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THE GSI GROUNDWATER NEWSLETTER

NUACHTÁN SCREAMHUISCE SGÉ

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An important event for geologists and hydrogeologists in Ireland occurred in May with the launch of a **professional body** called the **Institute of Geologists of Ireland**. This is a self-regulating body with professional standards and disciplinary powers to provide professional certification of geologists in Ireland, to represent the interests of all geologists on professional matters and to develop professional activities and services on behalf of members. Further information is given by Geoff Wright on page 2.

Limestones underlie approximately half of Ireland. Some areas, the Burren region for example, are known to be **highly karstified** with the karst groundwater systems being active at present. Other areas, those of very impure limestones for example, are presumed to be **non-karstic**, the aquifer being of the fractured/fissured type rather than dominated by solutionally enlarged conduits. While compilation work, which is part of the production of **groundwater protection schemes**, is improving our knowledge and understanding of karst, over much of the country the extent and significance of karstification is not known in any detail.

Information is required concerning karstification in Ireland because:

- increasing use is being made of groundwaters from limestone aquifers;
- groundwater protection plans require reliable information on the topic;
- geotechnical engineers require such data for many projects, e.g. road construction;
- mining developments in recent years have involved discussion on and investigation of karstification in the proposed mining areas.

As a means of improving our knowledge and making information available, a **Karst Features Database** has been set up. This is described by Morgan Burke on page 3.

Global water shortages threaten to reduce food supply by more than 10% in many countries, according to the World Watch Institute, an environmental policy group in Washington D.C. Melissa Swartz raises issues regarding the **future of global water resources** on page 11.

Other articles in this Newsletter include a useful discussion **on total petroleum hydrocarbons** (page 13) by Anita Furey, advice on **drilling wells** (page 9) by Shane O'Neill and an introduction to **gypsum karst** on page 7.

Editor

Institute of Geologists of Ireland Launched

The sixth of May 1999 saw the launch of a new professional body for geologists in Ireland, the **Institute of Geologists of Ireland (IGI).** The inauguration ceremony took place in the GSI lecture Theatre and the guest of honour was Dr Michael Woods, T.D., Minister for the Marine and Natural Resources, whose department administers mineral and petroleum prospecting in Ireland's land and sea areas. Dr Woods presented certificates of membership to a representative number of IGI's professional members.

The launch of this new body resulted from consultation between Ireland's main geological organisations, including the Irish Association for Economic Geology (IAEG), the Irish Group of the International Association of Hydrogeologists (IAH) and the Irish Quarrying and Mining Society (IMQS), which have become sponsoring bodies of the new Institute, providing the initial funds to get the organisation going (assisted by several commercial sponsors). By the end of 1999 the IGI had achieved a professional membership of 116, including about 20 hydrogeologists. The IGI is currently managed by a Transitional Council representing the various sponsoring bodies. IAH is represented on IGI's Transitional Council by Eugene Daly (Vice-President and chair of the continuing professional development (CPD) committee), and Geoff Wright. In the first half of 2000 the Transitional Council will be replaced by a fully-elected Council at the Institute's Inaugural General Meeting.

The IGI has been set up as a self-regulating body with professional standards and disciplinary powers to provide professional certification of geologists in Ireland, to represent the interests of all geologists in Ireland on professional matters and to develop professional activities and services on behalf of members. The IGI has replaced IAEG as Ireland's representative on the European Federation of Geologists (EFG), and therefore is empowered to register the title of "European Geologist" (EurGeol) in Ireland.

Besides processing membership applications, the Council has been working on a number of fronts, including:

- **Continuous Professional Development:** A committee is examining practice in other countries. IGI plans to hold its own courses on professional matters, but to rely on IAEG, IAH, etc. for technical courses.
- **Constitution:** A draft constitution is under review by the IGI Council and by a solicitor, barrister and accountant.
- **Inaugural General Meeting:** planned for early next year. A new elected Council will be formed, with presidents of sponsoring organisations retaining observer status.
- **European Federation of Geologists:** EFG is working with representatives of other member countries to improve EFG and widen its membership. IGI Council member Gareth Ll Jones is the new EFG President, and IGI President Eibhlín Doyle is our other representative on the EFG Board. EFG is lobbying MEPs to secure European-wide recognition and standards.
- **External relations:** outside EFG, IGI is working to secure mutual recognition with equivalent bodies in USA, Canada, Australia, etc., and working with them on issues such as professional standards and ore reserves/resources definitions.
- **IGI website:** set up by Peter O'Connor and Bernard Murphy Associates.
- **Professional Indemnity:** IGI is researching provision of professional indemnity insurance for members, as well as for itself as a body.
- **Geoservices Directory:** is being prepared.
- **Social:** A couple of enjoyable social events have been held.

The IGI's secretary is Julian Menuge, c/o the Geology Department, University College Dublin, Belfield, Dublin 4.

The IGI website is at http://www.igi.ie

Geoff Wright, Groundwater Section, Geological Survey of Ireland

The GSI Karst Features Database

Introduction

Carboniferous limestones form the bedrock over approximately half the area of the Republic of Ireland. As a result of this, karst is a very significant aspect of the environment in the country. The full extent and degree of karstification in all areas of the country is poorly understood. Areas such as the Burren in County Clare are known to be exceptionally karstified with the karst groundwater systems being highly active at present. Regions of more impure limestones are assumed to be non-karstic, with the groundwater flow regime being of the fissure-fracture flow type as opposed to being dominated by solutionally enlarged conduits that are found in places like the Burren. However, over a much wider area there is uncertainty as to the degree and extent of karstification, whether currently active or inactive. This area coincides mainly with the central limestone lowlands of the country which have thick beds of glacial deposits overlying the bedrock in many areas.

More information is required concerning the extent and significance of karstification in the Republic of Ireland by a number of interests, for example, hydrogeologists, engineers, mining geologists, planners and academics. As a result of the urgent need for data, a joint Geography Department, Trinity College Dublin and Groundwater Section, Geological Survey of Ireland research project was initiated to address this issue (Burke, 1998). The principal aim of the investigation was to improve knowledge of karst in Ireland through the compilation and querying of a Karst Features Database which stores information on known karst features. This paper is a brief outline of some of the topics discussed in the joint research project.

The Karst Features Database

The Karst Features Database (a customised version of Microsoft ACCESS) is an inventory of known karst features in the Republic of Ireland. Information is recorded in the database for a variety of karst feature types including caves, enclosed depressions, dry valleys, turloughs, swallow holes, karst springs, estavelles, limestone pavements and epikarst. These karst feature types encompass all karst phenomena that occur in the Irish landscape. General details relevant to these features, such as grid references, county names, townland names, map numbers and the limestone lithology type in which the features occur, can be recorded in the database. However, each of the defined karst feature types has a different appearance in the landscape and therefore have different characteristics. Some features, such as caves, have length and volume whilst other karst phenomena do not. A distinction can also be made between those features which have areal extent and those that have point occurrence. As a result of this, specific details pertinent to each of the karst feature types may also be stored, such as overall passage length of a cave or the response time of a karst spring to a rainfall event.

The primary purpose of creating a Karst Features Database was to compile and store details of known karst features in the Republic of Ireland. Data were compiled from a variety of sources including maps, literature and company records. Subsurface karst data were also obtained from borehole records and a telephone survey of active limestone quarry operators.

The contents of this database can be queried and analysed using the basic ACCESS query tools, for both applied and academic purposes. Consultants or other professionals may require details of karst features in an area of interest or relevance to a particular project. For instance, a list of any karst features that may occur within a defined area around a proposed development can easily be generated. The contents of the database can also be analysed to improve knowledge of karstification in the Republic of Ireland. For example, the database was queried to determine if any patterns exist in the geographical distribution of the karst features and to examine if limestone lithology has an influence on the development of karstification. Examples of these analyses are described below. However, prior to any content analysis of the database based on geographical or lithological influences on karst occurrence, it was necessary to identify distinct karst regions and limestone lithology types.

The Karst Regions

Five distinct karst regions can be identified in the Irish landscape based on contrasting topographical, geomorphological and geological environments. These include two upland and three lowland regions. This classification recognises the differing reliefs, hydraulic gradients, thicknesses of overburden and effects of glacial erosion and structural geology in the different parts of the country. The regions are:

1) The upland Burren plateau in Co. Clare.
2) The north-west upland limestone plateau of Counties Fermanagh, Cavan, Leitrim and Sligo.
3) The western lowland limestones in Counties Mayo, Galway and Roscommon which in many areas are covered by thin (0.5-2.0m) and, in places, no subsoils.
4) The eastern lowlands which are mantled by thick beds (up to 30m) of soils and subsoils. This region includes Counties Louth, Monaghan, Longford, Meath, Westmeath, Offaly, Dublin, Kildare, Laois and Carlow.
5) The structurally controlled lowland limestones in the south of the country. This region includes Counties Tipperary, Kilkenny, Wexford, Waterford, Cork, Kerry, and Limerick.

The Limestone Lithologies

The Irish karst landscape consists of a variety of both active and inactive karst features. These are developed in a number of different limestone lithology types. Most of these limestones were formed during the Dinantian Period which ended approximately 325 million years ago. Five different limestone lithology types were identified for the purposes of this research; namely, clean bedded, clean unbedded, cherty, argillaceous (muddy) and other limestone types.

Content Analysis of the Database

Table 1 shows that the majority of karst features are recorded in the upland Burren plateau region. In contrast to this, fewest karst features are recorded in the eastern lowlands which is the most extensive karst region. The western lowlands, the structurally controlled southern region and the upland limestone plateau in the north-west region display approximately the same degree of karstification. However, it should be noted that karst data for Co. Fermanagh are not included in the analysis of the north-west karst region.

Relief and thickness of overburden cover appear to influence the geographical distribution of karst features, with more development recorded in upland areas and in regions mantled with a relatively thin (0.5-2.0m) cover of subsoils. However, it is also possible that karst features are more obvious in areas with thin subsoils and that further karst, whether active or inactive, is yet to be discovered buried under thick subsoils. This may be especially true in the eastern lowlands region. The geographical distribution of karst features may also be in part a function of the distribution of the different limestone lithology types. Table 2 shows the number of karst features per 1000 km^2 of each lithology category. Clearly, the clean bedded limestones, which mostly occur in the western lowlands and in the Burren, display the best development of karstification with more than twice the amount of karst features per 1000 km^2 of limestone than the next most karstified lithology, the cherty limestones. This is due to well developed bedding and the high purity of these pale grey fossiliferous shelf limestones rendering them more prone to solution than the other lithology categories. Pure limestones tend to be brittle, allowing the development of open fractures. Bedding planes, joints and faults host and guide almost all parts of the underground solution conduit system. These zones of absent rock behave as preferential flowpaths for groundwater circulation and it is along these lines that karst systems are generated.

Table 1. Table showing number of karst features per 1000 km^2 of limestone per karst region

The Burren	Western Lowlands	The South	The Northwest	Eastern Lowlands
420	86	78	70	23

Table 2. Table showing number of karst features per 1000 km^2 of each limestone lithology type

Clean Bedded	Cherty	Clean Unbedded	Other	Argillaceous
180	80	70	62	20

In contrast, the argillaceous (or muddy) limestones, which underlie most of the eastern lowlands, are the least karstified limestone lithology. This is due to the impure nature of these dark argillaceous bioclastic limestones. Impure limestones are not as brittle as pure limestones and deform more readily. Deformation of these rocks tends to seal fractures and prevent water movement. The high percentage of insoluble impurities clog proto-conduits and the interbedded shales and mudstones impede the circulation of groundwaters thus preventing karstification. Examples of this lithological type include the Ballysteen, Meenymore, Glencar and Tober Colleen (of the Calp) rock units.

The cherty, clean unbedded and other limestone categories all demonstrate approximately the same degree of karstification. The limestones in the cherty category are generally soluble blue-grey pure crinoidal limestones with flat seams and nodules of black or blue chert forming approximately 50% of the rock. It is likely that the insoluble chert rich beds influence the underground water routes by preventing vertical movement of water but facilitating lateral movement above the chert beds resulting in greater solution of the karstifiable limestone in these zones. The influence of chert rich beds on underground water routes in the Slievenaglasha Formation in the Burren, Co. Clare is apparent. All caves in this formation remain perched above the cherts for their explored lengths. These all become impenetrable bedding caves when the cherty beds are reached (Drew, 1988). However, Ford & Williams (1992) claim that vertical penetration of percolating surface waters may also be possible in these rock types as the chert sheets are rarely thicker than 10cm and are normally perforated so that water flow across them is possible. Other examples of cherty limestones include the Crosspatrick and Clogrenan Formations in the south and south-east midlands and the Dartry Limestone in the north-west of the country.

The clean unbedded lithology type, which mostly consists of pale grey biomicritic Waulsortian 'reef' limestone, is very pure and thus susceptible to solution. However, these limestones are massive and unbedded. A mountain building episode at the end of the Carboniferous period (the Variscan Orogeny), created an extensive network of faults and fractures in the Waulsortian rocks of the south of Ireland. These faults and fractures have gradually been solutionally widened resulting in the formation of cave systems and other karst features in the south of the country. The clean unbedded limestones further to the north in the eastern lowlands region do not display the same degree of karstification as those in the structurally controlled synclines in the south. This is perhaps due to less structural control as a result of which, groundwater circulation is not easily facilitated in the massive unbedded limestones. However, it is also possible that thick subsoils have buried karst features that remain to be discovered.

The rocks in the Other Limestones lithology are classified as 'undifferentiated limestones' on the Geological Survey of Ireland 1:100,000 scale bedrock maps. These limestones also display good development of karstification. A possible explanation for this it that the limestones are either pure and well bedded or structurally controlled massive Waulsortian limestones which favour the development of karst.

Conclusions

The overall aim of the research was to improve the understanding and knowledge of Irish karst. Content analysis of the Karst Features Database has revealed that all limestone lithology types are prone to varying degrees of karstification. Geographical regions underlain by clean unbedded limestones, other limestone types, cherty limestones and especially clean well bedded limestones are more susceptible to solution. Therefore, these lithologies are more likely to display groundwater flow regimes dominated by conduit flow and subsidence features, whether currently active or inactive. In contrast to this, impure argillaceous limestones are less susceptible to karstification. The groundwater flow regimes in the areas underlain by this lithology are more likely to be of the fissure or fracture flow type with little evidence of subsidence or other karst features.

These observations have important implications for groundwater resource studies and the understanding of karst aquifers.

It has been demonstrated that the Karst Features database is a useful tool for improving knowledge on karst in Ireland for both practical and academic purposes. However, in order to maintain its value and usefulness to planners, engineers, hydrogeologists, mining geologists and academics, it is essential that continued data compilation is sustained. Any existing karst data in the possession of companies, which has not been already recorded in the database and any new information from drilling, geophysics, etc, should be sent to the Groundwater Section of the Geological Survey of Ireland. For further details please contact Vincent Fitzsimons at (01) 6041499.

Acknowledgements

The author would like to express gratitude to David Drew of the Geography Department, TCD and Donal Daly of the Groundwater Section, GSI for supervising the research. Thanks are also due to the Groundwater Section, GSI and the IAH (Irish Group) for financial assistance. The input from the members of the Karst Working Group during the early stages of the research is also acknowledged. Many thanks to Mr. Philip Jutson for programming the Karst Features Database.

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Morgan Burke, Minerex Environmental Ltd., (formerly Groundwater Section, GSI & Geography Dept, TCD)

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Irish Speleology 17 : Call for Contributions

It is intended to produce a new volume of this journal of the Speleogical Union of Ireland in Spring 2000. It will have an emphasis on conservation and access issues, as it will be produced to coincide with a symposium on the topic. However, it is a forum for all cave and karst related matters, especially of Irish interest, and any contributions are welcomed. Anyone who is not familiar with the journal style and format may contact the editor for more information. A range of articles is usual, from full scientific papers to cave surveys and descriptions, with opinion and discussion papers also welcomed. It is particularly suitable for publishing scientific information (such as a series of water tracing results), which might not be suitable for a full paper elsewhere, but which in the caving community may lead to new discoveries or ideas.

Please send contributions or contact the editor as soon as possible to:

Matthew Parkes, Geological Survey of Ireland, Beggars Bush, Haddington Road, Dublin 4
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Gypsum Karst

Introduction

When 'true' hydrogeologists go on holidays, they will never waste an opportunity of visiting a SHOW CAVE! Thus it was that in Spain this summer, the family were (willingly) brought to a cave near Sorbas in Almeria. It was a pleasant surprise to find that it looked different to all the caves that I had previously visited in that there were none of the typical features of limestone caves, for instance no stalagmites or stalactites. In fact, the caves were in gypsum. While solution of limestones and karstification has been an inevitable interest, concern and occasional source of frustration as a hydrogeologist working in Ireland, it was only recently (I am somewhat embarrassed to say), as I listened to and talked to Tony Cooper of the British Geological Survey, that I became aware of gypsum dissolution, the problems that it can cause and the differences from limestone dissolution. The following material is taken, in most instances directly, from papers written by Tony and his colleagues. Whether you are an engineer or a hydrogeologist, it may add another dimension to your knowledge of karst; at least it did to me. Its relevance to Ireland will be considered in the next Newsletter.

Gypsum Dissolution

The outstanding feature about gypsum ($CaSO_4.2H_2O$, the raw material of plaster) is that it dissolves rapidly in flowing water, at a rate about 100 times faster than that of limestone! Unlike the relatively slow formation of limestone karst, gypsum karst can develop on a human/engineering time-scale. For instance at Ripon in Yorkshire, a 3 m cube of gypsum was dissolved by the River Ure in 18 months and the associated gypsum face was undercut by 6 m in the subsequent 10 years. This high dissolution rate means that caves will form in gypsum and fast flowing water in them can remove up to 0.5 to 1.0 m of gypsum per annum from cave walls. Some of the longest and most complex cave systems in the world are developed in the gypsum karst of the Ukraine. Under suitable groundwater flow conditions caves in gypsum can enlarge at a rapid rate resulting in large chambers. Collapse of these chambers can propagate through the overlying rocks to break through at the surface and form subsidence hollows. By this mechanism, holes up to 20 m deep and 40 m across, continue to appear suddenly in gypsum areas throughout the world.

Gypsum Geohazards – Examples

Gypsum karst throughout the world constitutes a geological hazard responsible for subsidence and difficult engineering conditions. It is responsible for subsidence and collapse (sometimes sudden and catastrophic) in urban areas around Paris, Madrid and Zaragoza (Spain), Stuttgart (Germany), Pasvalys and Birzai (Lithuania), Perm area (Russia), and Shanxi and Hebei coalfields (China). At least 24 dams have been affected by gypsum dissolution problems including 14 in the US, 3 in China, and others in Switzerland, Argentina, Siberia, Venezuela, Guatemala and Peru.

In England, Ripon suffers the worst subsidence caused by gypsum dissolution in Permian and Triassic rocks. Here at least 30 major collapses have occurred in the last 150 years. Numerous sags and small collapses also occur in farmland areas. Catastrophic subsidence has caused about £1,000,000 worth of damage and generated problems for both planners and engineers. Special engineering measures for construction of roads, bridges and railways are used including: incorporating several layers of high tensile heavy duty reinforced plastic mesh geotextile into road embankments and car parks; using sacrificial supports on bridges, so that the loss of support of any one upright will not cause the deck to collapse; extending the foundations of bridge piers laterally to an amount that could span the normal size collapses; and monitoring systems. Changes in the water table are thought to be the most common triggering mechanism for subsidence related to gypsum caves in England. Many of the collapses occurred after flooding or periods of prolonged rain. The subsidence may also be aggravated by water abstraction; firstly, as it lowers the water table, and secondly it can induce considerable flow of water, unsaturated with respect to calcium sulphate, into the aquifer thereby actively dissolving the gypsum. It has been calculated that one major abstractor, pumping water from a gypsiferous sequence, was effectively removing up to 200 m^3 of gypsum annually from the vicinity of a factory; the factory and surrounding area had suffered active subsidence.

Planning for Gypsum Geohazards

In Ripon, the area is divided into 3 development zones: A, B and C. Within Zone A there is no gypsum and no special planning constraints would be imposed. In Zone B, where the gypsum is present at depth and the risk of subsidence is low, a ground stability report prepared by a competent person would usually be required and the problem should be considered in local planning. Zone C has gypsum susceptible to solution at present. Zone C is subject to stringent planning controls to enable development to proceed. These include the requirement that a detailed geotechnical report prepared by an officially recognised 'competent person' is produced. Only when it can be shown that the risk of subsidence has been considered, and that the site investigation and structural design have taken this into account, will the development get planning permission.

In Lithuania, groundwater in the gypsum karst is such a valuable resource that it is protected from pollution. The susceptibility of gypsum karst to pollution was analysed by looking at 19 geological, hydrogeological and hydrological variables, then each area was given a susceptibility grading. Four divisions of agricultural land use have been defined, based largely on the number of sinkholes per square kilometre.

- ♦ Land Group 1 (up to 20 sinkholes/100 ha). Grain crops should compose at least 50% of arable crops, perennial grass 40% and root crops (potatoes and sugar beet) not more than 10%. Fertilizers are limited to a maximum of 90 kg/ha of nitrogen/phosphorus/potassium (NPPt active ingredients) and 80 t/ha of manure. Triazinic herbicides and Chloroganic insecticides are prohibited.
- ♦ Land Group 2 (20-50 sinkholes/100 ha). Grain crops should compose 43% of arable lands and perennial grass 57%. Root crops are prohibited as is the setting up of new orchards and gardens. Fertilizers are limited to a maximum of 60 kg/ha of NPPt and 60 t/ha of manure.
- ♦ Land group 3 (50-80 sinkholes/100 ha). Perennial grass and pastures only are allowed. Fertilizers are limited to a maximum of 60 kg/ha NPK. Mineral nitrogen fertilizers are prohibited as are pesticides (except for fungicides).
- ♦ Land Group 4 (80-100 sinkholes/100 ha).Only grass meadows and forests are allowed. All fertilizers and pesticides are prohibited.

In addition, for the area around each sinkhole, in all four agricultural categories, the law is that there must be a 25 m exclusion zone for agriculture, and around some an earth barrier to prevent runoff entering the hole. Ecologically sound agricultural plans have been designed for each land group, and organic agriculture is being introduced to the region.

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Donal Daly, Groundwater Section, Geological Survey of Ireland

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A Suggested Methodology for Maximising the Probability of Drilling a Successful Well

Current Approach

Drilling of production wells is normally a two stage process. The first stage is the drilling of exploratory wells The second stage is the reaming out of those exploration wells or drilling down beside the exploration wells. The exploratory well is usually drilled with a downhole hammer (DHH). These exploratory wells are normally opened at a diameter of 200mm down to competent bedrock and temporary mild steel casing installed into that open hole down to bedrock. The hole is then drilled on at an open hole diameter of 150mm until a water bearing structure or structures are encountered that have sufficient yield to meet the objectives of the production well. Once the exploratory well has been drilled and successfully encountered a water bearing feature, then the 150mm mild steel casing is either retrieved from the exploratory hole and the exploratory hole reamed out or the drilling rig simply moves over a metre or two and a production well is drilled from surface. The production well is either drilled with DHH or with tricone. In very poor and incompetent ground then tricone drilling would be by far the best approach.

Potential Difficulties

It has been OGE's experience to have drilled exploratory wells as part of a large de-watering programme. These exploratory wells were invariably located in the most weathered and incompetent rock that could be located. As a consequence of the poor drilling conditions it often resulted in the drillers having to drive in 150mm temporary mild steel casing through the poor ground near the surface to permit them to drill on to depth. This driving of the casing through the near surface weathered material sometimes resulted in the drillers being unable to remove that casing when it came to reaming out the exploration well. This meant that the drillers had to move over to drill the production well a metre or two away from the original pilot hole. This resulted in a dilemma as to which side of the pilot hole to drill on. It was assumed that the pilot hole was drilled vertically. However, after one particular incident, it was established that the exploratory hole was far from vertical. A production well drilled to one side of an exploratory hole that had an estimated airlift yield of 125m^3 per hour resulted in a well which had a yield of less than 50m^3 per hour.

The Solution

The cause of this apparent discrepancy in yield was investigated. A verticality wireline log was run down the exploration hole. It was discovered that the base of the pilot hole was 7 degrees off the vertical at a depth of 150 metres. This resulted in an offset at the base of the pilot hole from the original collar position of 18.28m. The verticality log also established the bearing of the deviation. It was to the south west. The production well had been drilled 5 metres away from the original exploratory hole and on the northern side of the hole. The production well had a vertical deviation of 1 degree over its entire length. Therefore the production hole missed the original water bearing feature encountered in the exploration well by some 15.66m.

Suggested Methodology

Therefore as a consequence of this the following procedure was established:

1. Exploration holes to be drilled to refusal using downhole hammer;
2. The exploration hole to be wireline logged using a verticality log;
3. Calculation of the deviation from the vertical and the resultant bearing;
4. Setting up of the production well over the fissure encountered at depth in the exploration well based on the results of the verticality log.
5. The production well was drilled using tricone, direct mud or water circulation, and a near bit pendulum assembly. This would maximise the verticality of the hole regardless of the ground conditions.

This methodology proved extremely successful, guaranteeing a large water make from production holes whose location was dictated by the drilling of an exploratory well.

Cost Implications

The relative costs for each stage were as follows:

1. The production well – a nominal cost of 100
2. The pilot hole – a nominal cost of 5
3. The wireline logging – a nominal cost of 1.

Therefore the overall costs of the exploratory well and the wireline logging were an extremely small fraction of the overall total costs of the drilling of the production well. This slight additional cost was considered extremely good value as it maximised the probability of the production well encountering the same fissure zones as were encountered in the original exploration well. The time taken to drill a 150mm finished open hole to a depth of 150m using DHH is approximately two days. The hole can be wireline logged within a day. Therefore within three days a precise drilling target can be identified at a precise depth and the production well drilling rig set up accordingly.

Shane O'Neill, O'Neill Groundwater Engineering

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Bob Aldwell Retires from GSI

Bob recently retired from GSI after a distinguished career which spanned four decades. Following his graduation from TCD in 1960, he joined GSI. His initial work included Quaternary mapping and he worked very closely with the Agricultural Institute (the forerunner of Teagasc).

By 1970 however his attention was increasingly focused on that topic for which he will be best remembered: groundwater. He actively promoted the value of groundwater as a natural resource, and how that needed to be carefully managed. He played a central role in establishing the Groundwater Section in GSI and ensuring that its work has been recognised as being of increasing importance to Ireland. He played a competent role internationally, at EU level as well as in organisations such as the International Association of Hydrogeologists and the International Hydrological Programme.

Following his promotion to Principal Geologist in 1979 Bob undertook responsibility for all aspects of Environmental Geology in GSI. This allowed him to maintain his interest in, and commitment to, groundwater. However his brief also covered Quaternary and Marine Geology, both of which were developing strategic importance at the time. At various times he has also had responsibility for Bedrock Mapping and Mineral Resources – indeed he served on the Board of the UNESCO/UNEP Working Group on the Impact of Mining on the Environment.

Bob had a key role in the establishment of COST Action 65 "Hydrogeological Aspects of Groundwater Production in Karstic Areas" and was elected Vice-Chairperson of the follow-up Action 620 on "Groundwater Vulnerability in Karstic Areas". While maintaining a keen interest in all aspects of GSI activity, in recent years he had a central role in securing Government approval to undertake the Seabed Survey, the first comprehensive mapping programme of our very extensive seabed area.

Bob had a profound influence on the practice of hydrogeology in Ireland. He has always encouraged younger scientists to fully participate in the profession. Through his international contacts he has stimulated many new activities in Ireland, using his legendary diplomatic and networking skills. We in GSI will miss Bob's many positive contributions but we are pleased that he will continue his involvement in groundwater through COST Action 620.

Peadar McArdle, Geological Survey of Ireland

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The Future of Global Water Resources

As we all know, water is a limited and precious resource, even here in Ireland where we may sometimes feel that too much of it falls from our skies. According to the World Water Commission, almost 450 million people in 29 countries face water shortage problems - a figure that is projected to jump to nearly 2.5 billion people by 2050. "Even if we do everything we can to make irrigated agriculture more water efficient, humanity will still need at least 17 % more fresh water to meet all its food needs than is currently available...the world water gap," says Dr. Ismail Serageldin, Chairperson of the World Commission on Water for the 21st Century and vice president of the World Bank. To address these issues the World Water Commission and the World Water Vision project were formed to increase public awareness and to find possible solutions.

World Water Vision Project

The World Water Vision project is sponsored by the World Water Council, the World Bank and the many principal UN agencies involved with water including: FAO; United Nations Development Programme (UNDP); United Nations Environment Programme (UNEP); UNESCO; United Nations University (UNU); World Meteorological Organization (WMO); World Health Organization (WHO); and UNICEF. Government sponsors include Australia, Belgium, Canada, Denmark, France, Japan, Luxembourg, the Netherlands, Sweden, the United Kingdom and the United States.

By using the voice of the masses, the World Water Commission hopes to show politicians and other decision makers that world water issues demand attention, thus the creation of the World Water Vision project. This project seeks to involve everyone who depends on water - and who doesn't? - in this project through consultations. These consultations are intended to give the largest possible number of individuals at the "grass-roots" level a chance to decide on the kind of future that they want for themselves and for future generations. Consultations are held through meetings organised by the various participating organisations around the world. Results of these, and other discussion sessions, are to be presented at the Second World Water Forum and Ministerial Conference in The Hague, Netherlands in March 2000. The aim of this conference is to convert public awareness on water into political commitment.

Overall Objectives

That said, the World Water Vision aims to balance the competing demands on water, both human and natural (i.e., domestic, agricultural, industrial and environmental), through a holistic approach to ensure sustainability of the resource. In order to balance these various needs, they hope to establish an integrated decision making process that recognises the interdependence of water needs in these many sectors. The main objectives of using such an integrated approach are to:

- Empower women, men and communities to organise to obtain access to safe water and hygienic living conditions.
- Produce more food to create more sustainable livelihoods for women and men per unit of water applied ('more crop and jobs per drop'), and ensure access for all to the food required for healthy and productive lives.
- Manage human water use to conserve the quantity and quality of freshwater and terrestrial ecosystems that provide services to humans and all living things.

To meet these objectives, the Commission overseeing World Water Vision believes that the following actions are required:

- Manage land and water resources using a basin-level, systematic approach. This will include provision of the appropriate institutional mechanisms, participatory management and full access to information.
- Full-cost pricing of water services for all human uses, including drinking, waste water treatment and irrigation. This must be accompanied by (i) subsidies to low-income communities and individuals so that they have the means to pay for their

minimum water requirements, and (ii) participation of users in water management.
- Substantial increases in publicly funded research, development and dissemination of innovative technological, social and institutional approaches to integrated water resources management for topics not driven by market-driven R&D.
- Restricted sovereignty in the application of integrated water resources management in international surface and groundwater basins.
- An increase in private sector investments in water infrastructure.

The Discussion Process

To facilitate consultations and discussions at the regional and local levels, the project developed three scenarios to be envisioned by the groups. These outline possible futures we may face depending on potential changes in water usage, in the coming years. Thematic panels are also established to discuss issues such as biotechnology, energy technology, information and communication technology, and institutions and the implications these areas have on water resources. For example, the biotechnology panel recently discussed issues such as saline-tolerant plants and the potential for using wastewater for irrigation. Summarised results from these panels can be found on the web page, along with full reports that can be downloaded. Results from the discussions and panels will be presented at the above-mentioned conference in the Netherlands.

Getting Involved

The easiest way to find out more about the World Water Vision project and to express your views on the future of water usage is to visit the project's web page at **http://watervision.org.** This well-organised web page has information regarding the consultative process at the regional and 'sector' levels, additional information on the thematic panels including preliminary results and downloadable reports, a youth involvement page, and a search engine for the site. Visiting the Vision Explorer page allows you to participate in global discussions about the future of water. Unfortunately, when I tried to login, Netscape crashed. Hopefully all of you interested readers out there will have better luck!

Melissa Swartz, Groundwater Section, Geological Survey of Ireland

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Geological Survey of Ireland Web Page

The GSI's web page has recently been moved and overhauled. The new and improved web page can be found at **www.gsi.ie**. Besides general information on the services and publications the GSI provides, links to other earth science and groundwater sites can be found. Please keep in mind the site is still under construction. In addition, if you know of interesting sites than can be added to the links page, please let us know!

Melissa Swartz, Groundwater Section, Geological Survey of Ireland

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Total Petroleum Hydrocarbons : A Short Discussion

Introduction

This article is intended to give a brief introduction to petroleum products and serves to explain some of the most common analytical techniques used to detect and quantify petroleum in water and soil contaminated with these products. Petroleum contamination arises from spills and leaks from overground and underground sources.

Common everyday petroleum products such as petrol and diesel, for example, are derived from crude oil. Crude oil petroleum is separated into its constituents by a process of fractional distillation. The basic principle of this distillation process is that crude oil petroleum is separated into the hydrocarbon fractions which have similar numbers of carbon atoms which relate, in turn, to similar boiling points ranges (see table below). The most common petroleum fractions obtained from crude oil are: Petrol, Kerosene (Paraffin), Diesel, Lube oil, and Asphalt.

Common hydrocarbon fractions with their respective carbon ranges and boiling point ranges are given below. It should be noted that these carbon and boiling point ranges tend to vary slightly in different literature:

Fraction	Carbon Range	Boiling Point °C
Petrol	$C_4 - C_{12}$	35 to 200
Kerosene	$C_{10} - C_{15}$	150 - 300
Diesel	$C_{12} - C_{28}$	270 - 350
Lube Oil	$C_{20} - C_{40}$	350 – 500
Asphalt	C_{40+}	>500

These fractions or petroleum products comprise a complex mixture of hundreds of individual hydrocarbon compounds which are mostly composed of: aliphatic[1]; aromatic[2]; and heterocyclic[3] compounds.

Total Petroleum Hydrocarbons

Total Petroleum Hydrocarbon (**TPH**) is a common parameter which is analysed by the laboratory when water, or soil, is suspected of being contaminated by a petroleum product. It should be noted however that while the TPH analysis is carried out by nearly all laboratories, the actual analytical techniques and definitions used to determine TPH can vary enormously between laboratories. It is crucial to understand the laboratories' method of analysis and definition of Total Petroleum Hydrocarbon when interpreting and comparing TPH data. The differences in analytical methods and even the definition of TPH can make it enormously difficult for regulatory and private organisations to compare and contrast TPH data.

At its simplest, TPH is an estimate of the amount of hydrocarbons present between the carbon range C_4 to C_{40}. (as mentioned, each laboratory will have its own definition). This range of carbon extends from the volatile hydrocarbon compounds with the lower boiling points (see table), to the non-volatile compounds found at the higher boiling point ranges.

There are several common methods of analysis which the laboratory uses to detect TPH in water/soil. Infra Red (IR) and Thin Layer Chromatography (TLC) are two basic techniques mainly used to screen for hydrocarbons and will therefore not be discussed further (as the hydrocarbon content is often significantly overestimated).

One frequently used, sensitive and accurate method of analysing TPH is obtained by using the Gas Chromatography – Flame Ionisation Detector (GC-FID) method. An added benefit of this method is that analysis using GCFID allows the carbon chains to be displayed on a graph known as a chromatogram: this aids in identifying which petroleum product is present and gives information on the degree to which it is weathered (i.e. by volatilisation/evaporation) or biodegraded (i.e. by bacteria).

As mentioned, there is a volatile and a non-volatile component to TPHs. Some laboratories which specialise in analysing organic contaminants will subdivide the TPH analysis into two components and analyse them by GCFID. The two major components in the analysis of Total Petroleum Hydrocarbons (TPH) are known as the Diesel Range Organics analysis (DROs) and the Petrol Range Organics analysis (PROs).

The **Petrol Range Organics (PRO)** analysis by GCFID gives a measurement of the **total volatile** hydrocarbon content typically in the carbon range C_4 to C_{10} which include: aliphatic alkanes[1] and mono-aromatic hydrocarbons[2] (Note: another sensitive and accurate method employed to analyse PRO is Gas Chromatography – Mass Spectroscopy or GCMS). The PRO analysis may identify leaded and unleaded petrol and kerosene.

Other common volatile hydrocarbons included in the Petrol Range Organics analysis are: BTEX (the mono-aromatic hydrocarbons[2]: Benzene, Toluene, Ethylbenzene and Xylene) and MTBE (Methyl Tertiary Butyl Ether, which is an unleaded petrol additive).

The **Diesel Range Organic (DRO)** analysis by GCFID, gives a value for the non-volatile or **extractable** hydrocarbon content (hydrocarbons are extracted from water or soil by using solvents such as methylene chloride). The DRO analysis detects petroleum hydrocarbons typically in the carbon range C_{10} to C_{40} which include: aliphatic[1], aromatic[2] and heterocyclic[3] compounds. This analysis may identify kerosene, diesel and lube oil.

Conclusion

The term Total Petroleum Hydrocarbons has a defined range of carbons which can vary significantly from laboratory to laboratory. There are many methods used to screen and analyse for TPH. Many laboratories subdivide the TPH analysis into two components to take account of the volatile and non-volatile nature of the hydrocarbons. It is crucial that that the analyst is consulted when interpreting and comparing TPH results.

[1] ***aliphatic compounds*** are the hydrocarbons which contain alkanes, alkenes and alkynes.
(**alkanes** have carbons joined by a single bond. Alkanes are also called saturated hydrocarbons or paraffins. They can be straight chained *e.g. methane*, branched *e.g. isoprenoids such as pristane*, or cyclic *e.g. cyclopentane*)
(**alkenes** have carbons joined by a double bond. Alkenes are also known as unsaturated hydrocarbons or olefins, *e.g. ethene*.)
(**alkynes** have carbons joined by a triple bond, e.g. acetylene.)

[2] ***aromatic hydrocarbons*** are closed ring, or cyclic, hydrocarbon structures (e.g. the simplest mono-aromatic is based on the benzene ring).

[3] ***heterocyclic compounds*** are cyclic molecules that contain atoms other than carbon or hydrogen e.g. sulphur, oxygen, sulphur or chlorine.

Anita Furey, K.T. Cullen & Co. Ltd.

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IAH (Irish Group) News

Technical Discussion Meetings: Programme for early 2000

11th January **Permeability Characteristics of Glacial Tills** by Bruce Misstear, Melissa Swartz and Eric Farrell. The venue is the IEI Lecture Theatre, Clyde Road, at 18:30 hrs. ***(This is the annual joint IAH/Geotechnical Society of Ireland Meeting).***

1st February **Fate and Transport of Industrial Contaminants in Naturally Heterogeneous Aquifers** by Georg Teutsch, Professor of Hydrogeology, University of Tubingen, Germany. This is the **David Burdon Memorial Lecture.**

7th March The **Younger Hydrogeologists Forum**

The February and March lectures will take place at the GSI Lecture Theatre. They start at 18:00 hrs, with tea/coffee served at 17:30 hrs. For further information contact either Donal Daly (01-6041490) or Kevin Cullen (01-2941717)

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Annual Portlaoise Seminar

The annual seminar will be held on 11th and 12th of April 2000. The theme is "Groundwater and the Law". Further details will be circulated.

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New Committee

The IAH (Irish Group) held its AGM on 9th November 1999. After three dedicated years, Bruce Misstear stepped down as Secretary. The IAH would like to take this opportunity to thank Bruce again for all his work. Anita Furey agreed to leave her post as Field Trip Secretary and take over the position of Secretary. The position of Field Trip Secretary was then gracefully accepted by Morgan Burke and we wish him every success. The current committee now comprises:

President: Geoff Wright (wrightge@tec.irlgov.ie)
Secretary: Anita Furey (afurey@ktcullen.ie)
Treasurer: Margaret Keegan (m.keegan@epa.ie)
Portlaoise Secretary: Shane Bennet (bennet@iol.ie)
Field Trip Secretary: Morgan Burke (mburke@minerex.iol.ie)

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IAH on the Net

The new International Association of Hydrogeologists web site is now live and can be accessed at http://www.iah.org. It's up to date and very impressive.

Any IAH member who has an Email address but has not received IAH (Irish Group) Email shots to date, please let Anita Furey know (afurey@ktcullen.ie).

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IAH Congress in Cape Town, South Africa, 26th November to 1st December 2000

The next IAH Congress is due to be held in Cape Town, South Africa in 2000. The topic is "Groundwater: Past Achievements and Future Challenges". The congress will take a global perspective on groundwater issues, encompassing the range of current debate and focusing the transfer of understanding in areas where we are worlds apart. For more information contact: Deirdre Cloete (deidre@iafrica.com) Tel: +27 21 886 4496, or visit the web site: fred.csir.co.za/conferences/iah/

Anita Furey, IAH (Irish Group) Secretary

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CONTRIBUTIONS FOR THE NEXT ISSUE OF THE NEWSLETTER

The GSI Groundwater Newsletter aims to improve communication among scientists and engineers involved in groundwater. It includes news, developments, reviews and opinions on all aspects of groundwater - exploration, development, management, water quality, pollution and energy. It is published 2-3 times each year.

Your contribution to the dialogue would be welcome. **Contributions for the next issue should arrive before 1st May 2000** to:

The Editor,
GSI Groundwater Newsletter,
Geological Survey of Ireland,
Beggars Bush,
Haddington Road,
Dublin 4.
