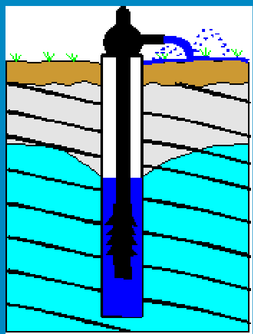

Groundwater Newsletter

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Inside this issue:

Groundwater animals	2
Vulnerability mapping project	6
Landspreading buffer zones	8
Relative impacts of N and P	13
Conceptual model of lowland karst	15
Groundwater—lake interactions	20
The Pathways Project	23
Low productivity aquifers	25
Groundwater hand pumps	26
QA in sampling and analysis	27
Assessing pollution trends	30
IAH annual field trip report	34
Aquifer parameters project	36
Geothermal Assoc news	36
IAH news (AGM and TDM)	37

Groundwater animals found in Irish aquifers

This issue of the Groundwater Newsletter covers a wide range of interesting topics from the practical to the more unusual. We start off with the latter: Joerg Arnscheidt and Karin Eriksson's article on the specially adapted groundwater animals found in aquifers in Ireland, with Karin later providing us with her insights into groundwater use in times gone by around the country (p.26). Returning to more familiar territory – the application of geoscientific information to risk assessment – Monika Kabza, Orla Murphy and Melissa Spillane provide an update of the GSI's national groundwater vulnerability mapping programme and Donal Daly comprehensively outlines the role of buffer zones around groundwater sources for landspreading.

Nitrate, phosphate and ammonium values are turned on their head by Anthony Mannix and Donal Daly, giving us some interesting perspectives on their relative impacts in water and soils. Anthony also provides practical views and 'lessons learned' on water quality sampling and analyses (p.27), which Matthew Craig further explores in his article on the assessment of groundwater pollution trends in groundwater bodies.

Ireland's interesting and ever-challenging karst environments are the focus of both Caoimhe Hickey's (p.15) and Conor Quinlan's (p.20) PhD theses. Continuing with the research theme, the multi-disciplinary 'Pathways Project', which is developing a catchment management tool that will model the fate and transport of a range of contaminants through the different Irish geologlcal pathways, is outlined by Marie Archbold and Raymond Flynn (p.23).

The recent IAH fieldtrip is reported on by Peter McConvey (p.34) and Vincent Fitzsimons shares his experience of the very relevant Low Productivity Aquifers Seminar (p.25). One of Vincent's impressions, the need to share resources, data and understanding, is reiterated in Taly Hunter Williams' request for data to enhance the up-coming aquifer parameters project (p.36).

Special thanks go to all the contributors for their continued support for the newsletter; new contributors are always welcome. Finally, I would like to take this opportunity to wish all our readers a very happy Christmas and new year.

Monica Lee, Groundwater Section

GSI

Amazing animals in Irish groundwater

There is a unique and diverse range of specially adapted groundwater animals living underground in Ireland. An EPA funded Strive project is underway to learn more.

When organisms in groundwater make headlines, they tend to be negative. A typical news story would describe a case of groundwater contamination by pollution from surface sources. Raising the fear factor even further, it would also feature 'scary' microorganisms, either pathogenic themselves or indicators of the potential presence of pathogens, which got flushed into shallow groundwater sources.

2010 is the international year of biodiversity. We feel therefore that it is time to reveal one of groundwater's 'dark secrets': there are animals living in groundwater and they naturally belong there! The good news: there is no indication that the presence of these small obscure beings carry any negative implications for human health. Instead, the endemic species amongst them represent some of the most unique and truly indigenous elements of Irish fauna!

What makes groundwater animals special?

The space occupied by our planet's groundwater aquifers has been shaped by a long and eventful geological history. It is not only vast, but also of a very heterogeneous nature. Any individual animal species which solely depends on this subterranean environment, would therefore have to overcome many natural barriers in order to attain a wide geographical distribution. Hydrological, geological, hydrogeochemical and other aquifer features can severely impede faunal migration from one groundwater body to another. Where such barriers result in a high degree of biogeographic isolation for subterranean environments, groundwater ecosystems tend to be characterised by high numbers of endemic species, i.e. species that are unique to the particular area where they have been found. Some groundwater species are also rare, because they represent the last survivors from taxonomic groups which have disappeared from surface waters a long time ago. Species from the ancient crustacean group of Syncarida (in Ireland: *Anthrobathynella stammeri*) for example, are 'living fossils'; earliest fossilised records from this group have been found in carboniferous strata. Being rare and unique unfortunately also implies that some endemic groundwater species would be particularly vulnerable to extinction, if habitat degradation or contamination were to occur.

Adaptations and strategies for survival

Animals may find living conditions in groundwater ecosystems very challenging. But a long history of adaptation and evolution has made them masters of survival. Complete darkness has rendered pigmentation and eyes unnecessary (Figure 1) and life in confined spaces favours slender body shapes. Amazing physiological adaptations enable them to survive periods of extremely low oxygen concentrations, yet they still do need some oxygen to survive.

Fortunately, groundwater does not tend to be a very productive environment. Otherwise, aquifers with low recharge rates would soon be completely void of oxygen due to microbial heterotrophic activity, which would thus render them uninhabitable for groundwater animals. Contrary to stream environments with a potential for relatively quick recovery, such groundwater environments would remain depleted of oxygen after any substantial pollution event with easily biodegradable organic substances because of the much longer water residence time.

Low ecosystem productivity has an obvious drawback for animals, as it means a lack of foodresources. Groundwater animals rely on a highly efficient metabolism in order to cope with

Figure 1. Left: *Niphargus kochianus irlandicus*, an Irish groundwater amphipod (the picture shows a very small specimen of 2.5mm length, large animals can be 10mm long). Right: Ventrolateral view of a *Niphargus kochianus irlandicus* head. Remnants of eye structure are still visible (arrow), but have no function for sight due to lack of pigmentation. (Quanta SEM scans by Barry O'Hagan)

their resource poor environment. They also have to feed on anything they can find and scavenging is common.

As a trade off for their slow and efficient metabolism, groundwater species take a long time to reach the maturity required for reproduction. Mature female groundwater animals tend to have fewer but larger eggs than taxonomically comparable surface water species. If such a low fecundity is sufficient to ensure a species survival, predation risk in groundwater must be low. The large egg size suggests that the scarcity of food sources in groundwater environments forces females to equip offspring with a larger 'initial survival ration' for a successful recruitment.

Finding partners for reproduction is quite a challenge, considering the complexity of aquifer interstices and the animals' low abundance. The comparatively long life spans of groundwater species increase their chances of encountering a partner.

Groundwater animals in Ireland

Historic records of subterranean aquatic fauna are quite scarce for Ireland. Particularly noteworthy however is the pioneering work of Mary Crichton for the Irish Biological Records Centre (Hazelton, 1974). Historically, Irish groundwater fauna has mostly been recovered from caves, springs, hyporheic zones of streams and even from lakes with groundwater input. In contrast, recent attempts to extend systematic groundwater fauna sampling over the whole island (Figure 2) have almost entirely focused on groundwater level monitoring boreholes and dug wells.

After a pilot survey in 2006, research of Ireland's crustacean groundwater fauna has continued with an EPA funded research project (EPA STRIVE W- MS-1-S1) carried out by the Universities of Ulster, Koblenz-Landau, Loughborough and NUI Galway. In addition to a detailed all-Ireland survey, it comprises phylogeographic and autecological investigations on Irish groundwater 'shrimps'. The widespread dismantling of old hand pumps and subsequent closure of associated wells lends a sense of urgency to research on the biogeography of Irish groundwater fauna. However, newly drilled boreholes, e.g. recent enhancements of the Irish groundwater monitoring network by the EPA, have also generated additional sampling sites in some regions.

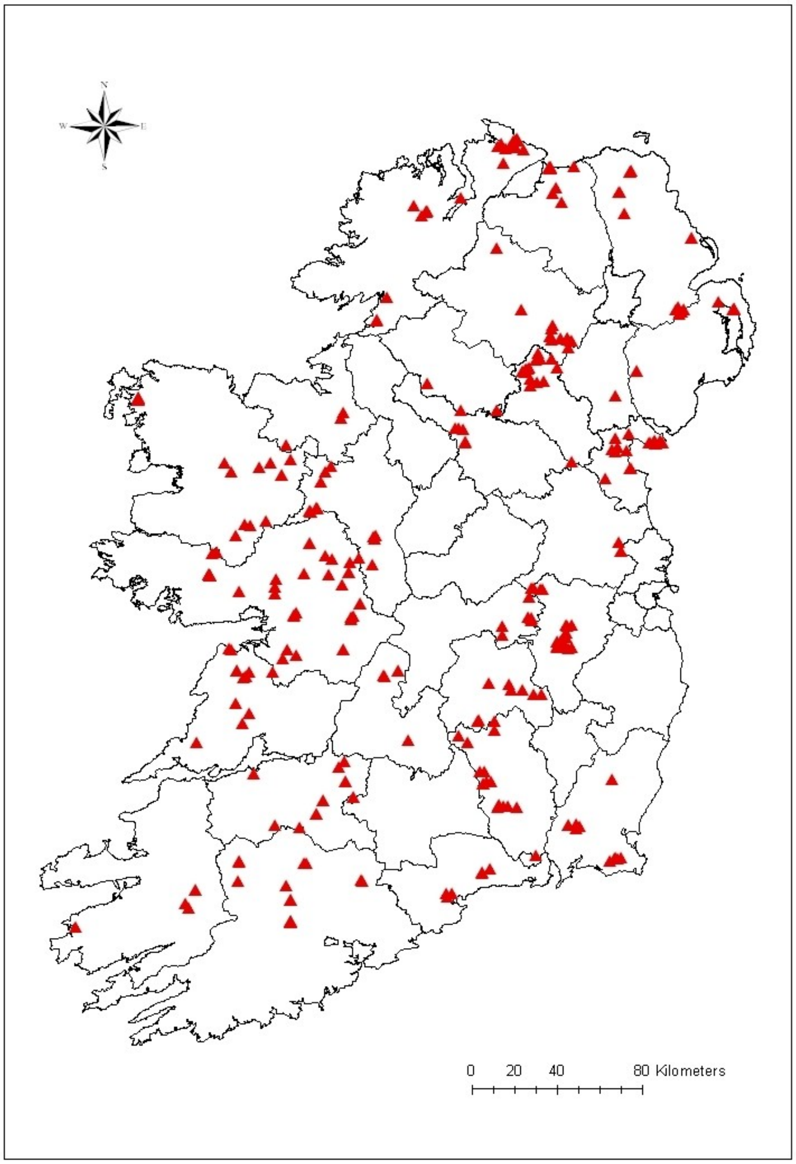

Figure 2. Map of sampling sites for aquatic subterranean fauna from the 2006 pilot survey and the current EPA funded survey. By focussing on groundwater wells and boreholes wide geographic coverage was achieved.

In Ireland, groundwater fauna is largely, but not exclusively associated with limestone aquifers and sand/gravel aquifers with fissure flow or intergranular flow. Animals are mainly found in shallow depths up to 20 metres and some species can survive a minimal oxygen concentration of 0.6 mg/l.

Recent surveys have significantly extended the biogeographic range of previously known Irish groundwater animals. The largest endemic Irish groundwater organism, a shrimp-like species which is visible to the naked eye (*Niphargus kochianus irlandicus*), has now been recorded as far North as the upper Lough Erne. It is also the most frequently encountered species. The second endemic groundwater shrimp species, *Niphargus wexfordensis*, was originally perceived to be confined to county Wexford. New records now extend its biogeographic range far beyond county borders all the way to the west coast of Ireland.

With *Microniphargus leruthi*, the first non-endemic groundwater shrimp species has been discovered in Ireland (Arnscheidt et al., 2008). This species also exists in Britain and continental Europe.

Three subterranean ostracod species have been recorded in Ireland for the first time; there are first records for at least two subterranean copepod species; one of those is even new to science (genus *Moraria*). The list of Ireland's subterranean aquatic species is bound to expand further as the research continues.

What happened during past glaciations?

Conventional wisdom seemed to suggest that glaciations would eradicate groundwater fauna. Increasingly though, evidence is emerging which suggests that this does not hold universally true. Endemic crustaceans have recently been discovered as far North as Iceland (Kristjánsson & Svavarsson, 2007). Even though we do not encounter a similar intensity of geothermal heat as volcanic Iceland, the presence of endemic groundwater species in Ireland would suggest that they may indeed have survived on this island. Yet, their apparent absence from regions North of Lough Erne would still suggest that glaciations may have had an impact on restricting their current biogeographic range.

Phylogeographic investigations are currently assessing the genetic heterogeneity between individual endemic *Niphargus kochianus irlandicus* populations. If there was a large genetic difference between animals from different regions, this would provide evidence for their present range being due to survival of many individual populations in different regions, while strong genetic homogeneity would suggest rapid postglacial recolonisation from few refugial source areas.

Future investigations

Initial results are encouraging in that they have revealed the existence of a relatively diverse fauna, considering that Ireland had been repeatedly subjected to glaciation. Current advances in the biogeography of groundwater species in Ireland will prepare the ground for tackling fundamental questions of groundwater ecology in collaboration with other sciences, e.g. hydrogeology. How reliant are the animals on food import by groundwater recharge? What are their main food sources? Can they inform us about aspects of Ireland's palaeohydrology? ...

For practical applications, groundwater fauna may have potential for bioindication of surface water intrusions and for indicating hydrological connectivity and groundwater quality.

Last but not least...

We would be grateful for anyone who encounters small white animals in a borehole or well to contact us, so that we can arrange for a sample to be taken.

For anyone who wants to find out more about groundwater ecology, a literature review will soon become available on the EPA website.

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Acknowledgements

We thank the EPA for funding the current survey and we are deeply indebted to the dedicated staff of EPA, GSI, NIEA and GSNI for their invaluable help with selecting and locating sampling sites.

Joerg Arnscheidt and Karin Eriksson
University of Ulster

The National Groundwater Vulnerability Mapping Project and the National Groundwater Protection Scheme

A comprehensive national programme of vulnerability mapping is underway and is progressing in 4 phases. The maps will be complete in 2012 and will be available on the GSI website

A Groundwater Protection Scheme (DELHG/EPA/GSI, 1999) serves as a practical and effective means for land-use planners and water resource managers to protect groundwater and prevent pollution. It provides guidelines for the planning and licensing authorities in carrying out their functions, and a framework to assist decision-making on the location, nature and control of development and potentially polluting activities.

Until 2007, Groundwater Protection Schemes (GWPSs) in Ireland were undertaken on a county basis. They were jointly funded by each respective Local Authority and the Geological Survey of Ireland (GSI). In 2007, part of the National Development Plan funding secured by the GSI was allocated to a National Groundwater Vulnerability Mapping Programme. This programme comprises a four year, intensive mapping schedule in order to complete the vulnerability maps for the remaining counties that do not already have county-based vulnerability maps and GWPSs. The programme commenced in 2008 and is managed by the Geological Survey of Ireland (Monica Lee and Natalya Hunter Williams), undertaken and co-supervised by Tobin Consulting Engineers (Coran Kelly, Melissa Spillane, Monika Kabza and Orla Murphy), and co-supervised by independent consultant Robbie Meehan. Although the production of the groundwater vulnerability map is funded from the National Development Plan, contributions from each local authority fund the final GWPS product.

The fundamental concepts still underpin the GWPSs although the mapping methodologies have improved, predominantly through:

a) the availability of additional datasets (DEM, digital aerial ortho-photography, and Teagasc Subsoils, Soils and Habitat Maps),

b) the consolidating of experience gained through producing the county-based schemes, and

c) improvements in, and increased utilisation of, GIS software, which has enabled rapid comparisons of multiple datasets, ability to print all available data in various combinations to aid field interpretations, more accurate digitising of lines.

Overall, the holistic mapping approach used has become more systematic, which has resulted in time-efficiencies and some improvements in accuracy gained in the production of the component layers of the vulnerability maps (depth-to-bedrock and subsoil permeability maps) since the inception of the GWPSs. All of these developments have enabled the vulnerability and GWPSs to be produced in a shorter timeframe.

Each of the four phases of the National Mapping Programme (Figure 1) are divided into periods of collation of all available data, six months of fieldwork (subsoil permeability mapping, and permeability and depth-to-bedrock drilling programme), data analyses (subsoil permeability descriptions – BS5930; particle size analyses), data interpretation (permeability units; depth-to-bedrock contours) and map digitisation based on all of the available data.

During Phase I (2008/09), Counties Dublin, Leitrim, Longford, Louth, Sligo and Westmeath, were completed (green on Figure 1). At the end of Phase II, Counties Carlow, Limerick, Offaly, Waterford and Wexford will be finalised (purple on Figure 1). Phase III will include Counties Mayo and Tipperary (yellow on Figure 1), and finally, Phase IV will comprise North and West Cork, and Kerry (pink on Figure 1). Almost 50% of the country will have been mapped by the mapping team at the end of this four year project.

As part of the data collation component of work, the GSI is currently looking for the any ground investigation information (specifically geo-referenced drilling data, depth-to-bedrock information and grain size analyses) for the counties in the mapping programme. The more data there are, the more accurate the end products will be, which will benefit many users, including much of the readership. Therefore, if you have, or know of, any available data, it would be greatly appreciated if you could contact the mapping team.

Please feel free to contact Melissa Spillane in the Groundwater Section of the GSI if you have such information (email: melissa.spillane@gsi.ie or phone: 01 6782658).

Please note that the vulnerability maps will be made available on GSI website on completion of the work. However, specific data are not shown and sources can be kept confidential if requested.

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Melissa Spillane, Monika Kabza, Orla Murphy
Geological Survey of Ireland and
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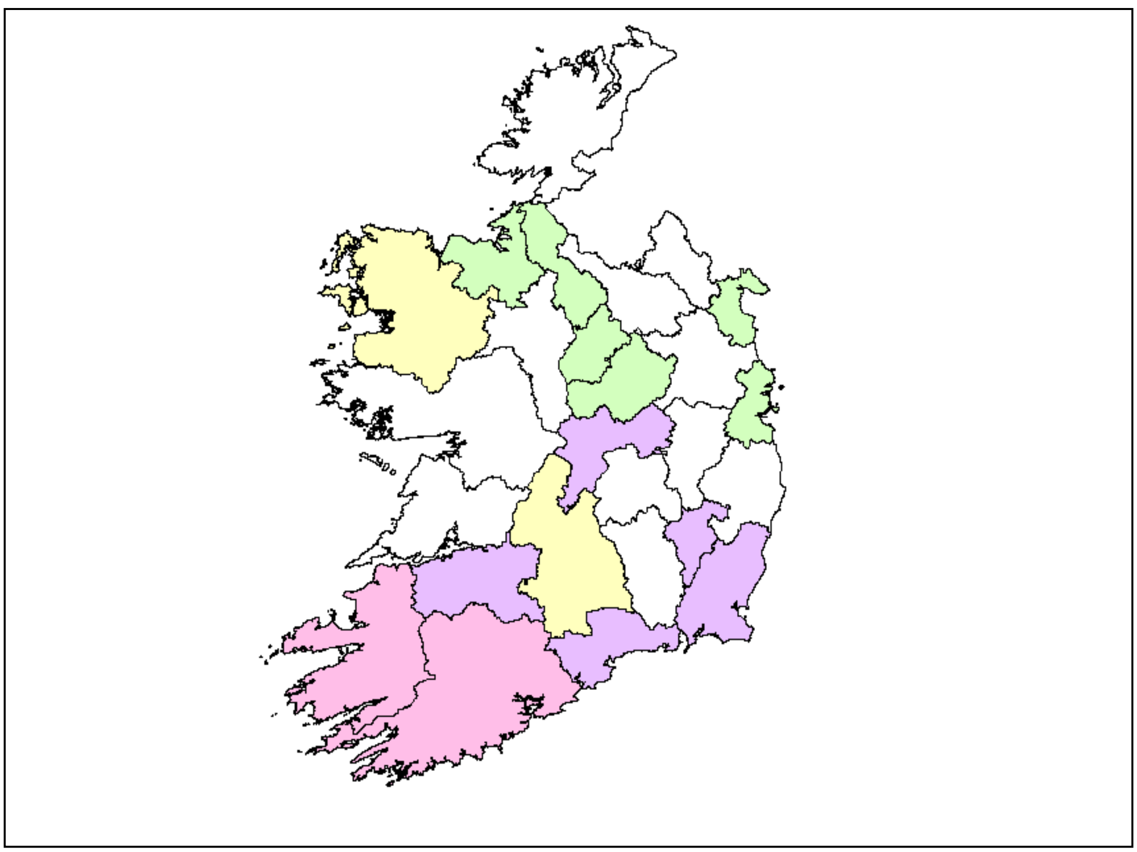

Figure 1. Vulnerability mapping programme schedule. Phase I, now complete, is coloured in green and comprises Counties Dublin, Leitrim, Longford, Louth, Sligo and Westmeath. Phase II is in purple and includes Carlow, Offaly, Limerick, Waterford, and Wexford. Phase III (Counties Mayo and Tipperary) is in yellow and Phase IV is in pink and incorporates North and northwest Cork and Kerry.

The Role of Buffer Zones in Protecting Groundwater Sources from Landspreading of Organic Wastes

The EPA recommends the delineation of scientifically-based landspreading exclusion zones in the vicinity of groundwater abstraction points. Exclusion zones should be based on readily available or obtainable hydrogeological information and should use a risk based approach

Context

The aim of Article 17 of the European Communities (Good Agricultural Practice for the Protection of Waters) Regulations (S.I. No. 101 of 2009) (called the GAP Regs in this article) is to prevent pollution of water from fertilizers and soiled water. Article 17 (2) specifies setback distances for application of organic fertiliser and soiled water on land in the vicinity of water abstraction points, such as wells, springs, watercourses and lakes. These distances vary from 25 to 200 m, depending on the daily abstraction amount or number of people served by the source. Article 17 (5) (a) enables a local authority to specify alternative distances following prior investigations and consultation with the Environmental Protection Agency (EPA).

Buffer zones or setback distances are a commonly used as a means of reducing the likelihood of impacts on water from human activities. For instance, in circumstances where the soil in the vicinity of a stream or lake is a gley, the presence of a buffer zone would reduce the impact of landspreading, and the bigger the buffer zone, the lower the risk. Also, in the case of wells, where the soil/subsoil has a low permeability there could be lateral movement of pathogens at the surface or at a shallow depth and then down the outside of casing where construction/grouting is inadequate. Therefore a small buffer zone is justified as a means of reducing the likelihood of pollution in this circumstance. However, the beneficial role of buffer zones in the vicinity of public and group scheme wells and springs in Ireland, most of which are drawing water from bedrock aquifers, is less clear cut.

Landspreading of Organic Fertilizers as a Threat to Groundwater

Microbial pathogens and nitrate are the two most widespread pollutants, from a public health perspective, in groundwater. These pollutants are present in organic fertilizers (e.g. slurry) and soiled waters. However, the threat posed by landspreading, undertaken in compliance with the GAP Regs, is generally less than from on-site wastewater treatment systems (OSWTSs) (such as septic tank systems for single houses), farmyards, grazing animals and inorganic fertilizers, for the following reasons:

- The nutrient loadings are substantially less than that arising from grazing animals (15-35% of the total organic loading arises as slurry depending on the duration animals are housed).
- The pathogen loadings are also lower than from grazing animals, not only because their relative input is less but also because some pathogen die-off occurs in slurry pits and dungsteads.
- Organic fertilizer is spread evenly in a thin layer (approximately 3-5 mm) over the land surface, thereby facilitating uptake of nitrate and die-off and attenuation of pathogens. This contrasts with the focused loading in urine patches (see photo), dung pats and areas where localised spreading of soiled water occurs; or release of effluent 0.5-1.5 m below the surface in the case of OSWTSs.

Nevertheless, organic fertilizers contain nutrients and microbial pathogens and pose a threat to the water quality of wells and springs.

Photo 1. In terms of hydraulic loading, each cow urinates approximately 10 times per day in a field at a rate of ~3 l/urination over an area covering 0.2-0.5 m^2/urination. So, taking a volume of 0.003m^3 deposited over an area of 0.5 m^2 results in an instantaneous recharge rate of 6 mm/urination, equivalent to an instantaneous hydraulically charged nitrogen load of more than 500 kg/ha (information from Pamela Bartley).

The purpose of the requirements of Article 17 is to minimise the risk to these wells and springs. The risk depends largely on well head protection, borehole construction and the hydrogeological settings in the vicinity of the drinking water sources.

Setback Distances – Use of Arbitrary Fixed Radii

The use of 'arbitrary fixed radii' around wells/springs is a common approach taken internationally in delineating planning and protection zones to aid decision-making on the location of potentially polluting activities. They have the advantage that they are easy to administer and enforce, require little technical expertise and give some protection. However, they tend to over-protect the land area down-gradient of a well/spring, may under-protect the land area up-gradient of the water supply, they take no account of vulnerability or pollutant attenuation and are difficult to justify scientifically. Yet, in certain circumstances, their use is unavoidable, as the information required for a more scientifically-based alternative may not be readily available. For instance, if the zone of contribution (ZOC) and Inner Protection Area (SI) (as described in DELHG/EPA/GSI, 1999) have not been delineated, alternative distances are not an option in most circumstances.

If alternative distances are not being considered, the arbitrary fixed radii in Article 17 (2), which vary from 25–200 m, must be applied. Where the abstraction is >100 m^3/d, the required setback distance is 200 m; this represents an area of 12.6 ha. In many circumstances, this area is larger than is required to protect the well/spring from landspreading of organic fertilizers and soiled water. Consequently, it is recommended that the use of arbitrary fixed radii should be avoided, except perhaps as a 'first step' or where short distances are being proposed for practical reasons to deal with particular issues.

Delineation of Landspreading Exclusion Areas – Recommended Approach

The EPA view on the delineation of exclusion areas is influenced by the following factors:

- A risk-based, 'weight of evidence' approach is preferred. Definitive scientific solutions to delineating exclusion zones are not common.
- Adequate information must be available and provided to enable a good conceptual understanding of the hydrogeological setting (this information should, in any case, be already available to enable proper development and protection of the source).
- Two pollutants – microbial pathogens and nitrate – pose the greatest threat from landspreading.

- Maintenance of the safety and security of drinking water sources, by ensuring the absence of microbial pathogens, is based on taking a dual approach – prevention and water treatment, particularly in relation to *E. coli* and *Cryptospiridium*.
- In areas where nitrate concentrations are relatively high, landspreading of organic fertilizers is not likely to be the main source of nitrate where the requirements of the GAP Regulations and good nutrient planning are followed. In addition, where average nitrate concentrations are >50 mg/l, it is unlikely that prohibiting landspreading, except in the autumn, will reduce concentrations significantly.
- Disposal of soiled water by landspreading (via soiled water irrigation systems) has been shown to cause excessive leaching and localised plumes of high nitrate (Bartley and Johnston, 2005.) Therefore, it is essential that there is compliance with Article 18 (5) and Article 18 (6) of the GAP Regulations. Also, it is preferable to dispose of soiled water outside the ZOCs of sources.
- Where the hydrogeological setting indicates that there is a low risk from landspreading, minimum setback distances should be based on the standard of the well head protection and the degree of water treatment.

The alternative setback distance in the vicinity of a well/spring and, where relevant, exclusion areas at a distance from a well/spring are based on consideration of three issues, which can be considered independently:

1. Protection from microbial pathogens;
2. Ensuring that nitrate concentrations do not exceed 50 mg/l;
3. The adequacy of the well head construction and protection.

1. Providing Protection from Microbial Pathogens

The exclusion area for landspreading is influenced by the existing groundwater quality:

- Where samples of untreated water contain zero *E. Coli* or are in the range 1-10/100 ml the exclusion area is based on consideration of nitrates and well head construction.
- Where *E. Coli* numbers in untreated water are >10/100 ml in one or more samples, the reasons for the 'gross' contamination should be identified and appropriate exclusion areas delineated. For instance, options include extending setback distances along sinking streams in karstified aquifers or excluding landspreading in outcrop and shallow rock areas (X vulnerability) in the Inner Source Protection (SI) area.
- *Cryptospiridium* may enter groundwater from the land surface in areas of extreme (E) vulnerability. If areas such as this are present in the ZOC, an adequate treatment barrier to *Cryptosporidium must be installed.*

With regard to pathogens, for developments within the SI area, where the boundary is usually hundreds of metres up-gradient, increasing setback distances by a few tens of metres provides an illusion of reduced risk rather than a real reduction. The horizontal velocity close to wells in Irish bedrock aquifers, where the hydraulic gradient is highest, is several metres/day and in many circumstances greater than 10 m/d. Where there is a pressure, such as landspreading, the critical factor in protecting wells from pathogens is the overlying soil and subsoil, not horizontal distance. It is the vertical dimension or perspective, expressed as vulnerability, which is the key rather than the 'plan view' perspective, expressed as setback distances (see Figure 1). Other important factors in reducing the risk to human health are good well design and construction, and water treatment. Consequently, while they have a role, it is recommended that there should not be an over-emphasis (or sole reliance) on setback distances in the vicinity of wells and springs.

2. Providing Protection from Nitrate

The existing nitrate water quality is also a factor :

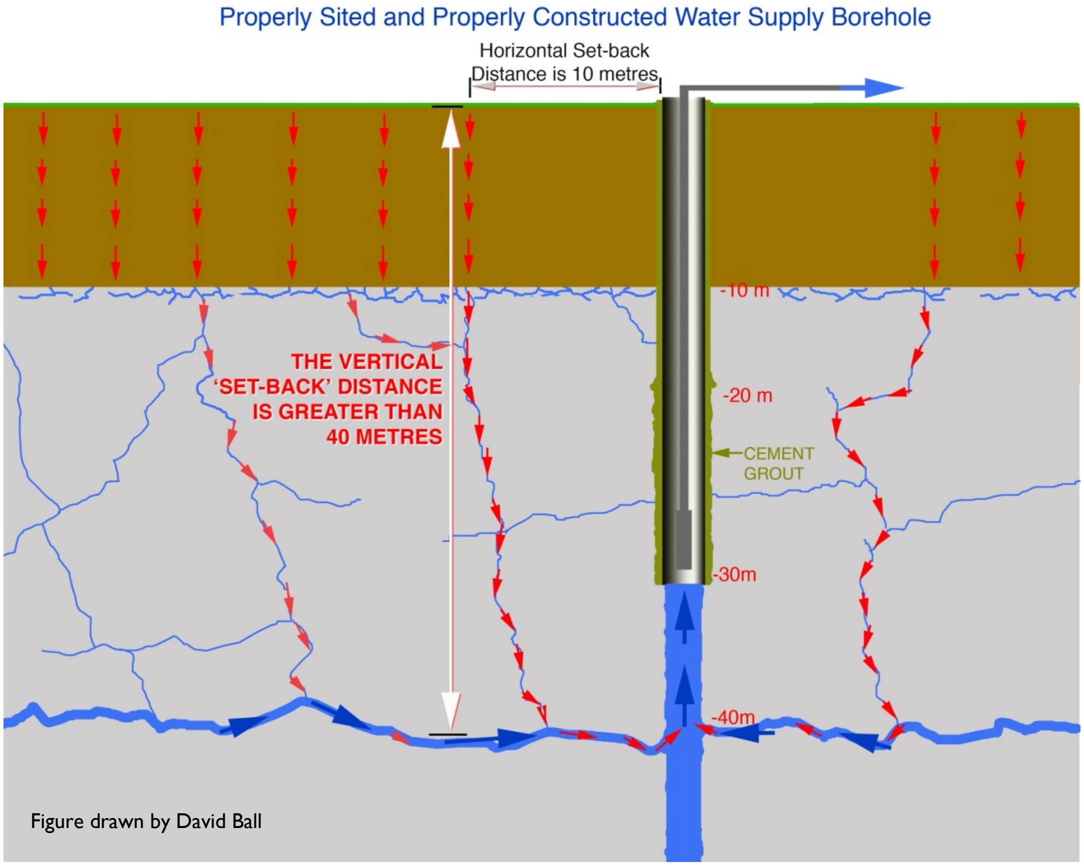

Figure 1. The role of properly sited and constructed boreholes in delineating landspreading exclusion zones. Comments: (1) It would take years (probably >10 years) for a drop of water to move vertically through the sub-soil to the top of the bedrock in this situation. In contrast, horizontal groundwater flow velocities in fractured (occasionally karstified) bedrock close to a well (where the hydraulic gradient is relatively high) would be several m/d and often >10 m/d. (2) The cement grout around the well ensures no bypassing of the protection provided by the subsoil.

- Where the mean nitrate concentration is <25 mg/l, the exclusion zone should be based on well head construction and providing protection from microbial pathogens.

- Where the mean nitrate concentration is in the range 25–37.5 mg/l with peaks above 37.5 and below 50 mg/l, disposal of soiled water should generally be prohibited in the ZOC during the prohibited application periods for landspreading of organic fertilizers in Schedule 4 of the GAP Regulations. Some exceptions may be acceptable in moderate (M) and low (L) vulnerability areas. The aim of this is to reduce the likelihood of the 50 mg/l maximum acceptable concentration being exceeded.

- Where the mean nitrate concentration is <50 mg/l with peaks above 50 mg/l, the exclusion area should consist of the SI/X area. In addition, no landspreading of organic fertilizers or soiled water should take place in the ZOC after 1st September. The aim of these requirements is to reduce rapid leaching and therefore the likelihood of peak concentrations exceeding 50 mg/l. If agreement on this cannot be obtained from the relevant land owner, consideration could then be given to extending the landspreading exclusion area. However, these measures alone, i.e. use of landspreading exclusion zones, may not be adequate to prevent the drinking water limit from being exceeded and consequently the public health implications must be considered.

- Where the mean concentration is >50 mg/l, other measures are needed to reduce the nitrate concentrations and the public health implications must be considered. As a means of reducing peak concentrations, the exclusion area should consist of the SI/X area. In addition, it is recommended that no landspreading of organic fertilizers or soiled water should take place in the ZOC after 1st September.

3. Setback Distances Based on Adequacy of Well Head Protection

The following arbitrary fixed radii are recommended around wells and springs:

- Where it can be demonstrated that well construction was undertaken in accordance with the IGI Water Well Guidelines (2007) and the subsoil thickness is >3 m (i.e. either H, M or L vulnerability), the minimum recommended distance is **10 m**. Where grouting has not been undertaken to the standards, but is regarded as 'good', the minimum distance should be **20 m**.

- Where there is >10 m subsoil ('low' or 'moderate' vulnerability depending on subsoil permeability), the minimum buffer would be dictated by the quality of the well construction, i.e. **10-30 m**.

- Where well head construction and protection is inadequate, a 'fallback' arbitrary minimum distance of **30 m** is used; in circumstances where there is a steep slope to a well/spring and the soil has a low permeability, a greater distance is recommended, to reduce the likelihood of polluted surface water and shallow groundwater collecting around the well. A similar distance is recommended up-gradient of springs, with a reduced distance down-gradient, which should depend on the slope away from the spring. The relevance of well head protection is illustrated in Figure 1.

Conclusions

1. Landspreading of organic fertilizers undoubtedly poses a threat to groundwater in certain physical/hydrogeological settings. Microbial pathogens and nitrate are the two main pollutants arising from landspreading.
2. However, the threat is generally less than that posed by on-site wastewater treatment systems, farmyards, grazing animals or inorganic fertilizers.
3. Arbitrary fixed radii are a good 'first step' in delineating a protection area, but if a large distance is chosen, they are often not scientifically defensible.
4. A risk-based approach to delineation of landspreading exclusion zones using readily available or obtainable hydrogeological information is recommended in this paper. The most important hydrogeological factor is the groundwater vulnerability, as represented by the permeability and thickness of the subsoil.
5. Well design and construction are important.
6. In many, though not all, circumstances the resulting landspreading exclusion zones will cover less area than that delineated using the arbitrary radii.
7. The EPA recommends the delineation of scientifically-based landspreading exclusion zones in the vicinity of groundwater abstraction points. While they have a role, it is recommended that there should not be an over-emphasis (or sole reliance) on setback distances in the vicinity of wells and springs.

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Note: this article is a summary of Daly, D. (2010). Landspreading of organic fertilizers and setback distances from groundwater sources. Proceedings of IAH (Irish Group) Seminar. Tullamore.

Donal Daly,
Hydrometric and Groundwater Section, EPA

Relative impacts of nitrate and phosphate in water and soils

Some facts and figures about the relative impacts of the presence of nitrate, phosphate and ammonium in the environment are presented to get you thinking!

Phosphate
1 kg P when present as PO_4 will pollute **29,000,000 litres** (29 Ml) of water (or 6.4 million gallons) as the Environmental Quality Standard (as a mean in surface water) and Threshold Value (as a mean in groundwater) is 0.035 mg P/l.

Ammonium
1 kg of N when present as NH_4 will pollute **15,000,000 litres** (15 Ml) of water as the Environmental Quality Standard (as a mean in surface water) and Threshold Value (as a mean in groundwater) is 0.065 mg N/l.

Nitrate
1 kg of NO_3 will pollute **27,000 litres** (0.027 Ml) of water as the Threshold Value (as a mean in groundwater) is 37.5 mg NO_3/l.

Or alternatively
1 kg of N when present as NO_3 will pollute **120,000 litres** (0.12 Ml) of water as the Threshold Value (as a mean in groundwater) is 37.5 mg NO_3/l (or 8.5 mg N/l).

With regard to phosphate, this shows that high 'pressures' are not needed to cause a significant impact. With regard to N, the importance of the form of the N is demonstrated.

Phosphate
If all P from a typical septic tank entered a stream without any attenuation, you would need a flow of >3l/s to keep the concentration below the Environmental Quality Standard of 35 ug/l (good/moderate status boundary under the Water Framework Directive)

Phosphate
If you had a stream with an average flow of 10 l/s, all the P that would be needed to bring the concentration of PO_4 above the Environmental Quality Standard of 25 ug/l (high/good status boundary), would be 8 kg/yr or 22g/d.

The amount of N that would need to be leached from soils to result in exceedance of the Threshold Value of 37.5 mg/l as NO_3 is shown in Figure 1. This Figure indicates that for infiltration rates of 300 and 600 mm/year, the loss from soil would need to exceed 25.4 and 50.8 Kg N/ha/year respectively.

The amount of P that would need to be leached from soils to result in exceedance of the Environmental Quality Standards of 0.035 and 0.025 mg/l as P, respectively, is shown in Figure 2. This Figure indicates that relatively low losses (<0.25 Kg P/ha) are required to result in exceedance of Environmental Quality Standards.

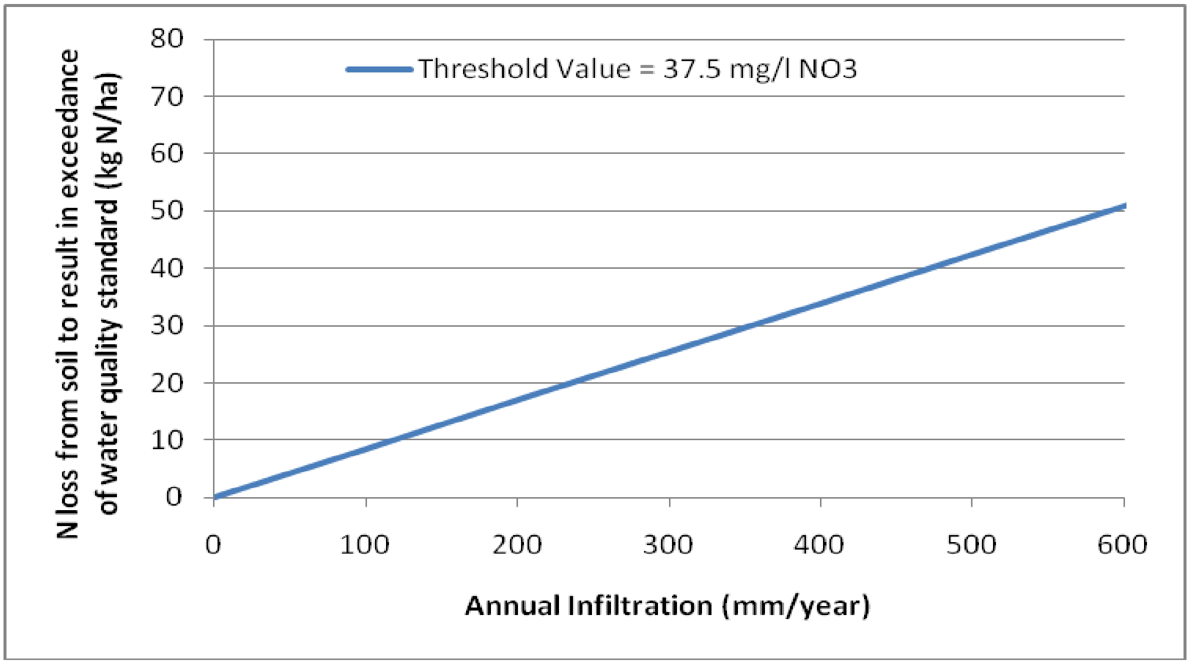

Figure 1. Calculation of N Loss Required to Exceed Threshold Value

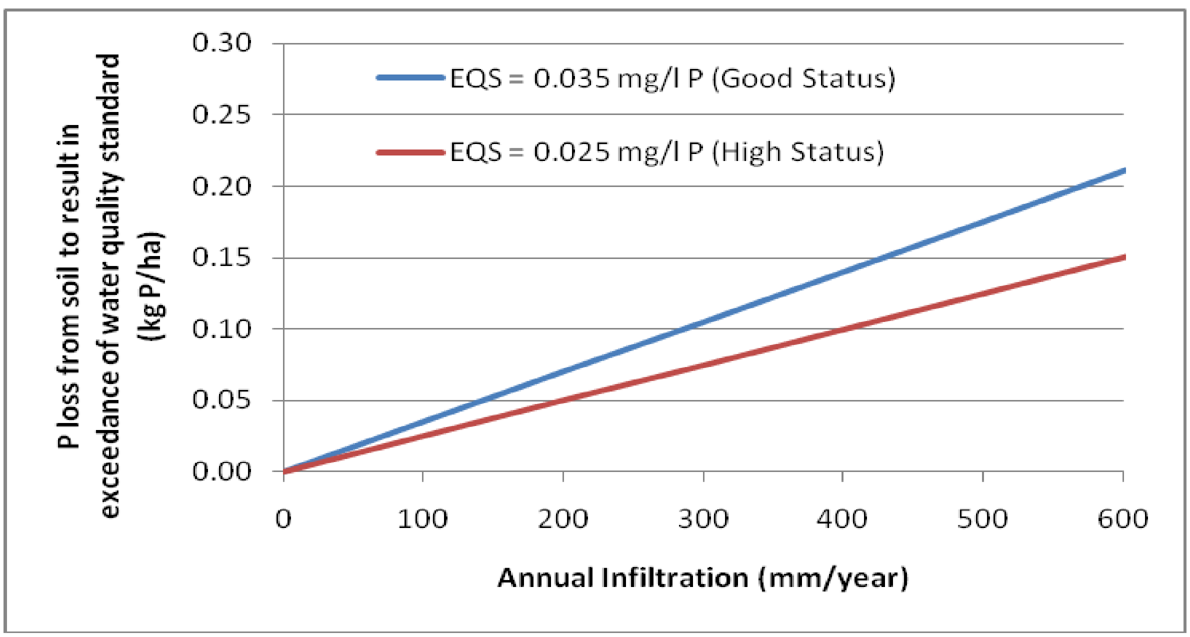

Figure 2. Calculation of P Loss Required to Exceed Environmental Quality Standards

Anthony Mannix and Donal Daly
Hydrometric and Groundwater Section
EPA

A conceptual model of the karst of Co. Roscommon

Extensive field investigations, using a number of different techniques, have shown that in a lowland environment that would not normally be considered optimum for a high level of karstification, well developed karst can occur.

Introduction

The limestone lowlands of Ireland are the principal source of groundwater for the country. Moreover, the low-lying limestones underlie the most productive agricultural land and all the large towns and cities (Drew 2008). However, the lowlands are not obviously karstic. Glacial sediments, principally till and peat deposits, overlie the limestones in varying thicknesses. This mantle of Quaternary deposits allows a surface drainage system to exist in places. The Irish western lowlands are often characterised by high water levels and severe flooding in winter. By contrast, some rivers become dry in summer months. In areas artificial drainage systems were constructed to alleviate flooding. This gives rise to a glacio-fluvial karst environment with low groundwater gradients and complex surface water - groundwater interactions. An understanding of this complex karstic landscape is not only essential to management of the groundwater resources but has wider implications such as surface water hydrology, agriculture and ecology.

The Study Area

Roscommon is a inland county occupying some 2,500km^2. It is a low-lying county characterised by expanses of peat-land, river meadow and lakes and is bounded by the River Shannon to the east and the River Suck to the west. Ninety percent of the county is underlain by limestones, 86% of which is considered pure and well bedded. There is a very high dependency on groundwater, especially karst springs, in Roscommon. Eighty nine percent of water usage is provided by groundwater (compared to national average of 25%). The poorly understood karst system has led increasingly to problems of water supply and quality.

Methods used

Five main different investigative techniques that were employed to characterise and understand the functioning of this lowland karst environment. These were karst landform mapping, dye-tracing, geophysical investigations, bedrock core-drilling and spring chemistry and discharge analyses. The techniques were intended to be complimentary and to obtain the maximum reliable information on karst hydrogeological conditions. Table 1 summarises the different methods used.

Conceptual Model

The investigation revealed a surprisingly high level of karstification in Roscommon. There was a high density of karst landforms found (0.7 per km^2) (Figure 1). The location of these surface expressions of karst if affected by limestone lithology and subsoil. Eighty percent of all landforms mapped provide recharge to the aquifer, 13% act as discharge points, and 7% are not specific. Large numbers of small recharge features were found but allogenic recharge is uncommon, making up only 0.6% of all point recharge.

Clustering is a significant feature of the distribution, with mostly recharge landforms located on the limestone plateaux, where subsoil is thinner; and discharge points in low-lying areas, frequently around the periphery (Figure 1). Landforms densities of 80 to 90 per km^2 are common on these plateaux (Plate 1). Influent landforms are frequently aligned in parallel dry valleys running NW–SE (following the direction of ice movement at the end of the last glaciation). The influent landforms are generally small and indicate a young karst (Plate 1).

Table 1. A summary of the different investigative methods used

Method Used	What it entailed	Main Results
Karst Landform Mapping	County wide geomorphological mapping of karst landforms.	Over 1,300 karst landforms were mapped and 1200 were visited. Four 'new' caves were found and surveyed.
Spring Chemistry and Discharge Analysis	EC and flow readings for 270 springs. Karst springs monitored in more detail.	55 springs chosen as karst springs and flow variability assessed and compared. Water quality analyses conducted in selected springs. 5 main springs clusters found.
Dye Tracing	Tagging sinking waters with individual dyes and monitoring all possible outlet points for a period of time.	Water tracing experiments enabled identified subsurface routes, groundwater flow velocities to be estimated, recharge areas to delineated and groundwater catchment areas to be delineated.
Microgravity Geophysics	Readings of subsurface gravity values in order to detect cavities. Carried out by Keele University.	All of the areas surveyed showed conclusive evidence of large cavities or voids. Void depths and dimensions were modelled showing a conduit system with conduits at different depths.
Bedrock Core drilling	Drilling down into specific locations to reveal the nature of the bedrock underneath.	Large karst conduits were found at every site including some very large (>1.5 m to 6.5 m in diameter) cavities. Drilling also corroborated the conduit systems indicated by the geophysical investigations.

The investigations show that the limestone plateaux act as recharge zones and springs at periphery act as discharge zones. It is thought that this short flow system of recharge and discharge common throughout Roscommon. Thus, these fragmented highly karstified 'islands' producing small drainage basins with short flow paths were surprising considering expanse of limestone.

There is thought to be a complex relationship between surface water and groundwater as many streams sink and rise again. This is further evidenced by the presence of turloughs and gaining and losing streams. A well developed epikarst layer is a feature common to all areas investigated and is important in facilitating large quantities of horizontal flow. The fast flow rates found from the water tracing experiments are considered significant and indicate that high hydraulic conductivities exist, at least in certain localised zones. The triple porosity of the aquifers (fractures, solutionally enlarged openings and conduits) was demonstrated with a varying dominance of the conduit porosity and a more dispersed flow system. Aquifer storage was also demonstrated, which is important in providing base flow perennial springs. The occurrence of groups of karst springs, some with extremely variable discharges and some with low variability shows the complexity and limitations of the karst system, as these are thought to represent base flow and overflow springs. The feature of overlapping catchment was displayed by the dye-tracing experiments.

The high numbers of large conduits found is significant, as conduits usually only underlie a tiny percentage of a karst drainage basin. This demonstrates both the high level of

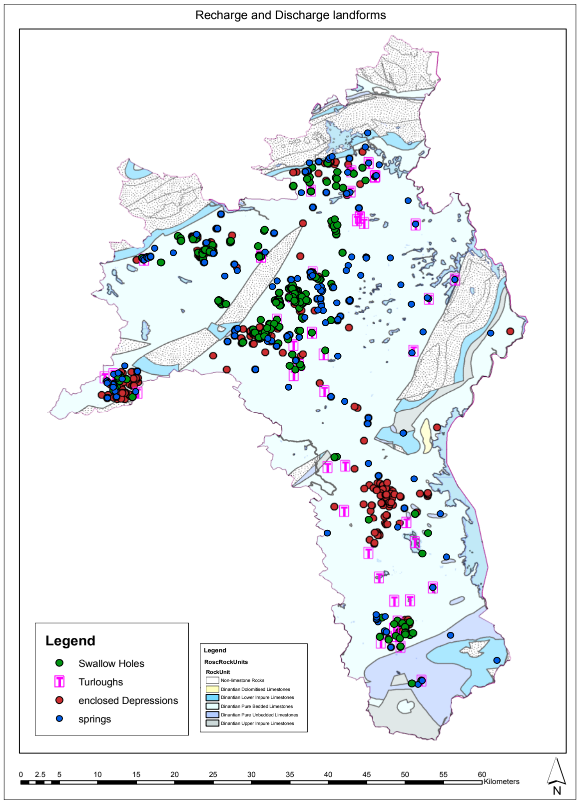

Figure 1 The distribution of selected karst landforms in Co. Roscommon

karstification in Roscommon and the benefits of using several techniques together. Where conditions are right, large active stream caves can form /or get reactivated (Plate 2).

A conceptual model was developed, to reflect the aspects, landforms and hydrology of karst found in Roscommon (see Figure 2). Recharge zones are located on the plateaux, which are largely devoid of surface drainage. These plateaux are characterised by a high level of recharge landforms some of which are aligned at the bottom of the dry valleys. There are also well -developed epikarst zones, with many shallow fractures/small conduits. This epikarst zone is thought to laterally transmit large amounts of flow. Some recharge also penetrates deeper into a shallow conduit zone. The flow moves from these plateau areas to the periphery, where it emerges at springs, in discharge zones. Both perennial and overflow springs exist and are depicted (note winter and summer flow lines in figure 2). These springs give rise to surface

Plate 1 Clustering and alignment of enclosed depressions, Mewlaghmore, Castlerea, Co. Roscommon

drainage, which is common in the lower lying areas. Streams, lakes, rivers and turloughs are common. Artificial drainage systems are also widespread in low permeability subsoil such as peat. The river shown in this model is considered influent during low flow conditions and effluent during high flow conditions, which may lead to flooding. The turlough shown in this model is an epikarst turlough with very a shallow flow system, though some turloughs may connect with deeper (<20m b.g.l.) channels. This shallow epikarst flow is thought to dominate the groundwater movement in the lower regions, although some deeper conduits may exist. The subsoils are thin or absent on the plateau and thicker on the plains.

Plate 2 Pollnagran Cave, Frenchpark, Co. Roscommon

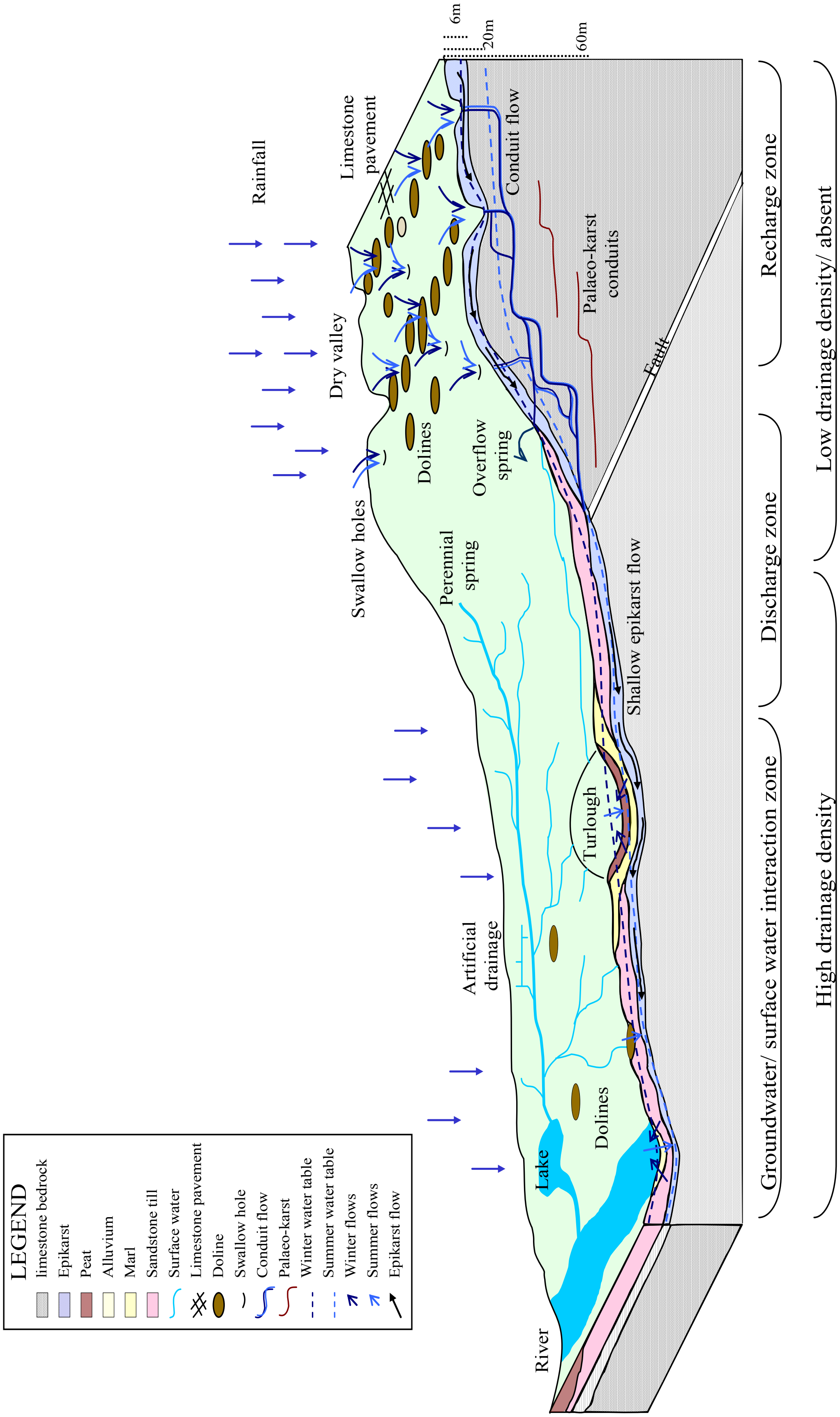

Figure 2 Conceptual model of the karst of Co. Roscommon

Conclusions

The findings of this research demonstrate that in an environment that would not normally be considered optimum for a high level of karstification (with its low gradients, lack of allogenic recharge, covering of glacial material and very few caves) well developed karst can occur. This is evidenced by the dye-tracing through flow times, numbers and dimensions of conduits found from the drilling, alignment and densities of karst landforms, spring chemistry and discharge data analyses and geophysical investigations. It has also shown that high hydraulic conductivities can exist in low gradient environments. The flow rates found all over Roscommon, are comparable to the flow rates found in the western lowlands and the upland karsts both in Ireland and the UK. The importance of a shallow epikarst flow system was demonstrated in Roscommon (and in other areas in the western Irish lowlands) as was the high level of groundwater surface water exchange. It would be interesting to examine this in other lowland fluvio-karst environments.

This study provides an important major conceptual model of lowland karst in Ireland. Together with the numerical model for the Gort area (OPW, 1998) these two models provide the only models of lowland karst in Ireland and perhaps worldwide. The karst of Roscommon shares many similarities with other karsts in lowland Ireland. This is especially true of the karst of the west and less true of the karst of the east and south. It is thought that the conceptual model of Roscommon, would apply well to the karst to the west and to some degree to the karsts east of Shannon. Aspects of the model would apply to the limestone synclines to the south.

Vast amounts of information were gathered and assessed from using the different investigative techniques in conjunction. By employing a combination of methods there was much greater confidence in the results, as each technique greatly enhanced the success, accuracy and reliability of the next one. It is rare that one has the resources to employ all of the above methods but it is hoped that the significant benefits of using more than one hydrological method has been demonstrated.

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Send an email to groundwaternewsletter@gsi.ie to receive a digital copy of the newsletter or download it from www.gsi.ie

Groundwater– lake interactions in the Meath-Westmeath lakeland region

Permanent lakes in karstified limestone areas in Ireland can be classified along a spectrum from karstic turlough-like lakes with a high degree of interconnectivity to the groundwater system, to less or non-karstic lakes which are less connected to the groundwater system

Limestones outcrop over about half of the total land surface area of Ireland. It is likely that all of the limestone is karstified to some degree (Drew et al., 1996). A feature of some karstified regions is the presence of temporary lakes known as turloughs. Extensive research has been completed on the hydrology of these landforms in the past. There is also evidence that lakes of intermediate type exist that can be classified as semi-permenant, such as Lough Funshinagh in Co. Roscommon (Drew and Burke 1996) and Lough Na Súil (Nasool) in Co. Sligo (Coleman, 1965) which drain completely every decade or so, but never annually.

A study was undertaken on part of the Meath-Westmeath lakeland region (Fig 1) to investigate whether permanent lakes on karstified limestone bedrock shared any hydrological characteristics with these temporary and semi-permenant lakes, in terms of the nature of their connection to the groundwater system.

The study area included the lake catchments of Lough Lene, Lough Bane, White lake and the Ben Loughs which are situated in an area approximately 25 km north of Mullingar in Counties Westmeath and Meath. The area is underlain by the Derravaragh Chert Carboniferous limestone of the Lucan Formation. The topography of the area is dominated by a series of northwest-southeast trending hills rising to approximately 200 m in height. The area is blanketed with varying depths of glacial tills (up to 15 m in the valley floors to an absence of cover on the hilltops). The bedrock is classified as a Locally Important Aquifer which is karstified.

The methodology involved conducting a pilot study comprising of desk and field studies on the lake catchments. Data collection methods included karst landform mapping; stream flow measurement; lake surface level measurement; hydrochemistry measurement; and water tracing. Data analysis methods comprised of analysis of mapped drainage network and lake surface area change from 1837 to the present day; hydrometric analysis; calculation of water budgets; and quantitative water trace analysis.

Dolines (enclosed depressions in karst) from 0.5–100 m in diameter were identified in three of the study catchments, swallow holes (both active and inactive) were identified in two of the study catchments, and an estavelle (two way swallow hole/spring) in one catchment. There is evidence from the 6 inch maps that Lough Bane was drained by a swallow hole in the past but no trace of this feature could be located in the field. No karst surface features were identified in one of the study catchments (the Ben Loughs).

GIS based cartographic analysis and field observation showed that the drainage system in the Meath-Westmeath Lakeland Region has been de-karstified by drainage schemes in a similar manner to parts of east Co. Galway and Roscommon (Coxon and Drew, 2000) and that the present drainage system in all of the study lake catchments is artificial in many places, with channels straightened, deepened and lake levels lowered since 1837. In this period, the surface area of Lough Lene appears to have been reduced by 11% and Lough Bane by 17%. In effect, due to drainage improvements, karstic type flow paths which may have operated to/ from these lakes may now only function periodically or not at all.

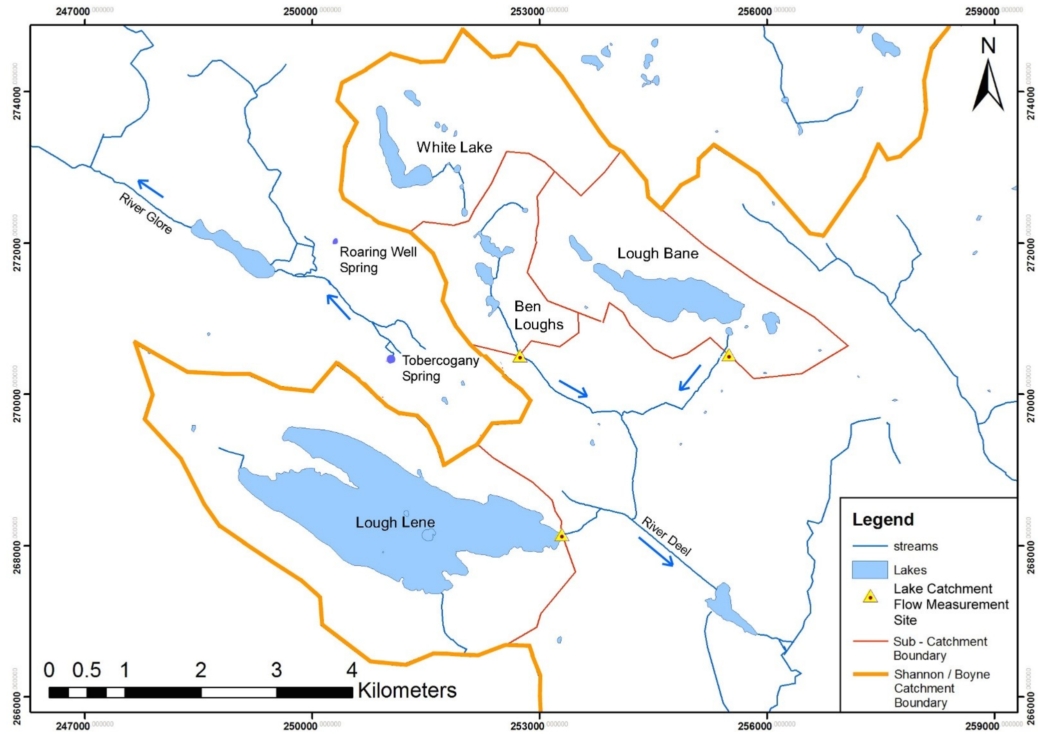

Figure 1. Study Area (map source data Ordnance Survey Ireland)

The lakes studied display different degrees of connections to the surface drainage network. One catchment (Ben Loughs) is drained by a surface channel that flows all year round; two (Lough Bane and Lough Lene) are drained by surface channels that flow for approximately three seasons of the year; and one (White Lake) is not drained via a surface channel at all. None of the lakes studied receive surface inflows of >2 l/s. Seasonal fluctuations of the lake levels in the lakes studies also showed clear differences between sites. The Ben Loughs surface level fluctuated within a range of <0.2 m, and Loughs Lene and Bane exhibited surface level ranges of approximately 0.4 m, while the surface level of White Lake fluctuated within a range of approximately 2 m seasonally.

Underground flowpaths from two of the lake catchments were proven by water traces, one previously known from Lough Lene via swallow holes to the Tobernacogany spring – a distance of 1.7 km, gradient of 0.005 and straight line velocity of 71 m/h; and a connection from a swallow hole at White Lake to the Roaring Well spring – a distance of 1.2 km, gradient of 0.01, and straight line velocity of 137 m/h. No underground connections were proven from either Lough Bane or the Ben Loughs.

Water budget results indicate differences between the study catchments with some providing recharge to groundwater and some receiving discharge from groundwater. Some of the lakes in the area are likely to receive groundwater discharge at some times of the year while providing recharge at other times.

The lakes in the study area were compared based on the degree and type of connectivity they have to the groundwater system (Table 1). This involved scoring each lake on five parameters: a) whether they drain via swallow holes or estavelles at present; b) whether there is evidence that they drained via swallow holes or estavelles in the past; c) whether they are filled via groundwater/throughflow or by surface streams; d) whether they are connected to the surface drainage network; and e) whether they are a temporary or permanent water body. The more turlough-like (karstic) a lake in terms of its hydrology, the closer to zero it scores in this matrix, the higher the score the more non-karstic (non-turlough like) in terms of its hydrology. The scores for Loughs Lene and Bane, the Ben Loughs and White Lake in this matrix show that while none are hydrologically turloughs, they – particularly White Lake – display turlough like qualities. All of the lakes can be considered as hydraulically connected to the groundwater system and possess differing degrees of interconnectivity with it along a continuum from highly connected to somewhat or less connected. The differences in how the study lakes interact with groundwater show that permanent lakes on limestone bedrock in Ireland can be classified along a spectrum from karstic turlough-like lakes with a high degree of interconnectivity to the groundwater system, to less or non-karstic lakes which are less similar to turloughs and are relatively less connected to the groundwater system.

On a practical level, understanding the hydrology of permanent lakes on karstified limestone bedrock in Ireland is becoming increasingly important. With the growing use of lakes as storage reservoirs for wind generated energy, it is important to highlight the fact that lake basins in limestone areas are commonly not held in sealed basins but are closely connected with the groundwater system. It must be understood that such lakes exist along a spectrum from 'highly' connected to 'less' connected to the groundwater system and a simple distinction between turloughs and permanent lakes is inadequate, and that suitable hydrological and hydrogeological investigations are required for any development involving hydrological modification to karstic lakes.

This study was carried out as part of a PhD entitled *'Groundwater – Surface Water Interactions in Lowland Karst: The Westmeath Lakelands',* part funded by Trinity College Dublin and the International Association of hydrogeologists (Irish Group).

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Conor Quinlan, Hydrogeologist

Table 1. Karstic or non-karstic lake typology matrix

Turlough-like (0)	**White Lake**	**Lough Lene**	**Lough Bane**	**Ben Loughs**	**Non-karstic (1)**
Drains via swallow holes or estavelles at present	0	0	1	1	Drains to surface drainage network at present
Drained via swallow holes or estavelles in the past	0	0	0	1	No evidence of past discharge to groundwater
Fills via groundwater discharge or throughflow	0	0	0	0	Fills via surface channel
Not connected to surface drainage network	0	1	1	1	Connected to surface drainage network
Temporary lake	1	1	1	1	Permanent lake
Total	1	2	3	4	

The Pathways Project - Integrating contaminant fate and transport with Irish hydrological processes

The Pathways Project is developing a catchment management tool that incorporates flow and contaminant transfer and attenuation through the different geological pathways, in the Irish context

The Contaminant Movement along Pathways Project (*Pathways*) is an EPA STRIVE funded project led by the Queen's University of Belfast (QUB), partnered with Trinity College Dublin (TCD) and University College Dublin (QUB). The project will address the challenge of integrating knowledge of hydrological processes and water-borne contaminant fate and transport, to assess their impact on aquatic ecosystems. These findings will be used to develop and populate a catchment management tool (CMT).

A number of studies have already shown that data sets derived from a diverse range of environmental and geo-scientific disciplines, reflecting the variability of environmental conditions across Ireland, display considerable potential in shedding further light on pollutant behaviour in the hydrological cycle. The *Pathways* programme will build upon these studies. Integration of relevant aspects of these data sets and research into a CMT is anticipated to assist considerably in determining appropriate measures to be undertaken to maintain or improve hydrological conditions in River Basin Districts (RBDs).

The *Pathways* project started in August 2008 and is scheduled for completion by July 2013. The programme aims to assess and model relevant contaminant fate and transport processes operating in the hydrological cycle in Irish RBDs. More specifically, project researchers will develop a CMT to simulate diffuse contaminant transport and attenuation along hydrologically relevant pathways connecting critical contaminant source areas and aquatic receptors. Pathways under consideration include overland flow, interflow, shallow groundwater (see Plates 1–3) and deep groundwater. The principle contaminants of concern include nutrients (nitrogen and phosphorus), pathogens and sediments. The project also examines ecological impact of pesticides and will aim to identify critical source areas where contaminants may disproportionately affect aquatic ecosystems.

Initial project activities have focused on the delivery of a Project Inception Report that reviews previous relevant research and identifies knowledge gaps in the current understanding of hydrological processes across Ireland. Report findings indicate that the *Pathways* project is the first project to attempt to simultaneously model transport and attenuation of contaminants along four or more hydrological pathways. A finalised version of the project inception report will be available from the EPA website (www.epa.ie) in late 2010.

The second phase of the Pathways project is now under way and focuses on acquisition of supplemental data to improve the confidence with which the CMT may be employed. The lack of knowledge on particular hydrological processes influencing the fate and transport of

Plate 1 Overland flow, Co. Wexford

Plate 2 Preferential pathways at 1 m depth which promote interflow, Mattock catchment, Co. Louth

the contaminants of concern has highlighted the need for these additional field based-investigations in areas with geological, climatic and land use settings representative of wider conditions across Ireland. The further studies completed will aim to permit improved characterisation / establish the relative significance of the hypothesised pathways in a range of settings.

Field-based data acquisition activities will be carried by hydrogeologists, hydrologists, ecologists and environmental scientists. This multi-disciplinary team will collect data to build on existing information while focusing on filling knowledge gaps necessary for identifying critical source areas, and defining transport and attenuation processes operating along the hydrological pathways connecting contaminant sources to aquatic receptors. The data sets collected during field-based investigations will be employed to constrain and refine hydrological and hydrogeological numerical models; these models will act as the basis for the development of the *Pathways* CMT. The field-based investigations are on-going in the four study catchments:

- Carrigans Catchment, Gortinlieve, Co. Donegal;
- the Mattock Catchment, Collon, Co. Louth/ Meath;
- Nuenna Catchment, Freshford, Co. Kilkenny;
- Glen Burn Catchment, Mount Stewart, Co. Down.

It is anticipated that the *Pathways* CMT will be used by the EPA, River Basin District (RBD) Managers and/or local authorities to manage water quality and help meet WFD requirements. Coming months will see the identification and creation of the pathways CMT end-user group who will provide feedback throughout the development of the tool and ensure the project delivers a robust CMT adapted to the purposes of the defined end-user.

If you would like more information on the *Pathways* project please contact Marie Archbold (Project Manager) at m.archbold@qub.ac.uk.

Marie Archbold and Raymond Flynn,
Groundwater Research Group, School of Planning, Architecture and Civil Engineering, Queen's University of Belfast.

Plate 3 Spring discharge, Nuenna catchment, Co. Kilkenny

Low productivity aquifers — some thoughts from a recent conference

The recent IAH (UK) and Geological Society conference on low productivity aquifers, which was held in Edinburgh in early September, was well attended by representatives from consultancies, Geological Surveys, academic institutions and regulatory agencies in Ireland (North and South), Wales and Scotland. This shows the degree of interest in Low Productivity aquifers in these islands.

From my own perspective, I see these aquifers as worthy of particular attention. Whilst the largest groundwater supplies are obviously in the more productive aquifers, higher numbers of supplies, and arguably greater challenges for protection, are in the lower productivity aquifers. In Scotland, for example, indications from a database in preparation suggest that, nationally, smaller private groundwater supplies supply only 10% of the total volume of larger groundwater abstractions. However, there are more than 4 times as many of these smaller supplies.

Whilst the stereotypical image of landscapes associated with low productivity aquifers may be mountains and peatland, there are significant areas which are subject to quite intense land use; for example in Carlow and Aberdeenshire. In one low productivity catchment in Aberdeenshire, arable land comprises 50% of the total and the average population density in the catchment is approximately 38 inhabitants/km^2. In this catchment, initial indications are that the groundwater pathway transmits over 80% of the total nitrate load of approximately 2000 tonnes/year of nitrate that leaves the catchment. In areas like this, the aquifer pathway has particular importance in assessing the impacts of activities like landfill, septic soakaways and agriculture on private drinking water supplies, rivers and estuaries.

My sense is that we are doing a good job, across these islands, of raising awareness with stakeholders in the community of the need to understand the groundwater pathway, with diffuse pollution-focused projects providing a particular driving force.

For those of us involved in site-specific assessments, we know that a conceptual understanding of flow is always good practice before we get into the nitty-gritty detail of boreholes and measurements. However, in the current financial climate, the role of national and regional risk screening is increasing in importance, as we all need to focus more limited resources on the most important aspects. This makes a conceptual understanding even more important because it inevitably underpins the broad assessments that are required to determine what areas and issues require attention. In practice, this means that the quality of our conceptual understanding has direct implications for the environment and communities in low productivity areas.

Broad scale conceptual models have been developed and are in use for this purpose. However, I would suggest that our service would be more robust if the concepts were agreed across these islands. Ireland has clearly been a leader in this area over the years and more latterly through the EPA Strive funded 'Pathways Project' (*see previous article*) and the Griffiths funded 'Poorly Productive Aquifers Project' (*see previous issue*). However, the obvious quality of the work here only serves to emphasise the need to integrate work across these islands to share resource (eg access to sampling points) and to share understanding. For example, information from new techniques such as age dating could be used to add value to more flow-oriented assessments but also to provide a context within which the age data can be understood.

Overall, the old cliché applies - we have come along way but there is much more to do. Low productivity aquifers are important for the environment and for communities. The tighter financial circumstances that we all find ourselves in increase the need for risk screening, and to share our resources. This means a conceptual understanding of flow is not just an academic exercise. It has implications for those live on them, and use them. More than ever we need an accepted broad scale conceptual understanding of flow in these aquifers.

Vincent Fitzsimons,
Groundwater Unit Manager,
Scottish Environmental Protection Agency.

Beauty and memories fading away

While sampling groundwater fauna from wells all over Ireland, University of Ulster PhD student Karin Eriksson, a Swedish national, has developed a particular fondness for the beauty of Ireland's remaining manual water pumps which unfortunately are disappearing fast. Sadly, many of these magnificent pumps already have been stolen from their original sites to be sold on as garden features.

Photo by Karin Eriksson
University of Ulster

A traditional Irish water pump, one of the few remaining witnesses from an era of a very intimate relationship with local groundwater

A Drink of Water

She came every morning to draw water
Like an old bat staggering up the field:
The pump's whooping cough, the bucket's clatter
And slow diminuendo as it filled,
Announced her. I recall
Her grey apron, the pocked white enamel
Of the brimming bucket, and the treble
Creak of her voice like the pump's handle.
Nights when the full moon lifted past her gable
It fell back through her window and would lie
Into the water set out on the table.
Where I have dipped to drink again, to be
Faithful to the admonishment on her cup,
Remember the Giver fading off the lip.

Seamus Heaney

Confidence in groundwater sampling and analysis methods and results

It is more cost effective to spend the extra money incorporating robust quality assurance checks into water quality analyses, as without confidence in the data, the results are meaningless

The quality or suitability of various methods of sampling, and hydrochemical and microbial analysis of groundwater, is something that cannot be taken for granted. Significant thought and effort is generally put into selection of drill targets or monitoring locations, drilling, well construction and other aspects of a project. The same effort might not be put into sample collection and analysis. Potentially, the groundwater samples collected may be sent to the most convenient laboratory (either logistically or financially), by the most favourable means, and results of analysis may be accepted with little question. By taking deliberate steps in the sampling and analysis regime, the confidence in the resultant data can be greatly increased. These steps may include prioritisation of parameters of importance, review of sample collection methods and sample transport, as well as quality control measures in laboratory analysis.

As part of the Environmental Protection Agency's (EPA) groundwater monitoring regime, there is continual review of methods and procedures for groundwater sampling and analysis, with input from interested parties in other disciplines, groundwater researchers and consultants, and with continual reference to development in international guidelines and standards. As expertise develops in relation to particular areas of interest, for example analysis of the different fractions of phosphorus using different methods of analysis, the relevant information is fed back into the subsequent review of sampling and analysis. In the last number of years there have been some significant (and often freely available) documents produced internationally which can be of great help to groundwater professionals in relation to sampling and analysis of groundwater. These include the International Standard (ISO 5667), USGS Groundwater Sampling Methodology (2010; but frequently updated), Australian Groundwater Sampling Methodology (2009) and New Zealand's National Protocol for State of the Environment Groundwater Monitoring (2006). There are certain standard methods that should be adhered to, but after this the adaptability of programmes using experience and relevant guidance is key to providing the best results.

The reason for requiring confidence in groundwater quality data will vary with every project and based on this, the focus of quality control measures may be adjusted. The data from the EPA's national groundwater monitoring quality monitoring network are used in a number of areas including groundwater body status classification, in determining trends in groundwater quality and in a number of research areas including projects running under the EPA STRIVE programme. The National Parks and Wildlife Service (NPWS) also utilises the dataset in their assessment of priority habitats e.g. wetlands. Consultants working in diverse fields routinely request groundwater quality data from the EPA for use in various projects.

In terms of sampling procedures, there are many simple improvements that can increase confidence in the data. These may be as simple as ensuring that the bottle type and volume are appropriate for each required parameter. Temperature blanks can be included in your cooler box, which can be checked and documented by the laboratory on receipt. Some analyses require the exclusion of air when capping sample bottles. The use of gloves (and type of gloves) can potentially have an effect on analyses. I have heard an anecdote from an analyst about unexpectedly high zinc concentrations in a number samples which was, after intensive investigations, linked back to the use of sunscreen in the field on a fine summer day (always a recommended precaution!).

In sampling for the national groundwater monitoring programme, the EPA requirements include the use of flow through cells for the collection of field parameters (Photo 1). A minimum sample bottle volume is required for certain parameters to reduce the potential impact of sorption effects. High quality in-line filters are used when appropriate to remove bacteria, phytoplankton and particulate material that could impact on sample stability or analysis. Sampling equipment must always be clean to prevent carryover of contaminants from one site to another. In transportation of samples, high quality cooler boxes are used with ice packs and a temperature blank in each box to ensure samples remain cool on receipt. A maximum transport time is specified with all samples reaching the laboratory by the following morning at the latest. If samples do not reach the laboratory within the required time period and specified temperature range then samples may potentially be discarded and re-sampling required.

Photo 1. Sampling field parameters using a flow through cell

Procedures to investigate the quality of analyses can go beyond the ionic balance (Figure 1), though this important check should not be overlooked. Blind duplicate samples can be sent to a lab to determine repeatability, blanks can be sent to discover potential for error or contaminant carry over in analytical or sampling equipment and spiked samples used to determine accuracy. Samples can be split in the field and duplicate samples analysed at a second laboratory, thereby allowing a comparison of results of analyses over as wide or narrow a range of parameters as is required. It must be remembered that laboratories will carry out their own internal quality control/quality assurance measures. These may include blank, spike and duplicate samples and requesting of a summary of the results of these procedures may be useful if there are queries in relation to the result of an analysis. As part of the EPA monitoring programme, trip and field blanks and/or spikes are analysed. This can involve analysing part of the sample at the laboratory and transporting the remainder of the sample to site, filtering and processing on site and transporting to the lab as a real sample (see Figure 1, after ISO 5667). This type of analysis allows for comparison to identify errors due to sampling vessels, sample transportation and contamination during sampling.

In examining the results of groundwater analyses, there are some relatively rapid checks that can be carried out to look for potential error. This includes the comparison of samples with historical data from the same site for unexpected results. Results of analyses at different sites carried out during the same time period can be compared for contamination of samples by analysis methods or sample methods, e.g. analyses may require examination if the results of a number of samples processed on the same day return unexpected levels of any parameter. Simple reporting errors may be picked up through the examination of data e.g. error in automated conversion of units may lead

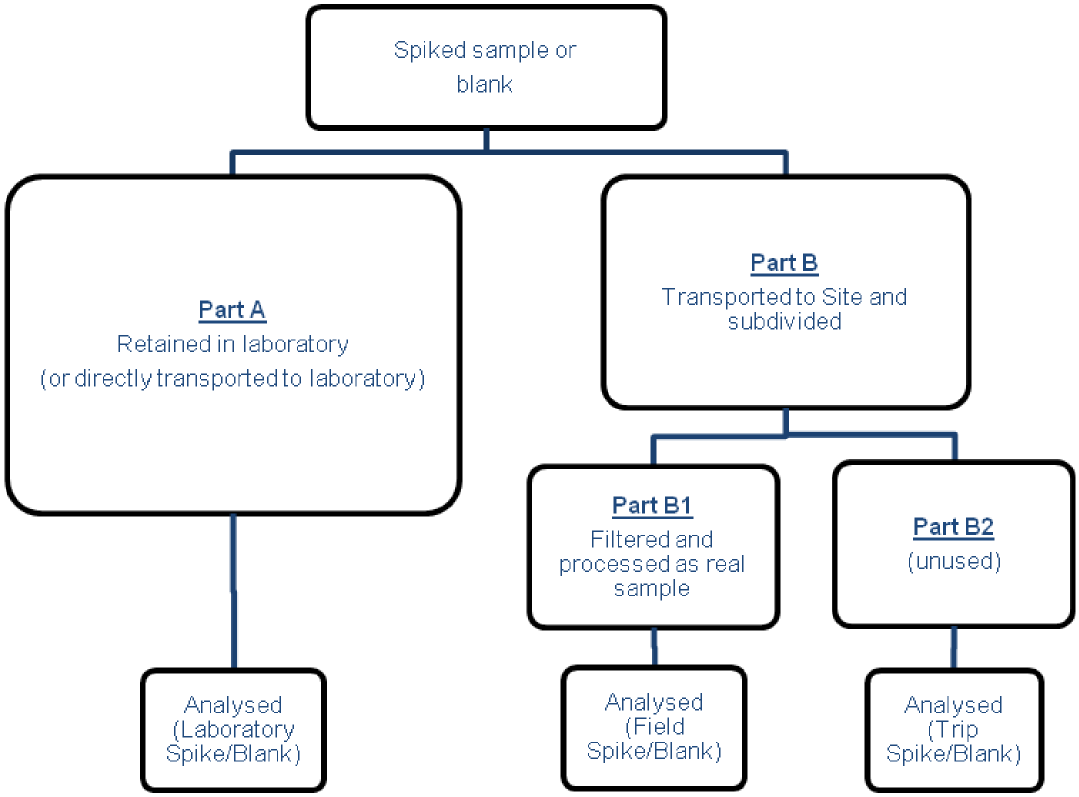

Figure 1. Outline of methodology for processing spikes and blanks (after ISO 5667)

to reporting of less than limit of detection or unexpectedly low or high results for a number of samples. Copy and paste errors may be evident through the reporting of the same value for a particular parameter for a number of samples.

The cost and extra time taken for quality control measures may seem significant. However, without confidence in your data, then the value of time and money spent on the entire project may be undermined. One of the main aims for any procedure for sampling and analysis of groundwater should be to minimise the uncertainty that may exist. The development of a working relationship with your laboratory will allow you to question 'standard' protocol and potentially improve your understanding in the process. The establishment of a quality assurance procedure can save considerable time when interpreting and explaining the data. This questioning of methods and results of groundwater sampling and analysis can mean that you have more confidence in your data and in turn, in decisions arising from the data. This may have implications for a whole range of projects, from the fate of a drinking water supply to the assessment of impact on an ecosystem.

The following are the internet addresses for some recent groundwater sampling and analysis guidance documents online:

Australia:
http://www.ga.gov.au/image_cache/GA15501.pdf

New Zealand:
http://www.mfe.govt.nz/publications/water/national-protocol-groundwater-dec06/index.html

United States Geological Survey:
http://water.usgs.gov/owq/FieldManual/index.html

Anthony Mannix
Hydrometric & Groundwater Section
EPA

Assessing Groundwater Pollution Trends

Trend assessments at 119 national groundwater monitoring points. Results show that environmentally and statistically significant trends requiring reversal for nitrate were present at two monitoring locations

The European Communities Environmental Objectives (Groundwater) Regulations, 2010 (S.I. 9 of 2010) establish a new strengthened regime for the protection of groundwater in line with the requirements of the Water Framework Directive (WFD; 2000/60/EC) and the Groundwater Directive (2006/118/EC). Part VI of the Regulations indicates that the Environmental Protection Agency (EPA) is required to undertake an assessment of pollution trends, including the identification of significant and sustained upward trends in the concentration of pollutants in groundwater bodies.

The EPA has generally followed the procedures set out in EU Guidance Document No. 18: Guidance on Groundwater Status and Trends (EC, 2009) and UKTAG Guidance on Groundwater Trend Assessments (UKTAG, 2009).

Initial Assessment of Trends

Trend and trend reversal assessments must be based on monitoring data gathered at individual surveillance and operational monitoring points, although this may be supplemented by additional representative data from other sources. Trend assessments must be undertaken for parameters that are placing a groundwater body at risk of failing a groundwater chemical status objective, i.e. those parameters that relate to drinking water, saline intrusion, surface water or groundwater dependent wetland assessments.

In the context of the WFD, a significant and sustained upward trend is a trend that is both statistically and environmentally significant, causing an increase in concentration of a pollutant, group of pollutants, or indicator of pollution in groundwater for which trend reversal would be required.

Annual average concentrations were calculated for parameters deemed to be placing a groundwater body at risk over a period of ten years (1999–2008). Annual averages have been calculated because the annual monitoring frequency has varied historically, and prior to 2007, the monitoring frequency was insufficient to distinguish seasonal variations in parameter concentrations. Assessments were undertaken for conductivity, chloride, sulphate, sodium, ammonium, nitrate, molybdate reactive phosphorus (MRP), iron and manganese, as these are the only parameters that are placing a groundwater body at risk, and that have data records greater than six years.

Non-parametric statistical methods are required for trend assessment because many groundwater systems have considerable seasonal variability in parameter concentrations, which can impact on trend assessments. The non-parametric Seasonal Kendall test is a statistical method that reduces the impact of seasonality on trend assessments. Where significant trends have been detected, the Sen's method can be used to project the trend into the future, as this method is robust when there are outliers or gaps in the time series data.

An Excel program MAKESENS (incorporating a Mann-Kendall test for trends and a Sen's test for slope projection) has been developed by the Finnish Meteorological Institute for detecting and estimating trends in time series using annual values. MAKESENS performs two types of statistical analyses. Firstly, the presence of a monotonic increasing or decreasing trend is tested with the non-parametric Mann-Kendall test, and secondly, the slope of a linear trend is estimated with the non-parametric Sen's method.

MAKESENS reports a positive value for an upward trend and a negative value for a downward trend, and assigns a probability that there is a significant trend. Where no value is reported, the trend is not deemed to be significant.

Results

Trend assessments were undertaken at 119 monitoring points (Figure 1). The remaining 160 monitoring points had insufficient data to undertake the trend assessment in this River Basin Planning cycle.

The general pattern for trends (Table 1) indicates that the ammonium is the only parameter that appears to be showing a significant number of monitoring points with statistically significant upward trends. However, the ammonium trends are mainly a function of the proportion of samples that are at or below the limit of quantification. In these instances half the limit of quantification is used, which skewed the trend.

Approximately 13% of all groundwater bodies in Ireland are at Poor Status due to groundwater contributions of molybdate reactive phosphorus (MRP) to surface water bodies that are at less than Good Status. Whilst groundwater bodies are at Poor Status due to MRP, only three monitoring points show a significant upward trend in MRP concentrations. This is probably because the diffuse inputs of MRP to the groundwater system are generally of a low concentration; but episodic MRP spikes, caused by heavy rainfall and the dynamic karst environment (e.g. sinking streams, swallow holes etc.) can cause elevated average concentrations in groundwater. All three monitoring points had environmentally and statistically significant upward trends. However, these trends are partly a function of historical data gaps which have distorted the trends to some degree and confidence in the trends is lessened as a result.

EPA groundwater monitoring point, Ryewater catchment, Co. Kildare

Table 1. Summary of monitoring point trends for assessed parameters

Parameter	Sites with No Significant Trend	Sites with Downward Trends	Sites with Downward Trends that are Statistically Significant	Sites with Upward Trends	Sites with Upward Trends that are Statistically Significant	Sites with Upward Trends that are Statistically & Environmentally Significant
Conductivity	17 sites	69 sites	15 sites	33 sites	4 sites	1 site
Chloride	3 sites	86 sites	30 sites	30 sites	7 sites	7 sites
Ammonium	3 sites	6 sites	0 sites	110 sites	42 sites	7 sites
Nitrate	7 sites	56 sites	11 sites	56 sites	14 sites	2 sites
MRP	9 sites	42 sites	1 site	68 sites	3 sites	3 sites
Sulphate	5 sites	50 sites	13 sites	64 sites	12 sites	0 sites
Sodium	12 sites	72 sites	9 sites	35 sites	2 sites	0 sites
Manganese	3 sites	90 sites	33 sites	26 sites	3 sites	2 sites
Iron	11 sites	63 sites	12 sites	45 sites	1 site	1 site

A small number of significant upward trends were detected for iron, manganese, sulphate and sodium, although very few of these trends were environmentally significant. Natural processes such as denitrification or local geological conditions are thought to be the cause of the elevated concentrations of these parameters.

While the chloride trends are not a concern in relation to drinking water supply because the concentrations are generally less than 50 mg/l, they may indicate the intrusion of saline waters. The majority of monitoring locations with statistically significant upward chloride trends are located close to the coast and it is assumed that the elevated chloride concentrations are naturally occurring. The remaining sites with statistically significant upward chloride trends show no other evidence of saline intrusion, e.g. upward trends in electrical conductivity.

The overall picture for nitrate trends at the monitoring points indicates a relatively stable picture nationally, with approximately 47% of monitoring points showing upward trends, 47% showing downward trends, and the remainder not showing any significant trends. Environmentally and statistically significant upward trends are evident at Durrow, Laois (Figure 1) and Ballyheigue, Kerry (Figure 2) where average concentrations were also above the Threshold Value of 37.5 mg/l NO_3.

While both Ballyheigue and Durrow have environmentally and statistically significant upward nitrate trends, both monitoring points showed a decline in the average nitrate concentration in 2008, which suggests that programmes of measures currently in place, or the prolonged periods of heavy rainfall experienced during 2008 may have had an impact on the nitrate concentrations. However, as the environmentally and statistically significant upward trends are still apparent, the groundwater bodies are placed at poor status in relation to the drinking water objectives of the WFD and therefore the groundwater bodies

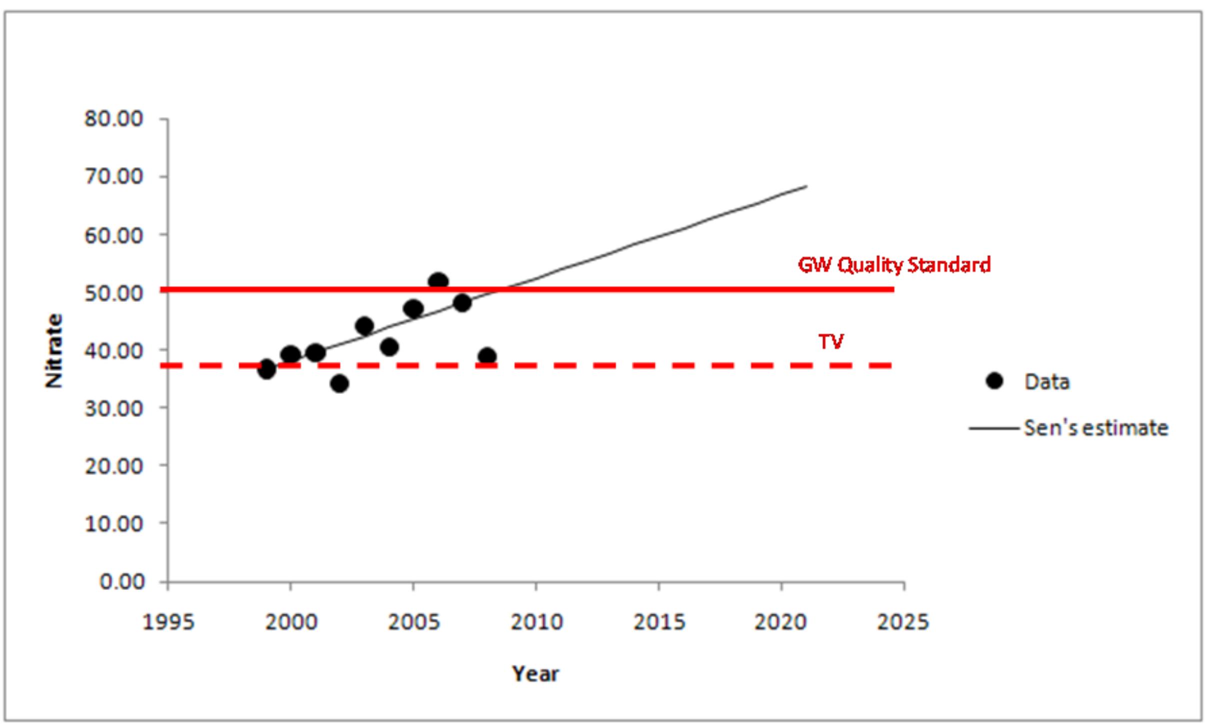

Figure 1. Environmentally and statistically significant upward trend for nitrate at Durrow, Co. Laois

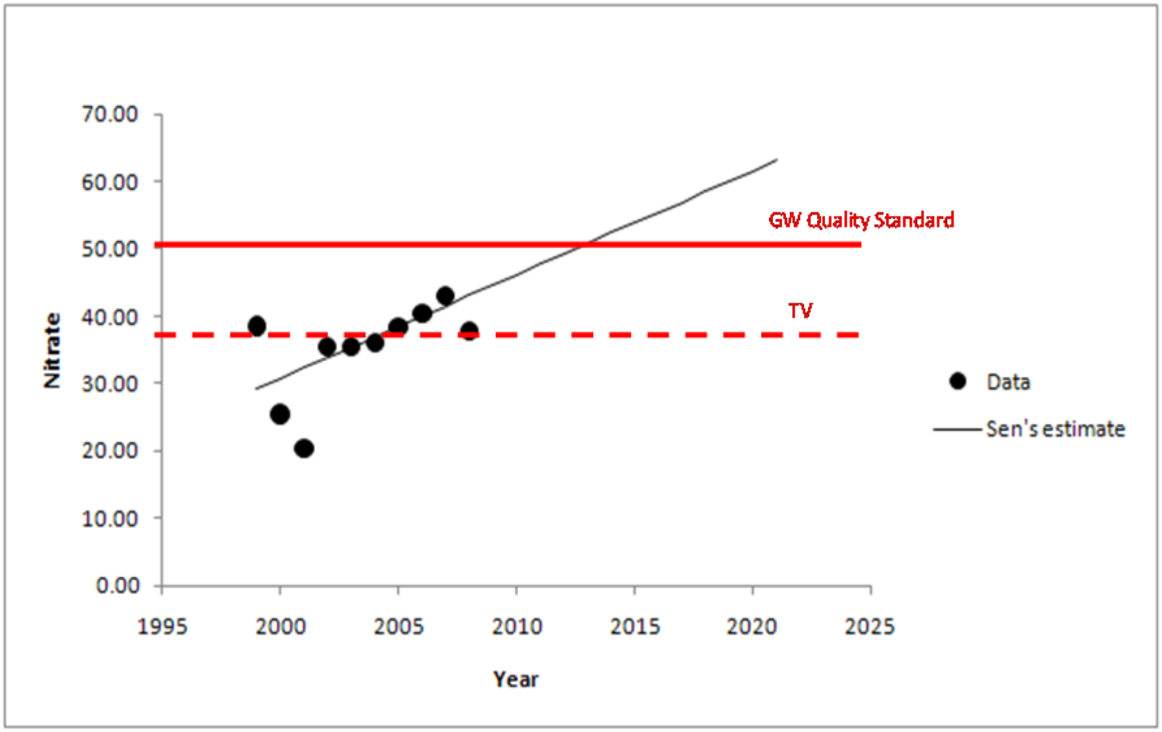

Figure 2. Environmentally and statistically significant upward trend for nitrate at Ballyheigue, Co. Kerry

must also be identified as having environmentally and statistically significant upward trends.

As such, there is a requirement to reverse trends in these groundwater bodies. The average concentration of Nitrate at both Ballyheigue and Durrow in 2008 was greater than 75% of the Nitrate Threshold Value of 37.5 mg/l NO_3. Therefore the start date for trend reversal is 2009 and programmes of measures to reverse trends should be introduced immediately.

Conclusion

Trend assessments have been undertaken for 119 monitoring points in the National Groundwater Monitoring Network. Assessments were undertaken for conductivity, chloride, sulphate, sodium, ammonium, nitrate, molybdate reactive phosphorus (MRP), iron and manganese, as these are the only parameters that are placing a groundwater at risk of failing the status objectives of the WFD and have data records greater than six years.

Environmentally and statistically significant trends were detected for nitrate at two monitoring locations (Ballyheigue, Kerry and Durrow, Laois), and the trends will require trend reversal. As the average nitrate concentration already exceeds the nitrate Threshold Value of 37.5 mg/l NO_3, the starting point for trend reversal is now, i.e. the 2nd River Basin Planning cycle. Therefore, ongoing monitoring is required to demonstrate that Programmes of Measures are effectively reversing the trend.

Further trend assessments will be undertaken in the 2nd River Basin Planning cycle and will include trend assessments at monitoring points where monitoring began in 2007 and where sufficient historical records were not previously available.

Matthew Craig
Hydrometric & Groundwater Section, EPA

If you want to go East, don't go West — the 2010 IAH field trip report

The annual IAH field trip was held in early October and was a great success. Read a summary of the events here and download the field trip guide from the IAH (Irish Group) website

The first weekend of October saw the annual IAH field trip take place. The trip was based between the Avoca area and the Copper Coast, Waterford and proved popular, with close to 45 people attending some or all the trip.

The site visits kicked off on the Saturday with a thorough and very interesting description of development of a groundwater source in a shallow sand and gravel aquifer, intended to supplement water supply to Arklow town, by Gerry Baker of WYG. Visits were made to two borehole sites where a description was given of the drilling and testing process. Gerry also outlined the particular concerns relating to groundwater quality assessed during the investigation, given the location of the supply downstream of the Avoca mines site. An overview was also given of the modelling work carried out which, along with the field data, helped determine the pattern of groundwater flow down the valley, interestingly showing different areas of influent and effluent conditions along the river. This modelling work also aided the delineation of catchment protection zones for the sources.

Eibhlin Doyle (DCENR) at Avoca mines

Gerry Stanley (GSI) with portable xrf

After lunch in the pleasant surroundings of the Meeting of the Waters, the group was shown one of the EPA gauging stations on the River Avoca by Michael Browne (EPA), located next to an adit discharge and partly installed to help with understanding point source and diffuse source discharges from the Avoca mines. Following this, Eibhlin Doyle (DCENR) and Gerry Stanley (GSI) took the group into one of the closed mine areas and gave an overview of the history of the mine workings and the assessment of risk undertaken for this and other significant mines in Ireland with respect to long-term environmental impact, health and safety and potential for industrial heritage development. They were supported by Roger Olsen from CDM who expanded on the hydrogeological and geochemical model for the site. There was much interest in the hand-held XRF, 'the hair-dryer' used by the GSI as a rapid screening tool for metal concentrations at mine sites with a demonstration on its use given by Gerry Stanley.

The day was not yet over and as the group headed to Waterford, a stop was made at a quarry in the Ordovician volcanics near to Gorey, where Gerry Baker (WYG) give an overview of the assessment currently underway with respect to a possible extension to the quarry. This proved an interesting site which raised common issues amongst those attending relating to the negotiation between site owners and environmental consultants regarding the level of expenditure required to achieve a suitably robust environmental assessment. The site also exposed the diversity of volcanic rock types with many of us wishing we had brought along our university lecture notes on this particular topic.

Following a very enjoyable overnight stay and group meal in Waterford, we headed to Garrarus, near to Tramore where Orla Murphy, Monica Kabza and Mellisa Spillane from Tobin Consulting outlined the work the were undertaking for groundwater vulnerability mapping. The site location, a coastal exposure of glacial till over bedrock, was perfect for this topic with the start of the day made all the better with fantastic weather. The group was also given a practical demonstration of the how the subsoils are consistently classified based upon GSI guidance developed from BS5930, followed by

Demonstration of subsoil description techniques

Des Cowman leading the group down to an adit site

an opportunity for the group to get their hands dirty and try it for themselves.

At this location we also met Tina Keating, the Copper Coast Geopark geologist, who gave an overview of the geopark before taking us to meet Des Cowman at an industrial heritage mine site near Dungarvan. Des gave a fascinating description of the history of the mines in this area, the technology employed at the time, along with an insight into the people who worked the mines and the conditions they endured. It was most interesting to hear how some of the workings extended out beneath the sea and to think about what the miners must have felt as they worked, with some reporting hearing the cobbles move as the tide came in and out (albeit possibly due to a ventilation feature). The visit was rounded off at the Geopark geological garden where examples of the different rock types in the area are well displayed. Following a much needed lunch in the village of Kill, the group returned to Dublin having spent a most enjoyable day along the Waterford coast in fantastic sunshine.

The field trip guide can be downloaded from the IAH (Irish Group) website at http://www.iah-ireland.org/current/events.htm

Peter McConvey
Field trip Secretary

Aquifer Parameters Project

The GSI Groundwater Programme and the EPA will be working jointly on a new 'Aquifer parameters' handbook in the near future. The study will compile and assess aquifer parameter data during a short study, with the aim of assembling a preliminary database of aquifer parameters for various rock types and aquifer classes. The parameter database will be of use to hydrogeologists and engineers, and will help to quantify groundwater flow and contaminant transport parameters, and the degree of heterogeneity in different rock units. We would also like to establish a database of subsoil groundwater flow parameters (including permeability, porosity, dispersivity, TOC, etc.).

Can you help to augment our data holdings?

Many consultancies and individual consultants have been very generous to the GSI with their time and data over the years. If you have additional good quality data for bedrock or sand/gravel aquifers, or subsoils, from pumping tests, slug tests, falling/rising head tests, etc., we would be grateful to receive digital copies or hard copies. If you would like us to facilitate copying/scanning, we can try to arrange this.

Taly Hunter-Williams,
Groundwater Section
GSI


Dinantian Pure Bedded Limestone, Nuenna catchment, Co. Kilkenny

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Geothermal Association of Ireland— recent activities and future events

The Geothermal Association of Ireland (GAI) was set up in 1998 to promote the development of geothermal energy in all its forms in Ireland. The GAI has an active committee with diverse backgrounds. Committee members, who are listed on the GAI website (details below), include hydrogeologists, engineers and geologists.

The GAI has held two field trips this year, in the west and in the southeast of Ireland, and has published a bumper newsletter, which can be downloaded from the website.

Forthcoming events include a one-day Conference in March 2011, and an Installation of the Year competition, in which the best domestic and best commercial geothermal systems will be awarded prizes. In addition, in honour of the GAI's former Treasurer, Brecan Mooney, who sadly was lost in the floods last November in Cork, a memorial Bursary/Prize will shortly be established.

If you are interested in geothermal energy, please consider becoming a member of the GAI, or participating in GAI's events - details and membership forms can be found on the website: http://www.geothermalassociation.ie/

Taly Hunter-Williams and Monica Lee
Joint Secretariat
GAI

Previous issues available at www.gsi.ie

Contributions for the next issue of the Groundwater Newsletter should arrive by 31 March 2011 to: Groundwater newsletter @gsi.ie (*no spaces*)

The contributors are responsible for the content of the material in this Newsletter. The views expressed are not necessarily those of the Geological Survey of Ireland.

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IAH News

AGM on Tuesday 7th December at 7.30pm in 'The 51 Bar', Haddington Road, D4

An invitation

Once more the Annual General Meeting is upon us (Tuesday 7th December at 7.30pm in 'The 51 Bar', Haddington Road). The AGM is an opportunity for you, as members to:

- have the Committee report to you,
- elect new officers to the Committee,
- to voice your views on matters relating to hydrogeology and groundwater in Ireland, and the work of the Committee on your behalf.

While an AGM is often seen as a boring necessity, in recent years we have attempted to de-fuse that boredom by developing the idea of the culinary AGM and a very successful tradition has now ensued. We should like to encourage you to come again this year by continuing that tradition of 'meets with eats' together with wine and soft drinks. We will attempt to keep the reporting element as short as possible and we would welcome your input on our various activities. Nevertheless, the AGM is for you, the Members of the Association, and you can make it go on as long as you want, however we hope that we will finish about 9.30pm at the latest.

Formal aspects

1. The IAH (Irish Group) AGM will take place in 'The 51 Bar', Haddington Road on Tuesday 7th December 2010 starting at 7.30pm.

Elections

2. Morgan Burke has completed three years as Secretary and is therefore stepping down from this position. The position of Secretary is therefore vacant from December 7th.
3. Orla McAllister has completed three years as Treasurer and is therefore stepping down from this position. The position of Treasurer is therefore vacant from December 7th.
4. Shane Herlihy has completed one year as Conference Secretary but wishes to step down from the post due to personal circumstances. The position is vacant from December 7th.
5. Peter McConvey has completed three years as Fieldtrip Secretary and is therefore stepping down from this position. The position of Fieldtrip Secretary is therefore vacant from December 7th.
6. Suzanne Tynan has completed one year as Education and Publicity Officer but wishes to step down from the post due to personal circumstances. The position is vacant from December 7th.
7. David McLorinan has stepped down as Northern Ireland Secretary so a new officer is needed.

The Committee would also like to hear from members who are interested in volunteering to serve on the Conference Sub-Committee.

Please…..

1. If you would like to be a candidate, or nominate/second someone else as a candidate, for election to any of the Committee positions that are vacant, send nominations to Morgan Burke (burkemorgan@gmail.com) before 5pm on Friday 26th November.
2. Send an email to me or Caoimhe Hickey (caoimhe.hickey@gsi.ie) as soon as possible to tell us whether you are coming to the AGM to allow for catering.

The Committee and I hope to see you at the AGM on the 7th December.

Morgan

Next Technical Discussion Meeting
Results from the Dublin SURGE Project (Soil Urban Geochemistry)
Mairead Glennon (GSI)
December 7th at 6pm at the GSI. Tea/coffee from 5.30pm. Followed by the AGM