INTERNATIONAL ASSOCIATION OF HYDROGEOLOGISTS (IRISH GROUP)

8TH ANNUAL SEMINAR

KILLESHIN HOTEL, PORTLAOISE

P R O G R A M M E

TUESDAY 12TH APRIL		SPEAKER & ORGANISATION
The Future of Groundwater Development in Ireland		
10.15	Registration & coffee/tea	
10.45	Welcome and Introduction	Mr P Bennett, President, Irish Group & Geological Survey of N Ireland
11.00	Keynote Speaker: The Future of Groundwater Development	Mr Glyn Jones, University College, London
12.00	Groundwater for Public Supply	Mr P Callery Wexford County Engineer
12.30	Groundwater for Group Schemes	Mr T Geraghty, Department of the Environment
13.00	Discussion	
13.15	Lunch	
14.30	Aquifers of the Future: (1) The Mid-Kildare Gravels	Mr G Wright, Geological Survey of Ireland
15.00	(2) The Kiltorcan Sandstone	Mr E Daly, Geological Survey of Ireland
15.30	Tea/coffee	
16.15	The Future of Well-Drilling	Mr B Dunne - Driller, Dromiskin, Dundalk
16.45	New Uses for Groundwater - fish farming, irrigation, bottling, energy	Mr K Cullen, Consultant Hydrogeologist
17.15	Discussion	
17.30	(approx.) Close	

WEDNESDAY 13TH APRIL

Environmental Impact Assessments		
9.30	Environmental Impact Assessment: The Directive	Mr G Walker, AFF
10.00	Environmental Impact Assessment	Mr D Kelly, IIRS
10.30	Discussion	
10.45	Coffee/tea	
11.15	Environmental Impact Assessment: Tara Mines - A Case Study	Mr B Dallas, Enviroplan Services Ltd
11.45	Hydrogeology & Environmental Impact Assessment of a Proposed Large Open Cast Mine at Ballymoney	Mr D Finlayson, Hydrotechnica, Shrewsbury
12.15	Discussion - Close	
12.45	Lunch	

Talk to the IAH (Irish Group) at Dublin, 12 April 1988

THE FUTURE OF GROUND WATER DEVELOPMENT

G.P. Jones, University College London

INTRODUCTION

Given that the subject of this talk is a fairly well-worn theme, it is not surprising that during its preparation I experienced a feeling of "deja vu", and during its presentation I am sure that others will feel the same.

To my mind, the future of ground water development is inseparable from the future of hydrogeologists, and in what follows hereafter there is therefore a presumption of the continuing availability of hydrogeological expertise.

A natural starting point for this talk is with an analysis of the title. In any consideration of the "future", we certainly should not be thinking of the next fifty years which is far too long for rational discussion. Equally, the next ten years is too short a period over which to expect significant change. An appropriate length may be to look at a period of about 25 years, which is also appropriate because it may be related to an effective working life as well as emphasising that the future lies not with us, but with the next generation, that is, with people who have not yet become hydrogeologists.

Turning to "ground water"; by strict definition we are restricted to the water lying below the water table, though in practice we extend our interest to the water in the unsaturated zone when it is likely to have important effects on either quantity or quality of replenishment. More importantly in the context of this talk, it needs to be recognised that subsurface waters extend down to considerable depths, far in excess of those customarily drilled for water wells. In the future, therefore, the focus of concern for the hydrogeologist must be all subsurface void spaces and the fluid(s) they contain.

Finally, the concept of "development" needs to be very different from that of conventional use. To my surprise, the dictionary definitions make no mention of use nor indication of benefit. They refer to 'growth', to make 'more elaborate' or to 'bring to maturity', all concepts which I am happy to relate to hydrogeology, but falling short of my expectation.

Any look to the future needs a check as to where we are now. We all know the principal of uniformitarianism that states "the present is the key to the past"; in the absence of a crystal ball there is much relevance in the claim that the present is also the key to the future.

The major present-day fields with which hydrogeological activities are associated are:-

Ground Water Resources
Hydrocarbon Resources
Energy Resources
Mineral Resources
Waste Disposal
Storage Space Resources
Ground Water Engineering

In the time available, I cannot deal in equal detail with all the aspects of hydrogeology which I will mention. What is common to workers in all the fields is a 3-D conception of subsurface voids, an appreciation of fluid flow mechanisms, and above all a need to express the description of prevailing hydrogeological conditions in a quantitative rather than qualitative manner.

GROUND WATER RESOURCES

The provision of a pure and wholesome water supply will always remain the premier benefit to be derived from the practice of hydrogeology. In the future, as in the past, this will require knowledge of regional lithology and tectonics to identify the void nature, the flow system, and water quality characteristics. Attention to detailed knowledge of local hydraulic properties will always be essential if properly located and designed wells are to yield adequate sustainable supplies.

To achieve this, the hydrogeologist will have to call upon an expertise that can only be gained in the field. The project scale may range from single well to multiple well-field with or without regional development, and with capital costs in proportion. In all cases, the judgement involved whether by an individual or a team of specialists in the sequence from conceptual model, via exploration phases including remote sensing and surface geophysics, to drilling with borehole log interpretation, well completion procedures and phased development, demonstrates the classic application of science for the benefit of mankind.

Even more in the future than now, the computer will be to the hydrogeologist what the hammer is to the field geologist - an essential tool. Instead of being an institutional facility, the spread of powerful personal computers will bring to individual desks the ability to pursue a number of activities that have direct relevance to our branch of science. At its simplest, the PC is a word processor; it also provides a data handling, retreival, printing and plotting facility for a variety of databases, and serves as a calculator for the simplest and complex of mathematical and statistical problems. It will offer an opportunity for the combination of analytical and numerical methods as complementary tools for the analysis of aquifer test data and the quantification of those hydraulic properties that are essential for more advanced modelling. The hydrogeologist of the future should also be able to take advantage of the recently available PC versions of 3-D mainframe flow models which allow regional simulation for sensitivity analysis or predictive purposes.

To a large extent, in the developed countries of the world, is is generally assumed that the quantification of ground water resources has been or shortly will be completed. Future hydrogeologists need not despair, because such assumptions have frequently been shown to be unfounded. Overseas, in the so-called 'developing' countries, the location and exploitation of ground water resources will continue to provide a mixture of personal satisfaction and frustration for many years to come.

Present-day problems of diffuse- and point-source pollution from domestic, industrial and agricultural origins are currently receiving much attention from both scientist and the public. Nevertheless, one does not need to be a pessimist to realise that despite the aquifer protection measures already being implemented or planned in those countries that can afford them, the hydrogeologists of the future will still frequently find themselves having to devise remedial action for pollution events.

HYDROCARBON RESOURCES

An understanding of fluid flow systems is a pre-requisate to successful development of both ground water and hydrocarbon resources. However, it is worth emphasising that oil and gas are essentially minority fluids in a predominantly ground water flow regime. The main differences are in the depth at which the resources are tapped and the relative cost of the products which is transmitted in turn to most of their respective activities. One other difference which should not be overlooked is the predominantly simple single-phase liquid (water) compared with the complex multi-phase (gas-brine-oil) fluid systems typical of most hydrocarbon resources.

In both the exploration for and extraction of hydrocarbons hydrogeological knowledge is at a premium. 3-D stratigraphical, sedimentological and structural appreciation of the lithological sequence, together with an understanding of the ground water flow systems allows the identification of potential reservoirs. Hubbert's remarks of 25 years ago to the oil industry that "in addition to our customary procedures ... we must now add regional ground water hydrology" are if anything more apposite now to the search for smaller fields as the larger deposits become depleted.

Where hydrogeological colleagues can learn greatly from petroleum industry practice for future application is in the design and operation of producing wells.

ENERGY RESOURCES

Naturally-hot ground waters have been used since time immemorial for bathing and therapeutic purposes, but modern utilisation of steam for electricity generation dates from the turn of the present century, when the first geothermal power station was built in Italy. Despite a steady increase since that time (and particularly over the past decade), geothermal energy constitutes a small, though locally important, part of the total energy consumption of the world.

Heat flow from the Earth's interior is widespread and diffuse, with geological features usually defining its geographical location and hydraulic parameters determining its economic significance. The hydrogeologist is well suited to play a key role in this exploitation since the geological environment will to a large extent control the nature of the source, while ground water is the medium for the heat transfer, either in liquid or vapour form.

High enthalpy (>150^{o}C) sources are commonly restricted to tectonically active regions associated with plate boundaries. The reservoirs usually form at depth in fractured crystalline-rock systems with highly mineralised fluids that require high-level technology for their exploitation. A comparison with shallow, fresh-water aquifer systems is more apparent than real, except that replenishment is equally critical. The type of geothermal system depends on the relationship between replenishing ground water (R) and the prevailing heat supply (H).

Away from tectonic zones, low enthalpy resources are found widely distributed with waters having temperatures up to 60^{o}C at depths approaching 2km, and can be separated into two types. Storage systems are commonly found in thick sedimentary formations with the contained water being old or very old, not in active circulation and with water temperatures equal to that of the containing rocks. Cycle systems are categorised by actively circulating fluids fed by precipitation and are much the more common of the two systems.

Two further contrasting categories of geothermal energy utilisation are worth mentioning; firstly, HDR at great depths and secondly, the constant temperature of ground water at shallow depths. The 'hot dry rock' (HRD) schemes under consideration in the UK and USA are a type of storage rsource that utilises the thermal energy available at kilometres below the surface by artificially creating a fracture permeability medium and circulating injected water via a pair of boreholes. Already in many parts of the USA, and increasingly in other parts of the world, advantage is being taken of the constant natural property of ground water temperature in conjunction with heat pumps. These mechanical devices extract heat energy from water and makes it available for cooling or heating purposes in domestic or industrial buildings, using the aquifer as either a sink or source.

Whatever the form of utilisation, geothermal resources will in certain circumstances offer a viable alternative to the current fossil fuel dominated energy sources. The fact that the latter are finite and must ultimately become more depleted, more scarce and more costly, means that in favourable areas the geothermal sources will become increasingly attractive. The value of hydrogeological expertise in the development of these subsurface fluids is self evident, and needs no further elaboration.

MINERAL RESOURCES

In dealing with the products of the extractive industry, we need to include the metallic as well as the non-metallic groups of minerals.

Currently accepted views on the origin of ore bodies generally propose sea water or meteoric water as the sources of those fluids which as ground waters leached trace elements from the rocks and transported the material in solution to preferentially-favourable areas for precipitation as ore bodies. The accumulation of these mineral deposits has been controlled by temperature, pressure, hydrodynamics and fluid-rock interaction, and recent work on geothermal systems has confirmed the analogy of some with ore - forming systems. Palaeohydrological conditions over a wide range of depths from the land surface down to many kilometres are considered to have given rise to a variety of mineral deposits from coal to uranium.

Having only possibly assisted with the location of the deposit, the hydrogeologist should definitely be involved with both the extraction and restoration phases, regardless of whether the operations take place as surface open-cast or subsurface deep mining. The conventional demands for hydrogeologists in the extraction phase are twofold; firstly, to ensure the provision of a suitable water supply and secondly, to provide assistance with dewatering i.e. the removal of water from the workings.

In any mining operation there is a pressing need for water to be used in various forms of mimeral processing in addition to drinking and ablutionary purposes. This frequently means that substantial supplies of different categories of water quality have to be located and quantified as part of the economic mining feasibility study before the actual decision is made.

Removal of water from workings (deep, shallow, or at the surface) is usual in order to allow mining to take place in relatively dry conditions. Proper design of a dewatering scheme requires detailed knowledge of local hydrogeological conditions and the required depth(s) to which to lower the water levels. Depending on the objectives, shallow well-point systems (staged, if necessary) or deep well systems can usually provide satisfactory solutions, particularly given the assistance of computer aided design.

Solution mining can be used to extract a variety of minerals such as sulphur, copper, uranium and not forgetting common salt. Leaching of the minerals is usually accomplished by injection of fluids ranging from natural or super-heated water to chemically treated liquids which are subsequently pumped to the surface to undergo removal of the solutes. Such 'in-situ' mining is frequently claimed to reduce environmental damage but this will only be so if particular care is taken to avoid the effects of subsidence and migration of the frequently toxic leachates.

Throughout the world, environmental and economic pressures have ensured stricter regulation of mining-waste disposal facilities, whether it be the 'hole-in-the-ground' or the 'tailings dam'. Increasing use of hydrogeological and hydrogeochemical knowledge will be necessary in the location, operation and closure of waste facilities.

WASTE DISPOSAL

By comparison with surface waters, ground water has long been considered to be generally pure and bacteriologically safe, though already this is no longer true in many parts of the world, and will be exacerbated in the future. In recent years much of the emphasis in ground water investigations has shifted from problems of supply to considerations of ground water quality. Through the activities of man, ground water can become contaminated from a variety of point- and diffuse-sources, such as:

- sewage effluent ... ... septic tanks and cess pits
sewage treatment works
- agricultural activities ... inorganic fertilisers
animal wastes and slurries
pesticides and herbicides
silage liquors
- domestic wastes ... ... landfill sites

- industrial wastes ... ... landfill sites
  lagoon sites
  mineral workings
  deep wells

- surface drainage and spillage ... soakaways
  storage tanks
  road salt
  road and rail tankers

- mining activities ... ... mine drainage
  spoil heaps
  tailings dams

- electricity generation ... spoil heaps

- radioactive wastes ... ... low level
  intermediate level
  high level

Fortunately, biodegredation, chemical and dilution processes take place as water infiltrates through the unsaturated zone and percolates through the saturated zone, so that under favourable conditions, these attenuation processes may result in the reduction or removal of undesired substances.

Knowledge of the hydrogeological environment may ensure that pollution of existing ground water sources can be avoided or minimised. A monitoring well network will hopefully become mandatory for every known site where any risk may be anticipated.

The level of appreciation of the interrelated hydro - chemical processes within and below waste facility systems has increased significantly over the past decade, and is destined to be the field of hydrogeology where greatest advancement may be expected in the future. Fundamental to this change is use of solute transport models, which even more than flow models depend upon a wealth of information that is expensive to obtain both in time and money. The eminently fair principle that 'the polluter pays' is open to abuse in practice, and one can foresee a great increase in legal representations, depending on the severity of the available legislation and the vigilance of the implementing agancy.

STORAGE SPACE RESOURCES

I have long been an advocate of the view that the subsurface void space itself is a resource instead of being only a container for some fluid, and in the future this concept of deep storage will no doubt be pursued with more vigour. Exempted from this consideration are artificial excavations such as caverns and tunnels, though artificially-created fracture voids would qualify.

The principle is based on the premise that considerable natural voids of interstitial and/or fracture nature exist underground in a continuum that vastly exceeds any potential surface storage facility. To take advantage of this 'resource' it is necessary to combine hydrogeological knowledge with injection well technology in a reversal of the normal abstraction process.

Gas and compressed air are two fluids that already have been introduced into subsurface aquifers, while the storage of fresh water or treated sewage in saline-water aquifers is a newer aspect. Even more with an eye to the future is the idea of large scale artificial thermal energy storage (ATES) in aquifer systems. The feasibility of storing water heated to 150oC in suitable aquifers at depths in excess of 200m with a view to subsequent recovery for space heating is sufficiently promising for experimental work to have begun.

GROUND WATER ENGINEERING

The related applied geoscience of Engineering Geology overlaps with Hydrogeology in the feld of Ground Water Engineering, with ground water being a 'problem' rather than a 'resource'. In terms of civil engineering application, the hydrogeological work may be restricted to either lowering pore pressure or lowering water levels.

The scale of pressure relief activities is generally of hundreds of metres whereas lowering of water levels may extend for hundreds or thousands of metres. Furthermore, pressure relief by its very nature presumes 'confining' conditions, while water level lowering requirements are applicable only to unconfined conditions. Pressure relief and the normal dewatering for building foundation work are essentially temporary activities. Available techniques involving shallow well systems have been well proven over a number of years and are likely to continue without significant change into the forseeable future.

One obvious consequence of the cessation of pumping water from an aquifer is the rise of water level. This can lead to serious flooding of basements which were constructed at a time when the water levels were artificially depressed. The situation may be worsened in urban areas by leaking mains (water or sewage). Short term and long term solutions are both necessary through local relief drains and regional abstrction, but the responsibility and funding of such operations is less esy to resolve than the hydrogeological response.

EDUCATION AND TRAINING

From the foregoing it is obvious that the hydrogeologist of the future must be a person of many parts. Yet in Europe there is no undergraduate course to direct the essential balance of education over 3 to 4 years. Instead resort has to be made to a 12 month training course with the taught element taking up half to three-quarters of the time depending on the institution, and with little opportunity to make up for any deficiencies in previous education. Nevertheless, the production of postgraduates with a training in hydrogeology appears adequate to satisfy the long-term demand for such personnel. They are usually well equipped with knowledge of fundamental principles and techniques, as well as some insight into their application. These people have a training in hydrogeology but are not yet hydrogeologists.

Being conciuos of my owm traditional background and with no formal qualifications in hydrogeology, I would be the last to advocate any single route for the career development of hydrogeologists. Various alternative routes can be followed with the basic sequence of Education - Training -

Experience, or some modification of it so long as it is remembered that no one can teach 'motivation' or 'experience'.

Given the wide range of knowledge that will be required at different times by the hydrogeologist of the future, there seems to be a requirement for some formal training arrangements devised specifically to meet the demands of the hydrogeologist who needs up-dated refresher training in selected aspects of the subject where progress is more rapid.

In conclusion, my ideal hydrogeologist of the future would be literate and numerate; he or she would combine technical competence with imagination; a first hand appreciation of the complexities of field conditions with a gift for simplification of essentials; the ability to rationalise a conceptual model and quantify it in the form of a numerical simulation; and display flexibility of mind with firmness of purpose.

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GROUNDWATER FOR PUBLIC SUPPLY

P. CALLERY,
CO. ENGINEER,
WEXFORD CO. COUNCIL

INTERNATIONAL ASSOCIATION OF HYDROGEOLOGISTS (IRISH GROUP)

April, 1988

SUMMARY

Many of the Counties in Ireland rely heavily on groundwater for public supply, even though our groundwater resources are not developed to the same extent as some of our European partners.

County Wexford has two well developed aquifers which will form a major part of the County Council's water supply system in the future. Water quality from these resources is good. Iron and manganese levels are high in some cases and some supplies will require treatment for removal of these constituents. Nitrate levels are not a problem in groundwater in County Wexford at present.

Because of intensive agricultural development in the County, Wexford County Council has developed a firm aquifer protection policy.

A number of major schemes based on groundwater are at an advanced state of planning. Production costs of water from boreholes appears marginally cheaper than production from surface water sources in the County.

GROUNDWATER FOR PUBLIC SUPPLY

MR. P. CALLERY, WEXFORD COUNTY ENGINEER

Introduction

1. Unlike many of our European partners Local Authorities are entrusted with the provision of public water supply in Ireland. I hope in this paper to give a picture of the current position of groundwater development in a County which relies heavily on groundwater to meet the consumption needs. Wexford has been one of the pioneer Counties in Ireland in groundwater development. The County is fortunate to have two major aquifers : (i) The Volcanic Series, running diagonally across the centre of the County from the north east to the south west and (ii) The Carboniferous Limestones in the south east corner of the County, south of Wexford town. While the river Slaney forms the backbone of the County and is used for public water supply abstraction, other areas of the County have limited surface water resources. In particular, the south east corner of the County is extremely limited in this regard.

   In the 1970's, before the imposition of Government restrictions on Local Authority finances, Wexford County Council had a healthy credit balance. The County Manager and the County Engineer at the time, realising that Central Government would be clawing back any unused credit balances, decided to use this money to develop groundwater to augment public schemes which were operating at over capacity. Approximately £300,000 was spent in this way and this enabled exploratory work to be undertaken which provided many high yielding wells. The Sanitary Services Small Schemes Programme, which enabled Local Authorities to carry out schemes up to the value of £50,000 without the necessity for formal and detailed approval from the Department, was also extensively used to develop these wells. The County Council, in this way, has developed valuable aquifer resources in Wexford and is committed to a solid programme of groundwater development in the future. This policy is firmly enshrined in the County Development Plan.

The National Picture for Groundwater in 1988

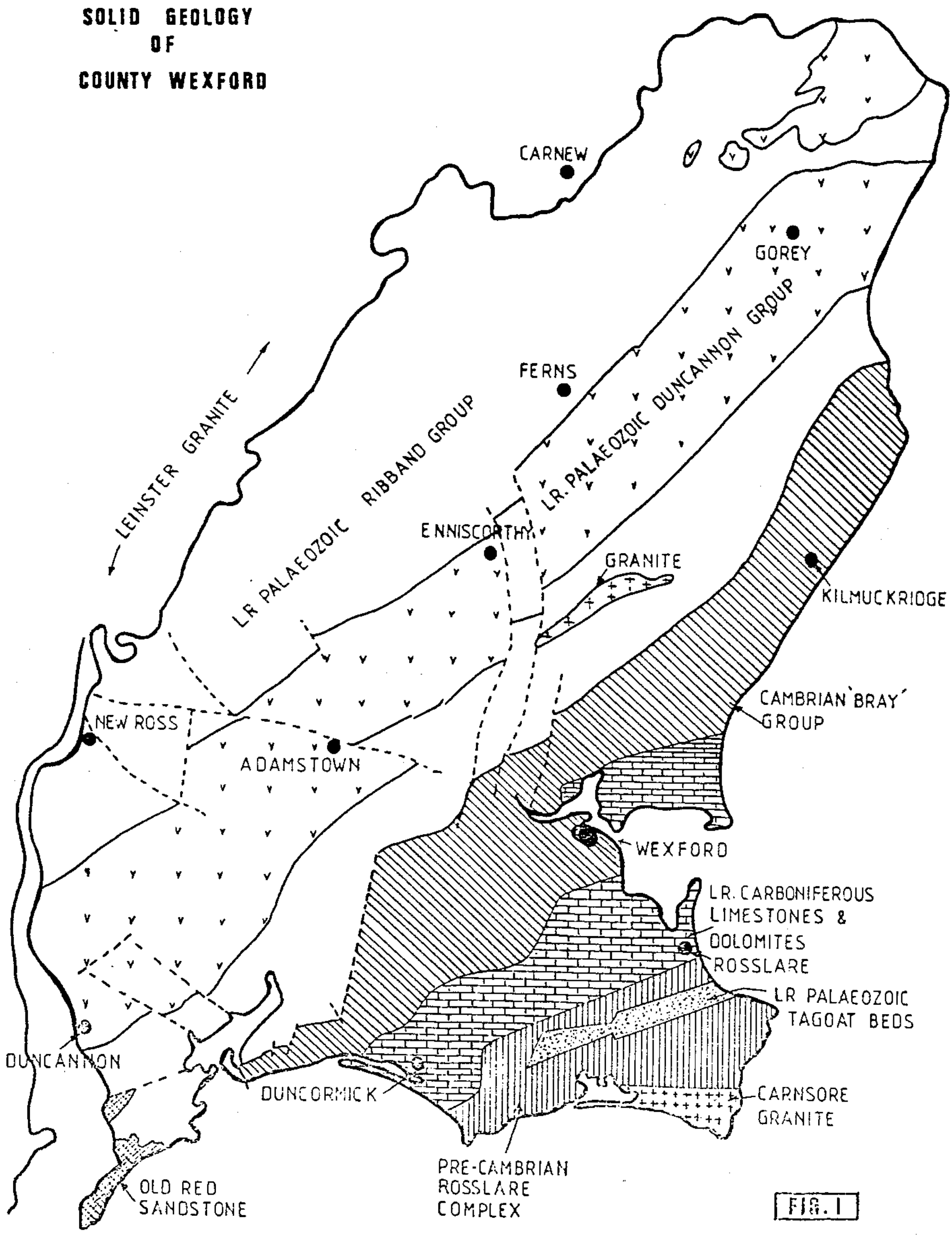
2. Groundwater currently provides 20% of total water usage in Ireland. Certain Counties rely heavily on groundwater for public and private supply. Appendix I gives an indication of the picture Nationally. Appendix II shows the picture among the English Water Authorities for comparison. The picture relative to some other European Countries is indicated in Appendix III.

The Volcanic Aquifer in County Wexford

3. This aquifer consists of the Lower Palaeozoic Duncannon Group which stretches in a band across central County Wexford from the Gorey Area in the north east to Duncannon in the south west. The aquifer also extends across the Barrow Estuary into County Waterford. The aquifer consists of volcanic rock and shales. Overburden generally consists of glacial till and the thickness of overburden varies from 5 metres in the Adamstown area to 30 metres in the Gorey area. Boreholes in this aquifer were first developed in the late 1970's and major wells now exist at Coolgreany (640 m^3/day), Clogh (Barnadown 1864 m^3/day), Enniscorthy (Kilagoley - 909 m^3/day) and Edermine Industrial Site (2273 m^3/day). The diameters of the major boreholes in this aquifer are 250mm and typical construction details are indicated on Figure 2.

In 1987 a successful groundwater investigation has been carried out in the Camross/Adamstown area. Seven trial boreholes were investigated with individual yields up to 2,000 m^3/day. It is envisaged that these boreholes will form the basis of a Regional Water Supply Scheme. This Scheme would supply the area of the County to the south east of Enniscorthy as far as the village of Taghmon. This village has a very unsatisfactory surface water source of public supply from the Corock River. Located in a highly developed agricultural area, this river is subject to severe pollution from agriculture. The County Council is often faced with turning off the public supply and supplying the village with water transported by tanker from Wexford town.

The aquifer at present provides water for the Gorey Regional Water Supply Scheme (2,273 m^3/day), Enniscorthy Town (909 m^3/day) and the Edermine Borehole, capable of producing 2,273 m^3/day, will shortly be used to augment the Sow Regional Water Supply Scheme. Figures 3 and 4 indicate yields of existing and proposed boreholes throughout the County.



SOLID GEOLOGY
OF
COUNTY WEXFORD
CARNEW
GOREY
FERNS
LR. PALAEOZOIC DUNCANNON GROUP
LEINSTER GRANITE
LR PALAEOZOIC RIBBAND GROUP
ENNISCORTHY
GRANITE
KILMUCKRIDGE
CAMBRIAN 'BRAY' GROUP
NEW ROSS
ADAMSTOWN
WEXFORD
LR. CARBONIFEROUS LIMESTONES & DOLOMITES
ROSSLARE
LR PALAEOZOIC TAGOAT BEDS
DUNCANNON
DUNCORMICK
CARNSORE GRANITE
PRE-CAMBRIAN ROSSLARE COMPLEX
OLD RED SANDSTONE

FIG. 1

Typical Production Borehole In Volcanic Aquifer

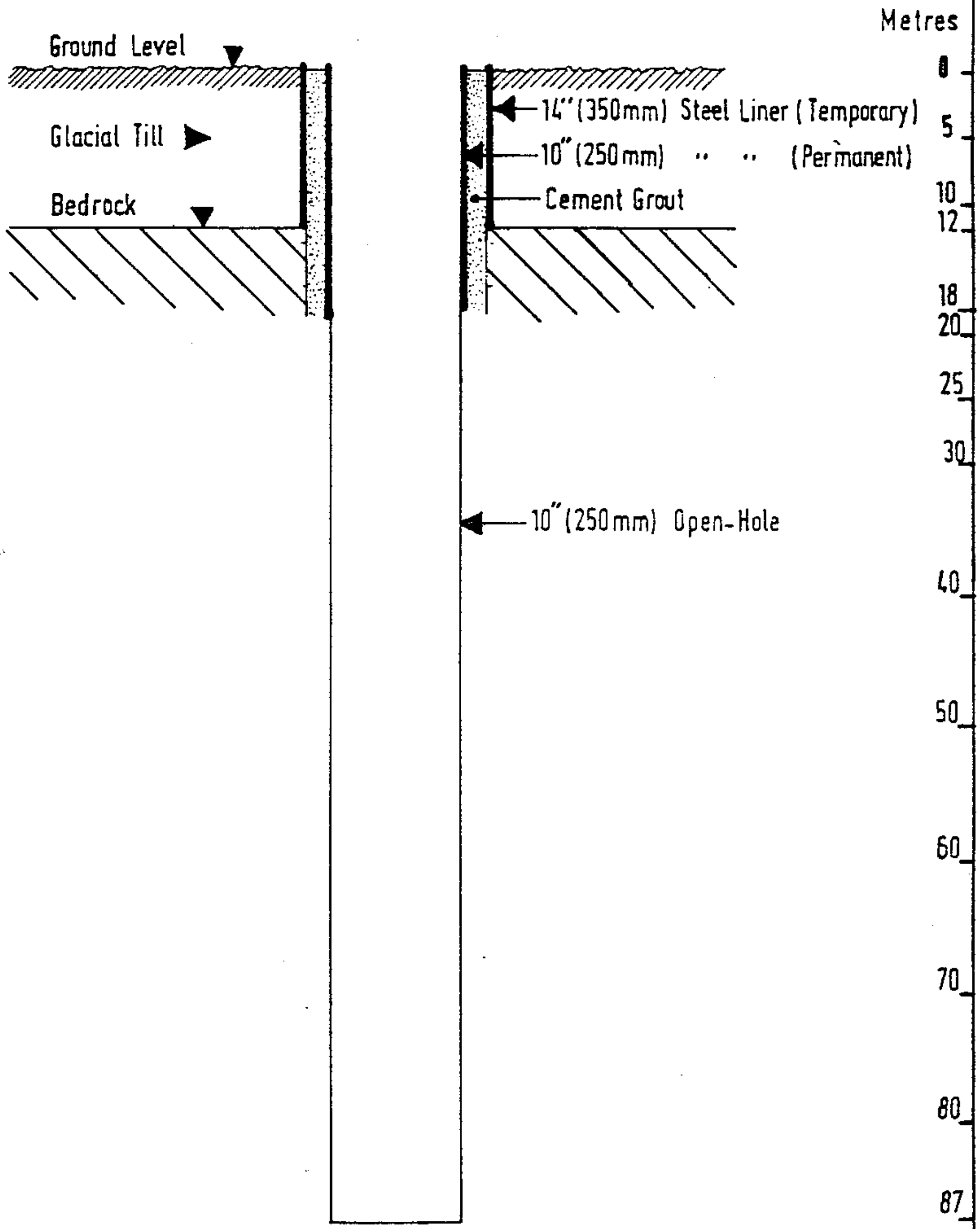


FIG. 2

The Limestone Aquifer

4. The E.S.B. carried out extensive site investigation for the suggested Nuclear Power Station at Carnsore. This project now appears to have been shelved. However, during the site investigation, the dolomitic limestone aquifer south of Wexford was investigated as a possible source of water. This investigation yielded a number of very successful boreholes with yields in excess of 1,000 m^3/day. The aquifer runs in a south-westerly direction along a line approximately from Rosslare to Duncormick. A number of boreholes have already been developed, feeding into existing water supply schemes.

The South Regional Water Supply Scheme abstracts water from the Owenduff River at Taylorstown (5,500 m^3/day). In recent years this scheme has been unable to meet the demand from the surface water source and has been augmented by three major boreholes in the Mayglass area supplying approximately 3,600 m^3/day. The scheme serves the south of the County from the Hook Head to Rosslare Harbour and the boreholes supply into the eastern section of this scheme.

Wexford Town Water Supply is also augmented from this aquifer with boreholes at Drinagh, south of Wexford Town, supplying 3,400 m^3/day. These wells serve the south of the town, providing water mainly for three important industries - Wexford Creamery, Cow & Gate Ltd. and Schoepp Velours.

Fardystown Regional Scheme

4.1 This scheme is the major groundwater development proposal in the County and is planned to supplement the existing South Regional Scheme by taking over the supply of the south-east corner of County Wexford. An extensive well field of twelve production boreholes has been developed and tested in 1987. This well field will provide a yield of 14,000 m^3/day from this aquifer. Figure 4 gives an indication of the yields of these boreholes. The total scheme is estimated to cost £8.5m and is phased to be constructed over a period between 1988 and 2001. Contract documents for the initial construction phases are with the Department of the Environment for approval. P. H. McCarthy Son & Partner are the County Council's Engineering Consultants and Mr. Kevin Cullen is Consultant Hydrogeologist.

FIG. 3

WEXFORD COUNTY COUNCIL

SCHEDULE OF PRODUCTION BOREHOLES

(Only Schemes serving ⩾ 227m^3/day are listed)

SCHEME	BOREHOLE NAME	AQUIFER TYPE/GEOLOGY	YIELD m^3 / day
South Regional Water Supply Scheme	Busherstown 1	Carboniferous Limestone	1364
	Busherstown 3	" "	909
	Rathmacknee 1	" "	1364
	Ballykelly (Drinagh)	" "	909
	Ballykilliane (Drinagh)	" "	1591
	Rowestown (Drinagh)	" "	909
Gorey Regional Water Supply Scheme	Barnadown Upper 1	Ordovician Volcanics	1864
	Moneycross Upper	" "	409
Enniscorthy Water Supply Scheme	Killagoley 1	Ordovician Volcanics	909
Sow Regional Water Supply Scheme	Ballina	Sand / Gravel Aquifer	273
Kilmuckridge Water Supply Scheme	Knocknasillogue	Sand / Gravel Aquifer	364
Coolgreany Water Supply Scheme	Knockgreany	Ordovician Volcanics	640
Carrickbyrne-Newbawn Water Supply Scheme	Carrickbyrne	Ordovician Volcanics	360
Clonroche Water Supply Scheme	Clonroche	Ordovician siltstones/ shales	227

FIG. 4

WEXFORD COUNTY COUNCIL

SCHEDULE OF PROPOSED PRODUCTION BOREHOLES

(Estimated Yields Based on Pumping Test Data from Trial Boreholes)

SCHEME	BOREHOLE NAME/NO.	BOREHOLE LOCATION	ESTIMATED YIELD m^3 / day
Fardystown Regional Water Supply Scheme (Carboniferous Limestone Aquifer)	T.W. No.1	Walshestown	1354
	T.W. No.2	Walshestown	1700
	T.W. No.3	Walshestown	1745
	T.W. No.4	Mount Pleasant	1670
	T.W. No.5	Hardyregan	1286
	T.W. No.6	Churchlands	1110
	T.W. No.7	Mayglass	2061
	T.W. No.8	Busherstown	1505
	T.W. No.9	Harpoonstown	1090
	T.W. No.10	Mulrankin	1675
	T.W. No.11	Mulrankin	1952
	T.W. No.13	Mountcross	1090
Camross/Adamstown Regional Water Supply Scheme (Ordovician Volcanic Aquifer)	31/1	Aughnaphort Bridge	620
	31/2	Adamstown	1400
	31/10	Tomgarrow	2000
	35/7	Raheenacloonagh	2000
	35/8	Aughavanagh Ford	1600
	35/9	Ballyshannon Bridge	550
	35/10	Ballyshannon	2000
Gorey Regional Water Supply Scheme (Ordovician Volcanic Aquifer)	Barnadown Upper No. 2	Barnadown Upper	1364
Sow Regional Water Supply Scheme (Sand/Gravel Aquifer)	Edermine 1	Edermine	2273
Kilmuckridge Water Supply Scheme (Sand/Gravel Aquifer)	Newtown 1	Newtown	360

Wexford Town Augmentation

4.2 Contract documents for this scheme are presently being finalised. The scheme is designed to abstract 5,500 m^3/day from boreholes in the Limestone Aquifer. The water will be pumped to a treatment works at Sinnottstown Lane and from there to a storage reservoir of capacity 5,680 m^3 at Starvehall. The main water supply for Wexford Town comes from the River Sow, which is a tributary of the River Slaney and the groundwater from the Limestone Aquifer will basically supply the southern area of Wexford Town and the large Industries which are located there. J. B. Barry & Partners are the County Council's Consultants for this scheme. The estimated cost is £2m.

Groundwater Quality

5. In general, the quality of the groundwaters in County Wexford is excellent. Figure 5 indicates the characteristics of the water quality from the Volcanic and Limestone Aquifers.

The water from the Volcanic Aquifer is relatively soft and does not have excessive levels of iron and manganese. On the other hand, the Limestone Aquifer provides a hard water, approximately 300 mg/l, and iron and manganese levels are in excess of the Maximum Admissable Concentrations as outlined in the E.E.C. Directive on drinking water M.A.C. levels are .05 mg/l for manganese and 0.2 mg/l for iron.

Treatment for Removal of Iron and Manganese

6. A Pilot Treatment Plant for this purpose was installed at Fardystown in 1987. Two treatment methods have been tested, namely Relite and Manganese Dioxide Filtration. Preliminary indications are that Manganese Dioxide provides the most cost effective removal of iron and manganese. Figure 6 gives an indication of the efficiency of removal of both these filtration media. Aeration was also employed in the pilot plant, but it appears that this will be unnecessary to achieve the required level of removal. The cost of this pilot plant will amount to approximately £30,000, and the results obtained from the trial programme will also be used for the Wexford Town Augmentation Scheme, where the water will also be treated for the removal of iron and manganese.

WEXFORD COUNTY COUNCIL

TYPICAL CHEMICAL ANALYSES OF MAJOR AQUIFERS

PARAMETER	UNIT		Fardystown Scheme Borehole No.1	Camross/ Adamstown Scheme Borehole Nos.35-7	Gorey Regional W.S.S. Barnadown No.1	E.E.C. STANDARDS	
						Guide Level	M.A.C.
Calcium	Ca	mg/l	85	20.4	31.2	100	-
Magnesium	mg	mg/l	21	7.3	7.8	30	50
Sodium	Na	mg/l	22.4	15.	4.0	20	178
Potassium	K	mg/l	2.4	1.3	1.40	10	12
Bicarbonate	HCO_3	mg/l	354.	70.7	107.3	-	-
Sulphate	SO_4	mg/l	7.	9.5	6.50	25	250
Chloride	Cl	mg/l	36.	26.0	21.0	25	-
Ammonium	NH_4	mg/l	0.01	0.1	0.05	0.05	0.50
Nitrate	N	mg/l	<0.10	0.7	2.6	5.6	11.3
Zinc	Zn	mg/l	0.03	N.E.	0.03	0.4	-
Copper	Cu	mg/l	<0.03	<0.04	N.D.	0.1	5.0
Iron	Fc	mg/l	0.50	<0.05	0.0	0.05	0.2
Manganese	Mn	mg/l	0.24	<0.02	0.0	0.02	0.05
Lead	Pb	mg/l	<0.01	N.E.	N.E.	-	0.05
Fluoride	F	mg/l	0.12	N.E.	N.D.	-	1.5
Carbon Dioxide	CO_2	mg/l	N.E.	N.E.	N.E.	-	-
O-Phosphate	P	mg/l	0.01	N.E.	N.E.	-	-
pH	Units		7.7	6.7	6.95	6.5 →	8.5
Hardness	$CaCO_3$		300.	81.	110.	-	-
T.D.S.	mg/l		372.	130.	N.E.	-	-
Colour	HAZEN		<5.	5.	0	1	20.
Turbidity	N.T.U.		1.7	0.4	N.E.	1	10.
Conductivity	μS/cm		685.	220.	293.	400	-
Alkalinity	$CaCO_3$	mg/l	292	58.	88.	-	-
Coliforms	MPN/100ml		0.	0.	N.E.	-	<1.
E.Coli	MPN/100ml		0.	0.	N.E.	-	<1.
Temperature	$^{\circ}C$		N.E.	N.E.	11°	-	-

N.E. - Not Examined N.D. - None Determined < Less Than

FARDYSTOWN REGIONAL WATER SUPPLY SCHEME

PILOT TREATMENT PLANT - SAMPLE RESULTS FOR IRON & MANGANESE REMOVAL

(NOTE: E.E.C. Directive - M.A.C. - Iron 0.2mg/1, M.A.C. - Manganese 0.05mg/1)

DATE	RAW WATER		FILTER MEDIA	TREATED WATER	
	IRON mg/1	MANGANESE mg/1		IRON mg/1	MANGANESE mg/1
7/12/87	0.02	0.20	Manganese Dioxide	0.0	0.0
19/ 1/88	0.02	0.10	Manganese Dioxide	0.0	0.0
28/ 2/88	0.02	0.05	Relite M50	0.0	0.0
11/ 3/88	0.08	0.15	Relite M50	0.0	0.0

Preliminary assessment of results is that manganese dioxide is more efficient than relite M50 for the following reasons:-

1. Expensive dosing of chemicals (potassium permanganate in this case) not required with manganese dioxide.

2. For similar depths of filter media the manganese dioxide filter can treat approximately double the quantity of water.

Aquifer Protection Policy

7. Wexford is known as the Model County. This name refers to the model practice of agriculture by the Wexford farmers. The development of extensive groundwater resources in an intensely agricultural area poses its problems for the protection of these resources. In 1987 the Council engaged a consultant hydrogeologist to advise on a policy of aquifer protection which should be applied in the County.

Detailed discussions were undertaken between the Council's engineers and planners and the consultant in order to lay down the standards of protection which should apply. A prime consideration was that the development restrictions should be perceived to be reasonable in order that they would be accepted by the elected representatives and the public. Policy guidelines have now been prepared and it is proposed that this policy will be incorporated in the 1989 review of the County Development Plan in order to provide statutory backing for the proposed restrictions. Aquifer protection strategies in other countries were examined before the guidelines were finalised. The proposals are summarised in Figure 7.

It can be seen that the aquifer as a whole will be protected by strict development control. In general, effluent generating activities within the area of the aquifer will require individual examination, perhaps even to the extent of hydrogeological survey. This is considered necessary in order that the aquifer will be protected from pollution. This Aquifer Protection Policy will be regarded as unduly restrictive by many of the elected representatives Many landowners will feel that their land development potential has been diminished. No doubt there will be claims for compensation. However, in order to protect valuable groundwater resources for future generations, it is absolutely necessary that these controls should be introduced. It is intended to limit these controls to the two major aquifers, the Volcanic and the Limestone initially, rather than have blanket controls over the whole County, which, at this stage, might be unreasonable. In any event, in the areas outside the two major aquifers the development control process under the Planning Acts will enable the County Council to closely monitor developments which could injure other potential groundwater resources.

COUNTY WEXFORD - AQUIFER PROTECTION POLICY

ZONE 1 - Source Protection Zone.

Sub-Zone 1 (a)

EXTENT : 10m. from public groundwater abstractions
PROHIBIT : All activities with any degree of pollution risk.

Sub-Zone 1 (b)

EXTENT : 100m. from public groundwater abstraction.
PROHIBIT : Septic Tanks.
Soakaways of any type.
Spreading of sewage sludges.
Burial grounds.
Waste disposal sites.
Storage of industrial chemicals.
Storage or disposal of farm chemicals.
Foul sewers or house drains.
CONTROL : Application of fertilizers.
Spreading of manure or slurry.

Sub-Zone 1 (c)

EXTENT : 1 km. from public groundwater abstractions.
PROHIBIT : Waste disposal sites.
Storage of industrial chemicals.
Intensive agricultural developments.
Construction of waste liquid ponds.
CONTROL : Septic tanks - 0.4 ha. sites
Construction of foul sewers.
Construction of soak pits.
Use of farm chemicals.

Sub-Zone 1 (d)

EXTENT : 100m. from surface water courses and areas vulnerable to groundwater pollution.
PROHIBIT : as in Sub-Zone 1 (b)
CONTROL : as in Sub-Zone 1 (c).

ZONE 2 - Major Aquifer Protection Zone.

EXTENT : Area underlain by major aquifer.
CONTROL : Waste disposal sites.
Storage of industrial and farm chemicals.
Construction of waste liquid ponds.
Intensive agricultural developments.
Construction of septic tanks: 0.4 ha. sites.
Use of farm chemicals.

Production Costs of Water

8. The average cost of production of water from wells in County Wexford is 4.2p/m^3 (19p/1,000 gls.). For comparison, the cost of production of potable water from surface water sources is 4.5p/m^3 (20p/1,000 gls.). The County Council charges consumers at the rate of 20p/m^3 (90p/1,000 gls.).

Future Trends in County Wexford

9. The present consumption of water in the County is 40,900 m^3/day consisting of 60% surface water and 40% groundwater. By the year 2000 it is predicted that consumption is expected to rise to 54,000m^3/day and by that stage the breakdown will be 50% surface water, 50% groundwater.

Role of Regional Laboratory

10. The Regional Laboratory in the south-east has prepared Water Quality Management Plans for the major rivers in the region. The Laboratory is now turning its attention to groundwater resources within the region. Under Section 15 of the Water Pollution Act, it also appears that Local Authorities will be required to make Water Quality Management Plans for groundwaters. It is hoped that the Laboratory can make a start on the collection of data on the major groundwater resources in the south-east and aim towards the preparation of Water Quality Management Plans for the major aquifers. Considerable amounts of valuable data related to groundwater resources have already been collected by various counties within the region. This information could form the basis for a comprehensive groundwater study which would be undertaken by the Regional Laboratory and lead towards the ultimate preparation of Groundwater Quality Management Plans.

Nitrate Levels

11. Rising nitrate levels in groundwaters have been causing concern in many countries in recent years. This does not appear to be a problem with the Wexford aquifers. In general, the nitrate level is less than 1 mg/l. The E.E.C. guide level is 5.6 mg/l and the maximum admissable concentration is 11.3 mg/l. On the other hand, it is worth noting that a number of surface waters in the south-east part of the country, in particular in the Wexford area, have indicated rising nitrate levels. The following list of rivers in

the south-east exhibit nitrate levels, on occasion, higher than the E.E.C. Guideline Level. The figures in parenthesis indicate the maximum concentration (mg/l N) recorded in each case.

Aghalona (13.0)	Clonough (9.0)	Kings (6.1)
Bann (6.7)	Douglas (6.4)	Lask (7.3)
Banoge (7.1)	Duncormick (6.0)	Mountain (6.6)
Barrow (7.2)	Glasha (5.2)	Nuenna (8.4)
Brackan (8.8)	Gowran (6.0)	Owenavorragh (6.5)
Burren (10.0)	Inch (6.4)	Urrin (5.1)

These surface water sources will require careful monitoring for nitrates over the years, particularly where they may be considered for use as sources of public water supply. It is heartening to note the low levels of nitrate in the Wexford groundwater and, hopefully, that situation will continue.

Conclusion

12. County Wexford is committed to the maximum utilisation of its extensive groundwater reserves in the future. The value of this resource is clearly recognised by the County Council and the aquifers will be carefully protected by the Council's development control policy for future generations. The quality of the groundwaters are excellent and many high yielding wells are available in the established aquifers. The major sources of good quality surface waters available in County Wexford occur in the Slaney System. This is an excellent fishing river and a designated salmonid river under E.E.C. Directive. The groundwater resources available to County Wexford will mean that it should not be necessary to abstract further water from this river for public supply. In this way it will be possible to conserve the river Slaney in its natural condition and and not interfere with its development potential as a major fisheries and tourism attraction. Groundwater has a most important part to play in the future development of this County.

WATER ABSTRACTION AND PERCENTAGE OF GROUNDWATER BY LOCAL AUTHORITY FOR 1988

IRELAND

AUTHORITY	PUBLIC WATER SUPPLIES megalitres/day (a)	TOTAL QUANTITY ABSTRACTED megalitres/day (b)	GROUNDWATER AS A % OF TOTAL ABSTRACTION %
Carlow County Council	16.1	22.0	13.0
Cavan County Council	17.0	38.3	28.0
Clare County Council	36.18	39.0	19.8
Cork County Council	84.4	86.4	44.0
Cork Corporation	48.0	48.0	10.0
Donegal County Council	15.4	16.5	0.5
Dublin County Council	95.0	95.0	0.1
Dublin Corporation	253.0	253.0	Nil
Galway County Council	72.4	83.9	27.0
Galway Corporation	40.0	40.0	0.0
Kerry County Council	63.7	63.7	18.0
Kildare County Council	34.5	35.0	28.0
Kilkenny County Council	15.7	27.2	52.0
Laois County Council	10.5	10.5	54.0
Leitrim County Council	8.2	8.6	11.2
Limerick County Council	43.1	51.1	39.0
Limerick Corporation	36.0	36.2	0.6
Longford County Council	15.0	15.0	28.0
Louth County Council	35.8	35.8	9.0
Mayo County Council	45.5	52.3	18.3
Meath County Council	35.2	46.9	36.5
Monaghan County Council	24.6	24.6	15.5
Offaly County Council	23.5	25.9	33.0
Roscommon County Council	29.6	34.8	86.5
Sligo County Council	20.6	21.1	13.0
Tipperary North Riding	19.0	23.2	76.0
Tipperary South Riding	46.0	49.0	1.8
Waterford County Council	48.4	49.3	49.0
Waterford City Council	20.0	20.0	0.6
Westmeath County Council	21.0	21.0	0.04
Wexford County Council	36.4	40.9	40.0
Wicklow County Council	27.35	27.35	7.0
TOTALS	1337.13	1441.55	20

NOTE: Urban Council water usage included in figures for relevant County

(a) Countywide water supply (surface water & groundwater)

(b) (a) above plus water used by industry & agriculture.

APPENDIX II

Water abstraction and percentage of groundwater by water authority area for 1984

ENGLAND AND WALES

Water Authority	Water supplies megalitres/day	Total quantity abstracted megalitres/day	Groundwater as a percentage of total abstractions
North West	1,842	4,039	13
Northumbrian	964	1,004	10
Severn Trent	2,127	6,043	18
Yorkshire	1,318	2,369	13
Anglian	1,660	2,013	50
Thames	3,923	4,311	42
Southern	1,303	1,447	71
Wessex	712	894	46
South West	507	872	13
Welsh	2,039	9,374	2
Total (England & Wales)	16,394	32,366	20

APPENDIX III

Ground and Surface Water Abstraction Percentages for Public Use

EUROPE

	Groundwater %	Surface water %
Belgium	70	30
France	50	50
Federal German Republic	71	29
Italy	93	7
Netherlands	65	35
Sweden	46	54

References

1. An Foras Forbartha - The State of the Environment 1987

2. P. H. McCarthy Son & Partners - Fardystown Regional Water Supply Scheme, Preliminary Report

3. J. B. Barry & Partners - Wexford Town Augmentation Scheme, Preliminary Report

4. Lewis, Thomas, Barron - Contamination of Groundwater Resources and Impact on Potable Supplies - Proceedings of Institution of Water & Environmental Management 1987.

5. K. T. Cullen - Groundwater - An Aquifer Protection Policy

6. Wexford Co. Council - Groundwater in County Wexford - A Local Authority View, 1982.

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GROUND WATER FOR GROUP SCHEMES

T. Geraghty Department of the Environment

From the very early days there has been a policy in group scheme development of using ground water sources, where possible, if no public supply is available. The reasons are:

1. Drilled wells often provide water in the quantities requried by groups
2. There is usually no necessity for treatment
3. Maintenance and operational costs are small

It is now thirty years since the first group scheme was organised in Manor-Kilbride, Co. Wicklow. The source was a borehole. Most of the early group scheme activity was located in North Cork and Limerick, where Muintir na Tire played a strong role in promoting schemes. All of these were supplied from drilled wells. Typically, schemes consisted of twenty to thirty houses and associated farms. It became obvious after a few years, that, although state grants were intended for installing water in dwellings, most of the interest came from farmers, particularly in dairying areas.

The Department of Agriculture had been giving grants for farm supplies, usually for drilled wells; and the well drillers engaged in that work got involved also in drilling for groups. In the fifties and sixties, the Department of Agriculture gave grants for about 62,000 farm installations, and these used ground water as a source. Up to 5,000 individual wells were sunk every year.

On of the most important changes made by the Department of Local Government as it then was - was the requirements that to qualify for grants, the source would have to pass quality and quantity tests. A seventy two hour continuous pumping test was introduced for drilled wells, the hourly output based on three times the average of twenty four hour requirements. A contract was drawn up between well drillers and groups, in which the driller agreed to the test conditions, standing levels etc.

Hence, finding a source suitable in quality and quantity was the responsibillity of the well driller and a group scheme did not get to the design stage unless a source passed the tests. The outputs required were usually less than 2,000 G.P.H. If higher than this, second and third wells were drilled.

It is a tribute to those involved in the well drilling business at the time, that, even though site investigation was not very scientific, there were very few failures. The well drillers had a lot of experience and a 'feel' for the job and the diviner's encomium on the floods of water that were meeting at a particular point, was often justified. Drilling at that particular spot in a field more often than not resulted in a reasonably good supply.

Some of the sources did not continue to give satisfactory yields. There was no well development and deterioration of the supply might subsequently take place. On the other hand, not all sources were fully tested; since the group's immediate need was the criterion for testing, rather than the true output of the well. Even where Local Authorities took responsibility for testing, some did not provide a range of test pumps. If a group required 1,500 G.P.H., a test pump capable of pumping this quantity only, was used.

There are some counties, where there have been very few drilled well sources, e.g. Cavan, Monaghan, Clare, Leitrim. In these counties, group had to rely mainly on surface water sources. In Galway, where most of the rock formation is in limestone, drilled wells are the most common source for groups. There are, of course, no drilled wells in Connemara and very few in South East Galway, where the Limestone is not fissured. Altogether, there are ninety eight drilled wells in County Galway. Of these, fifty seven were originally County Council roadside wells with hand pumps, and forty one were provided by group committees.

The output of these wells is as follows:

10 yield less than 500 G.P.H.
19 yield from 500 to 1,000 G.P.H.
52 yield from 1,000 to 2,000 G.P.H.
15 yield from 2,000 to 3,000 G.P.H.
1 yields 5,000 G.P.H.
1 Gravel Aquifer yields 8,500 G.P.H.

Two springs yielding over two million g.p.h. each, were discovered by groups, and were later developed by the County Council.

In County Limerick, there are 64 group schemes with drilled well sources, 12 with springs. The yields follow a similar pattern to Galway's. Limerick County Council has thirty one drilled wells for public supplies and eight springs.

In County Roscommon, there are 260 group schemes in operation. 21 of these are served by drilled well sources, 26 by spring wells. 11 Groups get their water from lakes, while the remaining schemes are extensions off council mains.

In the early days many ground water sources were near houses. This generally occurred where the County Council handed over their roadside pumps to groups. The Group, therefore, was not involved in any risk in 'prospecting' for a source. These roadside wells were mostly selected at a convenient walking distance from groups of houses. The demand was limited to a few gallons per house per day, and at the time they were provided, there was very little risk of contamination. In some instances, in recent years, but fortunately not many, there have been problems of pollution. There are less problems where groups are involved in selecting their own well location - removed from houses, farmyards etc.

It is easy to see a progression from the development in the sixties when smaller convenient sources, capable of supplying 10,000 to 20,000 G.P.D. and servicing twenty to thirty houses, were developed, to a later stage when these sources, because of the population density or hydrogeological factors, were no longer suitable, when larger sources with outputs of up to 50,000 G.P.D. were required. Three or four drilled wells were required for these schemes. Again, in these cases, the maximum quantity expected for a drilled well was 2,000 G.P.H. There were occassional exceptions of 3,000 or 4,000 G.P.H. Spring wells were developed for schemes providing supplies for several hundred houses and associated farms. Groups have located some excellent springs with outputs of two million gallons per day. In most cases these were taken over the County Councils.

The third stage of development was in areas where the possibility of developing ground water supplies was exhausted e.g. the history of drilling in the area was poor, the supply contained too much iron, there were no spring wells. There were no prospects of County Council Regional Schemes. In these conditions, the only option was the development of upland lake sources serving very large areas. This is what occurred in Counties Cavan, Monaghan, Mid Clare.

The present position is that about 120,000 houses have been served from Group Schemes. 60% of the schemes would have as their source a local authority main. Of the remainder, approximately 2,000 schemes would have ground water supplies. It is estimated that 50,000 houses in the country have yet to be served with a piped water supply. Assuming that the same trends as pertained over the past 20 years will continue, there will be a need for approximately 600 ground water sources to serve 30% of these outstanding houses.

The schemes will tend to be smaller - catering for isolated clusters of houses, too distant from existing mains and in areas where there are unlikely to be any surface water and only small ground water supplies. On the other hand many of the existing 2,000 group schemes which depend on ground water sources, will find themselves over extended. In some schemes, the demand has trebled, within the geographical boundaries, since the design and construction of the scheme. This particularly relates to agricultural uses. Piped water supplies too have stimulated new house building in many areas with a previous history of depopulation.

In other schemes, the drilled wells have not maintained the required output and proper well development is called for. If a source has been contaminated, very often the only solution is a new source in a new location. Where these old supplies are seriously deficient in quantity or quality, the Department of the Environment are allowing second grants of up to 80% of the cost of bringing the supply up to standard. (If, of course, the deficiency in the supply results from neglect in maintaining the scheme in good working order, such a grant will not be considered).

It has to be said that many of the drilled wells in the sixties and the seventies were undeveloped. The techniques appropriate for the individual farm well, were merely extended to group schemes. The only changes normally made to this procedure, were the seventy two hour pumping test. Previously it was just a matter of baling until the water ran clear. Care was also taken in siting the bore to avoid possible pollution. Besides, the group's finances did not usually permit of anything but the minimum requirement, which was to provide the required quantity of potable water so that the scheme could be approved.

Detailed site investigations were not commissioned, even when it became possible to have them, because group committees could not commit themselves to spending money, especially if there was even a slight risk of failure. A letter to the Geological Survey Office was about as far as most of these committes would go. Nether did group finances permit of stand-by wells or an investigation of the full potential of the aquifer.

In larger schemes which have been over-extended, there is now an opportunity of remedying the situation by availing of the second grants to carry out proper site investigation and to develop the sources more thoroughly.

Even in Group Schemes, where the supply is by way of an extension from a Local Authority Scheme, the possibility for expanding or improving the total network is enhanced by adequate ground water investigation and development. There are very large group schemes in some counties supplied from lake sources. These schemes cover areas from fifty to one hundred square miles. Some schemes now need treatment. The capital cost of a treatment plant and the difficulties for voluntary groups in operating and maintaining any treatment works, are major causes of discouragement. even a preliminary investigation of ground water possibilities in areas several miles from the original source, would be worthwhile, if by supplementing the original supply with ground water, then capital, maintenance and operating costs could be reduced and minimised.

It should be emphasized again that the raison d'etre of group schemes is to provide water supplies to dwellings and associated farms. The system operates in order to extend an adequate supply from a suitable source to each group member. The responsibility for initiating the scheme, organising the members, locating the source, constructing and managing the scheme, is the group's.

The Department can issue guidelines or requirements so that the group will qualify for grants. The Geological Survey Office can advise on the likelihood of getting a suitable supply of water in a particular area. However, when it comes to making a contract with a well driller, who undertakes to provide a required amount of water at an agreed figure, they are on their own.

Much of the element of chance has been removed from this sphere insofar as the well drillers have brought their skills up-to-date and are more inclined to avail of modern, scientific methods and expertise in locating and developing sources. Already, some old group scheme sources have been very successfully redeveloped using these new methods.

New group schemes, designed to serve the remaining numbers of houses, still without piped water, are likely to be small in size similar to the earlier schemes. It may be difficult to locate sources close to reservoir sites which provide 50 feet residual pressure at the highest house in the scheme. Longer rising mains will thus be required but they might be regarded as a necessary part of source development. In any case it seems that locating sources for most of these, will be difficult, this being the principal reason why they have not already got a piped supply.

As I stated at the beginning, one of the reasons why ground water was favoured as a group scheme source, was that chemically and bacteriologically, it was suitable for human consumption. Partically all drilled wells were approved for quality. Some gave trouble, because of bacteriological contamination, after a few years in use, but this occurred chiefly where existing Local Authority wells, which were located too close to houses were developed as group sources.

There were also problems with contamination from silage pits. More care is obviously necessary in the protection of group water sources. People involved in well drilling are now much more aware of the hazards and wells are more carefully sited. There have been very few problems chemically. As would be expected in predominantly limestone aquifers, the water is usually hard. Where waters were corrosive due to free CO_2 or where the water could not be used due to high iron content, improvised aeration systems in wells or in reservoirs, reduced the concentration to acceptable levels.

Generally speaking the only treatment required for ground water supplies, was disinfection with chlorine and even this was often precautionary rather than absolutely essential.

Sixty per cent of all group schemes are extensions from Local Authority supplies. For groups, this is the preferred option as the supply is provided and maintained by the Local Authority without any financial risks or operational problems for group promoters. Ten per cent of schemes are supplied from lakes. These are large schemes usually in areas where there's a poor history of Group water supplies. Where it is considered necessary to provide treatment for these lake sources, another look should be taken at groundwater possibilities, before embarking on treatment works. The remaining 30% of existing schemes have ground water sources. It is probable that up to 1,000 of the existing group scheme ground water sources will require redevelopment over the next ten years. In addition there will be a probable demand for up to 600 new drilled wells for new schemes. The group water abstractions will be small in the context of the amounts of ground water available or compared with the Public Sector demand for water supplies. However it is important that the needs of people who organise and construct their own water supply schemes should be met by properly developed sources of supply. These seminars have over the years allowed us all to benefit not only from the knowledge and worldwide experience of experts such as the much late lamented Dr. David Burdon but also of others who were involved in developing water supplies for small communities in places such as Lesotho and Mali. Some small communities in Ireland still need help.

THE MID-KILDARE GRAVEL AQUIFER

G.R.WRIGHT

GROUNDWATER SECTION,
GEOLOGICAL SURVEY OF IRELAND

INTRODUCTION

Ireland has very extensive Quaternary deposits, often referred to as "Drift". These include a lot of sand and gravel deposits which can be excellent aquifers. Our first I.A.H. Groundwater Seminar at Portlaoise, in 1981, was devoted to the subject of gravel aquifer development, because we believed (as I still believe) that our gravel aquifers are underestimated and underdeveloped.

Most of our gravel aquifers are rather small, generally suited to development by single sources or small schemes. In practice, this is how most of them have been exploited to date, for instance at Brinny and Carrigtwohill, Co. Cork, and Cooley, Co. Louth, etc. We have few gravel aquifers extensive enough to be exploited on a large scale, and our best example is the Mid-Kildare Aquifer.

The Mid-Kildare Gravel Aquifer is essentially what has previously been called the "Curragh Aquifer". I have deliberately re-named it in order to make the point that the aquifer occupies an area much larger than the Curragh as we know it, and is therefore a much more substantial and important aquifer than might be thought.

It has been known for many years that a significant aquifer underlies the Curragh and its vicinity, and this received some press publicity in the 1970's. Our knowledge at that time was based on well records collected in the Geological Survey over many years and well surveys by Bob Aldwell in the 1960's and early 1970's.

Some examples of well records include:

Curragh Old Waterworks borehole, 111 ft deep, all in Drift, yield 10,000 gph.

Curragh borehole, 250 ft deep, rock at 234 ft, yield 20,000 gph.

Osborne Lodge, Curragn, borehole 140 ft deep, all in Drift, yield 2,000 gph.

Strand Hotel, Curragh, borehole 160 ft deep, all in Drift, yield 2,000 gph.

Rathbride Manor, Curragh, borehole 140 ft deep, all in Drift, yield 2,000 gph.

A number of other records from the area confirmed this general picture of deep unconsolidated Drift, much of it being sand or gravel and much of it being saturated. Clearly this type of geological deposit could be a very significant aquifer, and this was confirmed by the yields obtained from boreholes, despite a fairly primitive type of well construction.

In 1979, still with this very incomplete information, we had to make some kind of estimate of the extent of the "Curragh Aquifer" and its available groundwater resources for a national study commissioned by the E.C. (and published in 1982). We estimated that the aquifer was about 210 sq Km in area and had a total available resource of around 50 million cu m per year (equivalent to 30 Mgd), before making allowances for maintenance of stream flow.

In 1980, we got a better look at the nature and depth of the Curragh gravels. As part of an E.C.-funded R & D programme to develop and test a new type of drilling rig (Foraco), for mineral exploration through deep Drift deposits, some trial boreholes were drilled in various parts of Ireland. One of these boreholes was sunk at the Curragh, near to the Army camp, to a total depth of 67.4 metres (221 ft) and met limestone rock at 64.4 metres (211 ft). Thanks to the drilling system (double-tube reverse circulation, with air-flush) we got excellent samples of the strata, which were predominantly gravels. The water table was about 14 metres from surface, and the yield estimated from a short test was around 20,000 gph.

What was still lacking from our knowledge of this aquifer was the detailed information on its total extent and continuity to allow us to make a firmer estimate of its potential and justify feasibility studies for its future exploitation. Within the last couple of years, such information has become available through the Geological Survey's data release scheme for mineral exploration data.

In the late 1970's and early 1980's the region around the Curragh was being actively explored for base metal deposits by Marathon Mining and associated companies. In the course of their work, many boreholes were put down, mostly by methods which allowed good sampling and recording of the unconsolidated deposits. This work was overseen by a specialist Quaternary geologist, Dr J.Cohen. The information from most of this work (excepting one prospecting licence area which is still active) is now in the public domain. For the first time we can produce a reasonable (though by no means complete or perfect) three-dimensional picture of this gravel aquifer, as portrayed in the accompanying maps.

DATA SOURCES

1. Geological Survey 1/10560 field sheets provided information on rock outcrops and types.

2. Geological Survey well records gave some information on bedrock depths (though good logs were scarce) and some water level data.

3. Field maps of well surveys by C.R.Aldwell provided invaluable data on water levels and water table contours.

4. Some well survey was carried out in 1987 by Suzanne O'Sullivan, mainly to establish the exact location of wells on file.

5. Data from the Foraco drilling in 1980, including downhole geophysical logs by Eugene Daly, gave us our best view of the nature of the gravel deposits.

6. The principal data source was the Marathon Mining files and borehole logs, from which the cross-sections and maps have largely been compiled.

7. Rainfall and evaporation data were drawn from Meteorological Service publications.

GEOLOGY AND AQUIFER DIMENSIONS

The Mid-Kildare Gravel Aquifer lies in a shallow trough, oriented NE-SW, in the surface of the limestone bedrock. To the southeast this trough is bounded by the Lower Paleozoic rocks (slates, etc) of the Leinster Massif, and to the northwest by the low ridge of the Chair Hills - notably Dunmurry Hill, Grange Hill, the Chair of Kildare and the Hill of Allen - again mainly composed of pre-Carboniferous rocks.

Between these hills, the trough is underlain by bedded limestones and dolomites. Into this trough the last glaciation deposited a mixture of sediments which included a high proportion of sand and gravel, up to 70 metres thick in places.

The boundaries of the aquifer are quite well defined on its northwest and southeast sides but to the northeast and southwest they are much harder to make out. For the purposes of this evaluation the aquifer has been defined by the existence of at least 5 metres of saturated sand/gravel as seen from borehole evidence. On this criterion, the area of the aquifer is approximately 180 square kilometres. It is roughly ovoid in shape, with a maximum length of 21 Km and maximum width of 13 Km, and extends from near Naas in the northeast to Nurney in the south, and from Kildare town in the west to Kilcullen in the east, as shown in the maps.

The depth to bedrock was plotted for each borehole (as available) on 1/25,000 sheets, and depth-to-bedrock contours drawn. The areas within each contour are as follows:

Depth to bedrock (m)	Area (sq Km)
> 50	2.5
> 30	54.5
> 20	97.5
> 5	180.0

In the same way, using well-head levels (often only approximate) contours on the bedrock surface were also drawn. The areas within the contours were as follows:

Top of Bedrock (m OD)	Area (sq Km)
< 90	180.0
< 80	176.6
< 70	156.6
< 60	106.6
< 50	55.0

The saturated aquifer thickness was calculated using the above figures and water table data. Contours of saturated thickness were drawn up, with areas as follows:

Saturated Thickness (m)	Area (sq Km)
> 25	6
> 15	47
> 10	81
> 5	180

The above figures for saturated thickness are for the aquifer sequences only - i.e. allowance has already been made for non-aquifer material such as boulder clay. A minimum saturated aquifer thickness of 5m was used as the criterion for defining the limits of the aquifer.

The quantity of water stored in the aquifer should be within the range of 15,000 to 23,000 million cubic metres, or about 3 to 5 million million gallons.

GROUNDWATER QUALITY

Very little information is available on the groundwater quality in this aquifer. In general the water is very hard (340 - 380 ppm as $CaCO_3$, due to the high proportion of limestone in the gravels), and unpolluted. However, some local contamination can be expected, especially where the water table is near surface, and also perhaps in areas where tipping has taken place in former gravel workings.

RECHARGE

Mean annual rainfall values are available for eight rainfall stations in the vicinity of the aquifer for 1941-70, and for nine stations for 1951-80. The arithmetical means for these groups of stations are 846 mm and 834 mm respectively, so that an overall average of 840 mm can be taken.

Actual evapotranspiration for the area is estimated at about 450 mm per year. This gives an annual moisture surplus of 840-450 = 390 mm.

For an aquifer area of 180 sq Km, this gives a maximum available recharge of 70.2 Mcm/yr, equivalent to 42.3 Mgd.

AQUIFER DEVELOPMENT AND MANAGEMENT

The size of the groundwater resource which is available in the Mid-Kildare Gravel Aquifer is quite large in the context of a largely rural county. (N.B. some of the bedrock limestones are also good aquifers, as shown by boreholes at Kildare and elsewhere.) How could this resource be used?

The E.R.D.O. Settlement Strategy Report (1985, Appendix 10, Sanitary Services) said that the public water supply demand for County Kildare in the year 2000 was expected to be 87.5 Ml/day (19.25 Mgd), of which 85 Ml/day (18.7 Mgd) was expected to come from Dublin Corporation Waterworks at Ballymore Eustace, and the remaining 2.5 Ml/day from Co. Carlow's Rathvilly Waterworks. By that date, therefore, according to these plans, none of the County's public water supply will come from sources within the county.

At the same time, Dublin faces potential difficulties in planning for the expansion of its own supply. The E.R.D.O. report indicated that by the year 2011 the Eastern region (i.e. Counties Dublin, Kildare, Meath and Wicklow) might have to find an extra 100 Ml/day of water from new sources. The report made several suggestions as to where additional supplies might be obtained, with groundwater mentioned as the "most significant possible source of additional water within the region". The ERDO report went on to urge "an investigation of groundwater resources over the whole region as soon as possible." An alternative suggestion is for the piping of water from the River Shannon, about 80 - 100 Km away.

More recent population projections, influenced by the present emigration rate, suggest that the rate of growth in water demand for Dublin may be very small for the next decade or two. However, an economic recovery in the next few years could change this yet again.

Whatever the time scale may be, water demand in the region will grow, and in this context the Mid-Kildare Gravel Aquifer could contribute very substantially to the water supply of the County, and help to solve the future water supply problems of the whole Eastern Region. However, three principal objections can be expected:

1. Water discharging from the aquifer feeds Pollardstown Fen and the Grand Canal, as well as other streams around the margins. Abstraction from the aquifer could not be allowed to dry up these discharges, nor cause any other adverse environmental effects. However, good management of the aquifer (e.g. careful location of abstraction points, control of abstraction rates and monitoring of water levels across the aquifer) would ensure that none of these vital interests would be harmed. As an illustration, lowering the water table across the aquifer by an average of one metre over a no-recharge period of 250 days would yield about 18 million cubic metres, equivalent to almost 16 million gallons per day. If necessary in very dry periods the flow at Pollardstown Fen could be augmented by water from the abstraction scheme.

2. The aquifer will provide very hard water, whereas the population is accustomed to the soft water from Dublin Corporation. Against this it can be argued that: (a) there is good evidence that hard water is healthier than soft water, (b) people in many parts of Ireland use equally hard water, (c) water brought from the Shannon or Barrow would be almost as hard, (d) modern water treatment

technology provides a number of ways of ameliorating the hardness problem, and the water would require almost no other treatment except sterilisation, (e) Kildare water could be mixed with Dublin water to reduce the hardness.

3. Previous development of Irish gravel aquifers has encountered problems with both exploration and well construction, and in general, engineers and welldrillers (and some hydrogeologists!) have avoided gravel aquifers. However, I refuse to believe that we cannot develop the expertise in this country to cope with well construction in gravels. The basic techniques are well established, and well drillers all over the world, including many in developing countries, are successfully constructing high-yielding wells in gravels. Why not here? In the past, most such jobs have been small, one-off affairs, often done on the cheap. A major gravel aquifer scheme, such as Mid-Kildare would offer, is just what we need to develop the right expertise and to lay a firm foundation for the development of other gravel aquifers throughout the country.

FURTHER STUDIES

This study shows the Mid-Kildare Gravel Aquifer is an extensive and substantial groundwater reservoir. However, some gaps in our information still need to be filled in by a feasibility study:

1. There is little borehole information in the NW and SW of the aquifer. There is also one borehole at Curragh Grange (KLD 23/24) with an anomalous log which records a succession of glacial till with almost no gravel. Additional drilling is needed in these areas.

2. Further drilling is also needed to allow pumping tests for determination of the aquifer properties. In all the drilling there should be an emphasis on getting good samples of the strata for particle size analyses which will allow optimum well design.

3. More information is required on the groundwater quality. Samples should be taken from a number of high-yielding wells throughout the aquifer.

4. Water level recorders should be installed on representative wells to measure water level changes in response to rainfall, etc.

ACKNOWLEDGEMENTS

My thanks go to:

Bob Aldwell for his early work in Co. Kildare;

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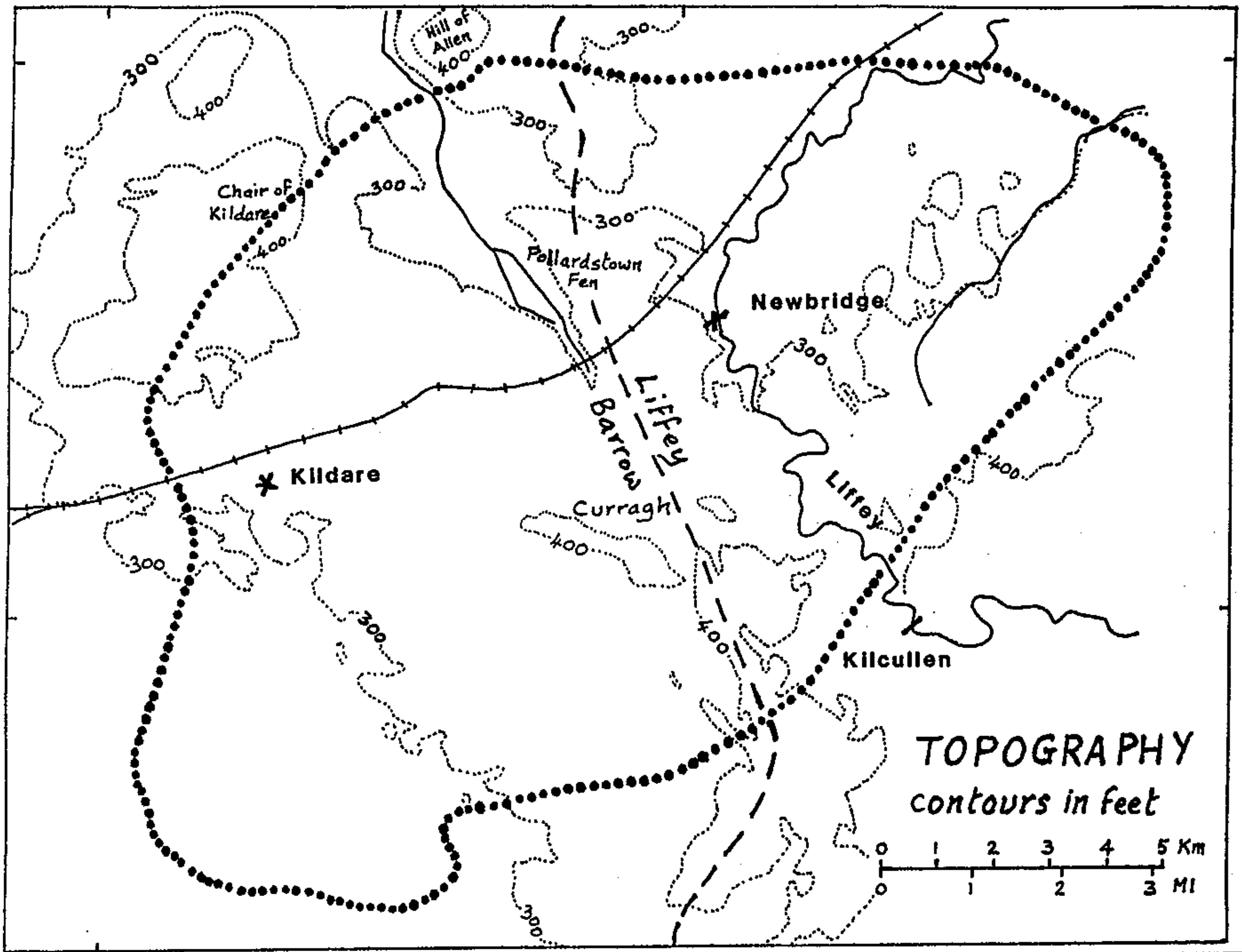
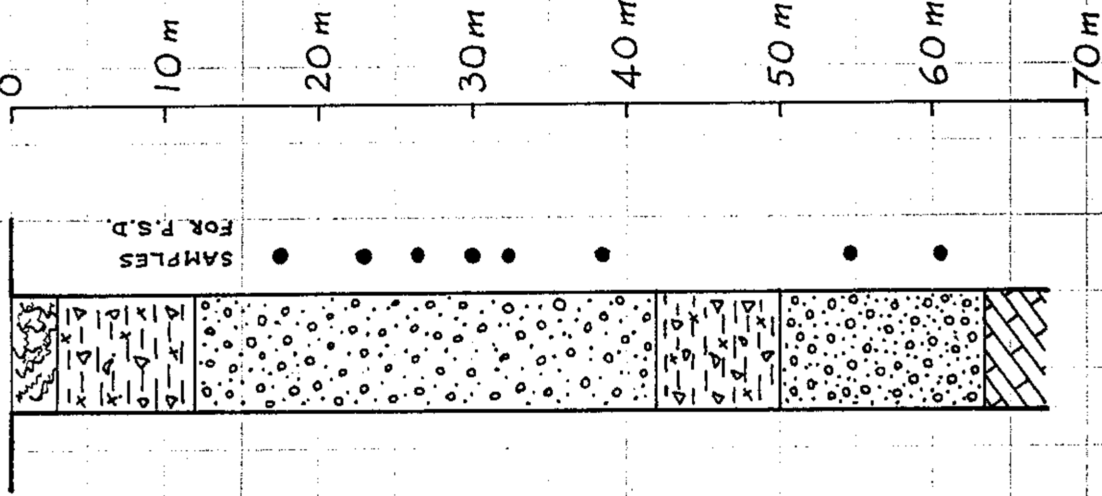
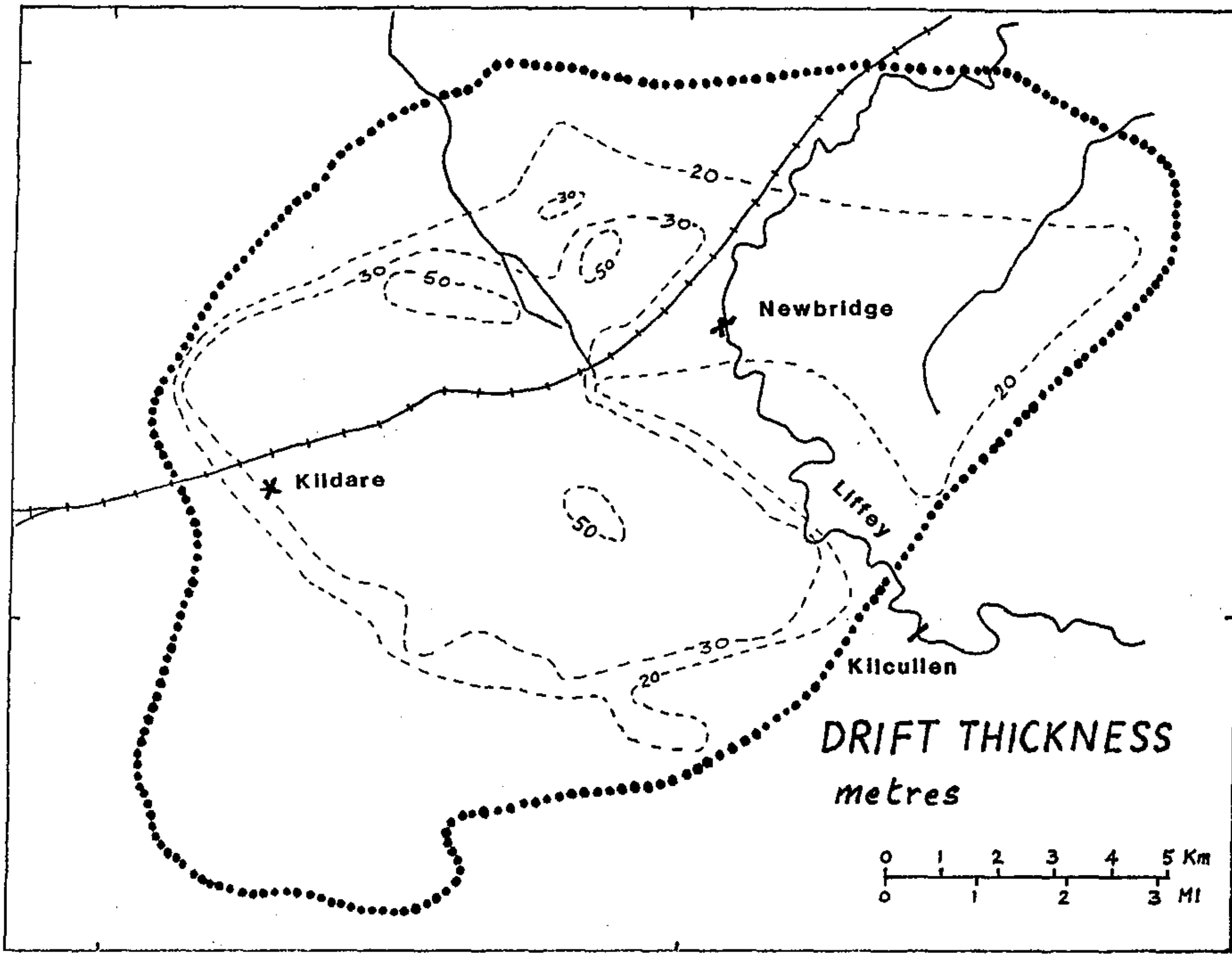
Suzanne O'Sullivan, who compiled much of the information for this paper.

Marathon Mining, and Westland Exploration Ltd, for their exploration work.



FORACO BOREHOLE
CURRAGH
July 1980

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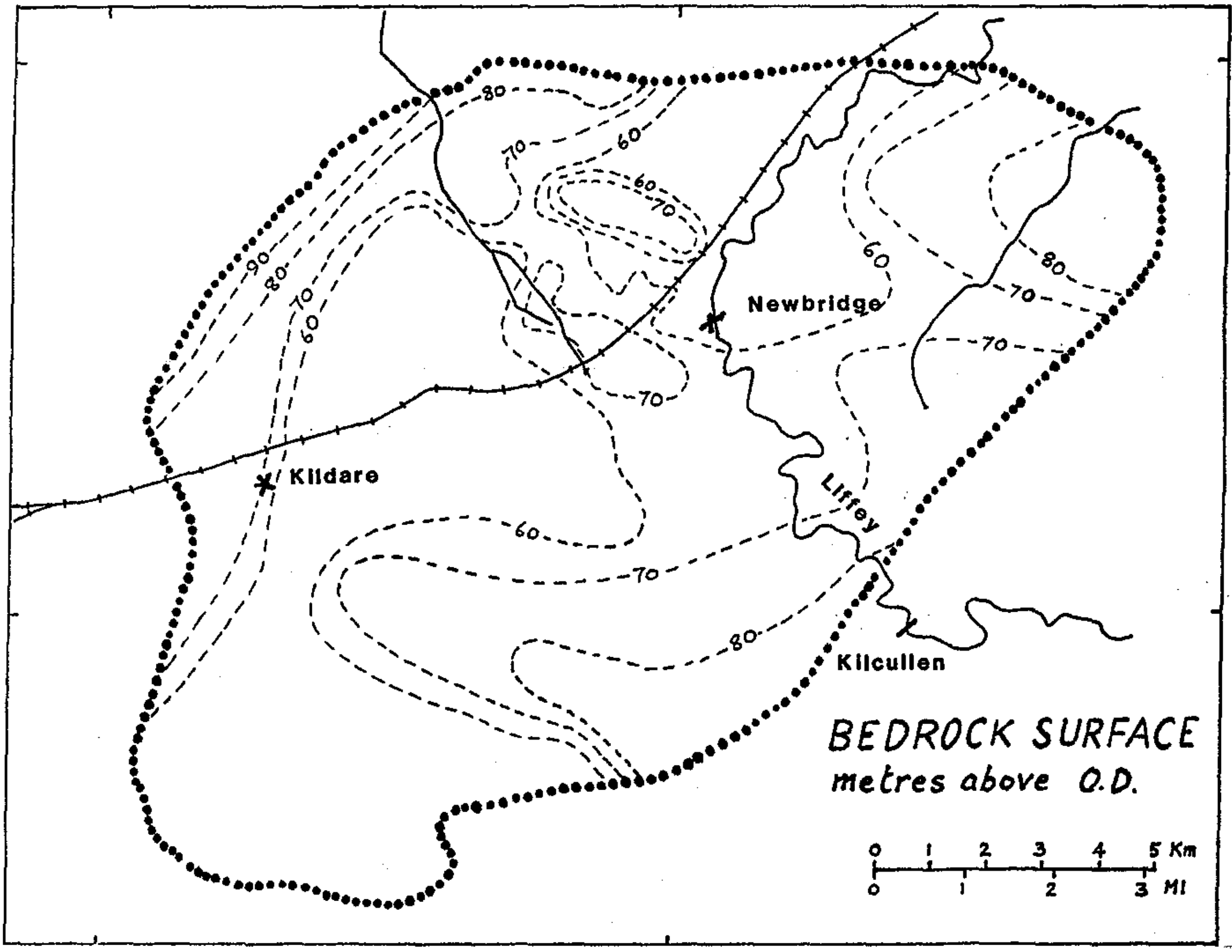
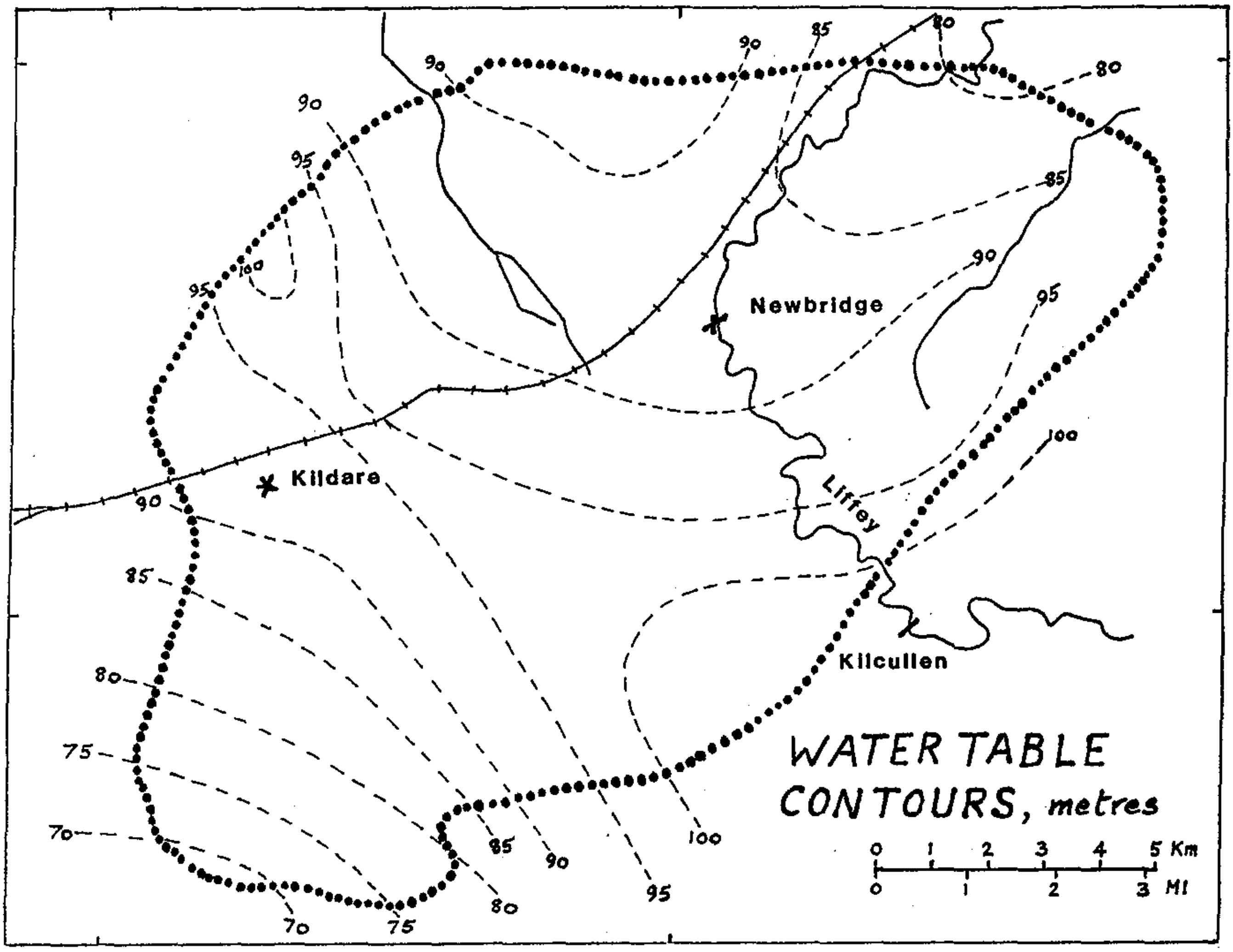
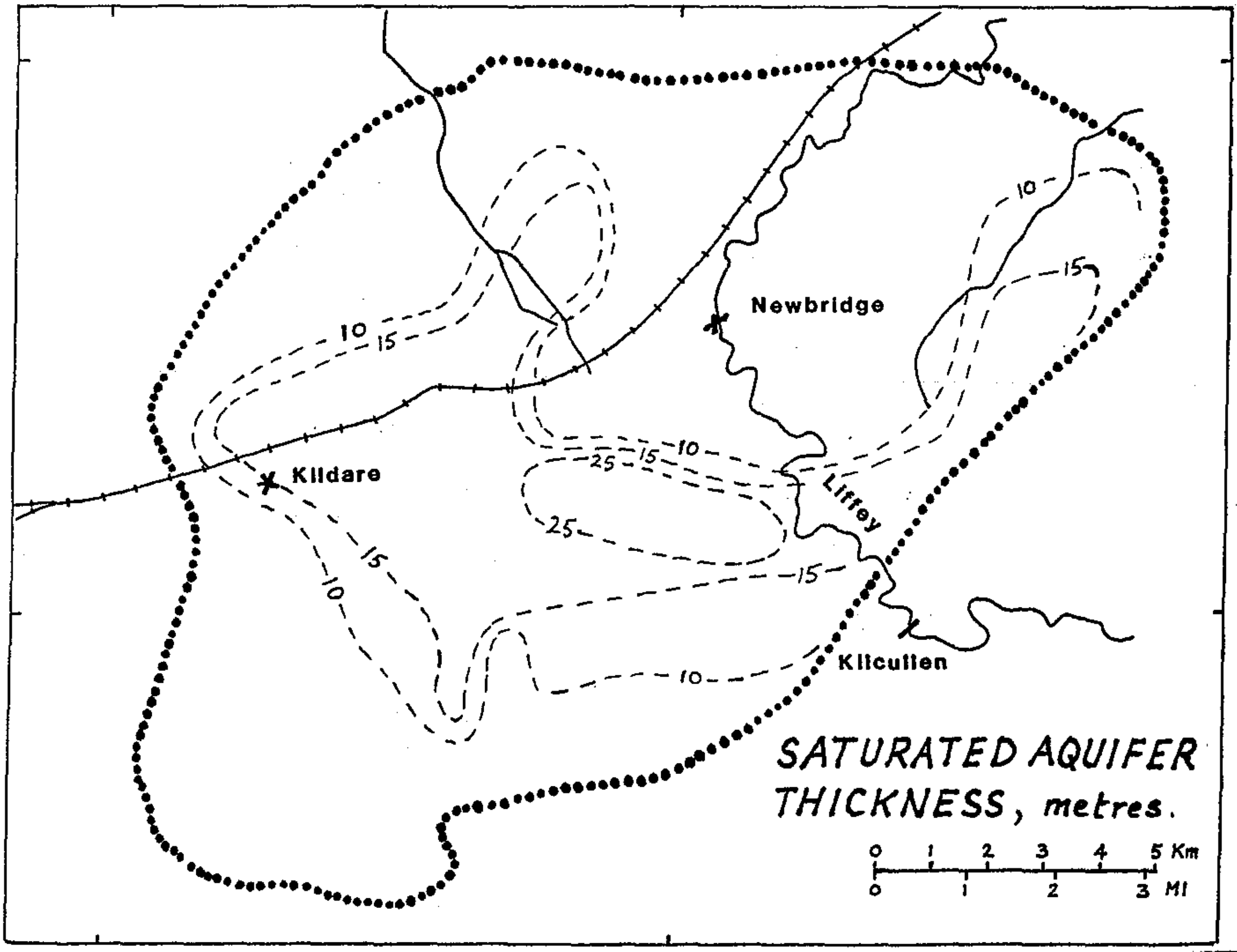
Kildare
Liffey
Kilcullen
20
30
50
DRIFT THICKNESS
metres
0 1 2 3 4 5 Km
0 1 2 3 MI


Newbridge
Kildare
Liffey
Kilcullen
60
70
80
90
BEDROCK SURFACE
metres above O.D.
0 1 2 3 4 5 Km
0 1 2 3 MI


WATER TABLE CONTOURS, metres
Newbridge
Kildare
Liffey
Kilcullen
0 1 2 3 4 5 Km
0 1 2 3 MI


SATURATED AQUIFER THICKNESS, metres.
Newbridge
Kildare
Liffey
Kilcullen
0 1 2 3 4 5 Km
0 1 2 3 MI

THE FUTURE OF WELL DRILLING

BRENDAN DUNNE. **DUNNES WATER SERVICES LTD.**

1. INTRODUCTION:

The other day I was drilling and I hit a good supply of water - 3/4 of a million gallons a day. This was for a private job but within two miles of a town that needs more water. The job before that, based on existing trial hole data, was to extract water from 50m down in limestone bedrock. It finished 15m deep in gravel with three times the anticipated yield. The job before that was to extract water from gravels at about 20m. It finished 40m deep with a yield of 1/2 million gallons a day, equal amounts from the gravel aquifer and the fractured bedrock.

These cases illustrate a number of points. The colossal amounts of groundwateer available in certain areas. The sketchy and often fallible nature of our information. And the existance of aquifers as yet undiscovered and unexplored.

In this paper I would like to explain a little bit about some of the drilling methods that can be used to tap these resources.

2. DOWN - THE - HOLE HAMMER DRILLING:

This is a very fast method of drilling and is the method most often used by water well drillers in Ireland today. It is primarily for rock drilling but can be used effectively in overburden.

Hammers come in different sizes 4", 6", 8" and bigger. They are operated by compressed air which moves a heavy piston very rapidly. Drill bits, known as button bits are made of hardened steel with tungsten carbide inserts or buttons. It is these buttons which actually do the drilling. Bit life can be extended by regrinding these buttons before they become too flat or lose their shape completely.

There is no weight required to operate the hammer other than the weight of the drill rods up to a maximum of about 3,000 lbs. Rotation speeds range from about 15 rpm to 30 rpm depending on the formation and the size of bit. Generally the harder the rock the slower the rotation speed.

Hammers require constant lubrication. This is achieved by means of an in-line oiler using a special rock drill oil.

Functions of the air are as follows;

i) To operate the hammer.
ii) To cool and lubricate.
iii) To remove cuttings.

3. HIGH VELOCITY FOAM INJECTION:

Foam injection is a relatively recent development which can be used in conjunction with air drilling. There are two main ingredients in a foam mix.

The foam itself which causes air bubbles in the water and a polymer which strengthens the bubbles and helps stabilize the hole. The two methods of using foam are high velocity and low velocity injection. Low velocity foam injection is possible only with rotary drilling. High velocity foam injection can be used with rotary and down-the-hole hammer.

The basic function of foam injection is to improve hole cleaning which in turn improves drilling rates and reduces bit wear. This is particularly important when drilling in damp conditions where a small amount of water causes a build up of cuttings around the drill rods, eventually causing a loss of air circulation.

With foam injection we are not dependant on maintaining the minimum up-hole velocity of 3,000 ft./min. associated with air flush. The annulus (the difference between the diameter of the drill rods and the diameter of the hole) is therefore no longer critical and so with the same size compressor and the same diameter drill rods we have the capacity to drill much larger diameter holes.

The polymer is necessary to strengthen the foam bubble if a lot of water is encountered. It also helps to stabilise the formation and to seal porous or fractured zones to help maintain circulation. Foam injection has the added benefit of cooling and cleaning the drill bit.

4. ROTARY DRILLING:

Rotary drilling is a very useful and highly versatile method of drilling. It can be used successfully in the most difficult of drilling conditions. Using either tricone or drag bit it depends on a combination of weight and rotation to achieve it's drilling action. To ensure drilling a straight hole this weight should be in the form of stabilizers and drilling collars immediately behind the bit.

The stabilizer is a piece of equipment which is the full, or almost full diameter of the hole and should be placed next to the drill bit. A drill collar is an oversized drill rod which is very heavy and should be placed in the drill string immediately above the stabilizer. One or more collars/ stabilizers are used depending on the weight required.

Steel tooth tricone drill bits are available in hard, medium and soft formation catagories. Bits for drilling soft formations are designed with long widely spaced teeth to permit maximum penetration into the formation. Bits for medium and hard formations have stronger more closely spaced teeth.

Rotary drilling can be classified according to the flushing medium used. As with hammer drilling the latest development is the use of foam polymer additives.

4.1 LOW VELOCITY FOAM INJECTION:

The idea with this method is to use the absolute minimum amount of air possible. The vigorous action of high pressure air and the consequent surging and differential pressures created are responsible for causing much of the collapsing in unconsolidated formations. The airlift effect of straight forward air flush extracts water from the formation thus causing erosion of loose material and fines. With foam injection however the cuttings are suspended in and lifted by the rising column of foam so there is no need to maintain high up hole velocity. In fact the amount of air used should be just sufficient to keep the column of foam rising in the hole at a rate of about 30ft./min. or upwards.

In a dry stable hole foam is mixed at a rate of 1 gallon per 100 gallons of water. If there is a lot of water, polymer must be added, about 2lbs per 100 gallons. The addition of polymer, as well as strengthening the foam bubble also helps to stabilize the formation by forming a light skin on the wall of the hole. The proportions of the mix must be varied according to the drilling conditions. An increase in water and stability problems demands an increase in the amounts of foam and polymer added.

Besides allowing holes to be completed in collapsing formations, the use of foam and consequent reduction in the amount of air required enables much greater diameters than previously possible with straight forward air flush. The amount of water used is small in comparison to mud circulation and there are no mud pits involved.

Having said this, however, foam injection does have it's limitations. It cannot counteract underground pressures. In order to drill waterladen sands and gravels we turn to mud circulation.

4.2 MUD CIRCULATION

This method of drilling can be used successfully to drill open hole in the most difficult conditions. A drilling mud should perform the following functions;

i) Stabilize the wall of the hole.
ii) Clean the bottom of the hole and lift cuttings.
iii) Seal the wall of the hole to prevent fluid loss.
iv) Cool and clean the drill bit.
v) Lubricate the drill bit.

The drilling mud supports the borehole and prevents caving by it's fluid pressure against the wall of the hole. This can be adjusted to counteract high formation or artesian pressure's tending to cause collapse by increasing the density or the weight of the mud. This is achieved by thickening the mud or by adding special weighting materials.

Mud is mixed to differing viscosities depending on the formation being drilled. In sands or gravel it will have a very high viscosity. In clay the viscosity is kept much lower. The standard method of measuring viscosity is the Marsh funnel.

The efficiency of removal of cuttings is dependant on the viscosity and the up-hole velocity of the mud. When cuttings are brought to the surface the mud must allow them to settle out as it passes through the settling pit. A good rule of thumb is that the mud pit should be at least three times the volume of the finished hole.

As drilling progresses a filter cake or skin builds up on the wall of the hole. This helps prevent erosion. It also helps to seal the wall of the hole and reduce fluid loss into permeable formations. In certain cases massive loss of circulation is experienced. This can be overcome by using purpose made additives which clog up the formation.

With traditional clay based muds this infiltration of permeable formation was a major problem as all the mud that entered the formation had to be removed or else have detrimental effect on the aquifer. With Revert, however, this is not a problem. Revert breaks down automatically after a length of time ranging from three days to seven days. Alternatively it can be artifically broken down by injecting chlorine into the borehole. This has the added benefit of disinfecting the well.

5. CONCLUSION:

These are just a few of the different drilling methods available. I have omitted the whole area of percussion drilling because it would need a paper unto itself. I have also omitted other important aspects of drilling such as reverse circulation, screens, gravel packing, grouting, developing boreholes and rehabilitation of old boreholes. However, I hope that what I have covered has been of interest to you and will leave you a little wiser.

The future is indeed bright for the well drilling industry. There is a new awareness of our hidden water resources. The need and the desire is there to develop them. There are exciting new markets with the prospect of drilling to exploit geothermal energy sources, the ever increasing demands of industry and farming and the private householders who increasingly demand cleaner fresher water.

The drillers for their part must strive to improve their technical expertise and the standard of workmanship and performance. Non completion of contracts to the original specification is a major problem. To this end I believe it would be beneficial if credit were given to contractors according to their standard of work. Real credit in terms of the client attaching a higher priority to performance and standard of work than to the selection of the lowest tender. In this way drillers will be motivated to improve performance and effficiency and to learn of and invest in new techniques and equipment. This would benefit the well drilling industry but more importantly it would benefit all those who need to employ its services.

In conclusion I would like to quote from a paper written by Mr. Bob Aldwell, the late Dr. David Burdon and Mr. Eugene Daly entitled 'Ground Water: Irelands hidden resource.'
"In Ireland the capital cost of the headworks (i.e. intake, treatment and pumping works) for development of ground water is less than 20% of the cost of developing a similar quantity of water from a surface source."

REFERENCES:

Drilling Experience Part 1 and Part 2. By Ray Rowles.

Ground Water: Irelands hidden resource. By C.R. Aldwell, D.J. Burdon and E.P. Daly.

Ground Water and Wells. Johnson Division, UOP Inc.

8th ANNUAL GROUNDWATER SEMINAR

APRIL 1988

Groundwater - An Economic Resource

K. T. CULLEN

GROUNDWATER - AN ECONOMIC RESOURCE

Groundwater is a marvelous asset in that it has many features that are useful to man in his never ending search for food, drink, energy and recreation. In areas of little rain it is the sole source of irrigation water and in most countries it is a major provider of clean potable water. In areas of volcanic activity it is a primary source of energy while everywhere else if can be used in conjunction with electrical powered heat pumps to provide heat at prices which are competitive with fossil fuels. And while it is possible to play golf on grass fairways in desert regions due to the use of groundwater for irrigation, many golf courses in this country are now using the same technique to keep the grass and fairways as lush as possible in our dry summer months.

We in Ireland are only now realising the extent of this resource beneath our feet and it should be our objective to see groundwater developed where it can add to the economic development of the country and to protect it from contamination. The national atmosphere of re-awakening allows us to look at our natural resources in a new light and groundwater must be equally considered. Suddenly, we are casting aside old ideas and theoretical constraints and everything is becoming possible. Why should our approach to groundwater be any different; most other countries have developed this resource to a high degree and they seem to manage perfectly well with much less recharge than falls on this island.

Groundwater is simply another resource which is no different from oil, gold or peat except that it is renewable. It can be located and quantified in a scientific way and developed to the best engineering standards. The day of relying on the hazel stick are gone and such remarks as "I know of a well that dried up" are now obsolete. Instead, we should be seeing how our neighbours have managed their groundwater and getting on with our development where it can help the economy of the country. To our advantage the vast bulk of Irish groundwater is not polluted as yet and we must capitalise on this situation and retain this position for future generations. The overseas concept of a clean,pollution free environment in Ireland extends to groundwater and while that view is correct at the present time it is our responsibility to maintain this situation for the future. In keeping with a positive outlook to the future I will discuss two recent additions to the national economy which have a groundwater input; the salmon farming and mineral water industries. The former is already contributing a large measure to the national economy and while the latter is not yet a hugh revenue earner it is a very typical subject.

Salmon Farming Industry

The value of Irish fish exports for 1987 was £130 m., the highest figure to date. A significant contributor to that amount was the salmon industry with both farm and wild salmon playing an equal role. It is expected that the farmed salmon will over take the wild salmon in export value in 1988 and continue to grow in the coming years. Farmed salmon production will amount to 5,000 tonnes in 1988 and is expected to double to 10,000 tonnes in 1990. This compares with a projected figure of 13,000 tonnes for the U.K. and 80,000 tonnes for Norway.

Groundwater has an important role to play in the development of this industry where the shortage of smolts has limited the expansion of the sea farms. The greater use of groundwater in the freshwater phase of the operation will help to maintain an adequate supply of disease free smolts.

Atlantic salmon were first farmed in the fjords of Norway where the cold waters caused a high mortality during the hatching and first feeding phase and resulted in a low number of early S1 smolts. Research quickly proved that the optimum temperature to hatch and rear Atlantic salmon to smoltification (15 months) is 10.5'C. Subsequently many Norwegian units switched to artificially heated water using heat exchanges and waste energy sources such as power station discharges.

Groundwater, with its constant temperature of 10'C - 11'C is an ideal medium to use as the feed water to a salmon hatchery as not only does it provide the necessary warm temperature but it has the added advantage of disease free status. A number of hatcheries are already using groundwater in Ireland with two units in Kerry and one in Galway. Plans are well advanced to begin construction of a complete groundwater based hatchery on the banks of the Boyne near Slane Bridge where the groundwater will be abstracted from a number of production wells drawing from the limestone and gravel aquifers already proven there.

Mineral Water Industry

At present this industry is in its infancy with three bottling plants in operation with a relatively small export market. Plant has now been installed to provide a large capacity and hopefully these companies and others will succeed in this market which is expected to grow substantially in the next number of years. The European mineral water market is valued at £4 billion with the U.S. market of a similar value.

The following items answer some of the most frequent questions asked about bottled water.

What is Mineral Water / Spring Water ?

There are several types of bottled waters. A clear distinction should be made between the mineral waters, which are most often sparkling and are generally used as an alternative to soft drinks, cocktails or used as beverages; and bottled "drinking water" which is consumed as an alternative to tap water and is used for cooking, and mixing with powdered milk etc.

In the U.S.A. the following definitions are in use:

Drinking Water Bottled water obtained from an approved source that has undergone special treatment or has undergone minimum treatment consisting of filtration and ozonation or equivalent disinfectant process.

Natural Water Bottled spring, mineral, artesian well or well water which is derived from an underground formation and is not derived from a public water supply and which is unmodified by blending with water from another source or by the addition or deletion of dissolved solids, except as it relates to ozonation or equivelent disinfection and filtration.

Spring Water Water derived from an underground formation from which water flows naturally to the earth's surface. "Spring Water" shall meet the requirements of Natural Water.

The E.E.C. Directive (1980) defines natural mineral water as

(a) by its nature, which is characterised by its mineral content, trace elements or other constituents and, where appropriate, by certain effects;

(b) by its original state

both characterictics having been preserved intact because of the underground origin of such water, which has been protected from all risk of pollution.

When Is A "Spring Water" A "Natural Mineral Water" ?

Sometimes it depends on who is selling and/or is buying. In California a bottled water can only be described as Spring Water if it issues by natural forces out of the earth at a particular spot. While in Europe there is great confusion as to whether the Mineral Water Directive applies to bottled waters which describe themselves as Spring Water.

Are Mineral Waters Disinfected / Or Otherwise Treated ?

The U.S. legislation allows disinfection by ozone or equivalent forms of disinfection and treatment to reduce the concentration of any substance which exceeds safety standards.

The E.E.C. Directive (1980) requires that "Natural Mineral Water" in its state at source, may not be the subject of any treatment or addition other than; (i) the removal of unstable elements such as iron and sulphate compounds, (ii) the removal of CO_2 and (iii) the introduction of CO_2. The Directive specifically prohibits disinfection by whatever means. The U.K. Statutory Instrument implementing the 1980 Directive defines source as "means any point of natural emergence or artificial abstraction of ground water".

Can Bottled Water Be Transported From Source To Bottling Plant ?

The U.S. legislation permits the water to be transported from its source to the bottling plant by pipes, tunnels or trucks. The E.E.C. directive requires that bottled waters should as natural mineral water be bottled at source.

When Is A Groundwater A Mineral Water ?

U.S. terminology requires that a mineral water has 500 mg/l of total dissolved solids.

The E.E.C. is much less strict and my understanding of the 1980 Directive is that as long as the water meets the strict bacteriological levels and is free from any harmful chemicals then all groundwaters can be classed as Natural Mineral Waters.

ENVIRONMENTAL IMPACT ASSESSMENT

- THE DIRECTIVE

G A Walker

April 1988

ENVIRONMENTAL IMPACT ASSESSMENT: THE DIRECTIVE

Environmental Impact Assessment which is being introduced into the European Community by Council Directive 85/337 - "on the assessment of the effects of certain public and private projects on the environment" - is not a new concept. In fact, the basic analytical approach used in EIA was developed by Leopold and others of the US Geological Survey in 1971. Indeed, there was also provision in Section 39 of the Local Government (Planning and Development) Act 1976, and Article 28 of the Local Government (Planning and Development) Regulations 1977, for the preparation by a developer

> of a written study of what, if any, effect the proposed development would have on the environment relative to the place where the development is to take place.

However, this legislation was somewhat limited in that it did not apply to exempted development (e.g. construction of a motorway by a local authority or major affestation projects), it allowed some discretion to local planning authorities as to whether an impact study should be sought and it only applied to developments the cost of which was to exceed five million pounds and where the proposed development would be likely to result in the emission of noise, vibration, smell, fumes, smoke, soot, ash, etc. The Directive will go some way towards remedying these deficiencies and will provide a more vigorous and transparent mechanism for assessing potential environmental impacts and for public communication.

Although quite brief (comprising a preamble, twelve substantive articles and three annexes) the Directive is quite complex and in addition, it is not yet clear how it will be implemented in Ireland. Teasing out all of its implications is beyond the scope of this paper and I intend to refer to only a few of its more significant dimensions - not necessarily in order of importance.

Logically perhaps the first question is 'what projects will be embraced by the Directive' and not surprisingly, this is where the first questions arise about its implementation in this country. Briefly, Article 4(1) refers to nine classes of project listed in Annex 1 and says that these shall be made subject to an assessment. The nine classes are oil refineries, thermal power stations, radioactive waste disposal installations, iron and steel smelters, asbestos works, integrated chemical plants, certain transportation links (motorwarys, railways, airports), ports, and toxic or dangerous waste disposal sites. However, Article 4(1) has a caveat ... it is subject to Article 2(3) which states that

> Member States may, in exceptional cases, exempt a specific project in whole or in part from the provisions laid down in this Directive

What will we in Ireland do? I wonder!

Also on the question of what projects are to be covered by the Directive, Article 4(2) states that

> Projects of the classes listed in Annex II shall be made subject to an assessment ... where Member States consider that their characteristics so require.

Annex II lists 81 activities in ten major categories (plus modifications to those mentioned in Annex I, and includes such diverse projects as geothermal drilling, extraction of minerals and ores, installations for the collection and processing of radioactive waste, chemical storage plants, tanneries, ski-lifts, urban development projects, waste water treatment plants, and knackers yards.

At least two points of interest arise from Article 4(2) and Annex II ... first, Annex II projects will be subject to an assessment "where Member States consider that their characteristics so require" and to this end

> Member States may inter alia specify certain types of projects as being subject to an assessment or may establish the criteria and/or thresholds necessary to determine which of the projects ... are to be subject to an assessment ...

Thus, in effect, each Member State can select from Annex II those projects which it wishes to include in the process. A UK Department of the Environment letter of January 1988 outlines proposals for the implementation of the Directive in the United Kingdom, proposals which were described in a recent issue of Planning as 'minimalist in the extreme'. Again I am prompted to ask the question 'What will we in Ireland do' and again, I wonder.

The second point of interest arising from Article 4(2) and Annex II is that many projects which under our previous legislation were regarded as exempted development, are now being brought into the planning process. Motorways, waste water treatment plants and waste disposal sites for example, may now be subject to EIA. This then begs the question who is to do the assessment - if a local authority is in effect the developer, then the same local authority cannot act as the judge of the application. On this point, Article 1(3) defines the competent authority as

> the authority or authorities shall be that or those which the Member States designate as responsible for performing the duties arising from the Directive

Clearly the competent authority cannot be the Department of the Environment - having approved the project for funding purposes they could not be expected to turn it down on environmental grounds. The most likely answer is An Bord Pleanala but EIA requires expertise not currently available within An Bord. This is yet another interesting question!

Having 'resolved' - perhaps not to your satisfaction - the problem of what projects are to be covered by the Directive, I would like to look briefly at the question of 'what is an EIA'. Article 3 states that

> The environmental impact assessment will identify, describe and assess in an appropriate manner, in the light of each individual case ... the direct and indirect effects of a project on the following factors:
>
> - human beings, fauna and flora
> - soil, water, air, climate and the landscape
> - the inter-action between the factors mentioned in the first and second indents
> - material assets and the cultural heritage

In addition, Article 5(2) says that the developer shall provide at least the following information

- a description of the project comprising information on the site, design and size of the project;
- a description of the measures envisaged in order to avoid, reduce and, if possible, remedy, significant adverse impacts;
- a non-technical summary of the information mentioned in indents 1 to 3.

Subsequent articles refer to the manner in which the public should be informed (Article 6), the exchange of information concerning projects likely to have a trans-frontier impact (Article 7) advising the Commission of the criteria or thresholds adopted under Article 4(2) - the discretionary list (Article 11) while a more detailed listing of information to be supplied is contained in Annex III. Significant in this Annex are the references to

> estimates, by type and quantity, of expected residues and emissions (water, air and soil pollution, noise, vibration, light, heat, radiation, etc) resulting from the operation of the proposed project (Annex III(1))

and to an outline of the alternatives examined, and to

> a description of the aspects of the environment likely to be significantly affected by the proposed project, including, in particular, population, flora, fauna, soil, water, air, climatic factors, material assets, including the archaeological and architectural heritage, landscape and the inter-relationship between the above factors (Annex III(3)).

Clearly, the range of skills required both to prepare an impact study (by the developer) and then to assess it (by the competent authority) is very wide, and this is why I doubt the in-house competence of An Bord Pleanala or, indeed, any single agency in Ireland.

Accordingly, I feel that we have to pay particular attention to the mechanisms by which the Directive will be implemented in Ireland.

On the subject of implementation, my final point, I have grave reservations. The Directive was adopted by the Council in June 1985 and Member States were advised to

> take the measures necessary to comply with this Directive within three years of its notification (Article 12(1)).

The Directive was notified to the Member States on 3 July 1985, so that compliance should be from 3 July 1988. However, various drafts of the Directive have been discussed within the Community institutions since 1979, so we were aware that a Directive - in some form or other - was in the pipeline, and would come into effect at some point.

Implementation of the Directive requires four major steps:

- amendment to the Local Government (Planning and Development) Act, 1963 and 1976 and other legislation;

- identification of criteria and thresholds under Article 4(2) and Annex II;
- specification of the Competent Authority and the mechanism by which each EIA is to be 'scoped' and following its preparation, assessed;
- specification of the mechanisms for public communication.

To date there has been virtually no discussion with non-governmental interested parties on any of these issues (although some agencies, such as Bord Failte, made observations to their parent departments more than twelve months ago), nor has any draft Bill been circulated. It is extremely unlikely, therefore, that we shall meet the 3 July deadline, and we have no idea whether we will take the 'minimalist' approach likely to be adopted by the UK or whether we will adopt the spirit of the Directive and seize the very real opportunity for environmental protection which the Directive presents.

There are a wide range of other issues which I have not mentioned but which are likely to be topics of discussion over the next few months - the cost of EIA, its impact on the time-scale for a proposed project, and the techniques of measurement and assessment, to mention only three. My major concern is that some interests will interpret the Directive as an attempt to slow down the development/job-creation process rather than an opportunity to provide a sound basis for sustainable development. Casting the debate in these terms will almost certainly ensure that the opportunity will be lost. I think we have the ingredients for an interesting summer!

INTERNATIONAL ASSOCIATION OF HYDROGEOLOGISTS

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AN ENVIRONMENTAL CASE STUDY OF TARA MINES LIMITED

by

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Summary

The Tara Mines Zinc/Lead Mine at Navan in the Irish Republic is the largest of its kind in Europe and formidably placed on a world scale. However, the most striking feature of the operation is its location on the edge of a pre-existing urban community, surrounded on three sides by extremely high quality agricultural land and with a major fishing river flowing over the ore body. This paper explains the overall complexity of the associated environment, the legal and social constraints existing and the place that Environmental Impact Assessment has played and currently plays in ensuring acceptance of the operation not only by the controlling authorities but by the general public.

Mining Background

Tara Mines Limited is 75% owned by Finland's largest mining and metallurgical company Outokumpu Oy and 25% by the Irish State. The mine was discovered in 1970 and the initial planning phase commenced in 1971. Underground development commenced in 1972 and work on the surface facilities started in 1975. Production commenced in 1977. Approximately 2.5 million tonnes of zinc, lead and silver bearing ore are mined annually which is processed into 400,000 tonnes of zinc and lead concentrates. Almost 1 million tonnes of waste material in the form of tailing is also produced annually. The multi-lense orebody lies within dolomitic limestone rocks of carboniferous age. Mineralisation is composed of primary sulphides viz. sphalerite and galena with a Zinc/Lead ratio of 5:1. Proven, probable and possible in situe ore reserves remaining, at the end of 1985, amounted to 51.2 million tonnes grading 8.84% Zinc and 2.64% Lead. The orebody is not yet fully delineated, remaining open to the West and South where diamond drilling is continuing. At the end of 1985, total ore mined out of reserves had reached 14.4 million tonnes.

Environmental Background

The non urban area immediately around the mine and the tailing disposal area, approximately 5km away, is intensively farmed for milk, beef, cereals, potatoes and horses. Productivity is average to high by European standards.

The Leinster Blackwater flows over the orebody and joins with the River Boyne in the town of Navan, nearby. Both rivers have a good and longstanding reputation as commercial and recreational fisheries, the former for eels, salmon and trout, the latter, as one of the best early salmon rivers in the country, for its February to May fish which are in the 16 - 18 lbs category and for later fish averaging 9 lbs. Spawning streams, especially for the Blackwater, are located adjacent to both the mine area and the tailings lagoon, the latter being bounded on 3 sides by them. The urban area of Navan has a population of 15,000 and apart from mining and its downstream industries and services, the local economy is based on the currently consumer sensitive areas of furniture and carpets.

There are approximately 100 residences located on the mine perimeter, with a local population of around 400 people. The original, essentially native, population of the early seventies with its understandable prejudices and apprehensions about mining has, today, been substantially diluted by Tara personnel and their dependents as well as those in the downstream sector. Generally speaking the community at large is supportive of the still expanding operation but little quarter is given and pressures to perform within subjective tolerance criteria as well as the regulatory and statutory controls are gradually increasing. It is within this context that the mine operates.

Planning and People

Private property enjoys remarkable respect in Irish society. This is manifest in the Constitution, (1) which provides for the protection of the property rights of the citizen, and the same ethos is reflected in the 1963 Local Government (Planning and Development) Act. (2) Whereas this and subsequent acts have much in common with planning legislation in other countries, Ireland is the only country in Europe in which the ordinary citizen has a right to participate in planning at all stages - from the area development plan through the planning application to the stage of appeal to the Planning Board.

Since 1978, water pollution control has come under the Local Government

(Water Pollution) Act, 1977 (3) which requires the licencing of discharges to sewers and receiving waters, including groundwater. A discharge is subject to such conditions as the local authority 'thinks appropriate'. This licence (4) adds nine further conditions to those imposed under the planning acts. An Atmospheric Pollution Act (5) is now in existence and it is expected that this legislation will result in additional and stricter controls including the licencing of certain processes with the imposition of reviewable conditions analogous to those attached to the Water Pollution Act licence to discharge just referred to. Besides statute law, common law provides remedies for pollution damage, particularly with regard to private nuisance, which has been defined as 'an unlawful interference with a person's use or enjoyment of land, or of some right over or in connection with it'. (6) The onus is on the defendent to prove that the nuisance is justifiable, (7) and it is a matter of concern that compliance with planning permission limits alone may not fully protect an operator.

Tara's overall operation is controlled, at present, by over 90 environmental conditions imposed in seven planning consents. These originate principally from four Planning Acts (2, 8, 9, 10) and the Water Pollution Act (3), and also from the Sanitary Services Act (11) and the Fisheries Consolidation Act (12). Apart from the actual conditions which derive their authority from the above acts, each of these imposes other more general, but nevertheless compulsory, constraints. Data in compliance with the conditions referred to above, must be submitted to the Local Authority on a regular, scheduled basis and it is closely scrutinised by it and its advisers.

Environmental Control Programme

Ireland does not have National heavy metal fallout limit values. What Tara, therefore, did to ensure a necessary level of protection, was to set self-imposed annual fallout limits with respect to zinc and lead. In doing so the major concern was that, while these annual fallout rates might appear satisfactory, a problem could occur in the long term due to accumulation in the terrestrial ecosystem, especially considering the indicated long life of the operation, now a further 20 years, at least. The approach developed was to specify ultimate metal levels in the soil which allow a safe margin for the protection of agricultural productivity and by calculating back, set safe annual limits for fallout rates.

Tara's atmospheric monitoring system includes an extensive network of directional deposit gauges around the site and tailing pond and also a series of high volume samplers located in strategic areas. This is supplemented by soil and herbage monitoring around the areas mentioned and also along farmland adjacent to the 65km of railway track between the mine and the port. This is an important part of the terrestrial monitoring programme, the objective of which is to ensure non-interference with man and his domestic and agricultural practices and also with wildlife.

An interesting aspect of this programme is the farm productivity surveys of lands adjacent to the main site and tailing pond. These provide the basis upon which any subsequent impact can be assessed and include a classification of existing farming systems on the basis of livestock inventories, stocking rates, areas under tillage or pasture and their productivity, soil type and potential land value. In certain situations, elsewhere in Ireland, it has not been uncommon for adjoining landowners to successfully seek retrospective compensation long after the alleged effect occured. In many such instances the farming system apparently affected was believed by the plaintiff to be considerably more productive than inherent circumstances and previous management would permit. Tara's periodically updated surveys will provide valuable information with which to counter such claims. The fact that Tara intensively farmed and closely monitored vegetation and stock on over 60 ha of its own property for 5 years, 3 of them after production commenced, has provided the company with immensely valuable information on the effect of the mine on agricultural productivity. This is not to say that claims e.g. for animal deaths, allegedly caused by the company, are not made, they certainly are. It is a fact that a percentage of animals die on every farm, every year, for a variety of causes both natural and accidental. It is probably a normal enough reaction for farmers to immediately suspect their apparently well to do mining neighbour when the cause of death is not immediately obvious. Where claims are made, the company has a comprehensive investigation procedure, with independently conducted post mortem and analytical requirements, which has so far proved most effective, in protecting the company. In this respect, it is Tara policy not only to absolve itself from blame but to estalbish, if possible, the actual cause of death.

Aquatic Monitoring

In this regard, apart from compliance with the more specifically stated planning permission conditions (compared with the non specific terms of the atmospheric conditions) and legal obligations such as the protection of riparian rights, the principal objective is to ensure protection of salmon, trout and eels both for their commercial and recreation fishing importance. The Tara method of effluent discharge is interesting in this respect. It consists of a transverse manifold placed across the river with nozzles at a critical angle which ensures effluent dilution and mixing within jet trajectories which allow non-mixing or clear water zones above and below the effluent plume. These zones permit safe migratory passage for young and mature salmon and eels.

In a location such as Tara's, the long term affect on fish stocks and fish condition is of fundamental importance. The extensive baseline surveys (which commenced in 1971 and which continued until production commenced in 1975)carried out on the main rivers and their tributaries have been invaluable. These established selected physical, chemical, ecological and economic parameters essential for the initial and subsequent assessment of environmental impact. The ecological studies established the natural fluctuations in plant and animal populations in relation to season, changes in water chemistry, changes in river bed composition and variations in river flow velocities. The physical examination included an assessment of the habitat status of each river and tributary with regard to such conditions as the number and location of pool/riffle complexes, river depth profiles and bed composition. Salmon spawning status was established by redd counts. Hydrological data was also collected since flow fluctuations influence the assimilative capacity of receiving waters.

Tara is still continuing aquatic ecological studies, as part of an ongoing environmental impact audit procedure, principally to establish concentrations of heavy metals in the constituents of the aquatic ecosystems with respect to baseline conditions and in 1984 conducted a repeat electro fishing survey of the waters immediately upstream and downstream of the effluent discharge manifold to obtain population and condition data for salmon, trout and eels. A further electro fishing exercise is due this year in compliance with a discharge licence renewal condition. The major river i.e. the River Boyne is designated as a salmonoid river under an E.E.C. directive (14) and this is also reflected in the conditions attached to the 3 year renewal of Tara's licence to discharge.

Based on experience, it is not only important to continually monitor the performance of the company in relation to adjacent waters, but it is also essential to carefully monitor the activities of third parties e.g. arterial drainage, with its devastating effect on fisheries, or upstream industries including intensive agriculture lest the consequences of these be wrongly attributed.

Ground water, including domestic wells, is also monitored regularly. This is particularly important because of the increasing local use of aquifers to supply community water requirements. Within such a context, it behoves a developer to thoroughly examine the ground water status of a potential mining location, as an integral part of an environmental impact assessment, to predict the effect of a proposed development on its quantity and quality. In the immediate area of a mine, supplies to pre-existing agricultural and industrial operations also to domestic dependents may be critical and the cost of their replacement, as a community relations gesture, may be significant in the overall development cost benefit equation.

Another ground water scenario arises in regard to waste, particularly tailings, and the selection of suitable disposal areas. Where choice is possible, it is obviously prudent to locate over an area where minimal risk is posed to underlying or adjacent aquifers.

At Tara, the supply problem was first confronted, as is normally the case, at the exploration stage. The company was, therefore, forwarned and in a position to consider early alternative arrangements for supplies to over 40 homes and two industrial premises by way of contributions to group water schemes.

As in other cases of self protection, it is also necessary to monitor ground water in order to identify other forms and sources of contamination which could be attributed, in error, to a mining operation.

Vibration and Noise Monitoring

Mining adjacent to residential areas is not unique, but each operation must be assessed on its own particular idiosyncrasies. Those at Tara certainly result in the response to blasting being the principal environmental and community relations problem.

Blasting at Tara Mines is subject to the normal production considerations of good fragmentation, minimum damage to mine structure and cost efficiency, as influenced by tonnage broken per blast, and also to a Local Authority planning consent condition that vibration from blasting must not exceed 7.62 mm/s peak particle velocity at any residence. Approximately 40 privately owned houses are situated adjacent to the current mining area and their location with respect to each underground blasting position is considered in blast design. The effective individual charge that is calculated to minimise vibration may be 150 kg in some locations or as little as 15 kg in others.

In fulfilment of its planning consent conditions the Company continually measures blasting vibration at 3 strategically sited locations around the mine site.

The imposed limit is regarded as extremely stringent, nevertheless, it has been possible to operate within it to a very large degree. Since 1972, there have been over 45,000 blasts with under 40 occasions when the limit was exceeded. This record, however, does not impress the residents who frequently react to levels as low as 1mm/sec peak particle velocity.

As well as vibration, operational noise has also been a considerable problem. The Company can, however, with a strict operational supervision, remain within the 55dB(A) daytime and 45dB(A) nightime limits. Noise is also monitored at the 3 vibration monitoring stations on a 24 hour/day, 365 day/year basis. There is also a specific and separate noise condition applied to blasting.

Tailings Disposal

A further environmental sector worthy of mention is tailing disposal. Tailing is the residual, finely ground (viz. 99% $< 75\ \mu$) host rock plus some zinc and lead remaining after the main sulphide ore fraction has been processed into zinc and lead concentrate form. This material is pumped in slurry form to a lagoon where it settles out, gradually filling the depository with slowly compacting solids, under water. With an operationally necessary fluctuating water table, beaches are periodically exposed which, in certain conditions, can dust but which are, apart from the immediate surface layer, saturated and, therefore, unstable for access.

A considerable amount of work has been done on the rehabilitation of tailing at Tara and at other similar Irish mines (15, 16). Investigation is, however, continuing into methods of achieving a long term ecologically stable solution and a current study is considering alternative methods of laying down tailing to achieve a more wind stable, access proof, and vegetation hospitable substrate.

Planning and EIA

Tara has now had 15 years experience in the planning, development, expansion and operation of a large base metal mine. This experience has emphasised several important facts which are described at length elsewhere but in summary are:-

(1) The undeniable importance of a sound ecologically based EIA as an important planning and decision making tool.

(2) The essential recognition of the importance of psycho and socio-economic components within the overall environmental context.

(3) The necessity for the active involvement of third parties at the earliest possible stage and the fostering of a continuing relationship with them.

(4) The advisability of early and continuing dialogue with planning and relevant statutory, regulatory and advisory bodies.

Each of these items is important within the context of EIA as applied to Tara's ongoing operation and each is worthy of a little expansion.

E.I.A.

It has already been admitted (17) that when Tara commenced its ecological and social approach to the task of mining the orebody, those closely involved were unaware of the existence of the procedure of EIA. Nevertheless, this label was ultimately attached to the methodology used with little distortion of the classical concept. Perhaps pragmatism played a larger part than adherents to the original concept would prefer, nevertheless, the Company believes that it got the mixture right and it now lives by it. Fuller's definition (18) viz "Environmental assessment is no more than an organised

and formalised process for collecting and evaluating information about the likely environmental consequences of a major development project" is essentially that of the Company with one qualification:-
Its use should not be confined to major development projects only. Small projects like small dogs can have big tails and may require meticulous consideration, also, modification of existing processes can, likewise, have complex effects. Use of EIA in such cases can clarify the presence and extent of adverse effect and assist in their mitigation.

However, the ultimate benefit of EIA lies in the breadth and depth of its scope and essentialy in the detail of the baseline pre-requisite. This all important procedure is not only fundamental to initial EIA based decisions, it is a benchmark for environmental performance audits throughout the life of an operation and thereafter and this must be borne in mind when defining the original criteria to be recorded.

In the case of most environmental components their status can not be effectively assessed on the basis of one quick series of counts, samples or analyses. Where seasonal or cyclical phenomena are involved and important the baseline must be extended so that the significance of these can be considered.

In Tara's case, the rule of thumb in determining what should be taken into account is to go for an overkill both in regard to extent and detail and gradually and carefully to prune back from there. This can be an expensive ideal, but so is missing or inadequately addressing a critical factor.

An example of this, in the case of Tara and it is not in the ecological field, was the Company's insistence, after considerable deliberation, on an archaeological investigation and survey of its proposed tailing disposal area. This ultimately warranted several very expensive pre-construction excavation projects but the alternative would have been a considerably more expensive suspension of construction activities following the issuance of a listing order which would insist on the proper excavation of the features involved and the subsequent certification that this had been completed in a professional manner, before work could re-commence. As a point of general interest, Tara's EIA check list also includes other heritage and cultural features as well as items of folklore interest. Important features which will ultimately be effected are recorded and archived by competent authorities.

Psycho and Socio-Economic Considerations

Right from the start, Tara insisted that people are part of the environment and recognised that the cultural and economic status also social behaviour of individuals and groups must be considered in any decision making process. At Navan in 1971, just as the orebody was discovered, the local community was beginning to luxuriate in the respectable status of a developing dormitory town for Dublin. The unemployment level was less than 1% and a mining operation, especially as envisaged by the public, was the last thing it wanted (17). Such attitudes and circumstances had to be assessed and analysed and the alternative benefits evaluated prior to making decisions.

Third Parties

We have entered an era when the people decide, hopefully by the democratic processses, what may proceed within their community. In addition, the general public is now more aware of environmental, social and civil rights issues (13) than it was 12 - 15 years ago when Tara was in the business of selling the original development to them. The Company, nowadays, must be prepared to respond to quite specific issues on a well informed basis and in a degree of detail which is acceptable to the public.

Involvement of a community is an essential part of the EIA process and for that matter an essential part of any planning process whether EIA is involved or not. However, a public must be prepared well in advance of having sight of an EIA or planning application if their approval is essential. This can only be achieved if the public is fully understood and this, in turn, can only be done if it is carefully analysed, categorised, attitudes identified, confidences gained and opinions altered. At Tara, public opinion surveys (19) were used to assess the success of this. Only then can the process of selling and persuading begin as it is Tara's experience that there is no short cut to achieving this.

Public meetings have sabotaged more good proposals than they have confirmed. Individual or small group confrontation has, therefore, always been the Company's practice and this is hardly likely to change. Once confidence and good will have been obtained, they must be retained. Such confidence today will buy out tomorrow's error, but only once. Tara, therefore, maintains an open door policy and residents are free to speak with environmental staff at any time, and for that matter, any member of Managment including the General Manager and Chief Executive Officer.

Statutory, Regulatory and Advisory Bodies

It has always been the policy to involve such bodies as the Local Authority, the Health Board, Fisheries Authorities, the National Museum, the Tourist Board and the Irish National Trust (the last two as bodies prescribed in the Planning Act (2)),at the earliest appropriate time. Each is kept fully informed of relevant progress and all are involved in the ongoing solution of important problems. The Company still meets on a monthly basis with the Local Authority and Regional Health Board, within the structure of a Joint Supervisory Committee comprised of Senior Management personnel from each. Meetings are also held at least twice per year with these officials and local elected representatives.

Tara favours inter personal dialogue with members of statutory, regulatory and advisory bodies on a regular basis with a view to developing mutual peer respect and understanding. With such a foundation, progress is more easily achieved.

The Environmental Impact Audit

At Tara, the process of environmental impact auditing is an accepted procedure for assessing environmental control performance and for ensuring that such control is being achieved at the least cost. In particular, where self-imposed limits have been applied to enable compliance with consent conditions, which control by principle rather than specific constraint, these must be examined, regularly, on a cost benefit basis. Also where changes in operational procedure or process modifications are suggested and no actual planning consent is required, they are subjected to an environmental audit.

Conclusion

Much of this paper is history, but in a country where this topic plays such a large part in our everyday lives, it is hoped that it will be seriously considered. If this is the case then it will be time well spent. Environmental Impact Assessment, from July 1988, will also be an integral part of the lives of planners and developers and I personally welcome its advent and commend it to all.

In closing, I most willingly acknowledge the generosity of Tara Mines Limited in permitting me to present a paper based on my experience, while on their Staff, from 1971 to 1987.

References

1. Constitution of Ireland: article 40.3.2 (Dublin: The Stationery Office).

2. Local Government (Planning and Development) Act, 1963 (Dublin: The Stationery Office, 1963), 227p.

3. Local Government (Water Pollution) Act, 1977 (Dublin: The Stationery Office, 1977), 21p.

4. Licence to discharge trade or sewage effluent to waters. Meath County Council reference number in register W82/3, 1982, 2p.

5. Air Pollution Act, 1987 (Dublin: The Stationery Office, 1987).

6. Rogers W.V.H. Winfield and Folowicz on tort, 10th Edn. (London: Sweet and Maxwell, 1975), 318.

7. Scannell Y. The law and practice relating to pollution control in Ireland, 2 Edn. (London: Graham and Trotma for the Commission of the European Communities, 1982), 215p.

8. Local Government (Planning & Development) Act, 1976 (Dublin: The Stationery Office, 1976).

9. Local Government (Planning & Development) Act, 1982 (Dublin: The Stationery Office, 1982).

10. Local Government (Planning & Development) Act, 1982 (Dublin: The Stationery Office, 1983).

References (Contd)

11. Local Government (Sanitary Services) Act, 1962 (Dublin: The Stationery Office, 1983).

12. Fisheries (Consolidation) Act, 1959 (Dublin: The Stationery Office, 1959).

13. Libby, D.J. et al The Tara Mines Story. In Transactions of the Institution of Mining & Metallurgy, Section A: Mining Industry, Volume 94, 1985, 28 - 40.

14. Directive on the quality of fresh waters needing protection or improvement in order to support fish life. Off. J. European Communities, L222, 1978, 1 - 10.

15. Jeffry, D.W. and Maybury, M. Scientific studies of mine waste revegatation. Irish J. Environm.Sci., 1, No.1 1980, 49 - 56.

16. Jeffry, D.W.; Maybury, M and Levinge, D. Ecological approach to mining waste revegetation. In Minerals and the environment Jones, M.J. Ed. (London: IMM, 1975), 371 - 85.

17. Dallas, W.G. Experiences of environmental impact assessment procedures in Ireland. In Planning and ecology Roberts, R.D. and Roberts, T.M. Eds. (London: Chapman and Hall), 1984, 389 - 95.

18. Fuller, G.I. The Environmental Assessment Directive, proposals for Implementation, paper presented to conference on The E.E.G. Environmental Assessment Directive: Towards Implementation. CEMP, Dept. of Geography, University of Aberdeen, 1986.

19. A survey of attitudes and opinions towards mining activities in the Navan area. Irish Marketing Surveys Limited unpublished report, 1974.

GROUNDWATER ASPECTS OF ENVIRONMENTAL IMPACT ASSESSMENTS

BY

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S U M M A R Y

Eolas (formerly IIRS) has carried out numerous environmental assessments in the past of major industrial projects in which groundwater proved to be an important factor. A number of examples of these are provided which highlight the importance of including groundwater in the Environmental Impact Assessment process.

The experience to date suggests that prior to commencing the E.I.A. careful consideration should be given to all potential grounwater aspects of a proposed project. Where groundwater proves to be relevant the E.I.A. should include an examination of existing and potential groundwater uses, existing groundwater quality and include a recommendation for groundwater quality monitoring. The depth of these investigations will be dependant on the scale of the potential grounwater pollution risks and the consequences of such pollution should it arise.

GROUNDWATER ASPECTS OF ENVIRONMENTAL IMPACT ASSESSMENTS

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Before proceeding with an E.I.A. it is normal practice to carry out a "scoping exercise" to determine the extent and form the assessment is to take. This is the most critical phase of any E.I.A. Close examination of each potential environmental aspect of a project must be undertaken before any aspect is included or more importantly excluded from the E.I.A. During this scoping exercise it is useful to start with a checklist within which will be a number of subheadings.

For the purpose of this paper those subheadings likely to impact on groundwater only need be considered. These are outlined in Table 1.

Table 1

Possible Groundwater Aspects of an E.I.A.

Groundwater Abstraction	- existing quality/quantity - other users - future users
Effluent Disposal	- spray irrigation - percolation/soakaway
Waste Disposal	- landfill leachate - landspreading - transport
Chemical Storage	- tank bunding - distribution pipework - transport
Mine Development	- minewater disposal
Other Considerations	- groundwater depletion - lowering of watertable

As can be seen this list includes those operations leading to indirect discharges to groundwater as well as the more obvious direct discharges. This results from the need for an E.I.A. to take account of other existing environmental Directives, in this case the relevant Directive being the "Directive on the protection of groundwater against pollution caused by certain dangerous substances" - (80/68/EEC). This Directive includes "indirect discharges" meaning " any action likely to result in the introduction into groundwater of substances within Lists I and II after passage through the ground or subsoil".

Typical examples of indirect discharges would be accidental spillage and landspreading of effluents or wastes. When considering a project it is important to recognise that such indirect discharge may impact at a location remote from the project location, as for example is frequently the case in landspreading of wastes.

In Ireland direct discharges to groundwater consist of industrial effluent disposal to percolation areas which, by implication, only handle very minor volumes and to our knowledge are confined to less than a dozen companies nationally. As such direct discharges are of less importance and are normally discouraged except for the simplest of effluents.

Eolas has carried out numerous environmental assessments in the past where some of the groundwater factors listed in Table 1 proved important. A number of examples are provided below with the intention of highlighting the need for the adequate E.I.A. scoping previously referred to.

Landspreading of Effluent and Wastes:

In order to protect surface waters from pollution increasing numbers of industries are rightly expected to carry out effluent treatment. This has knock on implications for groundwater quality protection.

A wide range of industry sectors give rise to effluent of which some 72% are organic in nature. These organic wastes are normally treated in biological plants such as high rate biofilters and activated sludge. A small fraction, less than 6% are treated by spray irrigation.

These biological treatment plant processes give rise to excess sludges with about a 2% solids content, which in some cases, will be mechanically dewatered to about 14% solids to facilitate disposal. The quantitites of biological sludges arising nationally for disposal are given in Table 2 below:

Table 2

Quantities of Biological Sludges Arising for Disposal

from each Industry Sector

	Tonnes of Solids arising per day	Vol. range m^3/day	
		2% solids	14% solids
Dairy	36.5	1822	260
Meat	8.8	440	63
Brewing/Distilling	5	250	36
Pharm/Fine Chem.	10.5	520	74
Textiles	1.5	70	10
Miscellaneous	7.2	360	51

Source: Wastewater Survey, D. Kelly, E. McMahon, 1984.

Disposal, with the exception of minor quantities going to landfill, is normally achieved by landspreading. Farmland is generally suitable for accepting these sludges which are organic in nature and when applied under controlled conditions can contribute, by virture of their nutrient content, to soil fertility.

Landspreading must be carried out in a manner that avoids runoff to surface waters, consequently the intention is to have the material biodegrade within the soil while it percolates downwards until meeting the water table. A combination of degredation, adsorption and nutrient uptake by plant growth ideally results in the liquid fraction being eventually virtually free of pollutants. Whereas disposal to land will prove satisfactory in the majority of cases it will be clear tha given the magnitude of the tonnages arising per day there is considerable potential for groundwater pollution occurring. This pollution potential will be greatest under the following conditions:

(i) Where unsuitable soil/geological conditions exist

(ii) Where volumes are high due to the absence of sludge dewatering.

(iii) Where application is outside the growing season.

The latter is particularly likely to occur in the case of the meat industry where peak loads arise in the wet winter months. The consequences of such pollution will be dependant on the existing, or future potential uses of the groundwater in question. An adequately designed E.I.A. must therefore address these issues.

Eolas has been involved in investigating a number of cases of groundwater pollution arising from waste disposal. In one such case a major food processor which disposes of excess biological sludges to land developed groundwater quality problems.

The landspreading site owned by the company, overlies the aquifer from which the plant abstracts much of its process water. Process water quality problems within the plant led to an extensive investigation of the aquifer by consultant hydrogeologist, K. T.Cullen, Eolas and others including the Geological Survey of Ireland. The investigation confirmed that groundwater contamination was attributable to the waste disposal practice as carried out at the time. The contamination consisted of raised Kjeldahal nitrogen, nitrate and ammonium levels exceeding at some locations, the permissible EEC limits for water intended for human consumption. The study also determined that the degree of contamination had been considerably limited by the disposal site being underlain by an impervious glacial till which partially isolated the aquifer from infiltrating pollutants. The degree of contamination resulting therefore was not sufficient to warrant the landspreading to be discontinued but did require a significant modification of the disposal practice in terms of application rates, avoidance of spreading at specific locations and other measures.

Two important points emerge from the above experience. Firstly, the pollution was only detected through process water problems rather than pollution monitoring as should be the case and secondly the impact of waste disposal was limited by favourable geological conditions rather than more closely controlled landspreading practice from the start.

In many other cases the disposal of wastes, from whatever industry sector, can be expected to be at lands remote from and probably outside the ownership of the company generating the waste. Furthermore, the site is liable to change with time as different disposal contractors, often farmers, are used.

The meat processing industry also generates significant quantities of biological sludges (Table 2 previous) including paunch, lairage and blood. Blood having a BOD of some 150,000mg/l has considerable pollution potential. The quantities of blood arising for disposal annually in Ireland are given in Table 3 below.

Table 3:

Quantities of blood generated and arising for disposal

(Based on animal slaughtering C.S.O. 1983)

Animal	m^3/year generated	m^3/year for disposal
Cattle	21,152	15,864
Sheep	2,858	2,144
Pigs	7,268	5,451
Total	31,278m^3/yr	23,459m^3/yr

A study by the British Food Research Association in 1982 showed that in Ireland some 75% of blood arises as a waste for disposal rather than used for byproduct production as in other countries. Disposal as a waste is occasionally by landfill but more typically by landspreading. The latter means of disposal is often unsatisfactory due to blood's high potential to cause surface water pollution and to create significant odour nuisance. To overcome these problems disposal by subsoil injection is a recent trend in Ireland with as yet unquantified implications for groundwater quality. Future meat plants proposing such a blood disposal route will require a close evaluation of its pollution potential.

Chemical Storage:

Many major industrial plants will have a need to store bulk liquid raw materials. These include fuel oils, concentrate acid/caustic solutions, organic solvents complex process chemicals and wastes. The storage of these materials has implications for groundwater quality protection.

Adequate bunding of storage tanks to contain any accidental spillage will usually be sufficient to cater for fuel oils and bulk concentrate acid/caustic solutions as would be associated for example with the dairy industry. Bunding i.e. the surrounding of the storage tanks with an impervious base and wall to contain accidental spillages is a normal requirement. Typically it should be in accordance with the U.S. Code of Practice for Storage of Flammable Liquids (National Fire Protection Association NFPA 3Ø). The bunding of the tanker offloading area may often also be necessary.

It is the more complex materials such as organic solvents frequently associated with for example the manufacture of pharmaceutical, fine chemicals and micro electronics that pose the greatest potential for groundwater contamination through spillage or leakage.

Leakages of bulk process liquids to groundwaters have been recorded overseas, in some cases with significant consequences for human health. One such incident occurred in California's Silicon Valley where 25Øm^3 of trichloroethane and dichloroethylene seeped undetected from a storage tank into the groundwater from a semiconductor manufacturing plant (allegedly Fairchild Camera and Instrument Corportion). The groundwater was a drinking water source for the local population and it was alleged that the groundwater contamination had caused a significant number of serious birth defects and other major health effects. Subsequent monitoring within the Silicon Valley area showed that at least 136 chemical storage leakage incidents had occurred from plants in recent years. Up to 1985 some $70m had to be spent in corrective measures.

In 1985 Advanced Micro Devices (AMD) proposed to set up a plant in Greystones, Co. Wicklow, for the manufacture of integrated circuits. Market conditions have since resulted in the indefinite shelving of this project. At the time Eolas was requested to carry out an E.I.A. of the project, and being aware of the associated risks of bulk storage, critically examined that aspect. Visits to the U.S. plant identified that the company had encountered some groundwater contamination problems in the past. Here waste solvents leaking from a corroded underground tank had gone undetected leading to objectionable levels of organic solvents in the soil and groundwater in the immediate vicinity of the plant. As groundwater was not used in the area no public health problems arose, nonetheless the company removed the contamination by installing a groundwater abstraction, treatment and return system. The principal reason for the leakage going undetected for some time was the local requirement for such storage tanks to be located underground and backfilled. This requirement, since abolished, prevented routine external tank inspection taking place.

To prevent any such occurance in Ireland the assessment identified the bulk chemical storage requirements, the potential sources of leaks, the uses of groundwater in the area and the spill prevention/leak detection measures proposed.

The principal materials to be stored were as follows:-

Organic Solvents	Inorganic Liquids
Acetone	Sulphuric Acid
Isopropanol	Phosphoric Acid
Xylene	Hydrofluoric Acid
n-Butyl Acetate	Hydrogen Peroxide

In addition to bulk storage other potential sources of leakage were identified as being, the interconnecting pipework within the plant carrying process chemicals, and pipework carrying effluent to the inhouse treatment plant.

The bulk liquid storage was to be in free standing tanks located below ground in leakproof bunkers. Interconnecting pipework was to be laid in leakproof concrete channels fitted with removable covers. Where not laid in channels pipework was to be routed through a leakproof basement area at ceiling level. These precautions when coupled with a proposed inspection routine would ensure that any leakage would be readily detected and allow for complete repair and spill recovery. These precautions were unusually extreme particularly since public water supply is provided solely by surface water sources remote from the factory.

Such spill detection/prevention measures would be outside the cost limitations for most developments. More typically containment is confined to bunding alone. In such cases where significant quantities of complex or dangerous liquids are to be stored a useful and comparatively low cost addition would be a groundwater monitoring programme.

At least one major company operating in Ireland is presently undertaking such a programme. Here monitoring of surface waters within the site showed minor levels of contamination consistent with the process chemicals being used. As no direct discharge to surface water takes place the contamination can only have arisen from leakage. Although groundwater is not a source of drinking water in the area the company are presently undertaking a groundwater quality survey to determine whether or not contamination has occurred. It is also the company's intention to continue the monitoring even in the absence of contamination, as is expected to be the case.

Mine Development:

The examples provided so far all relate to potential impacts in terms of contamination of groundwater. Under some specific circumstance however it is the groundwater itself that is the potential pollutant.

In 1985 Gypsum Industries Ltd of Kingscourt, Co. Cavan, proposed to develop a major opencast gypsum mine in the area. Eolas was commissioned by the company to assess the environmental implications of the development in response to a planning appeal.

As the opencast mine would penetrate below the water table significant quantities, up to 6,340m^3/day, of water would infiltrate into the mine and would require disposal to surface waters, namely to the upper Lagan/Glyde catchment. This minewater would be unavoidably contaminated by salt from the gypsum orebody through which it flowed. Analysis of similar groundwaters gave the expected levels of contamination (Table 4 below).

Table 4

Expected Composition of Quarry Wastewater

Conductivity	2500us/cm
pH	7.6
Sulphate (SO_4)	1800mg/l
Total Dissolved Solids	2524mg/l
Total Hardness	1652mg/l
Total Alkalinity	110mg/l
Chloride	64mg/l
Calcium	1346mg/l
Sodium	70mg/l
Potassium	6.4mg/l
Phosphorus $(PO)_4$	<0.05mg/l
Chromium	<0.1mg/l
Copper	<0.1mg/l
Lead	0.1mg/l
Zinc	0.3mg/l

< Means below limit of detection.

The principal and limiting characteristic in terms of safe disposal is the sulphate levels at 1,800mg/l. As there is no relaible cost effective treatment process for the removal of sulphate from high volume effluents it was apparent that receiving water quality standards would have to be met by dilution within the river system.

The feasibility of such a minewater discharge was assessed by identifying all the surface water uses in the downstream area and the necessary water quality standards required to protect those uses. Flow studies of the catchment showed that by balancing the discharge in lagoons and coupling the discharge pump with a flow monitor in the river it would be possible to guarantee the necessary level of dilution at all times.

Other Considerations:

Many major industries obtain their process water from groundwater sources. As industry can provide its own water at a lesser cost most large water users prefer this option. Of the total industrial demand, estimated in 1984 to be 242,000m^3/d, some 77% is obtained from private sources. At least 60% of the privately abstracted volume is taken from groundwater for reasons of cost and quality. Implied in any such individual major abstraction is the question of depletion of the resource in terms of other uses or more remotely the possibility of drawdown of the water table structurally effecting neighbouring buildings.

Such a case arose during the early 1980's when a major pharmaceutical plant at Innishannon, Co. Cork, was being expanded under the new ownership of the Shering Plough Corporation. At that time it was alleged by a nearby resident that the existing levels of abstraction had led to drawdown of the water table resulting in structural damage to the house. In response to this contention the company commissioned a consultant hydrogeologist working in association with Eolas to determine the behaviour of the aquifer during abbstraction.

The investigation involved pumping for an extended period at the proposed development rate of up to 1,632m^3/day. The drawdown rate at outlying areas was measured as 0.1m which coupled with the now known recharge characteristics of the aquifer was deemed not to pose a threat to buildings. Predictive computer modelling also showed that even under futher pumping rates of 4896m^3/day no adversè impact would occur.

A similar case is pending in Surrey, England, where Laporte Earths Ltd. propose to extract up to 175,000 tonnes/year of fullers earth. The contention of the local community is that this will lower water table levels thereby threatening a twelfth centuary church and the local tourist attraction, one of the four oldest yew trees in Britain.

Such objections can be regarded as extremely rare and would not normally require consideration. As was shown in the former case, at Innishannon, these fears were totally unfounded. Nonetheless both cases demonstrate the importance of anticipating local objections and if necessary discounting them in the E.I.A. rather than at a later planning appeal.

Conclusion:

The E.I.A. Directive will afford an opportunity to identify and address groundwater related aspects of future major developments. Whereas such future developments are less likely in the dairy industry the ongoing rationalization and hoped for expansion of the pig processing industry, and of the meat industry generally, will give rise to wastes with similar groundwater pollution potential. A necessary requirement for an E.I.A. for such developments is for the proposed disposal site, irrespective of location, to be assessed as regards groundwater pollution risks.

The examples given also show that bulk chemical storage, associated with a wide range of industry sectors, can lead to groundwater contamination. Where the contaminated groundwater is used for drinking water supply or food processing the potential consequences for public health are considerable.

In the case of major projects the E.I.A. should ideally establish:-

(i) Baseline groundwater quality

(ii) Groundwater uses and potential uses in the locality.

(iii) A groundwater monitoring programme.

(iv) The consequences in the event of contamiantion occurring.

The depth of investigation of each of the above factors will be dependant on the quantities/types of wastes arising for disposal and on the quantities/types of liquid chemicals stored, compared to the value of the groundwater at risk.

Other issues that may occasionally arise will be groundwater disposal from mine development where it is the groundwater itself that is the potential pollutant. Other examples, such as the unfounded fear of water table drawdown affecting buildings, highlights the need for the E.I.A. to anticipate, as far as possible, even remote issues rather than have them arise at a later planning appeal.

HYDROLOGY AND ENVIRONMENTAL IMPACT ASSESSMENT OF A PROPOSED LARGE OPENCAST MINE AT BALLYMONEY, NORTHERN IRELAND

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Abstract

Several tertiary basins containing economic reserves of lignite have been identified in Northern Ireland. The main potential user is the electricity power industry, and plans for the development of lignite are tied to the construction of a lignite power station. One of these deposits is at Ballymoney in County Antrim, where the feasibility of mining has been examined in detail by Meekatharra (NI) Ltd, a subsidiary of Meekatharra Minerals Ltd of Australia.

This paper deals briefly with the hydrogeology of the deposit and its interaction with the environmental impact of the proposals. Also touched on are wider hydrological issues. These include the diversion of surface water and the final restoration.

Introduction

Several tertiary basins have been discovered in Northern Ireland which contain economic reserves of lignite. In this context, economic is taken to mean of sufficient size to support a mine mouth purpose built power station. The argument about the relative cost of lignite or coal generated electricity is complex, topical, and will not be elaborated in this paper.

Ballymoney township in County Antrim (Figure 1) is built on such a basin.

The mineral exploration rights at Ballymoney are held by Meekatharra Minerals Ltd of Sydney, Australia. After a preliminary drilling programme, Meekatharra commissioned Hydrotechnica Ltd to investigate the hydrological and geotechnical aspects of the project and their effect on mine feasibility. This work was carried out between July and November 1987.

Geology

The solid geology is indicated on Figure 2, with the geological succession as set out in Table 1.

The basin has an axis running broadly SW - NE, with a nearly complete cover of glacial deposits. The latter vary in thickness from less than 10 metres to the south of the Tow Valley fault, to more than 50 metres in the pit area.

Hydrogeology

Site Investigation

The hydrogeological and geotechnical properties of the deposit were investigated in detail in 39 boreholes out of a total programme of 78 holes.

Permeability measurements were carried out in open hole and in 89 permanent peizometer installations. Pumping tests were conducted in MBA28, MBC35 and MB36. Packer testing of two kinds was deployed: conventional double packer, and rising head tests with a single packer. The latter were conducted over successively larger lengths, starting at the bottom of the hole.

TABLE 1

Geological Succession at Ballymoney

Period	Formation	Thickness at Proposed Pit Metres
Pleistocene	<u>Glacial Drift</u> Boulder Clay: Cobbles and boulders of basalt, fragments of chert, quartz and lignite in a brown sandy clay matrix. Glacial sands and gravels, laminated clays.	26 to 60
Oligocene	<u>Upper Lough Neagh Clay Group</u> Thick lignite horizons interbedded with blue-grey clay, sandy clay and minor ironstone (siderite) bands.	117 to 180
	<u>Lower Lough Neagh Clay Group</u> Green-grey to red-grey clay interbeds of sandy clay, lithomarge conglomerates, minor ironstone (siderite) bands and thin lignite coal seams.	50 to 150
?Eocene/Palaeocene?	<u>Antrim Lava Group</u> Upper Basalts - Olivine Basalt	Base not penetrated
	Interbasaltic beds - bauxite, ferriginous laterite, lithomarge, minor lignite beds and tholeiitic basalt.	
	Lower Basalts - Olivine Basalt	

Groundwater Occurrence

Groundwater occurrence is most easily described against a typical borehole sequence, as given in Figure 3.

The Glacial Drift is mainly boulder clay with subordinate sand and gravel deposits. These gravels appear to occupy channels in the sub-drift topography with their base at about 0 m AOD. Elsewhere the base of the drift is at 10 - 20 m AOD. The range of transmissivities in the basal sands and gravels is 5 to 40 m^2/day; pressures are up to 8 metres artesian.

Clay layers within the Upper Lough Neagh Clay (ULNC) group are of low permeability and not a contributor to groundwater flow.

However, the lignites with the ULNC are water bearing, but at transmissivities which are generally too low to be regarded as aquifers. Nevertheless, the presence of water is extremely important, a point which is explained below.

Transmissivities in the lignite vary with depth. The range of values is given in Table 2.

TABLE 2
Lignite Transmissivities

Seam Name	T m^2/day
Upper	0.003 to 0.48
Antrim	0.016 to 1.2
Bravallen	0.006 to 1.2
Culdoo	0.005 to 0.18

In fact lignite permeabilities are better correlated with depth below base of drift than with the particular seam in which the lignite occurs. Because of the basin structure, the same seam occurs over a wide range of depths.

Lignite piezometric pressures can be illustrated by the recorded values in the Culdoo seam, as shown in Figure 4. Heads are artesian in the centre basin by up to 9 m, and flow appears to be upwards into the river system. However, flows are small, less than 50 m^3/day over the contoured area in Figure 4.

Over the whole basin, the dominant factor in determining heads outside of the drift is the underlying basalt. This is generally of low permeability, but with piezometric pressures which derive from the higher ground S and SE of the Tow Valley fault. Recorded transmissivities in basalt and weathered basalt range from 0.00005 to 5.7 m^2/day.

Mining Proposals

Various potential mining areas were examined. The final proposals are shown in Figure 5.

These are for a single open pit with a maximum depth below ground level of 190 m. The ratio of overburden and interburden to mineable lignite is somewhat under 3:1. This is very low by international standards, but still leads to a pit of significant area.

The pit will be developed over a life of thirty years. Initial out of pit spoil areas will be developed to both the north and south of the mine; after 7 to 8 years operation, overburden will be progressively backfilled into the pit.

Three small rivers require diversion, the Greenshields, Breckagh Burn and Ballymoney River. Floods will be controlled by a balancing reservoir, which will also serve as a sedimentation lagoon for mine wastewater.

Environmental Impact Assessment (EIA)

The full EIA for Ballymoney, which is designed to meet EEC directive 85/338, is not yet complete. However, a comprehensive preliminary assessment was completed by W J Cairns and Partners in November 1987. W J Cairns have responsibility for all of the environmental impact assessment with technical inputs by Hydrotechnica on the hydrological issues.

The main topics to be addressed by the EIA are as follows:

Transport and access
Noise
Atmospheric Emissions
Hydrology and Drainage
Agriculture
Archaeology
Visual Impact
Socio-Economic Assessment
Resettlement

Hydrological impacts are fundamental importance and need to be examined.

Hydrological Impacts

The principal hydrological impacts are set out in Table 3.

TABLE 3
Principal Hydrological Impacts

Impact	Disciplines Required
1. Ground movement	Hydrogeology, geotechnics
2. Ground settlement	Hydrogeology, geotechnics
3. Land drainage	Hydrogeology, agriculture
4. Stream flow	Surface hydrology, hydrochemistry, aquatic biology, stream morphology
5. Terminal Lake	Surface hydrology, hydrogeology, biology, ecology, geotechnics

Ground movement is classified as a possible hydrological impact because water pressures in the lignites and interlayered clays are an important factor in the stability of slopes.

Impacts numbered 4, 5, whilst they have been surveyed for Meekatharra,will not be considered further in this paper.

Groundwater Modelling

The main tool used for assessing hydrogeological impacts was a three-dimensional groundwater model using the USGS three-dimensional finite difference (3DFD) scheme of MacDonald and Harbaugh, known as MOD.

The model was originally established to investigate an area to the south east of the proposed pit, but was subsequently used to assess the impact of dewatering the final pit.

The model grid is shown in Figure 6. The USGS scheme is cellular; there are 864 cells per layer equivalent to 925 nodes in a nodal scheme. Six layers are represented, as shown in Figure 7. Between these are three layers of low conductance, representing interstitial clays. Thus the equivalent 3D nodal number is approximately 8000.

The model does not exactly reproduce the stratigraphy in detail. This is because of the complexity commpared to the density of data. Also, since permeability in the lignite is depth related and not stratigraphically controlled, modelling the stratigraphy is not appropriate.

The model was run on a Dell 286/12 which is an 80286 based microcomputer having a clock speed of 12 MHz. Run time for a time variant solution of thirty years was about 4 hours.

Calibration was in steady state so as to give a reasonable fit to the piezometric heads recorded in the field. Field monitoring and piezometric database systems have been established to gain information on seasonal variations. Thus time variant calibration will be possible in the future.

After calibration, various simulations were made of the effect of dewatering wells and voids. The block centred model is capable of dealing with partly saturated cells, and so intermediate layers may be dewatered.

Nearly 20 simulation runs were conducted. An example is given in Figure 8, which shows the piezometric contours after 15 years of pit development, with pre-pit dewatering.

Impacts Relating to Changes in Groundwater Head

General

Having simulated changes in piezometric pressure in various layers, the possible impacts can be assessed.

Ground Movements

Ground movements related to instability were the subject of complex slope stability studies, the detail of which is outside the scope of this paper. However, it was found that water pressures needed to be controlled in those layers not amenable to conventional dewatering. These included the interlayered clays and the lower, less transmissive lignites.

Drainage schemes were devised based on close centred small diameter holes lined with 75 mm ID plastic screen. Installation would be by an Ardvaark track mounted mobile drill.

The physical configuration of the developing slopes means that these holes have to be installed with a downward inclination, as shown in Figure 9. To achieve adequate depressurisation, some means of evacuating water below the level of the collar is required: two schemes were devised, as illustrated in Figure 10. The first is dewatering under vacuum, the second uses an eductor system and compressed air.

The second scheme is practicable for the lower strata, and has the advantage of dewatering to close to the base of the hole. Because the permeabilities are so low, only infrequent blowing out of accumulated water would be required.

Ground Settlement

Ground settlement follows from the changes in water pressure in the lignites, the interlayered clays and the drift.

The greatest potential settlements are those in the interlayered clays. Calculations based on the consolidation characteristics of these clays and the changes in bounding heads lead to the conclusion that a maximum settlement gradient of 1:1000 will be superimposed on the existing topography.

Because the drift mantle will distribute strains, damage to buildings is very unlikely.

Land Drainage

Water levels in the drift will be lowered. The effect will be more marked in areas of basal sands and gravels, and in an area of sandyclays to the north of the pit.

However, the performance of the superficial soil/water system is dominated by the extensive agricultural drainage, installed at depths of 0.6 to 1.0 m. Given the high rainfall of the area, the additional recharge induced by changes in piezometric level will have very little effect on the top 1 metre of subsoil.

Thus any significant impact on agriculture is not foreseen.

Conclusions

Assessing the impact of large excavations into low and intermediate permeability materials requires the combined skills of the hydrogeologist and the geotechnical engineer.

This has been illustrated with examples from the feasibility study of the Ballymoney Lignite Project, a proposed opencast mine with a life of 30 years.

Thanks are due to Meekatharra Minerals Ltd for permission to publish this paper.

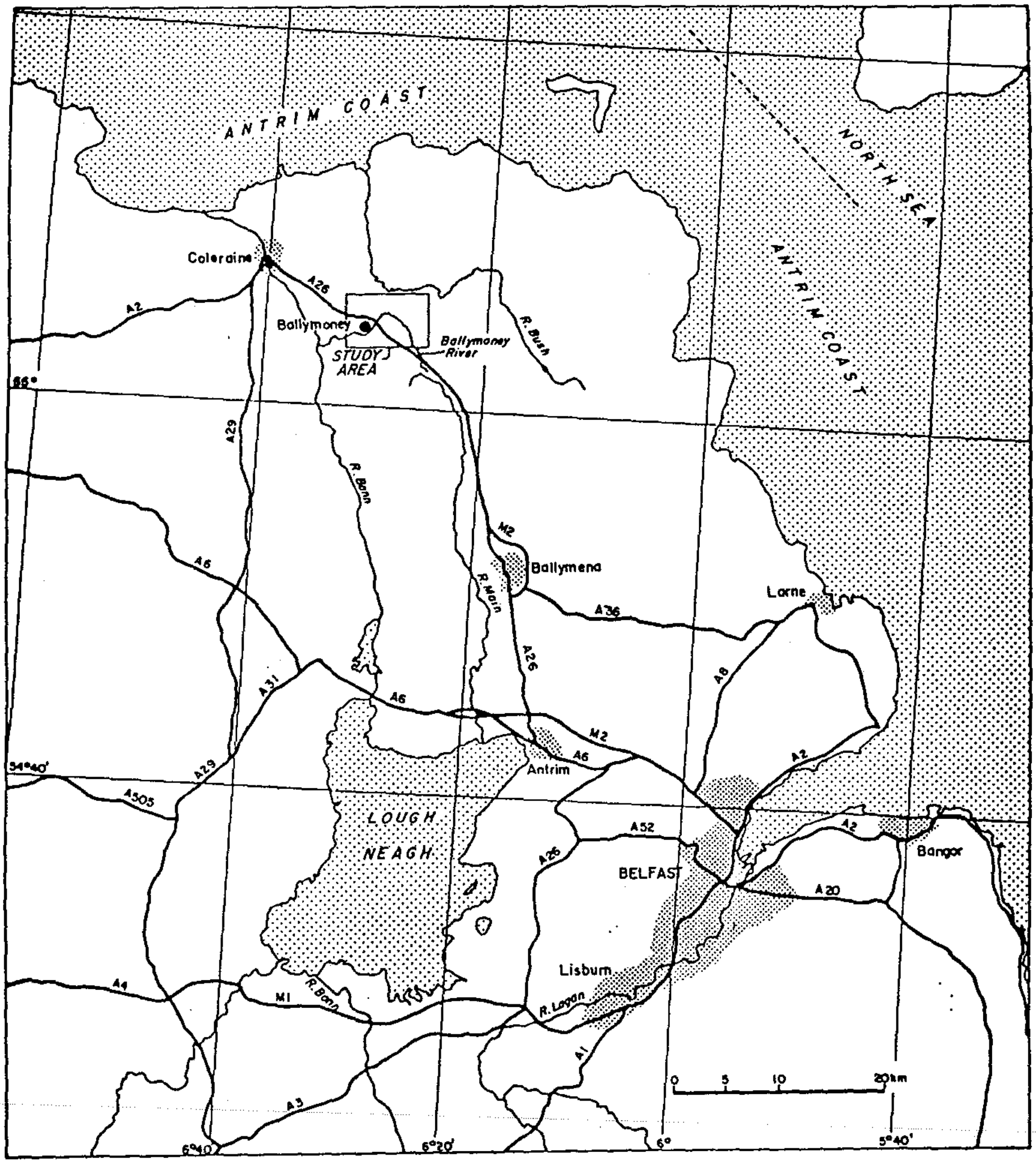


Figure 1 Location Plan

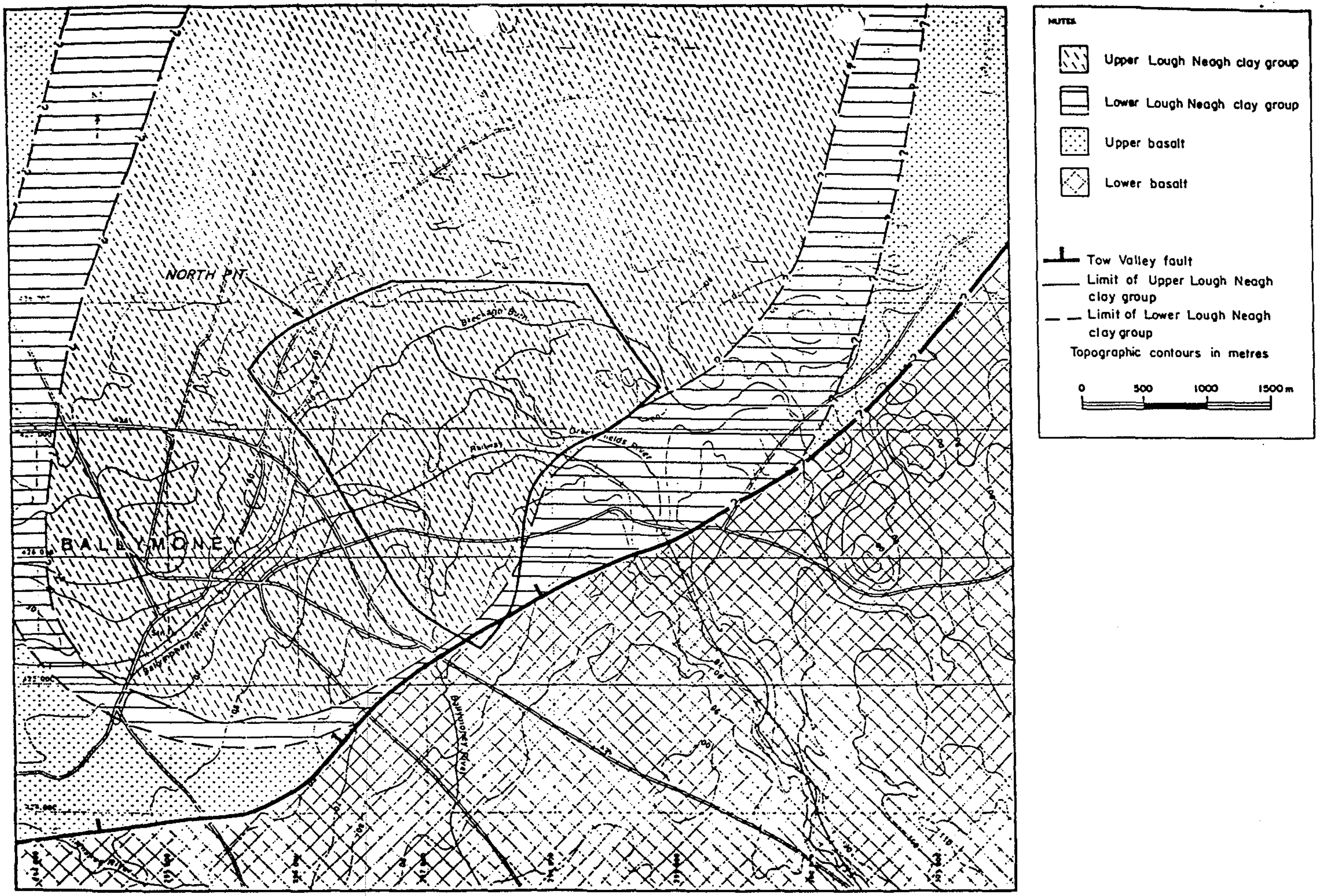


Figure 2 Solid Geology

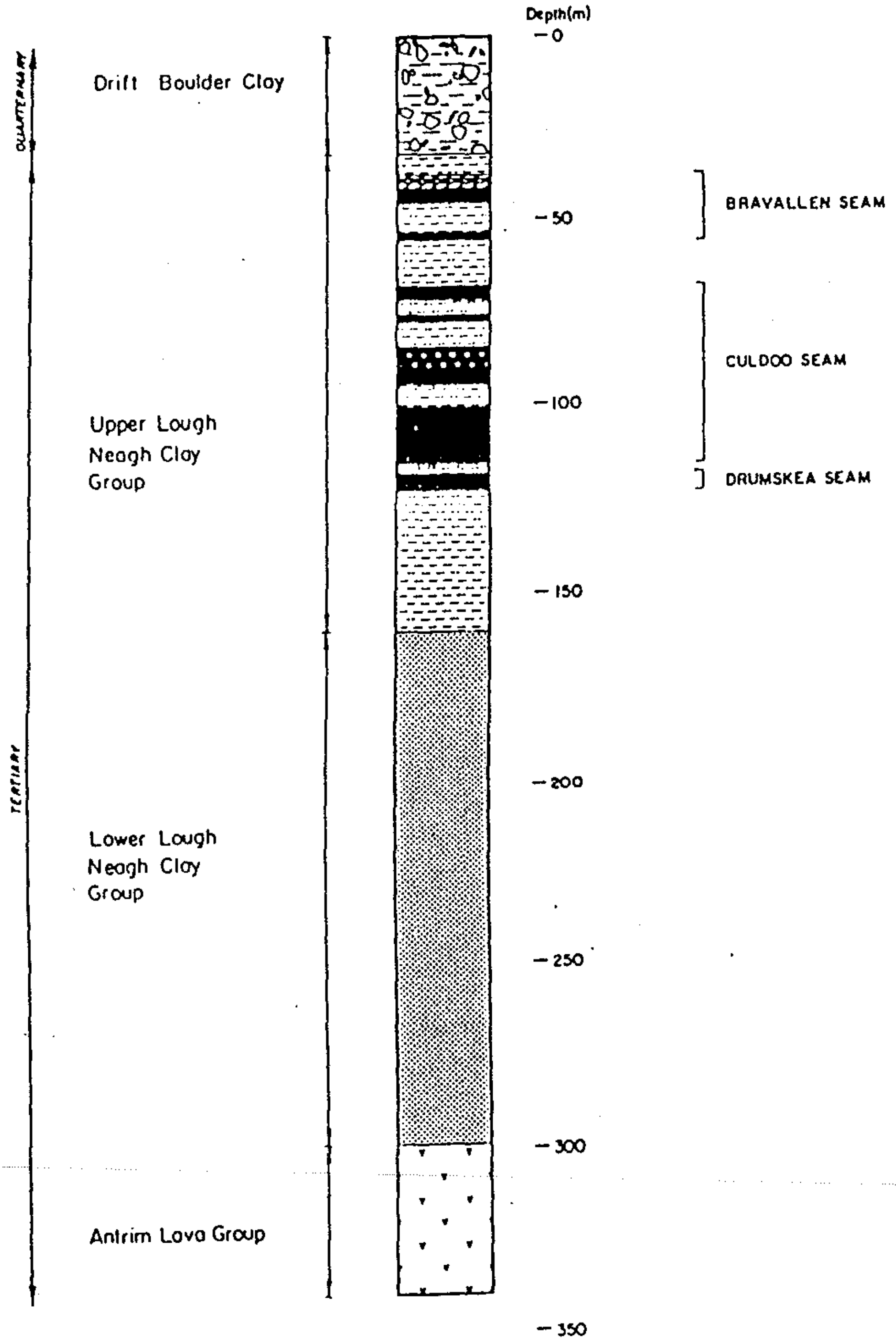
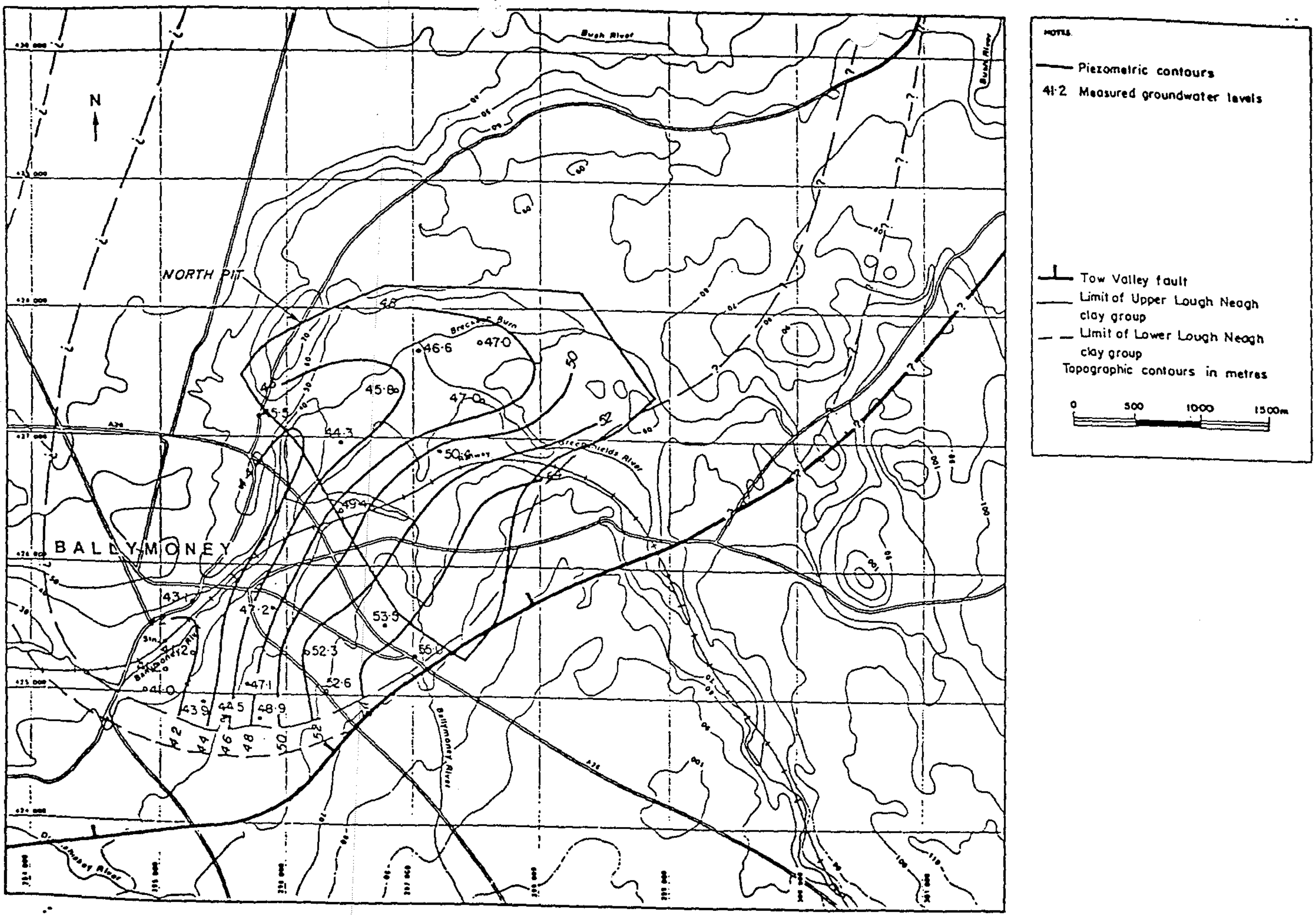


Figure 3 Typical Stratigraphical Sequence



NOTES
Piezometric contours
41·2 Measured groundwater levels
Tow Valley fault
Limit of Upper Lough Neagh clay group
Limit of Lower Lough Neagh clay group
Topographic contours in metres
0
500
1000
1500m
N
NORTH PIT
BALLYMONEY
Bush River
Ballymoney River
A26

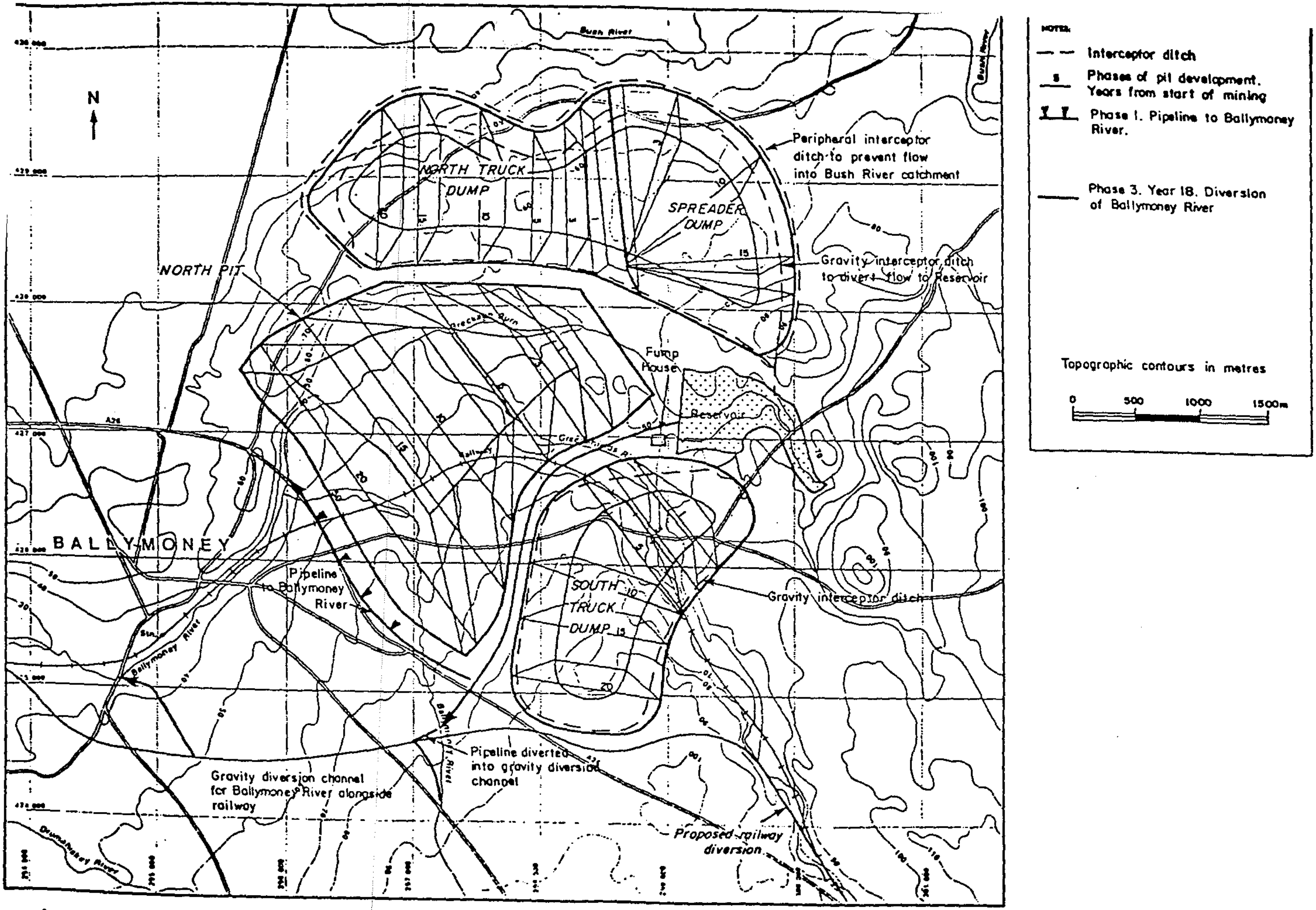


Figure 5 Layout of Mining Proposals

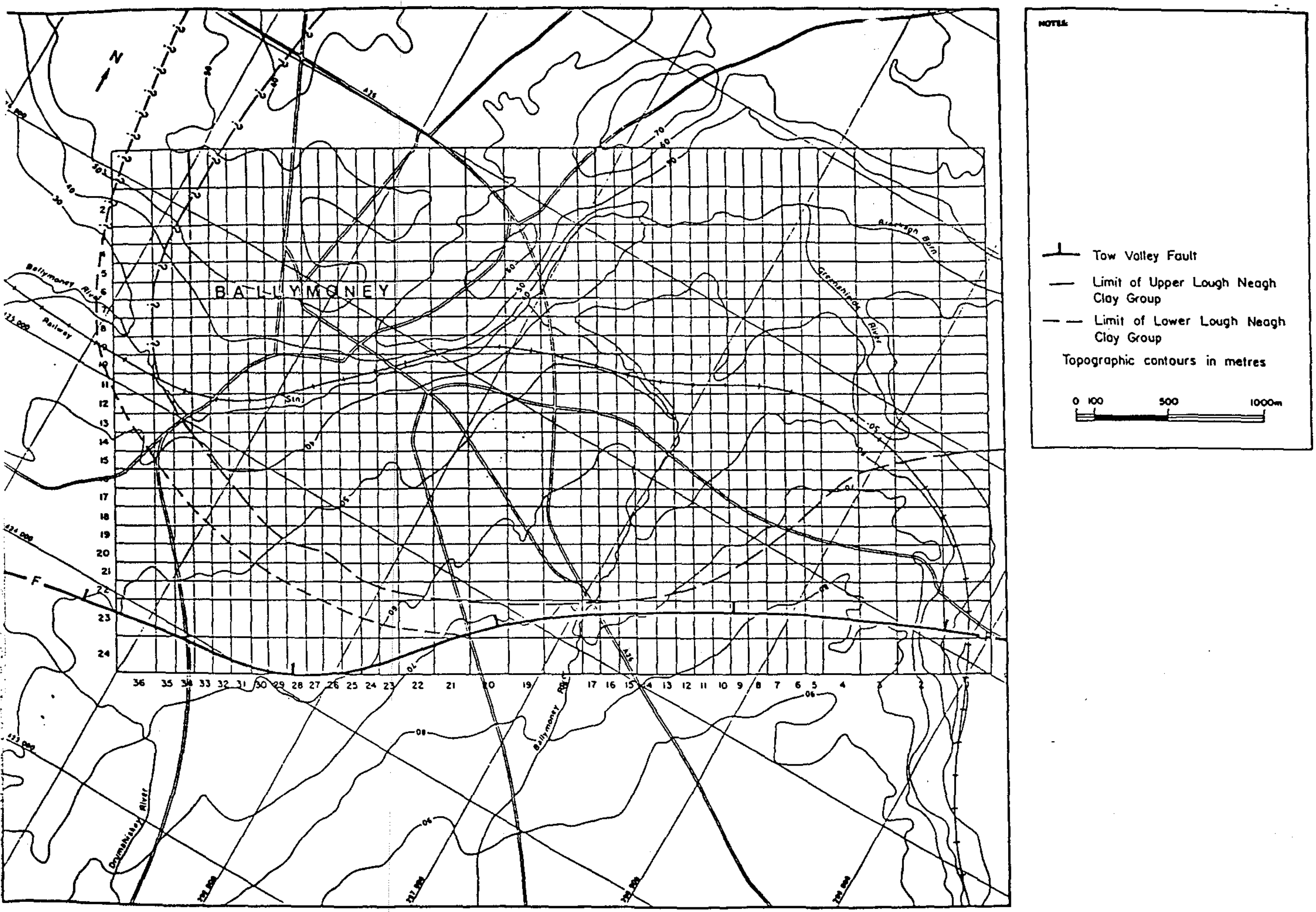


Figure 6 3D Model Grid

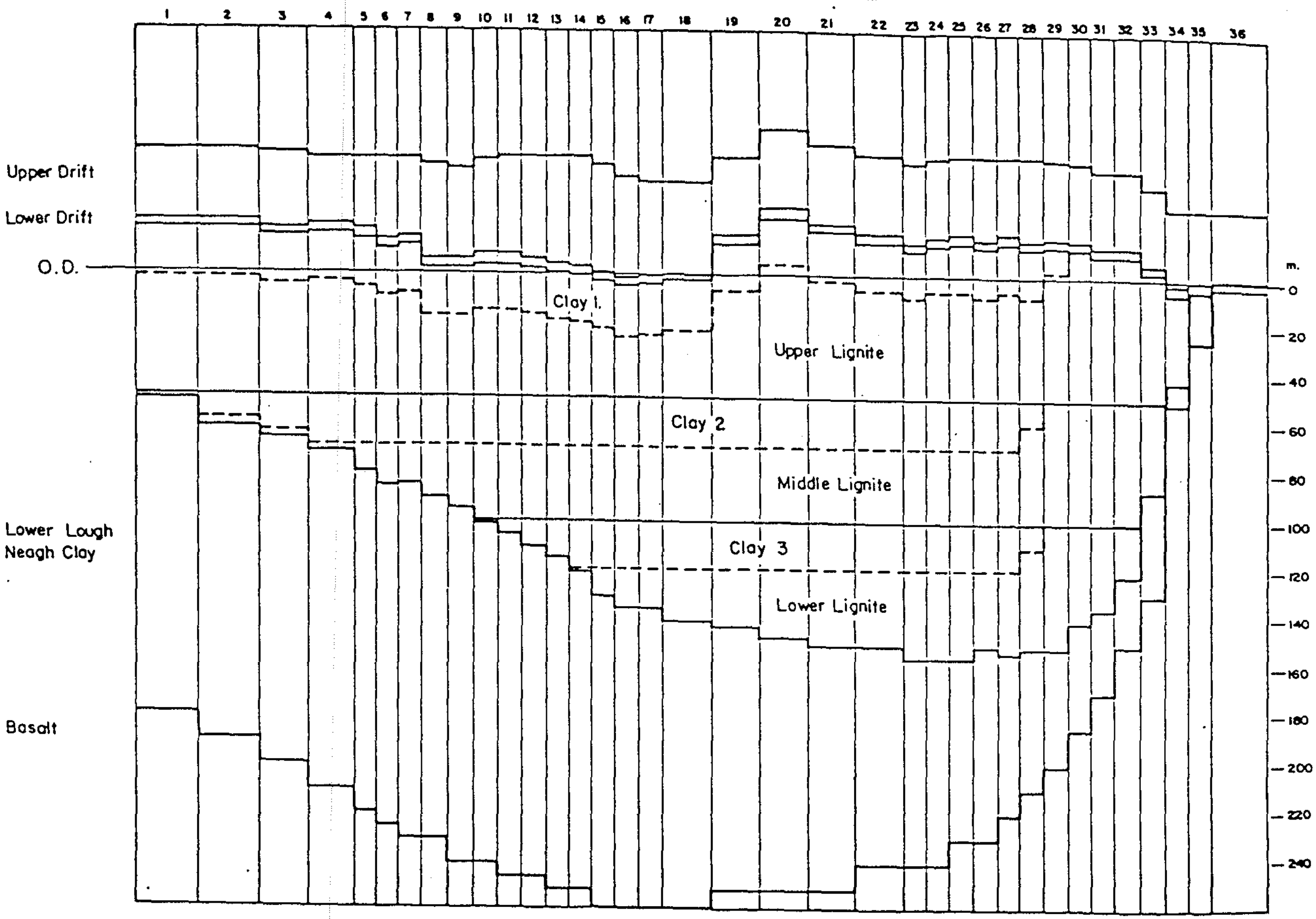


Figure 7 Vertical Slice through Row 16

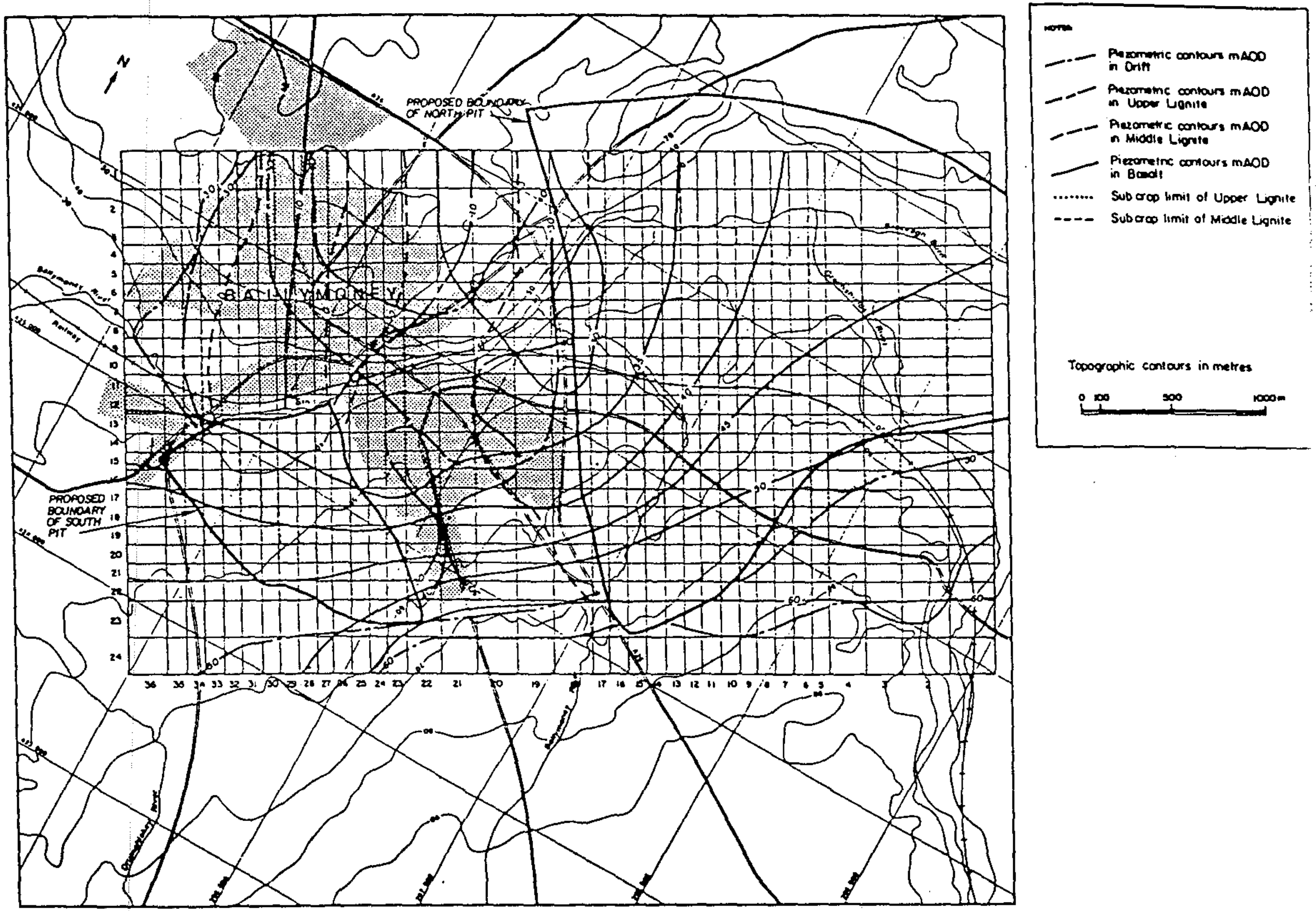


Figure 8 Peizometric Contours after 15 years of Pumping

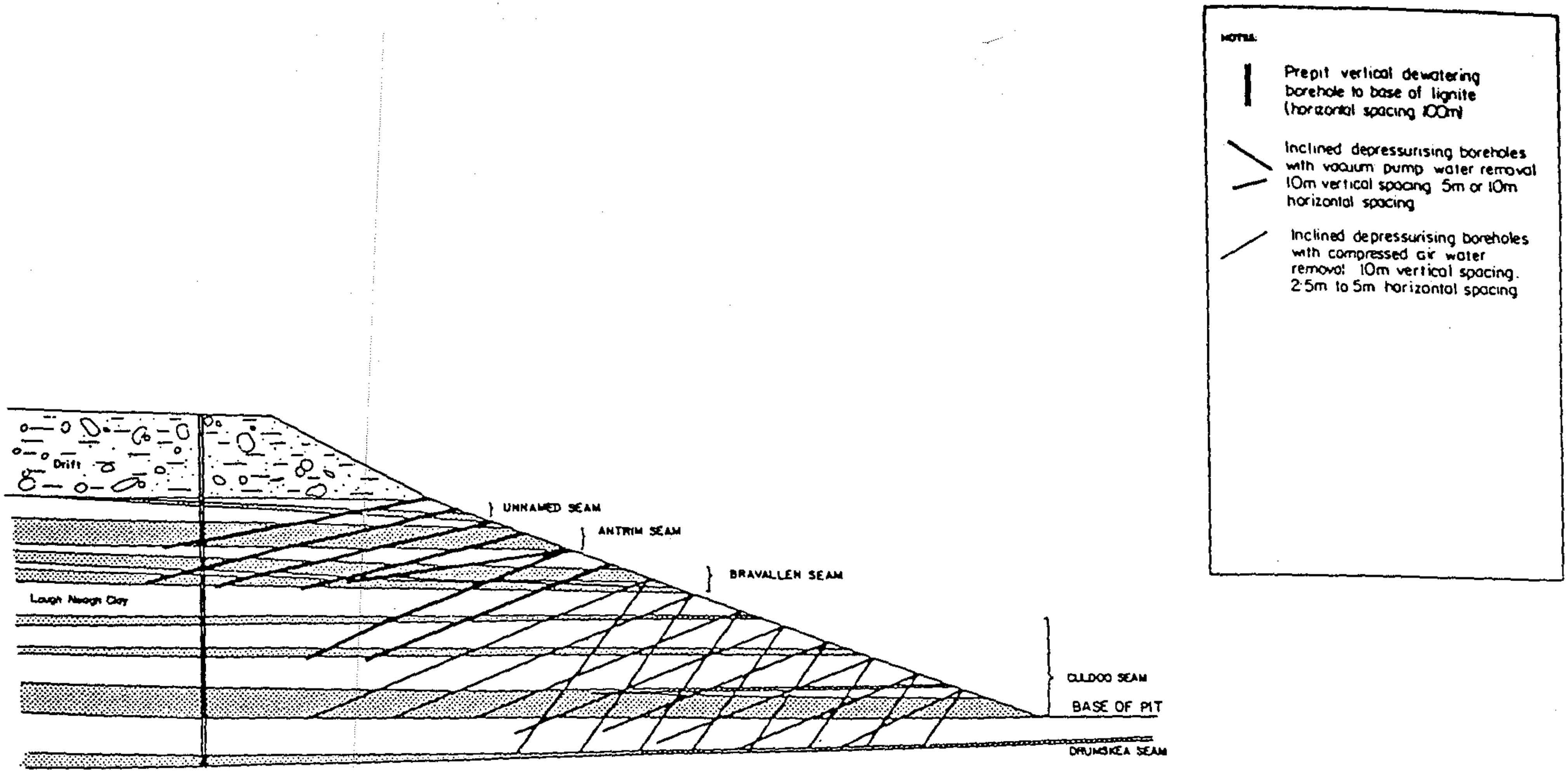
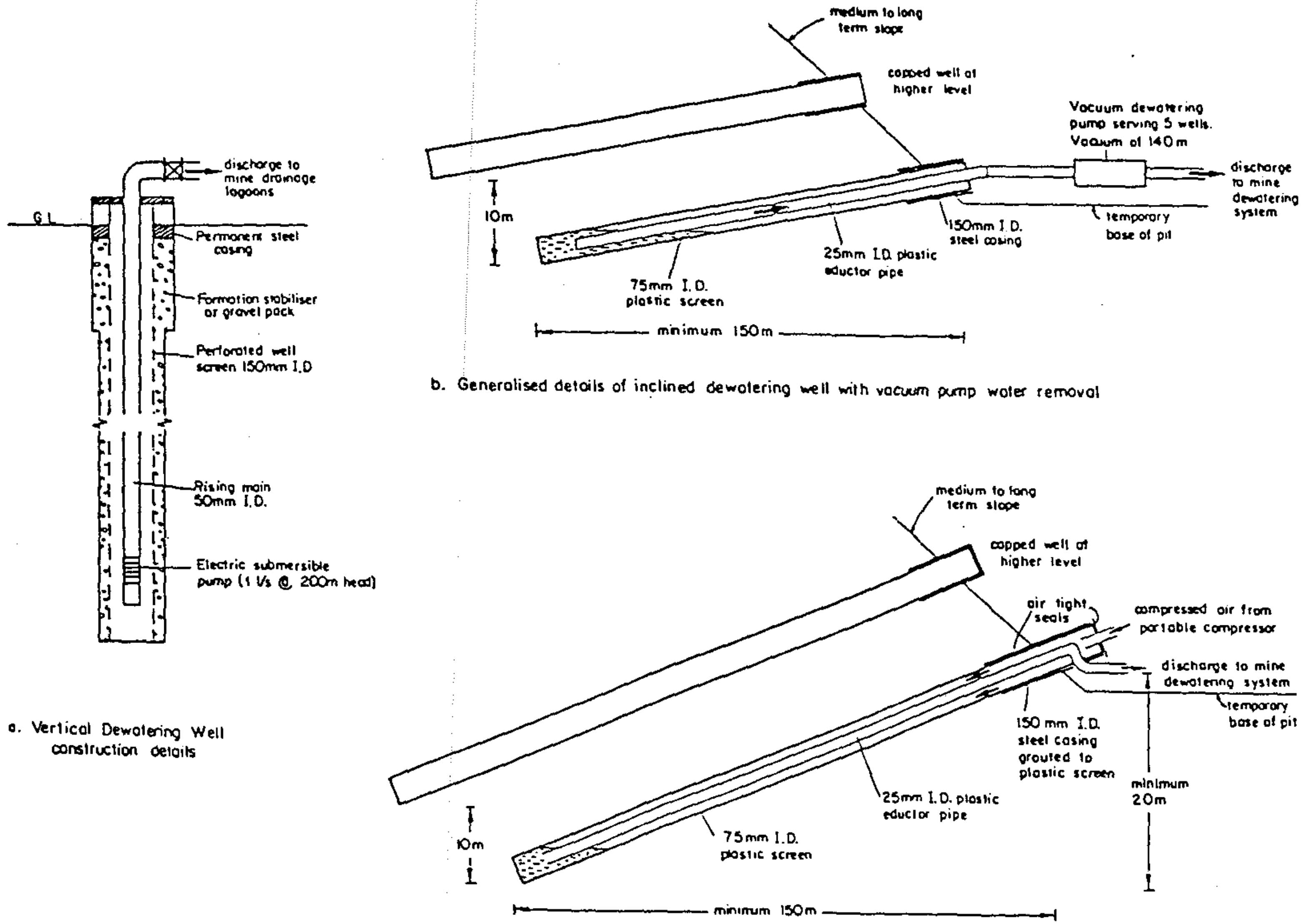


Figure 9 Slope Depressurisation



a. Vertical Dewatering Well construction details

b. Generalised details of inclined dewatering well with vacuum pump water removal

c. Generalised details of inclined depressurising well using compressed air water removal

Figure 10 Generalised Construction of Depressurising Systems