ISSN 0790 - 7753

THE GSI GROUNDWATER NEWSLETTER

NUACHTÁN SCREAMHUISCE SGÉ

- Exploration
- Development
- Management
- Quality
- Pollution
- Reviews
- News from abroad
- Opinion Forum

- Taiscéalaíocht
- Forbairt
- Bainistíocht
- Cáilíocht
- Truailliú
- Athbhreithniú
- Nuacht idirnáisiúnta
- Tuairimí

Published by the Geological Survey of Ireland
Beggars Bush, Haddington Road,
Dublin 4.
Tel: (01) 678 2811 Fax: (01) 678 2569

Foilsithe ag an Suirbhéireacht Gheolaíochta Éireann
Tor an Bhacaigh, Bóthar Hadington,
Baile Átha Cliath 4
Tel: (01) 678 2811 Fax: (01) 678 2569

Edited by: Donal Daly

No. 25 July 1994

IN THIS ISSUE

The term "**aquifer**" is one of the most used and basic terms among hydrogeologists and increasingly among water supply engineers. Yet it is a term that is imprecise in general usage. An important function of the GSI is to produce aquifer maps of the country. As a consequence, following consultation with groundwater scientists in the third level colleges and the private sector, the GSI has produced **general guidelines on aquifer definition** (page 2); guidelines that take account of the hydrogeological and groundwater development situations in Ireland, and which will be used as a basic component of groundwater protection schemes.

Vulnerability maps are now becoming an essential part of groundwater protection schemes and a valuable tool in environmental management. They are a means of presenting various, sometimes complex, hydrogeological parameters in the form of an easily understood term "**vulnerability**". However, examination of existing vulnerability maps and descriptions of vulnerability in the scientific literature shows considerable variation in the definition and the usage of the vulnerability concept. The GSI is now incorporating vulnerability maps into groundwater protection schemes. Suggested **guidelines on groundwater vulnerability mapping**, suitable for the Irish situation, are given on pages 10 to 15. This article is longer than the usual Newsletter article and is intended mainly for hydrogeologists. A quick overview of the vulnerability categories can be obtained from the table on page 12.

The market for **bottled water** has grown from virtually nothing in 1982 to 22 million litres in 1993. Shane O Neill, in two articles on pages 16 and 20, reviews the **legislative framework** for bottled water and tap water and considers the **protection** of a mineral water source.

Regional groundwater quality monitoring had not existed in the Republic of Ireland until the establishment recently of a network in the south-east of Ireland by the Regional Water Laboratory, Kilkenny. Two articles (pages 3 and 4) by Jer Keohane and Caroline Bowden summarise the situation. On page 6, Tony Cawley gives an overview of **water balance** studies in Ireland.

This **Newsletter** is two months late; it is intended to publish the next issue in three months time rather than the normal four. Consequently, articles for the next issue should reach me before **15th September**.

Editor

GENERAL GUIDELINES ON AQUIFER DEFINITION

Aquifers are usually defined as "rocks that contain sufficient voids to store water and are permeable enough to allow water to flow through them in significant quantities". The problem with this and all definitions of an aquifer is the qualitative nature of "significant" or other similar terms. A rock capable of giving enough for a house (20m^3/d) is an aquifer for the householder but is not adequate for a local authority supply. In order to clarify the situation, the GSI has categorised both sand/gravel and bedrock aquifers as shown in the following table.

SAND AND GRAVEL AQUIFERS
(i.e. Intergranular Flow Aquifers)

Two Categories

1. **Extensive** > 25 km^2
2. **Local** < 25 km^2

BEDROCK AQUIFERS
(i.e. Fissure Flow Aquifers)

Three Categories

1. **Regionally Important** (or Major)
   Two subdivisions:
   (i) Karstified areas (where conduit flow is dominant)
   (ii) Fractured areas

2. **Locally Important** (or Minor)
   Two subdivisions:
   (i) Generally Moderately Productive
   (ii) Generally Unproductive except for Local Zones

3. **Poor**
   This might be subdivided into:
   (i) Generally Unproductive except for Local Zones
   (ii) Generally Unproductive

In defining the bedrock aquifers, some and preferably all of the following (somewhat arbitrary) quantitative characteristics should be used: areal extent, well yield, specific capacity, throughput/baseflow.

	Regionally Important	**Locally Important**	**Poor**
Areal Extent (km^2)	> 25	-	-
Spring Lowflow (m^3/d)	> 4000		
Well Yield (m^3/d)	> 400	100 - 400	< 100
Specific Cap. (m^3/d/m)	> 40	10 - 40	<10
Throughput (Mm^3/d)	> 8	-	-
(based largely on the views of Eugene Daly, GSI.)			

The three main bedrock aquifer categories - **regionally important, locally important and poor** - are based on groundwater resources potential, which is indicated by areal extent, spring baseflows, well yield, specific capacity and groundwater throughput. It would be preferable to use permeability, transmissivity and specific yield values in defining aquifers, however this information is not generally available. Each of these categories is subdivided to illustrate significant variations in the hydrogeology.

The presence of **karstification** is an important feature in areas of **regionally important aquifers**; a feature that, if possible, should be shown on aquifer maps. It can indicate short groundwater travel time (high velocities), variability in well yields and vulnerability to pollution. For confined bedrock (usually sandstone) aquifers, the depth at which the top of the aquifer is 150m b.g.l. should be indicated on the aquifer map, if possible, as this is the general practical limit for groundwater development.

The **locally important aquifers** are subdivided into two categories: i) **generally moderately productive** and ii) **generally unproductive except for local zones**. The intention of this subdivision is to enable rocks with a moderate permeability and groundwater throughput to be distinguished from these with a low permeability overall and low groundwater throughput but with high permeability zones; zones that can supply a significant number of local authority and group scheme sources. In the latter case, storage is often augmented by the overlying subsoils.

Poor aquifers are subdivided into i) **generally unproductive** and ii) **generally unproductive except for local zones** to distinguish between rocks that are likely to either have or not have moderate permeability zones. This category includes rocks which would not normally fall within the scientific definition of an aquifer.

These subdivisions are important not just in indicating the potential for locating groundwater sources but also in assessing pollution risk and the measures and restrictions required when locating potentially polluting developments. So, for instance, the risk to groundwater from locating a landfill site on a "locally important aquifer that is generally productive" is greater than on the same category aquifer that is "generally unproductive except for local zones". As a consequence, the restriction required should differ in each situation.

The distinction between "**locally important aquifers** that are generally unproductive except for local zones" and "**poor aquifers** that are generally unproductive except for local zones" is not clear-cut. Where the information is available, it will be based on the magnitude of well yields and the probability of achieving these yields. In practice, it will often be influenced by the number of public supply wells in each zone and the views of the local authority. Consequently, this difference will depend both on hydrogeological and pragmatic considerations.

On reading this article you may feel that the terminology used is long-winded and somewhat of a "mouthful". However, it has the benefit of using simple language and of providing information at a glance.

It could be argued that there are too many bedrock aquifer subdivisions - a total of six. However, they allow the groundwater flow situation to be readily conceptualised. The relevance of the classification proposed here will become more clear as the new phase of groundwater protection schemes is being produced.

Feedback and alternative suggestions on these proposed definitions and terminology would be greatly welcomed by the GSI.

Donal Daly, Geological Survey of Ireland.

GROUNDWATER MONITORING AND USE OF GIS:

An EC funded (STRIDE) groundwater project has recently been completed at the Regional Water Laboratory in Kilkenny. The project was titled "The establishment of a groundwater database for the Southeast Region of Ireland" and ran from January 1993 to January 1994. For the purposes of this study the Southeast Region comprises counties Carlow, Kilkenny, Tipperary SR, Tipperary NR, Waterford and Wexford. The project comprised two constituent parts which were fully interdependent: (i) the establishment of a groundwater quality monitoring network, and (ii) the establishment of a GIS system.

For the monitoring network 125 points were selected. As far as possible, these comprised high yielding springs or boreholes used for public or industrial supply. Each point was visited to assess the location, topography, landuse and surface drainage characteristics of the point. In addition, possible sources of pollution, which might affect the source, were identified. Where available, constructional details of boreholes were collected. The points were sampled on two occasions during 1993 and analysed at the Regional Water Laboratory, Kilkenny.

A GIS system (ARCcad) was purchased and time was spent installing the system, customising the software and carrying out an evaluation of the GIS system.

The lack of constructional details on many of the boreholes is identified as a major deficiency in the monitoring network. Details of depth to rock, casing lengths, geological logs, well test details are as important as analyses in a groundwater database and an improvement in the collection of such data should be an aim of all involved in groundwater. A borehole is an engineering structure which should be designed, detailed and maintained as other structures are.

It is not intended to detail the results of analyses in this article and only general comments are made below. (If required, copies of the analyses are available from the Regional Water Laboratory). Generally the quality of groundwater in the Southeast Region is good and exceedances of the EC drinking water standards are rare. However human influence (which includes domestic, agricultural and industrial practices) on the groundwater environment is substantial and highlights the importance of groundwater protection schemes.

An evaluation of the usefulness of GIS was part of the study and a procedures manual for the use of the GIS system was prepared which includes a guide to the production of digital maps on AutoCad (jointly prepared by the GSI and Regional Water Laboratory).

Due to the complexity of Irish hydrogeology and the lack of information, it was concluded that the use of GIS is limited at present. As a visual presentation tool GIS is excellent but we would urge caution on the extended use of GIS spatial analysis operations because of the limits of the available data.

The project used a logical approach to the establishment of a monitoring network, which it is hoped will form the basis for the establishment of a national groundwater monitoring network. It is hope to further develop the database facilities of the GIS system and to use the display and query features more. The EPA also intend to broaden the application of the GIS system to surface water and air in the near future.

Valuable assistance and co-operation were obtained from the Geological Survey of Ireland and the local authorities in the establishment of the monitoring network and from Teagasc on the establishment of the GIS system.

Jer Keohane*, Regional Water Laboratory Kilkenny.
*(*now a hydrogeological and geotechnical consultant.)*

HEAVY METALS IN WATER

A second STRIDE project was also undertaken at the same time at the Regional Water Laboratory, Kilkenny. This project was entitled "A Study of Heavy Metals in the Natural Environment in Proposed Mining Areas". This project was concerned with the metals content of ground and surface water in the South-east Region.

Ore bodies containing substantial deposits of lead and zinc ores have been located at Galmoy, Co. Kilkenny and Lisheen, Co.Tipperary NR. It is thought that between the two deposits, there are over 20 million tonnes of mineable lead and zinc bearing ore. Because of the potential pollution problems associated with any large mining development, it is important to closely monitor metal levels in ground and surface water and compare these to background levels. Prior to this project, very little data was available for metals levels in ground and surface water in the region.

The metals which were analysed were Sodium, Potassium, Magnesium, Iron, Manganese, Zinc, Lead, Copper, Cadmium, Chromium, Nickel, Antimony, Aluminium and Barium. Surface waters from rivers adjacent to the proposed mines were sampled regularly during 1993, other surface waters and groundwaters were also monitored.

No significant contamination from metals was discovered in the region. A full set of results is available from the Regional Water Laboratory, Kilkenny.

Caroline Bowden, Regional Water Laboratory Kilkenny.

THE VALUE OF MAGNETOMETER PROFILING : A RESPONSE

As one who began his working life as a geophysicist and has spent the last 20 years practising hydrogeology here in Ireland, using magnetic surveys when and where appropriate, I am moved to comment on the article on "magnetometer profiling/groundwater conduits/waste disposal sites" in the GSI Groundwater Newsletter No. 24 January 1994, by P. J. Gibson and P. Lyle.

Their results are very interesting but I would proffer some cautionary advice:

(i) The "potential field" geophysical methods, of which magnetics is one, cannot provide a unique geological solution for any anomaly or combination of anomalies. Interpretation of the results is inevitably ambiguous with a choice having to be made between several possibilities. This is particularly true of the magnetic method, mainly because of the bipolar nature of the field, so the anomaly from a single geological body can consist of both a negative and a positive feature, but also because there are two distinct sources of magnetism - induced and remnant. Anomalies are further complicated by being largely dependent on the geographic orientation of the causative body. None of these factors are treated in the article.

(ii) As far as faults and hydrogeology are concerned, my own experience here shows that faults can have very contrasting effects on groundwater movement. They can produce fractured zones leading to enhanced groundwater flow but equally often, if not more often, they produce fault gouge zones that act as barriers to groundwater flow. There is no possibility of magnetic surveying differentiating between these two situations.

(iii) The electromagnetic (EM) method is usually more applicable in hydrogeology than ordinary magnetics. Despite the similarity in name, EM works on an entirely different principle, and responds to changes in electrical conductivity within the ground. Such changes can be contributed to by the presence or absence of water so one is at least dealing with a possible direct link with groundwater occurrence, which can never be the case with the magnetic method. EM is being used here, with moderate success, to site water boreholes.

To sum up, the magnetic method does have some applications in hydrogeology; but they tend to be particular and specialised, e.g. locating igneous intrusions beneath thick drift. However, the method is unlikely to be generally worthwhile for either water borehole siting or waste disposal work.

Peter Bennett, Hydrogeological and Environmental Services Ltd.

OVERVIEW OF WATER BALANCE INVESTIGATIONS[1]

A catchment water balance allows the quantitative evaluation of the distribution of total available water among the various components of the hydrological cycle. Essentially, it solves the continuity equation on the macroscopic scale, where the total volume of water entering the catchment is equated against the total volume leaving plus the change in water volume stored in the catchment over finite time intervals (e.g. month, year).

Ideally, water balance studies should provide an effective means of checking the validity of measured/estimated values representing the different hydrological components in the catchment water balance equation. Water balance investigations have been used to determine the net loss (leakage) via groundwater flow to assess the implications of changes in land management practices (i.e. afforestation, irrigation and drainage) on the distribution of water among the hydrological components. Unfortunately, measurement errors and the high spatial variability of some components cloud the findings of such analyses, thus reducing their effectiveness and reliability in terms of determining the distribution of water among the different components of the water balance.

The most reliable component of the water balance equation in terms of accuracy is runoff as this is an integrated measurement, unlike the other water balance components that have the problem of aerial representivity of point measurements. In Ireland river gauging stations controlled either by the ERU or OPW are generally operated in accordance with the BS 3680 which ensures measurement errors are less than 10%. In general the level of accuracy in flow measurements will vary from gauge to gauge depending on site suitability, namely, whether or not there is a natural or artificial control in place on the degree of calibration carried out. It may be argued that the majority of Irish gauges achieve higher accuracy than 90%, but it is unlikely that they will reach levels above 95% using the standard gauge and operating to BS guidelines.

Of the several hydrological terms comprising the water balance equation, evaporation is recognised as the most difficult to quantify directly from measurements. Evaporation is a complex process which is dependent on a sufficient supply of moisture and is also dependent on the availability of sufficient energy (i.e. temperature, sun light intensity, wind speed, etc.) to vaporise and transport available moisture. There are a number of methods for estimating evaporation, namely, pan evaporimeters, lysimeters (Thornthwaite) and vapour flux recorders which provide direct measurements of evaporation, and indirect measurements using climatological data in energy budget equations and empirical formulae (Penman, Morton, etc.). All of these methods have associated measurement errors and generally measure the potential evaporation rate where an abundance of moisture is presupposed.

The Penman method for calculating potential evaporation from open water and vegetation is widely used in Ireland with climatological data available at 14 meteorological stations throughout Ireland, (Rohan, 1976). The shortcomings of this approach are the values of the empirical coefficients used to represent vegetation cover and soil type which are based on UK experience (Smith, 1967) and thus not necessarily applicable to the Irish conditions. The use of the Penman formula to calculate evaporation/evapotranspiration using empirical crop parameters is questionable in terms of accuracy. Water balance studies provide a mechanism by which to check the accuracy of such estimates, based on the assumptions that the measurements of precipitation and discharge are accurate and that the other parameters such as storage and groundwater flow can be accounted for.

There is a misconception held that the precipitation estimates from rain gauges are relatively accurate in terms of estimating catchment precipitation. Studies have revealed that conventional rain gauges underestimate rainfall, typically by 3% to 30%, (Sevruk, 1981). Fitzgerald (1984) quotes an error for Irish conditions of 5% to 10%. Combined with these systematic errors are extrapolation errors, whereby a point measurement is extrapolated spatially to represent a large drainage area. This error is difficult to estimate as it will depend on relative exposure differences between the rain gauge site and the average exposure conditions of the drainage area which is being represented by this point measurement.

---

[1]*This article is particularly relevant at present in view of the international conference "The Balance of Water - Present and Future" taking place at TCD on 7-9 September. For details, contact the Conference Secretary at (01) 7021274.*

Given the systematic and aerial distribution errors associated with measuring the various components of the catchment water balance, the water balance method still remains the standard by which the various hydrological components are evaluated.

A number of water balance studies of Irish catchments were collated and a comparison was made between AE calculated from the water balance equation and the Penman potential evapotranspiration calculated by the Meteorological Service using climatological data for the relevant meteorological stations to the catchments. The results from these analyses are presented in the table below. In each of the water balance studies the precipitation term was adjusted by + 5% to compensate for underestimation by rain gauges as discussed above. Doyle (1985) using correction methods recommended by UNESCO/WHO for the Shannon catchment obtained an average annual adjustment of + 9% based on 27 years of data.

Table: Water balance studies

Catchment	**Area (km^2)**	**Data Set (years)**	**Gauging Stations RG**	**MS**	**AE=P-Q-G as % Penman PE**	**AE - Aslyng SMD method % Penman PE**
Moy Carmody (1978)	2,100	1952 - 1964	23	1	112%	n/a
Brosna Amala (1984)	1,210	1970 - 1978	10	2	104%	91%
Shannon Doyle (1985)	10,400	1958 - 1984	37	4	103%	96%
Deel Nikobasa (1984)	360	1965 - 1971	6	1	89%	n/a
Nuenna (Nore) Cawley (1990)	50	1976 - 1979	2	1	85%	82%
Suir Glay (1986)	2,100	1960 - 1979	14	4	113%	98%
Nore Glay (1986)	1.650 John's B	1960 - 1979	12	4	110%	94%
Nore Daly (in press)	2,400 Brownsbarn	1971 - 1982	10	1	110%	95%

Note: RG = No. of rain gauges use; MS = No. of Meteorological Stations used for Penman estimates.

This study was performed to evaluate the effectiveness and consistency of annual water balance investigations applied to Irish catchments. The results presented in the table cast a certain degree of doubt on the reliability of the adjusted Penman formula used by the Meteorological Service as a measurement of PE on a catchment scale. The general trend in results shows that for long-term (annual) water balances, the adjusted Penman formula underestimates PE. However, this is not conclusive given the lack of precision in the other water balance parameters.

In general, water balance investigations are limited in their application, particularly at the smaller time scales, by the high degree of uncertainty associated with evaluating its various components. The precipitation measurement error for example is often greater than 10 % and hence, all other components are affected by this lack of precision in the input term. An improvement in precipitation and discharge accuracies is a requisite to increasing the effectiveness, reliability and applicability of water balance investigations to water resource management and planning. A number of research areas suggest themselves for further attention:

- The formulation of long-term and short-term water balance models calibrated for Irish conditions.
- Detailed examination of precipitation data and the formulation of appropriate correction factors for Irish climatic conditions and rain gauges.
- Development/refinement of techniques to improve the aerial representation of point measurements (i.e. remote sensing techniques).
- The production of a handbook outlining a code of practice for water balance assessment in Irish catchments.

References

Amatali, M.A. (1984) "Water Balance of the Brosna Catchment", Dissertation to National University of Ireland.
Carmody, M.J., (1978) "Water Balance Concept Applied to the Moy and Beagh Catchments", Dissertation to the National University of Ireland.
Cawley, A.M., (1990) "Hydrological Investigations of Karst Aquifer System", Dissertation to the National University of Ireland.
Daly, E., (1994) "Water Balance Study of the Nore River Basin", in press.
Doyle, P. (1985) "A Water Balance of the Shannon Catchment", Dissertation to National University of Ireland.
Fitzgerald, D. (1984) "Monthly and Annual Averages of Rainfall 1951 - 1980", Climatological Note No. 7, Meteorological Service, Dublin, 1984.
Glay, E.B. (1986) "Water Balance Studies for the Nore and Suir River Basins", Dissertation to the National University of Ireland.
Rohan, P.K. (1986) "The Climate of Ireland" Government Sales Publication Office, Dublin.
Sevruk, B (1981) "Methods of Correction for Systematic Error in Point Precipitation Measurements for Operational Use". WMO, Geneva.
Smith, L.P. (1967) "Potential Transpiration in the British Isles", Tech Bull. No. 16, H.M.S.O., London.

Tony Cawley, MCS International.

REVIEW / SUMMARY

"The Trophic Status of Lough Conn: An Investigation into the Causes of Recent Accelerated Eutrophication" by M.L. McGarrigle, W.S.T. Champ, R. Norton, P. Larkin and J. M. Moore. Published by Mayo County Council in association with the EPA, Central Fisheries Board, North Western Fisheries Board, Teagasc, Bord na Mona, Department of Agriculture and Department of the Marine. 1993.

Lough Conn is a large (50km^2) angling lake in County Mayo. Algal blooms and scums have been found with increasing frequency. The objective of this report was to establish the extent and causes of the changes being observed in the lake and to make appropriate recommendations for the amelioration of any problems identified.

The report comprises 84 pages of text; it is well laid out and clearly written; and includes 18 colour photographs. The conclusions of the report are summarised below:

1. Nutrient loading to the lake has doubled between 1979-1980 and 1990-1991.
2. The principal sources of phosphorus are agriculture (230% of baseload or background natural loading), forestry (21% of baseload), rural septic tanks (16%) and Crossmolina sewage treatment works (14%).
3. The increasing nutrient supply from agriculture occurred in spite of the expenditure of £5 million upgrading farmyards in the Lough Conn Catchment since 1987. However this work was successful in containing the animal wastes. It was concluded that the main emphasis now needed to be on the proper use of the nutrients.
4. The forestry sector is unlikely to continue to contribute as Coillte has concluded that afforestation on the low fertility peatland is no longer economically viable.
5. With regard to septic tank systems, several recommendations were made:
    - Groups of houses with septic tanks should be actively discouraged within 400m of the lake.
    - Planning permissions should include a maintenance clause.
    - An educational campaign is suggested to improve maintenance of existing systems and to encourage the use of phosphate free detergents.
    - Regulations/recommendations should be prepared for contractors, who empty septic tanks, governing the disposal of sludge.

Donal Daly, Geological Survey of Ireland.

EXAMPLES OF GROUNDWATER VULNERABILITY DEFINITIONS

Definitions	References
The groundwater vulnerability to pollution maps described were prepared to show the likely infiltrating and spreading capacity of pollutants in aquifers, based on the type of surface geological deposits and hydrogeological conditions present.	Albinet, M. and Margat, J., 1971. Cartographie de la vulnerabilité a la pollution des nappes d'eau souterraine. Proc of Moscow Symp of IAHS on Groundwater Pollution. IAHS publn No. 3, p.58.
The term aquifer pollution vulnerability is used to represent the intrinsic characteristics which determine the sensitivity of various parts of an aquifer to being adversely affected by an imposed contamination load.	Foster, S.,1987. Proc of Symp on Vulnerability of Soil and Groundwater to Pollutants. Info No. 38 TNO, and RIVM, The Hague . 1143pp.
Groundwater vulnerability to pollution may be defined as the sensitivity of its quality to anthropogenic activities which may prove detrimental to the present and/or intended usage-value of the resource.	Bachmat, Y. & Collin, M.,1987. Proc of Symp on Vulnerability of Soil and Groundwater to Pollutants. Info No 38 TNO, and RIVM, The Hague . 1143pp
Vulnerability of a hydrogeological system is the ability of this system to cope with, both natural and anthropogenic impacts which affect its state and character in time and space.	Friesel, P.,1987, Proc of Symp on Vulnerability of Soil and Groundwater to Pollutants. Info No 38 TNO, and RIVM, The Hague . 1143pp.
Vulnerability of a groundwater is defined by its openness to recharge - that is the permeability of covering strata for water.	Sotornikova, R & Vrba, J.,1987. Proc of Symp on Vulnerability of Soil and Groundwater to Pollutants. Info No 38 TNO, and RIVM, The Hague. 1143pp.
The degree of intrinsic vulnerability of a water body is the possibility of infiltration and percolation of liquid or aqueous solutions of pollutants through the unsaturated zone.	Civita, M. 1988. Difesa Degli Acquiferi dell Alta Pianura Veneta, Stato di Inquinamento e Vulnerabilita delle Acque Sotterranee del Bacino del Branta. 21 pp. CNR Publicatione n. 207, Venezia.
Vulnerability is usually based on the evaluation of several resource attributes which most commonly include soil characteristics, lithology, composition or rocks and their permeability, depth to bedrock and depth to water.	Zaporozec, A., 1989. In working paper of UNESCO-IAH Working Group.
Vulnerability to quality degradation is the sensitivity of groundwater quality to be negatively changed as a consequence of anthropogenic activities.	Custodio, E., 1990. Aquifer vulnerability to salinization and contamination: Benefit from using environmental chemical and isotropic traces in Spain. IAEA, Vienna. 28pp.
Groundwater vulnerability is the relative ease with which a contaminant introduced into the environment can migrate to an aquifer under a given set of management practices, contaminant characteristics and aquifer sensitivity conditions.	USEPA 1992. Final Comprehensive state of Groundwater Protection Program Guidance USEPA 100-R-93-001.
Vulnerability is an inclusive concept that incorporates landuse and other cultural activities as well as physical level of sensitivity.	Ray, J.A. and O'dell, P.W. 1993. Diversity: A new method for evaluating sensitivity of groundwater to contamination. Envir. Geol. Vol 22, No. 4, p346
Vulnerability is a term used to represent the intrinsic geological and hydrogeological characteristics which determine the ease with which groundwater may be contaminated by human activities.	Daly, D., and Warren, W. P.,1994. Vulnerability mapping. GSI Groundwater Newsletter No. 25.

Bob Aldwell, Geological Survey of Ireland.

MAPPING GROUNDWATER VULNERABILITY TO POLLUTION

GSI GUIDELINES

Introduction

Since the late 1960s, groundwater vulnerability maps have played an increasingly important role internationally in the location and operation of potentially polluting activities, and in bringing the groundwater interest to the attention of decision-makers in the planning process. They have become a means of presenting various, sometimes complex, hydrogeological parameters in the form of an easily, but often intuitively understood, term "vulnerability". Vulnerability maps are now becoming an essential part of groundwater protection schemes and a valuable tool in environmental management.

In 1989 the Geological Survey of Ireland (GSI) recommended that groundwater vulnerability assessments should be used as a means of upgrading and improving groundwater protection schemes. As vulnerability mapping is the most important means of carrying out these assessments, guidelines were given which related typical Irish hydrogeological settings with a four-fold vulnerability rating: extreme, high, moderate and low.

In the coming months the GSI, in collaboration with some third-level colleges, will be preparing groundwater protection schemes for four counties - Offaly, Limerick, Meath, Tipperary (SR) and Waterford. Consequently the guidelines are being reviewed, firstly to reflect the quality of both available and readily available geological and hydrogeological data, secondly to include new ideas, and thirdly to identify minimum standard vulnerability maps.

This article suggests an appropriate definition of vulnerability for the Irish situation, gives the basis for the guidelines,outlines the background factors influencing the vulnerability ratings and then describes three sets of vulnerability guidelines that vary depending on the data availability.

Definition of Groundwater Vulnerability

Examination of existing vulnerability maps and descriptions of vulnerability in the scientific literature shows considerable variation in the definition and the usage of the vulnerability concept. Up to now there has been no generally accepted definition or methodology for the construction of vulnerability maps. The variation is highlighted in the following points:

1. The definition can be limited to the intrinsic geological and hydrogeological characteristics of an area or can also include land-use and management practices.
2. The aspect of groundwater that is vulnerable can vary. It can be "groundwater" itself; the "groundwater system", "aquifers"; "groundwater sources", such as karst springs; or "groundwater resources".
3. Groundwater can be taken to be vulnerable to a variety of impacts such as "natural impacts", "human impacts including groundwater abstraction", "contamination caused by human activities", "conservative pollutants", "specific pollutants", "point source pollution" and/or "diffuse pollution".
4. The objectives of the map can be to help in i) preventing groundwater pollution in general, ii) protecting groundwater sources, iii) designing monitoring networks, iv) responding to pollution incidents, v) or creating public awareness/education of the importance and fragility of groundwater.
5. Many vulnerability maps could be titled, depending on their purpose, more accurately as "groundwater sensitivity" maps, "groundwater (or aquifer) response to pollution" maps, "source (spring) response to pollution "maps or "aquifer attenuation capability" maps.

Such considerations affect both the scales of the maps, which can range from less than 1:10,000 to greater than 1:500,000, and the data required to compile the maps. For instance, the data required for a vulnerability map, which is part of a regional groundwater protection scheme designed to prevent groundwater pollution from occurring, might consist only of information on the geological materials that are present between the land surface and the groundwater and on details on recharge type, including the locations of point recharge. If the map is a source vulnerability map or is intended for deciding on the response to pollution incidents then, in addition to the above information, the residence time in the aquifer, transport rates, dilution, attenuation within the aquifer, etc., can be taken into account.

For the purposes of its groundwater vulnerability maps and reports, the Geological Survey of Ireland applies the following definition:
Vulnerability is a term used to represent the intrinsic geological and hydrogeological characteristics that determine the ease with which groundwater may be contaminated by human activities.

Basis for GSI Definition and Usage of Vulnerability Concept

In response to the differences and possible variations, as outlined above, and taking account of the hydrogeological situation in Ireland, it was decided that:

i) The definition of vulnerability will not include land-use and management practices but will be limited to the inherent geological and hydrogeological characteristics of an area.
ii) It is the vulnerability of "groundwater" that will be mapped and not "aquifers" or "groundwater sources"etc.
iii) Groundwater will be taken to be vulnerable to "contaminants generated by human activities" and not, for instance, "natural impacts". It will be assumed that the contaminants are relatively conservative.
iv) The primary objective of the vulnerability maps will be to give assistance in preventing pollution, as part of groundwater protection schemes.However, they will also help in creating awareness of the sensitivity of groundwater in certain hydrogeological situations.
v) The maps will show the vulnerability of the first groundwater encountered in either sand/gravel aquifers or in bedrock. This groundwater may not be the main resource beneath a site where there is a deep confined bedrock aquifer

The vulnerability of groundwater depends on the time of travel of groundwater (and contaminants) and on the contaminant attenuation capacity of the geological materials. As all groundwater is hydrologically connected to the land surface, it is the effectiveness of this connection that determines the relative vulnerability to contamination. Groundwater that quickly receives water (and contaminants) from the land surface is considered to be more vulnerable than groundwater that receives water (and contaminants) more slowly. The travel time and attenuation capacity are a function of the following natural attributes of any area:

i) the subsoils that overlie the groundwater;
ii) the recharge type - whether point or diffuse; and
iii) in the case of unconfined sand and gravel aquifers, the thickness of the unsaturated zone.

The subsoils are regarded as the single most important natural feature in influencing groundwater vulnerability to pollution. They can act as a protecting filtering layer over groundwater, depending on the type, permeability and thickness. So, for instance, the higher the clay content, the lower the permeability and the greater the thickness, the better the protection from contaminants. Groundwater is most vulnerable where the subsoil is absent or very thin.

The type and rate of recharge are particularly important in karstic limestone areas, where point recharge through swallow holes and sinking streams can occur. Attenuation is minimal, flow velocity is fast, and so groundwater is very vulnerable to pollution in these situations.

In sands/gravels, a deep water table reduces the likelihood of contamination because contaminants have to travel farther and are slower to reach the groundwater. This allows the various beneficial physical, chemical and biological processes, that occur in the unsaturated zone, to attenuate the pollutants.

The possible flow rates and attenuation of contaminants once they have entered groundwater in either bedrock or sand/gravel are not taken to be factors in vulnerability mapping because by then the impact has occurred and there is no further capacity to prevent the impact or protect the groundwater. (Obviously the degree of impact is another issue, which depends on a variety of factors including the pollutant loading.) However, they can be taken into account in considering the vulnerability of a specific well or spring. Also, the bedrock hydrogeology is not taken to be a significant factor in defining vulnerability. It is assumed, firstly that once contaminants enter groundwater in bedrock there is, owing to the fissure permeability that characterises Irish bedrock, little attenuation other than by (usually relatively limited) dilution, and secondly that an unsaturated zone in bedrock is not a significant factor. Consequently, it is assumed that, with the exception of karst morphological features that indicate rapid recharge (swallow holes, for instance), the only factor determining the vulnerability of groundwater in bedrock is the nature (type, permeability and thickness) of overlying subsoils or Quaternary deposits. It is considered that the hydrogeology of different bedrock types can be taken into account when the aquifer map is linked with the vulnerability map in preparing the groundwater protection map and code of practice. For instance, regionally important bedrock aquifers that are karstified can be so indicated on the aquifer map.

Background Factors Influencing the Vulnerability Ratings

In proposing guidelines, the following factors have been taken into account:

i) The main threat to groundwater in Ireland is posed by point sources - farmyard wastes, septic tank effluent, pollutants in sinking streams, and to a lesser extent leachate from waste disposal facilities, leakages and spillages. Consequently, in defining groundwater vulnerability to pollution the safest assumption is that the contaminants are being released from point sources below the ground surface at depths of 1-2m.

ii) Detailed geological and hydrogeological knowledge is lacking for many areas in Ireland, while at the same time the geology and hydrogeology of the country are complex. The bedrock has a fissure permeability only and, in the case of limestones, karstification may have occurred to varying degrees. The subsoils or Quaternary sediments are very variable in thickness, extent and lithology, reflecting their chaotic mode of deposition during the Ice Age. Also, there is seldom quantitative information on permeabilities, travel times or attenuation capacities, thus the vulnerability ratings are largely qualitative.

iii) For a groundwater protection scheme to be effective and used in the planning process, the number of zones should be small. As the vulnerability ratings influence the number of protection zones, it is necessary to keep them relatively simple and generalised.

iv) The ratings take account of the existing regulations and recommendations both in Ireland and abroad (e.g. SR6 : 1991).

Guidelines for Vulnerability Mapping Based on Optimum Data Availability

The following table gives the basis for the vulnerability guidelines being proposed and used by the GSI.

Vulnerability Rating		Hydrogeological Setting
Extreme	1.	Outcropping bedrock or where bedrock is overlain by shallow (≤ 3m) subsoil.
	2.	Sand and gravel aquifers with a shallow (≤ 3m) unsaturated zone.
	3.	Within 30m of karstic features (including along the area of loss of losing or sinking streams) and within 10m on either side of losing or sinking streams upflow of the area of loss. (In certain circumstances, for instance, where overland surface runoff is likely, greater distances may be needed.)
High	1.	Bedrock overlain by > 3m of high permeability sand and gravel, or 3-10m of intermediate permeability subsoil such as sandy till or 3-5m of low permeability subsoil such as clayey till, clay or peat.
	2.	Unconfined sand and gravel aquifers with an unsaturated zone > 3m.
Moderate	1.	Bedrock overlain by > 10m of intermediate permeability subsoil such as sandy till or 5-10m of low permeability subsoils such as clayey till, clay or peat.
	2.	Sand and gravel aquifers overlain by > 10m of moderate permeability subsoil such as sandy till or 5-10m of low permeability subsoil such as clayey till, clay or peat.
Low	1.	Bedrock overlain by > 10m of low permeability subsoil such as clayey till, clay or peat.
	2.	Confined gravel aquifers where overlain by > 10m of low permeability clayey till or clay.

These ratings assume the following:

- 1-2m of subsoil and, in the case of sand and gravel aquifers, a 1-2m thick unsaturated zone below the point of release of contaminants have a sufficient protecting capacity to allow a rating of high.
- Sand and gravel do not have a sufficient protecting capacity, no matter how thick, to merit a moderate rating.
- A minimum of 8m of sandy till or 3m of clayey till or clay, below the point of release of contaminants, enables a rating of moderate.
- Sandy till does not give sufficient protection to allow a low vulnerability rating no matter how thick it is.
- At least 8m of clayey till or clay below the point of release of contaminants are needed to merit a low vulnerability rating.

In order to draw a vulnerability map based on these ratings, the following geological and hydrogeological information must be available on maps.

1. Areas where the Quaternary sediment is generally less than 1m thick (bedrock outcrop or subcrop).
2. Sand/gravel deposits.
3. Till (boulder clay) deposits with details of basic matrix (textural) characteristics.
4. Peat: both cutover and intact bog.
5. Alluvium.
6. Lake clays.
7. Depth to bedrock map showing contours at 3m, 5m (in the case of clayey till and clay), and 10m.
8. Sand and gravel aquifers; with a differentiation between areas with thin (≤3m) and thicker (>3m) unsaturated zones.
9. Karstic features such as sinking streams, collapse features, etc.

Information with this level of detail is available for only a few small areas in Ireland and is never likely to be more widely available except perhaps around a limited number of major public supply sources. Routine Geological Survey mapping programmes provide adequate data with regard to the sediments but the paucity of depth to bedrock data is a problem. Consequently, these guidelines are aspirational. However, they do provide a basis for adaptation.

In extensive karst areas, detailed studies by a karst specialist are advisable. Further research on karstification may allow future refinement of the vulnerability ratings in karst areas.

Diffuse pollution sources, such as landspreading of organic wastes, are likely to become more important in the future. With a slight adaptation, the ratings can be used to take account of this by producing a map which applies the "extreme" rating to areas of outcrop, subcrop (subsoil normally 1m) and around karst features, whereas the remainder of the area with shallow subsoil (3m) could be ranked as "high".

Minimum Standard Vulnerability Mapping

The production of vulnerability maps for areas where the level of Quaternary geology information is poor is not recommended, as the level of uncertainty with the maps will make them indefensible and is likely to devalue the technique. Thus the minimum level of Quaternary geology information required in the short term (i.e. for present projects - Offaly, Limerick, Meath, Waterford and Tipperary S.R.) to enable defensible vulnerability maps to be drawn demands identification of the following:

1. Areas of outcrop and subcrop.
2. Sand and gravel areas.
3. Areas of till or boulder clay (permeability uncertain).
4. Lake clay and peat areas.
5. Peatland areas.
6. Areas where the subsoil is probably less than 3m thick.
7. Points where the subsoil is greater then 10m thick.
8. Sand and gravel aquifers in river flood plains.
9. Karst features.

From this information the following ratings are possible.

Extreme	1.	Bedrock outcrop.
	2.	In vicinity of karst features.
Probably extreme	1.	Areas of subcrop.
	2.	Shallow (≤3m) subsoil.
	3.	Sand and gravel aquifers in river flood plains (where depth to water table is likely to be shallow).
	4.	Alluvium.
	5.	Blanket bog.
High		Sand and gravel areas.
Probably High	1.	Bedrock overlain by > 3m subsoil (excluding sand and gravel).
	2.	Unconfined sand and gravel aquifers outside flood plains.
Moderate		Area in the immediate vicinity of a borehole with a subsoil thickness greater than 10m.
Probably Moderate		Areas with lake clay and cut-over raised bog.
Probably Low		Areas of intact raised bog.

On maps based on these ratings, the areas of extreme and high vulnerability will be over estimated. It is suggested that a vulnerability map, which is based on these ratings, is at the absolute minimum level and that even it may be difficult to defend. Consequently it is essential that in the future a higher quality of Quaternary geology information should be required to enable more confident pollution risk assessments and more defensible groundwater protection schemes.

Improved and Achievable Vulnerability Mapping

The key to improving vulnerability mapping in the medium term is the availability of good quality Quaternary geology maps. (In the longer term, greater hydrogeological understanding of the bedrock in Ireland and its varying ability to attenuate contaminants may impact on vulnerability mapping). Consequently it is recommended that, prior to preparing vulnerability maps, the Quaternary geology information should be improved by reconnaissance mapping, trail pitting, augering and grain size analyses. The following information should be obtained:

1. Areas where Quaternary sediment is generally less than or equal to 1m thick (outcrop and subcrop).
2. Sand and gravel deposits (> 1m thick).
3. Till deposits with details on texture (> 1m thick).
4. Peat.
5. Alluvium.
6. Lake clays.
7. Depth to rock map showing shallow subsoils (≤3m) and moderately thick subsoils (3m-10m) and areas of thick subsoils (probably > 10m). However, the 10m contour can only be attempted where the existing borehole information is adequate.
8. Sand and gravel aquifers with a thin (≤3m) unsaturated zone.
9. Karst features.

This information allows the following vulnerability ratings:

Extreme	1	Outcropping bedrock and subcrop.
	2	Within 30m of karstic features (including along the area of loss of losing or sinking streams) and within 10m on either side of losing streams upflow of the area of loss. (In certain circumstances, for instance where overland surface runoff is likely, greater distances may be needed.)
Probably Extreme	1	Areas with thin (≤3m) subsoil over bedrock
	2	Sand and gravel aquifers with a thin (≤3m) unsaturated zone.
	3	Alluvium.

	4	Blanket bog.
High	1	Areas where high permeability sand and gravel are > 3m thick.
	2	Areas where intermediate permeability subsoil such as sandy till is known, from borehole records, to be 3-10m thick.
	3	Areas where low permeability subsoil such as clayey till, clay and or peat is known, from borehole records, to be 3 - 5m thick.
Probably High	1	Areas where intermediate permeability subsoil such as sandy till is interpreted to be > 3m and ≤10m thick, from sparse borehole records.
	2	Areas where low permeability subsoil such as clayey till, clay and/or peat is interpreted to be > 3m and ≤5m thick, from sparse borehole records.
	3	Unconfined sand and gravel aquifers where the unsaturated zone is > 3m thick.
Moderate	1	Areas where intermediate permeability subsoil such as sandy till is known, from borehole records to be >10m thick.
	2	Areas where low permeability subsoil such as clayey till, clay and or peat is known, from borehole records, to be 5 - 10m thick.
Probably Moderate	1	Areas where intermediate permeability subsoil such as sandy till are interpreted to be > 10m thick, from sparse borehole records.
	2	Areas where low permeability subsoil such as clayey till, clay and/or peat is interpreted to be 5-10m thick, from sparse borehole records.
Low		Areas where low permeability subsoil such as clayey till and/or clay and/or peat is known to be > 10m thick, from borehole records.
Probably Low		Areas where low permeability subsoil such as clayey till, clay and/or peat is interpreted to be > 10m thick, from sparse borehole records.

Concluding Comments

These guidelines are based on pragmatic judgements, experience and limited technical and scientific information. Further research is needed into the factors that govern some of the ratings to enhance the defensibility of the guidelines. The guidelines will be reviewed on a regular basis as they are tested by on-going protection schemes.

The guidelines have been influenced by discussions with and contributions from Paul Johnston (TCD), Catherine Coxon (TCD), Malcolm Doak (Sligo RTC), Richard Thorn (Sligo RTC), Margaret Keegan (GSI), Eugene Daly (GSI), Geoff Wright (GSI), Natalie Doerfliger (University of Neuchatel),Jean-Pierre Tripet (Swiss Hydrological and Geological Survey) and Brian Adams (British Geological Survey).

Donal Daly and William P. Warren, Geological Survey of Ireland

----

IRISH BOTTLED WATERS

Introduction

The bottled water industry has enjoyed a phenomenal growth in Ireland in the last ten years. The market has grown from virtually nothing in 1982 to 22 million litres in 1993. So what has contributed to this growth? Tap water, rightly or wrongly, has had a bad press. People complain of suspended particles, a funny taste, scum inside the kettle or an oily film on the top of the cup of tea. Bottled waters on the other hand are associated with purity and wholesomeness. Surface water is more susceptible to contamination than groundwater. Groundwater, as a result of its very formation, has an in-built filtration system that will remove most of the major sources of pollution. The groundwater is created by natural processes but can be easily upset both by nature itself and by human activity. Hence there is a need for both legislation and standards to control the quality of the end product to ensure that no activity compromises the quality of the water.

Legislation

There are two primary pieces of legislation that control the production of bottled water. The first is the Natural Mineral Water Directive 80/777/EC which has been transferred into Irish law as S.I. 11/86. The other piece of legislation is the Drinking Water Directive 80/778/EC transferred into Irish law as S.I. 81/88. Both Directives are drawn from long-standing but different traditions of public health. They are compared in the table.

In addition to these two principle pieces of legislation there are controls on labelling and manufacturing in the case of non-mineral waters, and hygiene practice in the case of all bottled waters. Hygiene standards are controlled by I.S. 3219: 1990 which is the Irish Code of Practice for Hygiene in the Food and Drink Manufacturing Industry. Natural mineral waters must be labelled in accordance with S.I. 11/86 while the labelling of other bottled waters is controlled by 79/112/EC S.l 205/82 and its amendments S.I. 214/87, 202/88 and 228/91.

The main difference between the two Directives is their different assumptions as to the origin of water. 80/778/EC assumes that the water is from any source, is bacteriologically unsafe and may include a certain amount of waste water. This means that parameters and standards are applied that ensure that the water after treatment meets certain quality criteria. 80/777/EC assumes that the water is from a protected source. The emphasis is upon recognition of a source's natural purity, which is only accepted after thorough investigation. There are no treatments and no chemical standards. Finally 80/778/EC is a horizontal Directive covering all forms of water used for human consumption whereas 80/777/EC is a vertical Directive applicable to just one product. This is particularly evident in Articles 6 to l0 inclusively of 80/7771EC.

The main shortcoming of 80/777/EC is that it provides no guidelines as to maximum or minimum levels of any chemical parameters. There is no mention of any trace organic parameters to be monitored. Neither does it provide for any source protection against contamination which is necessary for both mineral and non-mineral bottled water. The Directive does not adequately protect the consumer and the onus is put upon the producer's responsibility and integrity to ensure that the finished product meets all reasonable health and trading standards.

Conversely, 80/778/EC, through its parametric approach to water quality, regulates elements that are not a risk to health but are assumed to be so by the public. Such standards are not based on current knowledge, certain parameters are missing that are a health risk, and some of the methods of analyses are unworkable.

Differences between Bottled Water and Tap Water

Logistical Differences: The first difference is cost. At present there can be an average charge of between £1.20 to £1.34 per l,000 gallons of public supply water to industry. This works out at about £0.003p per litre. A supermarket will charge about £0.50 for a litre of bottled water. Hence the bottled water manufacturer can afford to produce a very high quality water. A local authority is obliged to produce a water that meets all the water quality criteria of 80/778/EC with a limited budget.

The second difference is scale. At present Irish people consume an average of six litres per year of bottled water compared to an annual per capita tap water consumption of around 35,000 litres. It can be difficult to guarantee a constant quality of water supply when dealing with such volumes especially given the budget restrictions.

The third difference is that the raw product in bottled waters is groundwater which tends to require less treatment, if any, than tap water supplies which predominantly use surface water. Groundwater tends to have a much more stable chemical quality. It tends to have a lower, if not altogether absent, bacterial population. There is rarely any sediment present in groundwater. Hence the bottled water manufacturer is in a better position to offer a more consistent product with little or no treatment.

Table : Comparison of Directives 80/777/EC and 80/778/EC in the Context of Bottled Waters

80/778/EC: Drinking Water Directive	80/777/EC: Natural Mineral Water Directive
Article 1 sets the scope of the Directive as being water intended for human consumption, including bottled water.	Article 1 sets out the scope of the Directive.
Article 2 is more explicit and mentions water in food production and manufacturing. It is a quirk of Irish legislation that water is termed a food.	
Article 3 sets out the water quality criteria that bottled waters must meet.	Article 3 provides for the scope of exploitation of Natural Mineral Waters as set out in Annex II of the Directive.
Article 4 provides a derogation for natural mineral waters from this Directive.	Article 4 defines the permitted treatments of Natural Mineral Water which must not under any circumstances be bacteriostatic. The only treatments should be the removal of particulate matter greater than 1 µm or unstable chemical elements.

	Article 5 provides for the guideline values for TVC @ 22 and 37°C at the source and the maximum admissible levels in the finished product. It also provides for the type of media to be used for carrying out the analyses. This Article is the main difference between the two Directives.
	Article 6 provides for the use of tamper proof closures on the bottles. This is included here because the Directive is a vertical one rather than a horizontal one unlike the Drinking Water Directive.
Article 7 provides for the use and application of the water quality criteria set out in Annex I and which should be adhered to by bottled waters.	Article 7 controls the marketing and sale of mineral waters. It also provides for the use of terminology such as still, naturally carbonated or "sparkling". It determines what can or cannot be put on the labels including the compositional analyses.
	Article 8 sets the limits of exploitation of a particular source i.e. the same well or spring cannot be called several names.
	Article 9 controls the type of advertising used to sell a mineral water and the claims that can be made about it.
Article 11 provides for the protection of the raw water while Article 12 provides for adequate monitoring of the bottled water. However this monitoring need only take place on finished product and not on the source water prior to bottling. This Article also provides for the methods of analyses used in determining the quality of the finished water.	Article 11 provides the methods and procedures of microbiological analyses used as set out in Annex I.
Article 17 controls the advertising of the bottled water and any claims made as to its purity and uses.	
Annexes I, II, and III apply to bottled waters but many bottled waters have chemical parameters that are outside the MAC's set down in these Annexes. A highly mineralised bottled water would have difficulty meeting the water quality criteria of Annex I. The frequency of monitoring set down in Annex II is not adequate and many bottled water manufactures would have a much more stringent sampling regime. The normal frequency is equivalent to one test per 10,000 litres. This compares to a minimum frequency of one test per 5,000,000 litres used for public water supplies.	Annex I defines natural mineral waters and their characteristics. It also sets out the criteria to be used to assess whether or not a source is suitable to be recognised as a natural mineral water. It sets out in detail all the geological, hydrogeological, chemical and microbiological criteria that must be first met before source becomes a recognised mineral water.
	Annex II provides for the exploitation and marketing of the mineral water and in particular emphasises that if the source fails to meet any the water quality criteria set out in the Directive then the operation must shut down until the water once more is suitable to bottle within the meaning of the Directive.

The fourth difference is that is that because of the lower volumes involved, bottled water manufacturers are in a position to apply a more stringent quality assurance regime. 80/778/EC sets down a sampling regime which is dependent on the population size being supplied with tap water. Bottled waters have a sampling frequency that is a function of each day's production. There is normally a positive release system in a bottled water plant. This means that product is only released for public consumption when all the quality assurance tests have been completed and the results are within the finished product specification. Public water supplies do not have this provision.

A fifth difference is that bottled water manufacturers can recall a product that does not meet its quality assurance specification. Public water supplies cannot be recalled. Once the water is in the distribution system, save disconnecting the actual supply, it is very difficult to prevent the ultimate consumer from using the water. Responsible bottled water manufacturers will have a product recall plan that enables the destination of every case of water to be traced. A good illustration of this is the water contamination incident that occurred in Naas in October, l99l. As tap water recall was not possible, a series of nine circulars was issued by the UDC concerning the incident. These ranged from initial advice to boil the water before use, to instructions to flush out the internal systems, to boil water for brushing teeth, and finally warning parents to have their children immunised against polio. These circulars were issued over a period of 25 days. It was estimated that some 2,000 people were directly affected by the contamination. Contrast this against the infamous Perrier benzene contamination incident. At a cost of 22 million pounds, Perrier withdrew 160 million bottles of water in the space of one week to prevent any possibility of contaminated water being consumed and that was the end of the incident as far as the public were concerned.

Finally, the consumer when purchasing a bottle of water can examine the compositional analysis which is present on most bottled waters and all natural mineral waters. The consumer of tap water has no opportunity to scrutinise the compositional analysis of the tap water. They have to hope that it meets all the EC water quality guidelines.

Microbiological Differences: Natural Mineral Waters are not permitted to be treated and many other bottled water manufacturers choose not to treat or have minimum treatment e.g. the use of 0.2 or 0.45 µm filters. This means that the water must be free of pathogenic bacteria as it emerges from the ground. There have been no significant epidemiological events resulting from the drinking of bottled waters since the legislation was introduced in 1980. Tap water however is expected to be disinfected. It is permitted that non carbonated bottled natural mineral waters have a natural microbial flora that increases and decreases periodically. This is permitted under the Directive. This has no effect on the overall quality of the water and is, in fact, used as evidence that it has not been disinfected in any way.

About 75% of tap water in Ireland is from surface water. Before treatment it will be high in suspended sediment and organic matter. It can be a mix of river water and returns from sewage and sewage treatments. It will contain coliform and pathogenic bacteria and finally may contain residual trace organics. Groundwater, the raw material for bottled waters, on the other hand will have no suspended material, will not be a mix of any other waters, will be free of harmful bacteria and free of trace organics.

Microbiological analyses of bottled waters is carried out to ensure that there are no harmful bacteria present while bacteriological analyses of tap water are to ensure that all harmful bacteria have been removed by the treatment processes. Tap water will have residual levels of chlorine in it to ensure that it does not become recontaminated after it has left the treatment works.

Chemical Differences: Other bottled waters are controlled by the Drinking Water Directive and so there should be no difference in the chemical quality. Natural Mineral Waters do not have to adhere to the Drinking Water Directive. The primary difference is that 80/778/EC adopts a parametric and standards approach while 80/777/EC adopts a protected source approach and so there is no need for standards as the water is a totally natural product.

Differences In Treatments: "Treatment" in the bottled water industry is an emotive term. The natural mineral water producers are not permitted and claim not to apply any treatments to their water. Yet the physical submicron filtration of water is a treatment which many, if not all, apply. Other bottled waters controlled by 80/778/EC are permitted to treat their water and yet would not like to admit that they do so. The problem is that consumers equate the word "natural" with purity. In addition the concept of purity is further equated with safety and wholesomeness. The consumer does not want to know that in fact natural does not mean pure. The onus is therefore upon the producers of all bottled waters to ensure that natural does equate with purity and wholesomeness and the responsibility is upon the regulatory authorities to ensure that such water is produced in accordance with all legal and industry standard requirements.

80/777/EC does not set out to protect the consumer. There are no provisions within the Directive to permit the treatment of the water as an additional safety assurance after it has been proven to meet all quality criteria at the point of issue from the ground. The purpose of treatment should be to protect against unpredictable and undetected contamination entering the finished product. This is a "belt and braces" approach. Treatment should not be permitted to make a bad source good.

Tap water supplies are subjected to a much more rigorous series of treatments. There can be sand filtering, softening and flocculation to improve the odour, taste, colour, turbidity and hardness. The removal of unstable chemicals and chemicals outside permitted concentrations may also have to be carried out. Removal of organic compounds, chlorination and finally the addition of fluoride are all part of routine tap water treatment. The chlorine is not removed due to the need for residual chlorine to be present in the water until it reaches the ultimate consumer.

Irish Bottled Water Standard - IS 432 : 1992

The bottled water standard is voluntary and was developed by the bottled water industry for several reasons. The purpose of the standard is to ensure safety of both the raw water and the finished product. The emphasis is on prevention rather than detection. The standard applies to all packaged water irrespective of whether they are Natural Mineral Water, other bottled waters or water coolers. There are two Directives regulating the industry. It was considered better to provide a parametric list covering all bottled waters including Natural Mineral Waters. It would provide a similar standard for all bottled waters and so improve consumer confidence in the products. It was also considered as a positive piece of public relations. The standard has about 70 specifications and over 100 recommendations. The approach taken was to define standards that were practicable only in the context of Ireland. This was particularly true of the chemical standards set.

Future Developments

80/777/EC and 80/778/EC are to be revised. The EU wants to incorporate spring waters as part of 80/777/EC and make it more of a "horizontal" Directive. It is hoped that a more parametric approach will be adopted as regards standards for natural mineral waters and that the concept of guide-levels for parameters in the existing standards in

80/778/EC will be removed. A revision of 80/777/EC would provide an opportunity for certain treatments to be permitted. There is a strong lobby to have ozonation allowed. The purpose of allowing treatments is to ensure that a microbiologically wholesome water emerging from the ground remains so until bottled.

There is a general trend for individual EU member countries to develop their own voluntary standards for bottled water. Ireland has its own standard and the UK is in the process of developing one. The individual states in America are drawing up much stricter criteria for bottling water. "Spring water" for example must be exactly that and not from a borehole. The limits for trace organics are constantly being revised down to ever lower limits. Many states, such as New York and California, are insisting that all bottled waters are ozonated in the interests of consumer safety. The overall trend is to provide an even more unadulterated product using treatments that will guarantee the continued wholesomeness of the water without changing in anyway the original quality and taste.

Shane O'Neill, Trinity College Dublin.
(Original complete paper presented at an IEI conference entitled " Drinking Water - What Are The Issues ? " on June 3rd, 1993.)

HARD GROUNDWATER - ARE HARDNESS INHIBITORS A SUCCESS?

Hard groundwater is almost ubiquitous in Ireland - an inevitable consequence of our limestone-dominated geology. Scaling from hard water can cause irritation and problems, mainly for industry but also for domestic users. The January/February issue of World Water and Environmental Engineering reports that in Guinness's brewery at Park Royal in London an in-line water treatment system called "Colloid-A-Tron" is used to prevent scaling. In the past, seemingly, Guinness had to close down their steam injected calorifer every third day to allow descaling. Since Colloid-A-Tron was installed, the calorifer has stayed scale free, and has been so for several years, according to the article.

The system uses no chemicals or energy. The explanation given for the reported success is that the special alloy in the Colloid-A-Tron unit causes a rise in pH of water passing over it. This pH rise triggers a scaling reaction which causes the calcium carbonate in the water to form tiny microscopic crystals, which then pass harmlessly through the system without sticking to pipework and equipment.

Are they used in Ireland? Are they successful? In the recent past, hardness inhibitors (I don't know which brand) were been sold, door-to-door, in many areas. I haven't heard how successful they were. If any readers of the Newsletter have views or information, perhaps they could write a short article for the next issue.

Donal Daly, Geological Survey of Ireland.

AQUIFER PROTECTION WITH RESPECT TO A NATURAL MINERAL WATER SOURCE

Principals of Groundwater Protection for Bottled Water

In the context of a natural mineral water company, aquifer protection strategies which protect all ground water must be favoured over strategies which allow some degradation. Strategies that provide no aquifer protection or limited protection and depend on water treatment to provide a potable groundwater are avoided since recognised natural mineral water companies are not permitted under 80/777/EEC to treat their source water at all.

Legal Strategies Applicable to Bottled Water Sources

In Ireland the law pertaining to groundwater protection is fragmentary and piecemeal. It consists of indigenous legislation such as the Local Government (Water Pollution Act), 1977 and EC driven legislation such as 801681EC (S.I. 271192), the Groundwater Directive. There is also a problem with different agencies enforcing different laws. There are only 5 - 6 operational aquifer protection schemes in Ireland as yet. Planning officers could be considered the primary line of defence for groundwater protection but they have no formal hydrogeological training and might not be able to determine which planning criteria are the most important with respect to groundwater. There may also be a variation in the interpretation of the planning regulations from officer to officer.

Cost-Benefit of Protection

The aquifer protection policy will have cost-benefit implications by reducing the probability of a contamination event and so the expected benefits will always be positive. One can allow a contamination event to occur and hope to show by modelling that it will have no effect on the source. One can contain the contamination by interim measures such as counter pumping or finally one can develop a completely different source far removed from the original. In addition there are other benefits to protection. By protecting the source now, one can insure that it will still be suitable for production at any time in the future. By protecting the source one can be certain in the knowledge that it will continue to maintain the level of quality. Finally by protecting the source one will have the option of being able to sell on that source and be in a position to guarantee the quality of the source at the time of sale.

Management Strategies

The overall strategy should be one of total protection of groundwater as the overall policy is one of non - degradation by prevention. This could be achieved by the following:

1. Defining the critical recharge area(s) to the aquifer;
2. Identification of all potential sources of contamination and their prioritisation in terms of probability of pollution;
3. The development of a database containing all information on the catchment;
4. Delineation of the groundwater flow system by pumping tests, groundwater level monitoring and modelling;
5. Delineation of the zone of contribution to the well field (the capture zone);
6. Defining a series of groundwater protection zones about the well field;
7. The development of contingency plans including an alternative supply.

The above list of strategies could be attained under the following headings:

Hydrogeological Mapping	Databases
Vulnerability Mapping	Aquifer Classification
Application of DRASTIC	Zones of Attenuation
Hydrochemical Mapping	Land-Use Control
Standards of Groundwater Quality	

Groundwater Protection Zones

The delineation of a groundwater protection zone should be on both technical and non technical grounds such as geographical or sociological factors which could be defensible in a court of law. There cannot be a total ban on all activities in the general area of a natural mineral water company. A combination of groundwater quality mapping, aquifer vulnerability and land-use control should be used to delineate groundwater protection zones. Groundwater protection zones should be devised so that specific activities that normally are considered potential groundwater pollutants are allowed only if the technology or construction used is modified so that the potential for pollution no longer exists e.g. sewage treatment plant modified or its modus operandi modified or septic tanks of a certain specific construction or specification installed in the area of the catchment.

Groundwater Protection Modelling

Account needs to be taken of aquifer vulnerability mapping, land management and the integration of aquifer management techniques with realistic industrial and farming practices and policies. An added development would be the use of GIS systems to integrate several layers of relational information together to provide a means of modelling the groundwater protection area taking account of geology, hydrogeology, geomorphology, land-use, remote sensing data, potential point and diffuse sources of pollution, and infrastructure. Such a model could be used for risk assessment and analysis and as a management tool for local authority development plans. Remote sensing could allow aquifer protection areas to be updated seasonally to take account of land use changes and changing moisture content of soils. Ultimately a combination of remote sensing and GIS could facilitate the annual or twice yearly assessment of the groundwater protection area for a source.

Conclusions

The protection of a natural mineral water source can be broken down into three broad sequentially occurring phases. The first phase is data collection; the second is modelling of the aquifer and delineation of the ground-water protection area; and the third is using that modelling as a tool for management of the aquifer in conjunction with the data collected in phase l. All three are inter-related and mutually dependent.

There are various broad groundwater protection strategies available. There is the use of legal means to prevent groundwater contamination in the first place. There are a series of field work strategies such as vulnerability mapping, groundwater quality classification, databases of water quality, land-use surveys and modelling. There are also strategies that require co-operation with third parties. These could include land management with farming organisations, planning controls, environmental monitoring and general education.

Having assessed the area one can then use the results for planning purposes or for protecting existing sources and the development of new sources. The result could be the designation of special management areas that would require particular attention. Finally, there would be a need to provide an alternative well field completely separate from the existing well field. All potential sources of contamination in the new well field groundwater protection area will be examined at the out set so as to ensure it cannot be compromised in the future.

Shane O'Neill, Trinity College Dublin.

(Complete Paper originally presented at one day conference on aquifer protection at Geological Society Of London: Hydrogeology Group, February l5th, 1994.)

NEWS FROM ABROAD

England: Landfill and the "Dilute and Disperse" Principle.

The "dilute and disperse" principle and philosophy has failed once again in Cambridgeshire, where the clean-up of two landfills will run to millions of pounds, according to the National Rivers Authority (NRA). Drinking water from a public supply borehole showed increasing levels of mecoprop herbicide in 1987, which forced the water company to install treatment. The sources of pollution were shown to be two landfill sites which took pesticide washings. The sites were licensed on a "dilute and disperse" principle, even though they are on a limestone aquifer. Containment of the landfills and treatment of the pesticide plume are needed to prevent further pollution and protection of the aquifer. Options include surrounding the sites with bentonite cut-off walls and treatment of the plume with granular activated carbon.
Source: The ENDS Report, No. 229, February 1994.

England: VOCs in Sewage Sludge Pose a Risk to Groundwater

According to a recent study by the Institute of Environmental and Biological Sciences at Lancaster University, landspreading of sewage sludge containing high levels of volatile organic compounds (VOCs) could contaminate groundwater. As sea dumping of sludge ends in 1998, this research is particularly relevant now that alternative disposal strategies are being assessed. The mean total VOC concentration found was 105 mg/kg dry weight, with aromatic VOCs contributing 82%. Of the ten chlorinated VOCs analysed for, three - 1,1-dichloroethene and tri and tetrachloroethane - were found in all the sludge samples. However the study concluded that sludge disposal to farmland at typical application rates "is not expected to increase soil VOC concentrations to levels of concern in the majority of cases", but that "care must be taken in situations where a sludge with a high VOC content is applied at a high application rate" if groundwater contamination is to be avoided, particularly in areas with a high water table.
Source: The ENDS Report, No. 229, February 1994.

England: Unleaded petrol - A New Threat to Groundwater

During a paper at a recent conference in London on groundwater protection, a comment by Dr. P. Aldous, Principal Hydrogeologist at Thames Water Utilities Ltd., drew my attention to a new threat to groundwater - an additive used in unleaded petrol, methyl butyl tertiary ether (MTBE). As a user of unleaded petrol for environmental reasons, this news was somewhat depressing. An item in the ENDS Report explained the background to the comment of Dr. Aldous. MTBE is added to unleaded petrol as an octane booster, forming up to 5% of regular blends and as much as 15% of super blends. Unfortunately it is at least ten times more soluble in water than other constituents in petrol, and it dissolves and spreads rapidly in groundwater. According to Anglian Water and the NRA, MTBE contamination in East Anglia is now widespread. The compound is not particularly toxic, but has a low taste threshold at about 10µg/l; two cases with taste problems are known to the NRA. A survey by the Water Research Centre (WRc) found contamination at a number of sites, but with levels generally below 1µg/l. MTBE has one advantage - it is a good indicator of petrol contamination because of its solubility and low taste threshold and so it is likely to enable easier and quicker identification of pollution of groundwater by more toxic ingredients such as benzene.
Source: The ENDS Report, No. 225, October 1993.

Denmark: Infilling of Gravel Pits Poses Threat to Groundwater

The Agency for Environmental Protection in Denmark has found that in one county 19 out of 21 gravel pits were polluted with contaminated soil backfill and have warned county councils about the new-found threat to groundwater. The Agency estimates that 100,000m^3 of polluted soil may have been used to fill in gravel pits all over the country.
Source: World Water and Environmental Engineering, January/February 1994.

Compiled by the Editor
