Irish Groundwater Newsletter

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Issue 54 of the Irish Groundwater Newsletter comprises three sections. The first, Irish hydrogeology past, present and future, is more reflective in tone than is usual in the Newsletter. This is because 2016 marks the 60th anniversary of the setting up of the International Association of Hydrogeologists and the 40th anniversary of the setting up of the Irish Chapter. This seemed an appropriate moment to consider the past and the possible future for groundwater resource activity in Ireland. Whilst the IAH Chapter and hydrogeology in Ireland are not synonymous and awareness of groundwater as a resource pre-dates 1976 by some decades as the article by Bob Aldwell reminds us, since its inception, the Irish IAH Chapter has played a leading role in emphasising the importance of groundwater investigation, exploitation and management. Significant present-day aspects of groundwater management are described in two contributions and the Section is rounded off with a whirlwind tour of Irish hydrogeology in 2056 as envisaged by Gerry Baker.

Section 2 presents summaries of completed and on-going groundwater investigations over a range of topics, together with a timely article clarifying the terminology used in groundwater source protection.

The final section includes news from the main bodies involved with groundwater in Ireland and a listing of recent literature likely to be of interest to hydrogeologists working in Ireland –this will appear in alternate issues of the Newsletter.

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Irish hydrogeology past, present and future

Research

News

Irish hydrogeology past, present and future

Research in Hydrogeology

Hydrogeological News

Cover photo: Pumping test at Swan borehole, Laois, 1976. Photo by Bruce Misstear

Memories of Groundwater Use and Development in Ireland, from 1950 to 1976

C.R. Aldwell

Retired Geological Survey of Ireland

Celebrating 40 years: the establishment of the Geological Survey's Groundwater Section and the IAH (Irish Group)

The first half of the twentieth century was a turbulent period in Irish history as the population endured the privations of two world wars, the war of independence and the civil war, and an economic war with Britain in the 1930s. The provision of basic facilities such as piped water and sewerage was a distant dream for most of the population outside major towns. Problems with domestic water quality were common, and many rural people were forced to travel long distances to collect their water.

With the end of the Emergency in 1946, successive governments were finally able to make major decisions regarding social development including the introduction of widespread rural electrification. The availability of electricity meant that pumps could be installed in homes and farmyards to provide clean running water, thus increasing levels of hygiene and productivity. In 1950 the Department of Agriculture introduced a scheme of grants for the installation of piped water in farm dwellings, and this in turn led to the development of the Group Water Schemes. Water-on-tap now became an increasing possibility for large numbers of homes and businesses across the country. An increase in demand for groundwater resulted in the establishment of dozens of new well drilling firms. The period from 1960 to 1976 saw tens of thousands of new wells sunk throughout the Republic, at a rate of more than 5,000 wells per year at the

Figure 1 The daily drudgery of getting water from the river in early twentieth century Ireland. Taken from 'The Quiet Revolution – the electrification of rural Ireland' by Michael Shiel (1984).

Figure 2 One of the back-breaking chores of the farm wife in pre-electrification days. From Shiel (1984).

height of the well drilling boom.

Prior to the 1960s water supplies in Ireland came almost exclusively from surface water. It was only as a last resort that the Local Authorities might consider the use of groundwater. This perception persisted even in the face of some local examples of highly productive groundwater supplies, such as springs. At this time, some notably large supplies of groundwater from boreholes were utilised by major industries such as Erin Foods in Carlow, and Mitchelstown Creameries in Cork. A notable exception with regard to groundwater use occurred following a particularly dry year in 1959. In an unusual move the Town Engineer of Dungarvan in Waterford, Paddy Walsh, commissioned a production well on the banks of the Colligan River for public supply, which yielded 120,000 gallons per hour of good quality water. Walsh had gained some engineering experience in the Middle East and was obviously aware of the value of groundwater! By the early 1960s several Irish drillers (e.g., Barham Brothers in Belturbet; Dunnes in Mallow) were sinking high-yielding boreholes, mainly for industrial use.

Since the beginning of the twentieth century, the GSI had regularly provided free advice to people who wished to sink wells. The justification for this lay in the belief that the value of the information obtained by sinking the well would vindicate the time spent answering the query. In the early 1950s the Geological Survey of Ireland had a staff of just five geologists. The grant scheme introduced by the Dept. of Agriculture in 1950 soon led to an avalanche of groundwater-related queries to the GSI. The Acting Head of the GSI in 1950, Tom Duffy, was from a rural area in Monaghan and took these public requests very seriously. He was heavily involved in the preparation of water supply reports until his retirement in 1955, and in July 1951 unsuccessfully requested the appointment of a hydrogeologist to the GSI. Another key advocate of the national importance of groundwater issues was John O'Loan, who worked in the Department of Agriculture. O'Loan was heavily influenced by a study tour he had taken in the United States in the late 1940s to visit the Illinois State Geological Survey. He was greatly impressed by their work on rural groundwater, and proposed that the GSI

Figure 3
Two early advocates for groundwater issues in Ireland: John O'Loan (left) and Tom Duffy (right).

take on a similar, essential national role in providing informed, independent advice on groundwater to the farming community. O'Loan was instrumental in highlighting the water scarcity issues faced by farmers in karstified limestone areas in the west of Ireland.

In 1964 UNESCO set up the International Hydrological Decade (IHD) to coordinate water studies on a global level. An IHD committee of about a dozen hydrologists and one part-time hydrogeologist (the author!) was established for Ireland. A request from UNESCO for a report on groundwater in Ireland prompted the hasty formation of links with the newly formed Groundwater Division in the British Geological Survey. Given the limited resources available in Ireland at the time, priority groundwater mapping was first carried out in Kilkenny, shortly followed by studies in Athenry and Kinvara, Galway.

The increasing international interest in groundwater issues provided an impetus for the establishment of a fully-fledged Groundwater Section in the GSI in 1975, aided by the hire of newly qualified hydrogeologist Eugene Daly in 1971, and the part-time hire of world-renowned hydrogeologist David Burdon in 1974 (then retired). Along with this author and Eugene Daly, two new recruits (Dai Ede and Geoff Wright) completed the small team concerned with groundwater and its development in Ireland. As a progressive step, an Irish Chapter (Group) of the International Association of Hydrogeologists (IAH) was established for the whole island of Ireland with an inaugural lecture in 1976 in Trinity College Dublin. David Burdon was the first president and membership came from both sides of the border. It was agreed that the ethos of the organisation would be as outward-looking as possible given that the numbers of members was so small in the early days. Interestingly, the establishment of the Groundwater Section in GSI and the Irish group of the IAH coincided with two consecutive remarkably hot and dry summers in 1975 and 1976, which prompted an increased national interest in groundwater matters.

Since Ireland joined the then European Economic Community in 1973, living conditions for the population as a whole have improved significantly, and our attitudes to groundwater resource research and development have progressed alongside our European neighbours. In 1976, the first hydrogeological map of Ireland was included in the "International Hydrogeological Map of Europe", undertaken by the IAH and published by UNESCO. This new European project was a revolutionary step forward for hydrogeological mapping. The Irish map was for it's time the most up-to-date scientific presentation of the hydrogeological knowledge of Ireland, and comparable in scale and quality to the submissions of other European countries. This map can be taken to symbolise the emergence of groundwater studies in Ireland and the establishment of Irish hydrogeology as a respected scientific discipline in its own right.

Acknowledgements

Thanks to Sarah Blake for her assistance and encouragement in preparing this article and the slides for the accompanying Technical Discussion Meeting held on 1st November 2016.

ground water:

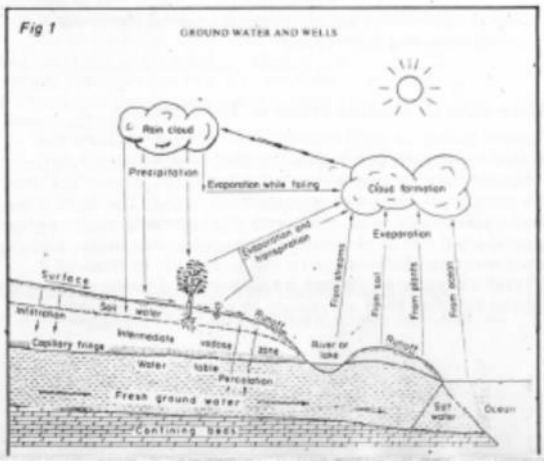
Ireland's hidden resource

by C R Aldwell, D J Burdon and E P Daly

Robert Aldwell was educated at St Marys, Rathmines. He studied Natural Science at TCD and took his BA Mod in Geology in 1960. He joined the Geological Survey in that year and has worked since mainly on ground water. He is a member of the National Committee of the International Hydrological Programme and the Advisory Committee of the Water Resources Division of An Foras Forbartha. He is also a member of the International Association of Hydrogeologists and of the working committee for the Hydrogeological Map of Europe.

David Burdon has many university degrees including the PhD. from Imperial College (1949) and the DSc from NUO (1963). He worked in India (9 years), Cyprus (3 years). He joined FAO in 1952. His work there included Syria (to 1960) in Greece (to 1963), at the Regional Office in Cairo and from 1964 – 1974 at FAO Headquarters, Rome. His posts included Chief, Water Resources Branch, Land and Water Development Division and from 1970 Consulting Hydrogeologist. He is presently hydrogeological consultant to the Geological Survey of Ireland and the Government of Libya, as well as Minerex Ltd. He is a member of many European and American Scientific Societies and has prepared numerous papers and reports.

Eugene Daly was educated at Blackrock College. He received a B.Sc from UCD in 1968 and an MS from North Carolina State University, in Hydrology and Water Resources, in 1971. In the same year he joined the Geological Survey of Ireland, and is currently working on the Ground Water Resources of the Nore River Basin. Last year he received a Diploma in Management for Engineers from TCD.



Traditionally, we think of Ireland as a land abounding in waters– "And her misty vales in summer are by falling waters fanned." To-day, as water is more and more used and misused, the need to search for, and develop additional water resources is becoming of increasing urgency.

Ground water A Renewable Natural Resource

While ground water in many ways resembles ores, fossil fuels and other natural resources obtained from the ground by mining or drilling, it differs sharply from them in that it is generally a renewable natural resource, replenished by a portion of the annual precipitation. From this basic difference there arises a number of considerations which affect the survey, the development and the management of ground water.

With reference to the survey and estimation of ground water resources, it is necessary to consider not only the geological environment through which the ground water moves, but also the source from which it is replenished. This replenishment of the ground water forms a most important phase of the overall hydrological cycle, as summarised diagrammatically in Figure 1, of the article. It should also be noted that as water moves through the different rocks, it is brought in close contact with them, and often dissolves and takes into solution some of their minerals. The salts so brought into ionic solution in the water may be studied to obtain information as to the genesis of the water. These salts may also affect the uses to which the water may be put. Organic or chemical pollution of ground water can take place, and could become more frequent as the country develops.

With reference to the development of ground water, there are dynamic factors to be considered, which do not affect ores and have very different application in oil fields. Such dynamic considerations include:– the effect of one ground water extraction structure on other nearby extraction structures or springs; land subsidence; the inflow of other water (possibly sea water) of poorer chemical quality induced by over-pumping of good quality ground water in certain areas; falls in water level and resultant increased lifts and costs of pumping, due to extraction exceeding recharge in any one ground water basin or area.

As regards management, ground water differs sharply from mining or oilfield practice, in that proper management should enable the ground water to be used indefinitely. Ground water management begins with ensuring optimum development, the prevention of over extraction which could cause serious falls in ground water levels or deterioration of quality, and with the protection of the resource from pollution and contamination. It may proceed to the concept of artificial (or induced) recharge and to the underground storage of flood water or of temporarily surplus surface water supplies. It may lead to the identification of dry rock openings which could store waste products in a manner which eliminates pollution and contamination effects. The economies of ground water also differ sharply from that of ores, and fossil fuels, in that it is generally consumed or used close to the point of production and seldom sent long distances to market or manufacture.

These fundamental differences are noted at the beginning of this article in order that these aspects of the ground water resources of Ireland may be stressed from the start, and so help

Figure 4 Front cover of a paper published in Technology Ireland in 1976. The paper summarised the knowledge on groundwater in Ireland at the time and made a case for the study and use of the resource.

The 40th anniversary of IAH (Irish Group): A few words on the contribution to Irish hydrogeology of Eugene Daly (1947-2014)

Bruce Misstear, *School of Engineering Trinity College Dublin and Secretary General IAH*

Celebrating 40 years: the contribution to Irish hydrogeology of Eugene Daly

As we celebrate the 40th anniversary of the Irish Group of IAH, it is timely to say a few words about the contribution to Irish hydrogeology of one of the Group's founding members, Eugene Daly, who sadly passed away on 28th January 2014.

Together with Bob Aldwell and David Burdon, Eugene played a key role in establishing the Groundwater Section of the Geological Survey of Ireland. Eugene was a geology graduate from UCD who completed a two year Masters in Hydrology and Water Resources at North Carolina State University, funded under a UNESCO International Hydrological Decade scholarship. This training lead to a continued interest in rainfall-runoff-recharge relationships and catchment water balance studies. Eugene joined the GSI in 1971, where he remained for 23 years, before setting up his own consultancy Eugene Daly Associates in 1994.

One of Eugene's major contributions to Irish hydrogeology was as a mentor of younger hydrogeologists, many of whom received their introduction to hydrogeology field work as summer field assistants with Eugene (for example: David Ball, Donal Daly and myself).

Figure 1 Pumping test at Swan borehole LS31/1, County Laois, 1976 (left – with Eugene Daly and Donal Daly standing beside the generator in the foreground); Eugene at a weir across the Nuenna River, County Kilkenny, 1975 (right). Photos by Bruce Misstear.

Figure 2 Sorting through Eugene Daly's technical papers. Photos by David Ball and Bruno Teillard.

Eugene was committed to careful field work (Figure 1), and passed on this enthusiasm to generations of Irish hydrogeologists and recently at the Environment Agency in the England.

After his death in 2014, his wife Margaret asked a few of his former friends and colleagues (David Ball, Tim Morgan, Bruno Teillard and myself) to sort through his copious technical papers and decide which ones should be kept (Figure 2). The Director of the GSI, Koen Verbruggen, subsequently arranged for the collection of the numerous boxes of papers and reports, for safekeeping at the GSI.

Whilst going through Eugene's technical papers we were struck by a number of things, including the thoroughness with which Eugene checked and revised documents (he kept all his drafts!), his detailed notes on field activities such as geophysical logging and pumping tests, and his numerous sketches of what are now generally referred to as conceptual hydrogeological models. Eugene was certainly a keen advocate of the excellent piece of advice given by Siegel (2008) that one should contour with one's head and not with a computer.

Figure 3 below shows a couple of examples of Eugene's sketches of conceptual hydrogeological models. (The drawing on the left and Figure 4 bring back fond memories to this writer of a trip to Inishmaan in 1975 for the purposes of downhole geophysical logging target blasting operations which were carried out to try to open fractures and bedding planes in several exploration boreholes).

One of Eugene's initiatives when he joined the GSI was to purchase a geophysical logging unit (a Gearhart-Owen Portalogger), which was mounted in the back of a Land Rover. Eugene thus produced the first downhole geophysical logs for water wells in Ireland (Figures 4, 5 and 6). A key application of geophysical logging was to identify aquifer horizons in boreholes for which no geological logs were available. For example, owing to their distinctive geophysical log profiles (single point resistance and natural gamma), the sandstone aquifer in borehole LS31/1 at Swan on the Castlecomer Plateau was identified as the Swan Sandstone and not the deeper Clay Gall Sandstone as had been previously thought (Figure 4). Notwithstanding Eugene's pioneering

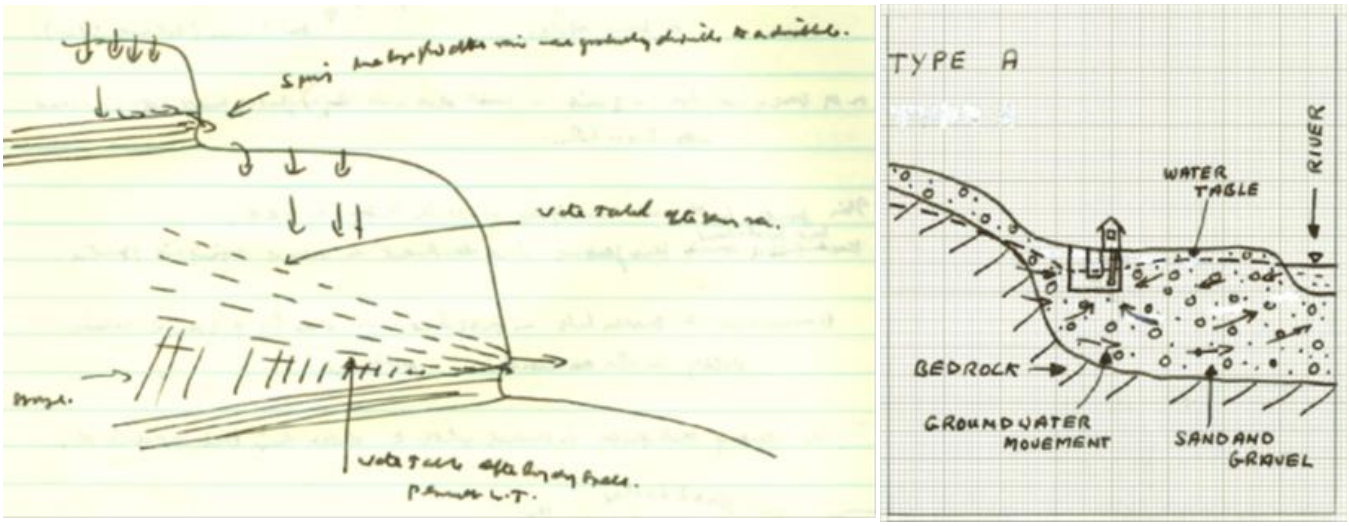


Figure 3 Sketches showing a conceptual hydrogeological model for springs on Inishmaan, County Galway (left); and an example of a hydrogeological environment suitable for an infiltration gallery (right)

work in this regard, geophysical logging has remained a much underused tool in Ireland.

In the days leading up to his death Eugene was still talking enthusiastically about hydrogeology. One of his concerns for the future of our discipline was that field work was not receiving the same priority as before. It would be a fitting legacy of Eugene's contribution to hydrogeology in Ireland if we continued to remember the importance of collecting good data in the field.

Figure 3 Setting up for geophysical logging an exploration borehole on Inishmaan in 1975. Photo by David Ball.

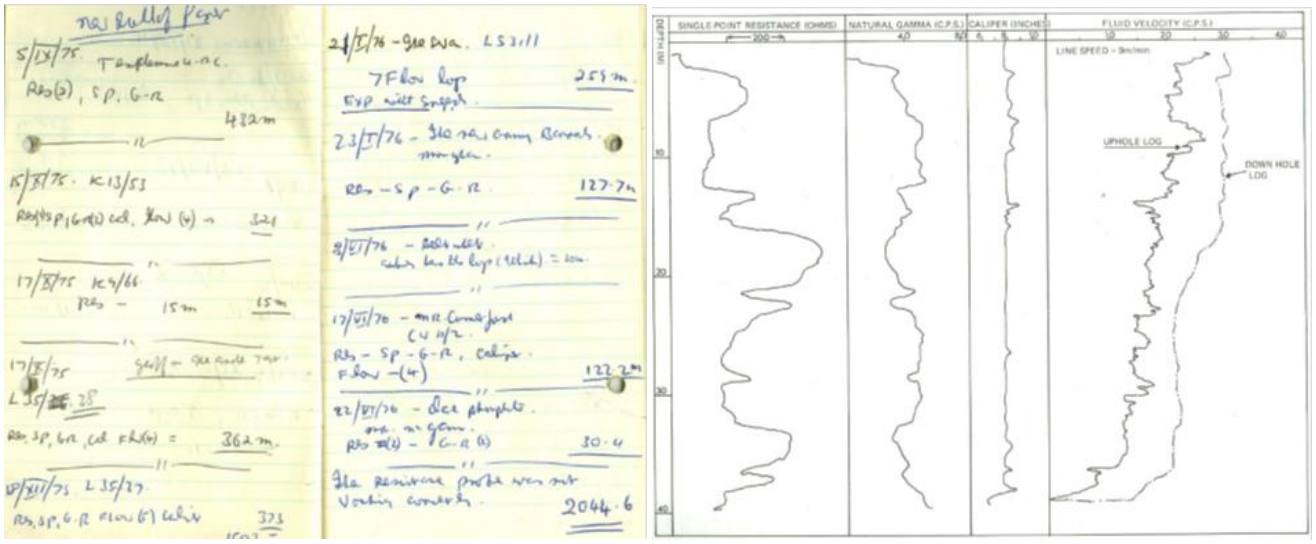


Figure 4 Excerpt from field geophysical logging notebook (1975/76) (left); Geophysical logs of borehole LS31/1 at Swan, County Laois (right) (Misstear et al., 1980)

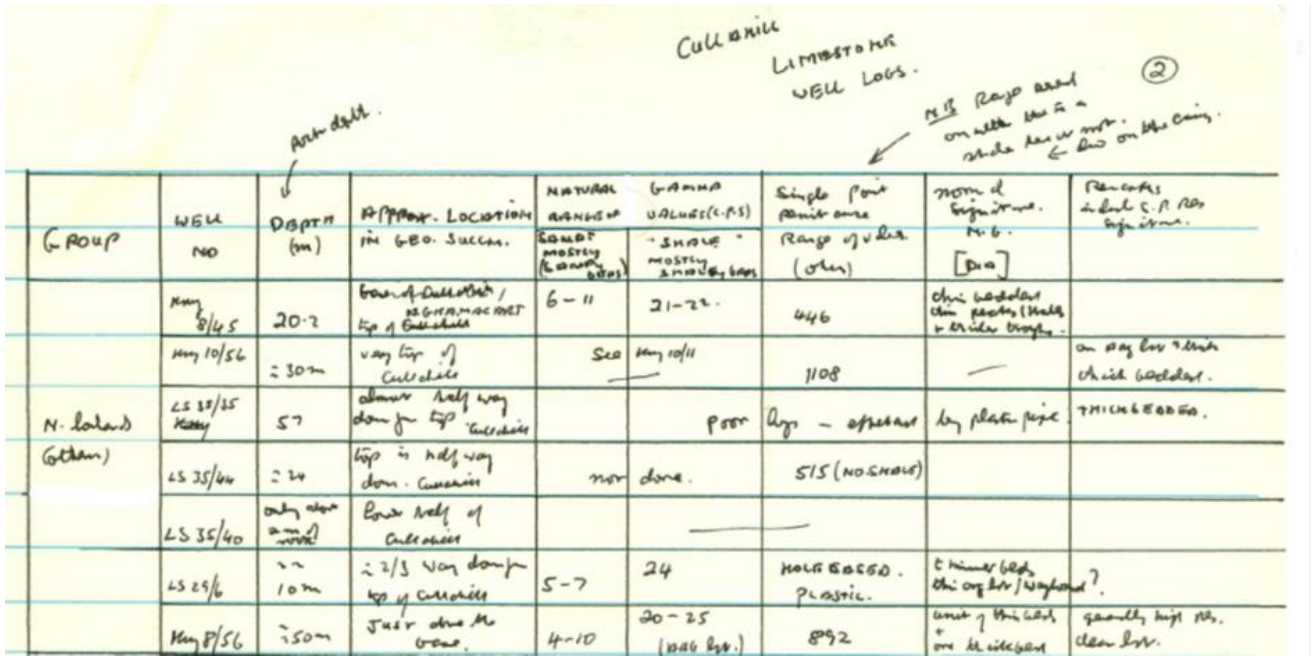


Figure 5 Detailed hand-written notes on geophysical logs in the Nore River basin (excerpt only)

Acknowledgements

Thanks to David Ball for photos and comments.

References

Misstear BDR, Daly EP, Daly D and Lloyd JW (1980) *The Groundwater Resources of the Castlecomer Plateau*. Geological Survey of Ireland Report Series RS 80/3, Dublin, 1980, 31 pp

Siegel D (2008) Reductionist hydrogeology: ten fundamental principles. *Hydrological Processes* 22: 4967-4970

The origins of the IAH Irish Group's annual conference

Geoff Wright
Retired Geological Survey of Ireland

Celebrating 40 years: the origins of the IAH Irish Group's annual conference

When the Irish Group of IAH began, there were very few hydrogeologists in Ireland. My old international IAH membership directory for 1980 records a membership of just 13, of whom probably 8 could claim to be hydrogeologists. (By 1990, membership had grown to 23, by 1997 to 48, and by 1999 to 61.) It was a few years before the group evolved into a professional body which could also open itself out to the wider groundwater community – i.e. those who were involved, perhaps peripherally, in the groundwater 'industry'.

The Annual Conference played an important role in this process, and in all my years of involvement with IAH - the meetings, field trips, etc., it's the conference which gives me the most satisfaction to look back on.

The initial seed was planted in 1979, when Douglas Gordon, on behalf of Atlas Copco, organised a 2-day meeting in Limerick, focussing on the introduction of the then-new 'Odex' drilling system, in which the casing can be drilled ahead of the borehole, using an eccentric under-reamer, with reverse circulation with foam.

I was impressed by the success of the meeting in attracting a variety of people involved in groundwater – primarily drillers, consultants and local authority engineers. Why couldn't the IAH convene meetings like this, and get our message out to a similarly wide audience?

When I became IAH group secretary in 1980, I wanted to pursue this idea. I had also become aware that gravel aquifers in Ireland were neglected - largely, it seemed, because few people knew how to go about developing them. So, I thought, why not convene a 2-day meeting, at a convenient location, focussing on gravel aquifers? In those days, the IAH committee had 3

Figure 1

David Burdon in Chad

Photo by David Ball.

members –the others then being David Burdon as President and Kevin Cullen as Treasurer. Kevin was keen on the proposal, David gave us his blessing, and off we went.

Our chosen venue was the Montague Hotel at Emo, near Portlaoise – being relatively central, easily accessible from Dublin, and having a suitably large meeting room and good car parking. It also had the great advantage of sitting on a gravel aquifer, which Eugene Daly had been dealing with a few months before. This gave us the chance to stage field demonstrations of gravel well development and resistivity surveys in the hotel grounds. The hotel management were very helpful. (One personal memory of the weeks before the event – returning home from a meeting between Kevin and I and the Manager in the hotel, I picked up my one and only Irish speeding ticket at Ballybrittas!) We were keen to attract as many well drillers as possible, so we chose to hold the meeting in late January 1981, when we though well drillers would be least busy.

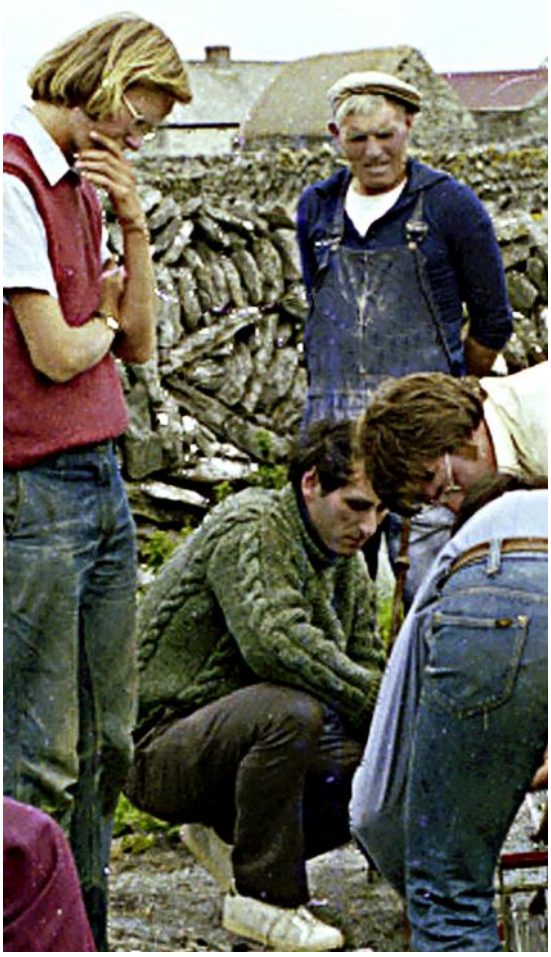


Figure 2 Bruce Misstear, Bob Aldwell, Eugene Daly and Donal Daly measuring a water level in 1975. Photo by David Ball.

One of the problems of holding a meeting of this kind is the up-front cost. We had no idea how many people would come – we thought 40 or so would be good – so we needed to keep costs down to a minimum, as the IAH group funds were very small. The GSI's director, Cyril Williams, was very supportive, so we were able to borrow the Survey's slide projector, overhead projector and screens (no Powerpoint in those days!) and use the Survey's photocopier. The 'proceedings' were, in any case, minimal – 36 pages in total.

We minimised speaker expenses by calling in favours – David Burdon's company, Minerex, provided Frank Collar to stage the geophysical demo, Johnson Wellscreens provided Bill Jungmann to give two talks, Ronnie Creighton from GSI came to talk about the origins of gravel aquifers, and my old mate Lewis Clark came over from England to give a couple of talks, using GSI's membership of the Water Research Centre to justify the trip. Ingersoll Rand and Johnson Wellscreens provided two short films, and Brian Williams gave a talk on Geophysical investigations. Finally, we had a series of short case histories from Eugene Daly, Kevin Cullen, Frank Collar, Peter Bennett, Rod Aspinwall, Lewis Clark and me. Altogether, a packed programme was offered, to end about 4 pm on Day 2.

Naturally, in the weeks leading up to the meeting there was considerable tension. Would anybody come? Would we cover our costs? In the event, the response surpassed our highest hopes, and we had 98 attendees – a figure which wasn't surpassed for several years. Even with a low attendance fee – I think it was £20 – we generated a satisfactory surplus, which provided a firm foundation for subsequent years. More

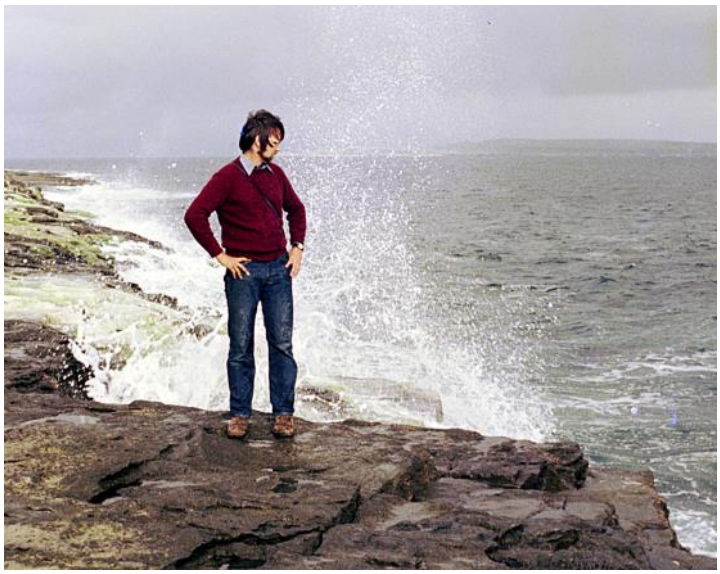


Figure 3 Eugene Daly in Inishmaan in 1975.

Photo by David Ball

importantly, perhaps, we acquired a reputation for a well-organised, informative meeting which we strove to live up to from then on.

This initial success emboldened us to try to turn the meeting into an annual event. For the 1982 meeting, which we moved to late March (to avoid potential road/weather problems), we chose 'Groundwater Development in Limestone Aquifers' – obviously relevant to Ireland's most important, and often difficult-to-develop aquifers . We probably made a mistake by depending too heavily on one speaker, an experienced American driller and friend of John Dunne (always a great supporter), but the meeting was still reckoned a success, and we followed up in April 1983 with a meeting on 'Cost Factors in Groundwater Development'. This time we switched to the Killeshin Hotel in Portlaoise, which remained the regular venue for many years afterwards. By this time, the 'Proceedings' had expanded considerably, and we could afford to commission professional photocopying.

By 1983, a pattern had been established. Several Irish welldrilling firms were always very supportive, but overall the response from the wider welldrilling community was less than we had hoped for. On the other hand, the meetings proved very popular with local authority staff and consultants, and to some extent the programme each year reflected this. When we began, I called the meeting a 'seminar', to reflect its educational aims, and it retained this title for many years. We established some fairly firm, though not immutable, principles: (1) we would choose the theme and find speakers who would speak to their topic, (2) we would only choose speakers who were known to be good presenters, (3) we would avoid overtly commercial presentations, (4) we would aim for a very high standard of presentation. I think that all the subsequent annual meetings have lived up to these same principles.

After our first three years, the organisation was taken over very successfully by a new committee (though I came back to it later in the 1980s). For several years the attendance was boosted by groups of postgraduate students, from UCG (thanks to Paul Johston), Sligo Technical College (Richard Thorn) and Trinity College (Catherine Coxon), and as a result the 1987 meeting, for instance, had 126 attendees. Commercial exhibits also became a welcome addition to the event, and provided extra revenue.

As the hydrogeological community in Ireland has grown and evolved, the annual conference has evolved appropriately. Clearly the event has become more oriented towards hydrogeology, but has retained its wider appeal. I think also the wider audience has become better able to interact with hydrogeologists. Moreover, the annual event has continued to have a social function, to be a meeting place where attendees can interact over meals, coffee breaks and after hours. Friendships have been formed and maintained. I don't think we talked about 'networking' in 1981, but that was definitely what we were encouraging. So I hope the annual conference will continue to evolve and to facilitate the interaction of IAH members with groundwater developers, users, regulators and managers.

Managing on-site waste water treatment systems for drinking water protection

Brian MacDomhnaill and Barry Deane
National Federation of Group Water Schemes

Irish hydrogeology past, present and future: A collaborative, community-based approach to managing on-site waste water treatment systems located within the zone of contribution of drinking water sources.

A project involving the Environmental Protection Agency (EPA), the National Federation of Group Water Schemes (NFGWS), the Geological Survey of Ireland (GSI) and the Local Authority Waters and Communities Office (LAWCO) aims to provide a blueprint for a community-based approach to managing on-site waste water treatment systems (OSWTS) located within the zone of contribution (ZOC) of drinking water sources.

Describing the 2-year collaborative project as the 'next logical step' in better protecting drinking water sources, NFGWS Senior Development Officer, Barry Deane, describes it as just one of several outcomes from the on-going ZOC delineation work being carried out by the Federation in conjunction with the Geological Survey of Ireland (GSI) and Dundalk Institute of Technology (DkIT). He said:

'Thanks to the delineation of groundwater source catchments by hydrogeologists working under the supervision of the GSI and the mapping of surface water catchments under the supervision of the Centre for Freshwater & Environment Studies at DkIT, group schemes now have the basic hydrological information to develop informed source protection strategies.

'We always intended that the reports produced by these studies would become working documents, rather than gathering dust on shelves...

Across the GWS sector, we are seeing... increasing awareness that what happens in the catchment may impact negatively on source water quality'

'We always intended that the reports produced by these studies would become working documents, rather than gathering dust on shelves. This is exactly what is happening. Across the GWS sector, we are seeing more and more attention being paid to well-head protection, to the identification and better protection of specific pathways – including sinking streams in karst limestone areas – and to increasing awareness that what happens in the catchment may impact negatively on source water quality.

'While agricultural practices undoubtedly give rise to most contamination issues in raw water sources supplying the GWS sector, the contribution of OSWTS as point source pollutants cannot be ignored.

'We are particularly pleased, therefore, that a pilot project conducted last year on 2 group schemes in County Louth – aimed at testing the capacity of group schemes to co-ordinate better management of OSWTS in their respective ZOCs – has led on to this more ambitious project that will include the participation of 6 schemes.'

Louth pilot

Established in response to the finding from the first phase of the EPA's National Action Plan on OSWTS that poor management of such systems is a major issue to be addressed, the Louth pilot

Figure 2: Door to door canvass conducted by NFGWS staff and representative of local GWS in Tullyallen GWS, Co Louth.

confirmed that householders within group water scheme ZOCs are positively disposed towards regular desludging of their OSWTS where that is co-ordinated by the local GWS board of management/committee.

Indeed, the scale of the positive response to the initiative surprised those involved, as all householders, bar one, agreed that it was a great idea and a large majority actually signed up to co-ordinated and tri-annual desludging.

The door-to-door canvass conducted by NFGWS staff and a representative of the local GWS also provided an opportunity to engage with local farmers, making the point that sludge from their own OSWTS should never be spread within the ZOC. Again, the response was positive.

Shortcomings identified in the course of the pilot project were included in a final report issued on 19 May last (available from http://www.nfgws.ie/f//OSWTS%20Pilot%20Evaluation%20final.pdf). Issues arose with identifying 'competent' as opposed to merely 'licensed' contractors, but the main shortcoming was the lack of a dedicated project driver. This meant that there were long periods of inactivity between various phases of the pilot project, so that momentum was lost.

It was to address this shortcoming, in particular, that the NFGWS applied to the EPA for funding towards a 2nd phase project that would see the appointment of NFGWS staff members as drivers. The EPA agreed to this request, recognising that it would strengthen awareness of OSWTS issues in a sector that includes some 70,000 rural households in privately sourced schemes and possibly as many householders again in the publicly sourced GWS sector.

Grant aid

Following on from the announcement of EPA grand-aid, NFGWS Development Officers Jean Rosney and Joe Gallagher were appointed in early August as Source Catchment Co-ordinators and a Steering Group was established shortly afterwards to oversee the project with the first meeting held on 17 August. The group includes representatives of the NFGWS, EPA, GSI and LAWCO.

Amongst the criteria that were applied in selecting schemes for the initial roll out of the project was the stipulation that they would have already completed ZOC delineation/ catchment mapping of their raw water sources and would be close to surface waters that are defined as 'high risk'.

In addition, the schemes chosen would have a local manager in place and would have at least one nearby primary school, as the project will work through schools to raise awareness about OSWTS and water quality issues.

Two surface water supplies were identified as meeting these criteria: Toonagh/Dysart on the edge of the Burren in North Clare and Erne Valley GWS in Cavan which draws its supply from Lough Gowna, a headwater of the Erne catchment.

Several neighbouring borehole schemes in the Thurles area of County Tipperary were identified as suitable also. These include, Rahealty GWS, Tonagha/Lahardan GWS, Graigue/Pouldine GWS and Ashill GWS, all of which are in the catchment of the River Suir.

Delivery model

The Project Co-ordinators will be tasked with further developing the programme delivery model, building on the experience gained through the Louth pilot, with particular regard to the conclusions and recommendations of the review report.

They will focus on community education through engagement with local primary schools, again building on the Federation's work in this area, as well as utilising infographics and other resources produced by the EPA.

Identifying and sourcing additional funding towards the on-going implementation of the OSWTS programme on future schemes will provide a further focus for the Project Co-ordinators, as will the completion of a national mapping strategy, as the provision of ZOC maps with households/townlands identified was a major factor in the success of the Louth pilot project.

Figure 2: Group Water Scheme selection. From left to right: Jean Rosney (NFGWS) Margaret Keegan (EPA), Taly Hunter Williams (Geological Survey) and Joe Gallagher (NFGWS)

The Local Authority Waters and Communities Office—An Introduction

Ray Spain and Alan Walsh
Local Authority Waters and Communities Office

Irish hydrogeology past, present and future: An introduction to the Local Authority Waters and Communities Office, set up to coordinate local authority Water Framework Directive (WFD) activities and to promote public participation in the WFD.

Background

The Water Framework Directive 200/60/EC (WFD) was adopted by the European Union in 2000 to establish a framework across member states for the protection and improvement of natural water bodies which include; rivers, lakes, estuaries, coastal waters and groundwaters.

Compliance with the WFD is to be achieved through River Basin Management Plans and a Programme of Measures that are reviewed every six years. We are now into the second cycle of those plans from 2016–2021.

The European Union (Water Policy) Regulations 2014 (S.I. No. 350 of 2014) was introduced to give effect to the WFD in Irish law. These regulations established a new three tier interlocking governance structure to implement the WFD across the entire country, with clear responsibilities assigned to the Minister for Housing, Planning, Community and Local Government, the EPA and Local Authorities, see Fig.1.

The obligations on Local Authorities as set out at tier three will require on-going monitoring, licencing and enforcement actions. The emphasis on public engagement stems from lessons learnt during the first cycle River Basin Management Plans 2009 - 2015, most notably the need for greater public participation in the making and implementation of those Plans and Programmes of Measures. These lessons can now be brought forward into the second cycle plan 2016 – 2021 and it is hoped that greater public engagement, knowledge sharing and cross sectorial collaboration will result in a single River Basin Management Plan (RBMP) for the whole country that is more relevant to the needs of local communities.

Figure 1: Three tier governance structure: make up and responsibilities.

Figure 2: LAWCO office locations

The Local Authority Waters and Communities Office (LAWCO) was set up February 2016 by Local Authorities to assist in the delivery of the tier three obligations. The office is managed jointly by Kilkenny and Tipperary County Councils and operates as a shared service on behalf of all 31 local authorities. This new office is tasked with delivering two key objectives in connection with the implementation of the WFD in Ireland:

(i) to coordinate the activities of all Local Authorities in areas connected with the Directive.

(ii) to promote public participation in the WFD process by engaging the public and communities in the management of their own local water environment.

LAWCO is headed up by Matt Shortt, Director of Services, Tipperary County Council and assisted by Carol McCarthy, Acting Senior Engineer, Kilkenny County Council. The office will have a staff complement of 3 regional coordinators, 3 specialist support staff based in Clonmel, Co. Tipperary and 12 community waters officers operating from different centres across the entire country, see Fig.2 map which shows these office locations.

Local Authority regional structures

A regional committee structure has been agreed by Local Authorities to oversee the coordination of efforts and resources within these regions. Each 'Local Authority Regional Water & Environment Management Committee' is chaired by a Chief Executive and includes senior management from the Local Authorities within each region. LAWCO staff will provide the secretariat to these committees and report back on progress on the ground.

The committees will prepare regional integrated catchment management programmes in partnership with public bodies, stakeholders, non-governmental organisations and local communities. This structure has oversight over the work of LAWCO and the application of measures by Local Authorities on the ground. They will determine regional priorities, within the overall RBMP framework and identify opportunities for collaborative actions between all water stakeholders, thus providing continued focus for the allocation of scarce resources.

Public participation

Public participation is a core element of the WFD and experiences to date have taught us that the success of any plans and measures will require a collaborative approach between communities, public bodies and all water stakeholders. Good examples of what can be achieved through local collaboration is evident in the annual 'Tidy Towns' and 'Pride of Place' programmes which are actively supported by Local Authorities.

A number of catchment initiatives with good community collaboration have been demonstrated through the EU LIFE Programmes such as: DuhallowLIFE, MulkearLIFE and BurrenLIFE and also throughout the country under the LEADER programme.

By looking to the experience of Rivers Trusts in the UK we can also see the effectiveness of com-

munity stewardship in water quality management. Is there capacity for a similar approach in Ireland?

Funding will be critical if communities are to take on a greater role in the management of their local water environment. LAWCO will provide technical advice and assistance in relation to local, regional, national and EU funding streams connected to water quality management.

River Suir catchment public engagement

LAWCO has set about engaging with local communities with a connection to the River Suir by holding a series of public meetings in towns and villages right across the catchment, which includes the counties of Tipperary, Waterford, Kilkenny and Wexford. The purpose of these meetings was to open out a discussion on the river, the benefits local communities derive from it and any local issues impacting on communities' enjoyment of the River Suir and its tributaries.

Thirteen meetings were held during September and October in towns and villages along the R. Suir extending from Templemore, near the source of the Suir in the Devils bit mountain, to Waterford City on the Suir estuary. A further six meetings are planned for November which will extend out to coastal communities in counties Waterford and Wexford.

As a result of these meetings LAWCO has developed linkages with Angling clubs, Tidy Towns committees, walking groups, other public bodies such as IFI and OPW, Heritage Officers and Environment staff, LEADER companies and many more groups with an interest in the River Suir catchment. Through these public meetings and this network of local stakeholders it is evident that there is an appetite among communities to get involved in the management of their local river and to work together across the wider catchment. LAWCO will facilitate communities and groups to become more involved in the management of their local waters and thus promote a bottom up approach to catchment management and the implementation of on the ground measures.

Draft River Basin Management Plan

Successful river basin management planning clearly requires an integrated approach to the protection, improvement and management of the whole water environment. The six-year cycle of planning, action and review of RBMP provides opportunity for the development of new approaches in the management of our natural waters to meet the demands society places on them.

Due to restrictions on scarce public resources during the recent economic recession Ireland is

Figure 3: LAWCO staff from left to right : Sheevaun Thompson, Alan Walsh, Michael Pollard, Fran Igoe and Bernie O'Flaherty

Figure 4: Photo of public meeting in Cahir, Co. Tipperary shows Fran Igoe discussing the significance of the Lower Suir SAC in a European context.

now running 2 years behind schedule with the 2nd cycle River Basin Management Plan and therefore the effective period for the next plan will run from December 2017 to December 2021.

Notwithstanding this fact a public consultation process in relation to the second cycle RBMP was carried out between July and December 2015 when the then Department of the Environment sought views on what are considered to be the Significant Water Management Issues in Ireland (SWMII). The submissions received under this process will feed into the forthcoming draft RBMP.

The draft RBMP will be issued for public consultation from December 2016 – June 2017and will be made available through Local Authorities. LAWCO will coordinate and assist Local Authorities with this consultation process. The 2nd Cycle RBMP will be published in December 2017.

The next steps

At the time of writing there are now nine Community Waters Officers in place with a further three to take up their post over the coming weeks. This will give LAWCO its full complement of 18 staff.

Initial efforts have focussed on community networking and making contact with interested parties for the purpose of developing forums where these parties (public agencies, communities and organisations) can discuss and develop themes connected with water quality management. LAWCO will provide technical assistance to community groups, advice on project planning and funding and facilitate the interaction and participation of all stakeholders in the wider catchment management.

LAWCO, through the 'Local Authority Regional Water & Environment Management Committees', will seek to coordinate the activities of Local Authorities in areas connected with the WFD, especially where cooperation across administrative boundaries is necessary. Cooperation and linkages with other public bodies will need to be developed for successful collaboration and delivery of projects focussed on improving the water environment, to this end LAWCO will open lines of communication and encourage knowledge sharing.

If we are successful, we will see many more examples similar to that of IRD Duhallow where communities have carried out successful water quality protection and enhancement projects. We will see public bodies joining forces to deliver projects such as the direct labour flooding works on the River Tolka by Dublin City Council and the OPW.

In this newsletter over the past number of years we have heard about the concept of integrated catchment management and the necessity for such an approach if we are to successfully meet our obligations under the WFD. For catchment management to be successful in Ireland, all sectors of society must work together. In this way it will be possible improve the quality of the water environment to meet our existing needs and to safeguard a healthy future for all. This approach is firmly set out in LAWCO's vision statement:

"To be relevant, to work collaboratively in an open, flexible and adaptable way that meets the ever changing needs of society and our natural waters."

Hydrogeology in the Future – The next 40 years of IAH Ireland.

Gerry Baker, RPS Aquaterra

Irish hydrogeology past, present and future: imagining Irish hydrogeology in 2056.

As the IAH Irish Group turns 40 we take a look forward and imagine what hydrogeology might be like in in the year 2056.

Will there still be a requirement for hydrogeologists in 2056? Yes, more than ever. As long as we toil on this earth (and possibly others) there will always be a need for experts in groundwater, whose conception of the water beneath our feet extends beyond underground rivers. Hydrogeologists will be sought to investigate, characterise, monitor, model and make predictions about groundwater. As biodiversity and water resources are continually stressed the conservation objectives of our protected habitats and resources will only become more stringent, and the burden and certainty of proof required that the predicted impacts of ceaseless development will be ever increasing.

We can expect major developments in our ability to characterise the hydrogeological environment. While there will no doubt be snazzy developments in groundwater models, these already have the capability to represent conduit flow processes, dual porosity media and complex strata topology. What we lack is the information to populate those models with a level of detail to adequately represent the hydrogeological environment.

It's hard to imagine what will be available to us in forty years from now. Try to envisage the technological leaps from 1976 to today and then to propel that forward at another 40 years at the current exponential rate of development.

Even now we don't understand the full capabilities of the technology we possess. For instance smartphones, these are the most technologically advanced piece of equipment you interact with on a daily basis. The smartphone is already one the hydrogeologists essential tools. From the basics like determining your location on site or getting to site with google maps and taking georeferenced photos, to industry specific apps for monitoring parameter stabilisation during purging, logging samples with the laboratory, downloading data from loggers, GIS apps to show your current location on a geology map.

The capability of smartphones and peripheral devices in 40 years time will be beyond our conception. For instance the advances we see in virtual reality interfaces will be pervasive where I expect we will be able to use our phones, or peripherals such as Google glasses, to see the mapped geology in 3D around us and why not also see geophysical data, the water-table or indeed groundwater flow in real time.

The phone will also have thermal imaging capability which will allow you to observe in real time where groundwater discharges to a stream or wetland habitat due to temperature differentials. Similarly you can download an XRF app to see the geochemical make up of your samples.

Some of the most exciting technological developments of recent years are drones and nanotechnology. Already drones are commonly used for detailed topographic surveys of landfills and mines. Drones will become smaller and capable of measuring a wider range of parameters. I forsee that we will have tiny amphibious drones/nanobots which can be released into karst swallow holes and from there they will laser map the internal geometry of a conduit system while monitoring the flow and

Figure: Geological Survey drone Photo: Eoin MacCraith INFOMAR

chemistry of the water flowing through it.

The capacity of remote sensing, airborne or satellite, will only improve with time. Already the Grace satellite monitors fluctuations in groundwater elevations, although at a fairly course grid. This will only improve with time. The amazing work of the Tellus programme is conceivably only the start of a new phase in how we map our resources, including groundwater. As airborne geophysical techniques develop there is every reason to expect the quality, accuracy and range of measurements to increase.

Water monitoring has been at the forefront of the Internet of Things (IoT) with the use of telemetry but we can expect all our equipment to automatically log measurements to the cloud. Water quality loggers will be able to monitor an increasing array of parameters in-situ. Our monitoring equipment will be powered by artificial intelligence such that it can make decisions to increase the frequency of monitoring if a spike event is occurring, or to broaden the range of parameters to suit the hydrochemistry.

Already we are immersed in data. We are befuddled with level logger data files that record data at one minute intervals. As more and more groundwater, surface water and drinking water sites are monitored at increasingly high frequencies we will be awash with data. However Big Data is pointless unless it yields big ideas. For that we need better data analysis and visualisation tools. Hydrogeologists in the future will need to be comfortable working with massive datasets and have the ability to present and visualise that data in engaging and meaningful ways to communicate their understanding.

Hydrogeologists in 2056 will be dealing on a daily basis with what we now call emerging contaminants. New technologies bring new materials and new wastes and we can't predict the issues the future emerging contaminants will yield and how far behind the plume we will be when their health implications and transport mechanisms are fully understood. When DDT and asbestos were in widespread use they were lauded. Similarly at present our non-stick house hold goods have been treated with PFOAs which are now known to be serious carcinogens. What new wonder material/product will emerge that will be embraced before the health effects are fully understood, just look at the proliferation of vaping in-lieu of any long term research on its health impacts!

With all that said, groundwater is for the main part a blissfully torpid beast. If you consider a drop of groundwater under your feet now and presume its situated in strata of fairly standard permeability (0.1m/d) and effective porosity (1%) and subject it to a fairly standard hydraulic gradient (0.001) then the distance that drop of groundwater would have travelled in the next forty years is only 146m!

However there is no getting away from the need to pump a borehole for extended periods of time to observe the response as the cone of depression expands. In this age of instant gratification there is something satisfying about the slow reveal and in forty years that will still be the case. It will also still be the case that the hydrogeologist will be the only one to conceptualise the results in the four dimensions and be able to communicate that to our 2D minded, flat-earth associates.

Looking forward to the next 40 years!

Groundwater source protection terminology used in Ireland

Taly Hunter-Williams[1], Coran Kelly[2], and Donal Daly[3]
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This paper aims to clarify terminology used for groundwater source protection .

Terminology

There are several terms used in Ireland for the areas around springs and wells, which can lead to a certain degree of confusion. The most widely used terms include catchments, zones of contribution, source protection areas, source protection zones, capture zones and safeguard zones, which are described as follows:

- **Zone of Contribution (ZOC)** is the land area that contributes water to the well or spring (Misstear et al 2006). It is a simple, intuitive, basic hydrogeological definition that is considered to be the best term for general use.
- **Catchment** is the land area that contributes water to the well or spring. Like surface water bodies, springs have natural catchment areas, whereas catchment areas to bore-

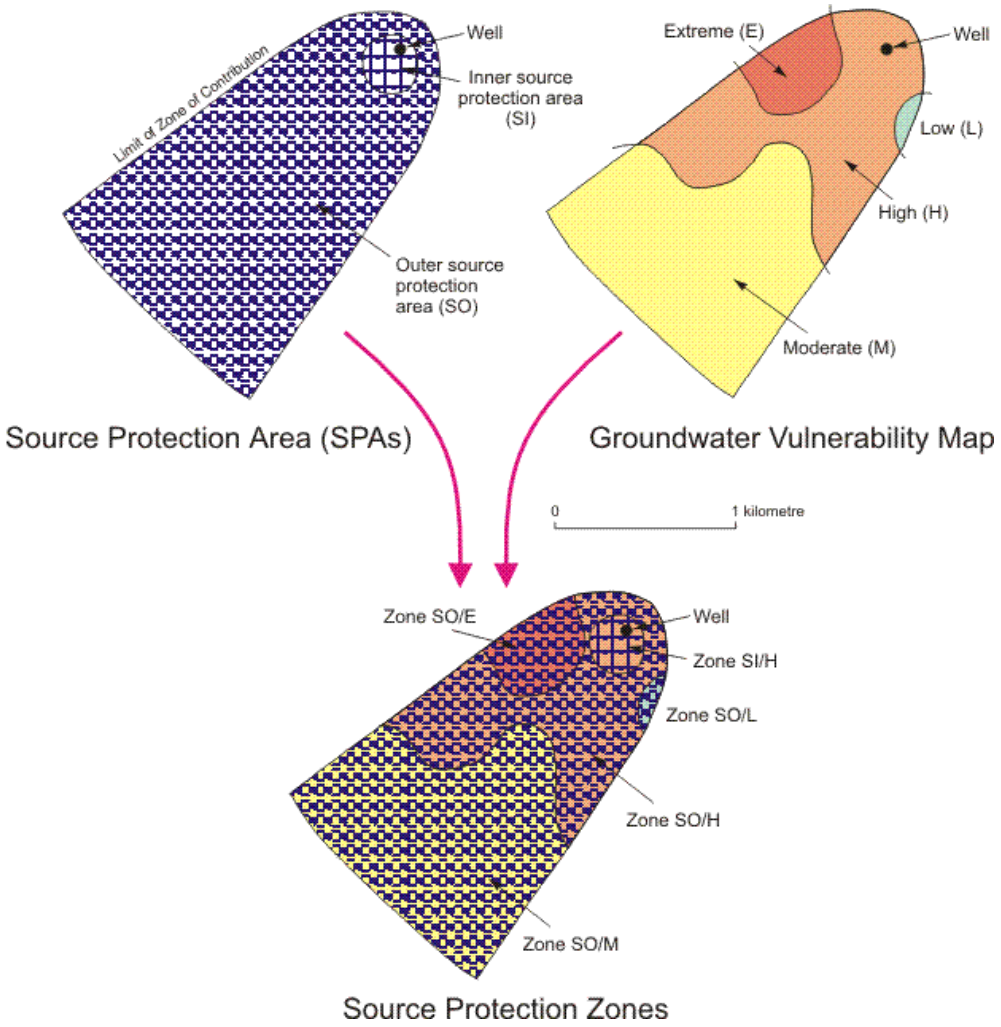

Figure 1: Source Protection Zones (DoELG/EPA/GSI, 1999)

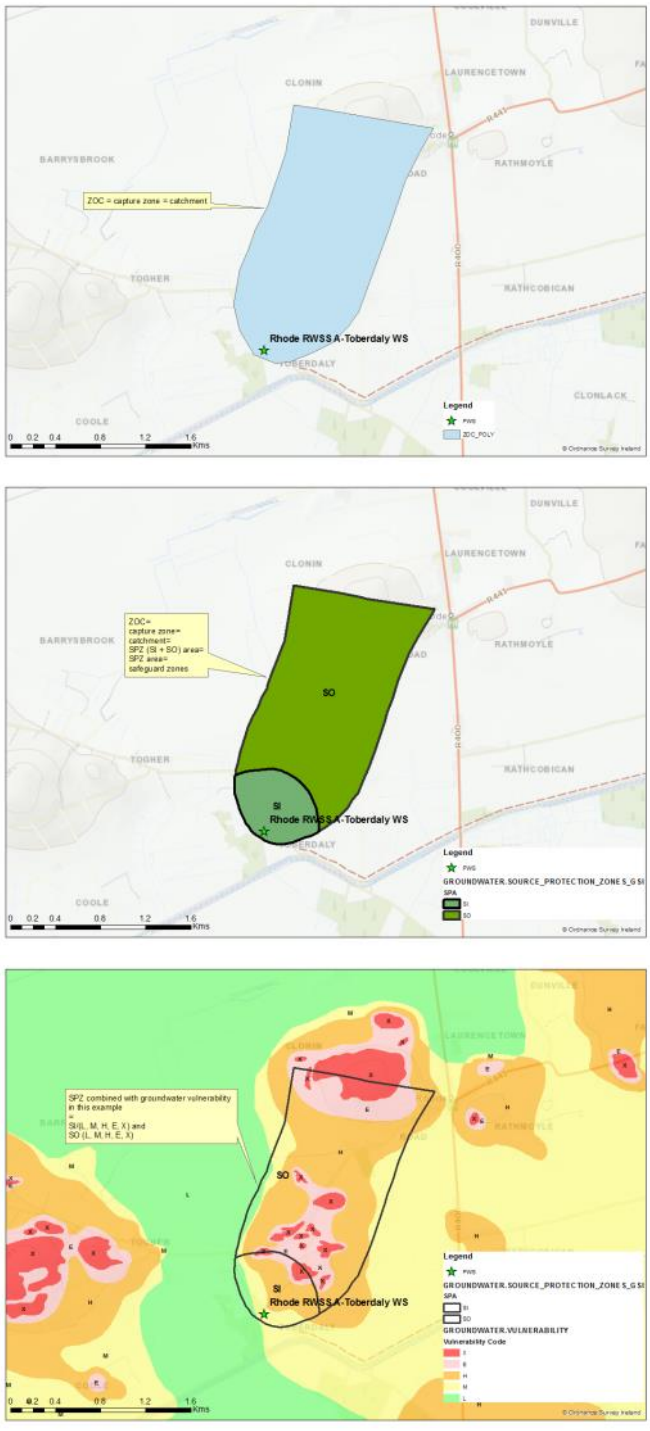

Figure 2 : Toberdaly Source Protection Zone

(a) zone of contribution / capture zone / catchment; (b) source protection zone (SPZ) including inner protection area (SI) and outer protection area (SO) / safeguard zone; and (c) source protection zone combined with groundwater vulnerability, in this example SI and SO comprise low, moderate, high, extreme and extreme X groundwater vulnerability.

holes depend on a number of hydrogeological and meteorological factors plus the abstraction rate.

- **Capture Zone** is a common term present in the literature and is equivalent to the ZOC.
- **Safeguard Zone** is a specific Water Framework Directive term that encompasses the same area as the ZOC.
- **Source Protection Areas**: The Geological Survey of Ireland developed this terminology and the methodology for delineating the areas (DELG, EPA, GSI, 1999). Two Source Protection Areas (SPAs) are delineated which, when combined, are equivalent in area, shape and orientation to the Zone of Contribution:
  - Inner Protection Area (SI), designed to give protection from microbial pollution.
  - Outer Protection Area (SO), encompassing the remainder of the zone of contribution (ZOC).

Different methods can be used to map the entire Zone of Contribution to a spring, borehole or dug well, resulting in different degrees of confidence associated with the boundaries of the delineated area. To be able to specify the Inner Protection Zone within the entire ZOC, knowledge or estimates of groundwater travel time within the aquifer are required (e.g. from site-specific hydrogeological parameters or tracer tests).

The ZOC and the SPA account for the 'horizontal' movement of groundwater. ***Source Protection Zones*** are obtained by integrating the Source Protection Areas with the groundwater vulnerability categories, as shown schematically in Figure 1. An example of the Source Protection Zones defined for the Toberdaly source is provided in Figure 2. The SPZ includes the complete pathway, both vertical and horizontal, for recharge and any entrained contaminants to the abstraction point.

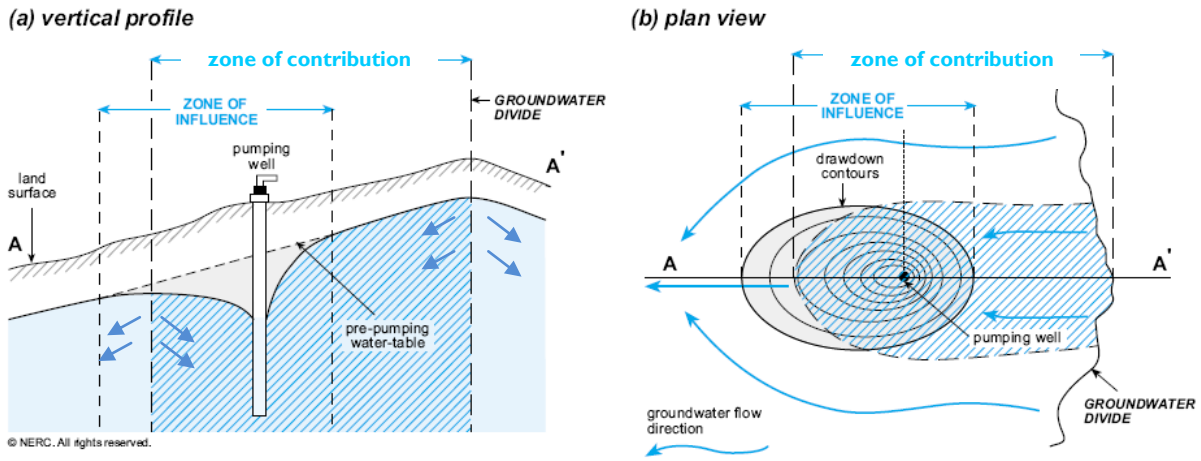

Figure : Illustration of zone of contribution (ZOC) and zone of influence (ZOI). (amended from USEPA)

Whereas the objective of delineating ZOCs is to define approximate areas that contribute water to an abstraction point, the objective of SPZs is to geo-scientifically characterise the pathway and receptor elements of risk to groundwater within the ZOC of a given source (Kelly, 2010). EPA prepared an advice note on "Source Protection and Catchment Management to protect Groundwater Supplies" that outlines the key measures and policies in place in Ireland (EPA, 2011).

While these three terms essentially encompass the same total area, there are differences and they should be used appropriately. It is recommended that for general usage the simplest, most basic hydrogeological term "ZOC" is used. "SPA" and "SPZ" are appropriate when considering protection of groundwater sources and when a sufficiently detailed study has been undertaken in order to delineate the areas and zones. The term "Safeguard zones" is only used with reference to implementation of the WFD (Daly, 2009).

Other Related Terms

- **Drinking Water Protected Areas** are a specific Water Framework Directive term and they encompass the same areas as Groundwater Bodies.
- **Groundwater Body** is a specific Water Framework Directive term used to subdivide aquifers into effective management units, largely based on hydrogeological rules in relation to the boundaries, e.g. a 'no flow' boundary (GW WG, 2005).
- **Drinking Water Safety Plans** is a risk assessment and risk management approach to ensure the 'safety' and 'security' of a water supply. In this context 'security' refers to the catchment to the supply and 'safety' refers to the quality of the treated water meeting drinking water standards. Further details are provided in an EPA Guidance Note on 'Developing Drinking Water Safety Plans (EPA, 2011).
- **Setback Distances, Exclusion Areas/Zones** are specific terms used to regulate the spreading of organic fertilisers and other farmyard activities around drinking water sources. The regulations (S.I. No 31, 2014) provide a range of setback distances from a water source depending on the daily abstraction or the number of people served. The regulations provide for alternate distances and/or zones to be proposed by a

local authority or Irish Water subject to EPA approval for abstractions supplying $10m^3$ or more, of water per day, or serving 50 or more persons. Further details are given in the EPA advice note No. 11 (EPA, 2011).

Distinguishing Zone of Influence and Zone of Contribution

"Unless the water table is horizontal prior to pumping the ZOC is not the same as the ***zone of influence*** of the pumping well (the zone contained by the radius of influence of the well)" (Misstear et al., 2006).

The zone of influence (ZOI) is defined by the "radius of influence" of a pumping well, i.e. the area where drawdown occurs due to pumping. Therefore, the ZOI boundary is where the drawdown is zero. The water table is unlikely to be flat in Ireland, therefore the ZOC and ZOI areas and boundaries will never be the same for pumping wells. In most circumstances, the ZOC will be larger than the ZOI. The difference between the zone of contribution (ZOC) and zone of influence (ZOI) is illustrated in Figure 3. As shown in Figure 3, the ZOC boundary will extend further up-gradient than the ZOI, but not as far down-gradient.

Summary

- Groundwater 'Drinking Water Protected Areas' comprise the entire land surface of the Republic of Ireland as all groundwater bodies are capable of yielding more than 10 m3/d as an average. We recommend only using this term for WFD implementation purposes.
- The simplest and most intuitive term conceptually for the catchment area of a well/spring is "zone of contribution (ZOC)".
- ZOC area = SPA area (SI+SO) = SPZ area = safeguard zone area = capture zone. While these terms encompass the same total area, they have different purposes. It is recommended using ZOC for general usage as the most basic hydrogeological term; SPA and SPZ as appropriate when considering protection of groundwater sources; and only referring to "safeguard zones" when considering implementation of the WFD.

References

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

Misstear, B. D., Banks, D., and L. Clark. 2006. Water Wells and Boreholes. Wiley & Sons Ltd. ISBN-13: 978-0-470-87989-7.

EPA Guidance Note No. 7. 2011. Advice on Source Protection and Catchment Management to protect Groundwater Supplies.

EPA Guidance Note No. 8. 2011. Developing Drinking Water Safety plans.

EPA Guidance Note No. 11. 2011. Advice on Prior Investigations and Technical Assessments for Good Agricultural Practice Regulations.

European Union (Good Agricultural Practice for Protection of Waters) Regulations. S.I. No. 31 of 2014.

Groundwater Working Group. 2005. Water Framework Directive (WFD) River Basin District Management Systems: Approach to Delineation of Groundwater Bodies. Guidance Document No. 2. Available on the http://www.wfdireland.ie/documents-wfd.html

Kelly, C. 2010. Delineating Source Protection Zones and Zones of Contribution for Monitoring Points. IAH (Irish Group) Annual Conference Proceedings. http://www.iah-ireland.org/conference-proceedings/2010.pdf

New collaborative project on groundwater flooding commenced by the Geological Survey and University of Dublin Trinity College

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A major new investigation into groundwater-caused flooding.

Introduction

Due to the unprecedented flood events of 2009 and 2015, flood risk management is seen as a major challenge facing communities across the country. Of particular relevance to the geoscience community is the phenomenon of groundwater flooding, which represents a significant flood hazard for many rural communities. Groundwater flooding is primarily associated with lowland karst groundwater flow systems in the west of Ireland (see GSI Newsletter Issues 51 and 53). The combination of low storage, high transmissivity and widespread groundwater-surface water interaction leaves these systems particularly susceptible to groundwater flooding (Naughton et al., 2015).

Groundwater flood risk management poses its own set of technical, environmental and socio-economic problems that differentiate it from other flood forms (e.g. fluvial, coastal etc.). Groundwater flooding can occur in a discontinuous manner across the landscape, often with no indication of flood risk prior to an extreme event, making effective land-use planning difficult. Unlike river flooding, where the flood is typically linked to high intensity rainfall, groundwater flooding is driven by cumulative rainfall over a prolonged period. It is this accumulation of water over a period of weeks or months that determines flood severity and duration. Furthermore, the long-term hydrometric data required for traditional flood frequency analysis does not exist for groundwater flooding, impeding the

Figure 1: Groundwater flooding in the Gort Lowlands, Co. Galway. Image provided by OPW

calculation of flood risk (combination of likelihood of an event and the damage caused by the event) as required in flood defence scheme assessments.

Project Genesis

Recent flood events have reinforced the need for a greater understanding of groundwater flooding as a geohazard, and improve our ability to quantify the location and likelihood of flood occurrence. In response to the serious flooding of winter 2015 specifically related to turloughs, the Programme for a Partnership Government (2016), under the area of Climate Change and Flooding, contains the following objective: "Turlough Systems: We will provide resources to the OPW to commission studies into individual problematic (prone to flooding) Turlough Systems, if requested by a local authority or another relevant State agency". The Geological Survey of Ireland (GSI), a division of the Department of Communications, Climate Action and Environment (DCCAE), were in a position to help deliver on this commitment through the existing groundwater and karst expertise and by the development of a new three year project on Groundwater & Turlough Monitoring and Modelling. A detailed project plan was developed over the summer of 2016 and funding was approved by DCCAE as an additional project of the GSI Groundwater Programme.

The GSI's Groundwater Programme has been studying karst systems and features, including turloughs, as part of the Groundwater Protection Schemes due to the critical role they play as potential contaminant pathways for aquifers. Work includes desk studies, field mapping, aerial LIDAR surveys and targeted research resulting in the development of the National Karst Database. This same approach and expertise will be enhanced, with additional resources and key collaborations with the University of Dublin Trinity College, to develop a new monitoring and modelling programme specifically in relation to groundwater flooding, focussing on turloughs. This new programme will provide the fundamental technical knowledge to enable the OPW and local authorities to develop appropriate flood mitigation measures, and allow for informed flood assessments to be made in future. It is proposed that a Steering Group will be put in place including principal stakeholders such as relevant state agencies and local authorities.

Previous studies of groundwater flooding have been based their conclusions in large part on historical or anecdotal data: the missing com-

Figure 2: Installing a water level logger in Lough Funshinagh, Co. Roscommon

ponent has been measured water level data at a planned monitoring network over a suitable timescale. This has limited the scope and conclusions drawn in existing studies (Daly, 1995; Naughton et al., 2015; Southern Water Global, 1998; Jennings O'Donovan & Partners, 2011). The proposed study aims to provide the requisite data to address this knowledge gap by establishing a permanent monitoring network, as well as developing analytical tools to help resolve issues surrounding groundwater flood mapping, frequency estimation and likely climate change impacts.

Aims and Objectives

This new programme will provide flooding and hydrogeological information that will enable the OPW and local authorities to make informed decisions with regards to groundwater flood mitigation measures. The collaboration between the GSI and Trinity College Dublin will also strengthen existing partnerships between the institutions and open new applied geoscience research opportunities in the fields of groundwater flooding, geohazards, groundwater-surface water interactions and remote sensing. Primary objectives of the proposed study are to:

- Establish a permanent monitoring network to provide long-term quantitative groundwater flooding data.
- Develop methodologies for improving groundwater flood hazard maps and real-time monitoring of groundwater flooding.
- Develop modelling/analysis methodologies for estimating groundwater flood frequency and the assessment of potential flood mitigation strategies for designated areas.
- Analyse the potential impact of climate change on turlough hydrological functioning and groundwater flooding.
- Investigate the influence of geostructural controls on turlough hydrogeology using 3D geological modelling and visualisation techniques.

Hydrometric data is a crucial component to understanding the dynamics of hydrogeological systems. Information such as stage and discharge are recorded at gauging stations across the country in rivers, lakes, boreholes and coastlines, providing data vital to local authorities and planning agencies for effective flood risk management. However, consistent long-term hydrometric data do not exist for groundwater flooding applications. A primary objective of this project is to establish a permanent monitoring network of key turloughs to provide key baseline data for flood risk and habitat management applications. An exploratory monitoring network of approximately 40 sites will be installed over the winter of 2016/2017 to develop an improved understanding of the hydrodynamics and flooding potential of turlough systems. Beginning in 2017, a subset of 20 sites representative of the spectrum of groundwater turlough flooding conditions in Ireland will be established as permanent telemetered stations providing real-time information on flood conditions.

The extensive data collected by the groundwater flood monitoring network will provide the necessary foundation to address further issues faced in groundwater flood risk management in turlough areas. Remote sensing technologies, such as satellite Synthetic Aperture Radar (SAR) data and high-resolution terrain models (LiDAR, photogrammetry), will be explored as a means to map groundwater flooding on a catchment scale in real-time. Research on turlough modelling carried out over the last ten years in the Department of Civil, Structural and Environmental Engineering in Trinity College Dublin (TCD) will be used to investigate the causative relationship between rainfall quantity, duration and flooding (flood frequency analysis) in key catchments, including the Gort Lowlands (Gill et al., 2013; McCormack et al., 2014; Naughton, 2011; Naughton et al., 2012). Once the model building process is complete, the models will be used to simulate the effects of various engineered flood mitigation measures on local and catchment hydrology. The latest downscaled climate change

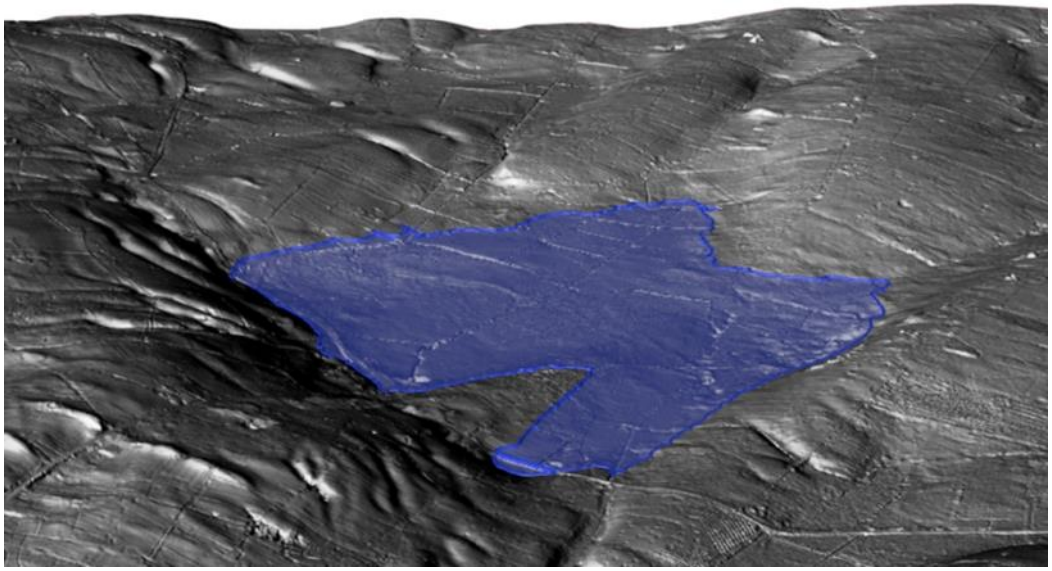

Figure 3: LiDAR imagery of Castleplunket turlough overlaid by 2016 high water level (Roscommon Co. Co.)

data for Ireland will also be used as an input to these hydrological models to analyse the potential impact climate change will have on turlough hydrological functioning and flooding behaviour.

Summary

The increased frequency, damage and disruption caused by groundwater flood events in recent years highlights the clear need for further research into the issue of groundwater flood prediction and risk assessment in karst regions. Due to the inherent complexity of karst groundwater systems and the lack of quantitative hydrological data generally available, this collaborative GSI/TCD project presents a unique opportunity to use a knowledge base gained by the project participants over the last decades to contribute to flood risk management practices in Ireland. The project will provide the necessary high-quality data, mapping and analysis techniques required to inform future planning decisions, and so help to ensure the sustainability of vulnerable rural communities affected by groundwater flooding as well as the turlough habitats themselves. The project will influence policy and governance by giving decision makers more information on the drivers and mechanisms of groundwater flooding in Irish karst systems, and allow them to make scientifically-informed decisions for better outcomes within the Floods, Water Framework and Habitats Directives.

References

Gill, L.W., Naughton, O., Johnston, P.M., 2013. Modelling a network of turloughs in lowland karst. Water Resources Research, 49(6): 3487-3503. https://doi.org/10.1002/wrcr.20299

McCormack, T., Gill, L.W., Naughton, O., Johnston, P.M., 2014. Quantification of submarine/intertidal groundwater discharge and nutrient loading from a lowland karst catchment. Journal of Hydrology, 519, Part B: 2318-2330. DOI:http://dx.doi.org/10.1016/j.jhydrol.2014.09.086

McCormack, T., Naughton, O., 2016. Groundwater flooding in the Gort lowlands. Groundwater Newsletter [Online]. Available: Groundwater Newsletter Issue 53

Naughton, O., 2011. The Hydrology and Hydroecology of Turloughs. PhD Thesis, University of Dublin, Trinity College, Ireland.

Naughton, O., 2013. An Overview of Groundwater Flooding in Ireland. Groundwater Newsletter [Online]. Available: Groundwater Newsletter Issue 51

Naughton, O., Johnston, P.M., Gill, L.W., 2012. Groundwater flooding in Irish karst: The hydrological characterisation of ephemeral lakes (turloughs). Journal of Hydrology, 470–471(0): 82-97. https://doi.org/10.1016/j.jhydrol.2012.08.012

Naughton, O., Johnston, P.M., McCormack, T., Gill, L.W., 2015. Groundwater flood risk mapping and management: examples from a lowland karst catchment in Ireland. Journal of Flood Risk Management: https://doi.org/10.1111/jfr3.12145

The influence of bedrock hydrogeology on catchment-scale nitrate fate and transport in fractured aquifers

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Understanding nitrate fate and transport in two diverse catchments in Ireland.

Introduction

Excess nitrate (NO_3) is a global environmental problem which is expected to worsen as a result of factors including the increase in human population, political stress and the development of growing economies (Erisman et al. 2011). Characterising catchment scale biogeochemical processes controlling nitrate fate in groundwater is a fundamental consideration when applying programmes of measures to reduce risks posed by diffuse agricultural pollutants to water quality.

Orr *et al.* (2016) have presented findings from research into the influence of hydrogeological setting on biogeochemical processes, aiming to characterise the dominant processes influencing nitrogen levels in groundwater in two Irish catchments underlain by bedrock aquifers with contrasting (physical and geochemical) hydrogeological properties, but having comparable nutrient loads and thin to no subsoil cover over much of their area. Their research considered the influence of spatial heterogeneity on biogeochemical processes within each catchment, both across the catchment and with depth. This was achieved through monitoring well tracer tests and the analysis of chemical and isotopic signatures of groundwater and surface water. Incor-

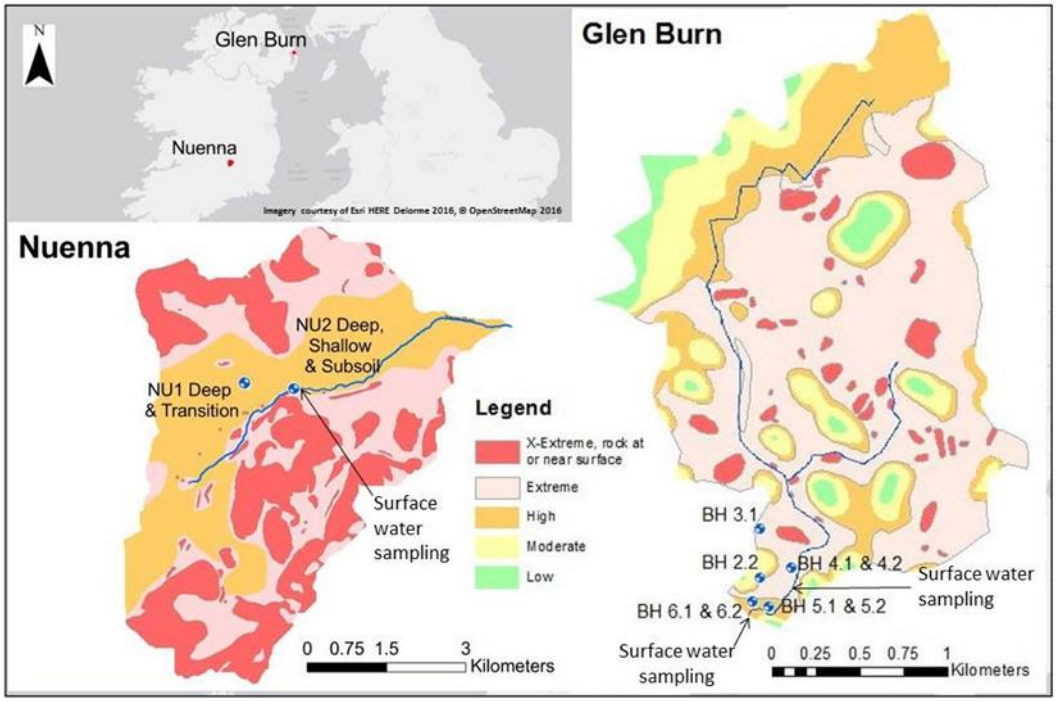

Figure 1: Catchment locations, groundwater vulnerability (GSI 2012 and Meredith 2010) and monitoring well layout in the Glen Burn and Nuenna catchments

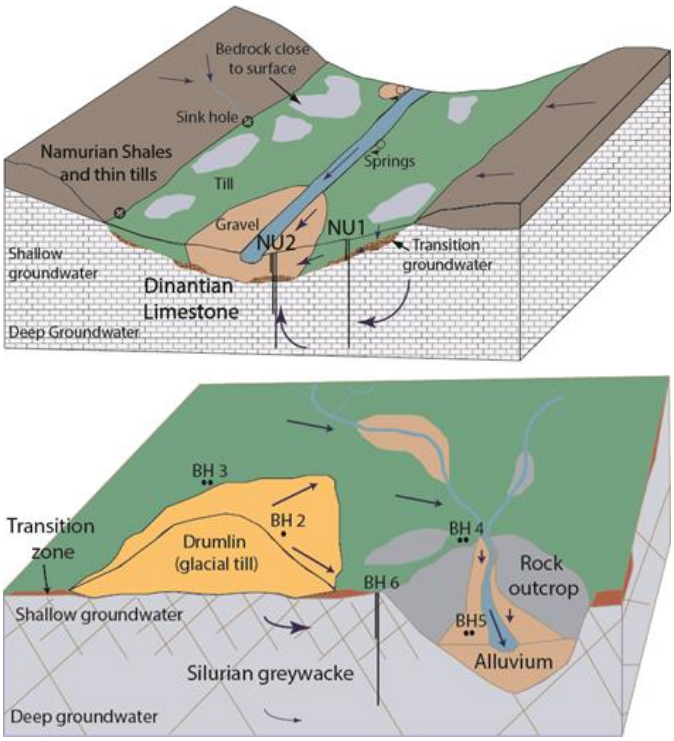

Figure 2: 2 Simplified conceptual hydrogeological models of the Nuenna (top) and Glen Burn (bottom) catchments. Arrows show flow direction and arrow weight reflects the flow volume. Not to scale.

porating the knowledge gained concerning biogeochemical processes into water quality catchment management tools can prove fundamental in reducing the risk posed to groundwater and surface water receptors.

Catchment descriptions

Research focused on two catchments; the Nuenna, a well drained catchment underlain by a regionally productive diffuse karst (Rkd) pure bedded limestone aquifer, and the Glen Burn which is a poorly drained catchment underlain by a poorly productive (Pl) Silurian greywacke aquifer (Figures 1 and 2). While both aquifers are fractured, transmissivity ranges are much greater in the Nuenna compared to the Glen Burn. Despite the differences in hydrogeological setting the catchments do not differ greatly in terms of nitrogen loading which is approximately 400 kg N/ha/yr and the landuse is predominantly pasture in both catchments.

Results and discussion

Nuenna, Co Kilkenny

Groundwater transport of nitrate in the Nuenna catchment is dominated by fracture flow in the deep groundwater where nitrate concentrations proved higher than in the shallow groundwater (Figure 2). Relatively little change in NO_3/Cl ratios or nitrate isotopic signature with depth suggest good mixing in the deeper part of the aquifer and that biogeochemical reactions are not a significant factor influencing nitrate fate once the nitrate enters the deeper bedrock (Figure 3).

Overall, nitrification is the dominant biogeochemical process influencing dissolved N mobility in the Nuenna catchment. Hydrochemical and isotopic findings suggest that widespread denitrification is unlikely across the Nuenna, although localised partial nitrification may be intermittently occurring in the shallow groundwater with limited impact on catchment surface water quality (Figures 3 and 4).

Glen Burn, Co Down

In the Glen Burn catchment findings show that the shallow groundwater is the dominant groundwater pathway for delivering nitrate to aquatic receptors. Water quality and isotopic analyses show that denitrification is likely to be occurring in the groundwater resulting in lower nitrate concentrations with depth (Figures 4 and 5). Water quality data suggest that both autotrophic and heterotrophic denitrification occurs, yet this varies spatially across the site according to available electron donors.

Nitrate concentration decreased with depth in the Glen Burn aquifer, which also corresponds to a reduction in the NO_3/Cl ratio (Figure 5). A decrease in NO_3/Cl ratio may indicate dilution from older water. However considering the drop in oxidation reduction potential (ORP) this would indicate suitable denitrifying conditions. This is supported by the significant enrichment of both the $\delta^{15}N$ and $\delta^{18}O$ indicating denitrification within the bedrock groundwater. More enriched

Research

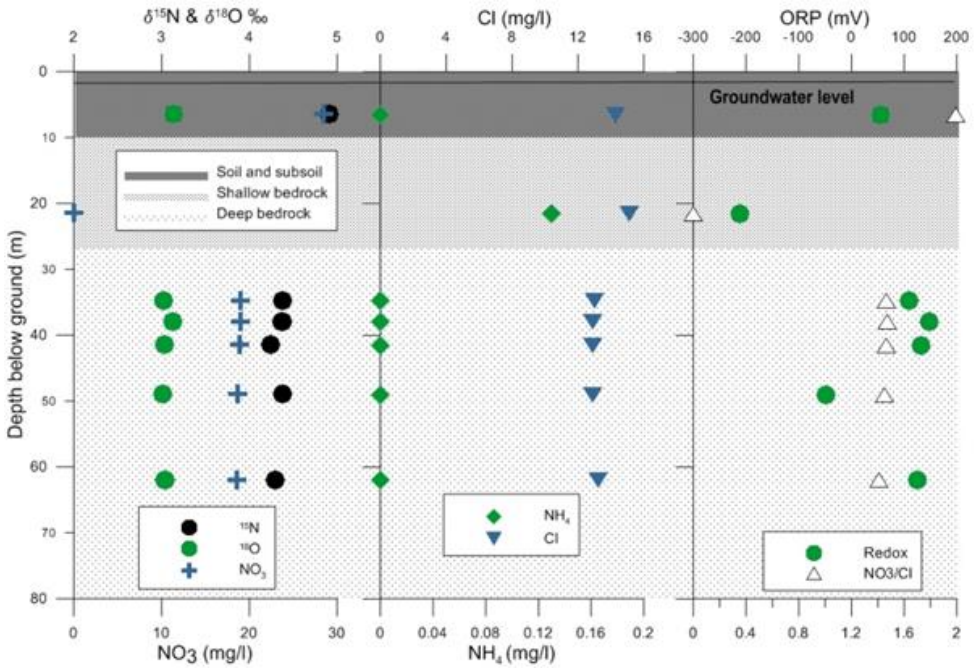

Figure 3 Variation of NO_3, NH_4, Cl, ORP concentrations and NO_3 isotope ($\delta^{15}N$ and $\delta^{18}O$) values with depth in the NU2 cluster, sampled using a packer system and low flow pump.

nitrate isotopic values in the deep groundwater compared to the shallow groundwater suggest that the rate of nitrate removal through denitrification continues at depth as it infiltrates downwards. This is supported by a general trend observed in groundwater samples showing lower groundwater nitrate concentrations, yet containing more enriched $\delta^{15}N$. Significantly, these values display an enrichment ratio of 1.7 between $\delta^{15}N$ and $\delta^{18}O$ (Figure 4) which is within the enrichment ratio range of between 1.3 and 2.1 attributed to denitrification (Böttcher et al. 1990; Aravena & Robertson 1998; Fukada et al. 2003).

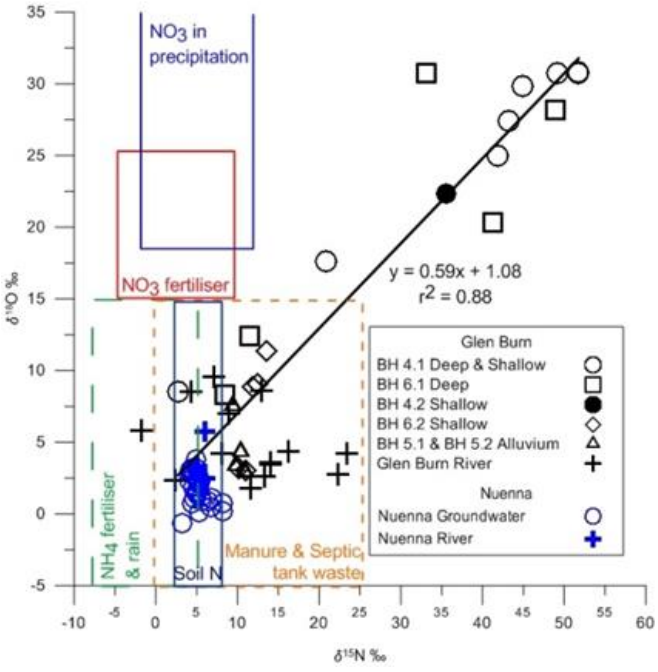

Figure 4 δ15N and δ18O in groundwater and surface water in the Glen Burn catchment. Boxes show the range of δ15N for manure and septic tank waste, NH4 fertiliser and soil N, adapted from Kendall (1998).

Conclusions

Groundwater quality in both the Nuenna catchment and the Glen Burn Catchment is impacted by agricultural contamination. However, the contrasting hydrogeological settings have a significant influence on the dominant biogeochemical processes influencing nitrate fate and transport. The bedrock in both catchments transports groundwater predominantly by fracture flow. However the variation in groundwater discharge via hydraulically active fracture sets with depth and the transmissivity ranges differ considerably in the two catchments investigated. This has considerable influence on the fate and transport of nitrate in the groundwater bodies.

Orr *et al.* (2016) highlights the importance of considering hydrogeological setting for groundwater quality monitoring and the implementation of contamination mitigation measures in catchments. In karstified aquifers nitrate management strategies should focus on the role

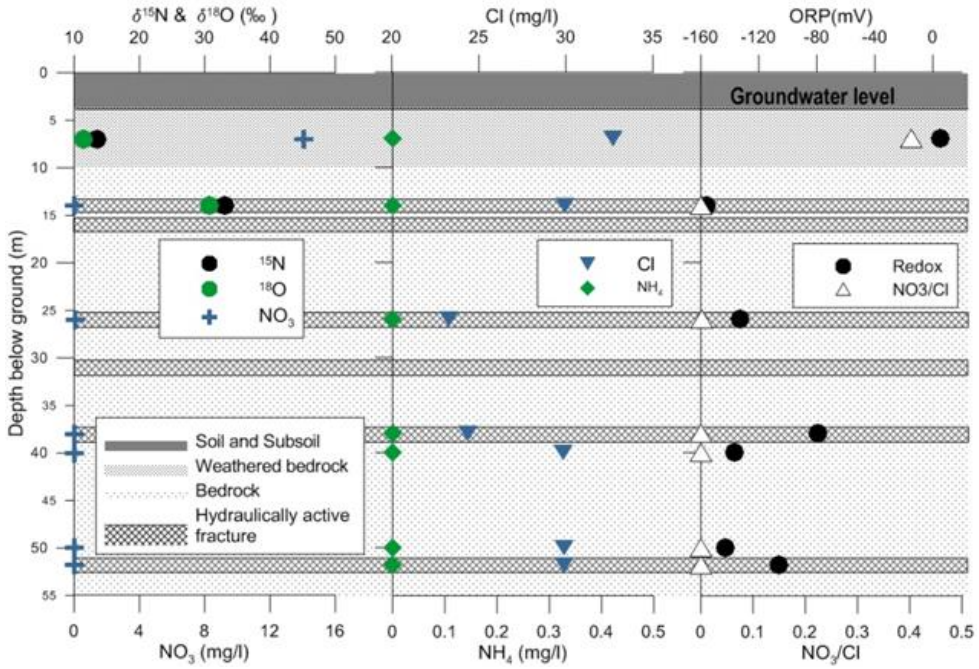

Figure 5 Variation of NO3, NH4, and ORP concentrations and NO3 isotope (δ15N and δ18O) values with depth in BH6 cluster, sampled using a packer system and low flow pump.

played by deep groundwater pathways and diffuse nitrogen sources, whereas in catchments underlain by lower permeability aquifers, the deep groundwater will be a less significant pathway for nitrate to enter surface water bodies and the focus of such management plans should be on delivering nutrients to receptors via pathways nearer the ground surface. Incorporating these considerations, when developing catchment management plans, can assist in addressing the impact of agricultural practices on the water quality of groundwater bodies and contribute toward achieving the aims of the Water Framework Directive.

References

Erisman, J.W., Van Grinsven, H., Grizzetti, B., Bouraoui, F., Powlson, D., Sutton, M.A., Bleeker, A., Reis, S. (2011) 'The European nitrogen problem in a global perspective', in Sutton, M.A., Howard, C.M., Erisman, J.W., Billen, G., Bleeker, A., Grennfelt, P. and Grizzetti, B., eds., The European Nitrogen Assessment Sources, Effects and Policy Perspectives, University Press: Cambridge, 9–31.

GSI (2012) GSI Data Downloads, available: www.dcenr.gov.ie

Meredith, S. (2010) Groundwater Vulnerability Mapping – Glen River Catchment, Ards Peninsula, Co. Down, MSc thesis, School of Planning, Architecture and Civil Engineering, Queen's University Belfast.

Kendall, C. (1998) 'Tracing nitrogen sources and cycling in catchments', in Kendall, C. and McDonnell, J.J., eds., Isotope Tracers in Catchment Hydrology, Elsevier Science B.V.: Amsterdam, 519–576.

Böttcher, J., Strebel, O., Voerkelius, S., Schmidt, H.-L. (1990) 'Using isotope fractionation of nitrate-nitrogen and nitrate-oxygen for evaluation of microbial denitrification in a sandy aquifer', Journal of Hydrology, 114(3-4), 413–424.

Aravena, R., Robertson, W.D. (1998) 'Use of multiple isotope tracers to evaluate denitrification in ground water: study of nitrate from a large septic system plume', Ground water, 36 (6), 975–982.

Fukada, T., Hiscock, K.M., Dennis, P.F., Grischek, T. (2003) 'A dual isotope approach to identify denitrification in groundwater at a river-bank infiltration site', Water research, 37(13), 3070–3078.

Research

An investigation of thermal springs in Ireland: their provenance, pathways and geothermal potential

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A study of the hydrogeology and hydrochemistry of thermal spring in the Dublin area.

Deep, thermal groundwater is currently being exploited for district-scale heating in many locations world-wide, including European cities such as Paris, Milan, and Southampton. It has recently been explored in Ireland as part of the IRETHERM project (funded by Science Foundation Ireland), one aim of which was to determine the suitability of Irish thermal springs as a geothermal energy resource. New hydrochemical and geophysical data were used to investigate the source of several Irish thermal springs. This research is the subject of a PhD thesis (Blake, 2016) and two publications; a detailed geophysical and hydrochemical study of Kilbrook spring in Co. Kildare (Blake et al., 2016a), and a hydrochemical study of several Irish thermal springs (Blake et al., 2016b). The findings of the hydrochemical study are summarised here.

In Ireland, average groundwater temperatures typically range from 9.5 to 10.5 °C. Thermal springs are considered to be those natural groundwater springs where the mean annual temperature is appreciably warmer than average groundwater temperatures. In this study springs with a mean annual temperature above 12.0 °C are considered thermal. Forty-two thermal springs and thermal shallow groundwater occurrences have been recorded to date in Ireland (Figure 1a). A subset of six springs in Leinster was studied in detail (Figure 1c) including two of the warmest springs in Ireland, St. Gorman's Well in Co. Meath (maximum temperature of 21.8 °C in this study) and Kilbrook spring in Co. Kildare (25.0 °C). Most of the springs have a Ca-HCO3 chemistry that is typical of groundwater circulating in limestone, however two have an intriguing Na-Cl hydrochemical signature that hints at a deeper source aquifer (the intermediate-temperature Louisa Bridge Spa Well in Leixlip, Co. Kildare, and St. Edmundsbury spring in Lucan, Co. Dublin).

Time-lapse temperature and electrical conductivity data

High-resolution, time-lapse temperature and conductivity data were collected from the springs at fifteen-minute intervals for the duration of the study period (2013 – 2015). Figure 2 shows some of the data from St. Edmundsbury spring, St. Gorman's Well, and Louisa Bridge Spa Well.

St. Edmundsbury spring and Louisa Bridge Spa Well are characterised by stable, intermediate-temperature profiles with little or minor influence from seasonal recharge processes (the temperature profile for St. Edmundsbury has been periodically affected by flooding of cold river waters but the groundwater temperature remains stable). By contrast, St. Gorman's Well has the most variable temperature profile, ranging from 10.5 °C to 21.8 °C. St. Gorman's Well has its annual thermal maximum at the end of the winter period and is coolest at the end of the summer period. The cooler temperatures are preceded by a relatively stable, intermediate-temperature phase with semi-diurnal fluctuations suggestive of influence from earth tides. The non-linear switch between these phases is indicative of conduit flow and mixing in a karst system (St. Gorman's Well is situated on Waulsortian limestone bedrock).

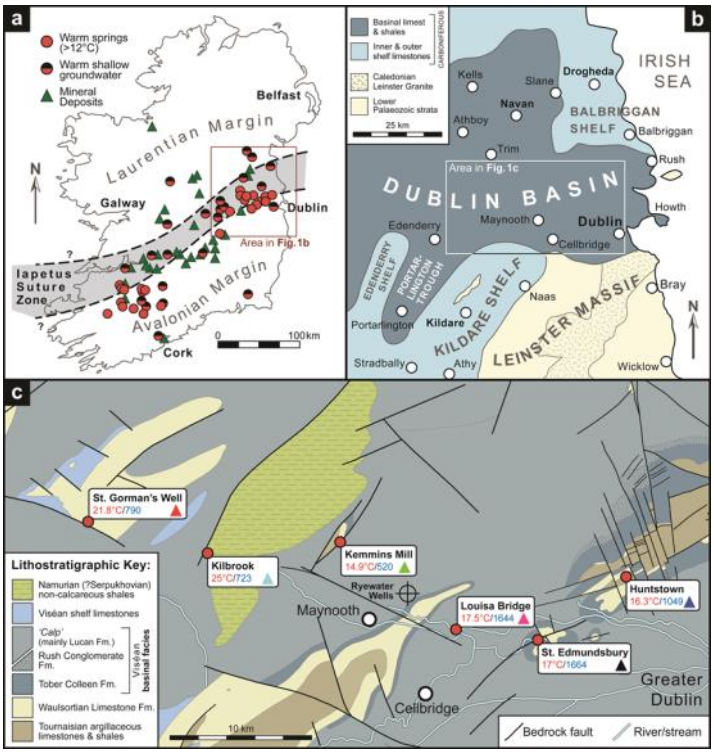

Figure 1: Location and geological setting of Irish thermal springs: (a) general locations of springs and shallow thermal groundwater occurrences; (b) generalised palaeogeographic map of the Carboniferous Dublin Basin during the Viséan Stage; and (c) detailed geological map of the study area. Maximum temperatures (red) and electrical conductivity values (blue) from this study given for each thermal spring.

Research

Hydrochemical investigation

Hydrochemical data from the thermal springs in Leinster were analysed using multivariate statistical methods and interpreted alongside the time-lapse temperature and chemistry data to investigate the provenance of the thermal groundwater. The hydrochemical data were processed beforehand using compositional (CoDa) statistical techniques. CoDa should be applied wherever data are compositional in nature (i.e., any data measured or expressed as parts of a whole such as ppm, mg/L, %, etc.) to ensure that the results of any subsequent analysis are not biased due to spurious correlations.

The data for all six springs (and two cold seepages) were analysed together using principal component analysis (PCA) (Figure 3). The samples form clusters in the biplot that correspond to each spring's location, with St. Gorman's Well displaying the greatest dispersion of sample points, and therefore the greatest seasonal variation in major and trace element chemistry. The PCA biplot can be interpreted in terms of hydrogeological processes acting upon the overall hydrochemistry of the group of springs. In Figure 3a, the PCA of major ion data suggests that two distinct independent hydrogeological processes (labelled S and C in Figure 3a) are controlling the major ion hydrochemistry of the springs. The "water-rock interaction" link, S, represents the effects of increased water-rock interactions and increased residence times on the hydrochemistry, and distinguishes those springs at the Na-Cl end of the link from the other Ca-HCO_3 springs, which are more typical of limestone aquifers such as are found in the Carboniferous Dublin Basin. A CoDa analysis of the Na-Cl-Br system for the saline springs indicated that they probably derive their excess chloride from the dissolution of evaporites. The "carbonate" link, C, represents the influence of dissolution of different types of limestone bedrock on the hydrochemistry (simplified as a trade-off between SO4 and HCO3). Those springs that lie close to the HCO3 end of link C are situated in more "pure" limestone (i.e., Waulsortian strata) than those more closely associated with SO_4, which are situated in the more clay-rich Calp limestone. The inclusion of trace element data into the PCA identified a third distinct process controlling the hydrochemistry (Figure 3b), the "mineralisation" link, M, which represents the influence of the dissolution of mineral deposits associated with the carbonate bedrock, particularly manganese (Mn). This process is less important in the control of the overall hydrochemistry as it affects only minor and trace ions, and metals in particular. The hydrochemistry of St. Gorman's Well is particularly affected by M in the late summer (July to October) when the thermal waters contain more dissolved Mn.

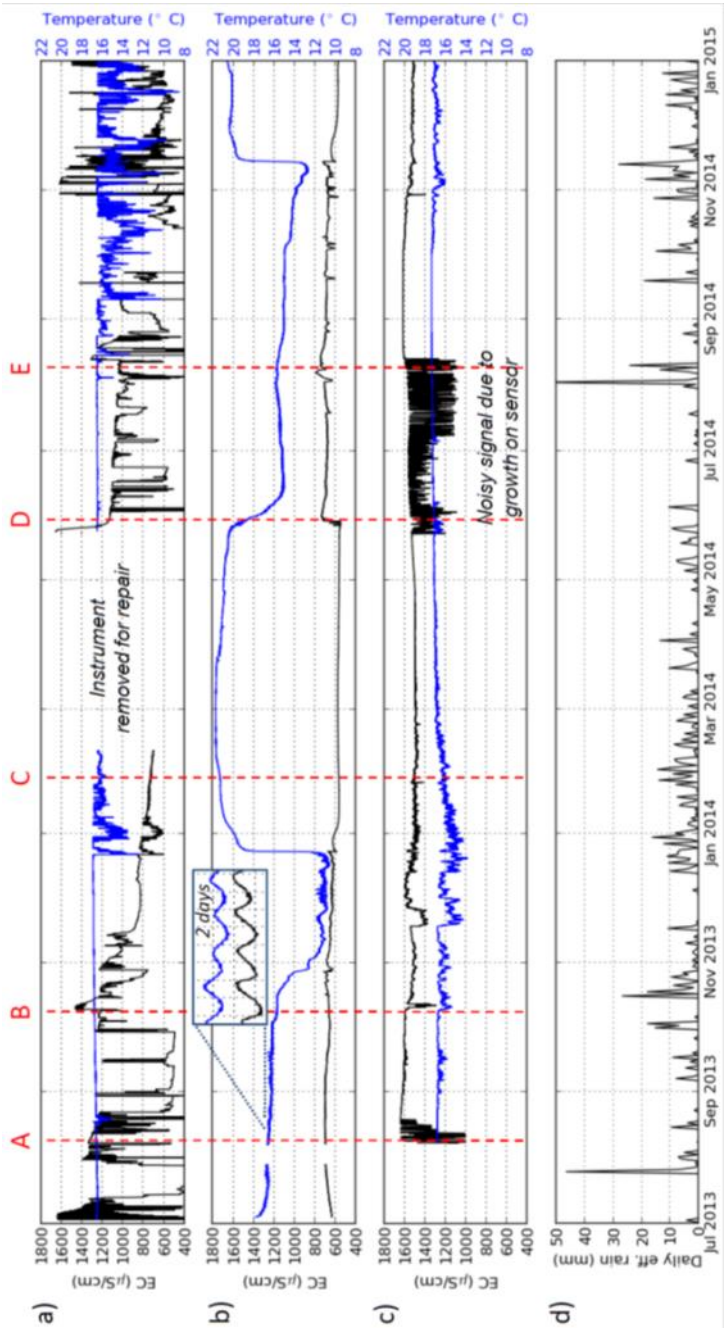

Figure 2: Time-lapse temperature (blue) and electrical conductivity (black) measurements. a) St. Edmundsbury spring. b) St. Gorman's Well (inset shows semi-diurnal fluctuations over two days in August 2013). c) Louisa Bridge Spa Well. d) Daily effective rainfall calculated from Met Éireann data (Dunsany synoptic station, Meath). Hydrochemical sampling seasons are indicated in red.

Main findings

The hydrochemical study demonstrated the usefulness of correctly applying multivariate statistical methods to compositional data in order to better understand the underlying hydrogeological processes governing the hydrochemistry of the target thermal springs. The statistical analysis also provided an insight into the seasonal hydrochemical variations of St. Gorman's Well, where the complex temperature and conductivity profiles are due to conduit flow and mixing within karstified bedrock.

Springs associated with the Na-Cl end of link S (Figure 3) are likely to have a moderate to high temperature with little annual variation. They are characterised by higher salinity and conductivity due to an increased residence time and water-rock interaction. The source aquifer is likely to be deep, confined and well-insulated from fluctuating near-surface hydrogeological processes. The excess chloride in these springs is not due to any anthropogenic contamination but instead derives from the dissolution of evaporites. The precise origin of the evaporites required to facilitate this process remains cryptic at present, and the source lithology may be either intra- or extra-basinal. The hydrochemistry of St. Edmundsbury spring and Louisa Bridge Spa Well is closely associated with the Na-Cl end of link S; they appear to be fed from the same aquifer (or two very similar aquifers), and must have their source beneath the carbonate Dublin Basin, perhaps within the Devonian terrestrial strata.

Springs with a closer association to link C rather than link S are likely to be cold, or cooler thermal springs (with the exception of St. Gorman's Well, which has extremely variable moderate to high temperatures). Depending upon their location along link C, they can be relatively enriched in either SO_4, which is probably controlled by the oxidation of sulfides such as pyrite, or HCO_3 and Si, which is probably controlled by the dissolution of pure Waulsortian limestones and associated chert layers. They are likely to have an unconfined or semi-confined source and a good supply of fresh, infiltrating, recharge waters.

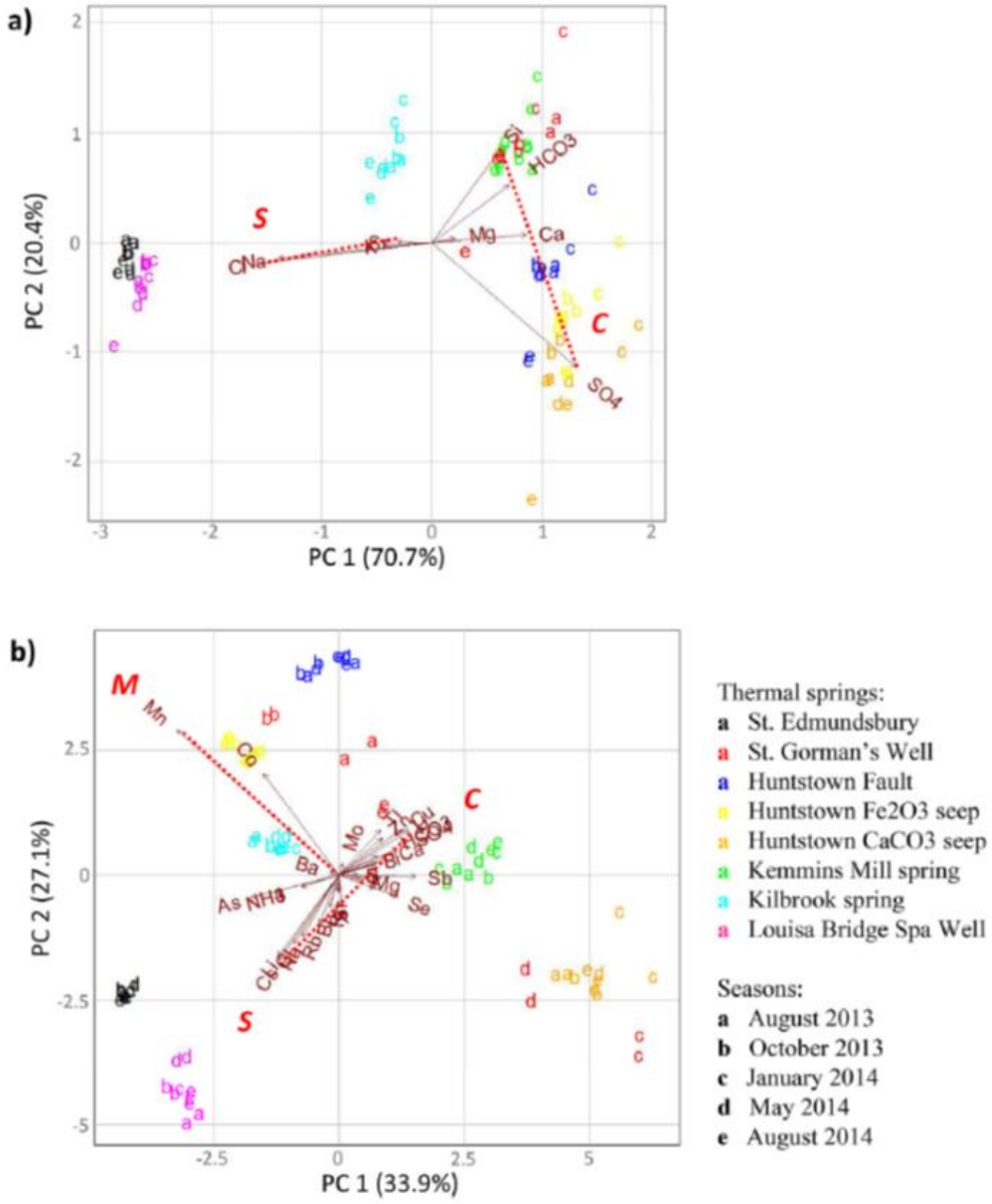

Figure 3: CoDa PCA biplots: a) major ions (78 samples, 9 variables) with orthogonal links S and C indicated; and b) major, minor and trace ions (78 samples, 30 variables) with orthogonal links M and S - C.

References

Blake, S., 2016. A multi-disciplinary investigation of the provenance, pathways and geothermal potential of Irish thermal springs. (PhD thesis), National University of Ireland Galway (accessible online https://aran.library.nuigalway.ie/handle/10379/5926).

Blake S., Henry, T., Muller, M.R., Jones, A.G., Moore, J.P., Murray, J., Campanyà, Vozar, J., Walsh, J., Rath, V., 2016. Understanding hydrothermal circulation patterns at a low-enthalpy thermal spring using audio-magnetotelluric data: A case study from Ireland. Journal of Applied Geophysics 132, 1-16.

Blake, S., Henry, T., Murray, J., Flood, R., Muller, M.R., Jones, A.G., Rath, V., 2016. Investigating the provenance of thermal groundwater using compositional multivariate statistical analysis: a hydrogeochemical study from Ireland. Applied Geochemistry http://dx.doi.org/10.1016/j.apgeochem.2016.05.008.

Environmental Flow Assessment for Irish Rivers

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Using Eflow methodology to characterise river flow regimes in Ireland.

Introduction

Freshwaters provide valuable ecosystem services to humans including economic security (e.g., fish, water supply); social security (e.g., flood protection, water purification); and ethical security (rights of people and other species to water) (Acreman and Ferguson 2010). Over twenty years ago, aquatic scientists and policy makers across the globe recognised that existing regulations on abstraction were inadequate to protect rivers and the ecosystem services they provide. There is consensus that historical approaches focused on maintaining minimum flows are inadequate to protect rivers and the ecosystem services they provide because such regulations do not address retention of natural fluctuations and patterns in flow characterising natural hydrologic regimes. Consequently, much attention has been focused on the development of environmental flow concepts that take into account the requirements of a range of biological communities, life stages, and ecosystem processes. Environmental flow, as defined in the Brisbane Declaration, '… describes the quantity, quality and timing of water flows required to sustain freshwater and estuarine ecosystems and the human livelihoods and well-being that depend on these ecosystems'.

Currently, Ireland is not considered at high risk from abstraction pressures due to high effective rainfall and relatively low population and industrial density. However, in order to meet mandates of the Water Framework Directive and develop national legislation on abstraction standards, the Environmental Protection Agency STRIVE research program funded the desktop study described here. The overarching goal of the research was to evaluate state-of-the-art environmental flow (EFlow) methodology to identify best practice, trial alternative approaches in catchments of contrasting hydrogeology, and provide recommendations to EPA for establishing a landscape-based framework for setting EFlow standards that will maintain ecological status and ecosystem services provided by Irish rivers. Specific objectives described here were to:

- characterise river flow regimes across a range of landscape settings in Ireland;
- assess current abstraction pressures; and
- identify information needs and research priorities.

Flow regime characterisation

We used long-term daily flow records maintained by the Office of Public Works and the EPA from 166 hydrometric stations with at least 15 complete years of data collected between 1985 and 2014 to generate 34 EFlow metrics reflecting flow aspects such as magnitude, frequency of high/low pulses, duration of high/low flow periods, timing, and rate of change. Cluster analysis of the EFlow metrics identified five flow regime clusters whose membership was differentiated by landscape features such as elevation, precipitation, subsurface permeability and soil drainage (Table 1). The most well-defined clusters represented the extremes of flow regime: cluster 1 rivers had flashy surface water-dominated regimes whilst cluster 5 included rivers with more stable flow in more groundwater-dominated

Flow Cluster	Baseflow Index	Elevation / Slope	Location	Soils classed by drainage	GW Vul (SubSoil Impermeability)	Bedrock Aquifer	Climate	Landuse	Land Drainage (modelled)	Channelisation
1 SW	Low	High	NW	Peat	Very high (X,E)	Poor Prod	High PPT	Past-peat & Forest	Low	Low
4 SW		Low		Poor	Low-Mod	Mod Prod	High PE	Past	High	High
2 LK		Mod	Not SE	Peat & Poor	High (E, X), Mod	Poor & Karst	Mod PPT	Past & Past-Peat	Mod	Mod
3 GW		Low	EA & SE	Poor to Int	Mod to High	Local	Low PPT	Past & Arable	High	High
5 GW	High	Low-Mod		Well	High	Local Reg; S&G	High PE	Past & Arable	Mod	Mod

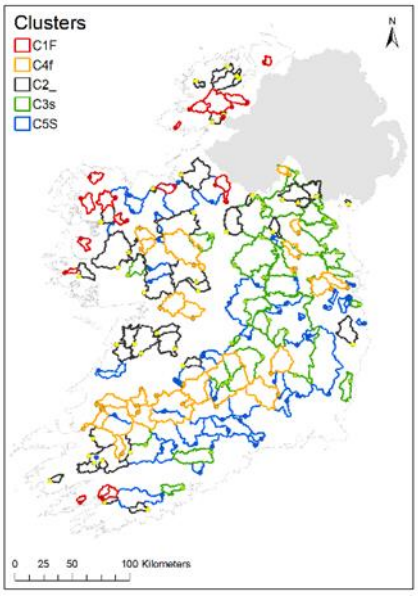


Figure 1: Overview of hydrogeology, climate and pressures influencing the five flow clusters and a map showing the location of cluster catchments. Abbreviations are Mod=moderate; Int=intermediate; Prod=productive; PPT=precipitation; PE=potential evapotranspiration; Past=pasture.

settings. An intermediate cluster (2) included many lake-influenced rivers. Agricultural activities appeared to influence the two least well-defined clusters (3 and 4). Catchments of rivers in these clusters were characterised by poorly drained soils with higher proportions of predicted land drainage and channelization, both of which may have altered flow leading to increased among-site variability in flow regime. Identification of reference sites representative of 'natural' flow in areas subject to centuries of alteration by agriculture may require a more appropriate definition of what is 'natural' in Ireland.

Effects of current abstraction on river flow

A national abstraction geodatabase was collated from disparate datasets to assess current abstraction pressures on the 164 of the study rivers described above. The geodatabase comprised over 4,600 surface water and groundwater abstraction points, which collectively abstract in excess of 5,382,000 m^3 of water per day. This study considered all abstractions, groundwater and surface water, as consumptive.

Based on these data, less than 5% of the effective rainfall[1] was abstracted from 150 of the 166 catchments analysed. However when abstraction was compared to flow exceedance values more than 10% of the Q95 flow was abstracted in 79 of the 166 catchments analysed (Figure 2). Because low flows are most common in summer, such abstraction could have important implications for river ecology. Using nomenclature of the first cycle of the WFD, these catchments would be classified as "at risk" or "probably at risk" of not achieving Water Framework Directive's good status due to abstraction pressures based on the ratio of abstraction to low flow. It is worth noting that these assessments are not directly comparable, as the assessment units vary. The 2008 WFD risk assessment used river water bodies, whereas this assessment uses catchments to hydrometric stations.

[1] Effective rainfall is defined as the proportion of rainfall which is potentially available to move through the terrestrial part of the water cycle; i.e., rainfall which is not evaporated or transpired.

[2] Q95 is defined as the flow which is equalled or exceeded for 95% of the flow record.

Research

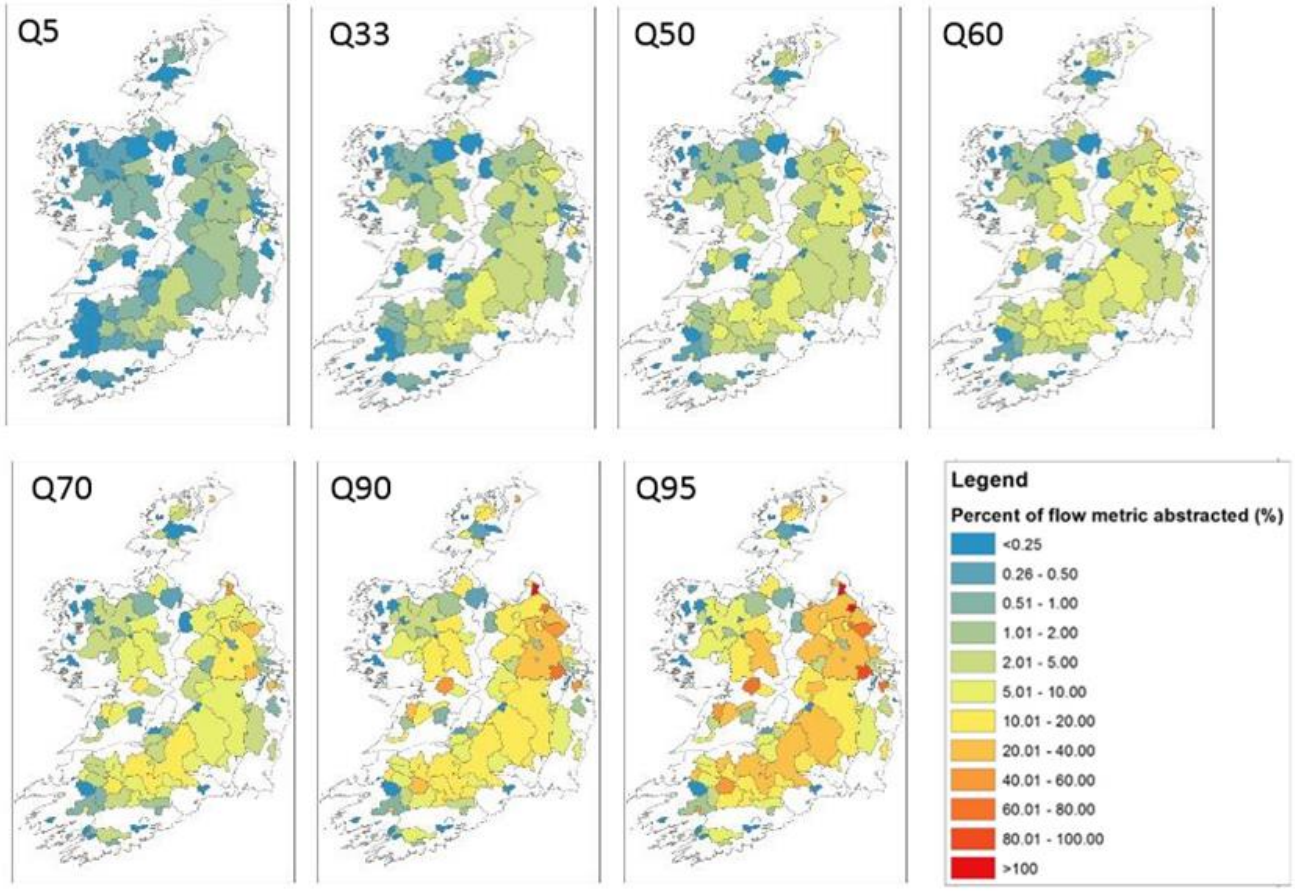


Figure 2. The percentage of the flow abstracted at selected flow duration exceedance percentiles from each of the surveyed river catchments.

Information and research needs to support national policy

Environmental flow considerations are integral to assessment of ecological status under the Water Framework Directive and for developing abstraction standards for Ireland. From our research, we identified two critical *data* needs.

- First, an integrated national database of both abstraction and discharge with adequate temporal resolution and accurate designation of water source is essential.
- Second, long-term records in the hydrometric network should be maintained at a representative set of stations including more emphasis on underrepresented small catchments.

An important *research* need is to develop ecology–flow relationships for assessing abstraction risk and for developing standards protective of ecological status. Combining flow assessment with hydromorphology assessment would acknowledge the close link between channel structure and flow regime. Abstraction licensing should remain flexible to adapt to future knowledge from research and monitoring efforts and future novel abstraction pressures and climate change.

References:

Acreman, M. C. and A. J. D. Ferguson. 2010. Environmental flows and the European Water Framework Directive. Freshwater Biology 55:32-48.

Webster, K. E., K. Tedd, C. Coxon, and I. Donohue. *In press.* Environmental flow assessment for Irish Rivers. EPA Research Report 203.

Hydrogeological News

This section of the newsletter contains news of interest to hydrogeologists in Ireland. It includes short reports on the recent activities of the IAH Irish Chapter as well as the IAH International. It also includes other groundwater related material such as new publications that may be of interest and where groundwater features in the media. If you are involved in, or aware of, any items which may be of relevance for this section of the newsletter please contact the editors at groundwaternewsletter@gsi.ie

All-Ireland Karst Landforms and Tracerlines Datasets

Thanks to the Geological Survey of Ireland's 2015 Short Call Programme, the fantastic work that has been done to develop the karst landforms and tracerlines datasets in the Republic of Ireland has now been extended into Northern Ireland so that both datasets are now truly all-Ireland, just like the karst itself. The karst landform database was first developed by Morgan Burke and the Geological Survey of Ireland in 1999 and has been added to over the last 17 years by many different contributers. Similarly the tracerlines dataset was created by Caoimhe Hickey and the Geological Survey of Ireland in 2007 and is updated as new information becomes available.

It is true that Northern Ireland is not as well endowed with karstified rocks, however, what it lacks in quantity, it makes up for in quality. The best known karst are the Marble Arch Caves, but there is much more karst than just the Marble Arch system. The Cretaceous Ulster White Limestone boast some remarkable features such as 30m deep dolines and vanishing lakes. Much of the karst potential has been investigated, mostly by cavers and speleologists such as Pamela and Tim Fogg, John Kelly, Gareth LI Jones, Gaby Burns, John Gunn and Les Brown who have been the most prolific in documenting such investigations and it is these folk that we must thanks for doing the hard work that has enabled these new advances in the datasets to be made.

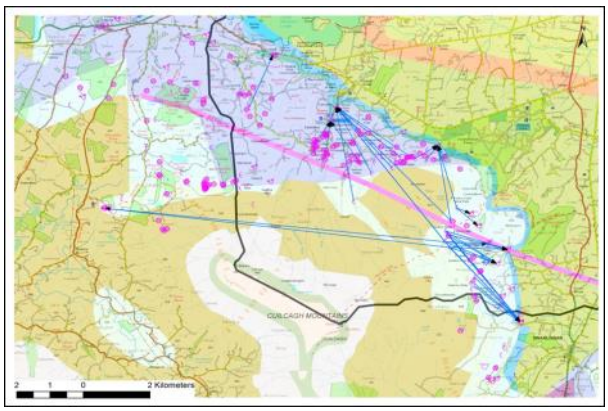


Figure 1 – Karst Landforms and tracerlines for an area around Cuilcagh Mountain

The present karst landforms dataset boasts over 6,500 points and the tracerlines dataset has almost 300 test results. With the inclusion of Northern Ireland, the landforms dataset will expand to over 7,000 points and the tracerlines dataset to around 350 test results.

The combined dataset is in the final stages of being processed and will be made available on open access data shortly. It is anticipated that the release of this data will spark a renewed interest in karst particularly in the north where awareness of karst is limited.

Far from being a complete dataset, this recent progress has once again highlighted the gaps that still remain and it is hoped that this new release will serve to remind practitioners about the value and limitations whilst at the same time encourage a surge in study and investigation. If you would like to report a karst landform that is not currently in the dataset please contact Caoimhe Hickey or Paul Wilson.

The All_Ireland Karst Landform and Tracerlines datasets will soon be available for viewing at http://spatial.dcenr.gov.ie/GeologicalSurvey/Groundwater/index.html

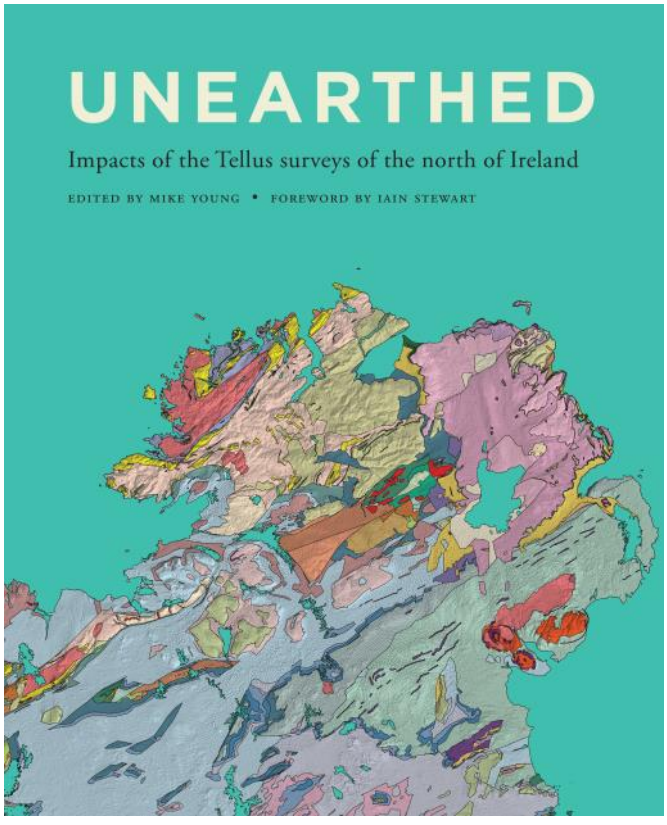
And download at http://www.dccae.gov.ie/natural-resources/en-ie/Geological-Survey-of-Ireland/Pages/Data-Downloads.aspx For more information on karst, please contact either survey or visit the GSI website at gsi.ie.

Paul Wilson and Caoimhe Hickey, GSNI and GSI

Book launch: Unearthed: impacts of the Tellus surveys of the north of Ireland

The book launch of 'Unearthed: Impacts of the Tellus surveys of the north of Ireland', took place on 5th October, at the Royal Irish Academy (RIA). The event was very well attended and included opening remarks by the Minister of Natural Resources, Sean Kyne, strategy and progress updates by the Tellus team and a discussion on future Tellus phases which was chaired by Sean Finlay. This was followed by a number of rapid updates on Tellus based research followed by the book launch and a discussion on geoscience data supporting policy and the economy.

The book outlines the Tellus surveys between 2004 and 2013. €15 million of government and EU funding was spent on high-resolution, airborne geophysical and geochemical sampling surveys of Northern Ireland and the six northern counties of the Republic of Ireland. The findings of the first two stages of Tellus, the largest collaborative cross-border programme of geoscience surveys ever undertaken on the island of Ireland are outlined in detail.



The book covers the extensive geophysical and geochemical data collected. 69 authors have made contributions, with sections on Mineral and Energy Exploration, Agriculture, Ecology, Environmental Mapping and Management, and Groundwater. Interesting examples and case studies are shown throughout the book, with chapters discussing how the Tellus data has been used for:

- Human health risks through oral bioaccessibility
- Association of environmental factors and health and their impacts on policy
- Radon risk mapping
- Geothermal energy potential in the Mourne Mountains
- Massive sulphide mineralisation in the Tyrone Igneous Complex
- Metallic contamination in soils in lower Foyle catchment
- Mapping waste disposal sites
- Gold exploration in the north of Ireland

The book is beautifully illustrated with interesting maps and images with a forward provided by Professor Iain Stewart. The book is essential reading for all those interested in what lies below our feet on the island of Ireland.

The book cost €30 and copies can be ordered from the RIA website https://www.ria.ie/publications/books/science/unearthed-impacts-tellus-surveys-north-ireland .

Or available as an ebook online at the following link:

https://www.ria.ie/publications/books/science/unearthed-impacts-tellus-surveys-north-ireland

Emma Scanlan
Tellus, Geological Survey

GSI and Teagasc sign a Memorandum of Understanding

The Geological Survey of Ireland (GSI) and Teagasc are deepening their long standing working relationship through the signing of a Memorandum of Understanding (MOU). The agreement was signed by Professor Gerry Boyle, Teagasc Director and Koen Verbruggen, Director of GSI at the Teagasc Ashtown Research Centre, Dublin on 20 October 2016.

Teagasc and the GSI have a long and productive association which goes all the way back to the production of the National Soil Survey of Ireland by An Foras Talúntais (AFT, Teagasc predecessor) in the 1980s. This has continued in recent years with sharing of data between the two organisations facilitating the production of a first national subsoils map. This was a key input to the Teagasc-led development of the national 1:250,000 scale Soils Map of Ireland.

One of the first new collaborations will be a joint research fellowship exploring the benefits of combining the Geological Survey Tellus and Teagasc Irish Soil Information System datasets.

Gerry Boyle and Koen Verbruggen signing the GSI and Teagasc MOU. Behind from left Frank O'Mara, Maeve Henchion, Karl Richards, Taly Hunter Williams, Monica Lee, Ray Scanlan, Aoife Braiden and Karen Daly.

GSI makes new appointments

The Geological Survey of Ireland, Department of Communications, Climate Action and the Environment, is happy to announce the appointment of Dr Sophie O'Connor and Russell Rogers as new staff Geologists.

Sophie graduated from University College Dublin with a degree in Geology. After a number of years gaining work experience in geology, geotechnical engineering and hydrogeology in both a consultancy and a Local Authority capacity, Sophie undertook a PhD (Eng) in geophysics and geotechnics, before returning to the consultancy environment.

Russell graduated from the University of Leicester with a degree in Geology, and followed with a MSc in Mineral Exploration from the Universite du Qubec, INRS. Russell has worked in mineral exploration consultancy both within Ireland and internationally since 2011, on projects involving a variety of geological settings and techniques.

The GSI is delighted to welcome Sophie and Russell and is looking forward to incorporating their skills and experience into existing and future projects.

GSI's rebranding

The Geological Survey's new branding was officially launched at Geoscience 2016 in Dublin Castle on 2 November 2016.

Geological Survey
Suirbhéireacht Gheolaíochta
Ireland | Éireann

Geological Survey's new logo

Monica Lee
Geological Survey

Catchments.ie wins web awards

Catchments.ie won two awards at the 2016 Realex Payments Web Awards which took place in Dublin on September 28th. The awards were:

- **Best Science and Technology** (Sponsored by BT Ireland / BT Young Scientists); and
- **Most Innovative Website**.

Catchments.ie has been developed and is maintained by the Environmental Protection Agency, and is a collaboration between the Department of Housing, Planning, Community and Local Government, the Environmental Protection Agency, and the Local Authority Waters and Communities Office.

Mari Cahalane of BT Young Scientist presents the Best Science and Technology Award to Paddy Morris of EPA Catchments.

The website is a great example of what collaboration between a Government Department, an Agency and Local Government can achieve.

The data on this website is the result of work being done by a huge range of people, including:

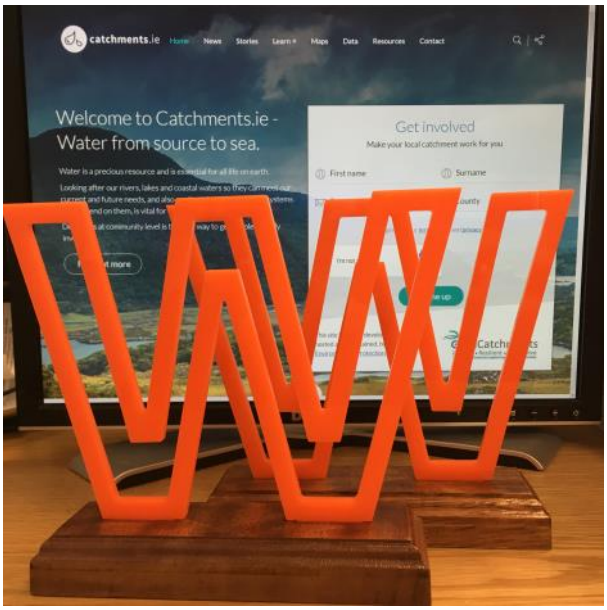
- EPA Catchments team, Informatics team, Biologists, Chemists, and Laboratories;
- All 34 Local Authorities; and
- Inland Fisheries Ireland.

We'll be doing some minor upgrades to the website between now and the end of the year, which will include adding dashboards for a high level overview of water quality data.

We'll also be updating our Status information with 2013-2015 data shortly once some testing is completed.

You can see all the other finalists on the Web Awards website – they are incredibly impressive websites, so we are absolutely delighted to be honoured with these awards.

A special thanks to Brian Durney who helped with the design of the site.



Realex Payments web awards

Catchments.ie has also won IRLOGI's Excellence in Media based Geospatial Data award and a Civil Service Excellence and Innovation Award.

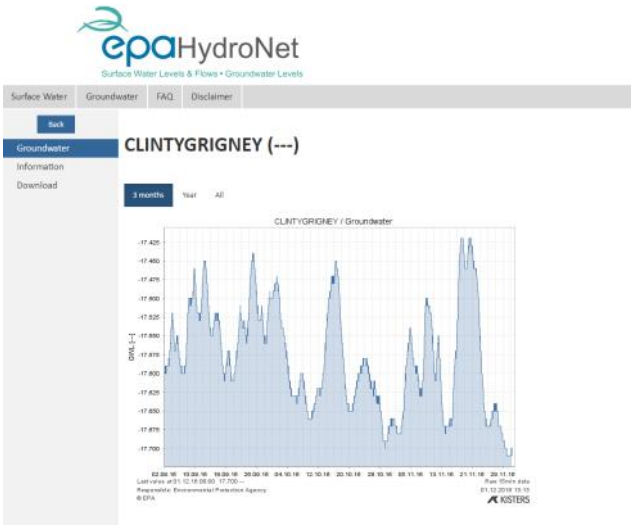
Paddy Morris
EPA Catchments

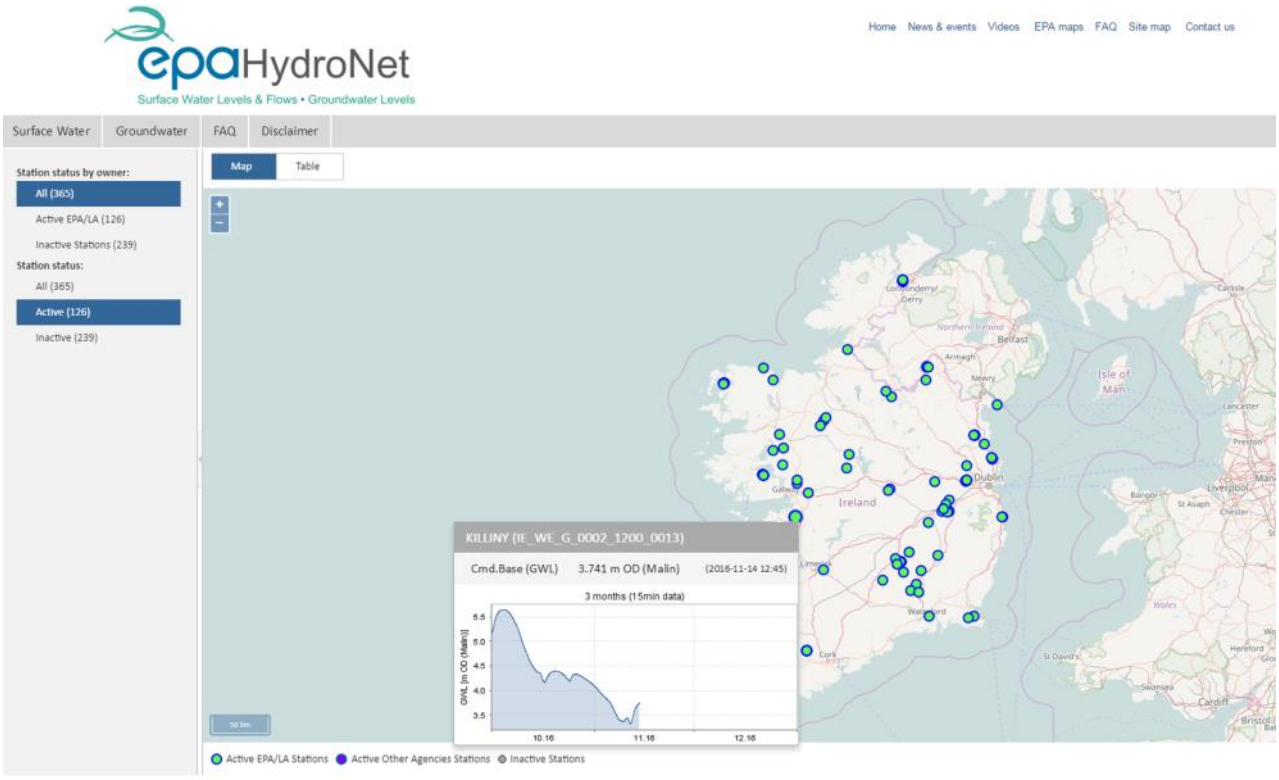
EPA launches update of HydroNet and groundwater quality data

The EPA has launched an updated HydroNet web portal providing access to river flow, river level and groundwater level data. The upgraded website will contain data from all currently active and all inactive historic EPA/LA hydrometric and groundwater level stations and will contain station details and data links for hydrometric stations operated by other organisations such as the OPW. The entire EPA hydrometric and groundwater level database has been made Open Data compliant and the entire data archive can be downloaded from the website. The updated portal contains improved data visualisation and search functionality. Work is currently underway to telemeterise the entire EPA groundwater monitoring network with the aim of providing groundwater level data on the website within 8 hours of the data being recorded by early 2017. HydroNet can be accessed at http://www.epa.ie/hydronet.

The EPA have also made their groundwater quality monitoring results available as Open Data through the EPA Geoportal. This data can be accessed at http://gis.epa.ie/GetData/Download

Conor Quinlan
EPA Groundwater and Hydrometrics





Figures Screen shots of the updated HydroNet web portal

MSc in Water Resources Engineering at NUI Galway

Existing water infrastructure is straining to meet current demands. Population growth, urbanisation, climate change and increasing energy demands, are placing unprecedented pressures on our water resources. The provision of sustainable and safe water supplies into the future will be addressed primarily by engineers. The recently launched MSc in Water Resources Engineering at National University of Ireland Galway is designed to provide engineers will the technical competences to provide solutions to deliver safe/clean water. Core modules will address technical aspects of water provision, water resource management and water / wastewater treatment. A primary objective of the programme is to ensure that students have a thorough understanding of modern hydrological modelling tools. The programme has a strong emphasis on the design of hydrological systems, with students working in groups to solve real world problems. Graduates of this programme will be in a position to make significant contributions to solving water resource problems in both industry and academia worldwide.

NUI Galway MSc Water Resources Engineering student

Water engineering has been taught at graduate level at NUI Galway for over 40 years. Over 400 senior hydrologists throughout the world received their postgraduate hydrological education here. The MSc in Water Resources Engineering is a re-launch of NUI Galway's International Postgraduate Hydrology Programme established by the late Prof Eamonn Nash. Many of the staff who lectured on the Hydrology Programme contribute to the current programme; so the recognised tradition of world-class teaching in water engineering at NUI Galway continues. NUI Galway staff are involved in many large scale funded research projects in water resources, facilitated by the world-class research facilities at NUI Galway. For example, through the NUI Galway/EPA National Centre for Water and Wastewater Demonstration, NUI Galway has become a centre of excellence in the design of innovative water and wastewater treatment technologies. For more information on the MSc in Water Resources Engineering visit the webpage here or contact the programme director, Dr Stephen Nash, at stephen.nash@nuigalway.ie.

NUI Galway MSc Water Resources Engineering student

Stephen Nash
NUI Galway

IAH Irish Group's Conceptual Site Model Showcase

The IAH (Irish Group) are seeking submissions from members of their best Conceptual Site Models to form part of a showcase at the next IAH conference. Conceptual Site Models (CSM) are one of the most important tools for the hydrogeologist to communicate their hydrogeological understanding to clients, planning bodies, consultees and the public in general. CSMs are now also a requirement of the new reporting templates for the EPA. However, it can be the case that hydrogeologists working within their own company do not have exposure to many other examples or strategies for presenting their CSMs.

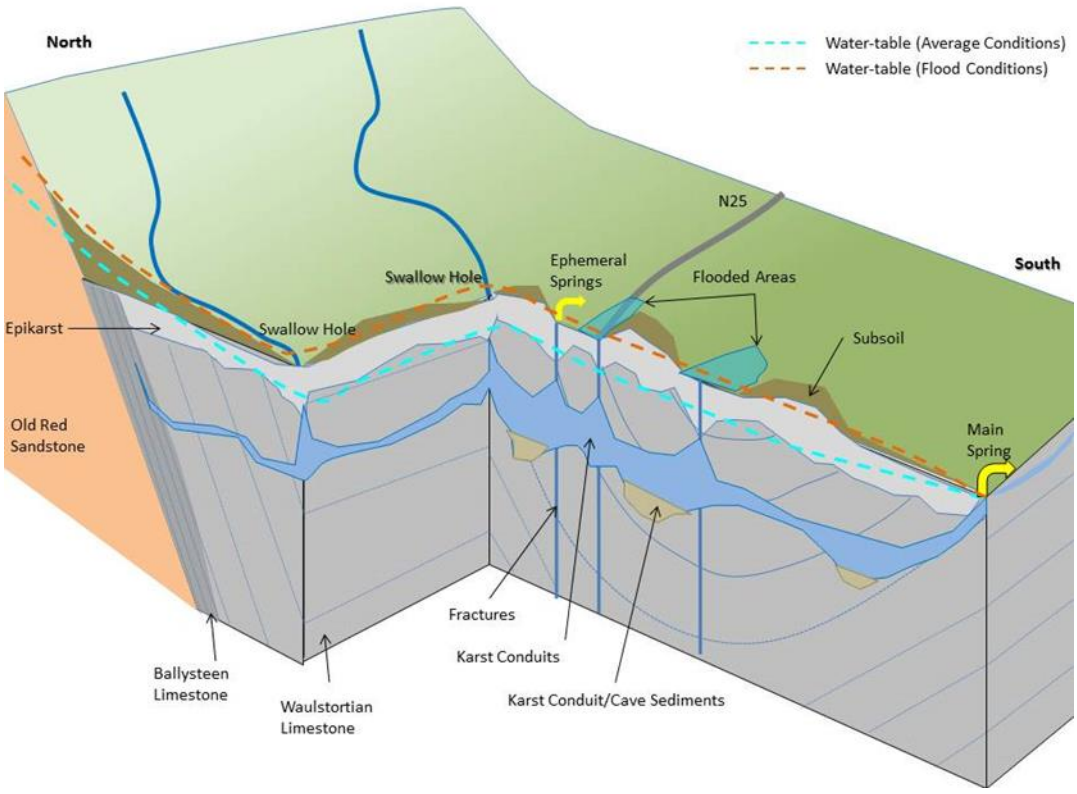
We ask members to email pdf examples of CSMs. These can include cross sections, borehole diagrams, flow process charts, etc. – basically, any visual communication tool which conveys hydrogeological understanding. Site specific details should be removed if and where confidentiality issues exist. The IAH will then produce a series of posters of compiled CSMs for display at the annual IAH Irish Group conference.

The authors of three of the better submissions will be given five minute slots at the conference to describe the CSM and provide insight into its purpose and development.

We hope that through this initiative we can all be inspired by the talent within our own membership. Please email your favourite CSM by 24th March 2017 to conference@iah-ireland.org.

If Conceptual Site Models are the secret weapon of hydrogeologists, it's time for the gun show!

Gerry Baker
Principal Hydrogeologist
RPS



Example of a conceptual model

Bob Aldwell receives National Honourary Membership of the IAH Irish Group

Bob Aldwell received National Honourary Membership of the IAH Irish Group on the 1st November at the Geological Survey. The award was given in recognition of his role as a founding member of the IAH Irish Group and his lasting contribution to hydrogeology in Ireland. The award was presented by David Drew after a Technical Discussion Meeting given by Bob entitled "A history of Groundwater Use and Development in Ireland from 1950-1976".

Katie Tedd

Bob Aldwell receives the National Honourary Membership of the IAH Irish Group. Photo: Gerry Baker

Mike Philcox receives Irish Geoscience Network's Lifetime Achievement Award

Mike Philcox receives Irish Geoscience Network's Lifetime Achievement Award. Pictured from left Pete Coxon, Mike Philcox and Gerry Stanley . Photo: Gareth Ll. Jones.

Dr Michael Philcox received a Lifetime Achievement Award from the Irish Geoscience Network at an event in the Royal Irish Academy on 21st October 2016. The award was in recognition of the contributions of Dr. Michael Philcox to the geosciences in Ireland, over a career spanning six decades (and counting).

The event included presentations marking the major contributions of Dr. Philcox to geoscience in the areas of: Carboniferous lithostratigraphy (presented by Prof. George Sevastopulo, Fellow Emeritus, Trinity College Dublin); Economic geology (presented by Dr. Rob Blakeman, Boliden Tara Mines); and Quaternary geology (presented by Prof. Colm O Cofaigh, Durham University).

The Irish Geoscience Network is an informal alliance of organisations, universities, societies and research groupings in Ireland involved in the geosciences.

Katie Tedd

Irish Group

IAH (Irish Group) 2016 conference

Sustaining Ireland's Water Future: The Role of Groundwater

Owen Naughton—Conference Secretary

The 36th annual IAH conference was held on the 12th and 13th April 2016 in Tullamore, Co. Offaly. Overall the event was well attended by over 150 delegates and a dozen industry exhibitors, and saw a host of esteemed Irish and international speakers presenting on various technical, legal and regulatory topics relevant to today's hydrogeological practitioner.

This year saw the 40th anniversary of the formation of the Irish Branch of the IAH. From the opening lecture by C.R. Aldwell in Trinity College Dublin, 23rd March 1976, the organisation has grown through the strength, dedication and enthusiasm of its members and continues to make a positive contribution to society and the environment today. We were delighted to be able to celebrate this anniversary with addresses from two longstanding members of our group. David Ball took us through the history of groundwater in Irish society, elucidating the 40 years of the IAH Irish Group and 45 years of modern hydrogeology. Bruce Misstear (Trinity College Dublin) then looked to the future, highlighting the opportunities and challenges in hydrogeology education and training.

In addition to the anniversary celebrations the theme of this year's conference was "Sustaining Ireland's Water Future: the Role of Groundwater". IAH (Irish Group) President Henning Moe opened proceedings with an introduction and welcome address. Following this we were honoured to host two keynote speakers, Prof. John M. Sharp and Prof. Beth Parker. Dr. John M. Sharp is Professor of Geology at the University of Texas. His hydrogeological research covers groundwater flow in fractured rocks, regional groundwater flow in carbonate rocks, and effects of urbanization on water resources protection and management. Prof. Sharp lent his experiences to speak on "Sustainability of groundwater resources: conceptual evolution, opportunities & challenges". Dr. Beth Parker is Professor at the School of Engineering at University of Guelph, Ontario. Her research is focused on developing improved field and laboratory methods for characterisations and monitoring of industrial contaminants in sedimentary rocks, clayey deposits and heterogeneous aquifers. Prof. Parker shared her latest research findings on "Contaminant plume characteristics in sedimentary rock aquifers: Insights from field research".

After lunch Donal Daly (EPA) provided expert insights into the progress in implementation of the Water Framework Directive (WFD) in Ireland. Donal highlighted the integrated catchment management (ICM) approach, which has become the accepted philosophy for water resource management in Ireland, and the importance of effective governance and community engagement. Dr. Rob Ward (BGS) followed this up with an insightful talk describing the work that has been done to interpret and understand the requirements of the WFD and Groundwater Directive, and how this understanding has been translated into UK guidance. Teri Hayes (AWN Consulting) presented a best practice approach to assessing the risk to the water environment as part of a Seveso Major Accident Hazard (Seveso III) assessment. The session closed with an enlightening talk by Les Brown (ARUP) where he summarised findings from long-term groundwater catchment monitoring at Fardum and Roosky Turloughs in Northern Ireland.

The final session on Tuesday comprised the second dedicated Early Career Hydrogeologists' Network session at the annual IAH (Irish Group) conference. We were pleased to once again host an ECHN session, which provided a valuable op-

portunity for young hydrogeologists John Weatherill (Geosyntec), Sarah Blake (DIAS) and Christopher Fennell (TCD) to interact with the wider hydrogeological community. At the end of a hard day, weary delegates were treated to a wine reception in the Tullamore Court Hotel followed by a barbeque at Hugh Lynch's Bar.

Wednesday opened with our third keynote speaker, Dr. Kevin Hiscock. Dr. Hiscock is Professor of Environmental Sciences at the University of East Anglia. His interdisciplinary research interests are in hydrochemistry, environmental isotopes and the impacts of land use and climate change on groundwater resources at regional and global scales. Prof. Hiscock presented results from a recent study which investigated future climate influences on groundwater resources. Results predict that many regions of the world will experience decreases in the groundwater store (GWS) at rates exceeding adaptive capacity. Together, renewable GWS and surface water may be insufficient to meet future irrigation demands, posing serious challenges to future food production.

This was followed by David Banks (Holymoor Consulting and Glasgow University), who gave a dramatic and entertaining account of the renewable heat potential from abandoned mines. David outlined how the water reservoirs contained in these mines may be used as a thermal resource or store, convert an ochreous reddish-orange environmental liability into a green renewable energy asset. Sophie O'Connor (GSI) then presented an overview of the Groundwater 3D ("GW3D") project, a multi-annual groundwater mapping project funded by the Department of Communications, Climate Action and the Environment (DCCAE) which aims improve national maps and conceptual models on groundwater systems in priority areas.

The final session consisted of three talks that considered different aspects of groundwater research. Prof. Bob Harris (University of Sheffield) gave an entertaining and enlightening presentation on the tribulations and successes in delivering relevant scientific research. Prof. Harris highlighted the need for researchers and policy-makers to work in partnership, to develop common worldviews and a common conceptual understanding about the subject in hand in order for good communication to take place. Prof. Laurence Gill (TCD) followed with a thorough overview of field research into the performance of on-site wastewater treatment that has been carried out by the Environmental Engineering Group in Trinity College Dublin across different parts of Ireland over the past 15 years. To round off the closing session Prof. Colin Brown (NUIG) described the results and challenges of groundwater research that has been carried out in coastal catchments under the Ryan Institute, NUI Galway's hub for environmental, marine and energy research.

The conference finished up on Wednesday afternoon with the technical workshop, wherein Les Brown (ARUP), Prof. Fiona Regan and members of the DCU Water Institute presented various environmental sensing technologies for groundwater applications. The workshop provided an informal and interactive environment where delegates learned a wide variety of sensing techniques and brought their own experiences to the debate.

The annual conference plays a vital role in funding the activities of the IAH Irish Group throughout the year. On behalf of organising committee Roberta Bellini, Les Brown, Eleanor Burke, Sarah Casey and John Dillon, I would like to thank all delegates, speakers and exhibitors for their support and hope this will continue in the coming years. We would also like to extend our appreciation to you all, the members, colleagues and friends of IAH Irish Group, for your support over the last 40 years and we are confident we can face the challenges facing Ireland's water future with the same spirit of openness and collaboration that has served our community well.

Irish Group

IAH (Irish Group) 2016 AGM

Katie Tedd

The IAH (Irish Group) AGM was held on 3rd November 2016 in the Geological Survey of Ireland.

The IAH (Irish Group) had its usual ***full programme of events*** in 2016 including eight monthly technical discussion meetings, the annual conference and fieldtrip, a hydrology training course, as well as involvement in outreach activities. IAH (Irish Group) membership numbers in 2016 have remained steady at 130 members.

Owen Naughton (conference secretary), Aisling Whelan (fieldtrip secretary), Shane Regan (education and publicity secretary), Roberta Bellini (sub committee) and Katie Tedd (secretary) have completed their terms of office and stepped down from the ***IAH committee*** at the AGM. Sincere thanks to Owen, Aisling, Shane and Roberta for their hard work and dedication to the IAH during their terms of office. At the AGM Barry Sexton was elected as Secretary; Robbie Meehan was elected as Fieldtrip Secretary and Philip Schuler was elected as Conference Secretary.

The IAH (Irish Group)'s ***bursary scheme*** continues to be successful in supporting students studying hydrogeology. Bursaries this year were awarded to Sara Raymond, Devon Kerins, Martin Collig and Matt Jones to contribute towards taught hydrogeology Masters courses. The IAH (Irish Group) are grateful to the following companies who supported the bursary in 2016: **Arup, David Ball, CDM Smith, Hydro Environmental Ltd, O'Callaghan Moran, Minerex Environmental Ltd** and **Parkmore Environmental Services**. Further details may be found on http://www.iah-ireland.org/bursaries/

The IAH (Irish Group) has made an application for ***charity registration*** charity with the Charities Regulatory Authority (CRA) and an application to Revenue for Exemption from Tax for Charities**.** The process is on-going.

The membership was agreeable to the committee's proposal to increase the number of ***sponsored members from developing countries*** from 4 to 10. As a good-will gesture in context of the potential twinning the committee would propose to sponsor members from Uganda.

There was discussion of the Fáilte Ireland's suggestion that the IAH (Irish Group) could consider hosting a future ***IAH congress***.

There was discussion from the membership regarding ***IAH's engagement*** with a wider audience and specific stakeholders who are both affected by and can benefit from the science of hydrogeology.

IAH (Irish Group) committee 2016/17

President :	Henning Moe
Secretary:	Barry Sexton
Treasurer:	Dominica Baird
Conference Secretary:	Philip Schuler
Fieldtrip Secretary:	Robbie Meehan
Education & Publicity:	Orla O'Connell
NI Secretary:	Paul Wilson
Burdon Secretary:	Morgan Burke
Conference Sub Committee:	Eleanor Burke
John Dillon	Sarah Casey
Les Brown	Sara Raymond

Irish Group

IAH (Irish Group) 2016 Annual Fieldtrip

Moy and Deel catchments

Katie Tedd

This year the IAH fieldtrip was held on 22-23rd October and explored the complexity of groundwater/surface water interactions in combined karstic and sand/gravel systems in the Deel & Moy catchments, Mayo. On the first day we focused on the Moy catchment with stops at Knock Airport, a sand and gravel pit and two karst springs used as water supplies (Killaturley GWS and Swinford PWS). On the second day we explored the interaction (or lack of) between the Deel River and the glaciofluvial deposits in its lower course and youthful karstification (or exhumation of old karst). The difficulties involved in distinguishing kettle holes from dolines was discussed and Ireland's biggest spring (poosibly) at Mullenmore was visited.

Many thanks to the contributors to this year's field trip: Coran Kelly, Robbie Meehan, Henning Moe, Malcolm Doak, Connie O'Driscoll and David Drew and fieldtrip secretary Aisling Whelan.

IAH (Irish Group) 2016 fieldtrip. Clockwise from top left: Discussion led by Robbie Meehan at Stripe sand and gravel quarry; discussion at Kilaturley spring; discussion led by Henning Moe at Swinford spring and dolines and kettleholes adjacent to the River Deel.

Recent literature relevant to Irish Hydrogeology

This section of the newsletter contains a bibliography of recent literature relevant to Irish hydrogeology compiled by the editors. If you are involved in, or aware of, any papers which may be relevant for this section of the newsletter please contact the editors at groundwaternewsletter@gsi.ie.

Groundwater recharge

Analysis of groundwater-level response to rainfall and estimation of annual recharge in fractured hard rock aquifers, NW Ireland

Z. Cai and U. Ofterdinger, 2016. Journal of Hydrology, 535, 71–84.

http://dx.doi.org/10.1016/j.jhydrol.2016.01.066

The use of aero-magnetics to enhance a numerical groundwater model of the Lagan Valley aquifer, Northern Ireland

N. Dickson, J.-C. Comte, J. McKinley and U. Ofterdinger. 2016. in M.E. Young (ed.), Unearthed: impacts of the Tellus surveys of the north of Ireland. Royal Irish Academy.

https://www.ria.ie/publications/books/science/unearthed-impacts-tellus-surveys-north-ireland

Geothermal

Understanding hydrothermal circulation patterns at a low-enthalpy thermal spring using audio-magnetotelluric data: A case study from Ireland

S. Blake, T. Henry, M. Muller, A. Jones, et al. 2016. Journal of Applied Geophysics, 132, 1–16.

http://dx.doi.org/10.1016/j.jappgeo.2016.06.007

Compositional multivariate statistical analysis of thermal groundwater provenance: A hydrogeochemical case study from Ireland

S. Blake, T. Henry, J. Murray, R. Flood, et al. 2016. Applied Geochemistry.

http://dx.doi.org/10.1016/j.apgeochem.2016.05.008

Groundwater quality

Assessing nutrient enrichment risk to groundwater-dependent ecosystems in the border counties of Ireland

R. Flynn, V. Perello, R. McKernon and V. McCarthy. 2016. in M.E. Young (ed.), Unearthed: impacts of the Tellus surveys of the north of Ireland. Royal Irish Academy.

https://www.ria.ie/publications/books/science/unearthed-impacts-tellus-surveys-north-ireland

The influence of bedrock hydrogeology on catchment-scale nitrate fate and transport in fractured aquifers

A. Orr, J. Nietsche, M. Archbold, J. Deakin, U. Ofterdinger and R. Flynn. 2016. Science of The Total Environment, 569–570, 1040–1052.

http://dx.doi.org/10.1016/j.scitotenv.2016.06.148

National assessment of arsenic within groundwater: A case study with Ireland

L. Morrison, E. McGrory and C. Brown. 2016. in Bhattacharya, Vahter, Jarsjo, Kumpiene, et. al. (eds), Arsenic research and global sustainability. Taylor and Francis Group, London.

https://www.crcpress.com/

Drivers and barriers among householders to managing domestic wastewater treatment systems in the Republic of Ireland; implications for risk prevention behaviour.

C. Devitta, E. O'Neill and R. Waldron. 2016. Journal of Hydrology, 535, 534–546.

http://dx.doi.org/10.1016/j.jhydrol.2016.02.015

Identifying contrasting influences and surface water signals for specific groundwater phosphorus vulnerability

P.-E. Mellander, P. Jordan, M. Shore, N. McDonald, D.Wall, G. Shortle and K. Daly. 2016. Science of The Total Environment, 541, 292–302.

https://doi.org/10.1016/j.scitotenv.2015.09.082

Karst

Quantifying the influence of surface water–groundwater interaction on nutrient flux in a lowland karst catchment

T. McCormack, O. Naughton, P. Johnston and L. Gill. 2016. Hydrology and Earth System Sciences, 20, 2119-2133.

https://doi.org/10.5194/hess-20-2119-2016

Groundwater flood mechanisms in lowland karst in Ireland: examples from a lowland karst catchment in Ireland

O. Naughton, T. McCormack, P. Johnston and L. Gill. 2016. Journal of Flood Risk Management.

https://doi.org/10.1111/jfr3.12145

Episodic speleothem deposition tracks the terrestrial impact of millennial-scale last glacial climate variability in SW Ireland

A. Fankhauser, F. McDermott and D. Fleitmann. 2016. Quaternary Science Reviews, 152, 104–117.

http://dx.doi.org/10.1016/j.quascirev.2016.09.019

Unconventional Gas Exploration and Extraction

Unconventional Gas Exploration and Extraction (UGEE) Joint Research Programme reports.

Various authors. 2016. EPA Strive report series.

http://www.epa.ie/pubs/reports/research/ugeejointresearchprogramme/

Groundwater Surface Water interaction

A combined remote sensing and multi-tracer approach for localising and assessing groundwater-lake interactions

J. Wilson and C. Rocha. 2016. International Journal of Applied Earth Observation and Geoinformation, 44, 195–204.

http://dx.doi.org/10.1016/j.jag.2015.09.006

Engineering geology

The impact of hydrogeology on the instability of a road cutting through a drumlin in Northern Ireland

D. Hughes, G. Clarke, R. Harley and S. **B**arbour. 2016. Quarterly journal of engineering geology and hydrogeology, 49, 92-104.

https://doi.org/10.1144/qjegh2014-101

Visual drainage assessment: a standardised visual soil assessment method for use in land drainage design in Ireland

P. Tuohy, J. Humphreys, N.Holden, J. O'Loughlin, B. Reidy and O. Fenton. 2016. Irish Journal of Agricultural and Food Research ISSN (Online) 2009-9029.

https://doi.org/10.1515/ijafr-2016-0003

IAH at 60

The International Association of Hydrogeologists (IAH): reflecting on 60 years of contributions to groundwater science and water management

W. Struckmeier, K. Howard and J. Chilton. 2016. Hydrogeology Journal, 24, 1069.

https://doi.org/10.1007/s10040-016-1434-7

Previous issues available at www.gsi.ie

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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If you are involved in an event which you would like to be advertised in the groundwater newsletter please email details to groundwaternewsletter@gsi.ie

Upcoming Events

2016

8 Dec 2016	**Irish Association for Economic Geology (IAEG)** - Pillo Hotel Ashbourne Paul Gordon (SLR consulting) - Social acceptance of geoscience activities and earth resources in Ireland http://www.iaeg.org/events
24-25 Nov 2016	**The Geological Society Brian Lovell Meeting** - Burlington House, London Water, hazards and risk: Managing uncertainty in a changing world http://www.geolsoc.org.uk/Lovell16

2017

10 Jan 2017	**Joint Geotechnical Society/IAH TDM** – GSI Les Brown; Esther Madden; Cathal Mac an tSearraigh; Heather Gibbons (Arup) - Designing Linear Infrastructure in a Karst Environment. http://www.iah-ireland.org/upcoming-events/
11-14 Jan 2017	**BT young Scientist and Technology Exhibition** RDS Ballsbridge http://www.btyoungscientist.com
24 Jan 2017	**IAH (Irish Group) Training Course** – GSI Statistics for hydrogeologists Contact Shane Regan educationandpublicity@iah-ireland.org
7 Feb 2017	**Joint IAH (Irish Group) and Geothermal Association of Ireland TDM** - GSI Gareth Farr (British Geological Survey) - Low enthalpy ground source heating in Wales: baseline mapping and operational systems utilising abandoned coal workings and shallow urban aquifers. http://www.iah-ireland.org/upcoming-events/
TBC Mar	**IAH (Irish Group) Burdon Lecture** - GSI Burdon lecture on development issues Speaker TBC http://www.iah-ireland.org/upcoming-events/
5-6 April 2017	**The SEAI Energy show** - RDS http://www.seai.ie/energyshow/
TBC Apr 2017	**IAH (Irish Group) Annual conference** http://www.iah-ireland.org/annual-conference/
TBC May	**IAH (Irish Group) TDM** - GSI Speaker and topic TBC http://www.iah-ireland.org/upcoming-events/
29 May - 1 Jun 2017	**LuWQ2017** – International conference on LAND USE and WATER QUALITY The Hague, The Netherlands http://www.luwq2017.nl/
TBC June	**EPA National Water Event** https://www.epa.ie/newsandevents/events/

The editors welcome feedback on the contents of this issue and the changes to the newsletter, as well as suggestions for contributions to the next issue.
Please contact: Groundwaternewsletter@gsi.ie

Contributions for the next issue should arrive before **28 April 2017.**