Environmental Protection Agency

Establishment of Groundwater Source Protection Zones

Cork North West Regional Water Supply Scheme (Doneraile) Shanballymore Spring

September 2010

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PROJECT DESCRIPTION

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

The project "Establishment of Groundwater Source Protection Zones", led by the Environmental Protection Agency (EPA), represents a continuation of the GSI's work. A CDM/TOBIN/OCM project team has been retained by the EPA to establish Groundwater Source Protection Zones at monitoring points in the EPA's National Groundwater Quality Network.

A suite of maps and digital GIS layers accompany this report and the reports and maps are hosted on the EPA and GSI websites (www.epa.ie; www.gsi.ie).

TABLE OF CONTENTS

TABLES & FIGURES

TABLES

FIGURES

1 INTRODUCTION

Groundwater Source Protection Zones (SPZ) are delineated for the Shanballymore source according to the principles and methodologies set out in 'Groundwater Protection Schemes' (DELG/EPA/GSI, 1999) and in the GSI/EPA/IGI Training course on Groundwater SPZ Delineation.

Shanballymore Spring is the main source for Doneraile Public Water Supply (0500PUB1104), a component of the Cork North West Regional Water Supply Scheme. The spring supplies the area around Doneraile and Shanballymore, serving approximately 3000 people (council records).

The objectives of the report are as follows:

- To outline the principal hydrogeological characteristics of the Shanballymore area.
- To delineate source protection zones for the spring.
- To assist EPA and Cork County Council in protecting the water supply from contamination.

The maps produced are based largely on the readily available information in the area, specific field work for this source and on mapping techniques which use inferences and judgements based on experience at other sites. As such, the maps cannot claim to be definitively accurate across the whole area covered, and should not be used as the sole basis for site-specific decisions, which will usually require the collection of additional site-specific data.

2 LOCATION, SITE DESCRIPTION AND WELL HEAD PROTECTION

Shanballymore Spring is located 1.2 km west of Shanballymore village, 5.7 km east of Doneraile and 5.5 km southwest of Kildorrery; on the north bank of the Awbeg river approximately 0.5 km east of the N73, in the townland of Clogher Demesne as shown in Figure 1. The spring discharges at the foot of a rock scarp, approximately 50 m back from the Awbeg river, at 56 mOD. The sump is uncovered and overflows to the Awbeg river over a newly constructed rectangular weir. The abstraction intake is in the uncovered sump area and the site is fenced off. The water is pumped to the top of the adjacent hill where the untreated water is chlorinated. The reservoir is located on top of the main plant. During severe rain events (as was the case in November 2009) the river floods the valley floor, backs up the spring discharge, drowning the weir.

3 SUMMARY OF SPRING DETAILS

According to Cork County Council figures the abstraction ranges from 2900 to 3500 m^3/day. The total spring outflow, including pumping is estimated to range from 70-300 l/s. The spring discharge and abstraction is discussed in further in Section 8.4 and Table 3-1 provides a summary of the details as currently known.

Weir at Shanballymore (May 2009, EPA)

Sump, Staff Gauge, Awbeg River in background (May 2009 EPA)

Table 3-1 Summary of Source Details

EU Reporting Code	IE_SW_G_082_04_024
Drinking water code	0500PUB1104
Grid reference	E166231 N107339
Townland	Clogher Demesne
Source type	Spring
Owner	Cork Co Co
Elevation (Ground Level)	56 m OD
Depth to rock	Rock at back of sump and where spring emerges
Static water level	Ground level (~0.5m above river)
Consumption (Co Co records)	2900-3500 m^3/d
Discharge Range (min-max) including pumping	70 – 308 l/s
Average Total Discharge	140-145 l/s
Hours Pumping (Co Co records)	Generally 23 hours /day
Depth of sump	~1.5m

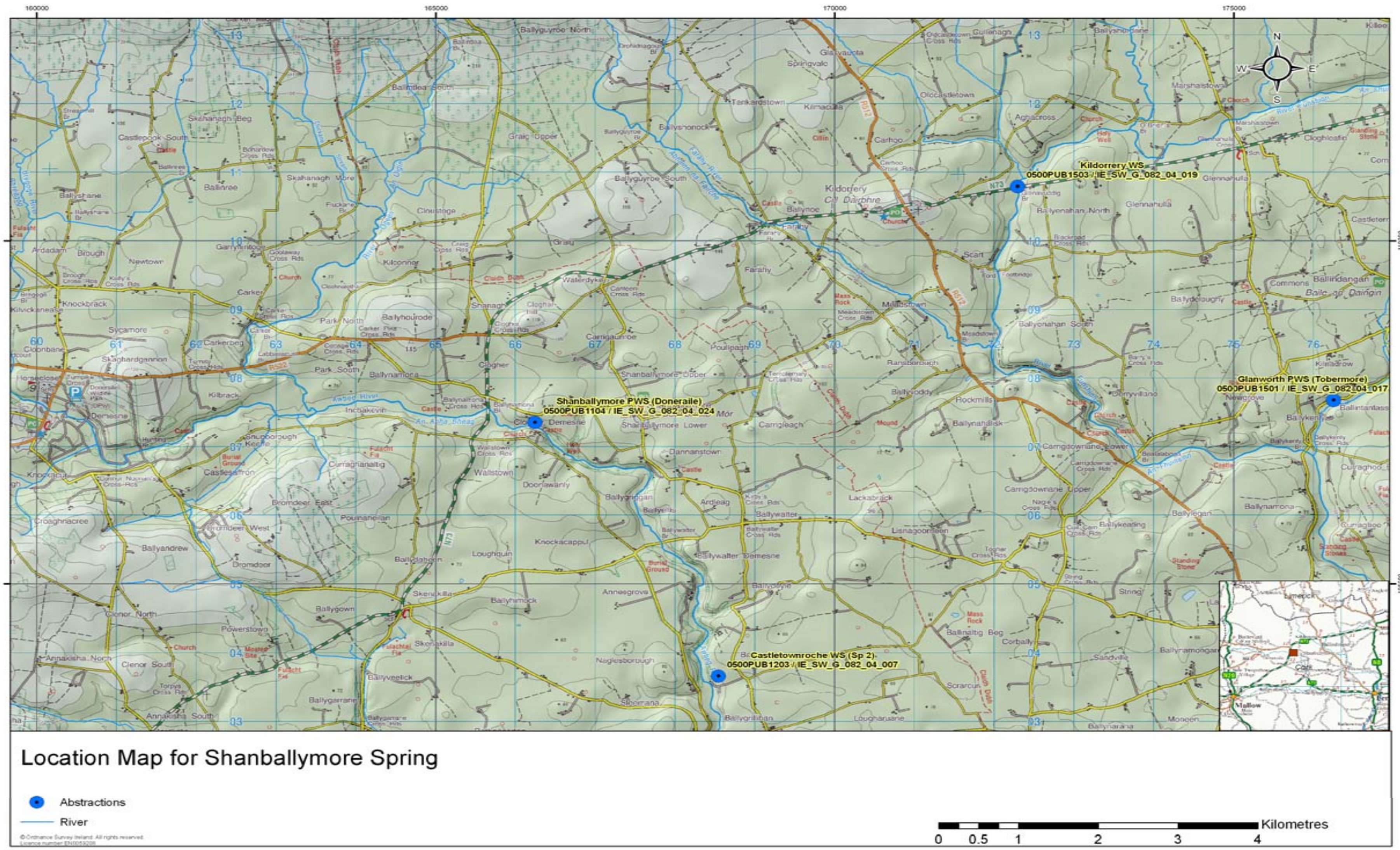

Figure 1 Location Map

4 METHODOLOGY

The methodology comprised data collection, desk studies, site visits, field mapping, discharge/conductivity/temperature measurements at springs and water tracing. A logger was installed by EPA Mallow office to assist with obtaining information on the discharge. Additional spot flow measurements were taken by EPA Mallow office for the spring at Ballinvoher (Castletownroche, also an EPA monitoring point and public water supply). Analysis of the information collected during the studies was used to delimit the SPZ. The water tracing was a multi-tracing experiment at four input locations using florescent dyes with detection by flurometer and spectrometer.

5 TOPOGRAPHY AND LANDFORMS, SURFACE HYDROLOGY AND LAND USE

The landscape to the north, east and southeast of Shanballymore Spring comprises a low plateau (broad interfluve) gently undulating between 60-110 m OD. The northerly extent of the plateau occurs at the foot of the Ballyhoura Mountains. At this point the land rises steeply to approximately 500 m OD from approximately 110 m. The Blackwater River demarks the southern extent of the plateau. The topography of the plateau can be subdivided into distinct landforms. Glacial deposits are present but glacial landforms are not very apparent. Though glacial landforms are not obvious there is a fluvial / karst intermix; fluvial in the main river valleys and karst on the interfluves (plateau) - a fluviokarst landscape. Obvious karst landforms other than springs in the valley floors are uncommon in the area examined.

Rivers are incised into the plateau at approximately 50 m OD. The main rivers are the Awbeg, Funshion, Farahy (a tributary of the River Funshion) and the Ogeen (a tributary of the River Awbeg). The Awbeg river initially flows west to east and then turns south just downstream of Shanballymore Spring, joining the Blackwater River south of Castletownroche. The Funshion river flows in a well defined valley, joining the Blackwater River, east of Fermoy. The incisions along the Awbeg river are particularly pronounced along the section between Clogher Demesne and Castletownroche. With the exception of a small stream entering the Ogeen River from the east, draining a forested area in Graig Upper and Cloustoge some 4 km north of Shanballymore spring, the plateau is devoid of a surface drainage system. This is an area occupying over 100 km^2, shown in Figure 2. It was assumed that the zone of contribution to Shanballymore Spring would be in the area between the Awbeg, Funshion, Farahy and Ogeen rivers as far south as Ballinvoher Spring (Castletownroche (PWS)) and this area was the focus of the study, also shown in Figure 2. All the springs in the study area are shown in Figure 2 and it is along the banks of the main rivers that the springs occur.

Land use in the study area is principally agricultural, split equally between tillage and pasture (dairying, cattle and sheep rearing) on the plateau. The narrow strip available on either side main rivers is used for pasture. The slopes of the Ballyhoura Mountains are forested. Shanballymore village is located in the study area. Shanballymore Wastewater Treatment Plant is located along the road between Shanballymore pumphouse and Shanballymore village - incidentally in the dry valley running to the Awbeg River at Clogher. The main Mitchelstown – Mallow road (N73) crosses the area north of Shanballymore Spring.

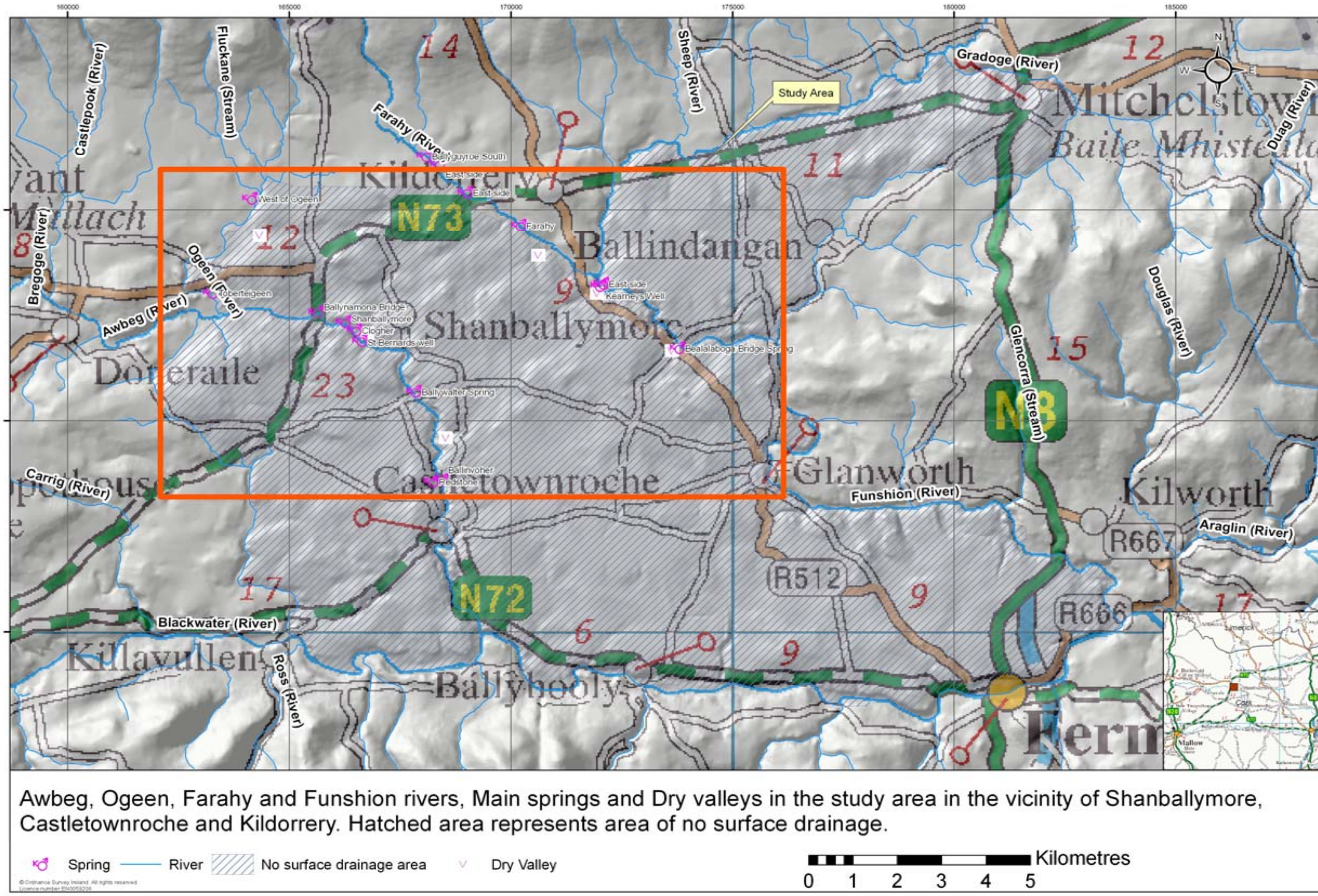

Figure 2 Main Rivers, Springs, Dry valleys and main focus of study.

6 GEOLOGY

6.1 BEDROCK GEOLOGY

The geological information is based the Geology of East Cork - Waterford Sheet 22, 1:100,000 Series (GSI, 1995). The bedrock map shown in Figure 3 indicates that the area is underlain principally by Pure Unbedded undifferentiated Dinantian Limestones. The Ballyhoura Mountains are occupied by Devonian Kiltorcan-type sandstones and Devonian Old Red Sandstones.

The geology is mapped in greater detail south of Shanballymore Spring and east of Kildorrery. Discussion with the GSI in November 2009 concluded that the limestones to the south of Shanballymore Spring are likely to extend northwest to meet with the corresponding units northwest of Shanballymore Spring and that the units east of Kildorrery would extend westwards and peter out.

The mapping to the south and east indicates considerable structural deformation with intense folding and faulting. Two major fault sets are widespread across the region; east-west trending (strike faults) and north-south trending (cross faults). A major synclinal feature is mapped to the east (Mitchelstown Syncline) and a smaller syncline to the southwest of Shanballymore Spring. The bedding is often steeply dipping particularly in the exposures bounding the Awbeg River. Very steep bedding was also observed in a cave at Carraigleagh Cave [Grid reference: 169255 107959] which is marked in Figure 4.

6.1.1 Karst Features

Hydrogeological mapping (September 2009) included investigating for karst features in the vicinity of the source. The karst features shown are both those recorded in the GSI Karst Feature Database and those mapped during the field work in 2009 by TOBIN, David Drew and Caoimhe Hickey. Figure 4 shows the karst features in the study area, and are tabulated in Appendix 1. The recognized karst landforms comprise springs, dry valleys, sinks, caves and a few dolines.

- A desk study of the maps (six inch) was conducted to locate all the springs in the vicinity of Shanballymore and Ballinvoher Springs along the Awbeg, Farahy, Ogeen, Funshion and Blackwater Rivers. The springs shown in Figure 2 and Figure 4 are those located in the study area. Field mapping was conducted to investigate the springs for both conductivity and approximate flow rates. The springs occur in the valley floors at the interface between the karst and fluvio environments.

- There are several dry valleys, shown in Figure 2 and Figure 4: into the Ogeen between Kilconnor and Ballyhourde; into the Awbeg River at Clogher just downstream of Shanballymore Spring; into the Awbeg at Ballydoyle, one kilometre upstream of Ballinvoher spring; into the Farahy River at Meadstown; and into the Funshion at Rockmills; into the Funshion at Bealalaboga Bridge.

- Active swallow holes were mapped through a combination of reviewing of the six inch maps, aerial photographs and field mapping: at Shanagh and Polleagh and in the forestry in Graig Upper. The swallow hole at Polleagh is located just inside the Meadstown dry valley. The Shanagh swallow hole is located within the Kilconnor dry valley. The sinks at Graig Upper occur on the limestone side of the sandstone/limestone boundary close to the northern edge of the plateau.

- Two caves were mapped: at Ballinaltig Beg, located on the plateau; and, at Carraigleagh, is located at the southern edge of Meadstown dry valley on the other side to Polleagh swallow hole.

- Local farmers indicate that small collapse dolines a few metres in depth and width ('Sluggeras') appear in the fields, usually filled back in. Such a feature is shown in the photographs below, and was located within a few hundred metres northwest of Polleagh swallow hole and is reported to be been approximately 3m deep. Additionally, there are few enclosed infilled depressions, holding stagnant water. The dolines and depressions occur on the plateau but are notably uncommon.

- Outcrops generally display solutionally enlarged features and in one instance a conduit was found in dry valley at Ballydoyle (between Shanballymore Spring and Ballinvoher Spring). See photographs below of the conduit, swallow holes and a collapse doline (sluggera).

Conduit in Ballydoyle drive valley [168536 104600] note gravels at bottom of conduit (12/10/2009)

Inflow at bottom of Polleagh Swallow Hole (2/11/2009).

Polleagh Swallow Hole [169023 108238] Note elevation change (2/11/2009)

Sluggera in field close to Polleagh Swallow hole (Mr. O'Brien) [approximately 168868 108322].

6.2 SUBSOILS GEOLOGY

According to GSI and EPA web mapping, the study area is dominated by two types of till: Till derived from Devonian Sandstone (TDSs) and Till derived from Namurian Sandstones and Shales (TNSSs). Karstified bedrock outcrop (KaRck) is distributed throughout the study area and the river valleys tend to be floored by alluvium. The subsoils are depicted in Figure 5. The soils on the till areas are dominated by 'dry' soil types: typically acid well drained deep mineral soils (BminDW) (EPA website and). There are 'wet' soils coincident with lower portions of the landscape underlain by Till derived from Namurian Sandstones and Shales (TNSSs). Within the study area no subsoil exposures were discovered. The GSI drilled seventeen auger holes to the south of the study area in Castletownroche (GSI, 2000) and the till is been classified according to British Standard 5930 and comprises sandy SILT and sandy CLAY. Based on the absence of permanent surface water features and secondary indicators of low subsoil permeability, it is considered that the till is generally free draining and that the subsoils are dominated by 'moderately permeable' subsoil.

6.3 DEPTH TO BEDROCK

Depth to bedrock varies greatly and unsystematically throughout the study area. Rock outcrops are distributed throughout the area. The GSI augering at Castletownroche indicates depths to rock up to 10 m in places, occasionally deeper.

7 GROUNDWATER VULNERABILITY

Groundwater vulnerability is dictated by the nature and thickness of the material overlying the uppermost groundwater 'target'. A detailed description of the vulnerability categories can be found in the Groundwater Protection Schemes document (DELG/EPA/GSI, 1999) and in the draft GSI Guidelines for Assessment and Mapping of Groundwater Vulnerability to Contamination (Fitzsimons, 2003). The Groundwater Vulnerability map (WFD) for the region, is dominated by 'High to Low' and is shown in Figure 6. The Groundwater Vulnerability map available in the Castletownroche (SPZ) report (GSI, 2000) indicates that the vulnerability is dominated by 'High' Vulnerability with 'Extreme' Vulnerability evidenced by outcrops, shallow and moderately permeable subsoils. It is considered that the vulnerability is predominantly 'High' to 'Extreme' across the study area with potentially smaller areas of 'Moderate'. In 2011 the regional groundwater vulnerability will be mapped by TOBIN Consulting Engineers on behalf of the GSI and this report should be updated to include the results of this mapping when the data and maps are available (2012).

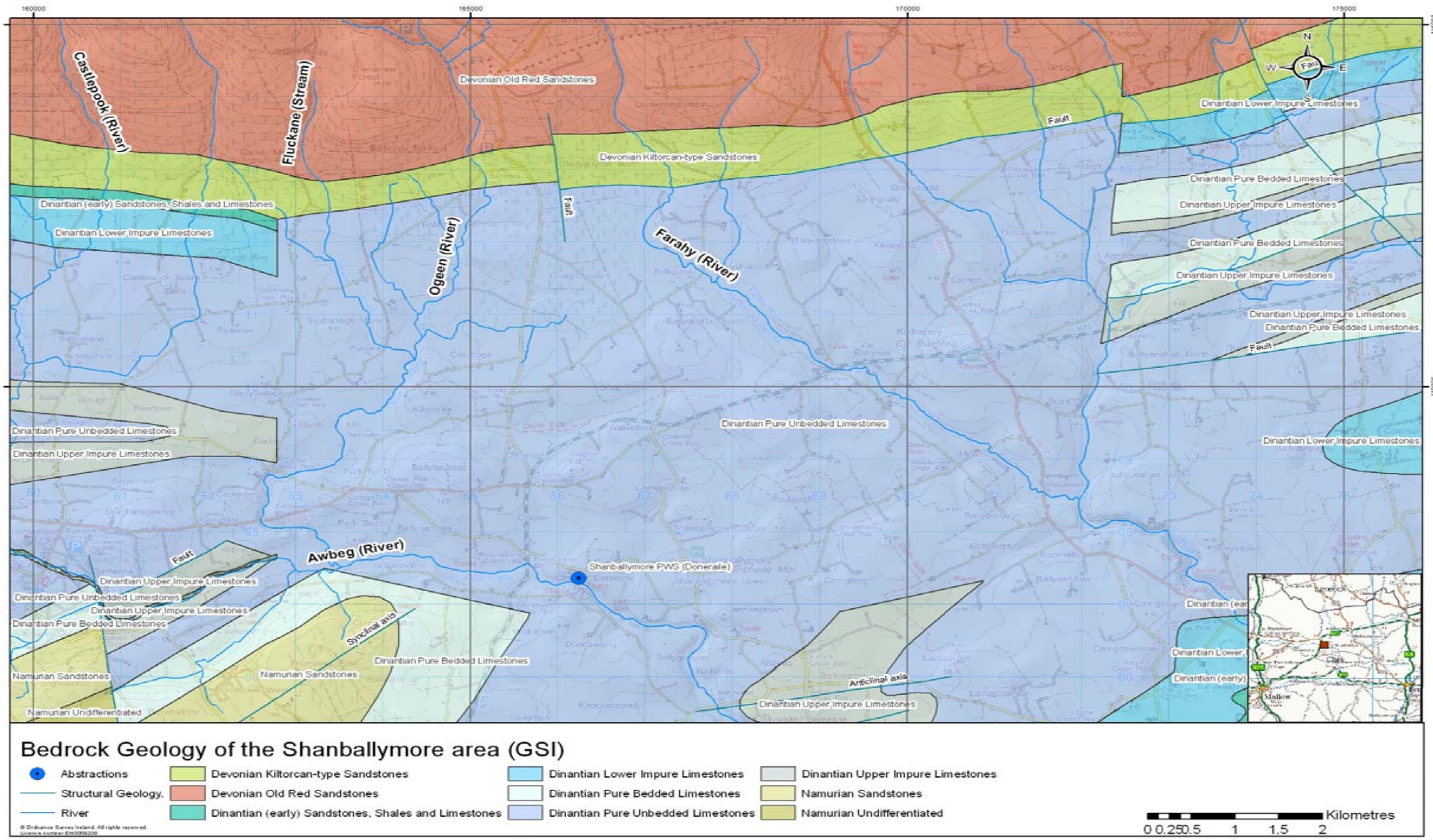

Figure 3 Bedrock Geology

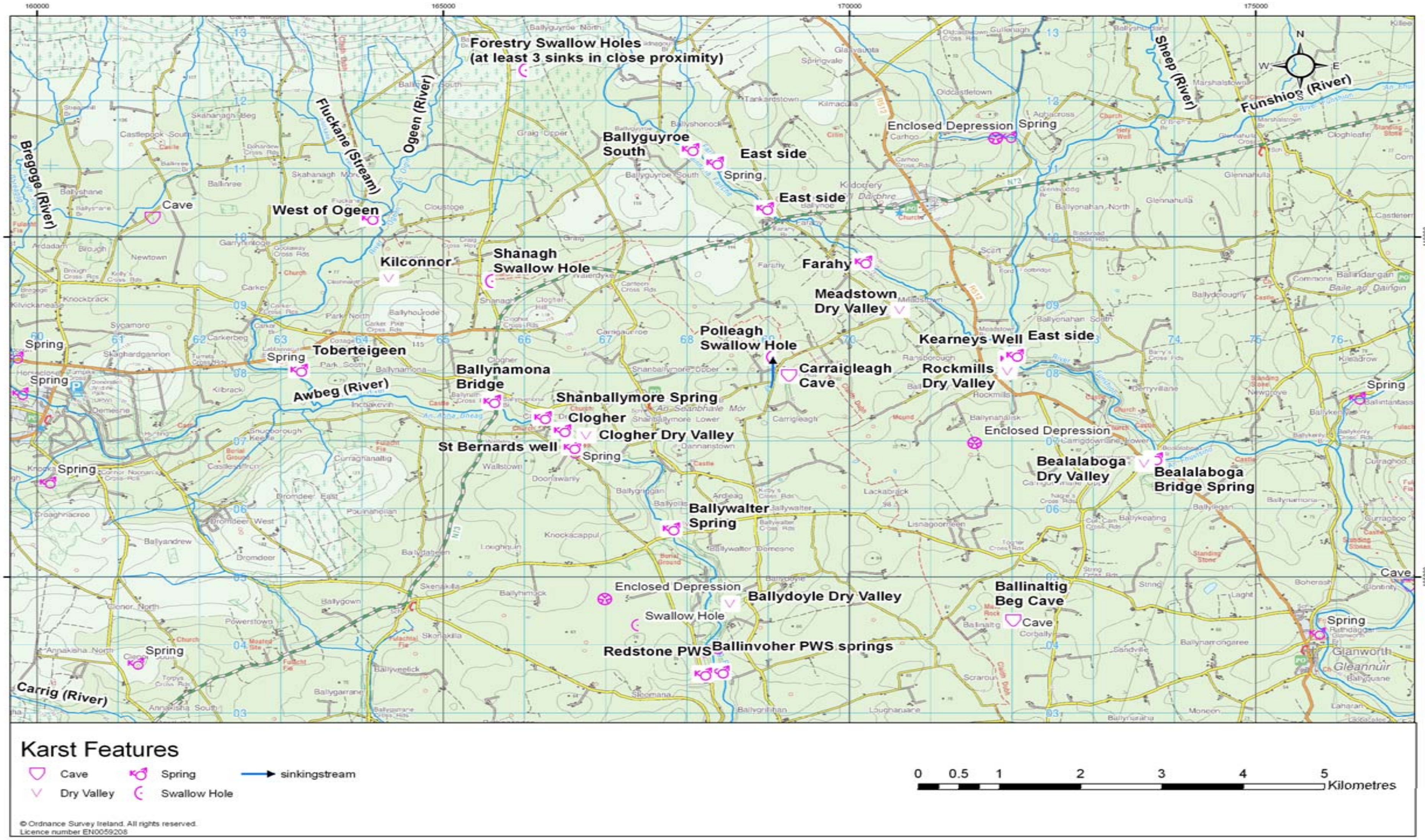

Figure 4 Karst Features map

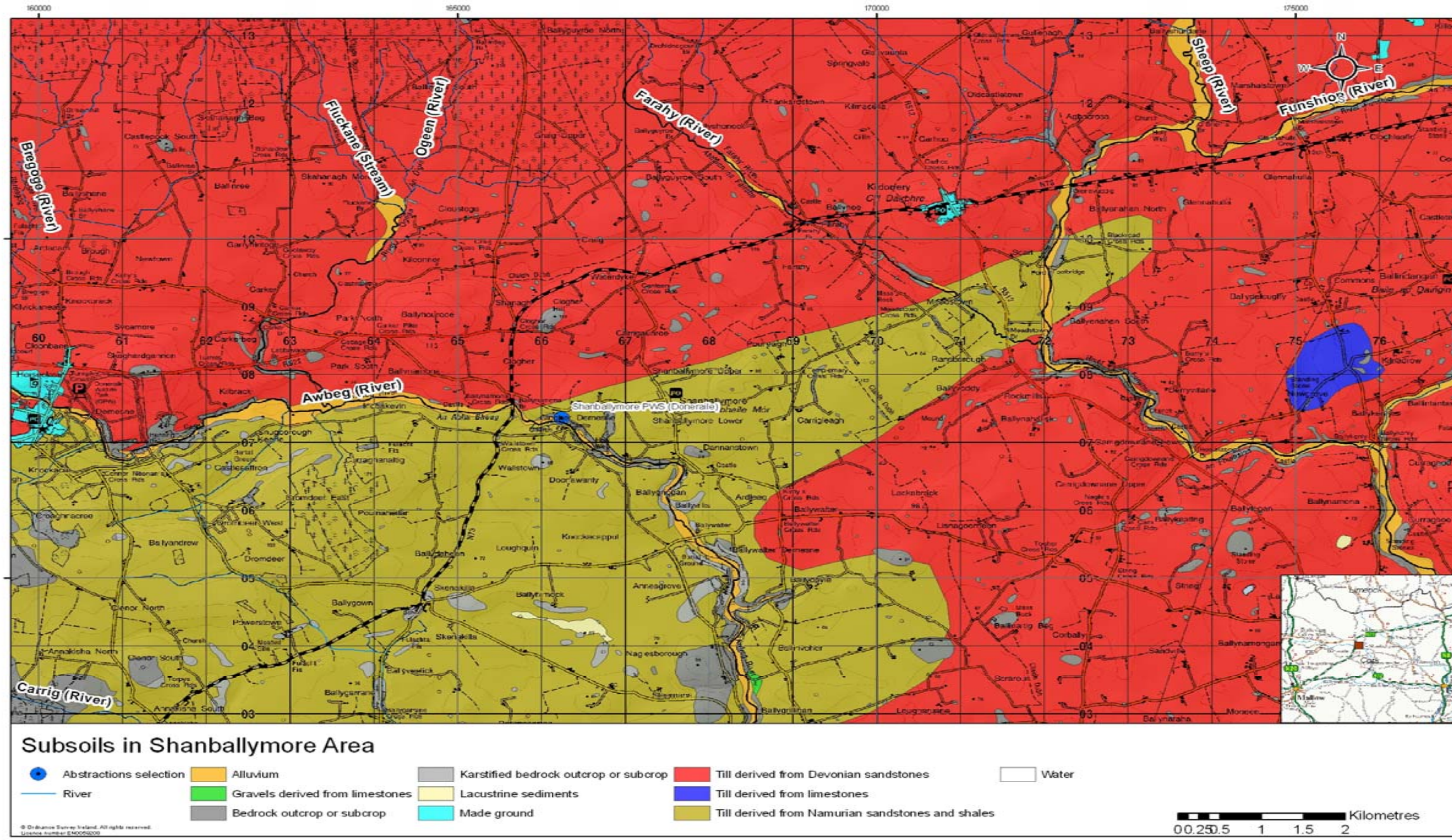

Figure 5 Subsoil Map

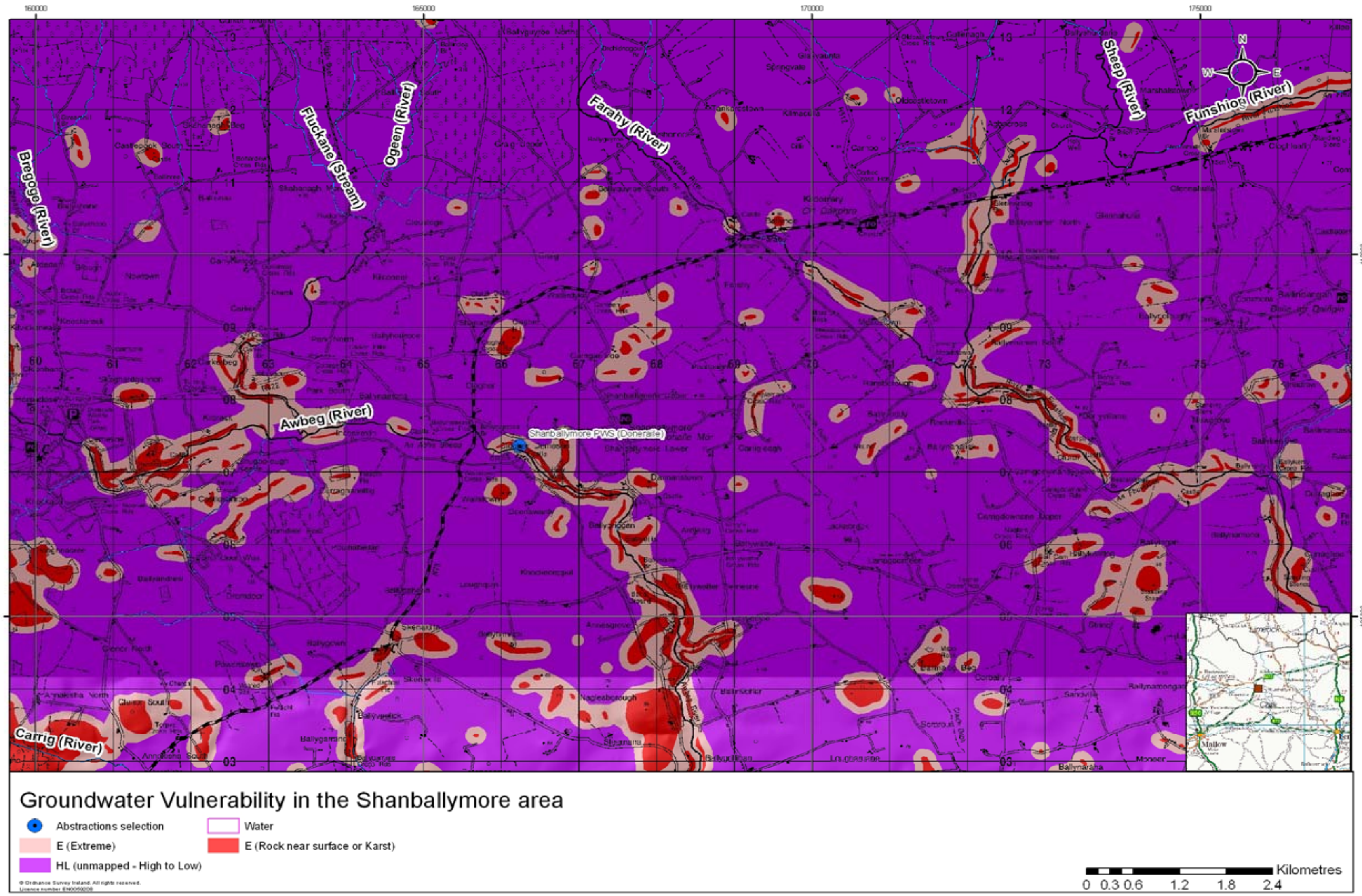

Figure 6 Groundwater Vulnerability

8 HYDROGEOLOGY

This section describes the current understanding of the hydrogeology in the vicinity of the source. Hydrogeological and hydrochemical information was obtained from the following sources:

- GSI Website and Database
- County Council Staff
- EPA website and Groundwater Monitoring database
- Local Authority Drinking Water returns
- The Lower Carboniferous Limestone Aquifer near Buttevant, Co. Cork, C.C.D.F.Van Ree & G. Rot 1981. Unpublished thesis, Vrije University Amsterdam. [This area of study ends at Ballynamona Bridge, just west of Shanballymore.]
- Castletownroche Source Protection Zones (GSI report, 2000)
- EPA spring discharge data
- Hydrogeological mapping by TOBIN, Trinity College Dublin and the Geological Survey of Ireland in September, October and November 2009
- Tracing by TOBIN, OCM, Trinity College Dublin and the Geological Survey of Ireland November 2009.

8.1 GROUNDWATER BODY AND STATUS

The area around Shanballymore is included in the Michelstown Groundwater Body which is of Good Status. The groundwater body descriptions are available from the GSI website: www.gsi.ie and the 'status' is obtained from the following website: www.wfdireland.ie .

8.2 HYDRO-METEOROLOGY

Establishing groundwater source protection zones requires an understanding of particular hydro-meteorological values in the area of interest. The data source is Met Eiréann.

Annual rainfall: taken to be 1000 mm. The contoured data map of rainfall in Ireland (Met Éireann; 1961-1990 dataset) shows that the spring and potential zone of contribution is located between the 1000 – 1200 mm average annual rainfall isohyets. Given the potential size of the zone of contribution the rainfall amounts are likely to vary: the contour map indicates that rainfall amounts increase to the north and north east over the Ballyhoura and Galtee mountain ranges. West of the spring, nearby historical rain gauges at Buttevant and Doneraile record amounts of approximately 970 mm/year.

Annual evapotranspiration losses: taken to be 428 mm. Potential evapotranspiration (P.E.) is estimated to be 450 mm/yr (based on data from Met Éireann). Actual evapotranspiration (A.E.) is then estimated as 95% of P.E., to allow for seasonal soil moisture deficits.

Annual Effective Rainfall: 572 mm. The annual effective rainfall is calculated by subtracting actual evapotranspiration from rainfall. Potential recharge is therefore equivalent to this, or 572 mm/year. See section on Recharge which estimates the proportion of effective rainfall that enters the aquifer.

8.3 GROUNDWATER LEVELS, FLOW DIRECTIONS AND GRADIENTS

Tracing tests were conducted during November 2009 and March/April 2010; the aim of which was to determine the zone of contribution to Shanballymore by injecting tracer at suitable points of naturally concentrated recharge (typically swallow holes), within the maximum possible zone of contribution – an area of approximately 15 km^2 to attempt to characterise dominant flow directions, typical flow rates and distinguish the likely zone (s) of contribution to Shanballymore Spring.

Dye was injected into the main swallow holes (Figure 2) in November 2009 and monitored at the springs. For the trace conducted in November 2009, the weather was very wet and all rivers were at high stage, and at a few locations the spring sampling was compromised by river water mixing with spring water as the river flooded the valley floor submerging the spring discharge points. This happened at Ballynamona, Ballywalter, Clogher Demesne and at Farahy. The springs that appeared to be unaffected were Ballinvoher, Shanballymore, Toberteigeen and Kearneys well: slightly higher and much larger spring discharges. There were no positive results from the tracing programme and was considered at the time to be largely due to the high flows in the rivers. A further tracing test was conducted in February 2010 at a lower stage. There were no positive results reported from this trace either. The results suggest that at the few sites of concentrated recharge the water is transmitted to the rivers in response to the regional hydraulic water table, rather than the springs, which are overflows to groundwater heading to the river resulting from locally focussed groundwater.

Groundwater levels: With the exception of the occurrence of the springs alongside the rivers, there are few hydrogeological data on groundwater levels in the study area. Van Ree & Rot (1981) record water levels in the order of 6-20 m bgl from boreholes and wells across the Buttevant to Ballynamona area. The Awbeg and Funshion rivers are assumed to be discharge zones for groundwater and regional hydraulic boundaries. Within the immediate vicinity of the springs and the rivers, the water table intersects the land surface. It is considered that the springs are overflows for groundwater that is heading for the river. Within the main topographical block between the Awbeg, Ogeen, Farahy and Funshion Rivers groundwater levels are not known precisely. The available relief between the interfluve/plateau area and the springs in the study area is in the order of 20-40 m. During high rainfall periods the swallow holes back up with water filling up the basins in which they occur. It is assumed that these maximum water levels represent the groundwater water table during these high stages. The stagnant ponds located on the top of the plateau areas do not have a groundwater signature and do not appear to act as focused recharge points and it is considered they do not reflect groundwater levels.

Groundwater flow directions are assumed to be principally towards the springs and rivers. Groundwater contours drawn by Van Ree and Rot (1981) indicate that in their study area (west of Shanballymore to Buttevant) the groundwater flow directions are principally to the Awbeg. It is assumed that that the groundwater system is valley orientated and line discharge in character. It is possible though that the River Blackwater is the regional base level and that groundwater through the interfluves area may be heading to the Blackwater. However, springs are concentrated along the Awbeg and Funshion; a search for springs along the Blackwater between the Awbeg and Funshion connections revealed very few small springs. Further the largest springs are located north of Castletownroche discharging to the Eastern bank of the Awbeg. Due to the larger outflows along the Awbeg River, it is considered that the dominant flow is toward the Awbeg River. It is assumed that there is a groundwater divide between the Funshion and the Awbeg River, coincident with the broad topographic divide occurring through the spine of the plateau.

Groundwater Gradients: Appendix 3 provides information on elevation, distance and likely groundwater gradients between the monitoring sites and the injection sites. The elevation of the input sites is expected to higher than the water table except in wet weather periods, therefore the true groundwater gradients are likely to be flatter than presented in the table. The gradients along the rivers are relatively flat, for example, approximately 0.002, from Shanballymore to Ballinvoher along the Awbeg River. Groundwater contours drawn by Van Ree and Rot (1981) suggest gradients in the order of 0.006 in the limestones.

The photographs below show the conditions of the Awbeg in the vicinity of Shanballymore Spring on the 16th November 2009 (the day of the trace); and, show Polleagh Swallow hole both prior to and on the day of the trace.

Shanballymore Drowned Weir (16/11/2009, Katie Tedd, EPA)

Polleagh Swallow hole start of (2/11/2009) Low Flow

Polleagh Swallow hole (2/11/2009) Low Flow

Polleagh Swallow hole 16/11/2009 (John Dillon, Tobin) High Flow

8.4 SPRING DISCHARGE

In the main study area, there are springs occurring along the banks of the Awbeg and Funshion rivers, as shown in Figure 2 and Figure 4, and listed in Appendix 2. The biggest springs occur along the Awbeg river and in particular Shanballymore, Ballinvoher, St. Bernards Well and Redstone Well appear to the biggest based on the available data. Redstone well and St. Bernards well occur on the western side of the Awbeg. Shanballymore and Ballinvoher occur on the eastern side of the Awbeg. There are two smaller outflows – Clogher and Ballywalter which occur between the larger springs at Shanballymore and Ballinvoher.

Only Shanballymore, Ballinvoher and Redstone have had any historical 'spot' flow data measured, and the estimates given in Appendix 4 for the other springs are based on estimates during the work in Autumn 2009. In general the other springs are single outflow points, the main exceptions being Ballinvoher where there are smaller discharges in close proximity and Toberteigeen which during the high water stage had several smaller overflow points in close proximity to the main discharge point.

The springs are principally concentrated along the Awbeg and Funshion with smaller springs discharing to the Farahy and Ogeen. Further the largest springs are located north of Castletownroche discharging to the Eastern bank of the Awbeg. A crude approximation of the outflows of the springs using the data in Appendix 2 indicates a discharge 250-350 l/s - the bulk of which is to the Awbeg. The approximate topographic area that could discharge to springs is in the order of 115 km^2, which potentially could generate over 700 l/s, suggesting the majority of groundwater flow is to the rivers. There is anecdotal evidence that there are groundwater discharges issuing from the bed of the Awbeg and it is also a gaining stream.

Shanballymore: A newly constructed weir (photograph in section 3) and a water level logger were put into the sump at Shanballymore Spring in September 2009 to provide continuous time discharge data (Hydrometric Staff, EPA, Mallow). The hydrograph provided in Figure 8 is the maximum value for each day where there was a period of no pumping. High flows in the Awbeg river can cause the overflow to back up and drown the weir as shown in the photographs in the previous section. This appears to occur when the overflow is above 0.2 m^3/s. A longer data record is required to establish a fully calibrated rating curve, however, the data provide useful information on the discharge and the behavior of the aquifer system. The data used to assess the discharge is data below 0.2 m^3/s and when there was no pumping. The data is considered to represent average total flow conditions. The outflow at Shanballymore Spring reacted within a day to a relatively large rainfall event (40.4 mm) on 6th October 2009. From 21st October onwards the outflow continued to rise in response to a very wet weather period culminating in the drowning of the weir around the 4th of November 2009.

Abstraction at Shanballymore: According to council records approximately 2900 - 3500 m^3/day of groundwater is abstracted from Shanballymore. Generally, the pumps are off early in the morning or late at night for approximately an hour. Occasionally pumping continues for up to 48 hours and longer without stopping. The response of the overflow appears to be almost instantaneous, and is assumed to represent the total discharge for that period in time.

Summary Total Discharge (overflow and abstraction) for Shanballymore:

Range: 70-308 l/s (6,000 – 26,000 m^3/day)

Median: 142 l/s (12,267 m^3/day)

Arithmetic mean: 145 l/s (12,528 m^3/day).

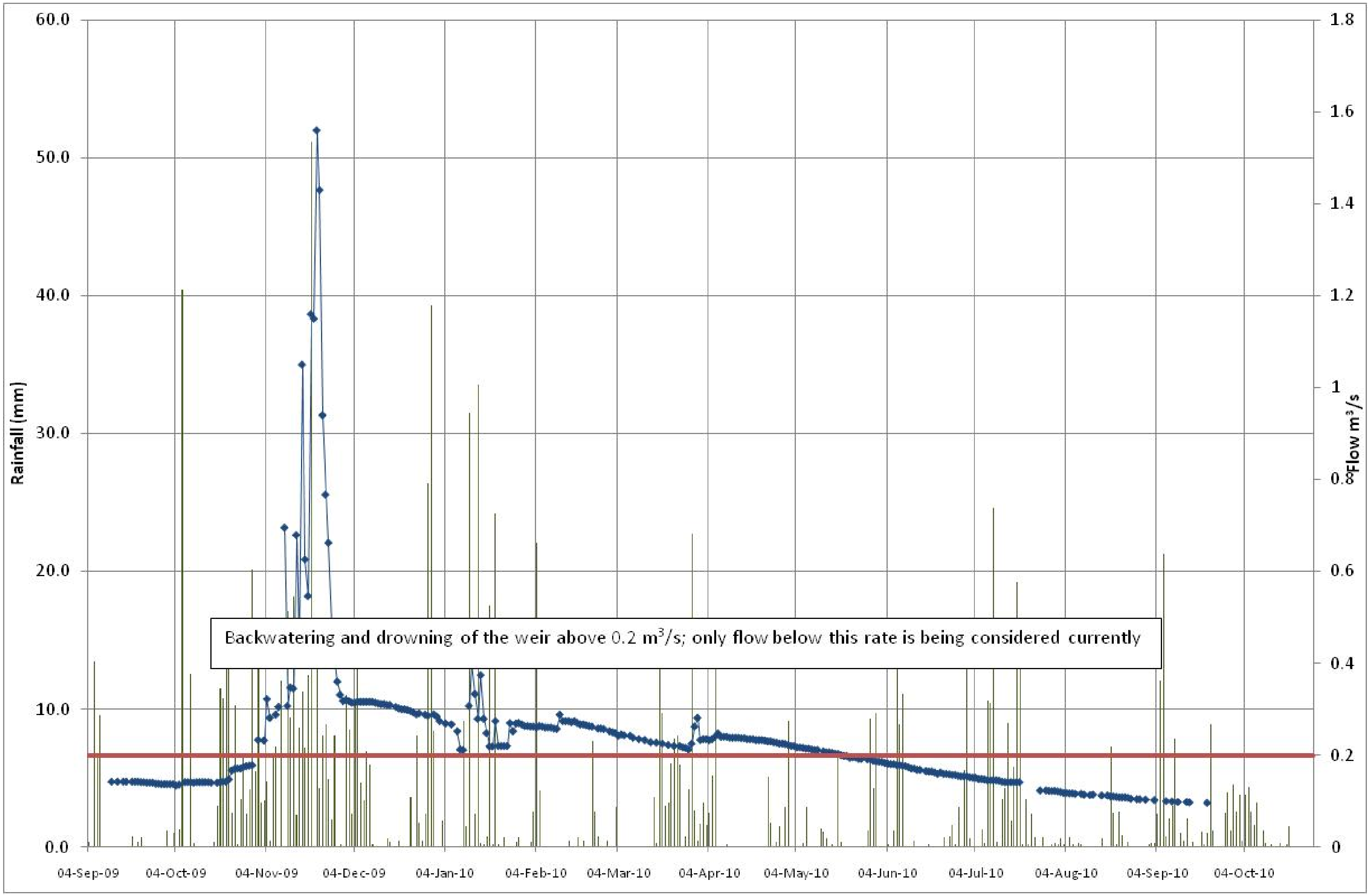

Figure 7 Rainfall (Cork airport) and Shanballymore flow data (EPA Mallow)

8.5 HYDROCHEMISTRY AND WATER QUALITY

The hydrochemical analyses of 32 untreated samples show that the water is moderately hard to very hard, with total hardness values of 152-377 mg l^{-1} (equivalent $CaCO_3$) and electrical conductivity (EC) values of 575-671 µS cm^{-1}, (average 627 µS cm^{-1}) indicating that the groundwater has a calcium bicarbonate hydrochemical signature (32 samples) (EPA data). The coefficient of variance of electrical conductivity of 5.5% is relatively low suggesting that recharge is dominated by diffuse recharge (Doak 1995).

Figure 8 shows the data for the key indicators of contamination and the main points are as follows:

- Nitrate concentrations range from 18.6-31.8 mg/l with a mean of 24 mg/l from 32 samples. The mean is less than the groundwater threshold value (Groundwater regulations S.I. No. 9 of 2010) value of 37.5 mg/l and less than EU MAC (50 mg/l). A slightly upward trend line through the data is observed, shown in Figure 8. The mean nitrate concentrations are noticeably lower than several of the other public water supply springs in North Cork, for example at Ballinvoher (Castletownroche PWS No2), which has a mean of 38 mg/l and Glanworth (Tobermore) which has a mean in excess of the EU MAC.

- Chloride is a constituent of organic wastes, sewage discharge and artificial fertilisers, and levels higher than 24 mg/l (Groundwater Threshold Value for Saline Intrusion Test, Groundwater Regulations S.I. No. 9 of 2010) may indicate contamination, with levels higher than 30 mg l^{-1} usually indicating significant contamination (Daly, 1996). Chloride concentrations range from 16-25 mg/l with a mean of 22 mg/l.

- The average concentration of Molybdate Reactive Phosphorous (MRP) is 0.02 mg/L P, which is below the Groundwater Threshold Value (Groundwater Regulations S.I. No 9 of 2010) of 0.035 mg/L P. The threshold value was exceeded once on 13/2/2003 with a reported concentration of 0.136 mg/l.

- The ratio of potassium to sodium (K:Na) is used to help indicate if water has been contaminated along with other parameters and may indicate contamination if the ratio is greater than 0.035-0.4. From 32 analyses the ratio exceeded 0.035 on two occasions: 4/9/2000 and 30/1/2005.

- Faecal coliforms counts were exceeded on 4 occasions out of 32 samples, generally in early autumn or winter, with one record of gross contamination: 33/100ml on 27/9/2001. Total coliform counts were exceeded on 9 occasions out of 32 samples. Ammonia concentrations are generally less than 0.01 mg/l (21 out of 32 samples), and twice have exceeded the threshold concentration of 0.065 mg/l on 30/7/2008 and 9/10/2009; the latter occasion coinciding with an exceedance of both faecal and total coliforms.

- Iron and manganese concentrations are generally low but on one occasion 20/8/1996, Manganese concentrations were recorded at 0.140 mg/l, greater than 0.05 mg/l (EU MAC) and Iron concentrations were recorded at 0.48 mg/l, greater than 0.2 mg/l (EU MAC).

In summary the water quality is generally good that is occasionally contaminated, usually in autumn and winter. Faecal and total coliforms and manganese are the only parameter to exceed the EU MAC and may indicate contamination from organic wastes. The concentrations of nitrates and chlorides are those expected from groundwater in an intensively farmed land. Further, the nitrate concentrations indicate a slight rising trend.

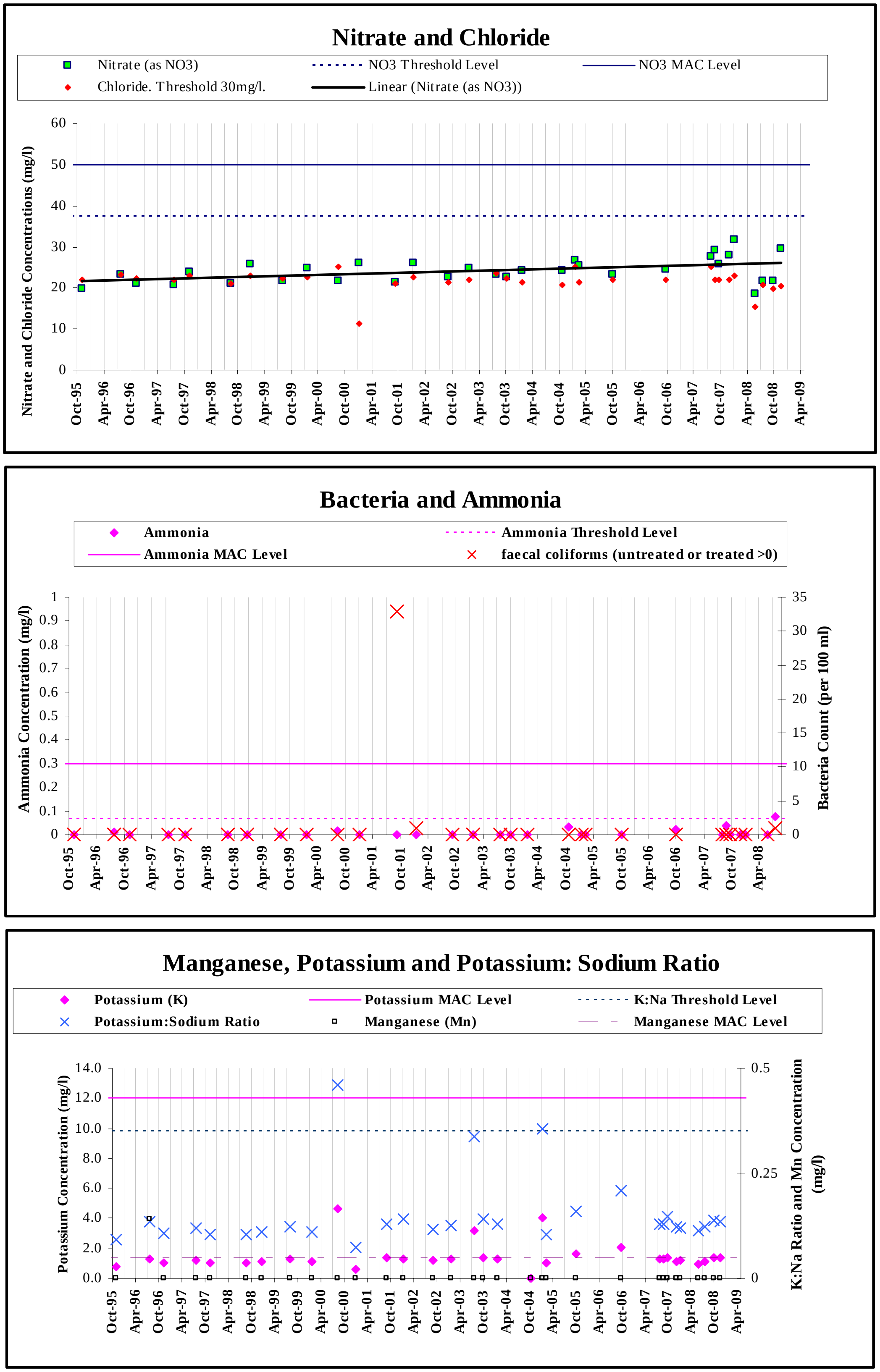

Figure 8 Key indicators of contamination at Shanballymore Spring

8.6 AQUIFER CHARACTERISTICS

The Pure Unbedded Dinantian Limestones which deliver the groundwater to the springs in the study area are classified as a Regionally Important Karst Aquifer (Rk^d) – dominated by diffuse flow. This is supported somewhat by the hydrochemistry - the coefficient of variability of conductivity for Shanballymore suggests that diffuse recharge component is signficiant; similiarly for Ballinvoher, though slightly higher. It is further supported by the apparent absence of dolines and swallows holes, although 'sluggeras' do occur.

Dry valleys, collapse features (sluggeras), disappearing streams, swallow holes, caves, and solution features on outcrop can be seen in the area and indicate that the rocks have undergone karstification. Several infilled cavities within the Waulsortian Limestone that have no surface expression have been interpreted from the geophysical surveys carried out in Glanworth and Kilworth. (Motherway, 1999).

The springs have a groundwater origin, and the Awbeg and Funshion Rivers have an electrical conductivity (470-500 $\mu S\ cm^{-1}$) that is significantly higher (four/five fold) than the Farahy and Ogeen rivers (110-143 $\mu S\ cm^{-1}$), indicating a significant groundwater discharge to the rivers as they pass over the limestones from the sandstones. The electrical conductivity or temperature of the Awbeg does not change noticeably between Ballinvoher (470 $\mu S\ cm^{-1}$) and Ballynamona (476 $\mu S\ cm^{-1}$), a distance along the river of approximately 5 km.

Van Ree & Rot (1981) suggest the apparent transmissivity to be in the order of 500 m^2/d and an effective porosity in the order of 4-5%. Test pumping of the Waulsortian Limestone at Downing Bridge and Moorepark suggested transmissivities ranging 15-3400 m^2/d (Motherway, 1999). The springs in the study area and in particular Shanballymore and Ballinvoher indicate high permeability and groundwater velocities. The lack of surface drainage on the karst plateau hints at the high permeabilities of the limestones.

The karst in the study area comprises solutionally enlarged channels but with a more distributed, less hierarchically organised/focussed system, i.e., it appears less developed. There may be significant structural/geological control on groundwater behaviour particularly where folding and/or faulting is present. Van Ree & Rot (1981) propose that faulting controls in combination with cherty units within the limestones for the location of the springs.

8.7 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 loss prior to entry into the groundwater system (*i.e*. annual evapotranspiration and runoff). The estimation of a realistic recharge rate is critical in source protection delineation, as it will dictate the size of the zone of contribution to the source (*i.e*. the outer Source Protection Area).

The primary evidence for estimating the recharge is that in the study area there is a lack of a surface drainage system apart from the main rivers. Further the majority of the subsoils at Castletownroche are classified as moderate permeability subsoils (GSI, 2000) and the groundwater vulnerability is predominantly 'high' to 'extreme', with a significant distribution of karst rock at the surface; and, that the area is known to have sluggeras throughout the area which act as rapid entry points for recharge.

The ***recharge coefficient*** for the area is therefore estimated to be 95%.

These calculations are summarised as follows:

Average annual rainfall (R)		1000 mm
estimated P.E.		450 mm
estimated A.E. (95% of P.E.)		428 mm
potential recharge		572 mm
runoff	5%	30 mm
Bulk recharge coefficient	95%	
Recharge		**543 mm mean annual**

8.8 CONCEPTUAL MODEL

The current understanding of the geological and hydrogeological situation is given as follows:

- The region comprises a fluvio-karst system – a karstic interfluve (plateau) with a fluvial system in the river valleys comprising principally the Awbeg and Funshion Rivers which are flowing the River Blackwater.

- The geology although dominated by karstified limestones indicates that there may be a significant structural/geological control on groundwater behaviour particularly where folding and/or faulting is present. The karst system comprises solutionally enlarged channels and other karst features at the surface but it appears to comprise a more distributed, less hierarchically organised/focussed system.

- The springs, generally single outflows, occur along the banks of the rivers at the base of the karst plateaus, thus appear to be overflows for groundwater that is heading to the rivers. The largest springs occur on the Awbeg, particularly on the eastern side – Shanballymore and Ballinvoher being the largest. The springs may occur where there is a local focus of groundwater flow – possibly related to structure.

- It is considered that the rivers are regional hydraulic boundaries and that groundwater discharges to the rivers and overflows to the springs.

- Principally due to the lack of surface drainage on the karst plateau it is considered that there is very little runoff and the majority of effective rainfall descends to the water table diffusely. There appears to be few sites of concentrated recharge and none of these indicated a positive trace to any of the springs.

- Due to the position of the springs and the base levels of the rivers and absence of the surface drainage on the plateau it is considered that the groundwater flow paths are relatively deep and long – several kilometers and up to 40/50m below the top of the karst plateau.

- Limitations to the conceptual model mainly lie with a lack of information on the following:

  ⇨ Detailed groundwater flow directions between the main springs to both the Awbeg and Funshion rivers. The underlying assumption is that groundwater flowing to Shanballymore Spring is predominantly derived from a north to south and northeast to southwest component. The tracing programme attempted to define and distinguish the zones of contribution to the main springs with a particular focus on Shanballymore Spring. It is still uncertain as to the most likely and most representative zone of contribution.

⇨ The assumption that the Ogeen and Farahy are discharge zones may not be entirely valid. The assumption is based on a number of small springs occurring along these rivers, but the rivers may also be acting in certain portions as recharge zones.

⇨ Site specific depth to bedrock and localized differences in the subsoil permeability. Information on the depth to bedrock would provide greater detail and confidence in the level of protection afforded by the subsoils.

⇨ Long term discharge data. Information on this is required to be confident on the size of the area required to provide the water to the spring.

9 DELINEATION OF SOURCE PROTECTION AREAS

This section describes the delineation of the areas around the source that are believed to contribute groundwater to it, and that therefore require protection. The areas are delineated based on the conceptualisation of the groundwater flow to the source, as described in the Conceptual Model.

Two source areas are delineated:

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

9.1 OUTER PROTECTION AREA

The Outer Protection Area (SO) is bounded by the complete catchment area to the source, i.e. **the zone of contribution (ZOC)**, which is defined as the area required supporting the total outflow from long-term recharge.

The size of the ZOC is a function of:

➢ the total outflow

➢ the recharge in the area.

The location of the ZOC is a function of:

➢ the groundwater flow direction and gradient

➢ the subsoil and rock permeability.

There are uncertainties with groundwater flow directions, in the outflow data (abstraction and overflow), and recharge estimates. Therefore to delineate the true contributing area is difficult, particularly in trying to distinguish a zone of contribution that may or may not be separate to zones of contribution to the other springs. The following table summarises the water balance estimations for deriving the zone of contribution to Shanballymore Spring. It is considered the most likely area is in the region of 8-10 km^2.

Table 9-1 Water balance estimations: flow, recharge and contributing area to Shanballymore Spring

Max Flow (l/s)	308
Min Flow (l/s)	70
Likely representative Flow (l/s)	**140-145**

Min recharge %	60
Max recharge %	100
Likeliest recharge %	**95**
Max probable ZOC (km²)	28
Min probable ZOC (km²)	4
Most likely ZOC (km²)	**8-10**

Primarily based on topography, hydrogeological mapping and groundwater flow assumptions the most likely zone of contribution is delineated as follows and is shown in

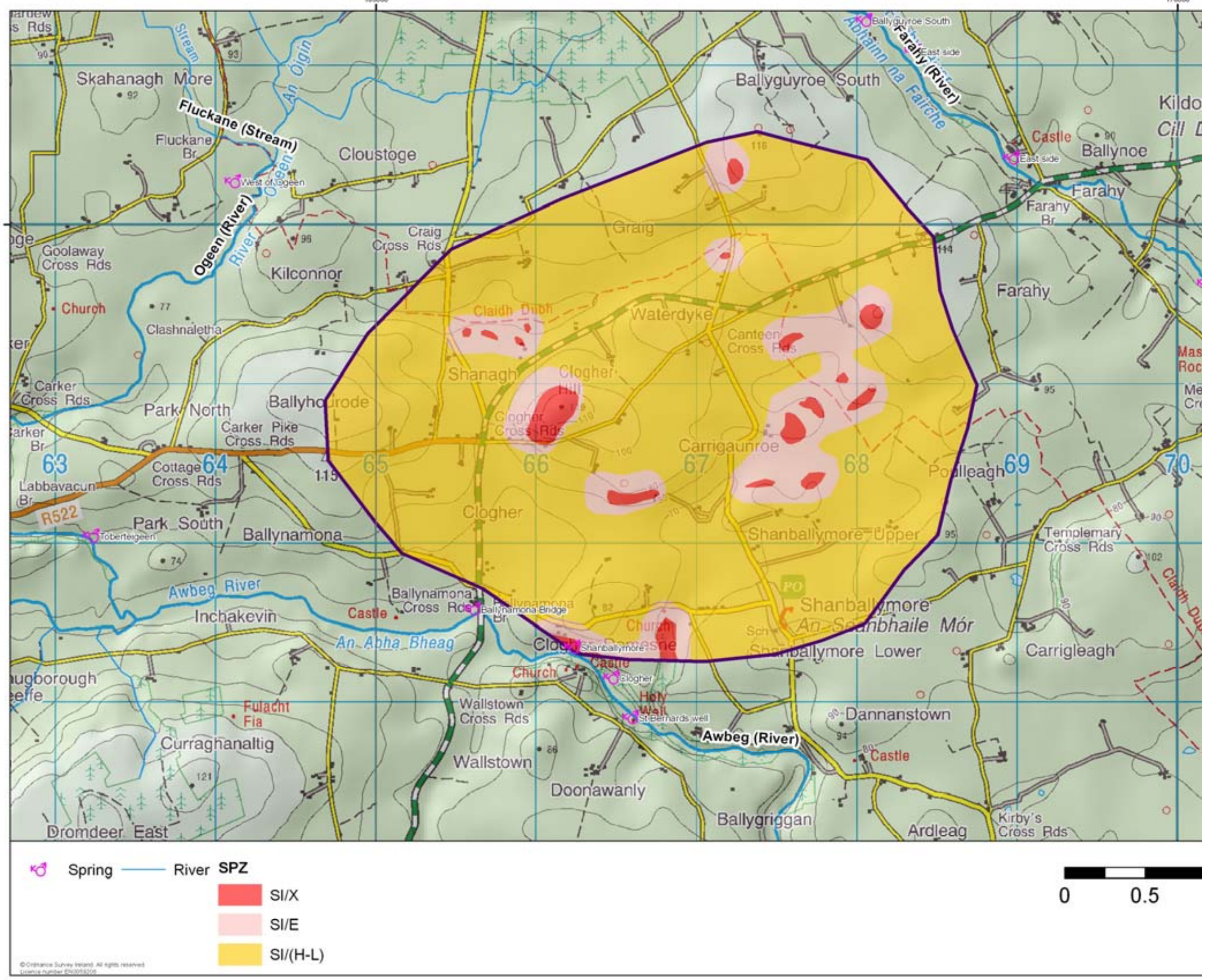

Figure 9. The area delineated by the boundaries described below is approximately 10 km².

The **Northern and Northeastern and Northwestern** boundaries are constrained by a topographic ridge through Ballyguyroe South, Graig and Ballyhourode, assumed to be an approximate ground divide. It is assumed that groundwater flows south to the Awbeg, and that there is focusing of flow at the spring. Shanagh swallow hole is within the boundary. A small stream joining the Ogeen occurs to the north of the ridge, draining Graig Upper and Cloustoge. There is uncertainty as it is not certain how the groundwater system operates. The tracing programme was unsuccessful in enabling greater confidence in delineating this boundary.

The **Western** boundary and the **Southwestern** boundary as far as Shanballymore Spring itself is based on topography. There is uncertainty regarding the boundary due to the spring at Ballynamona Bridge. There is likely to be some overlap between the zones of contribution to both springs but it is impossible to differentiate the contributing areas. However the flow at Shanballymore Spring is much greater and it is likely that a significant proportion of groundwater in this area flows to Shanballymore Spring. It is considered that groundwater west of this boundary flows to Toberteigeen or to the Awbeg river.

The **Eastern** boundary is based on topography, following a topographic divide east of Shanballymore, through to Farahy in the northeastern part of the catchment.

9.2 INNER PROTECTION AREA

The Inner Source Protection Area is the area defined by the horizontal 100 day time of travel from any point below the watertable to the source (DoELG, EPA, GSI, 1999). The 100-day horizontal time of travel to the source is calculated from the velocity of groundwater flow in the bedrock. The velocities are normally based on the results of the hydraulic test programme, however, in this instance, the Regionally Important Karst aquifer category, suggests that very rapid groundwater velocities are likely in this area due to karstification of the limestones. Groundwater flow can be focused and travel very fast. Results from tracing programmes in similar rock types indicate velocities in the order of hundreds of metres/day. On this basis, all of the ZOC is designated as part of the inner protection area to the source, denoted as SI.

10 GROUNDWATER PROTECTION ZONES

Groundwater protection zones are shown in Figure 10 and are based on an overlay of the source protection areas (SI) on the groundwater vulnerability. Note that the majority of the SI/(High-Low) area is considered to be dominated by SI/Extreme, SI/High with potentially smaller areas of SI/Moderate.

Table 10-1 Source Protection Zones

Source Protection Zone	% of total area (10 km^2)
SI/Extreme (Rock close)	2.6% (0.26 km^2)
SI/Extreme	12.6% (1.2 km^2)
SI/High-Low	85% (8.35 km^2)

11 POTENTIAL POLLUTION SOURCES

Though detailed assessments of hazards have not been carried out as part of this study, it is noted that there are many houses and farmyards within the ZOC. Land use in the vicinity of the source is described in Section 5; within the ZOC, livestock and pasture is the main land use.

Faecal and total coliforms may indicate contamination from organic wastes. The concentrations of nitrates and chlorides that would be expected from groundwater in an intensively farmed land.

The main hazards associated with the ZOC are considered to be agricultural (farmyard leakage, landspreading of organic and inorganic fertilisers) and potential oil/petrol spills. Though domestic septic tank and other treatment systems are not a major problem as is, the installation of any new systems should be monitored closely. The location of any 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 and lack of attenuation by subsoils. The main potential contaminants from this source are ammonia, nitrates, phosphates, chloride, potassium, BOD, COD, TOC, faecal bacteria, viruses and Cryptosporidium.

Roadways are present within the ZOC. The main potential contaminants from this source are hydrocarbons and metals.

12 SUMMARY

- Shanballymore (Doneraile) Public Water Supply comprises a spring west of Shanballymore village in Clogher Demesne, located in pure bedded limestone that is classified as a Regionally Important Karstified aquifer dominated by diffuse flow (Rk^d).

- Shanballymore Spring is one of a series of springs located at the foot of the valley sides along both banks of the Awbeg River. There are also smaller springs along the Ogeen, Farahy and Funshion Rivers.

- The total outflow, including abstraction, from Shanballymore Spring ranges from 70 - 308 l/s (6,000 – 26,000 m^3/day). The representative flow is taken as the median of 147 l/s (12,600 m^3/day).

- The limestones are karstified, evidenced by disappearing streams, swallow holes, dolines, conduits and caves.

- There are no streams between the main rivers and Blackwater river further south, an area of approximately 100 km^2.

- The depth to bedrock is relatively shallow and the subsoils are generally 'moderately' permeable. The groundwater vulnerability is considered to be 'extreme' to 'high'.

- An average recharge rate of approximately 540 mm per year occurs across the region.

- The natural hydraulic gradients in the aquifer are low, in the order of 0.002.

- Groundwater flow directions are considered to be mainly toward the rivers.

- In summary the water quality is generally good but occasionally contaminated, usually in autumn and winter. Faecal and total coliforms and manganese are the only parameter to exceed the EU MAC and suggest contamination from organic wastes. The nitrate concentrations indicate a slight rising trend.

13 RECOMMENDATIONS

To investigate further the hydrogeology and the uncertainties in the understanding of the system to investigate the groundwater flow system in this area (and possibly over a much wider area of the southern limestone's) is valley oriented and line discharge in character it is suggested that the following could be considered:

- Measure discharge at intervals along the main rivers (and any tributaries)

- Map the regional potentiometric surface
- Carry out water tracings with samplings along the rivers
- Examine the structural geology
- Do not assume sink to spring connections purely on the basis of proximity.

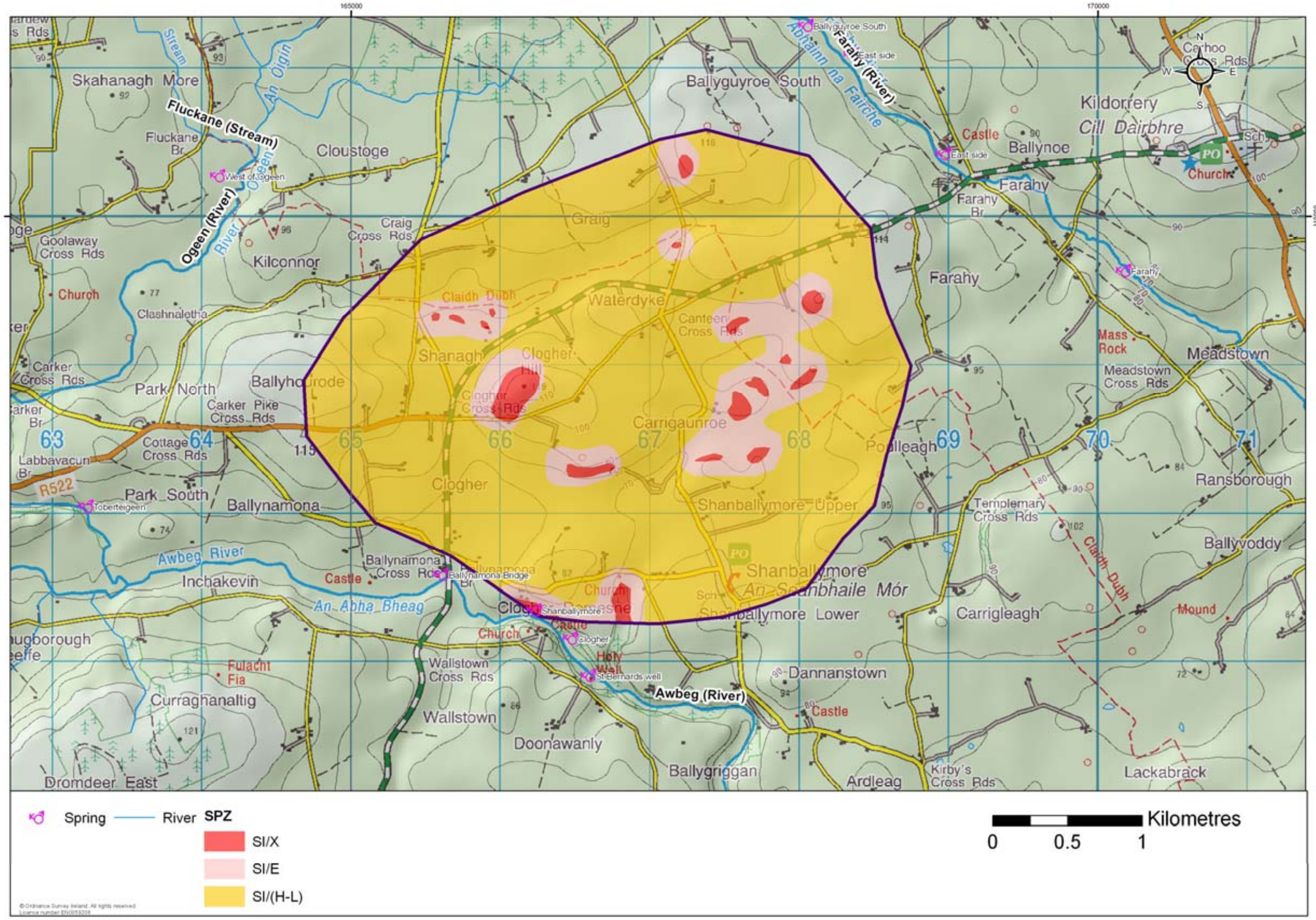

Figure 9 Source Protection Zones for Shanballymore

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APPENDIX 1 KARST FEATURES AROUND SHANBALLYMORE

Feature	Name	Easting	Northing
Cave	Carraigleagh Cave	169255	107959
Cave	Ballinaltig Beg Cave	172013	104358
Dry Valley	Ballydoyle Dry Valley	168536	104600
Dry Valley	Clogher Dry Valley	166763	107079
Dry Valley	Bealalaboga Dry Valley	173635	106663
Dry Valley	Rockmills Dry Valley	171948	108021
Dry Valley	Meadstown Dry Valley	170623	108923
Dry Valley	Kilconnor Dry Valley	164336	109390
Spring	Ballinvoher PWS springs	168412	103604
Spring	Ballyguyroe South	168044	111284
Spring	Ballynamona Bridge	165601	107586
Spring	Ballywalter Spring	167808	105702
Spring	Bealalaboga Bridge Spring	173753	106736
Spring	Clogher	166466	107157
Spring	East side Farahy river	168346	111090
Spring	East side Farahy river	168963	110420
Spring	East side Farahy river	172037	108263
Spring	Farahy (west side of Farahy river)	170170	109635
Spring	Kearneys Well	171962	108207
Spring	Redstone PWS	168197	103573
Spring	Shanballymore PWS springs	166224	107349
Spring	St Bernards well	166585	106907
Spring	Toberteigeen	163223	108044
Spring	West of Ogeen	164103	110272
Swallow Hole	Shanagh Swallow Hole	165561	109353
Swallow Hole	Polleagh Swallow Hole	169023	108238
Swallow Hole	Forestry Swallow Hole	165977	112452

APPENDIX 2 FIELD DATA FOR SPRINGS

Name	Easting	Northing	Elevation (mOD)	Q range (l/s)	Spring Conductivity µS cm^{-1} & Temperature ^{o}C	River Conductivity µS cm^{-1} & Temperature ^{o}C
Toberteigeen (Labbavacun Bridge)	163220	108044	60	<5->20	643 & 10	Ogeen 143
Ballynamona Bridge	165601	107589	56	<5	705 & 10	Awbeg 476
Shanballymore	166231	107339	56	>50->300	670 & 10	Awbeg
Ballywalter Bridge	167818	105698	50	>10	600 & 11	Awbeg
Ballinvoher	168437	103583	45	>50	720 & 11	Awbeg 470
Clogher demesne	166475	107154	54	<5->5	600 & 10	Awbeg
Ballyguyroe South	168044	111284	75	<5	542 & 10	Farahy 111
Farahy	170186	109636	65	~5	660 & 12	Farahy
Kearneys well (Rockmills)	171956	108216	50	<5->5	720 & 10	Funshion 500
St Bernards well	166593	106906	55	<5->40	705 & 10	South side of Awbeg

APPENDIX 3 MONITORING SITE RELATIONSHIPS WITH TRACER INPUT SITES

INPUT SITES/ SPRINGS (names and grid ref and elevation)	Polleagh 75mOD	Shanagh 78mOD	Ballynahalisk 83mOD	Forestry Ballyguyroe 105m
Spring 1 Shanballymore 166231 107339 56mOD	∆ altitude **19m** Distance **2.9km** Gradient **0.0065**	∆ altitude **22m** Distance **2.1km** Gradient **0.01**	∆ altitude **27m** Distance **5.6km** Gradient **0.005**	∆ altitude **49m** Distance **5.2km** Gradient **0.009**
Spring 2 Ballinvoher 168437 103583 45mOD	∆ altitude **30m** Distance **4.7km** Gradient **0.006**	∆ altitude **33m** Distance **6.4km** Gradient **0.005**	∆ altitude **38m** Distance **4.9km** Gradient **0.0078**	∆ altitude **60m** Distance **9.3km** Gradient **0.0065**
Spring 3 Ballywalter Bridge 167818 105698 50mOD	∆ altitude **25m** Distance **2.8km** Gradient **0.0089**	∆ altitude **28m** Distance **4.3km** Gradient **0.0065**	∆ altitude **33m** Distance **4.3km** Gradient **0.0077**	∆ altitude **55m** Distance **7km** Gradient **0.0078**
Spring 4 Clogher demesne 166475 107154 54mOD	∆ altitude **21m** Distance **2.8km** Gradient **0.0075**	∆ altitude **24m** Distance **2.4km** Gradient **0.01**	∆ altitude **29m** Distance **5.4km** Gradient **0.0054**	∆ altitude **51m** Distance **5.4km** Gradient **0.0054**
Spring 5 Toberteigeen (Labbavacun Bridge) 163220 108044 60mOD	∆ altitude **15m** Distance **5.8km** Gradient **0.0025**	∆ altitude **18m** Distance **2.6km** Gradient **0.007**	∆ altitude **23m** Distance **8.7km** Gradient **0.0026**	∆ altitude **23m** Distance **5.2km** Gradient **0.009**
Spring 6 Ballynamona Bridge 165601 107589 56mOD	∆ altitude **19m** Distance **3.5km** Gradient **0.005**	∆ altitude **22m** Distance **1.8km** Gradient **0.012**	∆ altitude **27m** Distance **6.3km** Gradient **0.0043**	∆ altitude **49m** Distance **4.9km** Gradient **0.01**
Spring 7 Kearneys well (rockmills) 171956 108216 50mOD	∆ altitude **25m** Distance **2.9km** Gradient **0.086**	∆ altitude **28m** Distance **6.4km** Gradient **0.004**	∆ altitude **33m** Distance **1km** Gradient **0.033**	∆ altitude **55m** Distance **7.4km** Gradient **0.007**
Farahy Upstream of Meadstown Bridge 170186 109636 65mOD	∆ altitude **10m** Distance **1.8km** Gradient **0.0056**	∆ altitude **13m** Distance **4.6km** Gradient **0.003**	∆ altitude **18m** Distance **2.9km** Gradient **0.006**	∆ altitude **40m** Distance **5km** Gradient **0.008**
St Bernards Well 166593 106906 55mOD	∆ altitude **20m** Distance **2.8km** Gradient **0.007**	∆ altitude **23m** Distance **2.7km** Gradient **0.0085**	∆ altitude **28m** Distance **5.4km** Gradient **0.005**	∆ altitude **50m** Distance **5.7km** Gradient **0.009**

APPENDIX 4 DISCHARGE DATA

Spot Flow Measurements at Shanballymore (not including abstraction)

Date	Overflow (m3/s)	Overflow (litres/sec)	Overflow (m3/d)
15-Aug-89	0.0942	94	8139
19-Sep-89	0.0559	56	4830
19-Sep-89	0.0533	53	4605
02-Oct-89	0.0414	41	3577
30-Aug-90	0.0365	37	3154
23-Jan-09	0.2313	231	19984
19-Jun-09	0.1311	131	11327
10-Sep-09	0.089	89	7690
21-Nov-09	0.3	300	25920

Daily Max (Non pumping times only, thus some days are taken out where pumping extended for over 24 hours)

Date	Time	Q (m3/s)
12/09/2009	03:15:00	0.142
14/09/2009	04:45:00	0.142
16/09/2009	01:30:00	0.142
17/09/2009	07:15:00	0.142
19/09/2009	01:45:00	0.142
20/09/2009	04:30:00	0.142
21/09/2009	08:15:00	0.142
22/09/2009	03:00:00	0.141
23/09/2009	14:15:00	0.141
24/09/2009	05:15:00	0.14
25/09/2009	02:15:00	0.14
26/09/2009	01:45:00	0.14
27/09/2009	00:30:00	0.138
28/09/2009	16:00:00	0.138
29/09/2009	11:00:00	0.137
30/09/2009	06:30:00	0.137
01/10/2009	05:45:00	0.137
02/10/2009	04:30:00	0.137
03/10/2009	02:30:00	0.137
04/10/2009	16:30:00	0.134
05/10/2009	07:15:00	0.136
07/10/2009	22:15:00	0.141
08/10/2009	00:15:00	0.141
09/10/2009	14:00:00	0.141
10/10/2009	03:45:00	0.14
11/10/2009	02:00:00	0.141
12/10/2009	00:30:00	0.141
13/10/2009	17:15:00	0.141
14/10/2009	07:30:00	0.141
15/10/2009	06:15:00	0.141
16/10/2009	05:45:00	0.14
18/10/2009	01:15:00	0.14
19/10/2009	06:15:00	0.141
20/10/2009	12:45:00	0.142
21/10/2009	06:15:00	0.142
22/10/2009	03:30:00	0.147
23/10/2009	21:15:00	0.167
24/10/2009	14:30:00	0.17
25/10/2009	07:45:00	0.171
26/10/2009	05:00:00	0.171
27/10/2009	02:45:00	0.174
28/10/2009	15:30:00	0.176
29/10/2009	06:45:00	0.177
30/10/2009	11:30:00	0.178
01/11/2009	19:30:00	0.233
03/11/2009	09:45:00	0.232
04/11/2009	16:30:00	0.322
05/11/2009	00:15:00	0.281
07/11/2009	23:45:00	0.288
08/11/2009	08:15:00	0.305
10/11/2009	08:15:00	0.695
11/11/2009	04:45:00	0.307
12/11/2009	09:00:00	0.347
13/11/2009	23:59:59	0.345
14/11/2009	08:15:00	0.679
15/11/2009	00:15:00	0.443
16/11/2009	14:15:00	1.05
17/11/2009	00:15:00	0.626
18/11/2009	13:45:00	0.546
19/11/2009	23:00:00	1.16
20/11/2009	00:15:00	1.15
21/11/2009	20:30:00	1.56
22/11/2009	00:15:00	1.43
23/11/2009	00:45:00	0.94
24/11/2009	00:15:00	0.767
25/11/2009	01:00:00	0.662
26/11/2009	04:30:00	0.482
27/11/2009	00:15:00	0.401
28/11/2009	03:45:00	0.36
29/11/2009	00:15:00	0.331
30/11/2009	04:15:00	0.318
01/12/2009	09:30:00	0.32
02/12/2009	07:00:00	0.318
03/12/2009	04:45:00	0.314
04/12/2009	03:15:00	0.314
05/12/2009	11:30:00	0.316
06/12/2009	01:30:00	0.316
07/12/2009	07:30:00	0.316
08/12/2009	00:45:00	0.316
09/12/2009	06:30:00	0.316
10/12/2009	05:00:00	0.316
11/12/2009	02:30:00	0.314
12/12/2009	00:30:00	0.312
13/12/2009	00:15:00	0.311
14/12/2009	07:00:00	0.311
15/12/2009	06:00:00	0.309

16/12/2009	12:00:00	0.309
18/12/2009	12:15:00	0.305
19/12/2009	03:15:00	0.302
20/12/2009	07:15:00	0.3
21/12/2009	02:45:00	0.3
22/12/2009	08:30:00	0.298
23/12/2009	05:00:00	0.296
24/12/2009	23:15:00	0.293
25/12/2009	23:45:00	0.289
26/12/2009	00:30:00	0.291
28/12/2009	03:00:00	0.288
29/12/2009	08:15:00	0.286
31/12/2009	05:45:00	0.289
01/01/2010	11:15:00	0.284
02/01/2010	12:15:00	0.274
04/01/2010	07:45:00	0.269
06/01/2010	09:00:00	0.267
08/01/2010	13:30:00	0.252
09/01/2010	00:15:00	0.212
10/01/2010	00:15:00	0.211
12/01/2010	23:59:59	0.307
13/01/2010	05:15:00	0.401
14/01/2010	03:00:00	0.333
15/01/2010	00:15:00	0.279
16/01/2010	08:30:00	0.374
17/01/2010	00:45:00	0.279
18/01/2010	00:15:00	0.248
19/01/2010	00:15:00	0.219
20/01/2010	01:30:00	0.219
21/01/2010	11:45:00	0.274
22/01/2010	00:15:00	0.22
23/01/2010	00:15:00	0.22
24/01/2010	00:15:00	0.22
25/01/2010	00:15:00	0.22
26/01/2010	11:15:00	0.27
27/01/2010	18:00:00	0.252
28/01/2010	15:45:00	0.269
29/01/2010	09:15:00	0.27
30/01/2010	05:45:00	0.267
31/01/2010	22:15:00	0.263
01/02/2010	05:45:00	0.263
02/02/2010	14:45:00	0.262
03/02/2010	08:45:00	0.262
04/02/2010	05:45:00	0.26
05/02/2010	03:15:00	0.263
06/02/2010	15:45:00	0.262
07/02/2010	08:45:00	0.26
08/02/2010	06:30:00	0.26
09/02/2010	05:00:00	0.26
10/02/2010	02:00:00	0.258
11/02/2010	09:00:00	0.257
12/02/2010	14:15:00	0.288
13/02/2010	06:45:00	0.274
14/02/2010	04:30:00	0.274
15/02/2010	01:30:00	0.274
16/02/2010	06:45:00	0.272
17/02/2010	01:15:00	0.274
18/02/2010	04:00:00	0.27
19/02/2010	07:15:00	0.267
20/02/2010	03:15:00	0.267
21/02/2010	09:45:00	0.265
22/02/2010	04:30:00	0.263
23/02/2010	00:15:00	0.262
25/02/2010	00:45:00	0.258
26/02/2010	04:15:00	0.258
27/02/2010	07:45:00	0.257
01/03/2010	01:15:00	0.252
02/03/2010	06:00:00	0.25
03/03/2010	15:15:00	0.248
04/03/2010	11:30:00	0.242
05/03/2010	03:45:00	0.245
06/03/2010	08:45:00	0.243
08/03/2010	05:30:00	0.242
09/03/2010	08:15:00	0.238
11/03/2010	04:15:00	0.235
13/03/2010	02:15:00	0.233
15/03/2010	03:15:00	0.228
17/03/2010	03:00:00	0.227
19/03/2010	04:15:00	0.225
21/03/2010	05:45:00	0.222
23/03/2010	07:15:00	0.22
25/03/2010	02:45:00	0.22
26/03/2010	03:30:00	0.217
27/03/2010	06:15:00	0.216
28/03/2010	22:45:00	0.212
29/03/2010	23:15:00	0.225
30/03/2010	10:00:00	0.262
31/03/2010	01:15:00	0.281
01/04/2010	06:30:00	0.233
02/04/2010	03:00:00	0.235
03/04/2010	00:15:00	0.235
04/04/2010	07:30:00	0.233
05/04/2010	05:15:00	0.235
06/04/2010	13:00:00	0.24
07/04/2010	03:30:00	0.247
08/04/2010	05:15:00	0.24
09/04/2010	08:30:00	0.24
10/04/2010	02:15:00	0.24
11/04/2010	05:30:00	0.238
12/04/2010	01:30:00	0.238
13/04/2010	06:00:00	0.238
14/04/2010	15:00:00	0.238
15/04/2010	04:00:00	0.237
16/04/2010	10:45:00	0.237
17/04/2010	04:30:00	0.235
18/04/2010	02:30:00	0.235
19/04/2010	00:15:00	0.235
20/04/2010	06:30:00	0.233
21/04/2010	04:45:00	0.233
22/04/2010	03:30:00	0.233
23/04/2010	02:00:00	0.232
24/04/2010	02:30:00	0.23
25/04/2010	01:30:00	0.23
26/04/2010	00:15:00	0.228
27/04/2010	02:30:00	0.227
28/04/2010	02:45:00	0.225
29/04/2010	03:30:00	0.225
30/04/2010	06:15:00	0.224
01/05/2010	03:15:00	0.222
02/05/2010	04:30:00	0.22
03/05/2010	15:15:00	0.22
04/05/2010	05:30:00	0.217
05/05/2010	02:00:00	0.217
06/05/2010	06:15:00	0.216
07/05/2010	01:45:00	0.214
08/05/2010	07:30:00	0.214
09/05/2010	04:15:00	0.212
10/05/2010	01:45:00	0.211
11/05/2010	07:45:00	0.211
13/05/2010	04:00:00	0.208
14/05/2010	04:45:00	0.206
15/05/2010	09:00:00	0.206
16/05/2010	05:30:00	0.205

17/05/2010	01:30:00	0.203	02/07/2010	14:15:00	0.152	28/08/2010	04:00:00	0.104
18/05/2010	11:00:00	0.203	03/07/2010	07:45:00	0.151	29/08/2010	07:15:00	0.104
19/05/2010	22:00:00	0.2	04/07/2010	03:30:00	0.151	31/08/2010	02:15:00	0.103
20/05/2010	05:45:00	0.198	05/07/2010	00:45:00	0.148	03/09/2010	06:45:00	0.102
21/05/2010	03:15:00	0.198	06/07/2010	12:30:00	0.148	07/09/2010	03:15:00	0.1
22/05/2010	23:45:00	0.194	07/07/2010	16:00:00	0.147	09/09/2010	02:45:00	0.099
23/05/2010	00:30:00	0.195	08/07/2010	02:15:00	0.145	11/09/2010	05:00:00	0.098
24/05/2010	17:00:00	0.195	09/07/2010	04:00:00	0.145	14/09/2010	05:45:00	0.098
25/05/2010	05:15:00	0.192	10/07/2010	23:00:00	0.145	15/09/2010	10:15:00	0.097
26/05/2010	08:45:00	0.192	11/07/2010	05:45:00	0.145	21/09/2010	15:15:00	0.096
28/05/2010	10:15:00	0.191	12/07/2010	02:15:00	0.144			
29/05/2010	10:15:00	0.191	13/07/2010	01:30:00	0.142			
30/05/2010	00:45:00	0.188	14/07/2010	04:00:00	0.141			
31/05/2010	06:45:00	0.186	15/07/2010	05:45:00	0.141			
01/06/2010	05:30:00	0.186	16/07/2010	08:45:00	0.141			
02/06/2010	05:30:00	0.185	17/07/2010	01:00:00	0.141			
03/06/2010	02:45:00	0.183	18/07/2010	03:15:00	0.141			
04/06/2010	04:00:00	0.181	19/07/2010	17:00:00	0.141			
05/06/2010	01:00:00	0.18	26/07/2010	15:00:00	0.123			
06/06/2010	16:45:00	0.18	28/07/2010	02:00:00	0.123			
07/06/2010	03:30:00	0.178	29/07/2010	00:30:00	0.122			
08/06/2010	08:45:00	0.178	30/07/2010	00:30:00	0.122			
09/06/2010	00:45:00	0.177	31/07/2010	15:15:00	0.122			
10/06/2010	00:15:00	0.176	01/08/2010	08:30:00	0.121			
11/06/2010	01:15:00	0.174	02/08/2010	08:00:00	0.12			
12/06/2010	00:30:00	0.171	03/08/2010	07:00:00	0.118			
13/06/2010	15:45:00	0.171	04/08/2010	06:30:00	0.118			
14/06/2010	03:30:00	0.168	05/08/2010	10:15:00	0.117			
15/06/2010	09:15:00	0.168	06/08/2010	08:15:00	0.117			
17/06/2010	14:30:00	0.165	07/08/2010	07:15:00	0.116			
18/06/2010	23:59:59	0.164	09/08/2010	03:30:00	0.116			
19/06/2010	00:15:00	0.164	10/08/2010	07:00:00	0.114			
20/06/2010	03:00:00	0.162	12/08/2010	02:30:00	0.113			
21/06/2010	05:45:00	0.159	13/08/2010	11:15:00	0.114			
22/06/2010	18:45:00	0.162	16/08/2010	13:15:00	0.112			
23/06/2010	05:00:00	0.159	18/08/2010	12:00:00	0.112			
24/06/2010	08:30:00	0.159	19/08/2010	06:45:00	0.11			
25/06/2010	03:30:00	0.158	20/08/2010	02:15:00	0.11			
26/06/2010	05:15:00	0.157	21/08/2010	01:45:00	0.109			
27/06/2010	01:45:00	0.157	22/08/2010	03:00:00	0.108			
28/06/2010	05:30:00	0.155	23/08/2010	03:15:00	0.108			
29/06/2010	04:45:00	0.154	24/08/2010	03:00:00	0.108			
30/06/2010	00:30:00	0.154	25/08/2010	05:00:00	0.107			
01/07/2010	01:00:00	0.154	26/08/2010	07:00:00	0.105			