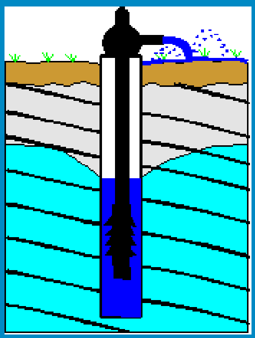

Groundwater Newsletter

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Inside this issue:

The many facets of wetlands

In this issue of the Groundwater Newsletter, we take a look at wetlands, both those constructed for the purposes of treatment of waste water, for which the Department of the Environment, Community and Local Government has recently published a guidance document (Donal Daly, pg 2); and those that are dependent on groundwater. Under the latter category, Shane Regan outlines his current research at Clara Bog, one of the best preserved raised bogs in Ireland which is dependent on groundwater and is not without its share of pressures; and Laurence Gill, Sarah Kimberley and Yvonne O'Connell describe various elements of a major study into the conservation of a special kind of groundwater dependent wetland, turloughs, which will shortly be drawing to a close.

Continuing with the karst theme, Pat Groves reports on a study he carried out into the sources of high ammonia at Lough Owel in Mullingar. The lake is spring fed and his work looked at the sources of the high ammonia and the pathways for its delivery to the lake. In making assessments of nutrient status in water bodies, Phil Jordan (pg 30) points out how important it is to consider the nutrient loads (i.e. concentration x discharge), as well as concentration, in order to gain proper insights into the sources of the nutrients, so that appropriate programmes of measures can be tailored.

The first assessment cycle under the Water Framework Directive (WFD) has now been completed and Matthew Craig summarises the findings in relation to groundwater body status and groundwater quality in Ireland. Matt has also penned a second short note to highlight the publication of two statutory EPA reports detailing the agency's methodologies for implementation of the WFD.

During the GSI's vulnerability mapping programme, large regions of extensive, but discontinuous, iron pans were found in Co Mayo, and to a lesser extent in Co. Tipperary. These pans occur typically in well drained, high rainfall areas, where minerals leach down through the soil profile and form a hard iron-oxide layer which creates a barrier to infiltration, in otherwise permeable subsoils. The vulnerability mapping team describe these features and comment on their implications. Finally, Coran Kelly (pg 21) reports on the aquifer parameters database and makes a plea for any additional data that could be made available.

Monica Lee, Groundwater Section and Jenny Deakin, Editor

Integrated Constructed Wetlands – Guidance document published

The Department of the Environment, Heritage and Local Government has launched a guidance document for the development of integrated constructed wetlands for farmyard soiled water and domestic waste water applications

Natural Attenuation

Can 'nature' attenuate pollutants and protect water from the impact of human activities? The answer is 'yes and no'! The challenge is in knowing, with reasonable confidence, the circumstances in which natural attenuation (as an alternative to construction and technology-based engineering solutions) will work satisfactorily. There are examples of false hopes; for instance, in Britain in the late 1970s and early 1980s, 'dilute and disperse' landfill sites were thought to be a relatively low cost (compared to engineered containment sites) and effective means of disposing of domestic refuse. By the late 1980s, it was realised that while some pollutants were attenuated, many trace organics, such as solvents, weren't. On the other hand, the realisation that the subsoils (Quaternary sediments) that overlie our bedrock in Ireland provides a protecting, filtering layer over groundwater by various physical, chemical and biological processes has led to the 'groundwater vulnerability concept' developed by the GSI and the subsequent mapping and use of these maps in groundwater protection schemes. Recent research by Teagasc/TCD is showing the role of denitrification in subsoils in reducing the amount of nitrate leached to groundwater. Further research on the role of bedrock in causing denitrification, and the ability to delineate areas where denitrification is likely, will enable mitigation measures to be focussed on the problematical areas.

ICWs – Another 'Natural' Solution

Most, if not all, readers of this Newsletter will be familiar with the role of 'reed beds' in treating pollutants, particularly wastewater from houses. However, recent research (Gill, et al., 2009) has shown that while horizontal flow subsurface reed beds are effective in reducing organic, suspended solids and bacteriological loads, they were far less effective in removing nutrients and bacteriophages. So, while they may have a role, they are by no means a complete solution. However, an Irish version of the 'constructed wetland' concept has been developed by DEHLG and Waterford County Council staff. This is called the 'Integrated Constructed Wetland' (ICW) concept. While I am not an expert on constructed wetlands, it appears to me that ICWs are an Irish-developed solution to treating wastewater that is more effective than 'reed beds' and can be as effective, and in some circumstances more effective, than conventional mechanical waste water treatment plants. While there are a number of provisos attached to this view, which are given below, on balance we now have in Ireland a solution to the treatment of domestic wastewater, farmyard soiled water and road runoff that can be effective and has other environmental benefits.

What are ICWs?

The ICW concept is based upon the free surface-flow of water/wastewater through a series of sequential linked shallow ponds that have been vegetated with a range of plant species. The footprint of these ponds is much larger than that used for similar hydraulic loadings in 'reed bed' systems. There is a long retention time in the ponds, which aids the deposition of suspended matter and reduction of B.O.D., nitrogen and phosphorus, facilitated by the action of specific plants. In addition to the pollutant reduction potential, they create new wetland habitats.

Guidance on ICWs

In November 2010, the then Department of Environment, Heritage and Local Government published "Integrated Constructed Wetlands: Guidance Document for Farmyard Soiled Water and Domestic Wastewater Applications", which can be downloaded from the following link: http://www.environ.ie/en/Publications/Environment/Water/FileDownLoad,24931,en.pdf

This 122 page Guidance document provides general details on ICWs, summarises the advantages and disadvantages with them, gives the site assessment requirements and gives relevant information on the regulatory process, ICW design, ICW construction and operation, maintenance and monitoring.

The Department of Agriculture, Fisheries and Food has also published "Minimum Specification for Integrated Constructed Wetlands, and Ancillary Works" which is the legal minimum standard for ICWs used for treating farmyard soiled water. This minimum specification is available at: http://www.agriculture.gov.ie/media/migration/farmingschemesandpayments/farmbuildings/farmbuildingspecifications/pdfversions/S133MinimumSpecICWs.pdf

Constraints

ICWs, while a major breakthrough, are not a 'silver bullet' that will resolve the treatment of wastewater. I am aware from discussions with colleagues in the EPA that unsatisfactory results have arisen in circumstances where the requirements of the new DEHLG Guidance were not followed, particularly with regard to pond sizes, and site selection, design and operation. Care must be taken to deal with the following issues:

- ICWs are not suitable, in my view, for wastewaters with a high nutrient loading, e.g. wastewater with ammonium concentrations >100 mg/l.
- They are not suitable in all locations, e.g., inner protection area of public water supplies.
- In order that there is minimal pollution of groundwater, where a geomembrane is not used, there must be a minimum of 1.0 m of subsoil beneath the ponds, with the upper 0.5 m having a permeability no higher than $1x10^{-8}$ m/s, with slightly greater thicknesses above karstified and sand/gravel aquifers.
- The ICW provides a significant reduction in

Glaslough Integrated Constructed Wetland, Pond 5. ***Photo by Pat Byrne***

phosphorus (P), whereby the P is contained in the ponds. Consequently, after a number of years, this phosphorus must be removed. Obviously, this P, on the one hand, is a valuable resource, but it has to be stored and used with care.

- High ammonium concentrations are usually present in the underlying groundwater. However, while this is a hazard that must be considered, it will not be a significant issue except where the permeability of the underlying subsoil is at or close to the limit of $1x10^{-8}$ m/s and there are ammonium sensitive waters nearby or there is a link to a receiving water body. Where the permeability is lower than this, the ammonium loading will be too low to cause any problems.
- Discharge licences to receiving waters are required from the relevant competent authority prior to construction and discharge.

Conclusions

We now have in Ireland a form of constructed wetland that can be effective in treating pollutants in wastewater in a sustainable manner and that has the additional benefit that it creates new wetlands. However, they must be located in suitable areas following a site suitability assessment, be installed and maintained properly, and be in compliance with the appropriate authorisation (such as wastewater discharge licence or authorisation, IPPC/Waste licence, Water Pollution Act licence) to a suitable receiving water. The DEHLG Guidance Document is a welcome step forward and provides the information required to facilitate the use of ICWs in an effective and sustainable manner.

Donal Daly
Hydrometric and Groundwater Programme
Environmental Protection Agency

Raised Bogs as Groundwater Dependent Ecosystems; an example from Clara Bog

Introduction

The protection of wetland habitats that are sustained by regional groundwater flows is a basic tenet of the EU Water Framework Directive (WFD). Such systems are considered to be ‘groundwater dependent terrestrial ecosystems’ (GWDTEs) and understanding their ‘environmental supporting conditions’, which are primarily represented by their dependency on the prevailing hydrological regime, is essential for the conservation of wetlands.

Raised bogs are generally considered to be isolated hydrological systems, separated from regional groundwater flows. Groundwater as a ‘supporting’ ecological condition is usually confined to the perimeter of a raised bog, where peat and underlying clay thin towards the margin, allowing regional groundwater and peat water to converge and mix, thereby giving rise to characteristic nutrient rich lagg zone vegetation. However, the relationship between groundwater and the raised bog body itself is complex and current research on Clara Bog suggests that groundwater provides some form of ‘support function’ to the bog and that it may be considered a GWTDE under the WFD.

Clara Bog

Clara Bog, located in Co. Offaly, is Ireland’s largest raised bog and is one of Western Europe’s premier raised bog wetlands. Though it has been designated a nature reserve since 1986 only c.465 ha of a total of c.665 ha is state owned. The areas of bog cover that are not part of the nature reserve is privately owned and until recently (turf cessation ban 2010) was cut locally for turf production.

Figure 1. Clara Bog – East and West

Importance

It is not the size of Clara Bog that makes it important, but rather the ecology it supports. Various ecological communities, referred to as ecotopes, characterise the bog surface and their positioning is dictated by the topographic gradient and by extension, the movements of surface water and their relative flow path lengths. A raised bog is considered to be 'healthy', or 'active, when it continually accumulates vegetative matter, which, over time, becomes peat, allowing the bog to 'grow' upwards. The existence of a 'living' layer, or acrotelm, is therefore paramount in raised bog conservation. An acrotelm exists where the topographic gradient is shallow and the subsequent saturated conditions allow the widespread development of Sphagnum species.

There are areas on Clara Bog where there is a good expanse of acrotelm. In addition to this, there are parts of the bog where the vegetation is indicative of more nutrient rich conditions – i.e. fen like vegetation. These botanical assemblages are referred to as *soak* systems and such ecotopes are absent from almost all other Irish and European bogs. Whereas plant species such as *Sphagnum* thrive in nutrient poor, or *ombrotophic*, conditions, the soaks contain plant species indicative of *rheotrophic* and *minerotrophic* conditions. Their occurrence is highly unusual as there is no upwelling of groundwater within the bog itself. Rather, large surface water catchments and long flow path lengths enrich these particular areas, meaning the water is nutrient rich due to longer residence times, relative to the surrounding areas.

A Changing Bog

Though one of the best preserved raised bogs in Ireland, Clara Bog has been extensively damaged in the past and it is estimated that the bog, as it exists now, covers less than half of the extent it once did in its pristine state. The bog may in fact be considered to be two bogs, Clara Bog West and Clara Bog East, as a road, the Clara to Rahan 'bog road', bisects the bog into two separate bog entities (Figure 1).

The effects of the bog road on the bog itself have long since stabilised. However, since the 1990's, Clara Bog West has subsided dramatically – by over 1.0 m in local areas and as far as 600 m from the high bog margin towards its centre. Coincident with this subsidence has been the development of bog pools and lakes due to differential rates of peat settlement. Such peat consolidation is a result of drainage associated with turf cutting and the development of a peripheral drainage system.

Hydrogeological Framework

Clara Bog West is being drained and to understand how, and the drainage pathways involved, it is first important to understand the geological setting in which the wetland is situated, and the relationship between the hydrogeological processes operating in the subsurface, with the hydrological and ecological processes operating on the surface. All of the physical processes are interlinked and contribute to the sustainability of the bog as an ecosystem.

Typical of most raised bogs in Ireland, Clara Bog formed in a topographic basin that was carved into the landscape following the retreat of the last glaciation, c. 10 ka. Material extracted from the bedrock by the glacial ice movements resulted in the deposition of mineral subsoil of varying lithology - till. Such subsoil types are unconsolidated superficial deposits and in the Clara region, they are saturated and in hydraulic contact with the underlying limestone bedrock aquifer. The composition of the till material reflects that of its underlying parent bedrock, Carboniferous Limestone. The bog is bounded by an east-west trending esker on its northern side and is surrounded by an undulating topography consisting of glacial till on its eastern, western and southern sides (Figure 2). In the Clara region, the till subsoil is widespread and is present throughout the landscape basin that is occupied by the bog. The till subsoil body is considered to be an aquifer and hosts the regional groundwater table.

Lying above the till subsoil is a clay bed of glacio-lacustrine origin. This clay layer represents an old lake environment which infilled the topographic depression following glaciation. There is little coarse material present within the clay profile; rather the small clay particles are compacted together to form a deposit that does not transmit water easily. The lacustrine clay effectively acts as an aquiclude, or 'hydraulic barrier', by isolating the bog from regional groundwater flows in the subsoil (glacial till) aquifer and thus preventing downward leakage of water from peat to the subsoil.

In the central areas of the old lake basin, fossil

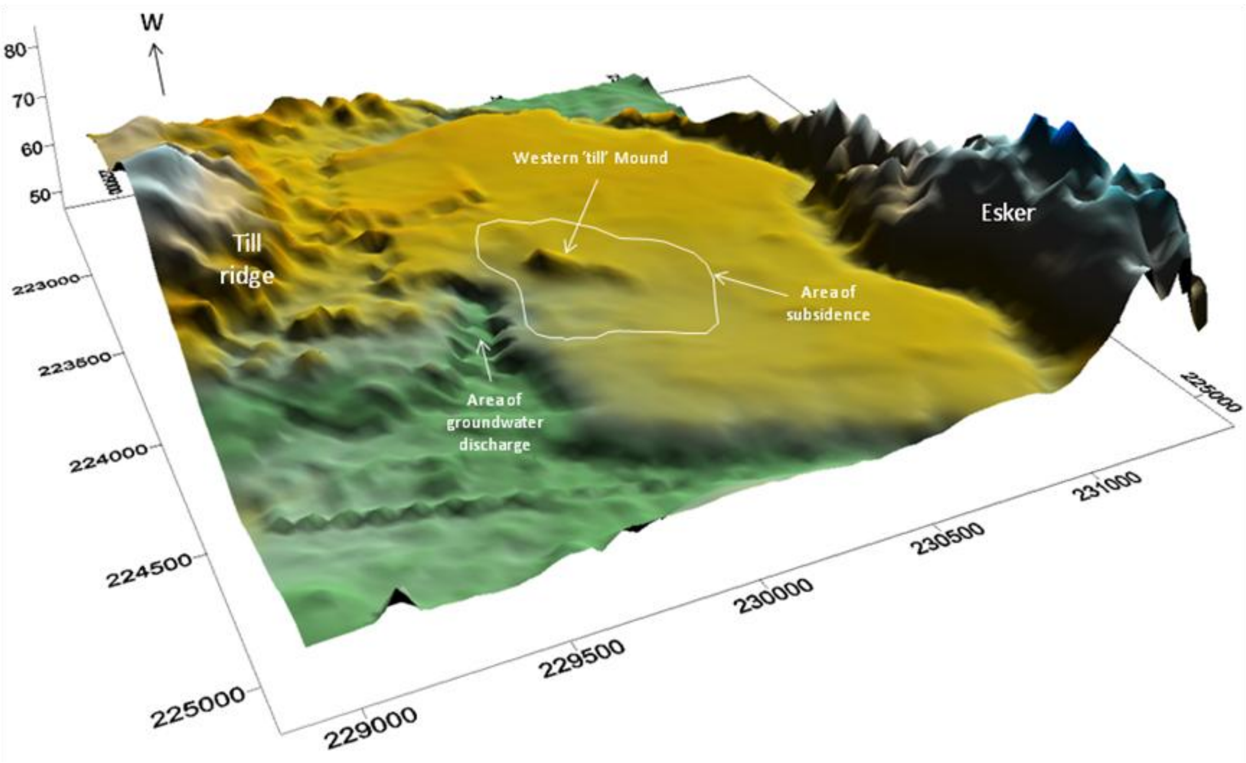

Figure 2. Clara Bog West digital terrain model

rich lacustrine sediment, marl, overlies the lacustrine clay. Interestingly, a sand lense, underlain by lacustrine clay, is found close to and bordering the marl unit, implying it is effectively a type of palaeochannel that at one time drained water from the centre of the old lake basin.

Drainage Pathways

Drainage associated with peat cutting has resulted in the rapid subsidence of Clara Bog West, leading to changes in flow patterns that support two internationally important soak systems, namely the Western Soak and Shanely's Lough (Figure 3). It is also leading to significant losses of the EU Habitat Directive priority habitat Active Raised Bog.

The results and observations to date indicate that water loss from the peat substrate is associated with decreased groundwater heads in permeable geological layers under the bog and it appears there are two main drainage mechanisms:

- The regional groundwater level has been lowered in local areas as a result of peripheral drainage works close to (within 2 m of) the peat-till interface cutting below the regional groundwater table, thereby creating an outlet for groundwater to discharge from beneath the peat bog. In the areas of the bog where lacustrine clay is absent and peat is underlain directly by till (mineral subsoil), a hydraulic connection exists between the high bog and regional groundwater table flow system. Water loss from the base of the peat profile in the high bog therefore occurs. The subsoil potentiometric surface in the till aquifer (Figure 3) indicates that this is the case, as the hydraulic gradient increases significantly where till directly underlies peat and where groundwater-fed face-bank drains border the high bog boundary. The potentiometric

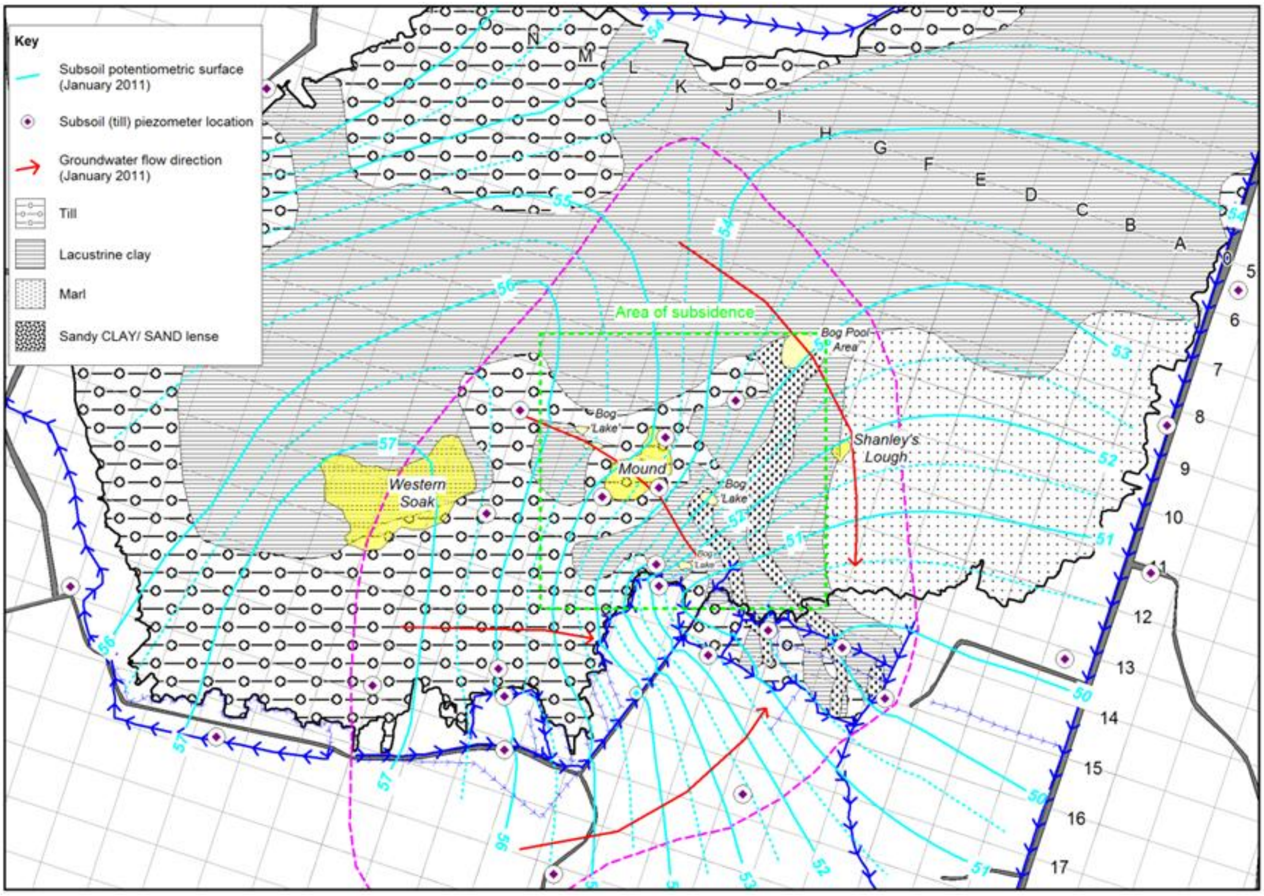

Figure 3. Regional groundwater table and flow pattern in Clara West

surface at the base of peat in the high bog is also found to mirror that of the regional groundwater table, implying water is being lost from peat to till (hydrograph analysis of piezometer nests on the high bog substantiate this inference). The phreatic water table gradient is also steep in such areas implying peat consolidation has increased the surface level gradient. As such, the water level patterns in till, peat and in the free water table in the upper peat layer are linked. Water loss from the peat to the underlying groundwater system is indicated where gradients are steep in areas where till directly underlies the peat profile.

2. Analysis of the deep peat potentiometric surface indicates that the occurrence of two sand lenses, overlying lacustrine clay and underlying peat, is an important drainage pathway. The sand lenses appear to have developed next to the old lake basin and next to the Western Mound (topographic high on bog underlain by a local till mound) and extend southwards into an area of cutover bog. Drainage in the cutaway area has presumably decreased the hydraulic head in the sand lense, which has induced a decrease in water level in peat surrounding the sand lens in the high bog.

Implication and Restoration

External drainage has created an enhanced hydraulic connection between the high bog and regional groundwater flow, resulting in vertical drainage from basal peat in the high bog that leads to peat consolidation and ultimately bog subsidence. It is noteworthy that both peat consolidation and groundwater level decrease have occurred in areas where lacustrine clay is absent and where there are palaeo-channels underlying the high bog. As such, the role of groundwater becomes apparent once the regional groundwater level has dropped. The inference is that maintenance of regional groundwater levels can be a critical support condition in the conservation of raised bog wetlands.

The implication for the design and implementation of measures for restoration of partly cutaway raised bogs is that shallow drain blocking may not be sufficient to arrest differential settlement and the long term decline in the bog surface. Under the WFD, raised bogs in themselves are not considered to be GWDTEs. However, the current study indicates that groundwater may provide a critical ‘support’ function to the sustainability of a raised bog.

The conservation and restoration of Clara bog is therefore intimately related to an understanding of the hydrogeological processes at work, the significance of which has important implications for the status of raised peat bogs under the WFD.

Shane Regan, Trinity College Dublin

The National Parks and Wildlife Service recently opened the Clara Bog Visitors Centre which is staffed seasonally by education guides. Further information is available from claraguides@environ.ie or 057 9368878

Download the NPWS brochure on the bog at http://tcsinfoland.ireland.ie/Content/multimedia/attachments/87315_66676_Clara%20Bog%20A3%20leaflet.pdf
Additional information is also available at www.npws.ie

Assessing the Conservation Status of Turloughs

An improved understanding of turlough ecohydrology is urgently required to meet conservation objectives for this priority groundwater-dependent habitat. This article presents an overview of an interdisciplinary research project commissioned to meet this demand

Project Background

Turloughs are groundwater-dependent wetlands characteristic of karst areas in western Ireland (Figure 1). The key attributes that distinguish turloughs from other wetlands are:

1. a minimum flooding depth of 0.5 m for part of the year,
2. a generally dry floor for part of the year,
3. inflow via springs and/or estavelles and
4. emptying to groundwater with no surface output.

Habitats with these particular characteristics have been reported in Wales (Campbell et al., 1992) and Slovenia (Sheehy Skeffington & Scott, 2008), however the vast majority of this ephemeral wetland type is found in the western region of Ireland (Sheehy Skeffington et al., 2006).

The main legislative drivers of turlough conservation are the EU Habitats Directive (HD; 92/43/EEC) and the EU Water Framework Directive (WFD; 2000/60/EC). Turloughs are classified as priority habitats (Code 3180) under the HD principally owing to their restricted geographical distribution, and many sites are designated as Special Areas of Conservation (SACs). Water-dependent SACs must be incorporated into WFD monitoring programmes. An improved understanding of the ecological requirements of turlough biological communities, and their spatial and temporal variation, is required for categorising the conservation status of the habitat as favourable or unfavourable, for the assessment of significant damage and for the development of suitable monitoring strategies.

Project Scope and Aims

The National Parks and Wildlife Service (NPWS) commissioned this interdisciplinary research project to provide a robust scientific foundation for assessing the conservation status of turloughs. The project began in April 2006 and is nearing completion. The project research team comprises personnel from the School of Natural Sciences and the School of Engineering in Trinity College Dublin. The disciplines included are

Figure 1. View of Blackrock turlough in Co. Galway (July 2007) as floodwaters drain to residual pools

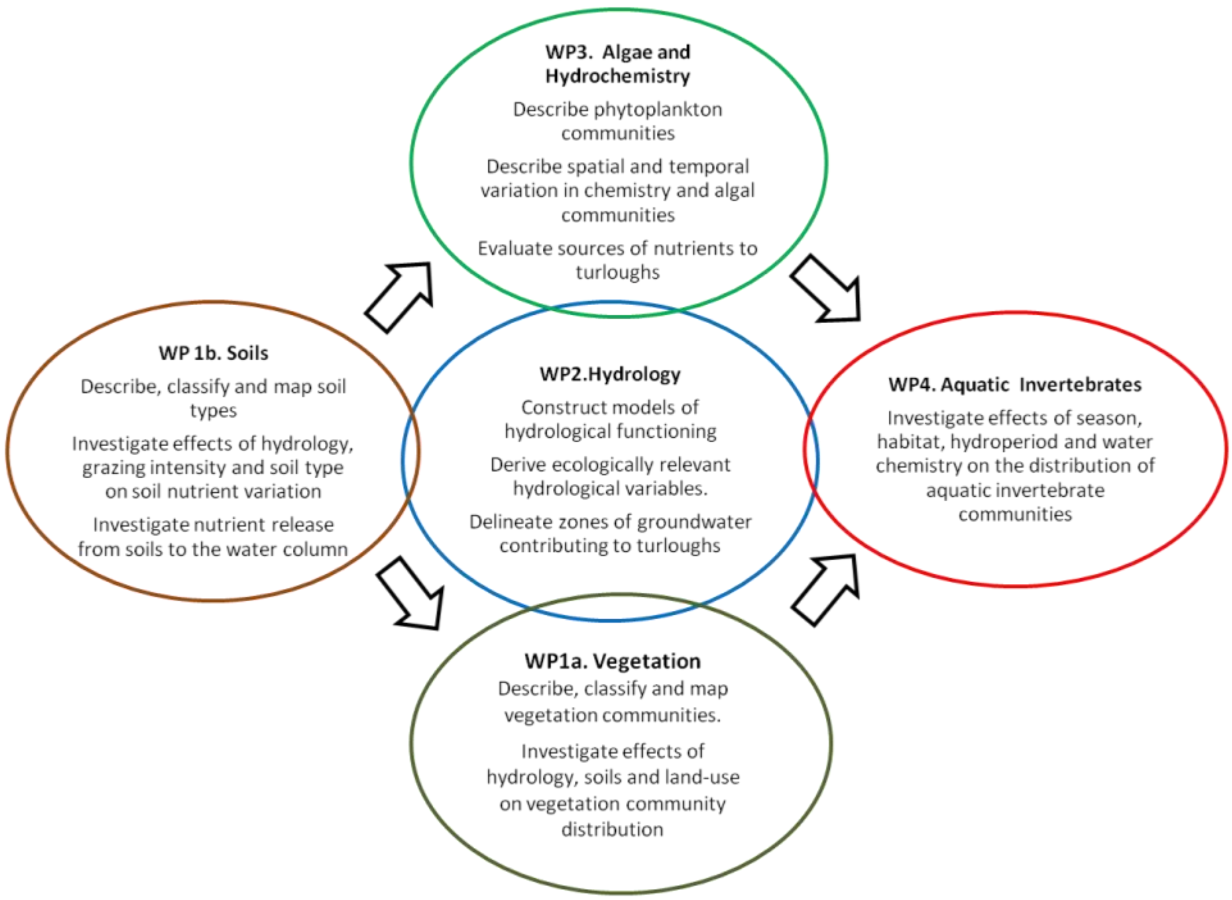

Figure 2. Summary of the project work packages and key tasks. Hydrological information feeds into each of the other work packages reflecting the critical influence of hydrological regime on turlough ecological functioning. Arrows indicate the flow of information associated with work packages 1a, 1b, 3 and 4.

Zoology, Botany, Geology and Environmental Engineering. Figure 2 summarises the project tasks and describes the links between the work packages. The overall project aim is to provide an improved ecological understanding of the main factors and processes affecting turlough biota. This will be used to formulate scientifically sound prescriptions for both monitoring and maintaining the international conservation value of this EU priority habitat.

The steering group for this project is derived from the NPWS, the Environmental Protection Agency and consultant turlough experts, many of whom are members of the Irish WFD groundwater working group (GW-WG).

Study Sites

Twenty-two turloughs were selected for study to represent the geo-hydrological spectrum and geographical range of the habitat (Figure 3). Selection was based on best available hydrological data, founded on the hypothesis that hydrology is the key determinant of the establishment and maintenance of wetland functions.

What have we learned so far?

Integration of work packages is ongoing, however some very interesting outputs have been collated to date. A selection of project findings is presented below.

- Turloughs had similar levels of chlorophyll *a* and nutrients to those reported for Irish and International lakes. Relationships between total phosphorus and chlorophyll *a* indicate P limitation of algal biomass in the majority of turloughs (Cunha Pereira et al., 2010a).
- Fast-growing flagellates and filamentous

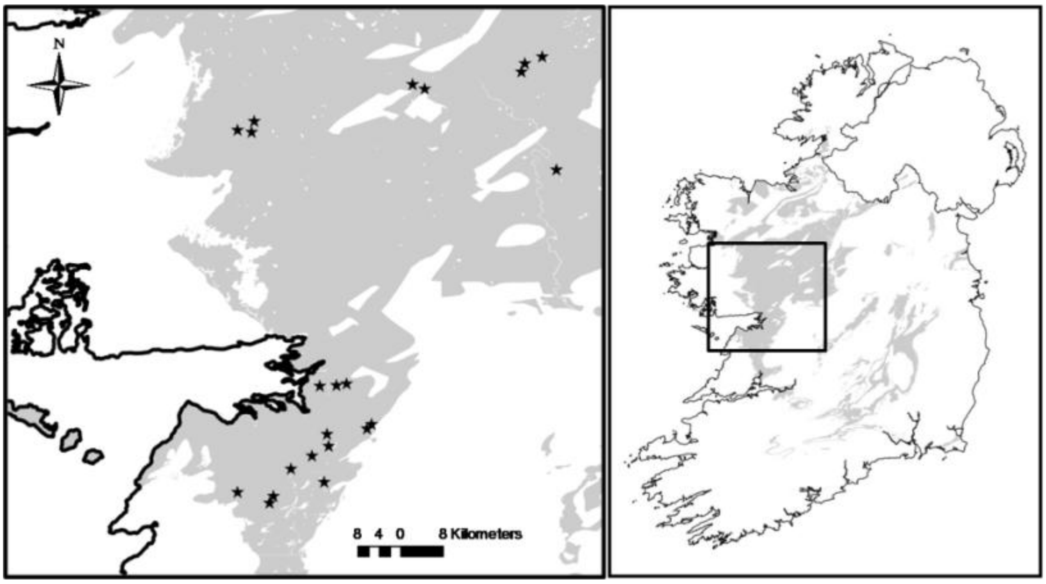

Figure 3. Geographical distribution of the 22 turloughs studied. Shaded areas correspond to areas of pure bedded limestone (geological data from the Geological Survey of Ireland Database: http://www.gsi.ie/Mapping.html)

algae were early floodwater colonisers in turloughs. Algal communities during spring were characteristic of ponds and slow-flowing rivers. Coloured/deep turloughs had very low algal biomass throughout the season and lacked a clear phytoplanktonic succession, with crytophytes and diatoms dominating throughout. These turloughs were not P limited and mean water depth and high water colour are probable factors limiting algal growth (Cunha Pereira et al., 2010b). Turlough macroinvertebrate communities are highly distinct and conducive to simple and cost-effective routine monitoring regimes. A single submerged grassland habitat sample located in any location of a turlough can provide a reliable metric of the macroinvertebrate community (Porst & Irvine, 2009).

- Flood duration and grazing regime were found to underlie a major gradient of soil property variation, the extremes of which were identified as acidic non-calcareous mineral soils and calcareous alkaline soils. Soil organic matter was found to be an efficient predictor of soil total nitrogen (Kimberley et al., 2011 under revision).

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Sarah Kimberley
Post-doctoral researcher, TCD
On behalf of the Turlough Project Team

The Hydrology of Turloughs and Hydro-ecologicial Indicators

Different modelling approaches have been used to successfully model the hydrological responses of turloughs. The models will be useful for flood predictions and understanding their unique flora and fauna

The modelling of underground flows through karst aquifers has received plenty of attention across many regions throughout the world. In general, the studies aim to link a precipitation input to a discrete and measurable outflow from the karst system at a spring. Various conceptual, analytical and numerical approaches have been used to derive such a relationship, from black box models to detailed physically-based models. The west of Ireland provides a different setting for karst hydrogeological studies to many other karst regions however, due to its low-lying nature whereby most of the karst lies at less than 150 m above sea level. For example, the main spring from the south Galway karst network around Gort discharges groundwater slightly below mean sea level at the coast which, critically, means that it is not possible to measure the net flows from the karst network. However, this low-lying landscape does provide unique karstic hydrogeological signatures in the form of fluctuating water levels of intermittently flooded topographic depressions - *turloughs*.

Turloughs are depressions in karst, which are intermittently flooded on an annual cycle via groundwater sources and have substrate and/or ecological communities characteristic of wetlands. Turloughs in Ireland have been the continuing focus of research interest mainly due to the unique flora and fauna in this type of aquatic environment, but also due to the risks of localised flooding. The flooding in turlough basins could occur as a result of several different hydraulic settings and configurations, but for many it is due to insufficient capacity of the underground karst system to take increased flows following excessive precipitation events, causing the conduit-type network to surcharge. Hence, the monitoring of water level fluctuations can be used to elucidate the hydrogeological controls and physical mechanisms forming the hydraulic system beneath the ground. A good example of this type of flooding occurs in the Gort-Ardrahan area of south Galway. This area experienced severe flooding during the winters of 1989-90, 1991, 1994 and 1995, the latter being the most severe. This led to the commissioning of a detailed hydrological study of this karst limestone region. Further flooding, most recently in November 2009, has reiterated the importance of developing a greater understanding of the hydrological processes involved.

The monitoring of the water levels in the turloughs in the low-lying karst near Gort in Galway has been taking place over several years but more recently several more turloughs in Clare, Galway and Roscommon have been added as part of the ongoing multi-disciplinary project entitled the *Conservation Status of Turloughs* funded by the National Parks and Wildlife Service (NPWS), described by Sarah Kimberley in an accompanying article. Three years of water level time series were collected from a range of turloughs chosen to represent the hydrological and ecological diversity of these habitats. The nature of this groundwater flooding shows significant variation, with turloughs exhibiting a range of response and recession characteristics; some having multiple flood events in the course of a year whereas others show a single event with a slow recession, as shown in Figure 1.

Detailed topographic surveys were carried on all the turlough basins, from which digital terrain models were generated (Figure 2). These models were used to transform water level into volume, thus enabling the quantification of turlough flow rates.

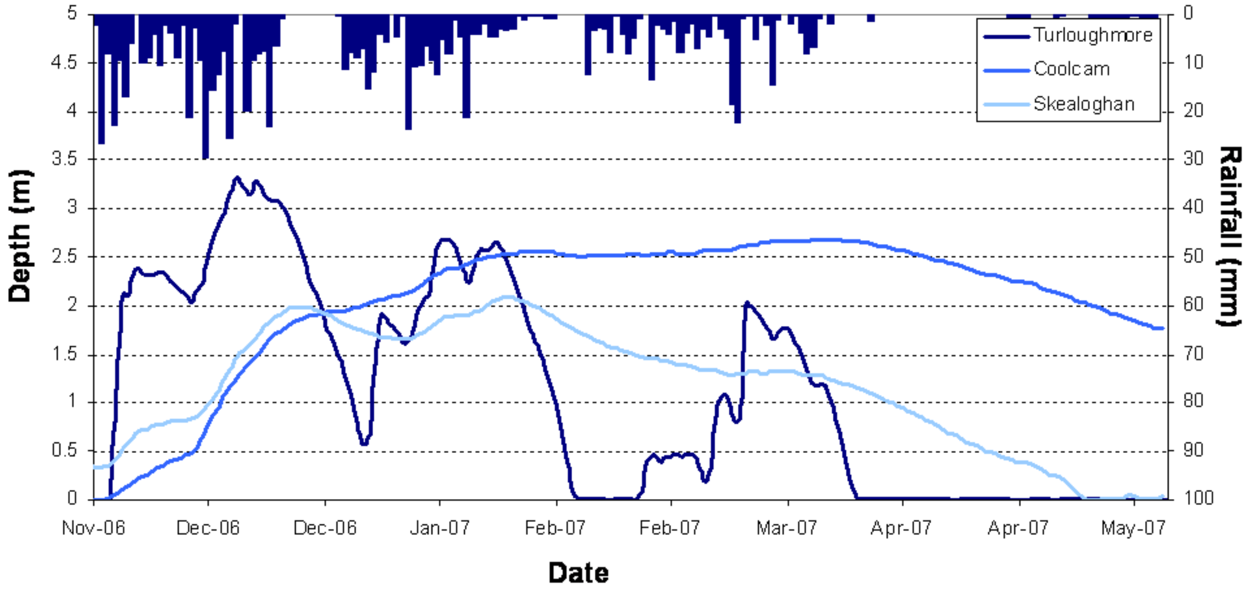


Figure 1. Turlough water levels during the 2006/2007 inundation period for Turloughmore, Skealoghan and Coolcam turloughs

Through the analysis and interpretation of these extensive datasets, a conceptual understanding of the hydrodynamics of these karst systems has been developed. Different mathematical analytical techniques (e.g. autocorrelation, Fourier analysis, wavelets etc) have been used on the water level time series between turloughs to establish the nature of the underground links,

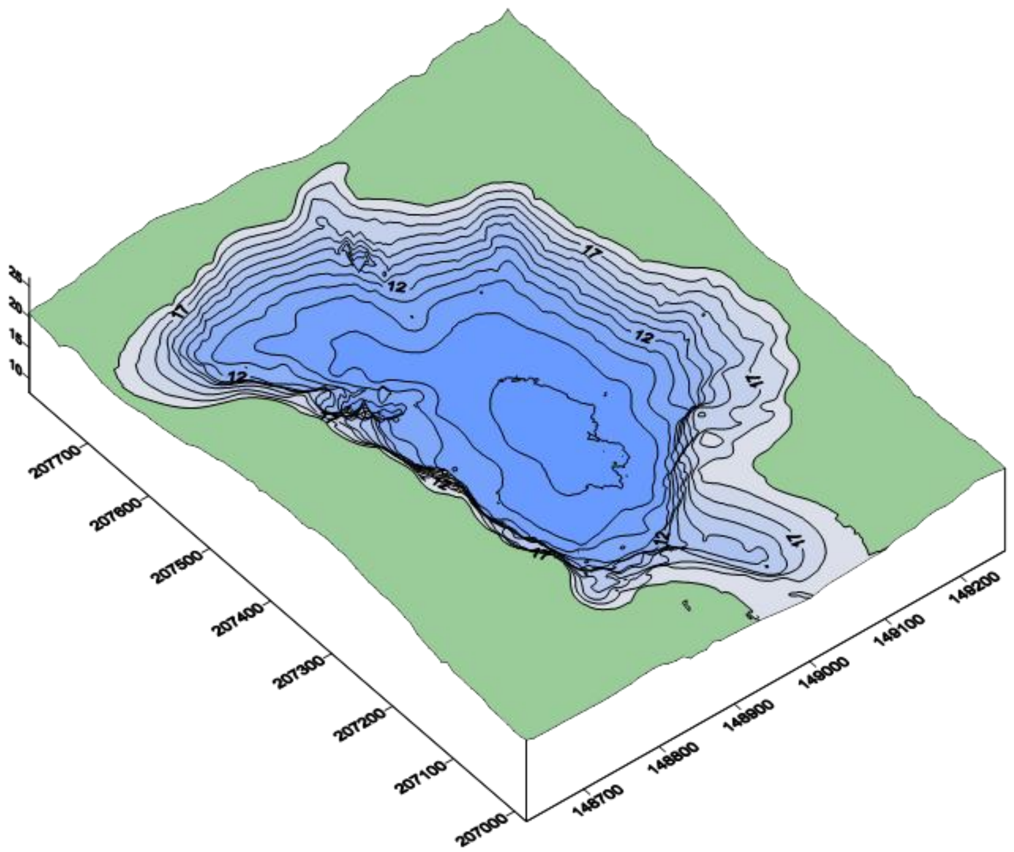


Figure 2. Three-dimensional surface and contour plot of Coy from Surfer®.

as well as tidal influences back on the hydraulic network. Such a tidal influence was clearly picked up, for example, in the case of the south Galway turloughs Caherglassaun, Garryland and Coole.

Calibrated mathematical models of the karst networks have been developed to establish seasonal flooding levels which can be correlated against specific ecology, as well as being a useful tool to predict future flooding levels. From this work, two different approaches have been made to develop mathematical models of the turlough systems: a general modelling methodology applicable to individual turloughs in isolation, and a physically based pipe network model of turloughs in the Gort-Ardrahan chain. In the first approach, two general models for predicting turlough water level from rainfall and evapotranspiration records have been developed. The first model uses an empirical model to estimate turlough volumes and water levels utilising aggregated rainfall over a defined interval (Figure 3). This technique produced characteristic hydrological parameters and was applied to all monitored turloughs in the NPWS project. The second model also predicts volume using rainfall as input, but utilises a more refined version of the reservoir modelling technique. The basis of this approach was the identification of characteristic equations governing turlough inflow and outflow based upon rainfall and stage respectively (Figure 4). This method was utilised for a subset of turlough sites. The models produce satisfactory results with practicable data requirements and are readily applicable to new sites using well defined field investigation and modelling procedures.

The second modelling approach has been more physically based, whereby the karst network has been developed using a pipe network model with the turloughs represented as engineered "ponds". The contribution to the karst network from diffuse flow through the epikarst via the matrix and fracture flow has also been modelled using a combination of a groundwater infiltration module and network of permeable pipes in series. This has been applied to the turloughs which are thought to be connected together in a linked conduit drainage network in the Gort lowlands, which receive a significant

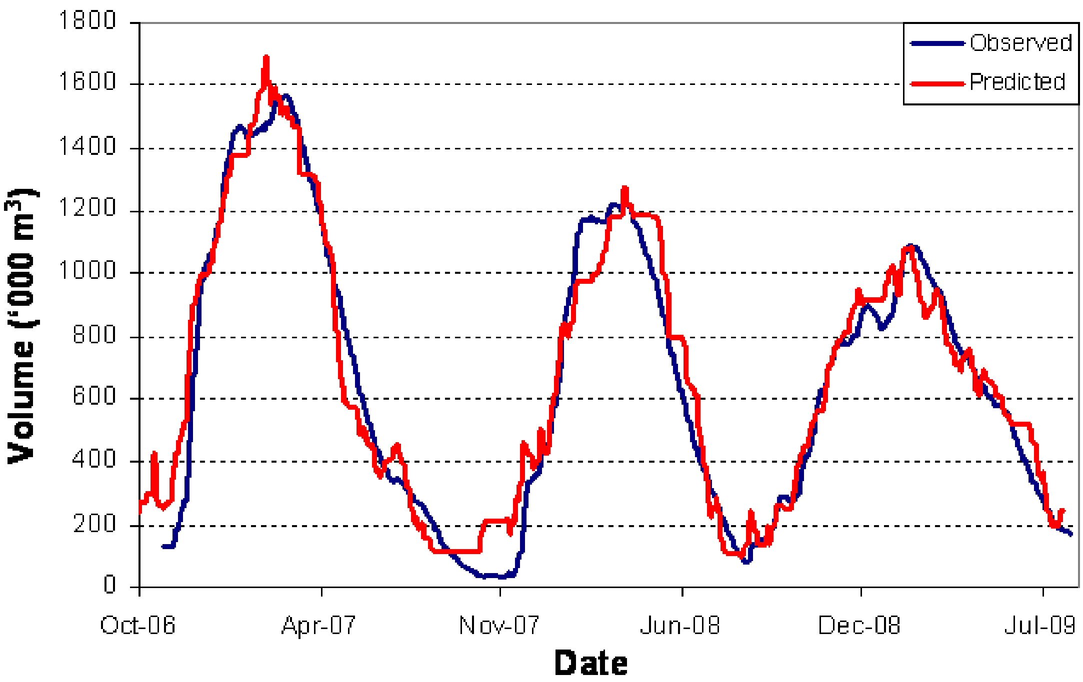


Figure 3. Aggregated rainfall model results for Coolcam turlough, Co. Galway

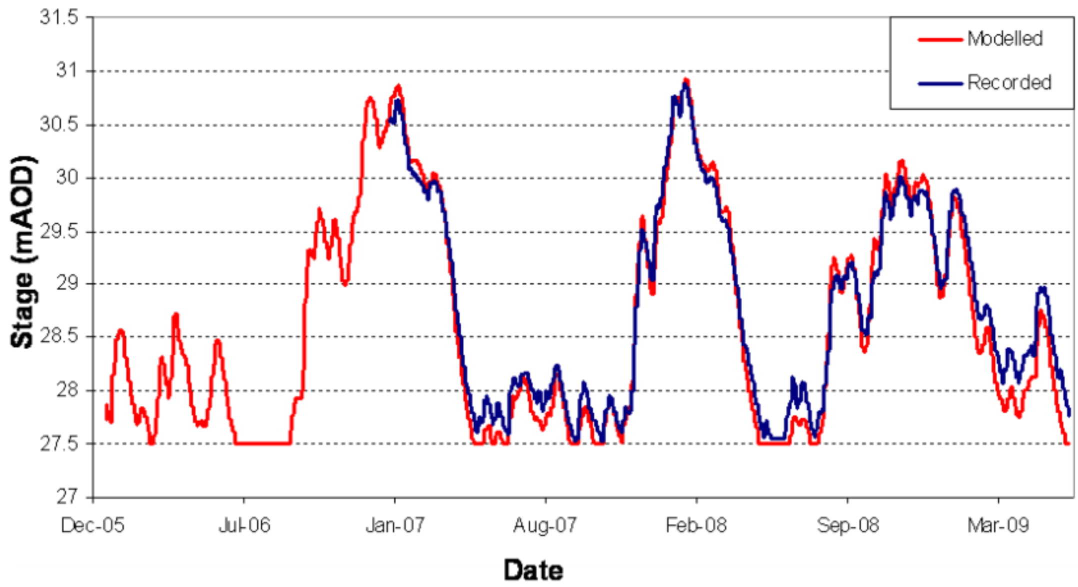
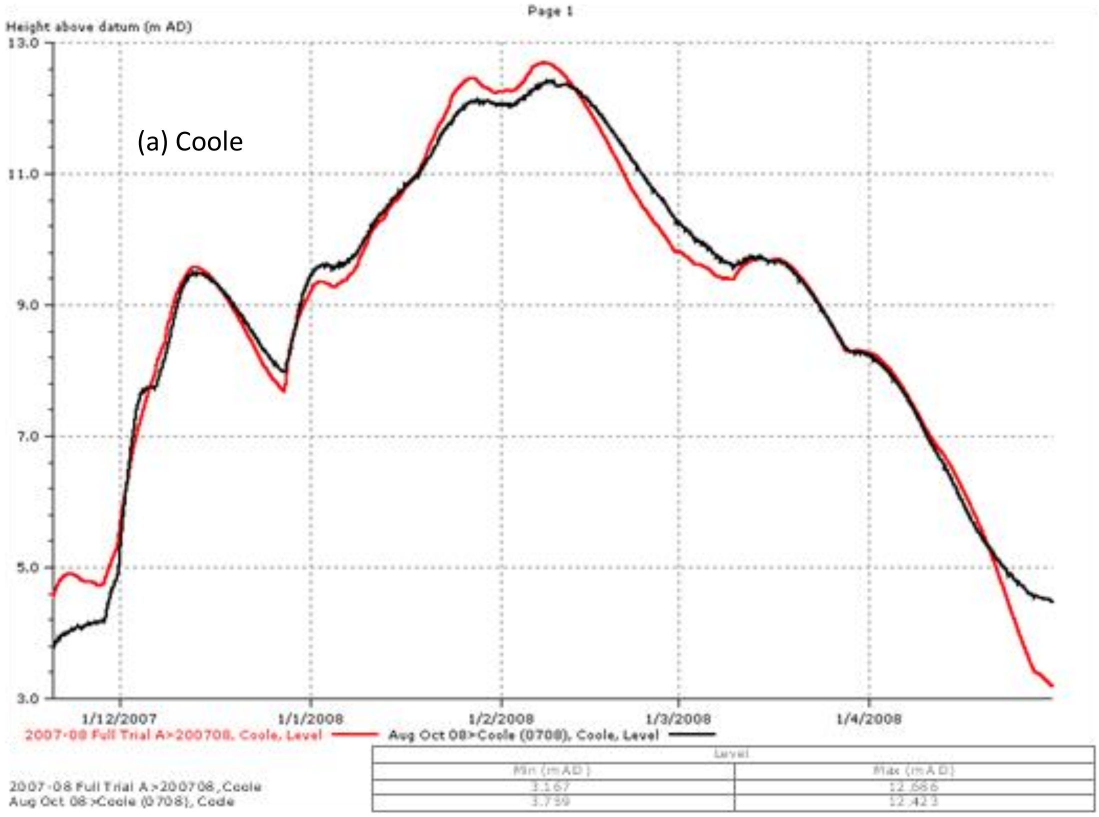


Figure 4. Recorded and modelled stage for Lough Gealain, Co. Clare using refined reservoir modelling.

part of their flow from the rivers draining off the Old Red Sandstone Slieve Aughty mountains that disappear underground when reaching the karst bedrock. This model has been calibrated against the continuous water level measurement in five turloughs (Blackrock, Coy, Coole, Garryland and Caherglassaun). A second rainfall-runoff model has also been developed to generate the flows draining off the Old Red Sandstone mountains down into the karst underground network for use in periods when river flow records are not available. This modelling approach has equally been able to simulate the observed levels well in the network of turloughs, as shown in Figure 5. Finally, measurements of relevant hydrological parameters have been used to describe quantitatively the behaviour of turloughs and the development of characteristic eco-hydrological indicators for use in the conservation of these protected groundwater dependent ecosystems.

Turloughs provide a habitat for many protected flora and fauna species and are designated a Priority Habitat in Annex 1 of the EU Habitats Directive (92/43/EEC). Hydrology is the primary driver of these unique ecosystems, and a better understanding of the flooding regime is therefore required for their future sustainability and conservation. Equally, under the Water Framework Directive (WFD) turloughs are designated as Groundwater Dependent Terrestrial Ecosystems (GWDTE). Indeed, the *Conservation Status of Turloughs* project was set up by the NPWS in order to provide a more comprehensive understanding of the pressures on these ecosystems, integrating the hydrology with land-use and catchment management. These hydrological studies and models have thus enabled hydro-ecological indicators to be defined and quantified for use against the ecological data collected in the turloughs. A number of indicators have been derived from water level, volume and area time series, while others emerged from the digital terrain and hydrological modelling processes. These include elevation, flood duration, hydroperiod, flood frequency, wet/dry periods, areal reduction rate and flood velocity. Work is currently ongoing comparing these indicators against the data from the parallel vegetation mapping and invertebrate sampling studies as part of the *Conservation Status of Turloughs* project to provide an integrated summary of the turlough hydro-ecology.

Laurence Gill, Paul Johnston and Owen Naughton, Trinity College Dublin



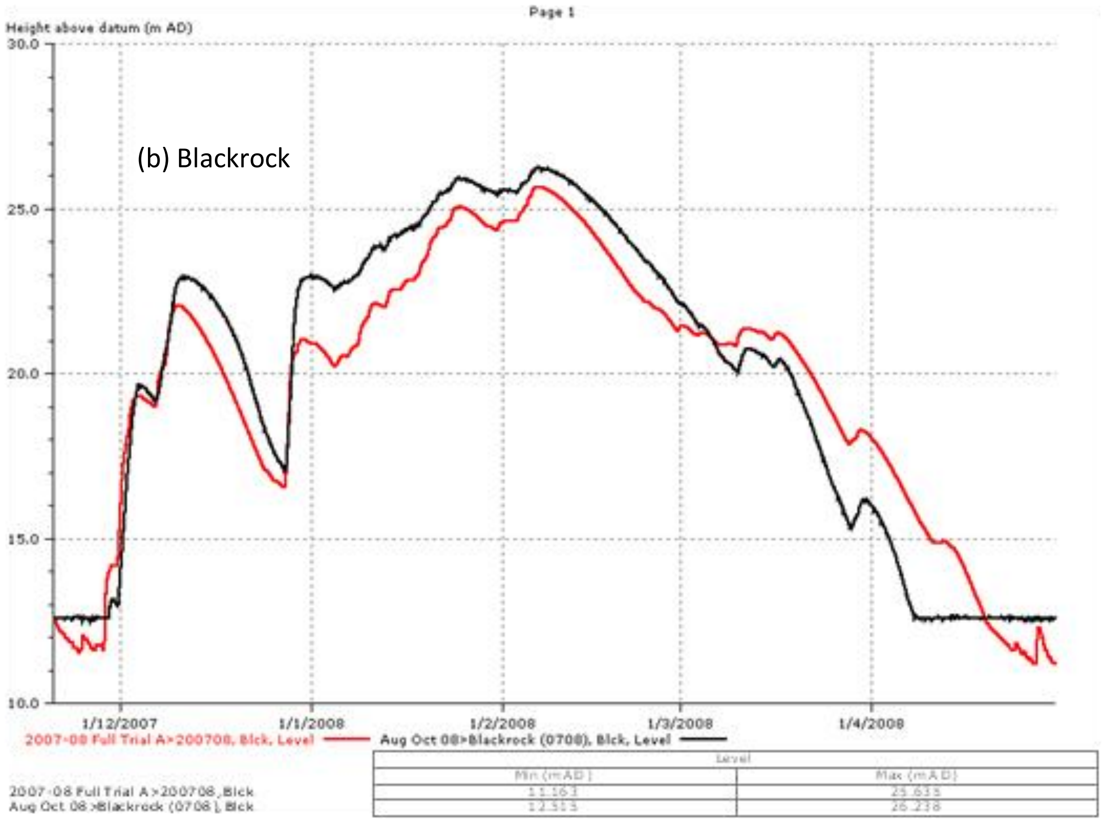


Figure 5. Results from model calibration (2007/08) karst network model. (a) Coole; (b) Blackrock.

A Geophysical Survey at Blackrock Turlough, Peterswell, Co. Galway

Using geophysics and geology to understand the conduit network beneath one of the turloughs studied as part of the Turloughs Project

Introduction

A geophysical survey was carried out in June 2010 in Blackrock Turlough, Peterswell, Co. Galway to investigate the geology beneath the turlough. Blackrock Turlough is located just off the N66, between Gort and Craughwell, at the foot of Slieve Aughty (Figure 1), 4 km southeast of Ardrahan and 6 km northeast of Gort. The turlough is approximately 550 m wide and 830 m long. It lies within the Gort-Ardrahan catchment area. At the time of surveying the turlough was completely dry (Figure 2).

In the Gort-Ardrahan catchment area, the groundwater flow is to the west, entering the sea at Kinvara, Aughinish Bay, Bell harbour and Ballyvaughan Bay. Typical winter rainfall conditions result in the karst system in the catchment area becoming saturated. The gradient of groundwater flow is low and the turloughs in the area act as large reservoirs which provide temporary storage to enable the transmission of the large volumes of water in the system to the sea (Figure 3).

Geological background

The Geological Survey of Ireland bedrock geology map for the area indicates that the

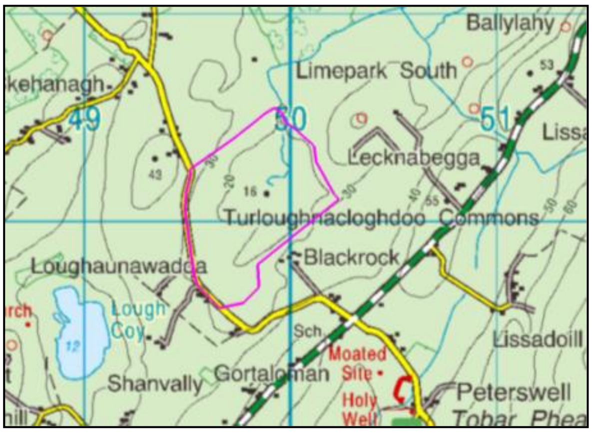


Figure 1. Blackrock turlough (outlined in magenta)

Figure 2. Dry turlough conditions June 2010 (King, 2010)

Figure 3. Water levels in September 2010 (King, 2010)

bedrock in the vicinity of the turlough is dominated by three members of the Tubber Formation limestones (Figure 4). North of the turlough, the bedrock comprises the Castlequarter Member: monotonous, light to medium grey, shelf limestone. South of the turlough, the bedrock comprises the Fiddaun Member: medium grey, clean, bioclastic limestones, dolomitised in parts. The majority of the turlough area lies within the Newtown Member which comprises cherty calcisiltites, micrites and fine-grained calcarenites (GSI, 2004). The chert horizons within the Newtown Member are evident in outcropping rock in the southwest of the turlough (Figure 5). The strike of the geological formations is NE-SW and the geological map indicates that the bedrock

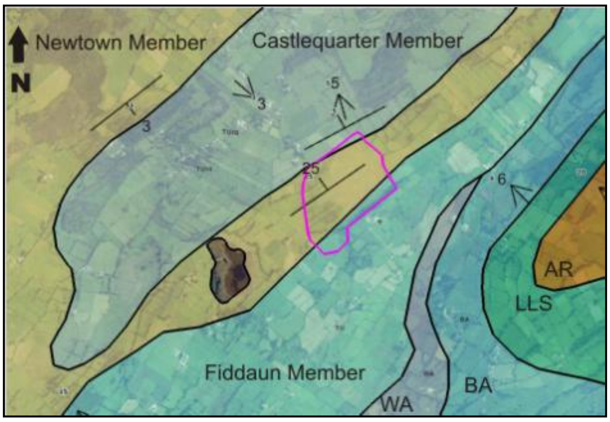


Figure 4. Geological setting (GSI, 2004). WA: Waulsortian Limestone, BA: Ballysteen Limestone, LLS: Lower Limestone Shale, AR: Ayle River Formation

underlying the turlough is dipping at an angle of 25° to the northwest. The Geological Survey of Ireland karst map indicates many karst features located within the Newtown and Fiddaun Members (predominantly turloughs, swallow holes, enclosed depressions and springs in the vicinity of Peterswell), very few within the Castlequarter member and none within the Waulsortian or Ballysteen Limestones which lie to the south of the Tubber Formation. Features evident across Blackrock turlough include surface depressions, a number of swallow holes and a dry river channel scar in the northeast (Figure 6) along which the turlough is fed by the Owenshree River and its tributaries which drain westward from the Slieve Aughty uplands. The water from the turlough drains to the southwest where it fills Lough Coy, a turlough located 0.5 km to the southwest, which subsequently drains to the Ballylee River further to the southwest.

Figure 5. Swallow hole and outcropping limestone

Figure 6. Dry river channel scar

Geophysical survey

The geophysical survey consisted of 2D resistivity profiling and was carried out using an IRIS Syscal Pro Resistivity system. In total, 6 x 470 m resistivity profiles were recorded, running NW-SE at intervals of 50 m and 100 m across the floor of the turlough (Figure 7). The profiles ran perpendicular to strike to maximise the contrasts

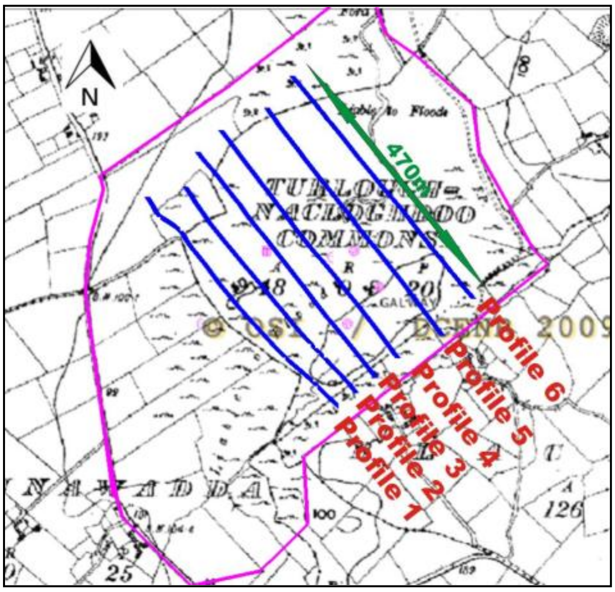


Figure 7. Profile locations (blue lines). Turlough outlined in magenta.

visible within the data. The profiles were recorded using 10 m electrode separations which allowed depths of investigations up to 100 m below ground level. Profiles were recorded using Dipole-Dipole, Wenner & Schlumberger arrays. Each array type records the resistivity values using differing electrode combinations. The data presented in this article have been recorded using the Wenner array. Data were inverted using Res2dinv software (Version 3.59, 2010), with convergence after five iterations with a maximum RMS error of 2.6.

Topographic survey

A topographic survey was also conducted during the geophysical survey. The contoured topography data is plotted in Figure 8. The surveyed elevations range from 11.29 m OD to 36.27 m OD. The topography contours indicate that the base of the turlough is broad and flat. The topography rises very steeply in the south, is slightly more gradual in the east and north, and rises relatively gently in the west of the turlough. The NE–SW trending elevated ridges along the bottom of the turlough are indicative of outcropping/ subcropping limestone bedrock.

During the flood events in the winter of 1994/95 and in November 2009 (Figure 9), the level of the water rose above the level of the road

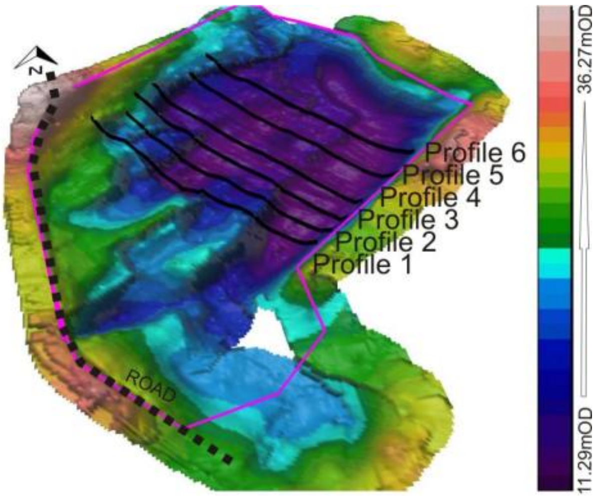


Figure 8. Topography contours. Vertical exaggeration x 3.

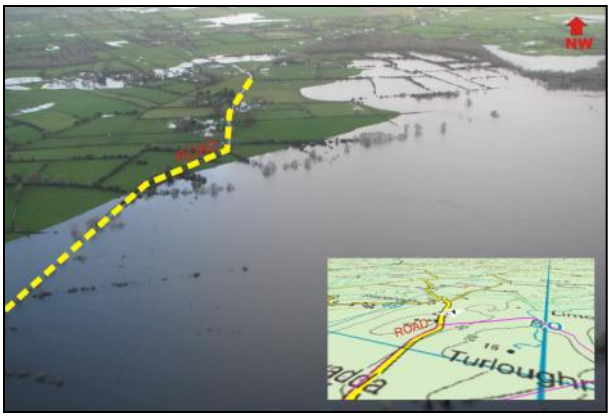


Figure 9. Flooding Event 2009. Road at perimeter of turlough highlighted in yellow (OPW, 2009). Insert – OS map.

which runs along the western perimeter of the turlough (approx 29 to 30 m OD). This would amount to an estimated 5.7 million cubic metres at the maximum level of the flooding (King, 2010).

Geophysical data

Major changes in subsurface resistivity are evident across the resistivity profiles. Figure 10 shows three parallel profiles running in a SE-NW direction. The upper 10 m to 15 m comprises predominantly low resistivity material (75–400 Ohm-m, blue tones in Figures 10 and 11) which thickens to approximately 35 m to the northwest of Profiles 3, 4 and 5. These low values may indicate highly weathered/karstified limestone with water and/or clay infill. There are fewer near surface low resistivity values on Profile 1 to the southwest. This profile is slightly more elevated and lies adjacent to outcropping/ subcropping limestone, suggesting that the underlying limestone to the southwest is less weathered/karstified in the upper 10 m to 15 m. Intermediate resistivity values (400–1200 Ohm-m) may indicate weathered/karstified limestone. The higher resistivity values (>1200 Ohm-m) can be interpreted as indicating unweathered limestone bedrock.

The resistivity values in conjunction with the geological data suggest two limestone lithologies that are represented by resistivity values of 1200

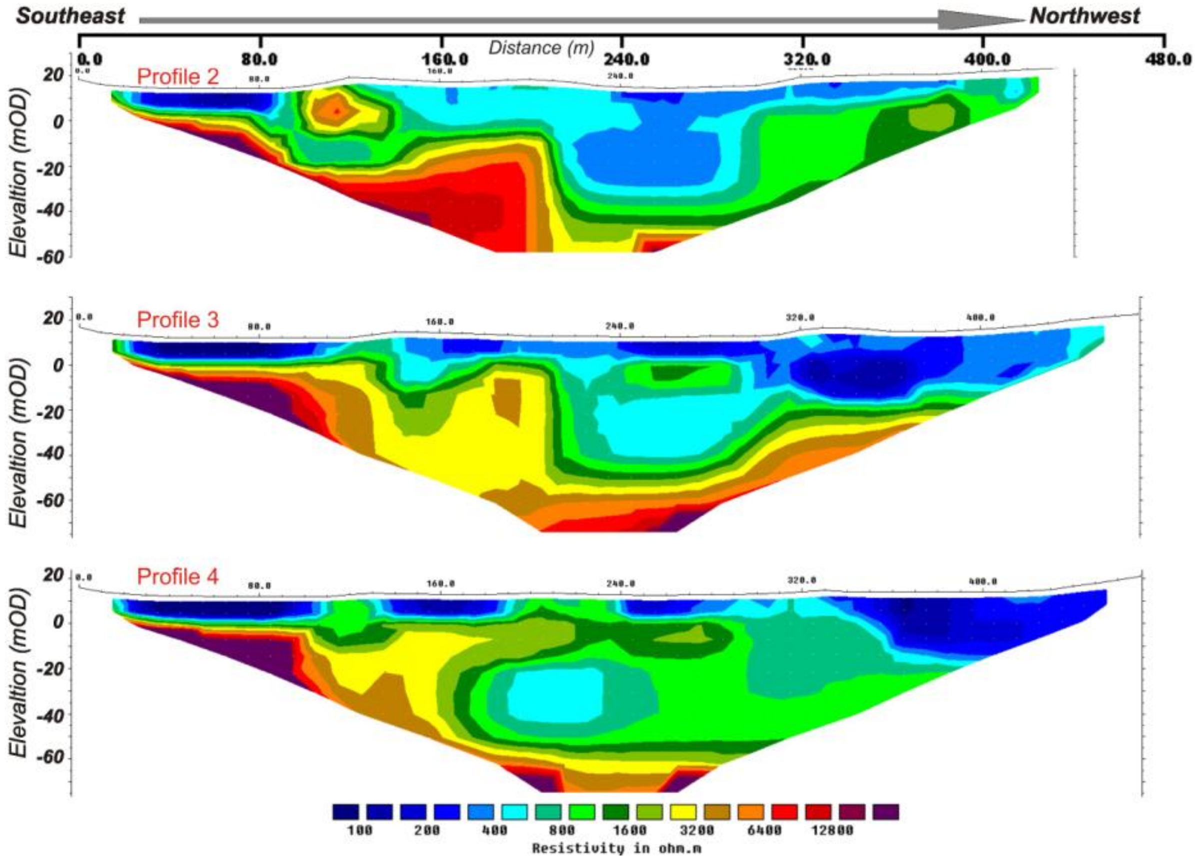


Figure 10. 2D Resistivity profiles 2, 3 and 4.

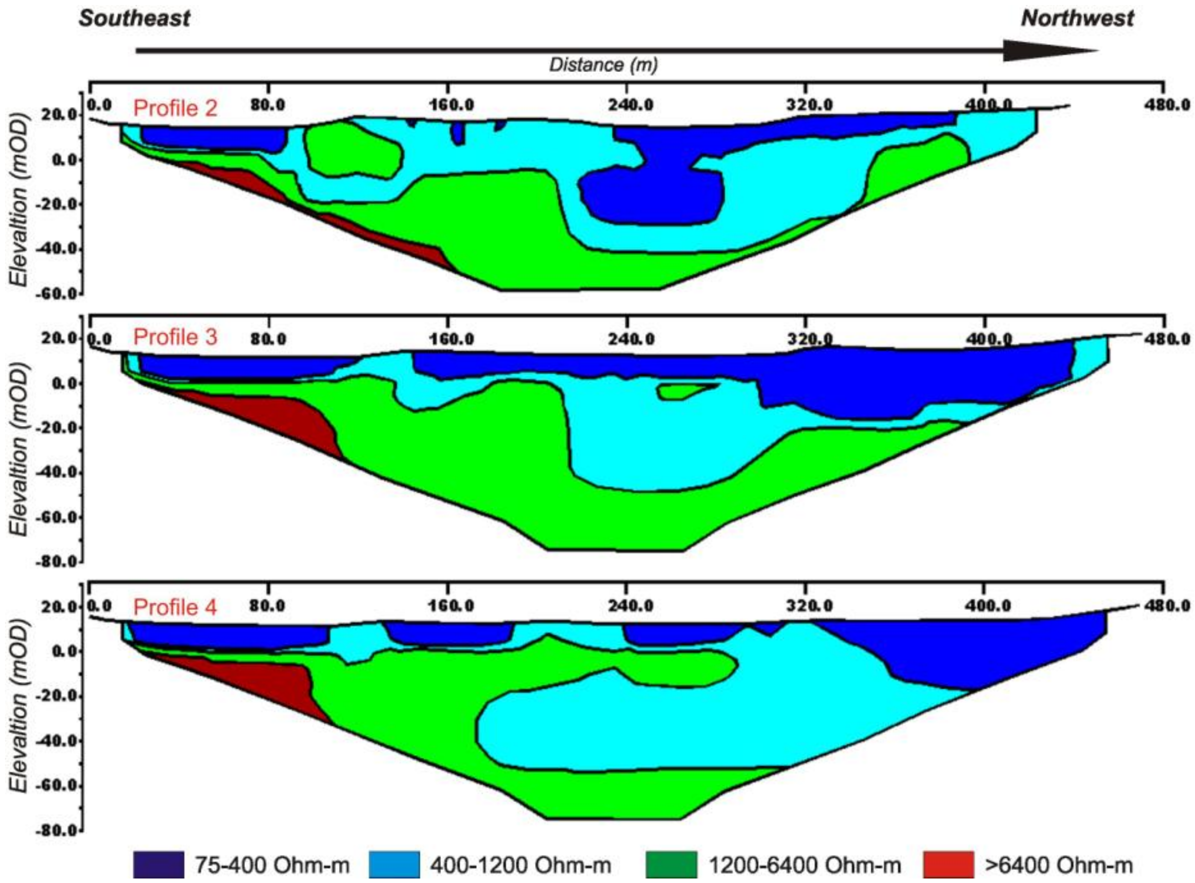


Figure 11. Resistivity variations across 2D Resistivity profiles 2, 3 and 4.

to 6400 Ohm-m and >6400 Ohm-m. All profiles record the higher resistivity bedrock (>6400 Ohm-m) coming to the surface in the southeast (Figures 10 and 11). This change in lithology is in line with the mapped change from Newtown Member to Fiddaun Member and with a sharp increase in elevation in the southeast.

Summary

Looking at the interpretation as a whole, there appears to be two near-surface channels of highly karstified limestone; a 100 to 150 m wide channel to the northwest and a slightly narrower (70 to 90 m wide) channel to the southeast (Figure 12). There is also a deep conduit/ karstified zone to depths of –40 to –50 m OD (i.e. 50 m to 60 m below ground level) running in a meandering NE–SW direction (Figure 12) draining the turlough to the southwest. The depth of the conduit is below sea level, which getting closer to the coast may have implications for freshwater-saltwater interactions across the coastal zone.

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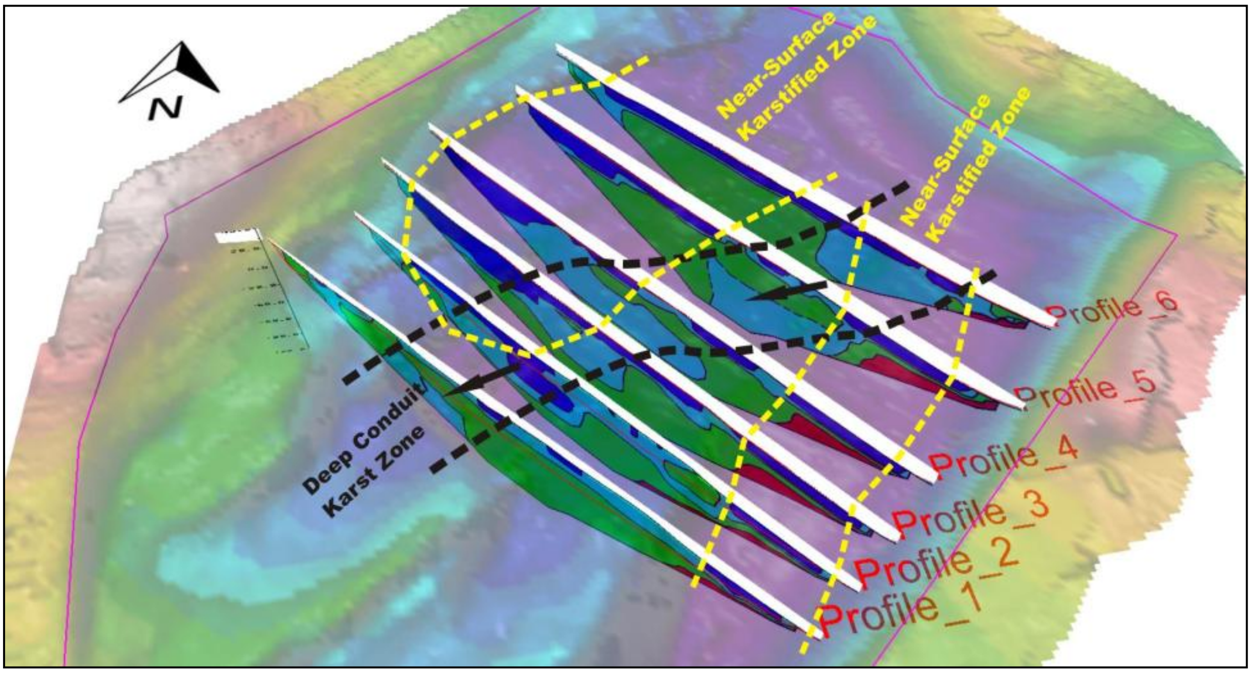

Figure 12. Conduit Interpretation; shallow karst zones indicated by dashed yellow lines and deep conduit/ karst zone indicated by dashed black lines.

A hydrogeological study of elevated ammonia levels in Lough Owel

A range of assessment techniques were used to determine that ammonia (from biological fixation and agricultural sources) is delivered to Lough Owel via surface runoff and rapid karst groundwater flow

Introduction

Lough Owel, at Mullingar, is a spring-fed lake with a relatively small catchment area. Land use around the lake is highly controlled with regular inspection and monitoring. The lake, a protected area, is a principal source of drinking water for Co. Westmeath. The lake has shown some deterioration in water quality from 2006 to 2009 when it was below its original oligotrophic status.

A study was undertaken in conjunction with Westmeath County Council, with assistance from the Geological Survey of Ireland, and focussed on recently observed elevated ammonia concentrations to the east of the lake.

Study Objectives and Methodology

The study was initiated with a view to protecting what is a valuable regional potable water resource. It was also driven by the need to ensure that surface waters and groundwaters are managed together, as directed by the Water Framework Directive (2000/60/EC). The overall objective was to contribute to understanding the source of the ammonia and its transport pathways to Lough Owel. The study essentially focused on the eastern extent of the lake where it is thought that the Derravaragh Chert Formation, a karstified limestone which abuts and underlies the lake, was contributing to the problem. Figure 1 outlines the study area (approx. 20 km²), the principal monitoring points used and delineation of the karstified limestone.

Mapping of the piezometric surfaces and karst features was carried out to understand the underground connections and assess whether the groundwater divide coincides with the surface water divide in the part of the catchment underlain by the Derravaragh Chert.

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Figure 1. Study area and focal points

Furthermore, groundwater samples were taken from springs, wells and boreholes and various hydrochemical analyses were carried out, including for agricultural contamination indicators such as chloride, potassium and coliforms (faecal and total), to achieve the primary objective of the study. Assessment was carried out within a 'source-pathway-receptor' model so as to assist in determining the correspondence of observed pollution, if any, with the potential sources of that pollution.

The research methodology also included the spatial-temporal analysis of subsurface temperature and electrical conductivity profiles along inferred flow paths. This assisted in determining groundwater flow patterns near the lake, identifying potential flow zones with depth and therefore potential replenishment zones within the aquifer.

As Lough Owel is thought to be influenced by its position within the regional groundwater flow system, it was also decided to conduct a surface water temperature profile along the eastern extent of the lake. Lower temperature readings highlighted areas of potential groundwater upwellings in the lake (e.g, the Portnashangan area) that should be targeted for further sampling.

Main Findings and Recommendations

The study area was perceived as part of a fractured and karstic hydrogeological system with subterranean connectivity to the lake.

Groundwater contours constructed from available data indicated that the groundwater divide generally coincides with the surface water divide as envisaged. Groundwater flow paths were interpreted and aided by identification of major flow zones with depth. Groundwater flow tends to be SW to Lough Owel and NE to the River Gaine, with local flow directions also observed. This is presented in Figure 2.

To further understand groundwater movement, bulk transmissivities (T) were estimtated for the western section of the study area. Groundwater through-flow assessments gave a T value of 178 m^2/d within the karstified limestone near Portnashangan. Sensitivity analysis carried out to include for the effects of low permeabilty soil cover (e.g. hard clays locally referred to as 'lack') resulted in a lower T estimate of 160 m^2/d, based on reduced recharge amounts.

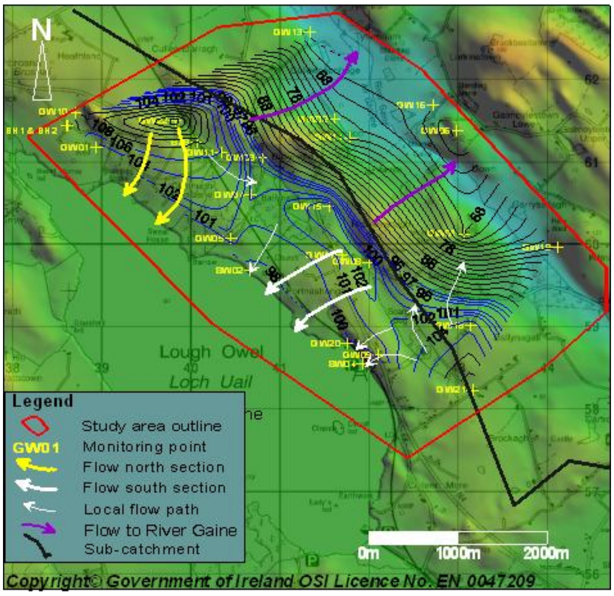

Figure 2. Groundwater contouring

Geological field assessments indicated secondary porosity/permeability aquifer characteristics (e.g. fractures) and therefore possible short-term responses to rainfall. Generally short underground residence times and lack of filtration within the fractured and karstified aquifer also means that groundwater in the study area is probably prone to pulses of contamination; this was observed during the study.

In terms of hydrochemistry, analyses essentially showed no evolution of groundwaters with distance. Calcium-bicarbonate is the main water signature, as may be expected. At Lough Owel, dissolved oxygen levels measured indicate some reducing conditions. With this in mind, it was concluded (from the investigation of two inferred flow paths from a recharge area to a discharge area) that redox conditions have a prominent role in the transport of ammonia.

Temporal and spatial assessments of agricultural indicator species (including nitrate and ammonia) were undertaken from May to August, 2009. Elevated nitrate and ammonia concentrations (max observed 1.65 mg/l NH_3-N in groundwaters at Portnashangan) do not always signify that anthropogenic pollution is taking place. However, field evidence suggested that agricultural practices are a source of diffuse contaminant loading.

In summary, ammonia contamination can be persistent at Lough Owel due to a combination of biological fixation and physical influences (such as surface run-off over low permeability soils and soils impacted by grazing animals). In addition, quick through-flow in the aquifer has the potential to both transmit and dilute contaminants, and possibly impact the lake bottom. Where animal urea, intermittent land spreading and artificial fertilizer use are considered the main potential sources of ammonia, then applicable recommendations were proposed.

These included:

- Future research on field potential with the estimation and analysis of soil hydraulic properties through infiltration testing;
- Assessment of run-off potential around the lake, to include in-depth survey of N-fertilizer and slurry/soiled water application time/rate;
- Use of methods for identifying groundwater origin (tracer use and isotopes in particular) is required to more accurately determine contaminant fate and transport including the potential source of groundwater upwelling in the lake.

Finally, the study showed that further groundwater pressure assessment is suggested vis-à-vis agrichemical usage around the lake. Delineation of areas around the perimeter of Lough Owel that are vulnerable to groundwater contamination is also recommended.

Summary of an MSc thesis (2009), 'Hydrogeological Investigation into Elevated Ammonia Concentrations in Lough Owel, Co. Westmeath' in conjunction with Westmeath Co. Co. and the GSI. (Research findings presented do not necessarily reflect the opinions of the respective organisations).

Pat A. Groves, ex-Cardiff University (2009)
Currently with White Young Green

What's New in Hydrogeology?

So what is new in hydrogeology then? I recently attended a half day poster conference in the Earth Sciences Department in Birmingham University to find out, and I must say it was fascinating. Amongst a wide array of current research topics, some of the wilder, and potentially more interesting topics from an Irish perspective, that caught my eye included:

- using bacteria to create low permeability barriers to reduce GW contaminant migration (Mark Cuthbert, Birmingham University);
- advances in identifying the groundwater requirements of groundwater dependent terrestrial ecosystems (Gareth Farr, Environment Agency);
- assessing the mobility of nanoparticles, a future class of contaminant found in a wide range of applications including anti-bacterial agents in socks (Bryony Anderson, Birmingham University); and
- using borehole water level responses to barometric pressure fluctuations as an indicator of aquifer vulnerability (Mahmoud El Araby Hussein, University of Leeds – the winning poster).

The conference was jointly hosted by the Hydrogeological Group of the Geological Society, the IAH, and the Water Sciences Group in Birmingham University. This year, most of the UK universities with hydrogeology courses were represented, as well as the Environment Agency and industry.

Participants have one powerpoint slide each to verbally introduce their poster and then the focus of the conference is looking at the posters and talking informally to authors. The afternoon wrapped up with wine, a prize giving ceremony, and a few drinks afterwards, followed by a curry for those that could stay on. All in all, it was an excellent way to become more acquainted with our UK colleagues and what they are up to. It is easy and relatively cheap to get to, and it certainly gets the creative brain cells going. Highly recommended!

Copies of the posters will be available on the Hydrogeological Group's website at: http://www.geolsoc.org.uk/gsl/groups/specialist/hydro/page9866.html

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GSI/EPA Aquifer and subsoils parameters database

Preliminary results and observations from the development of a Geological Survey of Ireland / Environmental Protection Agency database of hydrogeological parameters of aquifers and subsoils

Background

The EPA requires a significant number of licensees/permit holders, as part of their licence requirements, to carry out hydrogeological assessment of their sites. Such assessments often involve the undertaking of hydrogeological modelling to predict potential impacts. In many cases, site specific aquifer parameters are not available or are not suitable for modelling, and reasonable or 'best guess' default parameters are assumed for an aquifer. In many cases the values entered may not be appropriate to Irish conditions. Forde Consulting Group (2010) indicated in a briefing document for the EPA that an 'aquifer properties manual' specific to Ireland would be useful. Such a manual would facilitate quantitative groundwater risk assessments and provide surrogates where site-specific data cannot be obtained. Typical parameter values and ranges are presented for aquifer categories and rock unit groups.

Aquifer classifications are a critical component of Groundwater Protection Schemes (DoELG, EPA, GSI, 1999) and were determined by several criteria including hydrogeological data. However, a general lack of good hydrogeological data led the Groundwater section of the GSI to produce an aquifer productivity index based on plots of Specific Capacity (SC) against Pumping rate (Q) (Wright, 1997), termed 'QSC' graphs, to assist in the determination of aquifer classifications. Wright's original QSC plot is given in Figure 1.

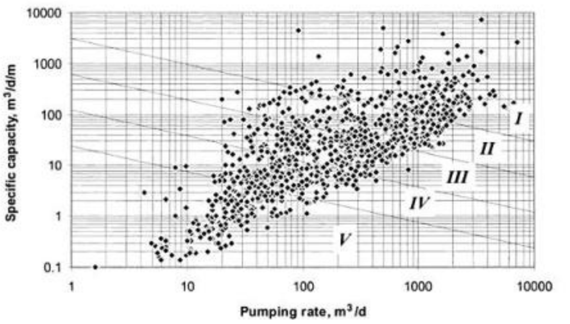

Figure 1. QSC graph for full dataset (c. 1100 bore-holes), showing productivity classes I, II, III, IV and V (Wright, 1997)

This project aims to build on this work as there are more pumping test data available since the 1990s. The database is termed the 'GSI/EPA Aquifer and Subsoils Parameters Database', because subsoils apart from the gravels are not considered to be an aquifer in Ireland. Therefore the distinction is made that there is a separate resource for the subsoils.

Database Sources and Structure

A large, representative and reliable parameters database is required to take account of the: nine aquifer categories; twenty seven rock unit groups; aquifer heterogeneity; main pathways (transition, shallow bedrock and deep bedrock; Groundwater Working Group); and, scale.

The data sources include:

- Reports databases at GSI (Groundwater, Geotech), EMD, EPA, and other agencies (Teagasc);
- Hydraulic (pumping test, falling head tests) data from consultants; and,
- International references.

A literature review of other national databases was conducted to research which aquifer properties were represented and how. The aquifer database structure draws on the Scottish EPA database (Ball *et al*, 2006), which in turn is based primarily on the BGS aquifer properties manual for England and Wales (Gale *et al,* 2006). The database is simply an Excel sheet comprising a record per borehole or spring or interval and each record includes information on the following:

- location, grid reference, waste licence no., GSI well no., EPA monitoring code, drinking water code, six inch sheet;
- geology, water strikes, pathway – transition, shallow or deep, elevation, depth;
- construction – grouted, interval zone / depth;
- hydraulic data;
- water level, gradient; and,
- relevant comments, source reference.

The hydraulic data includes information on:

- specific capacity;
- transmissivity;
- hydraulic conductivity;
- storativity, specific yield, porosity (effective), gradient;
- subsoils – where available bulk density, organic carbon content, cation exchange capacity.

In addition to the database, a summary table is being provided which will include a credible upper and lower value, and a 'best estimate' – representing the aquifer and rock unit group as a whole, for transmissivity, hydraulic conductivity and effective porosity. The purpose of a summary table is to provide sensible values for aquifer parameters that can be referred to and used for quantitative risk assessments. It comprises a matrix of aquifer parameters values for rock unit groups against aquifer category.

Inevitably there are gaps (no data or too few data for several rock unit groups). This is particularly the case for rock unit groups that occupy a small portion of the country, for example the Permo-Triassic Mudstone and Gypsum group. The summary table will include appropriate surrogate values from the most relevant international datasets and literature.

The database and summary table will be accompanied by a report and guidance document that:

- explains the summary table, the database structure and fields;
- facilitates informed decisions on the appropriate values to use;
- includes definitions of parameters;
- provides information for a particular rock unit group and aquifer type;
- outlines property inter-relationships, for instance specific capacity and transmissivity;
- explains the regional differences in hydraulic properties, for example of the Waulsortian (Dinantian Pure Unbedded Limestones); and,
- includes frequency plots for the aquifer categories and rock unit groups.

Preliminary Results

Much of the work to date has focussed on the bedrock aquifers and rock unit groups. Currently, there are several hundred records in the database, which is still being populated. The data comprise a mixture of pumping tests and smaller scale hydraulic tests such as rising head tests. There is a correlation between the numbers of records and the area occupied by a particular rock unit group or aquifer category as can be seen in Figure 2.

Preliminary frequency plots are given in Figures 3 and 4 for Regionally Important Fissured

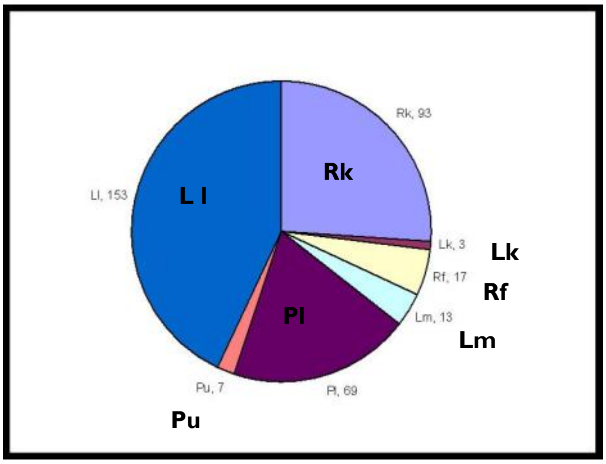

Figure 2 No. of records in each aquifer category

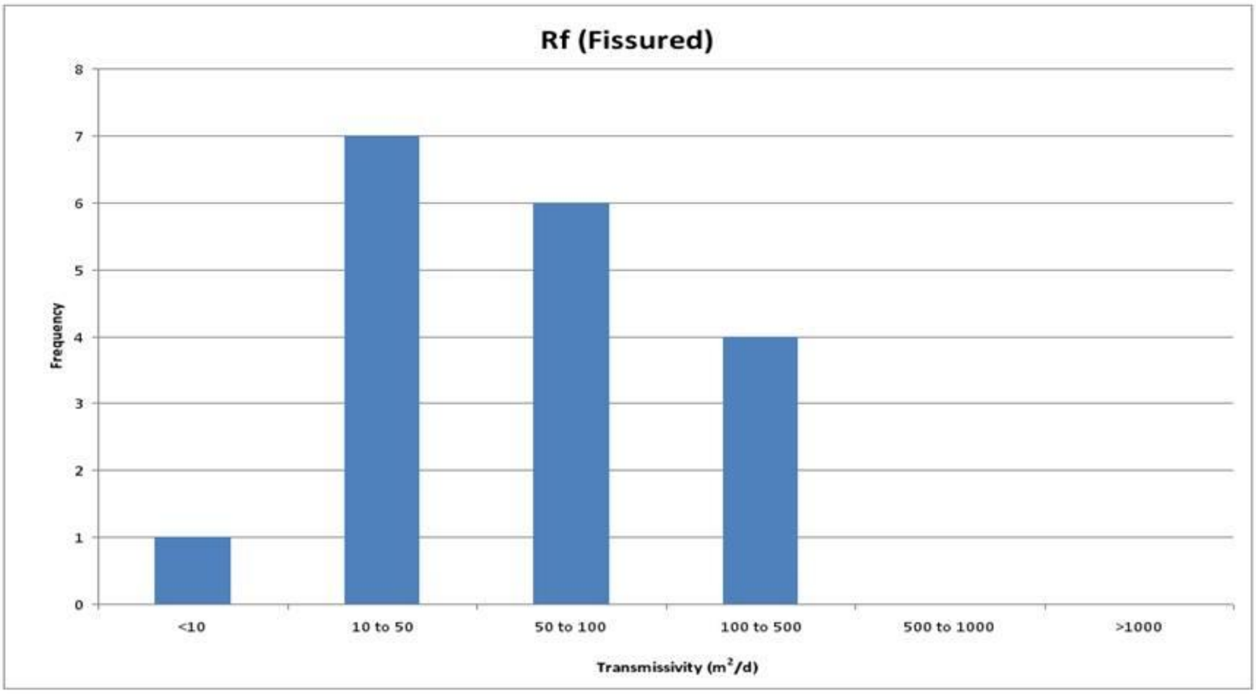

Figure 3. Preliminary frequency plot of transmissivity for Regionally Important Fissured Bedrock Aquifers (Rf)

Bedrock Aquifers (Rf) and Locally Important Bedrock Aquifers that are Moderately Productive only in Local Zones (Ll). The x-axis comprises six arbitrary transmissivity ranges: from very low values of less than 10 m^2/d, to very high values of greater than 1000 m^2/d.

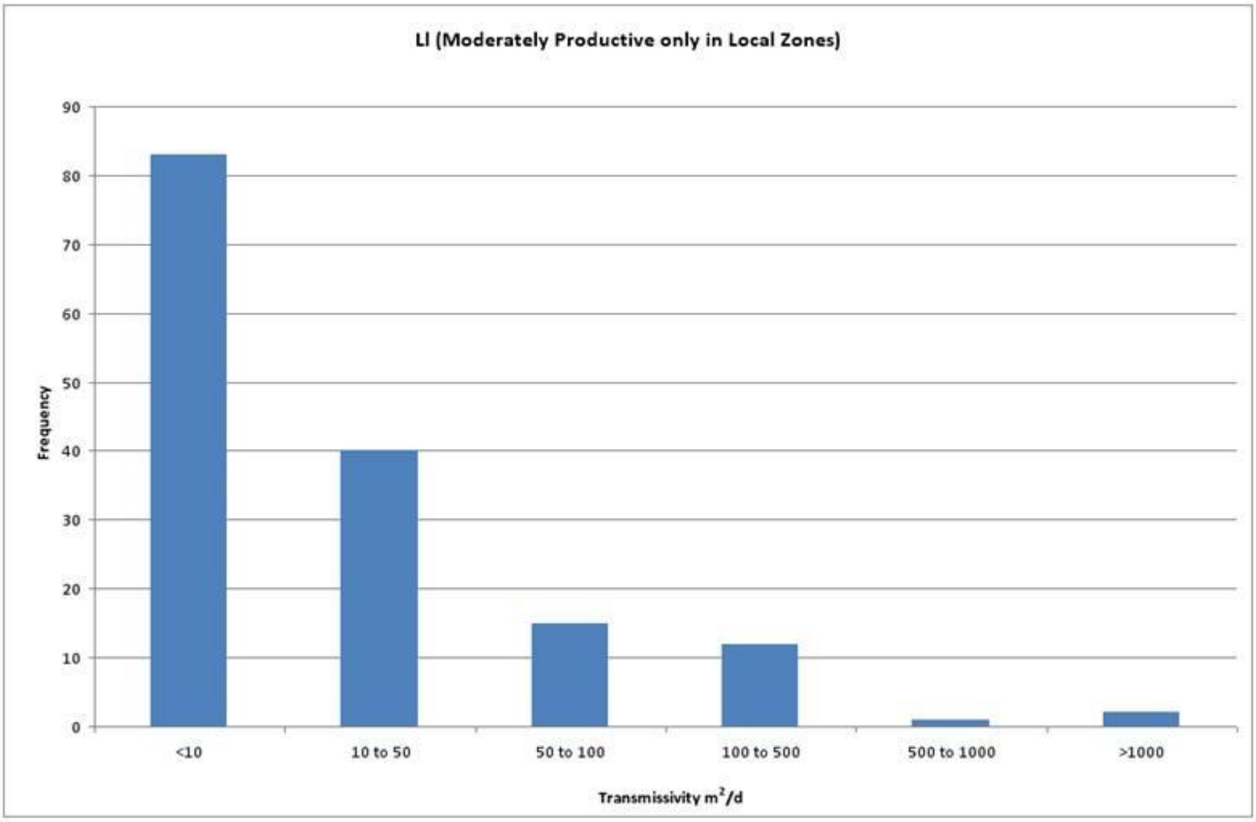

Figure 4. Preliminary frequency plot of transmissivity for Locally Important Bedrock Aquifers which are Moderately Productive only in Local Zones (Ll)

The data for the Regionally Important Fissured Bedrock Aquifers (Rf) to date indicates that the expected transmissivity values are in the order of 50–500 m^2/d; that the arithmetic average is 80 m^2/d and the median is 70 m^2/d for approximately 80 data points.

The results for the Locally Important Bedrock Aquifers that are Moderately Productive only in Local Zones (Ll) indicates that the bulk of the data falls into the lower ranges – less than 50 m^2/d. The arithmetic average is 50 m^2/d and the median is 10 m^2/d.

Conclusions

- An aquifer parameters database is being populated with data from pumping and hydraulic tests and from 'good' specific capacity data. The focus to date has been on the bedrock aquifers.
- Sufficient data are available for several of the rock unit groups and aquifer categories to provide statistically robust summary statistics for some hydraulic properties such as transmissivity and to a lesser extent hydraulic conductivity. There are few data on effective porosity.
- Where there are gaps, or no data, for either the subsoils or some of the rock unit groups and aquifer categories, the summary table of statistics will be populated by internationally available appropriate and relevant data.
- The database is considered to be an important step forward in providing useful and sensible values for the aquifers and rock unit groups to assist in quantitative risk assessments.
- A summary table and report will be published to accompany the main database.

If you have data that would be useful to include in the database please contact Taly Hunter-Williams (GSI) at taly.hunterwilliams@gsi.ie

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Groundwater Status, Threshold Value, Trend Assessment and Hazardous Substance Determination Methodologies

Two EPA reports have recently been produced outlining the methodologies for implementation of the Water Framework Directive

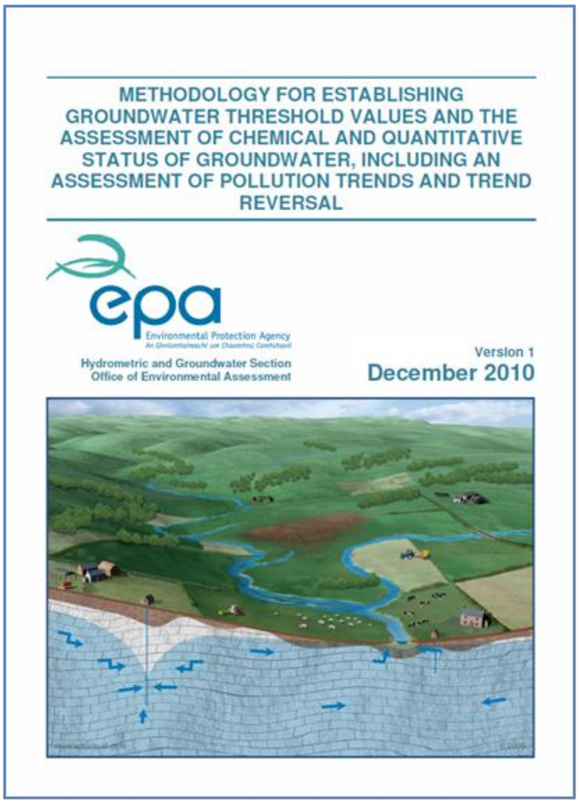
To meet the requirements of the European Communities Environmental Objectives (Groundwater) Regulations (S.I. 9 of 2010), the EPA is required to provide documentation on the implementation of the WFD.

Regulation 58 places a duty on the Agency to prepare and publish a detailed technical report on threshold values (TVs) for pollutants in groundwater, assessing the chemical and quantitative status of groundwater bodies and undertaking pollutant trend and trend reversal assessments.

Regulation 9(c–f) requires the Agency to identify and publish a list of substances which are to be considered hazardous or non-hazardous and which the Agency considers to present an existing or potential risk of pollution and to provide a methodology for substance determination.

Two reports (Figure 1) have been developed by the Agency's Groundwater team to meet these requirements, the first in response to Regulation 58 and the second in response to Regulation 9(c–f). The Reports are available on the EPA website for download http://www.epa.ie/downloads/pubs/water/ground/

The first report provides information on the rationale for deriving threshold values, the procedure and data requirements for each status test and the approach taken to assess



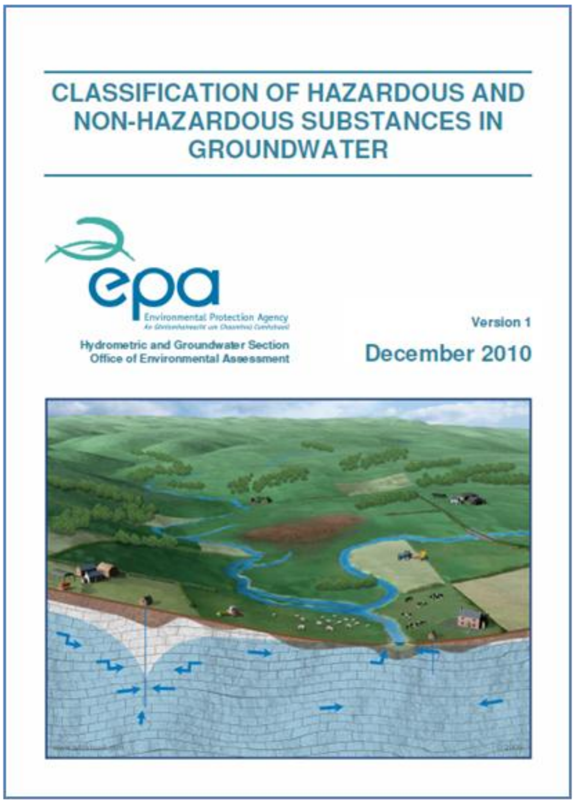


Figure 1. EPA Reports on WFD Threshold Values, Status and Trends Methodologies and Hazardous Substance Determinations

upward trends and trend reversal. The results of chemical status, quantitative status, overall status and trend assessments are reported in the River Basin Management Plans for each River Basin Management District, and are available from the WFD Ireland "Water Matters" website (http://www.wfdireland.ie).

The second report details the approach used to determine hazardous substances and provides a list of substances determined to be hazardous and non-hazardous. Where a substance is determined to be hazardous, its entry to groundwater should be prevented. Where a substance is determined to be non-hazardous, it's entry to groundwater should be limited to the extent that it does not cause a groundwater body to be at poor status or result in a statistically and environmentally significant upward trend in the concentration of a substance. The appropriate controls on hazardous and non-hazardous substances should be reflected in the conditions that surround activities that discharge to groundwater.

The historical procedure for identifying substances that should be subject to having their input to groundwater controlled followed the approach of the EC Groundwater Directive (80/68/EEC). Introduction of List I substances to groundwater was prohibited and List II substances were to be controlled to prevent pollution of groundwater.

A key difference between Directive 80/68/EEC and the approach proposed in the Regulations is that in Directive 80/68/EEC, hazardous substances were restricted to those belonging to the groups and families of substances included in List I of the Directive, whereas the Regulations require determination based on the intrinsic toxicity, persistence and bioaccumulation properties of a substance, and assessments are no longer restricted to families or groups of substances. The Regulations also include an override whereby a substance can be hazardous if it gives rise to an equivalent level of concern, e.g. highly toxic substances that are neither persistent nor liable to bioaccumulate may still be considered hazardous because of the impact they have if released into the environment.

To date a total of **746** substances have been considered for assessment and future substance assessments will be undertaken on an ongoing basis, with substances considered for review and determination once they are brought to the attention of the Agency.

Matthew Craig, EPA

Groundwater Quality in Ireland 2007-2009

While groundwater quality in Ireland continues to be relatively good in comparison to our European neighbours, nutrient enrichment leading to eutrophication of surface waters is an issue which needs to be addressed if we are to meet our WFD water quality targets

Background

The first assessment cycle of the Water Framework Directive has just been completed and the results form the basis of much of the EPA's Water Quality in Ireland 2007–09 report.

The conditions for assessing groundwater body status are identified in the Groundwater Regulations (S.I. 9 of 2010). There are five chemical and four quantitative tests (Figure 1). Each test is applied independently and the results are combined to give an overall assessment of groundwater body chemical and quantitative status. The worst-case classification from the relevant chemical status tests is reported as the overall chemical status for the groundwater body, and the worst-case classification of the quantitative tests is reported

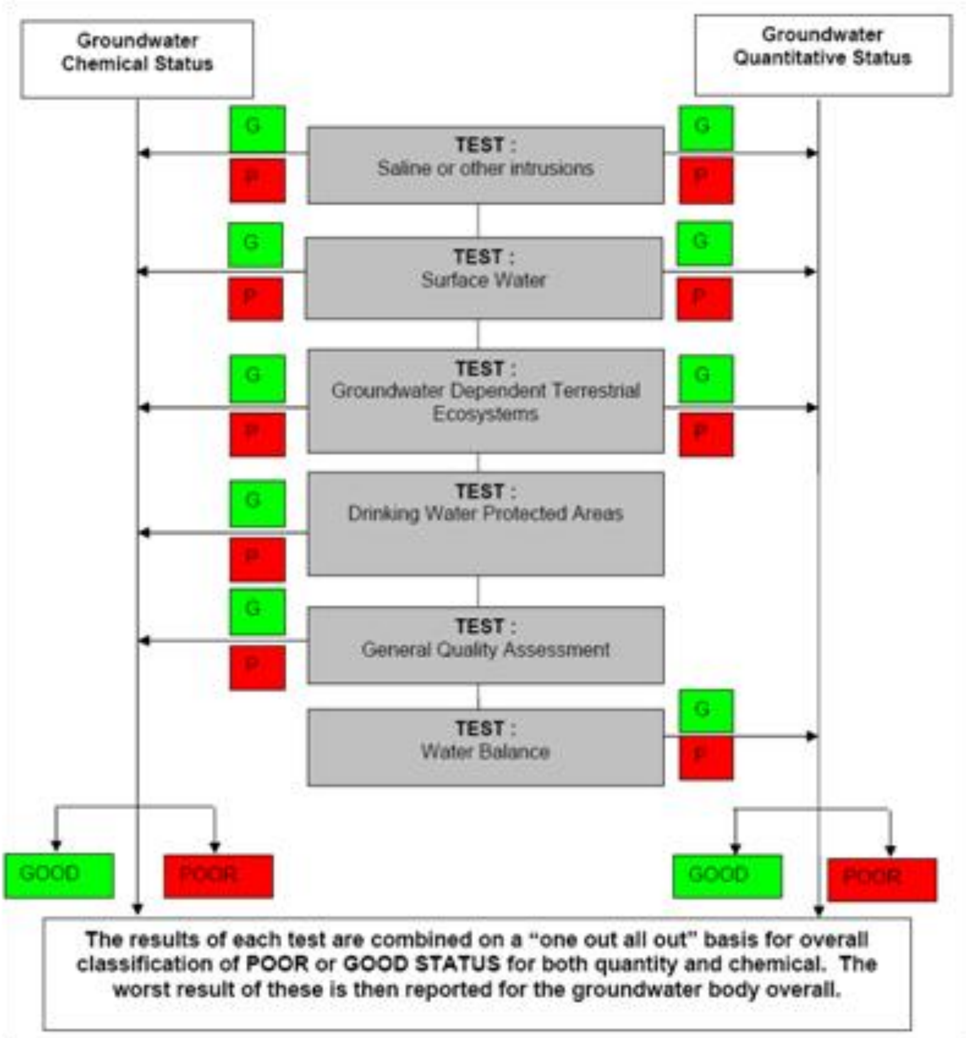


Figure 1. Overview of the status classification process

as the overall quantitative status for the groundwater body.

Often the contribution of groundwater to associated surface water bodies is forgotten; although groundwater often drives the quality of water at the surface as groundwater discharges (e.g. Figure 2) to rivers, lakes and estuaries. As such, poor quality water in surface water may be the result of pollution in groundwater. However, direct discharges, e.g. from wastewater treatment works, may also be the cause of water quality problems in surface water.

Groundwater Overview

Overall, 85% of groundwater bodies were of good status in accordance with the Water Framework Directive (WFD) assessment process (Figure 3). Problems are evident in the west of Ireland in areas with shallow soils and subsoils. Although the pressures from industry, humans and agriculture are relatively low, the absence of

Figure 2. Groundwater issuing from a spring in Co. Galway

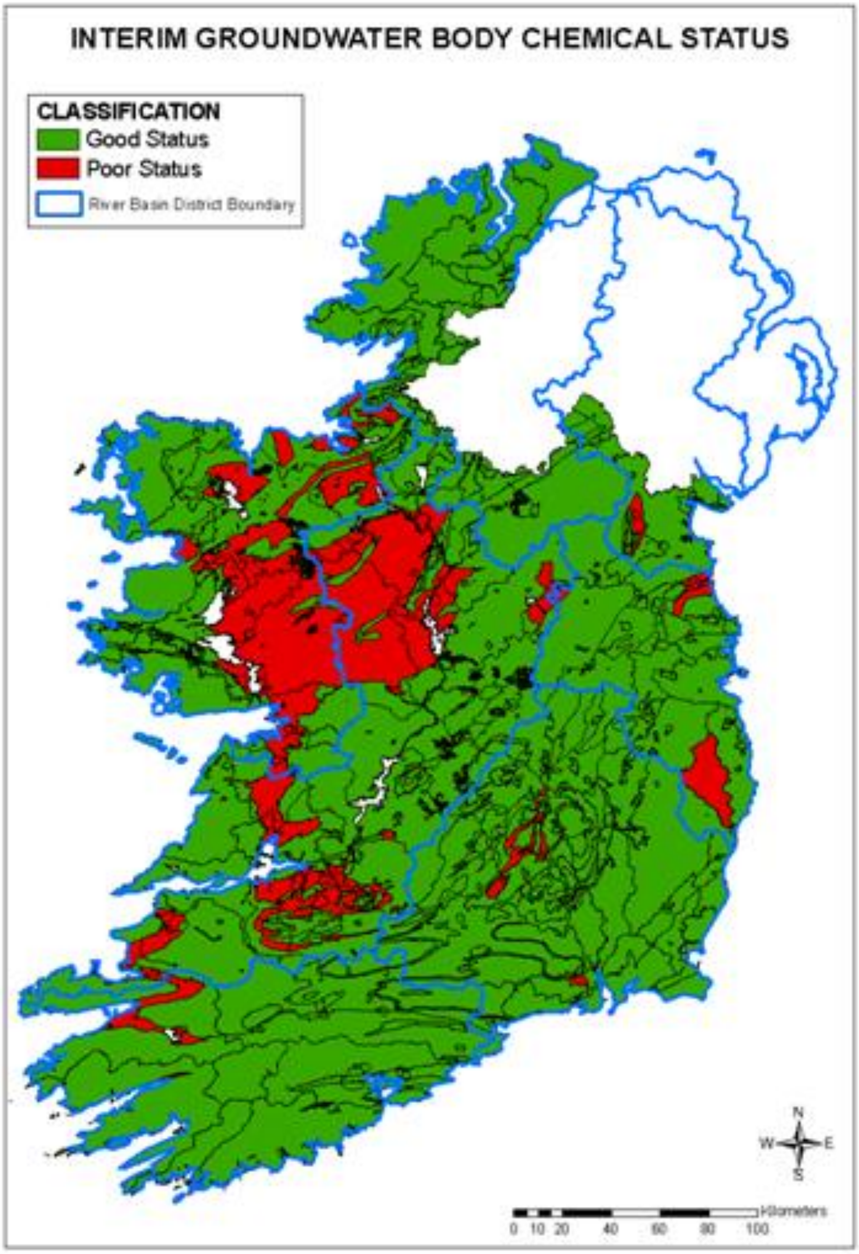


Figure 3. Chemical status of groundwater bodies

subsoils enables pollutants to enter groundwater relatively easily. Water can readily travel through the fractured limestone aquifers and ultimately the pollutants discharge in the streams, rivers and lakes, significantly contributing to nutrient enrichment problems in these water courses. A small number of groundwater bodies were at poor status due to statistically significant upward nitrate trends at water supply wells and because of the legacy of historic pollution from mining activities and industry.

Nitrates and Phosphates

Generally pollution of groundwater has decreased somewhat in recent times, with an overall reduction in nitrate e.g. Figure 4, and phosphate concentrations. Above average rainfall has played a key role, and it is likely that implementation of the Good Agricultural Practices Regulations, in particular, the increase in farm storage for manure and slurry, and the reduced usage of inorganic fertilizers have been beneficial. The dilution from rainfall is more

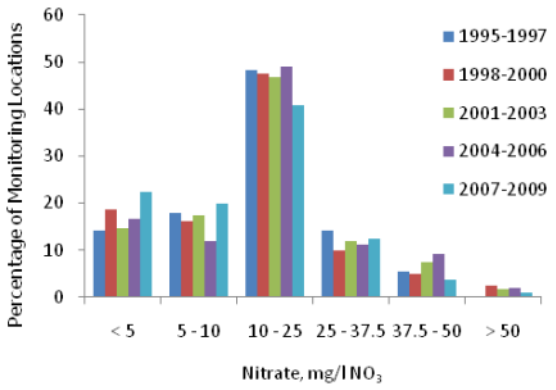


Figure 4. Nitrate concentrations in groundwater

prominent in the productive aquifers with monitoring data indicating that the greatest reductions in nitrate concentrations have occurred in the karst limestones aquifers in the south-east. However, nationally, the nitrate concentrations remain highest in the south-east and south of the country.

Ammonium and Microbial Pathogens

At the majority of monitoring locations, the mean ammonium concentrations were below the Drinking Water limit. Increases in ammonium were probably as a result of above average rainfall and pollutants not being attenuated by the soils and subsoils i.e. areas with extreme vulnerability. Positive faecal coliform counts were detected in 35% of water samples taken. Microbiological problems were observed in the areas where groundwater is more vulnerable to pollution (particularly at spring monitoring locations) because they have little natural protection from organic inputs. If abstraction wells are properly designed and installed, and are located in areas where the groundwater vulnerability is lower, the impacts of organic inputs should be minimal.

The Way Forward

In Ireland we perceive our waters to be clean and wholesome; resulting in good quality drinking water and good quality water in our groundwater, rivers, lakes and coastal waters. Generally this perception is reality, with many of our rivers and lakes, particularly in upland areas, being of pristine quality.

The main reason we see pristine water is lack of pressure from people, agriculture or industry and good practice when locating and installing potentially polluting activities. The reality is that Ireland does not suffer from an industrial legacy and the same level of agricultural intensification as many of our European counterparts and consequently we do not have the same overall degree of water quality problems seen elsewhere. Generally, as we move along water courses from upland areas to lowland areas and estuaries, the influence and impact of pollution becomes greater and waters are generally no longer pristine, although they may still be of high or good quality.

The most widespread cause of water pollution in Ireland is nutrient enrichment resulting in the eutrophication of rivers, lakes and tidal waters from agricultural run-off and discharges of wastewater. Further improvements in groundwater quality are required for both environmental and public health reasons. Key measures should include the optimal application by farmers of organic and inorganic fertilizers at times and in a manner that minimises leaching, and householders ensuring that their on-site wastewater treatment systems, such as septic tanks, are located, constructed and maintained properly.

While there is evidence of an overall improvement in water quality in Ireland, further actions are essential if we are to achieve our water quality targets for 2015 and 2021 as required by the Water Framework Directive. The EPA will work with the network of local authorities and other agencies in tackling the water quality challenges ahead.

Matthew Craig
Environmental Protection Agency

Considerations of nutrient status in water bodies

In addition to the concentration, consideration of the nutrient load, i.e. the concentration x the discharge, is important in assessing catchment nutrient sources, dynamics and impacts

The Agricultural Catchments Programme (www.teagasc.ie/agcatchments) operates a series of highly instrumented catchments as an evaluation experiment for the Nitrates Directive National Action Programme (NAP). The aim is to investigate, in the early years of the NAP, what is the status of receiving water bodies with regard to Water Framework Directive (WFD) metrics in agri-catchments and what are confounding factors with regard to meeting WFD water quality objectives at the scale of the small river basin (5–30 km^2) (Wall et al., 2011). Catchments outlets are highly instrumented (Figure 1) for water quantity and quality metrics, including sub-hourly and continuous measurements of phosphorus (P) and nitrogen (N). This gives an opportunity for a detailed analysis and interpretation of some of the issues of nutrient status in water bodies.

Nutrient Concentrations and Loads

Water bodies act as final receptors and vectors for chemical and sediment constituents and these are present as mass per unit water concentrations, for example, mg L^{-1} or g m^{-3}. The product of water volume, or discharge, from or to a system, and concentration defines the load (i.e. mass per unit time – g hr^{-1}, kg yr^{-1}, or normalised to g ha^{-1} hr^{-1} or kg ha^{-1} yr^{-1}, etc). All of the regulatory standards relating to water bodies in Ireland and throughout the EU use a chemical concentration metric to determine whether that water body is likely to cause, for example, a public health issue or impair the ecological quality of surface water bodies. The standard metrics are generally taken as mean concentrations over several routine sample campaigns; monthly sampling for P in rivers, for example, less frequent for groundwater bodies (P and NO_3-N) and estuaries (NH_4-N + NO_3-N).

The chemical status of any water body in time is linked to ambient and weathered conditions associated with soils and geology and also with pollution sources. These pollution sources have been operationally defined as point or diffuse, and are linked to direct discharges from discrete points in the landscape, and undefined sources in the landscape with a dependence on surplus water generation (runoff or drainage), respectively.

Temporal dynamics, or water residence time, is an important factor in the concentration status of water bodies; the longer the residence time, the fewer samples are required for representation of the mean annual concentration, often cited as a time-integrated mean if the sampling is undertaken on regular time-steps. This appears to be sufficient for water bodies such as deep groundwater or lakes where water residence times might be measured in months or years. In river systems, however, residence times are short for individual reaches and dynamic according to rainfall-runoff patterns. This residence time is also influenced

Figure 1. One of six ACP water quality stations with equipment measuring P and N fractions, turbidity, conductivity and temperature on a sub-hourly basis

by scale and the contribution of groundwaters; for example, meso- to macro-scale river basins with a higher baseflow index will increase reach residence time and this is especially noted during storm events where hydrographs will be 'stretched' and maximum discharges 'subdued'. Sampling rivers across a sufficient discharge gradient will yield a flow-weighted mean concentration of chemicals, etc.

This difference in runoff response is also important when comparing with 'flashy' river systems. Storm hydrographs here tend to be shorter-lived but of higher magnitude as less water is diverted to groundwater recharge and storage. The corollary of this response is a suppressed baseflow index with fair-weather flows being especially low. Both types of river system exist in Ireland, summarised as high and low baseflow index systems over productive and poorly productive aquifers, respectively. The transformation of both point and diffuse pollution sources to each system are important and for point sources, consent discharges should be linked to fair weather flows. As concentration is the metric in river systems for point source discharges, e.g industrial or municipal, integrating these loads into fair-weather river discharges is important to maintain river concentrations that do not impair ecology.

In rivers, N tends to show a decrease in concentration during storm events in moderate to well drained catchments and P an increase in concentration. However, this apparent dilution of N, as baseflows become diluted with storm runoff, requires careful interpretation. The apparent loss of concentration is an artefact of the rate of change of chemical compared with water and a consideration of the load may indicate that there is still a net increase in load per unit area of land – i.e. the input has not stayed the same (or decreased). Figure 2 shows this for a Co. Wexford arable catchment where storm runoff increases river discharge over short periods and the concentration of N, continuously monitored as total oxidised nitrogen (TON = NO_3 + NO_2), decreases during these periods. Load, however, is seen to increase during most storms and points to a degree of flushing from other pathways. Only one sustained 'dilution' of load occurs during this period during the largest

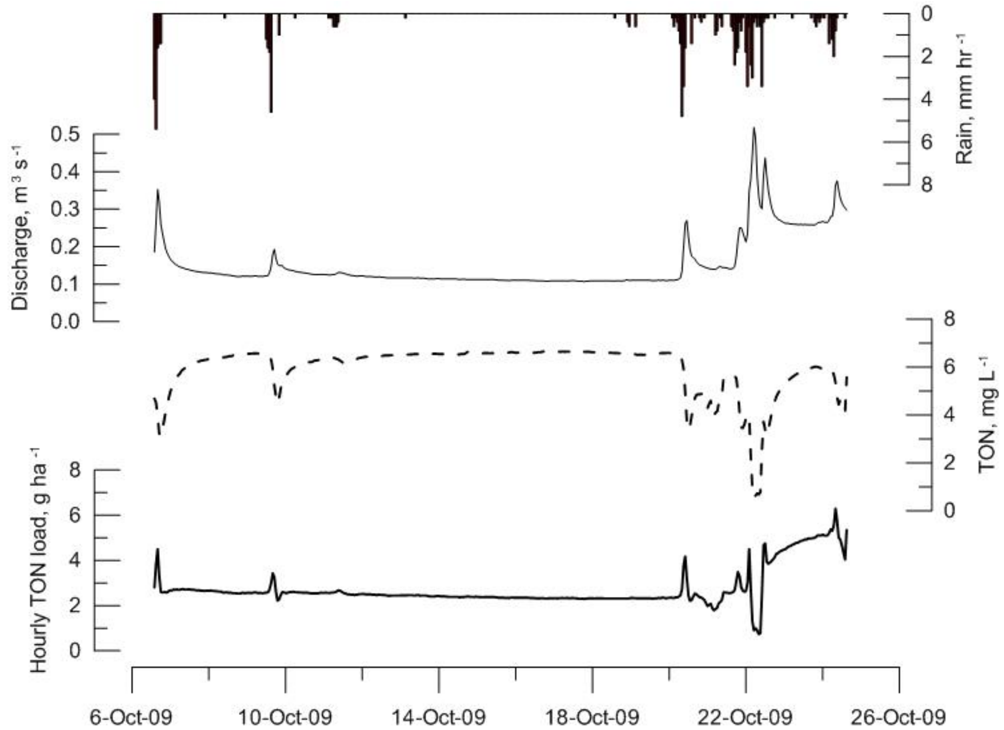


Figure 2. Rain, discharge and TON concentration and load during a series of autumn storms in a Co. Wexford catchment (~10km^2) (Based on data in Fealy et al., 2010).

event following 22nd October 2009. If baseflow TON concentration is an indication of the groundwater nitrate status, then river TON load is more likely to be a factor influencing the status of estuaries as the final receptors.

The environmental significance of septic system discharges is another example where care is needed with concentration/load interpretation. This quasi-point source of nutrient, sediment/sludge and bacterial contamination can be buffered, or not, by different hydrological regimes when river hydrochemical concentration is used as the impact metric. It is recognised that in rural catchments, the combined load of septic system discharges is a small part of overall nutrient loads where diffuse, storm dependent transfers predominate (Smith et al., 2005). However, as these daily loads are more or less constant from single households, even when considering a proportion of soil attenuation, the hydrological buffering of receiving rivers becomes important at low flows.

In Irish agricultural catchments, field and farm scale total P loads of up to 2.5 kg ha^{-1} yr^{-1} have been observed (Jordan et al., 2005; Douglas et al., 2007). Hypothetically, and using estimates of per capita P production (0.85 kg yr^{-1}; for example as mean of Foy et al. (1995) and Gray (1984)), and a typically high rural population density of 20 houses km^{-2} (with 4 inhabitants per house), would equate to a normalised load from septic systems of 0.68 kg ha yr^{-1} in a 5 km^2 catchment, assuming zero soil P attenuation. This soil attenuation is highly variable and the zero attenuation used here is based on a situation where tanks are not retaining sludge and are discharging directly to a water course. In reality, and even in soils of very low attenuation potential, there will be some degree of attenuation and this is more effective in deep soils of moderate to high permeability and where tanks are maintained. The septic system load is likely, therefore to be a proportion of the load used as an example above, and reported to be up to 58% of per capita P production by Smith (1977; i.e. 42% retained) in the basalt soils of Co. Antrim. Also using this attenuation potential gives a range of possible septic system TP loads in the sample 5 km^2 catchment of 0.39 to 0.68 kg ha^{-1} yr^{-1}; these loads would be proportionately less in catchments with lower population density. In mass balance calculations of source apportionment, the TP balance of the 2.5 kg ha^{-1} yr^{-1}, less septic system loads, would be ascribed to agricultural diffuse losses from soil and field surfaces with the bulk of transfers occurring during moderate to high runoff events.

Using the hydrological buffering principles outlined above, these small loads from rural point sources may, however, have high impacts on the river system during fair-weather flows. For example, for two catchments with different soil hydrology (well and poorly drained), low flow discharges of the equivalent of 0.04 mm hr^{-1} and 0.004 mm hr^{-1} (respectively) would be common. Using these sample data and example septic system loads (assuming constant discharges and a 50% P attenuation potential) above would equate to mean daily TP concentrations of ~0.11 mg L^{-1} in the 5 km^2 well drained catchment and ~1.1 mg L^{-1} in the poorly drained catchment. The poorly drained scenario is likely to be exacerbated due to lower soil attenuation potential of septic system discharges although mediated by attenuation in low gradient ephemeral stream sediments (Arnscheidt et al., 2007). The resulting small loads, therefore, have a proportionately higher potential impact, by concentration, at low flows due to lack of buffering potential in the poorly drained catchment, despite having similar point source magnitudes and even when assuming equal effluent attenuation.

In reality, patterns such as the example scenarios above appear to emerge in a number of highly instrumented catchments in Ireland, UK and the EU at varying scales (Jordan et al., 2007; Douglas et al., 2007; Foy, 2007; Palmer-Felgate et al., 2010; Withers et al., 2011). In two catchments in Cos. Wexford and Louth, these features have

Figure 3. One of six ACP hydrometric and water quality stations at ~10km^2 during low flow

been revealed in low flow periods. The two catchments are classed as arable (being a significant proportion of landuse) on contrasting soil types and are of a similar size (~10 km^2). Well and poor-moderate drainage provides contrasting base flow discharges as shown as normalised runoff in Figure 4a for Arable A and Arable B catchments. The high resolution P monitoring (Wall et al., 2011) provides two fractions (TP and TRP [total reactive P, termed MRP in Ireland]). A period of extracted data from low flow periods in 2010 during mid summer indicated that the Arable A catchment had very low P concentrations (~0.03 mg L^{-1} TRP) and this contrasted with Arable B which had consistent TRP concentrations of ~0.15 mg L^{-1} (Figure 4b). Using these concentrations, the magnitude of the potential 'impact' is evident in Arable B. However, the product of discharge and concentration gives an indication of hourly P load (Figure 4c) and these appear very similar for this period (~0.01 g ha^{-1} hr^{-1}), and at times higher for Arable A, indicating that the magnitude of the low flow 'source' can be similar. In Arable A, the persistent P source is related to a rural waste water treatment plant consented discharge which is diluted properly by high baseflows. In Arable B, clusters of single housing septic systems are among the likely causes of similar magnitudes of P loads but which are not effectively diluted in baseflows.

Policy implications

As would be expected, during storm events, P transfers from intensively managed soils with legacies of excessive fertiliser application are far greater than these background loads with hourly TP concentrations up to 1mg L^{-1} and hourly loads of up to 10g ha^{-1} in extreme storms in Arable B. These storm associated transfers are connected through the landscape by fast runoff flowpaths to river systems and can account for the bulk of annual P transfers from land to water. However, in terms of riverine impact, the question of duration or magnitude is important and especially when this is coincident with ecologically significant periods. High magnitude diffuse P transfers tend to be low duration and occur during the autumn to winter period. Measures within the Nitrates Directive National Action Programme are regulated to deal with this risk especially constraining nutrient management during winter periods. Low magnitude point source transfers tend to be high duration or persistent, by design, and when these are unbuffered (as above) can expose river systems to eutrophic conditions during summer low flows. This simple model has other variants and in some permeable catchments, the long recession of P in shallow groundwater runoff can also elevate low river flow P – but with a signal of decreasing concentrations to baseflow. The very high magnitude P transfers from winter diffuse events, does, however, have the potential to elevate the mixed water body concentration of standing waters such as lakes and reservoirs and the recovery of these will be related to reductions of external P load and also internal cycling dynamics.

River P concentration metrics are used for WFD reporting and also as metrics to ecological scores related to macro-invertebrate ecology, often based on very coarse resolution chemistry sampling (up to monthly). An immediate concern here is due to the very low probability of including signals of short duration, episodic diffuse events in river P databases when relying on coarse resolution data. Cassidy and Jordan (2011) have shown how at mini-catchment scale, there is next to no chance of recovering diffuse P

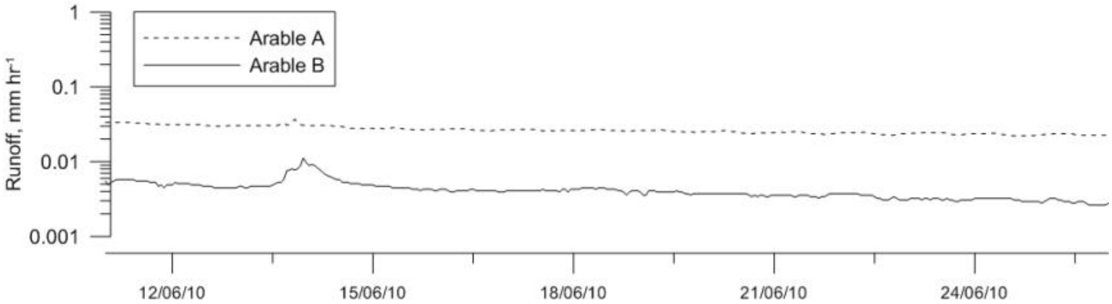


Figure 4a. Runoff during a low flow period in two contrasting arable catchments of similar size (~10km^2)

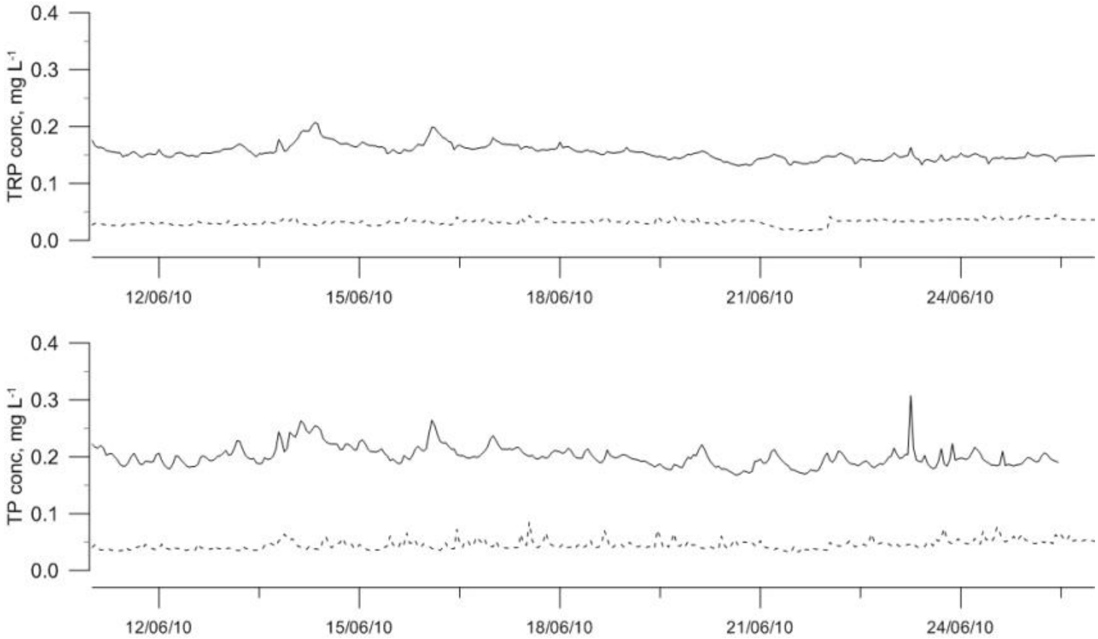


Figure 4b. Persistent phosphorus *concentrations* during the June 2010 low flow period in the two arable catchments indicating a higher potential trophic impact in the Arable B catchment

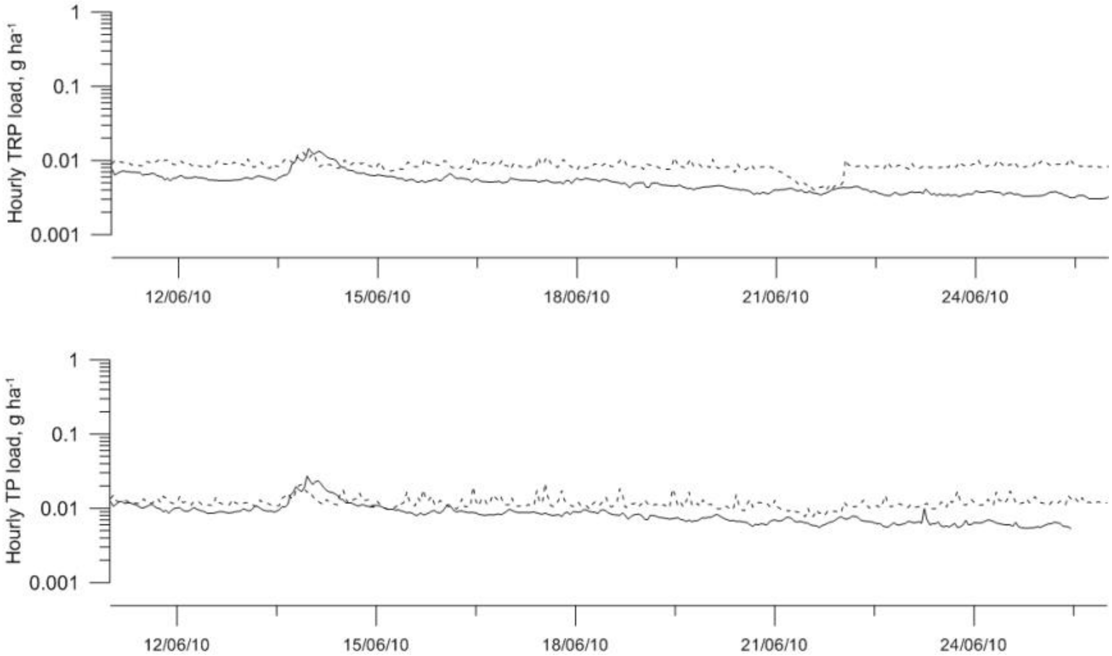


Figure 4c. Phosphorus *loads* during the same low flow June 2010 period indicating similar, and at times higher background loads in the Arable A catchment (compare with Figure 4b) which were diluted as concentrations due to higher baseflow discharges

signals from monthly or even weekly sampling regimes in flashy catchments. If it is correctly assumed that the same flashy catchments have a ubiquitous risk of low dilution potential for rural point sources, then routine sampling (i.e. monthly) has a high probability of quite effectively picking up the signal from point sources during high frequency low flows. The chemistry-ecology relationships in these catchments may also be biased towards rural point sources. Indeed, it is recognised that river ecology metrics used for WFD reporting are at least in need of review to relate to high-magnitude, short duration diffuse nutrient events (Hilton et al. 2006).

These are important points as expectation towards maintenance of and recovery towards good ecological status in rivers proceeds to WFD target dates and especially where catchment based mitigation strategies are aimed at abating both diffuse and point source nutrient transfers. For forward interpretation of national monitoring data, research questions on 'what source is being measured in rivers' and 'when/ where is the impact' are required and especially at river basin scales where both low magnitude/ high duration and high magnitude/low duration nutrient transfers are evident.

Notes

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Iron Pans in Mayo

Extensive iron pans have been found in Co. Mayo, with smaller areas in Co. Tipperary. The iron pans inhibit recharge and mask the higher permeability of the underlying subsoil layers

As part of the National Groundwater Vulnerability Mapping Project (see Groundwater Newsletter 48), the permeability of the subsoil and depths to bedrock were assessed and mapped in Mayo and Tipperary in 2010. This article aims to draw attention to extensive iron pans identified in Co. Mayo and to a smaller area also found in Co. Tipperary. The lateral extent of the iron pans is sufficiently large enough to be mapped out at the regional groundwater vulnerability mapping scale.

Iron pans occur in well drained acid mineral soil with high annual rainfall; minerals are leached from the upper horizons and are re-deposited further down the soil profile (see Figure 1). These can form a distinctive mineral layer or in some cases a layer of iron oxide accumulation also referred to as an 'iron pan'. These are associated with podzols and peaty podzol soils. This soil profile has distinctive horizons of bleached lower topsoil and a cemented iron oxide pan which appears as a red/orange band usually at the top of the subsoil.

Figure 1. Leached (bright grey) topsoil layer above an iron pan in Co. Mayo

While mapping the subsoil permeability in Mayo, a notable conflict is apparent between surface indictors and what was thought to be the true permeability of the subsoil beneath. Extensive rushes on slopes, drainage ditches installed along boundaries of fields and a waterlogged, poached appearance occur in these areas, which is usually indicative of low permeability subsoil (Figure 2).

Figure 2. Rushes above an iron pan, Co. Mayo

Figure 3. Iron pan in north Mayo above a 'gravelly SAND'.

Exposures into this subsoil uncover the presence of a strongly defined iron pan. These acid subsoils are defined by the BS5930 as 'silty SAND', 'gravelly SAND' and 'sandy GRAVEL' (see Figure 3). These divergences of indicators predominantly occur where glacial till derived from Devonian Sandstone has been deposited. Also noted is the high volume, between 800 and 2500 mm, of effective rainfall which increases the likelihood of iron pans occurring in this acid based sandstone till. The iron pans deposited within these profiles usually form at shallow depths, less than one metre. They change both in thickness (~5 to 150 mm) and strength, sometimes forming a completely solid plate and in other cases a band that can be easily crushed or bypassed and disappears entirely in places. Iron pans form an effective barrier which restricts drainage and root growth; this affects secondary permeability proxies, such as artificial drainage density and vegetation indicators (see Figure 2). These proxies are an intrinsic part of the mapping process helping to define the permeability boundaries used in the groundwater vulnerability mapping programme. Due to the discontinuity, these pans are not included in the overall permeability classification for the area. The areas in which they occur are mapped, however, both for future information and to define the 'true' moderate or low permeability subsoils which have been masked by these iron pan occurrences.

There are two large areas of iron pan occurrences which have been noted while mapping Co. Mayo. Provisional boundaries have been assigned to these two areas, the Nephin and Kiltamagh iron pan regions in central Mayo (see Figure 4). Although iron pans are also present in other areas, they have not been defined with boundaries as they either are not large enough to delineate at the Groundwater Protection Scheme mapping scale (1:50000), or there are not sufficient data to define them with confidence.

The Nephin iron pan region occurs exclusively on Devonian sandstone till located north of Clew Bay, extending northeast and almost as far as Lough Conn. It is bounded in the north and south by the mountain ranges of Nephin Beg and Croaghmoyle, respectively. The Kiltamagh iron pan region extends from the Namurian uplands near to Balla, eastwards, to the Roscommon-Mayo county boundary. The northern limit of this region is south of Swinford and Knock airport, while the southern boundary is located close to Kilkelly and runs through Urlaur Lough.

The many benefits of mapping out the extent of the iron pans include assisting with site suitability, groundwater vulnerability, recharge and risk assessments.

For site suitability assessments; an initial desk study and walk over might lead to a conclusion that the site is unsuitable but beneath the iron pan there is suitable depth of unsaturated subsoil. The invert levels of the percolation trench therefore need to be below the iron pan.

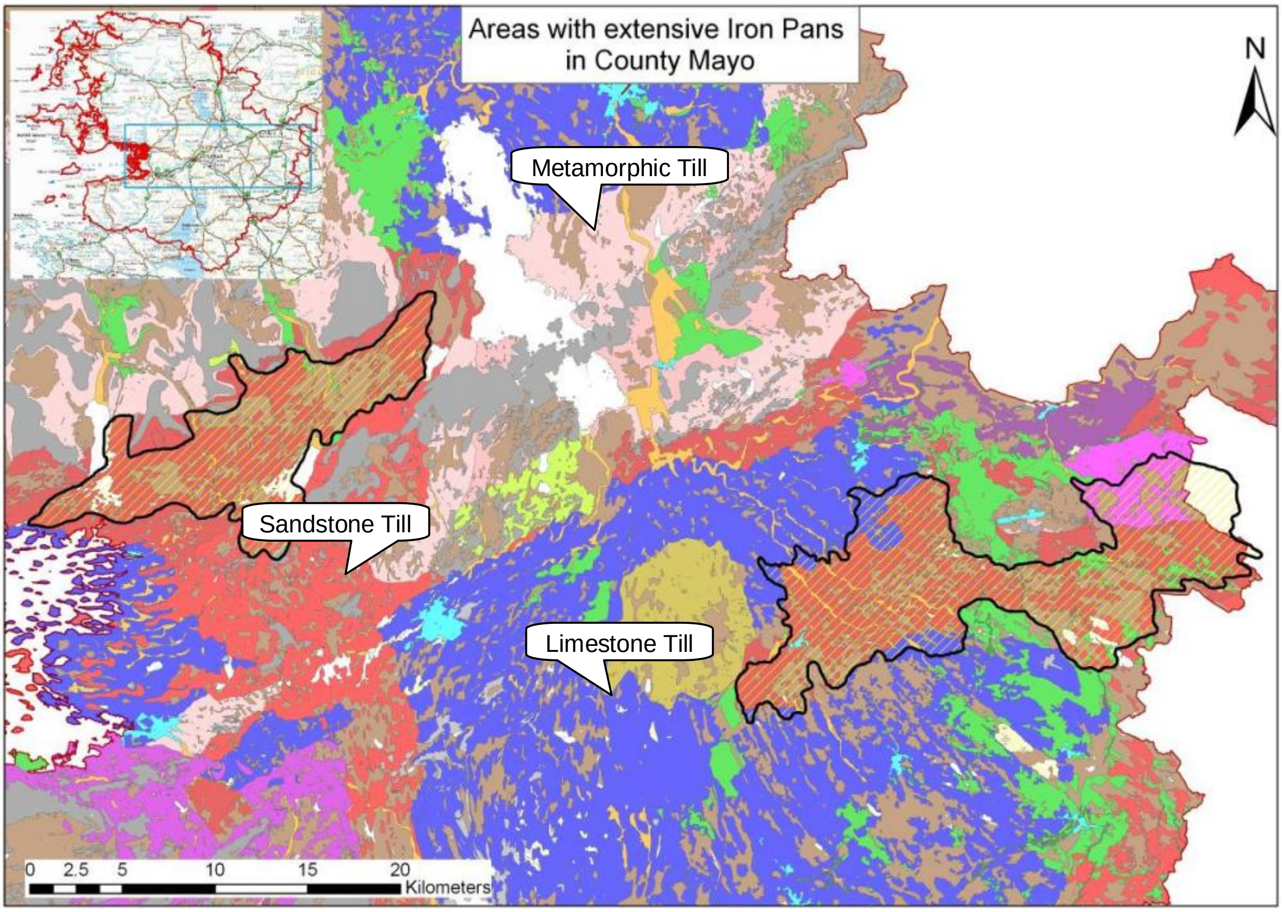

Figure 4. Location of Nephin and Kiltamagh Iron pan regions highlighted in black dashed lines

These highlighted areas will assist Site Assessors and Local Authority Staff.

Further impacts of these extensive iron pan features is the affect on surface water run-off. In these areas the surface water run-off is not compatible with the permeability of the subsoil. Therefore, although a region may be of 'Moderate Permeability' there will be high levels of surface water run-off more similar to that found in 'Low Permeability' regions. This, in turn, may have an impact on landspreading as it will lead to more vulnerable surface water in these areas than otherwise anticipated.

Lastly, this information may potentially be useful for local farmers. These features greatly affect the quality and drainage of the topsoil. If the locations of these extensive pans are known to farmers they may be able to amend farming techniques in order to break the impermeable pan layer and improve the quality of their land.

References

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

Kabza, M., Spillane, M., and O. Murphy. 2010. *The National Groundwater Vulnerability Mapping Project and the National Groundwater Protection Scheme.* Groundwater Newsletter No. 48.

Melissa Spillane, Monika Kabza, Orla Murphy, and Coran Kelly, Tobin Consulting Engineers
and
Dr. Robbie Meehan

Geothermal Association of Ireland — recent activities and future events

The Geothermal Association of Ireland (GAI) has had a busy 2011, which started with two one-day courses on ground-source heat at introductory and intermediate levels taking place on March 1st-2nd. The courses were taught by David Banks of Holymoor Consultancy, organised by the GAI and supported by the Geological Survey of Ireland, where the courses were held. There were 25 participants on the first course, and a maximum complement of 15 on the second course. Participants included hydrogeologists, drillers, developers, engineers, students and academics.

The main event on the GAI 2011 calendar was the Conference. The GAI held its second conference, in Kilkenny at the Newpark Hotel on the 10th May. This took place two and a half years after the first conference, which celebrated the 10th Anniversary of the GAI. The Committee pulled together an excellent line up of speakers from Ireland, UK and the rest of Europe, which covered four main themes: shallow and deep geothermal systems, and commercial and academic applications. Most of the presentations are available on the GAI website, and the full papers will shortly be collated into Newsletter 18. We are grateful for the support of the four sponsors, the seven exhibitors and the 84 attendees.

Good attendance at the AGM in June was assisted by holding it immediately after a site visit to the geothermal borehole field and system at IKEA, in north Dublin. Approximately 30 attended the site visit, with around two thirds of the group staying on for the AGM. The newly elected committee retains the experience of previous members, and combines this with the new input and experience of incoming committee members.

Upcoming events include a field trip, and the assessment & awards for the ‘Home Geothermal Installation of the Year’ competition.

The new GAI Committee 2011–2012. Left to right: Niall Burke (AIT), Mark Muller (DIAS), Róisín Goodman (SLR Consulting), Gareth Ll. Jones (Conodate), Brian Conor, John Burgess (Arup), Paul Sikora (Ecocute), James Byrne (Sirus), Alistair Allen (UCC), Taly Hunter Williams (GSI), Heather Murphy (Philip Lee) and Monica Lee (GSI)

Other Geothermal News

The IRETHERM project kicked-off in March this year. It is led by DIAS and has state, academic and industry partners. The four-and-a-half year, all-island, North-South aims to develop a strategic and holistic understanding of Ireland's geothermal energy potential through integrated modelling of new and existing geophysical and geological data. More information on this dynamic project can be found at http://www.iretherm.ie/

For more information on the GAI, please go to www.geothermalassociation.ie

Taly Hunter-Williams and Monica Lee
Joint Secretariat, GAI

GAI Annual Field trip 2011

When: Mid-October (Sat/Sun) 2011
Where: Likely to be based in Birr, Co. Offaly.
Details to be confirmed

IAH annual field trip, October 2011 — East Galway and South Mayo

When: 1–2 October 2011
Where: East Galway and South Mayo
Details to be confirmed

We return to the west this year for our IAH (Irish Group) annual fieldtrip. The general theme of this year is managing karst. We will look at the Agricultural Catchments Programme (Teagasc/DAFM) and it's work in a karst catchment in Mayo. Some of the complexities of catchment management in karst areas with outcropping bedrock and doline fields will be discussed.

On the Sunday we will be looking at the difficulties associated with delineation of catchment areas for springs in lowland karst areas. CDM will take us around some of the public drinking water supply springs in the karst lowland of East Galway, to discuss the problems in trying to define the contributing areas for each. There may also be one or two other surprises!

Further details will be circulated by email.

All welcome!

Next Technical Discussion Meeting

Cave Diving in Ireland

Artur Kozlowski

6pm Tuesday 4th October at the GSI. Tea/coffee from 5.30pm

Artur was born in Poland in 1977 and came to Ireland in 2006 with 13 warm water dives under the belt. He started learning cave diving with Welsh cave diving instructor Martyn Farr in 2007. In 2008 Artur explored Pollatoomary and recorded the deepest underwater cave dive in Ireland and Britain, at -103m. Since that time his main interest has shifted to largely unexplored, massive underwater cave systems underlying the Gort Lowlands in Co. Clare. In 2009 he started using a rebreather which resulted in spectacular discoveries in Gort area - including exploring 4km of new underwater passages with Jim Warny. At the same time Artur is actively sustaining traditional style cave diving exploration – dry caving with sidemount sump diving, mostly in challenging caves in the north of the country. Artur is a PADI, DSAT Tec Deep/Tec Trimix and TDI Cave diving instructor. Although based in Dublin, he teaches courses all around the country. Check out Artur's blog for some of his recent and older exploits! http://www.blogger.com/profile/14651632772541398712

Previous issues available at www.gsi.ie

Contributions for the next issue of the Groundwater Newsletter should arrive by 1 Oct 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 — annual Tullamore conference report

The 31st Annual IAH (Irish Group) Conference took place on the 12th and 13th April 2011 in Tullamore, Co. Offaly, with the conference having the overarching theme of 'Evolving Hydrogeology'.

The two-day event started with a keynote presentation by the President of IAH International, Mr Willi Struckmeier, on the IAH's role in the evolution of hydrogeology. Session 1 dealt with the ways in which practitioners are improving and applying our understanding of surface water and groundwater as an integrated resource with emphasis on modelling. Groundwater flooding mechanisms and flood mapping in Ireland were also discussed. Session 2 explored the issues surrounding groundwater contamination from unregulated landfill sites, with perspectives from the Regulator and consultancy, with Session 3 looking at management of contaminated groundwater, with focus on different remedial options, regulatory approaches and case studies on remediation in Ireland.

Student presentations (to accompany posters) were made between Sessions 2 and 3 and covered a wide range of research topics that related to the main sub-themes of the Conference. There was a wine reception at the close of the first day of the Conference, followed by a social event in a local bar, which was a great success with almost half of the delegates attending for dinner, music and dancing.

Session 4 looked at groundwater development in the extractive and geothermal industries with an initial presentation on mine dewatering from an international perspective. Following this, development of geothermal energy; how it works, the international perspective and its applicability and current status in Ireland was discussed. The final Session of the conference looked at the management of groundwater resources with a talk on groundwater nutrient patterns in intensive agricultural catchments, followed by a presentation from the National Federation of Group Water Schemes on the issue of water metering and reducing abstraction pressure on groundwater sources.

Given the current economic situation, the conference was once again extremely well attended, with approximately 165 attendees; including speakers, delegates and exhibitors. Approximately 20 exhibitor stands from Industry, including drillers, laboratories, equipment suppliers and consultants were set up at the conference. The overall level of support for the conference not only reflects the relevance of the talks being presented, but also the pedigree of the speakers. The proceedings of the 2011 Conference will shortly be available for download at:
http://www.iah-ireland.org/current/pastevents.htm

Matt Craig
Conference sub-committee