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The organisers wish to thank all the Speakers and their organisations for their presentations, and the Management and Staff of the Killeshin Hotel.

International Association of Hydrogeologists - Irish Group

Groundwater Development in Ireland - 1984

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Mr. K. Spellman	Snr. Executive Engineer Louth County Council
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INTERNATIONAL ASSOCIATION OF HYDROGEOLOGISTS

IRISH GROUP

"GROUNDWATER DEVELOPMENT IN IRELAND - 1984"

(Fourth Seminar on Groundwater Development)

Killeshin Hotel, Portlaoise: 03 and 04 April 1984

SYNOPSIS OF PAPER

GROUNDWATER DEVELOPMENT IN NORTHERN IRELAND

by

Philip G Holland

Dip Grad Studies (Birm)

CEng, FICE, MI Struct E, FIWES

Principal Water Resources Engineer

Department of the Environment for Northern Ireland

The Paper is complementary to the Paper by Mr J R Peter Bennett BSc FGS MIWES entitled "Groundwater Resources of Northern Ireland". Following a brief outline of the structure of The Water Service in Northern Ireland, an outline of the Legislation related to public water supplies is given. There follows a resume of the liaisonal arrangements between The Water Service and The Geological Survey of Northern Ireland and of the measures available for the qualitative protection of public underground water resources. Some information is then given about costs and charges prior to some comments being given about private (including agricultural) water supplies. It is hoped that listeners from the Irish Republic will be prepared to ask questions, and to provide anecdotes, designed to bring out the strengths and weaknesses of the development strategies for groundwaters in both countries. Formal presentation will be kept to a minimum and a typed paper will be available for retention.

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INTERNATIONAL ASSOCIATION
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PAPER NOTES

GROUNDWATER DEVELOPMENT IN NORTHERN IRELAND

by

Philip G Holland
DipGradStudies (Birm) CEng FICE MIStructE FIWES
Principal Water Resources Engineer
Department of the Environment for Northern Ireland

The (NI) Water Service

The Water Service is a component Service of DOE(NI)
It is the sole water and sewerage authority for NI and is responsible for all matters of "clean & dirty" water; except for urban & arterial drainage and for the provision of water recreation facilities, which are Department of Agriculture (Northern Ireland) responsibilities. Sea defences and harbours are responsibilities of The Works Service of DOE(NI).
There are 4 Water (operational) Divisions - at Belfast, Craigavon, Ballymena and ~~London~~Derry - and a Service HQ at Stormont. The Divisions are managed at Sub-Divisional level (broadly 3 Sub-Divisions per Division). Sub-Divisional populations range from 50 000 to 174 000, except for Belfast (405 000). Sub-Divisional land areas range from 300 km² to 2000 km². Total population 1.6 million: total land area 14122 km²

Groundwater Liaison

A Geological Survey of Northern Ireland exists: a component part of the British Geological Survey with special arrangements (explained) with NI

The GSNI is the hydrogeological advisor to DOE(NI)

The main hydrogeological advisory facets are

(a) aquifer exploration and evaluation
(b) performance monitoring
(c) refuse tip assessment

There are no advisory demarcations between "in-house" design and development and Consultant-aided projects

In general, a good liaisonal framework but somewhat dependent on good personal relationships

The Water Service operates a Hydrogeological Liaison Committee comprising Divisional and GSNI professional representatives

Qualitative Protection

In practice, weak and a cause for concern amongst "the professionals" in certain instances.

The Legislative power is available but the "operators" of the power do not give the matter a high priority because the risk points are generally isolated and the general pollutional threats in NI are not serious. There are some serious instances, however (explained)

Groundwater Quantities

Public water supplies in NI amount to circa 700 Ml/d to about 96% of the population

Groundwater use amounts to roughly 30 Ml/d (borewells) and 20 Ml/d (wells and springs). The borewell pumping capacity is circa 100 Ml/d (70 Ml/d in 1980: 10 Ml/d in 1969). Individual (Carboniferous) well fields can exceed 3 Ml/d. A stratified (Lagan Valley) Permian/Triassic sandstone complex yields about 10 Ml/d.

Private supplies are generally for non-potable water and usually small one-off developments. The incidence of these is increasing as metered charges rise (see Legislation provision (b))

Philip G Holland

29 March 1984

Personal Notes

GROUNDWATER DEVELOPMENT IN IRELAND - 1984

GROUNDWATER RESOURCES OF NORTHERN IRELAND

by

J R P Bennett

Geological Survey of Northern Ireland (GSNI)

20 College Gardens, Belfast

I DEVELOPED RESOURCES

1.1 The groundwater resources of Northern Ireland have still only been partially assessed, although utilisation of groundwater has increased rapidly during the last twenty years or so. Most of the increase has been for public supply but there has been a sudden upsurge in water well drilling for the private sector within the last two years, in response to escalating charges for mains water.

1.2 Historically thousands of shallow wells and springs provided groundwater supplies to a large proportion of the population, and from about 1875 on private industry began to construct deep bored wells in solid rock aquifers, mainly in the Permo-Triassic sandstones of the Belfast area. Total abstraction from wells up to 200m deep in that area appears to have reached a peak of at least 33 Ml/d in the 1930s. Usage declined again rapidly throughout the province as mains water supplies were extended into rural areas, reaching 88% of the population by 1978 and more than 96% at the present time. Some commercial concerns retained their own wells during the decades of free or cheap water: such abstractions are not licensed so no returns detailing quantities are available but it is estimated that at least 25 Ml/d are pumped for on-site use.

1.3 Natural springs harnessed for public use have contributed some 23 Ml/d of groundwater for many years but there is little potential to increase this significantly, except where it may be feasible to construct bored wells close to springs - this subject is covered in more detail later. Groundwater available for mains supply has been increased by constructing new bored wells, and the results have been substantial:-

Year	Total yield available from bored wells	
	Ml/d	mgd
1964	9	2.0
1977	28	6.2
1980	69	15.3
1984	98	21.6

(Total public supply from all sources about 700 Ml/d.)

It must be stressed that not all the available groundwater yield is utilised as yet since new aquifers and well fields are still in the process of development so not all wells which have been constructed and tested have been linked into the distribution system. Also, in some rural areas relatively high yielding wells can provide more water than is required for local demand at present. For example, in 1979 only 23 Ml/d were actually supplied from wells.

1.4 The total number of abstraction sites for public supply is still only about fifty. Very few new sources capable of yielding less than 1.0 Ml/d are brought into supply now, although in exceptional circumstances sources of down to 0.5 Ml/d may be developed to meet an isolated requirement which cannot be serviced by other means. Locations of wells are shown on Figs 1 and 2.

II EXAMPLES OF GROUNDWATER DEVELOPMENT

(i) Permo-Triassic sandstones, Lagan Valley

2.(i).1 The most extensive hydrogeological investigations and largest development of groundwater have been in the Lagan Valley southwest of Belfast. A major study commenced in 1970, and comprising investigation of existing wells, drilling of observation wells, monitoring of water levels, hydrogeochemical studies, and test production wells led to the conclusion, in 1976, that about 22 Ml/d (5 mgd) would be obtainable from between 10 and 15 bored wells in the area between Lisburn and Belfast. Development of this aquifer area is now almost completed. The yield prediction has turned out to be exact, although there had always been hopes that it could be higher, and will be obtained from 12 sites. However, drilling investigations have been required at double this number of sites before adequate high yielding wells were obtained. This had certainly not been expected and has been due mainly to the presence of Tertiary basalt dykes, which impede groundwater flow, intruded into the sandstones and also to more complex faulting and facies changes than had been anticipated. The area has a thick drift cover so outcrops are almost non-existent so very little detail was known about the geology of the aquifers.

(ii) Augmentation of spring sources by bored wells

2.(ii).1 Springs are, of course, simply natural discharge points for groundwater from aquifers. Most of the larger sources in Northern Ireland are already used for public supply but in common with springs elsewhere they flow most strongly in winter/spring and decline through the summer when demand is greatest, in some years drying up completely. Yet even when the natural spring discharge by gravity flow is very small or absent there may still be a substantial reservoir of groundwater in storage in the aquifer which is not being utilised. Such a situation is shown in Fig 3, portraying a common geological situation where a sand/gravel aquifer sustains a spring discharge by 'overspill' at an alluvial boundary.

2.(ii).2 Bored wells have been constructed at several sites of this type, allowing drawoff by pumping from a lower level to increase the yield. Even if the outcome is only to maintain the yield at the winter/spring level throughout the summer the development may be worthwhile, but experience to date has been that an increased overall yield can usually be obtained. This is partly due to the fact that the bored well when pumped usually captures other minor springs in the vicinity which could not be linked into the existing surface collection system at an economic cost.

(iii) Sand/gravel aquifer at Loughs Fingrean and Carn, Sperrin Mountains

2.(iii).1 This is an example of a fluvioglacial sand/gravel aquifer in an upland area which is being investigated with a view to augmenting the yield from an existing system of lakes and reservoirs which are used to supply the Omagh area. Storage is relatively small and the catchments are very limited since the lakes are close to a major watershed. It was apparent that drift thicknesses could be large and with sand/gravel at the surface there was good expectation of a useful aquifer or aquifers being present. Also, at first sight at least some of the lakes appeared to be perched on peat.

2.(iii).2 Drilling and pumping test investigations were commenced with the primary objectives of:-

(a) confirming the presence of aquifers and

(b) elucidating the hydraulic relationships between the lakes and groundwater.

Boreholes revealed more than 30m of drift deposits, mostly sand and gravel, along the axis of a N-S buried channel. The water table in these deposits is deep, as much as 10m below ground level, and slopes down from south to north indicating natural groundwater flow in that direction. Lough Carn appears to be completely perched on peat, but the situation at Lough Fingrean may be more complex. Monitoring of water levels has shown that the water level in Lough Fingrean is higher than the water table in the sand/gravel for most of the year but the situation is reversed during the summer months when the reservoir is drawn off heavily. When the drilling was carried out it was thought that Lough Fingrean was at least partially perched on peat but when the floor of the reservoir was exposed during the exceptional conditions of summer 1983 it became apparent that the bed extends below the base of the peat. Nonetheless the lake and other small ones around it still appear to be perched, presumably on weathered sand/gravel. During the dry conditions of 1983 useful quantities of water were pumped out of the aquifer, from observation holes lined with PVC pipe with sawn slots, into the reservoir system.

2.(iii).3 The investigations and assessment are far from complete but at this stage are more promising than at the outset. It is expected that comparable conditions exist elsewhere, possibly throughout Ireland, and remain to be developed.

III FUTURE DEVELOPMENTS

3.1 It is difficult to estimate how much more development of groundwater for public supply can be achieved, using relatively conventional approaches. There is certainly potential to develop Carboniferous aquifers in the southwest of the province but investigations in this area have been very scant, largely because of low demand for water and the ready availability of surface water. Geological remapping by GSNI at the 6 inch and 1:10 000 scales has only covered about 60% of the province so far but from past experience it can be expected to identify useful sand/gravel aquifers in the remaining areas, mostly in the west. It is considered that groundwater development is certainly past the 'half way' stage, but how far past remains to be seen.

3.2 Major discoveries are still possible and if an aquifer, most likely a sand or gravel, in hydraulic continuity with either Lough Neagh or the Lower Bann could be identified yields could even be spectacular.

3.3 It is expected that river augmentation using groundwater which has already been implemented on a very modest scale will become increasingly common. Also, when we have had more operational experience of the larger groundwater abstraction schemes artificial recharge of the aquifers in question may become an economic proposition.

FIG. 1 SOLID ROCK AQUIFERS (CHALK OMITTED)

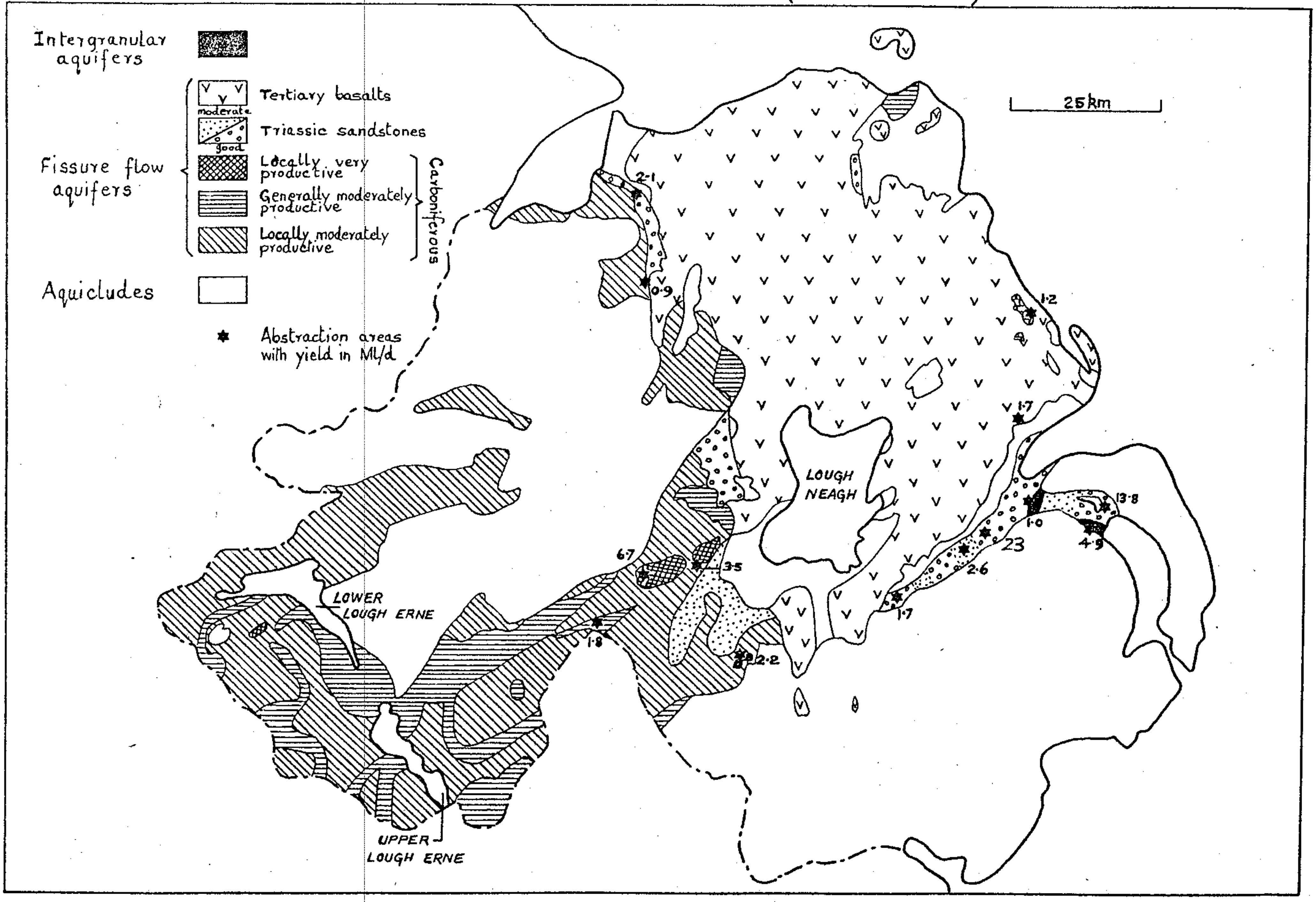


FIG. 2 UNCONSOLIDATED QUATERNARY AQUIFERS

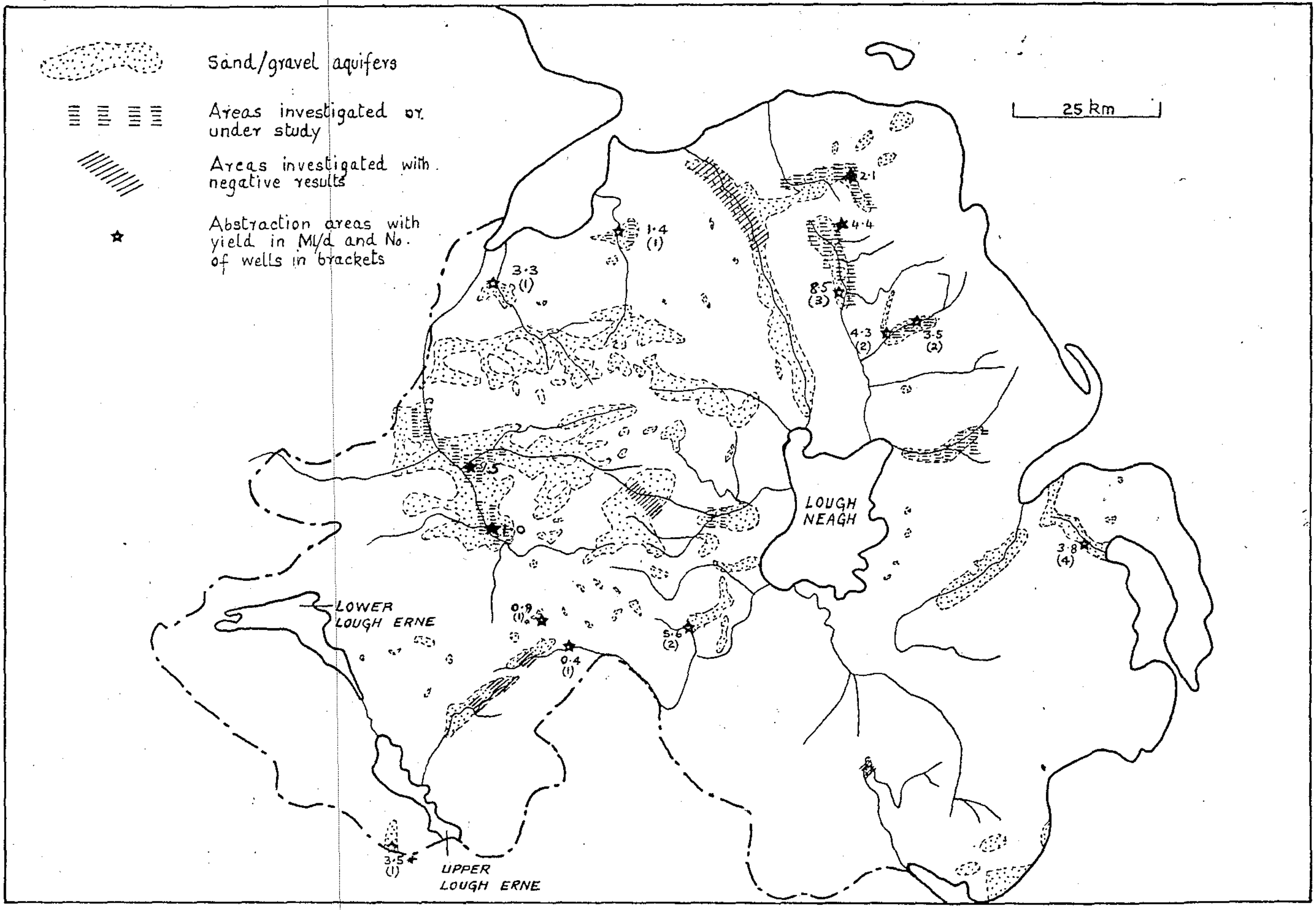
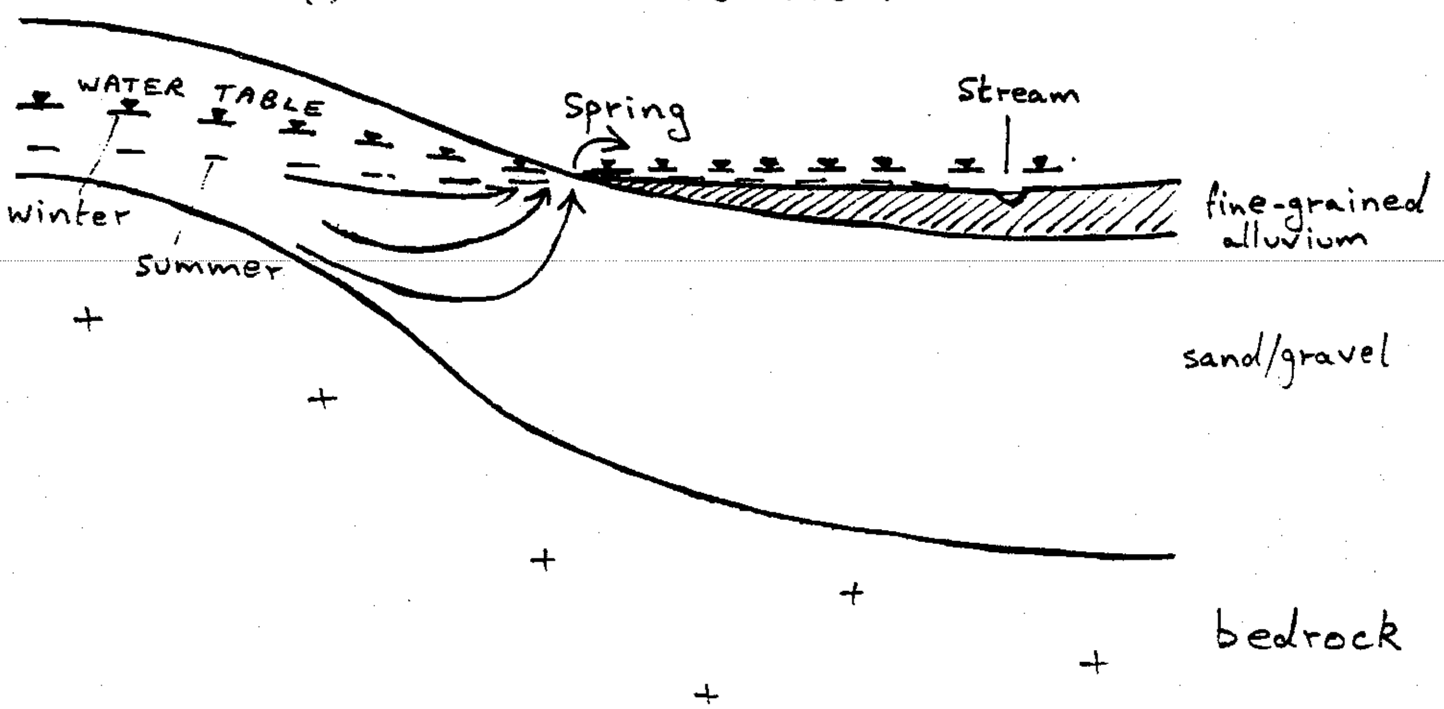
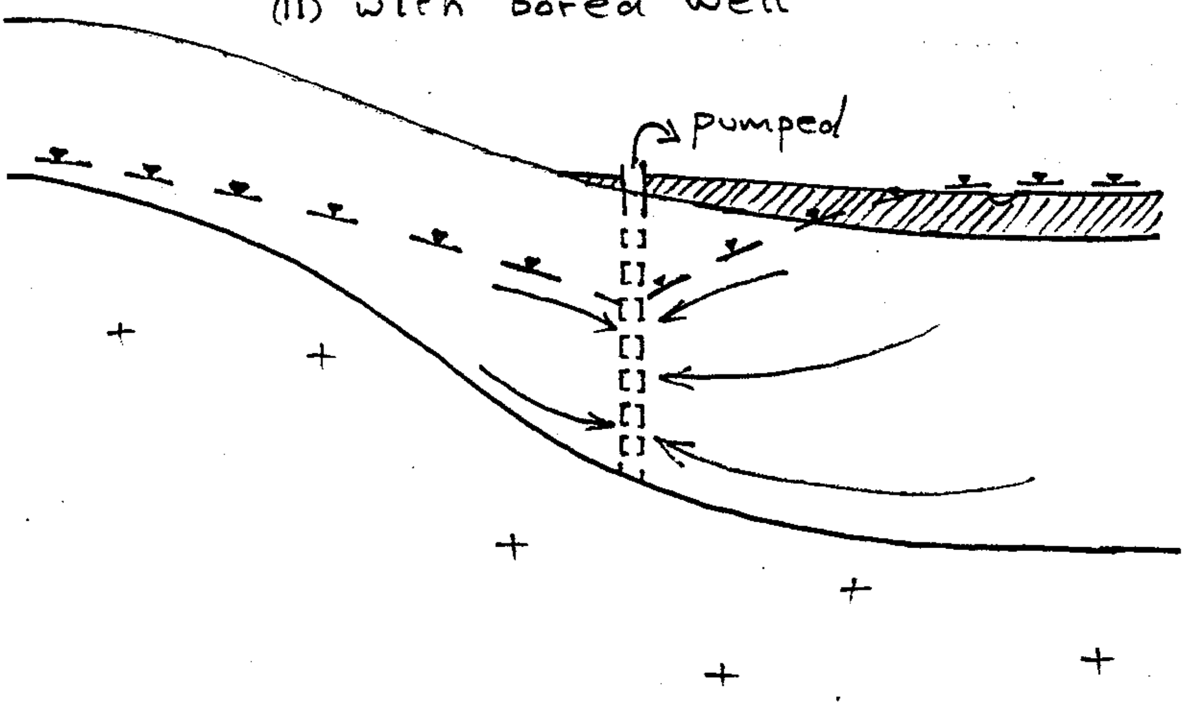


FIG. 3 AUGMENTATION OF SPRING SOURCES

(i) natural situation



(ii) with bored well



A NEW AQUIFER MAP OF IRELAND

G.R. Wright, Geological Survey of Ireland

1. Previous Aquifer Maps

The earliest "aquifer map" of Ireland (as far as I am aware) is one by Morrogh O'Brien (then Director of the Geological Survey), dated 1961 (Fig. 1). In fact, this very generalised map did not claim to be an aquifer map, but was a "groundwater availability map" intended to assist those seeking small supplies of groundwater for farm and domestic use. Nevertheless, it appears to have been the first attempt to represent the hydrogeological characteristics of the rock types on a national scale.

In the early 1970's Bob Aldwell and Eugene Daly made the first serious attempts to compile aquifer maps of the country. Three versions were produced around this time:

(a) A map at a scale of 1:1½ million, for the I.A.H. International Hydrogeological Map of Europe (Fig. 2). The maps (parts of 2 sheets) were compiled around 1972 but were not published until 1976 and 1980, with explanatory memoirs published in 1978/1980. The Northern Ireland portion of this map was compiled by Peter Bennett.

(b) A map at a scale of 1:**2m** for the Royal Irish Academy's Atlas of Ireland. This was essentially the same map as (a).

(c) A map at a scale of 1:2 million; this was a simplified version of (a) and showed rock aquifers only, omitting sands and gravels (Fig. 3). Versions of this map were reproduced in articles in "Mining Ireland" (1975) and "Technology Ireland" (1976).

Although all these maps were of value, their usefulness was limited by their small scale. However, the Survey lacked the detailed geological and hydrogeological information necessary to produce larger-scale maps for the whole country.

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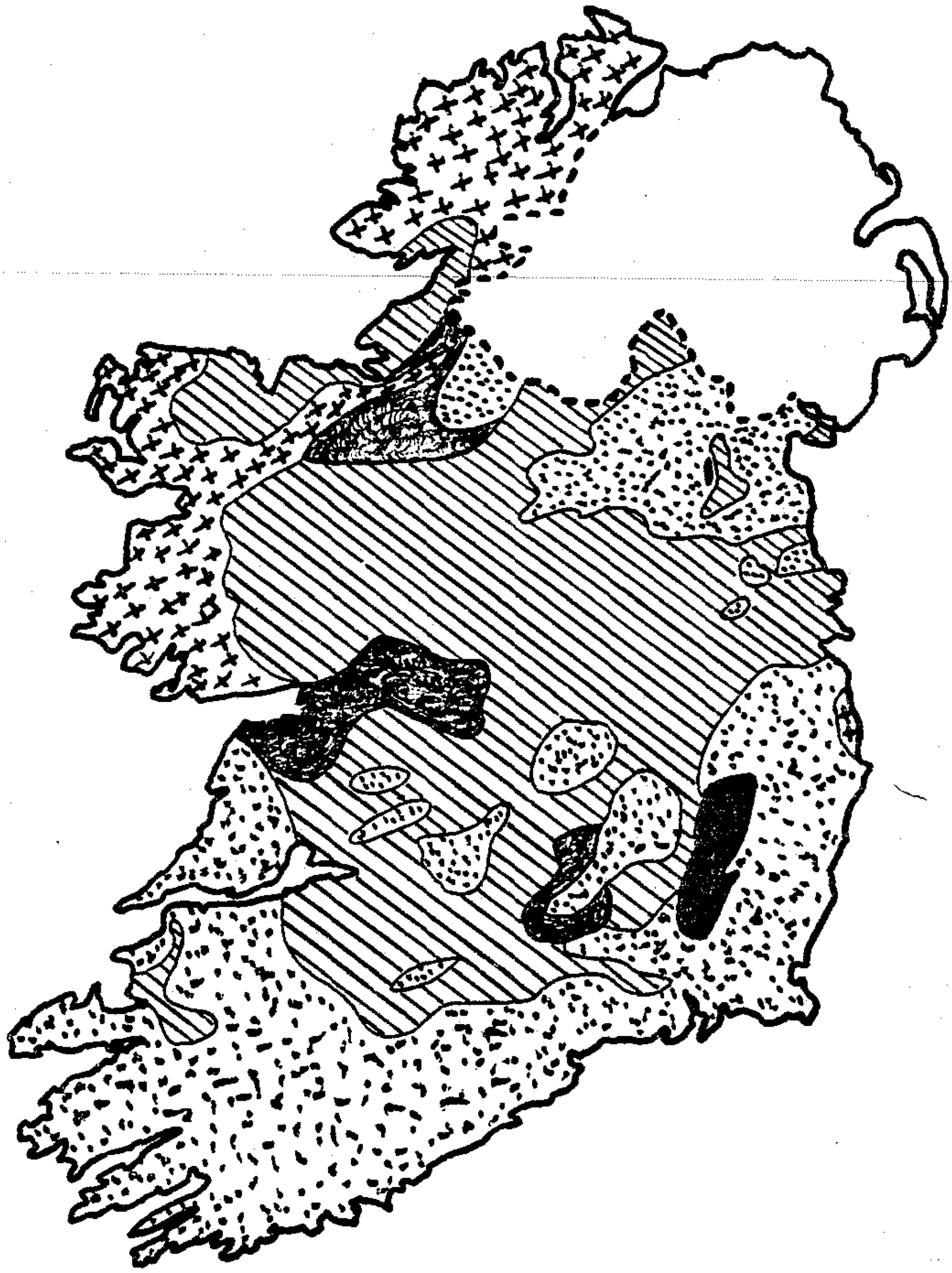
A GENERALISED MAP OF UNDERGROUND WATER IN IRELAND

M.V.O'BRIEN, 1961

A generalised map of sources of underground water for farm and domestic use.

Note that the scale of the map makes it impossible to show innumerable small sub-divisions and variations, including areas where water may be drawn from gravel and sand subsoils.



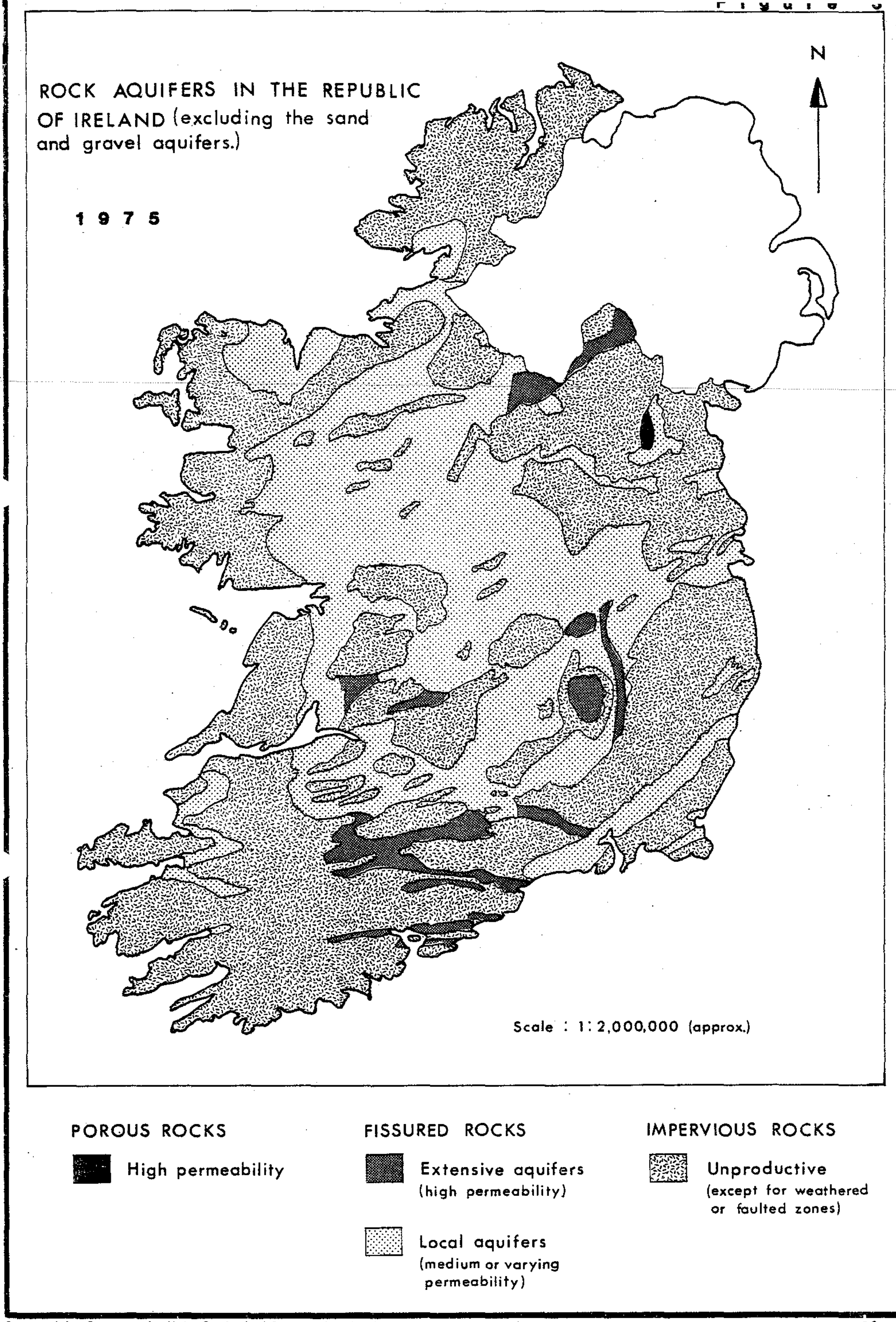
BORINGS OF MODERATE DEPTH INTO POROUS ROCKS

BORINGS OF MODERATE DEPTH INTO LIMESTONE

BORINGS OFTEN OVER 150 FT DEPTH INTO LIMESTONE

DUG WELLS AND BORINGS OF MODERATE DEPTH TO, AND A SMALL DISTANCE INTO, OLD ROCKS OTHER THAN LIMESTONE

DUG WELLS TO UPPER SURFACE OF ALMOST IMPERVIOUS ANCIENT ROCKS


ROCK AQUIFERS IN THE REPUBLIC OF IRELAND (excluding the sand and gravel aquifers.)
1 9 7 5
N
Scale : 1: 2,000,000 (approx.)
POROUS ROCKS
High permeability
FISSURED ROCKS
Extensive aquifers (high permeability)
Local aquifers (medium or varying permeability)
IMPERVIOUS ROCKS
Unproductive (except for weathered or faulted zones)

In 1978 the Survey was invited to take part in a Community-wide E.E C. study aimed at quantifying the Community's groundwater resources. A major component of this study was the preparation of an aquifer map of Ireland at a scale of 1:500,000, a much larger scale than anything previously attempted for the whole country.

2. Definition of Aquifers

The aquifers of Ireland had hitherto been identified only very approximately, and on the basis of information of very variable quality. The main reasons for this were a lack of hydrogeological investigation and an absence of up-to-date geological maps. In order to define the extent of aquifers for this study, an attempt was made, within the constraints of time and manpower available, to draw together as much as possible of the geological mapping and hydrogeological study carried out in Ireland. This entailed reference to university theses, mining company maps, and unpublished work within the Geological Survey, as well as published maps and papers.

Aquifers can be defined on the basis of:

(a) Lithological and/or structural characteristics of geological formations which indicate an ability to store and transmit water.

(b) Hydrological indications of groundwater storage and movement e.g. spring flows, absence of surface drainage, etc.

(c) Information from boreholes suggesting relatively high yields, etc.

Preferably evidence should be available of all three kinds. Unfortunately, over much of the country, evidence of only one or two of the above types is available. Thus in some areas there may be evidence of relatively good well yields without any indication of why the yields are good, making it difficult to even guess at the areal extent of the aquifer. In other places one may suspect that,

/...

for instance, a well-jointed sandstone should be a useful aquifer, but without any confirmatory evidence of good well yields (e.g. because the population is sparse) it is difficult to be confident about mapping the sandstone as an aquifer.

Inevitably, compromises had to be made, and in many areas rather approximate boundaries had to be drawn. Since different hydrogeologists worked on different areas, there were inevitably differing interpretations of the hydrogeology in different areas, and these could not always be completely reconciled. The resulging map can therefore only be regarded as provisional, and in the future, no doubt, considerable modifications will be needed.

3. The following notes summarise the reasons for delineation of the aquifers:

(a) Clean, well-bedded limestones from the Visean were classified as fissured aquifers; where karst flow is known or believed to predominate, the map shows accordingly.

(b) Other limestones are shown as aquifers only:

(i) where good well yields (over 250m^3/d) are known to be common, and/or

(ii) where strong folding (e.g. in the Southern Region) has produced strong joint systems leading to increased permeability.

(c) Quaternary sands and gravels, where known from mapping, were included as porous aquifers.

(d) Where Quaternary deposits are abundant and of significant thickness, and sands and gravels are believed to be quite widespread but not mapped in detail, the Quaternary deposits were indicated as "complex domain of poor or local aquifers".

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(e) The belt of volcanic rocks, interspersed with slates and greywackes, which runs through counties Wicklow, Wexford and Waterford in the Southeast Region, was mapped as an aquifer. Within the belt as mapped, only 40 to 80% of the area is actually underlain by the water-bearing volcanic rocks, the rest being occupied by essentially non-water-bearing rocks.

(f) Coarse, well-bedded and jointed sandstones were mapped as aquifers where there is at least some corroborative evidence to support the belief. The main sandstones involved are:

Triassic Sandstones

Upper Carboniferous Namurian and Westphalian ('Coal Measures') Sandstones

Lower Carboniferous Basal Sandstones and 'Calp' Sandstones

Devonian 'Old Red Sandstone'

In the case of the Triassic rocks, covering only one small area in the northeast of the country, the rocks have both a primary and a secondary permeability. In the other sandstones, only a secondary permeability can be expected. The 'Coal Measures' sandstones have been studied in some detail, and much information is available as a by-product of exploratory drilling for coal. Hence all Coal Measure sandstones were classed as aquifers, though their permeability is rather low.

The Namurian Sandstones are little known and normally are covered by impervious shales which greatly restrict infiltration. Consequently they were not generally included as aquifers.

The Calp Sandstones and Basal Sandstones (in the northeast) have been included as aquifers. The Devonian 'Old Red Sandstone' presents problems - in its main areas of outcrop in the south and southwest of the country it appears to be of very low permeability, but

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TABLE I.

AQUIFERS IN THE REPUBLIC OF IRELAND

GEOLOGICAL AGE	LITHOLOGY	TYPE OF FLOW	DISTRIBUTION	IMPORTANCE	REMARKS
Quaternary	Alluvium	I	Widespread	*	little known
	Fluvio-glacial sands/gravels	I	Widespread	***	should become more important
Permo-Triassic	Sandstones	I & F	Kingscourt area (E. Region)	**	little developed yet
Carboniferous Westphalian	Sandstones	F	S.E. Region	**	Artesian, low recharge
Namurian	Sandstones	F	S, S.E., N-W. Regions	*	low recharge, little used
Upper Visean	Clean Calcarenites	F	Widespread	****	generally karstified
Visean 'Calp'	Sandstones	F (? + I)	N.W., W., Shannon Regions	**	
Tournaisian	Massive Waulsortian 'reef' limestone	F	Widespread	*** **/*	- S. Region - elsewhere
"	Sandstones	F	N.W. & E. Region	**	'Basal Clastics', have some sulphate problems
Devonian 'Old Red Sandstone'	Sandstones	F	S.E., S., Shannon	**	little known
Ordovician	Tuffs, lavas	F	S.E., E. Region	**	patchy distribution

**** very important *** fairly important ** some importance
* only locally useful

I = Intergranular flow
F = Fissure flow

further north, where folding has been less intense, the uppermost portion of the series seems to be a moderate to poor aquifer. Therefore, wherever some corroborative evidence was available nearby, this uppermost part of the series was mapped as an aquifer.

4. The characteristics of the aquifer can be summarised:

(a) Fissure permeability predominates. The only widespread aquifers with intergranular permeability only are Quaternary sands and gravels. This is largely explained by the lack of Mesozoic and Tertiary formations in the country.

(b) Irish aquifers are relatively shallow. As far as is known, fissure permeability does not extend appreciably below about 120m (although a few borings have recorded saline water and some degree of fissure flow at much greater depths). In general, it appears that the limestones have not been appreciably opened up by solution below this depth, and fissures in sandstones tend to close up. However, further investigations may locate areas where this does not hold true.

(c) Irish aquifers are generally phreatic rather than confined but local confinement by boulder clay is quite common.

(d) Aquifers are often small in lateral extent, and their shape is complicated by faulting.

(e) Much of the country, especially in the west, is underlain by Karstic aquifers, where flow is largely restricted to conduits, wells are difficult to sink successfully, groundwater storage may be small and the aquifer easily polluted.

5. The most important aquifers in the country are the limestones, followed by the Quaternary sands and gravels, and then the various types of sandstone (Table I). Each aquifer has its own problem:

/...

TABLE I.

AQUIFERS IN THE REPUBLIC OF IRELAND

GEOLOGICAL AGE	LITHOLOGY	TYPE OF FLOW	DISTRIBUTION	IMPORTANCE	REMARKS
Quaternary	Alluvium	I	Widespread	*	little known
	Fluvio-glacial sands/gravels	I	Widespread	***	should become more important
Permo-Triassic	Sandstones	I & F	Kingscourt area (E. Region)	**	little developed yet
Carboniferous Westphalian	Sandstones	F	S.E. Region	**	Artesian, low recharge
Namurian	Sandstones	F	S, S.E., N-W. Regions	*	low recharge, little used
Upper Visean	Clean Calcarenites	F	Widespread	****	generally karstified
Visean 'Calp'	Sandstones	F (? + I)	N.W., W., Shannon Regions	**	
Tournaisian	Massive Waulsortian 'reef' limestone	F	Widespread	*** **/*	- S. Region - elsewhere
"	Sandstones	F	N.W. & E. Region	**	'Basal Clastics', have some sulphate problems
Devonian 'Old Red Sandstone'	Sandstones	F	S.E., S., Shannon	**	little known
Ordovician	Tuffs, lavas	F	S.E., E. Region	**	patchy distribution

**** very important *** fairly important ** some importance
* only locally useful

I = Intergranular flow
F = Fissure flow

(a) The development of the limestones suffers from the lack of detailed geological mapping which is required in order to distinguish the productive from the non-productive strata. Secondly, where the limestones are productive, owing to extensive karstification, they often present great problems to well drillers, owing to caving, dog-legging of boreholes, etc. Pollution of karstified limestones is also a problem. In the karstic areas of the west, in particular, the problems of development are more difficult because well-sinking is often unsuccessful because conduits are widely spaced.

(b) Development of Quaternary deposits is also hampered by lack of detailed mapping, but the problems of well-sinking are much more readily soluble, as the techniques of drilling, screening and developing sand/gravel aquifers are at least well established. The main task here is to disseminate the information to well-drillers and engineers. It is apparent that these aquifers hold enormous potential for the country.

(c) The sandstone aquifers of the country are reasonably well mapped geologically, but little known as aquifers, with the exception of the Coal Measures Sandstones. Many of them tend to suffer from restricted recharge owing to the presence of overlying shales.

6. The compilation of the map was completed in 1979 (though some minor corrections were made later), but publication of the final maps (3 sheets for Ireland) by the E.E.C. Commission is still awaited.

The map represents a great advance on previous work, and is in constant use in the course of our work, but we know that it is already out of date in several areas, and there is room for a great deal of improvement. Moreover, because of the specification for the map laid down by the Commission, the map is not ideal for the purposes of its potential users in Ireland.

In the future we hope to compile improved aquifer maps, preferably at larger scales, such as Eugene Daly's map of the South-East R.D.O. region.

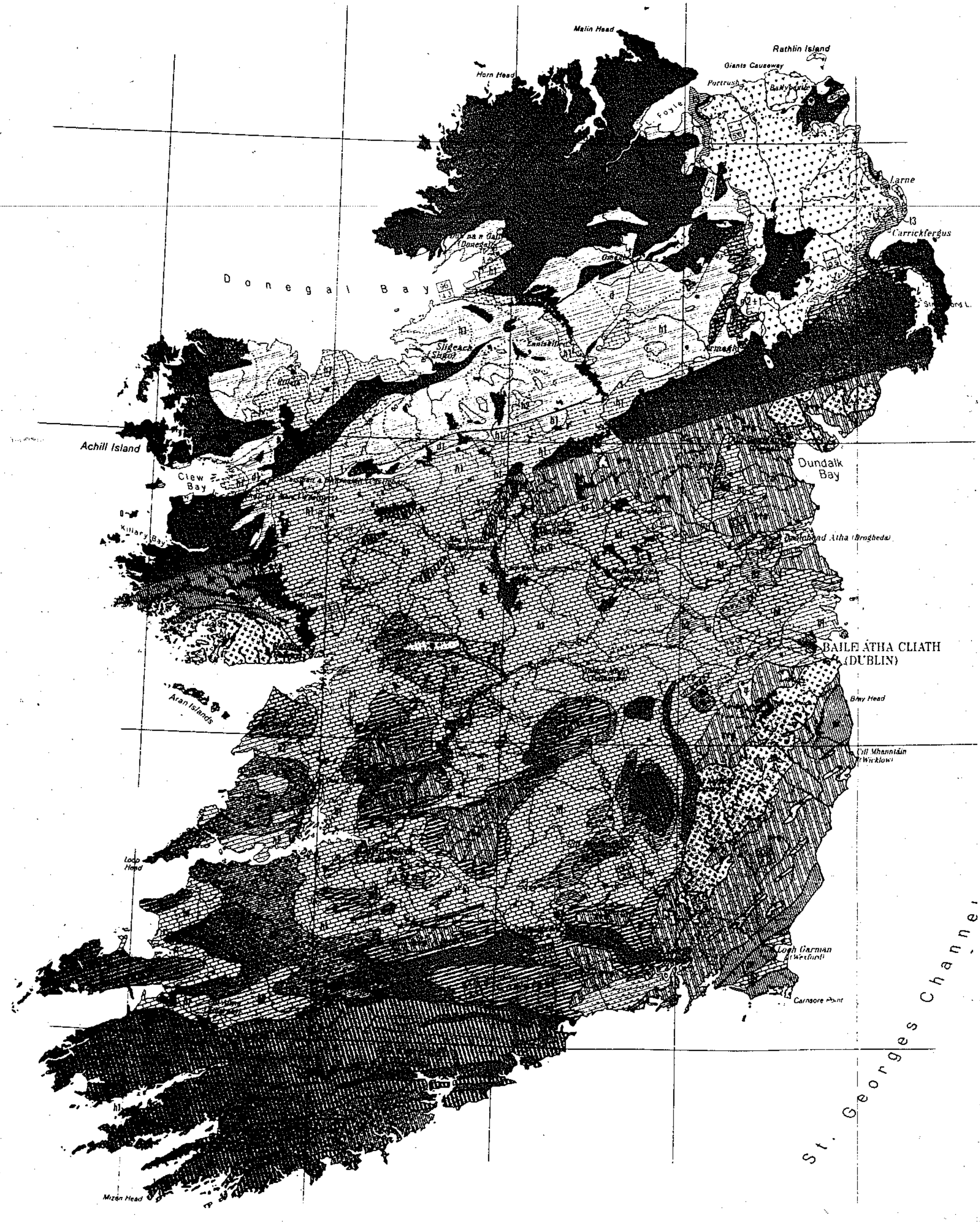
.../

COR.

International Hydrogeological Map of Europe

International Association of Hydrogeologists   Commission for the Geological Map of the World   Subcommission for Hydrogeological Maps

Published by Bundesanstalt für Geowissenschaften und Rohstoffe and UNESCO



AN APPROACH TO GROUND WATER DEVELOPMENT IN COUNTY MEATH.

F. Burke,
Senior Executive Engineer
Community & Environment,
Meath County Council,
County Hall,
NAVAN.

INTRODUCTION.

In this paper, I have been asked to outline Meath County Council's approach to the Development of the Ground Water Resources in its functional area. To do this, I feel it is necessary that the use of ground water be seen in the context of the development of the overall supply situation. In this regard, I would propose to outline in the paper the development of the water supply system in the county and expand on the areas where the proposals include for the development of a ground water resource. While the county has engaged in the past in some investigations into the use of ground water as a major water source, e.g. investigations in South Meath (limited to the vicinity of Summerhill, and Enfield), it is only in the last year that ground water development has been considered on a county wide scale. The fact that the ground water resources of the county, which Mr. C.R. Aldwell of the G.S.I. estimated to be some 60 - 70 million M^3/year or 39 m.g.p.d., are only now being given the consideration they deserve, is due in no small part to the work done by Mr. L.F. Sheeran in breaking down the barriers that existed to the allocation of public money to a risk venture, and to the development by the Meath Hill Group Scheme of a borehole source which is yielding a supply in the order of 10,000g.p.h. for a very small capital outlay.

COUNCIL POLICY.

It was, and still is, the policy of Meath County Council to provide and distribute an adequate supply of potable water to meet the domestic needs of the present and anticipated populations of the district, service, and local centres identified in the County Development Plan, and gradually to extend this service to serve smaller centres and intervening rural areas. In so far as supplies are available, it is also intended to meet the reasonable needs of commerce, industry and agriculture as well as community and recreational activities.

While the policy of the Council has remained constant over the years, the method adopted to achieve the objectives of the policy has changed. In the past the provision of supplies was confined to the various towns and villages in the county while rural areas were catered for by the provision of hand pumps and private supplies. The present trend is towards the provision of regional schemes to serve selected regions of the county. With the change in approach to the provision of water supplies, the approach to the development and use of ground water has also changed, and this will be obvious as the history and future proposal for the development of the water supply is outlined.

WATER SUPPLIES IN MEATH IN 1970.

Piped public water supplies in 1970 in Meath were confined, in the main, to the towns and villages of the county with individual sources, supplying the needs of each town or village. Table 1 gives an outline of the supply position at the time. The sources for the supplies were mainly rivers, or infiltration galleries adjacent to rivers with ground water only supplying Laytown, Nobber, and Dunshaughlin, which at the time accounted for only 7.3% of the daily production of water.

In addition to the provision of supplies to the main towns and villages, the Council over the years provided wells fed from ground water, and fitted with hand pumps to serve groups of houses in rural areas. In all, records of some 627 wells which were provided, were available for inspection. These were evenly spread throughout the county in that:-

133 were located in South East Meath.
122 were located in South Central Meath.
99 were located in South West Meath.
101 were located in North West Meath.
70 were located in North Central Meath.
102 were located in North East Meath.

On the whole, some very useful information concerning ground water resources in the county should have been available from the provision of these wells and it should have provided good baseline data for the future planning and development of these resources in the county, but, unfortunately, this was not the case. The well records contained little information of any value. A detailed analysis of the records on the 133 wells sunk in the South East Meath Area reveals the following:-

1) In 55 cases there was no information on the type of well.
2) In only one case was the type of overburden recorded and the depth of overburden in 27 cases.
3) There was no information on the type of bed rock encountered in the case of the 41 bored wells.
4) There was no information on well "yield" in 74 cases and on the remainder of the wells the reported yields would require to be re-assessed. In no case would a step or yield test have been carried out.
5) There was very little information available on water quality, with information being available in 30 cases on hardness, 19 cases on iron levels, and in 21 cases on pH.

The records on the wells in the other areas would be of a similar nature, but probably would be of more use. I have included this paragraph in the paper to suggest to other engineers involved in the provision of water supplies that full records of all well boring and testing should be kept as they will be of great benefit if ground water investigations are to be undertaken in your area at a future date.

ABLE NO. 1.

WATER SUPPLIES IN CO.MEATH IN 1970.

SCHEME	SOURCE	TREATMENT	DAILY OUTPUT GALS.PER DAY.	DESIGN CAPACITY G.P.D.	REMARKS
avan	River Boyne	Settlement.Slow Sand Filters.Chlorination.	600,000	500,000	Pre-chlorination introduced to reduce load on Filters.New scheme planned.
rim	River Knightsbrook	Settlement.Rapid gravity filters.Chlorination.	120,000	250,000	Scheme recently improved.
ells	River Blackwater	Slow sand filters. Chlorination.	250,000	300,000	
unboyne/Clonee	River Tolka Infiltration Gallery.	Pressure filter. Chlorination.	30,000	35,000	Supplementary supply being sought from Dublin Co.Council.
aytown/Bettystown	Springs	Pressure Filter. Chlorination.	70,000	90,000	
ldcastle	Lake Intake-LoughCreevagh	None	80,000	90,000	
thboy	River Trimblestown	Pressure Filter. Chlorination.	45,000	50,000	
uleek	River Nanny Infiltration Gallery.	Chlorination.			
shbourne	River Nanny Infiltration Gallery	Chlorination	200,000	250,000	

Scheme	Source	Treatment	Daily Output Gals.PerDay	Design Capacity Gals. Per Day.	Remarks
lane	River Boyne Infiltration Gallery.	None	50,000	60,000	Capacity of scheme limited by the capacity of the pumps.
obber	Borehole	None	20,000	30,000	
unshaughlin	Borehole	None	20,000	24,000	
allivor	River Stoneyford. Infiltration Gallery.	Chlorination	10,000	16,000	
rumcondra	River	Pressure Filter. Chlorination	10,000	15,000	
oynalty	Moynalty River	Chlorination Pressure Filter	10,000	12,000	
		Total	1,515,000	1,722,000 (1,822,000 allowing for over loading of Navan supply)	Overall 12% spare capacity available on design.17% spare available allowing for overworking of the Navan Supply.

DEVELOPMENT IN THE SEVENTIES.

A factor that has affected the supply of water in the county was the population growth and changing distribution pattern within the county.The results of the 1981 census show that the population of Meath in 1981 has increased by some 33.3% over the 1971 level. This in fact was the third highest growth in the Republic after Dublin and Kildare, and would in effect have been in excess of twice the national average of 15.6%. In addition, the growth rate within the county changed from district to district. This is shown in Table No. 2 (see Map No. 1 which shows a map of the Development Districts).

TABLE NO. 2.

Development District	Census 1971	Census 1981	Increase 1971-'81	% Increase
Navan	17,122	22,433	5,311	31.0%
Kells	11,762	13,671	1,909	16.2%
Trim	15,121	18,412	3,291	21.8%
Oldastle	3,807	3,985	178	4.7%
Meath (East)	9,207	13,190	3,983	43.3%
Ardee	2,546	2,915	369	14.5%
Dunshaughlin (incl.Ashbourne)	12,011	19,368	7,357	61.3%
County	71,576	95,419	23,690	33.3%

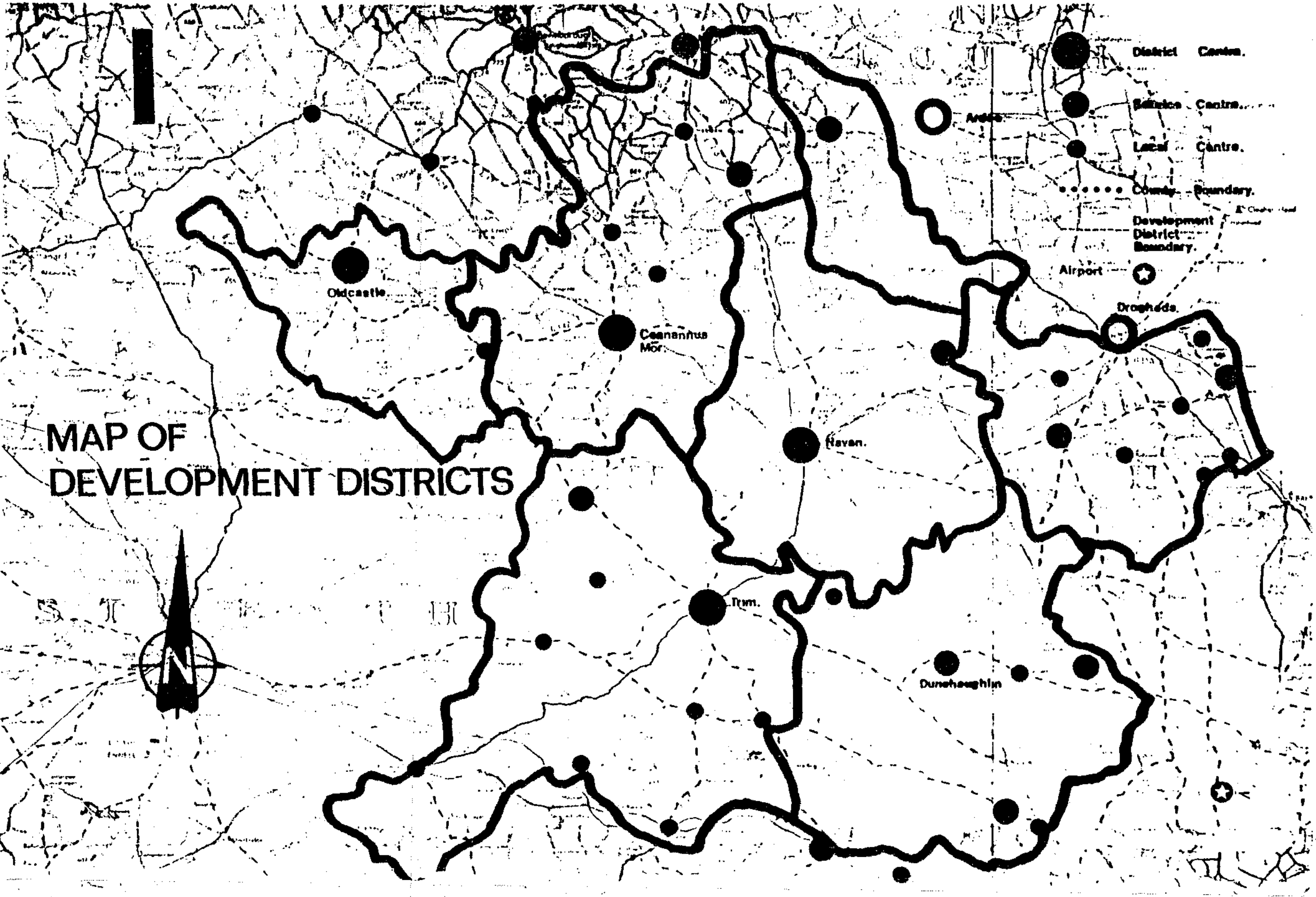
The Population figures clearly indicate that the main areas of growth were:-

1) East Meath and Dunshaughlin Development Districts, both of which are located within easy reach of Dublin and would in effect be accommodating part of the overspill from Dublin.
2) The Navan Development District.

Further investigation of these figures would indicate that the towns and areas immediately surrounding the larger towns would also have experienced substantial growth when compared with the remainder of the development district - this is shown on Table 3.

TABLE NO. 3.

Area (District Electoral Divisions).	Population 1971	Population 1981	% Increase	% Increase Develop area.
Kells Urban & Rural	2,653	3,663	38.1%	16.2%
Navan Urban & Rural	6,826	11,136	63.1%	31.0%
Trim Urban & Rural	2,297	3,526	53.5%	21.8%


MAP OF
DEVELOPMENT DISTRICTS
District Centre.
Local Centre.
County Boundary.
Development
District
Boundary.
Airport
Drogheda.
Oldcastle.
Ceanannus
Mór.
Navan.
Trim.
Dunshaughlin

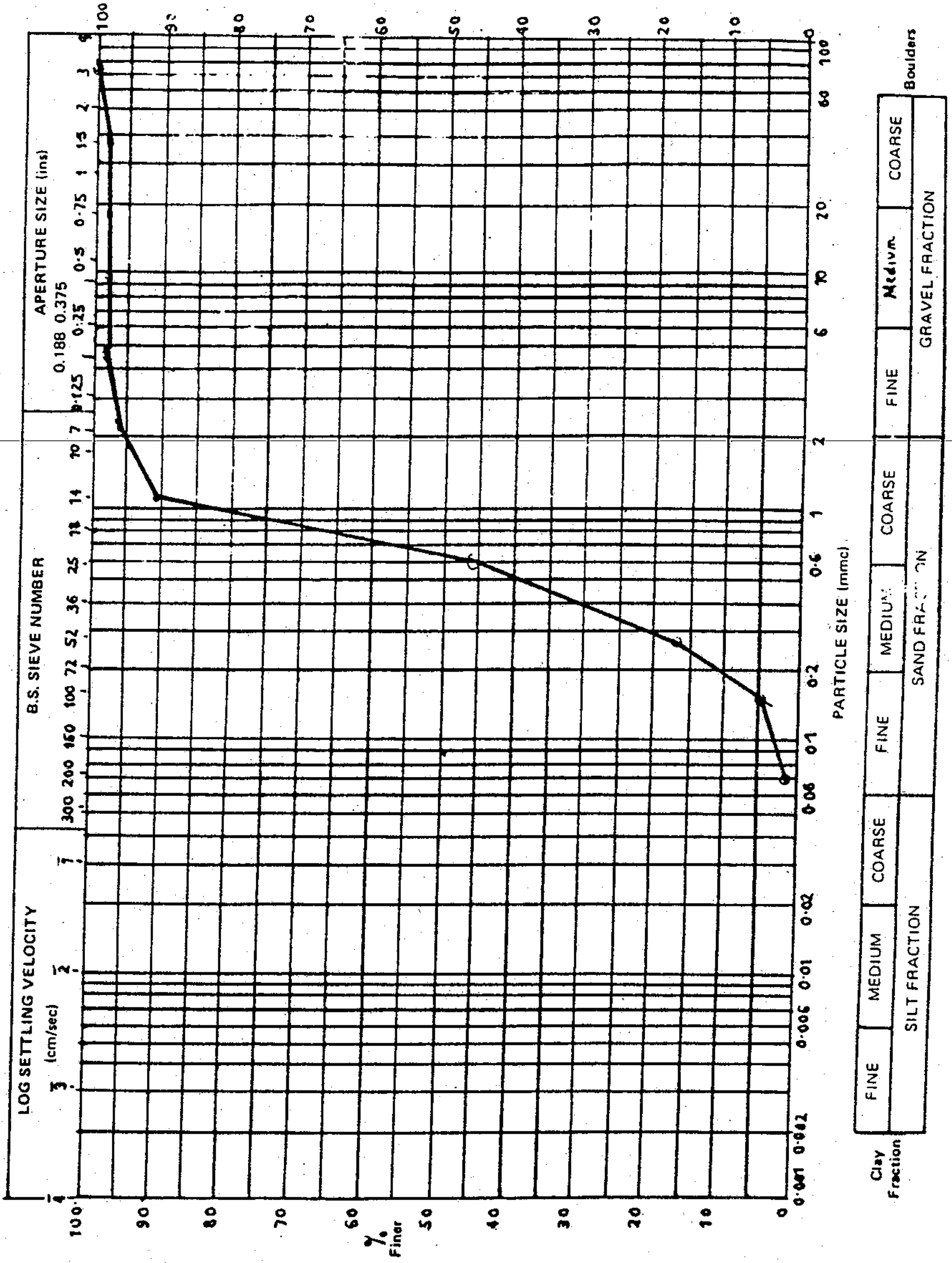
The trend in the development of water supplies in the seventies in Meath was for the provision of regional schemes to serve selected areas, and in this regard a number of developments took place (see map no. 2).

1) The council undertook the construction of a regional scheme to the East Meath Area, including Ashbourne, Ratoath, Dunshaughlin, and Dunboyne on a phased basis.

2) The Council undertook the provision of Phase 1 of the Navan and Mid-Meath Regional Scheme to serve Navan and the surrounding area including eventually Athboy, Dunderry, Robinstown, etc.

3) The Council are at present constructing Phase 1 of the Kells/Oldcastle Regional Scheme which will serve the Kells and Oldcastle Development Areas.

4) An investigation of the gravels in the Galtrim Moraine in the vicinity of Summerhill was undertaken with a view to serving a proposed South Meath Regional Scheme. The results of the trial borings indicated that yields of the order of 2,500g.p.h. were available, but this was not sufficient to meet the Council's requirements at the time, and it was decided not to proceed further with the investigation.



PARTICLE SIZE ANALYSIS	VISUAL DESCRIPTION sand.

Ulster Foundations Ltd
CRAIGAVON

Cooley	Report No: 425/F	Borehole No: 2
	Sample No: 14236	Depth 13.[illegible]

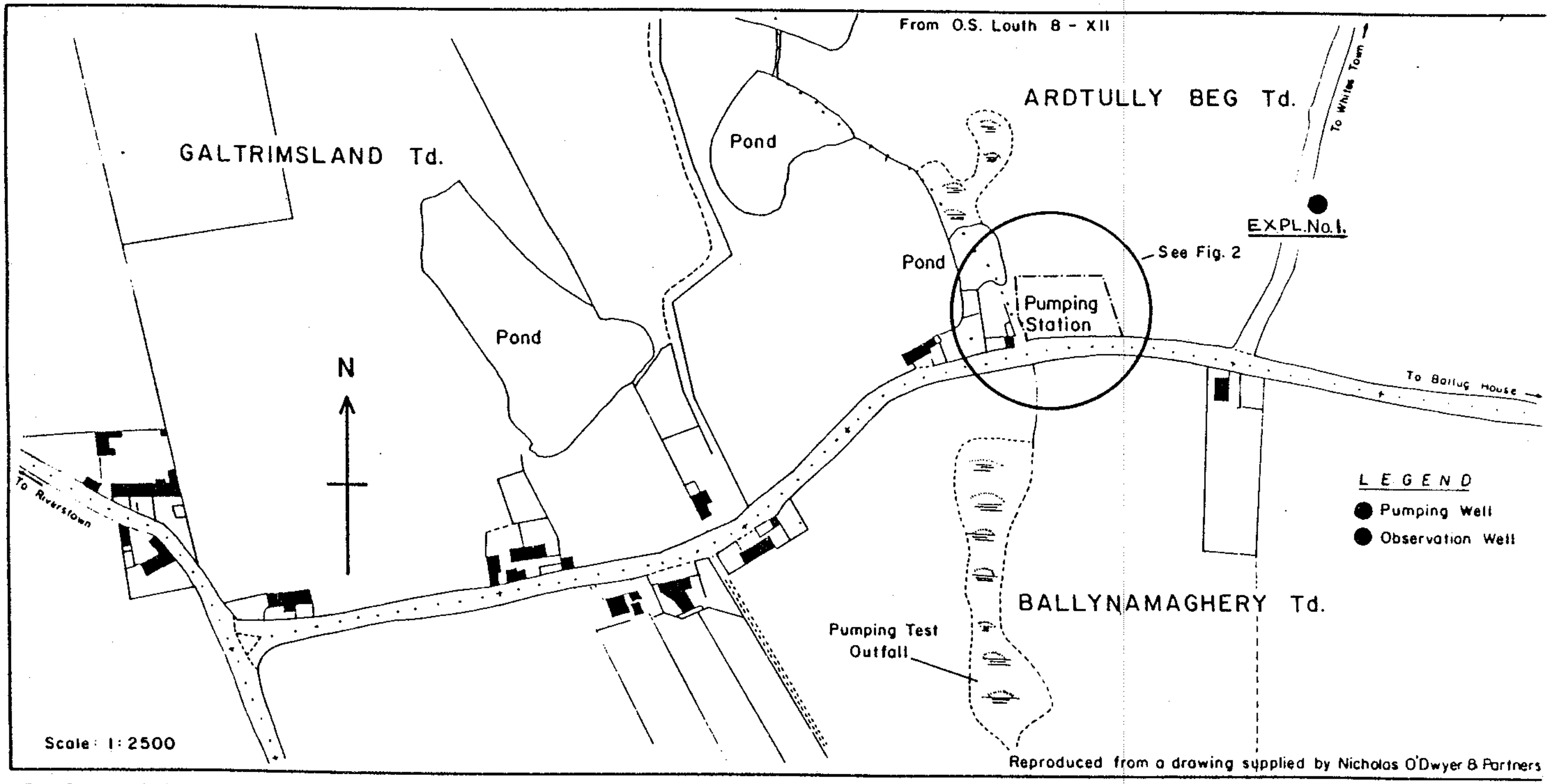
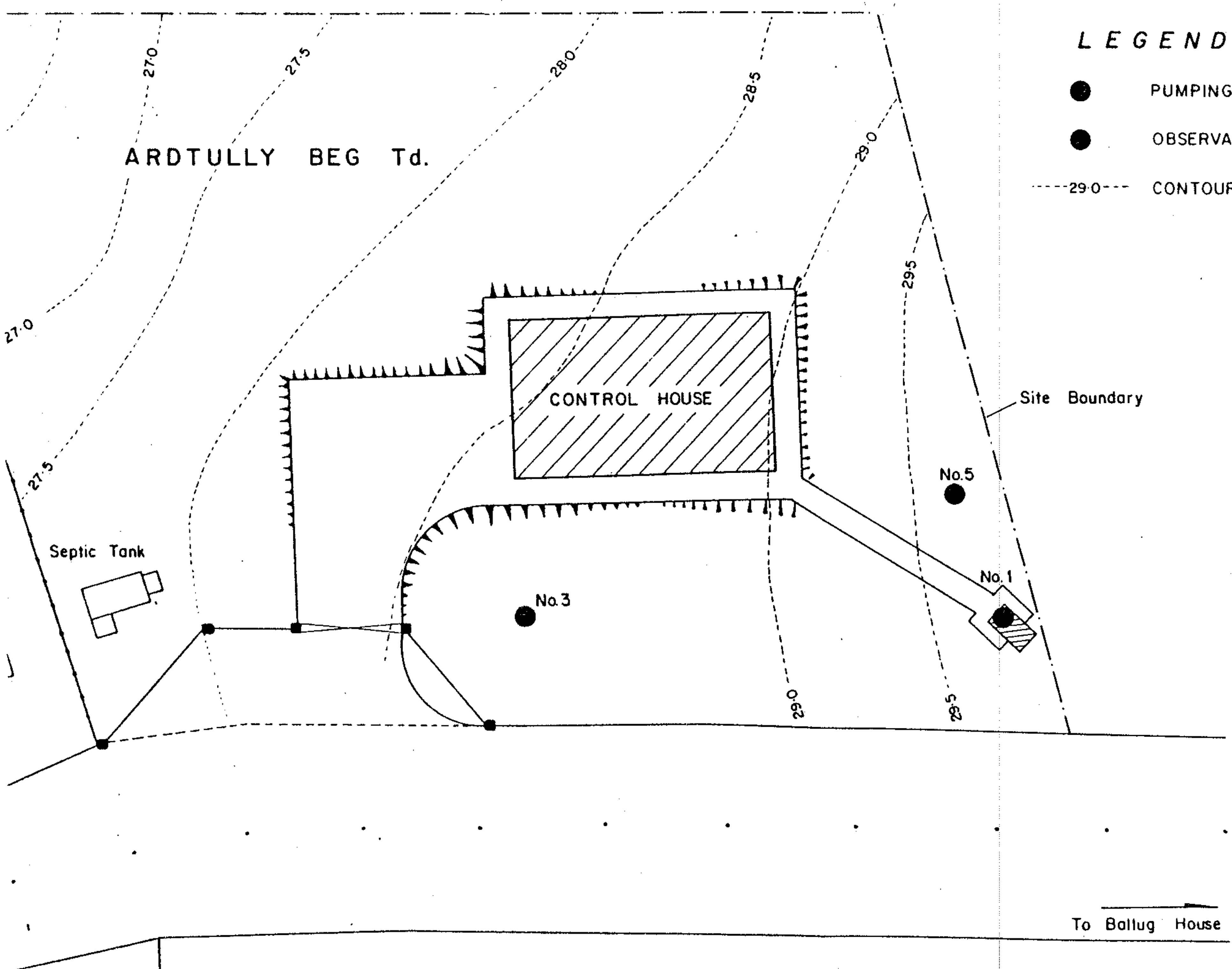


FIG.2. LOCATION PLAN OF ARDTULLY BEG PUMPING STATION.


LEGEND
PUMPING WELL
OBSERVATION WELL
29·0 CONTOURS (M.O.D.)
ARDTULLY BEG Td.
CONTROL HOUSE
Site Boundary
No.5
No.1
No.3
Septic Tank
To Ballug House
27·0
27·5
28·0
28·5
29·0
29·5

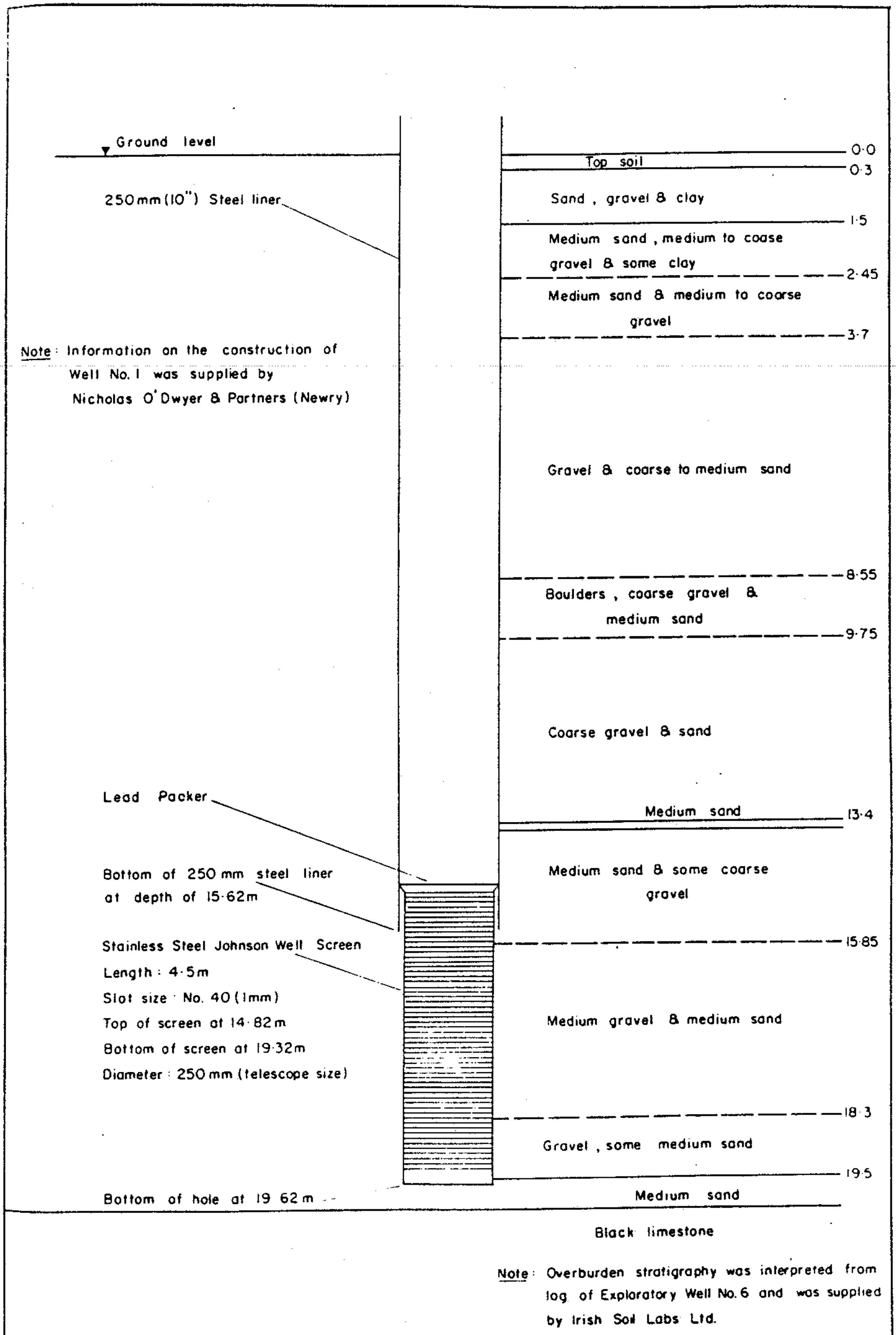


Fig. 4 DESIGN OF WELL No. 1, ARDTULLY BEG

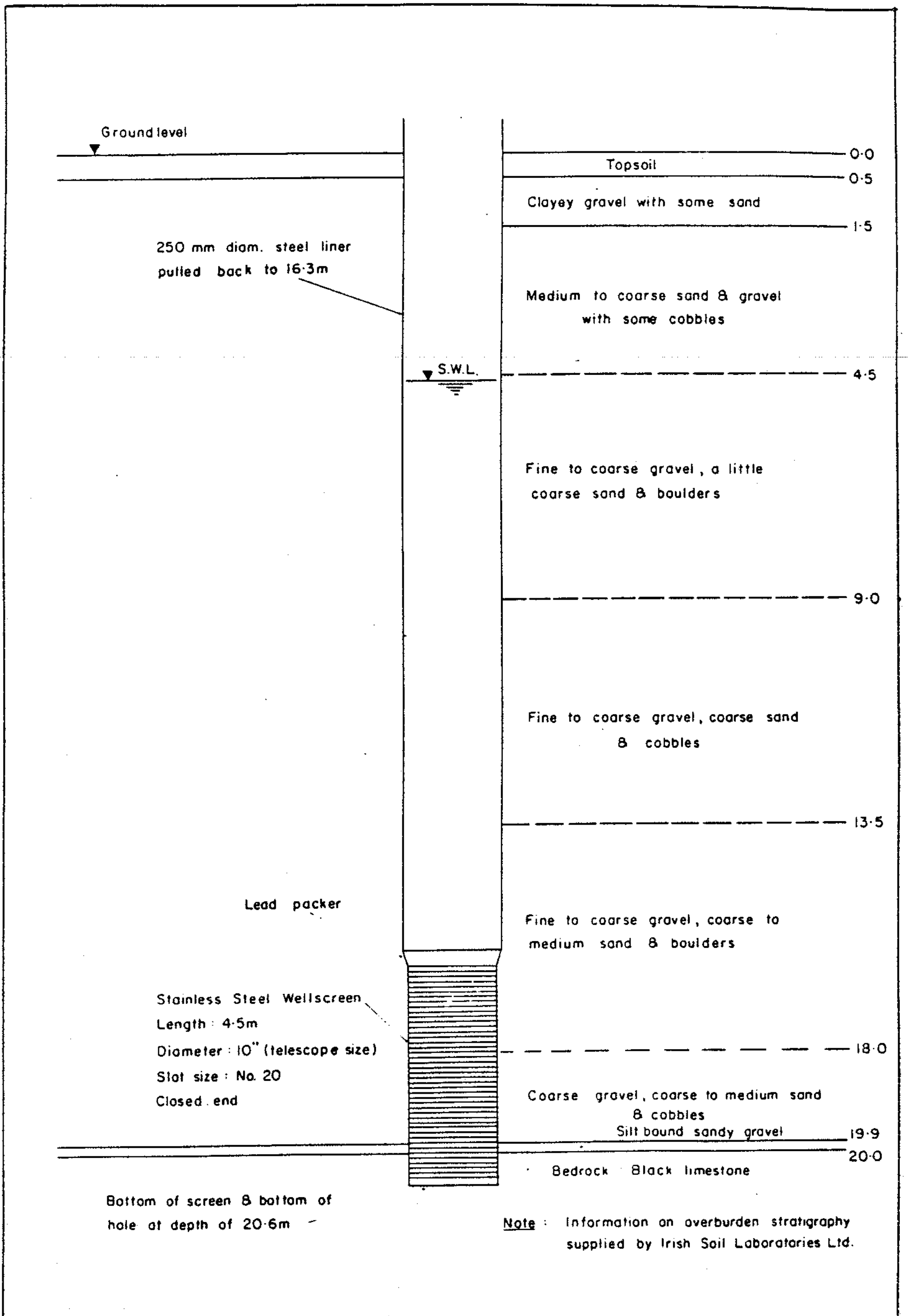


Fig. 5. DESIGN OF WELL No. 3 , ARDTULLY BEG.

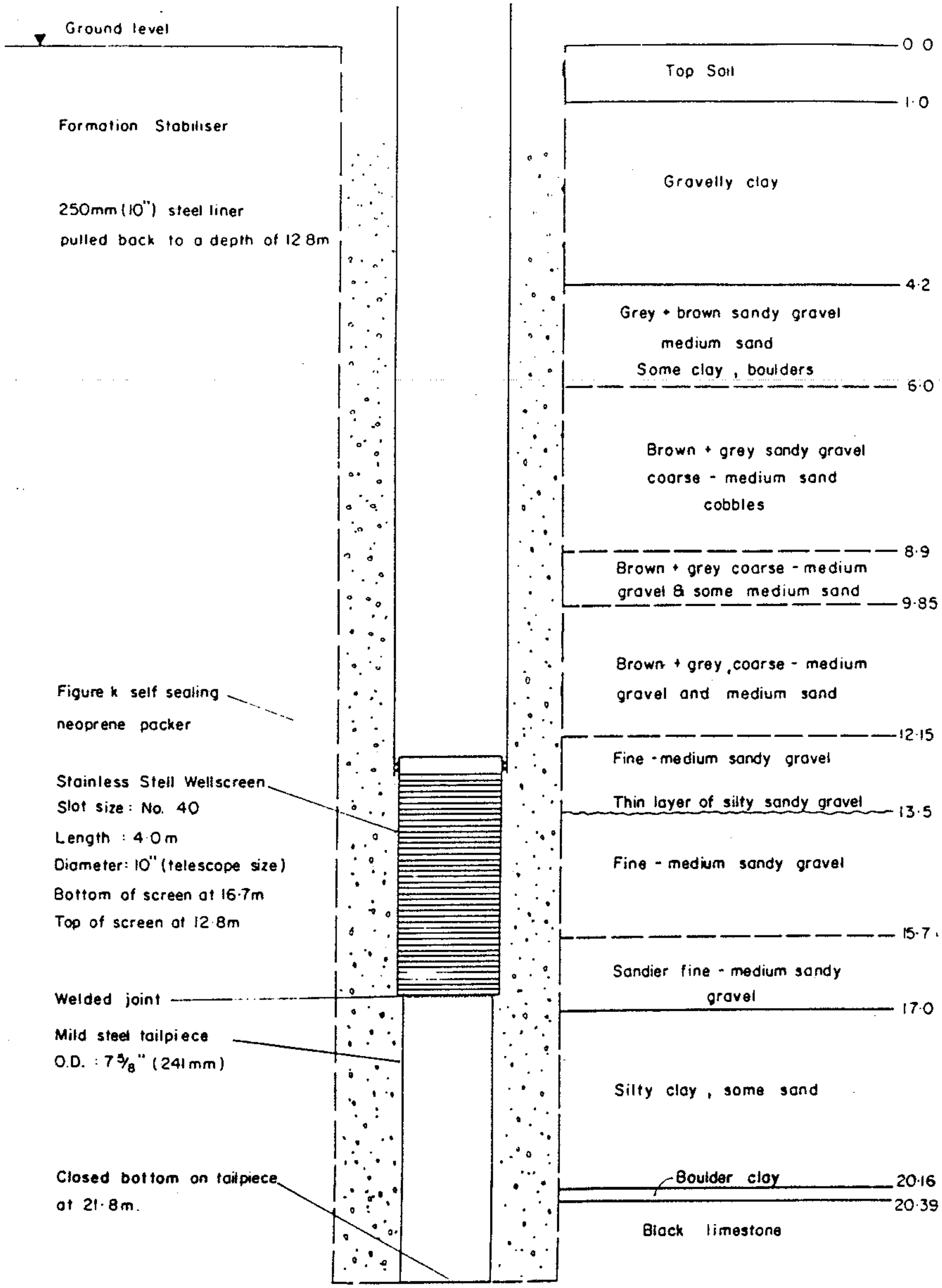


Fig. 6. PROPOSD DESIGN OF WELL No. 4 , ARDTULLY BEG .

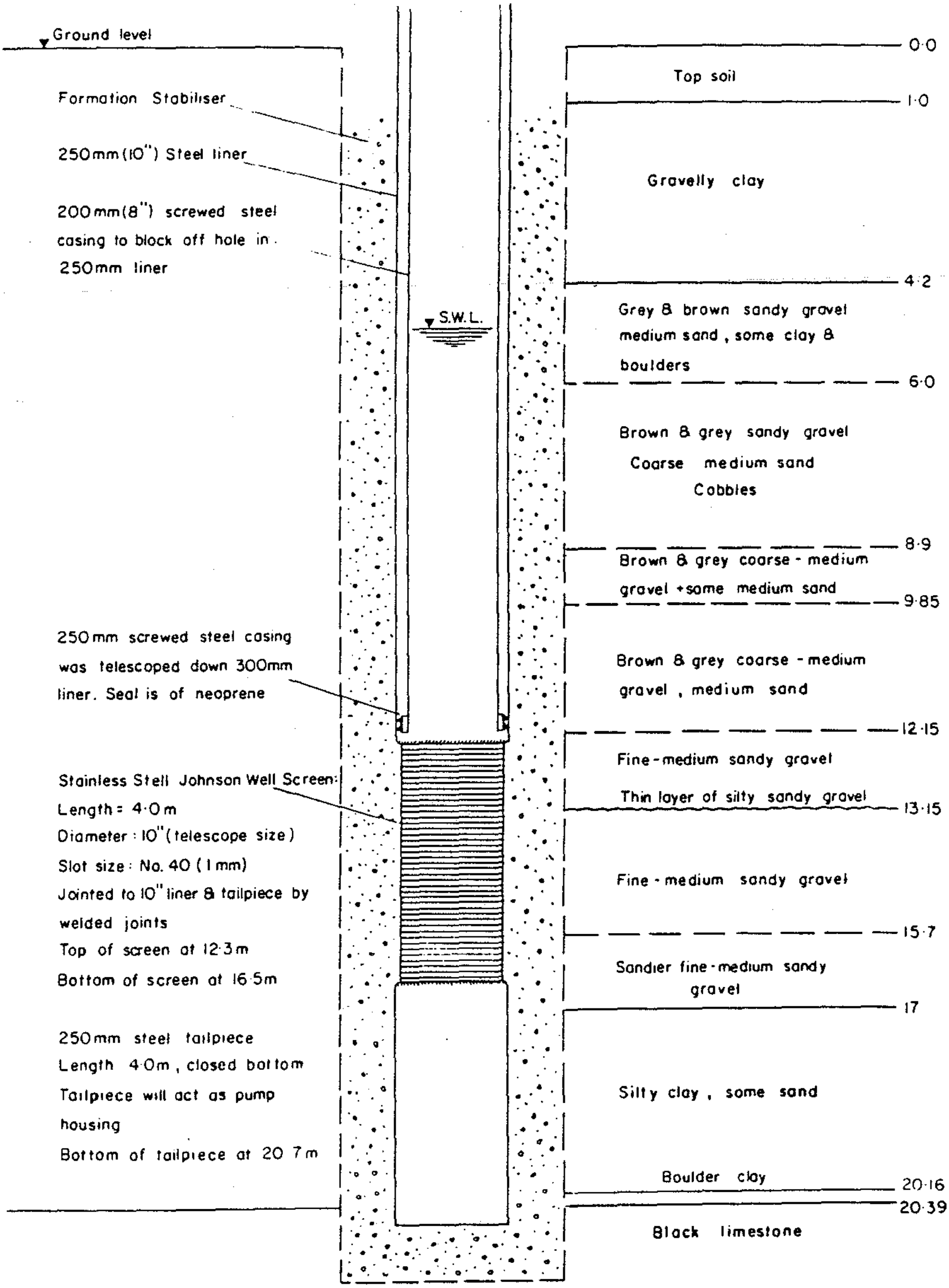


Fig. 7 DESIGN OF WELL No. 5, ARDTULLY BEG

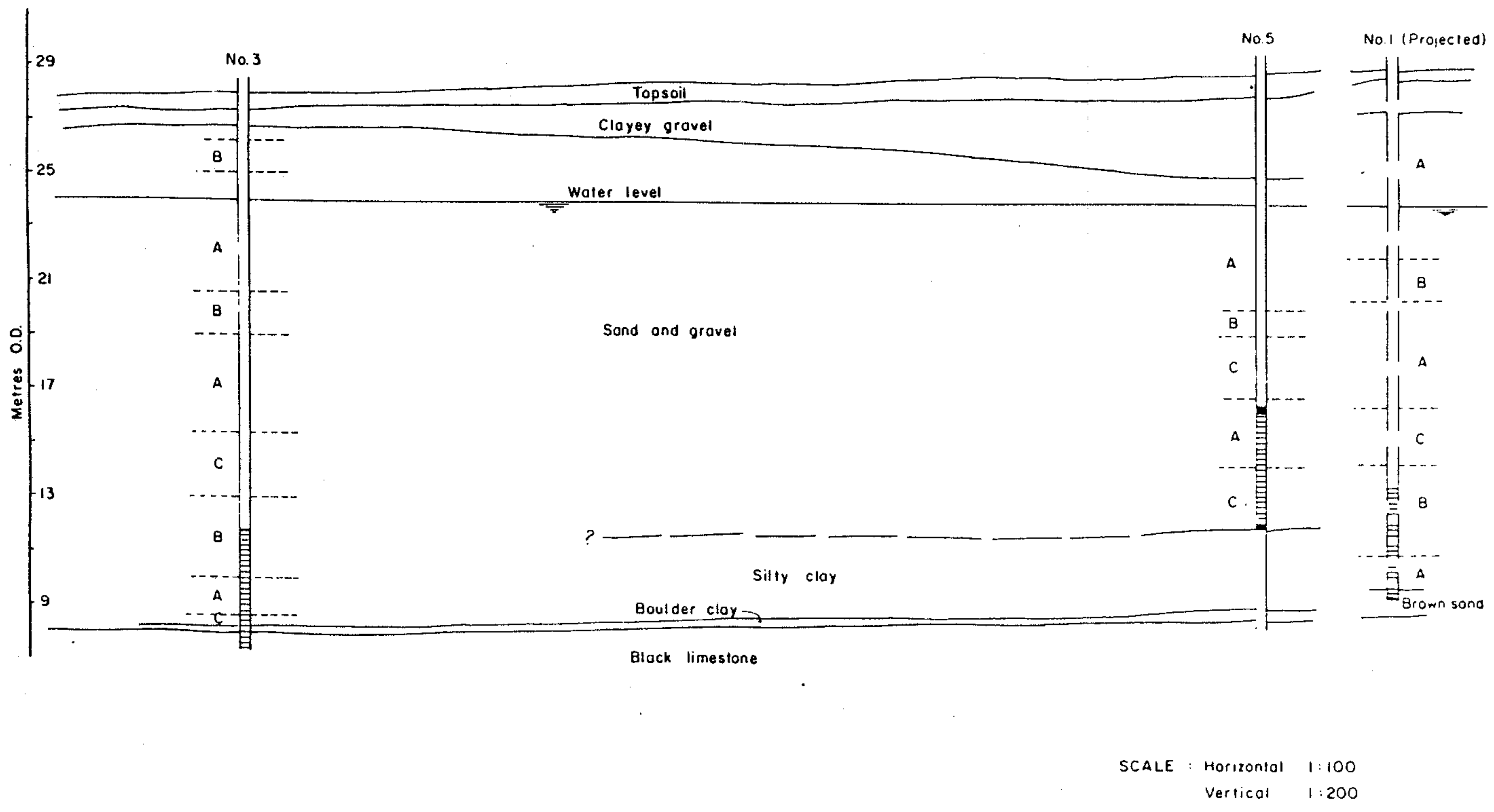
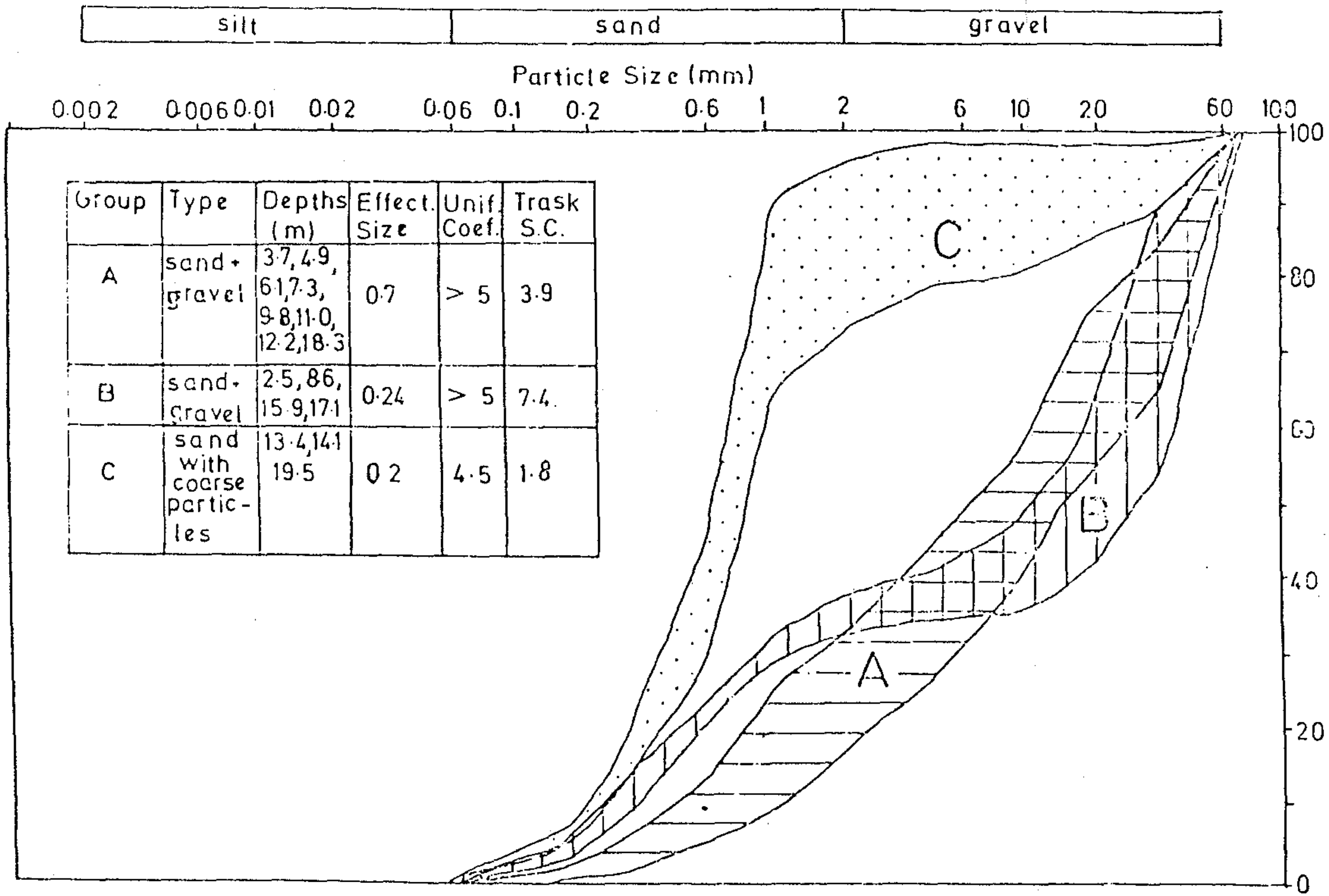


Fig. 8. CROSS SECTION THROUGH ARDTULLY BEG SITE, Co. LOUTH.



Group	Type	Depths (m)	Effect. Size	Unif. Coef.	Trask S.C.
A	sand + gravel	3·7, 4·9, 6·1, 7·3, 9·8, 11·0, 12·2, 18·3	0·7	> 5	3·9
B	sand + gravel	2·5, 8·6, 15·9, 17·1	0·24	> 5	7·4
C	sand with coarse particles	13·4, 14·1 19·5	0 2	4·5	1·8

Fig. 9 GROUPING OF SIEVE ANALYSES FROM WELL No. 1, ARDTULLY BEG. (By E. Daly, Geological Survey of Ireland)

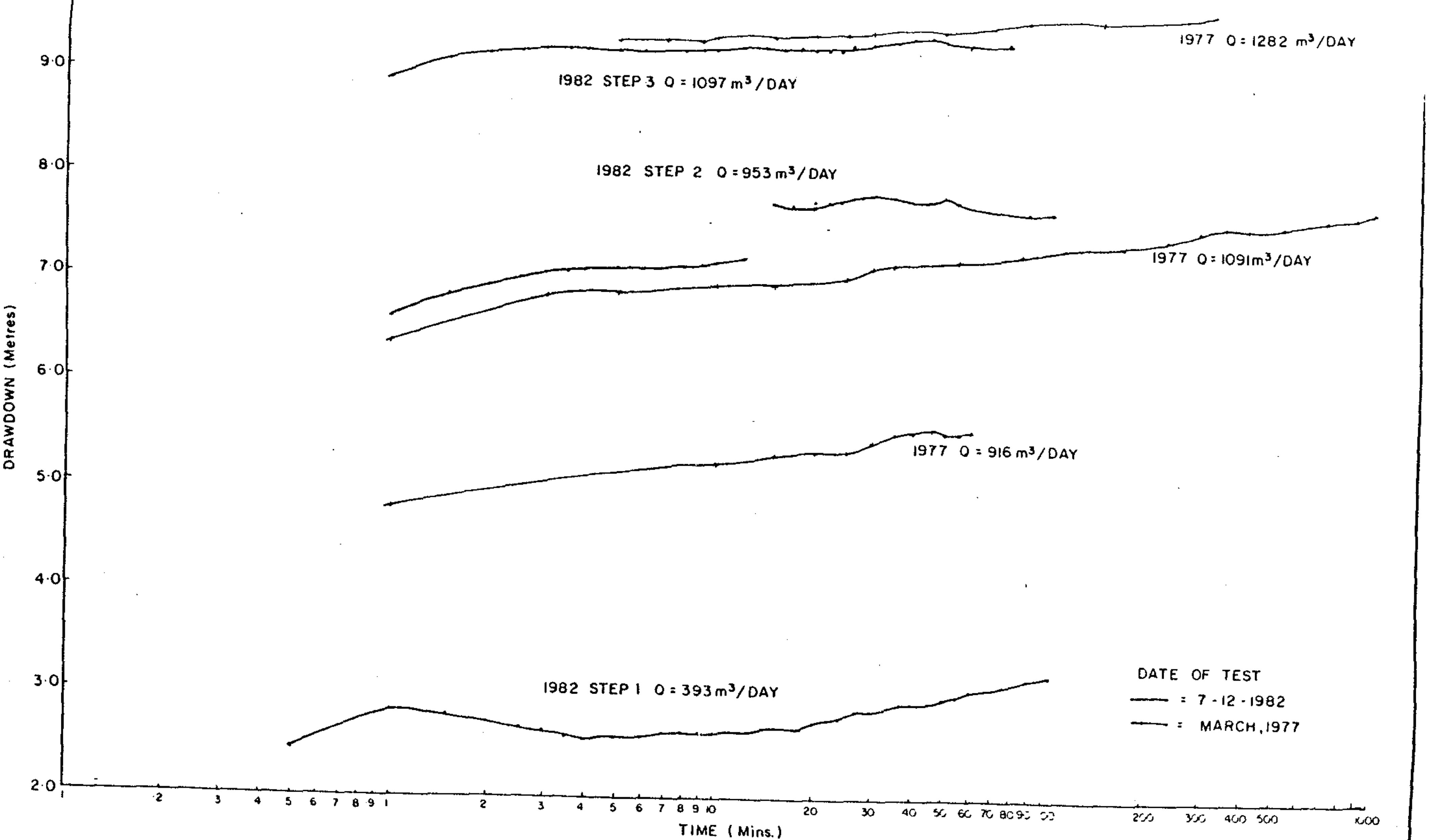
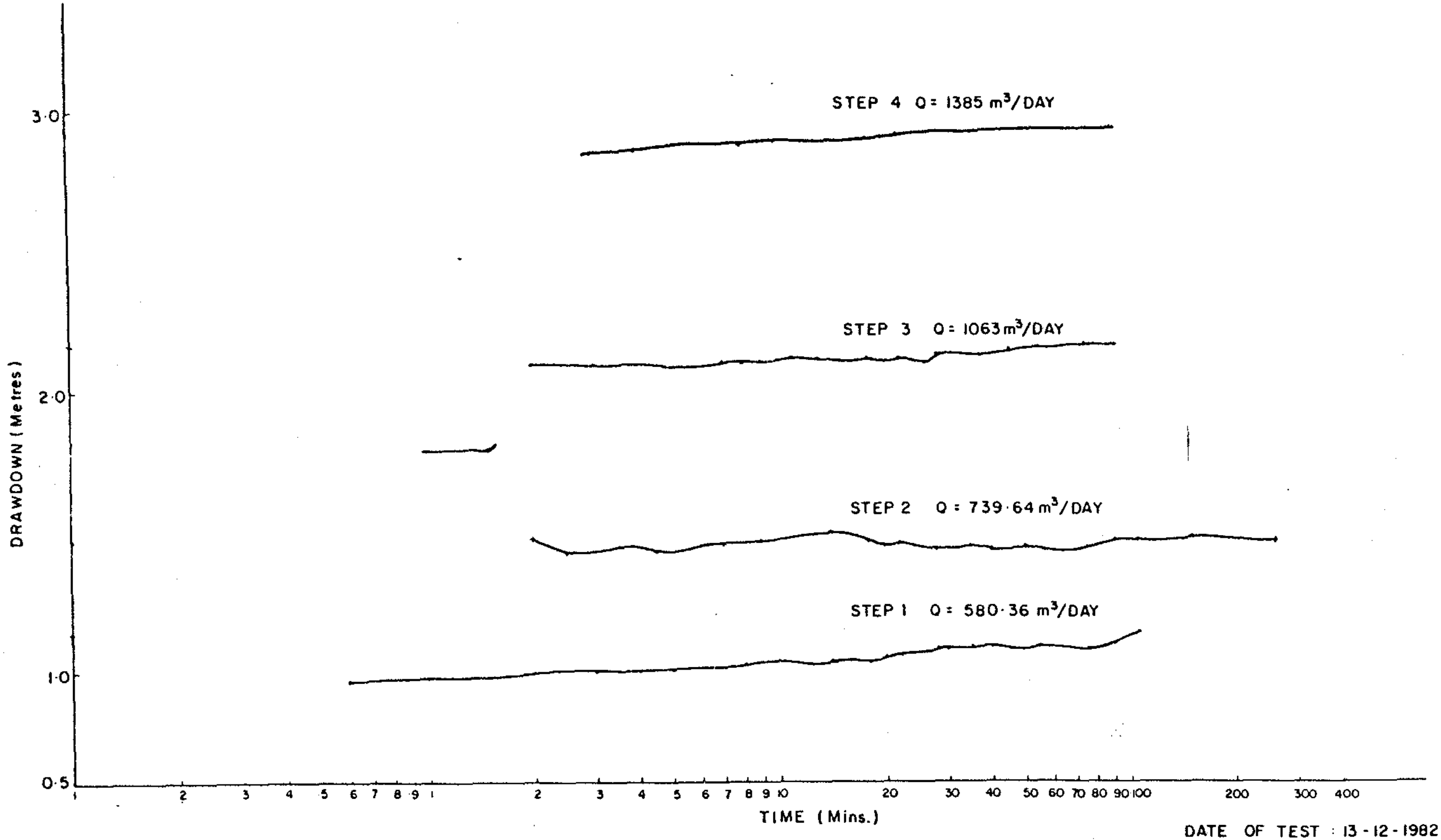


Fig. 10 STEP DRAWDOWN TEST, WELL No.1



DATE OF TEST : 13-12-1982

Fig. 11 COOLEY STEP DRAWDOWN TEST, WELL No. 5

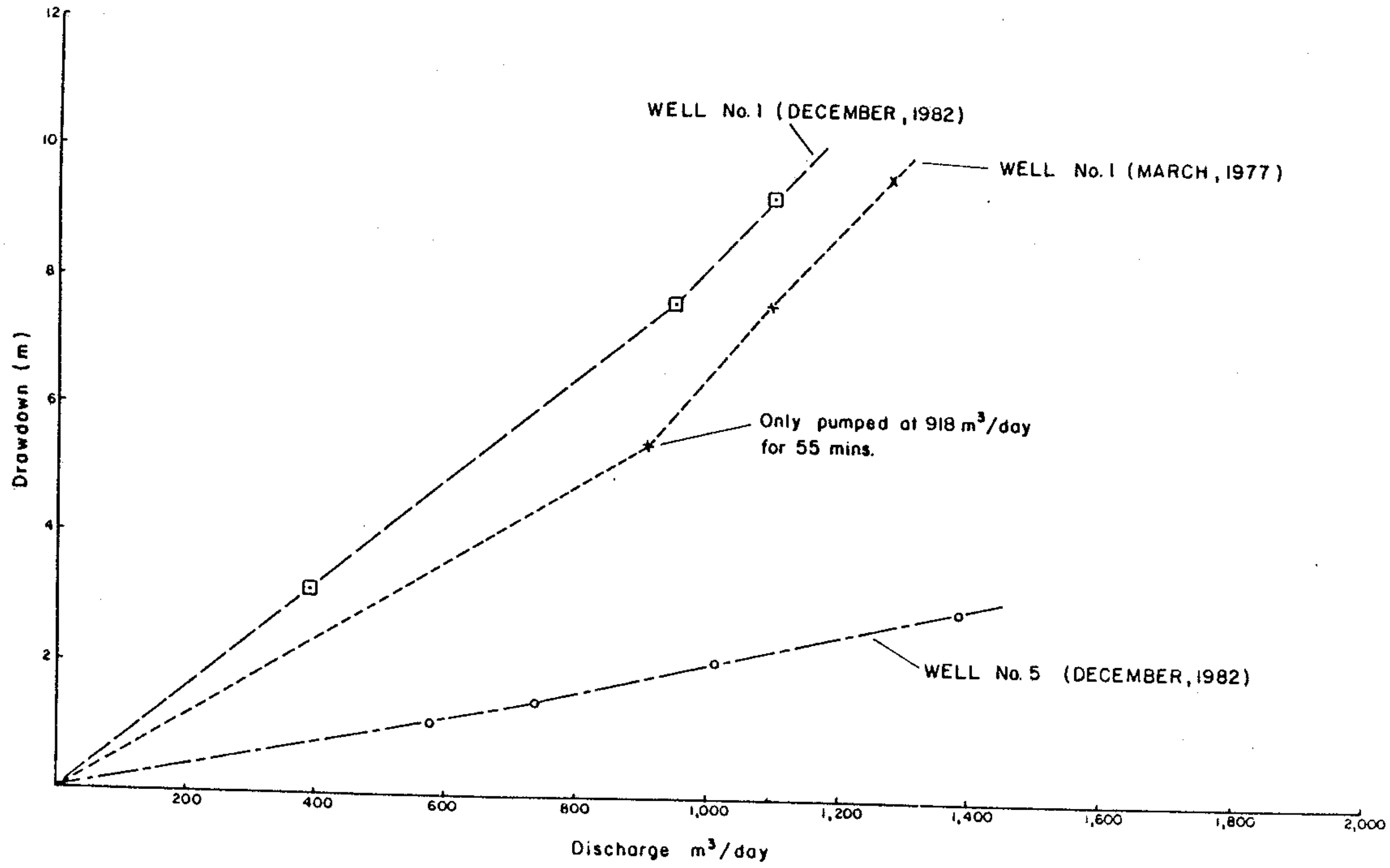


Fig. 12. DISCHARGE Vs DRAWDOWN FOR WELL Nos. 1 and 5, ARDTULLY BEG, Co. LOUTH.

		Date	Pump	Duration	Previous Rate (G.P.H.)	Pumping Rate (G.P.H.)	Pumping Rate (M^3/Day)	Drawdown @ End of Step (M)	Specific Capacity M^3/Day/M
Well No.1	Well No.1	7-12-82 Steptest Well No.1	Monolift	105 Mins	0	3,600	393	3.2	122.8
			"	105 Mins	3,600	8,740	953	7.67	124.3
			"	87 Mins	8,740	10,060	1,097	9.28	118.2
Well No.1	Well No.1	16- 3-77	4" Submersible	50 Mins	0	8,400	916	5.54	165.3
		Well No.1	"	1,315 Mins	8,400	10,000	1,091	7.68	142.1
		17- 3-77 Well No.1	"	330 Mins	10,000 For 960 Mins	11,750	1,282	9.64	133
Well No.5	Well No.5	13-12-82 Steptest Well No.5	Monolift	105 Mins	0	5,320	580	1.14	508.7
			"	157 Mins	5,320	6,780	739.6	1.47	503.1
			"	90 Mins	6,780	9,743	1,063	2.17	490
			"	90 Mins	9,743	12,694	1,384	2.94	471

TABLE 2: A comparision of the results from the step-tests carried out at Ardtully Beg

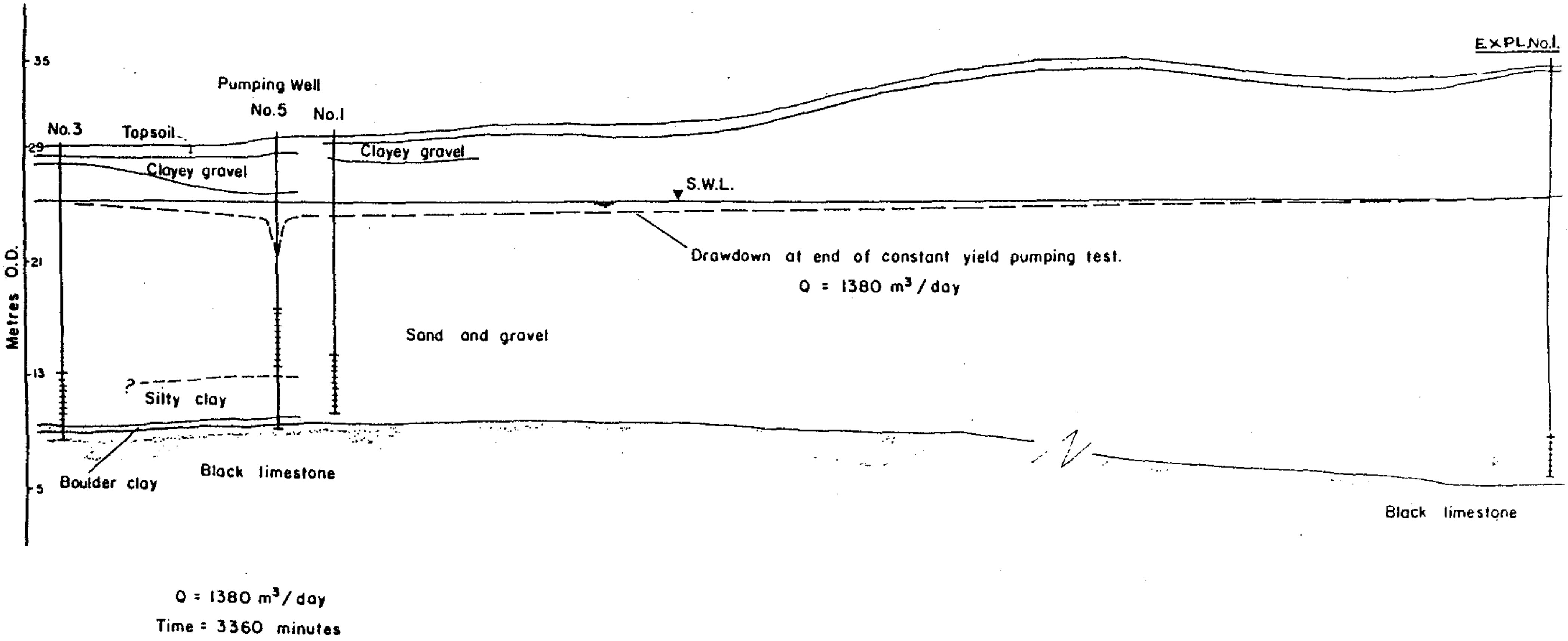


Fig.13. CONE OF DEPRESSION AT END OF CONSTANT YIELD PUMPING TEST OF WELL No. 5, ARDTULLY BEG, Co. LOUTH.

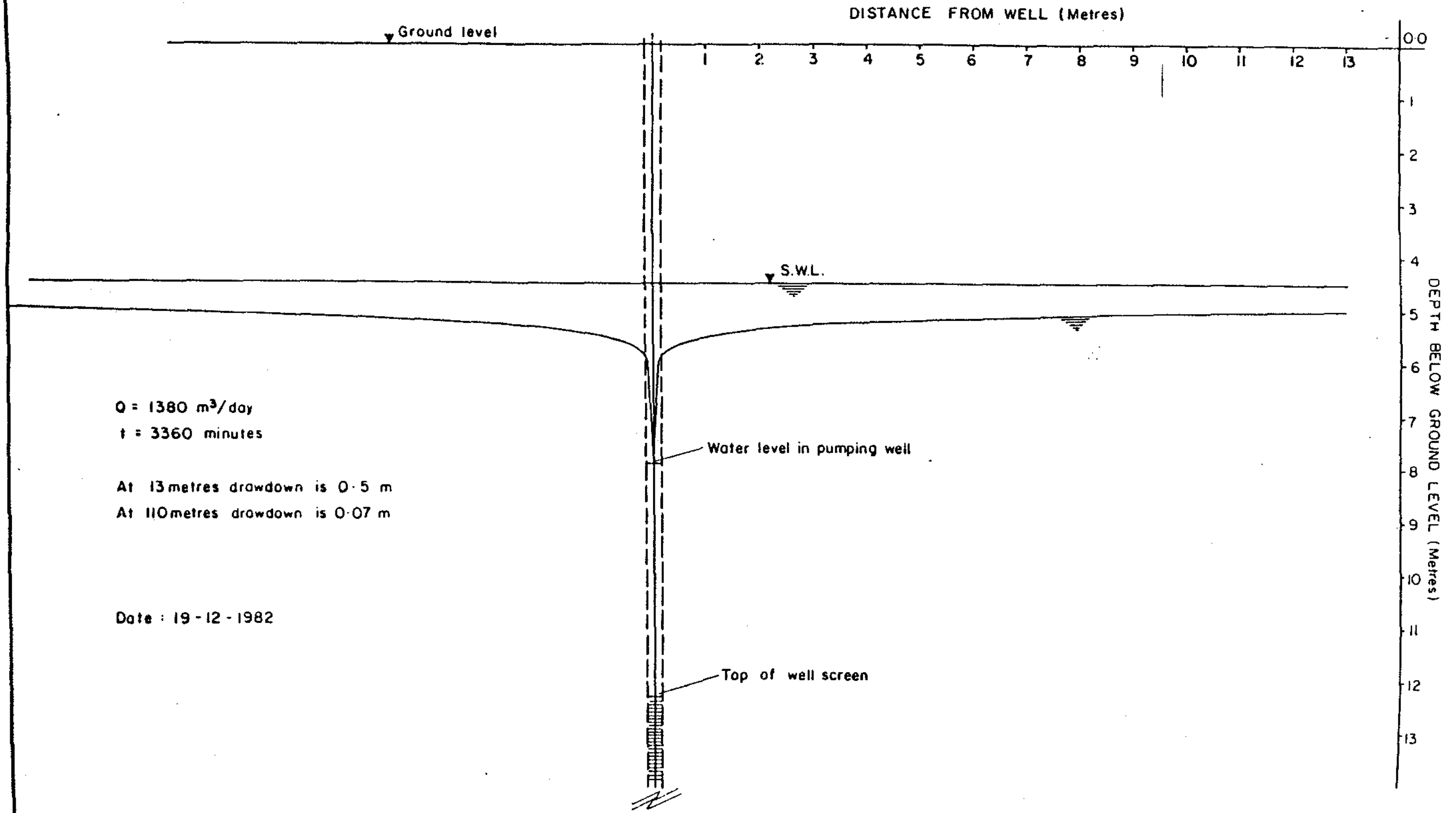


Fig.17. CONE OF DEPRESSION IN REGION OF PUMPING WELL No.5, ARDTULLY BEG, AT END OF CONSTANT YIELD DRAWDOWN TEST.

Well No.	Date Drilled	Depth (m)	Finished Diameter (mm)	Depth to Top of Screen (m)	Depth to Bottom of Screen (m)	Slot Size	Formation Stabilizer	Screen Packer	Tailpiece Length	Depth to Bottom of Tailpiece	Casing Material	Status
1	1977	20.62	250 mm	14.82	20.32	1 mm	None	Lead	-	-	Steel	In Production
2	Nov 1981	21.2	-	-	-	-	None	-	-	-	Steel	Abandoned
3	Mar 1982	20.68	250 mm	16.18	20.68	0.5 mm	None	Lead	-	-	Steel	Observation Well
4	Aug 1982	21.8	-	-	-	-	Yes		-	-	-	Abandoned
5	Oct 1982	20.7	200 mm	12.3	16.5	1 mm	Yes	Weld	4.0 m	20.7	Steel	To be Commissioned
Exp No.1	Jan 1975	30.5	100 mm	-	-	Slotted P.V.C.	None	-	-	-	P.V.C.	Observation Well
Exp No.2	Jan 1975	20.5	100 mm	-	-	Slotted P.V.C.	None	-	-	-	P.V.C.	Observation Well

TABLE 1: DETAILS OF THE TRIAL AND PRODUCTION WELLS DRILLED AT ARDTULLY BEG, CO. LOUTH.

Table 4:- Projected Pumping Levels in Well No.1 & 5 during the Winter and Summer Seasons.

Pumping Rate		Well No.1 Drawdown (m)		Well No.5 Drawdown (m)	
m^3/day	g.p.h.	Winter	Summer	Winter	Summer
818	(7,500)	—	7·1	—	—
1091	(10,000)	8·3	Excessive	2·6	3·1
1636	(15,000)	Excessive	Excessive	4·2	5·2
2182	(20,000)	Excessive	Excessive	6·2	Excessive

4th April 1984

HEALTH ASPECTS OF GROUND WATER QUALITY

F. Hill

Dublin Region Public Analyst

WATER BORNE DISEASE

In Autumn 1854 Dr. John Snow inferred that the vehicle of infection for the cholera outbreak which caused 616 deaths in the vicinity of the Broad Street Pump, London was the water from the pump. Water intake for the pump was from the faecally polluted Thames, at Battersea Fields. Snow based his inference on several incidents. A lady living in Hampstead had a predilection for the water from the pump and on Thursday, 31st August, 1854 a bottle of it was brought out to Hampstead and consumed by the lady on Thursday evening and also on Friday. She came down with cholera on the Friday evening and died on the Saturday. The lady's niece who was on a visit to Hampstead also drank of the water. She returned to Islington, was attacked with cholera and died. The gentleman in "delicate health" from Brighton arrived at 9 Poland Street adjacent to Broad Street to attend the obsequies of his brother who died from cholera. The gentleman was offered a piece of rump steak and a small tumbler of brandy and a glass of water from the Broad Street pump. Having consumed them he left for Pentonville. Next day he himself was struck down with cholera and died.

Snow noticed that none of the several brewery workers from the brewery adjacent to Broad Street came down with cholera. The brewery had its own well, the water from which was consumed by the men. Snow had the handle of the Broad Street pump removed and the epidemic waned.

DR. BUDD

In the late 1850's Dr. William Budd, a west country doctor observed that households scattered at random over the length of Clifton Terrace in Bristol in which cases of typhoid fever occured all had in common a factor that did not apply to the households that escaped, namely that

/...

they used water from a well at one end of the terrace that was known to become polluted with sewage after rain. Budd considered that the polluted well water was the cause of the typhoid outbreak. So back in the 1850's we have typhoid and cholera recognised as being water borne, a generation before the causal agents had been identified in the laboratory and long before the era of bacteriology had arrived. We now know that in addition to typhoid and cholera, bacillary dysentry, hepatitis A, virus gastroenteritis and poliomyelitis are also water borne. Hepatitis A virus is resistant to chlorine.

Dublin
Gastroent 1346 1978

In addition to viral gastroenteritis, all types of salmonella bacteria and pathogenic E.coli (in particular for children) can give rise to gastroenteritis.

<u>ADENO VIRUSES AND ENTERO VIRUSES</u>

The adeno viruses and the E.C.H.O viruses and the coxsackie viruses are present in sewage but have not been incriminated in outbreaks of disease due to water. All 3 are vulnerable to chlorine. Enteroviruses have been isolated from ground waters and it is clear that they are capable of moving through various aquifers.

It is now not always realised that the unhygienic sanitary conditions before the turn of the century were responsible for wisespread illness and death. The classic trio of bacterial water borne diseases are cholera, Enteric fever (typhoid and paratyphoid) and bacterial dysentry. The presence in sewage of the causative organisms of these diseases, namely vibrio cholera, salmonella species, and shigella sonnei is a consequence of these diseases in the community. Cholera is no longer endemic in developed countries and the last outbreak in the U.K. occured in 1893 causing 137 deaths. Cholera is endemic in Bengal and where it sporadically spreads to other regions of the world. The Public Health Act 1878 placed an obligation on Local Authorities to supply a pure and wholesome water to consumers. Wholesome in this context means not prejudicial to health.

Mortality from typhoid fever had already begun to fall sharply with the development of water purification methods in the second half of the nineteenth century. When the coliform group of bacteria was shown to be present in large numbers in sewage the early water bacteriologists published several papers aimed at trying to differentiate more precisely the coliform organisms particularly associated with excreta and those found

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in other situations. Sir Alexander Houston and no doubt others showed that a quantitative coliform test could discriminate between wells known to have caused enteric fever and ones that had not. Only when Wilson and Blair devised a good selective medium for the typhoid bacillus in the late 1920's did it become clear that the ratio of coliform organisms to pathogenic organisms in sewage was of the order of half a million to one. Given this and the fact that water purification procedures can virtually eliminate coliform organisms from raw water it is not surprising that a water with no coliform organisms is highly unlikely to cause typhoid, cholera or dysentry the classic triad of water borne microbial diseases.

E. COLI I

With the discovery of the colon bacillus (E. Coli I) by Escherich in 1885 it became clear that organisms characteristic of sewage must be identified to provide evidence of potentially dangerous pollution. This concept is still the main criterion by which routine waters are judged to be hygienically acceptable or not. Internationally if E. Coli I is found to be present in a water supply the water is automatically condemned.

Hence, E. Coli I is used as an indicator organism. It is invariably present in human excreta and to a lesser extent in the excreta of animals and birds. E. Coli I is present in numbers up to 5 X 10^8 per gram of human faeces. It is not as resistant as most pathogenic enterobacteriaceaeandtherefore might die out while pathogens would still be living. Natural die off of bacteria is extremely important and figures quoted for E. Coli I in clear sea water at 20^oC quote a 90% die off rate in 4 hours in day light to a 90% die off rate in 10 hours at night.

SIGNIFICANCE OF E. COLI I IN GROUND WATER

When E. Coli I is found in ground water we can short list the possible causes as (1) septic tanks located where the effluent can readily and rapidly flow away in the rock cracks or (2) the usage of cesspits rather than proper soak way systems such as porous pipes in a herring-bone system to disperse the septic tank effluent or (3) manures stored in farmyards or (4) farmyard run-off or (5) leaky sewers in urban areas. International standards for drinking water automatically would demand that the presence of E. Coli I in ground water deem the water to be unfit for human consumption. In effect the presence really means that

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we are increasing the risk of contacting a communicable disease transmitted by water. But the disease causing organisms would have to be present in the water. In Ireland hepatitis A causes most concern.

Significance of E. Coli I in Swimming Waters such as Dublin Bay

No satisfactory evidence linking the rise of a communicable disease with the degree of sewage contamination of coastal or other bathing waters has up to the present time being found and consequently microbial standards for bathing water are irrelevent to the public health. Nevertheless, the EEC Bathing Water Directive gives a mandatory value of 2,000 E. Coli I per 100 millilitres of water for bathing waters. This was a logical corollary to the philosophy already laid down in the programme of action of the European Communities on the Environment, a basic axiom of which was that the quality objectives were to be set for all aspects of the environment including water. What was required of the experts therefore, was an agreement on numerical standards rather than on public health. While the EEC bathing directive figure of 2,000 will have legal status in 1985 it has no public health significance and is best regarded as an administrative guideline concerned with quality recreational waters. It is not a predictor of the chances of getting disease from swimming in sewage polluted waters. Having regard to this administrative guideline of 2,000 there is a temptation to suggest when that figure is grossly exceeded as happens in some parts of Dublin Bay that there is a significant risk for swimmers. This suggestion is grossly unfair and frightening to members of the ordinary public who are inclined to believe the newspaper headlines for example "Swimming in Dublin Bay a Health Risk", says expert, Irish Times, 24th March 1984.

BRADFORD HILL'S CRITERIA

Bradford Hill who played a notable part in establishing a causal link between cigarette smoking and lung cancer lists nine criteria that epidimiologists should apply to the scrutiny of apparent associations between environmental agents and disease before concluding that the relationship is one of cause and effect.

In order to establish a cause and effect relationship between swimming at the Bull Wall and a particular communicable disease two procedures must be adopted. Firstly a statistically significant association between

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swimming at the Bull Wall and the occurence of the disease in question must be demonstrated. Statistically, significant associations are not necessarily cause and effect sequences. They must be further scrutinized before they are accepted as such.

A further study of the association such as taking into account the nine different viewpoints of Bradford Hill must be undertaken before we can claim causation. Hill's nine criteria for judging whether an environmental pollutant is causing disease are briefly indicated here.

An association between a polluted environment and a communicable disease is more likely to be deemed one of cause and effect if the association is strong. Next on Hill's list is the constitency of the observed association. Has it been repeatedly observed by different persons in different places, circumstances and times?. The third criterion is specificity which we have when the disease is not associated with other environments or the particular kind of polluted environment with other communicable diseases. The fourth criterion is temporality. In the context of swimming in sewage effluent polluted water the interval between exposure and the onset of disease should correspond to a known incubation period. Fifthly has the association a dose response curve showing an increasing incidence of the disease with increasing swimming at the Bull Wall. Sixthly the suspected causation should be biologically plausible or (7) at least not in conflict with other knowledge of the natural history and biology of the disease in question. The eight criterion appeals to experimental evidence as when the cause and effect relationship has been supported by experiment e.g. when swimming at the Bull Wall is discontinued and there is a dramatic fall off in the incidence of the disease. The removal of the handle of the Broad St. pump by John Snow and the decline of the cholera outbreak is a classic illustration of the point. Hill's ninth criterion is a fair analogy with some parallel context.

Hill points out that none of the 9 viewpoints can bring indisputable evidence for or against the cause and effect hypothesis and none can be required as a sine qua non. What they can do, with greater or less strength, is to help up to make up our minds on the fundamental question - Is there any other answerequally or more likely than cause and effect?

/...

W.H.O REPORT

A W.H.O. Working Group on Quality of Beaches and Coastal Water in 1974 concluded that potential health risks do exist in connection with bathing or swimming in polluted coastal waters. The degree of health hazards may vary from one area to another according to factors such as climate, tidal and coastal current characteristics and the local epidemiological situation. Compared with other possible hazards, however, such as sunburn, heat stroke or food poisoning, especially that due to the consumption of raw sea foods, the risk of contracting communicable diseases from bathing is limited so far as present epidemiological evidence goes.

The isolation of a pathogen from a polluted site cannot be deemed a health risk unless a quanititative relationship between exposure to the environment that contains it and the incidence of the corresponding disease has already been established.

WORK OF CABELLI ET AL

Cabelli et al in the Americal Journal of Public Health Volume 69, 1979, 690 studied swimmers at a "Barely acceptable " (BA) beach (a Coney Island beach) and at a "relatively unpolluted " (RU) beach (Rockaways). The rate of gastrointestinal symptoms was significantly higher among swimmers relative to non swimmers at the BA but not at the RU beach. A dose response type relationship of swimmers associated gastro intestinal symptomatology was not demonstrated.

GROUND WATER QUALITY AND CARDIOVASCULAR DISEASE

In the United Kingdom it has been established that there is an inverse relationship between cardiovascular mortality and water hardness. In Britain the softest water supplies are in Scotland, Northern England and Wales and the hardest in East Anglia and Southern England. There tends to be a North to South East gradient. Mortality from cardiovascular disease (heart disease and stroke) tends to follow the same pattern and several statistical studies have demonstrated an inverse relationship between cardiovascular disease and water hardness.

For 253 towns in England, Wales and Scotland having a population greater than 50,000 there is a highly significant inverse relationship between the hardness of drinking water and mortality from cardio-vascular disease. The relationship persists when age, sex, socioeconomic and climatic effects are taken into account and is not shown for mortality from non cardiovascular diseases. On average very soft waters towns have about 10% higher cardiovascular mortality than medium hard or harder water towns after adjustment for socioeconomic and climatic factors. There is however, considerable scatter in the data. The relationship also appears to be nonlinear in that most of the variation in mortality appears to take place at the soft end of the hardness range. It is concluded that cardiovascular disease is influenced by water hardness or by some factor closely associated with water hardness. This could be either a harmful factor in soft water or protective factor in hard water.

Studies carried out in Japan and the United States also show that mortality from cardiovascular disease seems to be higher in soft water areas. It has been shown that in situations where the hardness of water supplies has changed, there is a corresponding change in the cardiovascular disease mortality rate at least for men. The size of the water factor is small in comparison with other cardiovascular disease risk factors e.g. heavy smoking doubles the risk of a CVD event while very soft water increases it by 10%. The present situation does not warrant such drastic unwelcome costly and barely practical action as the hardening of soft water supplies.

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NITRATES IN GROUND WATER

In the last decade fears that the use of fertilizer nitrogen on the farm is contributing considerably to nitrate pollution of ground water have increased. There has been a progressive increase in nitrate concentrations in the Rhine, in Europe and in the Rivers Lee, Thames, Stour, Great Ouse, and Frome in the United Kingdom. The current situation regarding nitrate concentrations in ground water seems to be comparable with the surface water situation that is an upward trend - certainly in parts of the continent and the United Kingdom. Viets and Hageman in 1971 (U.S. Department of Agriculture Handbook No 413) drew attention to the seriousness of the problem. "The rate of water re-charge from deep percolation is so slow that possible nitrate pollution of aquifers from our modern technology will take decades. However, once nitrate gets into the aquifer, decades will be required to replace the water with low nitrate water. Fifty to one hundred years might be required to establish a time trend. By the time the trend was established a dangerous situation could be in the making that could not be corrected in a time shorter than it took to create it".

Large amounts of nitrogen are leached from the soil on ploughing but it is not possible to distinguish with certainty the relative importance of fertilizers and ploughing in enhancing nitrate leaching.

NITRATE IN DRINKING WATER

The present concern about high concentrations of nitrate and nitrite in drinking waters (and in food) arises because of evidence that the sustained ingestion of high concentrations of nitrate or nitrite can exceptionally lead to the medical condition known as methaemoglobinaemia and also to the production of nitrosamines, which are known animal carcinogens. Nitrates are relatively non toxic, probably because they are rapidly absorbed and excreted by the body; toxicity in general results only when the nitrate is converted to nitrite.

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METHAEMOGLOBINAEMIA

Methaemoglobinaemia first recognised in 1945 is a condition whereby in the presence of high concentrations of nitrite the Ferrous iron of blood is oxidised to feric iron giving rise to methaemoglobin, which is inefficient in reversibly binding oxygen and this in cycling it from the lungs through the body. Cyanosis occurs if more than 5% of the haemoglobin is converted to methaemoglobin; at 30-40% conversion hypoxia sets in; methaemoglobin concentrations greater than 50% are generally fatal. Infants, especially during the first three months of life are particularly suspectible to methaemoglobinaemia for at least four reasons:-

(1) Foetal haemoglobin (haemoglobin F) which persists in the blood stream of babies for some time is particularly suspectible to oxidation to methaemoglobin by nitrite.

(2) The poorly developed capacity to secrete gastric acids allows bacteria which reduce nitrate to nitrite to develop in the gastro-intestinal track of infants.

(3) The red blood cells of infants show reduced activity of an enzyme (NADPH dependant methaemoglobin reductase) which reduces the concentration of methaemoglobin in the blood.

(4) The total food intake for body weight of an infant is about three times that of an adult. Most recorded cases of methaemoglobin have been caused by feeding infants milk formulations which were prepared with water rich in nitrates.

The largest proportion of ingested nitrates and nitrite comes from the ingestion of foodstuffs, including foods where nitrate or nitrite has been added as a preservative, or Vegetables supplied with high concentrations of fertilizer nitrogen or manure. Only when nitrate levels in drinking water are above the WHO recommended limit for 50 milligrams of nitrate per litre (equals 11.3 milligrams per nitrate nitrogen per litre) is nitrate in potable water likely to make up more than 50% of the total nitrate ingested. Mathaemoglobinaemia appears to be an extremely rare condition within the United Kingdom with only ten cases having been reported in the past thirty years. In 1976 when nitrite concentrations in some water supplies in the U.K. were between 60 and 100 milligrams per litre, doctors were specifically asked to look for symptoms of methaemoglobinaemia but none was identified.

No case in Ireland.

10 cases in UK

/...

The levels of nitrates in some Irish waters as determined in the Public Analyst's laboratory in Dublin are shown in Table 1.
Daly and Daly of the Geological Survey in their recent study of ground water in the Barrow Valley concluded that the water in general is of good quality but that there are many contaminated ground water sources showing high nitrates. They consider that the main sources of nitrate causing contamination are farmyards, septic tanks, and sources in urban areas and that artificial fertilizer is not the main source of nitrate in contaminated wells. They consider that it may have added to the background nitrate levels but that it is not a significant problem at the moment. This conclusion is based on a combination of factors (1) the nitrate levels are varied and scattered randomly throughout the area, (2) the obvious point pollution sources are located close to many wells with high nitrates, (3) many of the wells with high nitrates are located in urban areas where fertilizer is unlikely to be the source and leaky sewers may be the culprits.

NITROSAMINES

Nitrosamines are powerful carcinogens in a wide variety of animal species and it is probable that at high enough concentrations there will also be carcinogenic in humans. However, as the Royal Commission on Environmental Pollution has emphasised there is no direct evidence that N-nitroso compounds or there precursors cause human cancer.
Chronic ingestion of nitrate may result in the production of nitrite which then reacts with amines to produce nitrosamines.
Nitrosamines may be formed in vivo in the stomach (as a result of acid catalysed reactions or by bacteriological activity at physiological pH), in the bladder (where bacterial infection may facilitate nitrosamines formation) and in the saliva of smokers. The content of both nitrates and nitrite in saliva have been shown to increase with increase in nitrate ingested in food. The average per capita weekly intake of nitrates in food and water in the U.K. is as follows:- meat products 37 milligrams, milk 87 milligrams, cheese 50 milligrams, vegetables 224 milligrams, potatoes 60 milligrams, water 105 milligrams.

not too signif. until WHO limit.

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HYDROGEN SULPHIDE (H_2S)

Traces of hydrogen sulphide may be found in good quality drinking water especially in districts on boulder clay. These traces can be produced by reduction of sulphates by bacteria in wells, lakes, bogs and reservoirs. The gas is not uncommon in water from aluminium containing organic matter and in which particles of iron pyrites are embedded. In interpreting such results attention should be paid to nitrogenous contamination and bacteriological examination. The Drinking Water Directive demands that hydrogen sulphide should not be detectable organoleptically. Rodier (Analysis of Water) specifies a limiting concentration of 0.05 milligrams of H_2S per litre. Sulphuretted hydrogen may be removed from a water by aeration, allowing the water to stand or by boiling it off. It should be remembered that hydrogen sulphide is a poisonous substance though not at the levels found in waters from boreholes.

IRON IN WATER

Surface waters may contain up to 0.5 parts per million of iron which may originate from leaching of the terrain treversed or from industrial contamination. Iron is often largely present in gravels, sands, chalk, limestone and sandstone. It may be present in levels of up to 10 ppm in waters from boreholes. Mineral waters especially thermo-mineral waters may contain more than 10 ppm.

Ferrous iron is quiet soluble in water and precipitates immediately after removal of carbon dioxide and oxidation by air. It may exist in solution, in the colloidal state and in the form of organic or inorganic complexes especially if polyphosphates are used in water treatment. Iron in water presents no in convenience from the physiological point of view. However, it gives an unpleasant astringent taste and the turbid aspects and red colour imparted to the water by iron are repellent to the consumer. Ferrugious waters also have the disadvantage that they stain laundry. Finally certain bacteria require large amounts of iron. These iron bacteria become attached to pipe walls and lead to corrosion accompanied by the formation of hard bulky concretions. The maximum permissible concentration of iron may be taken as 0.2 ppm (Drinking Water Directive). One part per million imparts a taste. To distinguish iron in well waters from that contributed by the liner samples taken at ½ hourly intervals during vigorous pumping will show a decrease in iron level if the contamination is derived from the liner.

MANGANESE IN GROUND WATER

The Drinking Water Directive gives 50 micrograms per litre as the maximum acceptable concentration of manganese. Manganese of different valencies may be found in water in the form of solutions, suspensions or complexes. Some underground waters contains amounts of the order of 1ppm. If we consider the amounts of manganese ingested every day with food the manganese in the water content cannot be considered toxic. It may however, impart an unpleasant taste in water and the appearance of manganese precipitates in water is not very attractive. Black manganese dioxide may appear in pipes particularly on the borders of Kildare and Carlow. In the home it is found to stain enamel and laundry even if present in very small amounts 0.1 ppm. In water treatment plants is stimulates the growth of aerobacter. These interfere with the action of sandfilters and may result in the formation of deposits in pipes. The element may however, be utilized in its pentavalent state as permanganate to eliminate organic matter by objectionable tastes.

Ingest from water 0.01 mg per day / person.

SULPHATES IN WATER

The Drinking Water Directive gives a maximum admissible concentration of 250 ppm of sulphate ion in water. Levels above this may lead to gastro-intestinal irritation.

SILAGE MAKING

The expansion in silage making (6 million tons in 1975) has added a new dimension to the farm waste disposal problem particularly when silos are sited in the catchment of lakes or near water sources particularly in flat country where streams and rivers are slow moving. Silage effluent is a very strong polluting agent with BOD of about 54,000 milligram per litre. It is 200 times more potent than domestic sewage. Ground or spring, water contaminated by such waste may become completely unsuitable for any purpose. One ton of silage has about 40 gallons of effluent.

In the Public Analyst's Laboratory, we are able to detect less than 1 part per million of silage effluent in the contaminated water supply. We do this by using the technique of Gas Liquid Chromatography and detecting the seven marker acids from silage effluent, - acetic acid, propionic acid, isobutyric acid, n-butyric acid, iosvaleric acid, n-valeric acid, and caproic acid. A litre of the sample of water is acidified with sulphuric acid and extracted into ether. The ether extract is made alkaline with caustic soda and the residue after evaporation is acidified to give the free acids which are injected into the gas chromatograph. The presence of organoleptically detectable quantities of silage effluent in water automatically leads to consumer rejection on aesthetic grounds.

The silage pit should have a natural or synthetic impermeable base and adequate collection and storage systems for the effluent should be installed.

Contains fatty acids - gives v. bad odour.

Conclusions

About 25% of our total water supply in Ireland is from ground water. It is the main source of supply for the food processing industry and for domestic supplies outside the urban areas.

As it is an important resource every effort should be made to protect it from contamination.

TABLE 1

****

Nitrate Nitrogen in 373 samples

January - May 1983

Taken: - Leinster Monaghan Cavan

	LOW	MEDIUM	HIGH
	3ppm	3-6 ppm	6 ppm
NO	283	56	34
%	76	15	9

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Groundwater Development

at

Kinvarra

for

Galway County Council

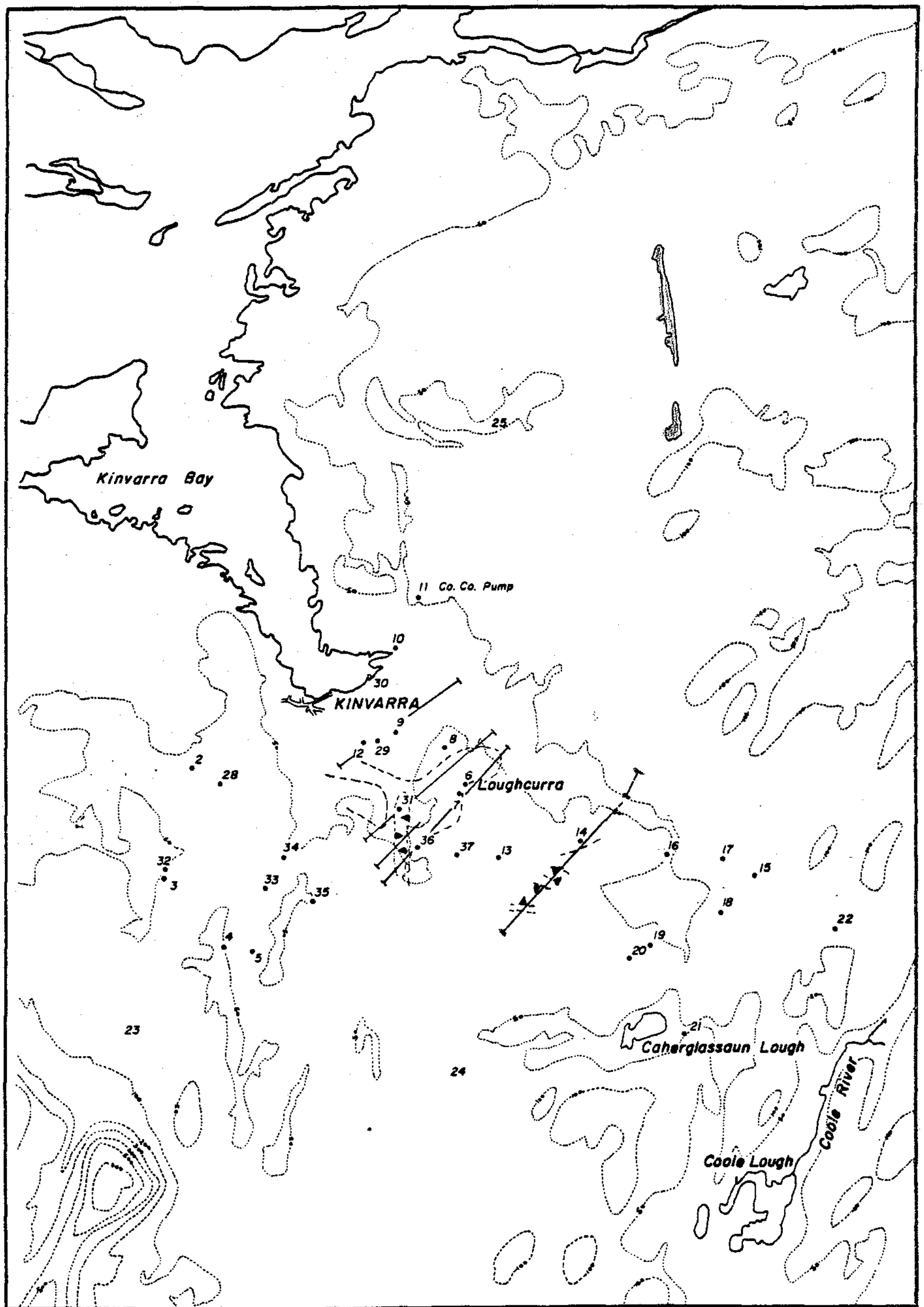
A recent groundwater development project on behalf of Galway County Council at Kinvarra located and developed a major groundwater source in a karst limestone environment.

Kinvarra lies on the western edge of a large area of lowland karst, where extensive areas of exposed limestone bedrock, disappearing rivers and turloughs replace the normal surface drainage network. Kinvarra Town and its environs obtain their fresh water supply from a water well located near the coast about one kilometre to the north east of the town. Unfortunately, this supply is prone to contamination by salt water due to its close proximity to the coast and the karst nature of the host limestone aquifer.

In 1982 the County Council commissioned a hydrogeological investigation of the Kinvarra area which consisted of geological mapping, data compilation and an extensive resistivity survey. The geophysical results identified areas of low resistivity 1.5 Kms south east of Kinvarra and these were chosen for testing by trial wells, one of which at Loughcurra South was completed in the Autumn of 1983.

The drilling results from Loughcurra South indicated that the area was underlain by limestones which contained two distinct and separate karst systems, separated by some 70 m. of unfractured and unweathered limestone. Both karst systems are capable of supplying large volumes of groundwater in the Winter months while in the drier Summer period only the deeper karst system would offer a secure water supply. Also, the shallow network of caverns respond to recent rainfall and so are very prone to contamination. The deeper aquifer contains groundwater which is much more mineralised than the shallower aquifer indicating that this water has a greater residence time and therefore not so vulnerable to contamination.

The results of this groundwater project has located and developed a groundwater source for Kinvarra Town capable of a supply in excess of 250,000 gal./day. Proper control and management of this resource will insure that Kinvarra can develop its tourist industry in the knowledge that it can offer its visitors an ample supply of potable water.



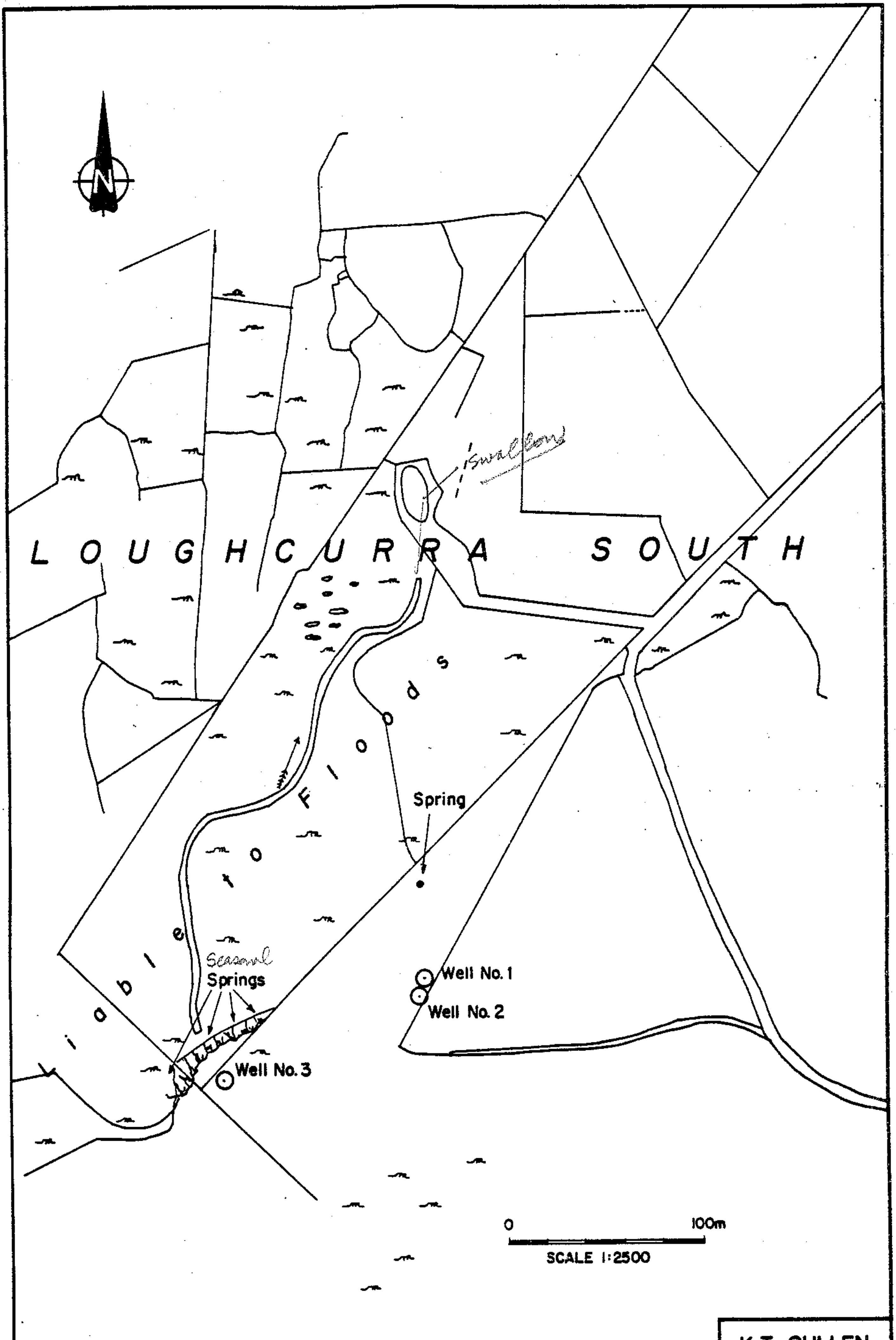
0 1 2 Miles
0 1 2 3 Kilometers
1 inch = 1 Mile

3 weeks 1 x 1½ miles } Resistivity
£3000 survey

Low Marcas successful.

Location map

VLF also useful. - 10 times quicker



LOCATION MAP.

K.T. CULLEN

REMARKS

COMPLETED WELL DESIGN

TRIAL WELL No. 1

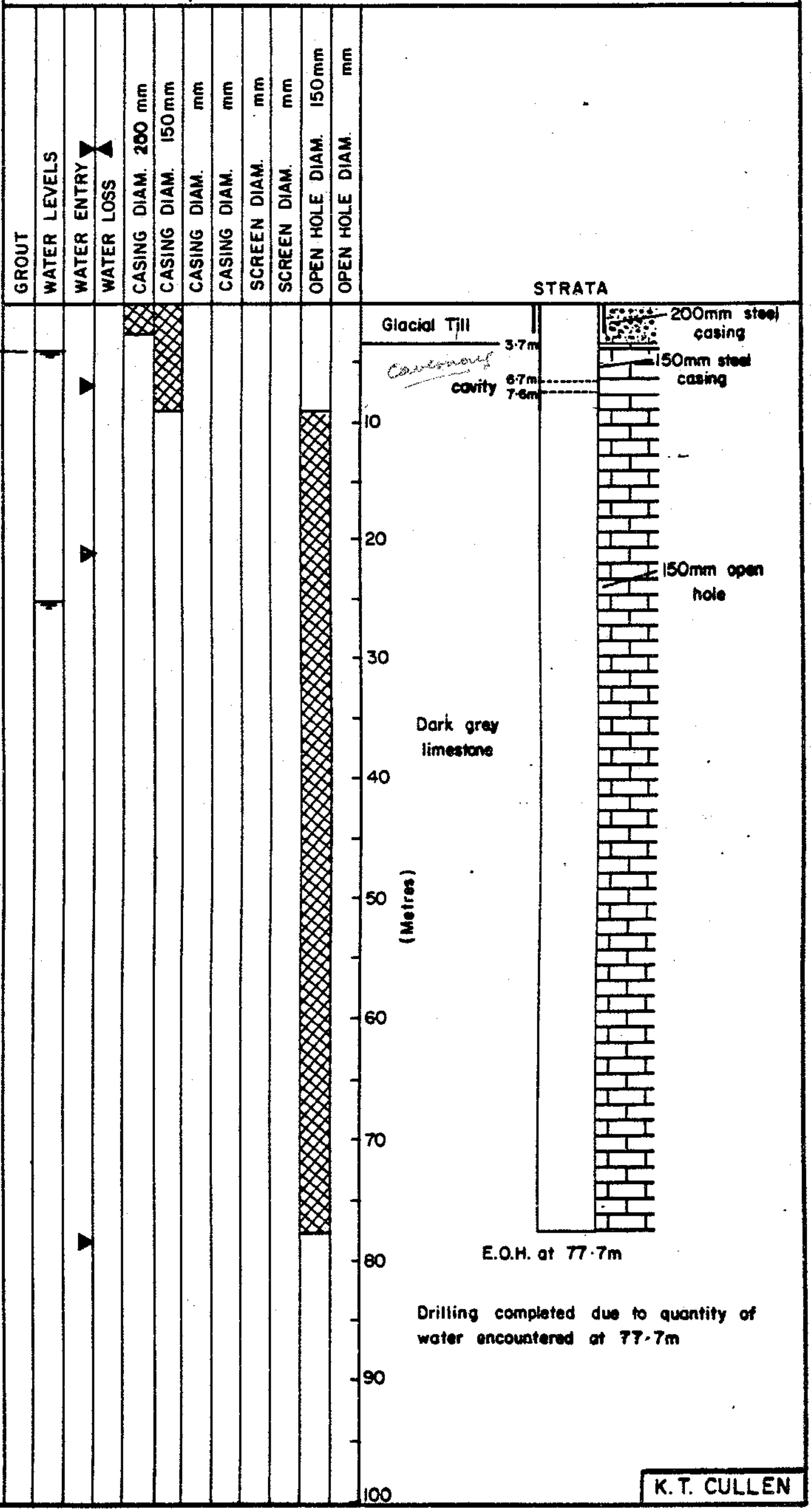
CLIENT: Galway County Council
LOCATION: Kinvara, Co. Galway
DATE: October, 1983

AQUIFER: Lower Carboniferous Limestone
OUTPUT: 740 m³/day
LOGGED BY: K. T. Cullen

S.W.L.

Water Level after 72 hours pumping at 740m³/day

fissure system.



K.T. CULLEN

REMARKS	COMPLETED WELL DESIGN	TRIAL WELL No. 2

CLIENT : Galway County Council

LOCATION : Kinvara , Co. Galway

DATE : October , 1983

AQUIFER : Lower Carboniferous Limestone

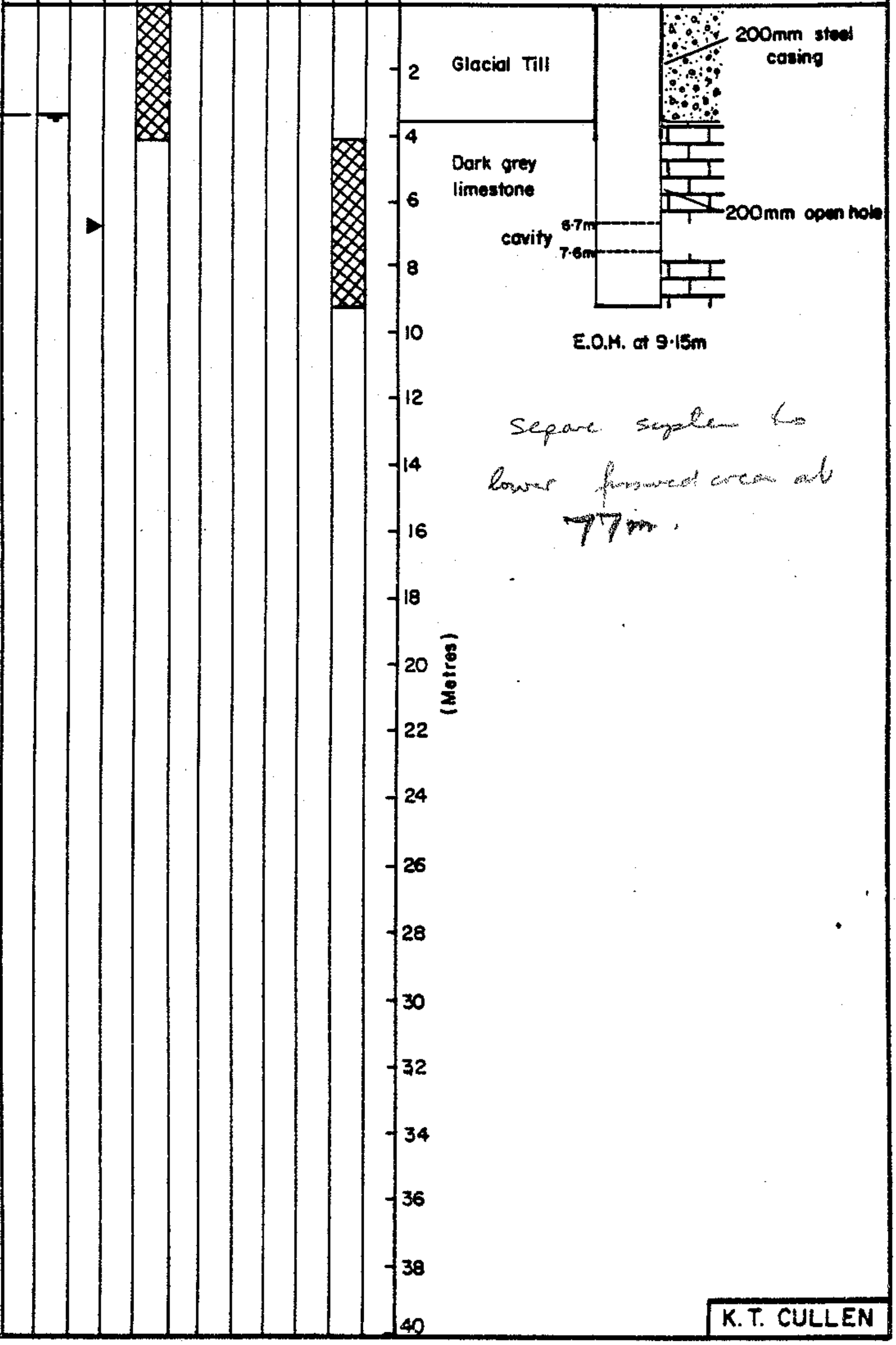
LOGGED BY : K.T. Cullen

GROUT	WATER LEVELS	WATER ENTRY ▶	WATER LOSS ◀	CASING DIAM. 200 mm	CASING DIAM. mm	CASING DIAM. mm	CASING DIAM. mm	SCREEN DIAM. mm	SCREEN DIAM. mm	OPEN HOLE DIAM. 200 mm	OPEN HOLE DIAM. mm	STRATA

OBSERVATION WELL

S.W.L.

Note : Water level fluctuates with tidal movements.



E.O.H. at 9·15m

Separate sample to lower fissured area at 7.7m.

K.T. CULLEN

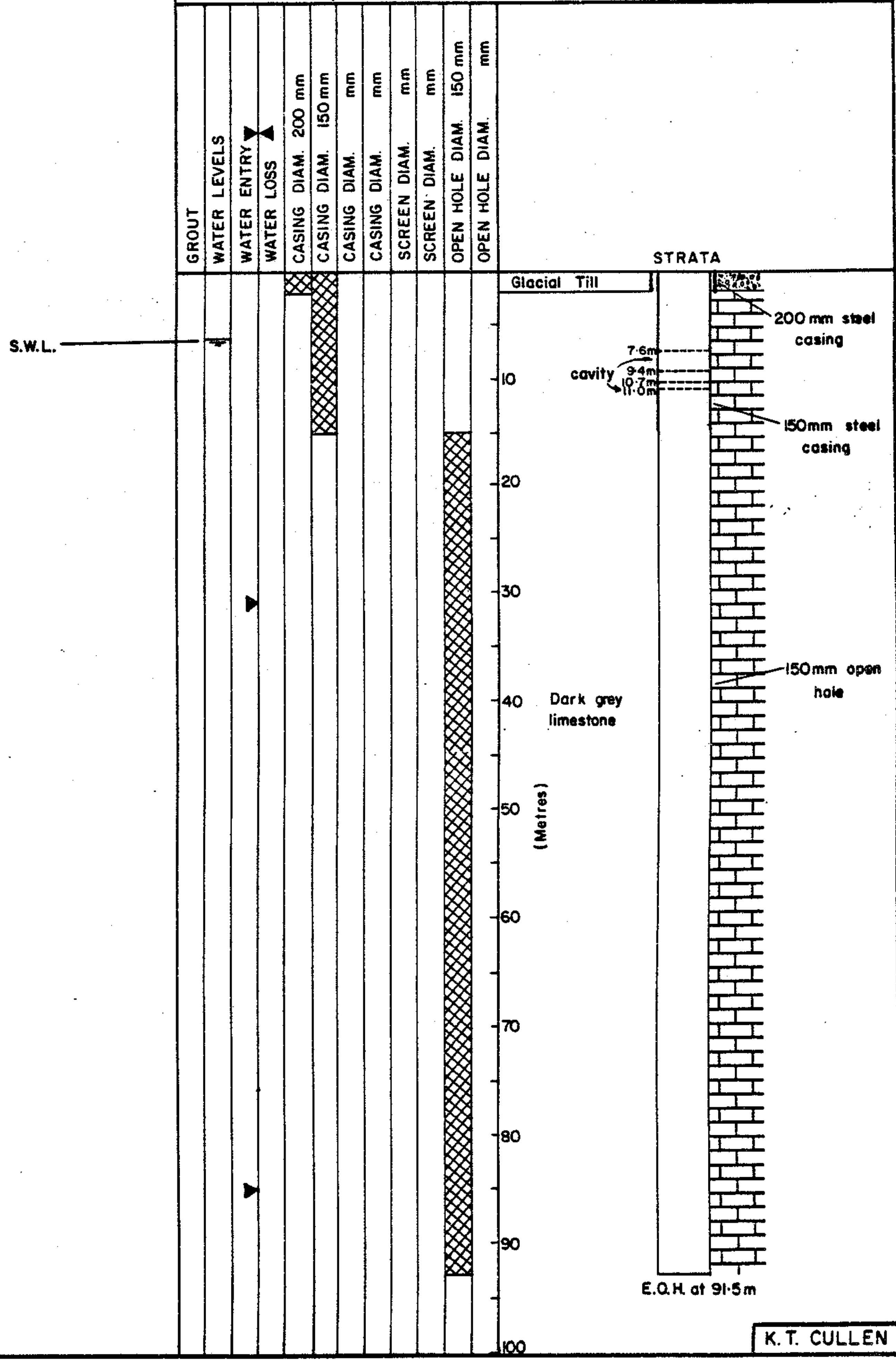
REMARKS

COMPLETED WELL DESIGN

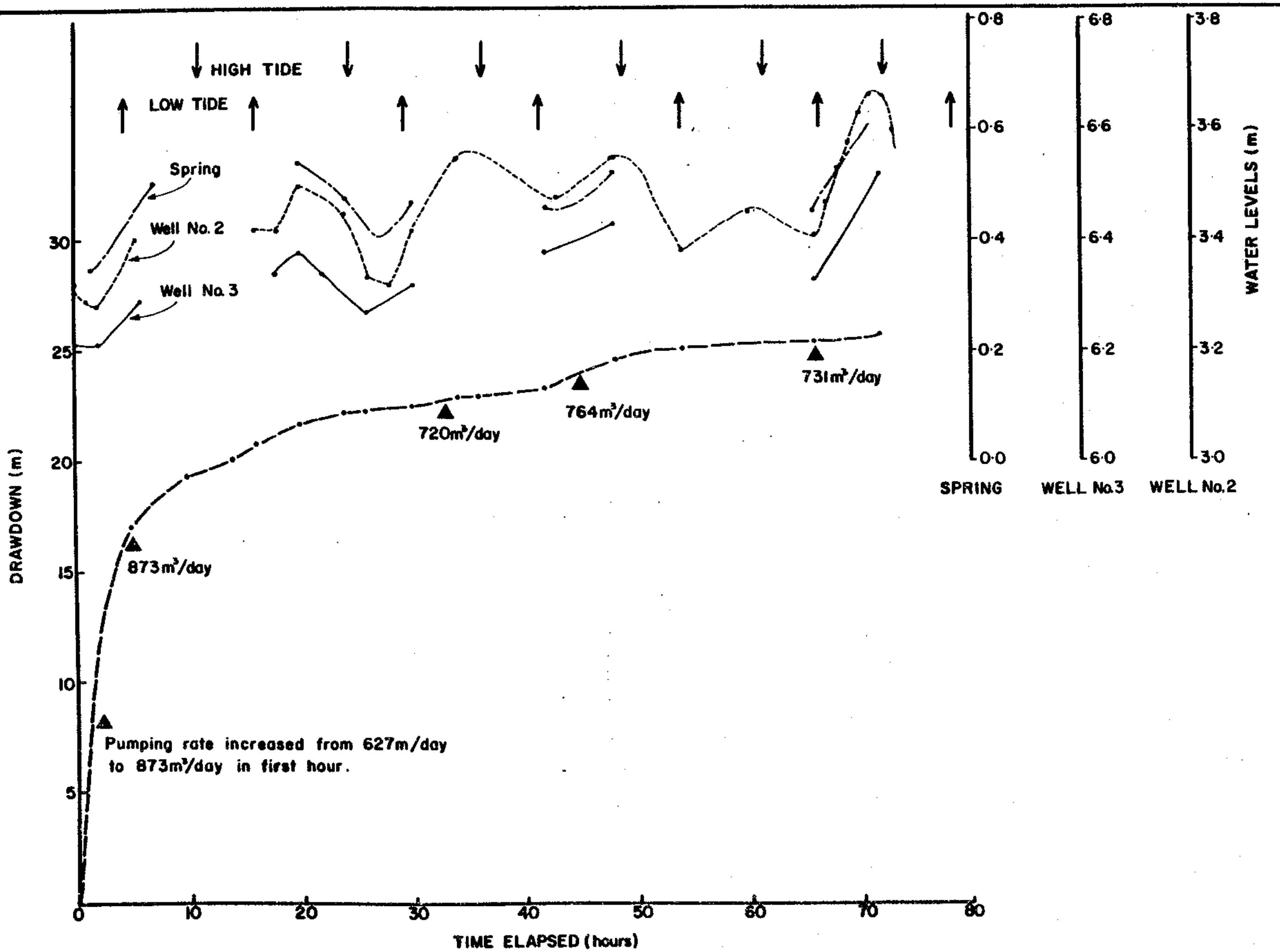
TRIAL WELL No. 3

CLIENT : Galway County Council
LOCATION : Kinvara , Co. Galway
DATE : October , 1983

AQUIFER : Lower Carboniferous Limestone
OUTPUT :
LOGGED BY : K. T. Cullen

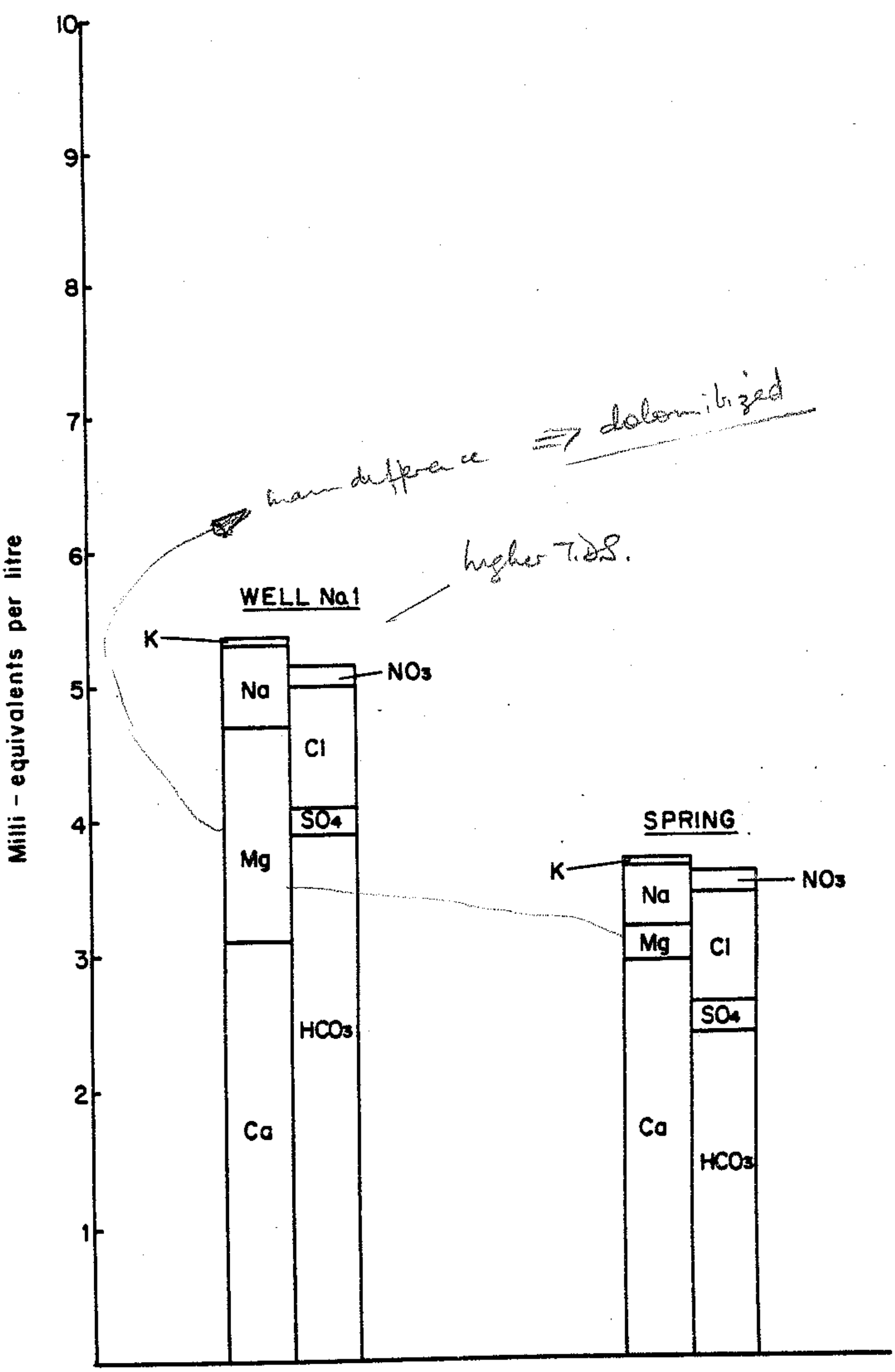


K.T. CULLEN



Relationship between water levels in pumping and observation wells during pumping test.

K.T. CULLEN



COMPARISON OF GROUNDWATERS FROM WELL No.1 & NEARBY SPRING.

K.T. CULLEN

Minerex
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805943

3

Groundwater Investigation and Development at Moneypoint Electricity Generating Station, Co. Clare

A Case Study

Introduction

9 m.g.d.

The ESB require a 2 m.g.d. supply of water at the Moneypoint Station when it becomes fully operational in the mid 1980's but before then a supply is needed to service the site during construction and for the commissioning of plant. A groundwater investigation and development programme was undertaken to obtain a supply of water from the site area.

Geology

The Moneypoint area is underlain by siltstones with subordinate sandstones and mudstones of the Central Clare Formation of the Namurian. These rocks occur as the result of a series of rhythmic sedimentation cycles each in the order of 100m thick and it was thought that the sandstone strata in each cycle might act as an aquifer. It was therefore intended that a number of separate sandstones would be used and that each would yield groundwater independantly. The groundwater potential of the formation had not been investigated before and examination of the sandstones at outcrop indicated that the intergranular permeability of the sandstones is poor owing to sealing with silica and carbonates. Joints in the sandstones are also sealed so the formation was unlikely to have good water bearing properties. The rocks are folded along east-west axes however and an anticline lies through the north of the site. It was therefore intended to drill along this axis in the hope that fractured sandstones would yield sufficient water.

D. J. BURDON D.Sc. D. J. BURNS Ph.D.
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VAT Reg. No. 8D 813608

Superficial deposits are thin or absent and have no groundwater potential.

Borehole Construction

Seven bored wells were attempted with the intention of drilling and test pumping successive potential aquifers in each well before drilling to greater depths. Experience on the first holes indicated however that the planned investigation was not worthwhile, and the drilling programme was altered accordingly.

Moderately good yields were obtained from sandstones at depths up to 150m in wells A, C and D but saline intrusion occurred at these depths and had to be stopped by grouting to 70m from surface. Yields from shallower aquifers that were intersected in these wells were not so good. The yields from wells B, E, F and G were poor.

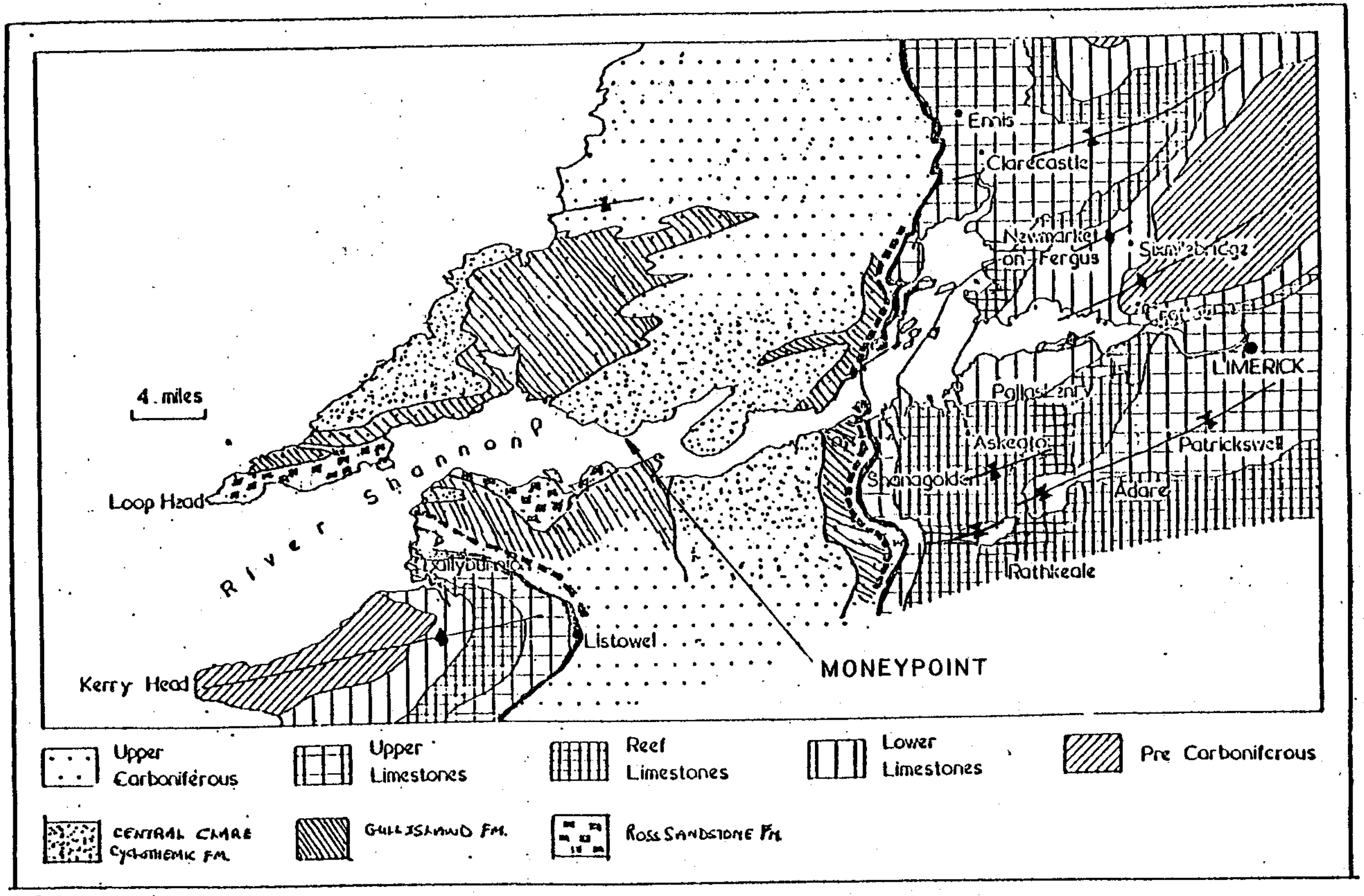
Logging of the holes by examination of drill cuttings was not possible and identification of sandstone horizons was done from drilling rate and geophysical logging data. This enabled a correlation of the sandstones and indicated that wells A, C and D had drawn water at depth from the same strata.

Well C ultimately was the most productive well, yielding good quality groundwater at up to 230 m^3/day from aquifers within 100m of surface.

The investigation showed that the Central Clare Formation is a poor aquifer in this area of Clare but that structural features determine the permeability of the rock. The best results may be obtained along fold axes (well C) with yields diminishing rapidly away from the axes (well A & D). And where there are no structural influences, permeability may decrease rapidly with increasing depth (wells B & E). Further from the coast, where there is no possibility of saline intrusion, it might be possible to obtain large quantities of good quality groundwater from the same formation.

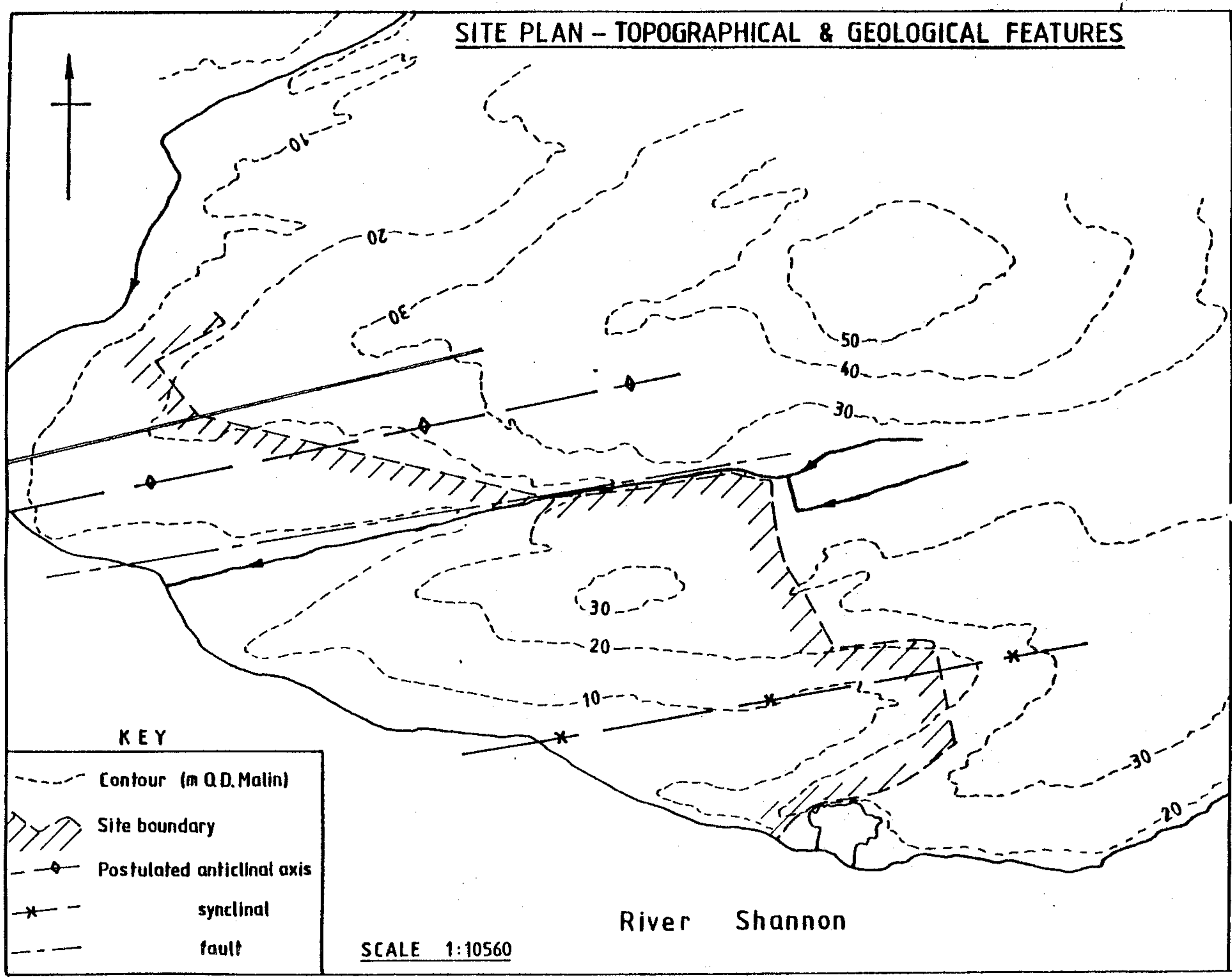
Acknowledgments to the Civil Works Dept. of the Electricity Supply Board.

Stephen Peel
HYDROGEOLOGIST

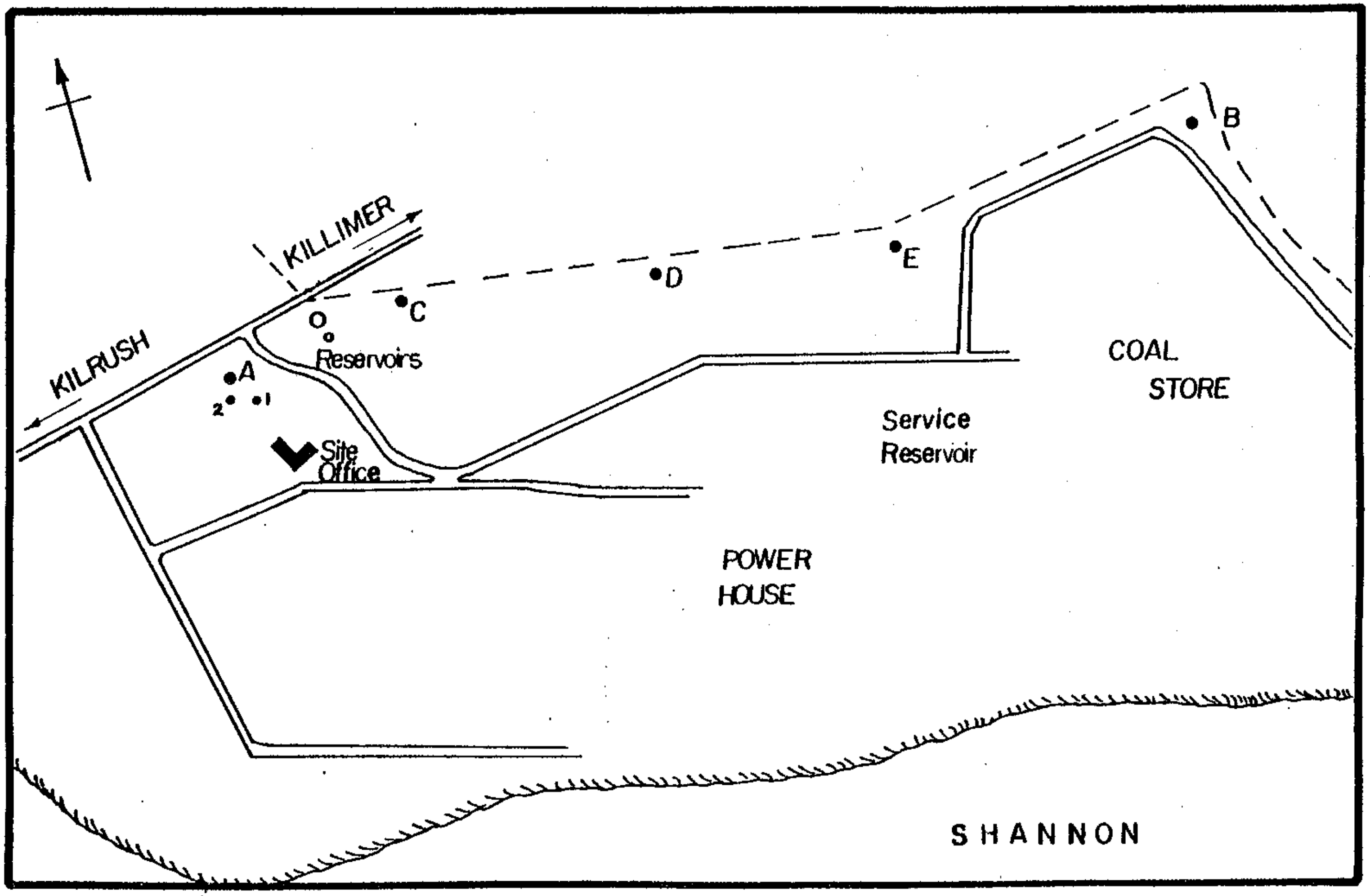


Reilly & Creighton, G.S.O.

SITE PLAN – TOPOGRAPHICAL & GEOLOGICAL FEATURES



Minerex Ltd



Moneypoint Site

Scale 1:10[4] (approx)

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FUTURE OF GROUNDWATER IN IRELAND

by

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FUTURE OF GROUNDWATER IN IRELAND

I - INTRODUCTION

This paper concludes the fourth annual seminar on groundwater development held by the Irish Group of the International Association of Hydrogeologists (IAH) at Port Laoise. In it, an attempt is made to present some aspects of the future of groundwater in Ireland. In all, some 17 aspects of groundwater's future are noted. There are many many more which are known to the participants in this Groundwater Seminar; and it is hoped that some of them will be brought up in the discussion on this paper.

The progress which has been made on the knowledge and use of groundwater over the seven or eight years past is remarkable. Williams in 1971 could report that there was then nil on the management of groundwater in Ireland. In 1977, a paper was presented to the Birmingham Congress of the IAH, entitled "Overcoming Obstacles to Groundwater Development in the Republic of Ireland". The four Port Laoise meetings in 1981, 1982, 1983 and now in 1984, are clear evidence on progress made and of the acceptance of groundwater as a part of the Irish water cycle; they must continue into the future.

In 1977, six spheres in which there were obstacles to groundwater investigation, development, use and management were identified. They fell under the headings (i) Natural and social environment; (ii) Organization; (iii) Lack of knowledge; (iv) Non-scientific approach; (v) Drilling skills; and (vi) Legal. Now, in 1984, groundwater is accepted as a major water resource, as set out in "Hydrology in Ireland", published in 1982 by the Irish National Committee for the International Hydrological Programme, (IHP).

Whereas in 1977, only 15% of water used in Ireland was groundwater, by 1982 "groundwater accounts for about 25 per cent of water supply in the

Republic of Ireland. At a county level, there is a wide range from less than 2 per cent for Dublin to almost 100 per cent in Roscommon" (IHP, 1982, p.22). These are general figures; a detailed survey of all farm, rural and group schemes from wells and boreholes, as well as urban schemes based on spring water (which is groundwater) as well as industrial supplies would show that, while surface water sources are still the major source of water supply in Ireland, the amount supplied from groundwater is greater than 25 per cent.

II - LEGAL AND ORGANIZATIONAL

II-1 National Groundwater Policy.

A general statement on the Irish groundwater position and potential would be of help. It could be widely circulated, and used as a basis for administrators and others responsible for the investigation, development, use and management of the Irish natural resources. It could be drawn up by those members of the Irish National Committee of the International Hydrological Programme involved in groundwater.

II-2 Legal

There is a need for legislation regarding basic aspects of groundwater, in particular, its ownership. This need has been increased by the concept that groundwater is a twofold resource, a water resource and an energy resource. We are fortunate to have an up-to-date report on "Legal Aspects of Groundwater" by Mr. M. Murphy; where do we go from there ?

In FAO's "Groundwater Legislation in Europe" it is noted for Ireland that "There is no specific legislation relating to ownership rights over groundwater; the laws governing property rights generally would apply largely to groundwater rights" (1964, p.78). This is not satisfactory. In particular, legislation is required to protect those who develop large scale groundwater, and rely on this water; others may not take it from them, as is possible since groundwater flows from one property to another. The 1977 Local Government (Water Pollution) Act defines an aquifer, and states that waters include waters in aquifers. This is the first mention of groundwater in Irish legislation; it is not satisfactory and touches only on one aspect (pollution) of groundwater. In "A Review of Water Pollution in Ireland" (1983), some aspects of the pollution of groundwater are treated (p.85-87, and A.4.4); they reveal the weakness of our position rather than the extent (fortunately very limited) of the pollution of our groundwaters. The position should be drawn to the attention of those responsible for our legal system.

III - KNOWLEDGE OF GROUNDWATER

III-1 Port Laoise.

This is the fourth such meeting organised by the Irish Group of the International Association of Hydrogeologists. It has been a major success in the diffusion of knowledge of groundwater. The first, in 1981, stressed "Development of Gravel Aquifers". The second, in 1982, stressed "Groundwater Development in Limestone Aquifers", and the third, in 1983, stressed "Cost Factors in Groundwater Development". And this present meeting has stressed "Groundwater Development in Ireland to Date". They have been most effective in diffusing knowledge of groundwater to all interested in it. They have become part of the technical calander of meetings in Ireland. They must be continued into the future.

III-2 Groundwater Surveys by Counties.

At this meeting, there have been reports on aspects of groundwater surveys in Cos. Meath, Wexford and Galway. A survey was made of the

North Riding of Tipperary in 1978. The county basis is a good one for hydrogeological investigations, and groundwater is generally used on a county basis. It is hoped that in the coming years, surveys will be made of the groundwater resources of all the 32 counties of Ireland.

III-3 Training.

At university level, some lectures on hydrogeology are given at TCD, UCG and Queens (Hydrology in Ireland, p.21), while groundwater is always included in general water engineering, as detailed in Chapter 7 "Education, Training and Research" of Hydrology in Ireland (1982). Since there are only two post-graduate (M.Sc. and Ph.D.) course in the whole UK (University College London and Birmingham), it would not be wise to set up formal hydrogeological post-graduate courses in Ireland. But the importance of hydrogeology should be stressed at under-graduate level, and possibly special sets of lectures given on hydrogeology.

The main field where training in hydrogeology and groundwater could be given is by meetings and possible training courses to qualified water engineers, to technicians and to people engaged in different aspects of drilling. This present meeting is a form of training. Other aspects of such training are given in many papers as Bray (1983) "Training and development for Water Engineers and Scientists". It might be possible for the Irish Group of IAH to organize a more formal annual training of two or three days duration; ACOT might support such a training programme.

IV - USE OF HYDROGEOLOGY

As used here, hydrogeology lays emphasis on the investigation and protection of groundwater; the word groundwater is used with reference to the extraction and use of this natural resource.

IV-1 Drainage.

From some recent work, as the IAH Prague Symposium in 1982, the interaction between drainage operations and groundwater regimes have been made clear. Drainage is a major operation in Ireland; since 1842, some 2.02 million hectares (almost five million acres) of Ireland (some 29.3% of the state) have been drained. The use of hydrogeology in these major operations has been almost nil. No doubt, excellent work has been done; but in the future still better work might be possible if some hydrogeological and groundwater concepts were applied, in particular to farm or agricultural drainage operations and schemes. In June, 1984, the Commission for Groundwater Protection of the IAH will visit Ireland, at the invitation of the Geological Survey working in close co-operation with An Foras Taluntas. It is hoped that relationships between drainage and hydrogeology will be discussed at some depth. This is a definite, firm, future aspects of IAH action on such an inter-relationship.

IV-2 Landfill Site Selection.

Hydrogeology is an essential in determining whether or not a possible site is suitable for dumping and other landfill site activities. Discharges from waste dumps are almost entirely through groundwater flow. The infiltration, the discharge, the permeability of the underlying formations and their connections through groundwater effluents with other aquifers, as well as the whole problem of groundwater pollution and contamination, are within the field of hydrogeology, and should be investigated by a hydrogeologist. The number of such landfill sites is on the increase; some of the older easier worked sites are full, and new ones must be selected. It is desirable that in all such cases, a hydrogeologist is employed in the selection and evaluation of such landfill sites.

IV-3 Pollution.

While pollution of surface waters is the responsibility of An Foras Forbartha, responsibility for the pollution of groundwater does not appear to be the specific, legal responsibility of any state agency or semi-state body. Many are involved, but the approach to pollution of groundwater in Ireland is rather haphazard. In the "Review of Water Pollution in Ireland" (1983) there are some references to groundwater; but there is no overall review of groundwater pollution. Hydrogeologists are needed to examine all cases of pollution; they are needed to guard against and to help to prevent further or future pollution. An Foras Forbartha deals effectively with surface pollution; one of their staff has examined a bad groundwater pollution case at Teesan Springs, Co. Sligo (Naughton, 1983). The Geological Survey has carried out some detailed nitrate pollution studies in the Barrow Valley and elsewhere, as Daly, 1981.

But there is clearly a need for a more systematic and overall approach. The subject "pollution of groundwater" might be a suitable one for a further Port Laoise meeting of the IAH.

V - GROUNDWATER EXTRACTION, SUPPLY AND MAINTENANCE

Efficient and reliable methods of groundwater extraction and supply result in satisfied customers and an increase in the demand for groundwater. Poor maintenance and resulting unreliability of supply are the common complaints against groundwater; they must be overcome.

V-1 Extraction of Groundwater.

Groundwater is extracted from wells and boreholes by a wide range of devices, from bucket-and-rope to jet, electrical submersible and many other types of pump. Electricity is the normal prime move, but diesel is also used and wind is, after a period of disuse, returning into use for pumping. In 1983, E. Creed gave us a valuable paper on "Pumping Costs" and L. Clark on "Optimising Groundwater Development". In general, methods for the extraction of groundwater have many snags and drawbacks; these mitigate against the full use of our groundwater resources. Break-downs at critical times, need and cost of repairs, unsteady maintenance, all mitigate against greater use of groundwater. It would seem that here research and experiment should be carried out to improve and make more reliable our means of groundwater extraction. As a suggestion for a discussion, what do those here think of the jet pump, powered by wind, and with no down-the-hole moving parts ?

V-2 Construction of Water Wells.

There have been really great advances in the drilling of boreholes and their conversion and equipping as water wells over the past seven years. The 1982 paper by H.M. Townsend refers. It is an achievement of which the well drilling industry in Ireland may well be proud. But more can be done, and casing, aquifer development, gravel packing, screening and related operations can be improved to produce highly efficient wells. As a result, all the drawdown will be due to aquifer characteristics, and not to failings in the water well; as in W. Jungmann's 1981 paper "Well Screens and Gravel Pack". And every extra foot of drawdown is extra cost of pumping. Here again, some research and experiment in this aspect of the extraction structure would seem desirable.

V-3 Card Index of the Geological Survey.

The card index of groundwater extraction points held by the Geological Survey is of very mixed standards. It needs reclassification, a very large task. But it also needs fresh and more accurate data. All connected with the groundwater industry should send data on groundwater extraction points to the Geological Survey on a regular and frequent basis. In the end, such a record will be invaluable as one aid is assessing with accuracy the groundwater regime and resources of the country.

V-4 Hydrochemistry of Groundwater.

Our groundwaters are mainly from limestone rock or limestone gravel aquifers. They are hard. Increasing use of detergents instead of soap has overcome some of this difficulty. Detergent makers, and allied bodies, might consider better types of detergent for use with groundwater. Again, groundwater may precipitate small amounts of iron and managanese when moving from an aerobic to oxidysing environments. The resulting stains are most unsightly. Here again is a field for research on which indeed some good advances have already been made.

VI - USES OF GROUNDWATER

Groundwater is both an energy resource (see VII following) and a water resource. Here, some ideas on four aspects of the use of groundwater are presented; there are many, many more.

VI-1 Farm Supplies.

Farm supplies from groundwater have to compete with piped regional supplies (whether from surface or underground sources), and from surface waters in rivers, streams, lakes and ponds. All types of supply have advantages and disadvantages; but it would seem that on balance groundwater supplies for farms (stock watering, dairy, cleaning, mixing with sprays, etc., as well as domestic supplies to the farmhouse) have certain advantages lacking in other types of supply. It would be well to study these groundwater advantages and to try to increase the use of groundwater by farmers.

While irrigation is almost unknown in Ireland, it could be introduced. It is so used in south-east England, and the following quotation from Evans (1983) on agricultural demand for water in lowland areas (SE England) is of interest "Agriculture consumes 75% of total rainfall by crop transpiration, leaving only 25% for river flow and groundwater recharge. Agriculture then draws directly on these resources, mostly for the purpose of irrigation, when they are scarcest. Finally, agriculture is a major user of treated water from the public mains" (Evans, 1983, p.513). Here in Ireland, water is so abundant that we generally forget that water is the essential input into agriculture; and where water is absent, there are only deserts, not farmlands. Droughts can occur in Ireland.

VI-2 Creamery and Allied Co-operatives.

Groundwater is ideal for large creameries and co-operatives, as Golden Vale, Mitchelstown and Ballyclough in Co. Cork. The constant temperature of the supply, and no need for complicated treatment, render groundwater very suitable indeed for use here.

VI-3 New Industries.

The ability of an area or organization to offer a copious supply of high quality water is a major inducement to new industries in choosing a location. In almost all cases, such new sources of supply are best opened up by tapping unused resources of groundwater. This may call for a proper survey to locate the resource, and pilot development to demonstrate its potential. Full-scale groundwater development can be done after the exact needs for water of the new factory or factories have been determined. There should be legal protection. And increased groundwater production, to suit expanding needs, seldom presents any problem.

VI-4 Export of Bottled Water.

There is increasing demand for good bottled drinking water in many of the evolving oil-rich countries of the arid and semi-arid world. Ireland has abundant water, and its export is feasible and economic. Groundwater is the best source of such waters, in temperature, chemical composition, purity and reliability. Groundwater should be developed for export, as in the 1978 report by Eugene Daly.

VII - GEOTHERMAL

Over the past five years, there has been a considerable amount of investigation into aspects of Irish geothermal energy. You have just heard a paper by Mr. Bob Aldwell on the current position; he mentions work done by UCC, UCG, the Geological Survey and Minerex Ltd. In 1983, J. Walls gave us an introduction to the subject with his paper "Groundwater - Source Heat Pumps - their Potential in Ireland".

It has become clear that the groundwaters of Ireland are not one natural resource - water; they are two natural resources - energy and water. But as yet almost no development of the energy of our groundwaters has taken place. Tuam swimming bath is the exception. There are possibilities elsewhere, as mushroom growing in Kildare, and a complex of school and swimming pool heating from the warm Spa waters of Mallow. There is a great need to push such development and use of our indigenous energy in Ireland.

So, the talk ends with emphasis on a form of groundwater development and use which will be general in 50 or 100 years, as oil decreases in amount and increases in cost, and the geothermal energy of the earth comes into more general use. Those attending this Port Laoise meeting of April, 1984, are urged to push forward the date when appreciable amount of our own energy are extracted from our own groundwaters.

VIII - REFERENCES

In a sense, this paper is a review of papers presented to the Port Laoise meeting of the IAH. These papers refer to work elsewhere, and have their own references. Nevertheless, the author has supplied some references here, giving an idea of the many fields where groundwater is being investigated and developed in Ireland. It is from the present position that we can plan the future.

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GEOTHERMAL RESOURCES OF IRELAND

Paper by C.R. Aldwell presented at
I.A.H. 4th Annual Seminar

"Groundwater Development in Ireland 1984

Portlaoise - April 4th 1984

As has been known for many years the Earth contains a vast store of heat in its interior. Temperature increases with depth on average at about 30°C/km but there are significant departures from this figure. The Earth has zones of weakness or geologically unstable areas. These allow very hot material to come close to the surface. The extreme example is an active volcano which produces molten magma at up to 1200°C at the surface.

The medium by which this geothermal energy is harnessed is natural groundwater.

There are then a small number of regions with high grade geothermal resources for example in Iceland and New Zealand and the rest of the planet with moderate or low temperature near-surface geothermal potential.

In terms of use geothermal energy is classed as high or low enthalpy. High enthalpy is that yielding water or steam at over 150 °C and thus capable of being used to generate electricity.

The great size of the geothermal heat source and its presence everywhere if, the problems of depth and permeability could be over-come, has encouraged much work in recent years. In particular the concept of Hot Dry Rock geothermal energy orthe artificial creation of permeability at great depth is looked to by some as one way of overcoming the current energy crisis

In the European Community we have seismically and volcanically active regions in Greece and Italy which produce water and steam at a few hundred degrees celsius. Geothermal development in Tuscany goes back over half a century and both the Greek and Italian Electricity Authorities are pushing ahead to harness their high grade geothermal energy.

In France there are two large sedimentary basins - those of Paris and Aquitain which contain high yielding aquifers with waters at 50 to 100° C. Even higher temperatures are present in the Rhine Graben at Strasbourg and in the Massif Central at Clermont-Ferrand. Temperature gradients, there are as high as 100°C per km. Be-cause of France's lack of energy sources, she has been harnessing since 1975 these medium temperature geothermal resources as quickly as possible.

Elsewhere in Belgium, Denmark and the U.K. major geothermal investigations including deep drilling have been carried out.

In Northern Ireland a bore-hole at Ballymacelroy nr Coal-island met warm water of over 60°C in Permian sandstone. A deep bore-hole at Larne, however, met unexpectedly low permeability at depth although the temperature of the water was satisfactory.

As a result of the 1973 oil price rises the E.E.C. embarked on an energy R and D programme. The E.E.C. countries spend close on IR£2,000 million a year on energy research of which about 10% comes from central funds. In the two four year energy R and D programmes since 1975 geothermal energy has been one of the three big expenditures with some IR£22 million being provided by the E.E.C.

Ireland did not participate actively in the first four year geothermal R and D programme. We had no tradition of either investigation or use of such energy and what information existed suggested that geothermal energy had no part to play in this countrys short and medium term energy needs.

As a result of the first programme, however, in which all the other member states took part and with the increased emphasis on the use of low and medium temperature energy it was decided to put together available Irish data within the framework of the second E.E.C. R and D programme 1979 - 1983. Irish participation was co-ordinated within the National Board for Science and Technology and the Commission entered into three contracts with the Geological Survey and the University Colleges of Cork and Galway - each organisation being responsible for specific parts of the Irish project. The Geological Survey sub-contracted part of their work to Minerex Ltd. The budget for the whole Irish programme was about IR£250,000 of which the E.E.C. paid half as well as providing valuable technical guidance. In the case of the Irish half, much of the money was in the form of the costs of existing staff in the Universities and the Geological Survey.

The work comprised:

1. the measurement of temperature and geothermal gradients in all available open deep boreholes.
2. the measurement of temperatures and heat flow in deep holes believed to be in equilibrium,
3. a study of warm springs,
4. a review of regional geophysical data in relation to the interpretation of deep geological structure.

<u>Thermal Gradient</u>

Measurement posed problems due to the small number of deep holes available and their uneven geological and geographical distribution. The majority are in Carboniferous Strata in the Central Lowlands due to the concentration of mineral exploration there. Allowing that water circulation is affecting many of the shallow holes the gradients in Ireland are normal for geologically stable regions and average about 20°C/km. Two areas where 30°/km is reached are the deep sedimentary basins in the mid-west and the north-west. It is suggested that these are due to the presence there of substantial thicknesses of Namurian sediments of low thermal conductivity.

<u>Heat Flow</u>

There are only about a dozen heat flow values for Ireland. The average heat flow density is $65 mWm^{-2}$, close to 'normal' global values. There is a suggestion of an increase in values northwards, but the numbers of readings are so few that no firm statement can be made at this stage.

<u>Warm Springs</u>

Warm springs have long been known to occur in two parts of the country - west of Dublin and north of Cork. Ireland's average air temperature ranges from 9° to 11°C. In most parts of the country average spring temperatures are within 2°C of this. In the course of the study, however, it was found that within a limited region of the south and east of Ireland springs with warmer than normal temperatures do occur and more widely than had been suspected. All are in districts underlain by Carboniferous Limestone. The major springs with average temperatures of over 13°C are shown on the slide together with a line showing the approximate limit of occurrence of springs with anomalous temperatures.

At several of the larger warm springs the physical parameters (temperature, pH, conductivity and discharge) and hydrochemistry were regularly monitored. The waters also were analysed for stable isotopes, tritium and inert gases. From these studies estimates have been made of the original reservoir temperature and hypotheses proposed regarding the origin of the waters. The three warmest springs all appear to discharge a mixture of a deep thermal component and a shallow colder water. Detailed geological and geophysical surveys of the warm spring sites have also enabled modelling of the origin of the thermal waters.

In the case of the Leinster springs the warmest, Kilbrook, shows a mean temperature of 22°C with a maximum of 24.7°C. The highest temperatures occur in late winter/spring a little after peak discharge. The mean flow of this spring is about 300 l/min with a marked seansonal variation. A characteristic of the Kilbrook spring flow is a strong response both to earth tides and changes in barometric pressure.

Of the Munster springs Lady's well at Mallow is the warmest. It has a mean temperature of 19.5° and a range from 17 to 22°C. The discharge is 600 l/min. The University College Cork team concludes that the warm water component of this spring originates from the Namurian sandstone, reaching the surface through faults in the overthrust limestone. In the Mallow springs highest temperatures occur in summer and lowest in winter. This has been interpreted as reflecting the seasonal difference in the proportions of the two component waters. The silica geothermometry suggests a maximum reservoir temperature of about 35°C.

A number of the cooler springs show more constant temperatures and discharges.

A summary of the main conclusions from the studies of the warm springs is:-

1. the geological structure and secondary permeability of the Carboniferous strata in the southern part of Ireland enables deep circulation of groundwater to occur.
2. at least some of the springs are a mixture of cold shallow groundwater and deeper warm water in varying proportions,
3. the warm water component rises from confined or semi confined aquifers at depths of 500 to 1000m,
4. thermal gradients in the vicinity of some warm springs as at Meelin (Co. Cork) are below average and the maximum reservoir temperatures of these springs are likely to be of the order of 30-35°C.

Deep Structures

A geophysical review of the regional gravity and aeromagnetic data was carried out using computer based interpretation methods. The gravity data show that the Leinster and Galway granites are large volume bodies with thicknesses of 6 to 8km. A buried granite may exist in Munster. The aeromagnetic data shows the magnetic basement beneath much of the Carboniferous Limestone lies at 4 to 6km. Two basins of interest are the northwest Carboniferous Basin and the Clare-Shannon Basin. The Kingscourt Graben also looks interesting.

Results of the work are:-

1. to provide an initial and partial picture of the thermal gradient and heat flow conditions in Ireland.

2. to confirm the expectation that Ireland does not possess high enthalpy geothermal potential,
3. to produce a better understanding and a geographical distribution of the slightly warm springs,
4. to highlight the sparsity of data for much of the country. Two important gaps in our knowledge are heat flows in the Irish granites and whether deep aquifers exist in some of the deeper sedimentary basins.

The Future of Geothermal Energy in Ireland - short term

There is now evidence to show that large quantities of above 11°C groundwater exist in a sizable area of Ireland. A number of demonstration projects are needed, chosen carefully so as to match the local availability of warm water and suitable users. In this regard the Mallow springs, being the warmest ones in a town seem an especially attractive prospect.

Medium term

Work is needed to establish the extent of deep aquifers. To-date groundwater developments in Ireland has been confined in most cases to the top 100m. The six deep on-land petroleum boreholes gave little encouragement to the existence of permeability at depth. The presence of warm springs coming from depths of at least 1km show however, that some deep aquifers are present in Ireland.

Long term

High grade geothermal energy development in Ireland must await technical progress in hot dry rock geothermal energy. The first medium sized HDR electricity generating station is forecast in the U.S.A. about 1990.

Lastly, I will quote a senior geologist of Union Oil who run the largest geothermal development in the world in California. At the E.E.C. geothermal seminar in Munich held at the end of 1983 he listed five reasons why low temperature geothermal energy should be considered by countries other than the most highly developed

i indigenous source with security of supply,
ii widely available
iii hard currency not needed
iv non inflationary-maintaince allowed at 2% p/a
v absence of enviromental problems.