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THE GSI GROUNDWATER NEWSLETTER

NUACHTÁN SCREAMHUISCE SGÉ

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In This Issue

Why concern ourselves with **recharge to groundwater** in Ireland? Sure don't we get plenty of (i.e. too much) rain!! Recharge has not been a big issue for hydrogeologists and water managers in Ireland to-date, due not only to our rainfall, which is fairly evenly spread throughout the year, but also to our low population density and usage of groundwater. However, it is now time for a change in attitude. The estimation of groundwater recharge is a requirement of the new **Water Framework Directive**. For instance, Article 4 states that Member States shall … '*ensure a balance between abstraction and recharge of groundwater, with the aim of achieving good groundwater status…'*. But, it is not just because the EU requires us to take account of it. In recent times here in the GSI, the need for both a better understanding and quantification of recharge through subsoils, particularly through tills, have become increasingly apparent. We need reliable estimates of recharge for: a) delineating **Source Protection Areas** around wells and springs (the size of the zone of contribution (ZOC) depends on the recharge); b) delineating **Nitrate Vulnerable Zones**; and c) assessing **groundwater vulnerability** (high recharge implies high vulnerability). Other reasons include: d) **quantifying groundwater resources**; e) **issuing abstraction licences** (licences will be required for major abstractions under the Water Framework Directive); f) assessing the groundwater contributions to rivers (**baseflow**) and to sensitive **wetland habitats**; g) identifying the implications of **changes in land use** and, perhaps more importantly, **climate** on water resources. However, **recharge is very difficult to estimate reliably**, so we need to remedy our lack of knowledge. In this Newsletter, we start the process with an article by Vincent Fitzsimons (page 2). One interesting conclusion of the article is that, in contrast to monthly estimates, **daily moisture budgets and recharge estimates** show that recharge can occur in summer – this has important implications for assessing landspreading and shows that preferential flowpaths alone are not needed to explain this. Details of a recent paper on recharge by Bruce Misstear are given on page 8.

This is a bumper edition of the Newsletter, with interesting articles on **discharge of stormwater to groundwater** by Coran Kelly and Vincent Fitzsimons (page 6); practical approaches to **preventing pollution of wells** (page 9); **Roscommon's longest known cave** by David Drew and Caoimhe Hickey (page 16); a summary of **gypsum karst in Ireland** by Mike Simms (page 18); a discussion on **sustainable sewage** by Ruth Buckley on page 20; an outline of recent results on **radon levels** in the St Petersburg area by Arkady Voronov (page 24); and an up-date on events in the **IAH (Irish Group)** by Anita Furey and Morgan Burke on page 26.

Editor

Number Games with Recharge

1. Introduction

In Ireland, recharge is commonly based on an estimate of 'effective rainfall', which is derived by subtracting average annual potential evapotranspiration from average annual rainfall. However, a variety of different approaches are also used. These include direct measurement, soil moisture budget estimations, aquifer response analyses, and baseflow analyses. In the traditional hydrogeological courses, soil moisture budgeting is an approach often advocated for temperate climatic regions. The approach can accommodate different lengths of budgeting period (e.g. day, ten-days, month) and different values to simulate different types of vegetation cover. A factor is sometimes also applied to account for differing losses to runoff in different hydrogeological environments, converting 'potential' recharge to 'actual' recharge.

This article presents a few selected results from a desk-based study which was undertaken to compare effective rainfall estimations with the results of soil moisture budgeting. The soil moisture budget estimates were made using different lengths of budget period, different simulated vegetation types, and different runoff factors. The assessment of these results is purely comparative - no calibration or validation has been used to advocate any one method or any one parameter.

2. Methodology

Basic meteorological data were provided by Met Éireann, from the synoptic station at Clones, County Monaghan. Daily, monthly and annual rainfall totals were supplied for the period from 1-Jan-94 to 31-Dec-98. Monthly and annual potential evapotranspiration (PE) totals were supplied for the same period. Daily pan evaporation data were supplied from the synoptic station at Kilkenny.

Three basic recharge estimation methods were compared: annual effective rainfall, daily soil moisture budgets, and monthly soil moisture budgets. Annual effective rainfall was estimated by subtracting five-year (1994 to 1998) average annual potential evapotranspiration from five-year average annual rainfall. Daily and monthly soil moisture budget estimates were made using a modified Penman-Grindley approach, which is described in more detail in Fitzsimons (2000).

The influence on potential recharge of three different types of vegetation cover (September cereals, permanent grass, and rough grazing) was simulated using three different sets of 'root constant' and 'wilting point' values. These values were taken from Lerner et al. (1990). The influence on actual recharge of four different runoff scenarios was also simulated, using factors for different subsoil permeability classes taken from Wright et al. (1982). One additional runoff scenario was simulated whereby runoff losses were also influenced by depth to groundwater and by subsoil thickness.

Daily soil moisture budget estimates required a set of daily PE values, which were not available from Met Éireann. A set of values was simulated for the Clones area using monthly PE data from Clones and daily pan data from Kilkenny. A limited number of evaporation pans are available in Ireland. After some informal discussions with Met Éireann, Kilkenny's pan was selected on the basis that the data is probably reasonably characteristic of the pattern of evaporation in Ireland's eastern interior. For each month in the 5-year period, the adjustment necessary to correct that month's pan total to the PE total was computed. This correction was then applied to all the individual daily pan readings within that month, to generate a set of daily PE simulations which reflected likely short-term variations in the evapotranspirative demand whilst ensuring that monthly and annual totals corresponded to the locally-derived PE data.

3. Selected Results and Analyses

Detailed results are presented in Fitzsimons (2000). A few points are highlighted in this article.

3.1 Potential Recharge in Summer

Figure 1 provides a summary of the results. Using **daily** soil moisture budgets, summer potential recharge was predicted in all scenarios, amounting to 6% of the total potential recharge in the permanent grassland simulation. Using **monthly** budget periods, no summer recharge was predicted in most scenarios. This difference between shorter and longer budget period results is not unexpected. Within the simplified confines of these simulations, the effect is due to the fact that short periods of heavy rainfall can eliminate the soils moisture deficit (SMD) over the period of a few days, but the total monthly rainfall in the summer rarely exceeds the total monthly evapotranspirative demand. The hydrograph in Figure 2 provides evidence of short, discrete periods of summer recharge.

Figure 1 also highlights a relation between predicted summer recharge and simulated summer root constant. The summer root constants used for grass, cereals, and rough grazing were 76mm, 140mm, and 13mm, respectively. 'Rough grazing' simulations produced significantly higher summer recharge (14% of the annual total) than the equivalent results for grass or cereals. Within the simplified confines of these simulations, this effect is due to the fact that smaller root constants are exceeded more frequently in the summer by the soil moisture deficit, resulting in smaller ratios of actual evapotranspiration to potential evapotranspiration (AE:PE). This, in turn, results in smaller soil moisture losses, and more frequent summer recharge. Simulations of a wide range of summer root constants have suggested that the relationship is not linear, with the influence of summer root constant being proportionally stronger at lower levels (below approximately 50mm).

3.2 Actual Recharge in Winter

In a number of simulations, actual recharge was estimated using assumed factors to represent lateral losses to interflow within the subsoil cover. The results were compared with simulations in which **additional** factors further enhanced runoff losses as the piezometric surface rose towards ground level. These factors were taken from Rushton et al. (1988) and are related to depth to the aquifer's piezometric surface and the thickness of the subsoil cover. A model was developed to incorporate these factors, and, as a consequence, to simulate the interaction of water levels with recharge and other boundary conditions. The model output was compared qualitatively with existing hydrograph data taken from a borehole in the north-east of the country. The model used assumptions of subsoil permeability ('low') and subsoil thickness (8m), which were based on a log of this borehole.

A comparison between predicted and modelled head variations suggested that the enhanced runoff factors may have some validity and may be worthy of more rigorous study. The main points highlighted are:

- The use of enhanced runoff factors tended to reduce the relative proportion of simulated winter recharge as compared to recharge in the other seasons. In fact, the total simulated recharge in the autumn (September to November) actually exceeded the winter total. All other factors being equal (e.g. boundary conditions, vertical distribution in transmissivity and storativity), this may help to explain the fact that borehole hydrographs can sometimes exhibit greater overall increases in autumn than in the winter.
- Predicted annual recharge increased by 250% for the same subsoil permeability and thickness, simply by changing the aquifer condition from confined to unconfined. This may help to explain situations where recharge through low permeability subsoils appears to be enhanced (on the basis of surface indicators) in areas where groundwater levels are low.

3.3 Annual Estimates of Potential Recharge

Figure 3 provides a comparison of average annual potential recharge estimates. Clearly, there is very little difference between estimations made using daily budgets, monthly budgets, or annual effective rainfall. All but one prediction falls within 6% of effective rainfall.

As discussed in Section 3.1, the difference between annual recharge estimates calculated from effective rainfall and from soil budgeting was due to the difference between actual and potential evapotranspiration in the summer months. As a consequence, annual effective rainfall based on annual PE data tended to overestimate evapotranspiration, and **underestimate** potential recharge when compared to the shorter budgeting periods. Daily budgeting produced different ratios of AE to PE for different simulated vegetation types, with smaller ratios (resulting in higher annual recharge) predicted for vegetation with smaller summer root constants. Annual AE:PE ratios for cereals, grassland and rough grazing were 0.97, 0.93 and 0.75, respectively.

It may be interesting to compare the AE:PE ratios above (particularly the grassland AE:PE ratio of 0.93) with a ratio of 0.95 which was taken from a summary of Eugene Daly's work on the Nore Basin (Daly 1994). Eugene's figure was also based on the soil moisture budget approach, but was derived from a different location (Kilkenny), a different budget period (monthly data from 1972 to 1981), and used a different method to derive AE from PE (the Aslyng scale). Note that Cawley (1990) has also estimated AE:PE ratios. His figures increased from 0.75 in 1976 to 0.89 in 1979. These figures were also taken from Kilkenny meteorological data and also used the Aslyng scale, but were based on daily budget periods.

4. Some Comments

The daily moisture budgets undertaken in this study do not necessarily require the presence of bypass flow mechanisms to simulate summer recharge.

The use of daily recharge estimation is considered achievable in Ireland, and, with the advent of readily-available and powerful spreadsheet packages, the moisture budgets can be computed quickly and easily on any office desktop machine. The main obstacle has been the lack of daily PE data. However, daily pan evaporation data is available for a few stations around the country, while monthly PE data is available for several more stations. It is suggested here that, through the calibration of regionally-derived daily pan data (e.g. from one of three regions – 'coastal', 'central', and 'north western') with locally-derived monthly PE data, a reasonable representation of short-term evapotranspirative changes can be obtained.

For grassland areas, the study provides no evidence to suggest that the use of daily soil moisture budgets will produce significantly different annual recharge estimations to those made on the basis of average annual effective rainfall. However, daily recharge estimations, preferably supported by estimates from a variety of different approaches, may be appropriate in certain circumstances. e.g.:

- Consideration of summer recharge. For example, the assessment of the zone of contribution around a well in a low storativity aquifer may require a consideration of seasonal changes.
- Model calibration with measured borehole and springflow hydrographs.
- Consideration of long-term pumping test data where recharge is thought to be influencing drawdown, and/or where drawdown may be influencing recharge.

In this study, the simulation of different vegetation types produced a range in potential recharge which was equivalent to 20% of effective rainfall. When compared to the effect of varying soil/subsoil permeability, which Wright et al. (1982) **estimated** could reduce potential recharge by as much as 80%, it is clear that soil/subsoil permeability can be a much larger source of potential variation, particularly in aquifers covered by low permeability materials. Subject to the results of more rigorous examinations, the study also provides some evidence to suggest that the position of the piezometric surface in the aquifer may exert a strong influence on recharge.

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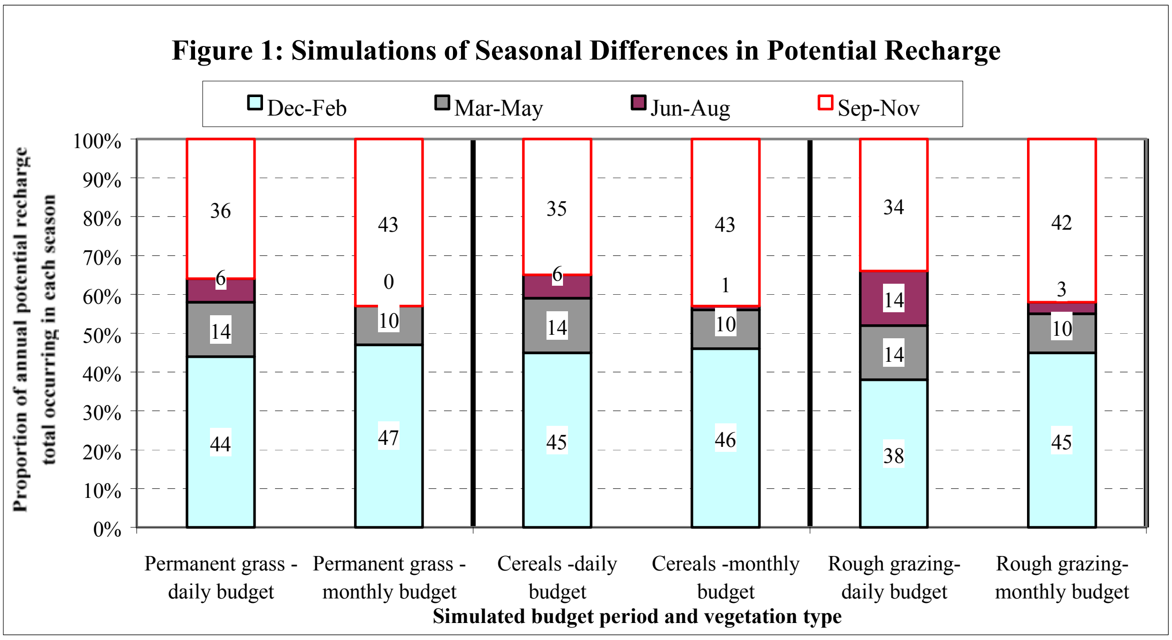

Figure 1: Simulations of Seasonal Differences in Potential Recharge

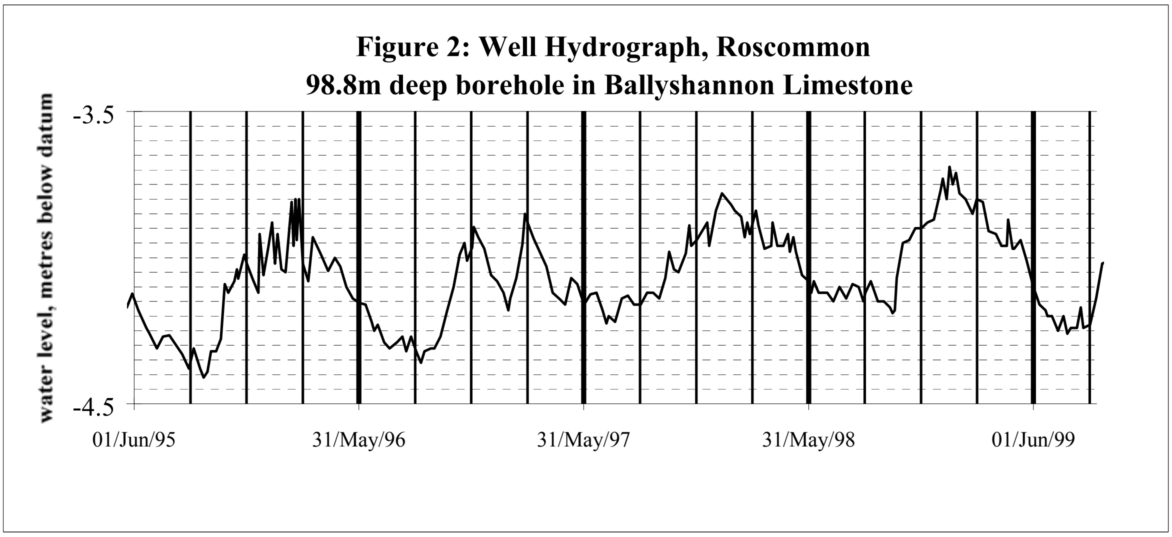

Figure 2: Well Hydrograph, Roscommon 98.8m deep borehole in Ballyshannon Limestone

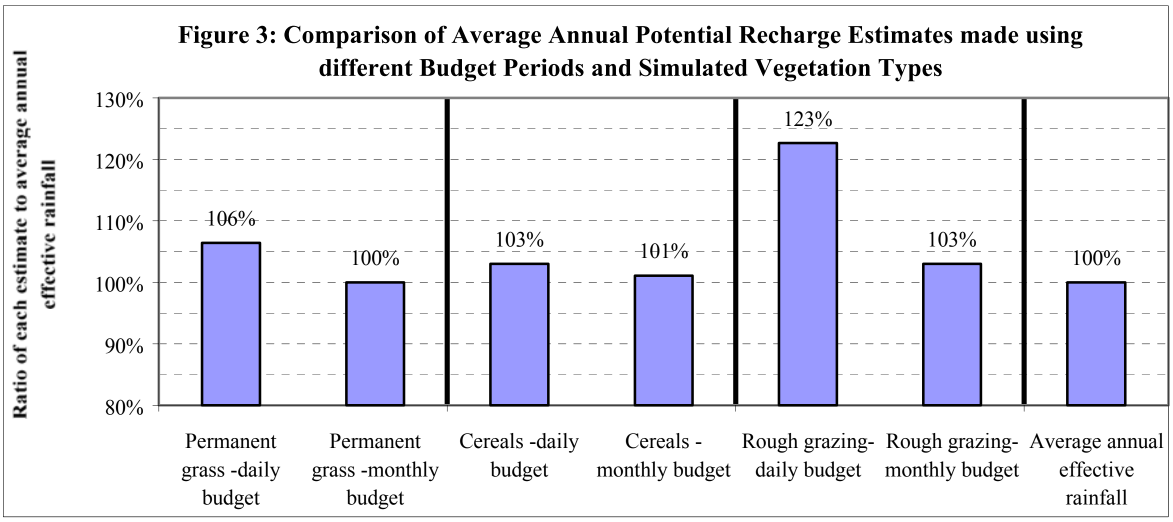

Figure 3: Comparison of Average Annual Potential Recharge Estimates made using different Budget Periods and Simulated Vegetation Types

Stormwater Contaminants and Treatment Approaches

Introduction

Stormwater runoff from urban areas and roads has been considered by us in the Groundwater Section as fairly 'innocuous' in the past. However, our involvement on the periphery of a recent project has brought to our attention the fact that stormwater runoff can actually contain quite significant levels of contaminants and that its discharge to soakaways is quite common. This article provides a summary of a literature review of stormwater contaminants and treatment methods. It draws heavily on an EPA research initiative currently under way (EPA 2000a) and on a CIRIA protocol from Britain (CIRIA, 1999).

Potential pollutants

CIRIA outline an extensive list of pollutants, given in Table 1. The EPA indicate in their project specification similar key pollutants, pointing out that under their classification of sediments "silt particles finer than 60µm carry the highest concentrations of pollutants but coarser particles may still account for a significant proportion of the total loading". Note that many of the substances listed below are "List 1" substances under the EU Groundwater Directive.

Table 1. List of contaminants and their overall classification. (adapted from CIRIA 1999)

Classification	Contaminants
Sediment	Carbon, organic solids, rubber, plastic, litter and plastics, grit, deicing grit, re-surfacing grit, asbestos, rust, metal filings, cement, sand, gravel, atmospheric dust, organic detritus, soil
Metals	Zinc, nickel, iron, rust, vanadium, cadmium, arsenic, lead, copper, chromium, manganese
Hydrocarbons	Petrol and oil, PAHs and MTB, hydraulic fluid, antifreeze, olefins, tar and bitumen, asphalt, PAHs, grease, solvents
Salts and nutrients	Nitrate, sulphate, ammonia, chloride, phosphate, urea, bromide, cyanide, fertiliser, organo-compounds, acid rain
Microbial	Excrement, organic solids, bacteria, viruses, flesh, blood and bone
Others	PCBs, herbicides, pesticides

- Average Hydrocarbon levels in urban runoff are 10-20 mg/l but can be higher for roads and industrial urban areas (Ellis, 1997). CIRIA guidelines indicate that even low concentrations cause problems with respect to oxygen demand, odour, taste and give rise to a surface sheen on surface waters.

- Herbicides from "hard surfaces" (roads, highways and urban environments) are responsible for up to 30% of exceedances in the UK (Ellis, 1997). Trace concentrations of herbicides and pesticides are problematical (CIRIA, 1999).

- Solids and heavy metals. The average concentration of suspended solids is 190 mg/l. A significant proportion of the polluting load arising from urban surfaces is associated with the fine particulate fraction (<60µm) of the discharge (EPA, 2000a). Average lead levels in urban runoff in the UK are about 200 µg/l (EU MAC in drinking water 50 µg/l) (Ellis, 1997). The decline in use of lead as a fuel additive may decrease its significance in the future. However, lead replacements such as MBTE and other volatile organic compounds also pose potential problems. CIRIA suggest that copper and zinc pose a significant threat, particularly due to their solubility in water.

- Generally, faecal coliform concentrations in urban stormwater are high, significantly above the guidelines for drinking water and other uses.

Treatment

There are numerous treatment systems that are described in detail by CIRIA (1999). Table 2 lists some of these systems along with typical removal efficiencies and costs that are associated with them. With respect to runoff from roads, the EPA are planning to compare and review systems that are currently in operation here in Ireland (EPA, 2000a).

Table 2. Typical removal efficiencies and costings for treatment systems. (taken from Ellis, 1997).

Treatment System	Capital Cost (£k)	Maintenance Cost (£k/pa)	Removal Efficiency (%)					
			Zn_{tot}	Cu_{diss}	Fe	Pb	SS	HCs
Kerb/Gully/Pipe System	180-220	1000	<------------------- 10 - 30 ------------------->					
Oil interceptors	10-30	300	30-50	<10	30-40	40-60	30-80	40-80
Combined Filter/French Drains	160-200	-	70-80	10-30	80-90	80-90	80-90	70-90
Infiltration Basin	20-50	2500	70-80	10-30	80-90	80-90	60-90	70-90
Sedimentation Lagoon	60-100	2000	60-80	20-30	90+	80-90	60-90	70-90
Detention Pond	15-30	350	30-40	<10	30-50	40-60	40-70	30-60
Grass Swales	15-40	350	70-90	50-70	90+	80-90	60-90	70-90
Wetland Systems	15-60	2500	<------------------- 50 - 80 ------------------->					
Sedimentation Tank	30-60	300	30-50	<10	30-40	40-60	30-80	40-80

From Table 2 it can be seen that no one treatment system can remove 100% of any of the contaminants listed in Table 1. Apart from inherent problems associated with each system, the contaminants provide numerous difficulties that need to be overcome. Some of the problems associated with the treatment of these contaminants are as follows:

- Hydrocarbons: "Oil interceptors and infiltration devices will have a negligible effect on the concentration of trace organics present in a dissolved or colloidal form. Whilst PAHs are generally insoluble and solid-associated, their co-solvent properties can enhance their solubility. MAHs (benzene, toluene) are quite mobile, as are the low molecular phenols, and in nutrient deficient aquifers their degradation is likely to be slow" (Ellis, 1997).
- Suspended solids and metals: There is evidence indicating that filtration and infiltration techniques regularly fail in handling these types of contaminants due to such factors as inappropriate sizing, lack of pre-treatment of solids and groundwater mounding (Ellis, 1997).
- Herbicides/pesticides: There are not enough data at present to determine the degradation of pathogens, herbicides, dissolved metals and hydrocarbons in groundwater. CIRIA guidelines recommend that a change of practice is introduced to reduce the levels of herbicides or to use degradable chemicals that do not cause long-term problems, because of the difficulties associated removing these contaminants from the runoff. The movement and fate of herbicides and pesticides is poorly understood.

Thus, it is recommended that the design approach should adopt a 'treatment train' methodology to dealing with runoff, i.e., utilising several methods to reduce/minimise the impact of stormwater runoff. For example, the US EPA require full tertiary treatment and disinfection for stormwater runoff prior to discharge to groundwater with respect to faecal coliform bacteria.

On the basis of a review of CIRIA guidelines, and on EPA site suitability guidelines for on-site wastewater treatment systems (EPA, 2000), an example of a possible 'treatment train', which might be appropriate for **discharge to groundwater** under certain circumstances, is as follows:

- An interceptor to remove floating hydrocarbons.
- Retention ponds and silt traps.
- Restrictions on herbicide usage.
- Regular inspection and maintenance of silt traps and interceptors. It is critical that no silt is allowed to block the percolation areas, if soakage is to continue in the long term.
- Discharge through a percolation area, sited using the EPA (2000) guidelines, with a minimum of 2m of unsaturated subsoil beneath the pipe invert. The primary purpose of this recommendation is to help treat partially-soluble hydrocarbons (e.g. benzene).

Comments

There are numerous potential contaminants in stormwater runoff that can be classified into 6 main groups; sediment, hydrocarbons, metals, salts and nutrients, pesticides and coliforms.

Many of the potential pollutants are "List 1" substances under the EU Groundwater Directive.
There are a number of methods in operation designed to remove the contaminants. Removal efficiencies are documented for each method. Many of the contaminants have properties that make 100% removal efficiency unlikely by one single method. If discharge of stormwater to ground is unavoidable, a treatment train approach may help to reduce the risk to groundwater.

The EPA will be producing recommendations for systems that are employed to treat runoff from rural dual carriageways and motorways. It is likely that they will also indicate systems that are currently not used here in Ireland which may be suitable for certain sites.

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Coran Kelly and Vincent Fitzsimons, Groundwater Section, Geological Survey of Ireland.

Useful Paper on Recharge
"Groundwater Recharge Assessment: a Key Component of River Basin Management" by Bruce Misstear

This paper highlights the importance of recharge in river basin management. It reviews and summarises, with examples, the different recharge estimation techniques: inflow estimation, aquifer response analysis, outflow estimation and recharge water balance. The paper is in the Proceedings of National Hydrology Seminar on River Basin Management, organised by the IHP and held in Tullamore in November 2000. If you wish to get a copy of the paper, let me know.

Donal Daly, Groundwater Section, Geological Survey of Ireland

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Cryptospiridiosis Outbreak in a Surface Water Public Supply in Northern Ireland

21/8/2000 Eastern Health and Social Services Board began to record an increase in cases of diarrhoea in the Poleglass area of Belfast.

22-23/8 No trace of organism in tests, but precautionary warning to media that vulnerable groups such as the elderly and immuno-compromised should boil their drinking water.

25/8 21 cases of cryptosporidiosis confirmed.

29/8 Samples taken on 24-26th showed an average of 0.1 oocysts per ten litres of water – one tenth of the treatment limit.

29 (late) and 30/8 positive tests with 1.3 oocysts/10 litres.

30/8 'Boil' notice delivered to householders.

31/8 A significant no. of cases were occurring in neighbouring areas; 'boil' notices issued to these areas; in total some 28,500 households and 90,000 people affected.

The area supply is treated by slow sand filtration, which should have provided an effective barrier against the organism. But an investigation of the brick-built conduit showed that it had apparently been damaged by builders laying pipes to a septic tank.

13/9 Damaged conduit was repaired and system cleaned out. Thereafter, analyses found water to be free of cryptospiridium.

18/9 'Boil' notice lifted. 132 cases of cryptosporidiosis confirmed by lab analysis by then. But hundreds of other cases likely to have passed without investigation.

As an interim measure to protect against cryptospiridium in areas supplied by the high-risk Silent Valley source, the Water Service have decided to end sheep grazing in the catchment until 2003, when a new £35 million treatment works is due to be completed.

Source: Article summarised from '**The ENDS Report**, No. 308, September 2000.

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Practical Approaches to Preventing Pollution of Wells

1. Introduction

Practical pollution prevention approaches depend on a variety of factors, which are often interrelated, and no one approach on its own is likely to be sufficient. These approaches are influenced, to some degree at least, by whether the well is privately owned or is a public supply well. The following is a comprehensive list of approaches, which can be used as appropriate.

- ‘Knowing your well’!
- Vulnerability assessments;
- Hazard surveys;
- Proper siting of wells and hazards;
- Performance criteria for hazards;
- Monitoring of well water quality;
- Assessments of water quality data;
- Well construction and sanitary protection;
- Disinfection;
- Public awareness.

2. ‘Knowing Your Well’

Whether you are a local authority engineer or a householder, a well is a vital engineering structure, providing an essential requirement for living – water! Also, it is a relatively large capital investment. Therefore it is advisable for well owners to understand and know about their source of water and to record relevant details.

2.1 Understanding Groundwater Flow to Wells

Prior to the start of pumping, water will have been flowing to and by the well from the up-gradient side, perhaps from a long distance - several kilometres in some instances, but usually at least tens of metres and frequently hundreds of metres. When water is pumped from a well, the water level in the well and the surrounding area is lowered. A hydraulic gradient is created towards the well from all around in the aquifer. During pumping, groundwater flowing by the well is drawn into the well as the nearby flowlines are directed towards the well. Pumping of the well causes some of the flowlines on the down-gradient side to reverse their direction and flow back towards the well. The entire land surface area contributing water to a well is called the **zone of contribution** (**ZOC**). The size of the area depends on the abstraction rate and the recharge (the amount of rainfall that infiltrates through soils, subsoils and bedrock to the water table). The shape depends on the local hydrogeology of an area. An idealised diagram of a ZOC is shown in Figure 1. Contamination of a well can only occur from potentially polluting activities or hazards in the ZOC; consequently, a knowledge and understanding of this area is a vital part of pollution prevention.

The factors to take into account in locating the ZOC are:

- likely size of ZOC;
- groundwater flow direction;
- shape of ZOC.

The likely **size of the ZOC** will depend on the pumping rate and the recharge. Taking conservative estimates for both, the recharge area required for domestic supplies will be in the range 1000-2500 m^2. In permeable rocks, this area will usually be a considerable underestimate for the ZOC because groundwater may be flowing in the direction of the well for a long distance, but is only intercepted for the short period each day when the pump is turned on. For public supply and group scheme wells, the ZOC will be much more extensive –over 5 km^2 for large supplies.

Most of the flow to a well comes from up-gradient. Therefore, the **groundwater flow direction** must be known if the ZOC is to be located. The water table can be visualised as a planar surface that is a subdued reflection of topography. Groundwater flow is usually to the nearest permanent stream. Therefore, the topography and nearby streams can provide a general indicator of groundwater flow direction. However, in permeable areas small changes in topography will not influence the water table, and in karst (cavernous) limestone areas flow directions are unpredictable.

For domestic wells, the ZOC can be visualised as a narrow zone – 15-30 m wide – starting at most 10 m down-gradient of the well and extending back up-gradient for at least 150 m in poorly permeable bedrock and more than 500 m in more permeable bedrock.

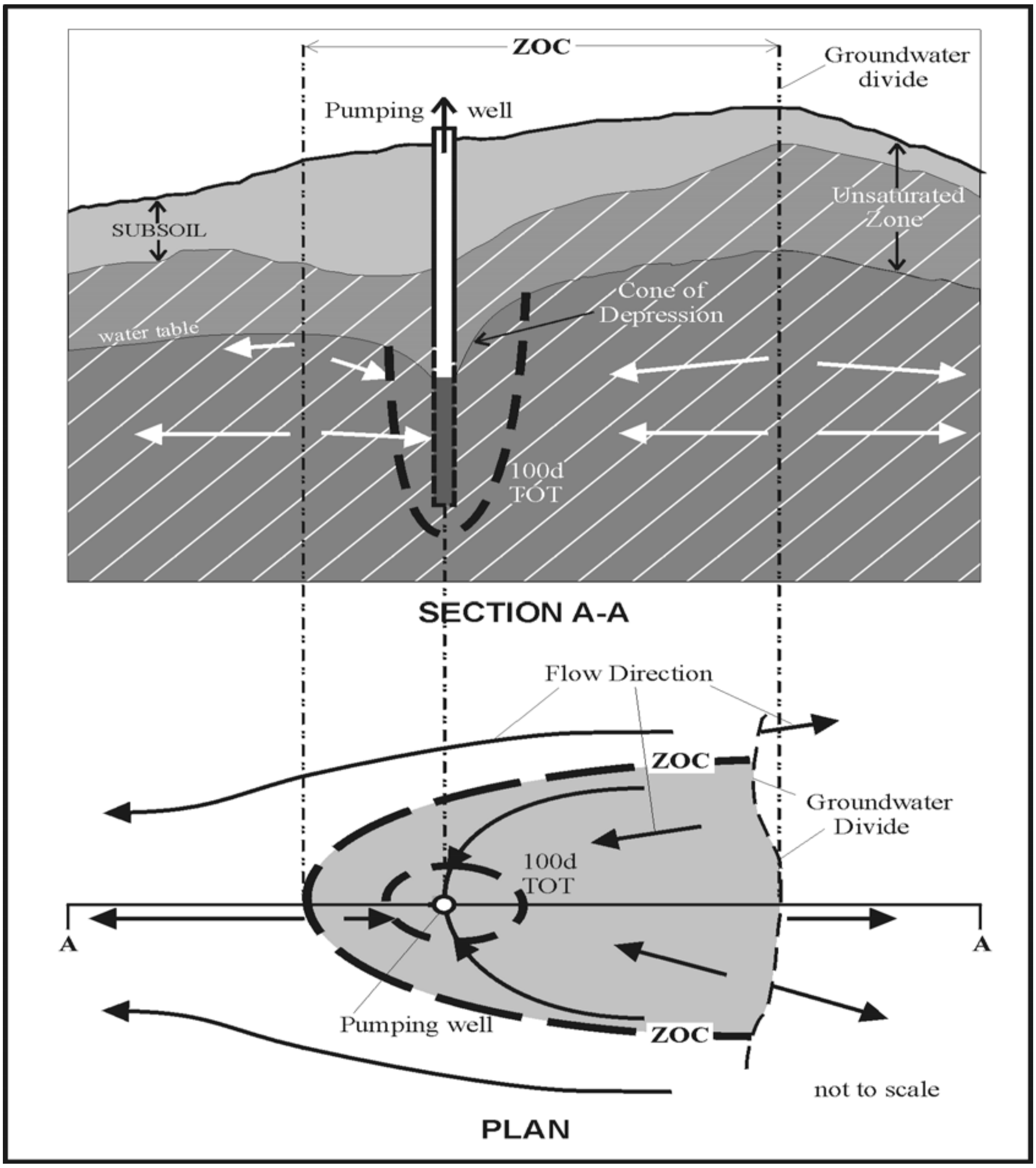

Figure 1. Conceptual drawing of the Zone of Contribution (ZOC) at a pumping well.

For higher yielding wells, the ZOCs are highly variable depending on pumping rate, recharge and the specific hydrogeology in the vicinity of the well. Consequently, it is not possible to estimate these without specialist help. In some instances, the ZOC will already have been delineated – the GSI have completed source protection zones around about 60 public supply wells. To give an idea of the possible dimensions, public supply sources yielding between 200-800 m^3/d have down-gradient boundaries 75-400 m away and up-gradient boundaries usually within 2.0 km.

It is recommended that every well owner standing at the well site should be able to visualise in 3-D groundwater flow to the well, the potential hazards in the ZOC and the possible threats to the well posed by the hazards. The information given here will assist in this; however, it is general and simplified, and more detailed and specific information would be required for public supply wells.

2.2 Recording Well Details

The GSI receives at least 200 queries every year from householders and engineers concerning problems with wells, e.g. pollution, high iron, silting, caving-in, pump stuck. Assisting with these queries is frequently made more difficult by the lack of information available on the well.

For householders, it is recommended that the following information should be collected and filed:

- Depth of well
- Diameter
- Depth of lining
- Diameter of lining
- Details on sealing/grouting
- Depth to bedrock

- Type of subsoil
- Type of bedrock
- Water entry levels
- Depth to any cavities met in drilling
- Static water level below ground
- Measured pumping rate
- Drawdown during pumping
- Estimated maximum safe yield
- Chemical and bacteriological analyses
- Drilling Contractor
- Date of drilling
- Drilling method

While this may seem a very comprehensive list to a householder at first glance, in fact the driller will provide most of the information, and in any case it is basic information that will assist if a problem arises. Engineers and hydrogeologists will use a dipper (an electric probe with a twin-core cable incorporated into a measuring tape on a revolving drum) to measure the static water level and the drawdown (the change in water level caused by pumping); householders could use a measuring tape and a weight (such as a bolt) tied to bailer twine.

If a householder is buying a house with an existing well, it is worthwhile checking on the precise location of the well, the well details and water quality information. If the existing water quality information is inadequate, insist on having the well tested, chemically and microbiologically.

3. Vulnerability Assessments

A vulnerability assessment of an area provides:

- information on the hydrogeological setting, in particular the permeability and thickness of the subsoils;
- information needed to evaluate the degree of risk posed by any hazard;
- information that can be used in decision-making on the location of hazards, the site investigation requirements and the type of engineering methods needed to prevent contamination.

For example, a well located in an area with ~1 m of soil and subsoil over bedrock, i.e. an extremely vulnerable area, is at risk from nearby septic tank systems, landspreading, etc. In contrast, a well in an area with >10 m of low permeability subsoil, i.e. low vulnerability, is well protected from contamination, and hazards such as septic tank systems and landspreading are unlikely to contaminate the well (provided surface water does not enter directly into the well).

It is advisable for householders to check for outcropping bedrock and enquire about the depth to bedrock prior to buying a site, if they need to drill a well. Local authorities are advised to carry out a preliminary assessment of vulnerability prior to choosing sites for public supplies.

Vulnerability maps have been completed for 9 counties – Offaly, Waterford, Tipperary (SR), Limerick, Meath, Wicklow, Clare, Laois, South Cork – and mapping has commenced in Kilkenny, Tipperary (NR), Monaghan, Roscommon and Kildare. However, a vulnerability assessment can be carried out, using the national guidelines (DELG/EPA/GSI, 1999a) on any site or area. The GSI can provide advice on this, if requested.

4. Hazard Surveys

Local authorities are advised to identify and map existing hazards in the higher risk areas, particularly in zones of contribution of significant water supply sources (DELG/EPA/GSI, 1999a). This would involve conducting a survey of the area and preparing an inventory of hazards. This may be followed by further site inspections, monitoring and a requirement for operational modifications, mitigation measures and perhaps even closure, as deemed necessary. New potential sources of contamination can be controlled at the planning or licensing stage, with monitoring required in some instances. In all cases, the risk, control measures and response category depend on the potential contaminant loading, the groundwater vulnerability and the groundwater value.

Prior to purchasing a site or a house, householders should look at existing developments and potentially polluting activities nearby and, together with consideration of the vulnerability, assess the likely risk to the well. The treatment system on the site may be located a good distance downhill of the well, but the neighbour’s system might be over the hedge, 10 m away!

4. Proper Siting of Wells and Hazards

The location of wells and hazards, in a way that minimises the probability of contamination, depends on the following:

- hazard contaminant loading (for example, the contaminant loading from a single house on-site wastewater treatment system is less than from a landfill);
- vulnerability of the site/area;
- hydrogeology of the site/area;
- whether the hazard is inside or outside the ZOC of the well;
- distances (often called ‘setback’ distances) between wells and hazards;
- the density of hazards;
- the planning control measures for hazards;
- risk assessment and management.

For regulatory bodies, such as local authorities, all these aspects are encompassed in the source protection component of groundwater protection schemes and the groundwater protection responses. Four examples are given below.

1. **Landfills**: in view of the contaminant loading, landfills are not acceptable in the ZOC of public supply wells (DELG/EPA/GSI, 1999b).
2. **Landspreading of organic wastes** from intensive farming enterprises: this is 'not acceptable' in the inner and outer protection areas, where the vulnerability is extreme (i.e. SI/E and SO/E); is 'not acceptable' in the inner protection area, where the vulnerability is high (i.e. SI/H); is 'not generally acceptable' in the inner protection areas, where the vulnerability is moderate or low (i.e. SI/M and SI/L); and is 'acceptable subject a maximum organic nitrogen load not exceeding 170 kg/ha/yr' in the outer protection areas, where the vulnerability is high, moderate or low (i.e. SO/H, SO/M and SO/L) (DELG/EPA/GSI, 1999c).
3. **Setback distances for on-site wastewater treatment systems:** Private wells down-gradient must be 30-60 m away, depending on the groundwater vulnerability, i.e. the permeability and thickness of subsoils (DELG/EPA/GSI, 2000).
4. **Setback distances for landspreading:** No spreading is allowable within 50 m of public supply wells or 30 m of karst features (DELG/EPA/GSI, 1999c). Farmers are advised not to spread within 50 m of their own or their neighbour's well.

However, groundwater protection responses are only available at present for three hazards – landfills, landspreading and on-site wastewater treatment systems. For the location of other hazards, the factors listed above need to be considered on a site by site basis, preferably using a general risk assessment approach. The level of investigation and evaluation prior to decision-making will depend on the degree of risk involved.

For everyone involved, use of 'common sense', based on some knowledge of groundwater flow, in locating wells is essential. So, choose the site carefully. Be wary of using diviners. As a general rule, a well should be located up-slope and as far as possible from potential pollution sources, such as farmyards and on-site wastewater treatment systems. If hazards are located outside the 100-day time of travel area (see Figure 1), faecal bacteria should not be present in the well water, provided sanitary protection is adequate. In addition, keep away from streams as pumping may draw in contaminated water. Avoid areas with shallow bedrock. If in doubt, get advice from the GSI or a hydrogeological consultant.

Local authorities are advised to buy large sites when planning and undertaking development of groundwater.

6. Performance Criteria for Hazards

Performance criteria include requirements on the design, construction, operation, maintenance and/or inspection of hazards. Examples include the EPA Landfill Manuals, the EPA Wastewater Treatment Manuals and the DoE/DAFF Code of Good Agricultural Practice to Protect Waters from Pollution by Nitrates (DoE/DAFF, 1996). These are particularly effective for new developments, but can also be used in dealing with existing developments.

7. Monitoring of Groundwater Quality

Monitoring for contaminants provides direct information on contamination, and a lot of emphasis and perhaps even over-emphasis is given to monitoring of groundwater in EU countries. However, monitoring, while desirable and useful, only provides an indication of the presence or absence of contamination, and is inadequate by itself to ensure protection. Monitoring results are useful in a reactive mode, in that they are generally available after exposure to the contamination has occurred. Monitoring results may be equivocal (Macler and Merkle, 2000): (1) if a well is positive for a pathogen or faecal indicator at a given time, uncertainties remain in the frequency and magnitude of this contamination, as well as in the types and health significance of other organisms that might co-occur; (2) if a system is found negative for indicators, it may in fact be contaminated, but the limitations of monitoring frequency, sample size, and level of quantitative analysis may not show this (for example, well water may not have *E.coli* – the indicator bacteria – but may contain viruses which are smaller than bacteria and some of which live longer); (3) a system that is negative may be without contamination now but not in the future. Also, in comparison to surface water, contamination of groundwater lasts far longer – for weeks, months and even years – because groundwater moves slowly. Therefore, emphasis must be on prevention rather than monitoring and remediation.

8. Assessment of Water Quality Data

Water quality data, whether from a monitoring programme or once-off sampling, enable not only a check on the presence of contamination but also an assessment of the likely source of contamination.

In assessing groundwater quality, the approach taken in the GSI is to distinguish between the terms 'contamination' and 'pollution'. Groundwater becomes 'contaminated' when substances enter it as a result of human activity. The term 'pollution' is reserved for situations where contaminant concentrations are sufficiently high to be objectionable e.g. above the EU maximum admissible concentration (MAC).

As human activities have had some impact on a high proportion of groundwater in Ireland, there are few areas where the groundwater is in pristine condition. Consequently most groundwater is contaminated to some degree although it is not necessarily polluted. In assessing groundwater quality there is often a tendency to focus only on the EU maximum admissible concentrations (MAC). In the view of the GSI, there is a need for assessment of the degree of contamination of groundwater as well as showing whether the water is polluted or not. This type of assessment can indicate where appreciable impacts are occurring and when monitored over time can be helpful in isolating potential sources of contamination before major incidents occur. Consequently, thresholds for certain parameters can be used to help indicate situations where significant contamination but not pollution is occurring. The thresholds for assessing water quality are given below.

Parameter	**Threshold** mg/l	**EU MAC** mg/l
Nitrate	25	50
Potassium (K)	4	12
Chloride*	25-50	250
Ammonia	0.15	0.3
Faecal bacteria	0	0
K/Na ratio **	0.4	

* depending on distance from the sea.
** in some areas a value of 0.3 may be more appropriate.

In certain exceptional circumstances, high ammonia, K and Na concentrations may be due to natural conditions: ammonia in peaty areas and in newly drilled wells; K from rocks with feldspars, such as decomposing granite and certain sandstones; and Na due to ion exchange in confined aquifers.

In the GSI, if we are examining an area with potential groundwater contamination problems, we assess the analyses as follows:
***E. coli* present** ⇨ organic waste source nearby (except in karst areas), usually either a septic tank system or farmyard.
***E. coli* absent** ⇨ either not polluted by organic waste or bacteria have not survived due to attenuation or time of travel to well greater than 100 days.
Nitrate > 25 mg/l ⇨ either inorganic fertilizer or organic waste source; check other parameters.
Ammonia > 0.15 mg/l ⇨ source is nearby organic waste; fertilizer is not an issue.
Potassium (K) > 5.0 mg/l ⇨ source is probably organic waste.
K/Na ratio > 0.4 (0.3, in many areas) ⇨ Farmyard waste rather than septic tank effluent is the source. If <0.3, no conclusion is possible.
Chloride > 30 mg/l (25 mg/l in some areas)⇨ organic waste source. However this does not apply in the vicinity of the coast (within 20 km at least).

In conclusion, faecal bacteria, nitrate, ammonia, high K/Na ratio and chloride indicate contamination by organic waste. However, only the high K/Na helps distinguish between septic tank effluent and farmyard wastes. So, while the analyses can show potential problems and indicate likely sources, other information is needed to complete the assessment. Also, this approach is not conclusive. Obviously, details of nearby hazards help in the assessment.

The EPA are currently developing guidelines and intervention values for the protection of groundwater (Keegan, M. *et al*., 2000), which will expand the advice given above.

9. Well Construction and Sanitary Protection

9.1 Role

This is a means of preventing pollution that is within the control of the well owner. Even if the well has already been drilled, improvements can usually be made.

9.2 Recommendations

1. The annular space outside the casing should be filled with a suitable sealant, such as cement or cement/bentonite grout to prevent surface water runoff or shallow groundwater seeping directly into the well. It is advisable to grout the casing for a minimum of 3 m into bedrock.
2. No unsealed openings should exist in the wall or along the joints of the casing.
3. A concrete slab, 150 mm thick, should be keyed in around the casing to a distance of at least 0.5 m from the casing.
4. The casing should protrude above the surface of the concrete slab.
5. A secure, watertight well cap should be fitted to prevent foreign matter or small animals from falling into the well.
6. The wellhead should be housed, preferably in a manhole with a manhole cover.
7. If the general land surface around the well is depressed or susceptible to flooding, it should

be raised and regraded so that it slopes away from the well.

8. If the well is in a field used by farm animals, it should be enclosed so that animals cannot get close – a distance of 10 m from the well is recommended. It is suggested that a relatively high wall should be used rather than a fence, which tends to attract farm animals with the consequent concentration of faeces and urine in the area least suitable!
9. Inspect the well at regular intervals.

Good advice on well construction is given in Briody (1995), Ball (1995) and NSAI (1992).

8.3 Well Construction Standards

In Ireland, a borehole is almost the only important feature of a house which is not governed by any regulations or standards (Wright, 1995; Ball, 2000). A modern house requires planning permission and must be built in accordance with detailed Building Regulations which ensure that certain minimum standards are observed. Mains services - electricity, gas, water and sewerage - are all constructed to national standards by certified installers. On-site treatment systems, where required, must also conform to planning conditions and, until now, to the guidelines of S.R.6 and Agrement Certificates, and in the future, to the EPA Manual (2000) and the Groundwater Protection Responses (DELG/EPA/GSI, 2000). However, a private well is covered by no standards, no regulations and no planning conditions. It is therefore not surprising that many rural boreholes are contaminated and that this is often due to faulty well construction.

In other developed countries some or all of the following are fairly closely regulated:

- Licensing of well drillers: qualifications, experience and health of drilling personnel
- Construction of wells: notification/permission to drill at a given site
- standards of construction and of materials used
- sealing of abandoned wells.

It is recommended that new national regulations should:

- ♦ Require well drilling contractors to be registered and set minimum standards for well drillers
- ♦ Set minimum standards for well construction, including procedures for sealing abandoned wells
- ♦ Require completion of well records for new water wells and submission to an appropriate authority.

10. Treatment

10.1 Role of treatment

Disinfection is an important means of protecting human health, but it should not be considered as a solution to groundwater contamination:

- ♦ it is not a sustainable strategy for managing groundwater in that it is merely treating the symptom of the problem;
- ♦ the EU Water Framework Directive aims to reduce dependence on purification and pre-treatment of drinking water;
- ♦ disinfection systems fail on occasions;
- ♦ chlorination may not be adequate to treat protozoa such as *Cryptospiridium*.

10.2 Recommendations

1. All new wells should be disinfected after drilling.
2. Existing wells should be disinfected on a regular basis (each Autumn is suggested). A GSI information sheet on disinfection of private wells is given in Table 1.
3. Drilling equipment should be cleaned and sterilised prior to drilling.
4. Householders with private wells in karst areas and extremely vulnerable areas should install a disinfection system such as an ultra violet (UV) light to reduce the likelihood of consuming microbial pathogens.

11. Taking Responsibility, Public Awareness and 'Common Sense'

'The primary responsibility for groundwater protection rests with any person who is carrying out an activity that poses a threat to groundwater'. This is the first sentence in 'Groundwater Protection Schemes' (DELG/EPA/GSI, 1999 (a)); it is a powerful principle that needs to be more widely accepted and followed.

"Command and Control" regulations are unlikely on their own to ensure successful prevention of contamination. Therefore other alternatives, such as public education, must supplement good planning regulations and enforcement. Greater awareness of the significance of hazards, such as septic tank systems and farmyards, as a source of water pollution and as a health risk is required. Also, a greater appreciation and understanding of groundwater, which is 'out of sight, out of mind' for many people, is needed. Improved awareness would lead to a more responsible approach to environmental issues and the use of 'common sense' in dealing with wells and the possible impacts of human activities.

Table 1 Disinfecting Wells
Method 1 Using Bleach (sodium hypochlorite, 3-5% available chlorine) 1. Obtain 2 gallons (9 litres) of 3% strength or 1 gallon (4.5 litres) of 5% strength (e.g. Parazone) 2. Make up to 5 gallons by adding water and mix thoroughly 3. If sampling during a pumping test, on the day before the test starts pour half of the solution into the well, start the pump and let it run briefly until water with a distinct smell of chlorine pours from the outlet pipe. Turn off the pump immediately. Add the remainder of the solution and leave overnight. Then pump to waste until the smell of chlorine disappears before taking a sample for analysis. 4. If sampling from a well that is connected to a house, pour half of the solution into the well, start the pump and open all taps until water from each tap has a distinct smell of chlorine. Stop the pump and add the rest of the solution. Allow to stand for 12-24 hours, then pump to waste until the smell of chlorine disappears.
Method 2 Using chloros (12% available chlorine) 1. Obtain 0.5 gallon (2-3 litres) chloros. 2., 3. and 4. as above.

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Pollawaddy Cave, Lisacul, Ballaghaderreen, Co. Roscommon

The cave is located some 7.5km southwest of Ballaghaderreen in the extreme northwest of Co. Roscommon and approximately 1.5km southwest of Lisacul village; NGR M 157317 289238, (50,000 map No. 32); Townland Carrownaknockaun; Altitude 94m O.D; Surveyed length 45.5m. The entrance is located part way up the southern flank of an 11m high east-west ridge just north of the point at which a small stream sinks. The cave entrance was noted by Donal Daly of the Geological Survey of Ireland some years ago and was explored and surveyed in September 2000 by the authors.

The original cave entrance was spacious - some 3m wide and 2m high but the farmer has walled in much of the opening and culverted the stream at the sink and entry is now via an easy squeeze and a 1m drop into a boulder-strewn chamber. The stream, small except following heavy rain, flows across the chamber and into a tunnel some 1m wide and 0.4m high trending almost due north. This streamway then bends to the right and has not been followed to a conclusion. The main route on is up a 1m climb into a dry passage which averages 1m x 1m for most of the remainder of the cave. The passage is floored by mud or degraded flowstone and the passage dimensions prior to infilling were probably at least 2m high and 3m wide. After 3m a low crawl is followed by roomier passage and then by a 1.5m muddy squeeze which was dug open. Beyond the squeeze the passage changes direction to run just south of east. A second even muddier excavated squeeze follows into a chamber and a cross-rift in which it is possible to stand. The passage ahead is blocked and the way to the left is sediment filled after 6m. The right hand passage leads through boulders to a rift which continues the original passage orientation of east-southeast before becoming blocked after 7m. A small stream crosses the passage at the beginning of this rift but it is not known whether it is the same stream as sinks at the entrance to the cave. The directions of almost all of the passages in the cave are controlled by one of two sets of joints as is apparent from the survey. However, the passages also seem to exhibit considerable lateral development (in the bedding?) though this part of the passage is largely infilled.

With a total surveyed length of 45.5m Pollawaddy becomes Roscommon's longest reported cave system, just ahead of Oweynagat near Rathcroghan to the southeast (Coleman 1965, Fenwick and Parkes 1997). Roscommon has an abundance of karstic features other than caves and the fact that only two caves are known within the county may be more a reflection of the lack of investigations rather than the true situation.

The cave is located in the Oakport Limestone Formation. This formation first outcrops to the east of Lough Key and takes its name from Oakport Townland, 7km to the east of Boyle. The outcrop then runs southwestwards in a band about 1.7km wide which is bounded to the northwest by the Kilbryan Limestone Formation and to the southeast by undifferentiated Visean limestones. Dips in the area are generally less than 10 degrees and the most significant structural feature affecting the Oakport Limestone Formation is a series of major faults with northeast-southwest or east-west trends. The Oakport Limestone Formation is a massive pale grey peloidal wackestone and grainstone limestone, generally shale-free, except for minor intervals of calcilutite and dark shale.

The resurgence of the cave stream is unknown but two major springs are known in the area. Some 2.5km to the northeast there is a spring on the banks of the Lung river near Bellanaheltia Bridge, whilst some 4.5km to the northeast is the spring of Pollaneghbrick close to the Roosky River. The water from a swallowhole at Corracoggil, 1km north of Pollawaddy, has been traced to both of these springs by the Geological Survey of Ireland.

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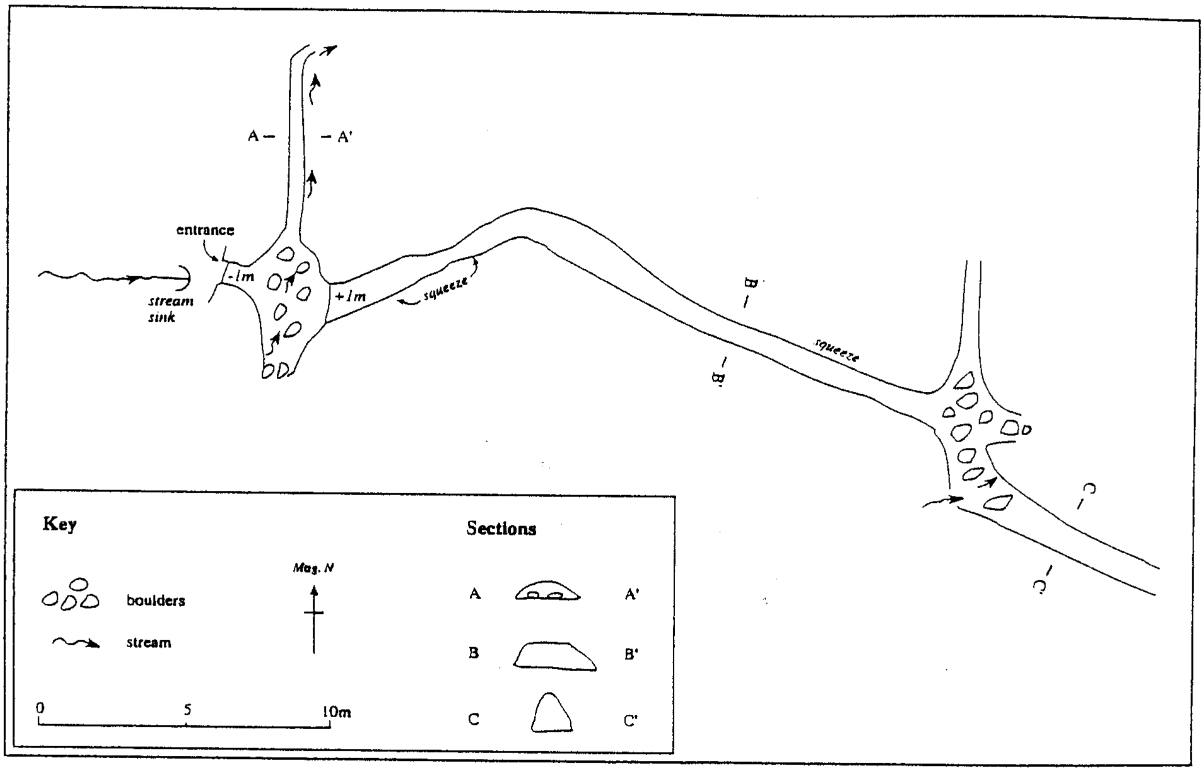

Figure 1 Plan survey of Pollawaddy Cave, Lisacul, Co. Roscommon. Surveyed by D. Drew and C. Hickey, September 2000.

Source: Article reproduced with permission from Irish Speleology 17*, November 2000.

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**Irish Speleology 17 is now available, though probably not from all good bookshops! Instead send a cheque or PO for £5 plus £1.20 postage and packing to the Editor, Matthew Parkes, Geological Survey of Ireland, Beggars Bush, Haddington Road, Dublin 4. Included in this issue are 7 papers representing the Proceedings of the Speleological Union of Ireland's Symposium held in May on Karst and Cave Conservation and Access. There are also exploration papers on important new discoveries in the Poulnagollum system, and Poulnagree in Co. Clare, as well as Pollnapaste in Co. Donegal. Research papers include one on caves in metamorphic limestones of the Dalradian Supergroup, and an analysis of the origin and occupation (by bears) of Poll na mBéar in Glenade.*

Gypsum Karst in Ireland

As described in the GSI Groundwater Newsletter, No. 36, gypsum (hydrated calcium sulphate) is about two orders of magnitude more soluble than limestone and hence gypsum karst landscapes are much more dynamic, in terms of their development, than those on limestone. However, in an Irish context gypsum karst forms only a minute proportion of the total karst encountered in this country since this mineral, and its anhydrous form Anhydrite, generally forms only a minor component of only a few localised sedimentary sequences in Ireland. There are only two significant occurrences of gypsum within the Irish sedimentary record, both within the Upper Palaeozoic. Gypsum also occurs on a very minor scale in the Upper Triassic Mercia Mudstone Group in north-east Ireland, where it is seen as thin (usually <2 cm) veins exposed on shore platforms. There is no evidence of significant karstification or karst-related collapse features associated with this Triassic gypsum. Another evaporite mineral, halite (sodium chloride), is a much more significant component of the Mercia Mudstone Group, particularly in the Larne-Islandmagee area, with deposits many tens of metres thick. However, the location of wet rockhead associated with these deposits, if indeed it exists, remains unclear and collapse features which have developed above the halite are demonstrably anthropogenic in origin.

Minor occurrences of gypsum/anhydrite have been reported from the Lower Carboniferous, particularly in the Meenymore Formation which extends across Fermanagh, Cavan, Sligo and Leitrim. Grennan (1992) reported up to three gypsum and/or anhydrite beds, with a combined thickness of more than 10 metres, in the Glangevlin area of Co. Cavan, to the north-east of Lough Allen. The presence locally of "boulders of gypsum" in the till to the west of Lough Allen (Wilkinson and Cruise 1886) demonstrates that gypsum in this area lies at or close to the surface and hence might be anticipated to experience karstification. Indeed, Grennan (1992) attributes the local absence of the Upper Gypsum Bed, and the occurrence of some brecciation, to dissolution where the gypsum lies at relatively shallow depth. However, whether this dissolution manifests itself at the surface as subsidence or collapse features has yet to be investigated.

The most extensive gypsum deposits in Ireland, and the only ones to have been investigated and exploited to any great extent, are those in the Kingscourt Outlier, straddling the Cavan-Monaghan border, whose geological context has been described by Gardiner and McArdle (1992). They occur in the lower part of a Permian mudstone-sandstone sequence and comprise two main units, with a combined thickness of 26-45 metres. The entire Permian succession here dips gently to the west and hence the gypsum beds might be anticipated to crop out, or be present at shallow depth, towards the eastern side of the basin and hence be susceptible to subaerial or shallow subsurface dissolution. Indeed, development of the Knocknacran open pit over the last decade has revealed substantial evidence of karstification in the past, although the extent to which it is occurring at the present day is unclear.

At Knocknacran the gypsum is associated with a substantial body of basaltic rock, of presumed Tertiary age, which has had a considerable influence on its karstification. Gardiner and McArdle (1992) noted that at its up-dip limit the Lower Gypsum Bed was apparently cut out by this igneous body. Simms (2000) interpreted this, and the highly irregular contact between the gypsum and the igneous body, as evidence for Tertiary dissolution and karstification of the gypsum at outcrop, with subsequent burial beneath subaerial, or subaqueous, lava flows preserving this palaeokarst surface. Gardiner and McArdle (1992) interpreted the irregular sub-basaltic surface on the gypsum as the result of 'doming' associated with volume changes in the hydration of anhydrite to gypsum. There is certainly some evidence for this (see their Plate 6, p. 307) but it is also clear that these domes experienced some karstification and dissection prior to basalt emplacement. The lack of post-burial modification of the palaeokarst suggests that it was effectively sealed by the thick, clay-rich altered basalt above through much of the ensuing Tertiary. However, the context of two distinct interglacial peat deposits discovered on the east side of the workings shows that dissolution of the gypsum had resumed by Pleistocene times. These peat deposits lie in a hollow in the gypsum at a point where the altered basalt cover has been breached, and are overlain by glacial till. Their configuration and relationship to the overlying till suggests that they occupy a subsidence doline which developed by subsurface dissolution of the gypsum beneath the peat bog prior to the last ice advance which emplaced the till above. The gypsum below these deposits, and at several other points on the north-east side of the workings where the gypsum is overlain directly by till and shallow dolines have developed, is in a collapsed and cavernous state suggesting currently active dissolution of the gypsum, although precise interpretation is complicated by the presence of old underground workings.

The development of these dolines is clear evidence of at least limited movement of groundwater downward through the gypsum, although this may not be as straightforward as it seems. It is thought that the gypsum originated as anhydrite, the anhydrous form of calcium sulphate, and the extent of subsequent hydration varies considerably across the basin (Gardiner and McArdle 1992). Dissolutional conduits, an essential requirement for the formation of dolines, can readily form in gypsum but not in anhydrite. There is a substantial volume increase associated with the hydration of anhydrite, such that any movement of water along fractures or conduits will cause self-sealing of those conduits. Gardiner and McArdle (1992) noted that it was the tops and bottoms of the evaporite units, adjacent to the mudstones, that had experienced the greatest degree of hydration. This implies groundwater movement along these boundaries and perhaps the removal of material in solution, although the associated hydration will have closed any conduits almost as fast as they developed. Another possible aspect of the influence of hydration on groundwater flow concerns the location of dolines above the gypsum at Knocknacran; these may have been controlled more by the areal distribution of extensively hydrated parts of the deposits than by the input points of surface drainage.

In conclusion, gypsum constitutes only a minute fraction of the karstifiable rock available in Ireland and, even then, shows little evidence of karst features. Those that have been documented are known only as a result of major excavations, and natural manifestations of gypsum karst at the surface have yet to be documented, if indeed they exist at all. Its implications for human activities would appear to be slight. The presence of karstified gypsum, and the organic material and siliciclastics commonly associated with karst subsidence, may affect the quarrying or mining of this material but there is no evidence of significant effects outside of this field of activity. The areas in which substantial gypsum, or anhydrite, deposits have been found are very largely overlain by agricultural land and are unlikely to pose any threat even where they occur at relatively shallow depth. However, considerable caution should be exercised when considering industrial or housing developments proposed for areas where gypsum occurs at shallow depth since deliberate or inadvertent changes to surface or underground drainage may have unforeseen consequences for gypsum dissolution which, since it occurs at such a rapid rate, may have significant implications for subsidence.

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A Discussion of Sustainable Sewage

Abstract
The problems attendant on the current treatment of wastewater are discussed in the context of global urbanisation and centralisation. Areas of particular concern are identified and the concept of sustainable sewage treatment developed. In particular, the need to develop a global plan which is easily implemented at a local level, is stressed. Difficulties with implementing environmentally sustainable wastewater treatments are discussed, emphasising the importance of public perceptions. Problems with the Irish Government's current attitudes to wastewater treatment are highlighted and more environmentally sustainable treatments proposed. Conclusions are drawn on the problems inherent in any drive towards sustainability.

What is the situation today?
Today's society is eminently unsustainable, the desire for success and wealth is driving people from rural areas to ever expanding cities. These cities produce large concentrations of human wastes of every kind: wastewater, solid waste, industrial by-products and transport pollution. First world countries are coping with many of these wastes by collecting them, processing them and then removing them from the confines of the city.

Rural communities are then having to cope with these wastes in the form of landspreading and landfills. Populations of a different kind are becoming concentrated in rural areas, where large animal concentrations produce wastes that need to be removed from these intensive units and disposed of. There is an overall move towards centralisation, with large populations of humans and animals separated from their food sources and vast areas of monocultural farmland separated from its nutrient sources. These nutrients are not unlimited and if they are discharged to water rather than being recycled they may become a limiting factor for agriculture (Otterpohl *et al.* 1997). The environmental cost of this unsustainable lifestyle is already being felt globally. The economic cost is increasing steadily, with subsidies required to keep farmers in business (e.g. the EU C.A.P. and similar subsidies in the U.S.A) and increasing costs for local authorities for waste disposal. Until this economic cost becomes prohibitive it is unlikely that public perceptions will be sufficiently changed to enable more widespread sustainability. The baseline is that monocultures tend to be unhealthy and unstable whether they are cities full of people, barns crammed with hens or large areas of wheat. They tend to concentrate and intensify environmental problems to the point where large scale, expensive remedies are required.

What can be done?
In the long term the development of ever more high-tech remedies, which can themselves cause problems, may not be the answer. For a treatment to be truly sustainable it must be able to operate without an ever increasing demand for resources such as electrical power (Larsen and Gujer, 1997) as this only causes pollution problems somewhere else. Sustainable sanitation must be low tech and robust, with an emphasis on local solutions to local problems. This means that people can no longer just flush the problem down the toilet and forget about it. Within cities numerous, small and easily managed operations may be far more sustainable than a few, larger, more expensive ones.

What is sustainable sanitation?
Sustainability in wastewater treatment cannot be mistaken for a slow improvement in conventional technology. It must mean a global shift towards the reintroduction of human activities into natural cycles rather than the steady removal of resources from land and their concentration in water as pollutants. This reintroduction process must be energy efficient and must not simply transfer the problem to a different time or place (Otterpohl *et al.* 1997). If this global aim is to succeed, it must be clearly outlined at a local level. People will be unsympathetic when confronted with the enormity of global problems, unless achievable and easily understandable action plans are presented to them which do not radically curtail their lifestyles in terms of costs and restrictions. The global aim must be achieved by locally adapted policies based on factors such as population density, lifestyle and wealth.

What is wrong with our current system?
1) Conventional wastewater treatment does not tie in to any natural cycle, instead it is a one way stream of nutrients and BOD being released into our waterways. Conventional farming does not form a cycle either, it requires the expensive production of artificial fertilisers to replace nutrients being lost by intensive grazing and runoff. These nutrients are finite and could become limiting in the future.

2) Conventional urban treatment combines all human wastes together: urine, faeces, sullage, urban runoff and sometimes industrial wastes. This combination waste is hard to treat effectively. Often important components required for efficient biological treatment are so dilute that they need to be added. Urine, the most nutrient rich component, is diluted until it is unsuitable for farm usage. Sewage sludge, the component which will now have to be landfilled, has less nutrients than urine and a high concentration of metals from the pipe network and from road runoff. The resultant wastewater contains too few nutrients for fertiliser use, but too many for continued addition to waterways. As legislation tightens on permitted nutrient levels in treatment plant effluent, more and more expensive processes will be required to remove these nutrients.

3) Urban wastewater treatment is centralised and consists of a few large plants fed by a high maintenance network of sewers. This serves to concentrate the discharged effluent to a few, high volume, points around the city.

4) Conventional treatment, such as activated sludge requires energy input and intensive maintenance.

5) Conventional rural wastewater treatment in Ireland relies heavily on septic tanks. Again, all the wastes from the house are combined. The septic tank system operates as a means of disposing of the nutrients rather than reusing them. The reliance on groundwater for drinking water creates a conflict between using groundwater as both a sink and a source, this has health implications.

6) Conventional wastewater treatment relies largely on water to dilute and disperse the effluent. The small amount of freshwater on the planet is placed under threat by this.

What is meant by sustainability?
Human expansion and environmental conservation are not compatible. In this sense, sustainability is currently an impossible aim, i.e. any solution has to be a compromise between human habitation and environmental sustainability.

Applying this to a concept of sustainable sewage:

- Changes to conventional sewage treatment methods will only be made when the alternatives are more economical and the conventional methods become financially unfeasible.
- In urban areas at least, a radical new system cannot be readily implemented since a sewerage network already exists.
- The populations of developed countries regard sewage as an unpleasant wasteproduct which must be disposed of rather than a potential source of nutrients and energy. (Literature on sustainable sewage seems difficult to obtain, tending to bear this out). If efficient use of sewage is to be made, these preconceptions need to be changed.
- The concept of sustainability is difficult to translate into policy since it does not become generally obvious that an activity is unsustainable until it fails. Thus, planners and politicians can argue that current methods of wastewater treatment in Ireland are sustainable since no major problems have arisen to date.
- Sustainability must not just be applied to the environment. e.g. a treatment method may be devised which prevents any degradation of the local environment but which fails since its costs continue to be prohibitive (economically unsustainable) or it restricts the human population too severely (politically unsustainable).

What would sustainable sewage involve?
If the conclusion that conventional sewage treatment is unsustainable is accepted, alternatives need to be examined. Although it is difficult to assess the long term sustainability of any single method or to quantitatively compare different methods (Chen and Beck, 1997) a sustainable sewage system should address the following issues:

1) The separation of the different types of wastewater since treating them together is proving a difficult and costly process. The idea of separating wastewaters is particularly attractive in the case of urine since it contains the greatest concentrations of N, P and K and is relatively free of pathogens (Larsen and Gujer 1997). Urine separation does not necessarily involve installing a separate urban sewage system. Instead, Larsen and Gujer suggest urine could be cheaply separated from other wastes by disposing of it at a certain, prescribed time of the day, when no other wastes were permitted to enter the sewers (obviously this would involve a great deal of public understanding and cooperation). Although this method involves the least expense it is unlikely to be socially sustainable. This method may be environmentally sustainable but could fail because it is likely to be socially unacceptable. Where urine could be

separated it would have a variety of uses:

- Addition to either private or municipal compost heaps as an activator (this method is already popular among organic gardeners).
- Transport to farms to be used as a liquid fertiliser.
- Addition to conventional treatment plants in order to optimise nitrification. This would remove the need to add artificial nutrients where the wastewater is too dilute (Larsen and Gujer 1997).

The separation of road runoff is also desirable in the urban setting. This runoff contributes much of the hydrocarbons and heavy metals present in municipal wastewater. A separate runoff system could be constructed to transport this and household "grey water" (water from sinks and baths etc.) to a separate treatment facility, possibly a non-conventional facility such as a constructed wetland environment. A controlled amount of urine could be added to this "grey water" to improve its nutrient content. Soil organic matter would serve to bind heavy metal content. These ideas obviously need much further work, which is not attempted in this essay. In drier urban areas this "grey water" could be recycled for cleaning streets, washing cars etc.

2) The remaining faeces component of sewage would contain a high proportion of solids (water used for toilet flushing would provide some dilution). This would be relatively free from heavy metals and could be dealt with in a combined organic solid waste and sewage treatment plant (Jeffrey, unpublished). This plant would anaerobically digest the sewage sludge to produce methane, this could then be used as a fuel source for the plant and elsewhere if possible. The resultant sludge could then be composted with organic solid wastes before being used as a soil improving compost by farmers (the organic fraction would be particularly useful for the binding of nutrients in the soil, preventing leaching to water).

What is the current situation in Ireland?

Only 14% of waste water arisings above the 2000 person equivalent are currently connected to secondary treatment plants. Only 4% of overall arisings throughout the country are connected to a treatment plant. The treatment plant in Dublin is currently only for primary treatment (Article 17, 1995). Existing treatment facilities will need to be extended and new plants built, particularly in coastal areas since 80% of sewage waste loads discharge to the marine environment. In Ireland, 10 sensitive areas have been identified under the terms of Article 5 of the Wastewater Treatment Directive, they comprise 4 lakes and 6 stretches of river where the discharge of wastewater is causing problems. By 2005 it is expected that urban wastewater treatment facilities in Ireland will produce approx. 113 000 tonnes of sewage sludge, this is 3 times that produced in 1992. Now that dumping sewage sludge at sea is no longer permitted (Article 17, 1995) a disposal problem exists. However, sustainability does not seem to have been identified as an aim for Irish wastewater treatment. In the many documents produced by the Department of the Environment on the topic of sustainability, none addresses the issue of sewage. In the 1995 Department of the Environment publication "Moving Towards Sustainability" sewage treatment is not given a separate chapter but is briefly mentioned in chapters on inland waters and the marine environment. The emphasis of the report is on the elimination of pollution to water by construction and adaptation of wastewater treatment plants to provide secondary treatment (and phosphorus removal when discharging to rivers and lakes) and to end sludge dumping at sea. These are engineering solutions to the problems and the report stresses the large amount of money being invested in these areas. It seems that conventional treatments are being accepted as a matter of course and no reevaluation of the situation is deemed necessary (DOE, 1995).

The Irish government regards the weaknesses in sewage services to be due to a lack of sewerage systems and the proliferation of septic tanks (DOE, 1990). It is true that septic tanks are a pollution issue, the percolation areas attached to them can and do cause problems for ground and surface water contamination. However, it is not always cost effective and sustainable to install sewerage systems that treat multiple source waste at a central plant, particularly in low population density rural areas. The emphasis, rather, should be on effectively improving the on-site wastewater treatment facilities. This may involve variations on the septic tank, such as constructed wetlands receiving the liquid fraction. It may involve alternatives to septic tanks such as biofilm aerated filters or rotated biological contactor (EPA 1998). Unfortunately both these methods require an energy input, making them less desirable. The most environmentally sustainable option of composting the sludge fraction with kitchen and garden waste prior to use on the land would probably meet with the most public opposition. A compromise where sludge from single sources was collected and centrally composted or anaerobically digested (with energy recovery) may be the best solution.

Conclusions

In constructing a plan for sustainable sewage treatment it must be remembered that there are a number of inherent problems:

- There is no way of gauging whether an activity is sustainable in the long term, until it is too late.
- Populations will be unwilling to change their way of dealing with sewage until a crisis stage is reached.
- Sewage treatment methods may be thought to be environmentally sound but may fail socially.
- Governments are often complacent that financial and engineering solutions can be successfully applied to problems of sewage treatment and water pollution.
- In developed countries, nutrients are not properly cycled, resulting in both problems of water pollution and a need to produce artificial fertilisers for agriculture.

An understanding is required that the entire method of collecting and treating wastewater needs to be reviewed and that any solution will have to be a compromise between environmental degradation and human development. Local solutions to local problems are required with individuals and local groups/governments taking responsibility for their own wastewater and treating it in the most acceptable way for their area. However, this has to be undertaken within more regional, national and global frameworks with an understanding that wastewater need not be waste but is part of the biological cycle.

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Ruth Buckley, Environmental Sciences Unit, TCD

Preliminary results from the investigation of radon levels in the groundwater of the St Petersburg Region.

Recently the Irish Group of Hydrogeologists assisted the Department of Hydrogeology of St. Petersburg University to purchase radiometric equipment for measuring groundwater radioactivity. The radon content of groundwater in the St. Petersburg Region has now been examined for several months. This article outlines the main results of the survey.

So far about a hundred groundwater samples have been tested from the main aquifers in the Region. Radon was detected in fifty of them. New data were also obtained on radium and helium levels. A full chemical analysis of sixty groundwater samples was carried out. Uranium was detected in a number of samples of rock and groundwater.

St. Petersburg is situated on the northwestern edge of the Russian Platform, which is of Archaean and Proterozoic age. The geological succession in the St. Petersburg Region comprises Precambrian, Cambrian, Ordovician and Devonian rocks overlain by Quaternary sediments.

The crystalline basement in the St. Petersburg Region is near the surface only in the northern part of the Karelian Isthmus, dipping steadily southwards to reach a depth of hundreds of metres below surface. Many of these rocks are granite. The upper part of the basement rocks contain fissured water, which is sufficient for local water supplies.

The 150 metre thick Precambrian Vendian sandstone rests on the irregular surface of the crystalline basement. It is the formation, which contains the Lower-Kotlin or Gdov aquifer. This aquifer is very well protected from surface contamination by the overlying thick Upper-Kotlin clay. The Gdov aquifer is widely used for water supply purposes and as a source for bottled water. In the St. Petersburg Region it lies at a depth of 100-150 metres before sinking southwards to greater depths.

The Ordovician limestone, which is one of the most important aquifers in the region, lies to the south of St. Petersburg. Known as the Izhora aquifer, it has an area of 3000 km^2 and supplies potable water to the southern districts of St. Petersburg. The Izhora aquifer thins northwards and is just 10-15 metres thick on the northern side of the Izhora Plateau, where it stands out as a distinct horizon. Unfortunately, this aquifer is greatly fractured, and having only a thin cover of Glacial deposits is vulnerable to surface pollution. A thin layer of uranium-rich Dictyonema shale underlies the aquifer.

The Cambrian-Ordovician aquifer is sandstone, while the Devonian rocks are mainly sandstones with some limestones.

The overlying Glacial sediments vary between gravel, sand and clay. They form both confined and unconfined aquifers and are used only as sources of local water supplies.

The recently obtained radioactive data allows a preliminary general classification of the aquifers of the St. Petersburg Region based on their radon content. This is of particular practical importance at present because new State Standards for drinking water came into force in 1999. Results to date show that in the St. Petersburg Region the radon levels in groundwater range from 4 to 1700 Bq/l.

The initial figures for the range of radon levels in the main aquifers, listed in order of age, may be summarised as follows:

Aquifer	**Bq/l**
Basement aquifer	100-400
Gdov aquifer	80-180
Cambrian – Ordovician aquifer	300-400
Izhora aquifer	50-100
Devonian aquifer	10-50
Quaternary aquifer	5-10

Among the hazardous areas so far discovered is the northern part of the Karelian Isthmus. High concentrations of radioactive elements have been recorded there as a result of the crystalline basement being close to the surface. The groundwater is enriched in radium and radon.

Another part of the Karelian Isthmus, where the Gdov aquifer overlies the crystalline basement, has also been shown as being hazardous. Again the groundwater is high in both radium and radon. In this case the matter is particularly serious since the Gdov aquifer is being extensively used for regional water supply and as a source for bottled water.

A third area of dangerously high radioactivity has been located along the contact between the Ordovician rocks and the Dictyonema shales. A spectacular example of radon-rich water in this area is Lopukhinka Lake, where the radon content reaches 400Bq/l. Many other interesting sites have been discovered and await further investigation.

The results obtained so far also indicate new uses to which the study of radon levels in groundwater can be put to assist in identifying areas where the population is at risk from radioactive contamination. The investigation of radon in groundwater is of such importance because the prolonged use of radon-rich water is suspected of posing a significant cancer risk for humans. Detailed study of the groundwater of the fractured upper zone of the crystalline basement is necessary and especially the Gdov aquifer, in view of its present widespread use for human consumption.

Study of the radon levels in groundwater also provides new opportunities for helping determine groundwater flow, e.g. indicating zones of groundwater discharge. This is of practical value in the case of the Baltic Sea and especially the Gulf of Finland. Contamination in the Gulf of Finland is on a regional scale and the interaction between surface and groundwater is complex, especially in the northern part of the Gulf.

Several papers and a short brochure entitled “Radon in water as an environmental hazard” have been produced as a result of this project. Reports have also been presented at international meetings. Plans for further investigations and the formulations of proposed remedial measures are underway.

A special international seminar “Radon, Helium and Other Radiogenic Components in Natural Water: Environmental Aspects” was held in St. Petersburg in June 2000. The preliminary results of the investigations were presented during the seminar and were received with much interest by the attending national and international scientists. The annual meeting of the IAH Mineral and Thermal Water Commission will take place in St. Petersburg University from September 24-30, 2001. The health aspects of water will receive special attention.

The current research on the radioactive components in natural waters being carried out in St. Petersburg University provides an opportunity for further Russian-Irish cooperation in the fields of hydrogeology and environmental science. Problems relating to radon are of importance in Ireland as well as in Russia. One way forward would be the development of a joint research project. Those interested are welcome to contact me at my email address arkad@AV3011.spb.edu

Prof. A.N. Voronov, Dept of Hydrogeology, St. Petersburg University

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IAH (Irish Group) News

IAH (Irish Group) and Teagasc Seminar on "Groundwater & Agricultural Practices", Johnstown Castle, Wexford, 22nd & 23rd September 2000.

A joint IAH (Irish Group) and Teagasc seminar entitled "Groundwater & Agricultural Practices" was held at Johnstown Castle, Wexford on the 22nd and 23rd September 2000. The objective of the course was to review agricultural practices and topics relevant to hydrogeology, for example, landspreading of manures and nitrate issues. The event was well attended with 44 delegates representing the Geological Survey of Ireland, the Environmental Protection Agency, Teagasc, Trinity College and various hydrogeological and engineering consultancies, registering for the first day.

Following the welcoming address by John Lee, Head of Research at Teagasc, Sean O'Regan, Teagasc Chief Environmental Advisor, spoke about farmyard pollution and grant aid to farmers to reduce pollution. After this presentation the remainder of the first day of the seminar was spent in the field visiting the various Teagasc experimental facilities. The field based activities were led by Owen Carton and other Teagasc personnel.

The first stop was a demonstration of landspreading where the traditional splash plate spreading technique was compared with the more recent band spreading method. Owen Carton explained that 50-60% nitrogen is lost to the atmosphere using the splash plate technique but only 20-40% is lost with the band spread methodology. Odour from landspreading is also reduced with the band spread technique. Consequently, band spreading is the preferred landspreading method.

Aidan Fanning described a lysimeter experiment to examine nitrate leaching in five different soil types which represent the principal soils in the country. Following this presentation, the group visited a milking parlour with Willie Murphy at the Teagasc Dairy Farm and examined dirty water control and spreading of dirty water.

After lunch Sean Diamond described soil moisture measurements using tensiometers with data loggers. Sean also explained the measurement of infiltration rates using double ring infiltrometers. The group then visited the Teagasc Organic Farm where Noel Culleton hosted a discussion on organic farming and constructed wetlands. At the next site Pamela Bartley described her research on nitrate leaching to groundwater from grasslands. Results to date suggest acceptable nitrate levels in the groundwater resources underlying the application areas. The final stop of the day was a demonstration of describing subsoils using the BS5930 standard by Vincent Fitzsimons and Melissa Swartz of the Geological Survey of Ireland.

A presentation session was held on the second day in the EPA lecture theatre with speakers from Teagasc, EPA and the IAH. Donal Daly of the GSI discussed groundwater vulnerability and protection issues followed by a presentation on soil hydrology and soil water regimes by Sean Diamond of Teagasc. Dave McGrath of Teagasc spoke about pesticides in Irish soils and Karl Richards of the EPA discussed agricultural nitrate and phosphorus in the environment.

The second half of the presentation session focused on landspreading issues. Vera Power of the EPA discussed the evaluation of groundwater protection assessment for landspreading from the EPA's perspective. The preparation of Environmental Impact Statements for landspreading proposals was discussed by Mark Conroy of Tobin Environmental Services and Donal Marron of K.T. Cullen & Co. Mark focused on the hydrogeological and hydrological assessment of organic waste landbanks and Donal discussed nutrient management plans for landspreading of waste.

The presentation session provided an excellent forum for discussion of the relevant issues raised during the two-day seminar. The IAH would like to thank all of the speakers and the Teagasc personnel who described the various research experiments at Johnstown Castle, especially Owen Carton who led the field activities. We also thank all the delegates who attended the seminar and Teagasc and the EPA for hosting the event.

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Technical Discussion Meetings : Programme for early 2001

9th January **Groundwater Control for Quarry & Mine Developments** by Tim Paul and Shane O'Neill.

6th February **The David Burdon Memorial Lecture** will be given by Dr. Stephen Foster former Assistant Director with the British Geological Survey. The title is "Groundwater Resources for a Thirsty World – some key issues for the 21st Century". **This year the IAH Irish Group celebrates its 25th Anniversary: details of the evenings celebrations will be forwarded to members closer to the date.**

6th March **The Younger Hydrogeologists Forum**

These lectures will take place at the GSI Lecture Theatre. They start at 18:00 hrs, with tea/coffee served at 17:30 hrs. For further information contact either Donal Daly (01- 604 1490) or Kevin Cullen (01 – 294 1717).

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Annual Seminar

The annual seminar will be held on 24th and 25th of April 2001 in the **Hodson Bay Hotel** in **Athlone**. **Please note the change from the usual venue**. The theme is "Gravel Aquifers – investigation, development and protection". Further details will be circulated.

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New Committee

The IAH (Irish Group) held its AGM on 14th November 1999. After three dedicated years, Geoff Wright (President), Margaret Keegan (Treasurer) and Shane Bennet (Conference Secretary) have stepped down from their posts. The IAH would like to take this opportunity to thank Geoff, Margaret and Shane for all their hard work. Catherine Coxon (Trinity College Dublin) was voted in as President; Kevin Forde (Dames and Moore) as Treasurer and Malcolm Doak (EPA) as Conference Secretary. Anita Furey (KT Cullen's) and Morgan Burke (Minerex Environmental) remain on as Secretary and Fieldtrip Secretary respectively. The current committee now comprises:

President Catherine Coxon (cecoxon@tcd.ie)
Secretary Anita Furey (afurey@ktcullen.ie)
Treasurer Kevin Forde (kevin_forde@urscorp.com)
Conference Secretary Malcolm Doak (m.doak@epa.ie)
Fieldtrip Secretary Morgan Burke (mburke@minerex.iol.ie)

Please feel free to contact any committee member with your comments or queries.

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IAH on the Net

In 2001, the IAH Irish Group will have its own web-site. In the mean time, the main International Association of Hydrogeologists web site can be accessed at http://www.iah.org.

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

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IAH Congress in Munich, Germany, 10th to 14th September 2001

The next IAH Congress is due to be held in Munich, Germany in 2001. The topic is "New Approaches to characterising groundwater flow". The primary aim of the conference is to create an interdisciplinary forum for presentations of the most recent advances in groundwater research with a special focus on selected key issues. For further information contact Interplan, Congress, Meeting and Event Management, Tel: 00-49-89-548234-0 or email: IAH@i-plan.de

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Finally, the IAH committee would like to take this opportunity to wish all its members a happy and prosperous New Year.

Anita Furey, IAH Secretary (Irish Group) and Morgan Burke, Fieldtrip Secretary.

New Book: Groundwater in the Celtic Regions[1]

This publication represents the first attempt to bring together the hydrogeological issues facing the Celtic regions of Britain and Ireland. Although aquifer units are often relatively small and complex, groundwater has been important in the Celtic regions for thousands of years. As Professor Ó Dochartaigh notes in his introduction, many of the myths, religious beliefs and place names of this culture are associated with water. Indeed, Professor Ó Dochartaigh goes on to advocate that 'Although hydrogeologists have an interest in wells and springs for their own purposes, any survey of such sources should include not only the necessary scientific analysis, but also record any local names given to wells or springs. Such language data would potentially serve to enhance relationships between the [humanities and sciences], and perhaps allow us to extend our understanding of the historical continuity of relationships between the Celts and their water sources'.

As well as their common history, this volume emphasises the shared environmental heritage of the Celtic regions. Important issues include the dominance of fracture-flow in the bedrock aquifers, groundwater protection, pollution from point and diffuse sources, water management in karst aquifers, the hydrogeological significance of glacial deposits and groundwater evaluation in areas for which there is comparatively little information available. The book is divided into seven sections:

- The Celtic peoples and groundwater
- Groundwater and the environment
- Groundwater protection
- Groundwater management and protection in karst aquifers
- Quaternary aquifers: resource evaluation and development
- Groundwater evaluation in data-scarce aquifers
- Groundwater supplies to island communities.

There are 21 papers in total, and authors from Ireland include Steven Barnes, Catherine Coxon, Donal Daly, Jenny Deakin, David Drew, Gavin McNeill, Bruce Misstear and Geoff Wright. The book is published in December 2000.

[1]*Groundwater in the Celtic regions: studies in hard-rock and Quaternary hydrogeology. Nick Robins & Bruce Misstear (Editors), Geological Society, London, Special Publication 182, 288 pages. List price £70, but there is a special offer price of £32 at present. Fax: +44 1225 442836. Online bookshop: http://bookshop.geolsoc.org.uk*

Bruce Misstear, Department of Civil, Structural & Environmental Engineering, Trinity College Dublin

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CONTRIBUTIONS FOR THE NEXT ISSUE OF THE NEWSLETTER

Contributions for the next issue should arrive before 1st April 2001 to:

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

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