calculated as 95 % of P.E. i.e. 456 mm/yr. Runoff is taken to be 50% of available recharge in the Grenagh area. This figure comes from the fact that there is a lot of rainfall in an area with quite a steep slope and moderately permeable sandy subsoil. Runoff is therefore estimated to be 373 mm. These calculations are summarised below:

Average annual rainfall	1202 mm
Estimated P.E.	480 mm
Estimated A.E. (95 % P.E.)	456 mm
Available recharge	746 mm
Surface Runoff (50%)	373 mm
Recharge	373 mm

This is a conservative estimate of recharge which allows for surface water outflow during periods of exceptionally heavy rainfall.

7.3 Groundwater levels

Groundwater levels in the area are variable, depending largely on elevation. The “static” water level in the Quarryhall Cross public supply on the 26/5/99 was 123.35 m O.D (or 10.85 m b.g.l.). However, the well may not have fully recovered after pumping and so the real static water level could be somewhat higher. The static water level in the nearby observation well was found to be similar. Only pumping water levels are available for the wells in the village, and these range from 127 to 142 m a O.D.

Water levels were also measured in some private wells in the area. These indicate that the water table varies from between 168 m O.D. in the higher areas to 123 m O.D. in the valley around the Quarryhall supply. These data come from wells in the Gortanimill Formation. No data are available for the

Ballytrasna Formation farther to the north. The water table seems to be, as expected, a subdued reflection of the topography of the area.

7.4 Groundwater flow directions and gradients

The water table in the area is generally assumed to reflect topography but is also influenced by the local permeability of the rock. Around the Grenagh area, water flowing northeast has a generally moderate to steep gradient of between 0.038 - 0.05 (taken from topography because of the lack of water levels available from wells), which is to be expected in these fairly low permeability sandstones and siltstones. Around Quarryhall Cross a gradient of groundwater flow to the south/southeast is indicated as 0.059, which is comparable to the gradient at Grenagh.

7.5 Aquifer Characteristics

A pumping test carried out by the G.S.I. on 26 May 1999 at the Quarryhall Cross well helped to obtain some values for aquifer characteristics for the Grenagh area. Unfortunately no pumping test could be carried out on the wells in the village for operational reasons, but the data at Quarryhall Cross can be extrapolated, due to the similarities in geology and groundwater flow direction and gradient.

Drawdown, after a 10 hour pumping cycle, was 7.12 m. With a final pumping rate of 63.3 m^3/d, this gives a specific capacity of 8.8 m^3/d/m. Analysis of the pumping test data using appropriate software provided transmissivity values in the range 1.81 - 3.86 m^2/d. An acceptable estimate of T for the aquifer seems to be about 2-3 m^2/d.

Graphical data from the pumping test indicates that water from the nearby stream is not being pulled into the well during the short term pumping. Conductivity in both the stream and the groundwater stayed fairly constant during the pumping test at about 220 μS/cm and 458 μS/cm @ 20°C respectively, indicating that the stream is probably not contributing to the well.

The pumping test also indicates that the groundwater flow to the well, is mainly happening in the upper few metres of more permeable bedrock. The area at the bottom of a valley around a stream would be considered to be more permeable anyway, as water will have been flowing towards the stream and picked out preferential pathways and created a fissured system. This idea seems to be supported by the drawdown curves for this well, which shows a permeable area close to the well and a drop off in permeability further away from the well.

7.6 Aquifer Category

The Gortanimill Formation is part of the Old Red Sandstone succession in the south of the country. The Gortanimill Formation is one of the more sandstone-rich formations within the Old Red Sandstone facies. Permeability is thought to be mostly secondary in nature with water moving through fractures and weathered zones. Using QSC graphs (which plot discharge (Q) against Specific Capacity (SC), see Wright (2000)), it can be seen that this well falls into a lower well productivity category. Other wells in this formation generally have higher yields, although specific capacity data are lacking. This formation is classed as a **locally important aquifer which is moderately productive only in local zones** (**Ll**). (For more information refer to the South Co. Cork Groundwater Protection Scheme (Kelly *et al*, 2000).)

7.7 Hydrochemistry and Water Quality

Results of laboratory analysis of water samples taken in April and September 1999 suggest that water in the public supplies in Grenagh is characteristic of a typical calcium-bicarbonate type water. The water in the Quarryhall well is a little harder than the water from the two wells in the village. Values from the *April* round at 173 mg/l $CaCO_3$ in Quarryhall indicate moderately hard water, while those between 56 and 72 mg/l $CaCO_3$ at the village wells, suggest moderately soft water. Values from the *September* round show somewhat harder water at Quarryhall (184.7 mg/l $CaCO_3$) but similar values to the April results at the village wells ranging 59 to 74 mg/l $CaCO_3$.

Other parameters measured, shown below in Table 1, show that this area may have high levels of Manganese, as indicated by the levels in excess of the E.U. MAC at the two wells in the village, at 0.07 and 0.11 mg/l. September results also show similar values. Raw water samples from April have also shown that E.U. MACs are breached at the well in Quarryhall with regard to total coliforms and *E.coli*. Both parameters have a count of 1 per 100 ml. Nitrate levels at the Quarryhall well are somewhat elevated at 31.1 mg/l NO_3 in April and 31.7 mg/l in September. Results from the September sampling round showed a serious breach in bacteriological standards in the old well (PW1) in Grenagh village, when a count of over 120 total coliforms was found (but no faecal coliforms). This is from an untreated sample as this supply is not normally chlorinated. Further sampling may have to be done over a period of time to see if this remains a problem, or if this is an isolated event. Overall, the chemical quality of the water is good in the Grenagh area.

Other water quality analyses are available from sampling by Cork County Council over several years. These results reflect the water quality in the wells in the village. A sampling point from one of the nearby Council houses was used. Once again some Iron and Manganese problems have been seen in these wells, along with some breaches of the MAC for Total and Faecal coliforms. Nitrate levels are presently not seen as a problem in these wells, although they are coming close to the E.U. guide levels.

	Results of Laboratory Analyses					
Location & Date / **Parameter**	**"Old" Well in village**		**"New" Well in village**		**Quarryhall Well**	
	13/04/99	14/09/99	13/04/99	14/09/99	13/04/99	14 /09/99
Conductivity (µS/cm)	200	201	181	187	365	372
Temperature (°C)	11	??	11	??	11	??
pH	5.7	5.8	5.2	5.3	6.5	6.6
Total Hardness	72	73.96	56	58.89	173	184.7
Total Alkalinity (mg/l)		37		17		128
Calcium	16.8	16.76	8.4	8.65	51.6	55.27
Magnesium	7.3	7.84	8.5	9.09	10.8	11.46
Chloride	25.8	24.9	29.2	28.1	27	27.2
Sulphate	8.8	12.4	11.1	14.7	10	13.2
Sodium	14.8	16.02	15.1	17.03	15	16.8
Potassium	1	1.05	1.1	1.109	2	1.96
Nitrate (as NO_3)	23.1	24.3	23.5	27.1	31.1	31.7
Iron	<0.05	<0.1	<0.05	<0.1	<0.1	<0.1
Manganese	0.11	0.1	0.07	0.07	<0.05	<0.05
Total Coliforms per 100 ml	0	>120	0	0	1	0
E.Coli count per 100 ml.	0	0	0	0	1	0

Table 1 Hydrochemical parameters obtained from sampling at Grenagh

7.8 Conceptual Model

- The groundwater catchments in the area are assumed to coincide with the surface water catchments. As such there is a groundwater divide between the supplies in the Grenagh area. Water north of this divide, which runs NW/SE along the ridge between the two sources, will flow northeast towards the wells in the village, while water to the south of it will flow southeast towards the well at Quarryhall.
- The groundwater divide around the wells in the village is only about 250 - 300 m away from these wells. Therefore the catchment for these wells is quite small. Groundwater within the catchment is expected to flow towards the River Martin and its small tributary, known as Lyradane Stream. Groundwater close to the well is therefore thought to flow towards the northeast.
- The groundwater divide around the Quarryhall well is thought to be coincident with the surface water catchment to the north of the well, along a ridge 160 - 185 m O.D. The pumping test has shown that it is unlikely that the stream is in hydraulic continuity with the groundwater system (at least in the short term of a 10 hour pumping test), and as such the groundwater catchment may not

extend southwards to the surface water catchment on the other side of the stream. Groundwater within this catchment is expected to flow towards the stream, and as such the groundwater flow close to the well is expected to be in a southeasterly direction.

- Both sources (the village wells and the Quarryhall well) are thought to be abstracting from the same geological formation, the Gortanimill sandstones and siltstones. These rocks are dipping to the south/southeast with dip angles ranging between 45^{o} and 65^{o}. Dips to the north, up to about 70^{o}, are also found near the village. This reflects the folding which these rocks have been subjected to. These sandstones and siltstones are thought to have a fairly low permeability as aquifer parameters around the Quarryhall public water supply show (as outlined in Section 7.5), and as such flow in these rocks is likely to occur in the upper weathered, fissured zones as well as in the areas affected by the folding. The lower levels of the aquifer are thought to be less permeable. The Gortanimill Formation (which is overlain by the Ballytrasna Formation to the northwest) is a **locally important aquifer which is moderately productive only in local zones** (**Ll**), according to the South Cork Groundwater Protection Scheme.
- Recharge to the groundwater system is thought to be mainly through the shallow subsoils in the area. Some direct recharge to the aquifer may also occur where rock is very close to surface, such as in the area around the village and some small areas around the Quarryhall supply. There is little known about the subsoils around the area of the wells in the village, but they appear to be sandstone tills (from aerial photography, see Section 0). As explained in Section 0, surface runoff in this area could be about 50% of available recharge. The subsoils around the well in Quarryhall seem to be quite shallow and well drained as explained in Section 0 and 0. Surface runoff in the area around Quarryhall is confined to the stream which flows eastwards quite close to the public supply well.
- The subsoils in the areas are thought to be quite free-draining, with permeabilities estimated to be moderate. The water level in the public supply well was about 10 m b.g.l on the 26th May 1999, (although this level may be a little lower than normal as the well may not have fully recovered at this point). In the observation well close by, it is a little higher, about 4 m b.g.l. The aquifer, namely the Gortanimill Formation, is thought to be unconfined.
- Natural groundwater gradients in the areas around the public supply well in Grenagh village are difficult to estimate due to the lack of reliable data from wells in the area. As such, topographic gradients are used as an estimate of groundwater gradients and are estimated at around 0.38 up to 0.05. Static water levels for the public supply wells are not available. Gradients around the Quarryhall public supply well are a little steeper (possibly indicating lower permeability rocks), at around 0.059 in a south/southeasterly direction.

8. Delineation of source protection areas

8.1 Introduction

This section describes the delineation of the areas around the wells that are believed to contribute groundwater to the public water supply in Grenagh, and that therefore require protection. The areas are delineated on the basis of the conceptualisation of the groundwater flow pattern, as described above. Given the limited amount of calibration data available, a full groundwater numerical model is not believed to add significant useful information to the conceptualisation.

Two source protection areas are delineated:

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

8.2 Outer Protection Area

The Outer Protection Area (SO) includes the complete catchment area to the source, i.e. the zone of contribution (ZOC), and it is delineated as the area required to support an abstraction from long-term

recharge. The ZOC is controlled primarily by a) the pumping rate, b) the groundwater flow direction and gradient, c) the rock permeability and d) the recharge in the area. The ZOC is delineated as follows:

i) An estimate of the area size is obtained by using the average recharge and the abstraction rate.
ii) The shape of the area is then derived by both analytical modelling and hydrogeological mapping techniques.
iii) To allow for errors in the estimation of groundwater flow direction and to allow for an increase in the ZOC in dry weather, a safety margin is incorporated by assuming a higher abstraction rate than the current rate.

8.2.1 Quarryhall Borehole

The average abstraction rate for the Quarryhall well was calculated using the rate noted during the pumping test in May. This rate of 63.3 m^3/d is thought to match fairly well with the average pumping rate over longer periods of time. For calculation of the ZOC, a factor of safety is built into this average discharge, and it is increased (typically by 50%) to allow for possible future increases in abstraction and for expansion of the ZOC in dry periods. For the puposes of calculation of this ZOC a discharge of 95 m^3/d was used. The recharge for the area is thought to be approximately 373 mm/yr, so the required area needed to provide the increased discharge above is 0.09 km^2, or 9 ha.

Hydrogeological mapping of the area around the Quarryhall source was used to delineate the ZOC to the well. The northern boundary of the ZOC is thought to be coincident with the surface water catchment. The southern boundary of the ZOC can be taken to be just north of the river about 5 m away from the borehole. During the pumping test it was shown that water from the southern side of the river did not reach the well, and as such this area cannot be included in the ZOC. The main flow direction of groundwater in the area is towards the south/southeast. In order to take account of the heterogeneity of flow, possibly in the upper few metres of the aquifer, a variation in the flow direction of $\pm$ 10^o was included as a safety margin. From these flow directions, the eastern and western boundaries of the ZOC can be drawn, as is shown in Map 3. The mapped ZOC has an area of approximately 0.119 km^2 (12 ha), which is comparable with the calculated area outlined above.

8.2.2 Grenagh Village boreholes

Long term discharges for the wells in the village are not available, nor are any data on yield tests or pumping tests. According to County Council staff, the old well in the pumphouse can typically pump continuously at about 163.5 m^3/d (although at the moment it is pumping at 17 gals/min, equivalent to 111 m^3/d). The new well outside the pumphouse is pumping only intermittently to serve the nearby Council houses and can yield up to 20 gals/min (equivalent to 130.8 m^3/d) for short periods of time. In order to calculate the area of the ZOC for these wells, the discharge of the old well was increased by 50% to a theoretical discharge of 245 m^3/d. This figure will allow for any increases in discharge from the well, and also take into account the intermittent pumping from the new well. However, as is shown on the ZOC map for this area of Grenagh, the possible groundwater catchment for these two wells is likely to be quite small because of their closeness to the topographic/catchment divide. Therefore it may be an unlikely scenario to allow for a 50% increase in abstraction, if in fact there is not going to be that much water available anyway.

The mapped catchment for the two wells has an area of approximately 0.123 km^2, as can be seen from Map ?. If the discharge of 245.23 m^3/d is used for the two wells and recharge is taken to be 373 mm/yr, as above, the calculated catchment would be in the order of 0.24 km^2. However if a discharge of 163.5 m^3/d is used (the current discharge from the wells), a catchment area of only 0.16 km^2 is needed. This figure is comparable with the mapped catchment which seems to support the idea that these wells are probably taking out as much water as possible from the catchment.

8.3 Inner Protection Area

The Inner Protection Area (SI) is the area defined by a 100 day time of travel (TOT) to the source and it is delineated to protect against the effects of potentially contaminating activities which may have an immediate influence on water quality at the source, in particular microbial contamination.

8.3.1 Quarryhall Borehole

Permeability values for the aquifer around this source were derived from pumping test data (see Appendix 1). However this estimate of permeability (0.13 m/d) is an average over the assumed 23 m depth of the aquifer. It is also assumed that a lot of the flow would be occurring in the upper few metres, in the upper weathered, fissured zones (as outlined in Section 0). Therefore actual permeability for these levels of the aquifer are possibly a lot higher. In the context of creating an inner protection zone based on the time it would take pollutants to reach the well, the higher permeability must be taken into account to give maximum protection to the borehole. Therefore, a permeability of 1 m/d was used to estimate the 100 day time of travel zone distance to the well. Using an effective porosity value of 0.03 and a groundwater gradient of 0.059, the 100 day time of travel distance to the well is estimated at 200 m (see Map 3).

8.3.2 Grenagh Village Boreholes

The geology of the area around the village is very similar to that at Quarryhall, and as such the permeability for this area of the aquifer can be extrapolated and taken to be 0.13 m/d. However it is also assumed that the permeability of the main flow zone of the upper aquifer could be much higher and a K value of 1 m/d is also used. Using the same porosity and a gradient of 0.05, the 100 day time of travel distance to the wells is estimated at 166.6 m (see Map 3).

9. Vulnerability

Much of the area around Grenagh is overlain by sandstone till deposits. As shown in Section 0 the texture of these deposits is quite permeable, ranging from a silty sand to a sand and gravel / sand. A permeability assessment was also made taking into account the drainage and vegetation of the area. The sandstone tills are therefore assumed to have a moderate permeability across the area. Depth to bedrock estimation, outlined in Section 0 above, was also used to delineate vulnerability zones. As the interpreted Interim Vulnerability Map (Map 2) shows, there is one area where rock is within 3 m of the surface and as such the groundwater is considered "extremely vulnerable" *(E)* to contamination. As part of the Interim Groundwater Protection Scheme for South Cork, only areas of extreme vulnerability are to be delineated. This will lead to an underestimate in the areas of lower vulnerability. Lack of borehole data in the area, or a better understanding of the subsoils do not allow a 5 or 10 m depth to bedrock contour to be drawn. Therefore, the other area in the ZOC where subsoils are between 3 and 5 (or 10) m thick, the groundwater is classed as being "highly vulnerable *(H)* (possibly moderate (*M*) in places)".

In the zone of contribution of the wells in the village, also outlined in Section 0, subsoils are also very shallow. The area around the village cross-roads has rock within 3 m of the surface and as such groundwater is considered "extremely vulnerable" *(E)* to contamination. The area surrounding this (within the ZOC) has subsoils between 3 and 5 (or 10) m thick and are classified as "probably highly vulnerable *(H)* (possibly moderate (*M*) in places)". There are also some definite points of vulnerability delineated by symbols on the interpreted Interim Vulnerability Map (Map 2).

10. Groundwater Protection Zones

The groundwater protection zones are obtained by integrating the two elements of land surface zoning (source protection areas and vulnerability categories) – a possible total of 8 source protection zones (see the matrix in the table below). In practice, the source protection zones are obtained by superimposing the vulnerability map on the source protection area map. Each zone is represented by a code e.g. **SI/H**, which represents an Inner Protection area where the groundwater is highly vulnerable to contamination. There are 4 groundwater protection zones present around the Quarryhall Public Supply well and 4 around the wells in the village (Map 3), as shown in the matrix below.

Matrix of Source Protection Zones

VULNERABILITY	**SOURCE PROTECTION**	
RATING	***Inner***	***Outer***

Extreme (E)	SI/E	SO/E
High (H)	SI/H	SO/H
Moderate (M)	~~SI/M~~	~~SO/M~~
Low (L)	~~SI/L~~	~~SO/L~~

The response measures imposing restrictions on certain developments and activities within these zones are included in the "Groundwater Protection Schemes" publication by the DELG, EPA and the GSI in 1999. These measures indicate the degree of restriction recommended in each protection zone.

11. Land Use and Potential Pollution Sources

Grenagh village

Land use around the wells is mainly limited to the council houses, beside which they are situated, and some farming activities (good pasture land) further up-gradient, along the road west out of the village, as well as the local G.A.A. pitch and pavilion and its septic tank system, directly upgradient. Some of the dwellings in the area around the village have their own septic tanks and there is one large common tank for the council houses. There are plans to link these into a sewerage scheme which will be constructed for the new development of houses that are being built on the road out of the village towards Rathduff. There is a farmyard further upgradient of the G.A.A. playing field, with many other potential organic pollutants.

Quarryhall Cross

There are a few houses directly upgradient which are not on any main sewerage drainage scheme and have either septic tanks or Biocycle systems. There are no plans to put them onto a mains scheme. There are a number of farms in the area. Pasture land above the well at Quarryhall, within the ZOC, could be a potential pollution source. Nitrate levels at the public supply well from the sampling round by GSI in April and September showed 31.1 and 31.7 mg/l NO_3 respectively. These levels are above the E.U. *guide* level of 25 mg/l (but below the MAC of 50 mg/l) although further monitoring of these nitrate levels would have to be carried out to prove contamination and to see if levels are rising. Raw water samples also indicate possible pollution due to total and faecal coliforms present.

Other hazards include septic tank systems, application of inorganic fertilisers and pesticides, and possible spillages along the roads up-gradient of the wells. No detailed assessment of hazards was carried out as part of this study.

The main hazards within the Zones of Contribution are considered to be landspreading and pollution from farmyards.

12. Conclusions and Recommendations

- The Grenagh Water Supply Scheme is fed from 3 wells, 2 of which are located in the village, while the other is located about 1 km away at Quarryhall Crossroads.
- The "old" well in Grenagh village, in the pumphouse, has a 'good' yield, while the deep "new" well outside, which at present supplies only the nearby council estate, has a 'moderate' yield. Very little data exist on the sustainability of the yields in these wells. The well in Quarryhall Cross has as a 'moderate' yield, which is confirmed by pumping test data.
- All the wells are located in the Gortanimill Formation which is classified as a **locally important aquifer which is moderately productive only in local zones** (**Ll**).
- The wells are located in areas of sandstone till and close to areas of rock outcrop or thin subsoil. As such they lie in areas of high and extreme vulnerability as shown on the Vulnerability Map.
- Water quality from the village wells is generally quite good, although the location of the sampling point for the historical data is not clear. The only concerns would be the levels of iron and

manganese and a possibility of bacteriological contamination indicated by the serious breach in the MAC for coliforms in one of the water samples in 1999. Chlorination of the supply in the village is recommended, particularly if there is to be a repeat of whatever contaminated it in September1999. There seem to have been no breaches of the EU MAC for nitrate in these wells although the levels recorded during the summer are quite close to or just above the guide level of 25 mg/l NO_3.

- Water quality at the Quarryhall well is also generally good although some coliforms were found in the April 1999 sampling. There may also be a need to monitor the nitrate levels in this well more regularly, as samples collected during April and September 1999 recorded 31.1 and 31.7 mg/l NO_3 respectively.
- The inner and outer protection zones delineated in the report are based on our current understanding of groundwater conditions and on the available data. Additional data obtained in the future may indicate that amendments to the boundaries are necessary.
- It seems that the catchment for the wells in the village is quite small and as such it is unlikely that any further public water sources could be exploited in this catchment.
- It is recommended that:
  - chemical and bacteriological analyses of raw water rather than treated water should be carried out on a regular basis (every 6 months). A treatment system should be installed for the village supply.
  - the chemical analyses should include all major ions - calcium magnesium sodium, potassium, ammonium, bicarbonate, sulphate, chloride, and nitrate.
  - particular care should be taken in allowing any activities or developments which might significantly increase nitrate levels or cause contamination at any of the wells.
  - the potential hazards in the ZOC should be located and assessed;
  - interim codes of practice should be drawn up for dealing with underground petroleum storage/transfer, and spillages along the roads in the area.

13. References

Cork County Council (chemical & bacteriological data and nitrate reports.)

DELG/EPA/GSI (1999) Groundwater Protection Schemes. Department of the Environment and Local Government, Environmental Protection Agency and Geological Survey of Ireland, 24 pp.

Kelly, D. & Wright, G.R. (2000) “Draft Groundwater Protection Scheme for South County Cork”, Groundwater Section, Geological Survey of Ireland.

Sleeman, A.G. & Pracht, M. (1994) “Bedrock Geology 1:100,000 Map Series, Sheet 25, South Cork”, Geological Survey of Ireland.

Daly, D. & Swartz, M. (1999) “Notes for Groundwater Section Staff: Using BS 5930 to describe subsoils” Geological Survey of Ireland.

Teagasc / Coillte Forest Inventory and Planning System (FIPS) project (1999) Draft Soils mapping.

Wright, G.R. (2000) QSC Graphs - An aid to aquifer classification in data-poor aquifers in Ireland. Geological Society of London Special Publication No. 182.

Appendix 1

Pumping Test Data

SITE Quarryhall Cross, Grenagh

DATE 26-May-99

Groundwater Section
Geological Survey of Ireland

PUMPING TEST PUMPING WELL

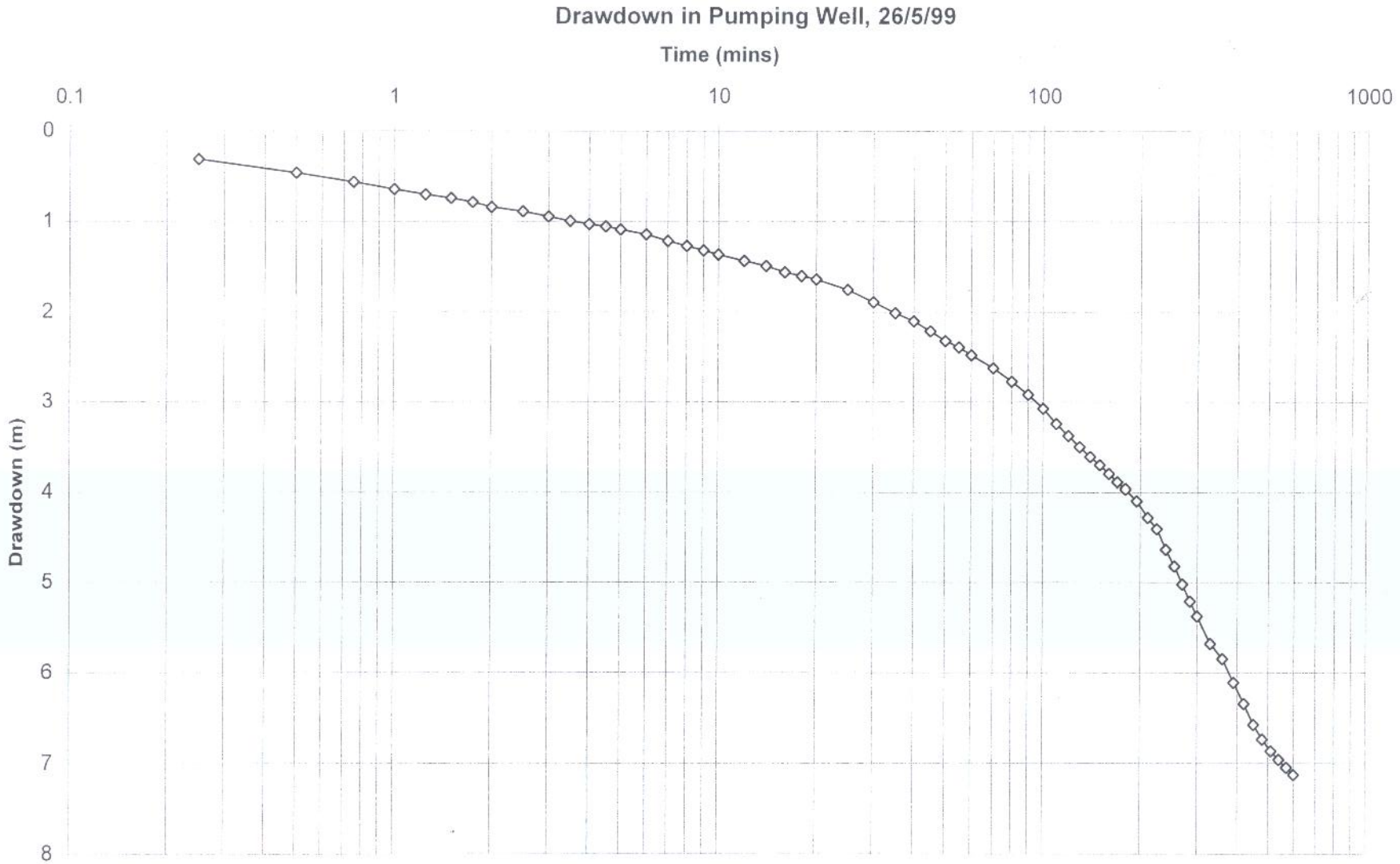
Project Title Sth Cork GWPS
Page No. .....1.....

Borehole Name	Quarryhall Cross	Well Depth	~23 m	Datum Point	Top of bar across top of casing
Borehole No.	1407NE W124	Well Diameter	150 mm	Height of Datum	0.06 m above g.l
Well Owner	Cork Co Co	Pump Depth	21.33 m approx	Ground Elevation	134.3 m a O.D.
Location	~60 m west of crossroads	Aquifer	Gortanimill Formation	Datum Elevation	134.36 m a O.D.
Grid ref.	15843 08345			Weather	Dull and dry
6" Sheet No.	CORK 51			Observer	D.Kelly

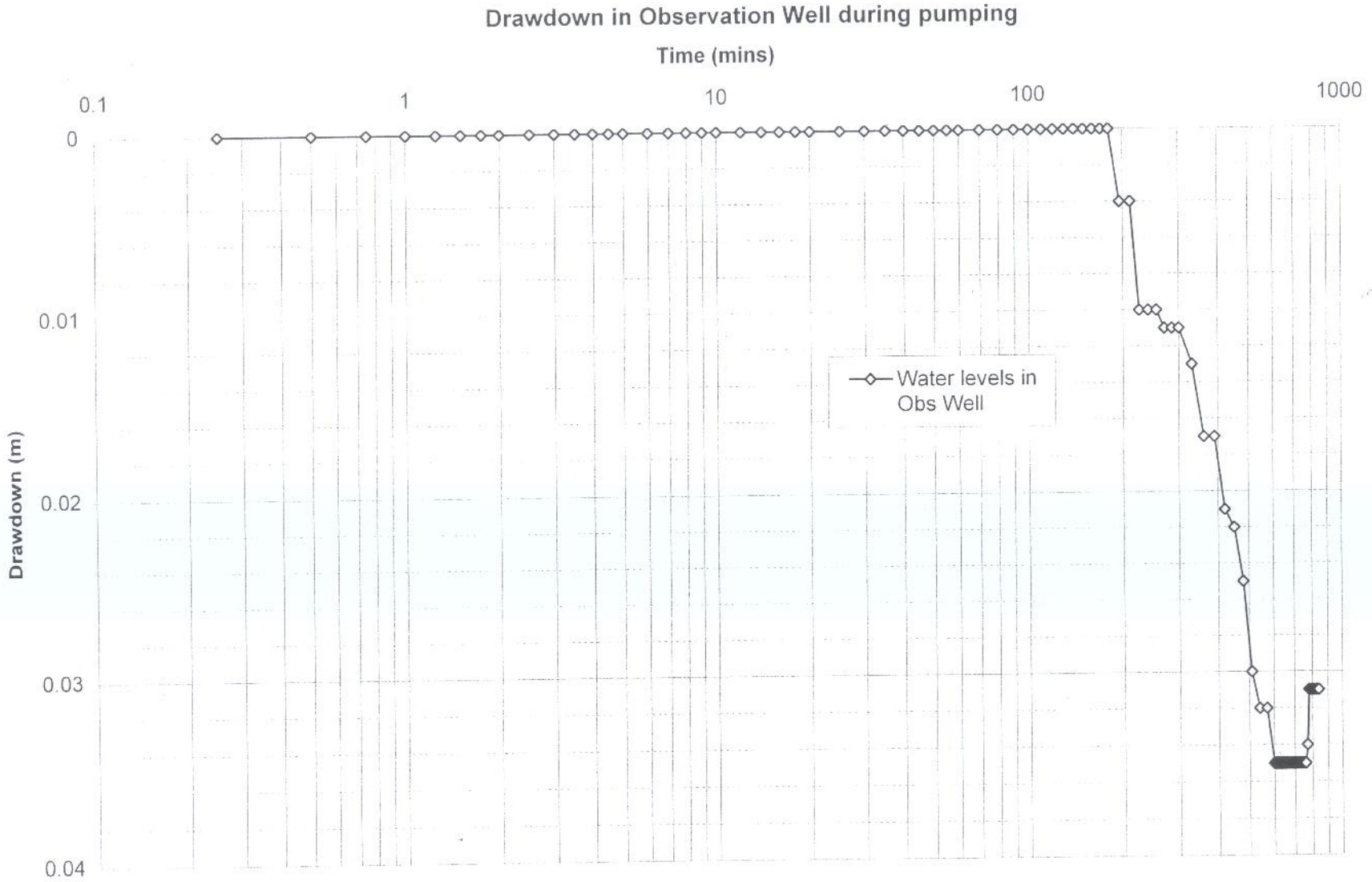
Date	Time	Elapsed Time	Water level below datum	Drawdown	Discharge		Discharge	Remarks	
		Mins	(m)	(m)	Meter	Spot	(m3/d)		
26/05/1999	07:00	0	10.91	0					
		0.25	11.22	0.31					
		0.5	11.37	0.46					
		0.75	11.47	0.56					
		1	11.55	0.64					
		1.25	11.61	0.7					
		1.5	11.65	0.74					
		1.75	11.695	0.785					
		2	11.75	0.84					
		2.5	11.8	0.89					
		3	11.855	0.945					
		3.5	11.905	0.995					
		4	11.94	1.03					
		4.5	11.965	1.055					
		5	12	1.09					
		6	12.055	1.145					
		7	12.125	1.215					
		8	12.18	1.27					
		9	12.23	1.32					
		10	12.275	1.365					
		12	12.345	1.435					
		14	12.4	1.49		10 gals/min	65.4		
		16	12.47	1.56					
		18	12.51	1.6					
		20	12.545	1.635					
		25	12.66	1.75					
	07:30	30	12.8	1.89		9.5 gals/min	62.13	Groundwater Conductivity	
		35	12.92	2.01				471 uS/cm @ 20oC	River conductivity
		40	13.01	2.1		10 gals/min	65.4		223 uS/cm
		45	13.12	2.21					
		50	13.23	2.32					
		55	13.3	2.39					
	08:00	60	13.385	2.475					
		70	13.53	2.62					
		80	13.68	2.77					
	08:30	90	13.825	2.915					
		100	13.98	3.07		10 gals/min	65.4	449 uS/cm @ 20oC	221 uS/cm @ 20oC
		110	14.15	3.24				10.9 oC	11.1 oC
		120	14.285	3.375					
		130	14.41	3.5					
	09:20	140	14.52	3.61					
		150	14.61	3.7		10 gals/min	65.4	449 uS/cm @20oC	221 uS/cm @ 20oC
		160	14.71	3.8				11.0 oC	11.2 oC
		170	14.8	3.89					
	10:00	180	14.875	3.965					
		195	15.005	4.095					
	10:31	211	15.19	4.28					
		225	15.315	4.405		10 gals/min	65.4	452 uS/cm @20oC	219 uS/cm @ 20oC
		240	15.545	4.635				11.2 oC	11.5 oC
		255	15.73	4.82					
		270	15.93	5.02					
		285	16.12	5.21					
		300	16.285	5.375		10 gals/min	65.4		
	12:30	330	16.59	5.68					
	13:00	360	16.755	5.845		9.5 gals/min	62.13	466 uS/cm @20oC	217 uS/cm @20oC
		390	17.02	6.11				11.8 oC	12.2 oC
		420	17.255	6.345					
	14:30	450	17.485	6.575		9.5 gals/min	62.13	475	217
		480	17.645	6.735				11.3	12.4
		510	17.775	6.865		9 gals/min	58.86	479	219
		540	17.87	6.96				11.3	12.4
		570	17.955	7.045		9 gals/min	58.86	479	
	17:00	600	18.035	7.125				11.2	
		600.25	17.46	6.55				Pump off at exactly 17:00	

Date	Time	Elapsed Time	Water level below datum	Drawdown	Discharge		Discharge	Remarks
		Mins	(m)	(m)	Meter	Spot	(m3/d)	
		600.5	17.29	6.38				
		600.75	17.13	6.22				
		601	17	6.09				
		601.25	16.85	5.94				
		601.5	16.78	5.87				
		601.75	16.695	5.785				
		602	16.635	5.725				
		602.5	16.5	5.59				
		603	16.37	5.46				
		603.5	16.31	5.4				
		604	16.235	5.325				
		604.5	16.175	5.265				
		605	16.13	5.22				
		606	16.06	5.15				
		607	16	5.09				
		608	15.935	5.025				
		609	15.87	4.96				
		610	15.795	4.885				
	17:12	612	15.665	4.755				
		614	15.55	4.64				
		616	15.415	4.505				
		618	15.3	4.39				
		620	15.195	4.285				
		625	15.015	4.105				
		630	14.885	3.975				
		635	14.79	3.88				
		640	14.69	3.78				
		645	14.605	3.695				
		650	14.51	3.6				
		655	14.425	3.515				
		660	14.345	3.435				
		670	14.24	3.33				
		680	14	3.09				
	18:30	690	13.8	2.89				
		700	13.61	2.7				
		710	13.415	2.505				
		720	13.24	2.33				
		730	13.08	2.17				
		740	12.92	2.01				
		750	12.8	1.89				
		760	12.65	1.74				
		770	12.55	1.64				
		780	12.43	1.52				
	20:15	795	12.28	1.37				
		810	12.15	1.24				
		825	12.03	1.12				
		840	11.92	1.01				
						Average Q =	63.31909091	

Quarryhall Cross, Grenagh



Quarryhall Cross, Granagh, 26/5/99



Appendix 2

(Water Quality) Hydrochemistry Data

Grenagh WSS Water Quality

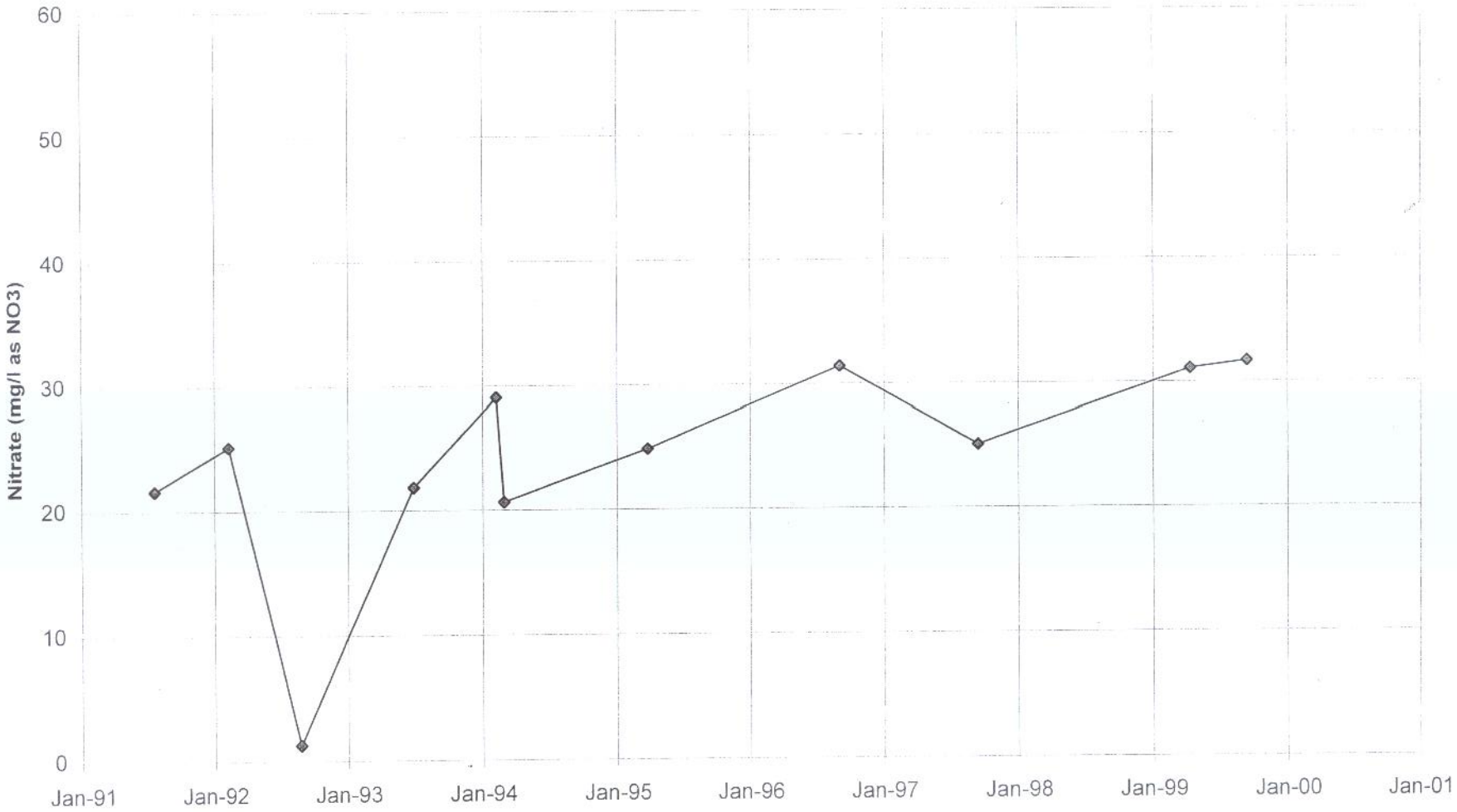
Greater than Guide levels
Greater than MAC levels

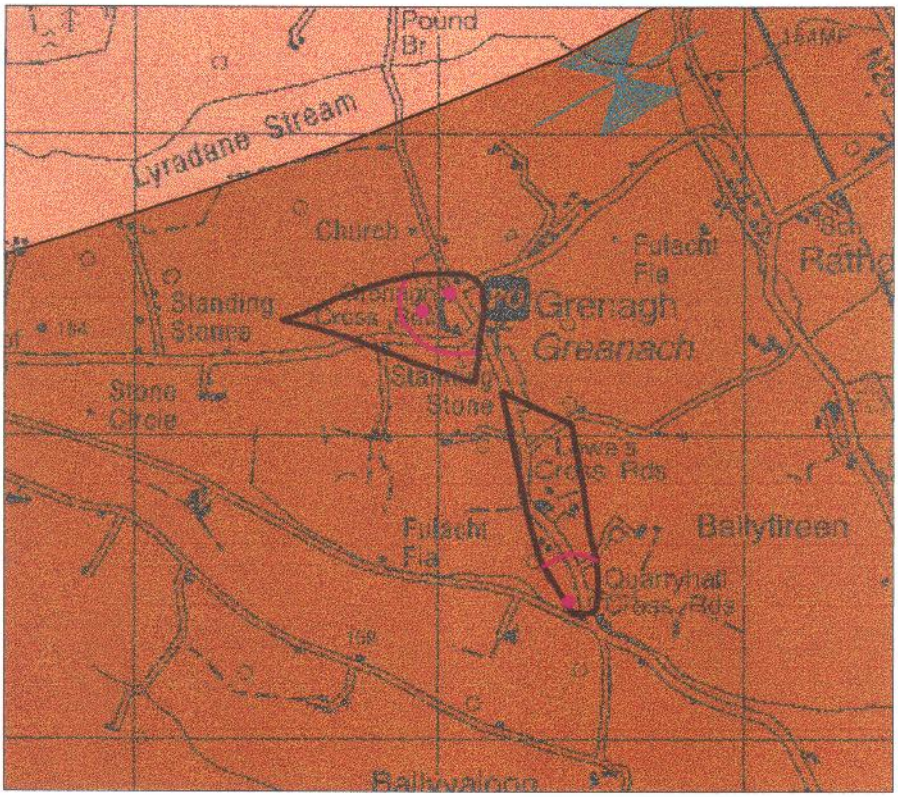
Hydrochemistry and Water Quality Database

Groundwater Section, Geological Survey of Ireland.

									Ratios		*Other Commonly Analysed Parameters*									*Bacteria*			*pH*	*Temp*	*EC (20)*
	Lab	Date	Ca	Mg	Na	K	SO4	Cl	K:Na	Mg:Ca	Alk.	TH	Fe	Mn	Nitrite	Nitrate	NH4	Al		E-Coli	TC	Treated	Lab	Lab	Lab
Units			mg/l	mg/l	mg/l	mg/l	mg/l	mg/l			mg/l CaCo3		mg/l	mg/l	NO2	NO3	mg/l	mg/l		no/100l		Y/N		oC	uS/cm
MAC			200	50	150	12	250	250					0.2	0.05	0.1	50	0.23	0.2		0	0				1500
	Inniscarra	14/10/1991																		0	0				217
	Inniscarra	11/02/1992													0	25.19	0.043			0	0		5.8	8	319
	Inniscarra	25/08/1992													0	1.28	0.026			0	0		5.8	14	219
	Inniscarra	15/09/1992																		0	0			14	301
	Inniscarra	31/03/1993																		0	0				212
	Inniscarra	25/05/1993																		0	1			12	208
	Inniscarra	29/06/1993													0.003	21.85	0.01			0	0		5.7	14	227
	Inniscarra	07/12/1993																		0	0				225
	Inniscarra	25/01/1994																		0	0				232
	Inniscarra	08/02/1994									11	66	0.42	0.041	0.003	29.08	0.001			0	0		5.7	7	192
	Inniscarra	01/03/1994											0.03	0.179	0.003	20.66	0.01			0	0		6.9	7.3	252
	Inniscarra	14/11/1994																		0	0				225
	Inniscarra	21/02/1995																		0	1				210
	Inniscarra	28/03/1995					10	28			46	77	0.1	0.164	0.002	24.89	0.02	0.03		0	0		5.8	7.5	216
	Inniscarra	20/11/1995																		0	6				200
	Inniscarra	21/05/1996																		0	0				221
	Inniscarra	03/09/1996											0	0	0.016	31.45	0.017	0.03		0	2		5.8	14	198
	Inniscarra	15/10/1996																		9	15				199
	Inniscarra	02/12/1996																		0	25				205
	Inniscarra	09/12/1996																		0	6				206
	Inniscarra	14/01/1997																		0	0				216
	Inniscarra	22/04/1997																		0	0				208
	Inniscarra	09/06/1997																		0	0				202
	Inniscarra	15/09/1997											0	0	0.013	25.07	0.026			0	3		5.7	11.3	202
	Inniscarra	13/04/1999	51.6	10.8	15	2	10	27	0.133	0.209		173	<0.05	<0.05	<0.013	31.1	<0.026			1	1	N	6.6		365
	Inniscarra	14/09/1999	55.3	11.5	16.8	2	13.2	27.2	0.117	0.207	128	184.7	<0.1	<0..05	<0.013	31.7	<0.026			0	0	Y?	6.6		372

Nitrate levels in Quarryhall Cross Borehole, Grenagh, 1991 - 1999





0 500m 1 km

Grenagh Water Supply Scheme

Map 1. Geology

BS Ballytrasna Formation

GM Gortanimill Formation

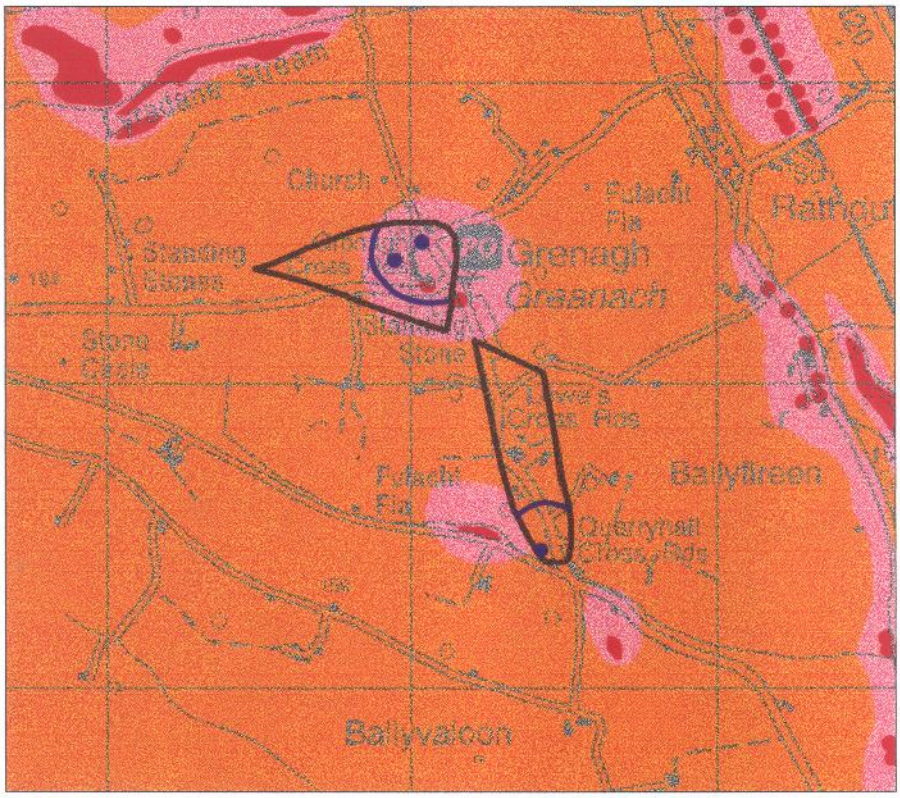
Synclinal Axis

Public Supply Well

Inner Protection Zone

This Bedrock Map is designed for general information and stragegic 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.

Zone of Contribution



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Grenagh Water Supply Scheme

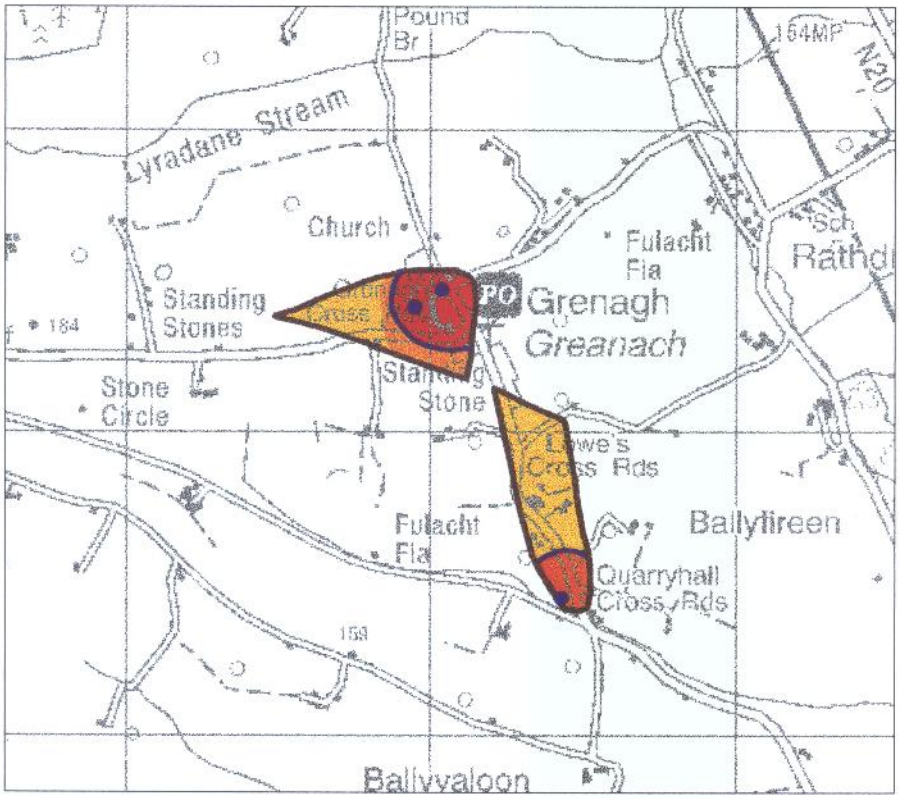
Map 2. Groundwater Vulnerability

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

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 assessements, and will frequently require site investigations to determine the risk to groundwater.



0 500m 1km

Grenagh Water Supply Scheme

Map 3. Source Protection Zones

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

Public Supply Well

Zone of Contribution

Inner Protection Zone

This **Source Protection Map** is designed for general information and stragegic 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.
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.