THE GSI GROUNDWATER NEWSLETTER

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PUBLICATIONS

At last the **Newsletter** can report on applied research into the **use of peatland to treat leachate** from waste disposal sites (see item by Gary Grantham on page 3). This research, which so far looks promising, could have major implications here in Ireland.

The initial results of a major study by Richard Thorn and Catherine Coxon on **variations in groundwater quality** (page 8) indicate the flexibility required in establishing a **monitoring programme** for mature karst limestone areas.

On page 5 Tony Cawley completes the summary of a **Galway farm survey**; Ben Dhonau provides interesting comments on **public relations** and the **location of unpopular developments** on page 7; on page 11 Shane O'Neill compares **multiple rate** with **multiple stage step pumping tests**; and on page 14 Eugene Daly warns that if the present **dry weather** continues **water resources** may be **under stress** from late July.

Ireland's good quality groundwater is now the source for an expanding **bottled water industry. Tipperary natural mineral water** is one of our leading brands. On page 2 Stephen Peel outlines the geology, hydrogeology and quality of the Tipperary source and indicates the natural protection from pollution present. In future issues we hope to have similar items on other major brands.

Some of the articles in this issue of the **Newsletter** are longer than usual, due to their particular interest. However we intend to return to our normal format of shorter (350 words) articles in future issues. **Items for the next issue should reach me before mid August.**

Donal Daly, Geological Survey of Ireland.

GROUNDWATER QUALITY AND POLLUTION

Tipperary Natural Mineral Water

Tipperary Water has its source in the village of Borrisoleigh, located at the edge of a low-lying outcrop of Dinantian limestone, in the catchment of the River Suir, which is characteristic of much of the Irish Midlands. The limestones, which are mainly dark and clayey, are locally impermeable and the groundwater source is in the underlying Devonian sandstone which was tapped by drilling through the limestone to a depth of 85 metres. Consequently the impermeable limestones protect the groundwater source from potentially polluting activities at surface.

The sandstone strata dip gently to the southeast on the flanks of a mountainous area of older Silurian rocks. Rainfall on this higher ground percolates through low permeability sandstones, shales and siltstones creating artesian conditions at the Tipperary source. The chemistry of the Tipperary source reflects this provenance, having a hardness of 175 mg/l ($CaCO_3$) which is about half that of groundwaters from the limestone aquifers that are widely used around the country. In addition, Tipperary Water has very low levels of trace inorganic and organic chemical constitutents.

Daily analyses indicate a consistently high bacterial quality, with low total plate counts. Other microbiological analyses indicate an absence of organisms which, if present, would be indicative of water pollution.

Tipperary Water is therefore a high quality groundwater. It satisfies the requirements of the EEC Mineral Water Directive and according to the criteria of the Directive it can be described as having a low mineral content. However, as with any water source which might be subject to natural processes, such as filtration or ion exchange, or be affected by human activities, whether from an agricultural or urban source, regular monitoring of water quality and of the factors that may influence the water quality is essential. Accordingly a programme of monitoring is followed to ensure that the high quality of the product is maintained in conformity with statutory requirements.

Stephen Peel, Minerex Ltd

Treatment of Landfill Leachate by Naturally Occurring Peat Deposits: A Case Study in West Wales

Introduction: Landfill leachate has the potential to cause serious pollution of ground and surface waters and needs to be carefully managed to ensure environmental degradation does not occur. On-site leachate treatment in aerated lagoons is proven technology in Britain and Ireland (see Robinson and Grantham, 1988), but many sites are small and remote from electricity supplies, making such treatment non feasible. However, such areas are often sited on or adjacent to areas of peat, and the possibility of using peat to treat landfill leachate is receiving increasing interest.

In west Wales, Ceredigion District Council (CDC) operate a landfill site which is situated on a large deposit of peat at Borth several miles north of Aberystwyth and to the south of the mouth of the Dyfi estuary. A trial study has recently been set up to evaluate the efficiency of using the naturally occurring peat as a treatment medium.

The Site: Tipping occurs directly on to the peat and has been occurring for approx. thirty years. Good landfill practices are followed. The site accepts predominantly domestic refuse which is deposited in thin layers within small bunded cells. Cell bunds and cover consist of imported clay and shales. Leachate generated within the wastes flows laterally from the site and collects in an open perimeter channel where it is diluted by run off of surface water from adjacent peat deposits and direct rainfall. The perimeter channel drains into a railway drainage system which itself discharges into a nearby river, the Afon Leri. The Afon Leri is a high quality salmon river, and the Welsh Water Authority (WWA) are concerned to safeguard the quality of the river. CDC wish to extend the tipping area to provide extra capacity for the district, but prior to granting their approval for any extension WWA requested that CDC demonstrate that such an extension would not impair the quality of the Afon Leri. CDC subsequently commissioned Aspinwall and Company to investigate leachate management strategies for the site, to ensure that leachate is managed in an environmentally acceptable manner, and to satisfy WWA that contamination of the river will not occur.

Hydrogeological Investigation: A hydrogeological investigation was undertaken to define the groundwater and surface water regimes and to assess the fate of leachate which migrates from the site. Sampling and analysis of groundwater within the peat deposits revealed that significant attenuation of ammonia levels and biological and chemical oxygen demands were occurring, whereas the mobile and generally non reactive chloride ion was subject only to dilution. It was apparent that the peat deposits were acting as a natural leachate attenuation medium. Therefore, we proposed that a small area of peat be used to treat leachate in a controlled manner, and that the efficiency and mechanism of the treatment process be evaluated. This would enable the requirements for a full scale treatment plot to be defined.

Leachate Treatment Trials: A circular area of peat (approximately 200m^2) was isolated by excavation of a surface water interception channel. Leachate is pumped from the perimeter channel around the site into a holding tank, where it is permitted to drain into a gravel filled sump, from where it infiltrates into adjacent peat deposits. Standpipe "Casagrande" piezometers were installed at various distances from the central sump and at different depths in the peat to monitor groundwater level and quality. Routine on-site monitoring is undertaken for pH, electrical conductivity, dissolved oxygen, temperature and ammonia using portable field instruments. Periodically, bulk water samples are submitted for a full laboratory analysis. Total rainfall is measured by a standard British Meteorological Office rain gauge, and rainfall events are recorded by a tipping bucket rain gauge linked to a data logger. The volume of leachate treated is measured and recorded.

In order to better understand and define the flow pattern and velocity of groundwater through the peat, a simple tracer test was devised and carried out using lithium chloride as the tracer.

Preliminary Results: Results of the trial are still being evaluated and processed. Preliminary results indicate that many leachate species, including heavy metals and ammonia are significantly reduced in concentrations in groundwater in the peat deposits compared to the concentration of these species in the source of leachate. The mechanisms for leachate attenuation and the efficiency of the treatment process are still being assessed.

Further information will be forthcoming when all results have been fully evaluated.

Reference: ROBINSON, H.D. and GRANTHAM, G. "The Treatment of Landfill Leachates in on-site aerated Lagoon Plants: Experience in Britain and Ireland". Water Research, Vol. 22, pp. 733-747, 1988.

Gary Grantham, Aspinwall & Co. Ltd.

Galway Farm Survey Results (Part 2)

Two river catchments were chosen in which an intensive farm survey was carried out, the Abbert and Grange catchments. In this analysis, only data from the Abbert catchment was used, with the aim of producing effluent volumes from agricultural sources which have a potential to pollute either surface or groundwater supplies. The parameter B.O.D. (biochemical oxygen demand) was used to denote the pollution strength of organic waste materials. Typical comparative BOD values in mg/l for farm effluents are :- silage effluent 60,000, cattle slurry 17,000 and soiled yard water 100, while domestic effluent has a BOD value of between 200 and 350 mg/l.

The survey data for the Abbert catchment covers 56% (14,000 ha) of the total catchment area, with a further 16% being classified as non-agricultural land (i.e. marked bogland & forestry). The remainder, some 7,500 hectares (28%) of agricultural land was unsurveyed. The values produced from the surveyed regions were extrapolated onto the unsurveyed ones by a method of dividing the catchment into zones and extrapolating their respective averages onto the unsurveyed regions of each particular zone. Calculation of effluent totals was carried out in accordance with guidelines published by the Dept. of Agriculture for a five month wintering period. The results are displayed in the table below.

The calculation of domestic effluent volumes for percolation via a septic tank system involves assuming that all houses supplied by public or group water schemes contribute to this volume, and that those not partaking of such schemes

Abbert Catchment Yearly Farm & Domestic Effluent Inputs

Effluent Sources	Effluent Volume m^3	B.O.D. conc. mg/l	B.O.D mass kilograms
Farm Slurry Runoff	46,000	17,000	780,000
Silage Effluent Runoff	11,000	60,000	660,000
Soiled Water Runoff	60,000	100	6,000
Total Effluent Runoff	117,000	-	1,446,000
Farm Slurry storage	66,000	17,000	1,120,000
Silage Effluent storage	7,500	60,000	450,000
Soiled water storage	8,500	100	850
Total Effluent Storage	82,000	-	1,570,850
Septic Tank Effluent	220,000	300	66,000

may be neglected from this volume. For the Abbert 800 houses are supplied, producing a yearly domestic effluent volume of 220,000 cubic metres.

An alarming if not disturbing statistic for this catchment is the high percentage of farms without adequate effluent storage or disposal facilities. In all, 40% of all housed animal effluent and 60% of the total silage effluent produced are allowed to runoff into nearby rivers and streams or to percolate directly into the groundwater. The bedrock of this catchment is karstic and thus rapid unfiltered transmission of runoff to the groundwater occurs. The soil cover functions as a natural layer which filters contaminants from the percolating water. In the case of the Abbert, and that of many karstic regions in Galway, the soil cover is relatively thin and there are a high density of fissures, fractures and ponors (swallow holes) open to the atmosphere, thus leaving little opportunity for attenuation of effluents. The degree of contamination depends on the proximity of these open fissures and ponors to effluent point sources and on the local permeability of the surrounding bedrock.

A lot of blame for contamination of water supplies has been attributed to septic tanks with inadequate percolation systems (i.e. soakpits in karst areas). Yet the survey results indicate that the agricultural waste runoff has the greatest potential to pollute - 7.5% of the total farm slurry runoff or 10% of the total silage effluent runoff are equivalent, in terms of BOD mass, to the total annual domestic effluent produced. Also these agricultural wastes are loaded over a shorter period of time and are thus more detrimental to water sources.

Effluent Sources	B.O.D. kilogram	Domestic Effluent as % of	Period of loading
Animal Slurry Runoff	780,000	7.5	5 months
Silage Effluent	660,000	10.	2-3 months
Domestic Effluent Volume	66,000	100	12 months

Another factor which may contribute to contamination of surface and groundwater sources is the land spreading of farm wastes. It is felt that this process is relatively pollution free, if the effluent is spread on suitable land which has adequate soil cover and sufficient distance from streams, springs and ponors. The effluent should also be spread during favourable climatic conditions and when there is a sufficient soil moisture deficit to allow minimal percolation to the watertable. Unfortunately our climate does not allow such favourable conditions to prevail for very long, such that a high percentage of land spreading occurs under unfavourable conditions, leading to a high risk of contaminating water sources.

If favourable conditions and correct procedures prevail, land spreading appears to be the only practical solution to the problem of farm waste disposal. For the Abbert catchment 40% of the total area is land spread with an average applied concentration of only 0.018 kgs/m^2 per annum. If the total catchment effluent volume was evently spread over all agricultural land, it would mean a BOD conc. of 0.015 kgs./m^2. This implies that there is plenty of room for greater intensification of farming practices, if and only if, correct procedures in land-spreading, control and storage of all farm effluent are enforced.

Tony Cawley, Dept. of Engineering Hydrology, U.C.G.

Pollution, Planning and P.R.

The Royal Institution of Chartered Surveyors and the Institution of Mining and Metallurgy held a joint meeting in Glasgow last September entitled "Mineral Extraction - is it worth it?". This dealt not with the economics of mineral extraction but with the increasing environmental pressure on and objections to mining and quarrying in Britain. Donal Daly tells me that there are many analogies between mineral extraction and waste disposal sites from this perspective.

Public unease manifests itself through the planning process by objections and appeals. The general climate in Britain is showing in refusals, and tough or sometimes unworkable conditions in approvals. Much of the meeting dealt with the experiences of companies in trying to influence public opinion.

I took a number of major points from the meeting from both the good and the bad experiences related by companies and planning officers. The views below are mine and may not have been universally shared.

1. The sins of the past are being visited on the present and future. Large sums are now having to be spent cleaning up old sites which may have been operated quite acceptably in their time. Moreover, the public sees what it now considers pollution from old sites (even if they were worked according to the then standards), doesn't like it and assumes that a new development will probably be the same.
2. Even a few current bad operations are liable to be taken as the likely norm. The public will, understandably enough, need a great deal of convincing that a new operation will not be the same.
3. I believe that these two points go a long way to explaining the negative initial attitude to many developments. The proposer will need to work quite positively to overcome this.
4. The experience of U.K. companies has been very mixed and this is reflected by their attitudes: notably, those which had adopted a positive attitude to P.R. to explain and demonstrate that there was nothing to fear (as long as there is nothing to fear) had fared far better than those who basically view the public as the "the enemy".
5. A concerted campaign is needed to get over the message that there is a real need for minerals (and waste disposal sites!) for the community and not just for private profits i.e. to counter the "not in my back yard" syndrome.

Some specific points:

a) A good reputation is very valuable for long-term acceptance; at least one company employs an environmental team to educate its own managers and stresses that good environmental management is not an optional extra to be dropped for short-term profits.

b) Large public meetings are one of the last great blood sports with the company staff as the quarry.

c) Talking directly to the individuals who may be affected and to elected members is well worth doing at small meetings.

d) The best P.R. with planning authoritites is to comply with planning conditions.

e) Be honest: don't promise what you can't deliver and deliver what you have promised. P.R. should be carefully designed and the guiding principle should be **"the truth well told"**.

f) Because many extractive (and waste disposal) operations are short-term, it is assumed that the locals ought to tolerate them and there is no need for the operator to be involved with the local community. This is a wrong assumption and generates hostility; being a good corporate citizen pays off in the long-term.

g) Much PR is long-term e.g. it is worth talking to schools.

Finally, David Bellamy, the well-known environmental campaigner was quite well disposed towards mineral extraction, properly managed. He saw many positive points especially in contrast to intensive agriculture and housing estates or industry. A particular point he made was **"Get the kudos"**. In other words if you are managing a site well let people know who is doing it: otherwise whoever eventually takes it over will get the credit.

Further details of the papers are available from:

Ben Dhonau, Geological Survey of Ireland.

Variations in Groundwater Quality - Implications for Monitoring Programmes

The interpretation of groundwater quality data, particularly where the data are isolated or sporadic, is influenced to a large extent by the degree of variability of water quality in the aquifer. The factors that influence the variability include hydrogeochemical effects - caused primarily by differences in rock type - and hydrogeological effects - caused primarily by the degree of fissuring and/or conduit development. Of these two factors the first is generally appreciated. However, the extent to which the hydraulic

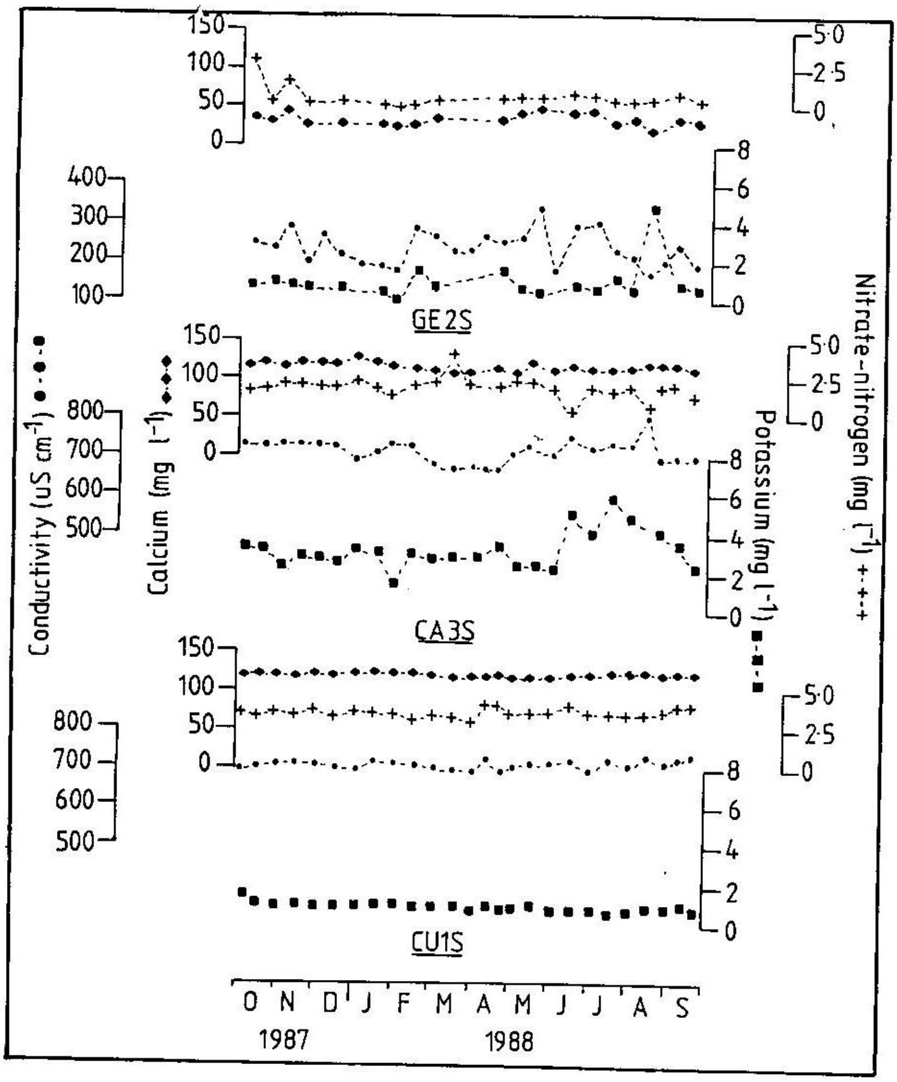


Figure 1. (After Coxon and Thorn, 1989).

characteristics control groundwater quality variations has only recently attracted attention.

Figure 1 shows the water quality variations (sampled fortnightly) at three springs in different hydrogeological settings. Site GE2S is fed largely by concentrated recharge via swallow holes into a mature karst aquifer in which the underground velocity varies from less than 31m/hr at low stage to 92m/hr at high stage. Site CA3S is fed partly by concentrated recharge into a karst aquifer with a velocity varying from 36 to 99m/hr and partly by recharge through an overlying gravel aquifer with flow rates of 1 to 2m/hr. Site CU1S is fed by intergranular flow through a sand and gravel aquifer.

Not only is the annual range greatest at the most karstic site i.e. GE2S but the time scale of change is also short. The rapidity with which water quality changes in the mature karst aquifer reflects the fact that water passes through the system very quickly. Clearly, there would be difficulties in interpreting sporadic or isolated water quality analyses from such an aquifer. In contrast, the lack of variability in the intergranular aquifer means that relatively few samples would be needed to characterise the water quality and thus interpretation of data is much easier.

It is obvious that sampling at regular intervals of six months, three months, one month, or even, as above, at fortnightly intervals is not sufficient to characterise the water quality variations in mature karst aquifers. Equally clearly it is not economically feasible to sample at shorter intervals, e.g.

every day. Since the short term changes in water quality that occur in karst aquifer are related to rainfall events, the best answer would appear to be to supplement a regular sampling programme (e.g. monthly) with intensive sampling of one or more flood events so as to determine the nature of the response of the aquifer to recharge. This should allow the personnel in charge of maintaining the quality of the water supply to predict when deterioration in quality is likely and thus take avoiding action.

This article is a summary of two papers presented at the IAH (Irish Group) 9th Annual Seminar on Groundwater Chemistry and Groundwater for the Bottled Water and Aquaculture Industries, Portlaoise, 25th and 26th April, 1989. Copies of the papers entitled 'Variations in Groundwater Quality' and 'Groundwater Monitoring' may be obtained from the authors. Some of the data also appear in: Coxon, C. and Thorn, R.H. (1989 - In Press) "Temporal variability of water quality and the implications for monitoring programmes in Irish limestone aquifers." Proceedings of IAHS International Symposium on 'Groundwater Management: Quality and Quantity' Spain, October 2nd-5th, 1989.

Richard Thorn, School of Science, Sligo R.T.C. and Catherine Coxon, Environmental Sciences Unit, T.C.D.

NEW PUBLICATIONS

Quarry Directory - Active Quarries and Pits in Ireland

For many years there has been an obvious and urgent need for a directory of active quarries and pits in Ireland. Such a directory is needed by planners, economists, engineers, geologists and especially by consumers and producers of natural materials. To meet this demand the Geological Survey of Ireland have attempted to compile the first comprehensive list of active quarries and pits in the country.

The Quarry Directory is based entirely on replies to a questionnaire sent by the GSI to all active surface workings known to them. **The Quarry Directory gives details of 257 quarries and pits.** Information on each site includes the quarry name, townland, county, national grid reference, owner/operator/enquiries to: name, address, telephone number, rock type, products, uses, specifications. Three maps and four indices accompany the text.

The Quarry Directory is an essential reference book for all involved in, or concerned with, extractive industries. It is available from Publication Sales, Geological Survey of Ireland, Beggars Bush, Haddington Road, Dublin 4, price IR£10 (incl. p+p).

Maeve Boland, Geological Survey of Ireland.

GROUNDWATER DEVELOPMENT

A Comparison between Multiple Rate and Multiple Stage Step Testing of a Thin, Shallow Alluvial Gravel Aquifer.

1. Introduction: Extracting water from a borehole causes a decline in local water levels. This drawdown is caused by hydraulic losses as the water moves from the aquifer into the well. Aquifer losses are due to the resistance to flow of water by the aquifer material as the water approaches the well. Well losses are due to the non-laminar flow of water as it enters the well via the screened section.

Step testing is conducted to determine which component of drawdown is due to well losses and which is due to aquifer losses. There are two types of step test - multiple rate test and a multiple stage test. The multiple rate step test involves the periodic incremental increase in discharge without allowing the well to recover between each increase. The duration of each step is exactly the same. A multiple stage test allows the borehole to recover fully between each increase in discharge. Each stage is also run for the same duration. Both methods allow the aquifer loss and well loss coefficients to be differentiated and quantified. This enables the calculation of the specific capacity of a borehole for a given duration of pumping, at a constant disharge.

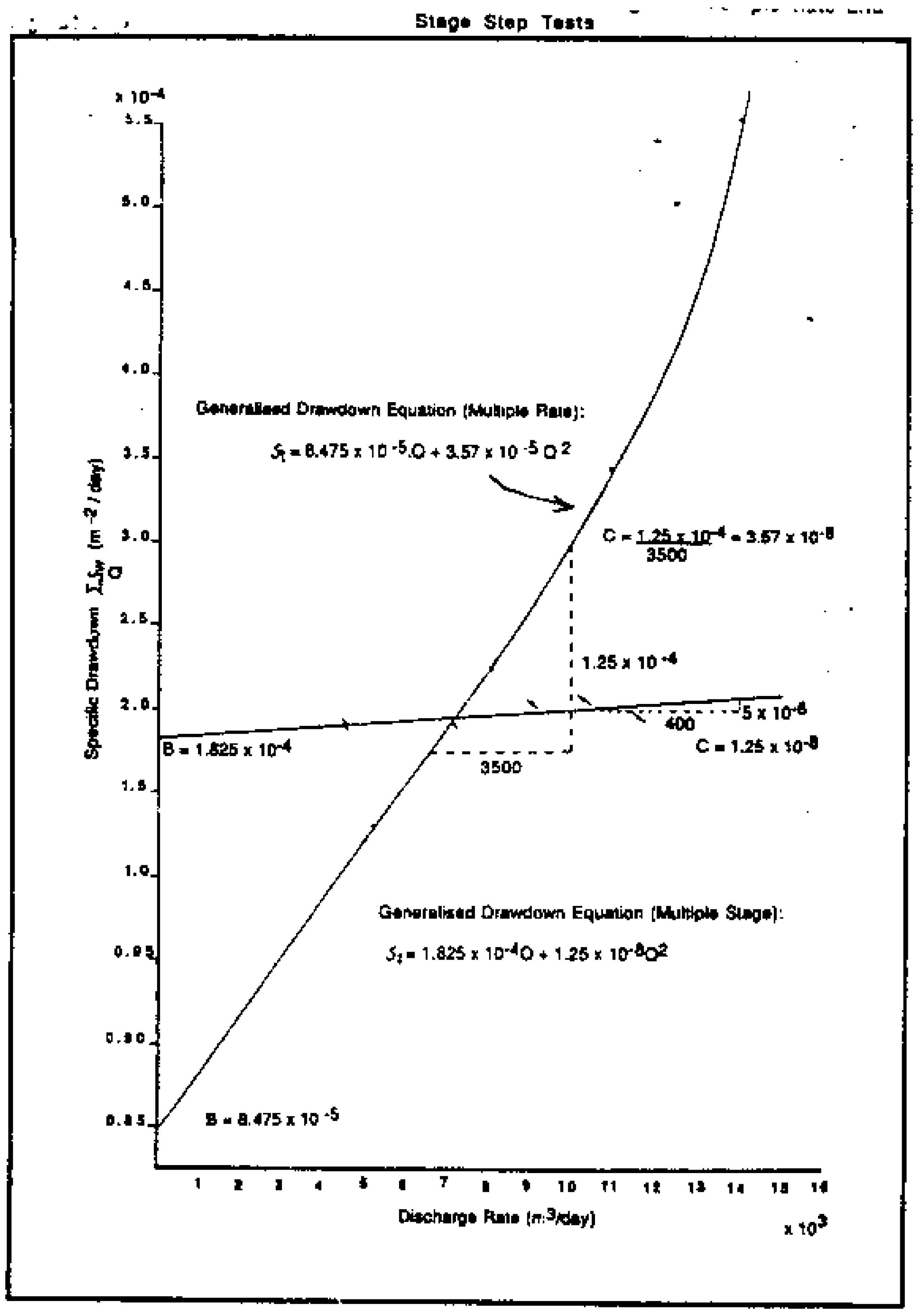
The aquifer in question is located in the centre of Dublin. It consists of thin - 4.5m - alluvial sands and gravels and is not very extensive. An 18" borehole was drilled into this aquifer to a depth of 12 metres. The water table was 3.5m b.g.l.

2. Step Test Analyses: A multiple rate step drawdown test was carried out first. The results were corrected for drawdown and plotted. Several analysis methods were attempted - Jacobs, Bruin and Hudson, Rorabaugh, and Eden and Hazel (1972) - but all proved unsatisfactory.

Therefore it was decided to conduct a multiple stage step test. This allowed the pumping borehole to recover fully before each increase in discharge. The results of these drawdown tests were more meaningful.

The final drawndown value for any given discharge increment, corrected for dewatering, was divided by the discharge for the stage to give a value for specific drawdown. The results of both types of step tests are plotted on Fig. 1 for comparative purposes.

3. Interpretation: The primary premise in any step test analysis is that the incremental increase in discharge is analogous to another pump being installed in that well, pumping at a rate equal to the increase in discharge. This principal of superposition disregards the fact that ideally the watertable should be at rest and horizontal prior to each new increase in discharge. However it has been shown widely in the literature that this principal is in practice valid.



In theory the flow within the aquifer should reach a steady state. The water level in the borehole being tested continued to decline throughout each step. This indicated that the flow within the aquifer throughout the multiple rate step test was always in a non steady state. In theory the aquifer is assumed to be homogenous and of uniform thickness. It is evident from the pumping test results carried out on other boreholes tapping the same aquifer that it does vary spatially in thickness and composition. The criteria that the well should fully penetrate the aquifer was satisfied.

The expected reaction of an ideal aquifer to pumping is an initially steep drawdown slope for the first few seconds or minutes as water is released from storage. This is followed by a shallower sloped line reflecting the lag effect of dewatering of the aquifer. Finally a steady state equilibrium is reached with a gradual linear decline in water levels over time. In the case of this aquifer, the drawdown plot remains as a curve getting steeper and steeper over time, without ever actually attaining some degree of equilibrium. This is due to the fact that one is dealing with a relatively thin aquifer that is being progressively dewatered. As a result of this, the saturated thickness of the aquifer is constantly being reduced. This means that the transmissivity is being lowered. Permeability is an intrinsic aquifer parameter and will remain relatively constant. This reduction in the value of the transmissivity gradually increases the slope of the drawdown curve such that a state of semi equilibrium is never reached.

After 7 days of constant pumping, at a rate of 14l/s, there was an actual drawdown of some 1.33 meters. In an aquifer only 4.60 meters thick this represented a 29% decrease in the saturated thickness of the aquifer. The consequences of this are that the use of multiple rate step test analyses, while correct in theory, are not applicable to this aquifer. The theoretical drawdown, as given by the generalized drawdown equation, does not, in fact, reflect the true reality of the situation.

The reduction in saturated thickness of the aquifer due to pumping still affects the results of the multiple stage step tests. However the effect can be minimized by allowing the well to fully recover between each stage.

4. Conclusion: In this shallow anisotropic, inhomogenous alluvial aquifer, the theoretical requirements for the use of multiple rate step testing are not met. The aquifer is too thin and not extensive enough. It has been found in general that multiple stage step testing gives more reliable results. If time permits it is recommended that multiple stage step testing be carried out in preference to multiple rate testing.

Shane O'Neill*, Environmental Resources Analysis Limited.

***Shane O'Neill** graduated with an honours degree in geology from Trinity College, Dublin in 1986. He joined ERA that year as an exploration geologist. His main work was using remote sensing and structural geology techniques to locate target areas for exploration drilling.

In 1987 he did an M.Sc. in hydrogeology at University College, London. Upon successfully completing his degree he rejoined ERA as a consultant hydrogeologist. His main areas of interest are ground water quality and the overall development of water resources in Ireland.

Editor

EDUCATION

Seminar at Sligo R.T.C.: "Bacterial Contaminations of Groundwater".

The School of Science, Sligo Regional Technical College, in conjunction with the I.A.H. is organising a one day seminar/workshop on **'Bacterial Contamination of Groundwater'.** The seminar will be held in the R.T.C. on **Friday 22nd September.**

The seminar is aimed, primarily, at the many people involved in the development and use of groundwater who don't have any training in bacteriology, e.g. many geologists and engineers. The seminar will consist of an introduction to environmental bacteriology as it relates to groundwater, a series of laboratory demonstrations and exhibits which will guide the participant through the various techniques used in the bacterial analysis of groundwater and a series of short talks on the applications of environmental bacteriology to groundwater studies. The topics covered in the taks will include; water tracing using microbes, bacterial survial in soils and the bacterial mobilisation of metals.

The cost of the seminar will be £60 which will include a copy of the proceedings and lunch and tea and coffee. There will be a discount for students and IAH members. Further details and a booking form will be issued at the end of August. The number of participants will be limited and participation will be on a 'first come first served' basis.

Richard Thorn, Sligo R.T.C.

A MESSAGE TO WATER SUPPLY ENGINEERS AND POLLUTION CONTROL OFFICERS

Could you cope with a water shortage this summer?

As a result of low winter recharge and the dry spell in May, groundwater and river levels in certain parts of the southeast of Ireland are unusually low for this time of year. If only average rainfall occurs over the next three months then groundwater recharge and near surface runoff will not take place in any significant quantities until mid-September at the earliest. In these circumstances water resources are likely to come under stress towards the end of July/early August. The consequences will include:

a) reduction in riverflow, hence less dilution of waste effluents;
b) reduction in well output especially in the case of shallow dug wells, boreholes with pumping levels close to the principal production zone and wells already with excessive drawdowns;
c) possible changes in well water quality;
d) reduction in the flow or the drying up of normally permanent seeps, springs and streams.

The areas most likely to be affected initially are areas underlain by impermeable strata (low storage) especially upland areas (steep gradients) and the upper (recharge) parts of some aquifers where the water table is frequently deep and with a large annual fluctuation. Some steps can now be taken which might minimize the consequences of a continuation of the dry weather:

1) monitor the existing position i.e. water levels/flows, output and quality and compare them with those of previous years;
2) monitor these general parameters on say a weekly basis to be able to predict the situation in August/early September;
3) if you face the prospect of a water shortage in some areas see if you can raise the output in other areas and/or develop groundwater sources on a temporary basis. Boreholes and wide diameter dug wells (in certain areas) can be brought into production cheaply and quite quickly;
4) implement water conservation measures early;
5) reduce effluent discharges or at least large discharges over short periods;
6) develop temporary surface storage if possible which could be released in the event of a pollution incident;
7) if the above is not sufficient pray for rain, lots of it.

There probably won't be a water shortage this year but there will be some day. Be prepared!

Eugene Daly, Geological Survey.
