INTERNATIONAL ASSOCIATION OF HYDROGEOLOGISTS (IAH) IRISH GROUP

ANNUAL FIELD TRIP 2016

“Combined Karstic and Sand/Gravel Systems - Deel & Moy Catchments"

Saturday 22nd October

Moy Catchment

(led by Coran Kelly, Robbie Meehan, Henning Moe, David Drew, Malcolm Doak & Connie O’ Driscoll)

- Stop 1 - Knock Airport
- Stop 2 - Sand and gravel pit at Stripe
- Stop 3 - Kilaturley GWS spring
- Stop 4 - Swinford PWS spring

Sunday 23rd October

Deel Catchment

(led by David Drew)

- Stop 1 - River Deel valley
- Stop 2 - Swallow holes, dolines, kettles, south of Crossmolina
- Stop 3 - Mullenmore spring and subsidence doline

Please note that the programme of visits is preliminary and subject to change pending landowner permission to access sites

Environmental Protection Agency

Hydrogeological Investigation of Springs Supplying the Swinford Public Water Supply Scheme and the Killaturly Group Water Scheme

December 2015

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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).

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Attachment A - Photographs

1 INTRODUCTION

A hydrogeological investigation has been carried out for the Swinford Public Water Supply (PWS) Scheme and the Killaturly Group Water (GWS) Scheme according to the principles and methodologies set out in 'Groundwater Protection Schemes' (DELG/EPA/GSI, 1999), the GSI/EPA/IGI training course on Groundwater Source Protection Zone (SPZ) Delineation, as well as the EPA Advice Note No. 7 (EPA, 2011).

The objectives of the report are as follows:

- To outline the principal hydrogeological characteristics of the area surrounding the sources.
- To assist the Environmental Protection Agency, Mayo County Council and Group Water Scheme owners/operators in protecting the water supplies from contamination.

The scope of this particular report is to investigate the potential Zone of Contribution (ZOC) to the springs. The springs are important water supplies and are significant hydrogeological features in the area. For this reason, the EPA included these springs in the SPZ project described previously.

The maps produced are based largely on the readily available information in the area, field walkovers, water tracing, water level measuring, flow measurements 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 METHODOLOGY

The technical standard to be achieved within Zone of Contribution (ZOC) delineation is that of the Geological Survey of Ireland, both in terms of implementation and reporting. The primary guidance document is 'Groundwater Protection Scheme Guidelines' (DELG/EPA/GSI, 1999). Accordingly, the methodology consisted of a desk study of available published information, site visits, walk-over surveys, field mapping, data analysis, data interpretation and reporting. A dye tracing programme comprising three separate dye injections was also conducted in conjunction with the GSI in 2012 and 2013.

3 LOCATION, SITE DESCRIPTION AND WELL HEAD PROTECTION

The study area is located in east County Mayo near the town of Swinford. The Swinford PWS is located approximately 2.5 km southeast of Swinford town, just off the R375, in the townland of Carrowcanada, see **Figure 1**. It comprises a single spring and spring chamber, from where raw water is pumped approximately 1.7 km due north to a reservoir situated in the townland of Kilbride, approximately 2 km east of Swinford. The overflow from the Swinford spring discharges into an unnamed tributary of the Spaddagh River which flows in a northwesterly direction and merges with the River Moy approximately 5.5 km to the west of Swinford.

The Killaturly GWS is located approximately 3.5 km east-northeast from the Swinford spring, and 4.3 km due east of Swinford town, in the townland of Killaturly. It sources water from two different locations:

a) Two springs which emerge from gravels beneath peat, approximately 0.2 km to the south of the GWS facility, at approx. coordinate E142197, N298836; and

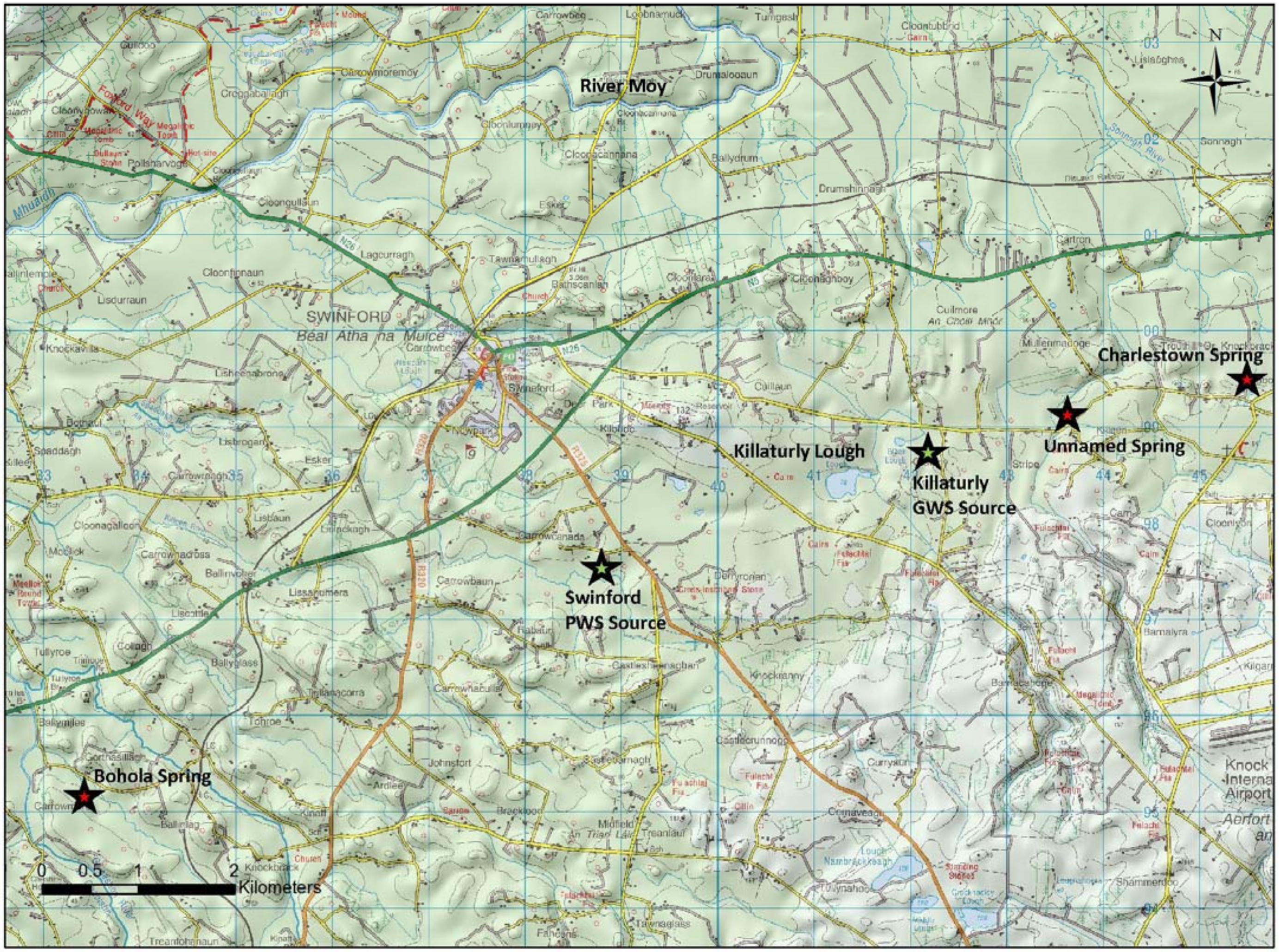

Figure 1: Location map of sources and study area

b) An *apparent* spring which reportedly emerges from the underlying bedrock (limestone) at the location of the GWS reservoir, and which is fed to the reservoir via two manholes/caisson structures (linked via a T-junction pipeline to the reservoir).

Regarding the gravel springs, water from each is piped via gravity into a constructed pond (**Attachment 1, photo 1**)**,** from where the water is directed to the GWS reservoir (**Attachment 1, photo 2**), also via gravity, through a 4-inch diameter pipeline. The pond has since been fully enclosed to protect against fouling by birds, weed and algal growth.

Regarding the apparent bedrock spring at the GWS facility, the precise nature and contribution of this is less clear. As described by the GWS caretaker, when the GWS facility was constructed, some 4-5 m of subsoils (including sands and gravels) were removed from the site to accommodate the construction of the underground reservoir. The excavation uncovered an apparent upwelling from the underlying limestone. Two caissons were sunk between the reservoir and the stream adjacent to the GWS facility in order to collect this water which is directed into the GWS reservoir. From here, the water is pumped into the GWS distribution system. Overflow from the reservoir is directed to the small stream which flows past the GWS facility and which is a tributary of the River Moy.

The Swinford and Killaturly water supplies are both included in the EPA's national groundwater monitoring programme, whereby samples are collected for water quality analyses on a quarterly basis. EPA technicians conduct 'spot' measurements of spring discharges at Swinford spring and streamflow adjacent to the Killaturly GWS several times each year. The stream which flows past the Killaturly GWS facility, and which receives overflow from the reservoir, is also fitted with an automatic data recorder (see Section 4) for continuous (15-minute interval) flow monitoring purposes. This recorder, which uses time of flight technology, is situated just upstream of a bridge immediately to the north of the GWS facility.

Finally, it should be noted that Killaturly GWS also owns a separate spring approximately 1.5 km to the northeast of the main spring, but this is not used for water supply, and is not part of the present GWS. It is referred to as the 'unnamed spring' on **Figure 1**.

4 SUMMARY DETAILS

A summary of the sources at Swinford and Killaturly are provided in **Table 1**. For the Swinford spring, discharge estimates obtained from the EPA range between 60 and 900 l/s, see **Figure 2**, with an estimated average of 190 l/s over the period of record. The spring is known to respond quickly to rainfall events.

At Killaturly, neither the gravel nor apparent limestone springs are monitored or gauged. The individual, relative, or even total contributions of the gravel and apparent limestone springs are poorly quantified. Given the engineered set-up of the GWS facility, reasonable estimates of the gravel spring contributions can be made. However, the relative contribution from the apparent limestone source beneath the GWS reservoir would always be an underestimate, as only an unknown proportion of this water is captured and directed to the GWS reservoir.

As part of this study, the total water captured from respective sources at the Killaturly GWS was measured as overflow from the GWS reservoir during non-pumping conditions. The reservoir has three small-diameter overflow pipes which are associated with two hydraulically interconnected reservoir chambers. Each of the chambers collects water from the gravels springs and limestone source, respectively.

Table 1: Summary of sources

	Swinford	Killaturly[1]
EU Reporting Code	IE_W_G_0033_16_019	IE_W_G_0064_16_012
Drinking water code	2200PUB1024	2200PRI2073
Grid reference	E138798 N297498	E142206 N298802
Townland	Carrowcanada	Killaturly[1]
Source type	Spring	Spring
Elevation (ground level)	Approximately 70 mOD	Approximately 80 mOD
Depth to rock	Unknown	Approx. 5-6 m
Static water level	Ground level	Ground level
Average abstraction rate	1100 m^3/day (~13 l/s) in 2013	785 m^3/day (~9 l/s) in 2013
Estimated discharge	Average[2]: 190 l/s (16,500 m^3/day) Range (min–max): 60–900 l/s	Average: 10-20 l/s[3] (<3,800 m^3/day)

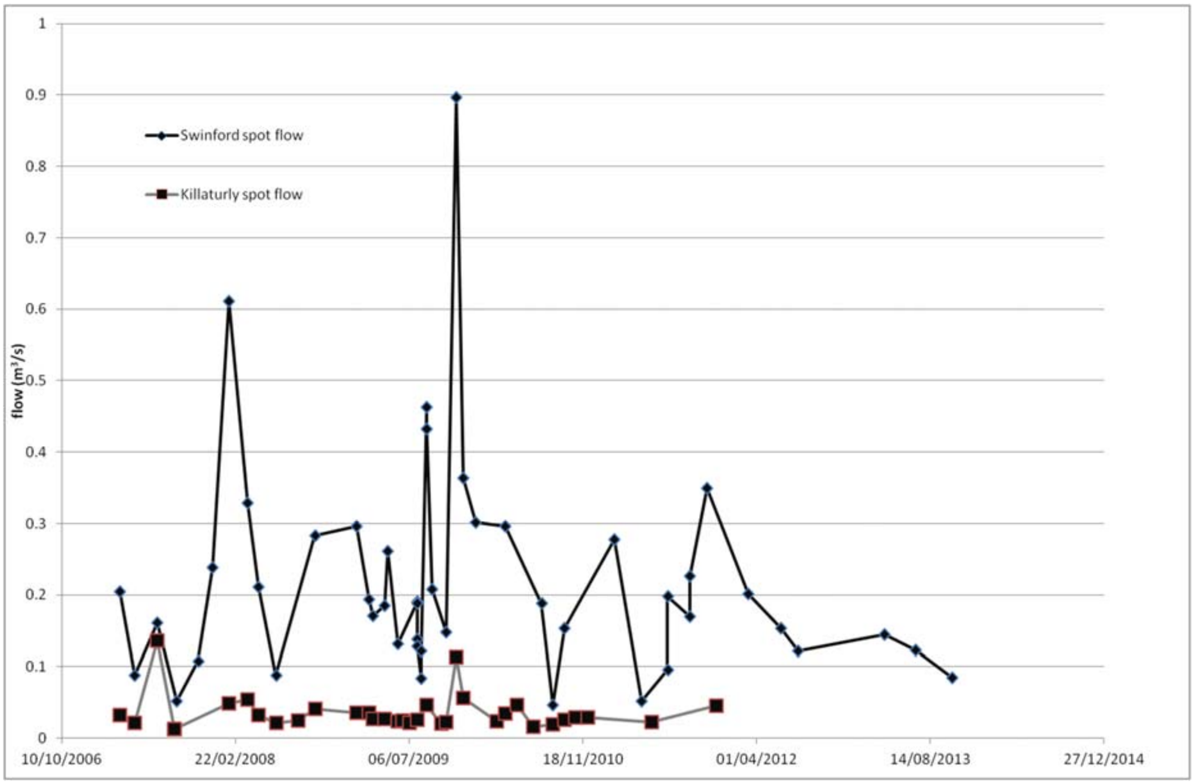

Figure 2: Spot flow measurements at Swinford *and* Killaturly

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[1] The spelling of Killaturly spring and turlough varies depending on the source of information used. For this report, the spelling shown on Ordnance Survey of Ireland maps, "Killaturly" has been adopted for consistency.

[2] Includes abstraction.

[3] Poorly quantified. Estimated from three measurements of reservoir overflows only, when the GWS reservoir was not pumped.

Thus, to estimate relative contributions from the contributing sources, the inflow pipe to the reservoir from the gravel springs was temporarily closed, and the changes in the total overflow from the reservoir under non-pumping conditions was measured during three site visits in October and November 2012, and March 2013. The overflow rates from each of the three overflow pipes were measured using a 10-L bucket and a stopwatch.

The total measured overflow ranged from 13-18 l/s on the three occasions of measurement. In each case, the overflow decreased by approximately 50-60% when the gravel source was shut off, from which it is inferred that approximately half of the GWS supply is sourced from the gravel springs.

The water emerging from the overflow pipes is clear, and the average field-measured electrical conductivity (EC) value was 550 µS/cm. The discharge from the gravel springs into the enclosed pond is relatively constant, even during prolonged dry weather events, and the water level in the pond appears, from visible inspection, to fluctuate seasonally by less than 20 cms. Only on rare occasions does the water in the pond spill over into a small channel before merging with the small stream that flows to north past the GWS facility.

An EPA automatic recorder station is located on the small stream which flows past the GWS facility, at a location immediately downstream of the overflow pipes from the GWS reservoir. The stream hydrograph from this station is presented in **Figure 3.** It shows several important characteristics:

- Flow values which consistently exceed the measured overflows from the GWS reservoir;
- A rapid response to rainfall events, similar to the Swinford spring, with peak flows of short duration;
- A gradual rise and recession through seasons, whereby the average seasonal rise and fall is approximately 0.05 m^3/s (in amplitude), with a maximum between November and February and a minimum in August/September;
- An apparent 6-7 month recession period between winter and summer seasons.

The corresponding flow duration curve, see **Figure 4**, shows a relatively narrow range of stream flows and is accordingly relatively ‘flat’. The mean flow (Q_{50}) is 44 l/s, whereas the Q_{50}:Q_{90} ratio is only 1.5. This is indicative of a stream with a high groundwater baseflow component and storage in the associated hydrogeological system. Graphs of cumulative rainfall and cumulative flow are depicted in **Figure 5**, and are closely correlated.

The Killaturly hydrograph, therefore, shows contrasting characteristics which, on the one hand depicts a hydrological response which is expected of a stream with a large groundwater baseflow and storage component, and which on the other hand shows hydrograph behaviour akin to ‘flashy’ springs, which is typical of karst terrains. The contrasting hydrograph characteristics are explained by the fact that the gauge records the sum of flow contributions from multiple sources of water, notably:

- Overflows from the GWS reservoir;
- Agricultural drainage channels from surrounding lands;
- Outflow from Black Lough, located due west of the GWS facility, which partly originates from surface runoff and spring discharge into the lough;
- Occasional overflow from the open ‘pond’ associated with the GWS gravel springs referenced previously.

Accordingly, the hydrograph response is attributed to both surface and groundwater influences.

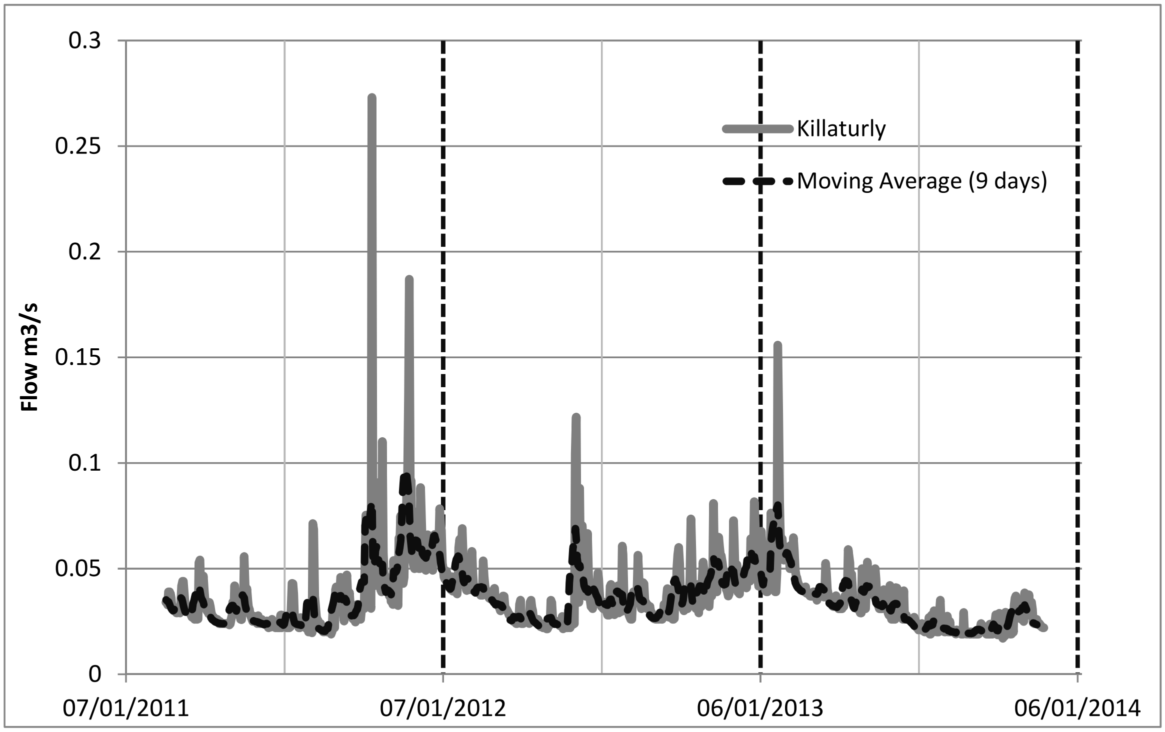

Figure 3: Estimated overflow (daily maxima) at Killaturly (EPA dataset)

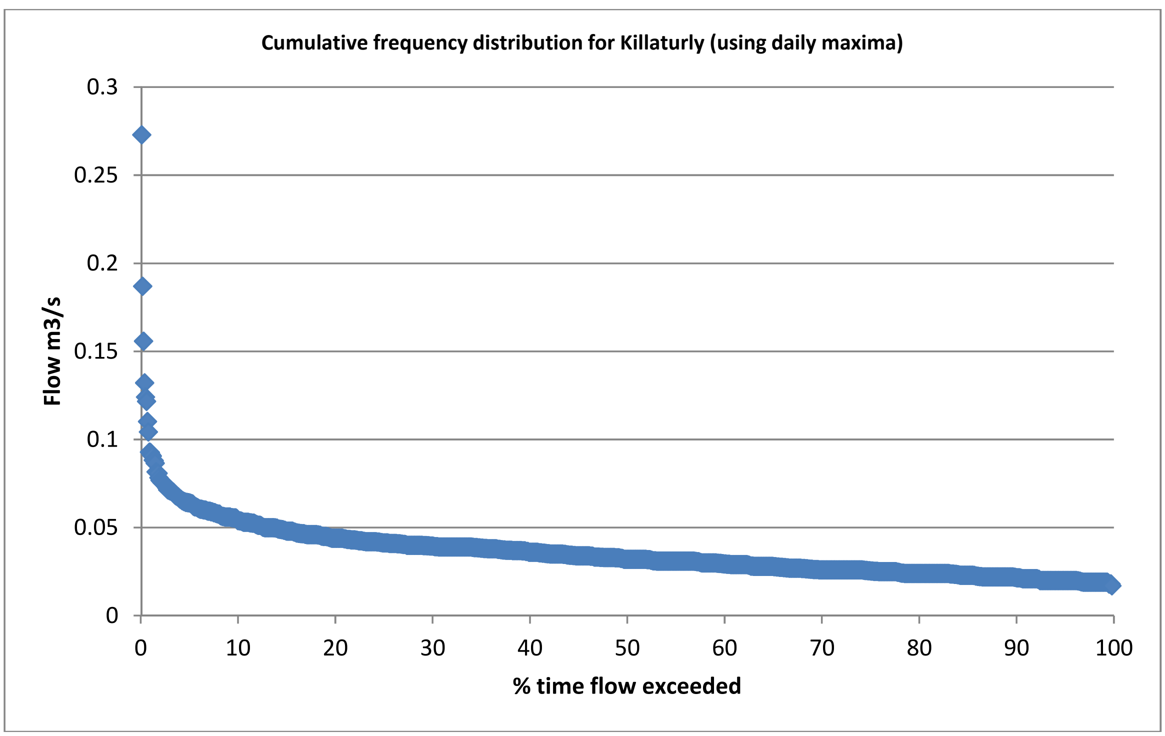

Figure 4: Flow duration curve (Killaturly)

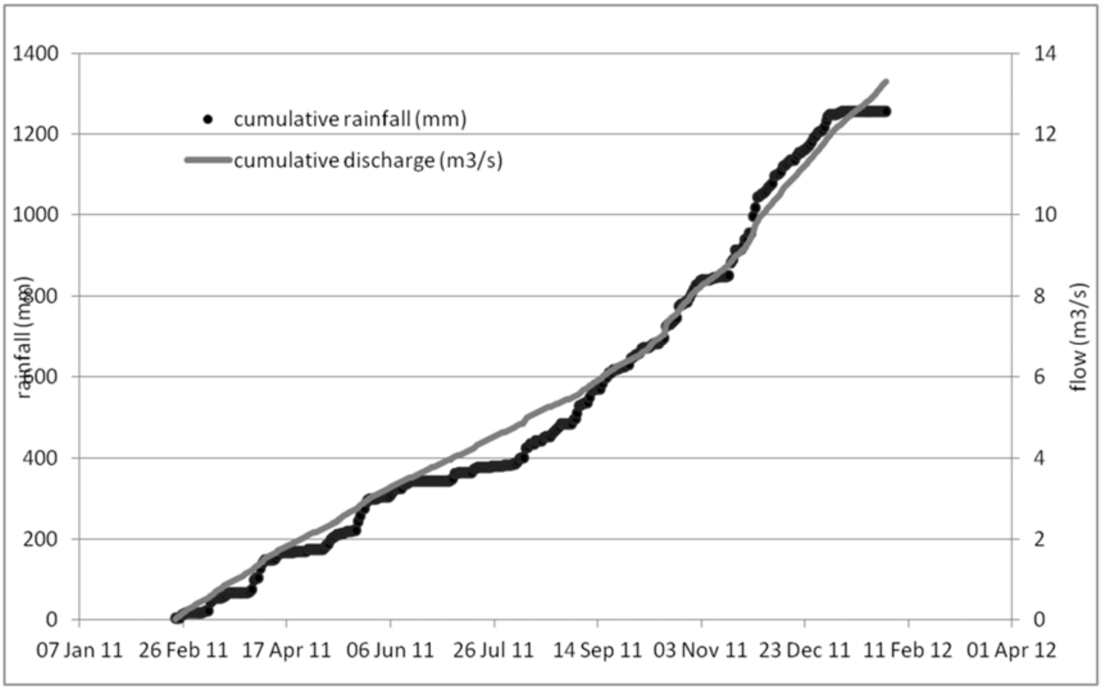

Figure 5: Cumulative rainfall and cumulative discharge (Killaturly)

5 TOPOGRAPHY, SURFACE HYDROLOGY AND LAND USE

The regional topography and surface hydrology shown in **Figure 1** depicts a landscape which comprises a geomorphological 'upland' region to the southeast of Swinford, in the direction of Knock Airport, termed the "East Mayo Plateau", and a 'lowland' region to the north along the River Moy, termed the "Swinford Ribbed Moraines". The topographic elevations range from 100–180 mOD in the upland region and 30-100 mOD across the lowland region. The topography of the 'upland' region is incised by a number of streams, particularly south of Killaturly. The 'lowland' region to the north features a landscape characterised by ribbed moraines trending southeast-northwest and which influence surface water drainage, including stream courses. The largest moraines are several kms in length and up to 1 km across.

The surface hydrology is characterised by several streams/rivers that flow between the ribbed moraines. The overall drainage pattern is towards the River Moy which in turn flows to the southwest past Swinford town before turning north to Lough Cuillin/Conn.

The area between the Swinford PWS and the Killaturly GWS is characterised by few and small lakes and ponds, as well as streams which partly or wholly sink underground at active swallow holes. This is hydrogeologically significant and is described further in subsequent sections of this report.

The Swinford spring discharges at an elevation of approximately 70 mOD, and the Killaturly spring source(s) discharges at approximately 80 mOD. There are three other springs of note in the study area: Bohola, Charlestown, and the unnamed GWS located approximately 1.3 km east of Killaturly spring (see **Figure 1** for locations). Killaturly, Charlestown and the unnamed GWS spring discharge from a similar elevation and are broadly coincident with the major slope change between the 'upland' and 'lowland' areas. Swinford and Bohola discharge further into the 'lowland' area, with Bohola discharging at an elevation of approximately 30 mOD. This suggests that separate spring horizons exist which may be related to geological controls.

Several surface karst features were noted and mapped during field work, including dolines and swallow holes where surface water sinks underground. The primary karst feature is Killaturly Lough, which has been mapped as a turlough by the National Parks and Wildlife Service (NPWS) and Coxon (1986). Goodwillie (1992) describes it as a 'permanent lake' and a 'composite wetland'. The water balance and hydrodynamics of Killaturly Lough are poorly understood. It overflows to the east during wet weather and high water level conditions, and the overflow joins a N-S flowing natural stream near the eastern margin of the lough, where swallow holes were mapped as part of this study, see **Figure 6**, and from where surface water is directed to the north via an artificially deepened channel which alleviates local flooding. In dry weather and low water level conditions, additional swallow holes are evident along this course, and field observations and anecdotal information suggest that the precise location, number and nature of active swallow holes vary in time. The loss of flow via swallow holes at the eastern margin of Killaturly Lough is documented by three sets of flow measurements taken upstream and downstream of the lough as part of this study, and which are summarised in **Figure 7.**

A second seasonal lake called Black Lough is located immediately to the west of the Killaturly GWS facility. It partly receives water via small springs, but there is no information to indicate it is a turlough. It contributes surface water outflow for most of the year to the small stream near the GWS which is gauged by the EPA, and the outflow dries up during prolonged dry weather events. During extreme wet weather conditions, surface outflow from Black Lough also discharges to the west, into the deepened channel leading north from Killaturly Lough.

There are additional isolated small lakes and ponds located in the 'upland' area, but these are not inferred to be of hydrological significance to the immediate study areas associated with the Swinford PWS or Killaturly GWS, given their distance from the sources and their different physiographic and geological settings (e.g. on different bedrock formations).

Land use in the vicinity of the sources is dominated by grazing for cattle and sheep. There is a sand and gravel quarry 2 km southeast of Killaturly spring. Knock Airport is located approximately 5 km southeast of Killaturly spring. There is a dense road network with one-off housing and farm yards distributed along the network, the majority of which are served by domestic waste water treatment systems.

6 HYDRO-METEOROLOGY

Understanding the hydrogeology of the springs supplying the Swinford PWS and Killaturly GWS requires an understanding of general meteorological patterns across the study area. The data source is Met Éireann.

Annual rainfall: The contoured map of rainfall data in Ireland (Met Éireann website, data averaged from 1981–2010) shows that the sources and study area are located between the 1200 mm and 1400 mm average annual rainfall isohyets: decreasing west to east. An average value of 1,300 mm applies.

Annual evapotranspiration losses: estimated to be approximately 475 mm. Potential evapotranspiration (P.E.) is estimated to be 500 mm/yr (based on data from Met Éireann). Actual evapotranspiration (A.E.) is estimated as 95% of P.E. (Hunter-Williams *et al*, 2013) to allow for seasonal soil moisture deficits.

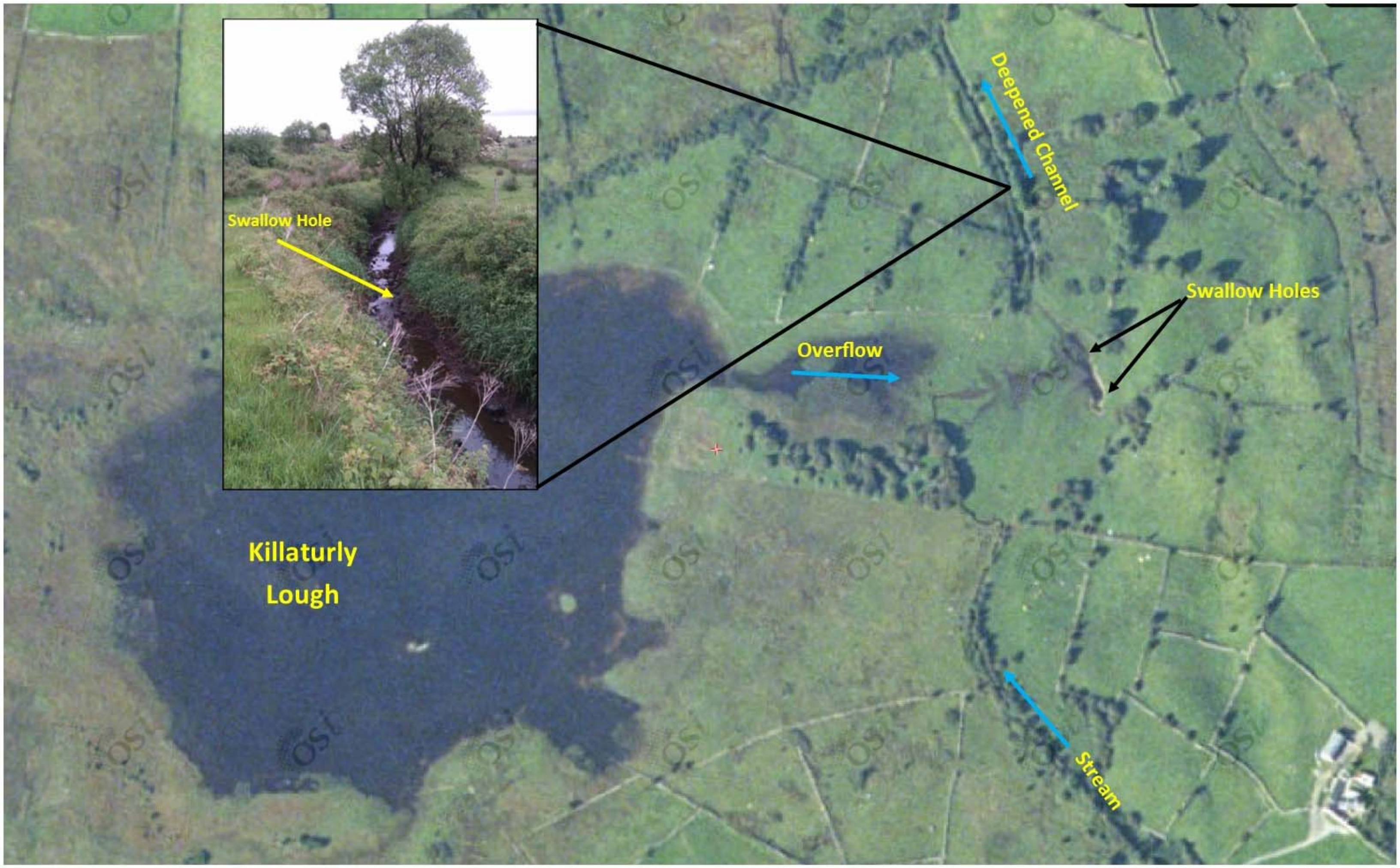

Figure 6: Swallow holes at eastern margin of Killaturly Lough

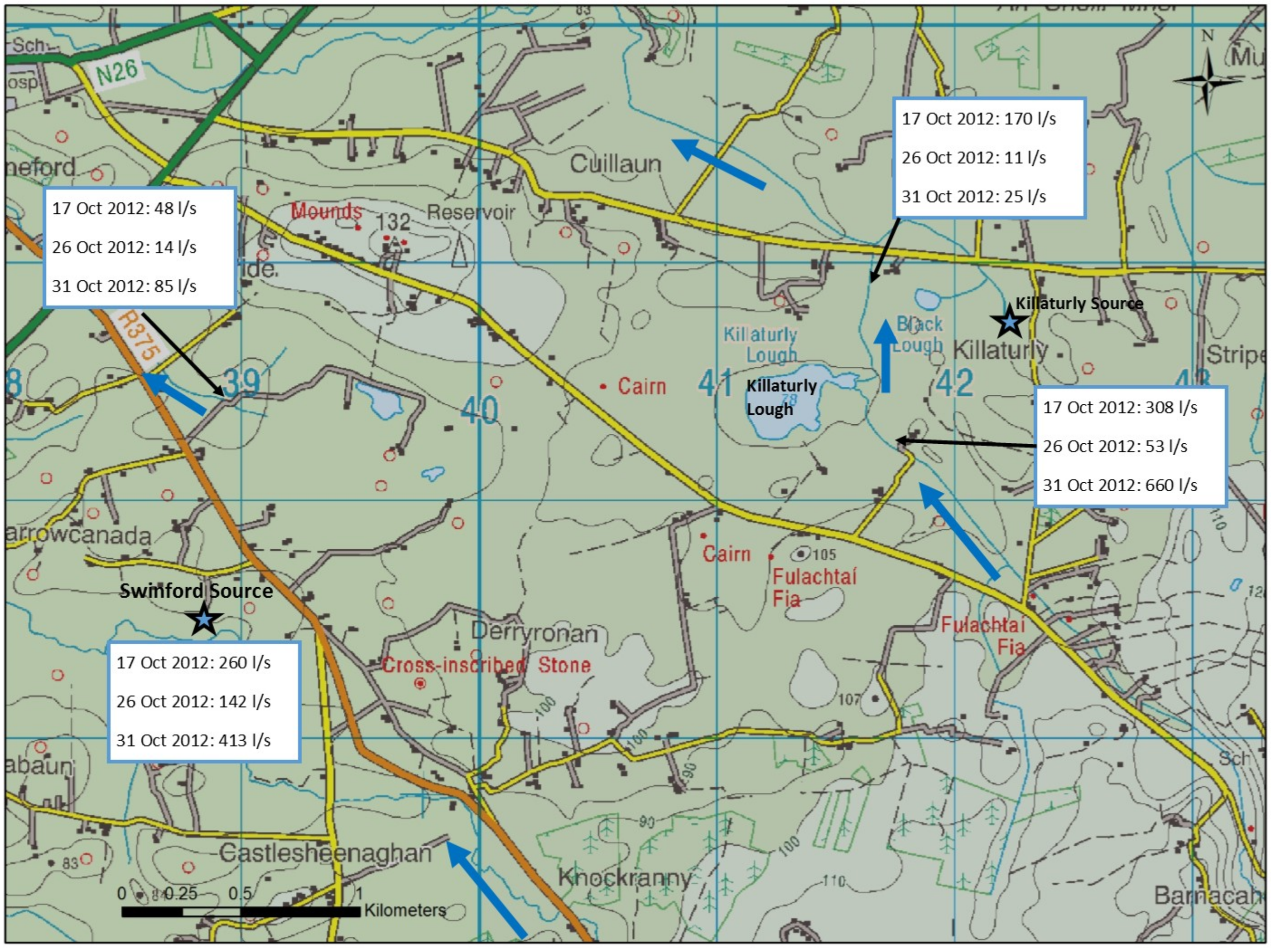

Figure 7: Loss of stream flow at eastern margin of Killaturly Lough

Annual Effective Rainfall: 725–925 mm. The annual average effective rainfall is calculated by subtracting actual evapotranspiration (475 mm) from rainfall (1200-1400 mm).

Reference is made in **Section 9.7** to recharge which estimates the proportion of effective rainfall that enters the groundwater system.

7 GEOLOGY

The geological characteristics of the study area were examined with the assistance of the following sources of information:

- Geology of North Mayo. Bedrock Geology 1:100,000 Map series, Sheet 6, Geological Survey of Ireland (Long *et al.*1992).
- Geology of Sligo-Leitrim. Bedrock Geology 1: 100,000 Map series, Sheet 7, Geological Survey of Ireland (Harney *et al.,* 1995).
- Geology of South Mayo. Bedrock Geology 1: 100,000 Map series, Sheet 11, Geological Survey of Ireland (McConnell *et al.,* 2002).

- Forest Inventory and planning system – Integrated Forestry Information System (FIPS-IFS) Soils Parent Material Map, Teagasc (Teagasc, 2006).
- Mapping and field observation from walk-over surveys.

7.1 Bedrock geology

The bedrock map of Ireland published by the GSI indicates that the Swinford and Killaturly sources are underlain by the Oakport Limestone Formation of Dinantian age which is interbedded with shales of the Ardnasillagh Formation, see **Figure 8**. The Oakport Limestone Formation is a pale grey, pure, well-bedded and massive bioclastic limestone which is fault-bounded by a geologically older sequence of volcanic rocks and the Boyle Sandstone Formation to the east, as well as the geologically younger Lisgorman Shale Formation to the north. The Oakport Limestone Formation is karstified as evidenced by mapped surface karst features and dye tracer tests conducted as part of this study, see **Figure 8** and Section 9 below.

7.2 Soils and Subsoils

The soils (**Figure 9**) and subsoils (**Figure 10**) of the study area reflect the underlying bedrock, whereby soils and subsoils are derived from limestones in the central portion of the study area and sandstones, shales and volcanics to the north, east and south.

Sands and gravels are present in the upland area to the southeast of the Killaturly GWS. The Killaturly gravel springs, the ‘unnamed spring’ in **Figure 1** and the Charlestown spring all discharge along the northern margin of the sand and gravel body shown on **Figure 10** which has been mapped by the GSI (see also Section 9).

Between the Swinford PWS and the Killaturly GWS, peat occupies low-lying areas in the landscape whereas linear, ribbed glacial moraines and drumlins trend roughly E-W towards the River Moy floodplain. The tills are derived from sandstone and limestone, depending on location and the underlying bedrock formation. Alluvium is mapped by the GSI along the majority of the stream channels in the region, especially in the ‘lowland’ region.

There are few bedrock outcrops or areas of ‘rock-close’ to the surface in the study area. Limestone outcrops on the isolated hill in Kilbride, approximately 2 km north of Swinford spring and 3 km west of Killaturly spring, and there are pockets of rock-close in the area between Swinford and Killaturly springs, notably between moraines and coincident with mapped swallow holes (e.g., at Derryronan).

The majority of the soils are mapped as ‘wet’, *i.e.*, they tend to be poorly drained, with smaller dispersed patches of well drained (‘dry’) soils, which tend to occur on southerly facing aspects or the uppermost portions of the drumlins. Iron pans are extensive across the areas dominated by the sandstone-derived tills, and widespread across the study area.

The total depths of soil and subsoil are mapped by the GSI to be greater than 10 m across the majority of the study area. Nonetheless, thin subsoil areas (‘windows’) exist as evidenced by sinking streams and swallow holes into the bedrock aquifer at several locations between the Swinford and Killaturly sources.

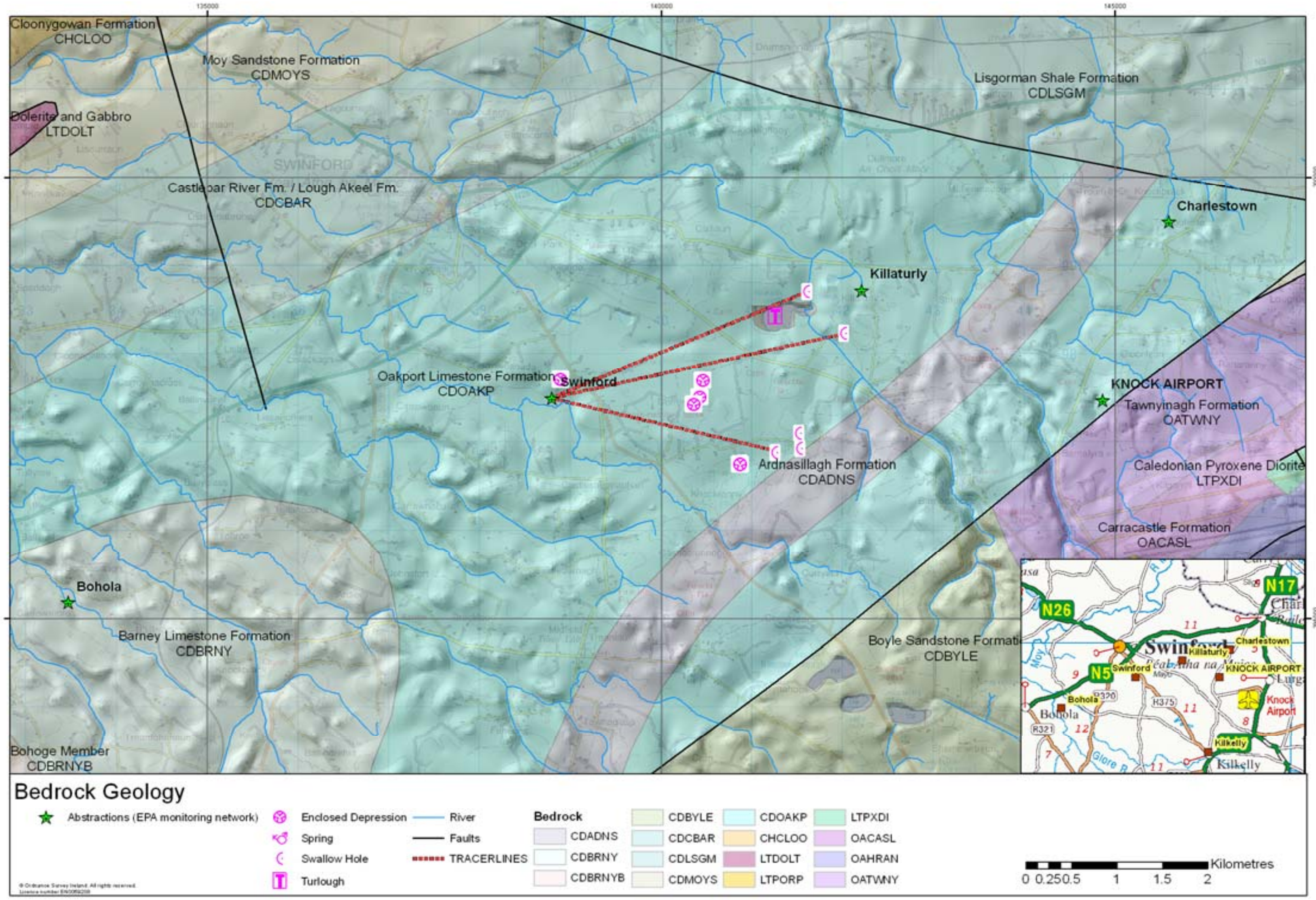

Figure 8: Bedrock geology map with dye tracer connections

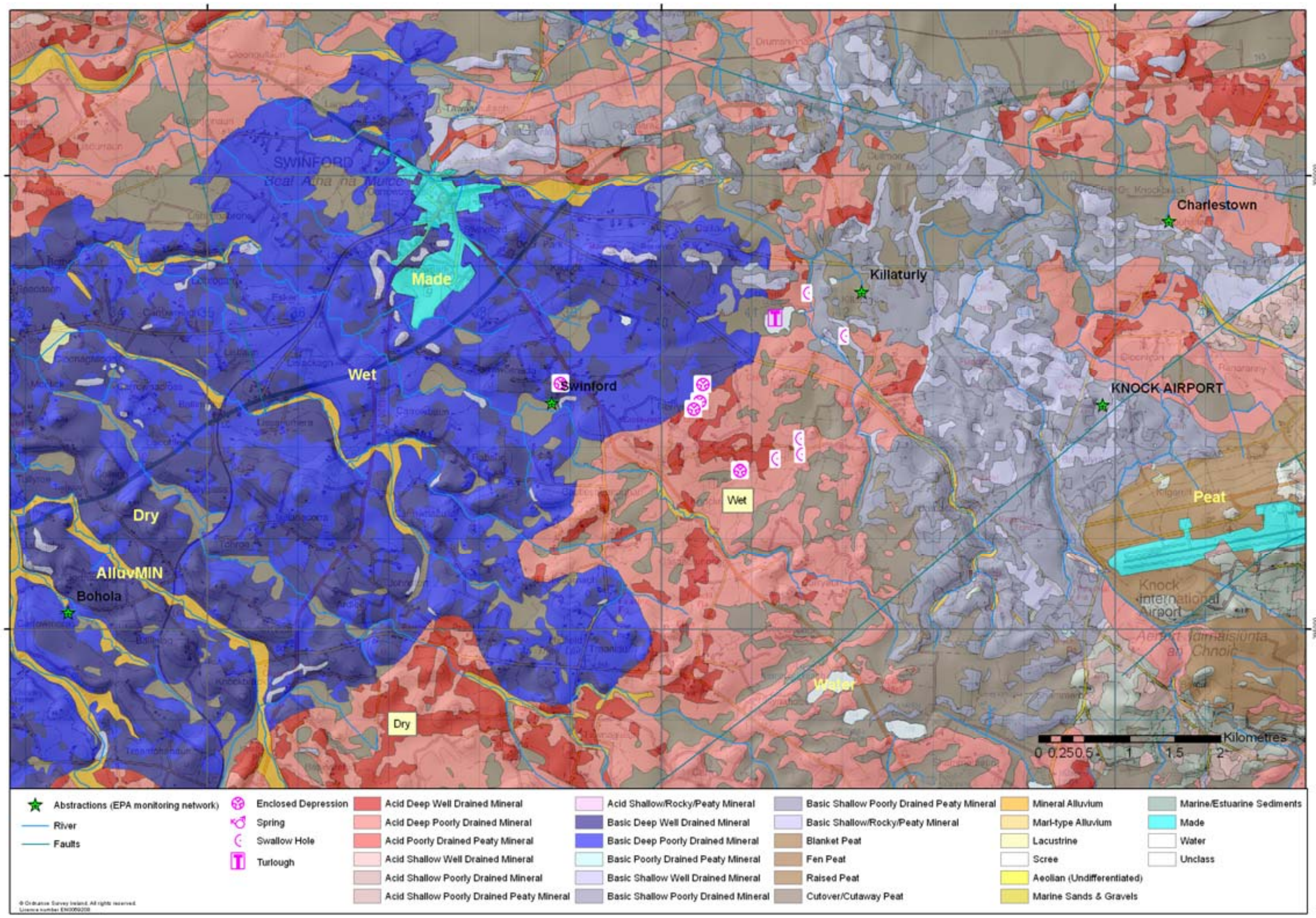

Figure 9: Soils map

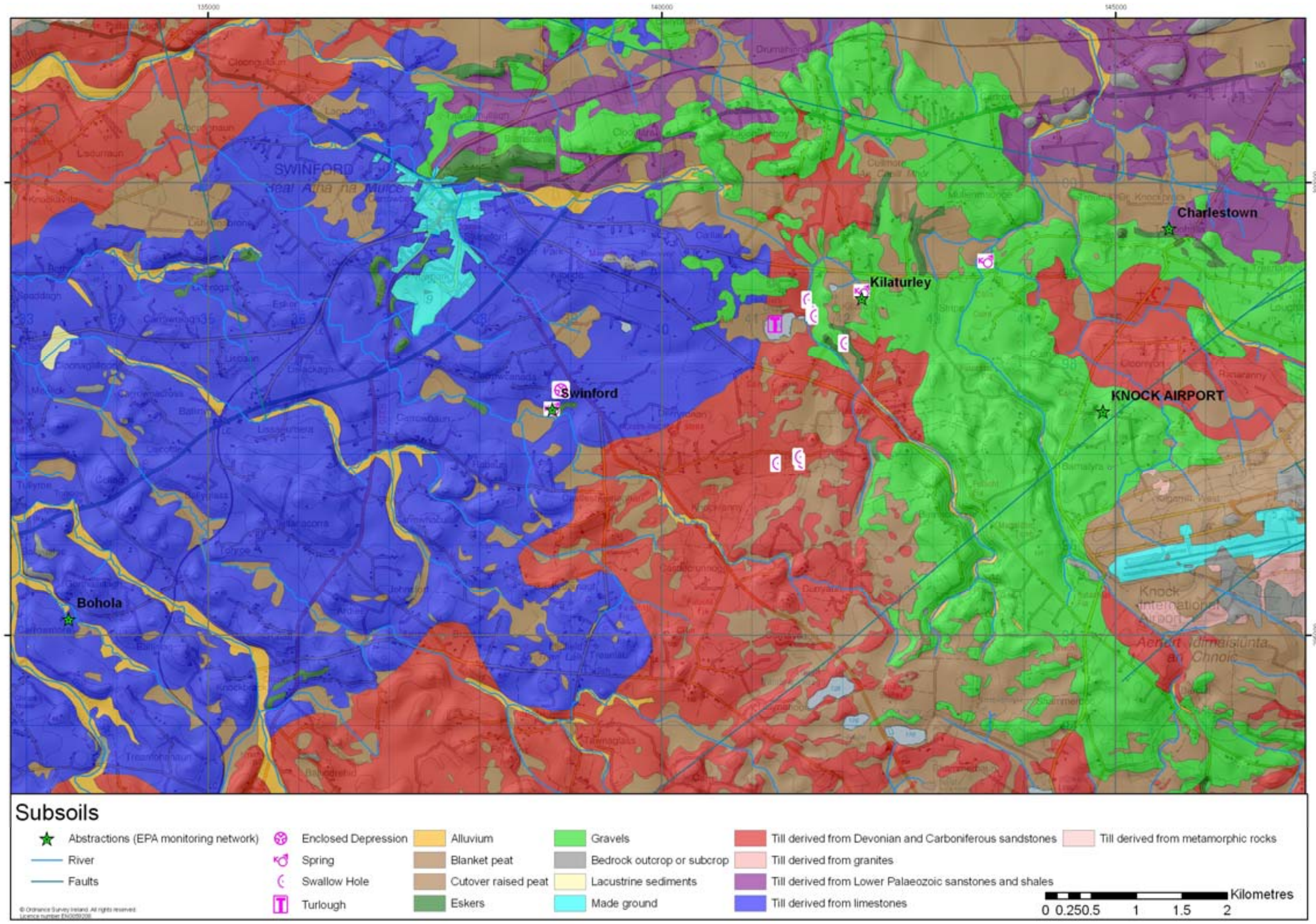

Figure 10: Subsoils map

8 GROUNDWATER VULNERABILITY

Groundwater vulnerability is dictated by the nature and thickness of the material overlying the uppermost groundwater 'target' – in this case the bedrock and sand and gravel aquifers supplying the springs. A detailed description of the vulnerability categories can be found in the "Groundwater Protection Schemes" publication (DELG/EPA/GSI, 1999) and in the draft GSI publication "Guidelines for Assessment and Mapping of Groundwater Vulnerability to Contamination" (Fitzsimons *et al.*, 2003). A groundwater vulnerability map has been developed for County Mayo by the GSI and the relevant portion of the map which encompasses the study area is shown in **Figure 11**.

In general, subsoil cuttings, particle size data and auger drill holes indicate 'moderately' permeable subsoils across most of the study area, with 'highly' permeable subsoils present where gravels occur. The associated groundwater vulnerability ranges from 'extreme' to 'low'. The 'moderate' vulnerability is based on the presence of 'moderate' permeability tills which are greater than 10 m thick. The 'high' vulnerability is based on the presence of 'moderate' permeability tills that are 5–10 m thick and 'high' permeability gravels. Areas of 'low' vulnerability are characterised by peat, mapped to be greater than 3 m thick. Areas of 'extreme' vulnerability comprise outcrops, areas of rock-close to the surface and areas with less than 3 m of soil and subsoil. Areas mapped as having as rock at/or close to surface and karst are denoted as 'X' on **Figure 11**. The GSI assigns an 'extreme vulnerability' buffer of 30 m distance around, and 10 m upstream of, karst point features.

9 HYDROGEOLOGY

This section describes the current understanding of the hydrogeology in the vicinity of Swinford spring and the Killaturly GWS. Hydrogeological, hydrochemical and other relevant information was obtained from the following sources:

- GSI website (www.gsi.ie) and databases;
- Local Authority drinking water returns and county council staff;
- EPA website (www.epa.ie) and groundwater monitoring database;
- Water Framework Directive website (www.wfdireland.net); and,
- Field mapping, tracer testing and measurements.

9.1 Groundwater body and status

There are two groundwater bodies (GWBs) relevant to the study area:

- **Swinford Bedrock GWB,** which is categorised as being at 'Poor Status' and 'at Risk' (1a)[4] by the EPA due to the "*Impact of GWQ on surface water ecology with groundwater contributing > 50% load to cause a breach of the River Phosphate EQS*". Swinford Spring is located in this GWB. The apparent bedrock contribution to Killaturly GWS is also part of this GWB.

[4] Further information on the groundwater body, risk and status can be obtained at www.gsi.ie and www.wfdireland.net

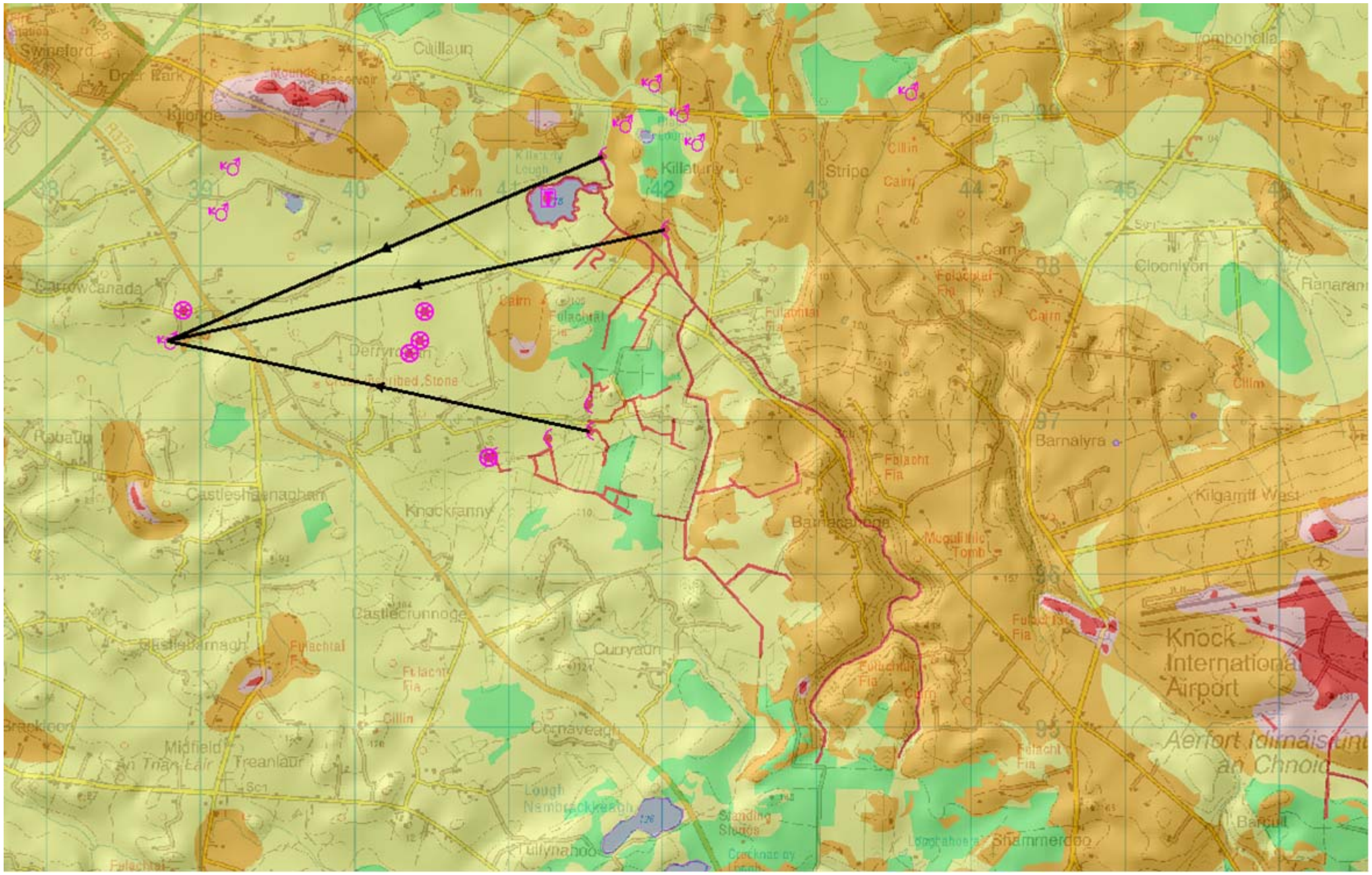

Figure 11: Groundwater vulnerability with main karst features and dye tracer connections

- **Moy Sand and Gravel GWB** which is categorised as being at 'Good Status' by the EPA. The gravel springs of Killaturly GWS, as well as the 'unnamed spring' are located along the margins of this GWB.

9.2 Groundwater levels, flow directions and gradients

With the exception of the spring elevations, no groundwater level data exist, thus groundwater flow directions and gradients are deduced from topographic interpretations and tracer tests in order to distinguish the likely catchment areas ('zones of contributions', ZOCs) to the springs.

A summary of results from the tracer testing are provided in **Table 2**. Tracer input, sampling locations and established tracer connections are shown in **Figure 12**. Tracers (optical brightener) were input into active and accessible swallow holes to the east and southeast of the Killaturly turlough. For each of three tests carried out, tracers were detected at Swinford spring, but not at Killaturly GWS or any other mapped groundwater discharge location. Thus, groundwater flow through the karstic limestone within the study area is inferred to flow in a westerly direction, and the interpreted ZOC of the Swinford spring encompasses the areas of Killaturly Lough and Derryronan.

Table 2: Summary information from the tracer tests

Input Site/elevation	Coordinates	Date injection	Dye	Summary results
Killaturly 77–80 mOD	141598/ 298707	14/6/2013	Optical Brightener 30 litres	Detected with cotton and fluorometer at Swinford spring (68–70 mOD); 3km SW on 19/6/2013 (less than 7 days (>17 m/hr)) Gradient: 0.003
Killaturly 90 mOD	142004/ 298228	30/11/2012	Optical Brightener 30 litres	Detected with cotton at Swinford spring (68–70 mOD) 3.3km SW on 7/12/2012 (less than 7 days (>15 m/hr)) Gradient: 0.006
Derryronan 85-88 mOD	141256/ 296901	25/10/2012	Optical Brightener 30 litres	Detected with cotton at Swinford spring (68–70 mOD) 2.5km WNW on 7/11/2012 (less than 10 days (>10 m/hr)) Gradient: 0.006–0.008

9.3 Groundwater quality

9.3.1 Swinford PWS

The water is moderately hard, with total hardness values ranging between 108–416 mg/l, and a mean of 235 mg/l (equivalent $CaCO_3$). Electrical Conductivity (EC) values average 507 µS/cm and range between 103–804 µS/cm, with a coefficient of variance of 28%, indicative of karstic conduit flow (Doak, 1995). The groundwater has a calcium bicarbonate hydrochemical signature. Alkalinity ranges from 105–416 mg/l $CaCO_3$. Samples are usually within acceptable turbidity limits, but samples regularly exceed the recommended colour threshold.

Figures 13 through 16 depict the available data for key pollutant indicators, which can be summarised as follows:

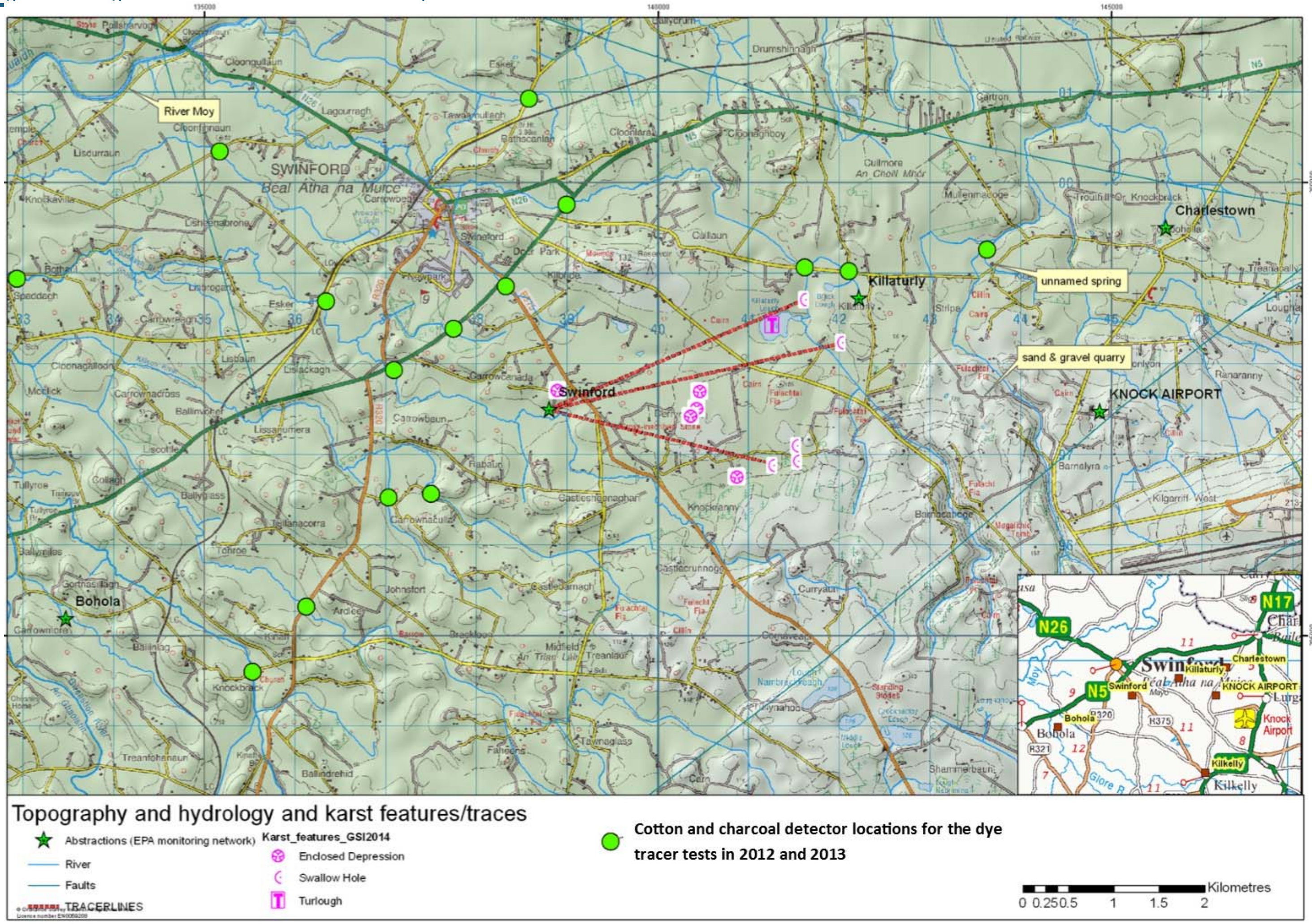

Figure 12**: Summary of dye tracer tests in 2012 and 2013**

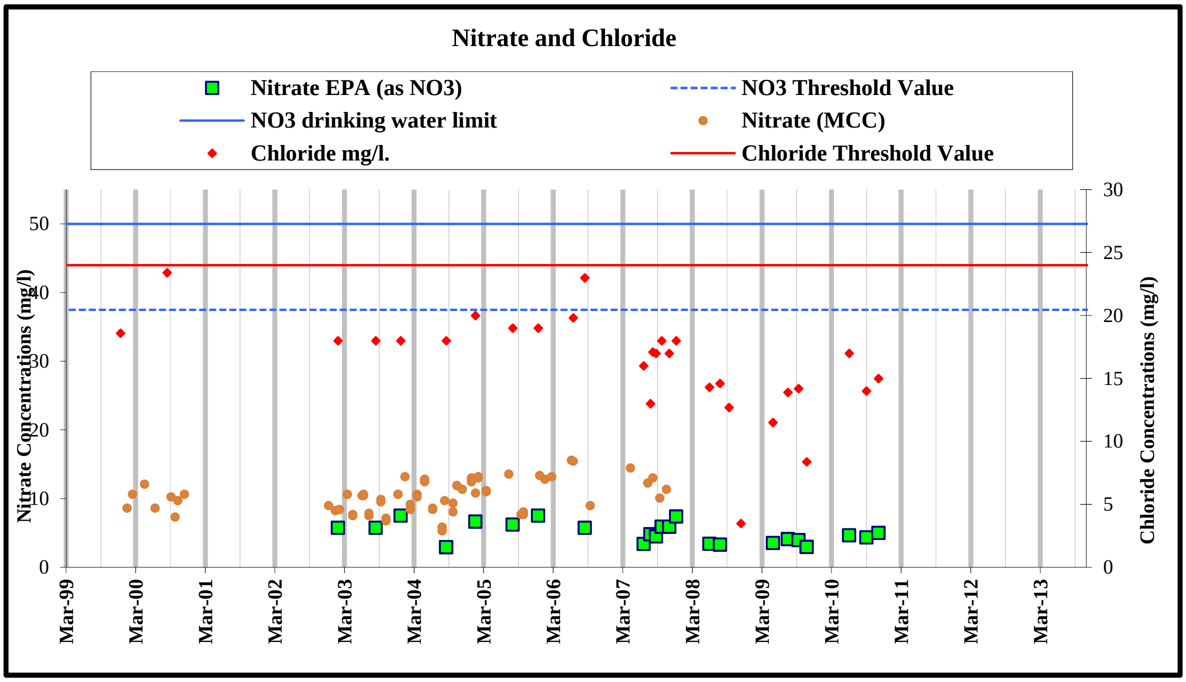

Figure 13: Nitrate and chloride concentrations – Swinford PWS

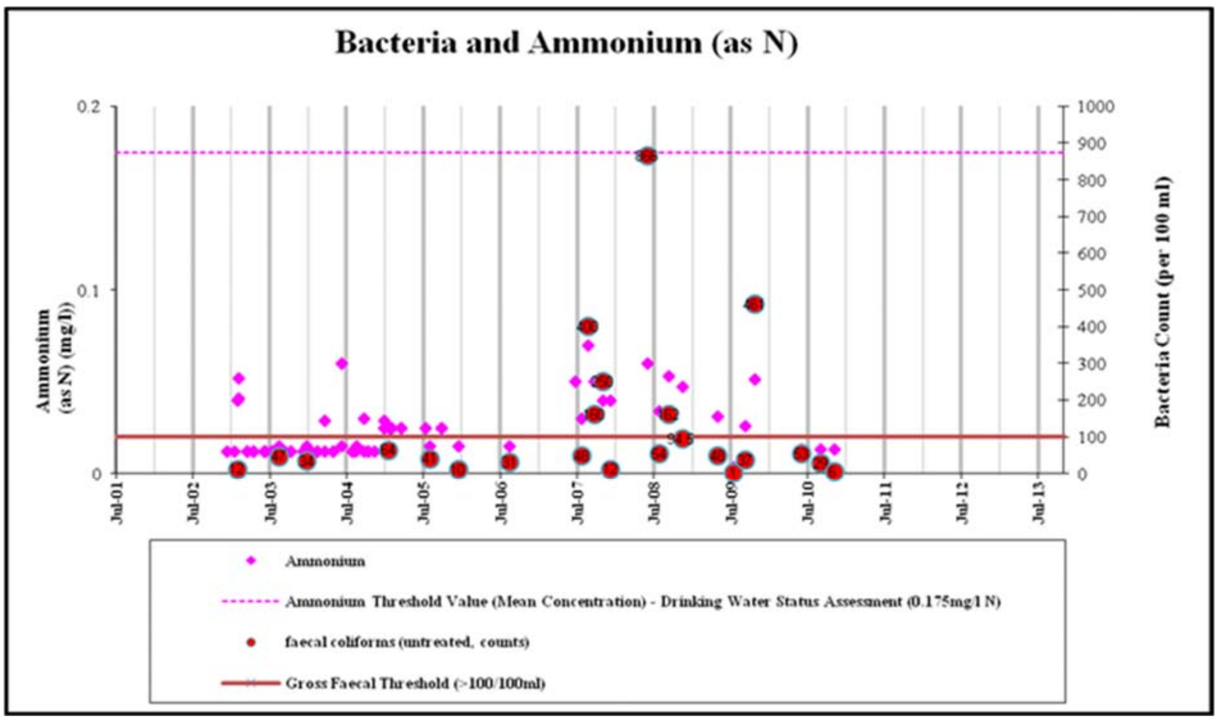

Figure 14: Bacteria counts and ammonia concentrations – Swinford PWS

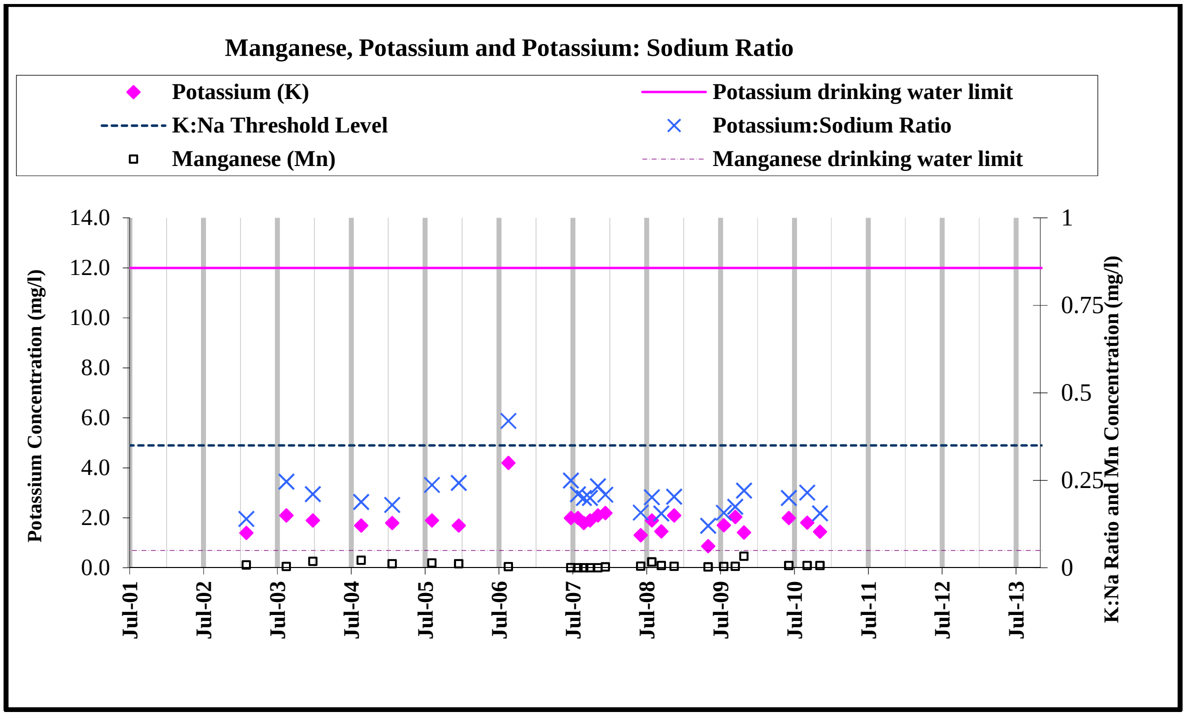

Figure 15: Manganese, potassium and potassium:sodium ratio – Swinford PWS

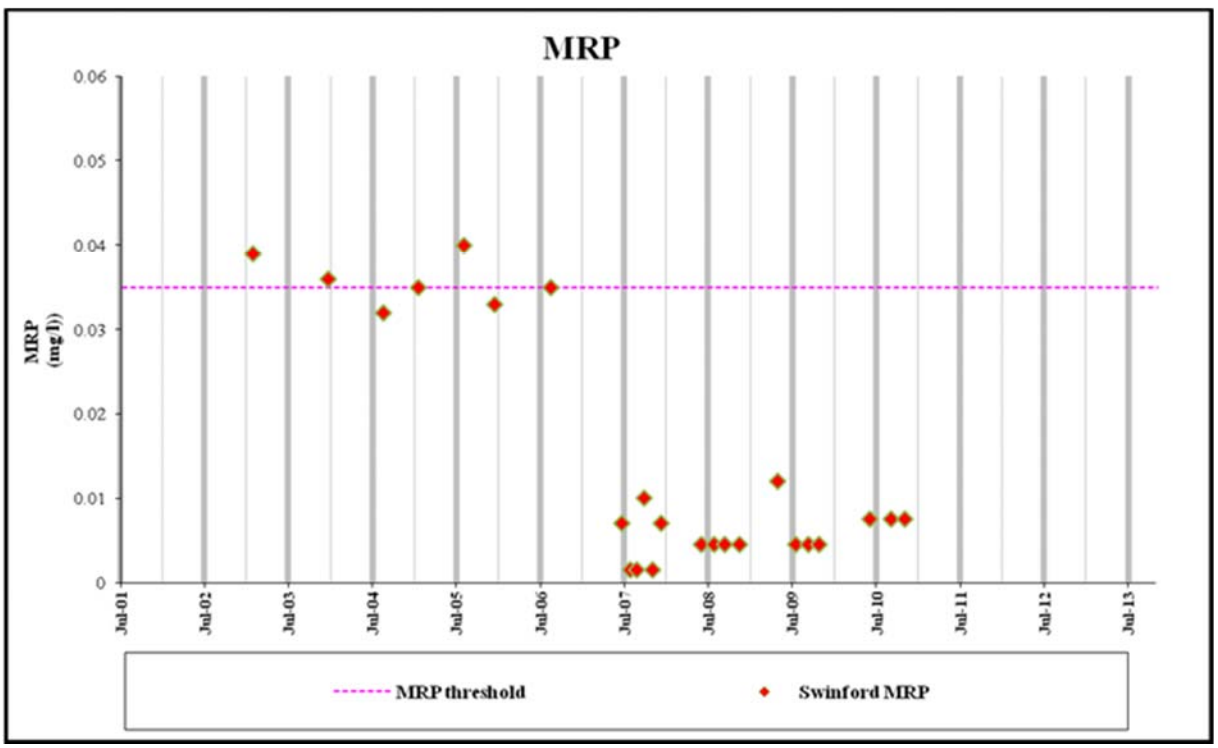

Figure 16: MRP concentrations – Swinford PWS

- Nitrate concentrations range from 3.0–8.5 mg/l as NO_3, with a mean of 5.5 mg/l. This is below the groundwater threshold value of 37.5 mg/l (S.I. No. 9 of 2010) and below the drinking water standard of 50 mg/l (S.I. No. 278 of 2007). Ammonia and chloride concentrations are also below their respective threshold values.

- Faecal coliform counts exceeded the drinking water limit of 0 counts per 100ml on every occasion from 2003 to 2010, and are regularly greater than 100 counts per 100ml, which is considered as 'gross contamination' (note, two samples in 2003 and 2007 at 1,300 and 3,000 counts per 100ml are not shown in **Figure 14** as they would skew the vertical scale and presentation of data). Generally, the contamination events coincide with autumn and winter seasons.

- The ratio of potassium to sodium (K:Na) is used to help indicate if water quality has been affected by organic pollutants. The relevant threshold ratio of 0.35 was exceeded on one occasion due to elevated potassium (4.2 mg/l).

- The average concentration of Molybdate Reactive Phosphorous (MRP) is 0.016 mg/L-P, i.e. below the groundwater threshold value of 0.035 mg/L P for "Good Status" (S.I. No 9 of 2010). The range is from 0.002 to 0.064 mg/l.

- Between 2002 and 2006, the average concentration of MRP was 0.039 mg/L-P. Between 2006 and 010, the average was 0.006 mg/L-P. The reason for the marked decrease in reported concentrations after 2006 is not clear.

- Iron concentrations are consistently elevated, with a mean of 0.19 mg/l and a range of 0.014-1.4 mg/l. Manganese concentrations are generally below its limit value.

- The concentrations of trace metals, herbicides and organic compounds are generally below laboratory limits of detection.

- In summary, bacteriological contamination is persistent in samples from the Swinford PWS spring, and gross faecal contamination occurs regularly.

9.3.2 Killaturly GWS

Hydrochemical analyses for Killaturly GWS were reviewed based on 17 untreated samples from 2007 to 2010 (EPA data), and 21 treated water samples data from 2000 to 2007 (Local Authority data for nitrate, conductivity, hardness, iron and manganese). The water is hard, with total hardness values ranging from 136 to 320 mg/l, with a mean of 274 mg/l (equivalent $CaCO_3$). EC values range between 377 and 614 µS/cm, (average 509 µS/cm), with a coefficient of variance of 10%, significantly lower than Swinford PWS. The groundwater has a calcium bicarbonate hydrochemical signature. Alkalinity ranges from 220–360 mg/l $CaCO_3$. Samples are within acceptable levels for colour and turbidity.

Figures 17 through 20 depict the available data for key pollutant indicators, which can be summarised as follows:

- Nitrate concentrations range from 0.3–15.0 mg/l as NO_3, with a mean of 6.5 mg/l, which is below the groundwater threshold value of 37.5 mg/l (S.I. No. 9 of 2010) and less than the drinking water standard of 50 mg/l (S.I. No. 278 of 2007). Chloride concentrations are also low, ranging from 12–17 mg/l, with a mean of 15 mg/l.

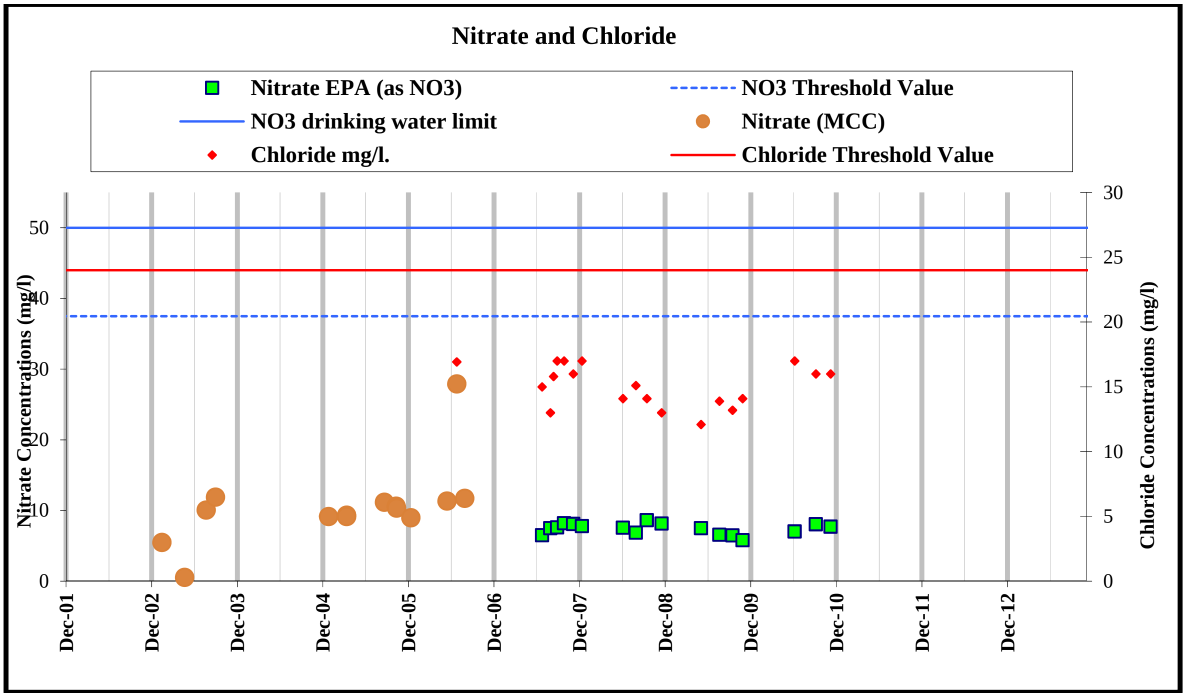

Figure 17: Nitrate and chloride concentrations – Killaturly GWS

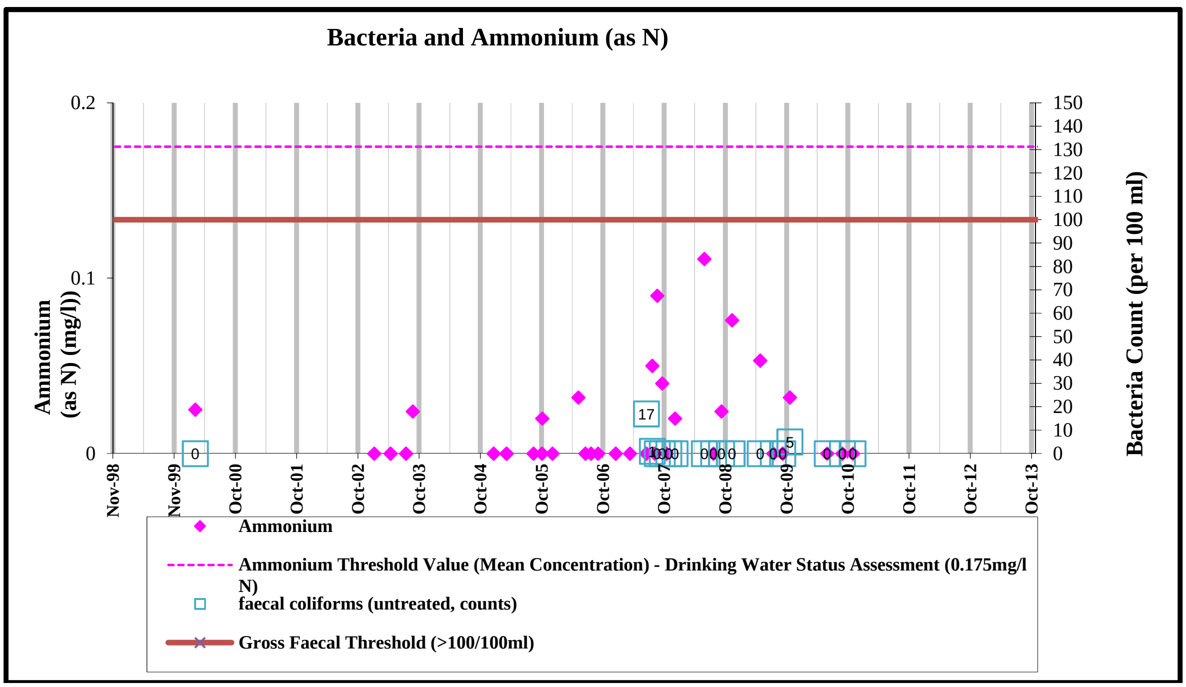

Figure 18: Bacteria counts and ammonia concentrations – Killaturly GWS

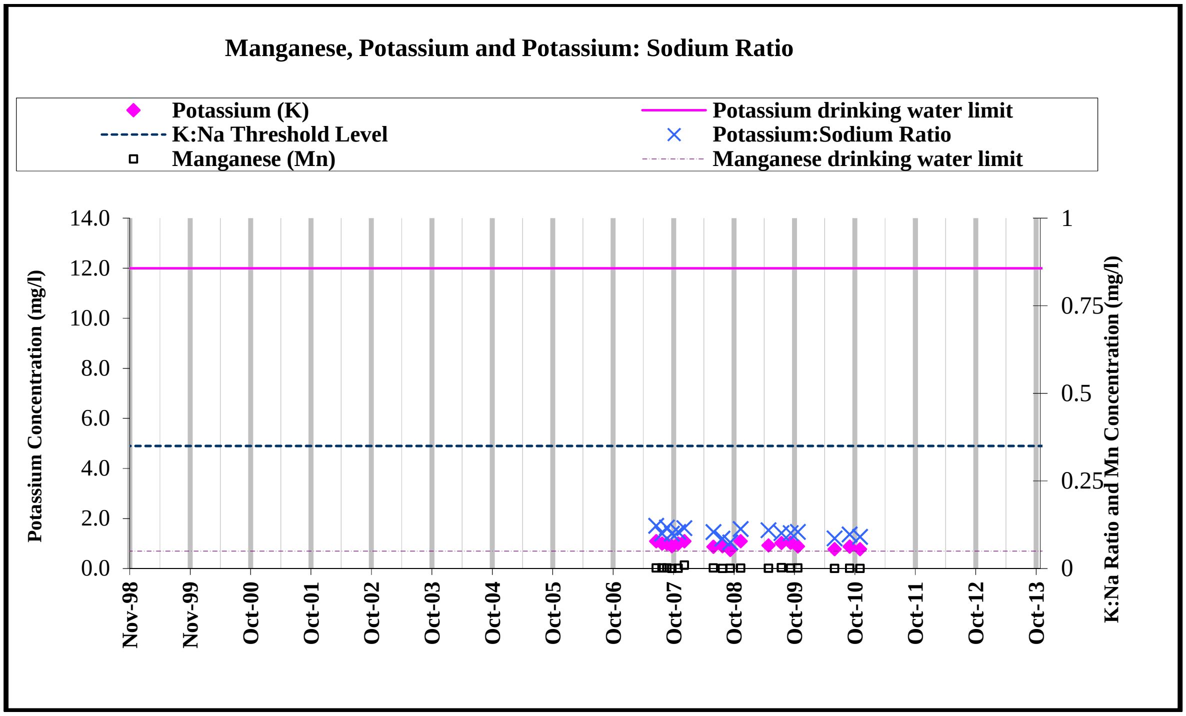

Figure 19: Manganese, potassium and potassium:sodium ratio – Killaturly GWS

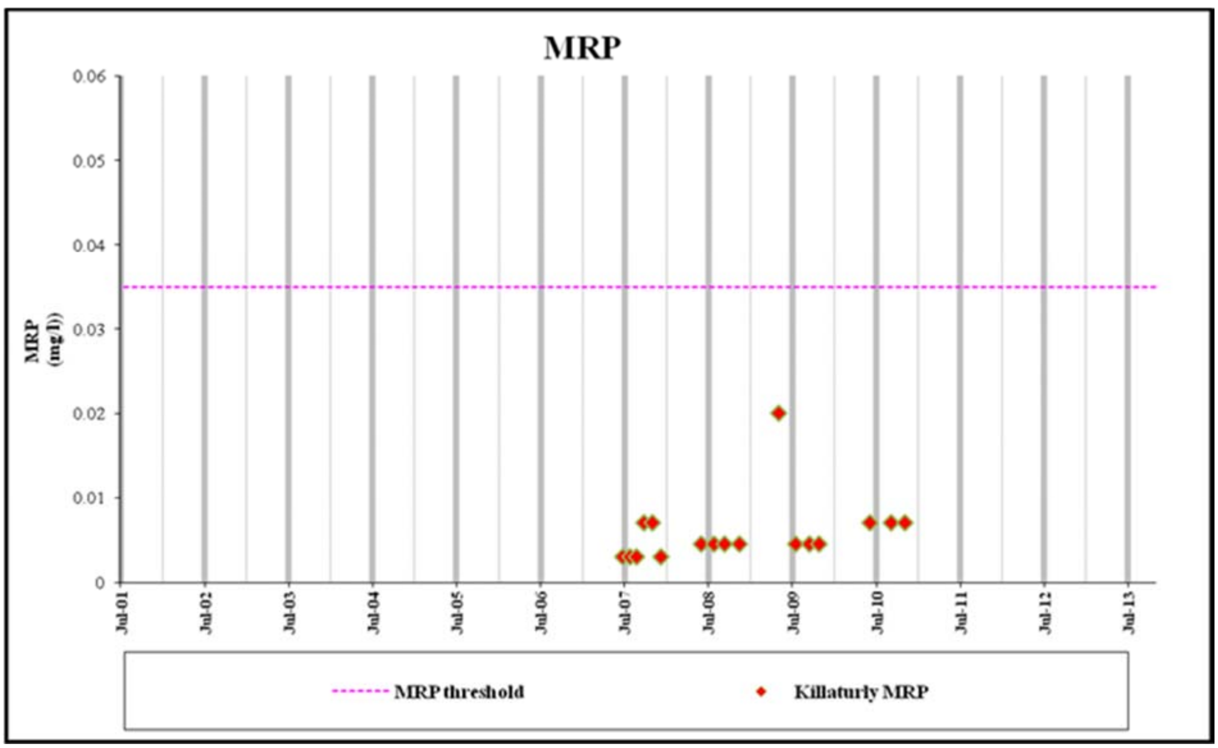

Figure 20: MRP concentrations – Killaturly GWS

- Faecal coliform counts exceeded 0 counts per 100ml on only three occasions from 2003 to 2010 in the EPA untreated samples (N=17). The counts in question were low and none exceeded 100 counts per 100ml, which is considered to be 'gross contamination'. Over the sampling period, the spring was uncovered. A cover over the pond which collects water from the gravel springs was installed in late 2013.
- The average concentration of Molybdate Reactive Phosphorous (MRP) is 0.006 mg/L-P, with a range from 0.003 to 0.02 mg/l. This is below the groundwater threshold value (S.I. No 9 of 2010) of 0.035 mg/L P for "Good Status".
- Iron and manganese concentrations are generally low, as is the ratio of potassium to sodium (K:Na).
- The concentrations of trace metals, herbicides and organic compounds are generally below laboratory limits of detection.

In summary, and in contrast to Swinford PWS, the water quality is considered to be of a high quality, and free from bacteriological contamination.

9.4 Aquifer characteristics

9.4.1 Limestone Bedrock

The presence of karst features within the study area is evidence for karstification of the limestone aquifer that supplies groundwater to the Swinford PWS, and possibly also in part the Killaturly GWS. The established tracer links described in **Section** □ are characteristic of an aquifer system in which groundwater flows preferentially through underground conduits. The limestone aquifer in the study area has been classified by the GSI as a '*Regionally Important Karst aquifer, dominated by conduit flow*' *(Rk^c)***.** The established flow rates (velocities) through the conduit system are greater than 10–20 m/hr, although an upper limit could not be established due to the tracer monitoring methodology employed, using passive cotton detectors which were collected and inspected on a weekly basis. The associated, established flow gradients range between 0.003–0.008.

9.4.2 Sand and Gravel

The Killaturly sand and gravel springs, the 'unnamed spring' and the Charlestown spring all issue from the Moy Sand and Gravel GWB which is currently classified by the GSI as a '*Locally Important Sand and Gravel aquifer' (Lg).*

Location-specific test pumping data to derive hydraulic properties of the gravel aquifer at Killaturly are not available. However, the gravel body is significant, and provides water to several supply schemes in the region. As such, properties summarised by the GSI (2004) for the Moy Sand and Gravel GWB, generally, are used as a proxy, whereby transmissivity values in the range 200-1,500 m^2/d would be considered feasible and reasonable for the Killaturly area. The following equations are also useful to estimate aquifer properties:

$$\textit{Transmissivity } m^2/d = \textit{mean spring discharge} / (\textit{gradient} * \textit{aquifer width})$$
$$\textit{Transmissivity } m^2/d = 3800m^3/d / (0.01 * 800m)$$
$$\textbf{Transmissivity = 475 } \mathbf{m^2/d}$$

Assuming an average aquifer thickness of approximately 30 m, the permeability can be estimated by:

Permeability m/d = Transmissivity / Aquifer thickness
Permeability m/d = 475 / 30
Permeability = 15 m/d

Velocity can then be estimated by:

*Velocity m/d = permeability * (gradient / porosity)*
*Velocity m/d = 15 * (0.01 to 0.016 / 19)*
Velocity =0.8 to 1.25 m/d

In terms of hydraulic gradients, location-specific data also do not exist. However, the streams that incise the sand and gravel body are used as a proxy to indicate a gradient on the order of 0.01.

Based on well hydrograph characteristics, notably hydrograph recessions, Tedd *et al.* (2012) estimated the specific yield (S_y) of aquifers in Ireland, guided by the following formula:

Estimated recharge to the aquifer = $S_Y \Delta h/\Delta t$

Where,
S_Y = specific yield
Δh = *water level variation over hydrograph recession period*
Δt= *recession period*

For the well hydrograph shown in **Figure 21** for a well at Crossmolina in the same Moy sand and gravel GWB as the Killaturly gravel springs, Sy is estimated from:

S_Y *= 800*0.5/2000 =* ***19%***

Where,

Δh*= 2,000 mm (2m)*
Δt *= 6 months (0.5 yrs)*
Estimated recharge to the sand and gravel aquifer (800 mm, see Section 9.7).

Accordingly, and without site-specific test data from Killaturly, a specific yield on the order 0.19 (or 19%) can be considered a reasonable proxy for the storage capacity of the S&G aquifer in the Killaturly area.

9.5 Conceptual Model

The conceptual hydrogeological models which apply to the Swinford and Killaturly supplies are summarised in **Figures 22** and **23,** and involve groundwater flow through both a karst conduit system and a sand and gravel groundwater body, as well as the possible interaction between the two.

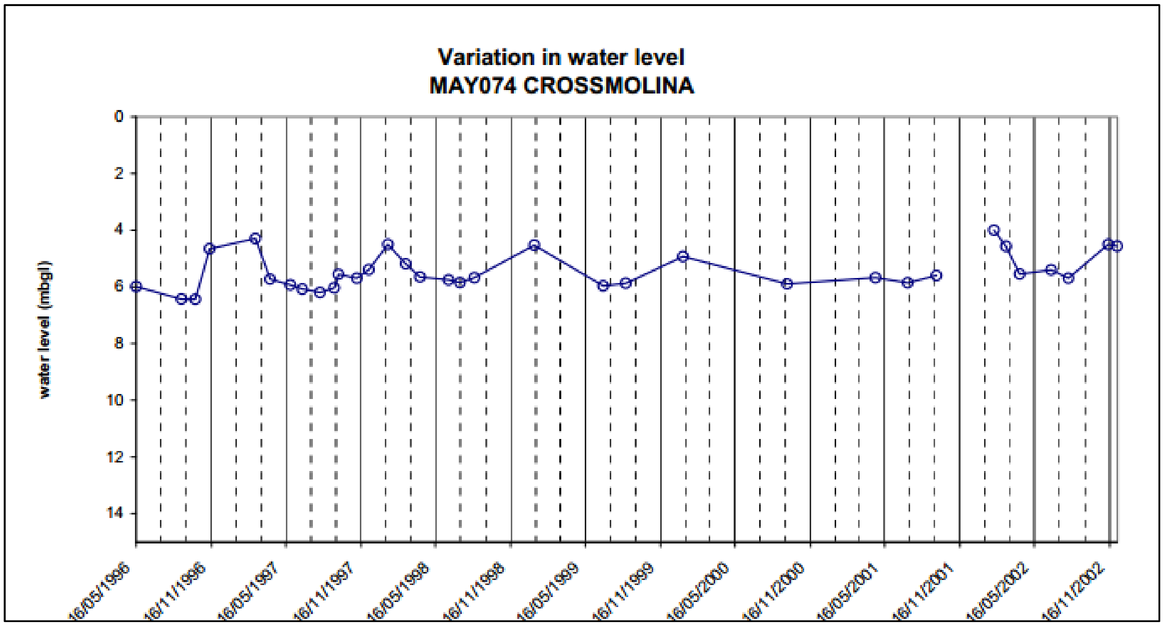

Figure 21: Well hydrograph - Crossmolina

9.5.1 Swinford PWS

Swinford spring is associated with a karstified limestone aquifer in which groundwater moves via fissures, fractures and open karst conduits to discharge locations along the Moy valley. Conduit flow to Swinford spring is evidenced by three dye tracer tests from the Killaturly and Derryronan areas to the east of the spring. Karst flow conditions are also indicated by EPA's discharge (flow) monitoring data, whereby the spring discharges respond rapidly to rainfall events, and by frequent documented pollution events from bacteriological sources which are transported rapidly through the karst system. The spring water quality also shows variable chemistry in time, notably large ranges in EC values and frequently elevated colour values.

From dye tracer testing, groundwater flow velocities in the karst conduits are in excess of 20 m/hr. Because of the combination of high flow velocities and areas of extreme vulnerability, which includes sites of concentrated recharge at swallow holes, both the bedrock aquifer generally, and Swinford spring specifically, are susceptible to pollution, with little or no attenuation potential for contaminants in the subsurface, other than by dilution.

There are several active swallow holes and sinking stream segments which preferentially and rapidly recharge the bedrock and karst conduit system near Killaturly Lough and Derryronan. The flow gradient is from east to west. All major karst features, including swallow holes, occur in the Oakport Limestone Formation.

9.5.2 Killaturly GWS

Killaturly GWS is partly a sand and gravel source but also an apparent bedrock aquifer source. Upwelling of groundwater from the underlying limestone was reported during excavations works of the GWS facility. Such upwelling implies that groundwater in the limestone discharges into the overlying sand and gravel body under inferred upward hydraulic gradients.

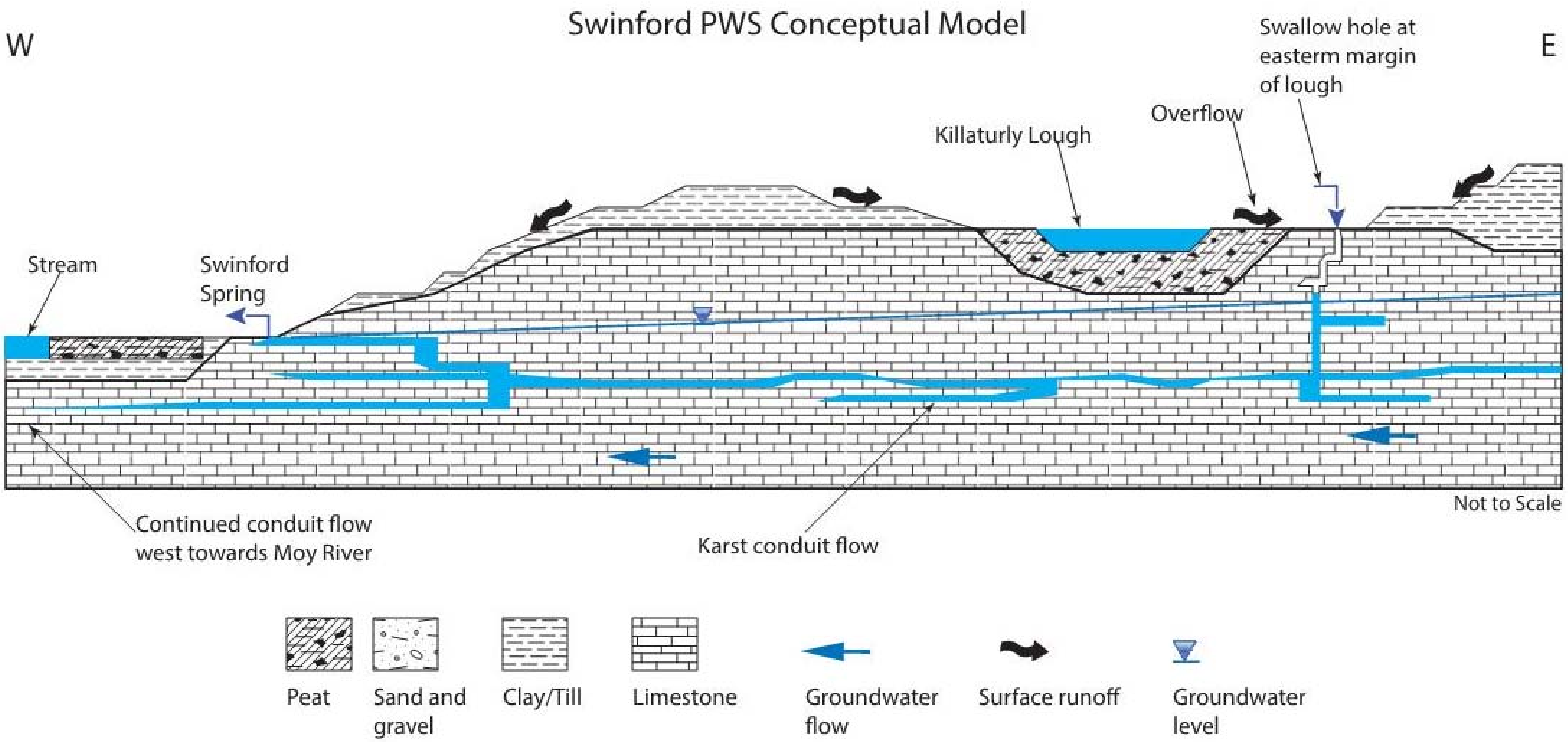

Figure 22: Conceptual hydrogeological model - Swinford

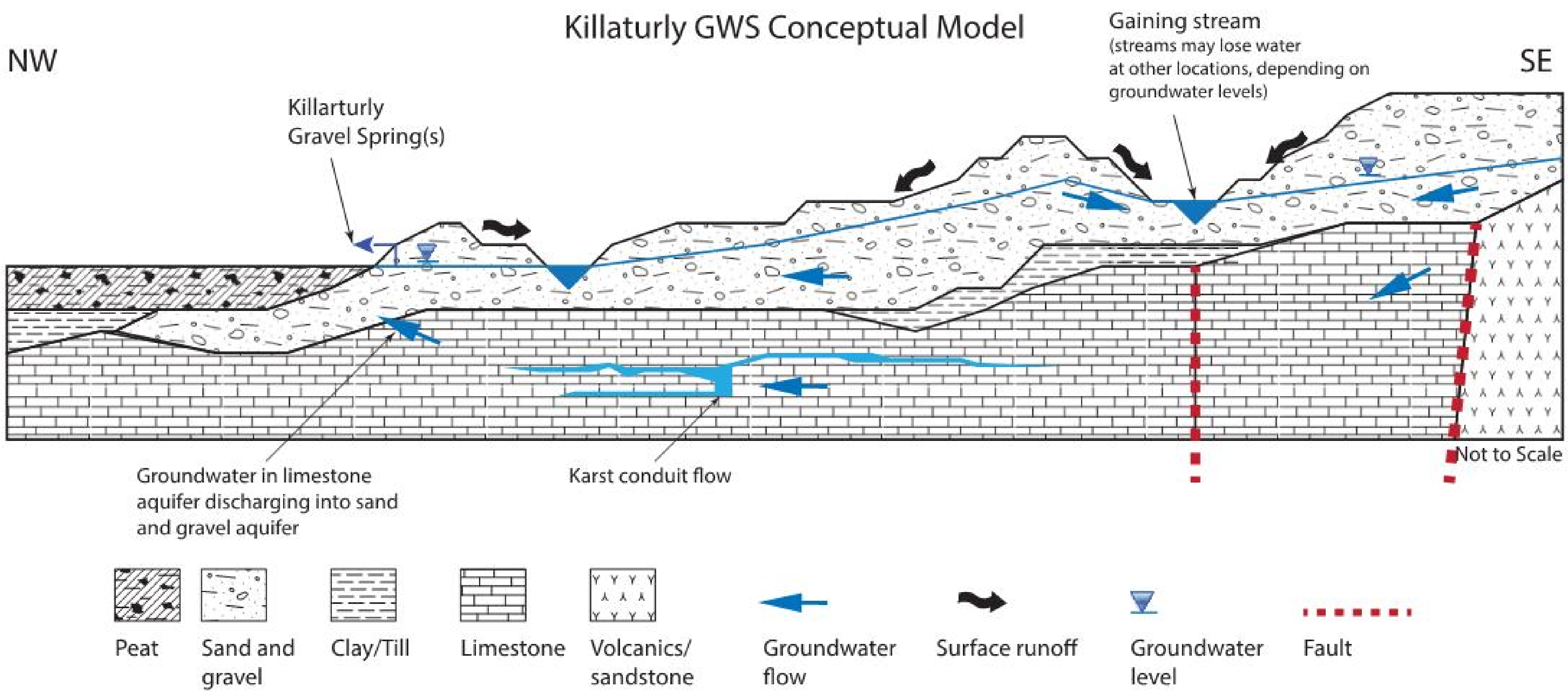

Figure 23: Conceptual hydrogeological model - Killaturly

The gravel springs at Killaturly are located near the margin of the regionally significant Moy Sand and Gravel GWB which also gives rise to other gravel springs in the area, presumably at locations where the sand and gravel deposits become thinner. Groundwater flow in the gravels is interpreted to be from southeast to northwest, with local differences expected as a function of the actual geometry of the sand and gravel body. Where streams flow across the gravel body, groundwater is inferred to discharge into the streams as baseflow, although there is presently no piezometric data available to verify this.

Unlike the Swinford PWS, which is affected by episodic water quality problems, the Killaturly GWS is consistently of good quality, with few to no exceedances of chemical limit values. This is inferred to be due to the hydrogeological nature of the sand and gravel aquifer, which naturally filters and otherwise attenuates pollutants that may enter the groundwater environment.

9.6 Potential zones of contribution

The boundaries of the areas which contribute water to a given source is referred to as the Zone of Contribution (ZOC). The ZOC of a groundwater source is effectively a groundwater catchment. They are influenced by the hydrogeology of a given area, and are determined from the considerations of:

- The total outflow at the source;
- The recharge to the associated groundwater flow system;
- Groundwater flow directions and gradients; and
- Subsoil and bedrock permeabilities.

The first two factors influence the size (area) of the ZOC, and the latter two factors influence the shape of the ZOC.

The likely groundwater catchments for the Swinford and Killaturly sources were investigated using a combination of hydrogeological mapping, dye-tracing techniques, and water balance estimations, as well as a conceptual understanding of groundwater flow.

The ZOC for the Swinford PWS source lies on the higher elevation ground to the east of the spring, as evidenced by the dye tracer testing, whereby dye materials injected near and east of Killaturly Lough were detected at the Swinford spring. Accordingly, and because the stream on the eastern margin of the Killaturly Lough is known to lose water to the underlying aquifer, it is reasonable to infer that the lough and its catchment is part of the Swinford ZOC. The losing stream is not a hydraulic boundary, and the underlying limestone aquifer extends east of the turlough. How far to the east is not known, and it is unclear if and how the Ardnasillagh Shale Formation influences groundwater flow patterns. The ZOC could potentially extend as far as the Ordovician volcanics near Knock Airport, which are categorized as a ‘Pl’ (poorly productive) aquifer by the GSI. The ZOC would not extent as far northeast as the Lisgorman Shale Formation, as this area is topographically lower than the Swinford spring.

The sand and gravel springs at Killaturly discharge from the base of the Moy Sand and Gravel GWB. The likely ZOC is expected to be on higher ground to the southeast, influenced by the actual geometry of the sand and gravel deposits. The precise boundaries of the ZOC are difficult to define without the availability of detailed groundwater level data. This is exaggerated when factoring in the streams which dissect the gravel and into which shallow groundwater probably discharges. Thus, the further away from the source, the greater the uncertainty becomes with ZOC boundaries.

9.7 Recharge and water balance

The term 'recharge' refers to the amount of water that replenishes 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 influences the area (size) of the ZOC to the source. At Swinford/Killaturly, the main parameters involved in recharge rate estimation are: annual rainfall; annual evapotranspiration; and a representative bulk recharge coefficient (Rc) which is estimated using Guidance Document GW5 (Groundwater Working Group, 2005). The Rc is described by combinations of groundwater vulnerability, subsoil permeability and soil type and is then applied against the annual average effective rainfall to derive annual average recharge (in mm/yr).

Killaturly GWS: The Rc that is proposed for the Killaturly S&G aquifer in a 'high' groundwater vulnerability setting, and overlain by well-draining soil/subsoil, ranges from 60–100%, with an inner range of 80–90% (Groundwater Working Group, 2005). Accordingly, a bulk Rc of 85% is proposed, in which case the average annual recharge is estimated as follows:

Average annual rainfall (R)	1300 mm
Estimated P.E.	500 mm
Estimated A.E. (95% of P.E.)	475 mm
Effective rainfall (potential recharge)	825 mm
Bulk Rc	85%
Estimated recharge across the S&G aquifer:	700 mm

The estimated discharge from the gravel springs, see Section 4, is on the order of 7-10 l/s. For an estimated recharge of 700 mm/yr, the ZOC area that would be required to supply this discharge rate from the gravel springs is less than 0.5 km^2. There is no long-term record available for the gravel discharges, thus considerable uncertainty applies to the area estimate of the ZOC. If the average discharge is actually greater than indicated, then the ZOC area required to balance the outflow is also greater.

As described in Section 4, an estimated, approximate 50% proportion of the water pumped from the GWS reservoir likely originates from the underlying limestone, which discharges into the sand and gravel aquifer. A flow and discharge contribution from the limestone aquifer implies that the limestone aquifer would also have a ZOC hydrogeologically upgradient of the Killaturly GWS. The actual flow and discharge contribution from the limestone to the sand and gravels is not known. Approximately 10 l/s is estimated to be captured and flows into the GWS reservoir. Thus, at a minimum, an approximately 0.5-1.0 km^2 ZOC is inferred but is not quantitatively demonstrated.

Swinford PWS: The derivation of a bulk Rc for the Swinford ZOC is more complex, given the range of combinations of soil, subsoil and groundwater vulnerability which applies to the area east of the Swinford spring. The applicable range is between 4% (peat over thick, limestone till) to 85% (rock-close, extreme vulnerability). However, on the basis of a majority area being mapped by the GSI as 'moderate' groundwater vulnerability with moderate permeability subsoils and poorly to well drained soils, a bulk Rc of 40% is proposed. In this case, the average annual recharge calculation can be summarised as follows:

Average annual rainfall (R)	1300 mm
Estimated P.E.	500 mm
Estimated A.E. (95% of P.E.)	475 mm
Effective rainfall (potential recharge)	825 mm
Applicable range of recharge coefficients	4–85%
Bulk Rc	40%
Estimated recharge across the majority of the area:	**330 mm**

The ZOC area that would be required to supply a measured average spring discharge of 190 l/s would be approximately 18 km^2. This is regarded as being a likely overestimate due to the presence of several swallow holes and a losing stream in the Killaturly Lough and Derryronan areas, which act as point sources of recharge, *i.e.* they drain surface catchments directly and quickly into the groundwater environment. As indicated in **Figure 7**, the stream losses to the east of Killaturly Lough alone contribute a significant (40-100%) proportion of the flow to the Swinford spring (on three different days of measurement). For this reason, the ZOC of Swinford spring would be expected to be smaller than the theoretically calculated area above.

Additional study, involving detailed flow measurements of additional water features during both dry and wet weather conditions, along with further dye tracer tests, would be necessary and is recommended to narrow down the potential ZOC boundaries for the Swinford source. For now, the potential areas that contribute groundwater to the respective sources and which would be recommended for future additional study are shown in **Figure 24**.

10 POTENTIAL POLLUTION SOURCES

The water quality at Swinford Spring is susceptible to pollution as evidenced by persistent organic contamination, notably high coliform counts. Land use in this area is mainly grazing (cattle and sheep), with some forestry, in areas which are characterised by active swallow holes and at least one losing stream. There are a number of houses and farms hydraulically upgradient of the spring which, by inference, pose a risk to the source. There are also several private homes outside the sewered area of Swinford which are on domestic wastewater treatment systems, potentially adding to the risk to groundwater quality. Finally, there are several roads present which, if runoff entered swallow holes, could also contribute to contamination of the source.

In contrast, the water quality at Killaturly GWS is free from microbiological contamination. Although the same potential sources of contamination exist within the preliminary ZOC of the GWS, the water is partly sourced from gravels which are generally less susceptible to pollution events, as sand and gravel deposits provide a natural level of protection from attenuation processes.

11 CONCLUSIONS

The groundwater sources for the Swinford PWS and Killaturly GWS are hydrogeologically very different. The Swinford PWS is a single spring which discharges from a regionally significant karstified limestone aquifer. The Killaturly GWS draws on groundwater from two gravel springs and likely also from the same limestone aquifer that is associated with the Swinford PWS.

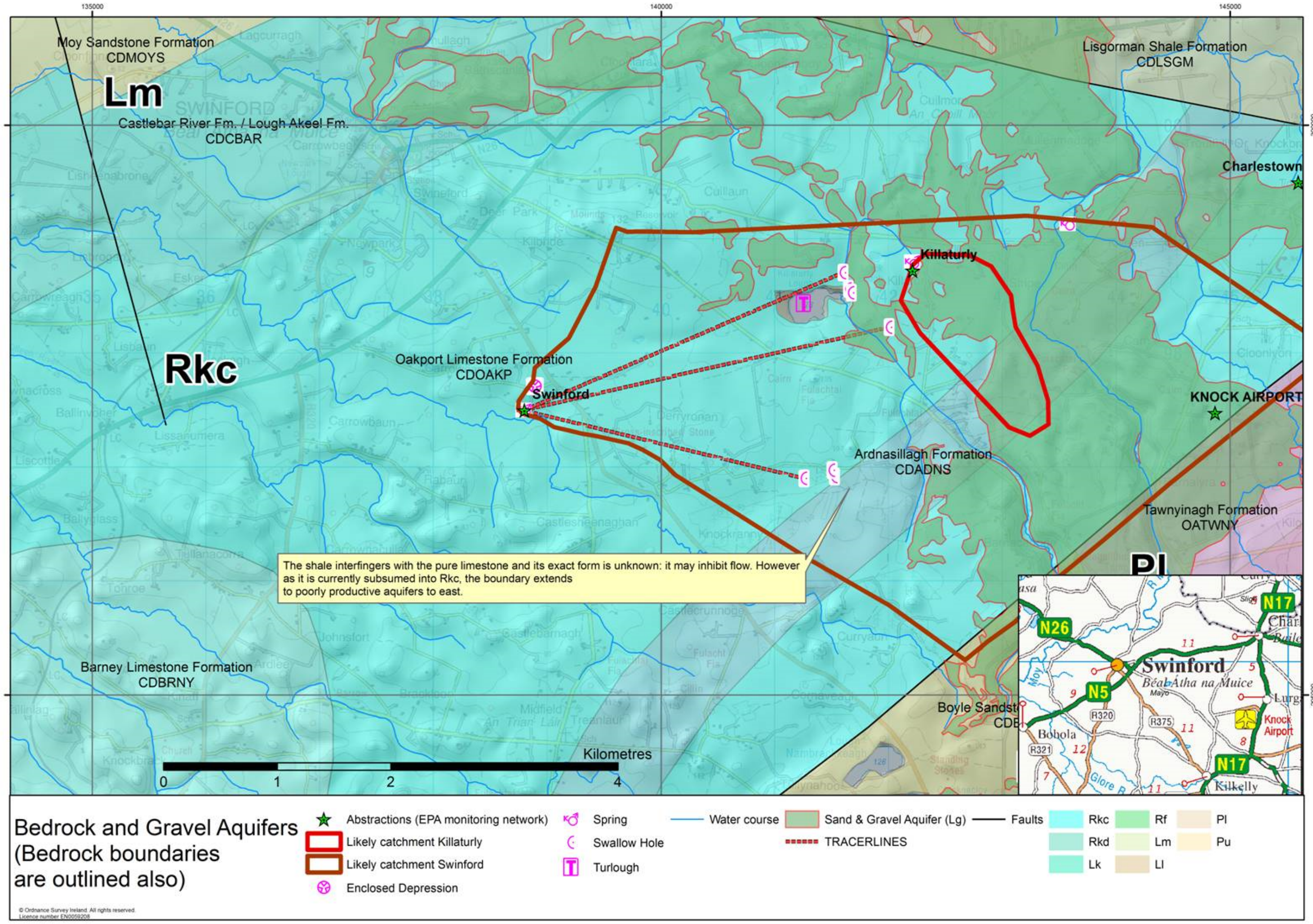

Figure 24: Potential groundwater catchments of Swinford and Killaturly sources

As outlined in Section 12, additional field work would be required to define the ZOC boundary(ies) with greater precision. Even though the precise boundaries of the zones of contribution of the two sources are not defined, they are conceptually well understood. The groundwater catchment of the Swinford spring is demonstrated to extend to the east of the source, whereas the groundwater catchment of the Killaturly sources is inferred to extend to the southeast and east of the GWS, partly shaped by the geometry of the Moy sand and gravel groundwater body. At Killaturly, the sand and gravel and underlying limestone aquifers are inferred to be hydraulically connected, whereby groundwater in the limestone discharges into the sand and gravel aquifer at the GWS location.

Due to the karstified nature of the limestone aquifer, the Swinford PWS is more susceptible to groundwater pollution and water quality impacts compared to the Killaturly GWS. Groundwater velocities in karstified limestone aquifers are typically measured in hours and days, thus pollution events far from the source can impact on the source in short periods of time. In contrast, the sand and gravel deposits of the Killaturly GWS provides natural protection from pollution events, acting as a natural filter and providing opportunity for physical-chemical attenuation processes underground. Groundwater travel times and contaminant migration rates would also be considerably slower (measured in months and years). Accordingly, the Killaturly GWS is less susceptible to potential contamination events.

12 RECOMMENDATIONS

Recommendations arising from the preliminary hydrogeological investigation of the Swinford and Killaturly sources are summarised below.

Swinford PWS:

The hydraulic behaviour of the Swinford spring is reasonably well documented, but periodic discharge measurements should continue in order to build up the database of discharge rates, to: a) document variability of flow during extreme weather events; and b) strengthen the estimate of the mean discharge, which is important for water balance estimates and delineation of zones of contribution.

To improve on the certainty of groundwater catchment boundaries, further detailed karst mapping and dye tracer testing should be carried out from other potential dye injection points in the study area (such as active swallow holes, losing sections of streams and dolines), both in proximity to, and distant from, the Swinford spring. Further measurements and quantification of stream flow losses on the eastern part of Killaturly Lough should be carried out to improve the understanding of the magnitude of stream losses during different flow conditions. This also includes verification (through observation) of the swallow holes at the eastern lake margin during dry weather (low flow) events.

Several smaller springs located to the north of the Swinford spring (and south of the hill which houses the Swinford PWS reservoir) should be mapped in greater detail, along with flow measurements of respective discharges. Although dye materials were not detected at these locations during the dye tracer tests described in the current report, these springs have their own zones of contribution which may share and/or could influence the actual groundwater catchment to the Swinford spring. As such, they should be afforded greater technical attention in the future.

Killaturly GWS:

The individual and combined quantities of groundwater that contribute to the GWS from the sand and gravel and underlying limestone aquifers remain poorly quantified, and should be investigated further through additional flow measurements associated with the GWS reservoir. This can be accomplished by controlling inflows to the reservoir from respective inflow pipes whilst measuring resulting overflows from the reservoir into the adjacent stream. A check valve is already installed on the inflow pipe from the gravel sources. The work would be done at different times of the year and would have to be carried out during non-pumping condition in order to remove a potential source of data interference.

Given the high water quality of the Killaturly GWS, and the fact that it appears to be located in a broader groundwater discharge zone, the hydraulic characteristics of and communication between the sand and gravel and limestone aquifers should be established/verified. The limestone aquifer would be part of the same susceptible groundwater body that sources water to the Swinford PWS and could, therefore, carry pollutants to the sand and gravel aquifer. Such work would require a hydrogeological field investigation involving:

- Surface geophysical surveys to establish depth to bedrock profiles and subsoil properties, along selected cross-sections past and hydraulically upgradient of the GWS;
- Subsoil (sand and gravel) characterisation;
- Drilling and installation of trial and monitoring wells in both aquifers;
- Hydraulic testing; and
- Groundwater level monitoring of both aquifers (including during hydraulic testing).

The Moy sand and gravel body is inferred to have a considerably greater groundwater potential than is currently sourced at the GWS. As such, the area could be a potential source for additional water supply.

The Swinford PWS and Killaturly GWS sources are part of a wider and likely interconnected hydrogeological flow system. Accordingly, further characterisation would also include more detailed mapping of springs and associated flow measurements, as these could influence the delineations and interpretations of zones of contribution. Reference was made previously to the cluster of smaller springs located to the west of Killaturly Lough. Several springs are also located east of Killaturly GWS, e.g. in the direction of Charlestown, including the ‘unnamed spring’ which is owned by the GWS.

Finally, it is recommended that an adequate barrier to Cryptosporidium be installed as part of the water treatment system for the supply at Swinford, which remains susceptible to pollution. Particular care should also be taken when assessing the location of any activities or developments which might cause contamination or adversely affect the springs used for water supply.

Given the vulnerability of the Swinford PWS to contamination, good agricultural practice relating to landspreading and slurry storage and disposal should be followed in the study area generally. Current livestock grazing activities should also be reviewed with local farmers in order to minimize the risk of impact on spring water quality.

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Attachment 1

Photo 1:

Killaturly GWS pond (prior to being covered) which collects groundwater from two gravel springs (inflow pipes visible below water level)

Photo 2:

Killaturly GWS facility with underground reservoir in foreground

Photo 3:

Caisson wells collecting ‘deep’ water from apparent upwellings of groundwater from the limestone bedrock

Photo 4:

Well drained sandstone-derived till

Photo 5:

Sand and gravel beneath peat

Photo 6:

Linear moraine ridges

Photo 7:

Shallow enclosed depression with linear moraine ridge in background

Photo 8:

Doline

Photo 9:

Inferred dry valley near eastern margin of Killaturly Lough

Photo 10:

Doline

Photo 11:

Doline

Photo 12:

Shallow enclosed depression

Photo 13:

Surface runoff into small swallow hole only apparent on removing soil layer

Photo 14:

Small inflow into active swallow hole

Photo 15:

Active swallow holes at Derryronan traced to Swinford Spring

Photo 13:

Flooded swallow holes at eastern margin of Killaturly Lough (looking west)

Photo 14:

Flooded eastern margin of Killaturly Lough (looking south) with deepened outlet channel in foreground

Photo 15:

Killaturly Lough (looking northwest), with Swinford PWS reservoir on hill in background

Photo 16:

Stream flowing towards wooded area containing an active swallow hole (near eastern margin of Killaturly Lough)

Photo 17:

Dye (optical brightener) being injected into swallow hole in wooded area in the above photograph—positively traced to

Photo 18:

Cotton detector suspended n stream during dye tracer test

QUATERNARY GEOLOGY

IAH Field trip

Mayo 2016

The Quaternary geology of the area north and west of Knock Airport is exceptionally complex.

The area is characterised by a huge complex of chaotic, haphazard topography, comprising a complex of landforms including

- long, linear ridges of amplitudes of 20m-30m and up to 7 km – 10 km long, oriented southeast to northwest;
- shorter, linear and quasi-linear ridges of 10m-20m amplitude and up to 500m long, oriented southwest to northeast;
- clusters of chaotic hummocks and clusters of hummocks, usually 5m-10m in amplitude and interspersed with sinuous ridges and deep hollows;
- deep, sometimes sinuous but generally linear, north to south oriented channels, up to 40m deep, and;
- wide, flat to gently undulating expanses of what is now peatland.

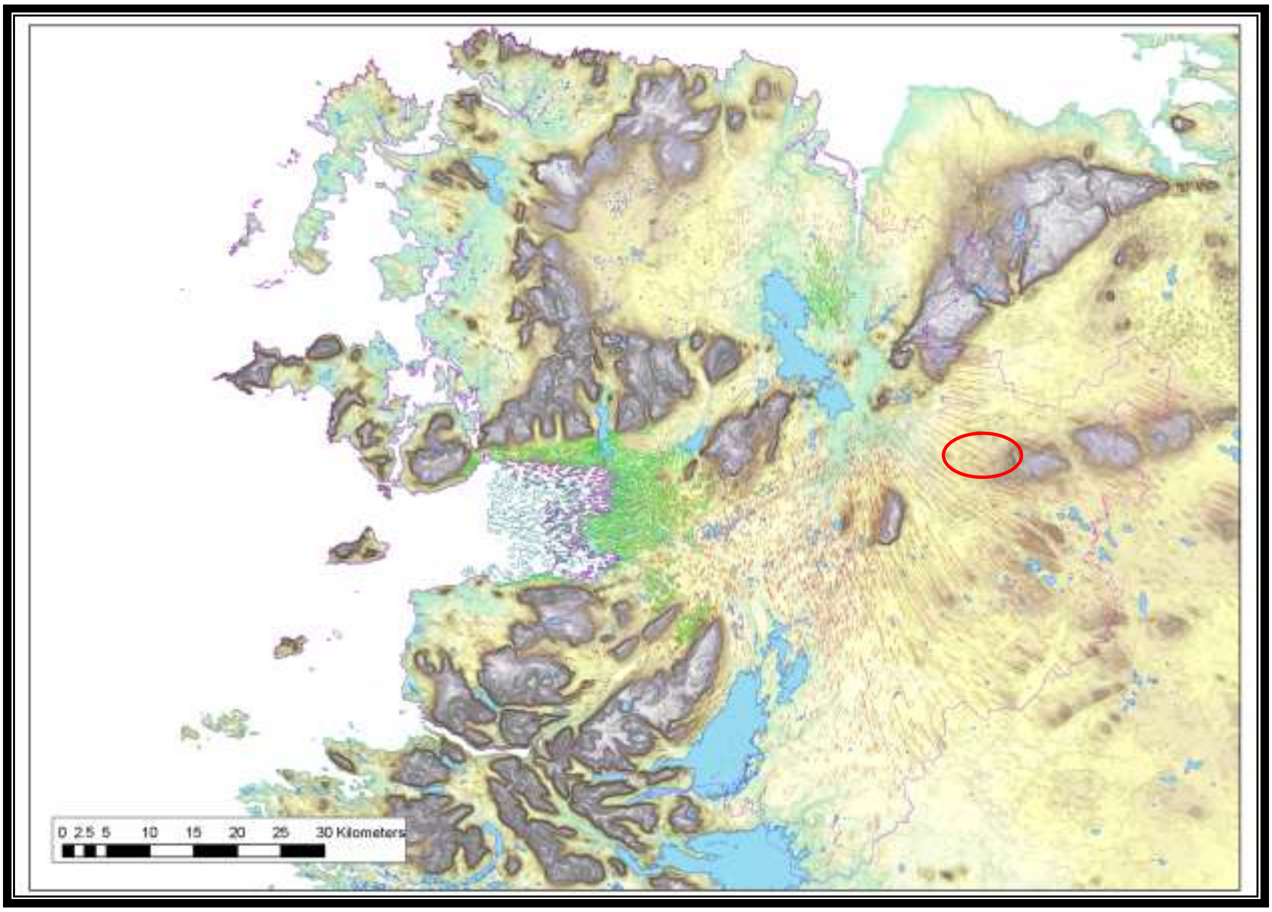

Figure 1: Subglacial bedforms in County Mayo, illustrating the area northwest of Knock Airport as a red oval.

The most striking geomorphological feature in the area southeast of Swinford is a bedrock-cored ridge, which has much outcrop and subcrop across its' extent, and which hosts the airport itself. The ridges has many localised ice moulded bedrock outcrops, which form crag and tail and roche moutonnée features and which all record ice flow towards the northwest.

The long, linear ridges of amplitudes of 20m-30m and up to 7 km – 10 km long, which are oriented southeast to northwest, are comprised of till (boulder clay), and are megascale glacial lineations, which are parallel or subparallel to the drumlins, crag and tails and streamlined bedrock forms of most of mid-Mayo (see Figure 1). These bedforms all show that ice flow during glacial maximum was southeast to northwest, offshore, across County Mayo. Striations from this part of County Mayo also all record ice flow towards the northwest.

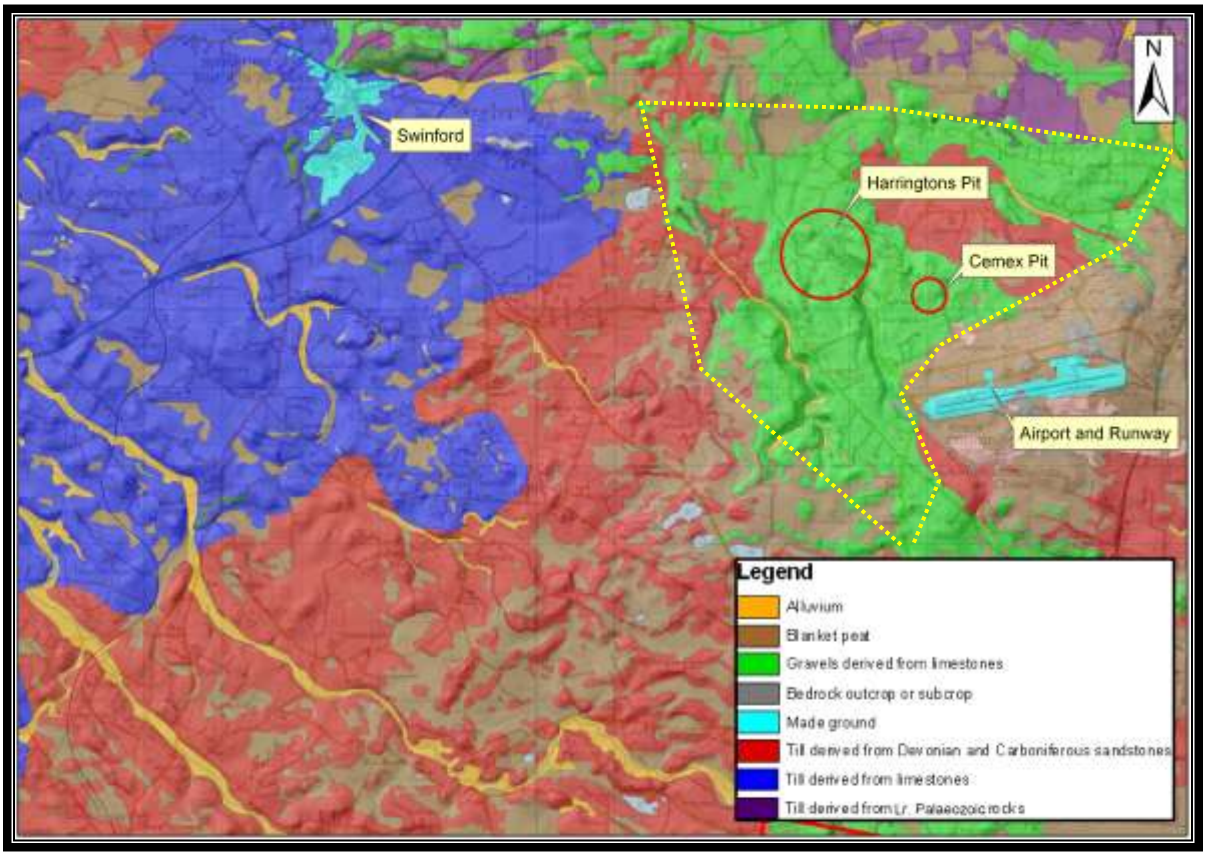

Figure 2: Subsoils Map of the wider study area in County Mayo, illustrating the area west of Knock Airport.

The lower amplitude ridges oriented southwest to northeast are also comprised of till. These have not been studied in any detail sedimentologically, but geomorphologically seem most likely to be subglacial 'minor' ribbed moraines. Some may have an element of meltwater erosion inherent in their form, as many appear as potentially eroded remnants of the larger ridges mentioned above. If this is the case, their most likely genesis is meltwater erosion during a large deglacial meltwater flood event, which is likely to have scoured them into their current form.

The clusters of chaotic hummocks and clusters of hummocks, usually 5m-10m in amplitude and interspersed with sinuous ridges and deep hollows, are comprised of sands and gravles. A particularly wide expanse of these occurs to the west of the ridge where Knock Airport has been built. The sands and gravels are up to 40m deep, and abut against and wrap around the entirety of the western side of the bedrock ridge.

These sands and gravels are dissected in two places by deep, south to north-trending, meltwater channels.

The majority of the lowlying areas between the ridges and sand and gravel clusters mentioned above have been invaded by raised peatlands in the last 9,000 years or so.

Sands and gravels at Barnalyra and Stripe

Cemex Pit (Barnalyra)

The currently-disused Cemex pit at Barnalyra is set within a number of relatively flat-topped, high ridges of sand and gravel, which have deep hollows set within, and many unusual geomorphic forms. The topography overall is hummocky and haphazard. The exposure in the pit is currently relatively restricted and poorly exposed but both a long profile along one flat-topped ridge and a cross section across the ridge have been examined. It was noted that limestone clasts are dominant and within the pit calcretions were present in places among the gravels.

The cross section exposure is up to 5m high and consists of coarse cobbles and boulder-gravel in a matrix of pebble-gravels and sands (Plate 1). Clasts are subrounded (many of the pebble-gravels are rounded) and are dominated by Lower Carboniferous petrographies. The cobbles and boulders are massive and unsorted within beds and are often openwork. In areas which are not openwork the clasts are held in a coarse sand matrix. Within the sections, areas of crossbedded, coarse to medium sands and fine gravels occur. These deposits drape the underlying cobbles and boulders and are again overlain by units of cobble-gravels in places.

Plate 1: Crossbedded, coarse to medium sands and fine gravels overlain by pebble and cobble gravels in the Cemex Pit.

Harrington's Pit (Barnalyra and Stripe).

This working pit is located 0.6km-2.1km northwest of the Cemex Pit (Figure 2) and has been cut into an apron of sands and gravels which drapes the main bedrock ridge hosting the airport, and the associated quasi-linear, hummocky topography in that area (the hummocks in this area form quasi-linear ridges radiating from higher ridges). This is a relatively deep pit (up to 20m deep) and covers almost c. 0.5 square kilometres. Many of the faces are slumped and only three of the better exposed faces were analysed and logged in detail. Structures of importance elsewhere in the pit were noted and are incorporated into the analysis.

The sediments are dominated by fine gravel to coarse boulder clasts which are subrounded and dominated by limestone petrographies. The sediments can be classified into three general facies: a cobbles to boulder-gravel facies; a fine grave facies; and a sand facies.

Plate 2: The dominant units of planar or trough crossbedded, coarse to medium sands and fine gravels in Harrington's Pit.

The cobble to boulder-gravel facies occurs in placers throughout the pit but is much more common along the southern and southeastern faces. The clasts are generally 8cm- 20cm. They are generally subrounded and are dominated by limestone. The cobble / boulder beds are commonly massive but in some cases are slightly crossbedded, dipping generally from south to north (no dips were accurately measured due to time constraints, inaccessibility and the coarseness of the clasts). Pods of pebble size (less than 30mm) clast supported gravels often fill the voids between the larger clasts. Clusters of large cobbles occur throughout the sections.

Relatively small, interbedded units of fine gravels and sands occur throughout the cobbles and boulder beds, most commonly at the top. Many of these smaller units of fine gravels are internally crossbedded and interbedded with sand units. In the basal few metres some sand beds occur; these are generally internally trough cross laminated and drape the larger clasts beneath them. In the middle portion of the pit, midway between the base and the top, a crossbedded cobble/boulder unit grades laterally into a crossbedded fine pebble unit which is interbedded with crossbedded sands and massive, coarse sands.

In the majority of the middle portion of the pit the sediments are dominated by units of alternate layers of pebble-gravels and coarse to medium sand. The sand is trough crossbedded, occasionally having small pebbles within. In places the sediments have been faulted due to collapse (Plate 3).

Plate 3: Faulting within sand and pebble gravels, owing to collapse, in Harrington's Pit.

Crossbedded units of coarse sand beds and fine gravels in this pit are supported by a medium to coarse sand matrix. Towards the centre of the section, many of the sand beds are slumped and normally faulted from collapse, and many of the larger boulders seem to have slumped and collapsed. Throughout the pit, the gravels comprising the hummocks show faults and slump structures. Many of the sand lenses are normally faulted and complete cross sections through hummocks show macro-scale collapse structures in the cobble gravels (vertical elongate clasts, pseudo-faults). Towards the north and northeast, the sand beds in the gravels become more laterally extensive, up to 0.3m thick and 12m-15m long in places. These dip to the north and northeast also (3^{o}-21^{o} dips).. Again, these show similar signs of collapse to the gravels elsewhere in the pit.

The sand beds are often parallel laminated or trough crossbedded and the entire sequence seems to represent large scale foresets. Topsets are absent from the sequence but the uppermost beds are shallow-dipping (3^{o}-4^{o}, Plate 3). The gravels are generally clast dominated but matrix supported. Cut and fill structures are very common and rip-up clasts are often present at sand/pebble-gravel boundaries.

Site investigations have shown that the sands and gravels at Stripe and Barnalyra are up to 40m deep. A gravelly till underlies these sediments in certain localities, between the bedrock and the sands and gravels.

Towards the north of the body of the sands and gravels the hummocks are somewhat linear but in general are more irregular than those to the south and southeast, and around the Cemex Pit. The mostly haphazard, hummocky topography has some deep kettle holes, the hummocks generally being 3m-4m high.

Interpretation of Harrington's and the Cemex Pits.

The entire sand and gravel area can be taken as comprising a single morphological unit as it comprises an almost fan-shaped area (see yellow dotted outline in Figure 2) of boulder, cobble and pebble gravels, but the change in topography is interpreted to reflect a change in depositional environment. The sands and gravels themselves are situated on relatively high ground, on the bedrock ridge hosting Knock Airport. This is the drainage divide between the modern Moy and Shannon Rivers.

The gravel body is comprised of gravels which were deposited under a very high energy flow regime by glaciofluvial processes. The sediments exposed in the Cemex Pit and in pockets at the southern end of Harrington's Pit show large-scale crossbedded cobbles and boulder units which are relatively shallow dipping, crudely from south to north. This section also exposes parallel-bedded, stacked units of fine gravels and sands.

The ridge is interpreted to be a channel fill feature deposited subaerially by glaciofluvial processes between separating ice lobes during deglaciation. The deep sands and gravels and the high bedrock scarp hosting Knock Airport at the east means that the channel was probably ice-walled at the west-southwest. Recent modelling by Greenwood and Clark (2009) have shown that as ice retreated in this area of western Ireland, and independent lobe of ice radiated out from the Clew Bay-mid Mayo area in all directions. The ice would have vacated the high bedrock ridge with a margin oriented northwest to southeast, and would have opened like a zip as it did so. This would have deposited huge amounts of sand and gravel material in the Barnalyra-Stripe area.

The channel into which the sediments were deposited is interpreted to have been walled by ice of this lobe to the southwest and west.

The sediments themselves are coarse and the large-scale crossbedded units are indicative of very high flow regimes. Fan-type sediments in the more distal areas (in the middle and northern sections of Harrington's Pit) suggest a subaerial fan origin. As no silt or clay lenses or beds are seen, a lacustrine origin is discounted for the sediments themselves (although these may be present at depth). The inclined sand and fine gravel beds are interpreted as foreset beds. These inclined beds were formed by avalanche and clast flow over an inclined ice or underlying sediment surface. As the majority of the sediments are of the high to medium energy flow regime (often in a small number of vertically stacked units) most of the coarse sediments are inferred as sheetflood and streamflood in origin. The foresets show a decreasing clast size distally from the apex of the fan-shaped area with cobbles more common in the Cemex Pit and the southern end of Harrington's Pit, i.e. generally further to the south. This suggests a continuity of sedimentation in the area of the coarse gravels (after Brennand and Sharpe, 1993). There is no distinct fining upwards in the sediments so there is no evidence of a general decline in flow power with time. The faults and slump structures common in the sediments (as well as the deep kettle holes at the surface) are a result of the melting out of buried ice masses. The facies patterns within the pits are very irregular and it is difficult to predict the exact geometry of the units suggesting that the depositional environment was highly unstable. The predominance of faults and slump structures supports this view.

Similar sediments to those present at Stripe and Barnalyra have been described from the Lanark area of Ontario, Canada, by Gorrell and Shaw (1991). The system at Lanark has a similar morphology to the Stripe-Barnalyra area, comprising an esker (present to the south at Kilkelly, but not seen in these pits), a suite of 'beads' radiating out from the esker and a series of fans which lie at the distal ends of the beads, several kilometres from the esker ridge. Sedimentologically, the system is also similar with coarse cobble / boulder gravels dominating the esker at Kilkelly and finer sediments comprising the beads and fans. The gravels at Lanark were interpreted to have been deposited into a subglacial lake (close to and at the ice margin) with ice beyond the grounding line decoupled from the bed. Subglacial rather than supraglacial deposition is advocated for the fans and beads due to the limited development of collapse structures in their sediment, their lateral position relative to the main tunnel and thrust faulting in their upper parts. The main and minor tunnels at Lanark (in which the 'beads' were deposited) were filled with water, with the exception of a narrow 'seal' where, at low flow, the minor tunnels became cut-off from the main conduit (Gorrell and Shaw, 1991). These sediments therefore differ markedly to those at Stripe and Barnalyra and the preponderance of collapse structures in east Mayo, as well as the absence of fans lateral to the Kilkelly esker and evidence for thrust faulting within the sediments, suggests a supraglacial origin for the east Mayo gravels.

From this the sediments comprising this hummocky gravel area are interpreted to be a supraglacial fan complex, deposited subaerially on stagnating ice. The sediments are coarse and probably intercalate both laterally and vertically with supraglacial stream deposits.

At some stage, a short-lived glacial lake may have formed between the ice and the ridge, and the bursting of same would have cut the deep meltwater channels that dissect the gravels.

Much further work is required sedimentologically and geomorphologically to further resolve the exact sequence of events during, and nature of, deglaciation in the area.

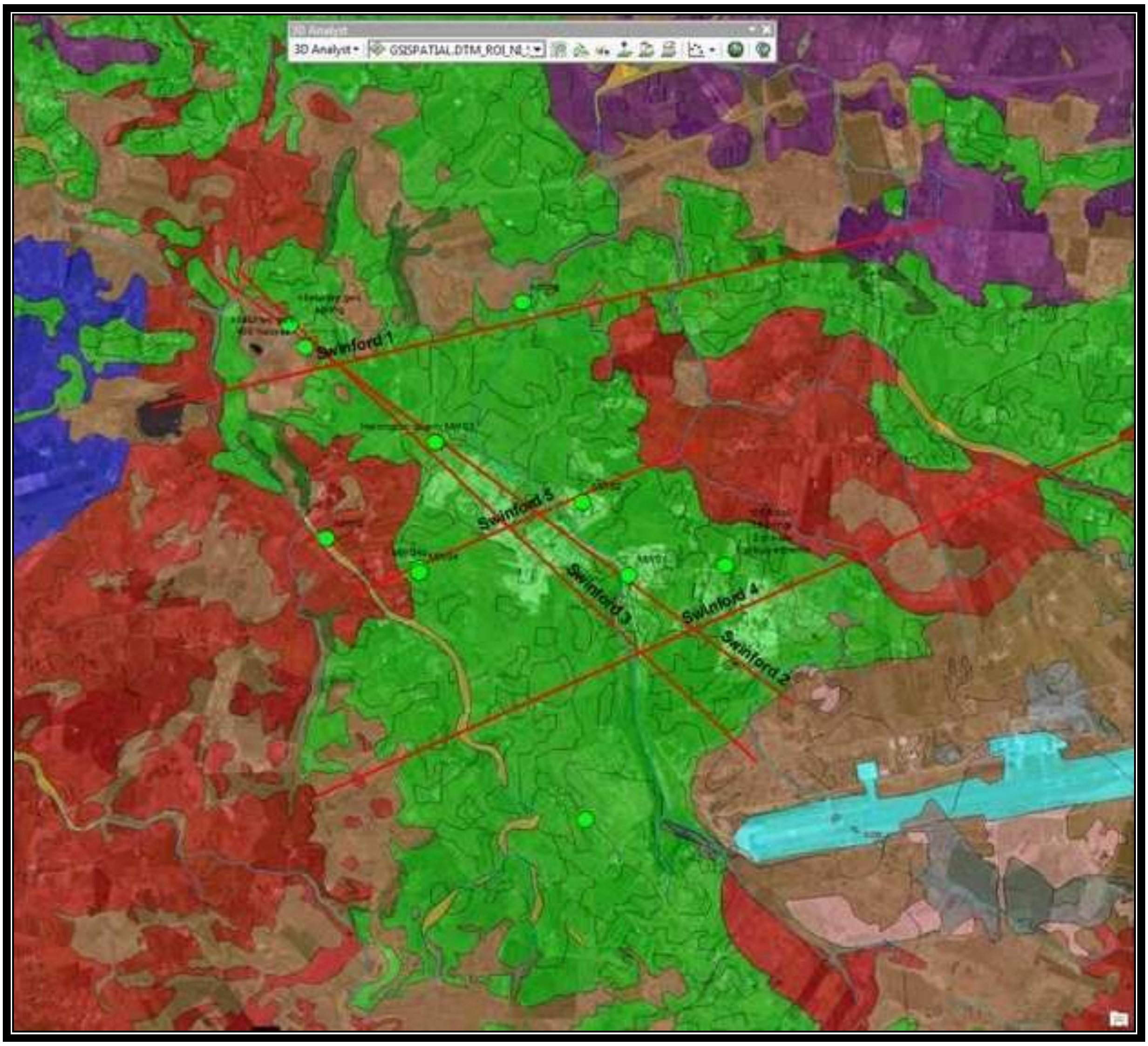

Figure 4: Detailed subsoils map of the body of sands and gravels , illustrating cross sections drawn for analysis.

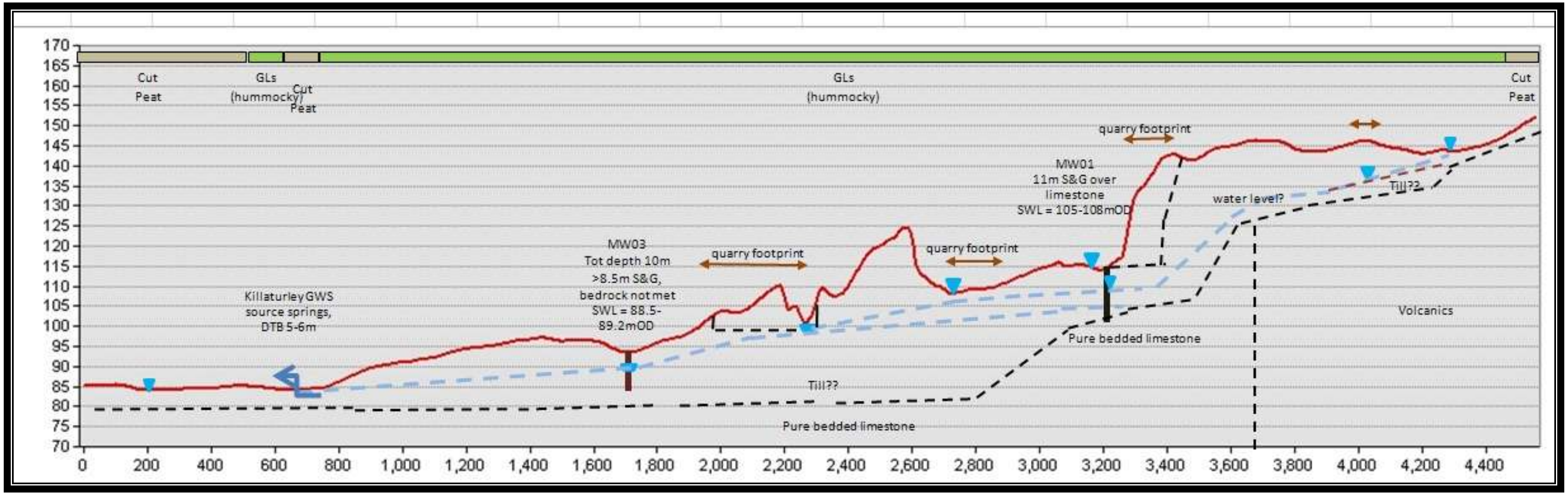

Figure 5: Northwest to southeast cross section through the sands and gravels ('Swinford 2' in Figure 4).

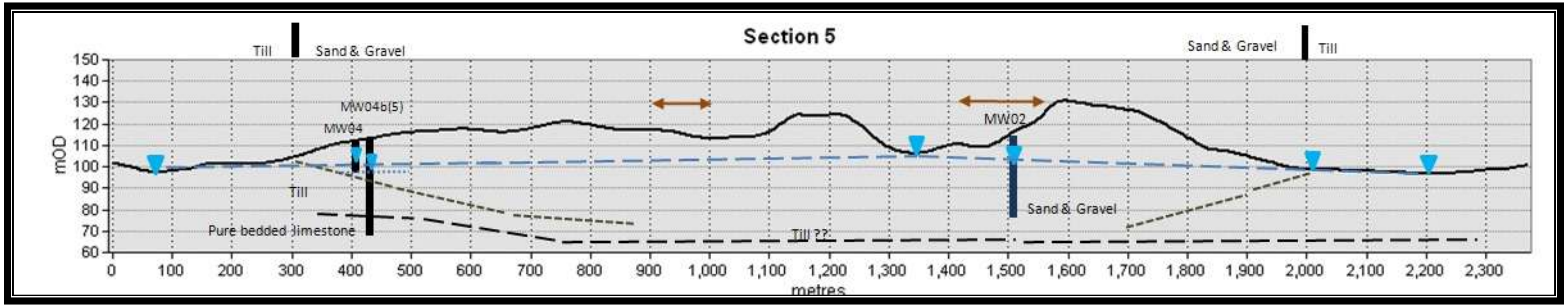

Figure 6: West-southwest to east-northeast cross section through the sands and gravels ('Swinford 5' in Figure 4).

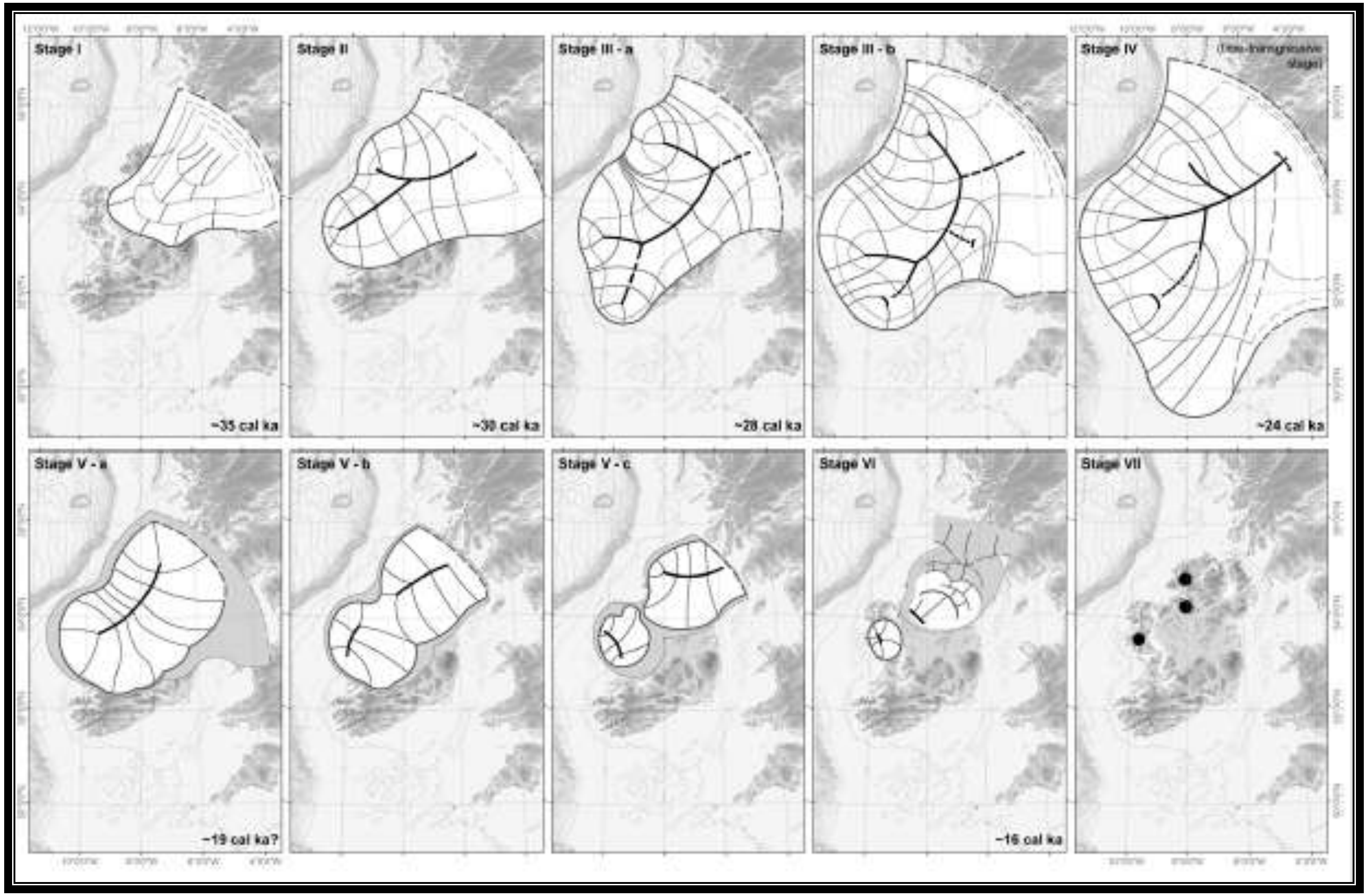

Figure 7: Ice sheet reconstruction of the Irish Ice Sheet during the last Ice Age (after Greenwood and Clark, 2009). Ice divides are in solid black lines, the outer line is the proposed ice sheet limit, flowlines join the divide to the margin, and formlines ('contours') help define the shape of the ice sheet. These reconstruction diagrams are abstracted from detailed evidence and are necessarily smoothed and stylised at this scale. See how ice flow across the study area was towards the northwest until early deglaciation(Stage Vb) when the ice centre shifted and two separating domes emerged.

References:

Brennand, T.A. and Sharpe, D.R., 1993. Ice-sheet dynamics and subglacial meltwater regime inferred from form andsedimentology of glaciofluvial systems: Victoria Island, District of Franklin, NWT. Canadian Journal of Earth Sciences, 30: 928-944.

Gorrell, G. and Shaw, J., 1991. Deposition in an esker, bead and fan complex. Sedimentary Geology, 72: 285-341.

Greenwood, S.L. and Clark, C.D., 2009. Reconstructing the last Irish Ice Sheet 2: a geomorphologically-driven model of ice sheet growth, retreat and dynamics..Quaternary Science Reviews, 28(27-28), 3101-3123.

Malcolm Doak, Irish Water

A) Switching from a spring to a borehole, at Swinford (ANB 2143 July 2016)

Here at Swinford Irish Water are conducting a pilot study of installing a 10” trial well, and to move away from using the spring for water supply:

- The spring suffers from Turbidity mainly and has more water than the town supply and IW abstraction point need.
- The spring issues c. 4,000 m^3/ d, when the water requirements are at 700 m^3/d.
- The approach to normally take at a spring is to set up a catchment management scheme and look at monitoring some of the historical GSI traces and their swallow hole inputs, particularly if this were a spring that provides 100% supply. Such would require a ZOC mapping programme and informing the local community of the ZOC, with a programme that might take 2 years.
- The ANB pilot is to drill an 8” or 10” diameter trial well in the compound and seek deeper groundwater, of better quality, and a better idea on the borehole’s ZOC. Ultimately with a deeper supply, we could aim to cement out the top 30 m of rock/fracture, conduits and subsoils.
- Do pump tests and understand can we tap a deeper conduit flow.
- Such an approach will reduce turbidity.
- Even if a deeper supply is not available, perhaps working with well screen and gravel filter might reduce it??
- The trial well will also allow an assessment interaction of pumping on the spring.

B) Asset Management Approach of IW Groundwater Abstractions

Internally at IW, we have worked up a document which sets out the works envisaged over the next three years. Key of which is the work over the next two quarters on the groundwater drilling standards and checklists for Asset Delivery to implement at the wellhead to audit our abstraction points for pumping regime and standard of the well point. IW is also working with GSI to agree an MOU on groundwater database management and sharing of information. Awaiting approval on this document.

C) New Groundwater Drilling Tender Competition and Consultant Hydrogeologists Notice ERVIA RFT 109502 – 16/244.

Future procurement for groundwater drilling AND groundwater professionals:

ETenders PIN has gone up. Briefing session in November. Highlight the 3 to 4 types of standard well construction details we have devised with Geoscience Ireland, which will be circulated at the Nov key even including our expectations for HSQE.

In terms of exploration, site investigation and pumping wells work, it should be noted they are considered construction work. The Construction Regulations 2013, and Schedule 1, -the particular risk, will trigger the PSDP and PSCS requirement for all groundwater works on a Well.

Any public well supply trial/production wells will be procures on this new framework, all drilling contractors require PSCS, and the design of the borehole and management of the drilling contract needs to be under a PSDP accredited consultant.

STATUTORY INSTRUMENTS.

S.I. No. 291 of 2013

SAFETY, HEALTH AND WELFARE AT WORK (CONSTRUCTION) REGULATIONS 2013

"Act of 1875" means the Explosives Act 1875;

"client" means a person for whom a project is carried out;

"confined space" means any place which, by virtue of its enclosed nature creates conditions which give rise to a likelihood of accident, harm or injury of such a nature as to require emergency action due to—

(*a*) the presence or the reasonably foreseeable presence of—

(i) flammable or explosive atmospheres,

(ii) harmful gas, fume, or vapour,

(iii) free flowing solid or an increasing level of liquid,

(iv) excess of oxygen,

(v) excessively high temperature,

(*b*) lack or reasonably foreseeable lack of oxygen;

"construction site" means any site at which construction work in relation to a project is carried out;

"construction stage" means the period of time starting when preparation of the construction site begins and ending when construction work on the project is completed;

"construction work" means the carrying out of any building, civil engineering or engineering construction work, other than drilling and extraction in the extractive industries as defined by the Safety, Health and Welfare at Work (Extractive Industries) Regulations 1997, and includes but is not limited to each of the following:

(*a*) the doing of one or more of the following with respect to a structure:

(i) construction;

(ii) alteration;

(iii) conversion;

(iv) fitting out;

(v) commissioning;

(vi) renovation;

(vii) repair;

(viii) upkeep;

(ix) redecoration or other maintenance, including cleaning involving the use of water or an abrasive at high pressure or the use of substances or mixtures classified as corrosive or toxic in accordance with Regulation (EC) No. 1272/2008[2] of the European Parliament and of the Council on the Classification, Labelling and Packaging of substances and mixtures or of the European Communities (Classification, Packaging and Labelling of Dangerous Preparations) Regulations 2004 (S.I. No. 62 of 2004);

(x) de-commissioning, demolition or dismantling;

(*b*) the preparation for an intended structure, including but not limited to site clearance, exploration, investigation (but not site survey) and excavation, and the laying or installing of the foundations of an intended structure;

(*c*) the assembly of prefabricated elements to form a structure, or the disassembly of prefabricated elements which, immediately before such disassembly, formed a structure;

(*d*) the removal of a structure or part of a structure or of any product or waste resulting from demolition or dismantling of a structure or disassembly of prefabricated elements which, immediately before such disassembly, formed a structure;

(*e*) the installation, commissioning, maintenance, repair or removal of mechanical, electrical, gas, compressed air, hydraulic, telecommunication and computer systems, or similar services which are normally fixed within or to a structure;

"contractor" means—

(*a*) a contractor or an employer whose employees undertake, carry out or manage construction work, or

(*b*) a person who—

(i) carries out or manages construction work for a fixed or other sum, and

(ii) supplies materials, labour or both, whether the contractor's own labour or that of another, to carry out the work;

"contractor responsible for a construction site" includes a contractor responsible for a part of the site over which the contractor has control;

"cycle track" means part of a road, including part of a footway or part of a roadway, which is reserved for the use of pedal cycles and from which all mechanically propelled vehicles, other than mechanically propelled wheelchairs, are

[2]OJ L353 31.12.2008, p.1

Revocations and savings

5. The following are revoked-

(*a*) the Safety, Health and Welfare at Work (Construction) Regulations 2006 (S.I. No. 504 of 2006),

(*b*) the Safety, Health and Welfare at Work (Construction) (Amendment) Regulations 2008 (S.I. No. 130 of 2008),

(*c*) the Safety, Health and Welfare at Work (Construction) (Amendment) (No. 2) Regulations 2008 (S.I. No. 423 of 2008),

(*d*) the Safety, Health and Welfare at Work (Construction) (Amendment) Regulations 2010 (S.I. No. 523 of 2010),

(*e*) the Safety, Health and Welfare at Work (Construction)(Amendment) Regulations 2012 (S.I. No. 461 of 2012), and

(*f*) the Safety, Health and Welfare at Work (Construction)(Amendment) (No. 2) Regulations 2012 (S.I. No. 481 of 2012),

(*g*) the Safety Health and Welfare at Work (Construction)(Amendment) Regulations2013 (S.I. No. 182 of 2013).

PART 2

DESIGN AND MANAGEMENT

Duties of clients, appointments of project supervisors

6. (1) Except as provided for in *paragraph (5)* a client shall appoint, in writing, for every project—

(*a*) a competent project supervisor for the design process, and

(*b*) a competent project supervisor for the construction stage,

and the client shall obtain written confirmation of acceptance of each of the appointments.

(2) Nothing in *paragraph (1)* prevents—

(*a*) a client being self-appointed as project supervisor if competent to undertake the duties involved, or

(*b*) a client appointing one individual or body corporate as project supervisor for both the design process and construction stage if that individual or body corporate is competent to undertake the duties involved.

(3) A client shall appoint the project supervisor—

(*a*) for the design process at or before the start of the design process, and (*b*) for the construction stage before commencement of the construction work.

(4) An appointment under *paragraph (1)* shall, as necessary, be made, terminated, changed or renewed.

(5) *Paragraph (1)* does not apply unless—

(a) the work involves a particular risk including but not limited to a risk referred to in *Schedule 1,*

(*b*) more than one contractor is involved, or

(*c*) *Regulation 10* applies.

(6) If all of the clients involved in a project agree in writing that one or more but not all of them shall be treated as the client for the purposes of these Regulations—

(*a*) the client or clients agreed on shall be subject to all the duties of a client under these Regulations, and

(b) after that agreement is made, the others shall not be subject to the duties of a client under these Regulations, except the duties under *Regulations 8(1) and (3).*

(7) Where a client appoints project supervisors, designers or contractors in relation to construction work on their domestic dwelling and not in the furtherance of a business, trade or undertaking, the project supervisors, designers or contractors must demonstrate to the client that they are competent and have allocated or will allocate adequate resources to enable them to perform their duties imposed under these Regulations or under other relevant statutory provisions prior to any works commencing.

(8) An appointment of a project supervisor under *paragraph (1)* does not operate to affect any duty imposed on the client before the making of these Regulations by or under any enactment.

Duties to ascertain suitability of project supervisor, designer and contractor appointees

7. (1) A client shall not appoint a person as project supervisor for the design process for a project unless reasonably satisfied that the person has allocated or will allocate adequate resources to enable the person to perform the duties imposed under these Regulations for that project supervisor position prior to any works commencing.

(2) A client shall not arrange for a designer to prepare a design unless reasonably satisfied that the designer has allocated or will allocate adequate resources to enable the designer to comply with *Regulation 15* prior to any works commencing.

Schedule 1

Regulations 12, 15 and 16

Non-exhaustive List of Work Involving Particular Risks to the Safety, Health and Welfare of Persons at Work

1. Work which puts persons at work at risk of—

(*a*) falling from a height,

(*b*) burial under earthfalls, or

(*c*) engulfment in swampland,

where the risk is particularly aggravated by the nature of the work or processes used or by the environment at the place of work or construction site.

2. Work which puts persons at work at risk from chemical or biological substances constituting a particular danger to the safety and health of such persons or involving a statutory requirement for health monitoring.

3. Work with ionising radiation requiring the designation of controlled or supervised areas as defined in Directive 96/29/Euratom[4].

4. Work near high voltage power lines.

5. Work exposing persons at work to the risk of drowning.

6. Work on wells, underground earthworks and tunnels.

7. Work carried out by divers at work having a system of air supply.

8. Work carried out in a caisson with a compressed-air atmosphere.

9. Work involving the use of explosives.

10. Work involving the assembly or dismantling of heavy prefabricated components.

[4]OJ L159 29.06.1996, p.1

SAND AND GRAVEL DEPOSITS AND KARST HYDROGEOLOGY IN THE LOWER VALLEY OF THE RIVER DEEL, CROSSMOLINA, CO. MAYO

David Drew

SAND AND GRAVEL DEPOSITS AND KARST HYDROGEOLOGY IN THE LOWER VALLEY OF THE RIVER DEEL, CROSSMOLINA, CO. MAYO

David Drew

1. South and west of Crossmolina, Co. Mayo is a triangular area of c.30km of sand and gravel deposits ,20m in thickness and characterised by hummocky terrain with numerous (kettle?) hollows, some containing water fro at least a part of the time.
The River Deel which originates in the Nephin range flows across these deposits flowing west-east, initially the river bed is within the gravels but over a 4.5km reach it is incised a few metres into the limestone bedrock. (Figures 1 and 2)
2. Drainage density is low on the gravels suggesting a high recharge to groundwater and it might be expected that the River Deel would act as the discharge zones for this groundwater and possibly also recharge the gravels on occasions. However, the flow regime in the Deel is not what would be expected of such a groundwater fed river – see the hydrograph in Figure 3.
3. Over the reach of the Deel in which it flows over bedrock water sinks into the limestone at multiple points/zones. At low flows all the flow is engulfed and the river bed is dry at Crossmolina.
4. Some or all of the water is presumed to drain to the spring at Mullenmore (Figure1) which has a consistent discharge of c.1 cumec and which rises up from sea level to flow into Lough Conn.
5. It is possible that deposition of the gravels caused the post-glacial course of the Deel to be modified to its present northern loop into Conn and possibly the underground flow is along the former course of the river.
6. Some of the 'kettles' seem to have become modified into active karst dolines whilst collapse and subsidence dolines are also developing in other locations close to the river and the spring.
Differentiating between fluvio-glacial and karst landforms?????

For hydrographs for the recent past visit: *waterlevel.ie*
Gauges:
34007 (Ballycarroon River Deel)
34117 (Mullenmore Spring)

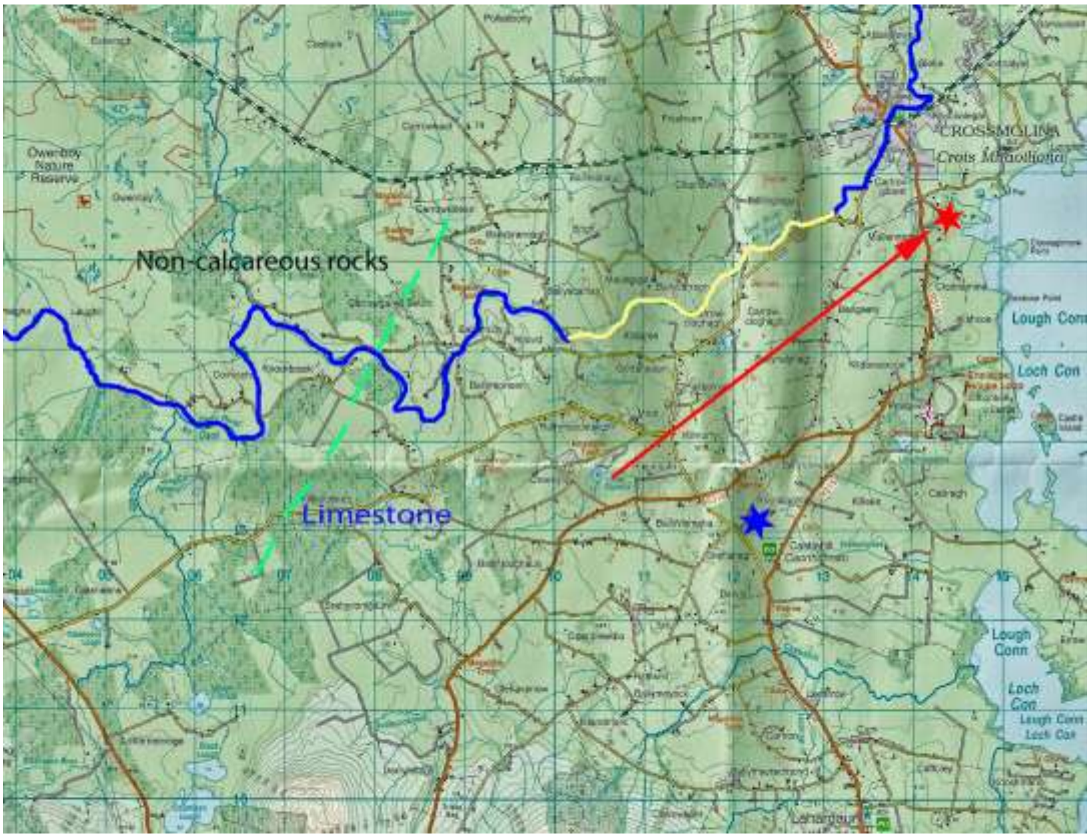

Figure 1Deel 50K

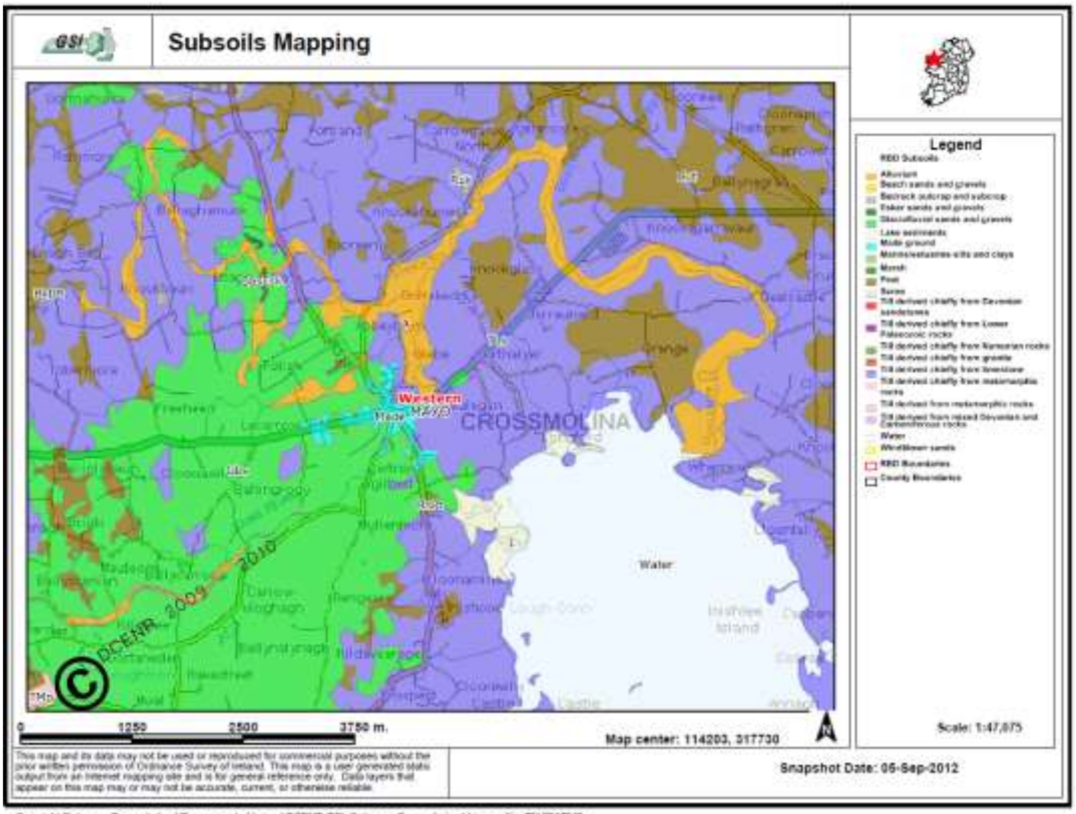

Figure 2 Deel suboil

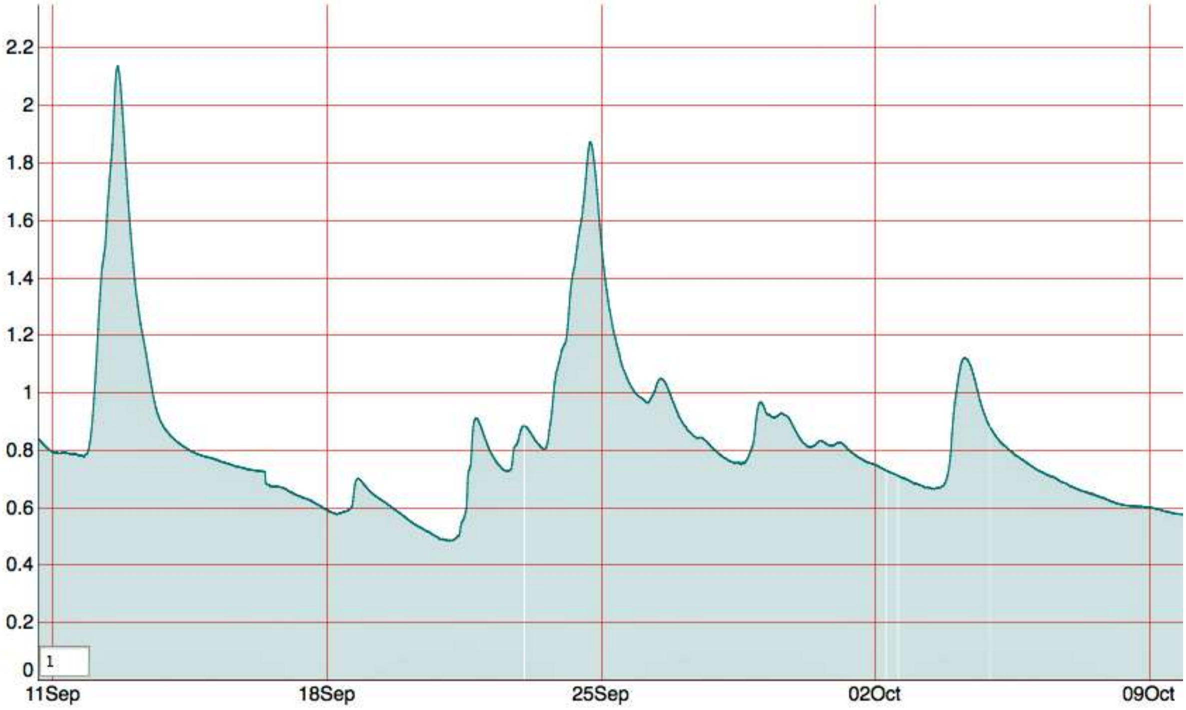

Figure 3 Deel Stage Sept 10th October 9th