ISSN 0790 - 7753

THE GSI GROUNDWATER NEWSLETTER

NUACHTÁN SCREAMHUISCE SGÉ

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Published by the Geological Survey of Ireland
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Dublin 4.
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No. 42 December 2003

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The degree of **microbial contamination of groundwater** in Ireland is very high, probably higher than in any other country in the EU. In many areas, at least 30% of private domestic and farm wells are polluted; in some highly vulnerable areas more than 50% are polluted, usually intermittently and usually by **faecal bacteria**. It is likely that there are areas in Ireland where more than 70% of private wells contain faecal bacteria at some time during their use. While the faecal bacteria themselves pose a threat to human health, particularly to babies and old people, viruses and ***Cryptospiridium*** may add to the threat. **Arguably, microbial pathogens are the single greatest threat to groundwater in Ireland**. This threat arises from a) the presence of **microbial pathogens in manure, slurry, dirty water and septic tank effluent**, and b) the **geological and hydrogeological situation** in Ireland where, **in a significant proportion of the country,** there is **minimal purification** provided once **effluent enters bedrock** and the **overlying protecting layer of soil and subsoil is shallow,** with the soil often containing **preferential flowpaths**.

The issue of **microbial pathogens** is highlighted in three separate articles by Murty Hanly, Marie Gillooley and Sean Moran (pages 2-12) on the presence of ***Cryprospiridium* in Lough Owel, the water supply for Mullingar**, which caused 26 people to become ill. As the lake is largely groundwater fed and as the vulnerability of the catchment is mostly 'extreme' and 'high', groundwater is considered to be a potentially significant pathway for *Cryptosporidium* to enter the lake. The **pollution incident that occurred at Walkerton**, Canada, when seven people died (see article on page 13), further highlights our need to take account of the threat from microbial pathogens in decision-making.

Other topics covered in this **Newsletter** include: **EPA licensing of contaminated land remediation** by Malcolm Doak (page 14); **acidising of boreholes** by David Ball (page 16); and using **microgravity to map karst features** by Caoimhe Hickey and Richard McGrath (page 22).

Donal Daly

Cryptosporidium in a Public Water Supply: The Westmeath Experience

Introduction

The supply of water for Mullingar town and for the central area of County Westmeath is taken from Lough Owel, a 3000-acre lake north of Mullingar. The lake is primarily spring-fed and has historically been of such high quality that the water required only sterilisation and fluoridation prior to distribution.

On the May Bank Holiday weekend of Friday 3rd May the Midland Health Board notified the Westmeath County Council that a significant number of people in the Lough Owel catchment had been infected with *Cryptosporidium*-based illnesses. The Council were also notified that a sample of water, taken from the Westmeath regional water network from the Lough Owel source, tested positive for the *Cryptosporidium* parasite and were advised that a Boil Water Notice be put in place immediately, for all consumers using this water supply until further notice. This was an unexpected development because the Lough Owel source had consistently met all the criteria under the Drinking Water Directive (E.U. Council Directive 98/83/EC) and had been tested for the indicator organism for *Cryptosporidium* as recently as April 8th 2002.

What is *Cryptosporidium*?

Cryptosporidium has emerged as a significant parasite in humans in recent years and it has become clear that water provides a major route of transmission. *Cryptosporidium* is a protozoan parasite found in humans and many other mammals. It is also found in birds, fish and reptiles. It is discharged in the form of very large numbers of oocysts by animals particularly during the lambing/calving season in March/April and again in the autumn period of September/October. It is resistant to allowable levels of chlorination in drinking water.

Tyzzer initially described *Cryptosporidium* in 1908. It is now generally accepted that there are eight species. *Cryptosporidium parvum* is the only species known to infect both man and livestock. *Cryptosporidium* is prevalent throughout the world; there are 250 - 500 million infections of *Cryptosporidium parvum* annually in Asia, Africa and Latin America. In developed countries, *Cryptosporidium* is one of the most common causes of gastro-enteritis. The commonest symptoms are diarrhoea and stomach cramps. Generally it does not cause serious illness. However, persons with an impaired immune system, young children and older persons are more susceptible to infection.

In England/Wales it accounts for 2.1% of cases compared to Salmonella (3.3%) and *Campylobacter* (7.6%). In Ireland 4% of admissions for gastroenteritis in under 14 year olds was due to *Cryptosporidium*. In fact it is the second most common cause after *E. coli*. It is usually transferred via the oral faecal route as a result of contact with infected animals. Studies indicate that over 50% of surface waters and 37% of drinking waters in the UK are contaminated.

Implementing the Boil Water Notice

The immediate task facing the County Council was to establish a means of communicating the contents of the Boil Water Notice to the 25,000 customers, (comprising approximately 11,000 homes and business premises) who would be affected by it. A large number of the customers affected were based in rural areas within a 20-mile radius of Mullingar town.

It was the stated policy of Westmeath County Council from the outset to provide the public with the most complete and up to date information at all times. This was achieved as follows:

- Local County Councillors were notified and provided with details.

- Local radio stations were requested to broadcast the existence of a Boil Water Notice every hour on the hour for customers served by the Lough Owel Water Supply and also to read out the areas affected. This broadcast was in place at 4.00p.m on the 3rd May.
- There was a free-phone number for information on the Boil Water Notice for the public and this was on air at 5.30 p.m. on the 3rd May.
- National radio and TV stations were notified and a news item was broadcast on the evening news both on radio and TV stations on the 3rd May.
- National newspapers and local newspapers were contacted and all national newspapers circulating in the area published an article on the outbreak of *Cryptosporidium* affecting customers using Lough Owel Water Supply in Mullingar town and its environs on their editions of Saturday 4th May.
- The Westmeath County Council website was immediately updated informing the customers of the Boil Water Notice and why the Boil Water Notice was in place. This web site is continuously updated, giving the public information on the results of the daily tests being carried out on the water and what actions are being put in place to deal with the outbreak of *Cryptosporidium*.
- The local Chamber of Commerce was informed and they in turn e-mailed all their members.
- The Midland Health Board notified all general practitioners, dentists, pharmacies and food premises including hospitals, nursing homes and preschool facilities in the catchment area.
- Westmeath County Council notified the local abattoirs and cutting plants.
- Notices were hand delivered to public houses, churches and schools.
- 11,000 leaflets were prepared and posted out to customers informing them of the Boil Water Notice and what precautions to be taken.
- A special meeting of the County Council was held on the 10th of May, which was attended by the Health Board representatives to inform the councillors, the Public and the Press of the current situation and to update them on actions taken to date.

Monitoring the Outbreak

A strategic working group representative of the Midland Health Board and Westmeath County Council was set-up to monitor the outbreak, to monitor the proposals to eliminate the cause and the plans to prevent a future occurrence and to keep the public informed of the progress being made.

The Health Board reported on the Epidemiological Investigation and monitored the age profile and conditions of patients presenting with symptoms. Twenty-six cases (50% male, 50% female) were diagnosed in the catchment area of the lake. The ages of cases ranged from 11 months to 38 years, with 75% of them under five years old.

The Environmental Section of the County Council carried out a risk assessment and identified possible sources of pollution and issued Section 12 Notices under the Water Pollution Act of 1977 where appropriate. Discussions were initiated with the farming community with a view to having the catchment area of the lake managed as a drinking water reservoir.

The Health Board and the County Council combined resources to have a large number of samples taken on daily basis tested. The results of all of these tests were posted on the Council's website immediately on receipt as part of the public information campaign.

The County Council Sanitary Services Section reported on progress in negotiations with the Department of Environment and Local Government for the provision of:

(a) A temporary filtration system and

(b) A permanent filtration system

The Department gave approval for the immediate planning of the permanent filtration system, which had been scheduled to start in 2004. A consultant was appointed to fast track the procurement of the temporary filtration system as an emergency measure.

Throughout the outbreak the council had an in-house expert group meeting regularly to update the public information and advise senior management on all matters arising in relation to the outbreak.

Lifting the Boil Water Notice

Based on an analysis of the Epidemiological and Environmental Investigations together with the test results being obtained from the water-monitoring regime it was decided to lift the Boil Water Notice on Thursday June 21st except for babies and those who are immuno-compromised. This was done on the understanding that:

(a) 24 hour monitoring of the source would be put in place and continue until the temporary treatment was operational.

(b) Enhanced surveillance of clinical infections by general practitioners.

(c) It could be re-implemented quickly in the event of cases or test results warranting it.

(d) Temporary treatment would be put in place as quickly as possible.

(e) Cleaning and flushing of reservoirs and the network would proceed to an agreed programme.

(f) Continuing risk assessment and management of the catchment area.

The same arrangements were put in place to inform the public of the lifting of the notice as had been put in place to inform them of its imposition.

Conclusions

1. The fact that this was the first outbreak of *Cryptospiridosis* in a public water supply in the Republic of Ireland in a hitherto pristine water source highlights the need to protect and manage all our public water sources as a primary food source at the cost of all other competing uses for the water where necessary.
2. Unfiltered water sources no matter how good their historical record may have been must be considered vulnerable to such outbreaks.
3. Public co-operation is essential during an outbreak such as the recent one at Lough Owel. This is more likely if they have confidence in the information being made available to them.
4. Co-operation and a mutually respectful working relationship between the Health Board and Local Authority staff on the strategic working group was extremely beneficial in reaching conclusions during the outbreak.
5. Although the outbreak has passed there will be a need to continuously monitor the source until it is filtered especially coming up to the next peak in outbreaks in September/October.

Acknowledgements

This article was originally published in Local Authority News. It was written in consultation with other Westmeath County Council staff.

Westmeath County Council gratefully acknowledges the assistance and support it received from the Department of Environment and Local Government, the Midland Health Board, Dublin City Council and Belfast City Council.

Murty Hanly, Westmeath County Council

Outbreak of *Cryptosporidium* in a Public Water Supply in County Westmeath

Introduction

In April 2002, the first outbreak of *Cryptosporidium* associated with a public water supply in the Republic of Ireland occurred in Co. Westmeath. The supply of public drinking water for Mullingar town and the central area of Co. Westmeath is taken from Lough Owel, a 3,000-acre lake, north of Mullingar. The lake is described as a single basin and is situated in the middle of Carboniferous limestone deposits. It is primarily spring-fed though karst fissures in the underlying limestone.

There are approximately 89 farms in the catchment area of the lake and the primary use of land in the catchment area is grassland farming. This is a high amenity area and the residential dwellings surrounding the lake are primarily served by septic tank systems. The water treatment system consisted of basic gross solid removal and disinfection. It did not include filtration.

The first case of *Cryptosporidium*, which was linked to the outbreak, was admitted to the Midland Regional Hospital, Mullingar on 23/04/02 and was found to be positive for *Cryptosporidium* infection on faecal sampling. On Friday, 3rd May – the Friday of the May Bank Holiday weekend – the first outbreak control team meeting was held in the Midland Health Board in relation to this outbreak. It was decided to recommend that Westmeath County Council issue a Boil Water Notice in respect of this water supply for the following reasons:

1. **Epidemiological Evidence**
   There were 8 cases of *Cryptosporidium* confirmed since the 1st April, residing in the water distribution network.

2. **Water Treatment**
   As this was an unfiltered supply there was no mechanism in place to remove *Cryptosporidium* from the water supply.

3. **Nature of Source**
   The water supply is a vulnerable to contamination with *Cryptosporidium* – it has a 13-mile shoreline surrounded by farms and domestic dwellings with single site sewerage treatments systems.

   This coupled with the lack of a filtration system meant the lake was a potential source of infection.

4. **The Population**
   The water supply services 25,000 people including 4 hospitals, 4 nursing homes, 331 food premises and 39 pre-school facilities and schools.

At the initial meeting of officials from the Midland Health Board and Westmeath County Council an Incident Management Team was established. A 3-pronged action plan was agreed as follows:

1. Epidemiology
2. Water Monitoring
3. Risk Assessment

At this and at all subsequent meetings the agenda covered these 3 main areas.

Implementing the Boil Water Notice

The immediate task facing the County Council and the Health Board was to establish a means of communicating the contents of the Boil Water Notice to the 25,000 customers - comprising of approximately 11,000 homes and business premises - which would be affected by it. A large number of the customers affected were based in rural areas within a 20-mile radius of Mullingar town.

Action taken by the Midland Health Board

It was considered of the utmost urgency to inform the following groups – the food industry, general practitioners, pharmacists, dentists, school principals and hospital consultants about the contents of the Boil Water Notice. Information leaflets were drafted in respect of all food premises – 4 hospitals, 4 nursing homes, 331 food premises and 39 pre-schools, and each individual premises was visited by an EHO on Friday 3rd May, to ensure the Boil Water Notice reached these premises rapidly and to address any individual queries that proprietors might have. A memo was prepared for all general practitioners, pharmacists, dentists and school principals who were operating in the area. In addition phone contact was made with all GP practices, dentists and pharmacists informing them of the situation and giving advice regarding use of the water in their practices. Memos were sent to all hospital consultants in the Midland Regional Hospitals at Mullingar, Tullamore and Portlaoise and the Senior Infection Control Sister for the hospitals was briefed on the situation. The Senior Laboratory technologist in the Midland Regional Hospital at Mullingar was contacted to inform him of the situation and the need for enhanced surveillance. The Microbiology Laboratory in the Midlands Regional Hospital at Tullamore was contacted and asked to report any cases of *Cryptosporidium* to the Department of Public Health immediately.

Action taken by Westmeath County Council
It was the stated policy of Westmeath County Council from the outset to provide the public with the most complete and up-to-date information at all times. As the Boil Water Notice came in to being during the run up to the election, local County Councillors were notified and provided with details. Local radio stations were requested to broadcast the existence of a Boil Water Notice every hour on the hour, for customers served by the Lough Owel water supply and also to read out the areas affected. This broadcast was in place at 4pm on the 3rd May.
A free-phone number for information on the Boil Water Notice for the public was also made available. National radio and T.V. stations were notified and a news item was broadcast on the evening news, both on radio and T.V. stations on the 3rd May. National newspapers and the local newspapers were contacted and all national newspapers circulating in the area published an article on the outbreak. The Westmeath County Council website was immediately updated, informing customers of the Boil Water Notice and why the notice was in place. This website was continuously updated giving the public information on the results of the daily tests being carried out on the water and what actions were being put in place to deal with the outbreak. The local Chamber of Commerce was informed and they in turn e-mailed all their members. The council also notified local abattoirs and cutting plants. Notices were hand delivered to public houses, churches and schools. 11,000 leaflets were prepared and posted out to customers.

Monitoring the outbreak
As earlier indicated an Incident Management team was established on the 3rd May 2002 – it comprised of the Principal EHO, the Senior EHO, the Specialist in Public Health and various representatives of the local authority including two Directors of Services. The team met on a weekly basis. The Specialist in Public Health reported on the epidemiological investigation. 26 cases, 50% male and 50% female were diagnosed on the catchment area of the lake. The age ranged from 11 months to 38 years old, with 75% of them under 5 years old.

The Environmental Health Department and officials from Sanitary Services, Westmeath County Council undertook daily monitoring of the water source in order to establish a profile of Lough Owel. Once this profile of the source was established, concentrated water samples were taken throughout the supply at representative sites in order to establish a profile of the entire network. Samples were also taken to test for *Clostridium perfringens*, an indicator organism, for *Cryptosporidium*. Results were assessed at each weekly incident management meeting and a weekly programme for water sampling was drawn up in line with recommendations from the Health Board, laboratory capacities and discussions between the Health Board and County Councils staff. Two types of water samples were taken for analysis – grab samples and concentrated samples. The results of all tests taken were posted on the council's website immediately on receipt.

The Environmental Section of the County Council carried out a risk assessment and identified possible sources of pollution around the lake, and issued Section 12 notices under the Water Pollution Act of 1977 where appropriate. Discussions were initiated with the farming community with a view to having the catchment area of the lake managed as a drinking water reservoir. The Environmental Health Department contacted the Meteorological Office for rainfall statistics and levels for the period from the 18/03/02 to 30/04/02. Looking at the information provided by the Council on possible sources of contamination and at the rainfall statistics, it was concluded that heavy rainfall might have facilitated the ingress of oocysts into the water supply.

The County Council's Sanitary Services Section reported on the progress of negotiations with the Department of the Environment and Local Government for the provision of a temporary filtration system and a permanent filtration system. The Department gave approval for the immediate planning of the permanent filtration system, which had been scheduled to start in 2004. A consultant was appointed to fast track the procurement of the temporary filtration system as an emergency measure. Two swimming pools are located within the catchment area and both voluntarily closed down once the Boil Water

Notice was issued. Subsequently however queries arose in relation to the reopening with regard to public health. Letters were sent to both, addressing the following 3 management areas:

1. Operational Control and Management;
2. Swimmer hygiene practices;
3. Education.

The "Environmental Health standards for Swimming Pools, Spa Pools, Hydrotherapy Pools and Other Multi-user Pools" was an invaluable reference source in relation to the reopening of both pools.

Rescinding the Boil Water Notice

Usually *Cryptosporidium* outbreaks linked to a water supply are due to a treatment deficiency, which can be rectified. However in this situation Lough Owel was an unfiltered water supply. Therefore criteria had to be developed to remove the Boil Water Notice in the absence of a filtration system.

Ms Marie Gillooly, Principal EHO, Ms Mari Greene, Senior EHO and Dr Phil Jennings Specialist in Public Health Medicine established the following criteria to rescind the Boil Water Notice in this particular outbreak situation. This decision was based on epidemiological evidence and environmental evidence including water monitoring and continued risk assessment.

1. Epidemiological Evidence

From an epidemiological perspective it was important that sufficient time had elapsed which would allow the Board to say with confidence that any new cases arising would be linked with starting to drink water again and not to the period before the issuing of the Boil Water Notice. This took into account factors such as potential delay in becoming aware of the Boil Water Notice, the incubation period of the illness, the duration of the illness, the length of time required for the faecal sample to be examined and the result conveyed to the Department of Public Health. Taken all of the above into account it was felt that a minimum of a 5-week period was required for the Boil Water Notice to be in place.

2. Environmental Evidence

(a) Source Water Quality

It was decided that a minimum of 7 clear concentrated samples taken at the intake of the public supply on Lough Owel, on 7 consecutive days should be obtained prior to removing the Boil Water Notice. Between the 10/06/02 and 17/06/02, 8 clear consecutive samples were obtained.

(b) Treated/Network Water Quality

It was decided to establish a baseline profile in respect of the distribution network in addition to the source. From the 05/06/02 to 20/06/02, concentrated samples were taken from numerous sites on the distribution network. In addition samples were taken and tested for *Clostridium perfringens*, which is an indicator organism for *Cryptosporidium* on the network. The results show that for the 2 weeks prior to the rescinding of the Boil Water notice, samples for *Cryptosporidium* were clear and in relation to sulphite reducing *Clostridium*, the samples were satisfactory.

(c) Continuing Water Monitoring

It was decided that Westmeath County Council should install a system for sampling continuously for *Cryptosporidium* over a 24-hour period[1] at the source, Lough Owel. However, until this system was installed at the source, it continued to be monitored daily by means of concentrated sampling. Concentrated samples were taken on the network by Westmeath County Council at various representative sites in addition to the samples that were taken following the implementation of the program for cleaning/flushing of water mains and reservoirs (see later). Samples for *Clostridium perfringens* were taken for 2 days per week for a period of 1 month at 4 representative sites on the network by the Environmental Health Department. The above sampling program was subject to ongoing review taking note of peak risk periods for *Cryptosporidium*, e.g. Autumn, and on the epidemiological evidence once the boil water notice was rescinded.

(d) Program for cleaning/flushing of water mains and reservoirs

A 16- week time period was involved in the total cleaning and flushing of the entire system. It was not reasonable, in light of all the other surrounding evidence, to leave the Boil Water Notice in place for an additional

[1] In the U.K. the Water Supply (Water Quality) Amendment Regulations 1999 S.I. 1527 set the legal limit of 1 oocyst per 10 litres when water was sampled over a 24 hr period. However this level was set as an operation standard and was not derived from known public health grounds.

16 weeks to complete this cleaning and flushing program. In light of the following factors it was decided that the program could be implemented after the Boil Water Notice had been lifted.

- The result of the water samples on the network for the previous 2 weeks were clear, hence, there was clean water flushing through the system for a minimum of 2 weeks.
- A specialist company was employed to complete the work of cleaning and flushing. In addition, the actual cleaning process would not allow accidental contamination of the supply.
- Sludge was disposed of in a satisfactory manner to designated sites where subsequent contamination of water courses was avoided.
- The County Council agreed to monitor and sample the water once works were completed on the network to ensure that the water leaving the particular reservoir was satisfactory.

3. Risk Assessment

An ongoing risk assessment plan was drawn up and implemented by Westmeath County Council.

4. The Process of Rescinding the Boil Water Notice

a) The Public

A letter was drawn up and approved by the Midland Health Board and Westmeath County Council in respect of lifting the Boil Water notice and containing advice to be given to the public.

b) Food premises, health care professionals and schools

Letters were drawn up and sent to the proprietors of all food premises, including hospitals, nursing homes, pre-school facilities and schools. Letters regarding the rescinding of the Boil Water Notice were also sent to GP's, consultants, dentists, pharmacists and schools. Infection Control Nurse in the hospital was contacted to advise her of the rescinding of the Boil Water Notice. A letter notifying the public that the Boil Water Notice was being rescinded was also sent to the Press.

5. Action plan for the reissue of a Boil Water Notice

Westmeath County Council drafted an action plan for the reissue of a Boil Water notice should the situation warrant it once the Boil Water Notice had been rescinded.

Conclusions

1. There was a sharp fall off of cases of *Cryptosporidium* after the Boil Water Notice was issued once the incubation period for *Cryptosporidium* had passed. There was only one confirmed case with the date of onset that lies outside the incubation period after the Boil Water Notice was issued. Therefore it is felt that issuing the Boil Water Notice was effective in curtailing the outbreak and reducing subsequent cases.
2. The prompt testing of the water supply by the Environmental Health Department was important in the overall management of this outbreak. The water was tested in this instance, as the EHO's knew that Lough Owel was an unfiltered water supply and therefore could be contaminated with *Cryptosporidium*.
3. Westmeath County Council identified two possible sources of contamination of the water supply with *Cryptosporidium*. Heavy rainfall may have facilitated ingress of the oocysts from the land to the water supply.
4. It is generally recommended that criteria should be in place for the rescinding of a Boil Water Notice before the issuing of same. However in this instance it was considered to be of the utmost importance to issue the notice in order to protect public health even though the criteria for rescinding the notice was not in place. The value of an annual monitoring program for an indicator organism, i.e., *Clostridium perfringens* in a water system that has no filtration unit must be questioned. Random spot sampling is unlikely to be effective for operational monitoring.
5. This outbreak highlights the need for a comprehensive surveillance and notification system of infectious diseases to facilitate early detection of an outbreak. This process was instrumental in the early detection of this outbreak of *Cryptosporidium*.
6. The Environmental Health Officers knowledge of the water system was crucial in the initial stages of the outbreak.

7. This is the first reported outbreak in the Republic of Ireland of Cryptospoiridiosis associated with a public water supply. Routine water monitoring does not include testing for *Cryptosporidium* or for the indicator organism, *Clostridium perfringens*.

Recommendations

1. *Cryptosporidium* should be included in the list of notable diseases.
2. Laboratory policy on the testing of stool specimens for *Cryptosporidium* should be standardised.
3. Water should be tested for *Cryptosporidium* where two or more cases of *Cryptosporidium* have been confirmed which are linked to the same water supply and where no other risk factors have been identified. Concentrated filtered water samples should be taken.
4. The County Council should systematically assess the potential risk of groundwater contamination by *Cryptosporidium*, particularly in unfiltered water supplies by application of a tripartite approach, which assesses source, catchment and hydrogeological factors.
5. In relation to a final treatment plant being installed at the Lough Owel site, monitoring should include the continuous turbidity measurement at the outlet of each filter on the final water using instruments capable of detecting changes of less than 0.1 NTU.
6. Westmeath County Council have implemented a 24-hour continuous monitoring system for *Cryptosporidium* at the source of the public water supply in Lough Owel until a suitable treatment plant has been put in place (i.e. a filtration unit).
7. In the event of an outbreak of Cryptosporidium occurring linked to a water supply it is important to issue a *Boil Water Notice* as soon as possible. The *Boil Water Notice* should not be deferred pending the development of criteria for its removal.
8. As each outbreak situation is different it would be extremely difficult to set criteria at national level for the implementation or rescinding of a boil water notice.
9. A good working relationship between the Health Board and the County Council, particularly the Environmental Health Department and the Sanitary Services section of the County Council is essential in an outbreak scenario. Links should be established before an outbreak occurs.
10. The value of using epidemiological evidence even in the absence of microbiological evidence, in identifying and managing an outbreak should be highlighted for all personnel involved.
11. Boil water notices should be clear in their instructions. They should indicate that water need only be brought to the boil as in an electric kettle and that water should be allowed to cool before use. A section on the prevention of accidental scalds should also be included.
12. When rescinding a boil water notice, it should be advised that immuno-comprised persons may need to boil all water from any source and allow it to cool before use.
13. Communication with the media is essential in every outbreak situation. It is recommended that a designated communications officer perform this task.
14. It is recommended that a system be prepared for the rapid dissemination of information to the public, as this can be a limiting factor in an outbreak situation.

Acknowledgements

This article was first presented at the 2003 Environmental Health Annual Conference in Portlaoise.

The authors wish to acknowledge the individual roles of the SEHOs and the EHOs in this outbreak – without their professionalism and commitment, this outbreak would not have been managed in such an effective and efficient manner. The Environmental Health Department gratefully acknowledges the assistance and support it received from:

- the Public Health Department, in particular Dr Phil Jennings, Specialist in Public Health Medicine.
- Westmeath County Council and all officials involved in this outbreak.
- Ms Rachel Chalmers, Head PHLS, Cryptosporidium Reference Unit, Swansea Public Health Laboratory.
- Professor Paul Hunter, Professor of Health Protection, School of Medicine, Health Policy and Practice, University of East Anglia.
- Miriam O'Byrne, City Analyst, Ringsend, Dublin.
- Dr. Brian Smyth, Regional Epidemiologist, CDSC, Belfast.
- Mary Keane, Principal EHO, ERHA.

Further information, copies of leaflets etc, etc, are available from the Environmental Health Department, Longford/Westmeath Community Care Area, Midland Health Board.

Marie Gillooly and Mari Green, Midland Health Board

The Outbreak of *Cryptosporidosis* in Westmeath – The Hydrogeological Background

Introduction

An outbreak of *Cryptosporidiosis* occurred in Westmeath in April 2002. The investigation of the outbreak identified that a significant number of the cases were located in areas served by the Lough Owel potable water supply. Testing of the supply system identified the presence of *Cryptosporidium* and established the intermittent presence of *Cryptosporidium* in the lake.

Westmeath County Council (the Council) carried out investigations to establish the source(s) of the *Cryptosporidium* in the lake, which identified groundwater discharge as a potential point of origin. O'Callaghan Moran & Associates were appointed by the Council to assess the significance of the groundwater pathway for the entry of *Cryptosporidium* in to the lake.

The Lough Owel catchment encompasses an area of approximately 24.5 km^2. The catchment is reasonably well defined by the topography to the east, south and west, with ridge-lines and crests establishing clear surface water sheds between the lake and the adjoining catchments and sub catchments of the River Inny, Lough Derravaragh and Lough Lene. The ground rises from an Ordnance Datum (OD) level of approximately 90 m at the lake shore line to a highest point of 171 m OD at Frewin Hill to the west of the lake. The lake itself is relatively deep, with the deepest point being approximately 21 m below the surface.

The local surface water drainage network is poor, and the only significant water feature in the catchment is Ballynafid Lake, which is located in a shallow depression to the northeast and drains into the lake. There is an area of bogland (Scargh Bog) to the east of the lake and another area to the south. The only area where there is any significant drainage system is to the south west of the lake.

The potential sources of *Cryptosporidium* within the catchment are farmyards, slurry/dung storage areas, grazing lands, landbanks used for spreading of animal slurries and wastewater treatment systems for domestic residences (septic tanks). The agricultural land use in the catchment is grassland dominated and is primarily used for grazing and silage production, with a small amount of tillage.

The Council carried out inspections of farm holdings in the area surrounding the lake, which identified 38 farm holdings located either within or in close proximity to the catchment boundary. The inspections included the collection of data on herd type and size, slurry storage capacity and an assessment of available landspreading capacity. While overall there is a slight surplus of landspreading capacity in the catchment, there are a number of individual farms where there is a significant deficit.

There is no municipal sewer system or large-scale wastewater treatment system in the catchment and all of the dwellings are provided with individual wastewater treatment systems, mainly septic tank systems. The Council carried out a survey of the domestic dwellings to establish the effectiveness of the wastewater treatment systems. The survey identified problems with a number of the treatment systems, primarily related to inadequate percolation areas.

Geology/Hydrogeology

Rocks from the Lucan Formation and the Derravaragh Cherts underlie the lake. The Lucan Formation, which underlies the northern, western, southern and a portion of the eastern area of the catchment, comprises Lower Carboniferous dark limestones and shales, also known as Calp. The Calp typically consists of dark grey, fine grained, graded limestone with interbedded black, poorly fossiliferous shales. The Derravaragh Cherts, underlie part of the eastern side of the lake and extend further east outside the catchment. This formation comprises cherty limestone and minor shales. Along the western side of the catchment the Calp limestone dips gently toward the lake. The overlying Derravaragh Cherts, dip to the northwest. The geological maps do not indicate the presence of significant faulting within the catchment.

The majority of the catchment is covered by glacial tills, which appear to be predominantly silty tills, with increasing clay content to the south of the lake. The subsoils vary in permeability (gravels, tills, peat, alluvium). Groundwater flow probably occurs through the more permeable sand and gravel dominated portions of the subsoil. The glacial tills, which probably account for 85% of the subsoils in the catchment, are likely to be significantly less permeable than the gravel.

During periods of heavy rainfall it is expected that some of the rainfall will run-off either as overland flow or shallow groundwater flow to drainage ditches and to the lake in these zones, particularly where the land is more steeply sloping in the western portion of the catchment. In these areas the potential for contaminated run-off entering the lake is high.

The Soils Map of Westmeath prepared by An Foras Talúntas, indicates that the topsoils in the catchment primarily to the west comprise shale, limestone and chert till. The soil is moderately well drained and has high silt content, a weak structure and, high water-holding capacity. It is liable to poaching and compaction and has a limited use range.

The soils description suggests that run-off may occur particularly in the winter period. However, drainage density is not particularly high in the catchment, which indicates that infiltration rates for rainfall are not significantly reduced as a result of poor drainage. Exceptions to this do occur as observed during field surveys in the western portion of the catchment, where localised areas of marshy ground with poor drainage were noted.

The south-western end of the catchment is underlain by gravels (approximately 1.2 km^2) derived from Carboniferous Limestone. The gravels appear to extend into the lake itself. To the east of the gravels, the subsoils comprise peat, which may overly the gravels closer to the lake. In the eastern portion of the catchment, there is a series of esker ridges comprising sands and gravels that trend northwest toward the lake. There are minor deposits of alluvium to the south and south east of the lake.

Information on depth to bedrock is derived from information provided from the Quaternary Section of the GSI and field inspection. Rock is within one (1) metre of the ground surface on the higher ground along the catchment boundary to the northeast and west of the lake, with outcrops close to the eastern shore of the lake. The southern end of this outcrop sequence appears to be exposed along the Esker ridge nearest the lake.

Based on the current understanding of the hydrogeology of the area, the GSI has provisionally categorised the Lucan Formation as being Moderately Productive only in Local Zones **(Ll)**. The GSI has not yet categorized the Derravaragh Cherts. There is the potential for enhanced permeability zones within this formation based on evidence of swallow holes and karst features in the adjacent catchment to the east. Although further field investigations are required to establish the aquifer classification, OCM assigned it a provisional category of Generally Moderately Productive (**Lm**).

Although there is no information on either the thickness of the gravel deposits to the south west of and abutting the lake, it was considered, based on the areal extent (1.01 km^2) that they could potentially constitute an aquifer (Ballard Gravels). OCM has assigned a provisional aquifer category of Locally Important (**Lg**) status to this aquifer.

Other subsoil units, namely the peat and glacial tills, are not considered to be significantly water bearing and are not categorized as aquifers. The tills are generally silty and are likely to be poorly permeable. The peat is also considered, based on information from peat deposits elsewhere, to be poorly permeable.

While there are some wells and springs shown on the OS maps and noted on the ground, it appears that the majority of the domestic water supplies in the area are obtained from the lake. However, based on the available information, groundwater is a significant contributing source of water inflow to the lake providing more than 20% of the overall water inputs to the lake.

Recent research suggests that bypass flow or preferentially flow along more permeable pathways occurs through soils to the groundwater system. In the Lough Owel catchment it is reasonable to assume that by-pass flow has the potential to occur in extremely vulnerable areas where the soil and subsoil cover is less than 1 m thick.

The likelihood of groundwater forming a pathway for the entry of *Cryptosporidium* to the lake is determined by the interaction of survival rates and the groundwater travel time.

The Lucan Formation is provisionally categorized as being highly to extremely vulnerable. Extremely vulnerable areas are located in the higher ground toward the top of the catchment to the west in Frewin Hill, where glacial tills, which provide some protection to the bedrock aquifer, overlie the formation.

Based on the findings of investigations in the Calp limestone formations elsewhere, groundwater flow paths in the Lucan Formation are considered to be relatively short ranging between tens to at most hundreds of metres and transmissivities are likely to be low. However, in the top 1 - 2 m of the bedrock where the bedrock is likely to be weathered and fractured the permeability is likely to be much higher than below this level. In this weathered zone groundwater movement particularly in steeply sloping areas is expected to be quite rapid possibly in the range of 10 to 100 m per day. At lower levels in the bedrock groundwater movement is likely to be much slower possibly 10 - 100 m per year.

Where the infiltration rates in the topsoils are high, it is considered that the top weathered zone of the Lucan Formation is a potentially significant pathway for *Cryptosporidium* to enter the lake. Where infiltration rates are low (poorly drained areas) it is considered, on the basis of the subsoil type, flow paths and transmissivities that the aquifer is not a potentially significant pathway for *Cryptosporidium* to enter the lake.

The Deravarragh Chert Formation is provisionally categorized as extremely vulnerable over approximately 19% of the catchment. In the extremely vulnerable areas and if there are more permeable zones present in the bedrock, say karst features, then there is the potential for groundwater flow paths to extend into the lake.
The residence time of the groundwater in the Derravaragh Cherts could range from weeks to years. If more permeable zones (karst features) are present, then flow paths could extend across the formation into the lake and travel time in the aquifer could be rapid. If such conditions exist then the aquifer could be a significant pathway for *Cryptosporidium* to enter the lake. However, where the permeability of the formation has not been enhanced, flow paths are likely to be short and travel times are more likely to be months or years, which may reduce the significance of the groundwater body as a contaminant pathway.

The presence of springs in the bottom of the lake has been reported. The origin of the groundwater discharging from the springs is unknown, but may emanate from either of the bedrock formations.

The gravels are considered to be extremely vulnerable to contamination. Groundwater flow paths in the gravels are likely to be in the range from tens to hundreds of metres and transmissivities are likely to be much higher than in the bedrock aquifers. However, because the gravels are located close to the lake on relatively low lying ground, the hydraulic gradient is much less than higher in the catchment and groundwater flow rates are likely to be much lower close to the lake. The gravels may be a potentially pathway particular where the vulnerability is extreme and there is a significant hydraulic gradient.

The existing study was based on walk over surveys and limited desk study information. More field work is proposed to obtain a more comprehensive understanding of the hydrogeological characteristics of the catchment and the potential for groundwater to act as the pathway for the entry of *Cryptosporidium* into the lake.

Sean Moran, O'Callaghan Moran & Associates

The Walkerton Pollution Incident (2000) – A Summary

- ♦ Walkerton is a small town (population <5,000) in Ontario, Canada, which uses groundwater as a source of water supply.
- ♦ In May 2000, many residents started to fall sick. By July 26th, seven people had died and 2,300 were seriously ill (some needing kidney transplants).
- ♦ Water testing showed faecal bacteria in the water, and *E. coli* 0157:H7 and *Campylobacter jejunii* were determined to be the primary cause of disease.
- ♦ The chlorination plant was not functioning properly.
- ♦ DNA typing techniques showed that farm manure from a cattle farm was the main *E. coli* source.
- ♦ In late April, cattle manure was spread on land to within 80 m of the water supply well that is mainly implicated with the problem. It was applied at a rate of 12 tons per hectare. Fresh manure can contain between 10^6 and 10^9 faecal coliforms per gram dry weight. The farm was following "best management practices".
- ♦ Heavy rainfall occurred between May 1st and May 12th – a cumulative total of 138 mm.
- ♦ The geology consists mainly of till (a 'stony, sandy silt to silt till'), with some sand/gravel overlying limestones. The soil and subsoil varies in depth from 2.4 to > 10 m (it is 2.4 m deep in the vicinity of the main implicated well.)
- ♦ The limestone is karstified, with tracer derived rapid groundwater flow rates – up to hundreds of metres per day (similar to the karst limestones in the west of Ireland).
- ♦ The precise route for movement of the microbial pathogens has not been proven. However, hydrogeologists who have studied the situation believe that preferential flow has enabled the pathogens to bypass the protection provided by the subsoil. According to one of the hydrogeologists giving evidence at an Enquiry, some of the water would be travelling slowly through pores in the subsoil, taking in the order of a year to reach bedrock, whereas some flow would be in days or less through preferential flowpaths. Other authors (Worthington, Smart and Rutland) undertook tracer experiments, in a similar hydrogeological setting in Ontario, to measure downward travel times through about two metres of sandy till above a cave. They found that the dye took less than an hour for breakthrough, thus confirming the potential role of bypass flow.
- ♦ Once the pathogens get through the soil and subsoil, they can be transmitted rapidly through the karstic limestone to the wells

***Sources**: Reports and papers by Stephen Worthington, Chris Smart and Wilf Rutland, and a Powerpoint presentation by Ken Howard.*

Implications for Ireland

1. The hydrogeological setting in many areas in Ireland is very similar to that at Walkerton – relatively shallow subsoil over karst limestone. Bypass flow through preferential flowpaths is likely to be occurring in many of our soils (for further information on this, see article 'Bypass Flow – Is it Relevant to Ireland?' in Issue No. 41 of the GSI Groundwater Newsletter), although probably not to the same degree as in Ontario. Just as in Ontario, rainfall intensities sufficient to generate bypass flow occur in Ireland. The hazards are similar – grazing animals and slurry spreading.

2. While landspreading of manure, slurry and dirty water may pose a threat to the aquatic environment in certain circumstances in Ireland, particularly if a sensitive or vulnerable receptor is nearby, the main concern, in my view, is to human health.

3. Should we be considering ways of minimising the loading of microbial pathogens in manure and slurry as a means of reducing the risk in areas of shallow subsoils ('extemely' vulnerable areas) overlying karstic bedrock? Would longer storage times be effective?

Donal Daly, Geological Survey of Ireland

EPA Licensing of Contaminated Land Remediation

Introduction
Since the mid 1990s the cleanup of contaminated sites, typically the small-scale petrol stations and miscellaneous industrial/storage yards, have generally been undertaken as part of 'brown-field' re-development, environmental due-diligence requirements, and EPA licensing requirements at IPC industrial sites. Remediation carried out under the Waste Management Act started in 1999, following the publication of new waste regulations.

Management Approach
In common with many other EU countries the Agency approach to managing contaminated land is risk-based and has licensed remediation projects using the *suitable for use* approach. Remediation projects addressed by the Agency are founded on the concept of the *source-pathway-receptor (SPR)* relationship. Arising out of this, remediation can be done by removing or treating the contaminant, blocking the pathway, or protecting the receptor. The order of presentation of these remedial interventions is deliberate as it represents the Agency's preferred hierarchical approach to contaminated land management (*i.e.* BAT). It is also important to recognise that the agreed remedial intervention is arrived at from the risk assessment based on a particular future use of the effected and adjacent land, as well as having regard to what is ultimately practicably achievable. Land use change, and owners of the remediated land have a responsibility to periodically re-evaluate risk, based on, *inter alia*, state of current knowledge, changes in law, changes in land use, monitoring results, *etc*. However, adopting conservative variables for the risk assessment may mitigate the amount of post intervention residual concern or liability. In the absence of a definitive legal framework for contaminated land management (water protection excepted), professionally undertaken interventions established on the *trinity* of SPR Analysis - Risk Assessment and Suitability for Use - and set against a preferred approach of 'remove/clean > block > protect', would be currently seen as representing best practice.

EPA Licensing
Recently there were two licensing regimes at the EPA – IPC and Waste Licensing[1]. The EPA has issued four waste licences for brown-field remediation to date (Nov. 2003). A waste licence[2] (issued by the EPA) is required for the on site treatment of soil or groundwater contaminated with hazardous concentrations of toxic parameters or when the removal of hazardous contaminated soils from a site necessitates some linked process such as soil blending or mixing or groundwater treatment. Each facility (Waste Licence Register Nos. 100-1, 108-1, 137-1 and 164-1) lies on Sir John Rogerson's Quay, Dublin 2, adjacent to the River Liffey and have a remediation strategy based on a quantified, site specific risk assessment. All four *waste* licences issued for contaminated land remediation embrace new technical approaches to remediation so as to deal with the waste *insitu* if possible (*i.e.* gravel washing, soil stabilisation, and permeable reactive barrier (PRB)) in order to meet the requirements of national government policy[3].

Of the 600 IPC licences issued by the EPA, up to 100 IPC facilities are considered contaminated, their cleanup or remediation being dealt with by the IPC licence. Currently up to 30 IPC facilities are understood to have significant contamination. Six of the facilities have a remediation strategy based on a site specific risk assessment similar to the waste sites above, and are using MNA[4] technology, hot spot removal, and/or pump & treat.

The Waste Management Act 1996 (Second Schedule, Part III) establishes a list of wastes and fourteen properties of waste, which might

[1] Section 34 Protection of Environment Act (Commencement Date 22 October 2003) will enable the Agency to issue a single licence at the Office of Licensing & Guidance.
[2] The governing legislation for a waste licence is the Waste Management (Licensing) Regulations 2000 (SI No. 185 of 2000).
[3] Changing our Ways 1998, Department of Environment and Local Government.
[4] MNA: Monitored Natural Attenuation.

render it hazardous. These properties all need to be examined in the case of contaminated land remediation to determine if the contaminated soils or groundwater are to be regarded as hazardous or non-hazardous waste[5].

Furthermore, one of the aspects listed in Article 2 of EU Commission Decision 2000/532/EC *(one or more substances classified as very toxic at a total concentration greater than or equal to 0.1% [equivalent to 1000mg/kg])* is key to determining and recognising hazardous contamination of soils[6].

Instances where groundwater is contaminated to hazardous levels are rare, based on the limited solubility of many toxic substances as shown in Table 1. The exception would be benzene, which has a relatively high solubility in groundwater, although benzene is rarely found in its pure phase as it is normally a component of a hydrocarbon mixture.

Its holder in accordance with section 48(1) of the Waste Management Act 1996 may surrender a waste licence. The EPA received two surrender applications for brown-field remediation projects (100-1 and 108-1). Both surrenders have been accepted by the EPA on completion of the activities described in the licence, and the sites were then made available for development.

[5] Soils and/or groundwater can only be regarded as a waste if discarded or intended to be discarded.

[6] The EPA commonly receives queries regarding diesel-contaminated soils and whether they should be considered hazardous waste if to be treated or discarded. The MSDS's for diesel/kerosene [CAS No. 8008-20-6] generally class these hydrocarbons as 'harmful or act as an irritant, may act as a carcinogen for prolonged occupational exposure', and the Dutch Intervention Value is 5,000mg/kg (mineral oil). Using the same Council Decision it is argued that the diesel contaminated soils would need to breach 250,000mg/kg to be considered a hazardous waste (one or more substances classified as harmful at a total concentration greater than or equal to 25% [equivalent to 250,000mg/kg]). However, diesel product under capillary tension can be released from the soils at concentrations much less than 250,000mg/kg if the soil is disturbed during excavation or treatment. The liberation of diesel product in this way should be regarded as the formation of a hazardous waste. Note: diesel/kerosene chiefly consists of C10-C16 alkanes, but also has a small fraction of aromatic compounds (xylenes, etc) and saturated rings (naphthenes), which could render soils hazardous if at a total concentration greater than or equal to 0.1%.

Source: This article is a summary of: Doak, M., Carty, G. and Lynott, D. 2003. *The Remediation of Contaminated Land in the Republic of Ireland.* Proceedings of Ninth International Waste Management and Landfill Symposium, 6-10 October 2003, S. Margherita di Pula (Cagliari), Sardinia , Italy

This paper may be downloaded from the EPA website: http://www.epa.ie/Waste/documents/

Table 1. Water solubility in groundwater of selected parameters (adapted from Fetter, 1999)

Parameter	**Water Solubility at 25°C mg/l at pH 7**
Organics	
Benzene	1780
Toluene	500
Xylene	200
Naphtalene	32
Phenanthrene	1.3
Pyrene	0.13
Metals#	
Barium	0.014
Cadmium	27
Arsenic	5
Mercury	0.003
Nckel	16
Zinc	0.7

The solubility of metals such as cadmium and zinc increase significantly with a decline in pH value; acidification can lead to increased levels of those metals in groundwater.

Malcolm Doak, Environmental Protection Agency

Acidising Adjacent Boreholes

A simple technique that might help a hydrogeologist's sense of confidence when choosing to drill a proper production borehole some metres away from a successful exploration borehole in fractured/karst limestone.

There is a common perception amongst clients and the general public that a successful well or borehole has almost magical or mystical properties. People often believe that the hole itself produces the water or that the hole is more important than the resource that sustains it. People are often, for example, concerned that if a new borehole is drilled next to an existing high yielding hole, then the new hole will, literally, dry up the source feeding the old hole. The proper view of a borehole is that it is merely an artificial construction that allows access to a groundwater resource and groundwater flow system. There is nothing intrinsically special, unique or sacred about a borehole, except that it should be constructed properly to prevent the ingress of shallow easily contaminated groundwater, and should be developed so that it efficiently exploits the available and sustainable groundwater resources. A borehole is merely an access point into a groundwater system.

The hydrogeological community also has to deal with their client's irrational beliefs when they translate into fears and uncertainties regarding exploration boreholes and production boreholes. Clients often want us to drill-out, or drill down, an existing, successful, exploration borehole because of the fear that if we drill a proper production borehole, five or ten metres away from an exploration borehole, "we may miss the vein of water". Similarly they regard a properly constructed production borehole as a failure if it does not provide the same yield as a successful exploration borehole. This perception is difficult to overcome with confidence, in non-carbonate sediments and igneous rocks, but the purpose of this note is to provide comfort for hydrogeologists when dealing with low yields from a production borehole in carbonate sediments close to a successful exploration borehole.

Two years ago I carried out a successful groundwater exploration drill programme in west Dublin, in my least favourite aquifer the Calp (Dublin limestone). I don't relish the Calp because I find that long sequences of black shaley limestone, plus the smell of hydrogen sulphide and associated problems of iron, manganese and ferrophyllic bacteria are tedious. However two years ago without much enthusiasm or optimism I drilled 4 boreholes at three corners of a large industrial site. I deduced from the first three holes that there was a northeast – southwest aligned fracture zone crossing the site, and I drilled the fourth hole near the first hole and this confirmed the deduction. After long pumping tests on the exploration holes, I proposed to the client that, in spite of my lack of optimism, there appeared to be a groundwater flow system that was, within their context, worth development. The first and fourth exploration boreholes gave sustainable yields of 1,500 to 2000 g.p.h. I should add that a thick layer 40 feet deep of dry black boulder clay covered the bedrock and the groundwater system was confined. The piezometric level was about 1.5 metres below ground level.

The client understood the value of a well field rather than a single borehole source. Last year I drilled three proper production boreholes complete with a high quality PVC pump chamber casing, fully cement grouted into the overburden and the upper bedrock. One production borehole gave a yield of 2,000 g.p.h. but the other two gave yields of 100 g.p.h. and 500 g.p.h. - a major embarrassment after spending about €20,000 of the clients money. The client's engineer also had the difficult task of reporting to his own board that he had just spent a lot of the company's money to construct proper production boreholes (under 'expert advice') and had actually got less water! However, even though it was difficult to convey my confidence in the face of this apparent failure, I was confident because there was obviously a zone of high transmissivity near by, and all I needed to do was to make a link.

I therefore used a very straightforward, and I'm sure most would agree, a common sense technique. In summary it consists of the following steps:

- To pump the nearest exploration borehole
- To create a flow and gradient towards this hole

- To then put concentrated Hydrochloric acid into the low yielding production hole

- To pump the exploration borehole to waste but measure the pH

- When the pH suddenly drops, then divert the flow (still containing some acid) back into the production borehole in order to increase the head differential between production hole and exploration hole

- Keep on re-circulating the water until all the acid had been neutralised.

The full details are mundane and as follows:

1. Wear boots, goggles, rubber gloves and disposable overalls.

2. Make up an injection system to get hydrochloric acid down to the open-hole section of the low yielding production borehole, i.e. where the bedrock is exposed in borehole below the pump chamber casing. This can consist of either continuous pipe, or lengths of joined pipe, around 2” - 3” in diameter. The pipe materials must be inert. The width of the injection pipe allows the concentrated acid to sink, mix and disperse in the injection pipe, and also to be flushed through at a reasonable rate by water added above the acid.

3. Insert a tube for siphoning acid into the injection pipe and secure the tube to the pipe.

4. Set up two or more 20 - 50 litre PVC containers of muriatic acid (industrial grade Hydrochloric Acid) on a stable surface elevated above the top of the borehole and injector pipe. Put a disposable, hand operated, siphon pump into a container of acid and connect to the tube to deliver acid into the injection pipe.

5. Set up a flow through cell or container at the pump discharge pipe for the exploration borehole in order to monitor changes in pH. Set up the pH meter to take continuous readings.

6. Start pumping the exploration borehole and discharge the water to waste. Monitor the fall in water levels in the exploration borehole and the production borehole to be acidised in order to determine the nature of the groundwater gradient between the two holes.

7. When the water level in the hole to be acidised is drawn down a few centimetres then start siphoning the acid into the injection pipe.

8. Siphon 40 - 60 litres of acid slowly into the injection pipe. The concentrated acid will react with the water in the pipe and some heat will be generated. However the water around the injection pipe will cool the injection pipe and the acid water mixture inside. The acid will not immediately sink or disperse out from the bottom of the injection pipe into the water in the borehole. Therefore take water from the discharge from the exploration borehole and slowly top up the level in the injection pipe. The water added at the top will displace the acid down the injection pipe. Calculate pipe volumes and the amount of water needed to flush the first acid through in about 10 - 15 minutes.

9. The first acid to leave the injection pipe and enter the borehole water near the injection site will be relatively dilute. This will start to react with the limestone wall of the borehole and carbon dioxide will be generated. You will not notice bubbles of CO_2 immediately because the CO_2 will be compressed by the weight of water in the pump chamber casing above. Therefore don’t be fooled into believing that your calculations are wrong just because you cannot see any immediate reaction.

10. Add a further 10 litres of water at the top of the injection pipe to flush through another 10 litres of acid. Wait for 5 -10 minutes and then flush through another 10 litres of acid. After about 20 -30 litres of acid there could be a noticeable frothing and perhaps surging in the water around the injection pipe, caused by the large volumes of CO_2 eventually reaching the surface. This water is not particularly dangerous, because any acidity will be dilute.

11. It is important to measure water levels in both boreholes from the time that the acid has reached the open-hole section of the borehole. If the drawdown in the injection well does not increase then it shows that acid has not yet worked its way from the injection hole out into the more permeable fractures or solution

cavities feeding the pumping borehole. If the drawdown does not increase within about half an hour then it is time to inject more acid into the borehole.

12. Repeat the procedures above to inject acid into the borehole.

13. Continue monitoring the water levels and the pH of the discharge water from the pumping borehole.

14. Eventually the sign of a breakthrough will be a simultaneous fall in water levels in the injection borehole and a fall in pH in the water from the pumping borehole. The fall in pH will be quite sudden and dramatic. The pH will fall from around 7 to about 0.5 -1.5.

15. Divert all the pumped water into the top of the injection borehole in order reuse the acid and to keep acid flushing through the newly opened fractures. It may be necessary to partly close the valve on the discharge pipe and reduce the pumping rate to avoid over filling the injection borehole. However, keep the head of water in the injection borehole as high as possible in order to maintain a high gradient between the two holes. It should be possible to increase the discharge rate as the connection between the injection borehole and the cavity system feeding the pumping borehole improves.

16. Continue pumping, and measuring the pH of the pumped water. It will be probably necessary to continue pumping overnight to completely neutralise the acid. The water re-circulating between the holes will probably be a dark grey - brown colour from the un-dissolved clay-shale fraction of the limestone. The water may smell of hydrogen sulphide from the sulphides in the limestone.

17. Start pumping the discharge to waste when the pH has reached 6 -7, and pump until clear.

18. Install a pump in the production borehole; pump until clear, then let water levels recover, and then carry out a suite of step tests and a constant discharge test. It is certain that the yield of the production borehole will have improved and the efficiency of the production borehole probably will surpass the efficiency of the original exploration borehole. This is because the acid moving between the holes will have further opened up the cavities in the limestone bedrock between the two holes. The long-term sustainable yield will still depend on the overall transmissivity and storage in the aquifer and the recharge to the groundwater system.

Using the above technique, the yields of the two low yielding boreholes were increased from 100 and 500 g.p.h. to 2,500 and 3,300 g.p.h.

I have previously used this technique in Galway, Limerick, Greece and Malaysia. I have used it for boreholes that are up to 20 metres apart. It can be used in any sedimentary formation where there is either carbonate cement or where there has been secondary calcite mineralisation partially in filling fractures and joints.

David Ball, Consultant

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Fieldtrip to Gortadroma Landfill and Ennis

The 2003 annual IAH (Irish Group) fieldtrip weekend was held in October and was based in Ennis. A visit to Gortadroma Landfill in west Limerick was made on Saturday morning with the remainder of the trip based in the Ennis area focusing on flooding and water supply issues.

The visit to Gortadroma was led by Ms.Eleanor Boland, RPS-MCOS. The Ennis Flood study was led by Anita Furey and Teri Hayes while the Ennis Water Supplies were led by Catherine Coxon.

Saturday 4th October.

On Saturday morning the group viewed the Aughinish Alumina (AA) site from a vantage point as access was not allowed at weekend. Bauxite is processed to extract alumina at the site. The extensive red 'mud stack' spoil deposits a by-product of processing were clearly visible. The key hydrogeological aspects of the site were briefly introduced by Fionnuala Collins based on available hydrogeological reports.

At Gortadroma Landfill, the group were given an overview of the development of the landfill by Eleanor Boland, Project Engineer, RPS-MCOS. This included a description of the impact of EU and national legislation and of national and regional waste management policy on the development of the landfill; a background history of the landfill; details of recent construction works and current operational controls.

The group then walked over existing capped cells and viewed a new cell in which the leachate drainage blanket was visible. Leachate is being pumped from the four original unlined cells, which are contained by a bentonite cut-off wall. Currently there are 9 other lined cells, which have been constructed according to modern engineering standards. Leachate is redistributed in the newer cells through series of HDPE slotted pipes in the waste via a circulation chamber in the cap. Alternatively leachate can be pumped from the collection sumps within the waste to the on-site leachate treatment plant.

Currently gas is being collected on site by a series of wells (63 No.) in the waste connected to a ring main by a manifold system, which draws the gas to a gas flare. A gas collection layer is also installed below the liner of the cap to distribute the gas evenly over each cell and avoid localised build up of gas. There are plans to harness the gas and convert it to electricity, which can be fed into the National Grid.

Fresh leachate from new lined cells and older leachate from older unlined cells are combined and treated in the leachate collection and treatment area. The leachate treatment plant provides biological treatment, secondary clarification and tertiary polishing. It comprises:

- a raw leachate storage lagoon;
- a biological treatment lagoon;
- an aeration basin;
- a polishing lagoon & clarifier,
- a sand filter,
- a peat filter and
- a treated leachate lagoon.

Currently treated leachate is being stored on site and tankered off site to a wastewater treatment plant. However once the system is properly commissioned it is planned to discharge the treated water to the White River in accordance with the conditions of the waste licence emission standards.

Following lunch the group returned to the Ennis area. At Clarecastle the barrage on the River Fergus was visible. It was constructed in the last century to control flooding by preventing high tides from reaching the town of Ennis and environs.

The group then visited Whelans quarry, at Fountain Cross, north of Ennis, to look at the local rock type. We were met by the manager – Louis Grijalva. Confidentiality agreements were signed such that site operations were not permitted to be photographed. The discussion within the quarry was led by Anita Furey.

The quarry was largely dry with only one relatively small area where excavations had reached the water table and some pumping of groundwater was being carried out.

The northern quarry face was comprised of largely competent rock with very little fracturing, a shallow zone of epikarst and thin or absent overburden. In contrast, overburden was encountered on the southern side and the limestone in this area was relatively highly fractured and weathered.

Our final stop on Saturday was Drumcaranmore swallow hole/Loughvella turlough located adjacent to a service station. The discussion of flooding and water quality issues was led by Teri Hayes, Catherine Coxon and Anita Furey. The turlough was not present at this time of year so we were able to view the swallow hole itself into which a small stream of water was flowing. There was a strong odour of animal manure around the swallow hole, which is used by grazing animals for drinking water. Tracer studies have been undertaken in this area and have identified that it takes less than 12 hours for the water to reach Drumcliff Spring from where public water supplies are pumped.

Sunday 5th October.
On Sunday morning, the group congregated on the banks of the River Fergus and the history of Ennis flooding problems was introduced by Anita Furey. Developers have pushed to build in the floodplain, however to date this has been resisted by the local Council.

Following this, we visited Poulacorey swallow hole, north of Ennis town. Water from the Ballygriffy River sinking in this swallow hole passes to Drumcliff springs approximately 1 km to the south in 7-9 hours. Potential hazards in the vicinity include a graveyard, a farmyard and direct cattle access to the sinking stream. In addition, the sinking stream water has high levels of iron, turbidity and colour due to its source on the Namurian shale to the west, and this is reflected in problems with those parameters in Drumcliff springs following heavy rainfall.

Mary Burke, Senior Executive Chemist with Clare County Council, met us at Poulacorey swallow hole and then brought us to Drumcliff springs, from which the water supply for Ennis is pumped. We looked at the spring and sumps, and examined the source protection maps for Drumcliff drawn up by the Geological Survey of Ireland. The need for further implementation of source protection measures was discussed, and additional alternative water supplies for the rapidly growing Ennis area were also debated.

The final stop of the weekend was the swallow hole in the ground of St. Flannans college where a discussion of further flooding issues was led by Anita Furey.

Fionnuala Collins, IAH (Irish Group)
Fieldtrip Secretary

The IAH would like to thank the following:

- Eleanor Boland, Project Engineer (RPS-MCOS)
- Sinead Kennedy, Executive Engineer, Environment Section, Limerick County Council.
- Catherine Coxon (Trinity College Dublin),
- Teri Hayes, Director (White Young Green) and
- Anita Furey, Project Manager (P.J. Tobin & Co. Ltd)
- Enda Whelan, Whelans Quarry, Fountains Cross, Ennistimon Road, Ennis. (with special mention to Louis Grijalva);
- Mary Burke, Senior Executive Chemist, Environment Section, Clare County Council, New Road, Ennis, Co. Clare.
- Kevin Forde, Senior Hydrogeologist, URS, Cork for summaries of the hydreogeological aspects of Aughinish Alumina and of Drumcarranmore Swallow Hole/Turlough.

Papers/information sheets presented during the fieldtrip are available on line at iah-ireland.org

Gortadroma Landfill Aeration lagoon

Recent Developments in Mapping of Karst systems using Microgravity

Introduction

In September 2001, microgravity surveying techniques were employed in north Roscommon to aid the understanding of its karst hydrogeology. The work was carried out as part of ongoing research in TCD on the Karst Hydrology of Roscommon, in conjunction with the Geological Survey of Ireland and the Applied Environmental Geophysics Research Group at Keele University. Two main areas of north Roscommon were looked at in particular, in the hope of using microgravity to detect and delineate subsurface karst landforms.

County Roscommon is situated in an area of low-lying limestones, which in Ireland represent the most important aquifers economically but the least known about. In these areas, the karst landforms are often less apparent because they are usually covered with a mantle of subsoil. Consequently, little research has been carried out on them and they are often not protected sufficiently from pollution. The basis of the research being undertaken is to improve this knowledge of the workings of hydrology in these low-lying limestones areas and attempt to conceptualise them. Roscommon was chosen as an example of lowland karst due to its abundance of unmapped karst features and very high dependency on groundwater (which makes up 89% of water usage).

Geophysical setting

Previous successful geophysical work in the Gort to Kinvara lowlands encouraged the GSI to use microgravity in these two areas of Roscommon. Two catchment areas were highlighted for potential work, where detailed field investigations and water tracing experiment had been recently undertaken. The two chosen areas were near the towns of Boyle and Castlerea, where there are two large public supply springs. The town of Boyle is situated in a relatively low-lying area with the Plains of Boyle to the south, the Curlew Mountains to the northwest and Lough Key to the northeast. The drainage density in the area is very low with a total absence of surface drainage on the entire uplands of the Plains of Boyle. Rockingham Spring, which is the public supply spring for the town, is located at the base of this upland plateau 5km to the east of Boyle. The geology in the area comprises rock units that are Carboniferous in age. They are mainly clean, well-bedded limestones, which comprise of the Oakport and Ballymore Limestones.

Till is the dominant subsoil type in the area and is generally thin (less than 3m in thickness). The situation for the area around Castlerea is similar. There is an upland plateau located 3km east of the town, trending east to northeast. Again there is a noted absence of surface streams here. Much of the area is underlain by Undifferentiated Visean Limestone, which is described as pale grey, clean, medium grained bedded limestone. There are five main springs located along a fault line to the east, two of which (Longford Spring and Silver Island Spring) are used by Roscommon County Council as sources of drinking water for the town and surrounding rural population. Again the subsoils are thin in the area, especially in the upland plateau region where depth to bedrock is less than 3m.

Field Investigations and Dye Tracing

A karst-mapping programme was undertaken in November 2000 to help delineate the catchment boundaries for these two sources. This mapping revealed a high degree of karstification in both these areas. Not only have clints, grikes and epikarst been observed but there is also a high density of karst landforms especially dolines and swallow holes.

A particular feature noted, especially in the Castlerea area were the linear assemblages of collapse features (or dolines) and swallow holes located at the bottom of dry valleys, suggesting a highly developed, possibly conduit dominated, underground drainage system. Water tracing experiments were then undertaken to yield information about the catchment areas of the large springs, and also to aid understanding of groundwater flow in these highly karstified areas. Water tracing experiments enable subsurface routes to be identified, minimal groundwater flow velocities to be estimated, areas of recharge to be delineated, and sources of pollution to be identified. Both experiments were multi-dye traces involving four to five different dyes. These dyes were injected simultaneously into the karst system and separately identified from water samples. Both of the dye tracing experiments proved successful, providing connections from the sinkholes in the upland areas to the springs. The experiments showed unusually rapid flow rates (over 250m/hr) and very peaked dye hydrographs, which indicate a well-developed conduit flow system with little storage capacity.

Microgravity

Gravity surveying involves the measurement of subsurface geology on the basis of variations in the Earth's gravitational field generated by differences of density between subsurface rocks. Common applications of microgravity include the detection of mining induced cavities, the monitoring of fluid changes in hydrocarbon reservoir and the monitoring of time varying water levels in aquifers. In this case microgravity was employed to detect voids or cavities and to establish whether the groundwater pathways are well-developed conduit systems as the field mapping and dye tracing inferred.

Cavity detection is revealed by the minute reduction in the gravitational acceleration as a result of density contrasts causing an associated missing mass over a void. The gravimeter used was the LaCoste and Romberg D-meter, which consists of a measured weight on a spring scale. The weight represents the Earth's gravity, since gravity is contained in the definition of weight. If the value of gravity is large then the spring will be more stretched out than it will at positions having a smaller pull of gravity. For this reason, gravimeters respond only to the vertical component of gravity of an anomalous mass. They are extremely sensitive and can measure minute variations in the acceleration of gravity and have a sensitivity of about 0.001 milligals (i.e.1000thof 1cm^{-2}) (McGrath, 2002).

Method

Microgravity was measured in two ways. Firstly lines or profiles were carried out. Potential microgravity profiles were identified adjacent to springs and sinks, across lines of dolines and were orientated perpendicular to the subsurface groundwater pathway. Gravity was measured every 5 meters along the profiles and base station readings were taken every 1–1.5 hours. The sites were topographically surveyed to 1mm accuracy on the same day as the gravity acquisition with a Sokkia SET-3C Total Station. The data were reduced in an Excel spreadsheet package called 'GravReduce', where a Bouguer density of 2.0gcm^{-3} was used. Figure 1 shows the Reduced Bouguer gravity data at the Mewlaghmore site. Due to the poor weather conditions during surveying, the data was moderately noisy. For anomalies to be seen clearly and to allow depth estimates and density modelling to be done, the data were then cleaned. Using 'Gravmag', a 2.5 dimensional forward modelling gravity software package, a quick simple model of the data was made. The calculated gravity from a simple shape with a density in contrast to its surrounding rock was compared with the observed gravity seen from the measured field data. The calculated gravity was made to fit the observed by changing its size, orientation, depth and density and hence produce a simple model. The Euler Deconvolution method was used which is a method that analyses the gradient of the curve generated by the body's gravity effect and finds a solution by plotting where the body would be to produce that gravity effect. Figure 2 shows Euler Deconvolution solutions to the Silver Island Spring Profile. All microgravity fieldwork and modelling was carried out by Richard McGrath of Keele University.

Results

Six profiles were surveyed in total (five in the Castlerea area and one in the Boyle area). Most of the results proved quite conclusive as the solutions began to cluster. The results obtained at the six profiles are summarised below.

1. *Mewlaghmore:* Modelling indicates a large deep conduit, which is overlain by much shallower smaller conduits. The main anomaly is estimated to be 30m wide with a thickness of 6m and a top depth of 26m. The smaller anomalies are about 5-8m wide and 2-3m thick at a top depth of 10m.

2. *Longford Spring:* The results showed two conduits of equal size here. They have widths of 10m, with top depths at 11m and a thickness of 6m.

3. *East of Longford Spring:* Results suggest one large conduit with a width of 10m, top depth of 11m and a thickness of 5m.

4. *Silver Island Spring:* This profile produced the largest amplitude anomaly, and indicates a main circular conduit at a depth of 8m with a diameter of 17m.

5. *Lissalway:* Results here are inconclusive as it took a considerable amount of processing to bring out the very subtle anomalies here. The profile suggests that there is one main anomaly at a top depth of 4.5m, 10m wide and 2m thick.

6. *Rockingham Spring:* The profile here indicates one main anomaly with a top depth of 10m, a

thickness of 5m and a width of 10m. There is also a secondary but still significant anomaly further to the east, which indicates a deeper conduit with a width of 12m, thickness of 3m and a top depth of 16m. Figure 3 shows the Gravmodelling of Rockingham Spring gravity anomaly (McGrath, 2002).

Drilling

In August 2002 the Geological Survey of Ireland carried out a drilling programme in order to investigate these underground conduits in more detail. Further geophysical work was then undertaken in order to accurately locate the best sites for drilling. Two profiles in Castlerea were chosen for more comprehensive investigation. The methodology used was the same as before except this time microgravity was carried out in a grid system with readings being taken every 5m along parallel profiles 5m apart. This gave a very detailed microgravity map. Figure 4 shows the map produced. Four successful holes were cored in total in the survey with three in Castlerea, one in Boyle. The results of the drilling programme are summarised below.

Mewlaghmore 1: This hole was drilled as a control in area where geophysics showed no anomalies. This hole is the most northern borehole marked in figure 4. Drilling revealed 100% core recovery of clean fractured limestone. The limestone had numerous small solutionally widened fissures and cracks all the way through. A fracture zone was encountered between 18.5 and 21.5m with dolomitisation resulting in 40cm of a crumbly gravel material. No core was missing and no cavities were encountered. Plate 1 shows a picture of the core taken from this hole.

Mewlaghmore 2: The location for this hole was picked as an example at the main geophysical anomaly at the side of a large doline. Average core recovery from this hole in total was only 55%. Bedrock was extremely broken and fractured until 24m. A large fracture was encountered at 10m with 60cm of soft sediment and clay layers recovered. Another cavity was encountered at 11.2m with a depth of 1.4m and was presumed to be filled with clay and soft sediment. Another large cavity was encountered at 16.6m with a depth of 1.7m. A major cavity was encountered at 18.6m, with a thickness of 4.5m, where only a few pebbles and gravely clasts were recovered until 23m. There was 100% recovery for the rest of core. The limestone got increasingly cherty from 30m onwards. Plate 2 shows an example of core taken from this hole.

Longford Spring: No major cavities were found in this core, although 3 medium-sized conduits and two smaller ones were encountered. The first 15m were very fractured with 5 large fissures and numerous clay filled layers encountered. Two large fissures/small conduits (10m) were encountered at 9m and again at 16.8m. One medium sized conduit was encountered at 9.7m with 25cm of soft sand and silt being recovered. Another fracture zone was encountered at 18m with 40cm of sand and silt recovered and 60cm of rounded pebbles and missing core at 19m. From 20m onwards the limestone is very dolomitised and weathered with many calcite geodes but with a full core recovery.

Rockingham Spring: Highly karstified limestone was encountered here with an epikarst layer to 6.5m with numerous air filled cavities including a 60cm cavity at 1m, where the drilling water disappeared. A large air filled cavity was encountered at a top depth of 10m, with a thickness of 1.5m. Another large fissure was encountered at 18.2m with a thickness of 40cm. The rest of core remained very fractured but with 100% core recovery.

Conclusions

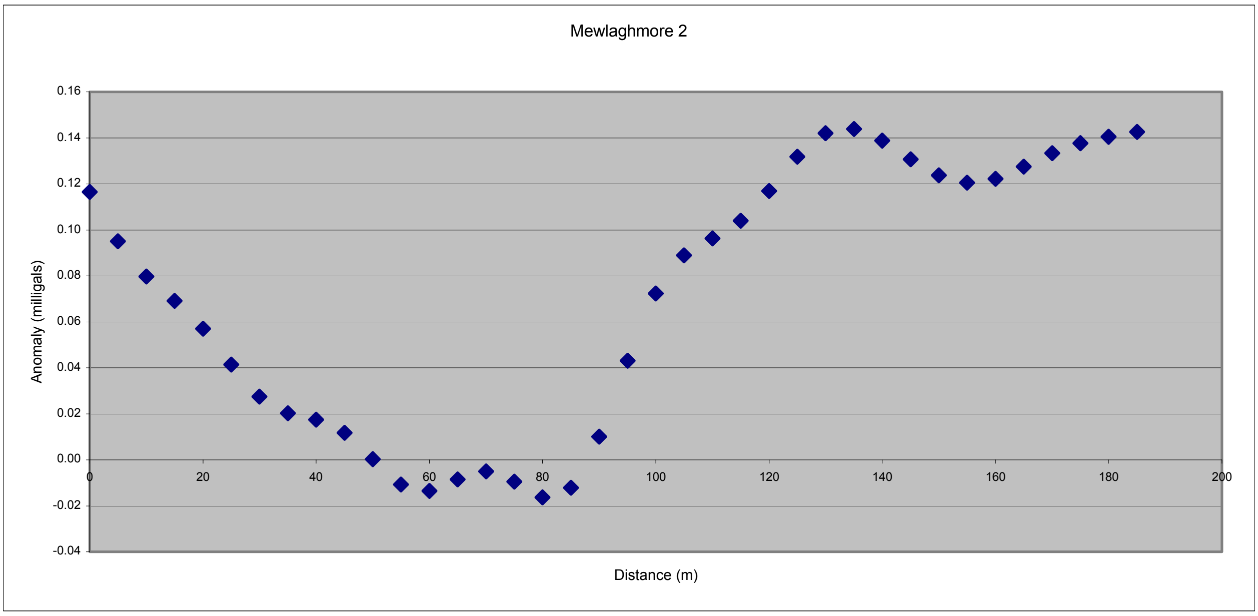
The purpose of the geophysical survey was to determine whether the subsurface pathways, previously identified by field mapping and dye tracing from the sinkholes to the springs in the two catchments, were conduit flow or diffuse flow. The geophysical work was also used to calculate the dimensions of the suspected cavities and their depth below the surface. The results from the microgravity demonstrated fairly conclusively the existence of these underground conduits, which are then backed up by the evidence from the drilling. For example, the anomaly found at Mewlaghmore suggests that there is a conduit system rather than a single pathway. This not only fits well with the field evidence with its numerous scattered dolines and sinkholes but also with the drilling.

The control borehole in this area (Mewlaghmore 1), located only 40m away from the main anomaly area and in the exact same lithology, showed how accurately the cavity was located using microgravity. This control borehole showed no evidence of cavity development as the microgravity suggested, with 100% core recovery throughout. The geophysical work at Mewlaghmore 2 suggests a large deep conduit overlain by smaller shallower conduits, which were subsequently proven by the drilling. The dimensions and the top depths of the conduits suggested from the geophysical survey are an over-estimation but still provide a close indication to the actual situation. This is also the case in the Rockingham Spring area. The geophysics suggested a main anomaly with a top depth of 10m, which is exactly where the cavity was found. The thickness of this void was again an overestimation but this could be due to the numerous smaller shallower cavities found in the top 6m that the geophysics didn't account for.

The results from the Longford spring area were less convincing with no major cavities found despite the results from geophysics suggesting two equal sized anomalies. Instead numerous smaller conduits were found. This could be explained by numerous reasons including the wrong location of the borehole as no detailed grid microgravity survey was carried out here but the microgravity certainly demonstrated that some voids or anomalies were present. Overall, microgravity proved very useful in achieving the objectives of this study. It proved the existence of the subsurface cavities and located them accurately. However, in a karstified area like this where the bedrock is highly fissured and the subsoil varies in thickness, the exact dimensions and depths of the results could prove inaccurate, especially where only a small amount of geophysics was carried out.

Caoimhe Hickey, Trinity College Dublin & Geological Survey of Ireland
Richard McGrath, Consultant

Figure 1 Reduced Bouger gravity data at the Mewlaghmore 2 site



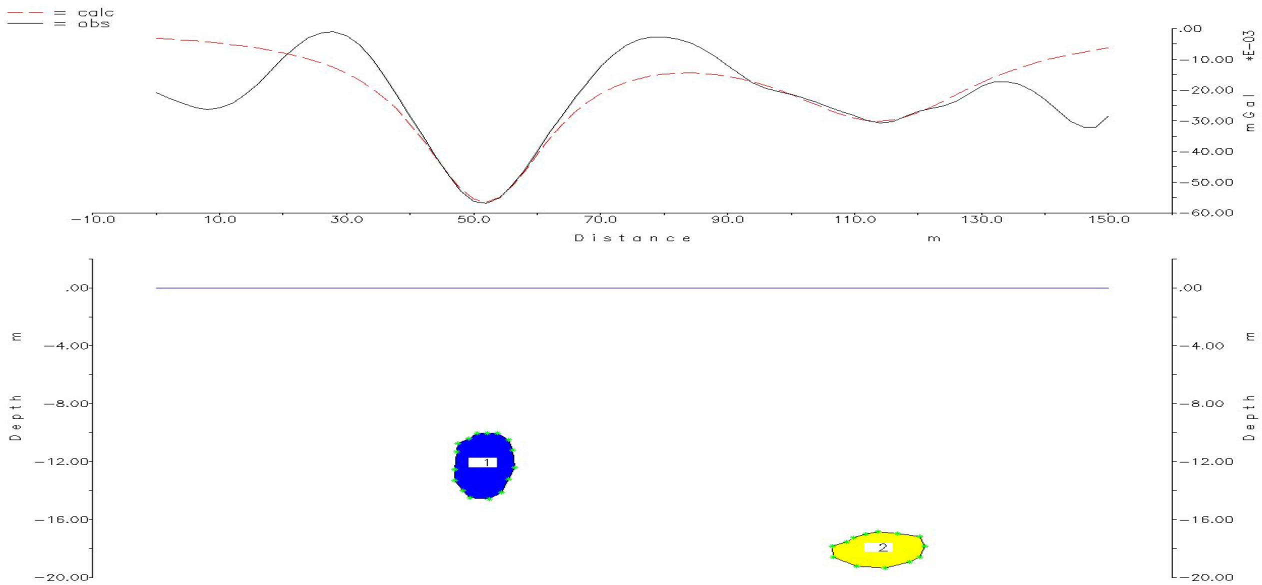


Figure 2 Euler Deconvolution solutions to the Silver Island Spring profile.
A cluster of solutions is visible at a depth of 10m

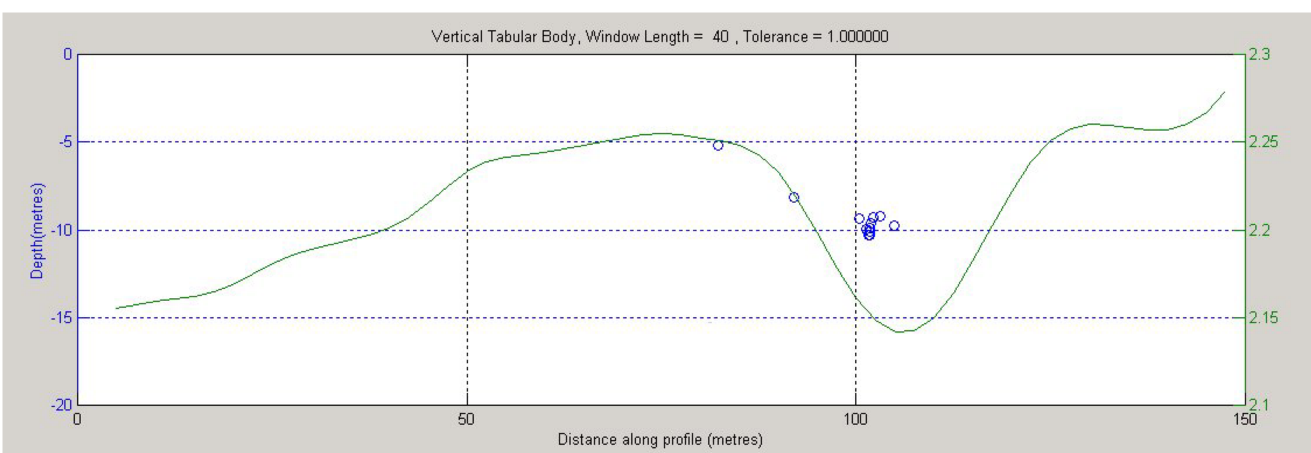


Figure 3 Gravmag modelling of the Rockingham Spring gravity anomaly.
Density values are of Limestone (2.5 gcm^{-3}) and water (1.0gcm^{-3})

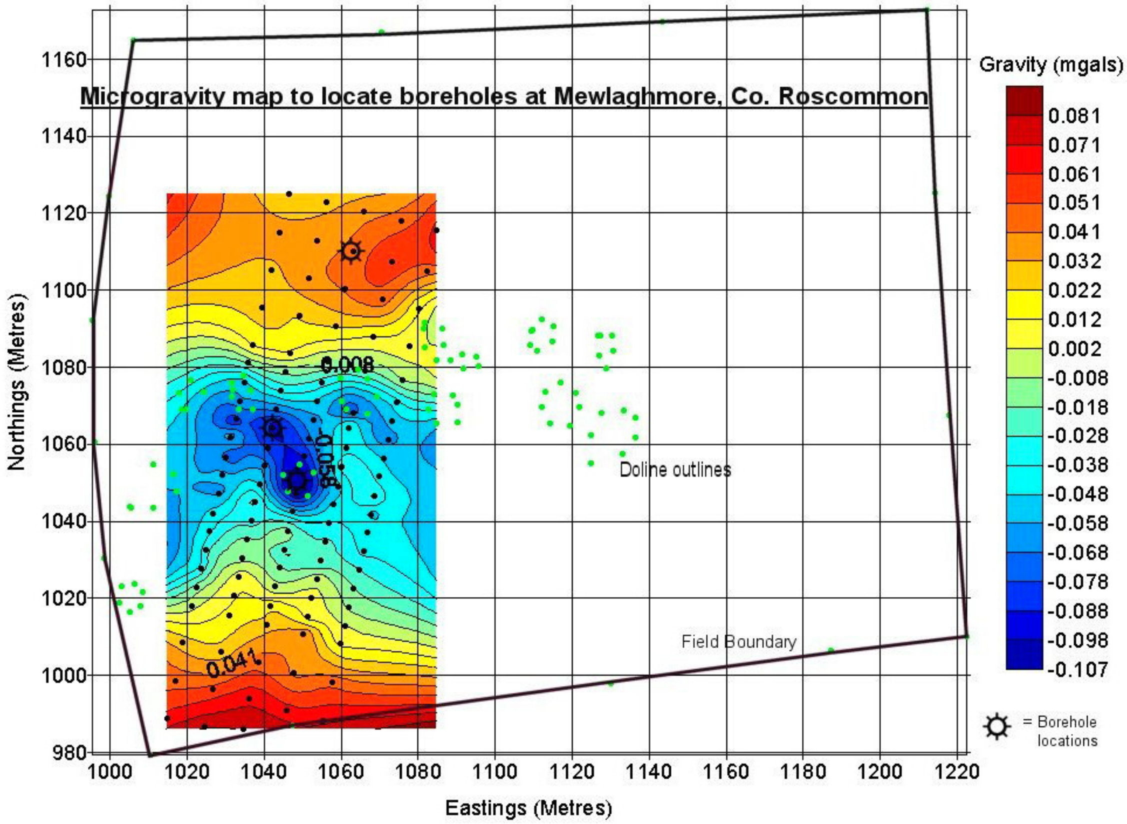


Figure 4: Microgravity, in a grid system at Mewlaghmore showing locations of boreholes

Plate 1: Mewlaghmore 1
Showing 100% recovery with clean fractures

Plate 2: Mewlaghmore 2 Very broken, many cavities with poor core recovery

CONTRIBUTIONS FOR THE NEXT ISSUE OF THE NEWSLETTER

Contributions for the next issue should arrive before 1st May 2004 to:

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