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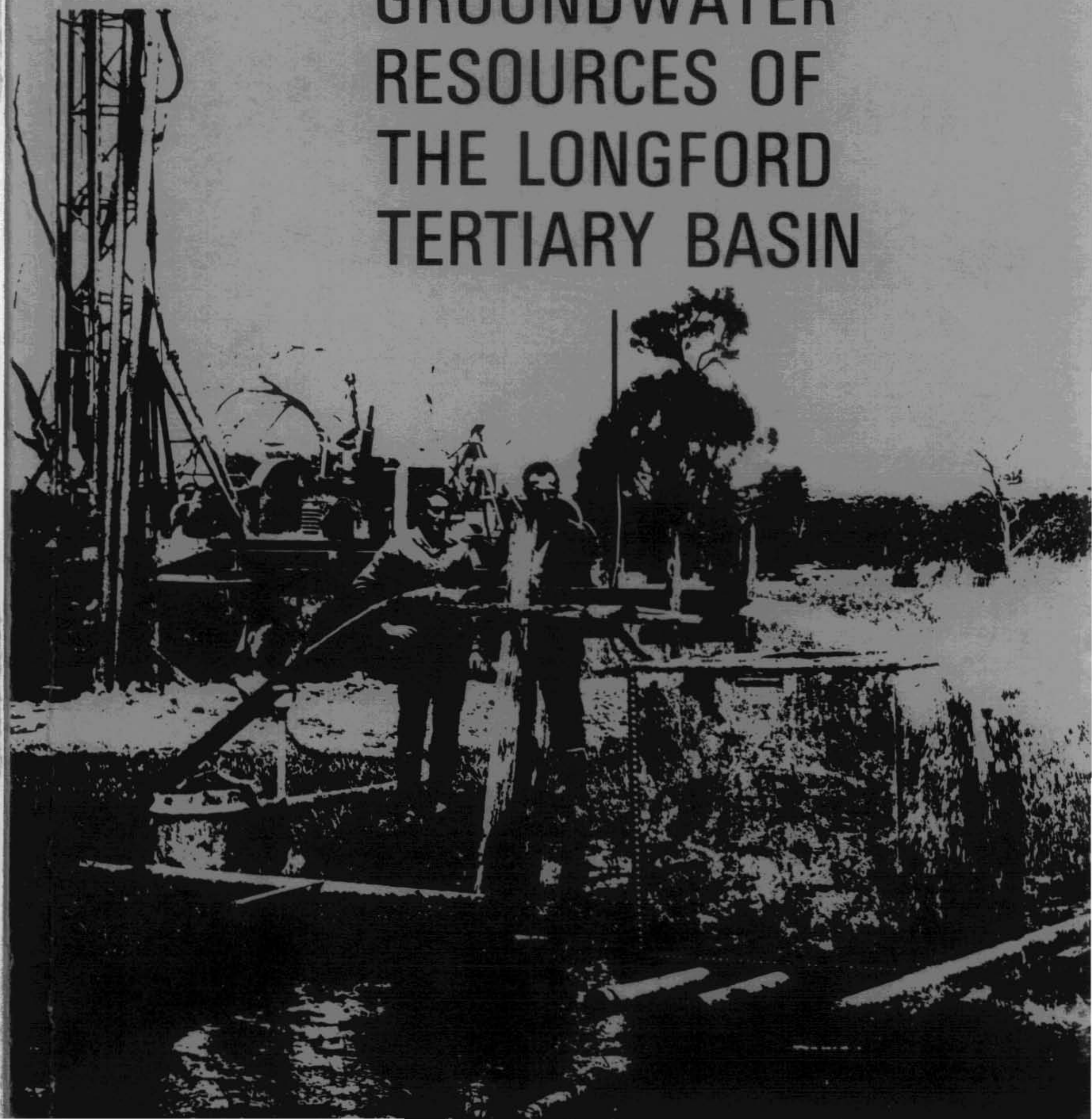

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TASMANIA DEPARTMENT OF MINES

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GEOLOGY AND GROUNDWATER RESOURCES OF THE LONGFORD TERTIARY BASIN

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PREFACE

The results of an investigation into the groundwater resources of a large area of agricultural land in central northern Tasmania are reported in this publication. This investigation has shown that groundwater can be obtained over a large proportion of the area studied, and in amounts ranging from stock supplies to small irrigation quantities. It is hoped that the information contained in this report will benefit property owners and other water users in planning how to obtain their future water requirements, as there is a viable alternative to surface water at many locations. The co-operation extended by property owners to our Department's officers during the survey is appreciated.

H. MURCHIE, Director of Mines

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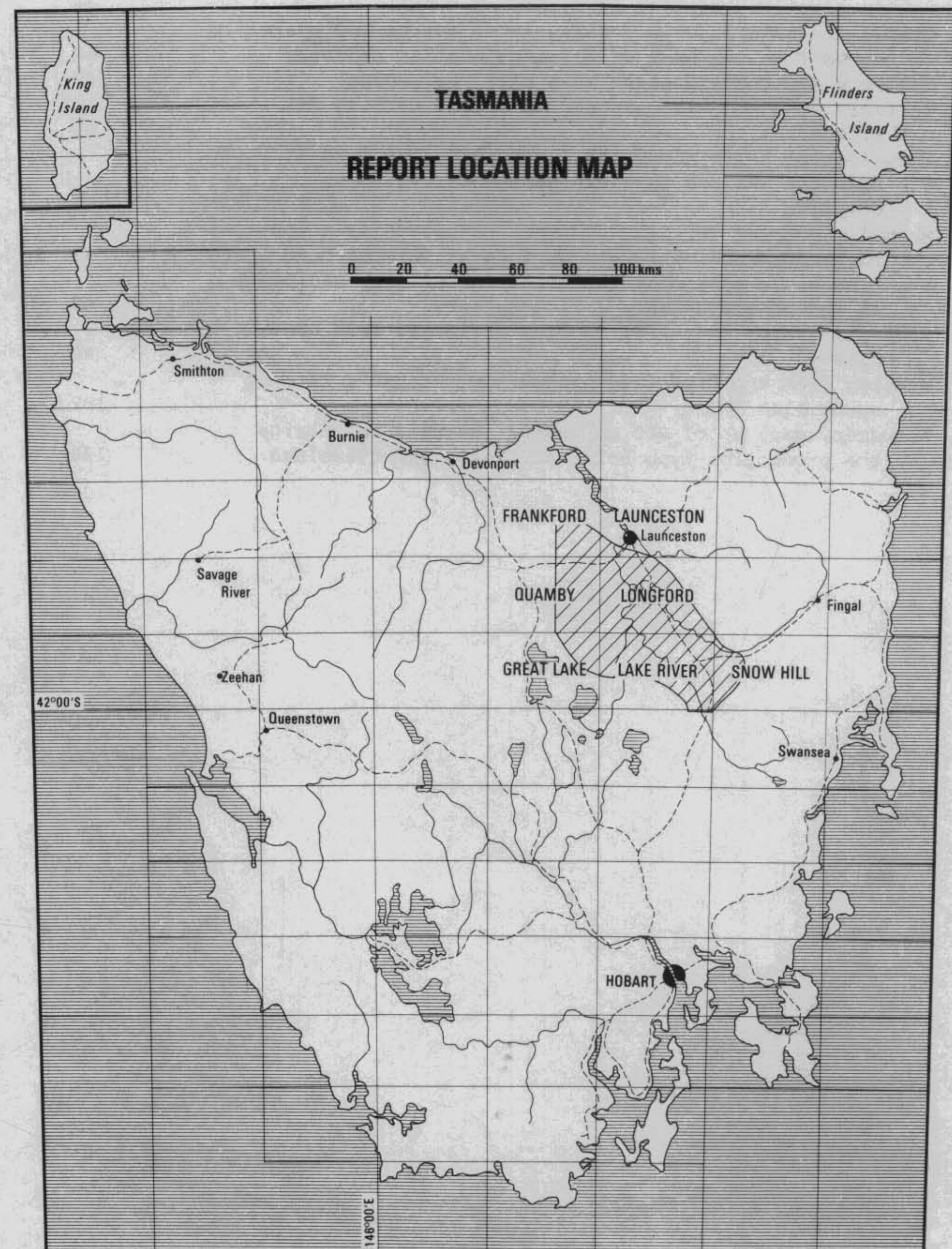


Figure 1. *Location of study area*

ABSTRACT

Investigations into groundwater occurrences in part of the Launceston Tertiary basin have been undertaken. Up to about 790 m of freshwater Palaeocene to Eocene sediments have been deposited in a north-west trending, oval shaped trough. A discontinuous central ridge divides the basin into two sub-basins, although the two areas were probably joined for at least the final 174 m of sedimentation. Basin development probably commenced during the Late Cretaceous to Early Palaeocene, and the formation of the basin is probably related to movements associated with some of the later stages of the separation of Australia and Antarctica.

The sediments in the basin comprise mainly interbedded clay, silty and sandy clay, sand, gravel, and conglomerate with minor lignite beds and fragments. Basalt is interbedded with the Middle to Upper Eocene beds. Later basalt and interbedded sediments occur, and are probably Tertiary in age. Probable later Tertiary and Quaternary gravel, recent windblown sand, and flood-plain deposits overlie the earlier Tertiary sediments. At least two periods of lateritisation appear to have taken place; one pre-Tertiary sedimentation and the other after the main period of sedimentation, probably Middle to Upper Tertiary in age.

Extensive drilling as part of this survey and information from other drilling (*e.g.* contract water boring, coal exploration drilling, uranium prospecting drill holes, and oil prospecting holes) has provided details of the sedimentary sequence and positions of potential water-bearing horizons.

Most of the information on groundwater occurrences is confined to depths of about 150 m, but some geological information is available for deeper levels. Aquifers were located in most parts of the basin above this level. The water is confined at most locations, although some unconfined aquifers occur.

Aquifers in most of the western sub-basin consist of fine to medium sand, while in the southern part of the eastern sub-basin there are fine siliceous gravel beds which supply water. Conglomerate and boulder beds supply most of the water in the southern part of the western sub-basin and the northern part of the eastern sub-basin, although occasional horizons of fine-grained sand occur in these areas. Basalt in the northern part of the western sub-basin and the southern part of the eastern sub-basin, and in other isolated areas, provides a reliable aquifer. Permian and Triassic sediments around the margin and within the basin have been drilled in a few places, usually with success, and provided the topography is favourable the success rate in these rocks should be high. Only a few holes have been drilled in dolerite, but the success rate is likely to be lower than for Permian and Triassic rocks. Rocks older than the Permian have not been drilled.

The quantity of water that can be withdrawn in most areas of Tertiary sediments is in the small to moderate irrigation rates. In the western sub-basin and the northern part of the eastern sub-basin, rates in the range of 1000-2500 m^3/day may be possible, while rates as high as 6500 m^3/day may be obtainable at some locations in the southern part of the eastern sub-basin. The transmissivity and storage coefficient of aquifers were determined from pump tests

lasting about 24 hours at aquifer type locations. These were:

	Transmissivity	*Storage coefficient*
Cressy	74-101 m^2/day	1.1-1.6 x 10^{-3}
Cleveland	1353-1624 m^2/day	3.9-4.7 x 10^{-2}

The quality of all the water located is good enough for stock use and much of it would be suitable for irrigation on well drained soils. In some areas the water may not be suitable for irrigation, or may be of only marginal use (*e.g.* an area between Cressy and Longford to Toiberry and the southern part of the eastern sub-basin). To some extent the chemical composition of the water can be related to the aquifer material.

An estimate based on available information suggests that 5.9 x 10^9 m^3 of water may be stored within the area to a depth of 150 m, of which about 3.9 x 10^9 m^3 would be available for extraction. No estimate of recharge can be made; this will have to wait until the water is being used extensively and water useage and potentiometric surfaces are monitored. Artificial recharge is a possibility because of the large volumes of water brought by rivers from higher rainfall areas. Water quality may improve if this is undertaken.

INTRODUCTION

The Launceston Tertiary Basin (Johnston, 1875) contains the largest continuous area of unconsolidated Tertiary sediments in Tasmania. Because of the possibility of permeable water-bearing beds occurring in these sediments, a groundwater survey of part of the basin was commenced in 1965; this survey has involved geological mapping, particularly around the margins of the basin, drilling, pump testing, and collection of groundwater data. The part of the Launceston Tertiary Basin examined is referred to as the Longford Basin, and covers parts of seven quadrangles (fig. 1); Launceston, Frankford, Quamby, Longford, Lake River, Great Lake, and Snow Hill. Geological maps of the first six of these quadrangles have been published at scales of 1:63 360 or 1:50 000. The margins of the basin were mapped as part of the groundwater survey and incorporated in these maps.

About 150 km^2 of Snow Hill Quadrangle, previously unpublished, is included on the geological map (fig. 2). In addition, parts of the Longford Quadrangle were remapped, mainly for more detail as to basement occurrences between Mt Arnon and Hummocky Hills. The basin and margins, as mapped, cover an area of about 3000 km^2, of which about 1700 km^2 is underlain by Tertiary sediments or basalt. Basement rocks covering an area of about 200 km^2 project through the Tertiary deposits.

The first recorded drilling in this area was in 1886, when attempts were made to find extensions to coal seams in Triassic rocks at the Norwich mine north-east of Longford. Two holes were drilled on the property 'Belmont' near Longford, the deepest going to 272 m in Tertiary sediments, indicating the extensive depths of sedimentation. Another hole was drilled at Carr Villa, 5 km south of central Launceston, at about this time. The first recorded drilling for groundwater in the basin was in 1929 at the Conara railway station, where two holes were drilled by the Department of Mines through basalt into underlying gravel. Holes were drilled in several parts of the basin on a contract basis in the early 1950s, meeting with mixed success. Several holes were drilled by the Department of Mines in the early 1960s, while a few holes have been drilled by private drilling contractors in the late 1960s and 1970s.

The systematic study of groundwater resources was begun in 1965 by W.R. Moore who supervised the drilling of about 60 hand augered holes, totalling about 183 m, and 104 power augered holes totalling about 1600 m, to examine near-surface material in the north-west portion of the Tertiary basin. This work extended over a period of about 9 months and the results were published as part of the Quamby Quadrangle explanatory notes (Pike, 1973). In addition, Moore made reconnaissance examinations of the geology of the north-west margins of the basin. M.J. Longman supervised the drilling of five rotary holes along Oaks Road between June 1966 and March 1967. Deep drilling to provide a coverage of the whole basin commenced in late 1967 and 56 holes were drilled with a Failing 1000 rotary drill and 16 holes were drilled with a percussion drill. The rotary drill operated almost continuously within the basin for about 3½ years until May 1971 and the percussion drill operated for about 12 months at various times from April 1968 to October 1969. Other drilling within the basin has included diamond drill holes at Cressy and White Hills, two oil prospecting holes in the north-western part of the basin, shallow auger drilling mainly around the margins of the basin, 122 uranium prospecting holes, and foundation drilling at Perth. Information from all the above drilling has been used in the compilation of this report. Locations of drill holes are shown on Figure 3.

M.J. Longman made reconnaissance geological observations on the margin

Table 1. TEMPERATURE RECORDS

Station	Length of record (years)		Mean monthly temperatures (°C) Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean annual temperature (°C)
Cressy	27	max.	23.7	22.8	21.4	17.2	13.9	11.6	10.9	12.2	14.3	16.6	18.8	21.6	17.1
		min.	8.6	8.9	7.4	4.9	2.9	1.3	0.9	1.8	3.1	4.6	6.0	7.6	4.8
Launceston	68	max.	24.3	24.6	22.2	18.6	15.2	12.5	12.1	13.4	15.6	17.8	20.5	22.8	18.3
		min.	11.2	11.4	9.8	7.3	5.1	3.4	2.7	3.5	5.2	6.7	8.4	10.1	7.1
Launceston Airport	31	max.	23.1	22.6	20.7	17.0	13.6	11.3	10.7	12.1	14.1	10.8	18.4	20.9	16.7
		min.	10.1	10.1	8.9	6.5	5.3	3.1	2.5	2.9	4.0	5.6	7.0	8.9	6.2
Ellinthorp (Ross)	14	max.	23.7	22.9	21.1	16.0	13.4	10.9	10.6	11.6	14.2	16.4	18.3	21.2	16.8
	13	min.	8.5	8.9	7.6	4.4	3.2	0.9	0.8	1.2	2.9	4.7	6.0	7.6	4.7
Deloraine East (Ashley)	9	max.	22.7	23.4	20.9	17.8	14.2	11.7	11.0	11.9	13.9	16.6	18.3	20.6	16.9
		min.	9.5	10.2	8.3	5.5	3.5	0.9	0.7	1.8	3.3	4.7	7.0	8.5	5.3
Palmerston	13	max.	23.9	24.4	21.5	17.7	14.2	11.3	11.0	12.0	14.2	16.9	18.8	21.3	17.3
		min.	8.5	9.2	7.7	4.8	3.0	1.0	0.5	1.9	3.1	4.2	6.3	7.6	4.8
Campbell Town	7	max.	24.0	23.9	21.1	17.5	14.1	11.2	10.9	11.9	14.3	16.8	18.6	22.1	17.2
		min.	9.2	9.5	8.1	5.2	3.6	0.8	0.5	1.4	3.2	4.3	6.4	8.0	5.0

of the basin between Bracknell and Westbury and extended, in conjunction with D.E. Leaman, an earlier gravity survey by A. Hinch to cover the whole of the Tertiary basin. Longman and Leaman together spent a short time doing resistivity probes in the Carrick area, while P.C. Stevenson also did some resistivity probes in various parts of the basin. E. Williams and M.J. Clarke advised on geological problems, particularly in the margin areas. J.G. Pitcher carried out a well and bore survey in the Longford Quadrangle over a period of about two months.

LOCATION AND ACCESS

The area under examination (fig. 1) extends from 8 km south of Campbell Town to Launceston, west to Westbury and south to the Poatina area. Two main highways extend through the area; the Midland Highway runs approximately north-south through the eastern part and the Bass Highway runs through the northern part from east to west. As most of the land comprising the basin is agricultural, there is a good network of roads throughout the area. In the north-west portion of the basin, property sizes average between 200 - 400 ha and roads are common throughout that part. In the eastern and southern part of the basin, properties are larger and although roads are less common, passable tracks allow access to most areas. Around the margins of the basin in the higher country access is usually poor, with only occasional timber tracks.

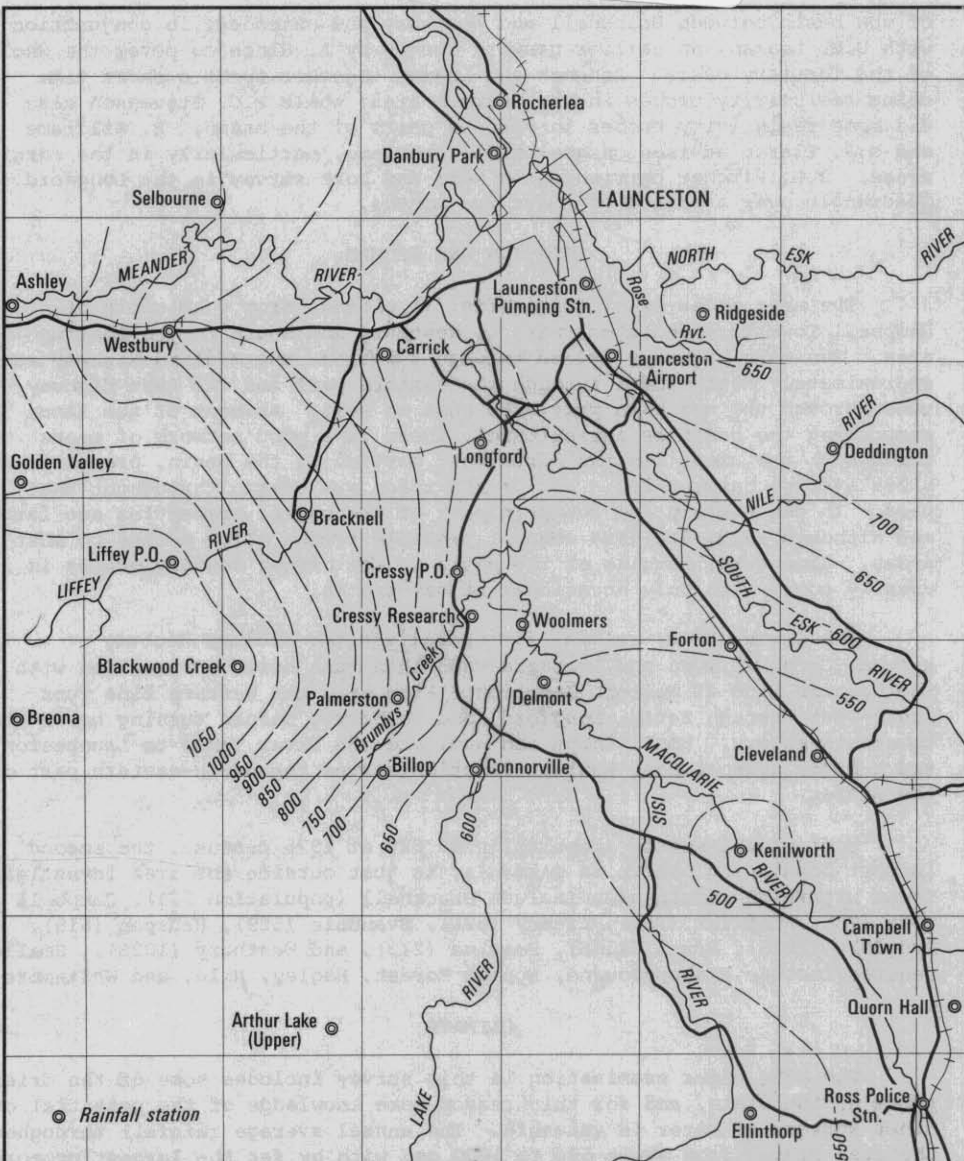
The South (Main) railway line parallels the Midland Highway between Campbell Town and Powranna, and then runs north to junction with the Western Line at Western Junction. From here the Western Line runs south-west through Perth, Longford, and Toiberry, before turning north-west towards Westbury. Small ships can navigate the River Tamar to Launceston and a major airport near Western Junction serves the north-eastern part of the State.

Most of Launceston (population 63 629 at 1976 census), the second largest population centre in Tasmania, is just outside the area investigated. Towns within the basin area include Bracknell (population 271), Campbell Town (936), Carrick (227), Cressy (621), Evandale (529), Hadspen (619), Longford (1825), Perth (1166), Poatina (213), and Westbury (1028). Smaller centres include Bishopsbourne, Epping Forest, Hagley, Nile, and Whitemore.

CLIMATE

The area under examination in this survey includes some of the drier parts of the State, and for this reason some knowledge of the potential of other sources of water is valuable. The annual average rainfall throughout the area ranges from about 500 to 1000 mm, with by far the largest proportion of the area being in the lower half of this range. Rainfall contours plotted from figures obtained from the Bureau of Meteorology, together with some information from farmers records within the area, are shown on Figure 4. The areas surrounding the basin have a much greater rainfall. To the west, the land is mountainous and receives most of the rain brought by prevailing north-westerly winds. Much of the rain brought by easterly or north-easterly winds has similarly been dissipated before reaching the area. To some extent the area is in a rain shadow from the two main directions that rain could be expected. Rainfall figures from some centres within the area are given in Table 2.

Rainfall varies quite markedly from the average in dry and wet years and the figures in Table 3 indicate this variability. Temperature has a wide range, both annually and diurnally. Occasionally summer shade tempera-



RAINFALL CONTOURS & DRAINAGE LONGFORD TERTIARY BASIN

W.L. MATTHEWS

Figure 4.

Table 2. RAINFALL RECORDS

Station	Length of record* (years)	Annual✓ average (mm)	Monthly average (mm)											
			Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Ridgeside (Evandale)	58	624	39	35	36	48	56	62	66	63	60	66	46	49
Selbourne	41	853	35	60	41	69	84	87	109	109	79	76	53	52
Westbury	67	825	43	52	47	63	79	84	102	91	79	78	54	55
Launceston Airport	39	707	40	50	39	58	63	61	86	78	63	67	51	54
Woolmers Settlement	43	604	38	40	32	46	56	56	63	61	52	64	44	52
Evandale	12	641	29	54	39	58	68	50	80	71	55	57	39	43
Bracknell	8	845	40	63	58	48	75	64	134	113	83	57	54	57
Ross	34	497	32	39	36	40	39	41	45	45	43	50	37	53
Newnham (Rocherlea)	51	738	40	45	39	58	71	73	93	81	69	68	51	51
Billop	19	686	26	47	34	76	66	56	72	80	63	71	48	49
Kenilworth	30	478	32	39	32	39	37	33	47	44	41	47	41	46
Campbell Town	55	546	36	40	34	46	46	45	50	47	47	56	46	54
Ross (Ellinthorp)	38	595	37	47	40	55	49	43	58	56	52	57	49	55
Campbell Town (Quorn Hall)	57	531	46	35	36	44	40	48	44	44	47	55	43	51
Palmerston	8	777	36	74	52	47	65	51	112	107	80	55	42	58
Arthur Lake Upper	32	775	45	50	53	62	62	75	85	79	69	77	61	58
Breona	26	1844	81	101	85	150	169	199	265	226	185	154	128	103
Deloraine (Ashley)	76	941	46	48	52	71	85	104	120	110	93	88	65	61
Blackwood Creek	13	1083	30	76	50	116	118	105	130	138	100	87	68	66
Carrick	64	694	36	42	41	54	66	68	84	75	63	65	48	55
Connorville	39	599	32	44	32	55	48	53	65	67	51	59	44	49
Cressy (Cressy House)	26	611	31	48	31	56	57	48	54	63	50	60	46	49
Cressy (P.O.)	72	627	36	40	36	50	59	60	72	65	57	62	42	49
Cressy (Research)	28	613	34	46	32	52	57	51	80	61	55	56	45	46
Danbury Park	22	740	30	47	30	68	86	68	90	83	65	72	59	42
Epping Forest (Forton)	39	554	33	38	32	52	46	47	59	56	47	55	43	47
Golden Valley	50	999	47	58	47	77	97	101	139	123	93	91	63	65
Launceston	78	708	43	37	39	55	68	77	80	74	69	68	48	50
Liffey	37	1092	51	65	51	80	102	113	146	136	113	103	68	66
Longford	74	618	36	37	39	50	57	61	69	63	55	62	43	47

* to 1972. Some stations closed before 1972.

✓ Figures changed from points to nearest whole millimetre. Annual averages may differ slightly from total monthly averages.

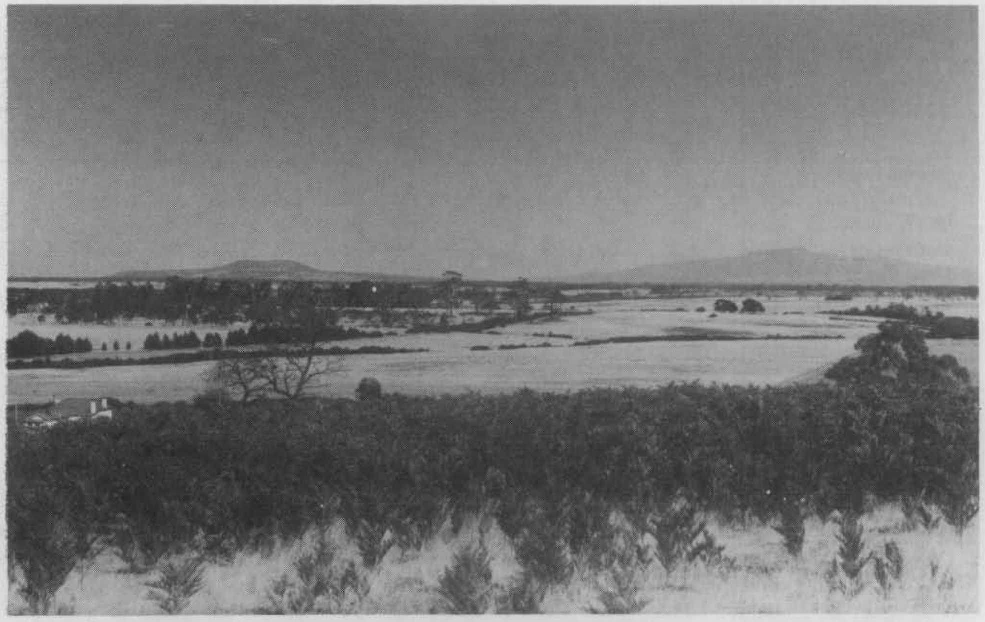


Plate 1. *View south from Perth over the flat northern section of the basin towards Hummocky Hills (centre) and Millers Bluff (right). Hummocky Hills forms part of a discontinuous ridge dividing the basin into two sub-basins.*

Plate 2. *Looking west from Evandale towards Hummocky Hills and the western margin of the basin. The area immediately behind the railway line is the flood plain of the South Esk River, the river course being marked by trees.*

Table 3. VARIATION OF RAINFALL FROM AVERAGE

Station	Length of record (years)	Rainfall (mm)		
		Average	Maximum	Minimum
Carrick	62	693	1028	375
Connorville	39	599	900	310
Cressy Post Office	70	624	911	382
Forton (Epping Forest)	39	554	941	317
Golden Valley	50	999	1435	607
Launceston pumping station	78	708	1041	460
Longford	73	617	940	363
Ridgeside (Evandale)	58	624	970	362
Westbury	65	823	1188	488
Campbell Town	53	543	842	324
Kenilworth	29	475	644	323

tures may exceed 38°C, while in winter it is common to have temperatures below freezing. Snow in winter is a common feature on the surrounding mountains but seldom extends to the plains. Temperatures for seven stations within the basin area are given in Table 1.

Rivers from the higher rainfall areas extend through the area and flooding of the flatter country around these streams is a fairly common occurrence. Flooding of built up areas of parts of Launceston, Longford, and Campbell Town has occurred.

PHYSIOGRAPHY

The part of the Launceston Tertiary Basin included in this study is a relatively flat area surrounded on all sides by much higher country (Plates 1, 2), except for the narrow extensions of the basin to other areas. There are some higher areas within the basin that are underlain by basement rocks; these were either faulted in these positions during the formation of the basin (*e.g.* Hummocky Hills-Dicks Banks and Mt Arnon) or are due to dolerite intrusions up fault planes (*e.g.* McRaes Hills and hills south of Bracknell). The margins of the basin are underlain by basement rocks consisting of Triassic and Permian sediments, Jurassic dolerite and Cambrian slate and volcanic rocks.

Davies (1959), in describing the development of landforms in Tasmania, presented the concept of five, and possibly six, major distinct surfaces for the whole of Tasmania; these developed due to planation and an intermittent elevation of the land surface. Davies suggested that the geology was not a controlling factor and that the surfaces developed across geologic boundaries. The Launceston Tertiary Basin is included in the 'lower coastal surface', which ranges in height from about 90 - 275 m above sea level. This surface occurs extensively along the north coast of Tasmania, but usually in narrower strips in other parts of the coastline. Within the basin itself are the monadnocks of Mt Arnon and Hummocky Hills, which Davies regards as remnants of his 'higher coastal surface', which is about 365 - 460 m above sea level. This surface also surrounds large sections of the basin. An area which he regarded as part of the 'St Clair surface' (730 - 820 m above sea level) abuts the basin along part of the eastern margin and a small section of the western margin, while another section of the western margin comprises the 'higher plateau surface'. Davies regarded the four higher surfaces as uplifted subaerial erosion surfaces and the lower coastal surface as probably a marine-cut surface. No definite indication of marine influence has been noted anywhere within the area examined.

Apart from the basement areas within the basin, there are few places where rapid changes in relief of greater than about 30 m occur. Most of the basin is drained by the South Esk River system, which in its lower reaches between Hadspen and Trevallyn passes over dolerite which has formed an artificial base level and greatly retarded the erosion rate of the softer sediments upstream. This has resulted in the formation of broad flood plains and meandering stream courses throughout much of the basin (Plate 2). Exceptions to this gentle topography occur in the catchment of the North Esk River, which includes Rose Rivulet, in the north-east part of the basin. Here, downcutting and erosion of the Tertiary sediments is not retarded by resistant bars and the valleys around these streams are more deeply entrenched (Plate 3). The presence of terraces in this area indicates that base levels have changed throughout the erosion period, either by changes in sea level or differential erosion rates. Relief of about 100 m around Rose Rivulet is common. Other exceptions to the gentle relief, but less severe, occur where resistant horizons within the Tertiary system retard erosion. Examples of this include basalt-capped hills south of Westbury, laterite capped horizons around Hummocky Hills and north-west of Campbell Town, and some gravel capped terraces.

Nicolls (1960) described and named a series of terraces within the area: the present floodplains (Canola Floodplains), 1.5 - 3.1 m above normal river water level; Brumby Terraces, 2.5 - 5.5 m above present flood plain level; and the Brickendon Terrace, a surface extensively underlain by quartz gravel. In addition, Nicolls described what he regarded as an older surface, the Woodstock Surface, which was underlain by laterite or lag pisolitic iron oxide and which has been largely removed. However, it seems likely that the relationships between the Brickendon Terrace and Woodstock Surface should be reversed. Drilling north of Epping Forest on the Midland Highway, where the Brickendon and Woodstock surfaces are adjacent, indicates that quartz gravel similar to that of the Brickendon Terrace underlies the lateritic deposits of the Woodstock Surface.

The same situation has been found in auger holes north of Hummocky Hills. It is possible that the gravel encountered in IH 67 at 20 - 26 m and in some of the uranium prospecting holes, particularly F1, F2 and F3 at depths of 10 - 23 m from the surface, may be equivalent to the gravel occurring on the Brickendon Terrace to the east and north of these holes. It is apparent that extensive deposits of quartz gravel were distributed over a wide area towards, or at the end of, the main sequence of the presently preserved sedimentation in the basin. This may have been caused by the blocking of some stream channels at that time with basalt flows and the development of a braided stream system over an existing flat surface, or the gravel may have been deposited from meandering and laterally moving stream channels. Clay overlies the gravel beds in some drill holes and this in turn is overlain by pisolitic iron oxide gravel and lateritic deposits.

Subsequent erosion has exposed the quartz gravel and the fines have often been removed, leaving lag gravel deposits over extensive areas. The surface on which the quartz gravel occurs is thus regarded as being older than the laterite surface. It has been buried and is partly exhumed. Nicolls (1960) indicates that some of the Brickendon Terrace also shows signs of lateritisation. The above relationship between the Woodstock surface and the Brickendon Terrace may remove the need for two periods of lateritisation in this part of the sequence.

It is likely that some of the quartz gravel equivalent to that underlying the laterite near Epping Forest and north of Hummocky Hills has been eroded, transported and re-deposited. Some of the thick gravel occurrences around Perth, Longford, and Carrick may be partly of this origin and the surfaces on which they are deposited may be younger. Quartz gravel, which may be equivalent to Brickendon gravel, overlies basalt north-west of Evandale. Between Longford and Hummocky Hills there are areas of iron oxide-cemented boulders of quartz conglomerate and red iron oxide-stained quartz pebbles on the Brickendon Terrace, whereas further east towards the Midland Highway and to the south-west, the gravel is white or at most stained light brown with iron oxide. It appears that the former have been subject to lateritisation and the lighter coloured gravels were either buried during lateritisation or have been more strongly leached.

Several levels of terrace systems have developed around Rose Rivulet and the lower parts of the North Esk River. These have been preserved by being capped by gravel, either dominantly quartz, dominantly dolerite, or a mixture of basalt, dolerite, and quartz. The terraces are obviously of different ages, but it is difficult to build up a sequence of ages as at least one, and possibly more, are exhumed levels. The quartz gravel north and south of Evandale at about 170 m a.s.l. probably lies on a surface of similar age to the Brickendon Terrace. The remnant of a terrace containing basalt, dolerite, and quartzite pebbles around the homestead on the property 'Ridgeside' is at about the same level as a terrace north of Rose Rivulet underlain by similar material, and at about the same level as the siliceous gravel around Evandale. The terrace material north of Rose Rivulet is overlain by a basalt flow. A lower group of remnants of a surface at about 110 - 140 m a.s.l. occurs between 'Sunnyside' and 'Ridgeside' (Plate 3). This is capped by rounded dolerite gravel with occasional quartzite pebbles. Sutherland (1971) also recorded basalt fragments, but these are not common if present. These are possibly the surfaces which Nicolls (1960) suggests may be the equivalent of the Brumby Terraces (*i.e.* Quaternary in age). However basalt near 'Sunnyside' overlies this gravel and for this reason the gravel must be regarded as Tertiary. This appears to be an exhumed surface. Similar gravel underlies basalt north of Cocked Hat Hill. This gravel probably represents terrace deposits around the South Esk River before it was diverted south around Longford by basalt extrusions.

North of 'Sunnyside' are dissected remnants of a streamward sloping terrace on either side of Rose Rivulet at about 50 - 70 m a.s.l. (Plate 4). This terrace is capped at some locations with a mixture of siliceous and dolerite boulders, and at other places by dominantly siliceous material. Along the lower reaches of the North Esk River towards St Leonards terraces capped mainly with dolerite boulders have been formed at 30 - 40 m a.s.l. (Plates 5, 6). On either side of the North Esk River are remnants of terraces 70 - 90 m a.s.l. which are mainly capped by siliceous gravel. It is not known how these sets of terraces relate to those around the South Esk River, although the last mentioned may be a continuation of the Brickendon Terrace.

The gravel deposits on the surfaces and terraces in the Rose Rivulet

Plate 3. *Remnant of a terrace capped with up to 10 m of mainly rounded dolerite boulder beds, 3 km north-east of Evandale. Note the development of landslips on the slopes below the terrace. The valley between the road and the terrace is occupied by one of the entrenched tributaries of Rose Rivulet.*

Plate 4. *Streamward sloping terraces around Rose Rivulet at 'Corralinn' [EQ185052], north of 'Sunnyside'.*

Plate 5. *The flood plain of the North Esk River, 2.5 km south-east of St Leonards, is bordered with terraces capped largely with dolerite boulders.*

Plate 6. *Two terrace levels occur near the North Esk River one kilometre south of St Leonards. These are capped mainly with quartz gravel and some dolerite boulders. A major landslip has formed below the top of the upper terrace.*

and North Esk River valleys are more resistant to erosion than the underlying clay and silty clay sediments. Steep slopes have developed from the remnants of the terrace surface to the foot of the valleys and landslips, both active and old, are a common feature in these areas (Plates 3, 6).

DRAINAGE

Almost all of the basin falls within the drainage catchment of the South Esk River system (fig. 4); the only exception is the north-eastern section which is drained by the North Esk River system. All rivers rise outside the basin area.

The South Esk River flows in a general north-westerly direction to Evandale, where it has been diverted west to Longford. At Longford it joins the Macquarie River and flows north-west to Hadspen, where it is joined by the Meander River. From Hadspen the South Esk flows over dolerite toward Launceston and the River Tamar.

Rivers of the South Esk system have broad flood plains over large sections of their course within the basin and are shallowly entrenched (Plate 2). During winter these flood plains may be covered a number of times. This is largely a result of rain falling in the catchments of these streams outside the basin area in higher rainfall zones.

A smaller system, the North Esk River and its tributaries, flows through the north-east part of the basin. This system enters the River Tamar from the east and is surrounded mainly by steep sided slopes with only narrow flood plains for most of its extent. However, in its lower reaches around St Leonards, the North Esk River has developed a fairly wide flood plain which is subject to frequent flooding (Plate 5).

Because of the proximity of the elevated South Esk River to the deeply entrenched Rose Rivulet near Evandale, capture of the former by the latter is likely to occur in the future. Nye and Blake (1938) reported that it nearly happened in the 1929 floods, although Nicolls (1960) doubts whether an extraordinary flood would reach the top of the saddle and suggests that capture will eventually take place by headward erosion of a tributary of Rose Rivulet. Nicolls also discusses a number of river captures in the western part of the basin.

SOIL

The distribution of soil types and their description in two quadrangles, Longford and Quamby, has been prepared by the CSIRO (Nicolls; 1958, 1959). The following summary is derived largely from his work.

The higher levels of the Tertiary basin sediments have lateritic podzolic soils with either a sandy or silty A horizon. Some of these soils have considerable thicknesses of pisolitic ironstone gravel and these have been little used for agriculture until recently, when the native vegetation has been cleared for woodchipping and the land sown to pasture. Areas where thick gravel occurs include around Hummocky Hills, west of Epping Forest and Cleveland, and north and south of Bracknell. Areas where only small amounts of pisolitic iron occur have been extensively used for agriculture. On lower levels and on river terraces, meadow podzolic soils and usually dark, alluvial soils occur. Grey and brown soils have developed on areas of windblown sand. All have been extensively developed for agriculture.

Soils developed on Tertiary basalt include lateritic krasnozems in the north-west part of the basin, in part of the area underlain by basalt in the Campbell Town area, and other small isolated areas such as east of White Hills on the Blessington Road. Brown earth, black earth, and prairie soils are developed on basalt in other areas such as near Campbell Town. All soils on basalt have been developed for agriculture, although the brown earths around Campbell Town-Epping Forest are often rocky.

Lateritic krasnozems have developed on dolerite in some areas but brown earths have normally developed. Some cultivation has taken place where the soil is deepest, but soil accumulations are usually only thin. Often the country underlain by dolerite is steep and rocky and only suitable for rough grazing.

Yellow podzolic soils have developed on Permian and Triassic sediments and these are used for agriculture where the topography is not too steep.

VEGETATION

A large proportion of the basin area is farmland and much of the natural vegetation has been removed. It has been the practice of most farmers to leave some vegetation as shelter in grazing land, but where cultivation of the soil is regularly undertaken, few of the original trees remain.

The forested areas that remain within the basin are classified as dry schlerophyll forest, but grade to savannah where the tree cover is sparse, with natural grasses forming the undercover. The forested areas are dominated by species of *Eucalyptus, Acacia, Casuarina,* and *Banksia*. Wet schlerophyll forests occur alonq the side of the Western Tiers and around the eastern margins of the basin where the rainfall increases. These forests are dominated by eucalypts and some logging is possible.

ECONOMIC ACTIVITY

The economy of the area is essentially agriculture based. Much of the area has workable soils and the topography is such that easy tillage is possible. The rainfall controls to a large extent the type of farming that has been undertaken. Grazing of both sheep and cattle is probably the most important agricultural occupation, although dairy farming is carried out in the north-west part of the basin where rainfall is higher and in areas where it is possible to irrigate the land. Wheat is grown in some of the lower rainfall areas. Other major crops include barley, blue peas, lucerne and fodder crops. Poppies, from which pharmaceutical products and oil can be extracted, have become a popular crop at some locations in recent years. With the installation of an extensive irrigation scheme west of Cressy and Longford using water from the tail-race of the Poatina hydro-electric power station, development of cash cropping on a much larger scale is likely to take place in the future.

Timber is cut for sawn timber production around the margins of the basin and much of it is transported to Launceston for milling, although mills are also established at Campbell Town and Western Junction. Over the last few years, timber for woodchipping has been cut, particularly from within the basin area. This is transported to the lower Tamar for chipping and export overseas. A timber treatment plant has been established at Longford. Other industries in the area include a brick factory and a large poultry farm near Longford. An abbatoir at Longford supplies meat to the local and export markets. Quarrying of gravel takes place in many locations throughout the basin. Although most of Launceston is just outside the area under study, some of the population living in nearby towns such as Perth, Longford, and Cressy work in Launceston. Light industry such as textiles, engineering, and food handling concerns are important employers of labour. Launceston, being by far the largest centre of population in this region of the State, is an important commercial, retailing, educational, and service industry centre.

Much of the Tertiary basin area was settled soon after the founding of Tasmania and many of the houses and buildings on the larger properties are striking examples of early colonial architecture. Such buildings have a developing tourist potential as well as an historic interest.

The rivers running through the basin have been stocked with trout and fishing encourages visitors from outside the area. Deer shooting is an established sport during the open season. The Poatina Power Station is one of the larger electricity generating stations in the State and as well as employing people within the area, inspections of the power station can be made.

Part 1: Geology

INTRODUCTION

The geology of the Longford Tertiary Basin is shown in Figure 2 and a detailed description of the Tertiary sediments in the basin is given in this report. As this report is primarily concerned with these sediments, only brief descriptions of the pre-Tertiary rocks, which form the higher parts of the basin and the surrounding country, and the Quaternary sediments are given here.

As previously mentioned, the area covered by this report forms parts of seven quadrangles (fig. 1), six of which have been previously mapped and published at either 1:50 000 or 1:63 360 scale. More detailed descriptions of the geology of the Launceston, Quamby, and Frankford Quadrangles are given in the respective Geological Atlas Explanatory Reports.

Much information on the geology of the basin has been derived from drill hole data. Where referred to in the text, the hole type has been abbreviated as follows: IH - investigation hole; CH - contract water bore; DH - diamond drill hole; OP - oil prospecting hole; MP - uranium (mineral) prospecting hole; PH - proline auger hole.

Proterozoic-Cambrian(?)

Proterozoic-Cambrian(?) rocks are exposed in the south-west of the basin and consist of slate, phyllite, and basic volcanic rocks (mainly tuff), with minor limestone beds. These rocks occur in the O'Connors Peak - Little Billop area in the catchment of the Lake River, in a window formed by the erosion of the Permian and Triassic rocks and Jurassic dolerite. Most of these older rocks are strongly foliated, with the foliation dipping towards the north-east or east. They are overlain unconformably by basal Permian beds.

An isolated outcrop of dolomite occurs at Brumbys Creek, 10 km south-west of Cressy [EP008769]. It is a fine-grained grey rock and is similar in appearance to the Smithton Dolomite, although no definite correlation is suggested.

Ordovician-Devonian

Ordovician-Devonian rocks occur in the north-western part of the basin near Frankford; these rocks consist of interbedded quartzite and slaty siltstone with a conglomerate horizon. They cover only a small portion of the study area.

Lower Permian glacio-marine sequence

STOCKERS TILLITE

This formation unconformably overlies the Proterozoic to Cambrian(?) rocks and consists of tillite beds, conglomerate, sandstone, rhythmite, and occasional lime-rich lenses. The formation crops out over extensive areas along the western margin of the basin and is variable in thickness because of the uneven topography on which it was deposited. It probably reaches a maximum thickness of about 140 m in the area around the southern margin, although as little as 6.5 m was recorded at Golden Valley (Clarke, 1968). It may be absent altogether at some locations. At Hellyer Gorge, in north-west Tasmania, the basal part of the Lower Parmeener Super-Group has been dated as Carboniferous (Gulline, 1967). Samples from the Lake River Quadrangle have been dated as Permian on palynological evidence, although the Carboniferous/Permian boundary has not been definitely fixed on the basis of microflora and it is possible that some of the formation in this area is Carboniferous in age.

QUAMBY MUDSTONE

The Quamby Mudstone is dominantly a dark grey, often pyrite rich, poorly bedded mudstone and siltstone containing occasional pebbles. Lenses of limestone occur at some locations. Fossils are not common, although the limestone lenses are sometimes rich in brachiopods. Glendonites are common at some locations. The formation ranges in thickness from about 75 - 120 m and is exposed along the western margin of the basin.

GOLDEN VALLEY GROUP

This group consists of fossiliferous siltstone and pebbly sandstone with an impersistent richly fossiliferous pebbly limestone 1 - 2 m thick towards the base. The group is 45 - 60 m thick and is exposed along the western part of the basin.

Lower Permian freshwater sequence (Liffey Group)

This group comprises the lower freshwater beds and consists of clean, cross-bedded quartz sandstone and thinly bedded carbonaceous shale. The uppermost sandstone is marked by abundant worm casts. The sandstone members crop out strongly and form benches, whereas the shale members are poorly exposed. The group is about 30 m thick and occurs along the western margin of the basin.

Upper Permian freshwater sequence

POATINA GROUP

The Poatina Group consists of 80 - 100 m of interbedded siltstone, sandy siltstone, sandstone, and pebbly sandstone, with occasional thin conglomerate beds. Parts of the group are richly fossiliferous, particularly some of the upper beds. The group occurs along the Western Tiers and on the western side of McRaes Hills. Equivalent rocks also occur near the northern margin of the basin.

BOGAN GAP GROUP

This group consists of 200 m of blue-grey well bedded mudstone and sandy mudstone with a few pebbles. There is one sandstone bed in the middle of the group and one thin fine-grained conglomerate near the top. There are occasional marine fossiliferous horizons, and worm casts are common at some levels. Apart from around the northern margin of the basin, the Bogan Gap Group is the only part of the Permian system that is exposed to the east of the Tiers Fault.

The group is widely distributed throughout the area with exposures along the Western Tiers, along the eastern margin of the basin, and around the northern margin. It was also encountered in some of the boreholes in the north-east part of the basin.

JACKEY FORMATION

This is the top member of the Permian sequence and is a freshwater deposit consisting of carbonaceous shale and micaceous sandstone. It is rarely exposed and appears to lens out to the south along the Western Tiers. It has not been recognised in any other part of the basin margin. The thickness is variable, McKellar (1957) having estimated the thickness at 43 m; this is probably near its maximum in the area.

Triassic

Triassic freshwater sediments occur extensively around the margins of the basin and along the central ridge. The boundary between the Jackey Formation and the base of the Triassic is poorly defined, with the first massive sandstone bed above the carbonaceous shale usually taken as the base of the Triassic. These sediments attain a thickness of about 600 m along the Western Tiers, but the thickness is unknown in other parts of the basin where they occur in country of low relief.

The sediments comprise dominantly even-grained cross-bedded quartz sandstone, which appears to form the basal part, with lithic sandstone and shale, sometimes carbonaceous, forming the upper part. Where possible, the Triassic has been divided between these two lithologies and where no division can be made they are undifferentiated. Occasional mud pellet conglomerate occurs in the sequence and coal has been mined from shale and lithic sandstone horizons about 6 km north of Longford.

Jurassic dolerite

Dolerite is particularly common around the margins of the basin and throughout the central ridge. It was encountered in many drill holes, including the two oil prospecting holes drilled in the deepest part of the basin. It is generally intrusive into Permian and Triassic rocks, although it intrudes older rocks at some locations in the south-western part of the basin. Dolerite occurs as sills and dykes, but the actual attitude is often difficult to determine because contacts with the host rocks are often covered by the overlapping Tertiary sediments. In some parts it is shallowly transgressive; this can be seen in levels of intrusion along the Western Tiers. Probable centres of intrusion occur at Mt Arnon between Longford and Launceston (Longman and Leaman, 1971), and on the Lake River just west of Millers Bluff, where a dolerite body appears to have vertical contact with Permian rocks. The sediments intruded by the dolerite are sometimes severely indurated, particularly if the body of dolerite is underlying the sediments as at Hummocky Hills. Where the dolerite is sill-like along the Western Tiers, it appears to attain a thickness of at least 300 m.

Tertiary sediments

INTRODUCTION

The first detailed examinations and reports on the Tertiary sediments of the area were made by Johnston (1874, 1875, 1888). Strzelecki (1845) had previously made some geological observations in the area, describing lignite in the valleys of tributaries of the River Tamar, and showed sandstone on his section from Drys Bluff to Launceston. He mapped the sediments in Epoch 4, which was a group made up of sand and gravel. Strzelecki also described the soils of the Longford and Hagley areas in some detail.

Johnston (1875) used the name Launceston Tertiary Basin to describe the trough in which the Tertiary sediments occur, and included areas such as Ross, Tunbridge, York Plains, and the Fingal Valley. Johnston also named some parts of the sequence, referring to Breadalbane Lignite, a lignite bed about 1.2 m thick, Corra Lynn Agglomerate [which Carey (1947) described as a conglomerate], and Windmill Hill Beds, which Johnston described as interbedded clay sediments and tuffaceous sand. He named the whole of the Tertiary sequence the Launceston Beds. Narrow, largely unexamined extensions of the basin along the River Tamar north of Launceston, west from Westbury, east along the South Esk River from Glen Esk, and south from Campbell Town have not been included in this study. Another possible continuous extension is south of 'Auburn', although dolerite cropping out just north of that property would mean a narrow channel connection. Apart from these locations, the basin is surrounded by surface-exposed basement rocks. Later workers who have examined some parts of the basin include Nye (1926), Nye and Blake (1938), Carey (1947), McKellar (1957), Pike (1973), Gulline *et al.* (1973), Longman (1966), and Sutherland (1971). Nicolls (1958, 1959, 1960) mapped the soils of a large part of the basin and described the system of terraces and erosion levels. Hinch (1965) and later Longman and Leaman (1971), using his work and extending the coverage, produced a gravity map of the area.

NATURE OF THE BASIN

Terrestrial sediments of largely Palaeocene to Eocene age were deposited in an approximately oval shaped north-west trending basin. This basin parallels the direction of the Bass Basin to the north and its formation is probably related to some stage of development of the Bass Basin. The Bass Basin contains sediments as old as Early Cretaceous (Robinson, 1974), whereas the oldest dated material from the Launceston area is Palaeocene, with the majority of the sediments being dated as Eocene (Esso Australia Ltd, letters of 9 July 1971, 19 October 1966; Appendix 13). The sediments in the Bass Basin are non-marine from the Lower Cretaceous to Middle Eocene (Robinson, 1974). The Launceston Tertiary basin sediments are also non-marine, although Harris (1968) records microplankton at Legana and S.M. Forsyth (pers. comm.) located rare specimens of the acritach *Mictryshidium* in one sample south of Hagley; this may suggest some marine or brackish environment influences from time to time. Upper Oligocene non-marine sediments underlying basalt at George Town have been recorded by Sutherland (1971). These are the only known Tertiary sediments younger than Eocene, although Sutherland suspects some of the sediments interbedded with basalt flows are younger than this.

A central ridge of basement high also trends in a north-west direction and divides the basin into two parts, which Carey (1947) referred to as Lakes Cressy and Tamar. Drilling has shown that this basement high is not continuous and at least 174 m of Tertiary sediments (extending to at least four metres below present sea level) occur north of Hummocky Hills. Thus the two areas of sedimentation were connected for part of their depositional history. Contours on the basement (in metres depth from the surface) are shown on Figure 2; these have been drawn using the available drill hole information and surface exposures. Drilling has shown that the western part of the basin is deeper than most and probably all of the eastern part and this is supported by gravity information (Longman and Leaman, 1971). The gravity survey suggests local depressions in the central area of the eastern sub-basin, but in detail the gravity has not indicated depths to bedrock accurately in this area (although in general it has indicated the extensive areas of deeper sedimentation throughout the basin.

In the Cleveland area, basement rock was struck at 120 m (84 m a.s.l.) from the surface (Middleton, 1973). A diamond drill hole at Carr Villa, 5 km south of Launceston, struck dolerite at about 170 m (about 78 m below sea level). Investigation Hole 51, in the northern part of the eastern sub-basin, struck Permian sediments at about 137 m (about 67 m below sea level).

Between the northern and southern parts of the basin, investigation holes did not extend to basement in most cases; *e.g.* IH 44 went to 170 m (15 m below sea level) before being stopped in hard conglomerate. A gradient from south to north is suggested from drill hole information, although the maximum depth of the central part of the basin is not known. It is also unknown whether these holes were sited in the locally deepest part of the basin.

Basement rocks were struck in many holes around the margin of the western sub-basin, but many holes within the basin ended in Tertiary sediments. Two oil prospecting holes struck basement at about 686 m (506 m below sea level) and 792 m (637 m below sea level) from the surface. These were sited on results obtained from the gravity survey (Longman and Leaman, 1971). Little is known of the maximum depth to basement from south of Delmont to Campbell Town, as the two investigation bores in this area ended in conglomerate. It seems likely that the depth of sedimentation shallows in a southerly direction as in the southern part of the eastern sub-basin.

It is probable that the two oil prospecting holes have penetrated two of the deeper zones of preserved Tertiary sedimentation within the basin. There has obviously been some erosion of the later sediments, so that the total original thickness was greater. Part of McRaes Hills on the western side of the basin has previously been covered by Tertiary sediments, as there are remnants up to about 210 m above sea level along the top of this low range. To the north-east and north-west of Campbell Town, Tertiary sediments are preserved on the sides of valleys to a height of about 220 m above sea level. It seems quite likely that much of McRaes Hills was covered with sediment and the valley between McRaes Hills and the Western Tiers was probably also filled. Only thin remnants of Tertiary sediments are preserved in this valley, particularly north-west of 'McRaes Hills' property, as drilling shows basement rocks to be at shallow depth. McKellar (1957) suggests that some of the sediments overlying bedrock in this area may be Tertiary in age. To the south, near Billop and Woodside, deeper remnants of Tertiary sediments may occur, as some auger holes did not reach definite bedrock. At the completion of the main sedimentation period, a much larger area was covered and sedimentation may have extended to even higher levels than is suggested above.

From drilling results, some average slopes for the sides of the troughs can be calculated. Dolerite outcrops near Bracknell are 3.2 km from hole OP 1, which struck dolerite at about 686 m from the surface. This indicates an average basement slope of about 12° between these two points. The exact position of the diamond drill hole which went to 272 m on the property 'Belmont' near Longford (Johnston, 1888) is unknown. Blake (1959) placed the drill hole on the present day property 'Belmont', not far from the homestead, but Johnston describes the deeper area as "one mile south-west of the Norwich coal field". The average slope of the basin side is probably fairly steep in this area. The sides of the basin are probably fault scarps against and over which the sediments have been deposited. At the margins, the basement would slope at much greater angles than these average values.

The gravity interpretation of Longman and Leaman (1971) suggests a striking unsymmetrical basin shape, but the depths of the above holes and IH 22, 5 km south-west of Longford (which was drilled to 308 m without striking basement) suggests that it may not be markedly unsymmetrical.

FORMATION OF THE BASIN

Carey (1947) was the first to propose a detailed mode of origin for the basin, postulating an early Miocene peneplain being broken up by normal step faulting to form a graben structure with a central horst. Some blocks were tilted in this action, others warped and buckled. Uplifted areas were related to isostatic readjustment of old orogenic roots. Carey dated the major north-west fracturing as Lower Miocene. Longman (1966), after detailed study in the north-eastern part of the basin around Launceston, produced a model in which a constantly south-west dipping surface was fractured by normal faulting, down-throwing to the east. This fracture model was extended across to the western margin of the basin and is the model used in the gravity interpretation of Longman and Leaman (1971).

It is tempting to think of the basin being formed in association with the intrusion of the Jurassic dolerite, which must have been responsible for widespread faulting. In addition, many of the observable major faults have a dominant dolerite or pre-dolerite age [*e.g.* Tiers Fault (Carey, 1958) and the fault along the western side of Mt Arnon (Longman and Leaman, 1971)]. However the absence of recognisable Late Jurassic and Cretaceous sedimentation does not support this idea. The rock distribution from drill hole information suggests that some of the larger faults must have formed after the dolerite intrusion. The age of the oldest sediments (Palaeocene) suggests a late Cretaceous or early Tertiary initial formation and subsequent subsidence during the Lower Tertiary, as most of the sediments appear to be Eocene in age.

Griffiths (1971) postulated a sequence of events resulting in the formation of the Bass Basin. In late Jurassic, NE-SW tensional stress produced NW-SE faulting as Australia and Antarctica separated. This resulted in the beginning of the formation of the Bass Basin. In mid-Cretaceous a further series of downwarps occurred as Tasmania moved clockwise relative to Australia. During the Tertiary, further NE-SW tension resulted in further basin formation.

Significant events in surrounding basins may be related to the formation of Tasmanian basins. Reynolds (1967) described basin wide seismic unconformities in the Otway Basin at about the end of the Lower Cretaceous, between the Upper Cretaceous and Tertiary, and above the Palaeocene-Eocene succession. In the Gippsland Basin he recorded at least two such unconformities, and these are in the same general position as the upper two in the Otway Basin. However James and Evans (1971) considered that the Lower Tertiary sediments in the Gippsland Basin were conformable with and similar to the Upper Cretaceous. Like the Bass Basin and Launceston Tertiary Basin, the Gippsland Lower Tertiary sediments are dominantly non-marine. Robinson (1974), in describing the Bass Basin development, outlined three structural provinces; the south-east part which showed the first major structural growth in the Early Cretaceous and the central and north-western parts where structural growth occurred in the Early and Late Tertiary.

It is apparent that some of the tensional forces which developed to form the Bass Basin extended into northern Tasmania and resulted in the formation of the Tasmanian Tertiary basins. As the oldest dated sediments in the Launceston Tertiary Basin are Palaeocene, it is probable that the earlier tensional stresses and downwarping that developed the Bass Basin did not extend to the Launceston Tertiary Basin to any marked extent or if they did, subsequent sedimentation has not been recognised. Cretaceous sediments have recently been dated in a bore hole in north-east Tasmania (Forsyth, 1980).

Williams (1976) postulated that the Tamar Valley had been a zone of tectonic activity prior to the Carboniferous and suggested a north-west trending wrench structure to account for the markedly different Lower Palaeozoic sedimentary rocks on either side of the river alignment. Earlier (Williams, 1967; 1969) he had shown that structural features formed at different times in older rocks in Tasmania exhibit repeated directions. Tertiary structures (faulting, zones of volcanism, and sedimentary troughs) in the Tamar region as well as the remainder of the Tertiary basin repeat the pre-Carboniferous north-west trend.

However forces in the nearby regions have produced other than north-west and north trending structural features. Elliot (1972) describes an east-west rift valley filled with non-marine sediments which formed in the Early Cretaceous and extended from the Gippsland Basin to the Otway Basin. This cuts across the direction of the Tasman Geosyncline and possibly the pre-Carboniferous structural feature aligned along the River Tamar. Although north and north-west trending structural features are common in the area, forces producing other trends have thus occurred. The forces producing structural features along the Tamar in pre-Carboniferous times are obviously different to those producing the Tertiary features, the Tertiary forces being almost certainly tensional.

The formation of the Launceston Tertiary Basin is thought to be related to forces developed in the region during the separation of the Australian and Antarctic continents, similar to the formation of the nearby and much larger Otway, Dunoon Embayment, Bass, and Gippsland Basins. The continental separation commenced well before the formation of the Launceston Tertiary Basin and the formation of the basin is probably related to some later phases in the development of the larger basins to the north. Palaeocene-Eocene sedimentation is similar in the Launceston, Bass, and most of the Gippsland Basin(s), all being largely non-marine fluviatile, lacustrine and deltaic-type deposits. The later marine Oligocene-Miocene sediments of the other basins are largely and perhaps entirely absent from the Launceston Tertiary Basin. This may be because of rising basement highs separating the basins, because the level of the Launceston Basin was always higher than the Bass Basin, or warping may have taken place parallel to the Tasmanian coastline.

Although the initial formation of the basin was probably structural, some part of the basin formation may have been by erosional processes and perhaps a large part by loading of the land surface by sediments. The expected depression by loading an isostatically stable land surface with up to 760 m of sediments with a density of 1.9 is about 460 m (R. Underwood, pers. comm.).

The actual form of the basin is probably more of a graben structure than that depicted by Longman and Leaman (1971). It is apparent that parts are not simple graben structures, as indicated by the difficulties expressed by Longman (1966) with the dolerite at Punchbowl in Launceston with respect to the South Tamar area. Sutherland (1971) suggests that the Tamar Trough may become a graben structure north of Hillwood. The Port Sorell Basin has also been interpreted as a graben by Longman and Leaman (1971), and the nearby larger basins, Bass, Gippsland, and Otway have been recognised as essentially graben structures. If tensional forces are the forces prevailing in the formation of these basins, it is difficult to envisage how the structural model of Longman and Leaman (1971) could develop. Recognition of the fact that the observed gravity results appear to fit the model in a broad sense should not be disregarded, however.

NATURE OF SEDIMENTS

The sediments in the basin comprise alternating beds of clay, silty clay, sandy clay, sand, gravel, and conglomerate. Lignite fragments are common and there are minor lignite beds and seams. Disseminated grains of siderite are widespread in some areas. Near the maximum thickness of sediment was probably penetrated in oil prospecting holes north-west of Bracknell and near Hagley. These penetrated 686 m (OP1; collar 180 m a.s.l., base 506 m below sea level) and 792 m (OP2; collar 155 m a.s.l., base 637 m below sea level) before entering dolerite. Shale fragments occurred in the final 30 m and 110 m respectively of each hole before entering dolerite. These fragments appeared in the drill cuttings without any apparent gradation from the softer sediments above and were as lithified as some Triassic sediments. (The appearance of the lithified chips in the hole near Hagley approximates the highest recorded *Lygistopollenites balmei* Zone (Palaeocene) assemblages in this hole. Palynological examination of cuttings sampled through the 110 m interval have all yielded Palaeocene assemblages which are not regarded as being contaminants. The lithified chip samples from near Bracknell have also yielded Early Tertiary assemblages - S.M. Forsyth, pers. comm.). Two other holes, IH 22 and IH 27, were drilled to about 300 m in Tertiary sediments and a diamond drill hole near Longford penetrated 272 m of sediments without striking basement rocks. Thick sections of the Tertiary sediments have therefore been sampled.

A feature of the sediments is the presence of lignite fragments throughout much of the section. The diamond drill holes at Longford (DH1) and Carr Villa (DH2) (Johnston, 1888) were primarily aimed at locating Triassic coal and these encountered only occasional thin seams of lignite, the thickest being 1.2 m at 244 m depth at Longford. A diamond drill hole near Cressy (DH3), drilled to 141 m as part of this survey, encountered only fragmentary lignite pieces up to about 50 mm across. In the deeper rotary drilled oil prospecting holes, the return for long sections was mainly small lignite fragments and it may be that in these locations there are some beds of lignitic material which may be much thicker than those previously reported; these would probably be too deep to exploit. Lignite bands about one metre thick are known to occur and have been exploited on a small scale at some places (*e.g.* Legana, Rosevale, east of St. Leonards, Breadalbane). In some parts of the basin, particularly in the Evandale area, wood fragments have been replaced by iron oxide in near-surface beds and leaf impressions are common in iron oxide-rich boulders.

Conglomerate beds

Conglomerate beds are fairly common in the northern part of the eastern sub-basin, and the southern part of the western sub-basin. The conglomerate comprises mainly rounded dolerite and quartzite boulders ranging up to about 80 mm across. These are usually set in a matrix of smaller weathered dolerite fragments and quartz. The conglomerate has varying degrees of compactness, sometimes occurring as loosely cemented boulder beds as encountered in IH 42 and IH 43. Some conglomerate is extremely hard and siliceous and resembles greybilly (*e.g.* IH 10 at 32 m, IH 11 at 18 m). These were extremely difficult to drill but were only 150 mm thick and were penetrated slowly. A granite boulder was included in a conglomerate bed at 73 m from the surface in IH 54. It may have been derived from pebbly beds in the Permian which could have been exposed in the area during Tertiary times or it may have been river-transported from north-east areas during the Tertiary. Rounded granite boulders occur in Quaternary gravel on the banks of the South Esk River at Glen Esk, these being derived from exposed granite areas further upstream near Avoca. Because of the rounding

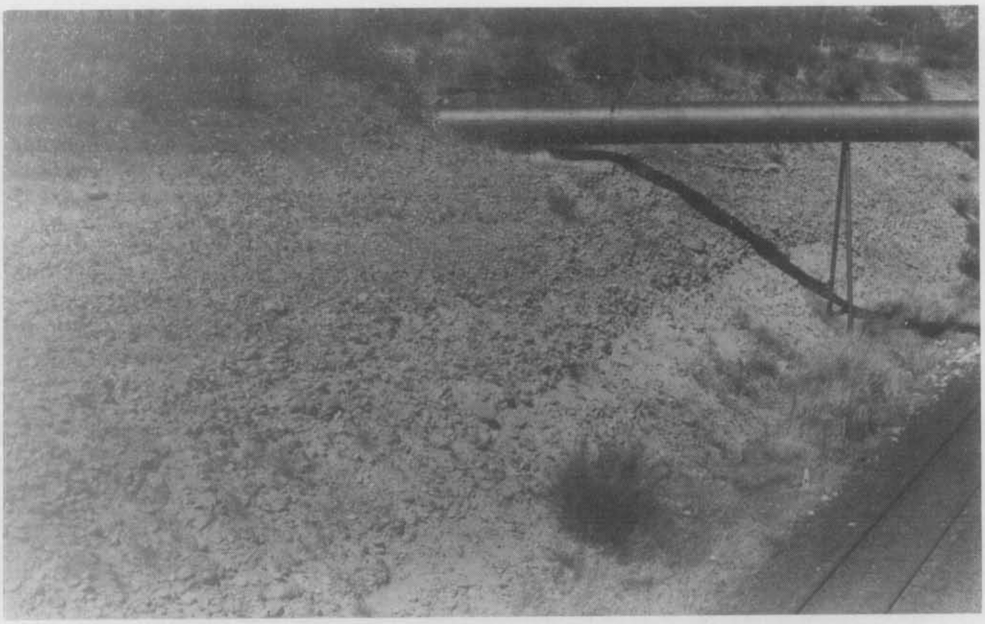


Plate 7. *Dolerite boulder beds of probable Tertiary age exposed in a railway cutting at Rocherlea, 6 km north of Launceston.*

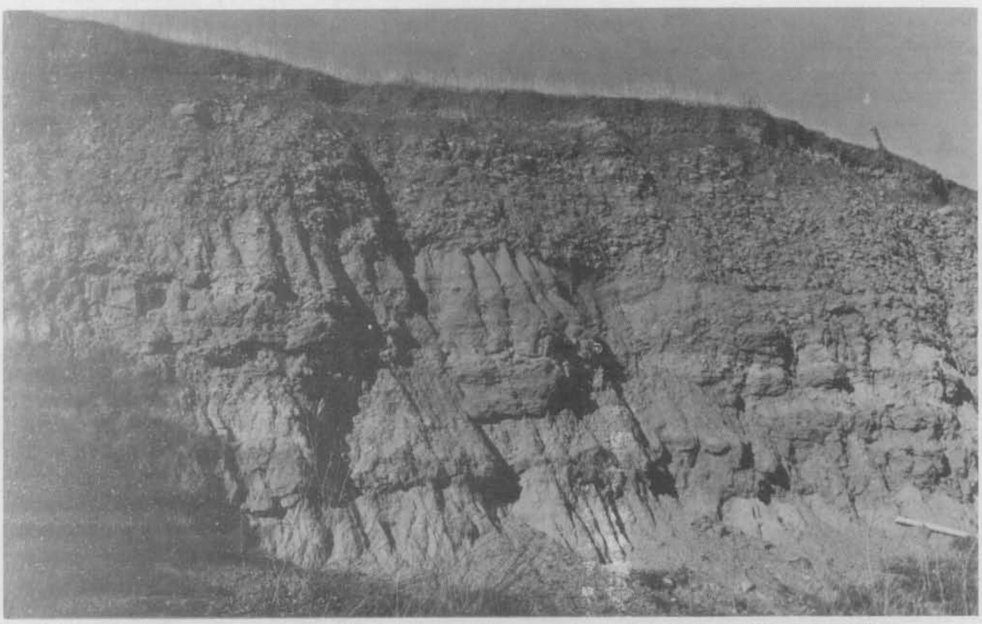


Plate 8. *Gravel and sand made up dominantly of quartz and quartzite exposed in the heel of a landslip on the edge of a terrace one kilometre south of St Leonards. This terrace and landslip are shown on the right-hand side of Plate 6 (p. 21).*

of the fragments they are regarded as having a fluvial origin.

Several conglomerate horizons were encountered in some holes. Hole 44 had two conglomerate beds, one about 8 m thick, and the hole was finally stopped at the second horizon at a depth of 170 m (15 m below sea level) because of its hardness. In IH 52, the final 50 m was nearly all conglomerate, eventually preventing further drilling.

Thin sections were made of several borehole samples of conglomerate and descriptions prepared by G.B. Everard are given below.

Sample 71-599; 29.0 m, IH 4 [EP138914]. The hand specimen is a medium-grained variegated white and green rock consisting of feldspar and a ferromagnesian mineral. The specimen shows an igneous contact on one face which contains quartzite pebbles and black carbonaceous material.

In thin section, the texture is semi-ophitic with some clear crystals of labradorite about 0.25 mm long, partly enclosed in crystals of pyroxene up to 2 mm long and semi-opaque with alteration to biotite, chlorite, and serpentinous material and carbonate. The pyroxene has selvedges of magnetite and acicular apatite is commonly associated with the feldspar. A very fine-grained mesostasis is cloudy with alteration.

Sample 71-600; 29.0 m, IH 4 [EP138914]. The hand specimen is a predominantly yellowish-green rock composed of rounded pebbles about 10 mm long in a friable sandy matrix with fine sub-parallel veins of carbonate cutting the whole rock, even passing into the pebbles.

In thin section, the pebbles consist of greywacke-type sediment containing quartz, feldspar, and lithics in excess of the fine-grained brownish matrix. A small minority of pebbles consist of quartzite.

The material between the pebbles consists of angular quartz grains and a few cloudy grains of feldspar in a matrix of brownish carbonate. In addition each pebble has a rim of fibrous carbonate and carbonate veinlets cut some pebbles. Needles of apatite occur in parts of the matrix.

The rock is a conglomerate in which the finer material of the matrix has been replaced by carbonate.

Sample 71-601; 32.0 m, IH 10 [EP066774]. The hand specimen is a dark brown rock with quartz or quartzite fragments ranging mainly from 10 mm long down to microscopic sizes. The specimen contains many holes, long in comparison with their diameter, which vary from 2 or 3 mm down to hairline dimensions, of irregular roundish shape, some lined with a little carbonaceous material, which may be the impressions of plant remains.

In thin section, the rock consists of grains of silica bonded by reddish-brown hydrated oxides of iron. Some of the larger grains are rounded or may show some rounding, with rounding occasionally seen in grains as small as 0.25 mm. Both wind deposited and water deposited material is present. The grains consist mainly of quartz showing signs of recrystallisation, but some quartzite and schistose quartzite is also present.

Sample 71-602A; 76.2 m, IH 10 [EP066774]. The hand specimen is a medium to fine-grained, greyish rock.

In thin section, the rock consists of angular grains of lithics, quartz, and feldspar in a siliceous and carbonate matrix.

Sample 71-602B. Similar to 602A, but with the addition of pebbles, mainly of fine-grained greywacke-type rock, averaging about 10 mm in length. This rock is somewhat like 71-600.

Sample 71-603; 17.7 m, IH 11 [EP052765]. The hand specimen is a fine-grained brown rock similar to 601 and with similar holes due to plant remains. In thin section, the rock is paler than 601 and of more even grain size, the larger fragments not being present. It consists of angular to sub-rounded fragments of quartz set in a mainly siliceous matrix. Plant remains have been silicified but a little carbonaceous material remains to outline the original cellular structure.

Some recrystallisation of quartz has occurred and in the hand specimen the gradation from sandstone to quartzite can be seen. The fine siliceous matrix sinters, and dark organic material is partly burnt out. Recrystallisation of the larger particles follows. Specimens 601 and 603 show increasing induration.

Sample 71-604; 62.5 - 62.8 m, IH 35 [EP123766]. The hand specimen is a soft, brown, porous fine-grained rock effervescing with acid in the cold, the acid colouring rapidly. The rock contains a few rounded pebbles of quartzite from 3-300 mm.

In thin section, the rock is a granular aggregate of crystalline calcite stained brown with iron oxides. There are occasional grains of quartz and feldspar and some interstitial clayey material. The grain size is about 0.05 mm.

Sample 71-605; 83.3 - 83.8 m, IH 37 [EP196670]. The hand specimen is a dark brown, soft but very fine-grained and compact rock effervescing with acid in the cold. It contains pebbles of dolerite with rounded edges up to 30 or 40 mm across and a variety of smaller fragments including quartz.

In thin section, the rock is a dense, fine-grained mass of yellow-brown calcite with aggregate polarisation except where recrystallisation has begun. Angular grains of quartz and feldspar averaging 0.1 mm across are common. Around the larger dolerite pebbles the grain is coarser and a thin band of white recrystallised calcite surrounds the pebble.

Sample 71-606; 32.0 - 42.7 m, IH 38 [EP247661]. The rock is a conglomerate containing rounded pebbles of quartzite, basalt, and dolerite. The matrix contains lithic fragments up to about 2 mm in length with a carbonate cement which effervesces on warming.

Sample 71-607A; 44.2 - 45.7 m, IH 40 [EP234937]. This specimen is on the contact between dolerite and quartzite. A brownish mineral like iddingsite is prominent in the dolerite at the actual contact, together with traces of a bright green mineral like garnierite.

Sample 71-608; 116.4 - 117.3 m, IH 41 [EP209845]. The hand specimen is a greenish yellow rock, consisting of rounded pebbles of quartz, quartzite, slate, and schist in an indurated fine-grained clayey matrix. A pebble of dolerite about 50 mm long is in the centre of the specimen.

The thin section shows the central dolerite pebble to consist largely of relatively fresh laths of labradorite averaging 0.2 mm long, but the augite is brownish and semi-opaque and there is much carbonate present. The rest of the specimen is a mass of quartz grains and lithics in a groundmass of secondary quartz and clay material.

Specimen 71-610; 58 m, IH 46 [EP249986]. The hand specimen is a dark greenish weathered rock with black fine-grained pebbles about 20 mm long and fine white veinlets traversing the matrix.

In thin section, the matrix consists of dark brown opaque clay material stained brown with iron oxides and containing angular to semi-rounded fragments of quartz and feldspar. The fine veinlets consist of fibrous carbonate and carbonate fills interstices between other materials. The larger pebbles consist of weathered dolerite and some of the smaller rounded fragments are schistose.

Specimen 71-611; 51.5 - 52.4 m, IH 44 [EP196928]. The hand specimen consists mainly of a bluish-grey medium to fine-grained rock containing feldspar and ferromagnesian material. One corner and side of the specimen display rounded pebbles in a matrix of finer grained clastic material.

In thin section, the massive part of the specimen consists of dolerite with glomeroporphyritic tendencies. Crystals of pyroxene averaging 1 mm long tend to occur in clusters with the intervening spaces made up of stubby laths of labradorite and mesostasis.

The clastic part is a conglomerate made up of pebbles of dolerite, quartzite, schist, and mudstone in a matrix of quartz grains, carbonate and weathered doleritic material. The dolerite which makes up the greater part of the specimen is probably the edge of a boulder.

Specimen 71-612; 169.2 - 169.8 m, IH 44 [EP196928]. The hand specimen is a greenish black clastic rock with rounded lithic pebbles and veinlets of calcite.

In thin section, there are rounded pebbles of coarse to medium-grained dolerite, very fine-grained dolerite (probably from a chilled margin), with altered feldspar in a matrix containing quartz, feldspar and pyroxene.

Specimen 71-614; 73.2 - 73.5, IH 54 [EP274876]. The hand specimen is a porphyritic dark rock with phenocrysts of quartz and feldspar up to 1 mm long in a medium-grained dark matrix containing feldspar and quartz, the feldspar being white and cleaved and the quartz dark and glassy. Black flakes of biotite up to 1 mm across are also common.

In thin section, a hypidiomorphic texture appears in the material filling the interstices between the phenocrysts which contains crystals of clear quartz, cloudy feldspar, and dark brown and green strongly pleochroic biotite. A little white mica is also present.

Specimen 71-615; 45.7 - 47.9 m, IH 52 [EQ185052]. The rock is a conglomerate containing pebbles of dolerite up to 50 mm or more in a matrix formed from the debris of weathered dolerite and consisting of angular grains of feldspar and pyroxene in opaque clay material stained by serpentinous residues.

Specimen 71-616; 82.3 - 83.8 m, IH 52 [EQ185052]. This rock is a pale coloured conglomerate with pebbles 20 - 30 mm long, the whole being somewhat weathered.

It contains pebbles of dolerite, quartzite and mudstone in a matrix of quartz and clay, together with fresh feldspar and lithic fragments. Fine cracks that have developed around the peripheries of dolerite pebbles, in the matrix, and across mudstone pebbles have been filled with crystalline silica.

Earlier(?) quartz gravel horizons

Widespread fine-grained gravel horizons made up almost entirely of siliceous material occur in the southern part of the eastern sub-basin. These are usually within about 40 m of the surface, but may deepen towards the north. The deposits occur around the entrance of the South Esk River to the basin and have been located from south-east of Conara to just south of Powranna. They were first recorded when struck in two water bores at Conara railway station in 1929, where they underlie basalt. They also underlie basalt in boreholes at some other locations, but at others, no identifiable basalt has been found over them, although the basalt may be so deeply weathered as to be unrecognisable in drill cuttings. Two or more horizons of fairly clean, coarse sand to fine gravel beds have been encountered in some holes. Although it is not proven, it seems likely that at least one horizon is fairly continuous over a wide area, whereas others may be lenticular in nature. The boreholes are spaced too far apart to allow detailed correlations. The gravel is almost certainly a fluvial deposit and rapid lateral variations could be expected.

The age of these beds in relation to the dominantly dolerite conglomerate to the north is not known. They may be equivalent in age to the upper horizons of these conglomerate beds, but the lower conglomerate, such as in IH 44, is thought to be older.

The gravel is made up dominantly of clear quartz with some milky vein quartz, occasional quartzite fragments, and agate. Much of the coarser grained material, with an average diameter of about 50 mm, comprises angular to sub-rounded fragments of quartz with irregular surfaces and is almost certainly derived from the weathering of granite and has probably been transported downstream by the ancestral South Esk River. The dominant grain size in most beds is coarse sand, but there is a considerable size range, and fine sand is also included. The vein quartz and quartzite fragments generally make up the larger material. Heavy minerals are widespread, although they do not make up a large percentage of the material. Concentrates of material from two levels in IH 58 contained the following minerals (identification by G.B. Everard):

Depth (m)	*Description*
22.9 - 29.0	90% quartz with small amounts of zircon, topaz, tourmaline, ilmenite, rutile, and garnet.
30.5 - 38.1	70% quartz, 25% zircon, 5% rutile, with traces of tourmaline.

The magnetic fraction of many of the gravels contained highly magnetic spherical particles varying in size from about 30 - 375 µm.

Apart from the dominantly dolerite conglomerate already discussed, coarse-grained sediments are rare in the western sub-basin. A thin bed of dominantly quartz gravel occurs between Longford and Cressy at 60 - 80 m from the surface. About 200 mm was recovered in the diamond drill hole near Cressy, while in rotary drilled holes, both investigation groundwater holes and uranium prospecting holes, samples containing gravel fragments were obtained over thicker sections. Once struck, the coarser horizons of unconsolidated sediment tend to contaminate samples from deeper sections of the hole. The coarser material from the diamond drill hole (about 10% is greater than 5 mm diameter) consists mainly of sub-rounded to angular milky vein quartz and black chert. Fragments range up to 20 mm diameter. The finer material consists mainly of poorly sorted angular clear and milky quartz with a few chert fragments. It seems probable that much of this material is derived from the weathering of Permian sediments in the basin margins. The gravel might be a series of lenses, but because of its fairly regular occurrence, it is probably largely continuous and a dip of about 0.3°S is suggested from intersections in boreholes.

Siliceous gravel has been struck in holes between Mt Arnon and Hummocky Hills (*e.g.* IH 1 and 4 at 15 - 17 m and 13 - 27 m respectively). It is not known whether they are related to the horizon between Cressy and Longford as they are at shallower depths. In other holes, pebbly clay with quartz fragments occurs at some horizons (*e.g.* IH 3, 5, 7). This may be the lateral equivalent of the gravel between Cressy and Longford, as it occurs at similar depths.

Later(?) quartz gravel horizons

Apparently later quartz gravel occurs on the surface over a widespread area between Conara and Longford. This is the gravel on the Brickendon Surface described by Nicolls (1960), and is also the gravel that Johnston (1874, 1875) described in detail. The gravel consists of rounded quartzite and quartz fragments (both milky vein quartz and clear), usually less than 50 mm in diameter but occasionally larger, embedded in a matrix of quartz sand, silt, and clayey sand. Occasional agate, silicified wood, and indurated fossiliferous Permian fragments can be found. Small spherical zones of iron oxide staining are frequent. Just north of Epping Forest and west of Powranna, this gravel underlies laterite and lag lateritic pisolitic gravel.

There is little doubt that the red iron oxide cemented siliceous conglomerate north of Hummocky Hills and light brown to white siliceous gravel to the east are of similar age and are probably of similar age to surface gravel exposed around Evandale. They are regarded as Tertiary as they are older than the lateritisation. Blake (1959) mapped these gravels as Quaternary and Nicolls (1960) suggested a late Tertiary? post-basalt age. Quartz gravel overlies basalt just north of Evandale.

Later(?) dolerite boulder beds

Rounded dolerite boulder beds occur at the surface from north of Evandale around Rose Rivulet through to near St Leonards and further north to north of Rocherlea. There are some siliceous pebbles included in these boulder beds and Sutherland (1971) reported finding a few basalt fragments, apparently around 'Sunnyside'. These beds occur on terraces around Rose Rivulet and underlie basalt on the basalt capped hill opposite 'Talisker'. It is not known whether these are the same age as those around St Leonards and Rocherlea, but they are similar in nature and composition and may mark the course of the South Esk River in pre-basalt times. It is possible that they are similar in age to some of the dolerite conglomerate found in drill holes nearby. They are regarded as Tertiary as they underlie basalt.

At a higher level around the homestead 'Ridgeside', boulder beds with abundant basalt boulders extend over a small area. Basalt-rich boulder beds also occur around White Hills.

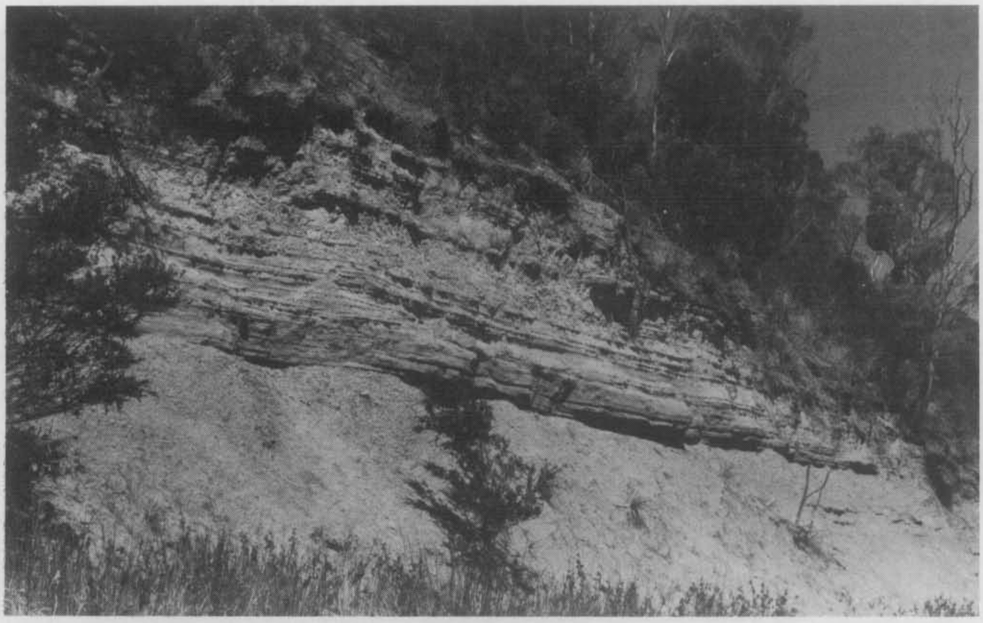


Plate 9. *Tertiary sediments exposed in a cliff at the edge of the River Tamar at Legana, 13 km north-west of Launceston. The more competent beds are sandstone.*

Plate 10. *Tertiary sediments, composed of sand and clay, exposed in a road cutting on the Southern Outlet Road at Prospect, 3 km south of Launceston.*

Laterite and lateritic lag gravel deposits

Laterite and lag deposits of pisolitic iron oxide formed by lateritisation extend over wide areas and have developed on Tertiary sediments, Tertiary basalt, and Jurassic dolerite. There appears to be at least two distinct ages of lateritisation.

Carey (1947) records lateritised dolerite underlying the Tertiary sediments at a number of locations in the Launceston area. These occur particularly in the St Leonards area, where small zones of massive laterite and bauxite occur along the boundaries of dolerite and Tertiary sediment. The Tertiary sediments and basalt were affected by a later period of lateritisation and this extended across dolerite in some areas. This lateritic stage is often represented by extensive deposits of pisolitic iron oxide gravel, but extensive areas of massive laterite also occur. The massive deposits are best exposed along the banks of watercourses, where low cliff sections up to about two metres thick occur. Mineralogical studies of clay in the Tertiary sediments show gibbsite to be a fairly common constituent, suggesting that there may have been other periods of lateritisation.

Sand beds

Clean sand beds are relatively uncommon in the eastern sub-basin. Aquifers in fine-medium grained sand beds have only been found in a few bore holes including some in the north-east of the sub-basin (*e.g.* IH 50, 51, and 54). At most other locations within the sub-basin sand beds are often clayey; this is probably a function of the proportion of the surrounding area underlain by Triassic sandstone at the time of deposition. It is apparent that dolerite and Permian sediments provided much of the source material to fill the trough in the eastern sub-basin.

There is a widespread occurrence of clean, fine to medium-grained sand beds in the western sub-basin; there are few areas where such beds have not been struck at some level down to 150 m below the surface, and most holes contain a number of beds. In addition, there are clayey sand and sandy clay beds. Although the spacing of drill holes is wide, it is apparent that most sand beds are lenticular and it is difficult to correlate particular beds between holes, unless the beds are thick, when it may be possible to trace them for a few kilometres. An example of this is demonstrated in Figure 5. Electric and lithological logs of holes IH 12, 13, 14, and 15 cover a distance of about 9.5 km, over which a thick sand bed appears to lens out. The bed has been found in bores 3-4 km to the south, and west from the line joining IH 12-15; the thick sand beds in IH 17 and 18, some 4 km to the west, are probably the equivalent bed. It may extend further than this suggests but correlation becomes less certain with distance.

Material from the test bores suggests that the sand comprises mainly clear angular quartz grains with an average diameter of about 0.2 - 0.5 mm. Coarser sand with average size in the range of 0.8 - 1.25 mm across was struck in the oil prospecting holes which sampled from deeper zones. These again comprise mainly angular clear quartz fragments. Sand in IH 39 had an average grain size of about 0.9 mm.

Heavy mineral concentrates from aquifer material in some bores were identified by G.B. Everard as;

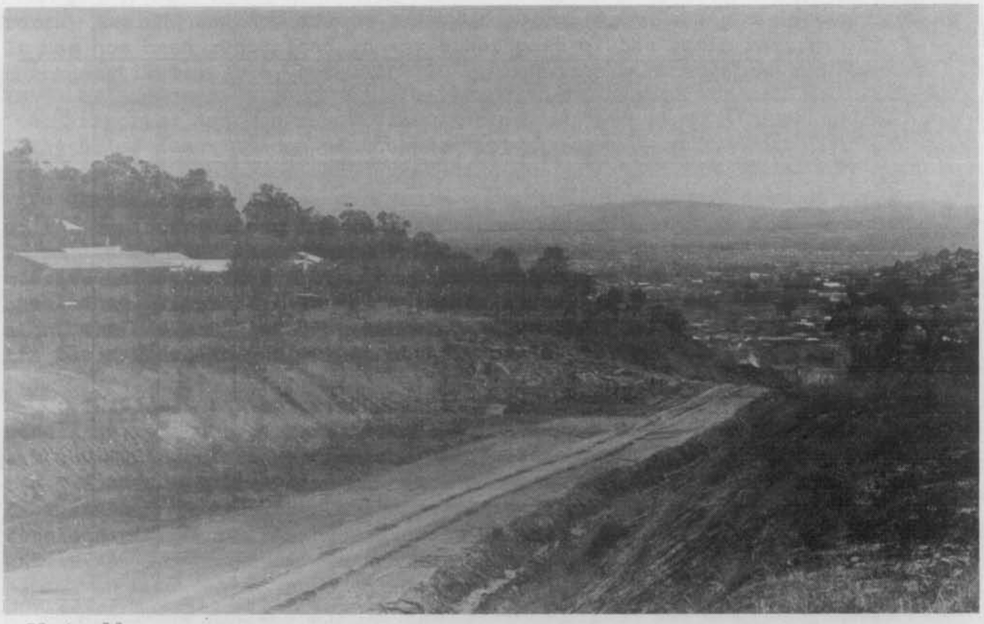


Plate 11. *View looking north along the Southern Outlet Road from Prospect towards Launceston and the River Tamar valley. The tertiary sediments to the left overlie dolerite in the centre of the picture.*

Plate 12. *A small wedge of Tertiary sediment is preserved in a low in the pre-sedimentation surface at the Vermont Road overpass, Bell Bay railway line. Dolerite crops out under the bridge and on the left side of the photograph almost to the cutting top.*

Hole	*Content*
IH 3	Abundant yellow siderite grains in quartz sand.
IH 21	Ilmenite 30%, zircon 30%, quartz 20%, siderite 15%.
IH 22	Quartz and quartzite fragments with 5% ilmenite and magnetite, 2% zircon, traces of feldspar and tourmaline.

Some sand beds occur in the sequence which mainly comprises weathered feldspar laths with some quartz grains. When rotary drilled, these beds tend to be pulverised and arrive at the surface as sandy clay, but their true nature can be seen when cored. Thin section descriptions prepared by G.B. Everard of two richly feldspathic samples from diamond drill hole DH 3 at Cressy and fine-grained clayey sandstone with mica from Hole B on Oaks Road are given below.

Sample 81.1 m; DH 3 [*EP046867*]. A fine-grained friable soft whitish rock with reddish brown grains up to 0.3 mm across, scattered freely in the paler matrix. Minute flakes of sparkling white sericite are common, and there are occasional small flakey masses of graphite.

In thin section by transmitted light, the matrix is brown with embedded clear angular crystals of quartz and feldspar, there being twice as much feldspar as quartz. The feldspar is untwinned, optically negative, with a large optic axial angle and a refractive index just above that of balsam. It is therefore probably oligoclase. The quartz grains tend to be somewhat rounded.

The matrix consists of clay minerals, minute wisps of mica, and feldspathic material in an advanced state of decomposition and comprises about 50% of the rock.

Sample 87.5 m; DH 3. A pale coloured, medium-grained, friable, poorly consolidated rock composed of angular grains of quartz up to about 1 mm across in a clay matrix with patches of carbonaceous material and partly decomposed feldspar.

Under the microscope the fine-grained material contains an appreciable amount of fresh feldspar in the albite - oligoclase range.

Sample 71-598; 163.4 - 163.7 m; IH B [*DP978975*]. The hand specimen is a fine-grained, friable, poorly consolidated, pale greyish or brownish rock consisting largely of angular grains of quartz and minute books of mica, together with black carbonaceous material and some faint brownish staining due to iron oxides.

In thin section, the quartz appears as angular grains averaging 0.05 mm across. Biotite and muscovite show as minute ragged plates of similar or smaller size filling interstices between grains. The rock is very porous, but some finer material has probably been lost in the preparation of the section.

There is a fine irregular banding in the rock which may be due in part to bedding and slumping, and in part to solution banding.

Table 4. CLAY MINERALOGY OF WATER BORE SAMPLES

Hole	Depth (m)	Montmorillonite Area (mm^2)	%	Illite Area (mm^2)	%	Kaolinite Area (mm^2)	%	Gibbsite Area (mm^2)	%	Quartz Area (mm^2)	%
OP 1	274	228	12			653	69			351	19
OP 2	365.8	648	53			256	42			72	6
IH *A*	9.1-11.9			39	15	266	52			330	32
IH 2	10.7					228	58			324	42
	86.9	154	5	46	7	1080	77	54	2	245	9
	146.3					231	87			72	13
IH 15	12.2	trace?		trace?		425	82			189	18
	74.7*			53	8	1035	78			221	8
	152.4					432	92			72	8
IH 21	7.6					160	77			95	23
	56.4			68	23	390	65			147	12
	144.8					108	49			221	51
IH 36	24.4[x]					360	59			450	37
	59.4	56	4			560	89			83	6
	152.4					256	57			391	43
	187.5			55	8	1080	83			229	9
IH 44	18.3			190	14	2250	81			263	5
	112.8					195	84			72	16
	167.6	41	3			546	91			65	5
IH 50	12.2	480	64			117	31	10	1	30	4
	19.8	180	59			45	30	8	3	25	3
	33.5	176	29			198	64	18	3	26	4
	42.7	152	44			83	49	12	4	12	4
	61.0	33	3			598	93	25	2	32	3
	91.4	56	4			588	93			30	2
	103.6	75	10			306	84			43	5.9
	131.1	39	22			117	67			36	10
IH 51	0-1.5					146	85			52	15
	4.6-6.1					228	88			60	12
	9.1-10.7					252	93			40	7
	30.5					240	95			25	5
	61.0					169	91			35	9
	91.4					154	91			29	9
	118.9	63	5			585	92			45	4
	137.2	72	7			434	90			30	3
IH 52	0-1.5					140	89			34	11
	9.1					113	86			38	14
	18.3	45	5			377	90	15	2	26	3
	29.0	59	9			286	87			26	4
	45.7	78	13			238	81			33	6
IH 57	6.1					207	62			252	38
	61	77	4	68	13	736	71			263	13
IH 68	1.5-3.0	188	17	90	33	162	29			228	21
	47.2					350	74	56	6	188	20

* undetermined peak at $2\Theta = 14.15°$, 162 mm^2, 6%

x undetermined peak at $2\Theta = 14.3°$, 42 mm^2, 3%

Fine-grained sediments

Beds of fine-grained material made up of clay, silty clay, and sandy clay comprise the dominant material, by volume, deposited in the basin. Much of the material recorded in the sample description logs has only been subjected to visual inspection in the wet state. Large sections of the material drilled were very plastic when wet and a high clay mineral as well as clay size content is suggested. Some of the samples called 'clay' may have a considerable proportion of silt size material and a little sand size material; where silt and sand size material was recognised, samples were called silty or sandy clay. From sizing analyses undertaken on samples from the Quamby Quadrangle section of the Tertiary basin (Threader, *in* Pike, 1973), many of the samples described as 'clay' by visual logging were recorded as having a dominant percentage of their size range in the coarse silt and sand size fractions. Getty Oil undertook microscopic examination of the dried material in adjoining areas and in many cases described the material as 'clay'. Similar materials in the north-east of the basin and along the River Tamar to the north have been examined in detail and where visually examined materials have been described as 'clay', they almost invariably have a high percentage of clay mineral as well as clay size particles. When these materials are mixed with water, they frequently flocculate because of their chemistry and if a dispersant is not used in the preparation for sizing, misleading results could be obtained if only sizing is considered. It seems likely that much of the material sized as sand in samples from the Quamby Quadrangle boreholes is finer than suggested by Threader (1973). The main purpose in describing the materials originally was to identify aquifers during the drilling, and there is a tendency to describe anything that is too fine-grained to be an aquifer as clay, with various adjectives such as sandy or silty.

The coarse fraction (>63 μm) in clayey sediments is often about 10% or greater and in most cases is not visible in the raw sample. It consists mainly of quartz fragments, with occasional zones rich in sand size grains of siderite. Small amounts of magnetic material are also present, usually magnetite and ilmenite.

The mineralogy of the finer fractions was examined by X-ray diffraction. Peak areas on the resulting diffractograms have been measured and values of percentages are given using the usual weightings given to peak areas (Pierce and Siegel, 1969). The samples subjected to X-ray diffraction analysis were largely the fine silt and clay size fractions. These were pipetted onto a glass slide and allowed to settle and dry. The resulting 'percentages' are only approximations, and in the best preparations, can only be regarded as semi-quantitative. These are probably only accurate to within 10-20% and may be less accurate. They should however be comparative, as the same method was used for all samples. The results are shown in Tables 4-6. Kaolinite was the most abundant clay mineral in most samples and apart from quartz, is the only mineral that is present in all samples. Except in rare cases, montmorillonite is found in greatest abundance close to areas of Tertiary volcanism. There are exceptions (*e.g.* OP 2). Holes IH 50, where it occurs in every sample, IH 52 and IH 51 are sited near areas where there has been volcanism. Hole DH 4 near White Hills, which also has abundant montmorillonite, penetrates a series of volcanic flows and sediments. Surprisingly gibbsite is present in many of the samples containing montmorillonite and it is apparent that material from lateritised surfaces was introduced into the interbedded sediments.

Over most of the western sub-basin the surface is underlain by 30 - 50 m with thicknesses up to 80 m locally of almost continuous clay. This

Table 5. CLAY MINERALOGY OF DH 3, CRESSY

Depth (m)	Illite Area (mm^2)	Illite %	Kaolinite Area (mm^2)	Kaolinite %	Gibbsite Area (mm^2)	Gibbsite %	Quartz Area (mm^2)	Quartz %
12.9- 14.5	17.5	26	88	65			24	9
22.4- 23.1			66	85			24	15
25.6- 26.2			66	84			25	16
32.3- 33.8			75	86			24	14
55.3- 56.8			120	88	18	7	14	5
79.7- 81.1			360	92			63	8
75.1- 76.2			96	91			18	9
75.1- 76.2	10	6	280	84			68	10
129.8-130.1	21	6	672	91			43	3
130.1-130.8	18	4	735	92			60	4
138.7	15	3	788	91			95	6
141			238	81			108	19

Table 6. CLAY MINERALOGY OF DH 4, WHITE HILLS

Depth (m)	Montmorillonite Area (mm^2)	Montmorillonite %	Illite Area (mm^2)	Illite %	Kaolinite Area (mm^2)	Kaolinite %	Gibbsite Area (mm^2)	Gibbsite %	Quartz Area (mm^2)	Quartz %
10.31- 10.68	40	50			10	25	6	8	14	18
24.38- 24.78	522	90			18	6			25	4
25.08- 25.38	168	60	9	13	27	19			23	8
34.6 - 35.5	203	55	12	13	32	17			53	14
35.51- 37.02	248	89			9	7			11	4
46.01- 47.53	195	67			30	21	6	2	30	10
48.18- 49.05	18	7			98	73	25	9	28	11
48.18- 49.05	75	15			187	74	25	5	33	7
49.05- 50.57	115	36			78	49	25	8	25	8
50.57- 52.09	28	7			143	76	25	7	40	11
52.74- 53.61	91	22			135	65	28	7	26	6
55.13- 56.65	293	25			390	67	50	4	145	4
56.65- 58.17	66	11			196	66	22	4	118	20
59.69- 61.61	288	28			360	69	26	3	15	1
61.61- 63.13	113	52			83	38	25	6	20	5
63.13- 64.65	224	40			147	52	26	5	23	4
64.65- 66.17	297	45			154	47	36	6	14	2

commences with a 10 - 20 m layer of red-brown oxidised plastic clay which changes to a dark grey to dark brown colour at deeper levels. After the first sand horizon, the subsequent clay-rich beds are a light grey colour or sometimes light brown. In some bore holes (in particular IH 17 and 18) extensive depths of brown pellety clay were drilled. Clay usually comes to the surface as plastic lumps or as a slurry from deeper levels, but in these holes and occasionally for short sections of others, small clay pellets about 3.0 mm across were recovered, suggesting extensive *in situ* fracturing of the clay. Plastic clay occurs at the surface in all of these holes.

Magnetic spheres

Small magnetic metallic spheres ranging in diameter from 0.035-0.375 mm occur in many of the gravel aquifer samples from the southern part of the eastern sub-basin, as well as in some of the sand beds in the western sub-basin. They are also common in some of the samples from the oil prospecting holes and occur at depths down to 698 m. Despite their common occurrence, it is only possible to extract small quantities by weight. A partial chemical analysis on spheres from hole OP 2 gave the following result:

Fe	66%	Co	0.001%
Ni	0.006%	Mn	0.36%
Cr	0.03%		

It is probable from this that these spheres are largely magnetite, and this has been confirmed by X-ray diffraction analysis. When examined under magnification, the spheres are shiny, black, and metallic. They have a vitreous lustre on broken surfaces and inside have a fine network of etchings or furrows which may be related to crystal structure. The larger spheres have a cavity inside which is irregular in shape and scalloped. The smaller spheres are usually solid.

When first encountered it was thought that the spheres were probably derived from the abrasion of weldings on the drill bit or some other part of the drilling equipment, but some appear to be included in the matrix of the sediments, indicating they are not recently introduced. It is possible that they are small nodules or concretions of magnetite, although most magnetite is regarded as having a high temperature of formation. The most likely explanation appears to be that they are of meteoritic origin. Microtectites of similar size and shape (although other shapes occur) have been located in ocean bed sediments in the Indian and Southern Oceans and extending as far as just south of Japan in the Pacific Ocean (Glass and Heezen, 1967). Spherules of similar size were found associated with the 1908 explosion in the Tungska Valley, Siberia. However in both these occurrences the material is siliceous.

Siderite

Siderite occurs quite commonly throughout the upper parts of the Tertiary sequence in the western sub-basin and in the trench through the ridge dividing the two sub-basins. Hole DH 3 near Cressy and many of the surrounding rotary-drilled holes encountered numerous thin seams, which tend to be much harder than the enclosing sediments. Getty Oil recorded hard seams in the logs of uranium prospecting holes as silcrete, and there is little doubt that most, if not all, are siderite seams. Electric logs conducted as part of that survey have narrow sharp peaks, which are almost certainly due to the siderite seams. These logs have low gamma ray readings and high self potential (low peaks) and resistivity (sharp high peaks).

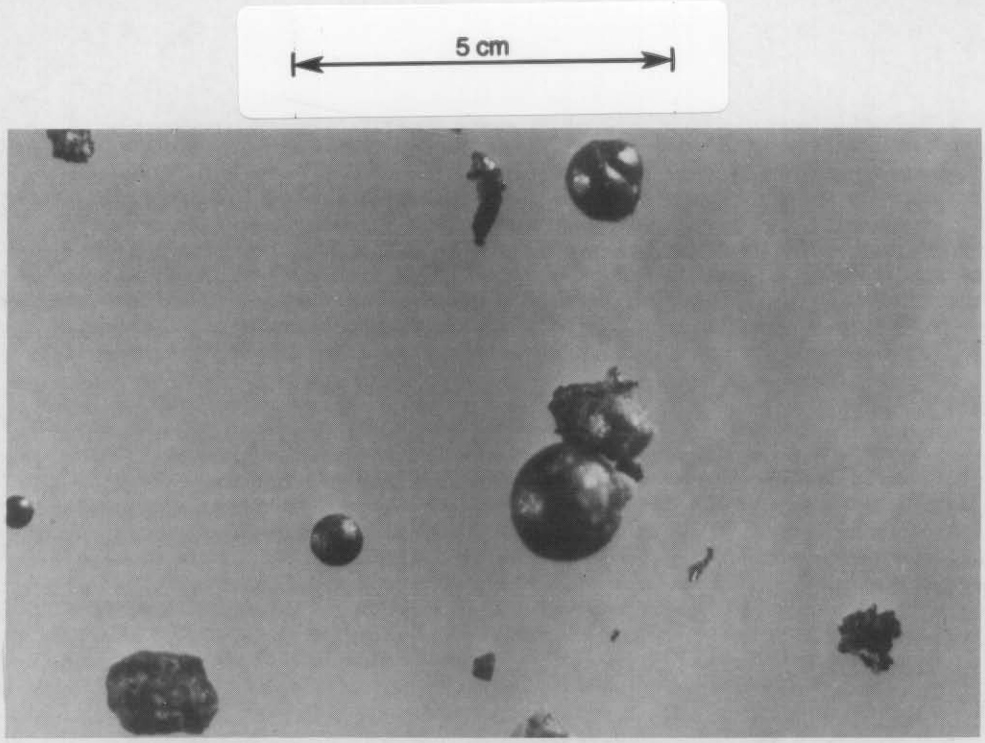


Plate 13. *Small magnetic spherules contained in Tertiary sediments in the Longford Basin. Magnification approximately x50.*

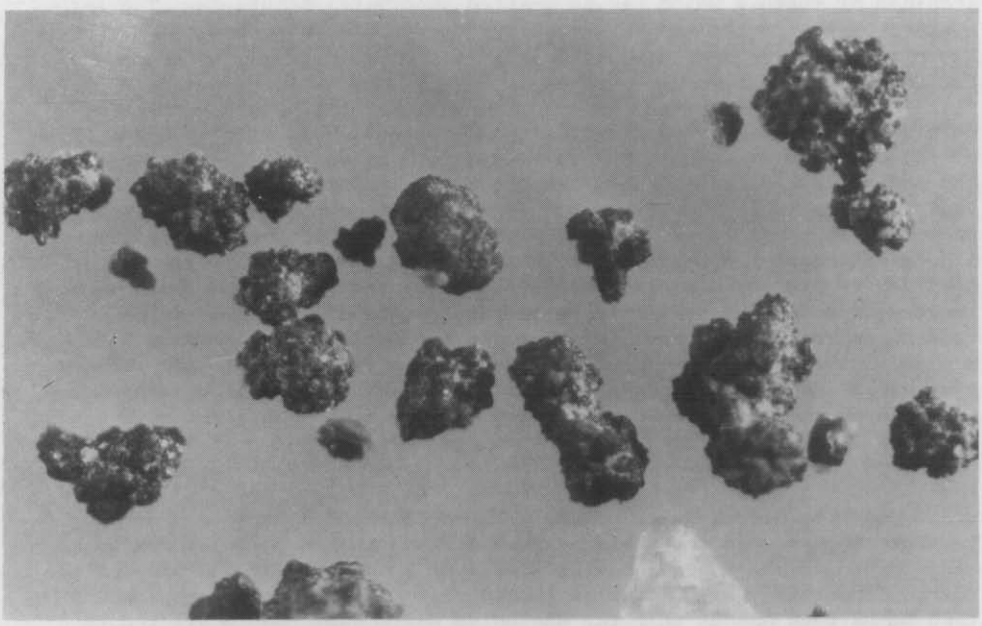


Plate 14. *Siderite grains contained in clay sediments from the bottom of Diamond Drill Hole 3 at Cressy. Magnification approximately x50.*

The levels where these have been recognised are listed in the drill logs (Appendix 5).

The thickest seam encountered in DH 3 is about 200 mm. Purity varies from seam to seam, with the normal components of the enclosing sediments making up the impurities. As well as occurring in seams, siderite also occurs as discrete grains disseminated through the sediments. The seams are made up of very fine-grained carbonate and are usually brown and earthy in appearance. The isolated grains are brown and waxy-like, have a botryoidal growth pattern, and are irregularly shaped. It is likely that the material identified as foraminifera in the logs of the uranium prospecting holes prepared by Getty Oil are siderite grains. Siderite spherules have been mistaken for foraminifera in other locations; Seiglie, Pannella, and Smith (1979) describe siderite grains from a borehole in northern Puerto Rico which had previously been identified as several species of foraminifera according to grain shape. In general, the siderite appears more frequently in the clay and silty clay horizons than in the sandy beds, although yellow grains of siderite were collected from sand aquifers in IH 3 and IH 21. As well as the numerous seams in the diamond drill hole, there are abundant concentrations of siderite grains in the lower parts of the core.

Siderite has been recorded previously from some other locations in the Tertiary sequence in Tasmania; *e.g.* Beauty Point where it occurs as nodules up to about 300 mm across and at Spring Bay on the East Tamar, where it is present in a bed about 500 mm thick. From previous information on the composition of the Tertiary sediments, it was not expected that siderite would be so abundant. Curtis *et al.* (1975) report that siderite is quite common in massive clay sequences in many parts of the world. Many overseas occurrences of siderite are enclosed in marine, particularly near-shore deposits, as the iron has a terrestrial origin and there is only a small amount of iron in sea water. Siderite is usually a mixture of iron, manganese, calcium and magnesium carbonates, rather than just iron carbonate. James (1966) proposed a classification for iron-rich sediments, and the siderite in the Tertiary sediments in the Launceston Tertiary Basin appears to fit his 'blackband and clayband' group. These consist of fine-grained siderite with varying amounts of clastic material and organic matter. They tend to have a higher $FeCO_3$ content (commonly 90% or more) relative to Mn, Ca, and Mg carbonates than marine deposited siderite. James regards the origin of most of this class of siderite deposit as diagenetic, with some of the more continuous layers possibly deposited in marine swamps or brackish water in the presence of organic matter. Mostly it occurs in lenses and nodules up to about 300 mm thick.

Partial chemical analyses of material from two seams in DH 3 are given below:

Depth (m)	68.5	71.9
Acid Soluble Fe (%)	36.7	33.1
Mn(%)	2.7	0.17
Ca(%)	0.72	1.0
Mg(%)	0.17	0.72
Loss on ignition at 1000°C(%)	27.7	27.2
Acid insoluble (%)	11.4	19.4

Although the analyses are incomplete, calculation of the per cent iron carbonate of the total carbonates (disregarding the amount of acid insolubles) is greater than 90% in each case. The manganese content is low in one sample and moderately high in the other.

Grains of siderite were separated from a clay rich section towards the bottom of DH 3. These grains probably make up about 3% of this material. The siderite has an irregular miniature botryoidal growth form and there is little doubt that these grains are diagenetic.

Brief thin section descriptions by G.B. Everard of siderite seams from hole DH 3 are given below:

Depth (m)	*Description*
20.6	Fine-grained, banded, rather crumbly brown rock, soluble in HCl with effervescence on warming. Consists of a mass of pale brown crystals of siderite averaging 0.3 mm long and opaque clay material stained with limonite. The finely crushed particles are magnetic. Density = 3.05.
26.9	Similar to the first sample but with fainter and finer banding and better consolidated. Density = 3.15.
68.5	Similar to the second sample under the microscope, but in the hand specimen is a tough, well consolidated rock. Density = 3.4.

These three specimens all consisted of interlocking grains of siderite with varying amounts of clay mineral stained with limonite, which reduced the density and cohesion of the rock.

Vivianite

Vivianite, a hydrated iron phosphate, has been found in the core of DH 3 as bright dark blue earthy nodules up to 20 mm across from a depth of 19.2-22.4 m. It was recorded in several of the uranium prospecting holes in the surrounding area (*e.g.* P 1 (17.7 - 97.3 m); P 3 (15.6 - 70.1 m); P 4 (18.9 - 56.4 m); R 6 (15.2 - 54.6 m); S 3 (24.4 - 36.6 m); S 4 (27.4 - 39.6 m); S 7 (27.4 - 59.4 m); S 10 (14.3 - 53.3 m); S 13 (19.8 - 39.6 m); T 5A (16.8 - 61.0 m, 67.1 - 94.5 m); T 5B (18.9 - 32 m)). The mineral has been found in Tertiary sediments in north-east Tasmania and near Port Sorell. The origin of the phosphorous in these nodules is unknown, but it is unlikely to be derived from phosphate fertilisers at these depths. It may have formed as a result of the inclusion of bone fragments in the sediments. It is usually found embedded in clay sediments.

G.B. Everard described a sample as 'a very fine-grained pulverulent mass of a striking blue colour. It is soluble in hydrochloric acid and reacts strongly for phosphate.

Under the microscope, it consists of a mass of minute birefringent grains with refractive index greater than 1.58. The grains are strongly pleochroic from deep blue to pale bluish green.

The substance is therefore the mineral vivianite.'

Barite

Almost spherical nodules of barite about 30 mm across were excavated from an irrigation channel south-west of Cressy. The barite is very finely crystalline and cream to light brown in colour.

Silica stone (greybilly and silcrete)

Small areas of hard siliceous sandstone and conglomerate occur at several localities throughout the basin. Several occurrences are near Campbell Town, where they are in close association with and appear to underlie basalt. The most widespread occurrences are south of Cressy, where there is no known basalt in the surrounding areas. Here, the silica stone appears to overlie progressively less consolidated gravel. Another small area occurs north of Hagley. These rocks vary in their components in that some, particularly the most northern and the most southern occurrences, comprise mainly cemented sand, while others comprise cemented rounded and angular quartz and quartzite fragments.

Opinions vary as to the mode of formation of such rocks. Browne (1972) suggested that the formation of the rock is a result of the action of solutions associated with basalt and where there is no overlying basalt, the presence of silcrete in an area indicates that basalt formerly overlay the area. Taylor and Smith (1975) regarded the cementing as low temperature, with the overlying basalt acting as a cap rock to provide a confined aquifer in the sand bed. Stephens (1971) considered that silcretes formed in association with laterite formation, with the silica transported away to a different location and precipitated. G. Joplin (*in* Paterson, 1967) described greybilly at Wilmot as having a chalcedonic cement in fine-grained samples and a quartz cement which is in optical continuity with the grains in the coarser grained samples. Some other Australian silcretes also have a part chalcedonic cement.

No particular mode of formation is suggested for these siliceous rocks, but there must be some doubt that they only occur in association with basalt as in the most extensive areas, basalt appears to be absent. There is apparently no basalt above the thin layers of greybilly-like material in IH 10 and 11. However it is of interest to note that much of the chalcedony (agate and cornelian, *etc*) in Tasmania appears to be associated with basalt; it occurs in post-basalt gravel and at some locations nodules can be seen *in situ* in the basalt. The formation of wood opal is also associated with volcanic activity in the Tertiary. There are therefore siliceous solutions associated with the volcanism in some locations. The areas where these siliceous rocks occur and basalt is absent are near a large fault, the Tiers Fault, and solutions coming up this may have extended into gravel beds nearby.

Titanium is found in fairly high percentages in many silcretes on mainland Australia (Hutton *et al.*, 1972) and in some deposits appear to have been concentrated in greater proportions than other constituents. Everard reports some rutile grains in one of the samples, but these may be grains in the original sediments.

Thin section descriptions of silica stone by G.B. Everard are given below. Descriptions of material from IH 10 and 11 is given in the section on conglomerate.

Sample from near junction of Macquarie Road and Lake River Road. In thin section, the rock consists of angular quartz grains, without any special matrix. Minute opaque crystals of magnetite are unevenly distributed in dark patches, with only occasional individually visible crystals. Rare grains of rutile average about 0.2 mm across.

The rock is a ferruginous orthoquartzite.

Sample 72-305; 'Rosedale', 5 km west of Campbell Town. The hand specimen is a grey, fine-grained, dense-structured, siliceous rock, with many visible grains of glassy quartz well below one millimetre diameter down to the limits of visibility and occasional grains of quartz and quartzite above one millimetre diameter. Brown stains of hydrated iron oxides mark the rock which has a sub-conchoidal fracture.

In thin section, the rock consists of angular to sub-rounded grains of quartz in a matrix of finer grained quartz, and grains of magnetite, largely altered to limonite. However, there is no real distinction between the individual quartz grains and the quartz of the matrix, the one grading into the other.

The rock is a ferruginous quartzwacke.

The quartzwacke probably owes its induration to the introduction of silica in aqueous solutions, rather than to effects due to heating.

AGE OF SEDIMENTS

Johnston (1888) divided the strata of the area into three groups by age:

(*a*) the upper zone or Neogene which included the unstratified terrace gravel and hard ferruginous nodular clay boulders (probably lateritic areas).

(*b*) the middle zone or upper Palaeogene which included the tuff, tuffaceous sand and basalt.

(*c*) the lower zone or lower Palaeogene, which included the thick clay, sand, and lignite deposits.

At the time Johnston subdivided these deposits, the currently used divisions in the Tertiary had not been developed. However if Johnston's ages are regarded as Upper, Middle, and Lower Tertiary respectively, there has been little advance on the general subdivision of the strata with respect to age to the present day. It seems likely that the basalt has a wider age range than Johnston suggested, although as he indicated it seems likely that the basalt extrusions began towards the end of the main period of sedimentation.

Carey (1947) gives a Miocene age for the sedimentation, while Cookson (1957) described spores from Evandale as Palaeocene to Eocene in age. Gill and Banks (1956) dated plants from bores in Launceston and from an outcrop in Rose Rivulet near Evandale as Palaeocene - lower Eocene. Harris (1968), from palynological examinations, dated sediments from Rose Rivulet, Legana and Legana Cliffs as Palaeocene and one sample from Spring Bay as Eocene.

Samples from a number of boreholes were submitted to Esso Australia Limited for palynological study, and S.M. Forsyth and M. Dettmann have also examined samples from boreholes. The results of these examinations are given in Table 7 and Appendix 12.

There may be some minor conflict in the age determinations of some of these sediments. For instance Harris' determination of Palaeocene ages

Table 7. PALYNOLOGICAL DATING OF SEDIMENTS

Hole	Source	Depth (m)	Age
OP 1	S.M. Forsyth	670.6	Tertiary - pre middle Miocene
OP 2	Esso (1971)	152.4	early Eocene
		304.8	early Eocene
		457.2	early Eocene
	S.M. Forsyth	682.8-688.9	Palaeocene
		749.8	probably Palaeocene
DH 3	Esso (1971)	3-6.1	barren
		30.5-33.5	middle-late Eocene
		70.1-73.2	middle-late Eocene
		137.2-140.2	barren
DH 4	S.M. Forsyth	3	barren
		31.3-31.7	barren
		34.6-35.5	barren
		47.5-48.5	middle Eocene
		52.8	late early Eocene-middle Eocene
IH *A*	M. Dettmann	164	middle Eocene
IH *B*	M. Dettmann	163.1	middle Eocene
IH 27	Esso (1971)	15.2-21.3	contaminated with recent pollens
		102.1-108.2	early Eocene
		176.8-182.9	early Eocene
		304.8-308.5	early Eocene
IH 30	S.M. Forsyth	22.9-48.8	middle-late Eocene
IH 31	S.M. Forsyth	18.3-29.0	middle-late Eocene
IH 32	S.M. Forsyth	6.1-13.1	middle-late Eocene
IH 36	Esso (1971)	15.2-21.3	contaminated with recent pollens
		100.6-103.6	middle-late Eocene
		187.5-192	indeterminate
IH 40	S.M. Forsyth	36.6-47.7	late Eocene
IH 44	Esso (1971)	15.2-24.4	middle-late Eocene
	S.M. Forsyth	15.2-25.9	middle-late Eocene
		36.6-48.8	middle-late Eocene
	Esso (1971)	45.7-48.8	middle-late Eocene
		106.7-109.7	Eocene
		187.6-192.0	Eocene
IH 57	Esso (1971)	45.7-61.0	middle-late Eocene
IH 67	S.M. Forsyth	13.7-16.8	barren

for three samples from Rose Rivulet (presumably up the sequence, but locations are not definitely known) may conflict with Esso's ages for the lower determinations in IH 44. This bore extended below sea level and Esso gives an Eocene age for the lowest samples. However sedimentation at similar present day levels may have taken place at different times. Forsyth (pers. comm.) dates sediments on the north side of Rose Rivulet as early Eocene. Sediments at close positions in DH 4 at White Hills appear to have widely differing ages, suggesting a period of erosion or no sedimentation between the two samples. The lowest sample from hole OP 1 appears younger than sediments at similar levels in OP 2.

It is apparent that although some Palaeocene sedimentation appears to have taken place, as recorded in the deepest parts of OP 2 (Forsyth) and possibly at Rose Rivulet (Harris), the bulk of the sedimentation is Eocene in age. The problem of age determination is discussed in greater detail in Appendix 12.

MODE OF DEPOSITION

Johnston (1888) regarded the thick unconsolidated sediments in the basin as lacustrine, with deposition being closed with a period of volcanism. Montgomery, in a lecture in 1892, described the sediments as lake deposits filling a slowly subsiding basin. Carey (1947) favoured this idea and suggested that there were two main basins of deposition separated by a central ridge. Nicolls (1960) doubted that the sediments were lake deposits and suggested that there was no seaward barrier to such a lake. Middleton (1973) suggested that an alternation of fluviatile and lacustrine conditions were present during deposition.

It is apparent from the type of sediments in some areas that the depositional environment was not entirely lacustrine. Conglomerate beds, particularly in the northern part of the eastern sub-basin and occurring at several levels between Symmons Plains and Launceston, suggest fluviatile conditions. These are often some distance from the edge of the basin. Around the margins of the basin, localised beds of such deposits could be produced by streams running into a lake. However the material incorporated in the conglomerate and boulder beds appears, in some cases, to be absent from around the margins of the basin. Hole IH 42 struck a gravel bed containing boulders of rounded quartzite up to 75 mm in diameter between 99 and 102 m from the surface. Much of the section between 79 and 116 m in IH 43 was bouldery clay, with many of the boulders being quartzite. Gravel (mainly quartz and quartzite) was struck between about 27 and 35 m in IH 44, with conglomerate with quartzite and dolerite fragments between 49 and 55 m and conglomerate again at about 170 m from the surface. IH 52 was drilled mainly in conglomerate or clay and boulders from 44 to 94 m, while IH 54 struck conglomerate containing dolerite and one granitic boulder at 73 m. Rounding of dolerite takes place over a short distance in a stream bed and it seems possible that short streams peripheral to a lake could introduce these into lake deposits. However quartzite boulders would take longer to round and it seems likely that these conglomerates are partly derived from peripheral stream material and partly from a central basin stream which brought the siliceous material from a more distant location. There may have been impoundment between the conglomerate deposits of different ages due to tectonic movements or due to basalt extrusions blocking stream channels in later stages of deposition. The gravel beds below the basalt in the Conara - Epping Forest area are also fluviatile deposits and are probably largely derived from erosion of the granite areas around Avoca. The material forming the Brickendon Terrace is probably also mainly derived from the same area, as it contains vein quartz, quartzite, and clear granite-like quartz. Conglomerate beds in the southern part of the western sub-basin probably also have a fluviatile origin.

The main part of the western sub-basin has probably had a mainly lacustrine history, with deltaic deposits forming around the mouths of streams entering the lake. Water depths probably varied due to intermittent tectonic activity caused by crustal tension or due to loading of the sediments. A number of the sand beds are clean and well sorted, as evidenced by their ability to allow water to flow through them at fairly high rates. It is unlikely that these beds could be produced without some re-working, despite the presence of thick quartz sandstone beds in the Triassic sequence surrounding the basin. It is likely that these beds were re-worked on the shore of the lake by wave action and changing water level, with the finer material being removed. Sediments between the clean sand beds are less sorted or finer and were probably deposited in slightly deeper water. Some fluviatile periods may be represented in this part of the sub-basin (*e.g.* the thin siliceous fine gravel in the Cressy-Longford areas at about 60-80 m from the surface). The lower sand beds in the oil prospecting holes tend to be coarser than those at about 150 m, suggesting a higher energy deposition system.

The lateral lensing of beds may be a function of the deposition pattern or may be due to deposition followed by part erosion and further deposition. The probable different ages of sediments only a few metres apart in DH 4 at White Hills may suggest a period of erosion or no deposition before the upper dated sediments were deposited. This suggests an intermittent lacustrine and fluviatile environment.

The clay which blankets a large part of the western sub-basin to depths of up to about 80 m suggests the final preserved sedimentation to be largely lacustrine. It was obviously a period of quiet sedimentation and outlets from the basin may have been blocked by basalt extrusions, causing deeper water sedimentation.

The sediments are regarded as non-marine, although there are occasional signs of a marine influence. Harris (1968) records microplankton from Legana from which he postulates a possible marine or brackish environment. Forsyth (pers. comm.) identified a marine acritarch in sediments from IH 30.

Tertiary basalt

Basalt occurs in several areas within and around the basin (fig. 2). The main occurrences are in the Campbell Town - Epping Forest area, around Whitemore, Westbury, Hagley, Evandale, White Hills, and St Leonards. Other small surface outcrops occur and basalt also underlies sediments in drill holes at a number of locations. These areas have been marked on Figure 2.

Basalt crops out in the four open extensions of the basin; *i.e.* west of Westbury, the River Tamar area north of Launceston, the upper South Esk River and the valley south of Campbell Town. These are obviously old drainage channels along which the basalt flowed. In occupying these valleys, the basalt appears to have diverted the stream beds to other courses in a number of locations (*e.g.* diverted the Elizabeth River south from a basalt filled valley about 6 km north-east of Campbell Town). The Macquarie River probably entered the eastern sub-basin south of Campbell Town, but the basalt now occupying this valley diverted the river west of Mount Augusta and it now enters the southern part of the western sub-basin (Nye, 1926). The Meander River appears to have been diverted north between Deloraine and Westbury. The diversion of the South Esk River near Perth to the south around Longford is well documented (Nye and Blake, 1938; Carey, 1947; Nicolls, 1960). The South Esk may have been diverted on entering the basin near Glen Esk from passing through the Epping Forest area. East of Glen Esk, the South Esk River follows about the same course as in pre-basalt times.

Basalt from various parts of the basin has been described by a number of people. Johnston (1888) described the basalt as upper Palaeogene in age and overlying the main sequences of clay, sand, and lignite. He recorded extensive sheets and dykes of basalt with associated tuff and related the volcanic activity to the Victorian pattern of two main phases; an older and a newer phase. Nye (1926) described basalt around Campbell Town as an olivine-free basalt with flows up to 30 m thick, weathering at a slow rate compared to most other basalt in Tasmania. He regarded the basalt as closing the Lower Tertiary after the deposition of the lacustrine deposits. Edwards (1950) regarded the basalt of the Launceston area as Pliocene or younger, the Midlands basalt forming broad plains around old river valleys. He indicated that all Tasmanian basalts are olivine basalts and classified them into types depending mainly on glass colour, texture, and whether titanaugite or colourless augite was present. His Midlands type (localities include Campbell Town, St Leonards, and Nile), which he described as petrologically similar to the newer Victorian basalt, contains black or brown glass, colourless augite and phenocrysts of olivine partly altered to iddingsite in an intergranular groundmass of labradorite and augite. It is commonly grey in colour with many small vesicles. Edwards described basalt around Perth, Longford, Breadalbane, and Evandale as petrologically similar to the older Victorian basalt in containing titanaugite, but these overlie the lacustrine sediments which were regarded as Pliocene or younger at that time. He suggested that the basalt in the area was derived from two or more co-existing magmas and that petrology does not provide a method for definitely distinguishing the 'older' and 'newer' basalts.

Sutherland (1971) suggested eruptions in the Tamar region probably commenced in post upper Eocene and continued to at least mid-Tertiary. He also examined the petrology of basalt from the St Leonards-Evandale-Longford areas and indicated possible eruptive centres and ages of various flows.

Sutherland gives a tentative age of Eocene to mid-Tertiary for a lateritised area of basalt east of White Hills. The only age limitation he gives for other basalt in the north-eastern part of the basin is that it overlies Palaeocene - Eocene sediments or is post-dissection of these beds. Sutherland suggests that basalt at various levels along the River Tamar may be Oligocene to Pliocene in age on field relationships. He records a suggested upper Oligocene age for sediments underlying basalt at George Town.

The nearest basalt which has been radiometrically dated (Sutherland, Green and Wyatt, 1973) occurs at Great Lake to the west of the basin. Dates of 21.8 - 23.6 Ma or late Oligocene - early Miocene were obtained. Sutherland (1969) suggests that rather than volcanism occurring in two main phases as is apparent in Victoria, and as suggested by previous authors for the Tasmanian situation, volcanic activity appears to extend relatively unabated from late Eocene to early Pliocene.

During the groundwater survey, basalt or conglomerate containing basalt boulders overlain by sediment was struck in a number of drill holes. Some of these sediments have been subjected to palynological examination. Esso Australia Limited in 1971 examined samples from a number of boreholes. This included two samples from IH 44 at depths of 15.2-24.4 m and 45.7-48.8 m from the surface. Between these two intervals there is either a basalt flow or a conglomerate containing basalt boulders. Both samples were given an age of middle to late Eocene. Subsequently S.M. Forsyth has examined a further batch of samples, including duplicate samples from IH 44. His results are summarised in Table 8.

From these results at least some of the basalt can be regarded as upper or middle to upper Eocene. Radiometric ages to support these dates were not possible because drill core specimens were unsuitable for processing. However a sample from Wesley Vale near Devonport in north-west Tasmania has since been dated as upper Eocene (Cromer, 1980) [Post basaltic sedimentation commenced earlier in the Longford Basin (Lower or Middle *Nothofagidites asperus* zone) than the radiometrically dated late Eocene rocks near Devonport, which are

Table 8. RELATIONSHIP OF BASALT TO DATED SEDIMENTS

Hole	Depth (m)	Age	Relationship to basalt
IH 30	22.9-48.8	Middle-late Eocene	Basalt at 53.3 m and fragments from 51.8 and possibly higher in hole.
IH 31	18.3-29.0	Middle-late Eocene	Weathered basalt at 29 m unweathered at 39.6 m.
IH 32	6.1-13.7	Middle-late Eocene	Basalt fragments from 12.2 m unweathered basalt at 32.3 m.
IH 40	36.6-47.7	Middle-late Eocene	Basalt fragments in conglomerate at 45.7 m.
IH 44	15.2-25.9	Middle-late Eocene	Overlies basalt (flow or in conglomerate?) at 24.4-27.4 m.
IH 44	36.6-48.8	Middle-late Eocene	Underlies basalt (flow or in conglomerate?) at 24.4-27.4 m.
DH 4	47.5-48.5	Middle Eocene	Underlies the lowest basalt flow encountered in this hole.

overlain by rocks containing *Proteacidites tubercolatus* zone assemblages. This may indicate that these basalts are slightly older - S.M. Forsyth, pers. comm.]. A similar age for volcanism to the older series in Victoria has been shown to occur in Tasmania, with the older basalt appearing to be that which Edwards (1950) regarded as petrologically similar to the older Victorian basalts. This basalt (*i.e.* titanaugite containing) extends as far south as Epping Forest.

Basalt appears to have been mainly extruded along fissures, as there is a marked absence of tuffaceous material and agglomerate in most areas. These extrusions were probably located along the older fault lines forming the basin; most of the volcanic rocks in the Bass Basin are located along fault lines (Robinson, 1974). There appears to be a centre in the area between Evandale and Breadalbane, as evidenced by the presence of some tuff in various locations (Johnston, 1875) and as indicated by gravity survey (Longman and Leaman, 1971). There is also coarse-grained basalt on Cocked Hat Hill which suggests either a centre or a thick flow.

Petrological information collected as part of this study is limited to a few thin sections of basalt encountered in drill holes and a few samples from the Campbell Town area. These have been described by G.B. Everard.

Sample 72-304 [*EP410570*]. The hand specimen is a fine-grained greenish grey rock, with common vesicles up to 3 or 4 mm diameter. Black magnetite crystals in strings and patches give the rock a rather blotchy appearance. Phenocrysts of olivine up to 1 mm long are common and show alteration to a yellowish powder. On wetting the rock there is a strong odour of Fuller's earth.

In thin section, as well as being porphyritic, the rock shows intergranular and intersertal textures consisting of pale brownish or greenish granular augite and a little glass of similar colour in a network of andesine laths about 0.1 mm long. Magnetite is prominent in black areas and strings of minute crystals. Phenocrysts of olivine are largely altered to fine opaque material, with granular unaltered mineral towards the middle.

The rock is an olivine andesine basalt.

Sample 72-306 [EP383570]. The hand specimen is an aphanitic chocolate coloured rock with phenocrysts of dark glassy, and opaque yellowish silicate mineral up to about 1 mm long. Vesicles occur up to 3 or 4 mm across and are lined with greenish yellow zeolite. The larger vesicles are slightly flattened.

In thin section, the texture is intergranular, consisting of grains of pyroxene and magnetite filling the interstices between twinned laths of acid labradorite. The smaller pyroxenes are largely euhedral and have a reddish brown staining. The phenocrysts are mostly fresh enstatite, but others are altered in part to serpentine and stained red along cracks by iron oxides.

Of the two basalt samples, 72-304 is an undersaturated rock containing olivine and glass indicating rather rapid cooling. The feldspar is andesine. Weathering has produced clay minerals.

72-306 is a saturated rock and slow cooling has left it without glass, but consisting of labradorite together with enstatite and augite. Weathering has resulted in very fine-grained limonitic and haematitic staining.

Sample 71-609; 14 m, IH 45 [EP208969]

The hand specimen is a fine-grained black rock with pearly cleavage faces of feldspar crystals up to 1 mm long.

In thin section, the texture is intergranular, composed of narrow laths of labradorite averaging about 0.75 mm long, which form a network enclosing granules of pyroxene, olivine, and magnetite.

Scattered through the rock are larger subhedral and anhedral crystals of olivine partly altered to serpentine.

The rock is an olivine basalt.

Sample 71-607B; 44.2-45.7 m, IH 40 [EP234937]

The hand specimen is a black porphyritic rock with phenocrysts ranging up to about 1 mm long in an aphanitic groundmass.

In thin section, the groundmass shows hyalopilitic texture and consists of minute laths of labradorite, octahedra of magnetite, and microcrysts of pyroxene together with a brownish glass.

The phenocrysts consist of octahedra of magnetite about 0.25 mm diameter and crystals of olivine and pyroxene up to about 1 mm long. The olivine is colourless, cracked and usually altered in part to iddingsite. The pyroxene is a pale brown augite and there are also patches of brownish glass.

The rock is an olivine basalt.

Sample 71-613; 36.6-37.8 m, IH 49 [EP184953]

The hand specimen is a fine-grained, charcoal-grey crystalline rock with crystals at the verge of visibility and occasional small vesicles filled with white material.

In thin section, the texture is intersertal and porphyritic. Phenocrysts up to 1 mm long and irregular patches of iddingsitised olivine are common and euhedral crystals of brownish augite up to 0.5 mm occur. The main bulk of the rock consists of a network of multiple twinned labradorite crystals averaging 0.25 mm long enclosing minute grains of augite and magnetite in a brown glass. Analcite is common as irregular patches up to 1 mm long and as occasional veinlets.

The rock is an analcite olivine basalt.

Sample from 10 m, IH 63 [EP275757]

The specimen is a fine-grained black rock with visible sparkling prismatic crystals and some granular honey-coloured masses.

In thin section, the texture is intersertal, consisting of laths of labradorite up to 1 mm long and prisms of titanaugite with interstitial black glass and a little granular olivine. Olivine is also present as occasional larger euhedral crystals, about 1 mm long showing alteration along irregular cracks. The titanaugite and labradorite tend to be in ophitic relationship. A little brownish carbonate is also present.

The composition of basalt in the Campbell Town area is varied, with one sample containing andesine. Titanaugite occurs in basalt as far south as just west of Epping Forest. Weathering of the basalt is variable and this may be to some extent a function of the composition as suggested by Nye (1926). Some of the basalt has been lateritised and still retains an overlying laterite profile (*e.g.* just north of Campbell Town, south-east of Westbury, and east of White Hills). Alumina-rich laterite occurs in the Campbell Town area (Owen, 1954). Deeply weathered basalt underlies lateritised zones. Apart from areas where the basalt is lateritised, basalt in the north-west part of the basin tends to be more deeply weathered than in the Campbell Town area (or Midlands type of Edwards). The latter basalt is usually mid-grey in colour and has large numbers of fine vesicles. In many of the other areas within the basin, the fresh basalt is a dense dark blue rock with recognisable olivine in the hand specimen and few vesicles.

Quaternary

TALUS DEPOSITS

Talus deposits usually occur on steeper slopes below areas where the derived material occurs *in situ*. Where it is uncertain that *in situ* rock occurs and angular boulders occur in soil, these areas have usually been mapped as talus (*e.g.* dolerite talus along the low range north of McRaes Hills). The most extensive areas of talus are made up of dolerite. Small areas of basalt talus occur around the edges of isolated hills and often cover the contact with underlying sediments. Small areas of Permian talus occur south-east of Cressy. Dolerite and Triassic sandstone talus are common around the slopes of the Western Tiers.

The talus deposits are probably only a few metres deep, but notable exceptions are those recorded by McKellar (1957) which extend to depths of greater than 150 m along the Western Tiers. These are regarded as dominantly Quaternary in age.

ALLUVIUM AND TERRACE DEPOSITS

These deposits occur along the flood plains of stream channels and on surrounding slopes and terraces and consist of clay, silt, sand, and gravel. Some of the dolerite boulder and cobble beds on low sloping land between McRaes Hills and the Western Tiers have been described by Pike (1973). Their origin is uncertain but the explanation of Bravo (1969) that they are Pleistocene mud flow deposits appears the most likely, although Nicolls (1959) regarded them as alluvial fans. Where boulders are rounded, they no doubt have an alluvial origin but many are angular and probably have a different origin.

Nicolls (1958, 1960) has described some of the more recent terrace deposits in the Longford area. Most terraces are underlain by sandy clay, sand, and gravel, the gravel being mainly quartz, although areas around the Nile River and those between McRaes Hills and the Western Tiers, which he regarded as equivalent to these terraces, are made up of dolerite boulders. The present day flood plains are underlain by clay, sand, and gravel.

AEOLIAN DEPOSITS

Quaternary windblown and locally derived sand covers widespread areas between Longford and Campbell Town. The deposits comprise mainly fine to medium-grained quartz particles and are derived from old river channel deposits, sandy beds in the Tertiary sediments, or from weathered Triassic sandstone areas. Lagoons near Cleveland and Toiberry may have formed as blow-outs of sand beds mainly in areas underlain by Tertiary sediments. These lagoons are often surrounded by sand or have lunettes developed around their eastern ends. They are roughly oval shaped and elongated in a SW-NE direction, which is probably an indication of the prevailing wind direction at the time of formation.

LIMESTONE

A small deposit of freshwater, relatively unconsolidated limestone containing a gastropod *Lenameria* and an ostracod *Eucandora* (P.G. Quilty, pers. comm.) occurs south-west of Bracknell. It has a high calcium carbonate content. Analysis of this material gave the following results:

SiO_2	1.9%	CaO	52.8%
Fe_2O_3	0.49%	CO_2	42.7%
Al_2O_3	0.24%	H_2O	0.29%
MgO	0.83%		

Several Proline auger holes (PH 52, 130, 131, 132) were drilled to examine the extent of the deposit, and showed it to be very localised. A spring issues from the middle of the deposit and is heavily charged with H_2S gas. Pyrite was found in material from one of the auger holes. A chemical analysis of the water is as follows:

Item		*Item*	*mg/l*
pH	7.2	Mg	27
	mg/l	Fe	trace
		Al	nil
CO_3	-	K	16
HCO_3	-	Na	248
Cl	110	T.D.S.	870
SO_4	41	Hardness	270
SiO_2	29	Alkalinity	590
Ca	64		

The presence of H_2S prevented accurate determination of CO_3 and HCO_3 and also affected hardness determinations.

DIATOMITES

Diatomites have been recorded at Bishopsbourne (Gill, 1962) but no further investigation has been undertaken on these deposits. They are regarded by Gill as freshwater and Upper Cainozoic in age.

Part 2: Hydrology

GENERAL NATURE OF OCCURRENCE OF GROUNDWATER

INTRODUCTION

Groundwater refers to water occupying all the voids within a geological stratum (Todd, 1959). These voids include the intergranular spaces between separate mineral grains making up a sedimentary rock and fissures, which include joints, bedding planes and other fractures in compacted metamorphosed and igneous rocks. Vesicles in volcanic rocks are also capable of storing groundwater. Water rarely occurs as underground streams as suggested by diviners, although streams can occur in limestone country where solution channels have developed. The definition of Todd does not cover this occurrence of groundwater as all voids are not completely filled.

Little limestone or similar rock occurs in the Longford Basin and surrounding areas. Thin beds of limestone occur in the Permian sequence and small areas of Cambrian-Precambrian limestone and dolomite crop out in the south-western part of the basin, but no cavernous zones are known. Thin bands of siderite occur in the Tertiary sediments, but these are not wide enough to develop extensive solution channels.

Groundwater in the basin is mainly stored as intergranular water in the younger rocks and in fissures in the older rocks (*i.e.* slate, volcanic rocks (Cambrian), sandstone, siltstone (Permian) and dolerite). Some of the water in Permian and Triassic rocks, particularly in sandstone beds, may be intergranular, but it is possible that a large proportion of the water readily available from these units is fissure water (Leaman, 1971). Water occurring in basalt areas is stored in fissures, vesicles, and in weathered portions; basalt in some areas develops a deeply weathered profile over unweathered rock.

The main part of the investigation has centred on the Tertiary sediments. These are relatively unconsolidated and without strong development of bedding planes and joints, and consist of interbedded clay, sand, and gravel. Water stored in them is intergranular.

POROSITY

The amount of water stored in rocks depends on the amount of void space contained in the material. The measure of void space is porosity, which is the ratio of the volume of voids to the volume of material being considered and can be expressed as a percentage or fraction. Where fissuring in hard rock is closely spaced, the volume of void space per unit volume is comparatively high and these are ideal zones in which to drill. Where fissures are widely spaced throughout the rock the chance of obtaining useful quantities of water is diminished.

A few holes have been drilled in fissured rocks in the basin. Three holes in Jurassic dolerite produced varying results as far as quantity is concerned, indicating variable spacing and continuity of fissures. Two holes in Permian rocks were successful. Basalt has been drilled with success at a number of places, indicating closely spaced jointing, although in some areas vesicles probably store a large percentage of the water. Triassic sediments have been drilled in a few places with only moderate success, due to some of the bores entering extensive mudstone sequences. Water may be stored and supplied partly from fissures and partly from intergranular storage in sandstone beds. No bores have been drilled in the Precambrian-Cambrian rocks. It is difficult to measure the porosity of fissured rocks, but it is unlikely that porosity due to fissures is greater than about 5-10%, although vesicles in basalt and intergranular porosity in Permian and Triassic sandstones would increase the total porosity.

In materials where intergranular water occurs, the porosity depends on a number of factors, including grain size, degree of sorting of the material, and the packing. Grain size may not be important in determining the amount of void space in all cases. For example equal sized groups of spheres with the closest packing system have the same porosity (25.95%) regardless of the size of the spheres in each group. With other packing arrangements, the porosity can be increased to 47.64% (Lohman, 1972). No naturally occurring sand or gravel bed is made up of perfect spheres all the same size, although some deposits may be near this situation. The sand and gravel in the Tertiary beds are made up of angular to rounded grains, and with angular grains there is more chance of the packing being open than if they approach a spherical shape.

In general, the finer the sediment, the greater the porosity. Thus a silt generally has more void space than a sand and a sand has more void space than a gravel. When there is varying grain size in the material making up the aquifer, as can be expected from most naturally occurring sand and gravel, there is a resultant decrease in void space due to the finer grains filling the void spans between the larger grains. No field estimates have been made of porosity of the aquifers in Tertiary sediments. Todd (1959) lists some porosities which should act as a guide to the porosities that could be expected in the unconsolidated sediments throughout the basin.

Sediment type	*Porosity (%)*	*Sediment type*	*Porosity (%)*
Clay	45 - 55	Fine to medium mixed sand	30 - 35
Silt	40 - 50	Gravel	30 - 40
Medium to coarse mixed sand	35 - 40	Gravel and sand	30 - 35
Uniform sand	30 - 40		

Much of the material making up the aquifers in the western sub-basin is a fine to medium-grained fairly uniform sand and porosity would probably be in the range 30 - 40%. The gravel aquifers in the eastern sub-basin usually have a wide size range and probably range from 30 - 35% in porosity.

CLASSIFICATION OF SUBSURFACE WATER

Water occurs underground in various situations. After rain falls, part of it seeps into the soil and some is retained in the soil by entrapment in clay particles, between the grains of fine-grained material, and in humic matter in the soil. Under normal conditions, soil water does not saturate the soil; the exceptions to this would be during heavy rain or irrigation. Soil water is utilised by plants. The remainder of the water that seeps underground passes through the soil profile and enters an intermediate zone, where there is usually some water but not enough to saturate all the voids. This intermediate zone occurs between the soil and the water table (fig. 6*a*).

Directly above the water table is water which rises against gravitational force by capillary pressure. Capillary pressure can be demonstrated by the rise of water from a free water surface inside a very narrow tube

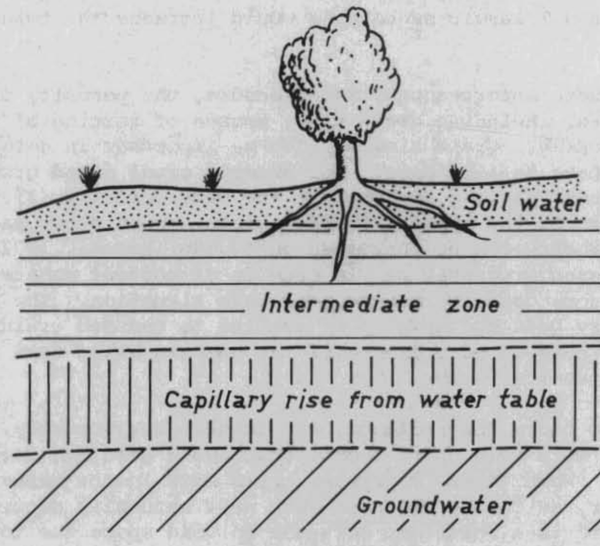


Figure 6a. *Groundwater zones*

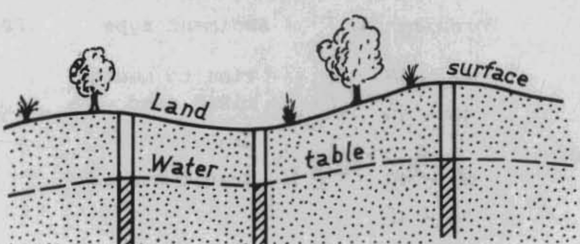


Figure 6b. *Unconfined water*

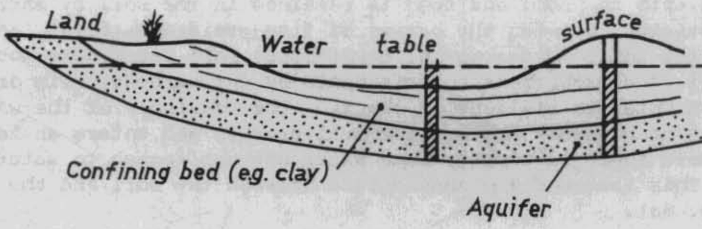


Figure 6c. *Confined water*

(capillary tube). The rise that will take place is inversely proportional to the radius of the tube. The pore spaces in many materials, being interconnected, act like a capillary tube and the water will tend to rise. The height of the capillary fringe above the water table is dependent on the size of the pore spaces; in fissured rock it is related to the width of the fissure, and for intergranular water on the grain size of the aquifer. The capillary rise in silt and clay can be several metres above the water table, while in coarse sand and gravel it may be only a few millimetres.

Water at the water table is at atmospheric pressure, with the pressure greater below the water table. Water will flow into a hole drilled through the water table surface and the free water level in the hole indicates the water table position at that point. Water will not flow into bores from zones above the water table. The positions of the boundaries of the above zones fluctuates throughout the year. After heavy rain the water table can be expected to rise, causing the capillary fringe above it to rise. The intermediate zone thus becomes thinner. After extended dry periods the water table usually falls, so the opposite occurs. There is less fluctuation in the water table in flat country than in hilly and undulating country. The water table may be at the land surface in flat country after heavy rain, so that the three zones above the water table disappear temporarily.

A drill hole at most points within the Longford Basin would pass through the above zones. As there is a thick clay layer over much of the basin, such a hole on reaching the water table may not be successful in supplying sufficient quantities of water to supply a water bore because of the low permeability. The capillary fringe above the water table would be thick in these circumstances. Holes drilled in some of the basalt areas, some of the areas of Tertiary sediments in the eastern sub-basin, and probably the Permian and dolerite holes obtained their water from unconfined water tables (fig. 6*b*). Where water tables were struck in thick layers of clay, more permeable zones were often located under the clay. Here the water is usually confined (fig. 6*c*).

UNCONFINED AND CONFINED AQUIFERS

If the water level in a hole remains at the level where it was first struck in the drilling operation, the aquifer is said to be unconfined (fig. 6*b*). The presence of unconfined water in an aquifer usually depends on there being large connected pore spaces from the surface to the water table.

If the water rises up the bore hole after the water bearing horizon is struck, it is said to be confined (fig. 6*c*). The aquifer must be overlain by a layer with a lower permeability than the aquifer (such as clay or shale) for confined conditions to develop. In some cases the water may rise to the surface and flow (artesian water). In addition to a confining less permeable layer overlying the aquifer, the aquifer in the catchment area must be at a higher level than where the bore is drilled. In Figure 6*c* the bore on the hill does not flow but the water rises appreciably above where it is first struck. The bore in the valley flows. In the catchment area where the bed containing the groundwater is exposed at the surface, the water contained in the aquifer is unconfined.

Most of the bores in the Tertiary sediments in the Longford basin encountered confined water, and some of the bores situated in low lying areas were artesian. There is at least six metres of head above the surface in some of the flowing bores.

It is not known whether this explanation is the reason for the occurrence of artesian water in the basin but it seems likely that as sedimentation proceeded, the load of the sediments would tend to depress the central part of the basin (where these sediments are thickest) more than around the edges. The sediments would thus acquire a dip towards the central part of the basin. This would be accentuated by greater compaction of the Tertiary sediments where they are thickest. If the sand beds containing the water extend towards the surface near the margins of the basin, confined water could form by this means.

An alternative to the above explanation is that if most of the water, particularly in the fine sand beds in the western sub-basin, is connate (trapped in the sediments at the time of deposition) and later sediments loaded these water bearing horizons, confined water could develop. This would only occur if the permeability of the overlying confining beds was very low and the effects of the load on the aquifer water were not dissipated by lateral or vertical flow of this water. The potentiometric surface in the higher parts of the relatively flat basin could be a few metres below the surface, while in lower areas such as around relatively narrow streams where a small amount of overburden has been removed, the potentiometric surface is above the landsurface (*i.e.* the water is artesian). The loading on the aquifer to produce surface flow is maintained by the widespread slightly higher country.

Which of the two above explanations for the occurrence of confined water is correct is not known. It is possible that both situations occur in different parts of the basin because of the lenticular nature of the sand beds.

SPECIFIC YIELD, SPECIFIC RETENTION, AND STORAGE COEFFICIENT

If the porosity and thickness of an unconfined aquifer are known, the volume of stored water per unit area can be determined. Not all of the water stored can be extracted, as some is held in the aquifer by forces greater than the free draining gravitational forces (*e.g.* by molecular attraction, surface tension, or capillary forces). Meinzer (1923) defined specific yield or effective porosity to describe the amount of available water; this is the ratio of the amount of water an aquifer will yield under gravity drainage, to the volume of aquifer. The specific retention is the ratio of the volume of water retained against the gravitational forces to the volume of aquifer drained. Both ratios can be expressed as a decimal fraction or percentage, and added together they equal porosity.

As the grain size of an aquifer increases, a greater proportion of the stored water will be yielded under gravity drainage because of the larger sized pores between grains and the decrease in grain surface area per unit volume. Thus although the porosity of fine sand is greater, the amount of water that can be extracted from gravel per unit volume may be greater. Lohman (1972) gives a range of 10 - 30% (0.1 - 0.3) as the range of values for specific yield in unconfined aquifers.

The term storage coefficient was introduced by Theis (1935) as a measure of the amount of water that can be stored or extracted from a confined aquifer. In a confined aquifer, the overlying strata is supported partly by the structural skeleton of the aquifer material and partly by the pore water. When water is pumped from such an aquifer, it remains saturated with water but some of the support of the overburden previously due to the water is removed and it transfers more load to the aquifer material, causing slight compression and a reduction in porosity. Pumping produces drawdown and thus reduces the head of pressure on the water in the aquifer and a slight expansion of the interstitial water takes place, *i.e.* part of the water released from storage in a confined aquifer is due to compression of the aquifer and part is due to expansion of the interstitial water because of a decrease in head on the water. Theis defined storage coefficient as the volume of water an aquifer releases from or takes into storage per unit surface area of an aquifer per unit change of head.

Many of the study bores in the Tertiary sediments encountered confined aquifers. The water level often rose to within a few metres of the surface and in some cases flowing bores were drilled. Pumping at 150 - 300 *l*/min often drew the water level down 30 - 50 m and the above effects would come into force. If by continuous pumping the head is reduced to the top of the aquifer over its whole extent, the aquifer becomes unconfined and water is released largely by gravity drainage. For an unconfined aquifer only a small proportion of the water taken into or removed from storage is due to compressibility of the aquifer material and the water. For most purposes therefore, the storage coefficient of unconfined aquifers is equal to the specific yield.

Todd (1959) gives a range from 5×10^{-5} to 5×10^{-3} for the value of storage coefficients for most confined aquifers. Storage coefficients have been calculated from pump tests on the production hole at Cressy and the values fall within this range.

PERMEABILITY AND TRANSMISSIVITY

Although a material may have a large porosity and can store large quantities of water, for it to be a useful water source it must have properties that allow water to be extracted at a high rate. For example the surface clay which occurs so extensively throughout the Longford Basin may have a porosity of up to 55% and is capable of storing large volumes of water, but it is often almost impossible to extract the water fast enough to supply a well or a bore. The property that describes the rate at which water can be withdrawn from an aquifer is its permeability. The flow of water through a porous medium obeys Darby's Law *i.e.* the rate of flow is proportional to the head loss and inversely proportional to the length of the flow path. The constant of the proportionability is the coefficient of permeability. The coefficient of permeability is thus the quantity of water that will flow through a unit cross-sectional area of a porous material per unit of time under unit hydraulic gradient. The transmissivity of an aquifer is the rate at which water is transmitted through a unit width of an aquifer under a hydraulic gradient of one. The transmissivity is therefore related to the permeability by the relationship $T = Kb$, where T = transmissivity, K = coefficient of permeability, b = aquifer thickness. Coarse grained sediments have a higher permeability and transmissivity than finer grained sediments because of the larger pores and conduits between grains. The gravel in the Cleveland area has higher permeability than the fine sand in the aquifers around Cressy and although the thickness of the aquifers at Cressy is often greater, the transmissivity of the aquifers at Cleveland is usually larger. The coefficient of permeability is approximately proportional to the grain size diameter in the aquifer (Lohman, 1972).

High permeability in fissured rocks depends on the fissures being interconnected to allow water to flow towards a well or bore. Thus where large flow rates are obtained in basalt, as well as being closely jointed to store large quantities of water, the fractures are largely interconnected.

PUMP TESTS

INTRODUCTION

Once it has been established that groundwater is present in an area, it is important to know how much can be withdrawn and at what rate. These factors can be determined by pump tests conducted on bores that penetrate the aquifer.

Pump tests were conducted on most of the bores drilled in the investigation program, although some in the Cleveland area were not tested owing to the unavailability of a pump at the time of drilling. The material drilled was frequently similar in nearby bores which were tested and these act as a guide to the amount of water that could be obtained. The pump tests undertaken on most of the investigation bores should not be regarded as indicating the exact yield from that particular area, but rather a minimum of the potential. The bores were drilled only as test bores and were not constructed in the manner of production bores. The test bores consisted of cased holes with slotted casing against the aquifers in the unconsolidated Tertiary sediments. The slots were generally widely spaced with a small percentage of open area. In rotary drilled holes, 152 mm diameter casing was installed, while in the percussion holes 127 mm diameter casing was used. Slots were cut with a cutting torch and were from about 1.5 - 3.2 mm wide and about 400 mm long. Most of the holes drilled in Tertiary sediments, particularly in the western part of the basin, had even fine to medium-grained sand aquifers and the slots were too large to retain the aquifer material during pumping, the bore producing sand and water during initial pumping. The system usually stabilised after a time and sand-free water was obtained. With more care in setting up the bores, water could have been withdrawn at a much greater rate in most cases. For this reason, two production-type bores were installed; one in the Cleveland area as a representative bore in the coarser grained aquifers and one at Cressy to represent the fine to medium-grained sand aquifer areas.

The information obtained from pump tests on the standard test bores without an observation hole is limited. It is possible to calculate approximate values of transmissivity from pumping and recovery stages from a pumped hole, but reliable values for storage coefficient are not possible. In each of the production-type bores, an observation hole was drilled nearby so that an approximate value of storage coefficient could also be calculated.

THEORY OF PUMP TESTING

The main purpose for test pumping bores is to determine such factors as the safe yield and the aquifer properties, transmissivity and storage coefficient. With a knowledge of these aquifer properties, drawdown can be predicted for points surrounding a pumped bore and in the pumped bore itself by substitution in the Theis equation for given outputs and times. Another factor that can be determined is the well loss or efficiency of the bore installation (*i.e.* whether the flow into the bore is near the greatest possible rate for a given drawdown). It is important that an efficient system is installed, because if well losses are high, costs of pumping will be higher than necessary.

All the pump tests were of the constant discharge type, except for one at Cleveland which was a short step-drawdown test.

CONFINED AQUIFERS

Theis non-equilibrium equation

Theis (1935) developed a method of determining transmissivity, and introduced the term storage coefficient for pump tests where equilibrium conditions (*i.e.* drawdown fairly stable with time) had not been reached. The method previously used required long periods of pumping till drawdown was almost stable. The Theis method depends on the following equation.

$$s = \frac{Q}{4\pi T}\int_{\frac{r^2S}{4Tt}}^{\infty} \left\{ \frac{e^{-u}}{u} \right\} du = \frac{Q}{4\pi T} .W(u) \quad (1)$$

$$= \frac{Q}{4\pi T} (-0.577 - \log_e u + u - \frac{u^2}{2.2!} + \frac{u^3}{3.3!} - \ldots) \quad (2)$$

Where $u = \frac{r^2S}{4Tt}$

Q = Rate at which well is being pumped (m^3/day)
s = Drawdown in observation hole or pumped well (metres)
T = Transmissivity m^3/m/day (m^2/day)
S = Storage coefficient
t = time since pumping began (days)
r = distance from pumped well to observation hole or effective radius of pumped well (metres)

W(u) is known as the well function and its value is shown in equation 2.

The Theis equation depends on the assumptions that;

(1) the aquifer is uniform in thickness and in all directions,
(2) the aquifer has infinite areal extent,
(3) the full section of the aquifer has been penetrated,
(4) the bore has infinitesimal diameter,
(5) the water removed from storage is discharged instantaneously, with decline in head, and
(6) the aquifer receives no recharge from any source.

For a given value of u, T and S can be calculated from the equation

$$T = \frac{Q}{4\pi S} .W(u) \quad (3)$$

$$S = \frac{4\ Ttu}{r^2} \text{ or } \frac{4\ Tu}{r^2/t} \quad (4)$$

For a constant Q (pump rate), Theis devised a method of solving these equations by superimposing the curve of a log plot of s against r^2/t (or 1/t if only one observation is used) on a type curve of W(u) against u (the type curve used in Figure 7 was a plot of W(u) against 1/u, so that only a plot of log s against log t is required).

The production hole at Cressy was pumped at 568.5 *l*/min (818.6 m^3/day) with drawdown observations in a hole 69.3 m away. The production hole had two aquifers from about 67.3 - 75.7 m and 112.8 - 128.9 m from the surface, the lower being much higher yielding than the upper. The levels recorded are given in Table 9. Standing water level was at 7.7 m in the observation hole and at 6.7 m in the pumped bore.

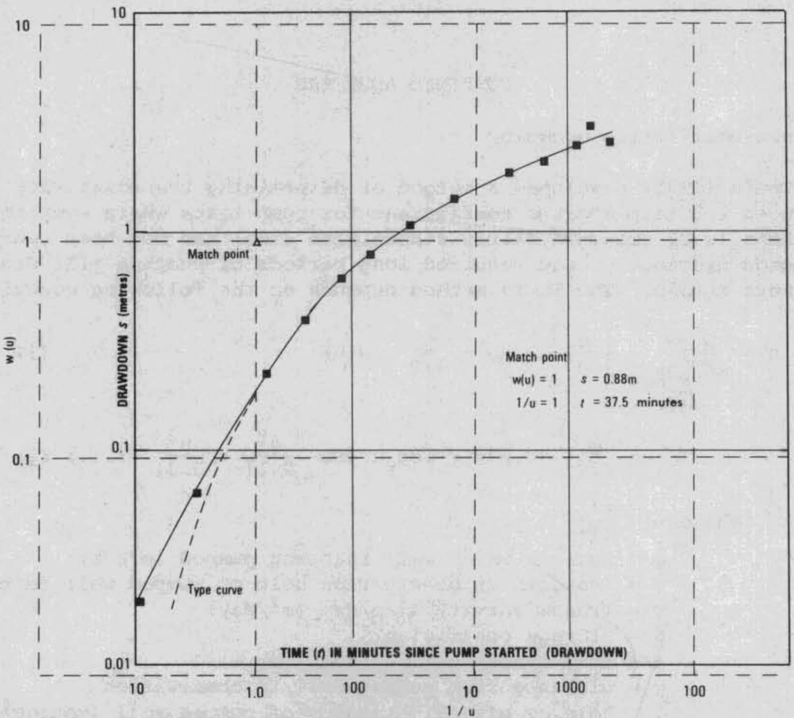


Figure 7. *Plot of drawdown data from Cressy production hole pump test (observation hole measurements) superimposed on a type curve of W(u) or 1/u for match point method of calculation of T and S.*

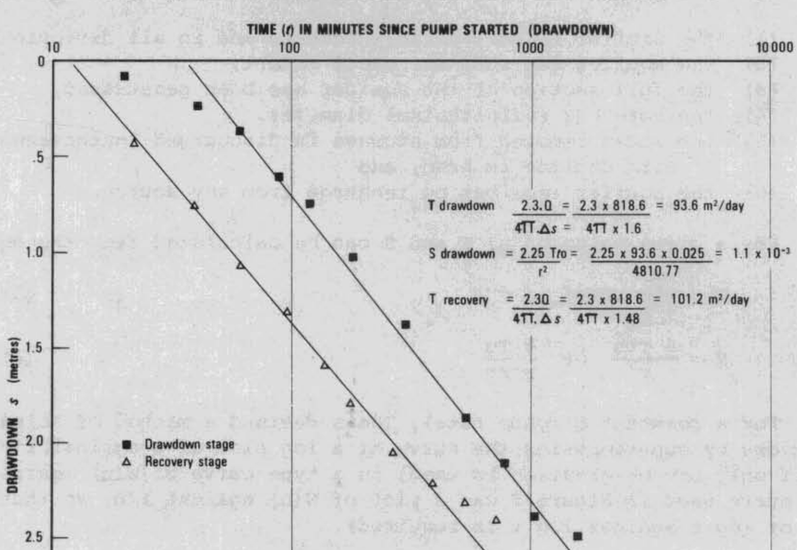


Figure 8. *Plot of drawdown and recovery data from Cressy production hole pump test (observation hole measurements) to use Jacobs straight line solution for T and S.*

Table 9. DRAWDOWN LEVELS IN OBSERVATION HOLE, CRESSY PRODUCTION HOLE

Time of pumping (minutes)	*Drawdown (m)*	*Time of pumping (minutes)*	*Drawdown (m)*
0	0	180	1.03
10	0.02	300	1.38
20	0.06	540	1.87
40	0.23	780	2.12
60	0.38	1020	2.39
90	0.60	1260	2.91
120	0.78	1530	2.49

A plot of log t against log s (fig. 7) produces a curve that approximates the standard curve of W(u) against 1/u for a large section of the pump test. The curve deviates from standard in the first part, this possibly being caused by the effect of pumping both the upper and lower aquifers together, even though the upper aquifer supplies little water. Superimposing the two curves for best fit, a match point can be selected with the following values:

$$W(u) = 1 \qquad s = 0.88 \text{ m}$$
$$1/u = 1 \qquad t = 37.5 \text{ mins } (2.6 \times 10^{-2} \text{ days})$$

Using equations 3 and 4

$$T = \frac{818.6 \times 1}{4\pi \times 0.88} = 74.0 \text{ m}^2/\text{day}$$

$$S = \frac{4 \times 74.0 \times 2.60 \times 10^{-2} \times 1}{69.3^2} = 1.6 \times 10^{-3}$$

Jacob straight line solution

Assuming that u is small when r is small and t large, only the first two terms of the well function need be considered.

For $u < 0.01$

$$s = \frac{Q}{4\pi T}(-0.577 - \log_e u) = \frac{2.3Q}{4\pi T}\log_{10}\frac{2.25Tt}{r^2 S}$$

From a plot of S against log t,

$$T = \frac{2.3Q}{4\pi\Delta s} \text{ where } \Delta s = \text{change in drawdown per log cycle}$$

$$S = \frac{2.25Tto}{r^2} \text{ where to = time intercept at drawdown = 0}$$

During the first part of pumping, u is large and the Jacob modified formula is not applicable. The formulae above can be applied to readings taken in both observation and pumped wells, although the storage coefficient cannot be calculated with any accuracy from pumped hole data because of the difficulty of accurately determining the effective radius.

Transmissivity can be calculated from data obtained from the pumped hole with reasonable accuracy. The calculation is often more accurate in the recovery stage, as it is sometimes difficult to measure exactly where the water level is during pumping. Small variations in the pump rate can also affect measured drawdown levels, giving an uneven plot.

Table 10. RECOVERY DATA FROM OBSERVATION HOLE, CRESSY PRODUCTION HOLE

Time since pumping began t (mins)	Time since pumping stopped t' (mins)	t/t'	Drawdown (m)
1540	10	154	2.49
1550	20	72.5	2.41
1560	30	52.0	2.31
1570	40	39.3	2.21
1590	60	26.5	2.05
1620	90	18.0	1.79
1650	120	13.8	1.58
1710	180	9.5	1.32
1830	300	6.1	1.06
2070	540	3.8	0.75
2670	1140	2.3	0.44

Table 11. DRAWDOWN AND RECOVERY DATA, UPPER AQUIFER (PUMPED HOLE), CRESSY PRODUCTION HOLE

PUMPED STAGE		RECOVERY STAGE			
Time pumped (mins)	Drawdown (m)	Time of test (mins) t	Time since pump stopped (mins) t'	t/t'	Drawdown (m)
0	0	179.5	0.5	361	31.67
0.5	1.88	180	1	181	30.10
1	3.45	180.5	1.5	121	28.68
1.5	5.23	181	2	91	27.23
2	6.3	181.5	2.5	73	25.96
2.5	7.7	182	3	61	24.79
3	8.28	182.5	3.5	52.4	23.62
3.5	9.14	183	4	46	22.43
4	10.03	183.5	4.5	41	21.39
4.5	10.9	184	5	37	20.40
5	11.73	185	6	31	18.39
6	13.26	186	7	26.7	16.74
7	14.61	187	8	23.5	15.27
8	15.93	188	9	21	14.20
9	16.97	189	10	19	13.26
19	24.28	199	20	10	6.86
29	26.54	209	30	7	4.29
59	30.33	239	60	4	2.52
119	32.31	299	120	2.5	1.14
179	33.28				

Standing water level: 11 m Pump rate 41.7 *l*/min (60 m^3/day)

Recovery measurements were made for most holes where pump tests were conducted. There are two methods of calculating the drawdown used in plots of recovery stage data:

(1) recovery is measured from an extension of the time - drawdown curve, between the projected position if pumping had continued and the actual water level in the bore.

(2) using a plot of residual drawdown without calculating recovery from an extension of the time - drawdown curve. This uses the relationship

$$s' = \frac{2.30Q}{4\pi T} \log t/t'$$

t = time since pumping began
t' = time since pumping stopped
s' = residual drawdown

A plot of s' against log t/t' allows T to be calculated.

$$T = \frac{2.3Q}{4\pi\Delta s'}$$

$\Delta s'$ is the change in s' for one log cycle of value of t/t'

The second method has been used to plot the recovery data. Using the pump data from Table 9 and the recovery data for the observation hole (table 10) the plot in Figure 8 is obtained. The plot and calculations in Figure 8 gave values of T drawdown = 93.6 m^2/day and T recovery = 101.2 m^2/day; these are larger than calculated by the match point method.

The recovery stage produces a slightly better line than the pumping stage, particularly in the latter stages of pumping. The reason for the rather irregular plots of the last two readings of the drawdown curve is not known; it may be due to an unrecorded pumping change. If pumping remained constant, it could mean that the cone of depression extended first to a less permeable zone followed by its extent into a more permeable zone. A check on barograph variations during the time of the pump test indicates that changes in atmospheric pressure were not the cause. The resulting storage coefficient calculation (1.1×10^{-3}) from this method is less than that calculated from the match point method.

This method was also used to plot pump test information on the upper aquifer in the production hole at Cressy, when it was isolated from the lower aquifer by a cement plug (Table 11).

The plots of these results (fig. 9) do not allow very reliable calculations of transmissivity. If a line is drawn through the final three points on each stage, an approximate straight line and maximum possible values of transmissivity are obtained. Whether 1.7 or 0.9 m^2/day, or the average of these, is the most realistic value is not known, but it is obvious that the real value is much less than that for the lower aquifer. When the thickness of the aquifers is taken into consideration, the permeability of the upper aquifer is also much less than that of the lower aquifer.

Pump tests were conducted on almost all of the successful test bores throughout the basin. A number of these bores contained several aquifers which were all pumped together. Plotted drawdown information is often irregular and transmissivity calculations are probably only an approximation. Bore construction was not uniform throughout. Transmissivity values calculated from these pump tests have been plotted on Figure 10 and contours drawn around the values. The same aquifers were probably tested in some

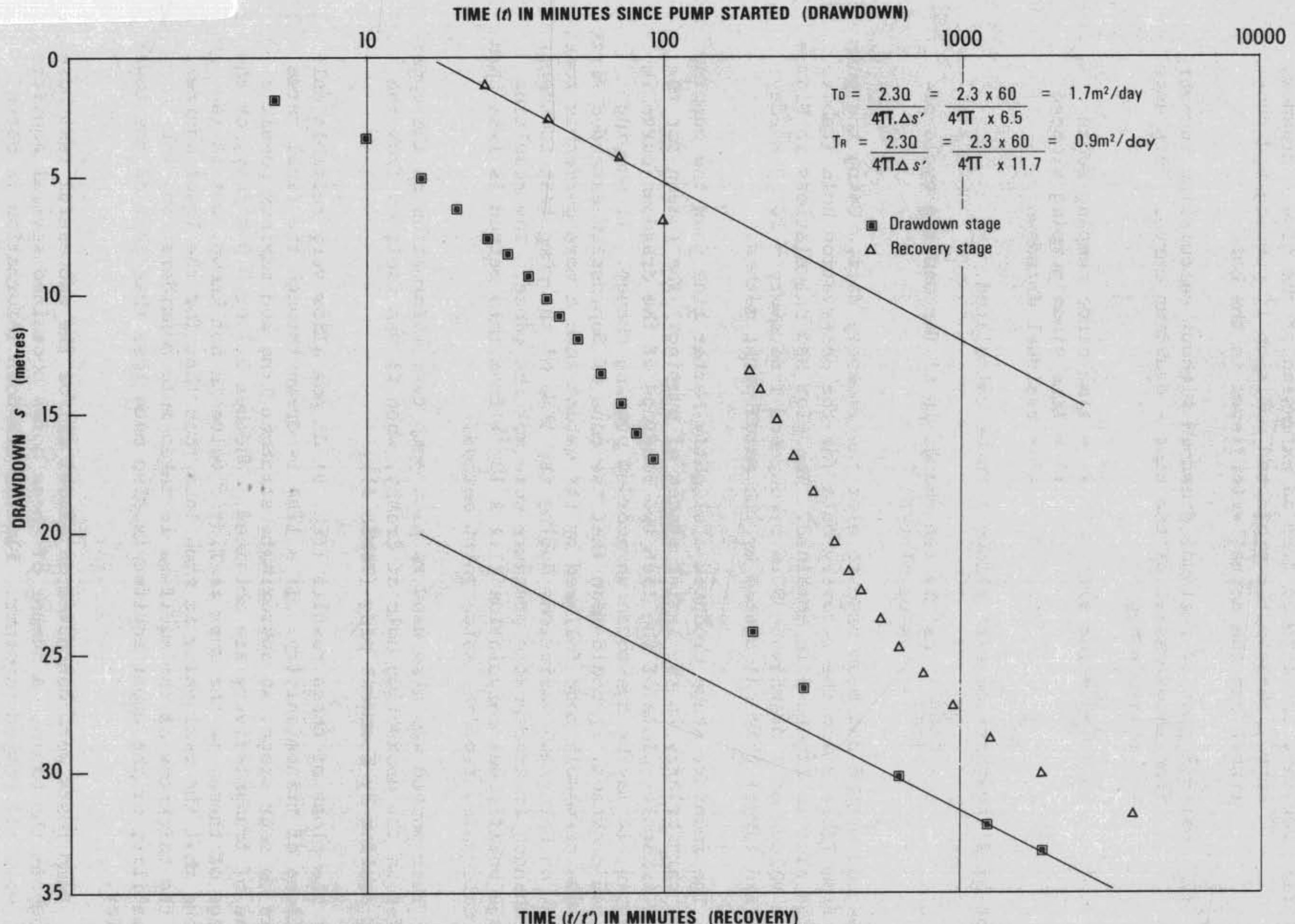


Figure 9. *Plot of drawdown and recovery data for top aquifer, Cressy production hole (pumped hole measurements) to use Jacobs straight line solution of T and S.*

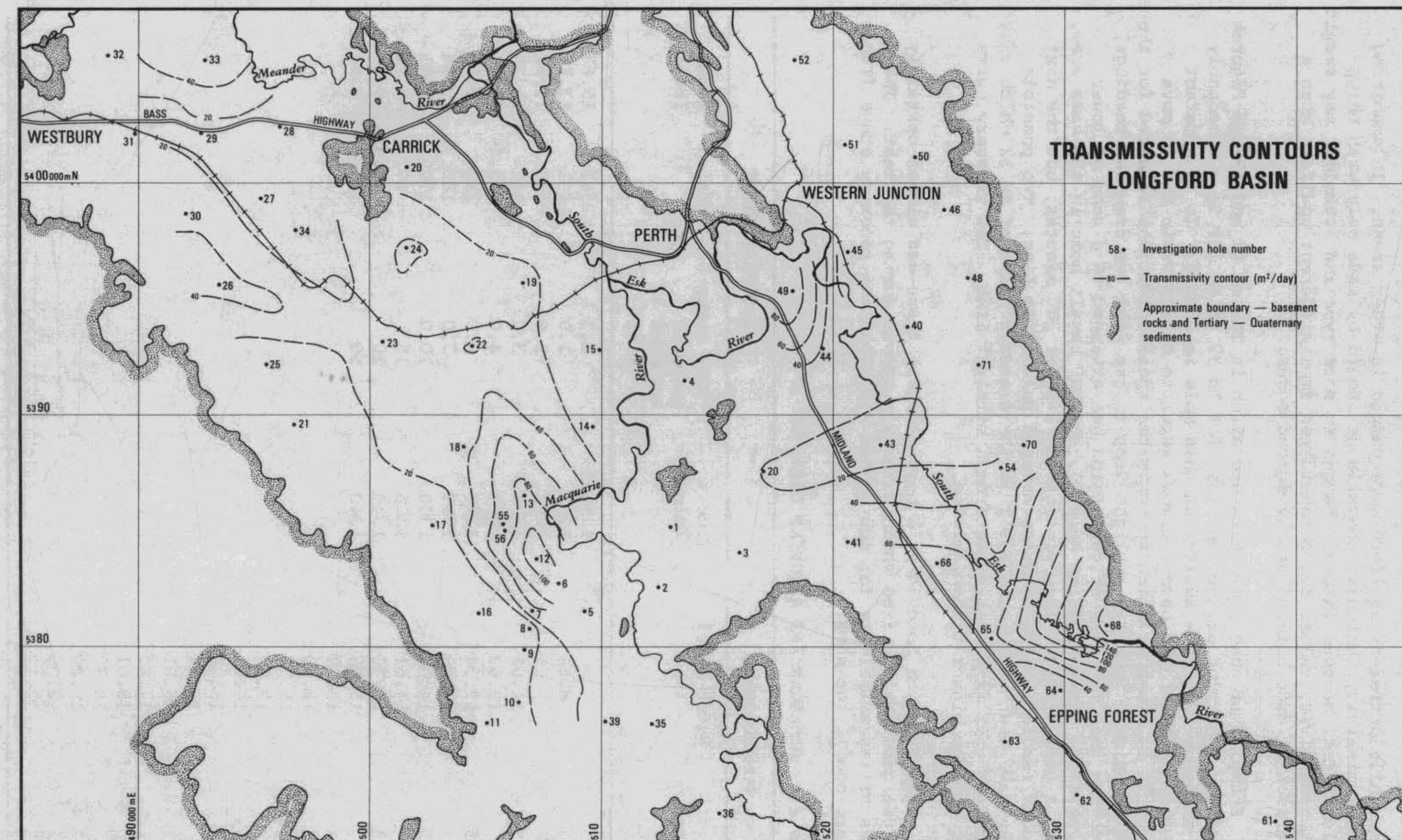

TRANSMISSIVITY CONTOURS
LONGFORD BASIN
58• Investigation hole number
Transmissivity contour (m²/day)
Approximate boundary — basement rocks and Tertiary — Quaternary sediments
WESTBURY
CARRICK
PERTH
WESTERN JUNCTION
EPPING FOREST
BASS HIGHWAY
MIDLAND HIGHWAY
Meander River
South Esk River
Macquarie River
5400000mN
5390
5380
490000mE
500
510
520
530
540

Figure 10.

areas, while different aquifers were pumped in other areas. In examining the transmissivity contours, comparisons should be made only with neighbouring bores, because lateral changes in rock type and lithology may result in transmissivity values being considered from different aquifers when a comparison is made between widely spaced bores.

Examples of some pump tests are given in Tables 12 and 13 and Figures 11 and 12. The plot of the pump test for IH 32 (fig. 11) is a reasonably good straight line; the aquifer in this hole is basalt. It is apparent that the nature of the basalt allows water to be stored in and to move through it in a manner which approximates those conditions required for the Theis equation. There is a slight drop in the last two drawdown readings, suggesting that the cone of depression has extended to a zone of lower permeability. Investigation hole 33, another basalt hole in the same area, showed a good straight line plot of log t≃s for 300 minutes, but the next drawdown reading at 1300 minutes dropped below this line. Two possible values have been calculated for T in the drawdown phase of IH 32 which vary because of this final departure from a straight line. The recovery curve gives an even higher transmissivity.

Investigation hole 34 is a bore in which there was almost certainly only one good aquifer from which water was pumped during the test. The values of transmissivity for the pumped stage and the recovery stage (Table 13) are nearly the same.

Table 12. DRAWDOWN AND RECOVERY DATA, IH 32

PUMPED STAGE		RECOVERY STAGE			
Time t (mins)	Water level (m)	Time t (mins)	Time since pumping stopped t' (mins)	t/t'	Water level
		1290.5	0.5	2581	15.67
0.5	8.56	1291	1.0	1291	13.11
1	9.91	1292	2.0	646	11.61
1.5	11.66	1293	3.0	431	11.25
2	12.62	1294	4.0	323.5	10.92
2.5	13.34	1296	6.0	216	10.59
3	13.89	1297	7.0	185.3	10.44
3.5	14.38	1300	10.0	130	10.11
4	14.61	1305	15	87	9.73
4.5	14.76	1310	20	65.5	9.50
5	15.06	1340	50	26.8	8.54
6	15.37				
7	15.60				
8	15.77				
9	15.90				
10	16.00				
12	16.26				
15	16.49				
20	16.81				
30	17.25				
60	18.01				
120	18.70				
180	19.20				
1230	22.05				
1290	22.12				

Table 13. DRAWDOWN AND RECOVERY DATA, IH 34

PUMPED STAGE		RECOVERY STAGE			
Time t (mins)	Water level (m)	Time t (mins)	Time since pumping stopped t' (mins)	t/t'	Water level
0.5	10.97	209.5	0.5	419	39.09
1	11.96	210	1	210	35.13
1.5	12.80	211	2	105.5	28.73
2	13.67	212	3	70.7	26.95
2.5	14.55	213	4	53.3	25.78
3	15.55	214	5	42.8	24.74
4	17.43	215	6	35.8	24.05
5	19.03	217	8	27.2	22.48
6	20.85	219	10	21.9	21.62
7	22.78	224	15	14.9	20.45
8	24.38	229	20	11.5	19.86
9	26.54	234	25	9.4	19.23
10	27.71	254	45	5.6	17.96
12	29.49	314	105	3.0	15.09
15	32.23				
19	36.09				
29	37.19				
89	42.82				
149	43.64				
209	45.57				

Pump test, IH 32 (fig. 11)

The pump was placed at 30.5 m from the surface. Slotted casing was installed from 12.2 m to 30.5 m. Standing water level was 5.5 m below the surface. The hole encountered 15.2 m of clay at the surface followed by basalt (fairly weathered) to 34.2 m. It is assumed that the water is confined. The hole was pumped at 280 *l*/min or 403.7 m^3/day.

Pump test, IH 34 (fig. 12)

Pump at 61 m from surface. Slotted casing was installed from 56.4 m to 88.4 m. Standing water level was 10.1 m below the surface. The hole encountered about 65.5 m of surface clay with one main sand bed from 65.5 - 88.9 m. Thinner sand horizons occur lower in the hole. The hole was pumped at a rate of 185 m^3/day.

UNCONFINED AQUIFERS

When part of an aquifer is drained during pumping, as in unconfined aquifers, modifications must be made to the drawdown data before the Theis non-steady state formula can be applied Jacob's correction (see Ferris *et al.*, 1962) is to subtract a figure $s^2/2b$ from the observed drawdown (s = drawdown, b = aquifer thickness). For an unconfined aquifer, a plot of $s - s^2/2b$ against t allows the standard non-steady formula to be used.

The aquifer at Cleveland where the production bore was installed is probably unconfined. Logging of materials from the hole indicates that gravel was struck above the standing water level, but as the hole was rotary drilled, it is not known whether it was a clean permeable gravel or a clayey

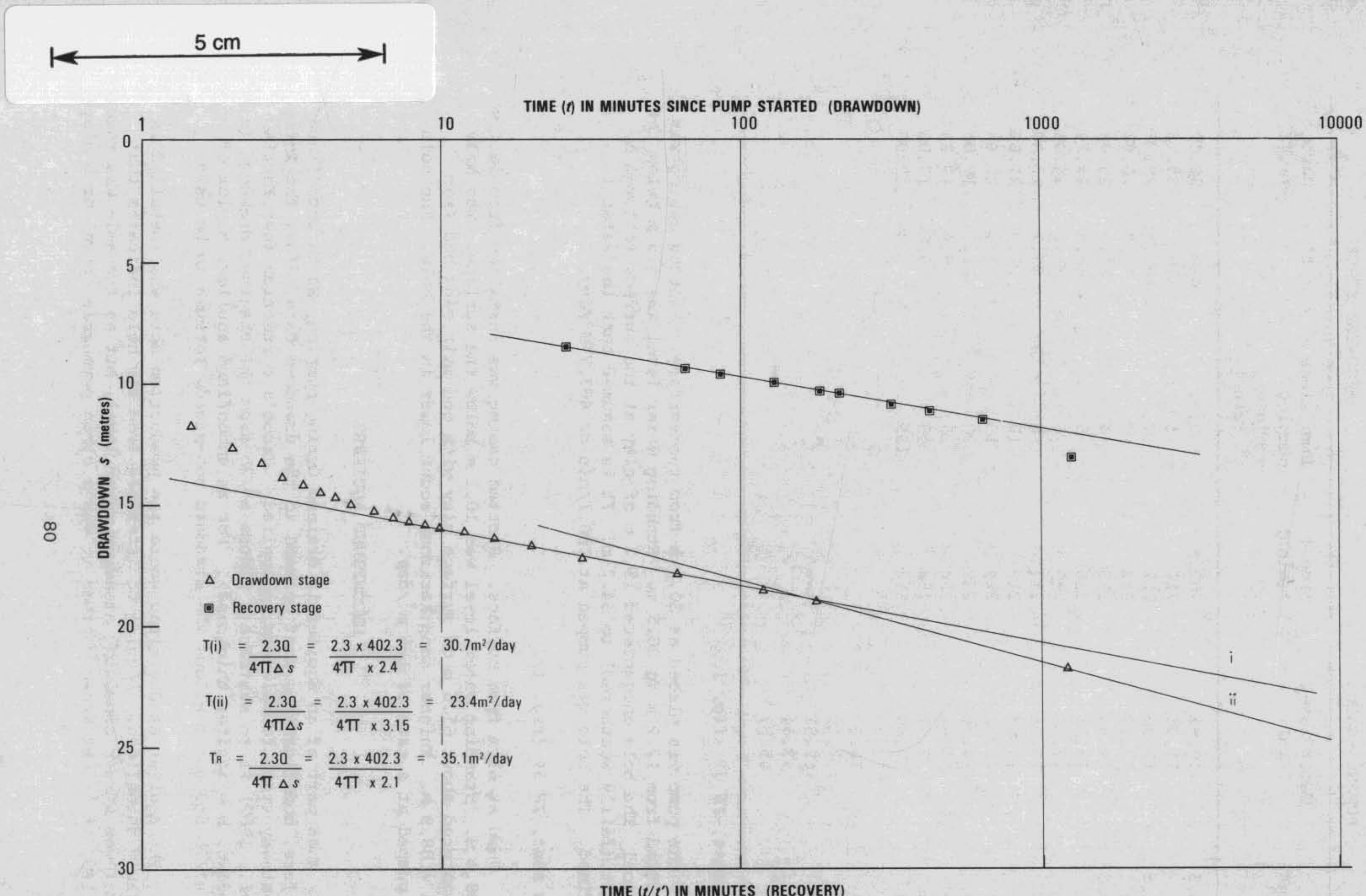


Figure 11. *Plot of drawdown and recovery data for Investigation Hole 32 (basalt aquifer).*

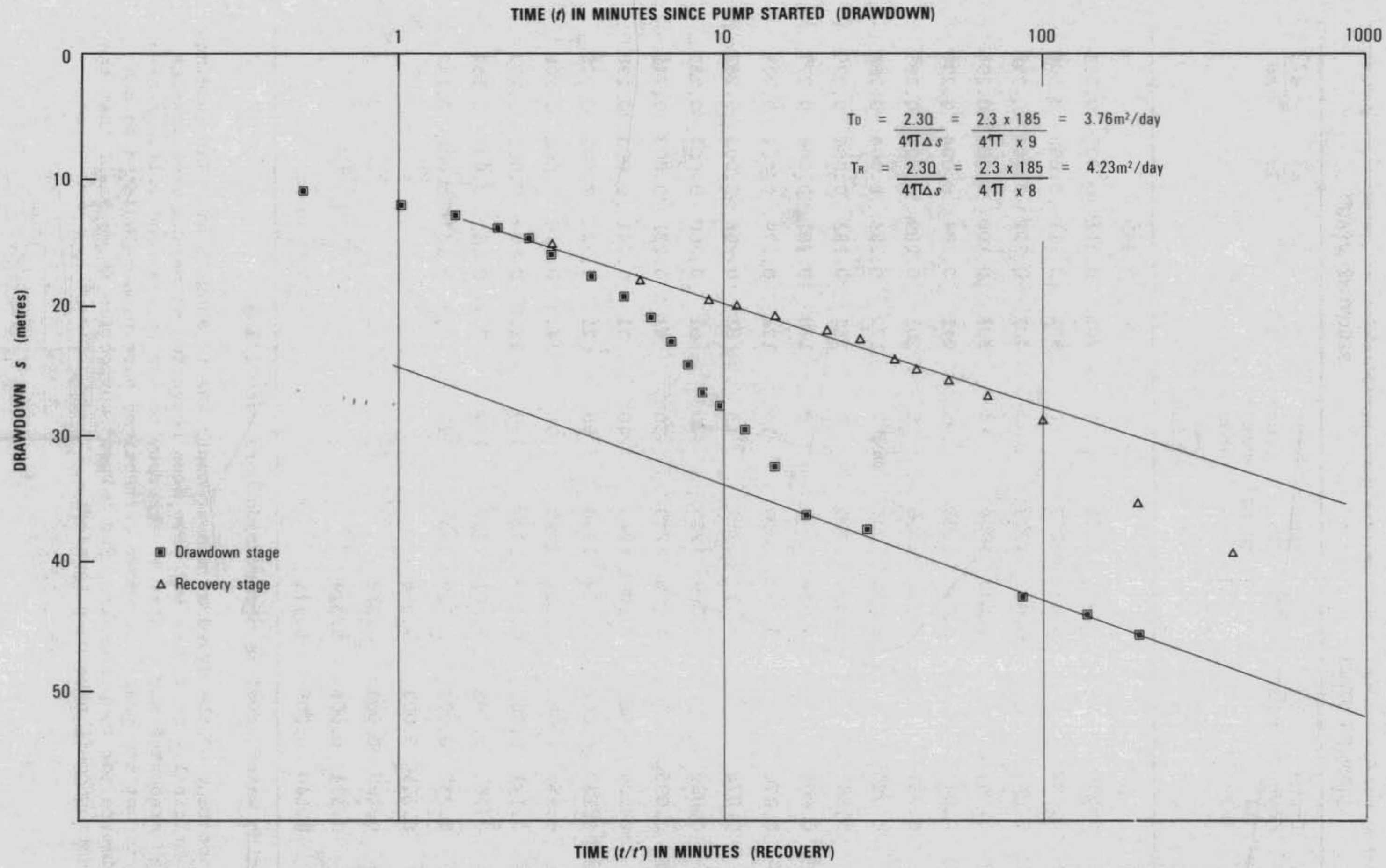


Figure 12. *Plot of drawdown and recovery data for Investigation Hole 34. This hole probably had only one main sand aquifer.*

Table 14. DRAWDOWN AND RECOVERY DATA, OBSERVATION HOLE, CLEVELAND PRODUCTION HOLE

PUMPING STAGE				RECOVERY STAGE					
Time (t) (mins)	Draw-down (s) (m)	$\frac{s^2}{2b}$	$s-\frac{s^2}{2b}$	Time (t) (mins)	Time since pump stop-ped (t′) (mins)	$\frac{t}{t'}$	s	$\frac{s^2}{2b}$	$s-\frac{s^2}{2b}$
0					0		0.340		
1	0.016		0.016	1201	1	1201	0.315	0.005	0.310
2	0.032		0.032	1202	2	601	0.311	0.005	0.306
3	0.041		0.041	1203	3	401	0.302	0.004	0.298
4	0.043		0.043	1204	4	301	0.300	0.004	0.296
5	0.044		0.044	1205	5	241	0.294	0.004	0.290
6	0.051		0.051	1206	6	201	0.289	0.004	0.285
7	0.056		0.056	1207	7	172	0.284	0.004	0.280
8	0.061		0.061	1208	8	151	0.283	0.004	0.279
9	0.064		0.064	1209	9	134	0.281	0.004	0.277
10	0.070		0.070	1210	10	121	0.279	0.004	0.275
15	0.078		0.078	1215	15	81	0.268	0.003	0.265
20	0.089		0.089	1220	20	61	0.260	0.003	0.257
30	0.095		0.095	1230	30	41	0.252	0.003	0.249
40	0.109	0.001	0.108	1240	40	31	0.241	0.003	0.238
60	0.130	0.001	0.129	1260	60	21	0.222	0.002	0.220
90	0.152	0.001	0.151	1290	90	14.3	0.210	0.002	0.208
120	0.171	0.001	0.170	1320	120	11.0	0.194	0.002	0.192
180	0.203	0.002	0.201	1380	180	7.7	0.159	0.001	0.158
240	0.232	0.003	0.229	1425	225	6.3	0.143	0.001	0.142
360	0.257	0.003	0.254						
600	0.292	0.004	0.288						
840	0.334	0.005	0.329						
1200	0.340	0.005	0.335						

Standing water level in observation bore was 22.3 m.

The accuracy of the drawdown measurements was to about 3 mm. The readings were originally in inches but have been converted to metric measurements and as presented may suggest an accuracy to the nearest one millimetre; this is not the case. Drawdown corrections have been calculated to one millimetre for completeness. The largest correction is so small that the correction could have been ignored.

gravel with a low permeability. If the aquifer is confined, it is only under low pressure. A plot of drawdown values for the observation hole (table 14) shows a poor fit with the type curve W(u) against $\frac{1}{u}$ (fig. 13), but there is reasonable correspondence over the later stages of pumping. Using the match point method to determine aquifer properties, the following values were obtained (the pumping rate was 1332 m^3/day):

$\frac{1}{u}$ = 10 (*i.e.* u = 0.1) s = 0.07

W(u) = 1 t = 48 minutes or 3.33×10^{-2}

using these data $T = \frac{QW(u)}{4\pi s}$

$$= \frac{1332 \times 1}{4\pi \times 0.07}$$

$$= 1514 \text{ m}^3\text{/m/day}$$

$$S = \frac{4T.tu}{r^2}$$

$$= \frac{4 \times 1514 \times 3 \times 10^{-2} \times 0.1}{22.7^2}$$

$$= 3.9 \times 10^{-2}$$

Plots of s against log t for both pumping and recovery stages in the observation and pumped holes are shown in Figures 14 and 15. The points for the drawdown stage of the pumped hole (fig. 15) are very irregular, this probably being due to water running over the electrical measuring device from higher up the hole causing false readings of the water level for some parts of the test. Any line drawn through these points is little more than a guess. Using Jacob's modified equations to determine aquifer properties, the following results were obtained:

Observation hole

Transmissivity - drawdown stage = 1624 m^2/day
recovery stage = 1353 m^2/day

Storage coefficient = 4.68×10^{-2}

Pumped hole

Transmissivity - drawdown stage = 2706 m^2/day
recovery stage = 1523 m^2/day

The data from a pump test in which the pump failed after 250 minutes is given in Table 16, with drawdown curves given in Figure 16. The transmissivity calculated from the observation hole data was 2756 m^2/day.

The storage coefficients calculated by using the two methods (match point method and the straight line solution) are fairly close in value. Transmissivity values calculated by both methods for the long pump test (except for the pumping stage in the pumped hole where information is unreliable) are also approximately the same. The shorter pump test gave a much higher transmissivity and is close to the value calculated for the pumped hole (pumping stage) in the longer test. The lower values are regarded as the more reliable.

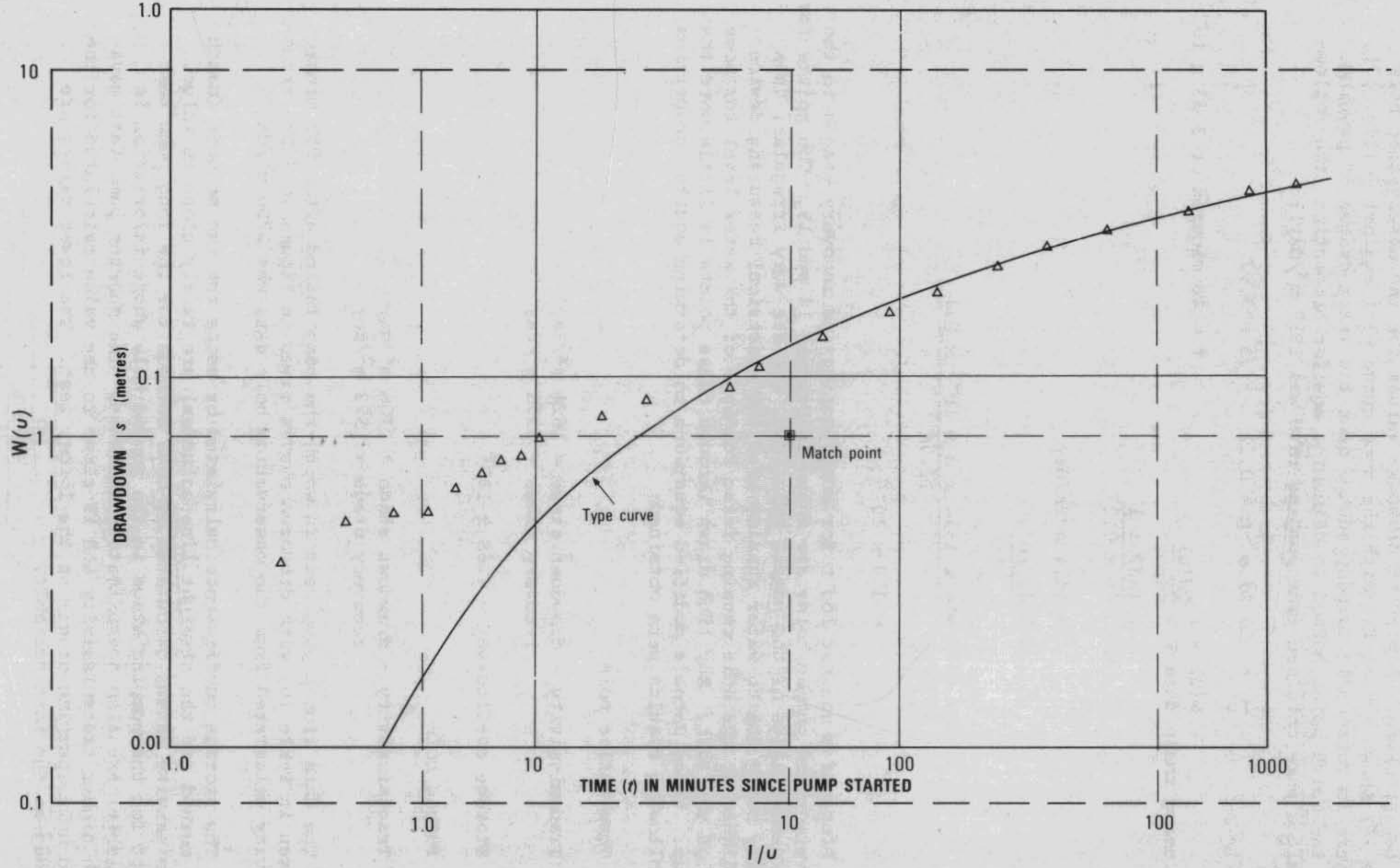


Figure 13. *Drawdown curve for Cleveland production hole (observation hole measuresments) - match point solution for T and S.*

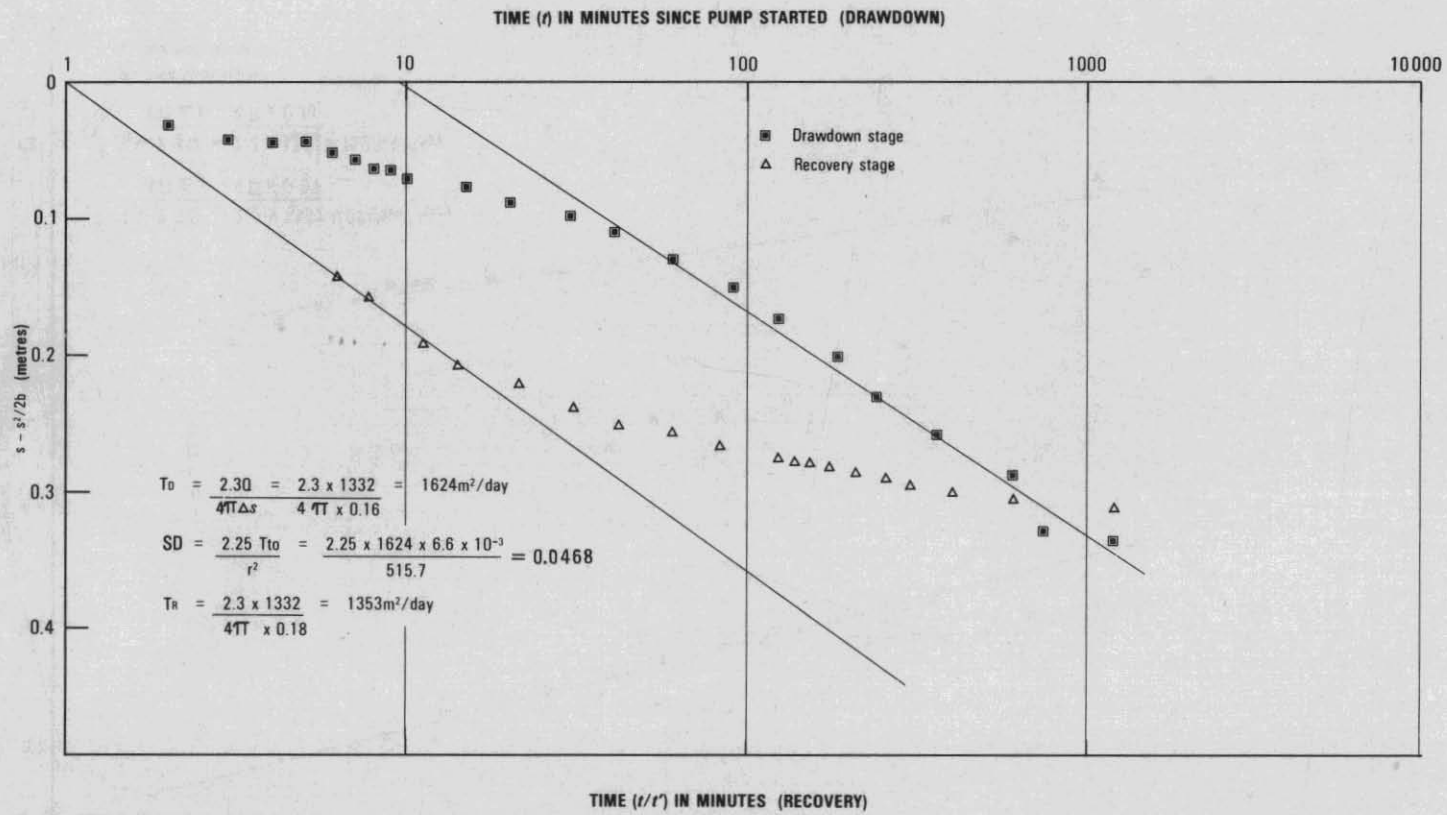


Figure 14. *Drawdown and recovery curves from observation hole measurements, Cleveland production hole - Jacobs straight line solution for T and S.*

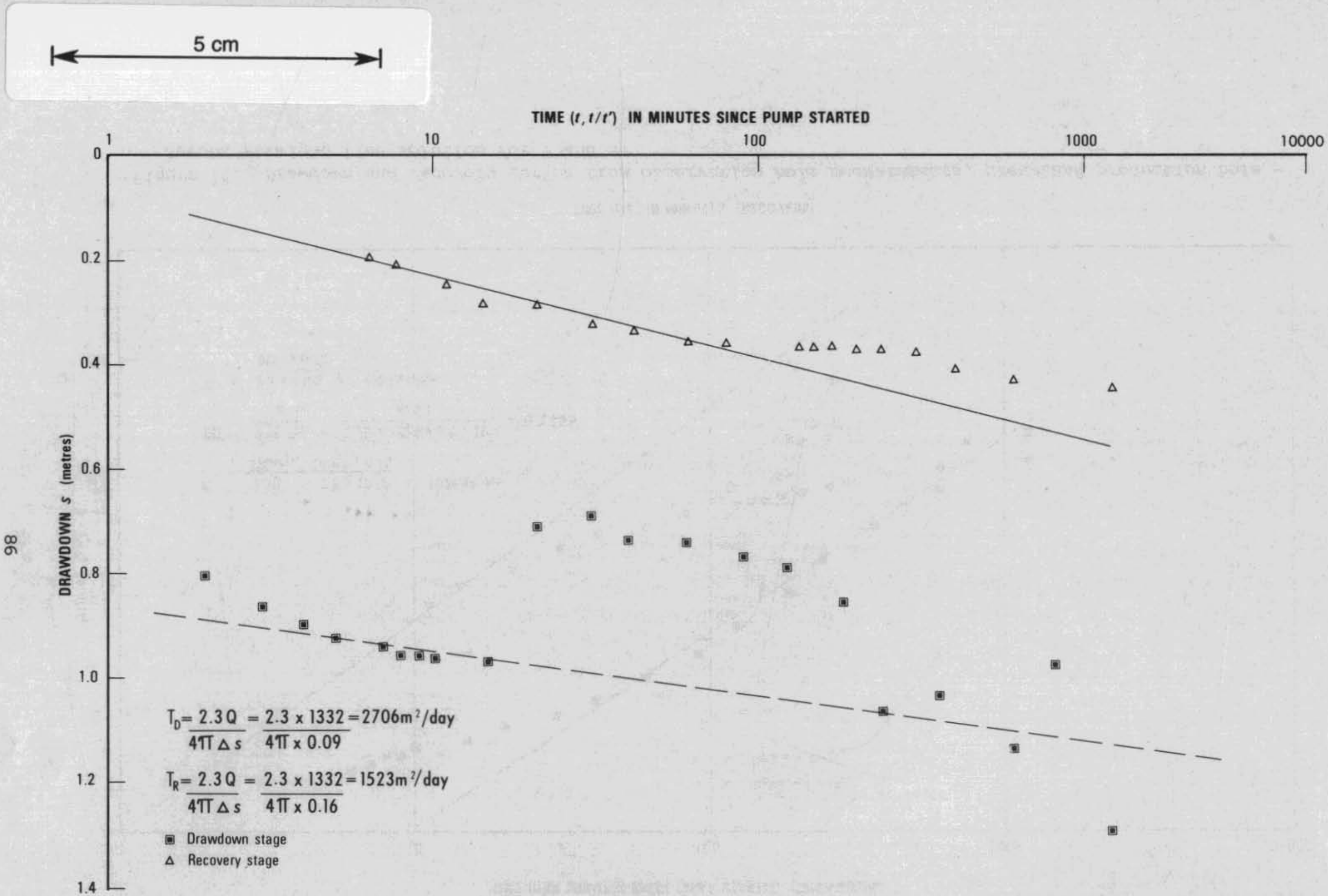


Figure 15. *Drawdown and recovery curves for pumped hole, Cleveland production hole. Drawdown information is not reliable.*

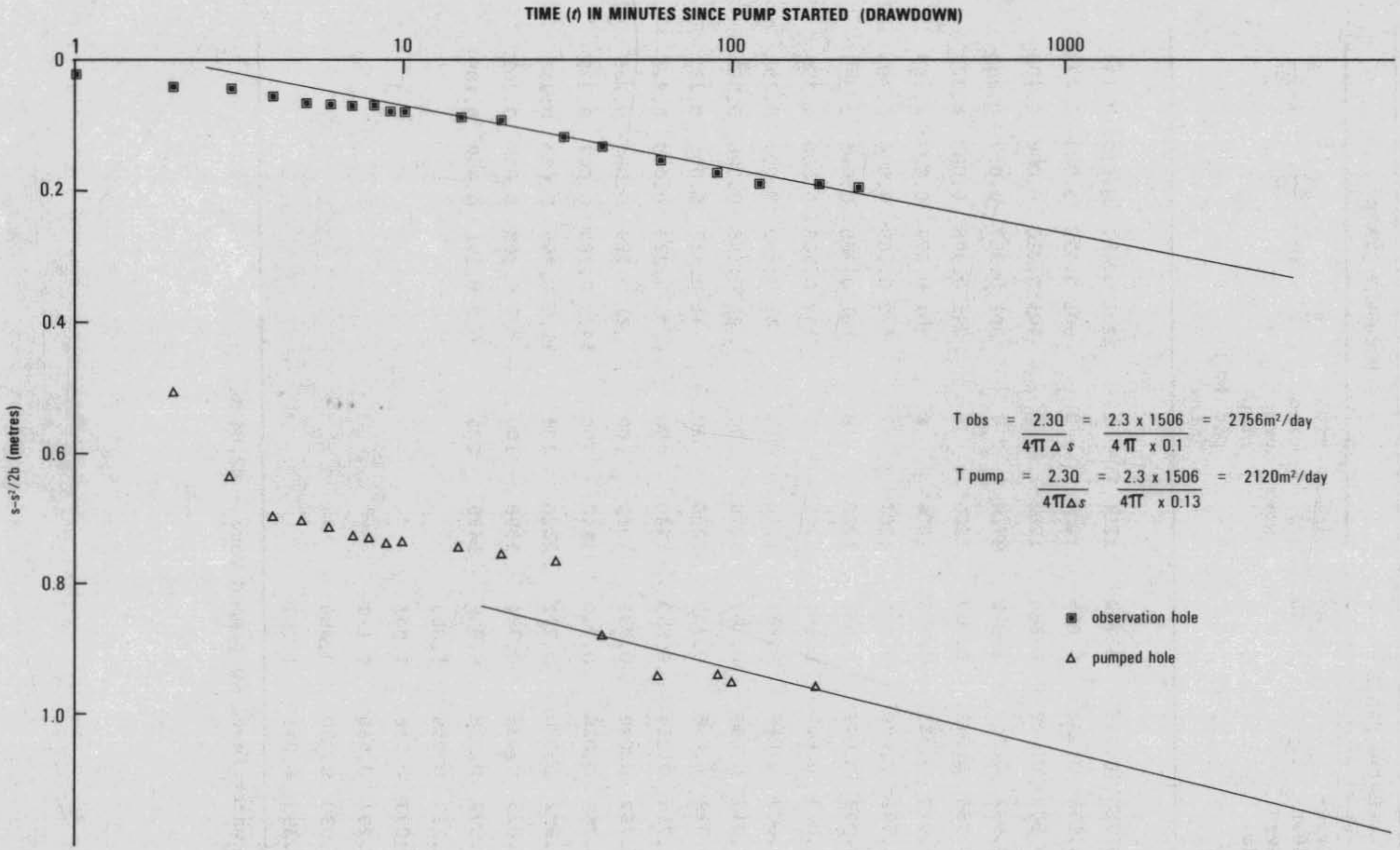


Figure 16. *Drawdown and recovery information, Cleveland production hole, for high output pump test. The pump failed after 250 minutes.*

Table 15. DRAWDOWN AND RECOVERY DATA, PUMPED HOLE, CLEVELAND PRODUCTION HOLE

PUMPING STAGE				RECOVERY STAGE					
Time (t) (mins)	Draw-down (s) (m)	$\frac{s^2}{2b}$	$s-\frac{s^2}{2b}$	Time (t) (mins)	Time since pump stop-ped (t´) (mins)	$\frac{t}{t'}$	s	$\frac{s^2}{2b}$	$s-\frac{s^2}{2b}$
0									
1	0.750	0.026	0.724	1201	1	1201	0.457	0.010	0.447
2	0.838	0.033	0.805	1202	2	601	0.432	0.009	0.423
3	0.902	0.038	0.864	1203	3	401	0.410	0.008	0.402
4	0.933	0.041	0.892	1204	4	301	0.387	0.007	0.380
5	0.960	0.043	0.917	1205	5	241	0.378	0.007	0.371
6	0.978	0.045	0.933	1206	6	201	0.375	0.007	0.369
7	0.991	0.046	0.945	1207	7	172	0.368	0.006	0.362
8	0.997	0.047	0.950	1208	8	151	0.365	0.006	0.359
9	1.003	0.047	0.956	1209	9	134	0.362	0.006	0.356
10	1.009	0.048	0.961	1215	15	81	0.359	0.006	0.353
15	1.015	0.048	0.967	1220	20	61	0.356	0.006	0.351
21	0.738	0.026	0.712	1230	30	41	0.337	0.005	0.332
30	0.716	0.024	0.692	1240	40	31	0.330	0.005	0.325
40	0.762	0.027	0.735	1260	60	21	0.289	0.004	0.285
60	0.768	0.028	0.740	1290	90	14.3	0.283	0.004	0.279
90	0.802	0.030	0.772	1320	120	11.0	0.245	0.003	0.242
120	0.826	0.032	0.794	1380	180	7.7	0.203	0.002	0.201
180	0.896	0.038	0.858	1425	225	6.3	0.191	0.002	0.189
240	1.125	0.059	1.065						
360	1.097	0.056	1.041						
600	1.207	0.068	1.139						
840	1.030	0.050	0.980						
1200	1.390	0.091	1.299						

Standing water level in pumped bore - 22.84 m.

Table 16. DRAWDOWN DATA FOR PUMP TEST, CLEVELAND PRODUCTION HOLE

PUMPED HOLE				OBSERVATION HOLE			
t (mins)	s (m)	$\frac{s^2}{2b}$	$s-\frac{s^2}{2b}$	t (mins)	s (m)	$\frac{s^2}{2b}$	$s-\frac{s^2}{2b}$
				0			
0				1	0.025		0.025
1	0.216	0.002	0.214	2	0.038		0.038
2	0.521	0.013	0.508	3	0.044		0.044
3	0.654	0.020	0.634	4	0.057		0.057
4	0.718	0.024	0.694	5	0.064		0.064
5	0.724	0.025	0.699	6	0.067		0.067
6	0.737	0.026	0.712	7	0.070		0.070
7	0.749	0.026	0.723	8	0.070		0.070
8	0.756	0.027	0.729	9	0.076		0.076
9	0.759	0.027	0.732	10	0.080		0.080
10	0.762	0.027	0.735	15	0.089		0.089
15	0.768	0.028	0.740	20	0.092		0.092
20	0.775	0.028	0.747	30	0.121	0.001	0.120
30	0.791	0.029	0.762	40	0.130	0.001	0.129
40	0.914	0.039	0.875	60	0.149	0.001	0.148
60	0.978	0.045	0.933	90	0.171	0.001	0.170
90	0.984	0.045	0.939	120	0.187	0.002	0.185
120	0.991	0.046	0.945	180	0.191	0.002	0.189
180	0.997	0.047	0.950	240	0.194	0.002	0.192

DELAYED DRAINAGE

The plot of log t against log s in the match point method for calculating aquifer properties for the Cleveland production hole is a poor fit on Theis type curves. The Theis formula depends on instantaneous drainage from the aquifer. For unconfined aquifers, water is supplied to a pumped bore by gravity drainage of the aquifer, expansion of the water in the aquifer because of drop in head caused by the pumping, and compaction of the aquifer material. These last two factors are small for unconfined aquifers. Where the aquifer material is fine-grained or has fine-grained beds interbedded with coarser material, delayed drainage usually occurs at some time in the pump test. The first part of the curve is due to the supply of water from zones near the bore; drainage is almost instantaneous and the drawdown/time data fits the Theis non-steady state formula fairly closely. As pumping proceeds the cone of depression falls, leaving zones above that have not been completely drained of all the available water, drainage rates being lower in fine aquifers than coarser aquifers. There is a stage when the proportion of this slower draining water, on reaching the bore, is large enough to deviate the drawdown/time curve from the standard Theis curve and produce a flattening. At later stages, drainage

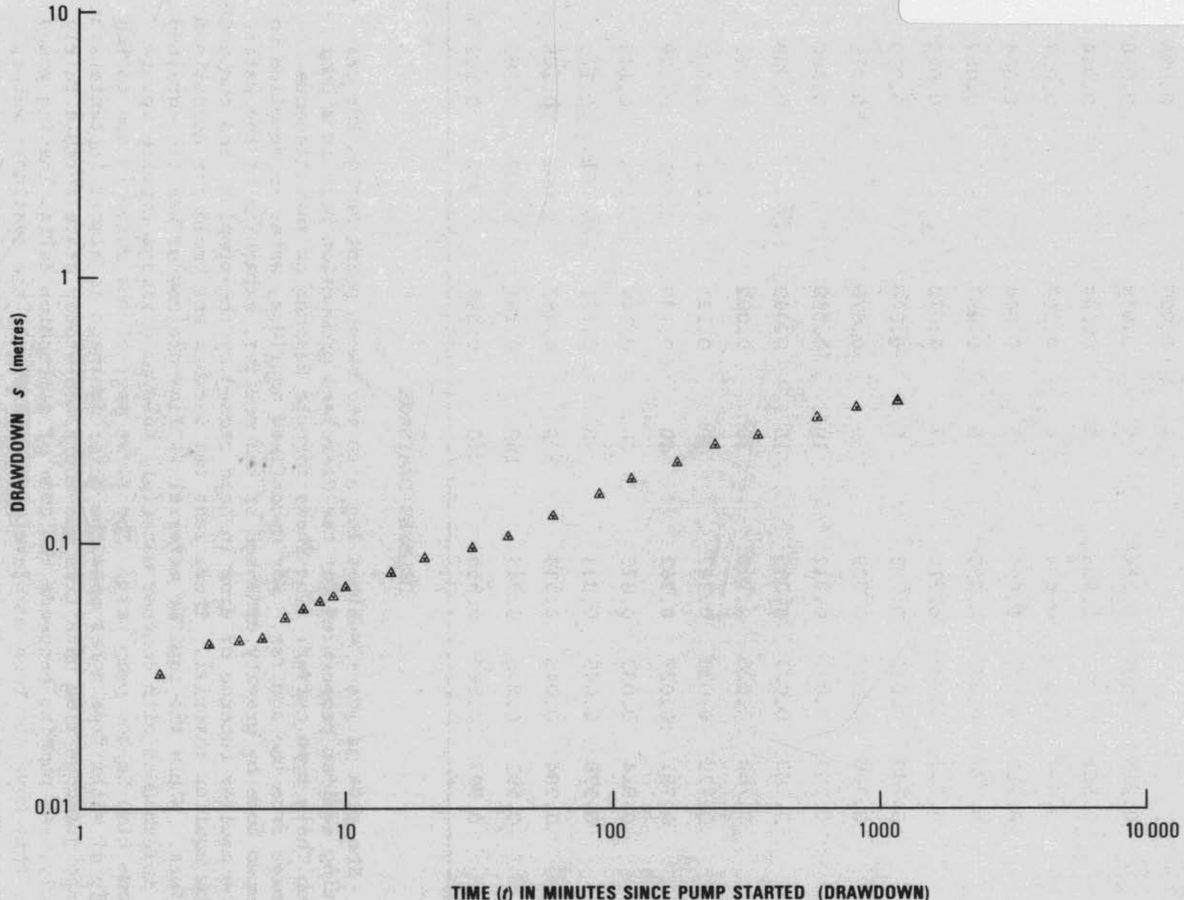


Figure 17. *Plot of drawdown data, Cleveland production hole. Inflexions suggest delayed drainage effects.*

and drawdown rates approach equilibrium, and observed drawdown/time data again approaches the Theis standard curve. Boulton (1963) produced a set of type curves to take this delayed drainage effect into account.

The plotted information for the Cleveland production bore (fig. 17) shows some flattening in the early stages of pumping where it is a poor fit on the Theis curve. Boultons curves have been used to calculate the effective storage coefficient by dealing with the plotted curve in two parts, an early stage and a later stage, as outlined by Hazel (1973).

From the early stage match point:

$$T_E = \frac{Q\ W(u)}{4\pi s} = \frac{1332 \times 1}{4\ \pi \times 0.11} = 964\ m^2/day$$

$$S_E = \frac{4\ T\ t\ u}{r\ 2} = \frac{4 \times 964 \times 7.01 \times 10^{-3} \times 0.1}{22.7^2} = 5.25 \times 10^{-3}$$

From the later stage match point:

$$T_L = \frac{1332 \times 1}{4\ \pi \times 0.088} = 1205\ m^2/day$$

$$S_L = \frac{4 \times 1205 \times 6.94 \times 10^{-2} \times 0.1}{22.7^2} = 6.49 \times 10^{-2}$$

The effective storage coefficient is the sum of these two storage coefficient figures, which is a little larger than the figures calculated by the other methods.

Using the Boulton delay index curve (Hazel), a time of about 100 minutes is calculated as the period of pumping in which delayed drainage affects the drawdown.

MULTIPLE-RATE PUMP TEST

Multiple-rate pump tests involve either a series of short pump tests at varying pumping rates, with periods of recovery in between, or continuous pumping with varying pump rates for equal periods of time. Drawdown is measured in the pumped hole. Such tests can be used to examine the state of development or deterioration of a bore by determining head losses. They can also be used to estimate the likely capacity of a bore where the testing pump is only capable of drawing down a small proportion of the total available drawdown, and safe yields can be predicted.

Jacob (1963) divided the cause of drawdown in a pumped well into two parts:

(1) that due to overcoming resistance to laminar flow in the aquifer; this follows Darcy's Law in that $s_L = BQ$ where s_L = drawdown due to laminar flow, Q is pumping rate and B is a constant variable with time.

(2) that due to turbulent head loss caused by the increased velocity adjacent to the screens or slotted casing, turbulent flow through the slots or screen, and turbulent flow up the bore which is proportional to Q^n; in most cases n is said to equal 2

Table 17. DRAWDOWN DATA, MULTI-STAGE PUMP TEST, CLEVELAND PRODUCTION HOLE

Time (t) (mins)			Drawdown (s) (m)	$\frac{s^2}{2b}$	$s-\frac{s^2}{2b}$	Pumping rate (*l*/min)
0			0			
1			0.737	0.026	0.712	675
2			0.768	0.028	0.740	
3			0.787	0.029	0.758	
4			0.794	0.030	0.765	
5			0.826	0.032	0.794	
6			0.838	0.033	0.805	
7			0.857	0.034	0.823	
8			0.864	0.035	0.829	
9			0.870	0.036	0.835	
10			0.876	0.036	0.840	753
15	0		0.889	0.037	0.852	753
	1		0.953	0.043	0.910	
	2		0.959	0.043	0.916	
	3		0.978	0.045	0.933	792
	4		0.978	0.045	0.933	
	5		0.981	0.045	0.936	
	6		0.981	0.045	0.936	
	7		0.984	0.045	0.939	792
	8		0.988	0.046	0.942	
	9		0.991	0.046	0.945	
	10		0.994	0.046	0.948	766
	15	0	1.001	0.047	0.954	
		1	1.238	0.072	1.166	
		2	1.264	0.075	1.189	970
		3	1.270	0.076	1.194	
		4	1.273	0.076	1.197	970
		5	1.283	0.077	1.206	
		6	1.286	0.078	1.209	970
		7	1.295	0.079	1.216	
		8	1.302	0.080	1.223	
		9	1.305	0.080	1.225	
		10	1.311	0.081	1.231	
		15	1.321	0.082	1.239	

i.e. $s_T = CQ^2$ where s_T = drawdown due to turbulent flow and C is a constant.

Total drawdown $s = s_L + s_T = BQ + CQ^2$ (1)

Jacob's modified version of the Theis equation for a pumped well (when u is small) is:

$$s = \frac{2.3Q}{4\pi T} \log 10 \frac{2.25Tt}{r^2 s}$$ which can be written in the form

$$s = (a + b \log t)\ Q \quad (2)$$

where $a = \frac{2.3}{4\pi T} \log \frac{2.25T}{r^2 s}$ and $b = \frac{2.3}{4\pi T}$

Combining equation 2 with equation 1 by adding the turbulence factor, the equation for drawdown in a bore can be written as

$$s = (a + b \log t)\ Q + CQ^2$$

A short period step drawdown test was conducted on the production hole at Cleveland with a time length for each step of 15 minutes. Such tests are usually preferable over longer time intervals. A drawback encountered in the test was the small variation in the pumping rate between stages, this being due to the small range possible with the diesel motor driven pump. Both of these factors detract from the value (and probably the reliability) of this test, but the results are of interest to compare with other information. Drawdown data are given in Table 17.

Using the method of analysis described by Hazel (1973), a plot of the drawdown/log time data is shown on Figure 18, together with the reconstructed true drawdown curve for each rate. The tabulated results on Figure 18 were calculated from these reconstructed time-drawdown plots. A division by Q of all terms in $s = (a + b \log t) + Q + CQ^2$ gives $s/Q = (a + b \log t) + CQ$, so that a plot of $s/Q \simeq Q$ is a straight line graph. Hazel devised a method to produce more values from this plot and these are shown on the table in Figure 19. Unfortunately in this calculation the three extra points have the same value on the vertical axis of the plot. A reasonable line can be drawn through the $\Delta\ s/Q \simeq Q$ points, the line passing through the range of the three calculated points. From Figures 18 and 19, the unknowns in the equation can be found.

$C = 1.14 \times 10^{-7}$ where C is the slope of the line in Figure 19.

From the slope of the lines of the plots of drawdown - log time, b can be calculated.

$b = \frac{\Delta s}{Q}$ where Δs is the drawdown per log cycle.

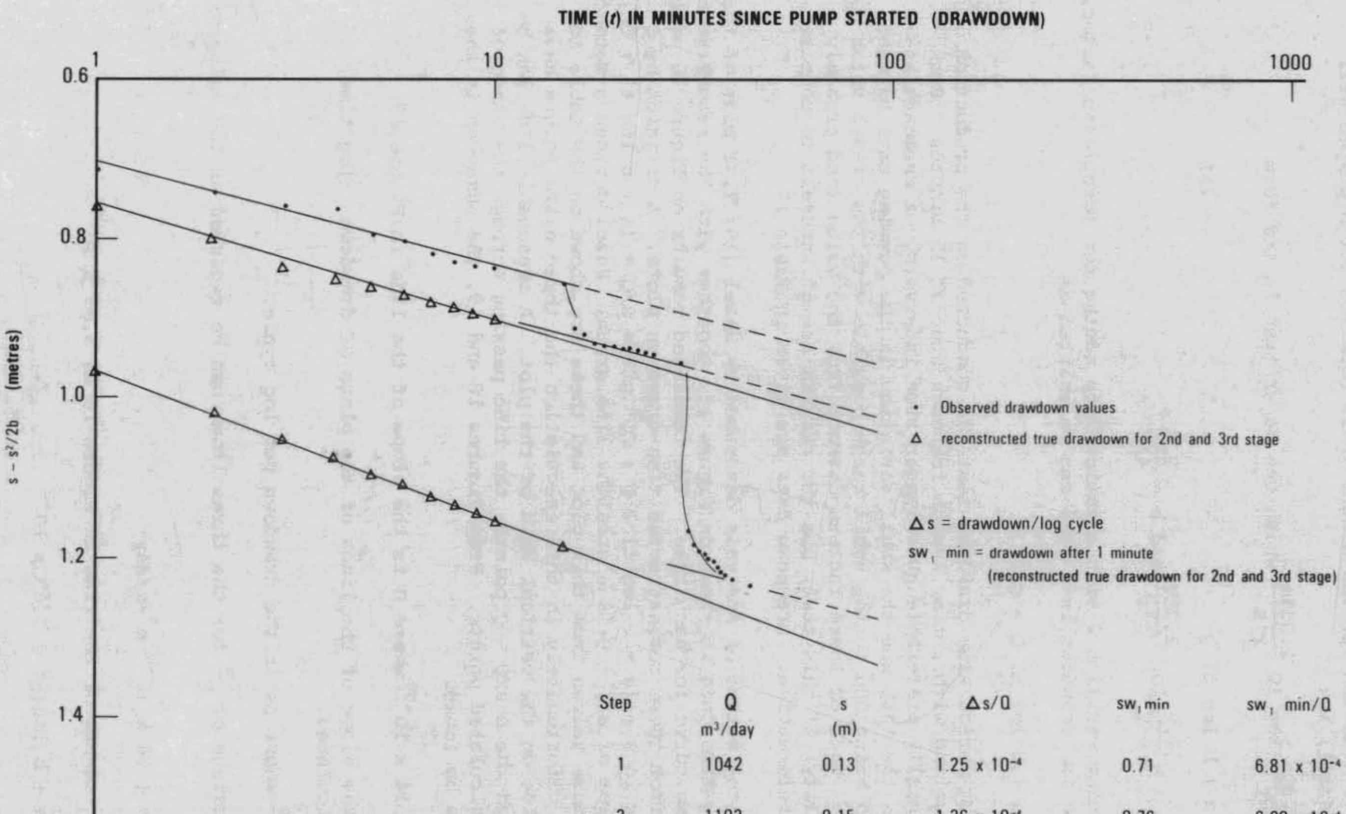
The average of $\frac{\Delta s}{Q}$ for the three lines can be regarded as the value of b

i.e. $= 1.34 \times 10^{-4}\ m^3/m/day$

The intercept of the line in Figure 19 is 5.65×10^{-4}

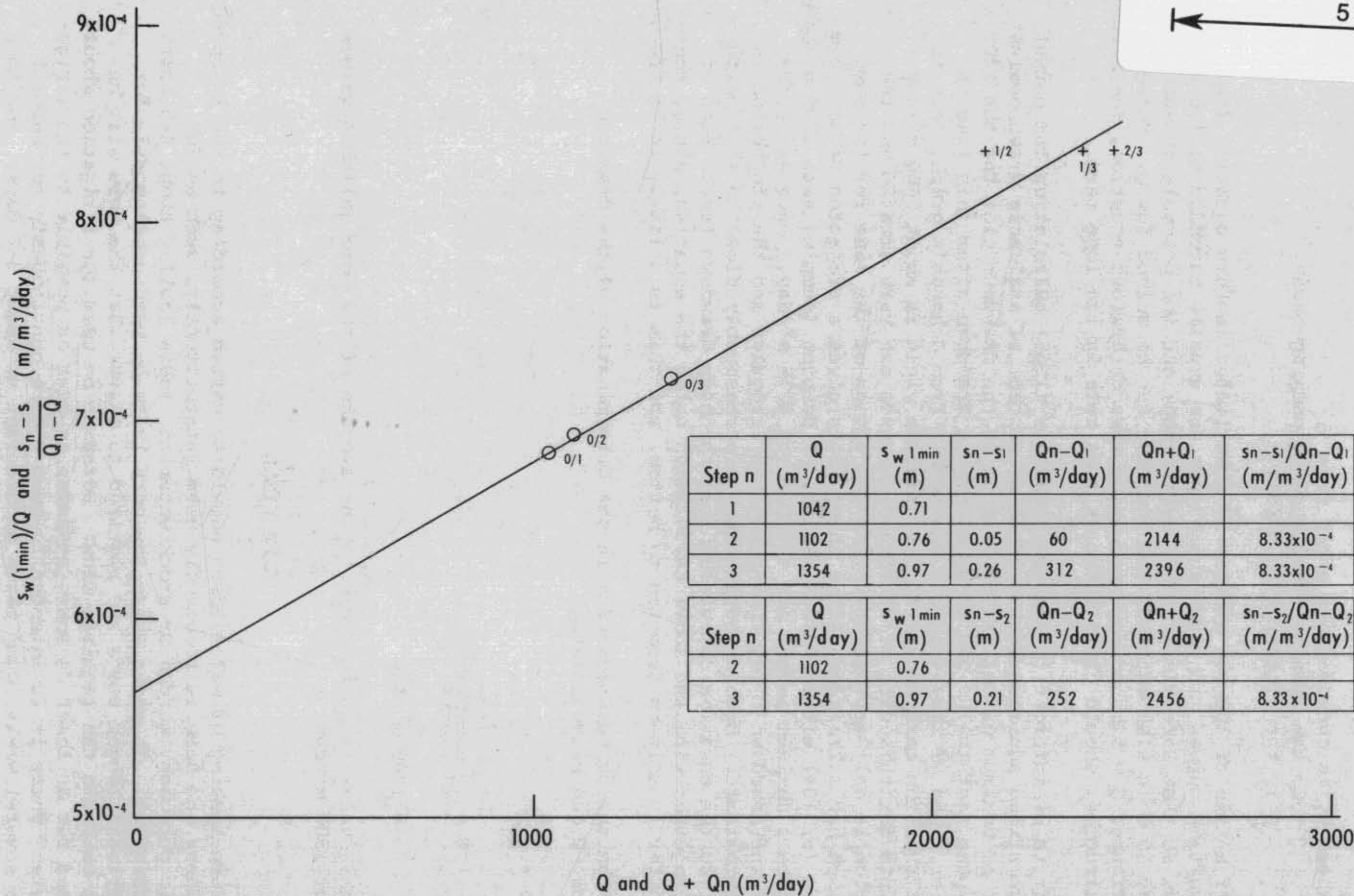
i.e. $a + b \log_{10} t = 5.65 \times 10^{-4}$

When the value of drawdown at time one minute is taken to plot this



Step	Q m³/day	s (m)	Δs/Q	sw₁ min	sw₁ min/Q
1	1042	0.13	1.25×10^{-4}	0.71	6.81×10^{-4}
2	1102	0.15	1.36×10^{-4}	0.76	6.90×10^{-4}
3	1352	0.19	1.41×10^{-4}	0.97	7.18×10^{-4}

Figure 18. *Plotted results of short term multi-stage pump test, Cleveland production hole.*



Step n	Q (m^3/day)	s_w 1 min (m)	$s_n - s_1$ (m)	$Q_n - Q_1$ (m^3/day)	$Q_n + Q_1$ (m^3/day)	$s_n - s_1 / Q_n - Q_1$ (m/m^3/day)
1	1042	0.71				
2	1102	0.76	0.05	60	2144	8.33×10^{-4}
3	1354	0.97	0.26	312	2396	8.33×10^{-4}

Step n	Q (m^3/day)	s_w 1 min (m)	$s_n - s_2$ (m)	$Q_n - Q_2$ (m^3/day)	$Q_n + Q_2$ (m^3/day)	$s_n - s_2 / Q_n - Q_2$ (m/m^3/day)
2	1102	0.76				
3	1354	0.97	0.21	252	2456	8.33×10^{-4}

Figure 19. *Plot of Q ∿ Sw(1 min)/Q for the multi-stage pump test, Cleveland production hole, together with additional points using Hazel's method. This plot allows determination of the unknowns of the drawdown equation.*

line, b log10t = 0 so that

$$a = 5.65 \times 10^{-4}$$

The equation for the drawdown in the well is

$$s_t = (5.65 \times 10^{-4} + 1.34 \times 10^{-4} \log 10t)\ Q + 1.14 \times 10^{-7}\ Q^2$$

Where s_t is the drawdown after time t,
t is the time in minutes since pumping began,
Q is the discharge in m^3/day.

If a time of 100 000 minutes is substituted in this equation (the drawdown/time curves with constant output are usually extended to 100 000 minutes, so that safe yield can be determined) and the possible drawdown of about 10 m is also entered, the equation can be solved for Q. Using these figures Q = 5403 m^3/day *i.e.* using this determined equation, the bore as constructed, should yield water at this rate in the long term.

It is of interest to compare Johnson's (1966) calculation for output from unconfined aquifers from a graph of percent of available drawn against percent of maximum output. A projection of the drawdown plot for the 1200 minute pump test to 100 000 minutes gives a drawdown after this time of 1.56 m or 15.6% of the available drawdown. From Johnson's graph, this is about 27% of the maximum yield, *i.e.* maximum yield is about 5000 m^3/day. The points for this part of the drawdown curve are very erratic and the projection is only approximate. The projection of the line for the pump test which had a breakdown after three hours gives a projected value 1.3 m drawdown (or 13%) after 100 000 minutes of pumping (pumping rate 1506 m^3/day). This gives a maximum output for the bore of 6275 m^3/day. Once again the plot of the drawdown : log time points is irregular and the projection is only approximate. However both values are reasonably close to that calculated from the equation calculated from the step drawdown test. Both of these, together with the above calculation using the equation, assume that the aquifer is uniform from top to bottom, and this is unlikely to be the case.

From the calculation of b in the determination of the drawdown equation, T can be calculated.

$$b = \frac{2.3}{4\pi T}$$

$$T = \frac{2.3}{4\pi\ 1.34 \times 10^{-4}}$$

$$= 1366\ m^2/day$$

This value is quite close to the average of the more reliable values of about 1500 m^2/day

SAFE YIELD

Pump testing of water bores should be varied according to the intended use. Where the bore is to be only used intermittently, such as for domestic purposes, garden or stock watering, tests lasting about 4-6 hours are sufficient. In cases where the bore is to be used continuously for long periods, longer tests are required to ensure that the bore will be able to maintain the required flow. Bores to be used for irrigation should be tested for at least 24 hours at rates as near as possible to the irrigation rate. Where it is intended to pump a bore continuously for several days to several weeks, pump tests should last at least 3-7 days. For town supplies, longer tests should be undertaken. In cases where the testing pump has only drawn the water level down a small proportion of the total possible drawdown, it is only safe to increase the tested rate about double when establishing a pump for permanent production, as turbulent head losses around the bore sometimes increase at a greater rate than expected (O'Shea, 1961). An approximation of the drawdown due to turbulence at higher rates can be gained by doing a multi-stage pump test over three or more stages (preferably at least four or five stages) of 20-100 minutes for each stage. This, together with the results of a longer pump test with constant output, should provide a guide to the safe yield for the particular bore and bore construction involved.

One method used in determining the safe yield after a pump test has been completed and the data plotted on semi-log paper is to extend the line produced to 100 000 minutes (except for town supplies, this time is probably about the annual limit of use for a bore). For example, by extending the line drawdown $\approx$ log time for hole IH 34 to 100 000 minutes, a drawdown to 60.8 m below the surface could be expected. The top of the aquifer is at 65.5 m below the surface. This latter depth can be regarded as the available drawdown. When a standing water level of 10.1 m below the surface is considered, available drawdown is 55.4 m without de-watering the aquifer. At 100 000 minutes 50.7 m of the drawdown is used. Theoretically the rate of pumping could be increased to 185 x 55.4/50.7 or 202 m^3/day and this should produce a drawdown of 55.4 m from standing water level after 100 000 minutes. In practice, some margin of safety should be allowed and the actual pump rate used in the test is probably near the rate that should be used if the bore was to be pumped for long periods. This applies to the bore as constructed for this test, with sparsely slotted casing against the sand. With closely slotted casing or a metal screen and surrounding gravel pack, pumping at the same rate should give a much smaller drawdown and thus a larger safe yield could be calculated.

MEASUREMENT OF PUMPING RATES

Rates of pumping were measured by passing the water through a circular orifice weir; this consisted of a length of 100 mm pipe with a 75 mm orifice on the discharge end. Pressure in the pipe is measured in a piezometer tube topping the pipe. The pressure or height of the water in the piezometer tube is related to the flow rate. As the device was made at the Department of Mines workshop and the 100 mm pipe was shorter than is recommended, pump tests with measured volume rates were conducted so that a curve could be constructed to cover the ranges of pumping rates likely to be used. Johnson (1966) gives an equation for the flow through such a weir as:

$$Q = 8.02\ KA\sqrt{h}$$

Where Q is the rate in gallons per minute
- K is a factor related to the ratio of the diameter of the orifice to pipe diameter
- A is the area of the orifice in square inches
- h is the head in the piezometer in inches

It was found that the theoretical curve was very close to that produced from the measured tests in the field, despite the variation in the recommended construction.

Part 3: Water Quality and Use

WATER QUALITY

INTRODUCTION

Quality is an important consideration when particular uses of groundwater are planned. Most of the water in bores, both investigation and contract, and some of the wells has been chemically analysed. The results of these analyses are shown in appendices 8, 9, and 10, and total dissolved solids (TDS) are shown on Figure 3. The salinity of non-analysed well water was determined with a conductivity meter, and can only be regarded as an approximation of total dissolved solids.

Salinity contours based on values of total dissolved solids have been drawn over some parts of the Tertiary sediments and basalt areas (fig. 3), using information obtained from investigation bores only (used because of similar penetration depths and wide aquifer sampling). These contours show a high salinity of the water in the southern part of the eastern sub-basin and a zone of lower quality water occurring from between Cressy and Longford to Toiberry.

PHYSICAL PROPERTIES

Physical properties which have a bearing on the use of water include temperature, turbidity, odour, and taste.

Temperature

Temperature is often a factor in determining whether water is useful for some industries; for example, groundwater has been used in cooling systems in some dairies in Tasmania.

The temperature of groundwater is relatively stable throughout the year. In the United States of America groundwater temperatures from 10-20 m from the surface are 1-2°C above the mean annual air temperature of the locality (Todd, 1959). Below these levels, the temperature increases about 1°C per 30 m increase in depth. A few water temperatures have been measured from the Longford area, mainly from aquifers 60-120 m from the surface; temperatures have ranged from 16-20°C. The mean annual temperature for Cressy is about 11°C. Using the above U.S.A. figures, near-surface water temperature could be expected to be about 12-13°C and water from 120 m would be about 17-18°C.

Colour

Colour in water is usually due to dissolved organic compounds, but can be caused by dissolved mineral matter (Todd, 1959). It is usually reported in milligrams per litre by comparison with a standard solution. Little or no colouration was noted in any of the deep bore water and any apparent colour that does occur is probably due to colloidal material rather than dissolved substances (*e.g.* IH 51). The water in some of the shallow wells has a colouration which can be attributed to contamination by plant and animal-derived matter from the surface.

Turbidity

Turbidity is a measure of the suspended material, usually clay, organic matter, and microscopic organisms, which may or may not settle. Unconsolidated sediments tend to filter out these particles if present at any stage and turbidity is seldom a problem. Turbid water usually has a low salinity, because the electrical effects of salts tend to coagulate and settle the clay particles (Hill, 1961). Occasional bores in the Longford area produced turbid water (*e.g.* IH 51).

Taste and odour

Taste and odours associated with water can be caused by bacteria, dissolved gases, and mineral matter. Some bore water encountered during drilling had a distinct odour, this probably being due to dissolved gases. A spring about three kilometres west of Bracknell had large amounts of dissolved hydrogen sulphide and a very strong smell.

Sodium chloride (common salt) in concentrations of about 400 mg/*l* has no distinct taste, but above this concentration it is noticeable (Ward, 1946). Other salts also contribute to taste and as many bores and wells produce water with a salt concentration greater than 400 mg/*l*, there is often taste associated with the groundwater.

BACTERIOLOGICAL PROPERTIES

Bacteria are not regarded as a common problem in underground water supplies, although problems can occur when septic tank outlets are below the water table. The bacteria which is usually tested for in water analysis is coliform bacteria, the type that occurs in the intestines of animals. Underground water supplies can be contaminated by seepage down the side of the bore casing, or in cavernous limestone country where caverns are connected with surface contaminated water. The bacterial content of a water sample is reported as the 'most probable number' (MPN) of coliform bacteria for a given volume. Routine analysis for bacteria is not undertaken and is usually only performed if contamination is suspected. Samples for bacterial analysis have to be collected in sterilised bottles; analyses in Tasmania are conducted by the Department of Agriculture at their Mt Pleasant Laboratory, Launceston and the Government Analyst, Hobart. Coliform bacteria could be expected in some of the unprotected wells.

CHEMICAL PROPERTIES

There are three sources of groundwater:

(a) *Juvenile;* this is new water from the earth's interior associated with magmatic or volcanic action and introduced into the surface water supply.

(b) *Connate Water;* a proportion of groundwater is made up of water that is trapped in sediments during deposition. It can be saline or fairly fresh water depending on the environment of deposition.

(c) *Meteoric Water;* this is rain water, a proportion of which after reaching the ground seeps down to add to the underground supply. Most groundwater that is utilised has this origin.

Juvenile water has, at some time, been at high temperature and increased temperature tends to increase the solubility of most compounds. It is therefore usually highly mineralised. Connate water, even though the sediments containing it may have been deposited in a terrestrial environment, is likely to be reasonably saline because of the time it has been in contact with the enclosing sediments. The salinity will depend largely on the chemical composition of these sediments.

Rain, although regarded as pure water, usually contains some dissolved substances before reaching the earth's surface. Dust particles associated with clouds contribute some dissolved solids and sea mist will contaminate clouds on occasions. Gases that make up the atmosphere are also soluble. At atmospheric pressure and 0°C, about 29 mg/*l* of air will dissolve in water (Johnson, 1966). The amount of gas that will dissolve is directly proportional to pressure and inversely proportional to temperature. Oxygen and carbon dioxide in rain water are the most significant of the gases that are dissolved, because their presence contributes to the weathering and dissolving ability of the water once it reaches the ground surface. After rainfall, some evaporation will take place, concentrating the already dissolved solids. As the water percolates through the soil, soluble salts present will dissolve and some carbon dioxide may be added to the water. Plant roots and decaying vegetation produce carbon dioxide which concentrates in the soil and ground air above the water table.

The final composition of the dissolved solids in groundwater depends largely on the type of soil and rocks through which the water passes. The solubility of a material in water depends on such factors as temperature, pressure, pH, and the relative amounts of other substances already present in the water. Silt, clay, and organic matter in aquifers will absorb ions and these can be replaced by exchange if these materials come into contact with water with a suitable composition. The final composition of water in the aquifer is reached by solution and absorption and will tend towards chemical equilibrium with its surroundings.

Tree and plant roots can also change the composition of water. Elements such as calcium, silicon, potassium, sulphur, magnesium, and sodium occur in wood ash in considerable quantities and these are extracted from the soil water or directly from an underground water source if the water table is shallow. Some modification of groundwater composition may also take place by bacterial action.

Methods of measuring dissolved solids

The amount of dissolved gas is rarely estimated in groundwater. The usual method of determining the composition of water is by chemical analysis, where the items which require determination can be estimated separately. An indirect method of determining the approximate salt concentration in water is by measuring electrical conductivity. Conductance is related to total dissolved solids content and temperature and is usually expressed in microSiemens/cm (μS/cm) at 25°C. Electrical conductivity multiplied by 0.60 to 0.85 gives an approximate value for total dissolved solids content of the water. The resulting figure is only approximate, as equal concentrations of different ions in solution can give a different conductivity. Specific ion conductivity meters are available and very close estimates of individual ionic concentrations can be made. A knowledge of the total dissolved solids content will give an idea of whether the water is suitable for a particular purpose.

Units of measurement

Various methods have been used in reporting the amount of dissolved solids in water (*e.g.* grains per gallon, parts per million, milligrams per litre, tons per acre foot and equivalents per million).

Grains per gallon, the imperial measurement, records the number of grains of dissolved matter per imperial gallon (there being 7000 grains in one pound). This unit is now little used.

Parts per million (ppm) is a measure of the quantity of dissolved matter by weight, regardless of whether imperial or metric measurements are used (*e.g.* 1 ppm can mean 1 tonne of dissolved solids per 1 million tonnes of water or 1 gram of dissolved solids per 1 million grams of water). Parts per million was probably the most widely used unit for expressing salinity, but has now been replaced by milligrams per litre.

Milligrams per litre (mg/*l*) is almost equivalent to parts per million. One litre of pure water at 4°C weights 1000 grams or 1 million milligrams. Small variations in temperature and low concentrations of dissolved solids will only vary the weight per litre by a small proportion and for practical purposes parts per million and milligrams per litre are the same.

Tons per acre foot is a unit used in irrigation practice and refers to tons of dissolved solids per acre foot of applied water.

All of the above methods of reporting data allow all dissolved solids to be considered. The units are related as follows:

1 mg/*l* ∿ 1 ppm
1 grain per gallon = 14.22 mg/*l*
1 ton/acre ft = 823 mg/*l*

A further method of describing concentrations of dissolved solids in water is microgram equivalents per gram of water; for most purposes this is the same as milligram equivalents per litre, or equivalents per million (epm). This is obtained by dividing mg/*l* by the chemical equivalent weight of the element considered. This unit is not normally used to describe concentrations of Si, Fe or Al, as they either do not occur in solutions as separate ions or the form in which they occur is unknown. Concentrations expressed in epm allow calculations of various factors which describe the usefulness of the water (*e.g.* SAR, ESP).

The units used in this report are milligrams per litre (mg/*l*) and equivalents per million (epm).

Factors measured in chemical analyses

Because a few elements make up most of the dissolved solids in water, standard water analyses which estimate these elements are usually undertaken. Minor constituents and trace elements are not determined unless required.

pH. This is a measure of the hydrogen ion concentrate and will indicate whether the water is neutral (pH=7), weakly acidic (pH<7) or weakly alkaline (pH>7). The factors which control the pH value are concentrations of carbonate, bicarbonate, and dissolved carbon dioxide. As solubility of CO_2 depends on pressure, the pH measurement of a surface sample of water will probably be different to the pH of the water when under pressure in the aquifer. The range of pH in the water samples analysed is from 3.8 to 9.5, with the majority in the range of 6-8. The low values could be due to acid in the collecting bottles contaminating the sample.

Carbonate (CO_3^{--}) and bicarbonate (HCO_3^-). Carbonate ions in measurable quantities are likely to be present when the pH is greater than 8.2 and bicarbonate ions when the pH is greater than 4.5 (Davis and De Weist, 1966). Water containing dissolved CO_2 coming into contact with carbonate minerals will dissolve the carbonates and form bicarbonate ions. The source of carbonate for ions occurring in solution in the Longford area could be carbonate-rich beds in the Tertiary sediments, or Permian limestone and carbonate-rich beds. Carbonate-rich travertine deposits are sometimes associated with basalt flows (*e.g.* Relbia area) and the weathering of dolerite and basalt. Generally, water from wells and bores in the district is comparatively low in these ions, apart from some bores in the eastern and north-western parts of the basin; these high values are probably associated with weathered basalt.

Chloride (Cl^-). Where sediments are non-marine, it is often difficult to account for the high chloride content of the groundwater, as the earth's crust only contains small amounts of chloride. Liquid inclusions in igneous rocks can be a source of some chloride, while more is added by solution of halite and other evaporite minerals. Concentration of chloride in rain and snow by evaporation probably provides the main source. The chloride concentration in rain is about 3-6 mg/*l* near coastal ranges, about 1 mg/*l* 100 miles inland, and about 0.3 mg/*l* 500 miles inland (Davis and De Weist, 1966). Weathering of apatite and feldspathoids such as sodalite, if present, could introduce some chloride into water (Muramatsu and Wedepohl, 1979). For 1955, Hutton (1957) measured the concentrations of chloride in rainwater for a series of stations in Victoria.

Distance from Coast		*Cl (mg/l)*
Miles	*Kilometres*	
½	0.8	24.8
10	16	8.8
60	96	4.3
120	192	1.1
160	257	1.4
200	322	1.4

All chlorides are soluble and they are not subject to widespread absorption and ion exchange (Davis and De Weist, 1966). Chloride is the predominant anion in most analyses.

Sulphate (SO_4). Igneous rocks have a low sulphate content (Davis and De Weist, 1966) but groundwater may contain quite high quantities, probably derived mainly from gypsum or the oxidation of pyrite. Rain can contain some sulphate. Most analyses contain some sulphate and the amount generally increases as the total dissolved solids increase. Nodules of barite ($BaSO_4$) were found in the excavation of an irrigation channel south-west of Cressy, suggesting a source of sulphate in the area.

Nitrate (NO_3). Nitrate is only a minor constituent of groundwater unless there is contamination by organic matter from the surface or from heavy application of nitrogenous fertilisers. Nitrate determination is seldom undertaken unless it is suspected that contamination is occurring.

Fluoride (F). Fluoride has not always been determined in the analyses presented but where it has, its value seldom exceeds 0.5 mg/*l*, although a few values are in the range 0.5 to 1.0 mg/*l*. The highest value obtained is 2.5 mg/*l* in IH 23. Most of the fluoride would be derived from fluorite, apatite, or other minerals containing the element. Most fluorides are not very soluble and this probably accounts for the low concentrations in water, as opposed to chlorides which are very soluble.

Silica (SiO_2). Although silicon is the second most abundant element in the crust, the solubility of its compounds is fairly low and its relative abundance in water is not high. In most analyses it is usually the fifth or sixth most abundant element. The amount of silica that will dissolve in water is little dependent on the pH unless it is over nine (Davis and De Weist, 1966). Water from IH 48 has a pH of 9.5 and the silica value is also high. The silica would be derived from quartz in sediments, amorphous silica, and by weathering of the many silicate minerals in basalt and dolerite.

Calcium (Ca). Calcium is one of the more abundant elements found in the water samples. This could be due to the water coming into contact with dolomite, limestone, and gypsum or from the weathering of rock-forming minerals such as plagioclase feldspar and pyroxene contained in basalt and dolerite. The solubility of calcium carbonate is dependent on the pH and this is largely determined by the amount of dissolved CO_2 present. Most of the calcium goes into solution as the bicarbonate below a pH of 8.2, and as the carbonate above a pH of 8.2 (Davis and De Weist, 1966). Gypsum can introduce calcium to water. No gypsum ($CaSO_4.2H_2O$) has been found in the Tertiary sediments around Longford, but some occurs in Tertiary sediments in some other parts of Tasmania.

Magnesium (Mg). Like calcium, magnesium is a common element in water samples, but is less abundant in the earth's crust. Chemically, it behaves in a similar manner, although the solubility of its compounds are greater; this is reflected by its greater abundance in sea-water. This is also affected by the removal of calcium from sea-water by plants and animals. Magnesium found in water samples could be derived from dolomite, pyroxene, olivine, and impurities in limestone.

Iron (Fe). Iron is one of the more abundant elements in the earth's crust, but only small quantities are usually contained in water samples. The solubility of ferrous and ferric compounds is dependent on pH levels. Most of the iron in the water samples is probably in solution as a bicarbonate, which becomes unstable on exposure to air and precipitates ferrous hydroxide.

A surface sample of water may not be representative of the iron content in the aquifer unless the precipitates are also analysed. The iron content of the water samples analysed is usually less than 1 mg/*l*, but IH 5 and 24 had 15 mg/*l* and a well water sample (72) with a colloidal suspension had 200 mg/*l*. Iron-containing minerals occur in basalt and dolerite and numerous thin bands of siderite and siderite-rich horizons occur in the Tertiary sediments.

Aluminium (Al). Like iron, aluminium is very common in the crust and is a constituent of many rock forming minerals (*e.g.* feldspar in basalt and dolerite). The low solubility of aluminium compounds makes its occurrence in groundwater of little importance; water with a pH range of 5-9 will contain less than 1 mg/*l* (Davis and De Weist, 1966).

Potassium (K). The amount of potassium in the crust is about the same as sodium but in natural waters the amount of potassium is very low compared to sodium. This is because potassium enters the crystal structures of clay and clay-like minerals during weathering. Feldspars, feldspathoids, and biotite are the main minerals containing potassium. Concentrations of potassium are seldom above 20 mg/*l* in the water samples analysed. Potassium salts are very soluble and will not usually be removed from solution except by ion exchange, absorption or by evaporation of the water, although vegetation concentrates potassium (Davis and De Weist, 1966).

Sodium. Sodium is the most abundant cation in most of the samples analysed. Sodium compounds are very soluble and although the properties of sodium are very similar to potassium, the size of its ion prevents it from entering clay mineral structures. Plagioclase feldspar, which is common in basalt and dolerite, is a source of sodium, and clay with absorbed sodium ions can be a source under conditions of base exchange. Rainwater also contains some sodium.

Total dissolved solids (TDS) and total ions. The value of TDS is determined by evaporating a known volume of water and weighing the residue. By this method, water high in bicarbonate ions might indicate a lower TDS than the total of the chemically estimated ions, owing to the breakdown of bicarbonate ions on heating to give off CO_2 and water. This is particularly noticeable in IH 30, where the total ions exceeds the TDS figure by over 200 mg/*l*. The total dissolved solids or total ions is often used as a guide to determine the suitability of water for a particular use without analysing for each individual ion.

Hardness. Hardness is that property of water which prevents a lather with soap being readily obtained and is mainly due to the presence of calcium and magnesium ions, although copper, barium, zinc, manganese, and iron will contribute if present. These ions, when in contact with soap, combine with the compounds in the soap and the salts so formed have a low solubility and a precipitate results. This will continue to form until nearly all of the above ions are removed from the solution. The corresponding sodium and potassium salts are soluble and these ions do not contribute to hardness.

Hardness is described as being either temporary or permanent, depending on whether the hardness is caused by calcium and magnesium carbonate and bicarbonate, or by sulphates and chlorides of calcium and magnesium (and the other cations mentioned above). The hardness caused by the bicarbonates is called temporary, because boiling the water will cause the bicarbonate to decompose and release carbon dioxide and precipitation of calcium and magnesium carbonate will follow. Boiling has no effect on sulphate and chloride salts, except to concentrate them.

In calculating the hardness of water, the amount of magnesium and calcium are taken and the equivalent amount of calcium carbonate is calculated with respect to these quantities (total hardness = 2.497 x Ca concentration + 4.115 x Mg concentration). The results are usually reported in mg/*l* of calcium carbonate.

Johnson (1966) gives the following classification for various ranges of hardness:

<50 mg/*l* soft
50-150 mg/*l* not objectionable for most purposes
>150 mg/*l* decidedly noticeable
200-300 mg/*l* usually has to be softened for domestic use.

The hardness value for many samples from both wells and bores are high throughout the district.

Alkalinity. Alkalinity is a measure of the waters ability to neutralise acid. Under most conditions, bicarbonate and carbonate ions produce this property. If the pH of the water is greater than 9 other ions such as hydroxyl ions can contribute, but this is rare. Temporary hardness and alkalinity have the same value in most cases. Alkalinity is measured by determining the amount of a standard solution of sulphuric acid needed to reduce the pH of the water sample to 4.5. It is thus a different pH level than is usually described as the division between alkaline and acid. A neutral solution has a pH of 7.

WATER USE

Groundwater can be used for the same purposes as surface water *i.e.* agriculture, domestic supplies, and industry. The quality requirements differ for the various uses.

Agriculture

STOCK WATER

Stock are normally tolerant to large quantities of dissolved solids, and various organisations have published approximate limits of the salinity of water that can be used. As conditions vary between locations, such limits should be regarded as a guide only. Stock can tolerate higher salinity water if they are feeding on lush green pasture than if they are on dry food. Stock sometimes need their diet supplemented with salts, so that in some cases it is beneficial to have at least some salts in drinking water. The upper limits of water salinity (in mg/*l* TDS) used by various state authorities for livestock are given in Table 18.

Table 18. RECOMMENDED UPPER LIMITS OF WATER SALINITY, AUSTRALIA

Class of Livestock	STATE					
	N.S.W.	Victoria	Queensland	South Australia	Western Australia	Northern Territory
Poultry	4 000	3 500	3 500	3 000[a]	3 000	
Pigs	4 000	4 500	5 500	3 000[a]	4 500	
Horses	7 000	6 000	5 500[b]	7 000	6 500	6 000
Dairy cattle	10 000	6 000	5 500[b]	7 000	7 000	6 000
Beef cattle	10 000	7 000	8 500[c]	10 000	10 000	10 000
Lambs and weaners		4 500			10 000	
Ewes in milk		6 000			10 000	
Adult sheep on dry feed	14 000	7 000[e]	14 500	13 000	13 000	12 000
Adult sheep on green feed		to 15 000	18 500	18 000	18 500[d]	15 000

Note: All values in mg/*l*

a. 4000 mg/*l* if on salt free rations, 1500 mg/*l* if on high salt diet.
b. 7000 mg/*l* if on green feed.
c. 10 000 mg/*l* if on green feed.
d. for short periods.
e. if unaccustomed to saline water; if accustomed, up to 15 000 mg/*l*.

Source: Victorian Irrigation Research and Advisory Services Committee (1969).

From these values, it can be seen that all water from wells and bores is useful for at least some stock. The majority should be useful for sheep and cattle watering and most should be suitable for all stock.

Other factors may affect the usefulness of water, particularly if the quality is borderline. During dry periods, stock drink more water and therefore take in more salt. Stock in poor condition cannot tolerate as much salt, while stock that are accustomed to high saline water are more likely to accept more saline water than stock accustomed to relatively pure water. Stock that are lactating require less saline water than dry stock.

The salt causing the salinity is also important. Ward (1946) published limits of magnesium, aluminium, iron, and nitrate for stock water supplies. A detrimental magnesium content is more likely to occur than the other substances, although iron and nitrate have been known to occur in such proportions as to affect animals in rare cases. High magnesium with high chloride or sulphate can cause scouring, loss of condition and, in extreme cases, has caused death. The suggested upper limits for magnesium are:

Stock type	*Magnesium (mg/l)*
Horses	250
Cows in milk	250
Ewes with lambs	250
Beef cattle	400
Adult sheep on dry feed	500

(Source: Victorian Irrigation Research and Advisory Services Committee, 1969).

Water from IH 6, 40, 49, 60, and 64, CH 46, and the proline holes at Delmont all contain more than 250 mg/*l* magnesium and care should be exercised in the use of this water. Several other water samples have over 200 mg/*l* magnesium.

In Queensland, fluoride has been known to affect the teeth of young animals if present in concentrations greater than 2 mg/*l*. Water from IH 47 had a fluoride content of 2.5 mg/*l*.

IRRIGATION WATER

As small to moderate quantities of irrigation water could be extracted from many localities within the basin and the water is variable in quality, the use of water for irrigation is discussed at some length.

The suitability of water for irrigation is dependent on many factors, including the total salinity of the water, the soil type, soil drainage, rainfall, temperature range, methods of irrigation, crops under irrigation, and the relative ionic concentrations.

Various methods have been devised as a guide to indicate whether a particular water is suitable for irrigation. Nye (1922) referred to a method devised by H. Stabler of the United States Geological Survey where a quantity known as the alkali coefficient is determined from a chemical analysis, the coefficient being the depth of water in inches that would render a four feet depth of soil injurious to most plants. The concentration of sodium, chloride, and sulphate ions are examined for this calculation. Simpson (1928) calculated a factor based on the assumed salts present from chemical analysis, which depended on the sum of the concentration of salts

$$NaCl + Na_2SO_4 + 2CaCl_2 + 2MgCl_2 + 2MgSO_4 + 4Na_2CO_3$$

In both methods, the water was classified into a range of values describing the suitability of the water, which also took account of such factors as climate, soil, and drainage.

Similar methods are employed today, although slightly different factors are determined. The United States Salinity Laboratory (1954) developed a system for examining irrigation waters for their restrictions of use. This method of examination forms the basis of the system used by many organisations who deal with irrigation waters. For example, irrigation waters in Victoria are examined chemically for:

(a) Total dissolved solids
(b) Sodium content and its relation to other ionic concentrates
(c) Specific ion hazard

These factors are investigated in conjunction with certain other conditions.

Total dissolved solids

Apart from the basic elements of carbon, nitrogen, hydrogen, and oxygen, plants require, and in most cases can only tolerate, minor amounts of other elements. As well as not requiring large quantities of salts for growth, a high salt content can increase the osmotic pressure of the soil solution which prevents the plant taking up sufficient water to produce the maximum possible growth rate. There is a close relationship between salinity, osmotic pressure, and growth rate. Evaporation and transpiration effects also tend to concentrate the salt content of the soil water by 2-10 times greater than that of the applied water (U.S. Salinity Laboratory, 1954). With highly saline irrigation waters, extremely high pressures can be built up in soil solutions.

Irrigation water in Victoria is classified by total dissolved solids content as:

Class 1 (0-175 mg/l): low salinity water; can be used with most crops on most soils, with all methods of water application, with little likelihood that a salinity problem will develop. Some leaching is required, but this occurs under normal irrigation practices except in soils of extremely low permeability.

Class 2 (175-500 mg/l): medium salinity water; can be used if a moderate amount of leaching occurs. Plants with medium salt tolerance can be grown, usually without special practices for salinity control. Sprinkler irrigation with the more saline waters in this group may cause leaf scorch on salt-sensitive crops, especially with high day time temperatures and low water application rates.

Class 3 (500-1500 mg/l): high salinity water; cannot be used on soils with restricted drainage. Even with adequate drainage, special management for salinity control may be required, and the salt tolerance of the plants to be irrigated must be considered.

Class 4 (1500-3500 mg/l): very high salinity water; not suitable for irrigation under ordinary conditions. For use, soils must be permeable, drainage adequate, water must be applied in excess to provide considerable leaching, and salt tolerant crops should be selected.

Class 5 (above 3500 mg/l): extremely high salinity water; may be used only on permeable, well drained soils under good management, especially in relation to leaching.

The United States Salinity Laboratory (1954) divides waters into four classes, with salinity values approximating the ranges of the first four classes in the Victorian classification.

These salinity ranges are only a guide to the suitability of the water, as different crops have different tolerances. Some relative crop tolerances are:

High salt tolerance: garden beets, asparagus, spinach, sea barley grass, kikuyu grass.

Medium salt tolerance: pomegranate, fig, grape, tomato, broccoli, cabbage, cauliflower, lettuce, sweet corn, potato, carrot, onion, pea, cucumber, trefoils, woolly clover, rye grasses, strawberry clover, lucerne, cocksfoot.

Low salt tolerance: most citrus and stone fruit, almond, blackberry, raspberry, strawberry, radish, celery, green beans, subterranean clover, vetches, white clover.

(Source: United States Salinity Laboratory, 1954).

A total dissolved solids content of 1000-1500 mg/*l in water* is regarded as the general limit for agricultural application. According to Johns (1961), irrigation water under conditions of good drainage should not have a salinity greater than half the salinity of a saturated soil extract that causes a 50% decrease in crop yield. However, salt tolerant crops have been grown under irrigation with water salinities of 3300 mg/*l* and even up to 6400 mg/*l* (Johns, 1961). In the Western and Little River districts of Victoria, farmers have been using water with greater than 3000 mg/*l* TDS for many years (Venables, 1970).

The total dissolved solids content of groundwater occurring at most locations in the Longford area would make it suitable for use in irrigation under certain conditions. The more saline waters would require better drainage and salt tolerant plants should be used if irrigated. Probably the best soils for high salt content water would be the soil on windblown sand, terrace gravel, Quaternary sand, and pisolitic iron gravel where drainage is often good. The poorer areas for high saline water would be the clay and silt soils which are fairly extensive throughout the area.

Sodium content and its relationship to other ionic concentrations

A high sodium content in irrigation water, when other ions (particularly calcium and magnesium) are low, can result in a breakdown in the soil structure. The effect of this is a marked decrease in permeability and a hardening of the soil. This can decrease the rate of, and in severe cases prevent completely, plant growth.

Clay minerals and organic matter in soil have the ability to adsorb various cations; the degree to which this is done depends on the ion and the relative ionic concentration in the water. If irrigation water with equal amounts (by chemical equivalence) of Ca, Mg, K, H, and Na is being used, the proportion of the various ions adsorbed by clay and organic matter will decrease in that order (Johns, 1961). Clay with a high proportion of adsorbed calcium and magnesium usually develops a crumb structure, making the soil permeable to water and air and allowing easy tilling. If water containing a high sodium content relative to calcium and magnesium is applied, the sodium will tend to replace the adsorbed calcium and magnesium in the soil, thus increasing the exchangeable sodium percentage. If these soils are then leached with fresher water (*e.g.* rain water), the adsorbed sodium ions will tend to hydrolyse, forming sodium hydroxide, which results in a rise in the pH of the soil (Johns, 1961). The effect of this is deflocculation (or breakdown of the crumb structure) of the clay in the soil and a reduction in permeability. This property has been used in surface water conservation by the use of sodium carbonate to reduce permeability and to increase runoff, and in the sealing of dams. A soil with an exchangeable sodium percentage (ESP) of greater than 15 is termed an alkali soil.

If the concentration of Ca + Mg is about equal to the sodium concentration in the water, good results are often obtained, despite the high total dissolved solids content (Johns, 1961). If Na>Mg + Ca, the waters usefulness is doubtful (U.S. Salinity Laboratory, 1954). The sodium percentage may be a guide in determining whether a water is useful for irrigation.

$$\text{Sodium percentage} = \frac{100(\text{Na} + \text{K})}{\text{Na} + \text{K} + \text{Mg} + \text{Ca}}$$

concentrations in equivalents/million (epm)

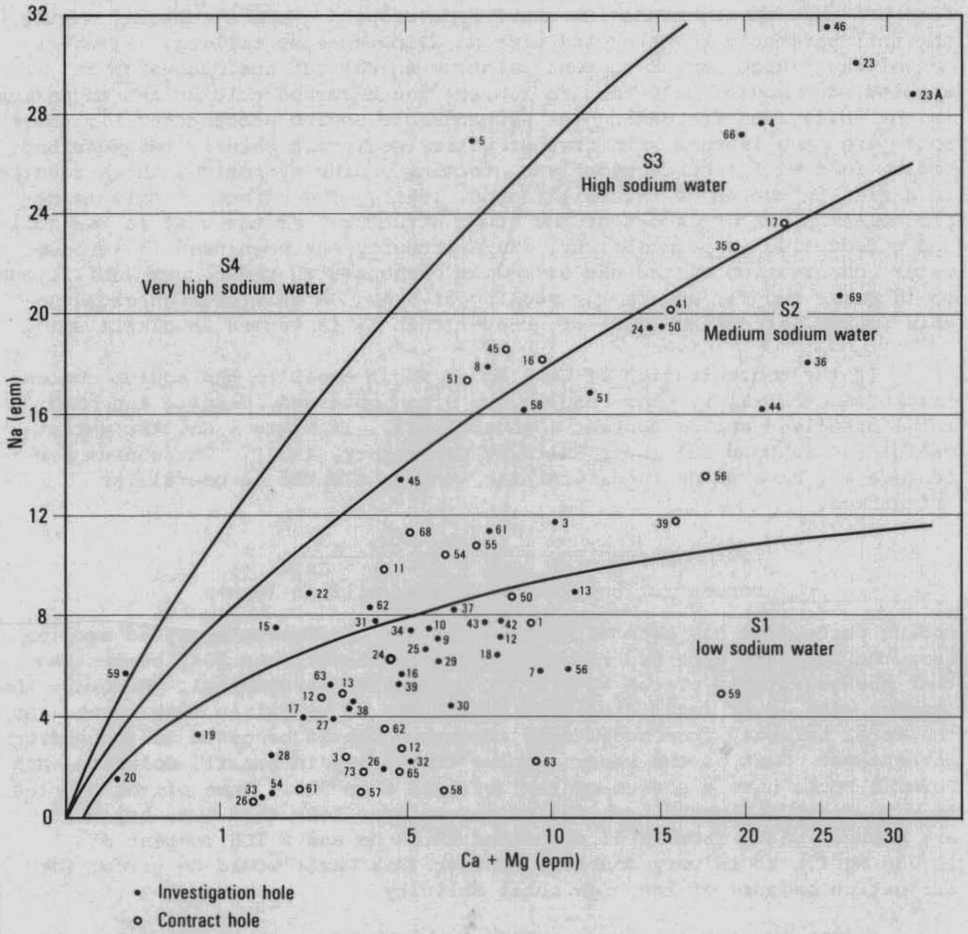
Sodium percentage has been determined for the chemically analysed samples from the Longford area and many have values greater than 50%, suggesting that the usefulness of the waters for irrigation is doubtful. However, the samples with lower total dissolved solids may be useful in many cases. As the total salinity increases, more attention should be given to the sodium percentage. Most of the water samples from holes in basalt, dolerite, and Permian rocks have a sodium content of less than 50%. Some of the samples from Tertiary sediments have sodium percentages less than 50%, but most are above. Water from PH 31 contained 48.4% Na and a TDS content of 11 730 mg/*l*. It is very doubtful whether this water would be useful for irrigation because of the high total salinity.

In 1954, the United States Salinity Laboratory proposed a new method of defining the sodium hazard, the sodium adsorption ratio (SAR).

$$\text{SAR} = \frac{\text{Na}}{\sqrt{\frac{\text{Ca} + \text{Mg}}{2}}} \quad \text{(concentrations in epm)}$$

Todd (1959) gave the following classification of various SAR values:

SAR	*Water Class*
10	Excellent
10-18	Good
18-26	Fair
>26	Poor



NOTE:— Some waters plot outside diagram. IH11, 40, 64, 65, 68 and CH36 and 46 probably fall in S4; IH6, 53, 57, and 60 in S3; IH 49 in S1.

Figure 20. *Classification of investigation and contract hole waters according to sodium hazard (diagram devised by U.S. Salinity Laboratory).*

Most water samples from the Longford area are in the excellent to good ranges. There are three with high SAR ranges; IH 48 and IH 59 with values of 33.9 and 33.2, and PH 29 with an SAR of 24.2, these being in the poor and fair ranges. Hart (1974) suggests SAR values of 8 to 18 as the usable limit, depending on such variables as soil type, total salinity, and other factors. The limit for sensitive crops may be as low as 4. Many of the analyses in this study indicate an SAR value of 8 or more.

When a particular water is being applied, the proportions of the various adsorbed ions in the soil reach equilibrium. For many soil types the United States Salinity Laboratory was able to relate SAR and the exchanageable sodium percentage (ESP) of the total adsorbed cations as:

$$ESP = \frac{100\ (-0.0126 + 0.01475\ SAR)}{1 + (-0.0126 + 0.01475\ SAR)}$$

i.e. from a calculation of the SAR value from a chemical analysis of irrigation water, the likely ESP can be calculated. If the ESP is greater than about 10-15%, then some damage to the soil structure can be expected, particularly if there is an expansive clay present (Hart, 1974). Lower ESP values can be detrimental in special circumstances. Many water samples in the Longford area contained ESP values (calculated using the above formula) greater than 10 and care would need to be exercised in the use of these waters, particularly on some soil types.

The United States Salinity Laboratory represented the sodium hazard of irrigation water diagrammatically by plotting the sodium concentration against the calcium and magnesium concentration (in epm) and dividing the diagram into four zones. From a chemical analysis, it can be determined into which zone a particular irrigation water will fall. The soil conditions recommended for each zone, as defined by the Laboratory, are given below. Chemical analyses of water from the investigation holes and the contract holes have been plotted on Figure 20.

Low sodium water (S_1)*;* can be used for irrigation on almost all soils with little danger of the development of harmful levels of exchangeable sodium. However sodium sensitive crops, such as stone fruits and avocados, may accumulate injurious concentrations of sodium.

Medium sodium water (S_2)*;* will present an appreciable sodium hazard in fine textured soils having high cation exchange capacity, especially under low leaching conditions, unless gypsum is present in the soil. This water may be used on coarse textured or organic soils with good permeability.

High sodium water (S_3)*;* may produce harmful levels of exchangeable sodium in most soils and will require special management such as good drainage, high leaching, and organic matter additions. Gypsiferous soils may not develop harmful levels of exchangeable sodium from such waters.

Very high sodium water (S_4)*;* is generally unsatisfactory for irrigation purposes except at low and perhaps medium salinity, where the solution of calcium from the soil or use of gypsum or other amendments may make the use of these waters feasible.

Water that has a high bicarbonate content can cause the formation of alkali soils. Part evaporation of the applied water results in precipitation of calcium and magnesium carbonate from solution and an increase in the SAR value of the soil solution; *i.e.* an increase in the ESP value. If there are more bicarbonate ions than needed to precipitate calcium and magnesium as carbonates, black alkali soils are likely to develop. Sodium carbonate solutions dissolve organic matter in the soil and it is reprecipitated at the surface, causing dark, impermeable, infertile areas to develop (Eaton, 1950). Residual sodium carbonate can be calculated to determine the possibility of black alkali soil formation. If Ca+Mg < CO_3+HCO_3 (concentration in epm), then residual sodium carbonate (RSC) is said to be present. The United States Salinity Laboratory tentatively classified RSC values as follows:

RSC in irrigation water (epm)	*Usefulness*
<1.25	probably safe
1.25-2.5	marginal
>2.5	not suitable for irrigation

Black alkali soil formation can take place with the use of low salinity water. Eaton (1950) described such soils around the River Nile in Egypt which had probably been irrigated with water containing about 300 mg/*l* TDS.

A few of the bores in the Longford area have residual sodium carbonate values, usually less than 1. Investigation bore 54 has an RSC value of 1.34.

The conditions that are found in various soil types where water unsuitable for irrigation is used were described by the United States Salinity Laboratory (1954). The soils were divided into saline soil, saline alkali and non-saline alkali soils, with the following characteristics:

Saline soil. Saturated soil extract has >2500 mg/*l* TDS, ESP <15%, pH <8.5, sodium seldom >½ soluble cations, and main anions are Cl and SO_4. Saline soils are generally flocculated with a permeability equal to or higher than that of similar non-saline soils and can be recognised by white crusts of salt on the surface.

Saline alkali soils. Saturated soil extract has >2500 mg/*l* TDS, ESP >15%, pH seldom >8.5. Appearance is similar to saline soils and as long as excess salts are present, soil particles remain flocculated. If the salt is leached, non-saline alkali soils are produced.

Non-saline alkali soil. Saturated soil extract has <2500 mg/*l* TDS and ESP >15%, with pH usually 8.5-10. Soil particles are dispersed and permeability is low.

Specific ion hazard.

Certain elements are necessary in small quantities for growth of plants; elements such as calcium, silicon, potassium, sulphur, magnesium, and sodium are taken up in considerable quantities while others, such as boron, molybdenum, copper, zinc, and strontium are also concentrated in plants. Large quantities of some elements in irrigation water may be toxic to the plant and affect the metabolic reactions. Toxic effects are sometimes indicated by affecting the appearance of the plant, or by causing a reduction in expected growth rate.

Johns (1961) discussed the affects of some ions when applied in excess. Some fruit crops and beans are affected by excess sodium, usually resulting in leaf burn. Calcium and magnesium in high concentrations can affect plant growth, while chloride and sulphate affects some plants and not others. Sulphate in high concentration has some affect on the growth of flax and some forage crops, while high chloride is known to affect vines, citrus, stone fruit and some berries. Bicarbonate in large quantities does affect some crops more than equivalent concentrations of chloride, but the main effect of excess bicarbonate is indirectly related to growth *i.e.* destruction of soil structure. Boron is essential for plant growth in small quantities but is toxic in large quantities. Soils in many parts of Tasmania, including the Cressy-Longford area, are deficient in boron (Lamp, 1964). Plants vary in their tolerance to boron, some being able to tolerate 2-4 mg/*l* (*e.g.* asparagus, lucerne, onion, and cabbage) while others can only tolerate about 0.3-1.0 mg/*l* (*e.g.* citrus and stone fruits).

Other considerations

In using water for irrigation, care should be taken to prevent salt from accumulating in the root zone because of evaporation and transpiration by the plants. For this reason a certain excess of water above the plants needs must be used to flush the more saline water away from the root zone. The more saline the water, the greater the proportion of the applied water that must be used to flush the root zone to prevent salt build up. This excess water is usually denoted as the leaching requirement. With higher salinities, more tolerant crops must be selected and soil permeability must be good. As often happens with the application of highly saline water, particularly with highly sodium charged water on clay soil, the permeability is reduced and this works against using more saline water.

Climate is also important when using more saline water. Where high temperatures are experienced over long dry periods, evaporation of the applied water is greater and a greater proportion of water is required for leaching. Where regular rains are experienced, leaching is not required to the same extent. In many areas where irrigation is carried out during the drier summer period, winter rains leach the salt that has built up in the soil during irrigation.

A further danger with irrigation is the rise in the water table bringing salt to the surface, or water logging if the water is not saline. Auger holes at various parts of the basin encountered particularly saline water in clay and sandy beds near the surface, and if a rise in the water table occurred bringing such water within the root zone of most plants, they would not survive. Webster and Webster (1965) describe these factors as they occurred in irrigation of part of Gippsland, Victoria. The quality of the applied irrigation water need not be important, as the water used in Gippsland was good quality.

Some bore water has been used to irrigate small areas or in gardens. The water has only been used over a short period and long term effects could appear after longer periods of watering.

J. Spencer (IH 3, TDS = 1440 mg/l)

Grown without noticeable effects: celery, cabbage, lettuce, tomato, potato, pumpkin, strawberry, peaches, white clover, hydrangeas, roses, bulbs, petunias, dahlias, christmas lillies.

Affected: The only noticeable effect was on raspberries which remained stunted.

L. D'Antoine (CH 55, TDS = 1805 mg/l)

Water used in hot water service had corroded element after 6-9 months use. Has been used on garden with no effect; lawn, shrubs, roses, apples, peach, apricots, nectarine, cherry.

W. Reynolds (CH 35, TDS = 2795 mg/l)

Does not affect: white clover, many shrubs, flowering fruit trees, bulbs.

Has affected and killed: roses, peas, raspberries, peaches.

J. Reynolds (CH 36, TDS = 2370 mg/l)

Unaffected: grass - wild white clover in particular, carrots, parsnips, cabbages, potatoes.

Affected: subterranean clover, raspberries, currants.

Domestic use

DRINKING WATER

The quality limits of water for human consumption and domestic use is variable according to the authority. In Tasmania, the Department of Health Services bases its standards of quality on a combination of that recommended by the World Health Organisation and the standards laid down by the U.S. Public Health Service of 1962. In many respects these have similar or identical ranges for the various constituents that can be tolerated or are recommended for domestic water supplies. The World Health Organisation standards for drinking water are given in Table 19.

Table 19. RECOMMENDED QUALITY LIMITS FOR DRINKING WATER, WORLD HEALTH ORGANISATION

Substance	*Maximum acceptable concentration*	*Maximum allowable concentration*
Total solids	500 mg/l	1500 mg/l
Colour	5 units*	50*
Turbidity	5 units†	25†
Taste	Unobjectionable	-
Odour	Unobjectionable	-
Iron (Fe)	0.3 mg/l	1.0 mg/l
Manganese (Mn)	0.1 mg/l	0.5 mg/l
Copper (Cu)	1 mg/l	1.5 mg/l
Zinc (Zn)	5 mg/l	15 mg/l
Calcium (Ca)	75 mg/l	200 mg/l
Magnesium (Mg)	50 mg/l	150 mg/l
Sulphate (SO_4)	200 mg/l	400 mg/l
Chloride (Cl)	200 mg/l	600 mg/l
pH range	7.0-8.5	6.5-9.2
Magnesium + sodium sulphate	500 mg/l	1000 mg/l
Phenolic substances	0.001 mg/l	0.002 mg/l
Carbon chloroform extract (organic pollutants)	0.2 mg/l	0.5 mg/l
Alkyl benzyl sulphonates	0.5 mg/l	1.0 mg/l

* Platinum - cobalt scale † turbidity units

Other components which may be hazardous to health are fluoride and nitrate. Fluoride in large quantities may cause fluorosis in young children and a limit of 1.5 mg/*l* is applied. A high nitrate content can also affect infants and the limit set is 45 mg/*l*. The maximum recommended bacterial content of water is an average monthly coliform content of one MPN per 100 ml.

The above limits as suggested by various authorities are often exceeded by individual water users or small communities; Ward (1946) reported two families in South Australia using water from bores with 8120 and 7230 mg/*l* TDS for several months without any apparent adverse effects.

From the chemical analyses in the appendices it will be noted that most of the water samples have concentrations of dissolved solids below the maximum allowable concentrations and many of the other waters could probably be used for human consumption as emergency supplies. The Department of Health Services should be consulted as to whether a particular water is suitable for drinking, particularly on a long term basis.

OTHER DOMESTIC USES

The other main domestic uses are for washing, use in hot water services, in septic tanks, and for garden use. The same factors affect the use for garden as those that apply to irrigation supplies.

For washing clothes and for bathroom use the water should be relatively soft, so that soap is not wasted in precipitating the calcium and magnesium ions present before a lather can be obtained. Most of the waters tested, in particular the bore waters, are relatively hard, sometimes due largely to permanent hardness and sometimes because of temporary hardness, or a combination of both. Another factor which affects the use of water for washing is the iron content. A concentration of greater than 0.3 mg/*l* will cause staining on porcelain and clothes (Johnson, 1966). Iron often occurs in solution as the bicarbonate and if aerated by spraying the water, the hydroxide is precipitated. The brown precipitate so formed can be filtered or allowed to settle. If the iron occurs as the sulphate in water with a low pH, or in water with high organic matter content or with considerable amounts of free dissolved carbon dioxide, special treatment is required to lower the iron content. Manganese can also cause staining when in smaller concentrations than iron, but is less common in groundwater in proportions that can be troublesome. Many of the waters analysed have iron contents of greater than 0.3 mg/*l* and would require treatment to prevent staining.

The use of groundwater in hot water services is fairly common and trouble is frequently experienced with incrustation and corrosion of the hot water service elements. Incrustation is usually caused by the compounds that cause temporary hardness. On heating, bicarbonates decompose and the carbonates are precipitated. This can be minimised by setting the thermostat at about 70.5°C, as scale forming only becomes marked above these temperatures (Hill, 1961). Corrosion of elements can take place by any of the usual means (see below).

An important domestic use of water is in septic tanks. McCarty (1964) has examined concentrations of various ions in the liquid and their effects on the micro-organisms that control the breakdown of the waste material. He found that some cations (*e.g.* sodium, potassium, and calcium) stimulate the growth of the organisms up to a particular ionic concentration, after which the affect becomes increasingly inhibitory to their growth. McCarty indicated that the toxicity appeared to be mainly due to the cation rather than the anion part of the salt and that even small concentrations of heavy metals such as copper, zinc, and nickel are extremely toxic to the organisms. The limits and effects of specific cations are (McCarty, 1964):

Cation	*Stimulatory* (mg/*l*)	*Moderately inhibiting* (mg/*l*)	*Strongly inhibiting* (mg/*l*)
Na	100-200	3500-5500	8000
K	200-400	2500-4500	12000
Ca	100-200	2500-4500	8000
Mg	75-150	1000-1500	3000

The micro-organisms can partially adapt to inhibiting concentrations and the middle column concentrations could probably be used, although the lower concentrations are recommended. Where two ions are present, the effect on the micro-organisms can be additive, but in some cases one cation can partially cancel out the effect of another.

Chemical analyses of water samples in the Longford area show that all samples fall in the range from below the stimulatory levels to below the moderately inhibiting level, with most of the bore water samples falling between the ranges for stimulatory and moderately inhibiting. The one exception is water from PH 29, which is probably in the moderately inhibiting range when all cations are considered. From the above information, all the waters tested could be used successfully in septic tanks.

INCRUSTATION AND CORROSION

Most natural waters have some incrusting or corrosive properties. Incrustation is a build up of material due to deposition and corrosion is the eating away of metal. They are due to different causes but have been known to occur together.

Burns (1969) and Johnson (1966) describe various aspects of water composition that cause these problems. A summary of some of these causes is given below.

Incrustation can take place on bore screens, slotted casing, pumps, and water pipes causing greatly reduced flow rates and can completely stop the flow. Most incrustation is caused by the deposition of calcium and magnesium carbonates and sulphates, iron and manganese oxides and iron sulphide. If the groundwater is under pressure, a reduction of pressure occurs around the well when pumped and this causes part of any dissolved CO_2 to be released. As the solubility of $MgCO_3$ and $CaCO_3$ depends largely on CO_2 being present, deposition of some of these compounds can take place. Iron and manganese in solution as the bicarbonate can, due to this process and also aeration, be deposited as the hydroxide, which will eventually dehydrate to the oxide. Sulphate reducing bacteria in water will cause H_2S to form, which when dissolved in water produces a weak acid which will dissolve iron, which will be reprecipitated as iron sulphide. Iron and manganese bacteria can live in groundwater with a high iron and manganese content and will cause the hydroxides of these elements to be precipitated as slimy substances. On dehydration, oxides are formed.

Corrosion of well screens, casing pumps, and piping is a common feature. It is caused by electro-chemical action and its establishment can be promoted by the joining of dissimilar metals, composition variation within the metal, surface deposits on the metal, variations in the conducting fluid, and external electrical currents entering the system. Factors which vary the corrosion rate are the presence of dissolved CO_2 (lowering pH of the water), dissolved oxygen, dissolved H_2S, total dissolved solids content, acidity, rate of movement of water over the metal, and temperature. High chloride and sulphate contents in water tend to prevent the formation of protective films on metals, while a water with high calcium and magnesium bicarbonate will tend to form protective layers on the surface of metals. Protective oxide films form readily on the surfaces of most metals; whether these films remain after immersion in water will depend on the chemistry of the water.

Burns (1969) lists the following factors for examination of possible corrosiveness of water.

(a) total dissolved solids, to determine whether the water is conductive (<200 mg/*l* is desirable).
(b) chloride content, to determine its aggressiveness to protective film (<70 mg/*l* is desirable).
(c) carbonate content (alkalinity), to determine protective film formation potential (less than 100 mg/*l* is desirable for hot water services because excessive build up may occur).
(d) pH, most metals are attacked when pH is less than 3. When pH >11 a few metals are attacked.

Wellington (1972), in a study of the corrosion of hot water elements (sheaths), suggested a limit of <100 mg/*l* chloride and TDS of <500 mg/*l*.

Inspection of the chemical analyses indicates that four samples contain less than 200 mg/*l* total dissolved solids (IH 28, 54, CH 60, and wells 15, 27, 31, 62, 100). A greater number have less than 500 mg/*l*. Chloride contents below 100 mg/*l* include IH 27, 28, 30, and 33, CH 58, 60, 61, and 65, and wells 9, 13, 16, 17, 19, 20, 27, 31, 33, 62, 69, 70, 72, and 76. Many of the samples have less than 100 mg/*l* of bicarbonate and carbonate and pH levels are not outside the range of 3-11.

It is apparent that few of the waters will not be corrosive to some extent. Where one item is below the limit suggested, the other item is above, so that only water from IH 28, CH 60, and wells 27 and 31 comply with Burns' limits for TDS and chloride content.

Although bicarbonate is below 100 mg/*l* in many analyses, it is relatively high in many others, suggesting that incrustation will be a problem with some of these waters.

RELATIONSHIP OF ROCK TYPE TO WATER QUALITY

It would be useful to be able to predict the quality of water that might be obtainable from an area and the relative amount of particular components contained in that water. The salinity contours (fig. 3) should be a guide to the type of water that is obtainable in various areas from deep bores. Triangular diagrams have been plotted for water from investigation and contract bores (figs. 21-24). These diagrams use proportions of particular ions in the water rather than absolute amounts. Plotted on this basis, water from some rock types plot in fairly small areas of the diagram, while the plots from other rock types are more scattered. Even where water from a particular rock type plots in a small area, there are usually occasional bores that are more scattered.

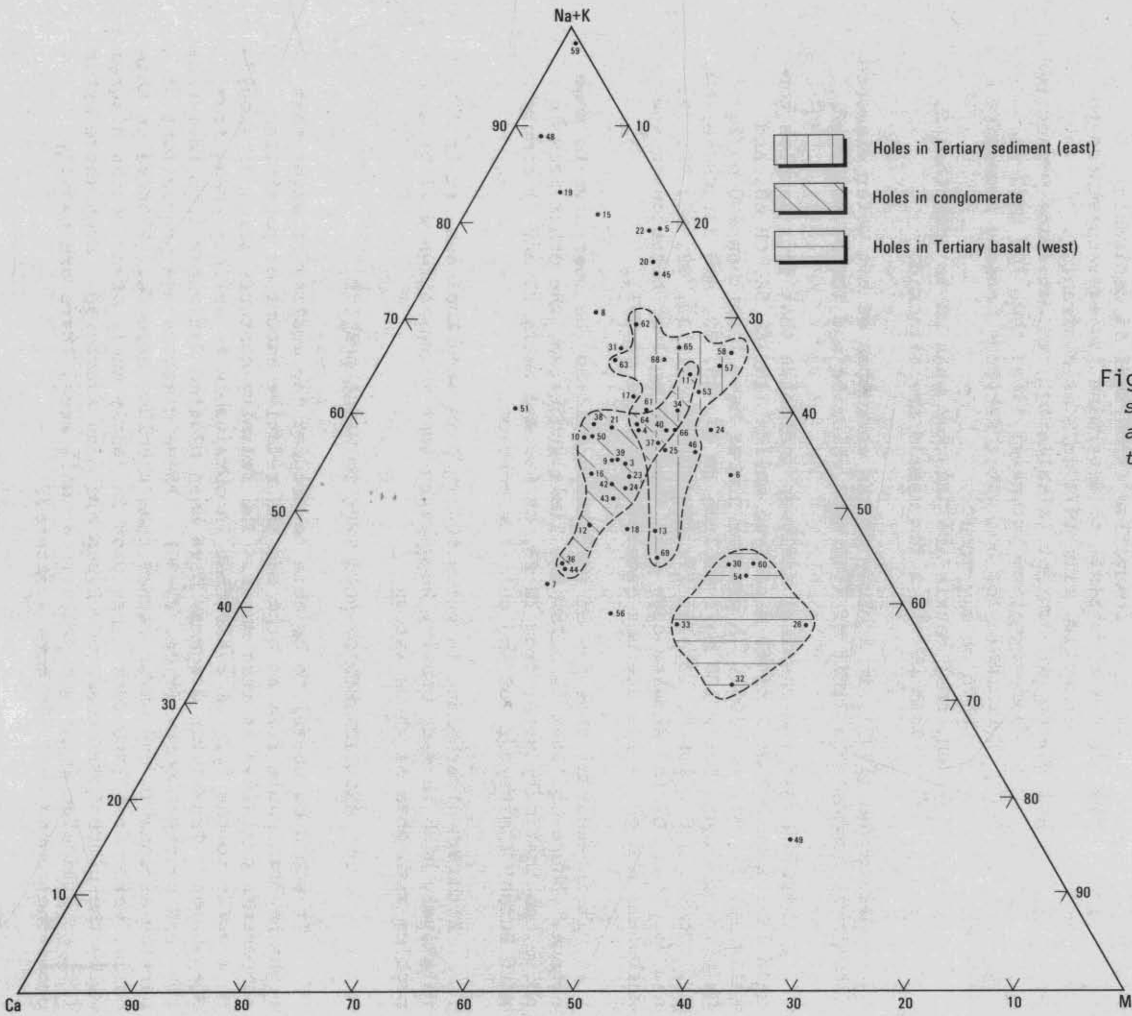


Figure 21. *Triangular diagram showing cation plots of chemical analyses of water from investigation holes.*

INVESTIGATION HOLES

Cations (fig. 21)

Water from Tertiary sediments in the eastern sub-basin (14 samples) all plot in one zone, except for IH 48, 50, and 51. These three exceptions are bores that entered Permian sediments at the base.

Holes in Tertiary sediments which penetrated conglomerate beds composed mainly of dolerite boulders (14 samples) fall in a zone with some overlap with the above zone. Exceptions are IH 8, 46, and 54. There are also some bores in this material in the western sub-basin.

Waters from Tertiary sediments in the western sub-basin (22 samples) are scattered throughout the plot, but many are concentrated in the zone with conglomerate beds.

Water from basalt (west) holes (5) plots in a zone except for IH 31, the water from which may originate from Tertiary sediment. This zone also contains IH 54 (conglomerate hole) and IH 60 (basalt east hole).

Water from basalt (east) holes (there are four holes with some basalt, but probably only three where water is derived from basalt: IH 45, 49, 60) are scattered.

Anions (fig. 22)

Water from Tertiary sediments in the eastern sub-basin plots in a zone which contains many other bore waters, including samples from Tertiary sediment with conglomerate beds (except for IH 54).

Water plots from Tertiary sediments (west) are scattered, but mainly plot in the above zone and in general have a high chloride content.

Basalt (west) holes all plot in one zone except for IH 31, which may be dominantly Tertiary sediment water.

Basalt (east) holes plot in a small part of the Tertiary sediment and conglomerate zone.

CONTRACT HOLES

Cations (fig. 23)

Waters from Tertiary sediments (14 samples) in both the eastern and western sub-basins are scattered with no definite zones.

Basalt (west) holes (8 samples) all plot in one zone which contains no other bores.

Basalt (east) holes (4 samples), either all or partly in basalt, are all contained in one zone. This zone contains two other bores, CH 1 in Tertiary (west) sediments and CH 17, for which there is no log, but which is probably Tertiary (east) sediments.

The plots of two samples from dolerite (CH 45, CH 46) are not close but have about the same Ca proportion.

Water plots from Permian rocks (2 samples) are fairly close, being high in calcium and with about the same proportion of magnesium.

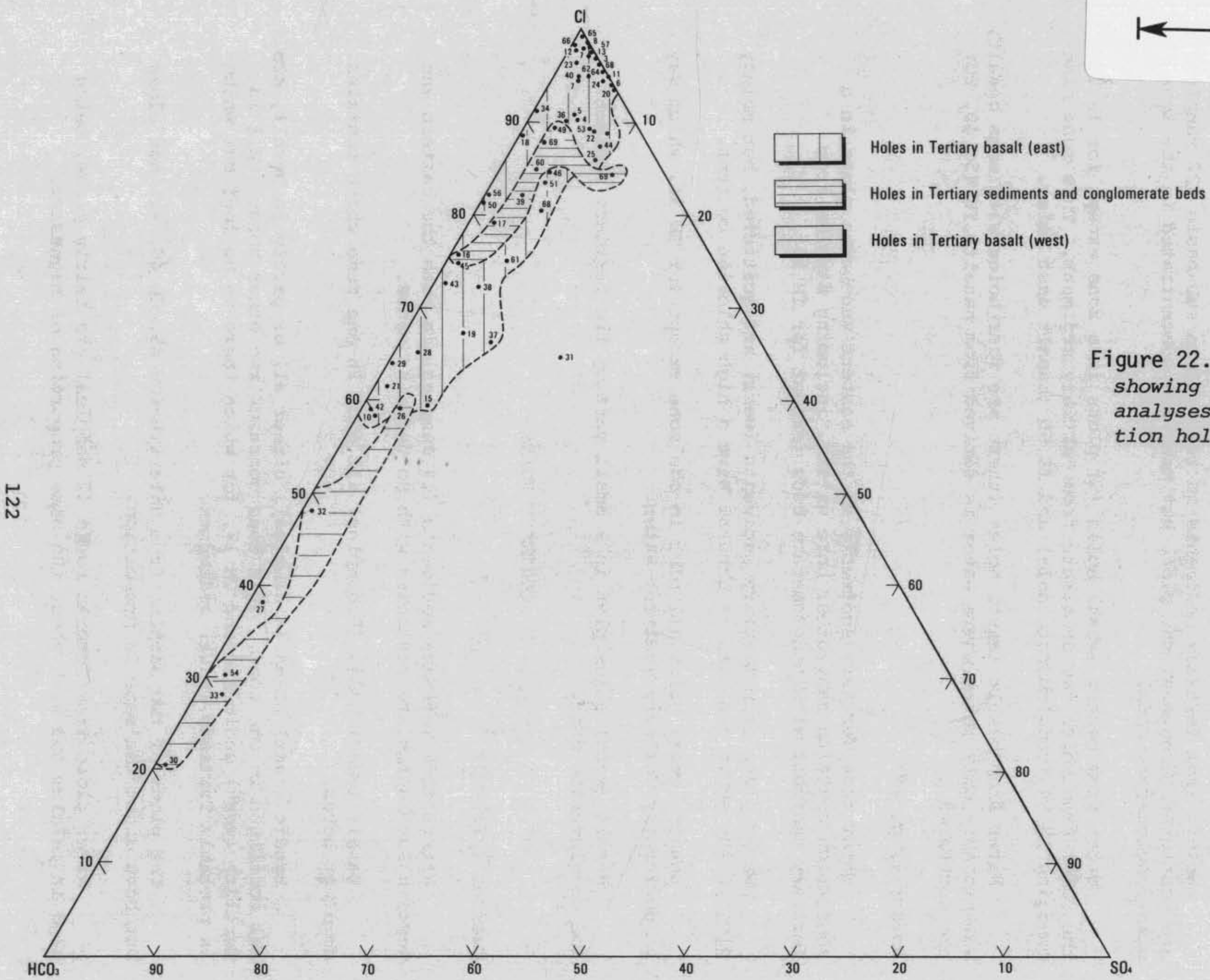


Figure 22. *Triangular diagram showing anion plots of chemical analyses of water from investigation holes.*

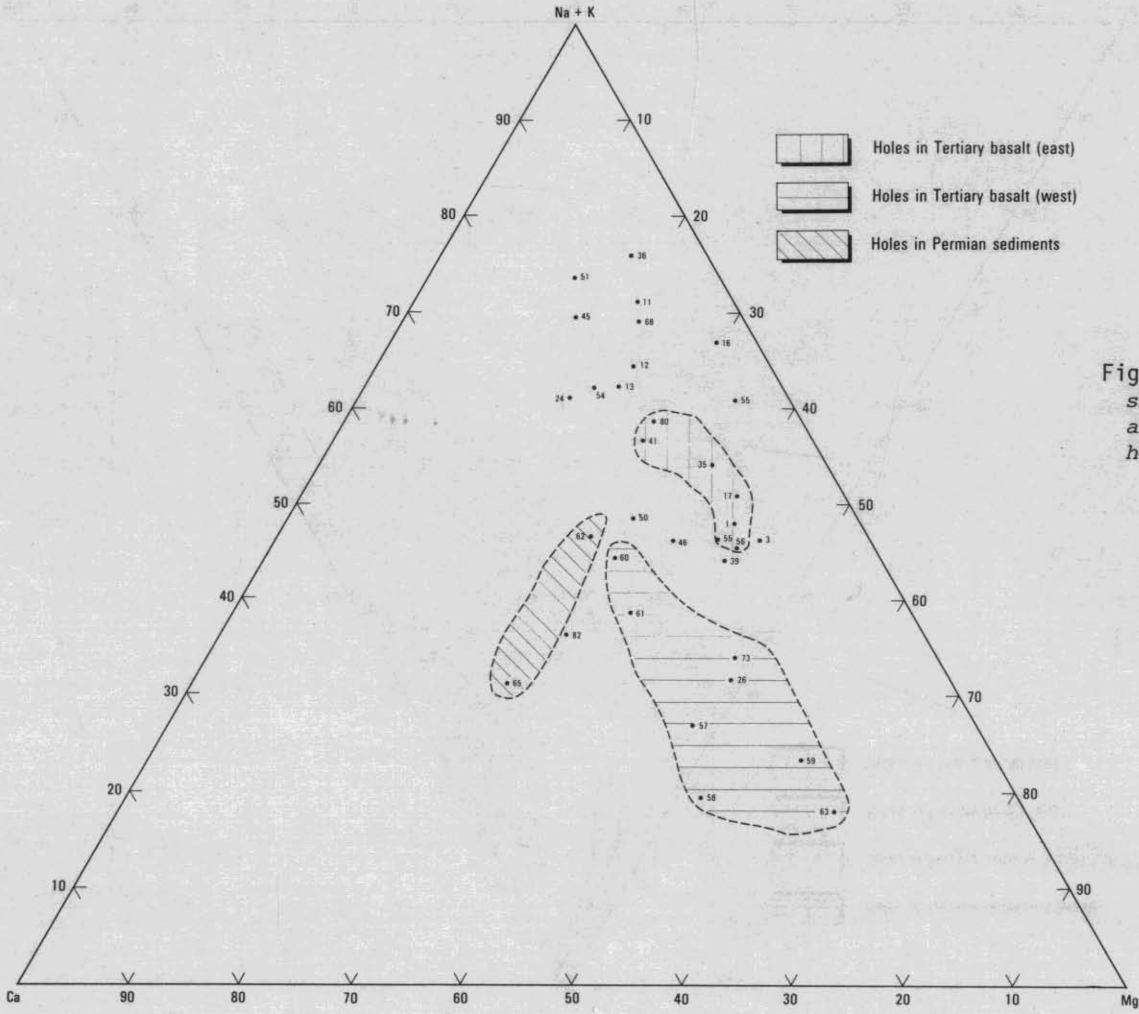
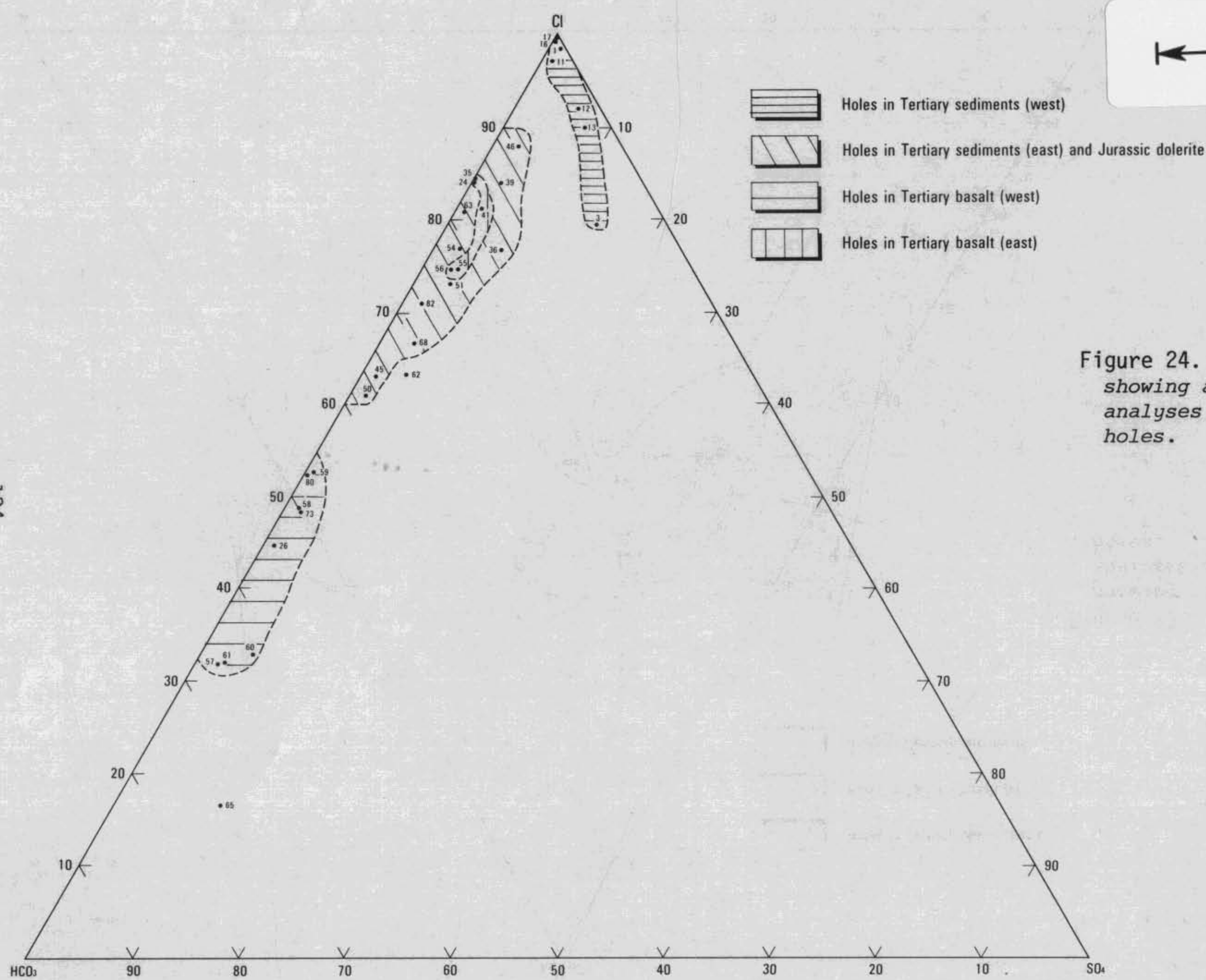


Figure 23. *Triangular diagram showing cation plots of chemical analyses of water from contract holes.*



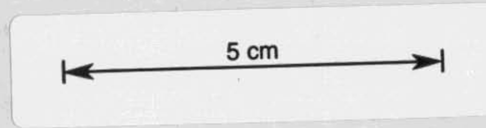


Figure 24. *Triangular diagram showing anion plots of chemical analyses of water from contract holes.*

Anions (fig. 24)

Water from the Tertiary (east) sediments (7 samples) plots in a fairly broad zone, containing all except CH 17 (no log available). It also contains the two dolerite bores CH 45 and CH 46 and the basalt (east) zone.

Water from the Tertiary (west) sediments (7 samples) is all included in one zone, except for CH 24 which contains no sulphate and may be an analytical error.

Basalt (west) waters plot in a separate distinct area containing all of the bores except CH 63.

Basalt (east) waters are all contained in one small area included in the larger Tertiary east area.

The most distinctive grouping in these diagrams are the fairly exclusive zones containing the basalt waters from the western sub-basin. These plot in different areas from the basalt water of the eastern sub-basin, which is similar to the water contained in the Tertiary sediments in the eastern sub-basin. The eastern Tertiary sediment water is slightly different from the west Tertiary water, and it seems probable that the eastern basalt influences the quality and proportions of the various ions in water. One of the effects appears to be an introduction of a greater proportion of bicarbonate ions, but the greatest difference is the much larger TDS content in the eastern waters, which is probably related to the basalt type. The conglomerate beds in Tertiary sediments tend to produce water with more calcium than is average for Tertiary sediments. The number of holes in Permian sediments and Jurassic dolerite is not large enough to form definite groupings.

VARIATION OF WATER QUALITY WITH TIME

Water from two bores, IH 3 east of Cressy and CH 55 at Epping Forest, has been sampled and chemically analysed over a period of about 30 months at approximate monthly intervals. The results of these analyses have been reported by Wellington (1979). The reason for sampling was to examine variations in the chemistry of the water with time and to determine whether any variations could be related to the rainfall pattern. The chemical analyses gave the following ranges of values:

Item	*IH 3, Cressy*	*CH 55, Epping Forest*
pH	6.4-7.9	6.4-8.2
	mg/*l*	mg/*l*
HCO_3	160-265	200-260
Cl	600-620	360-430
SO_4	1.5-11	13-31
SiO_2	2-17	24-60
Ca	73-130	27-50
Mg	49-70	57-80
K	11-20	2.9-4.1
Na	182-330	175-230
TDS	1190-1570	890-1090
Alkalinity	130-220	170-210
Conductivity (µS/cm)	1700-2400	1100-1700

For IH 3, 10 F determinations range from <0.5-2.5 with most <0.5, Fe<0.1 to 3.1 most <0.1, Al all <0.1, CO_2 all nil. For CH 55, 11 F determinations range from <0.5-2.3 mean about 0.7, Fe all <0.1 except one 0.15, Al all <0.2, CO_2 all nil.

These results show a considerable variation in water quality, with differences of up to 30% between maximum and minimum values in many cases.

Plotting the results of the determined items graphically and comparing them with rainfall (figs. 25, 26) shows no observable strong direct correlation between amounts of constituents in the groundwater and the intensity of rainfall. Some constituents appear to have lows in high rainfall periods (*e.g.* for CH 55, Na, Ca, Cl, and SiO_2; for IH 3, conductivity, Na, K, Mg, and Ca). Some HCO_3 and pH peaks in CH 55 are in the same direction as rainfall values.

Some delay would be expected with the effects of rainfall on changes in groundwater quality, so rainfall figures have been plotted back as far as June, 1975. The rainfall figures show a cyclic pattern of general highs and lows, the two high periods being from July to November, 1975 and December to May (or August), 1977 with general lower rainfall between. The variations of many of the groundwater constituents show the same kind of period, only later (*e.g.* Na, Cl for CH 55 and Na, Ca, SiO_2, K, and Mg for IH 3). It is possible that the first general peak in rainfall may have produced the general low in the middle period for many of the determined constituents. However, proving this hypothesis would require analysis over a longer period.

There are some noticeable relationships between constituents over the period of chemical analysis. For IH 3 (fig. 25), TDS and pH appear to have a reverse relationship, TDS and HCO_3 have a similar shape, while TDS and Ca, Mg, K, and Na have some peaks in the same direction and some in reverse directions. Surprisingly, TDS and conductivity do not show a strong relationship with peaks in the same direction; if anything there is more of a reverse relationship. SiO_2 and pH show a strong reverse relationship. Ca, Mg, K, and Na have similar shapes in some respects. For CH 55 (fig. 26), TDS compared with pH, HCO_3, SO_4, Ca, Mg, and SiO_2 show some peaks in the same direction, others in reverse directions. Na, Cl, and TDS show a close similarity, while TDS and conductivity peaks are mainly in the reverse directions. The correlation between pH and other items is poor. For some, the peaks are reversed for part of the period and in the same direction for the remainder. More of the HCO_3 peaks are in reverse to peak directions of Na and Mg than in the same direction.

The most surprising correlations are between the same item from the two bores. For conductivity, HCO_3, and TDS, a number of peaks are at the same time and in the same direction. pH for both boreholes is the same general shape and Ca and Mg have most of their peaks in the same direction for the same analysis. The reason for this is not known, as the water is almost certainly stored in different aquifers, CH 55 being in fairly shallow sand and gravel under basalt at Epping Forest and IH 3 in a deep fine to medium sand aquifer about 18 km further north-west. This may imply that similar chemical processes are going on in different aquifers at the same time. A remote possibility is that the correlation is due to laboratory technique.

Part 4:
Drilling and Well Data

INTRODUCTION

Information from a number of sources has been utilised in the compilation of this report. The positions of all the data sources are marked on Figure 3 and information on each is appended. These sources include 433 wells, 130 proline auger holes, 5 diamond drill holes, 122 uranium prospecting holes, 77 groundwater investigation holes, 74 contract water bores, and 2 oil prospecting holes.

WELLS

In the absence of permanent creeks in large parts of the Longford area, the early settlers resorted to digging wells. At least one attempt has been made to obtain water from wells on most properties and on many, several attempts have been made. Wells have been only moderately successful throughout much of the basin because clay beds occur near the surface over a wide area. However, even if a small amount of water was obtained, it was a useful addition to the supply in dry periods. The water requirements of the early settlers were probably lower than present day requirements, as less intense agricultural methods were used. Well digging was a skilled job and many of the wells that are still open throughout the basin are brick lined. Although many were probably dug more than 50 years ago, a large proportion of those in use are still in good condition. Many wells were not successful and have been filled in, while others that were more successful are now either capped or in the process of being filled in as alternative means of obtaining water become available.

Information on the well survey is given in Appendices 7 and 8. More than 433 wells were located, but information was collected from only a proportion of those in the Longford Quadrangle. Only information on numbered wells is given in the appendices.

Most wells are 6-15 m deep, but a few are 15-30 m with the deepest located being 36.6 m. Yields are variable but usually low; the figures given in Appendix 7 are only the estimates of the property owners and can only be regarded as approximate. No known pump tests have been undertaken. The water would be used as required and little account of the quantity would be made in most cases. Yields are often in the range of 1000-5000 *l*/day but rates as low as 45 and as high as 65 000 *l*/day are recorded.

The wells are usually about 1.2-1.5 m in diameter and most are pumped by a windmill, with a few using an electric pump and occasionally petrol motor driven pumps. They are mostly used for stock, with some used for domestic purposes and gardens. The water quality is variable and those used regularly are often a little higher in salt content than surrounding unused wells, suggesting that some of the water in the latter is direct runoff. Some of the variation throughout the area is probably due to the testing of samples at different times of the year. Water from a large proportion of those wells recorded in Appendix 7 from the Longford Quadrangle has been chemically analysed (Appendix 8). Only a few water samples from wells in other parts of the basin have been chemically analysed, but where the water was accessible, a sample was tested with a conductivity meter, from which an approximate value of total dissolved solids can be calculated. Many of the more successful wells are located on basalt in the north-west part of the basin or in areas where near-surface gravel beds occur.

PROLINE AUGER HOLES (PH)

Proline auger holes were mainly drilled around the margins of the basin and in areas where it was not known whether there were Tertiary sediments remaining. A total of 132 holes were drilled, amounting to 756 m of drilling. The extent of Tertiary sedimentation (or unconsolidated material overlying bedrock) in the flat area extending from 'Connorville' north-west between McRaes Hills and the Great Western Tiers and further north through Cluan was largely unknown, except for some information in areas where the Hydro-Electric Commission had conducted work. It was known that the depth of material above bedrock was shallow between McRaes Hills and the Great Western Tiers (Nicolls, 1959), with about six metres at some points (McKellar, 1957). As the project was aimed mainly at examining water occurrences in the Tertiary sediments, and the shallowness of sediment in this area did not warrant the use of larger drills, an auger drill with a depth limit of 15 m was used. Hole logs are given in Appendix 4.

Other areas where auger drilling was undertaken were on the margin of the basin south-west of Delmont, from west of Dicks Banks south to Winton (again near the margin of the basin) and from north of Campbell Town to north of Epping Forest along the Midland Highway. Two holes were drilled north of Hummocky Hills to examine the relationships of near-surface gravel beds, and three holes were drilled to determine the extent of a Recent freshwater limestone deposit north-west of Bracknell. As well as checking the depth to bedrock, materials above bedrock were logged and groundwater information recorded. Water quality was usually measured with a salinity meter and approximate values of TDS were recorded. Chemical analyses of water from two auger holes are recorded in Appendix 9. No pump tests were conducted on any of the auger holes.

DIAMOND DRILLING (DH)

The earliest known drilling in the basin, two diamond drill holes on the property 'Belmont', is recorded in the Secretary for Mines Reports of 1886 and 1887 and later by Johnston (1888). These holes were sunk in search of extensions to the Norwich coal seam. Another hole was drilled at Carr Villa, also in search of coal. The positions of these holes are unknown, except for their descriptive locality. Blake (1959) positioned one hole near the homestead on the property 'Belmont' and probably assumed that the other was nearby. Johnston (1888) stated that one hole, drilled to 272.6 m, was sited one mile south-west of the Norwich coal mine. This seems an unlikely area for such deep Tertiary sediments, as dolerite crops out close to this area on all sides except to the south-east. The bores have been placed on Figure 3 near the descriptive localities, with only one bore marked at Belmont.

A diamond drill hole was drilled west of Cressy as part of the groundwater survey and was projected to go to about 152 m, the depth to which most of the water investigation holes were sunk. Drilling difficulties prevented penetrating any further than 141 m. This hole allowed an examination of the sediments in an undisturbed state. It was hoped that undisturbed samples of the aquifer material would be obtained, but unfortunately they were too unconsolidated and were mainly washed away in the drilling process. Some of the slightly clayey sand beds were cored. Numerous siderite and siderite-rich seams were recovered and the core allowed study of the clay mineralogy and palynological examination without the danger of contamination from other levels, as is possible with rotary drilled holes.

Information from a hole cored near White Hills (DH 4) has been used to examine basalt and interbedded sediments. The hole was drilled to study the succession in a landslip area, but information on clay mineralogy and palynological determinations have been included. This hole was drilled to 66.2 m before being stopped. Broken basalt and sometimes unconsolidated conglomerate caused drilling difficulties over much of the upper sections of the hole. Logs of diamond drill holes are given in Appendix 3.

OIL PROSPECTING HOLES (OP)

Two holes were rotary drilled by private drill operator C.G. Sulzberger, in what are probably two of the deeper zones of Tertiary sedimentation. These were sited after results of the gravity survey (Longman and Leaman, 1971) became available. Both holes reached basement and valuable information was obtained as a result of this drilling. Although rotary drilled for most of their depth, core was taken at some levels and although most samples are disturbed, a guide to the sequence can be obtained. These samples have allowed spore dating on the deepest sediments overlying basement, which is critical in developing ideas on the timing and formation of the basin. As well, the clay mineralogy of some samples and probable aquifer materials have been examined. Drilling logs, assembled from a composite of sample description and the drillers log, are given in Appendix 6. A total of 1519 m of drilling was undertaken in the two holes.

Electric logs, consisting of single point resistivity, S.P., and gamma ray traces were run on hole OP 1 to a depth of about 560 m. These logs are shown in Figure 27, together with an interpretation of the likely aquifer depths.

URANIUM PROSPECTING HOLES (MP)

A drilling programme was undertaken by Getty Oil to investigate the prospects of sedimentary uranium within the basin and involved the drilling of 122 holes throughout most of the basin, except in the north-west part (Middleton, 1973). A total of 12 126 m of drilling was undertaken. These holes were sited in locations which were not drilled during the groundwater survey and have provided much additional information on the stratigraphy of the area. The holes were drilled on traverse lines and were more closely spaced than the water investigation bores and added to the knowledge of the extent of potential aquifers. The drilling used two rotary drills; an abridged version of the logs of these holes is given in Appendix 5. Electric logs were run in each hole and interpretation of these, together with the logs of samples, has been useful in pinpointing prospective zones for water in each borehole. These zones have been added to the written logs in Appendix 5 and are shown in Figure 28. Another distinctive feature on the electric logs is the siderite layers encountered in some parts of the basin. Although these are usually thin, they have been recorded, as they may be mistaken as basement when encountered in drilling.

CONTRACT WATER BORES (CH)

The first known contract water bores were two drilled at the Conara railway station in 1928 by the Department of Mines. Later bores were drilled around Longford, Cressy, and Hagley in the early 1950s, again by the Department of Mines. These holes had mixed success, mainly because of thick layers of near-surface clay in many areas. Gravel horizons were sometimes encountered and water was obtained. In the early 1960s, the Department of Mines drilled a few holes in the Cleveland area and north-west of Campbell Town, most of which were successful. In the later 1960s and early 1970s, private drilling companies drilled water bores in various parts of the basin, concentrating on the basalt areas in the north-west and the gravel and basalt areas in the south-east. Many of these holes were successful in obtaining water. Occasional bores have been drilled in the basin in the last few years.

The bores drilled by the Department of Mines up until the early 1960s were drilled with percussion plants. Holes drilled by private contractors since 1965 have mainly been sunk with rotary or hammer drilling. Information is recorded on 74 contract holes with a total of 2032 m of drilling.

The logs of these holes are given in Appendix 2. Although most of these holes are shallower than the investigation holes, they are useful as a guide to the occurrences and quality of water occurring at shallow depths. In the south-east of the basin, the water-producing gravel encountered in many bores is the only known widespread aquifer, apart from basalt. The contract holes have also provided information on groundwater conditions in rock types other than those tested with investigation holes (*e.g.* Permian and dolerite).

INVESTIGATION HOLES (IH)

Investigation holes were drilled on an approximate grid system 3-4 km apart, once it was realised that aquifers were widespread. Siting was made without making particular use of geological or geophysical methods apart from, to some extent, the gravity survey results (Longman and Leaman, 1971). These were used to predict areas of deeper Tertiary sedimentation. Resistivity probes to that stage were not useful. Fifty-six rotary holes were drilled for a total of 6268 m of drilling and 16 percussion holes, totalling 825 m, were drilled. Five holes (IH *A-E*) were drilled along the north part of Bracknell Main Road in a preliminary investigation involving 709 m of drilling. Logs of all investigation holes are given in Appendix 1. For the rotary drilled holes, logs of the materials collected at intervals of 1.5 m are given and borehole diagrams have been constructed using this information (fig. 29), together with information from electric logs (gamma ray, single point resistivity, and self potential) which were normally run. The drillers logs have also been used in constructing these, as often these logs are based on rates of drilling, with aquifers in particular being drilled through at a rapid rate, whereas clay zones are usually slower. The description of the material in most cases is based mainly on visual information. Microscope examinations and detailed descriptions of material from most bores was prepared by Tennaco Australia Inc., mineral lessees of most of the basin area before the involvement of Getty Oil Development Company Ltd. Material from bores in the north-west part of the basin in the Quamby Quadrangle was not examined by the company. These descriptions are detailed and have not been appended, but are available for inspection at the Department of Mines.

Samples collected during percussion drilling are more representative of the material being drilled at a particular level than is the case with rotary drilling. Casing is driven in percussion holes almost to where the bit is cutting and there is little contamination from upper levels. Rotary drilled holes often suffer contamination of samples for some distance below once an aquifer has been penetrated. This is particularly noticeable when a coarse-grained aquifer has been drilled, with less contamination where sand aquifers occur. With a suitable mud mixture, collapse of the sides of the hole is minimised. Usually the clay being drilled formed a suitable medium to keep the holes open while the drilling was in progress, enabling electric logs to be run after pulling out the drill rods. The advantage of

Plate 15. *Pumping from the Cleveland production hole at a rate of about 1140 l/min.*

Plate 16. *A reamer, made up from 200 mm casing, was used to enlarge production-type holes at Cressy and Cleveland to 300 mm diameter to allow a gravel pack to be introduced into the hole, surrounding the casing.*

rotary compared to percussion drilling is that the rate of drilling is much faster. Commonly over 100 m was rotary drilled in a day in the Tertiary sediments, whereas some of the contract percussion holes in the Cressy area took about a month to drill 30-50 m. Another advantage with rotary drilling is in the installation of slotted casing for testing or production. The zones against which the slotted casing is to be placed are determined from the drilling, and the casing is installed on completion of the hole. With percussion drilling, where casing is installed during drilling, the levels at which slotted casing is to be installed are not known, unless there is previous knowledge of the sequence. Slotted casing can be placed at the bottom of the casing line during drilling and pulled back to cover likely aquifers on completion of the hole. However difficulties arise if two aquifers occur which are required to be pump tested together. A danger with putting slotted casing on the bottom of the casing line is that it may bell out if forced and jam the whole casing string. The percussion drills, although capable of drilling to greater depths, were only used to drill holes to about 60 m. Difficulties often occurred around this depth and it became uneconomic to drill to deeper levels.

Short pump tests were conducted on most holes using only sparsely slotted steel casing. As the size of pumps available at that time was limited to one of about 150 *l*/min and another of about 300 *l*/min capacity, such a bore construction was suitable for most of the bores drilled, although much greater drawdown due to well loss could be expected than if better designed bores were constructed. More efficient bores were constructed at Cleveland and Cressy, representing the two most widespread aquifer types. Each bore had slotted casing with a surrounding gravel envelope and a nearby observation hole to measure drawdown to enable calculations of the aquifer properties. Larger pumps were available for these tests. The construction of these bores is described below, together with information on the construction of bores in different aquifer materials.

GRAVEL AQUIFERS

The gravel aquifers north of Campbell Town have great potential for the rapid supply of water, but their use will be limited by quality. Quantities as large as 4500 *l*/min may be obtainable at some locations if efficient bores are installed; this would require a bore of at least 300 mm diameter to enable a large enough pump to be installed. An even larger hole may be desirable so that the entrance velocity of the water into the bore is reduced, although development of the bore by surging would increase the effective diameter.

A large diameter hole was drilled at Cleveland for extensive pump tests (fig. 30) and a previously drilled hole was used as an observation hole. The depth and thickness of the aquifer had been established from the previously drilled hole and a grain size analysis had been made of the aquifer material. Lateral variation of grain size can be rapid in coarse-grained sediments and the material in the larger diameter bore was coarser than in the observation hole. The seive analyses of samples from test bores throughout the area show considerable variation (table 20) and it would be advisable to size the samples from the particular area that the bore is to be installed.

The uniformity coefficient of the aquifer material at Cleveland was 7.0 and it was unnecessary to place a gravel pack around the bore. However, as a screen was not available, slotted 150 mm casing was installed. Development such as surging is not as effective with slotted casing unless the slots are extremely close. A gravel pack was placed around the slotted

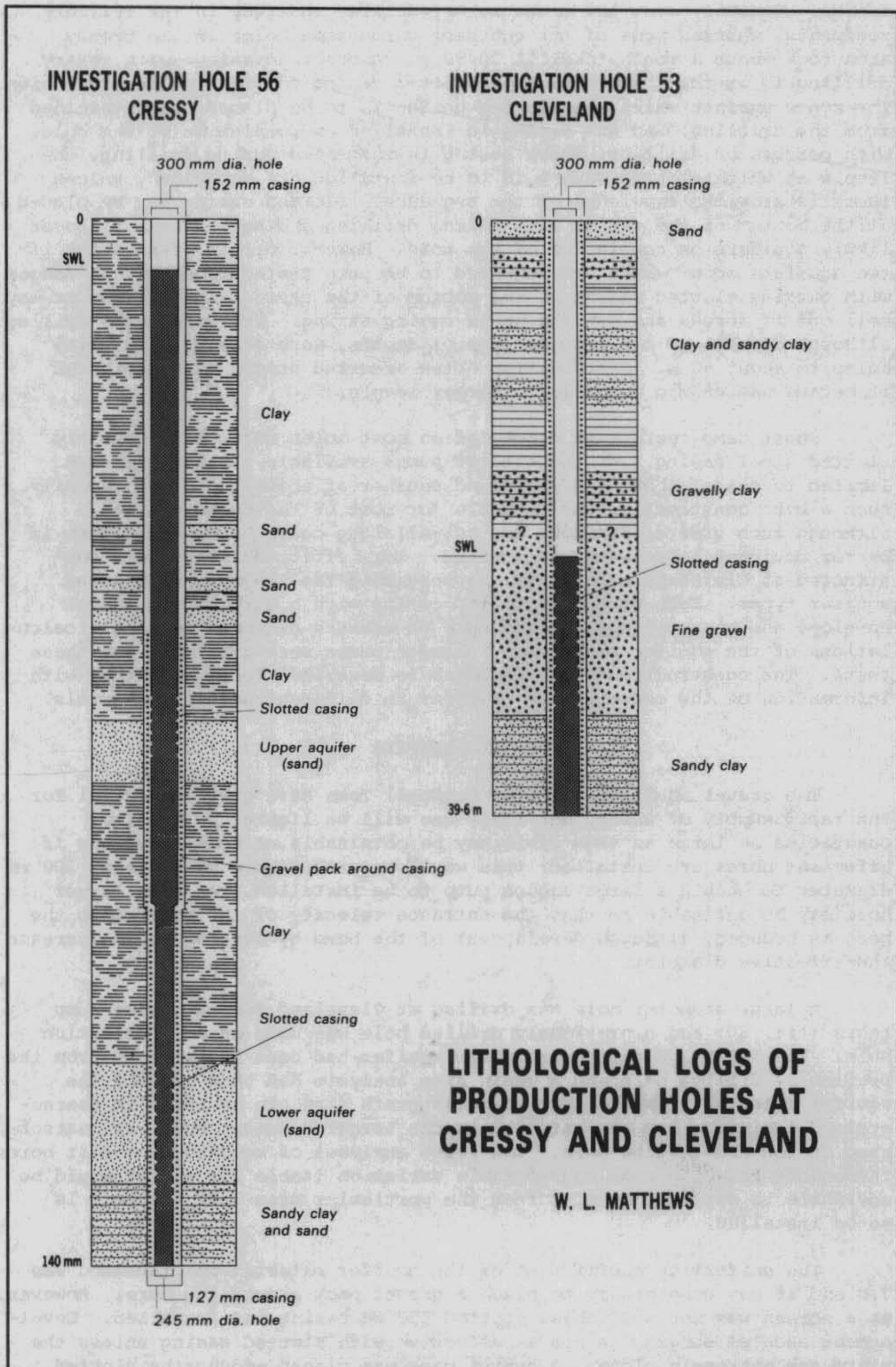

INVESTIGATION HOLE 56
CRESSY
300 mm dia. hole
152 mm casing
0
SWL
Clay
Sand
Sand
Sand
Clay
Slotted casing
Upper aquifer (sand)
Gravel pack around casing
Clay
Slotted casing
Lower aquifer (sand)
Sandy clay and sand
140 mm
127 mm casing
245 mm dia. hole
INVESTIGATION HOLE 53
CLEVELAND
300 mm dia. hole
152 mm casing
0
Sand
Clay and sandy clay
Gravelly clay
SWL
Slotted casing
Fine gravel
Sandy clay
39·6 m
LITHOLOGICAL LOGS OF PRODUCTION HOLES AT CRESSY AND CLEVELAND
W. L. MATTHEWS

Figure 30.

Table 20. SIZING ANALYSES OF COARSE AQUIFER MATERIALS, SOUTHERN AREA, EASTERN SUB-BASIN

Investigation hole	Depth (m)	Sizing Analysis Cumulative % retained (μm)								
		3350	2000	1003	500	250	125	63	+45	-45
57	25.9-33.5	26.1	36.5	58.3	77.9	89.8	96.6	98.8	99.4	100
58	22.9-27.4	22.7	45.6	71.3	84.8	93	97.3	99.1	99.7	100
58	32.0-39.6	11.2	36.5	61.9	81.9	91.3	96.4	98.5	99.2	100.2
63	18.3-21.3	22.6	33.7	51.2	82.2	91.3	97.4	99.2	99.8	100.1
64	18.3-19.8	5.6	27.7	70.8	91.5		99	99.7	100	100.2
64	48.8-53.3		0.1	1.2	6.9	44.7	91.4	97.7	99	100
65	7.6-12.2	33.9	46.7	65	84.4	93.8	97.1	98.8	99.3	99.8
66	3.1- 7.6	13	22.3	46.6	72.2	86	97.1	98.7	99.4	100
67			2.2	13.1	42.9	73.9	91.6	97.4	99.3	100.1
67	19.8-25.9	7.8	15.7	34.1	55.3	77.1	91.8	96.7	98.3	99.9
68	4.6-13.7	29	35.5	52.4	74	89.4	97	99.2	99.8	100
69	10.7-12.2	4.2	7.7	21.8	70.4	94.2	97.7	99.3	99.7	100

casing to increase the effective size, the bore having been reamed out to 300 mm. The slots were about 2-3 mm wide and resulted in about 8% open area over 7.6 m of the aquifer. Three metres of casing with 2-3% open area was placed above the aquifer. The casing was centralised in the hole with 75 mm brackets welded on the outside of the casing and the gravel was poured down between the bore walls and the casing.

The size ranges of the aquifer material, a theoretically suitable gravel pack, and the gravel used, are shown in Figure 31. The commercial gravel was a screen size + 45-63 μm and because this was too fine, a quantity of + 63-127 μm material was mixed with it. This increased the composite towards the theoretically suitable size range, but would also have increased the uniformity coefficient.

For a pump test of 20 hours with an output of 1332 m^3/day and 8% open area in the screens, an entry velocity of 45-60 mm/sec is calculated. This is above the upper limit of 30 as suggested by Johnson (1966), but below the 76 suggested by O'Shea (1961).

FINE-GRAINED AQUIFERS

Fine-grained aquifers occur mainly in the western part of the basin from around Cressy to Carrick. These comprise fine to medium-grained sand interbedded with dominantly clay-size sediments. The size ranges of these aquifers are given in Table 21.

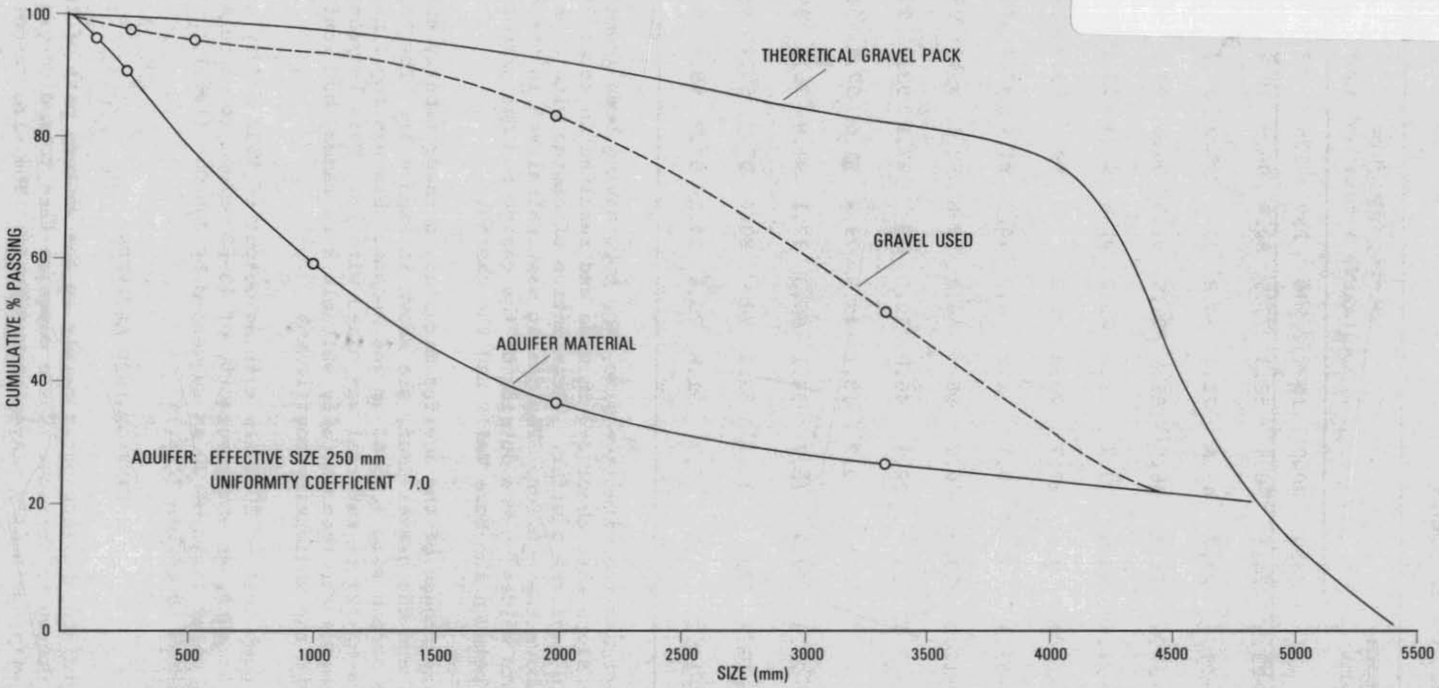


Figure 31. *Sizing of aquifer material in the Cleveland production hole, the most suitable size range for a gravel pack, and the size of the material actually used.*

5 cm

Table 21. SIZING ANALYSES OF SAND AQUIFERS, WESTERN SUB-BASIN

Investigation hole	Sizing Analysis Cumulative % retained (µm)						
	1003	500	250	125	63	+45	-45
3		0.6	65.7		97.1	98.7	100
7			0.8	65.6	90.4	95.6	100
8			26.7	94.8	98.6	99.3	99.9
12			5.7	72.6	95.3	98.6	100.1
29	1	12.6	74.7	94.6	98.4	99.3	100
36		2.1	77.3	97.8	99.6	100	
37		2.9	21.5	84.1	98.4	99.3	100.1
38	1.8	19.6	61.2	95.1	99.3	100.2	
40		0.3	18	85.9	97.3	98.7	99.9
41	0.9	8	50	94.3	98.3	99.5	99.9
45	0.2	1.2	27.9	96.4	99.6	99.8	100
46	0.2	0.5	11.5	92.3	98.9	99.6	100.1
47	0.8	8.7	40.5	93.2	98.1	99.1	100

Obtaining a representative sample of the aquifer was difficult where these aquifers were drilled with a rotary drill. The material that arrives at the surface is always contaminated with material from other levels and grading of the sample can be expected while travelling from the bottom of the hole to the surface. The samples that have been sized in Table 21 were obtained while cleaning up the hole with a bailer or were obtained in the early stages of pumping when the aquifer was not stabilised. The slots in the casing were large enough to allow the whole size range of material in the aquifer to pass through. Although some grading has probably taken place in these samples, they are regarded as reasonably representative of the aquifer.

Some coarser grained horizons were encountered in some localities (*e.g.* IH 19, 1, 4, 14, 22). These were fine gravel but were narrow and did not contribute much water except in the case of IH 19.

As previously mentioned, a large diameter bore with an observation hole nearby was drilled west of Cressy. From previous test holes in the area, it was known there were two aquifers; one at about 80 m from the surface the other about 110 m (fig. 30). The main water supplier is the lower aquifer. Samples had previously been obtained for seive analysis from IH 17, 22, and 12; these are shown on Figure 32, together with the gravel pack which would be suitable to contain an aquifer in this size range. The uniformity coefficient of these samples is low and the grain size small, making it advantageous to have a gravel pack. Metal screens

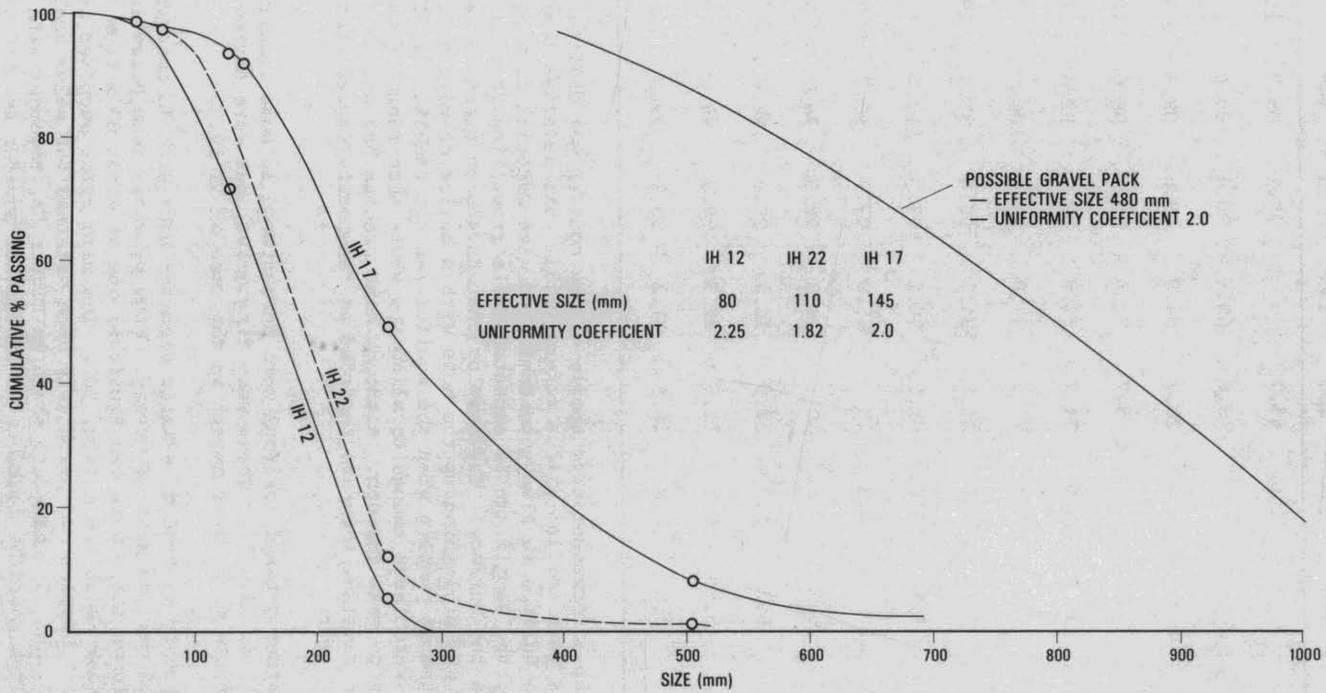


Figure 32. *Sizing of sand aquifer material from holes near the Cressy production hole and the size range of a suitable gravel pack material.*

were not available for the large diameter bore and slotted casing was used. When a slot burnt with a torch is not cleaned out, the approximate width averages about 1.6 mm as opposed to 2.5 mm when cleaned. However, 1.6 mm is larger than all the grades in the theoretically suitable gravel pack. A rounded coarse sand-fine gravel was obtained that would be retained by the slots and it was hoped that this would retain the aquifer material.

The hole was rotary drilled to about 137 m with a diameter of 245 mm; the top 92 m was reamed to 300 mm diameter. Casing of 152 mm diameter was installed to 92 m and 127 mm casing from 92-137 m, with slotted casing against the aquifers from 64.2-72.4 and 113.5-132.1 m. The casing had spacers welded to the outside to centralise it in the hole and the gravel was poured down the outside of the casing. Bailing, in an effort to clean the hole up before pumping, resulted in considerable quantities of the aquifer material being drawn into the hole. However when pumping began, very little sand was delivered with the water, suggesting that the aquifer grains bridged over the spaces between the larger gravel pack grains. A relatively low entry velocity into the bore probably also accounted to some extent for the low sand entry once pumping started. The 127 mm casing had an approximate open area of about 4% in the slotted section and at 545 *l*/min (assuming 38 *l*/min was supplied by the upper aquifer), the velocity of entry into the bore is about 60 mm/sec.

Although slotted casing appears to have been reasonably successful in this bore, it would be preferable for production holes to have either a greater number of narrower slots, so that a more suitable gravel pack could be used, or a specially made screen. Both should have a gravel pack to produce the most efficient bore.

Future drilling for groundwater

In planning drilling for underground water, account should be taken of previous results in the area for the particular rock type concerned. If few bores have been drilled nearby in the particular rock type, results of drilling in similar rock types in other parts of Tasmania should be considered. The range of rates at which water can be withdrawn from previous holes, either in the locality or in other areas, should indicate the kind of rate that could be expected from a proposed hole, particularly in the older rocks. The quality of water from previous holes should be considered, as this will have an important bearing on the use to which the water is applied. Because of the expense of drilling for groundwater, the cost of obtaining water from this source should be compared with the costs of possible alternatives (*e.g.* catchment dams or pumping from a permanent stream) before a decision to drill is made.

The present survey has indicated that the potential for the installation of water bores throughout much of the basin is good. Soon after the investigation began, it was realised that aquifers were more widespread than suggested by previous drilling, largely because many of the older holes had not been drilled deep enough to intersect the water-bearing beds. There are some small areas where water was not obtained in significant quantities. In general, only levels to about 152 m have been tested in the Tertiary sediments in the western sub-basin, and it is likely that further aquifers occur at deeper levels. The only real failures to this depth were in IH 2 and IH 15. Some other holes failed to reach this depth because of hard conglomerate (*e.g.* IH 9, 25, and 41) and it seems likely from results in other areas where conglomerate occurs, that had it been penetrated, the chances of obtaining water would have improved considerably. Although a few holes were drilled below 152 m, the potential to supply water below this depth has not been fully tested. The lithologies of the deeper sediments, particularly as shown in the oil prospecting holes, are promising.

The southern part of the eastern sub-basin was only tested to shallow depth, usually to about 45-60 m, because it was known from previous contract holes that good gravel aquifers were present in this area. Further aquifers may occur at deeper levels; to the north of this area, deeper conglomerate and boulder beds supply large quantities of water (*e.g.* IH 43 and 44). Some shallow percussion holes were drilled outside the gravel area and did not encounter water to the depth drilled; it is possible that these may have encountered water if drilled deeper. The uranium prospecting holes indicate that this is a strong possibility in most areas.

Comments are given below of groundwater prospects in the various rock types within and surrounding the basin.

Permian rocks

Only two bores have been drilled in the Permian rocks to deliberately search for water; both were contract holes. Several of the bores near the north-east margin of the eastern sub-basin entered Permian rocks, but in those tested, most of the water apparently came from the overlying Tertiary sediments. Permian rocks have been drilled for water at many locations throughout Tasmania with a high success rate, and it is likely that successful bores could be drilled in many areas around the margins of the basin where these rocks occur, provided other considerations are favourable. The steeper areas are less likely to have suitable sites than the flatter country and greater depths will usually have to be drilled if water is present. Where the Permian rocks have been baked by dolerite intrusions, it should be ascertained whether the Permian is a thin veneer overlying the dolerite, in which case the chances of obtaining water could be greatly decreased. The contact between the two rock types may be vertical or steeply sloping, and by moving away from the contact, the chance of encountering dolerite at shallow depth decreases and groundwater prospects should increase. Ideal situations to drill for water in the Permian rocks are the flat areas from north of Cluan almost to Billop to the south-east; this is the area where the two contract bores were drilled. Permian rocks underlie most of this flat area at relatively shallow depth, although some difficulty may be experienced in drilling through dolerite boulder beds at the surface and sites should be selected where these are absent or thin. Other areas in similar situations include the flat areas underlain by Permian rocks north and east of Millers Bluff, and south-east of Connorville.

Permian rocks in other parts of the basin are either close to or surrounded by dolerite. In most places the Permian appears to underlie the dolerite, and groundwater would probably be obtainable if further dolerite bodies do not occur at depth. These areas include the Permian rocks south-west of Mt Arnon and east and north-east of Evandale.

Drilling of fairly compact rocks, such as the Permian, could be undertaken by most kinds of water drilling plants. They have been successfully drilled by rotary, hammer, and percussion drills. Water is usually struck at a shallow enough depth to make the use of percussion drills economic. The quality is usually good enough to be used for most purposes, but the quantity is usually only large enough to serve as domestic, garden, and stock supplies, although small irrigation quantities may occasionally be obtained.

Triassic rocks

Only three water bores are known to be definitely in Triassic rocks and all are contract bores; these are CH 42 at Kenilworth, 15 km north-west of Campbell Town, and CH 71 and 72 at Stone Quarry, 14 km south-west of Cressy. Soft sandstone is mentioned in some driller's logs, but most of these are probably Tertiary sediments. Some of the investigation holes struck Triassic sediments at or near their final depth (*e.g.* IH 1, 6, and 7) but in each case, except perhaps for IH 6, most of the water was obtained from overlying Tertiary sediments. CH 42 was drilled mainly in sandstone and was successful. CH 71 and 72 were drilled in mudstone and only one was moderately successful.

As with Permian sediments, the success rate for water bores in Triassic rocks in other parts of Tasmania is high, particularly in regions where the sandstone:mudstone ratio is high. The same siting considerations suggested for Permian rocks apply to Triassic rocks, with the extra precaution that some of the areas with mudstone-rich sequences may have a higher risk of failure. Most of the Triassic rocks in the McRaes Hills - Westbury area appear suitable. Occasional small areas appear to be thin and underlain by dolerite at shallow depth and should be avoided. Areas of Triassic rock north of Millers Bluff, south-east of Connorville, and north of Kenilworth would probably contain suitable sites. Triassic rocks underlie some of the more recent deposits in the Kenilworth area and these areas are also prospective water suppliers. Small areas of Triassic rocks north-west and west of Campbell Town may provide suitable bore sites, but they should be closely inspected as dolerite is exposed nearby in every case. If the dolerite overlies the Triassic, which appears to be the situation in some cases, then the prospects of obtaining water should be good. The large area of Triassic rocks south of Hummocky Hills, where mudstone is interbedded with sandstone, may be suitable for obtaining water. The Triassic sediments on the northern part of Hummocky Hills are severely baked and underlain by dolerite and are unlikely to yield water.

Drilling could be undertaken by rotary, hammer, or percussion plants. The quality of water in Triassic rocks can be rather variable and is occasionally too saline for most uses apart from stock water. Quantities sufficient only for domestic, garden (if the quality is suitable), and stock supplies could usually be expected from these rocks.

Jurassic dolerite

Three contract bores, CH 45, 46, and 47 were drilled mainly in dolerite; CH 45 was successful, CH 46 struck a little water with poor quality, and CH 47 encountered only a little water. Drilling of dolerite has not been widespread throughout Tasmania and until more is undertaken definite advice on groundwater prospects cannot be given. In general, the prospects are not regarded as high in many areas, partly due to dolerite regularly occurring in elevated positions. Dolerite is usually in a fairly unweathered state and drilling with any equipment other than a hammer drill is slow and expensive.

Tertiary basalt

A number of bores, both investigation and contract, have been drilled in basalt. These are concentrated in the Whitemore-Westbury-Hagley area in the north-west of the basin and in the Campbell Town-Epping Forest area in the east. Two holes were drilled in basalt near Evandale. As in most other parts of Tasmania, Tertiary basalt has a high success rate for water bores.

Topography is important in siting drill holes, but in most areas throughout the basin, the basalt occurs on broad flats. The only striking exceptions are the laterite-capped basalt areas south of Westbury, near Campbell Town, and east of White Hills. There are extensive areas of flat land underlain by basalt in the areas where drilling has been undertaken. The quantity of water obtained is high compared to other rock types in the area, except for Tertiary sediments. Water is stored in joints and vesicles in the rock and where these features are prolific, bores giving higher yields can be expected. Rates of over 1500 *l*/min have been obtained (CH 56), which is sufficient to undertake small scale irrigation. The quality can be variable and, in general, the basalt areas of the south-east part of the basin produce rather poor quality water, while in the north-west quality is good. Basalt tends to be variably weathered and drilling in most areas where the rock is at least a little weathered could be undertaken by percussion, rotary, or hammer drilling. Where the basalt is unweathered, only hammer drilling could be economically used. The generally flat nature of the land surface where basalt occurs often means that good supplies of water can be obtained from relatively shallow depths and successful bores have been completed at depths of 15 m or less.

Tertiary sediments

Investigation drilling has shown that the Tertiary sediments contain aquifers at depths of up to 150 m in most areas. In much of the western sub-basin, fine to medium-grained sand aquifers occur at a number of levels. In the southern part of the western sub-basin, conglomerate beds appear to supply the water. In the southern part of the eastern sub-basin are coarser aquifers with up to fine gravel size material at depths usually less than about 50 m, while in the northern part conglomerate and boulder beds appear to supply most of the water, with occasionally some sand aquifers.

The salinity contours based on the investigation bores (fig. 3) indicate the water quality that can be expected. The use to which the water can be put in the higher salinity areas will be restricted. The results of the drilling, both investigation groundwater drilling and uranium prospecting, show that both the thickness of sand aquifers and the quantity of water obtainable is variable. There are very few areas where stock supplies could not be obtained at some level down to 150 m. Usually small irrigation quantities could be expected and at most locations 230 *l*/min to 1500 *l*/min or over could be obtainable. The full potential of the aquifers was not tested in the investigation holes (except for the two production holes) and it is possible that at some locations where thick beds of sand occur, well constructed bores may deliver quantities considerably larger than this range. In some parts of the gravel aquifers in the south-east of the basin (*i.e.* Conara to Epping Forest), rates of up to 4500 *l*/min or greater are possible. Quality is poorer in some parts of this area and although irrigation quantities are likely, the water may not be suitable for this purpose, despite widespread permeable soils.

In examining the possibility of obtaining water in an area within the basin, the logs of the nearest investigation bore or uranium prospecting hole should be examined. The probable aquifer materials in each of the prospecting holes are shown on the sections (fig. 28, 29). These boreholes will give some idea of the possible depths that will have to be drilled before water is obtained. With the rapid lateral variation in lithology however, the logs should only be used as a guide. If only a small amount of water is required, it may only be necessary to intersect one or two fairly minor sand horizons to obtain the required amount. If larger amounts are required, then a number of thinner beds or one major sand horizon should be penetrated. For example, near Cressy there are two main aquifers above 150 m; one at about 67-76 m from the surface which was pumped at about 42 *l*/min and the other at about 110-137 m from the surface which has been pumped at 570 *l*/min and may deliver double this quantity with a better constructed bore and greater drawdown.

The best means of drilling holes in these sediments is with a rotary machine circulating mud, either normal or reverse, the mud possibly being derived from the sediments. Although the sample return may not be as reliable in setting up a log of the hole as with percussion drilling, the speed of drilling is much greater. With hammer drilling, maintaining an open hole once an aquifer has been struck will be difficult. Where only a small amount of water is required, a small diameter hole with plastic casing about 100 mm in diameter would be a cheap solution. Slots cut with a thin blade should retain the sand. Where larger quantities are required, a small diameter pilot hole should be drilled. This should aim at determining the approximate size range of the aquifer materials, determing the water quality to ensure that it is suitable for the use to which it will be applied, and determining the aquifer thicknesses and positions. If possible, electric logs should be run after drilling. Some idea of the potential output may be obtainable by installing slotted plastic or steel casing and undertaking a short pump test with drawdown observations. The casing could either be removed and the hole reamed out to a larger diameter or a new hole drilled nearby. A metal screen or slotted casing surrounded by a gravel pack would be the most suitable construction, the latter being the cheaper.

If it is intended to pump the bore continuously for long periods after installation, a long pump test (at least three days) should be undertaken. Where the bore will be used intermittently for moderate periods at high rates, such as for irrigation, the pump test should last at least 24 hours and be combined with a multi-stage pump test of 4-5 stages, particularly if the testing pump does not have near the capacity of the projected production rate. Where pumping is only going to be over a few hours at any one time, the testing period can be less than these periods. Water samples should be collected for quality testing at least at the beginning and end of the pump test.

Other rock types

The pre-Permian rock types have not been tested in this study, but in other parts of the State older rocks are sometimes good and regular suppliers of groundwater. Quaternary sediments probably have limited potential for supplying water as they are usually thin. Where thick sand or gravel beds occur on low lying country, the potential should be high. Usually in the lower country the Quaternary is underlain by rocks with good water bearing potential (*e.g.* Tertiary, Triassic, or Permian).

DEVELOPMENT OF BORES IN UNCONSOLIDATED SEDIMENTS

Development of bores in unconsolidated sediments requires some special techniques. The hole requires support with casing or screens from the surface to the base of the aquifer. A screen or slotted casing is placed against the section containing the aquifer to allow the water to enter the hole. The size of the screen openings depends on the size of the material making up the aquifer. This requires a seive analysis of the aquifer material and these are usually drawn up on graphs (figs. 31, 32).

The size range and degree of sorting are important in deciding whether a gravel pack around the outside of the screen or slotted casing would be an advantage. Factors which are important in describing material making up an aquifer are:

(a) Effective size; the size of which 10% of the material is finer.
(b) Uniformity coefficient; the ratio of the size of which 60% is finer and the effective size.
(c) 50% size; sometimes used as index of fineness of an aquifer material.

Where it is not necessary to use a gravel pack around the screen, it is usual to select a screen with openings that will retain about 40-50% of the aquifer. Where a gravel pack is used, the screen or slot opening should be such that it retains about 90% of the gravel pack (*i.e.* the effective size of the gravel pack material). Gravel packs are most often used in aquifers that are made up of fine to medium-grained well sorted sand beds with a uniformity coefficient of about two or less. This is the kind of material making up most of the aquifer materials in the western part of the basin. O'Shea (1961) and Johnson (1966) suggest that 75 mm is a suitable thickness for the gravel pack. There are various methods of designing gravel pack material, but the end results are essentially similar, *e.g.* Johnson (1966) suggests multiplying the size of which 30% of the aquifer material is finer by four to six and drawing a size curve with a uniformity coefficient of 2.5 or less through the point so produced. Rounded particles are regarded as best for the gravel pack material. O'Shea (1961) suggests that the effective size of the gravel pack material should be four to eight times the effective size of the aquifer material or effective size of the gravel pack should be three to six times the 50% size of the aquifer material. Uniformity coefficient of the gravel pack should be two or less.

A gravel pack is most useful when the size range of the aquifer is small, because a screen with openings which retains nearly all the grains is required. It is possible to use a screen or slotted casing with larger openings when a gravel pack is used, thus increasing the total open area against the aquifer. This results in less drawdown when pumped. A gravel pack also increases the effective size of the bore without using large diameter screens or casing, which are more expensive. Where there is a larger variation in the size range of aquifer fragments (*i.e.* high uniformity coefficient), a screen or slotted casing with openings that retain only 40-50% of the aquifer can be used. With development techniques such as surging and backwashing, the fine material in the aquifer can be drawn into the bore and removed, leaving the coarser material around the outside. This forms an annulus of coarser material outside the casing, producing a natural gravel pack and also increasing the effective size of the bore. A bore with a gravel pack around slotted casing should be almost as efficient as a screened bore in many cases.

The reasons for increasing the effective size of a bore are partly to obtain a larger output, but largely to decrease the entry velocity of the water into the bore so that sand is not carried in with the water. There is only a small increase in output with increase in diameter of bores in unconsolidated sediments. Johnson (1966) gives an example of a 147 mm diameter bore with a cone of depression of 122 m in radius being doubled in diameter to 294 mm and giving a 10% increase in yield for the same drawdown. An increase in diameter to 588 mm increased the yield above the 147 mm bore by 22%. On doubling the diameter however, the surface area of the exposed aquifer doubles resulting in decreased water entry velocity and lowering the risk of pump damage due to sand entry.

AMOUNT OF WATER AVAILABLE

The drilling program has indicated that water is available from underground sources in most places within the basin. It is certainly available in quantities sufficient for domestic, garden (if the quality is suitable), and stock supplies and in most areas of the Tertiary sediments small irrigation quantities could be expected. Pumping rates may range from about 1000-2500 m^3/day in the western sub-basin and northern part of the eastern sub-basin and could be as high as 6500 m^3/day in the gravel areas in the southern part of the eastern sub-basin. The basalt in several areas is capable of yielding large quantities of water, with CH 56 south of Campbell Town yielding 2000 m^3/day when tested for short periods, even though it was only drilled to 15.2 m. It is likely that with deeper drilling, water could be extracted at an even greater rate. In the Campbell Town area and the area around Hagley in the north-west part of the basin, extensive sheets of basalt occur and these would store large quantities of water.

It is not possible to reach an accurate calculation of the amount of water stored within the basin but with some assumptions, an estimate can be made. As testing has been mainly confined to levels above about 152 m only this thickness will be considered. Sand beds at lower levels, particularly those encountered by the oil prospecting holes, suggest good prospects for supplies at lower levels. In the successful holes drilled, the average thickness of aquifer material would be at least 15 m (in many cases it is greater than this). This could be assumed to underlie 75% of the area underlain by Tertiary sediments and basalt, a total area of about 1300 km^2. Taking a porosity of 30%, a conservative figure for sand but higher than would be expected for most basalt, the total estimated stored water would be 5.85×10^9 m^3; of this, perhaps only about two-thirds may be extractable, *i.e.* 3.9×10^9 m^3.

The above estimate is not regarded as the total volume of water available, as some recharge from rainwater can be expected. It is not known how much recharge takes place, as this can only be determined when the groundwater is being used extensively and quantities used and water levels are monitored. Where there are thick layers of near-surface clay, such as in the majority of the western sub-basin, it is difficult to envisage much recharge. In some holes the clay was fractured and may be slightly more permeable than the plastic clay which is more common. The only apparent areas where recharge may take place is in areas of gravel north of Longford, where there are gravel aquifers at fairly shallow depth, and perhaps around the margins. If subsidence took place after some of the sand beds containing water were deposited, tilting of the aquifers towards the basin centre could be expected and the margins probably represent the best location for recharge. In other areas, such as the southern parts of both sub-basins, the aquifers are closer to the surface and the overlying material appears more permeable, even though some of it is clayey. In basalt areas, recharge can take place through weathered rock.

The possibility that the water is connate in some parts of the basin should be considered. However the evidence from the chemistry of the water does not suggest this. The water is comparatively fresh in most areas, even where there is a thick covering of clay, whereas if the water was of Tertiary age, higher salinities might be expected. In addition to the material in which the water is stored influencing composition, Chebotarev (1955) showed that a general change of composition of water can take place with time from bicarbonate-rich water to a chloride-rich water. Although many of the sediments have chloride as the dominant ion, in many analyses bicarbonate makes up a fairly high percentage of the total ions. These two factors taken together suggest that some recharge is taking place. In some areas the groundwater may be slow moving and this could explain the higher salinity, although rock composition is also regarded as having a strong bearing. No bicarbonate was analysed in auger holes PH 29 and PH 31 and these are distinct exceptions to the above.

Artificial recharge

Because of the clayey nature of much of the material overlying the aquifers, natural recharge is probably limited. With large quantities of flood water coming down rivers derived from rain falling largely outside the basin area, the potential for artificial recharge of aquifers is high. In the western sub-basin the potentiometric surface is high and water would need to be pumped into the aquifers under pressure to recharge them in their present state. With water use and drop of the potentiometric surface pumping in under pressure may not be necessary.

The shallower gravel aquifers in the southern part of the eastern sub-basin show great potential for artificial recharge. Large volumes of flood water come down the South Esk River each winter and if this water was pumped to a suitable recharge centre, such as the vicinity of IH 53 at Cleveland where the water table is low and the permeability of the gravel is high, large volumes of water could be pumped underground. It seems probable that the groundwater in this area is only slow moving which would account for some of the high salinity (although basalt composition and weathering is thought to contribute). With the introduction of artificial recharge, a greater head would be developed and faster movement of the groundwater would result. This should have a flushing effect and improve the quality. The side effects may be the formation of springs in some localities where the gravel approaches the surface and special drainage measures may be needed. More work in the form of closer spaced drilling would be required to establish the extent and continuity of the gravel beds. Quality is the main drawback for use of the water for irrigation in much of this area and if it could be improved, it may provide an alternative system to distribute water (as opposed to the conventional channel system) if irrigation is ever considered for this area on a large scale.

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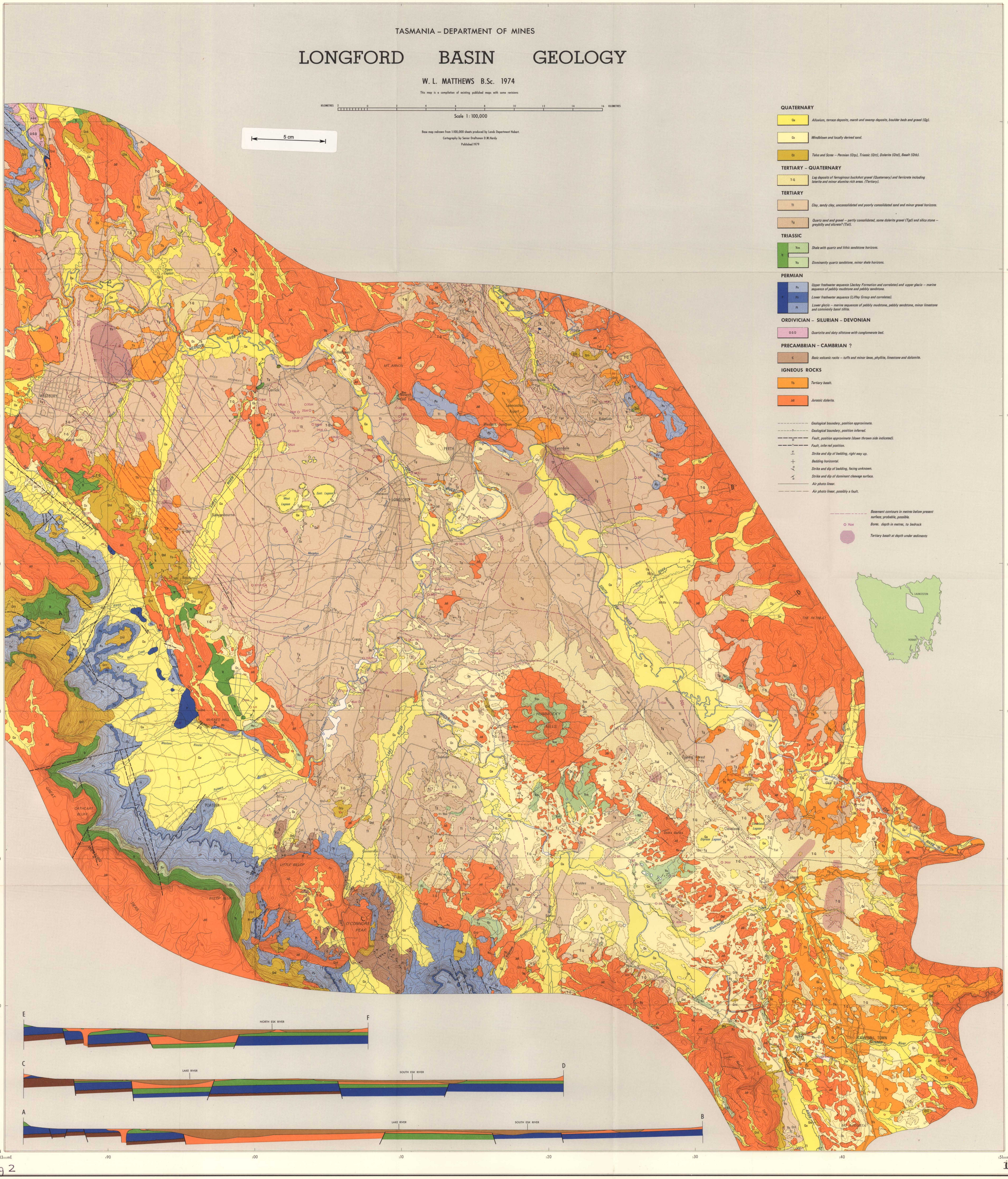

TASMANIA – DEPARTMENT OF MINES
LONGFORD BASIN GEOLOGY
W. L. MATTHEWS B.Sc. 1974
This map is a compilation of existing published maps with some revisions
KILOMETRES 2 0 2 4 6 8 10 12 14 16 KILOMETRES
Scale 1:100,000
Base map redrawn from 1:100,000 sheets produced by Lands Department Hobart.
Cartography by Senior Draftsman D.M.Hardy
Published 1979
5 cm
QUATERNARY
Qa Alluvium, terrace deposits, marsh and swamp deposits, boulder beds and gravel (Qg).
Qs Windblown and locally derived sand.
Qt Talus and Scree – Permian (Qtp), Triassic (Qtt), Dolerite (Qtd), Basalt (Qtb).
TERTIARY – QUATERNARY
T-Q Lag deposits of ferruginous buckshot gravel (Quaternary) and ferricrete including laterite and minor alumina rich areas. (Tertiary).
TERTIARY
Tl Clay, sandy clay, unconsolidated and poorly consolidated sand and minor gravel horizons.
Tg Quartz sand and gravel – partly consolidated, some dolerite gravel (Tgd) and silica stone – greybilly and silcrete? (Tsil).
TRIASSIC
Rm Shale with quartz and lithic sandstone horizons.
Rs Dominantly quartz sandstone, minor shale horizons.
PERMIAN
Pu Upper freshwater sequence (Jackey Formation and correlates) and upper glacio – marine sequence of pebbly mudstone and pebbly sandstone.
Pli Lower freshwater sequence (Liffey Group and correlates).
Pl Lower glacio – marine sequences of pebbly mudstone, pebbly sandstone, minor limestone and commonly basal tillite.
ORDIVICIAN – SILURIAN – DEVONIAN
O-S-D Quartzite and slaty siltstone with conglomerate bed.
PRECAMBRIAN – CAMBRIAN ?
€ Basic volcanic rocks – tuffs and minor lavas, phyllite, limestone and dolomite.
IGNEOUS ROCKS
Tb Tertiary basalt.
Jdl Jurassic dolerite.
Geological boundary, position approximate.
Geological boundary, position inferred.
Fault, position approximate (down thrown side indicated).
Fault, inferred position.
Strike and dip of bedding, right way up.
Bedding horizontal.
Strike and dip of bedding, facing unknown.
Strike and dip of dominant cleavage surface.
Air photo linear.
Air photo linear, possibly a fault.
Basement contours in metres below present surface; probable, possible.
O 75Jd Bores. depth in metres, to bedrock
Tertiary basalt at depth under sediments
LAUNCESTON
HOBART
LONGFORD
PERTH
WESTBURY
CRESSY
CAMPBELL TOWN
NORTH ESK RIVER
LAKE RIVER
SOUTH ESK RIVER
E F
C D
A B

Fig 2

GSB59

Fig 3 GSB59

TASMANIA – DEPARTMENT OF MINES

LONGFORD BASIN HYDROLOGY

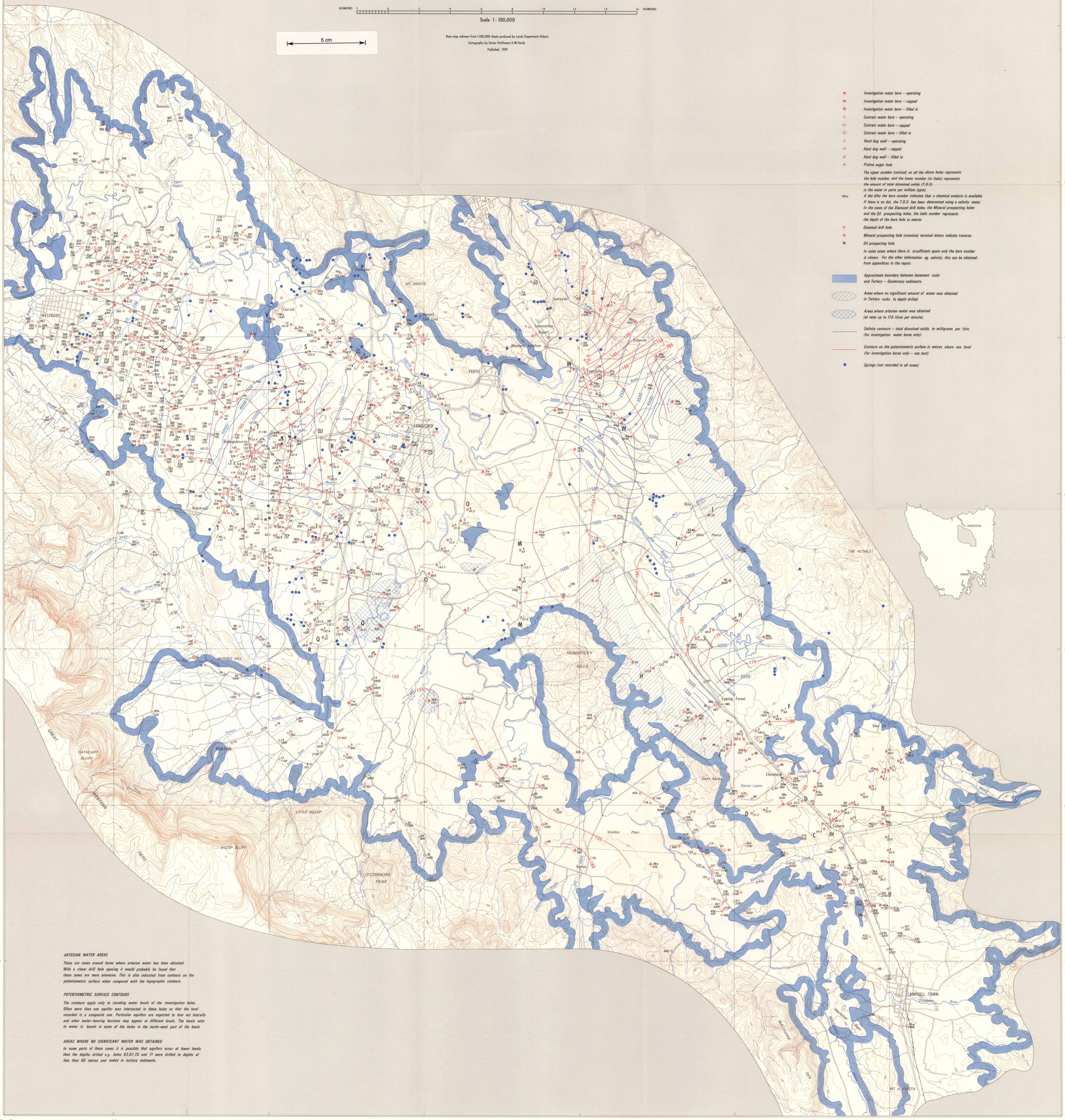
W. L. MATTHEWS B.Sc. 1979

KILOMETRES 2 0 2 4 6 8 10 12 14 16 KILOMETRES

Scale 1 : 100,000

5 cm

Base map redrawn from 1:100,000 sheets produced by Lands Department Hobart.
Cartography by Senior Draftsman D.M.Hardy
Published 1981



Investigation water bore – operating
Investigation water bore – capped
Investigation water bore – filled in
Contract water bore – operating
Contract water bore – capped
Contract water bore – filled in
Hand dug well – operating
Hand dug well – capped
Hand dug well – filled in
Proline auger hole

The upper number (vertical) on all the above holes represents the hole number, and the lower number (in Italic) represents the amount of total dissolved solids (T.D.S) in the water in parts per milliom (ppm).

160• *A dot after the bore number indicates that a chemical analysis is available. If there is no dot, the T.D.S. has been determined using a salinity meter. In the cases of the Diamond drill holes, the Mineral prospecting holes and the Oil prospecting holes, the italic number represents the depth of the bore hole in metres*

Diamond drill hole.
Mineral prospecting hole (uranium) terminal letters indicate traverse.
Oil prospecting hole.

In some cases where there is insufficient space only the bore number is shown. For the other imformation eg. salinity, this can be obtained. from appendices in the report.

Approximate boundary between basement rocks and Tertiary – Quaternary sediments.

Areas where no significant amount of water was obtained in Tertiary rocks to depth drilled.

Areas where artesian water was obtained (at rates up to 115 litres per minute).

Salinity contours – total dissolved solids in milligrams per litre. (for investigation water bores only).

Contours on the potentiometric surface in metres above sea level (for investigation bores only – see text).

Springs (not recorded in all areas)

ARTESIAN WATER AREAS

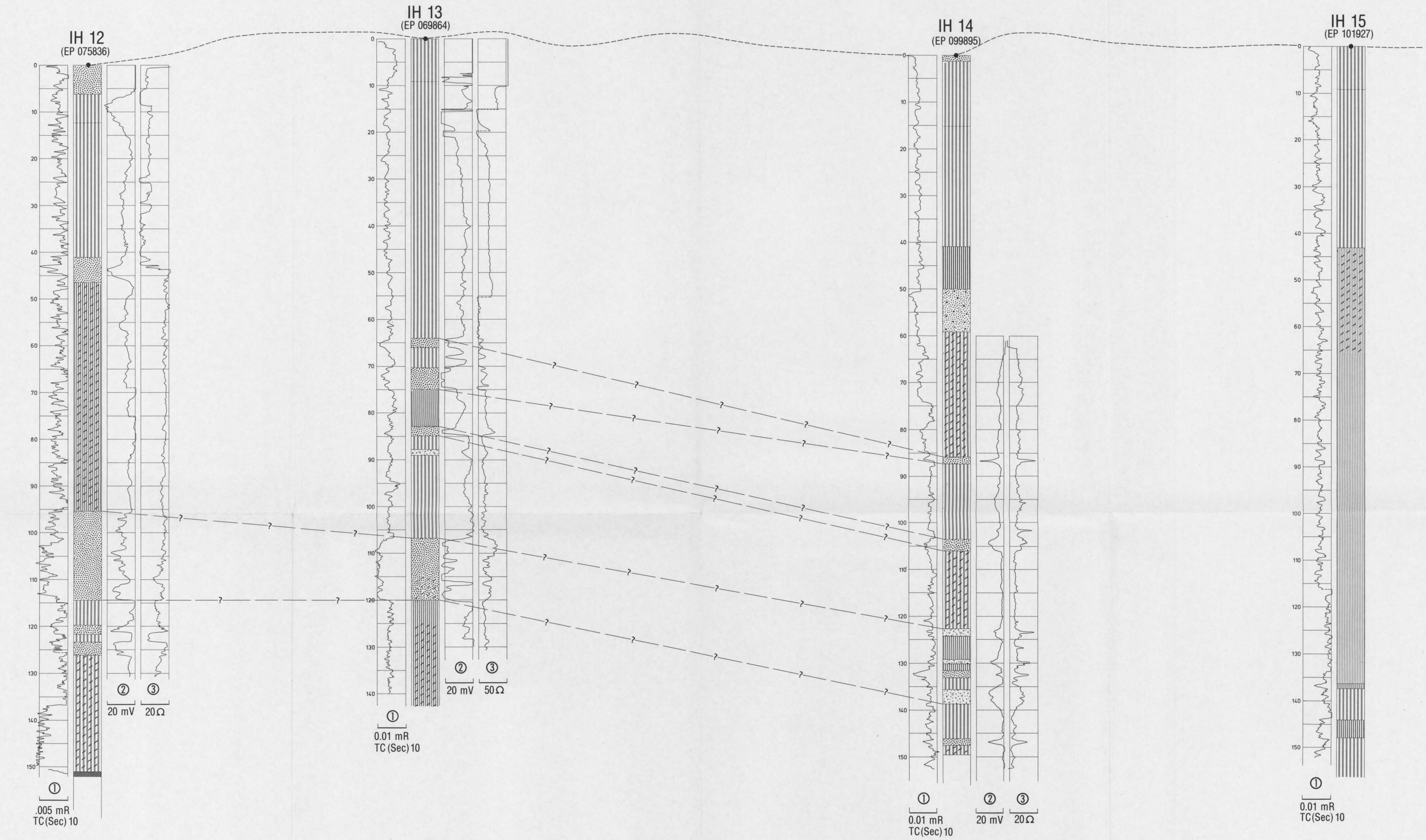
These are zones around bores where artesian water has been obtained. With a closer drill hole spacing it would probably be found that these zones are more extensive. This is also indicated from contours on the potentiometric surface when compared with the topographic contours.

POTENTIOMETRIC SURFACE CONTOURS

The contours apply only to standing water levels of the investigation holes. Often more than one aquifer was intersected in these holes so that the level recorded is a composite one. Particular aquifers are expected to lens out laterally and other water–bearing horizons may appear at different levels. The levels refer to water in basalt in some of the holes in the north–west part of the basin.

AREAS WHERE NO SIGNIFICANT WATER WAS OBTAINED

In some parts of these zones it is possible that aquifers occur at lower levels than the depths drilled e.g. holes 63,67,70 and 71 were drilled to depths of less than 60 metres and ended in tertiary sediments.



ELECTRIC AND LITHOLOGICAL LOGS IH12 - IH15

WITH POSSIBLE CORRELATIONS

W. L. Matthews

0 220 440 660 880 1100 m
Approx. horizontal scale

5 cm

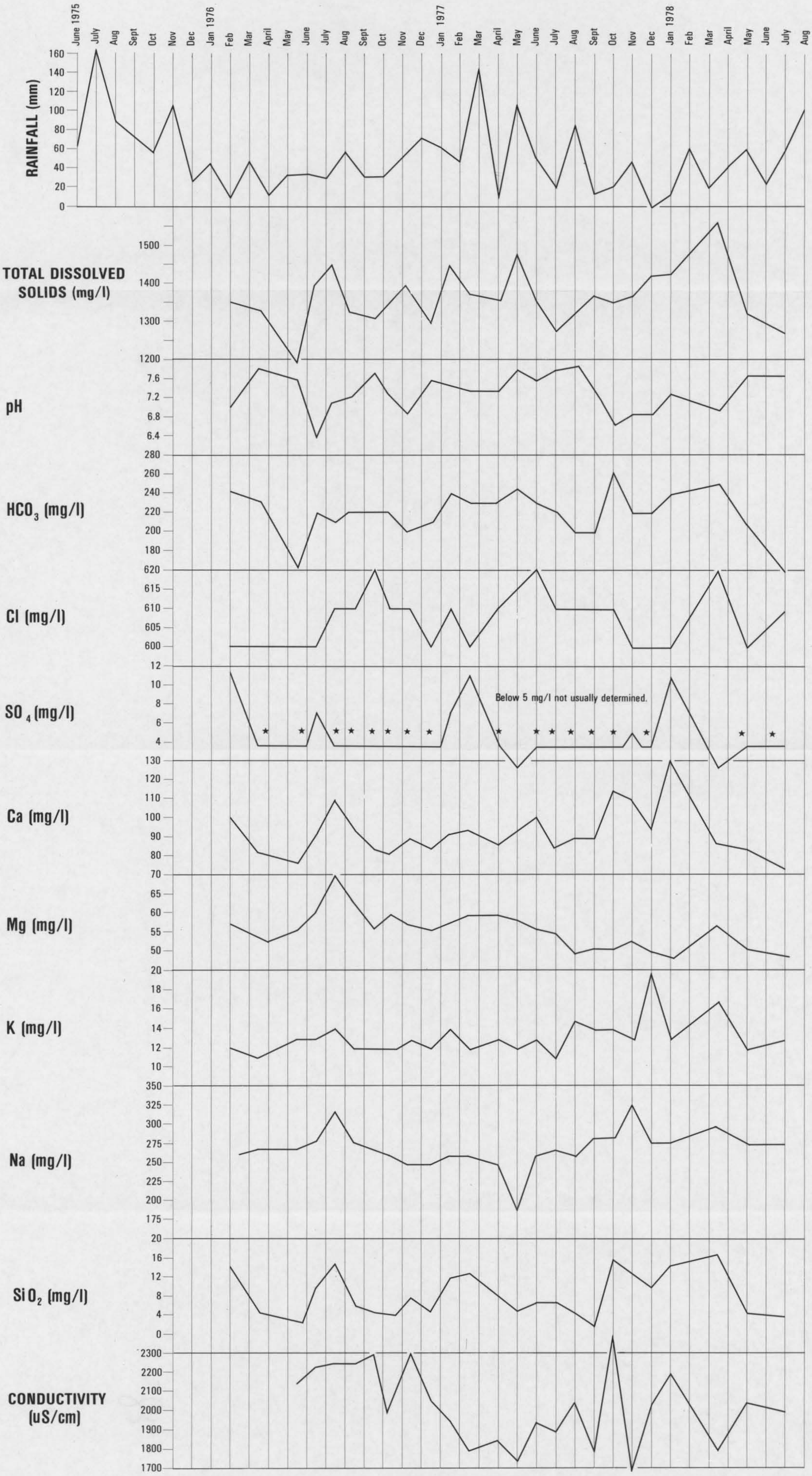
LEGEND

- Sand
- Clay
- Gravelly sand
- Clayey sand and sandy clay
- Mainly sand, a little clay
- Mainly clay, a little sand
- Lignite fragments
- Dolerite

GEOPHYSICAL WELL LOGS

① γ ray (mR/hour)
② Self potential
③ Single point resistance
-------Oxidised to this depth
Depths in metres

Figure 5



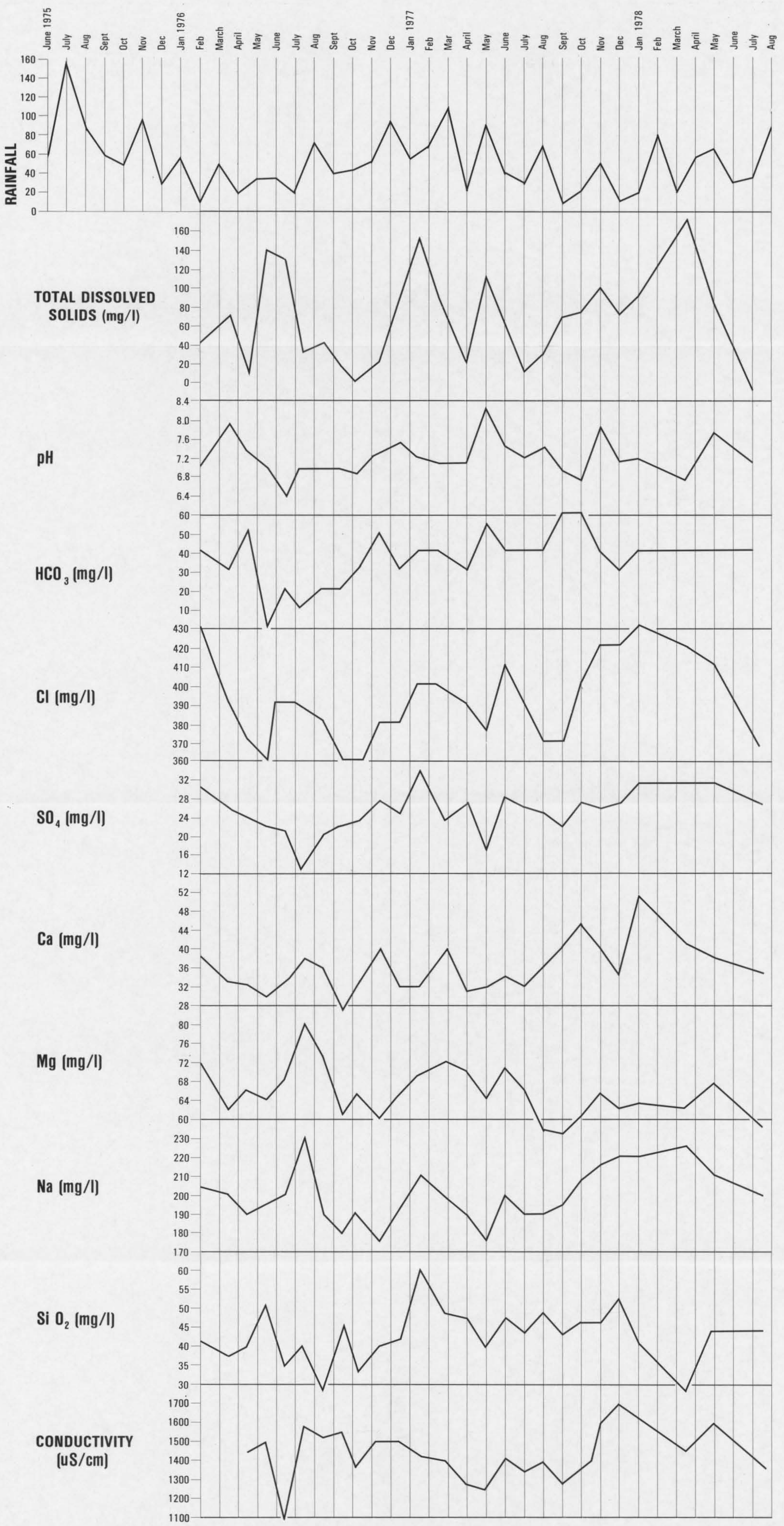
VARIATION OF WATER QUALITY WITH TIME, IH 3 (CRESSY)

W.L. MATTHEWS

Figure 25

5 cm

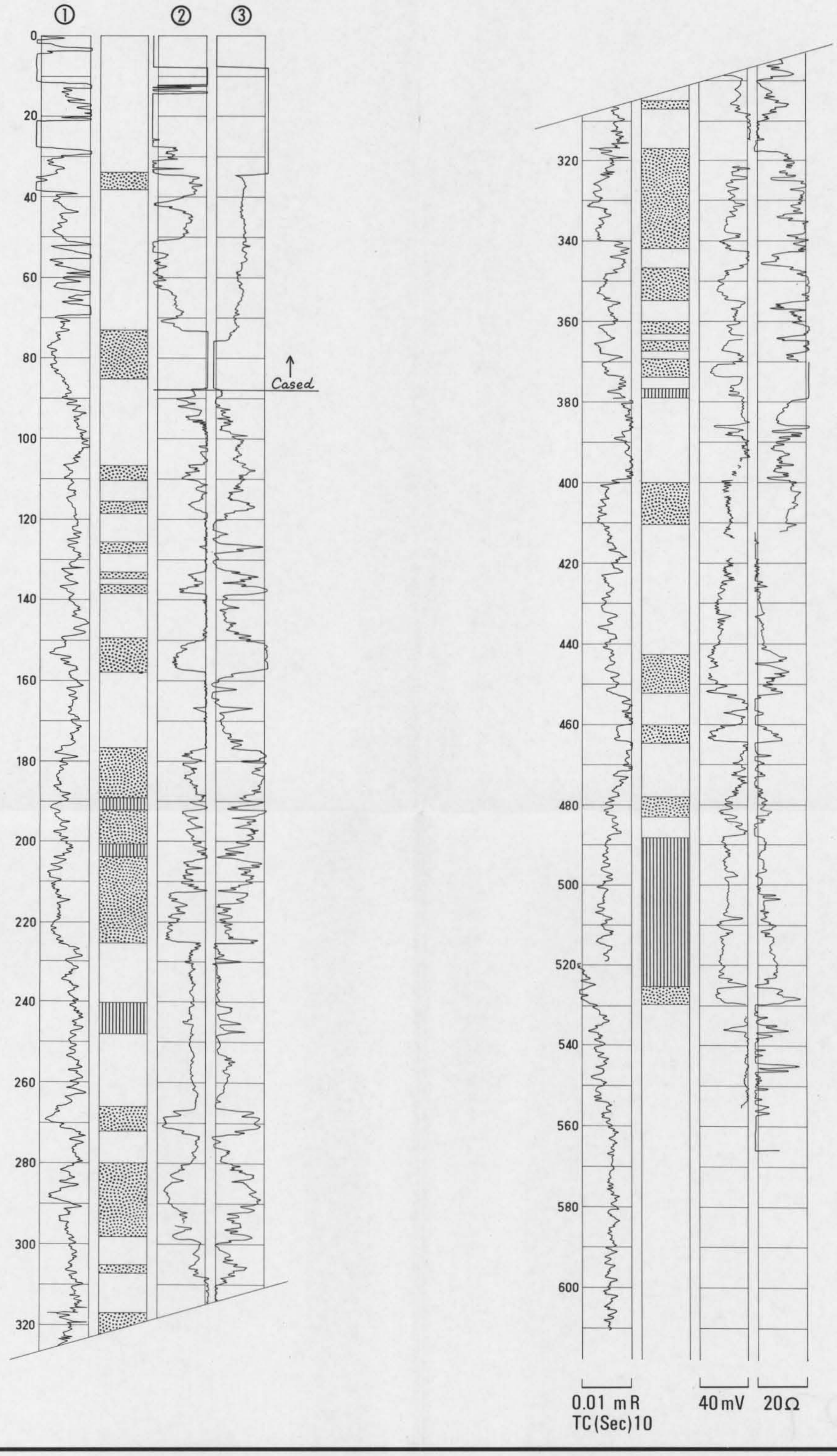
GSB59



VARIATION OF WATER QUALITY WITH TIME, CH 55 (EPPING FOREST) W.L. MATTHEWS

Figure 26

GSB59



ELECTRIC LOG — OIL PROSPECTING HOLE NO. 1

5 cm

LEGEND

Sand

Clayey sand and sandy clay

① ɣ ray (mR/hour)

② Self potential

③ Single point resistance

Depths in metres

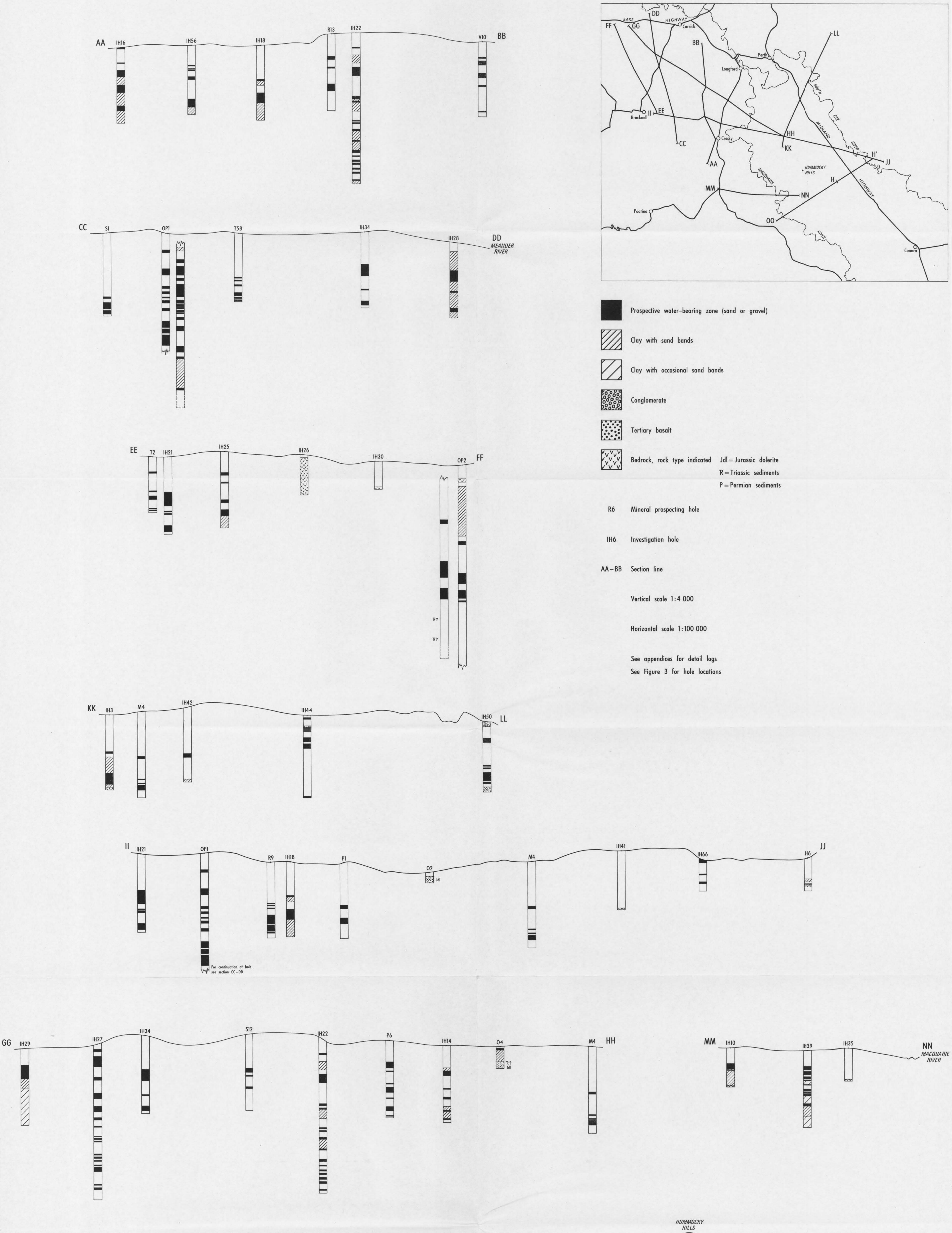
Figure 27 GSB59

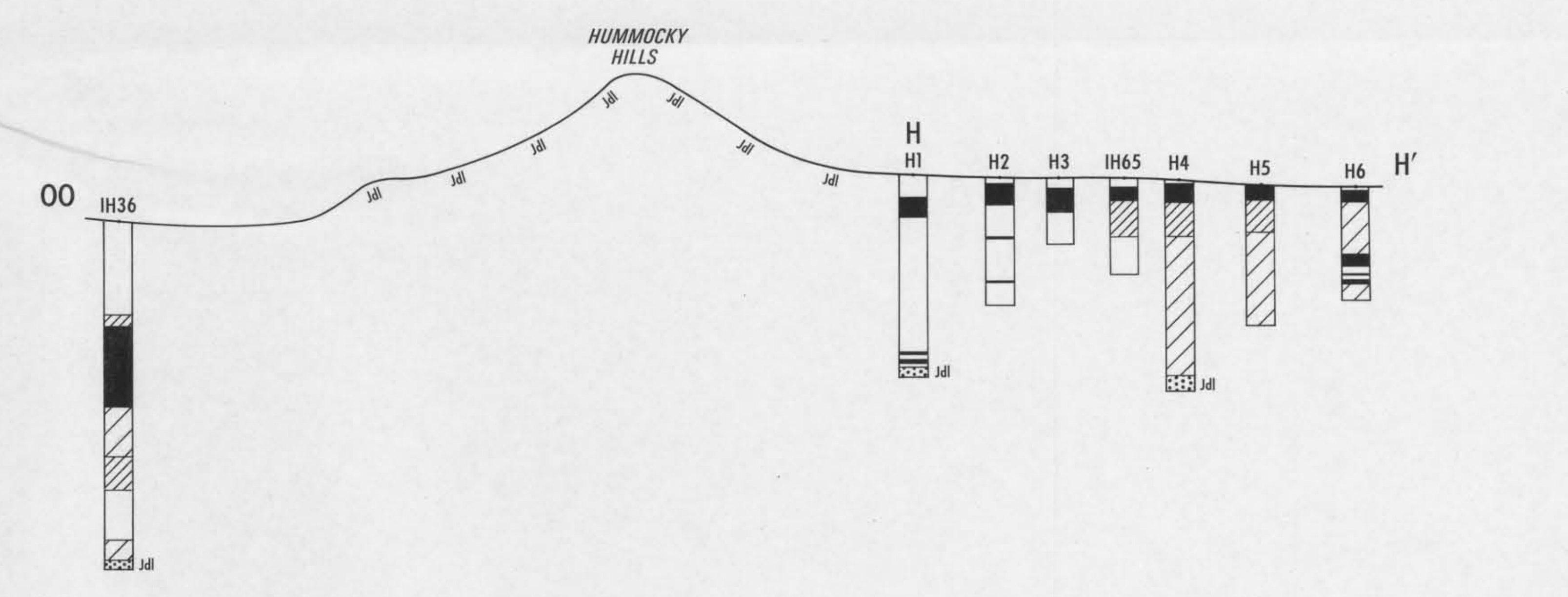
BORE LOG SECTIONS SHOWING PROSPECTIVE WATER – BEARING ZONES

GEOLOGIST :– W. L. MATTHEWS

Figure 28 (Sheet 1) GSB59

CARTOGRAPHY :– G. J. DICKENS





BORE LOG SECTIONS SHOWING PROSPECTIVE WATER – BEARING ZONES

GEOLOGIST :– W. L. MATTHEWS

5 cm

Figure 28 (Sheet 2)

GSB59

CARTOGRAPHY :– G. J. DICKENS

DEPARTMENT OF MINES TASMANIA

STRATIGRAPHIC COLUMNS OF INVESTIGATION HOLES, LONGFORD BASIN

W. L. MATTHEWS

VERTICAL SCALE 1:2 400
HORIZONTAL SCALE 1:100 000
BASE MAP ADAPTED FROM LONGFORD BASIN GEOLOGY MAP
COLUMNS COMPILED FROM SAMPLES OBTAINED AT 1.5m INTERVALS, ELECTRIC LOGS AND DRILLING LOGS

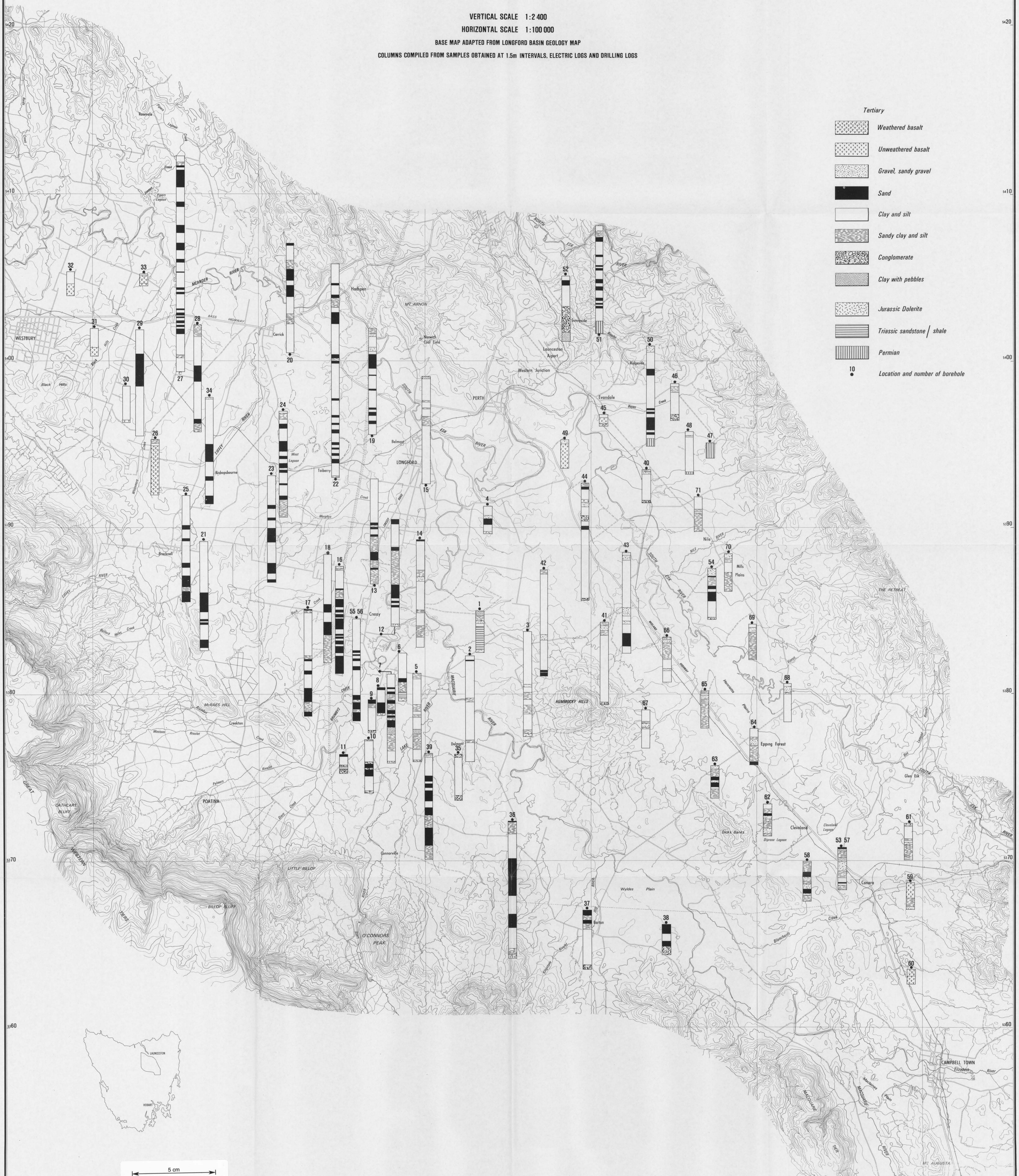


FIGURE 29

APPENDICES

The appendices to this report are included as microfiche in the pocket at the end of the Bulletin. Paper copies of all or part of these appendices can be obtained from the Department of Mines for the cost of reproduction. The locations of all drill holes and wells cited in the appendices (with the exception of Appendix 13) are shown on Figure 3.

Microfiche viewers are available at most major libraries.

LIST OF APPENDICES

APPENDIX 1

Logs of investigation holes

Hole 1 [EP132851]

Location; 6.5 km east of Cressy — *Commenced;* 9.11.67
Elevation; 152.7 m — *Completed;* 20.11.67

Depth (m)	*Description*
0- 3.1	Gritty clay
3.1- 6.1	Sandy clay
6.1-12.2	Light grey clay with some iron oxide pisoliths
12.2-15.2	Sandy clay
15.2-16.8	Grit with fine gravel fragments (angular clear quartz fairly abundant)
16.8-18.3	Yellow clay with a black staining
18.3-19.8	Black clay
19.8-22.9	Dark grey clay
22.9-28.9	Black shale fragments (Triassic)
28.9-30.5	Grey shale
30.5-42.7	Grey-green sandstone fragments
42.7-44.1	Grey shale
44.1-53.3	Grey-green sandstone (feldspathic?)
53.3-55.5	Baked dark shale
55.5-56.4	Fine dolerite with calcite veining

Slotted casing installed 15.2-18.3 m. A pump test at 46 *l*/min produced a drawdown to 8.8 m. Rate increased to 76 *l*/min and the water level drew down quickly to 57.3 m. Surging was performed in an attempt to improve the yield but no sifnificant increase occurred.

Hole 2 [EP126825]

Location; 6.5 km south-east of Cressy — *Commenced;* 20.11.67
Elevation; 145.7 m — *Completed;* 27.11.67

Depth (m)	*Description*
0- 6.1	Light brown clay
6.1- 7.6	Sandy material
7.6- 9.1	Clay with pebbles of sandstone
9.1-13.7	Light brown clay with a few iron oxide pisoliths
13.7-32.0	Dark grey clay
32.0-61.0	Dark grey-brown clay, iron oxide pisoliths
61.0-67.1	Light grey clay, a little sand
67.1-73.2	Light grey clay, a little sand, some wood fragments
73.2-83.8	Light grey clay, a little sand, occasional wood fragments
83.8-121.9	Light grey-brown clay, occasional iron oxide pisoliths
121.9-125.0	Clay, a little sand
125.0-132.6	Grey clay, some wood fragments
132.6-150.9	Grey-brownish clay, occasional iron oxide pisoliths, varying amounts of wood fragments

Appendix 1 (continued)

Hole 2 [EP126825] (continued)

Depth (m)	*Description*
150.9-152.4	Dark brown clay

The samples obtained at the surface did not indicate any promising zones. The hole was bailed for one hour without casing and drew down to about 98.4 m. Boiling was undertaken at a rate of 25-30 *l*/min and the hole was probably making about 6 *l*/min.

Hole 3 [EP162839]

Location; 10 km east of Cressy — *Commenced;* 27.11.67
Elevation: 159.1 m — *Completed;* 20. 1.68

Depth (m)	*Description*
0- 12.2	Brown and grey clay
12.2- 45.7	Dark grey clay, becoming grey-brown
45.7- 67.1	Grey-brown clay
67.1- 77.7	Grey-brown clay, few wood fragments
77.7- 80.8	Grit fragments (angular quartz, quartzite) in clay
80.8- 86.9	Grey-brown clay
86.9- 97.5	Grey-brown clay, some sand
97.5-107.7	Grey-brown clay
107.7-121.9	Grey-brown clay, a little sand
121.9-141.7	Sandy material, some wood fragments
141.7-147.8	Sandy material with clay
147.8-150.9	Clay with probable weathered dolerite
150.9-151.8	Dolerite, band of clay between rather weathered Jdl (May be boulders?)

Electric and sample logging indicated interesting zones at 76.2-80.8 m and below about 119 m. Slotted casing was put against the upper section and much sand and water was delivered. Solid casing was installed to 85.4 m and sand was still delivered with water. It is apparent that much of the water was delivered from the lower zone. The hole was bailed at 83 *l*/min and drew down to 24.4 m from a standing water level of 12.5 m.

Hole 4 [EP138914]

Location; 5 km south-east of Longford — *Commenced;* 7. 2.68
Elevation; 143.9 m — *Completed;* 12. 2.68

Depth (m)	*Description*
0- 3.1	Clayey sand
3.1- 7.6	Clayey grit
7.6- 10.7	Grit to fine gravel, more clay
10.7- 12.2	Dark grey clay
12.2- 13.7	Clayey sand
13.7- 18.3	Grit to fine gravel (up to 15 mm diameter) angular to rounded fragments, some clay
18.3- 22.9	Gritty sandy clay
22.9- 24.4	Gritty sandy clay with wood fragments

Appendix 1 (continued)

Hole 4 [*EP138914*] *(continued)*

Depth (m)	*Description*
24.4- 25.9	Wood fragments
25.9- 27.4	Gritty sandy clay with wood fragments 127 mm of hard conglomerate containing a wood fragment - baked Tertiary? Tb above?
27.4- 38.1	Clay with wood fragments
	0.6 m of unweathered dolerite

Most of section with grit was cased with slotted casing to 26.2 m. The hole was pumped at 99 *l*/min.

Hole 5 [*EP095814*]

Location; 4 km south-east of Cressy   *Commenced;* 16. 2.78
Elevation; 148.4 m   *Completed;* 5. 3.78

Depth (m)	*Description*
0- 9.1	Brown clay, a little sand, limonite fragments
9.1- 13.7	Brown clay
13.7- 36.6	Dark grey clay
36.6- 45.7	Dark grey clay
45.7- 53.3	Grey sand and sandy clay
53.3- 54.9	Sand, few pebbles
54.9- 59.4	Brown clay
59.4- 62.5	Sandy material with some clay and limonite nodules
62.5- 76.2	Grey and brown clay, some wood fragments
76.2- 80.8	Grey and brown clay
80.8- 82.3	Some quartz gravel fragments in clay
82.3- 85.3	Brownish clay
85.3- 91.4	Clayey sand, some wood fragments
91.4-109.7	Brown clay, little sand, some wood fragments
109.7-112.8	Dark grey clay with wood fragments
112.8-115.8	Brown to light grey clay
115.8-118.9	Baked shale(?) fragments
118.9-121.9	Grey clay, sandy clay
121.9-125.0	Blue and brown mottled clay

Below this rock was very hard; 0.6 m drilled but core not recovered. Dolerite chips seen in final samples in field.

Slotted casing installed from 79.3-85.4 m where some pebbles were obtained. The hole was surged and bailed and the flow was estimated at 7 *l*/min.

Appendix 1 (continued)

Hole 6 [*EP083826*]

Location;	Cressy Research Farm	*Commenced;*	12. 3.68
Elevation;	144.5 m	*Completed;*	20. 3.68

Depth (m)	*Description*
0- 4.6	Red-brown clay with limonite nodules
4.6- 13.7	Reddish brown clay, occasional limonite nodules
13.7- 30.5	Dark grey clay, few iron nodules
30.5- 38.1	Dark grey clay
38.1- 42.7	Sandy, clayey material, few gravel fragments
42.7- 48.8	Grey clay, some sand, few gravel fragments
48.8- 57.9	Clay, few limonite fragments
57.9- 67.1	Baked shale, sandstone fragments
67.1- 67.8	Dolerite

Interesting zones from electric log and samples at 36.6-42.7 m. Slotted casing placed at 39.1-42.7 m. The hole was cased to 56.4 m (top of the Triassic) and was surged and bailed to around 9 *l*/min. Casing was withdrawn to 39.6 m and the bottom collapsed. Bailing produced water at the rate of about 4 *l*/min.

Hole 7 [*EP072815*]

Location;	Cressy Research Farm	*Commenced;*	20. 3.68
Elevation;	143.6 m	*Completed;*	28. 3.68

Depth (m)	*Description*
0- 4.6	Brown clay
4.6- 18.3	Dark grey clay, very occasional pebbles
18.3- 21.3	Light grey clay with wood fragments
21.3- 25.9	Grey clayey sand
25.9- 27.4	Clay, some sand, large wood fragments
27.4- 30.5	Grey sandy material, occasional large wood fragments
30.5- 35.1	Sandy material, some large wood fragments and some gravel-chert Jdl? fragments, angular quartz
35.1- 38.1	Grey clayey sand with a few pebbles
38.1- 41.2	Brown-grey clay
41.2- 56.4	Mainly light brown clay-grey clay, a little sand, some large wood fragments
56.4- 73.2	Grey clayey sand, wood fragments a few pebbles from 64-65.5 m
73.2- 82.3	Grey clayey sand, 76.2-79.2 m appears a little sandier.
82.3- 93.0	Grey clayey sand with wood fragments
93.0-114.3	Mainly grey to brown clay, a little sand
114.3-118.9	Sand, sandstone fragments and limonitic material
118.9-128.0	Sand, clay, some sandstone fragments
128.0-130.2	Some weathered dolerite fragments, sand and clay
130.2-130.8	Fine dolerite with calcite veining

Hole artesian from above 91.4 m at 76 *l*/min. The main sand bands being at 56.4-89.9 m from the surface. Only 29.6 m of casing was installed and pumping at 265 *l*/min for 2½ hours resulted in a drawdown to 16.2 m.

Appendix 1 (continued)

Hole 8 [*EP071806*]

Location;	Cressy Research Farm	*Commenced;*	28. 3.68
Elevation;	145.1 m	*Completed;*	3. 4.68

Depth (m)	*Description*
0- 4.6	Sand, some gravelly material
4.6- 7.6	Brown to light grey clay
7.6- 18.3	Dark grey, some brownish clay
18.3- 22.9	Dark grey clay with angular fragments of hard material - iron rich band (grey in colour, not carbonate)
22.9- 25.9	Sandy material with sandstone fragments
25.9- 27.4	Sandy material with some gravel fragments up to 6 mm in diameter
27.4- 29.0	Pebbly material - quartzite, dolerite? fragments
29.0- 38.1	Dominantly sandy material with pebbles, few quartz and quartzite, one moss agate
38.1- 39.6	Fine gravel, sand and dolerite fragments
39.6- 40.2	Dolerite

The hole was artesian at 46 *l*/min. Casing was installed to about 27 m and the hole was pumped over a period of 2½ hours at 265 *l*/min with a drawdown to 21.1 m. After the use of calgon and a period of surging, hole was pumped for 5½ hours with drawdown to 18.3 m.

Hole 9 [*EP069796*]

Location;	Cressy Research Farm	*Commenced;*	22. 4.68
Elevation;	151.5 m	*Completed;*	22. 5.68

Depth (m)	*Description*
0- 1.5	Brown clayey sand
1.5- 7.6	Clayey sand
7.6- 10.7	Grey to brown clay
10.7- 12.2	Clay, some grit
12.2- 25.9	Dark grey clay
25.9- 42.7	Dark grey to brown clay, few angular pebbles
42.7- 44.2	Clay with a few angular quartzite fragments
44.2- 45.7	Dark grey clay
45.7- 47.2	Clay with brown quartzite fragments
47.2- 48.8	Dark grey clay
48.8- 50.3	Sandy clayey material - towards end dolerite and quartz fragments

Water struck between 47.2 and 48.5 m, flow at about 15 *l*/min.

Appendix 1 (continued)

Hole 10 [*EP066774*]

Location;	7 km south of Cressy	*Commenced;*	23. 4.68
Elevation;	158.8 m	*Completed;*	6. 5.68

Depth (m)	*Description*
0- 1.5	Clay with pebbles - some quartzite
1.5- 6.1	Light grey clay - iron stained
6.1- 15.2	Light grey clay becoming darker
15.2- 32.0	Dark grey clay, 75 mm of dark conglomerate (greybilly?)
32.0- 38.1	Sand, sandstone and dolerite fragments with clay
38.1- 39.6	Mainly wood fragments
39.6- 42.7	Sand, wood fragments with dolerite fragments
42.7- 45.7	0.7 m conglomerate; igneous rocks and baked sediments (2 rock sections, one dolerite, one dirty sandstone) followed by baked clay with wood fragments and calcite veining
45.7- 76.2	Igneous fragments (Jdl) sand, wood and clay areas where clay dominant. 0.3 m dolerite with veins
76.2- 77.1	Dolerite

Slotted casing installed 0-5.3, 33.2-38.4, 41.3-44.2 m. The standing water level was at about 6.1 m. Pumped for 4½ hours at 265 *l*/min which resulted in a drawdown to 27.9 m.

Hole 11 [*EP052765*]

Location;	8 km south of Cressy	*Commenced;*	7. 5.68
Elevation;	159.7 m	*Completed;*	13. 5.68

Depth (m)	*Description*
0- 3.1	Sand, some clay
3.1- 7.6	Red clay (iron oxide stained grey-brown clay)
7.6- 16.8	Dark grey clay
16.8- 18.3	76 mm conglomerate with quartzite fragments (greybilly?) 0.5 m sandy clay
18.3- 24.4	Dolerite and sand fragments
24.4- 26.5	Dolerite and sand fragments

8 *l*/min of water on bailing

Hole 12 [*EP075836*]

Location;	1.5 km south-east of Cressy	*Commenced;*	13. 5.68
Elevation;	144.2 m	*Completed;*	30. 5.68

Depth (m)	*Description*
0- 6.1	Sand
6.1- 12.2	Brown clay
12.2- 29.0	Dark grey clay
29.0- 41.1	No sample - clay?
41.1- 45.7	Brown clay (pelletty), a little sand
45.7- 47.2	Brown clay with wood fragments

Appendix 1 (continued)

Hole 12 [*EP075836*] *(continued)*

Depth (m)	*Description*
47.2- 48.8	Brown clay, some wood, occasional angular grit fragments
48.8- 50.3	Sand
50.3- 53.3	Sand, a little clay, wood fragments, occasional grit fragments
53.3- 56.4	Clay, wood fragments, a little sand
56.4- 59.4	Sand with wood fragments
59.4- 62.5	Grey and brown clay with wood fragments
62.5- 83.8	Brown clay with wood fragments, some sand
83.8-102.1	Grey clay, red iron-stained patches with iron nodules, some wood.
102.1-109.7	Sand, clay, wood fragments
109.7-112.8	Clay, a little sand, wood fragments
112.8-115.8	Sand, clay, some wood
115.8-121.9	Light grey, dark grey and reddish clay with wood
121.9-132.6	Variegated clay with wood fragments, very little sand
132.6-153.0	Variegated clay (a little sand at beginning) occasional iron nodules and staining
153.0-154.5	Dolerite

Slotted casing installed at 42.1-44.8 m and this zone pumped at 114 *l*/min for a drawdown to 21.7 m after 3½ hours pumping. Artesian at 9 *l*/min with a standing water level of 2.9 m above ground. Slotted casing was then installed at 36.3-44.4 m and 91.5-94.2 m. This system was artesian at a rate of 114 *l*/min and a head above ground level of at least 6.5 m; at this level water started to leak up the outside of the casing. A 2½ hour pump test resulted in a drawdown to 6.3 m below ground at a pumping rate of 296 *l*/min.

Hole 13 [*EP069864*]

Location;	2 km north of Cressy	*Commenced;*	31. 5.68
Elevation;	157.6 m	*Completed;*	20. 6.68

Depth (m)	*Description*
0- 3.1	Light brown clay, some limonite nodules
3.1- 12.2	Light brown clay
12.2- 30.5	Dark grey clay
30.5- 61.0	Dark grey clay
61.0- 74.7	Clayey sand
74.7- 80.8	Light grey clay, some sand
80.8- 85.3	Sand and light grey clay
85.3- 94.5	Sand and clay
94.5- 97.5	Clay, some sand
97.5-100.6	Coarser sand (almost grit) and clay
100.6-109.7	Dark grey clay
109.7-115.8	Grey sand
115.8-120.4	Grey sand and clay, some wood fragments (soft sandstone fragments?)
120.4-125.0	Sand (samples almost all sand)

Appendix 1 (continued)

Hole 13 [*EP069864*] *(continued)*

Depth (m)	*Description*
125.0-143.3	Sand and clay, some wood fragments
143.3-144.8	Mainly clay in sample
144.8-153.0	Sand and clay

Casing installed to 128 m with slotted casing in sandy zones. Hole pumped at 256 *l*/min for 4½ hours which resulted in a drawdown from a standing water level of 3.1 m to 21.5 m.

Hole 14 [*EP099895*]

Location;	5.5 km south of Longford	*Commenced;*	21. 6.68
Elevation;	141.1 m	*Completed;*	12. 7.68

Depth (m)	*Description*
0- 1.5	Sand
1.5- 15.2	Light grey-brown clay
15.2- 44.2	Dark grey clay
44.2- 51.8	Grey sandy clay
51.8- 56.4	Coarse angular sand, wood fragments
56.4- 59.4	Grit, some fine gravel fragments (quartz and quartzite), wood
59.4- 62.5	Coarse sand, grit, a little wood
62.5- 68.9	Brown clay with grit and wood fragments
68.9- 73.2	Dark brown clay
73.2-100.6	Dark brown material, some clay at beginning a lot of grit. Wood throughout
100.6-121.9	Grey material, mainly wood fragments, some clay, some sand and angular grit
121.9-135.6	Grey clay, a little sand
135.6-144.8	Grey clay becoming sandier
144.8-150.9	Grey clay, wood fragments, some sand
150.9-152.4	Dark brown clay with wood

A gravel band at about 61.0 m from the surface was pumped at 91 *l*/min. Casing was then installed to 140.2 m where there was a "sand" zone on the electric log. This was pumped for 3½ hours at 114 *l*/min with a drawdown to 59.1 m. The hole was artesian at a rate of 9 *l*/min. A pressure gauge indicated about 4.2 m head of pressure above ground level.

Hole 15 [*EP101927*]

Location:	2.5 km south of Longford	*Commenced;*	15. 7.68
Elevation;	146.6 m	*Completed;*	26. 7.68

Depth (m)	*Description*
0- 1.5	Light brown-grey clay, few pebbles
1.5- 9.1	Light grey-brown clay, a few iron oxide pisoliths
9.1- 25.9	Dark grey-brown clay
25.9- 32.0	Dark grey clay, fragments of limonite(?) cemented material (siderite?)
32.0- 42.7	Dark grey clay, few fragments of hard angular limonite(?) cemented material (siderite?)

Appendix 1 (continued)

Hole 15 [*EP101927*] *(continued)*

Depth (m)	*Description*
42.7- 45.7	Dark grey clay becoming lighter
45.7- 50.3	Light grey clay, a little sand
50.3- 56.4	Grey clay, few rotten wood fragments
56.4- 65.5	Grey-brown clay, a little sand
65.5-153.0	Light grey clay, few gritty fragments and a very small amount of sand

Electric log and samples indicate no strong signs of aquifers. Casing was installed to 74.0 m with 21.3 m of solid and 52.7 m of slotted. The standing water level was at 7.6 m and a bailing test over about 2½ hours indicated a flow rate of about 1.5 *l*/min.

Hole 16 [*EP048814*]

Location;	4 km south of Cressy	*Commenced;*	29. 7.68
Elevation;	150.0 m	*Completed;*	16. 8.68

Depth (m)	*Description*
0- 3.1	Brown sand with gravel fragments
3.1- 4.6	Grey and brown clay with grit fragments
4.6- 10.7	Mainly brown clay
10.7- 30.5	Grey clay, a little sand, occasional limonitic fragments at beginning
30.5- 35.1	Brown sandy clay
35.1- 45.7	Sandy clay with dolerite fragments, occasional small pebbles
45.7- 65.5	Brown clayey sand with varying amounts of wood fragments. Some limonite nodules
65.5- 77.7	Clayey sand with sandstone fragments. Triassic?
77.7-102.1	Sand, some samples with grit fragments
102.1-103.6	Sand with abundant wood fragments
103.6-114.3	Brown clay, some sand
114.3-153.0	Sand, varying amounts of clay, wood

Casing was installed to 55.8 m and the hole was pumped at 152 *l*/min. The water level drew down to 11.3 m after 4 hours of pumping. The bore was artesian at 4 *l*/min.

Hole 17 [*EP030851*]

Location;	3.5 km west of Cressy	*Commenced;*	20. 8.68
Elevation;	154.2 m	*Completed;*	29. 8.68

Depth (m)	*Description*
0- 1.5	Grey sand
1.5- 4.6	Clayey sand
4.6- 10.7	Brown clay with iron oxide pisoliths
10.7- 13.7	Brown clay
13.7- 24.4	No sample
24.4- 42.7	Pelletty brown-grey clay, a few iron oxide pisoliths

Appendix 1 (continued)

Hole 17 [EP030851] (continued)

Depth (m)	*Description*
42.7- 67.1	No sample
67.1- 77.7	Pelletty brown clay, some sand, some wood
77.7- 91.4	Pelletty brown clay, wood fragments, a little sand
91.4- 93.0	Pelletty clay, abundant sand, a little wood
93.0- 97.5	Pelletty brown clay, wood fragments
97.5-109.7	Pelletty clay wood fragments, very little sand
109.7-117.3	Pelletty clay, some iron nodules
117.3-132.6	Mainly grey sand, some clay
132.6-147.8	Brown clay, some sand, wood fragments, limonite nodules
147.8-152.4	Sand becoming more abundant, clay, wood fragments

Slotted casing installed from 21.3-68.6 m and hole pumped at 129 *l*/min for 5 hours when the water level was 41.8 m. Standing water level 0.6 m.

Hole 18 [EP043884]

Location; 4.5 km north-west of Cressy — *Commenced;* 30. 8.68
Elevation; 156.7 m — *Completed;* 11. 9.68

Depth (m)	*Description*
0- 16.8	Brown clay, a few limonite nodules
16.8- 54.9	Dark brown clay
54.9- 67.1	Brown pelletty clay
67.1- 79.3	No sample
79.3- 88.4	Coarse grey sand, some wood fragments
88.4-109.7	Pelletty brown clay, a little sand, wood fragments
109.7-125.0	Pelletty clay, a little sand, a few iron nodules, a few sandstone fragments
125.0-152.4	Mainly pelletty clay, some sand, limonite nodules

Standing water level 0.6 m above ground. Slotted casing installed between 70.1 and 88.4 m and the hole pumped for 5 hours at 152 *l*/min for a drawdown to 6.7 m below the surface.

Hole 19 [EP068956]

Location; 3 km west of Longford — *Commenced;* 16. 9.68
Elevation; 147.8 m — *Completed;* 30. 9.68

Depth (m)	*Description*
0- 9.1	Red sandy clay
9.1- 16.8	Quartz and limonite gravel, rounded and angular fragments, vein and granite(?) quartz
16.8- 25.9	Dark brown clay
25.9- 32.0	Gravel, mainly limonitic, some quartz fragments
32.0- 36.6	Brown clay
36.6- 42.7	Wood fragments
42.7- 57.9	Wood fragments with coarse sand and grit fragments
57.9- 68.6	Wood fragments, a few grit fragments
68.6- 70.1	Wood fragments with clay

Appendix 1 (continued)

Hole 19 [*EP068956*] *(continued)*

Depth (m)	*Description*
70.1- 79.3	Wood fragments
79.3- 86.9	Wood fragments with grit
86.9- 91.4	Wood fragments
91.4- 99.1	Wood with sand and grit
99.1-103.6	Wood fragments
103.6-118.9	Wood with sand
118.9-143.3	Wood with sand, some clay
143.3-152.4	Wood with coarse sand, fine grit

Slotted casing installed from 39.6-45.7 m and 48.8-50.9 m. The standing water level was 2 m below the surface. Pumping at a rate of about 152 *l*/min over 4 hours resulted in a drawdown to 11.7 m below surface.

Hole 20 [*EQ018006*]

Location; 2 km south-east of Carrick *Commenced;* 1.10.68
Elevation; 166.4 m *Completed;* 18.10.68

Depth (m)	*Description*
0- 1.5	Sandy lateritic material
1.5- 12.2	Red clay (iron-stained)
12.2- 24.4	Grey clay, some iron nodules
24.4- 50.3	Pink clay with abundant sand, some limonite nodules
50.3- 54.9	Dominantly clay, a little sand
54.9- 67.1	Clay, variable amounts of sand, limonite fragments
67.1- 79.3	Pink clay and sand, limonite nodules
79.3- 85.4	Clay, a little sand
85.4- 91.4	Sand with clay
91.4- 99.1	Pink clay and sand, limonite fragments
99.1-112.8	Grey clay, less sand, limonite fragments
112.8-114.3	Clay, a little sand with wood fragments
114.3-117.3	Wood fragments
117.3-121.9	Clay
121.9-153.0	Red and grey clay, very little sand, some limonite nodules

Slotted casing was installed from 30.5-54.9 m and standing water level was 5.7 m below the surface. Pumped at 129 *l*/min for 4 hours for a drawdown to 35.9 m below the surface.

Appendix 1 (continued)

Hole 21 [*DP969895*]

Location;	2 km north-east of Bracknell	*Commenced;*	22.10.68
Elevation;	181.7 m	*Completed;*	8.11.68

Depth (m)	*Description*
0- 42.7	Brown and red clay, much in pellets
42.7- 51.8	No sample
51.8- 74.7	Dark brown clay (one sample of reddish clay), very little sand
74.7- 91.4	Mainly sand
91.4-106.7	Mainly sand
106.7-111.3	Clay
111.3-115.8	Wood fragments
115.8-150.9	Wood, clay, very little sand
150.9-156.1	Wood, sand, clay

Slotted casing installed between 48.8-54.9 m and 76.2-100.6 m. Standing water level was 19.8 m below the surface and a pump test over a period of 3+ hours produced a drawdown to 52 m below the surface.

Hole 22 [*EP046929*]

Location;	2 km south-east of Toiberry	*Commenced;*	12.11.68
Elevation;	163.4 m	*Completed;*	6.12.68

Depth (m)	*Description*
0- 21.3	Red and brown clay, some limonite nodules at beginning, pelletty clay towards end
21.3- 30.5	Reddish pelletty clay, some coarse quartz sand in one or two bags
30.5- 42.7	No sample
42.7- 73.2	Pelletty clay - red-brown
73.2- 85.4	Pelletty clay - red-brown
85.4-114.3	Red-brown pelletty clay, wood fragments
114.3-152.4	Red-brown pelletty clay, wood fragments no sand seen, some hard angular brown fragments in parts
152.4-153.9	Wood fragments
153.9-157.0	Sand, clay, wood
157.0-178.3	Dominantly wood and clay
178.3-179.8	Sand and wood
179.8-184.4	Wood fragments
184.4-185.9	Sand and wood
185.9-187.5	Wood fragments
187.5-211.8	Wood, clay and wood
211.8-216.4	Sand and wood
216.4-221.0	Wood
221.0-228.6	Sand and wood, wood fragments
228.6-234.7	Wood and sand
234.7-240.8	Mainly wood
240.8-242.3	Clay sand, wood
242.3-245.4	Wood and sand
245.4-272.8	Dominantly wood fragments
272.8-275.9	Sand and wood
275.9-280.4	Wood fragments

Appendix 1 (continued)

Hole 22 [EP046929] (continued)

Depth (m)	*Description*
280.4-289.6	Sand and wood
289.6-304.8	Wood, clay, some sand

Casing installed to 152.4 m. Standing water level was 14.0 m below the surface. Pumped for 5 hours at 136 *l*/min and produced a drawdown to 38.7 m. Casing was withdrawn to 27 m from the surface and the water at about 24.4 m is artesian at a slow rate.

Hole 23 [EP008930]

Location; 3 km west of Toiberry — *Commenced;* 9.12.68
Elevation; 171.6 m — *Completed;* 16.12.68

Depth (m)	*Description*
0- 1.5	Clay with large iron pisolites
1.5- 10.7	Reddish clay with iron nodules (small)
10.7- 18.3	Brown clay with small wood fragments
18.3- 21.3	Dark grey plastic clay
21.3- 24.4	Grey clay, some grit fragments (quartz and iron)
24.4- 41.2	Brown-grey clay with some iron nodules
41.2- 48.8	Grey sandy clay
48.8- 50.3	Grey clay
50.3- 56.4	Grey clay, some sand, large angular limonite fragments
56.4- 79.3	Clay, some angular fragments of limonite
79.3- 86.9	Grey sandy clay
86.9- 91.4	Clayey sand
91.4- 94.5	Clay, sand, wood fragments
94.5- 97.5	Sand and wood
97.5- 99.1	Reddish brown clay
99.1-102.1	Sand and clay
102.1-105.2	Grey clay
105.2-106.7	Grey clay and sand
106.7-126.5	Clay with a little sand
126.5-135.6	Clay with sand (more abundant)
135.6-146.3	Dominantly sand
146.3-153.0	Sand and wood fragments

Slotted casing (one length of about 3 m) every 6 m from 36.6 to 103.6 m below surface. Pumped at 136 *l*/min over 4 hours and the drawdown was to 35 m from a standing water level of 16.2 m.

Hole 24 [EP018971]

Location; 5 km south of Carrick — *Commenced;* 28. 1.69
Elevation; 178.9 m — *Completed;* 13. 2.69

Depth (m)	*Description*
0- 1.5	Sandy clay with iron (oxide) nodules
1.5- 10.7	Pink sandy clay, occasional iron (oxide) nodules at start

Appendix 1 (continued)

Hole 24 [EP018971] (continued)

Depth (m)	*Description*
10.7- 13.7	Brown clay
13.7- 19.8	Brown clay, iron (oxide) fragments
19.8- 25.9	Sand and clay with iron (oxide) fragments
25.9- 32.0	Brown clay, grey clay, some wood fragments
32.0- 35.1	No return
35.1- 38.1	Brown clay
38.1- 41.2	No return
41.2- 53.3	Coarse sand, grit (angular) mainly of quartz, some wood fragments
53.3- 56.4	Clay and wood
56.4- 62.5	Clay, wood, angular siderite(?) fragments
62.5- 73.2	Clay with some concentrations of wood fragments, grit (iron oxide and quartz fragments)
73.2- 76.2	Clay and siderite(?) fragments
76.2- 85.4	Clay and wood fragments
85.4- 96.0	Clay, siderite(?) fragments, a little sand, wood fragments
96.0- 99.1	Clay
99.1-134.1	Clay and wood fragments
134.1-138.7	Sand and clay
138.7-153.0	Wood fragments and clay

Slotted casing installed from 15.2-76.2 m. Standing water level at 8.4 m. A pump test at 144 *l*/min drew the water level down to 19.2 m below the surface after 3 hours of pumping.

Hole 25 [DP507920]

Location; 3.5 km north of Bracknell — *Commenced;* 14. 2.69
Elevation; 176.2 m — *Completed;* 26. 2.69

Depth (m)	*Description*
0- 1.5	Soil and brown clay
1.5- 12.2	Light brown clay, few iron oxide(?) fragments
12.2- 30.5	Dark brown to grey clay
30.5- 48.8	Dark brown to grey plastic clay
48.8- 51.8	Sand and clay
51.8- 61.0	Dark brown-grey plastic clay
61.0- 67.1	Clay, some wood fragments
67.1- 73.2	Black to brown plastic clay, a little sand
73.2- 82.3	Grey brown plastic clay, a little sand
82.3- 97.5	Grey clay, sand becoming more abundant
97.5-102.1	Sand, some clay
102.1-114.3	Grey clay
114.3-129.5	Sand and clay (some sandstone fragments)
129.5-140.2	Clay, a little sand, some wood fragments
140.2-141.7	Grey plastic clay
141.7-144.8	Sand and clay
144.8-153.0	Grey clay, a little sand, some wood fragments

Standing water level 8.5 m. A pump test at 136 *l*/min over 5 hours resulted in a drawdown to 43.8 m.

Appendix 1 (continued)

Hole 26 [*DP937956*]

Location; 1 km south of Whitemore — *Commenced;* 27. 2.69
Elevation; 178.9 m — *Completed;* 19. 3.69

Depth (m)	*Description*
0- 1.5	Clayey sand
1.5- 4.6	Sandy clay
4.6- 7.6	Rounded gravel (up to 6 mm)
7.6- 38.1	Basalt, fine and weathered
38.1- 59.4	Basalt fragments
59.4- 64.0	Fine grained, veined vesicular basalt; 2.1 m recovered
64.0- 71.6	Basalt fragments
71.6- 79.3	Slightly weathered

Standing water level 6.2 m below the surface. Pump test at 167 *l*/min over about 22 hours drew the level down to 16.2 m below the surface.

Hole 27 [*DP954992*]

Location; 3 km north of Whitemore — *Commenced;* 20. 3.69
Elevation; 171.0 m — *Completed;* 22. 4.69

Depth (m)	*Description*
0- 1.5	Brown clay
1.5- 7.6	Light brown clay
7.6- 10.7	Light brown clayey sand
10.7- 12.2	Light brown sandy clay with large angular iron oxide(?) fragments
12.2- 19.8	Dark grey clay (some plastic)
19.8- 33.5	Light grey-brown sandy clay, becoming very sandy
33.5- 36.6	Coarse sand
36.6- 48.8	Light grey sand and clay
48.8- 53.3	Light brown clay
53.3- 76.2	Brown clay with varying amounts of wood fragments
76.2- 85.4	Mainly wood fragments
85.4-109.7	Brown clay, varying amounts of wood fragments, a little sand
109.7-111.3	Brown clay and wood fragments
111.3-114.3	Clay and sand
114.3-146.3	Clay and wood fragments
146.3-149.4	Clay and sand
149.4-182.9	Clay and wood fragments (mainly wood fragments from 161.6-176.8) very little sand
182.9-199.7	Clay and wood fragments
199.7-222.5	Mainly wood fragments, some clay
222.5-227.1	Clay, wood fragments, a little sand
227.1-243.8	Mainly wood, some clay
243.8-260.6	Mainly wood fragments, some clay, very little sand
260.6-271.3	Clay and wood fragments, a little sand
271.3-280.4	Mainly wood fragments
280.4-281.9	Clay and wood fragments
281.9-308.5	Mainly wood fragments, a little clay

Appendix 1 (continued)

Hole 27 [*DP954992*] *(continued)*

Casing installed to 152.4 m with slotted intervals. Standing water level 14.8 m. A pump test over 4 hours at 133 *l*/min produced a drawdown to 45.5 m below the surface.

Hole 28 [*DQ962023*]

Location; 5 km east of Hagley — *Commenced;* 23. 4.69
Elevation; 161.6 m — *Completed;* 5. 5.69

Depth (m)	*Description*
0- 1.5	Brown to grey sand
1.5- 3.1	Clayey sand
3.1- 15.2	Light brown sandy clay
15.2- 18.3	Black to dark grey clay (wood causing dark colour)
18.3- 48.8	Grey clay and sandy clay, some wood fragments
48.8- 53.3	Wood fragments
53.3- 54.9	Grey clay and wood
54.9- 62.5	Grey sandy clay, some wood fragments
62.5- 65.5	Sandy clay and abundant wood fragments
65.5- 68.6	Sand and wood fragments, some clay
68.6- 97.5	Sandy clay, some wood fragments
97.5-131.1	Grey sandy clay, a little wood
131.1-132.6	Wood fragments
132.6-140.2	Sandy clay, abundant wood fragments
140.2-153.0	Grey sandy clay with wood fragments

Slotted casing installed between 30.5 - 33.5 m and 61.0 - 76.2 m. Standing water level at 7.9 m below surface level. A pump test lasting 4 hours at a rate of 133 *l*/min produced a drawdown to 41.5 m.

Hole 29 [*DQ928022*]

Location; 2 km east of Hagley — *Commenced;* 5. 5.69
Elevation; 153.9 m — *Completed;* 22. 5.69

Depth (m)	*Description*
0- 1.5	Brown soil
1.5- 6.1	Iron-stained grey clay, a few iron oxide nodules
6.1- 10.7	Grey and light brown clay
10.7- 15.2	Dark grey plastic clay
15.2- 18.3	Brown clay, a few iron oxide nodules
18.3- 33.5	Grey brown clay, green and brown clay
33.5- 45.7	Grey sandy clay, some solid blue clay fragments, wood fragments towards end
45.7- 48.8	Very sandy grey clay
48.8- 51.8	Clayey sand with wood fragments
51.8- 65.5	Sand and clay
65.5- 85.3	Grey sandy clay
85.3- 88.4	Clay, sand and wood fragments
88.4-106.7	Grey clay with a little sand, variable amounts of wood fragments
106.7-118.9	Mainly clay, a little sand, some wood fragments
118.9-143.3	Grey clay, some sand in some zones, some wood fragments

Appendix 1 (continued)

Hole 29 [*DQ928022*] *(continued)*

Depth (m)	*Description*
143.3-153.0	Grey clay a little wood

Slotted casing installed from 27.4-45.7 m. A pump test lasting about 4 hours at a rate of 114 *l*/min produced a drawdown of 28.7 m from a standing water level of 4.0 m below the surface.

Hole 30 [DQ922987]

Location;	4.5 km south-east of Hagley	*Commenced;*	23. 5.69
Elevation;	174.7 m	*Completed;*	5. 6.69

Depth (m)	*Description*
0- 1.5	Brown clay with iron oxide fragments, grit size. Some quartz grit
1.5- 3.1	Dark brown clay (?)
3.1- 10.7	Brown to grey plastic clay
10.7- 12.2	Dark grey and brown plastic clay
12.2- 41.2	Clay pellets, weathered basalt fragments?
41.2- 51.8	Grey and dark brown clay pellets, fine grained basalt fragments?
51.8- 53.3	Basalt fragments
53.3- 53.7	Basalt, very broken

Standing water level 3 m below the surface. A pump test lasting 3½ hours at a rate of 152 *l*/min produced a drawdown to 25.4 m below the surface.

Hole 31 [*DQ901020*]

Location;	1 km south-west of Hagley	*Commenced;*	5. 6.69
Elevation;	155.8 m	*Completed;*	12. 6.69

Depth (m)	*Description*
0- 1.5	Brown soil
1.5- 9.1	Light brown to grey clay, a few iron nodules
9.1- 13.7	Medium grey to brown clay
13.7- 29.0	Dark grey-brown plastic clay
29.0- 39.6	Weathered basalt fragments
39.6- 40.8	Fine grained dark unweathered basalt with occasional calcite veins

Slotted casing installed between 0 and 39.6 m. Standing water level 0.2 m above ground level. Hole pumped at 15 *l*/min for 4½ hours for a drawdown of 39.4 m.

Appendix 1 (continued)

Hole 32 [*DP889054*]

Location;	3 km north-east of Westbury	*Commenced;*	13. 6.69
Elevation;	178.3 m	*Completed;*	25. 6.69

Depth (m)	*Description*
0- 1.5	Red clay soil
1.5- 3.1	Red-brown clay
3.1- 10.7	Light grey-brown clay
10.7- 12.2	Dark grey clay
12.2- 30.5	Basalt fragments

Slotted casing installed between 12.2 and 30.5 m. Standing water level was 5.5 m and a pump test of 21 hours at 280 *l*/min produced a drawdown to 22.1 m.

Hole 33 [*DP931052*]

Location;	3 km north-east of Hagley	*Commenced;*	25. 6.69
Elevation;	162.5 m	*Completed;*	1. 7.69

Depth (m)	*Description*
0- 1.5	Dark brown clayey soil
1.5- 16.2	Weathered basalt fragments
16.2- 17.4	Unweathered vesicular basalt

Slotted casing from 3.1-12.2 m. Standing water level 1 m below surface. A pump test at a rate of 296 *l*/min produced a drawdown to 5.5 m after 24½ hours pumping.

Hole 34 [*DQ968978*]

Location;	3 km north-east of Whitemore	*Commenced;*	2. 7.69
Elevation;	186.2 m	*Completed;*	15. 7.69

Depth (m)	*Description*
0- 1.5	Gravel, limonite nodules
1.5- 15.2	Brown and grey clay with red iron oxide staining
15.2- 42.7	Plastic dark grey-brown clay
42.7- 54.9	Light brown and cream clay pellets
54.9- 73.2	Red and dark brown clay pellets becoming more plastic towards end
73.2- 76.2	Brown clay, some sandy material, abundant wood fragments
76.2- 82.3	Mainly wood fragments, a little clay
82.3- 83.8	Sand and wood fragments
83.8-103.6	Wood fragments, some sand in some horizons
103.6-106.7	Wood fragments
106.7-132.6	Clay, wood fragments, a little sand in places
132.6-140.2	Clay, occasional wood fragments
140.2-143.3	Clay and wood fragments
143.3-149.4	Sand with wood fragments
149.4-153.0	Clay and wood fragments

Appendix 1 (continued)

Hole 34 [DQ968978] (continued)

Slotted casing was installed from 56.4-88.4 m. A pump test at 129 *l*/min produced a drawdown to 45.6 m from a standing water level of 10.1 m below the surface after a period of 3½ hours pumping.

Hole 35 [EP123766]

Location; 10 km south-east of Cressy *Commenced;* 24. 9.69
Elevation; 174.3 m *Completed;* 2.10.69

Depth (m)	*Description*
0- 3.1	Sand, grit and gravel
3.1- 24.4	Light grey and brown clay, a little gritty material, some larger ironstone fragments
24.4- 48.8	Gap in samples (sticky clay - driller)
48.8- 59.4	Dark grey-brown plastic clay
59.4- 61.0	Grey clay, a few wood fragments
61.0- 62.5	Clay and dolerite fragments
62.5- 62.8	Conglomerate? with mainly dolerite fragments
62.8- 65.5	Clay and dolerite fragments

No appreciable water

Hole 36 [EP153726]

Location; 18 km west of Cleveland *Commenced;* 3.10.69
Elevation; 160.6 m *Completed;* 25.11.69

Depth (m)	*Description*
0- 1.5	Fine brown sand
1.5- 18.3	Light brown sandy clay, sand decreasing from beginning, some limonitic fragments
18.3- 22.9	Light brown clay
22.9- 38.1	Light grey and brown clay
38.1- 50.3	No sample
50.3- 59.4	Darker grey clay, a few sand grains
59.4- 61.0	Grey sandy clay
61.0- 71.6	Grey clay with some sand
71.6-106.7	Sand, very abundant in grey clay
106.7-128.0	Grey sand with clay pellets
128.0-132.6	Mainly clay, some sand
132.6-135.6	Sand and clay
135.6-152.4	Clay and wood fragments
152.4-164.6	Wood fragments and clay
164.6-172.2	Clay with a little sand, wood fragments, some limonitic fragments
172.2-179.8	Brown clay, a little sand
179.8-181.4	Brown sandy clay
181.4-192.0	Brown clay with sandy horizons, a few wood fragments
192.0-195.1	Dolerite fragments
195.1-196.9	Dolerite

Slotted casing installed between 61.0 and 111.3 m. Standing water level at 14.7 m. After pumping at 235 *l*/min for 4½ hours the water level was at 39.0 m.

Appendix 1 (continued)

Hole 37 [*EP196670*]

Location;	16.5 km west of Conara	*Commenced;*	26.11.69
Elevation;	164.0 m	*Completed;*	3.12.69

Depth (m)	*Description*
0- 4.6	Sand, some gravel
4.6- 7.6	Brown sand
7.6- 13.7	Grey clayey sand
13.7- 18.3	Grey-brown sand
18.3- 27.4	Grey clay and sand, sand becoming less abundant
27.4- 61.0	Dark grey-brown clay, sandy at beginning, a few pebbles (one rounded quartzite pebble) towards end. Becoming plastic
61.0- 79.2	Dark grey plastic clay, 40 mm fragment of sandstone in first 1.5 m
79.2- 82.3	Dolerite fragments, very fine
82.3- 83.8	Conglomerate, final 130 mm may be dolerite. Dolerite boulders in quartz matrix, core very broken

Slotted casing installed to 51.8 m and hole bailed at 83 *l*/min for eight hours. Standing water level at 3 m below the surface. At the end of bailing level at 8.5 m.

Hole 38 [*EP247661*]

Location;	11.5 km west of Conara	*Commenced;*	4.12.69
Elevation;	160.3 m	*Completed;*	12.12.69

Depth (m)	*Description*
0- 6.1	Brown clayey sand
6.1- 7.6	Brown sand
7.6- 10.7	Clayey sand
10.7- 12.2	Gravelly red clay, (iron oxide pisoliths)
12.2- 19.8	Red clay with iron oxide pisoliths and occasional quartz pebbles
19.8- 32.0	Red-grey sandy clay
32.0- 35.1	Red clay with dolerite fragments
35.1- 36.0	Hard conglomerate with quartz and dolerite boulders with a sandy matrix
36.0- 42.7	Dolerite fragments with some quartz fragments

Slotted casing installed between 9.1-21.3 m and 33.5-36.6 m. Pumped at 265 *l*/min for 3 hours; produced a drawdown to 22.9 m from a standing water level of 8.3 m below the surface.

Appendix 1 (continued)

Hole 39 [*EP104767*]

Location;	9 km south-east of Cressy	*Commenced;*	29. 1.70
Elevation;	151.8 m	*Completed;*	9. 2.70

Depth (m)	*Description*
0- 1.5	Silty soil and brown plastic clay
1.5- 3.1	Sandy brown clay, a few gravel fragments
3.1- 4.6	Gravel (fine conglomerate size), quartz and limonite nodules
4.6- 12.2	Grey clay and gravel
12.2- 15.2	Brown clay, a little gravel
15.2- 18.3	Grey clay
18.3- 33.5	No return (plastic clay stuck in hole)
33.5- 41.2	Grey clayey sand
41.2- 44.2	Clayey sand with angular hard fragments
44.2- 53.3	Sandy clay some wood fragments
53.3- 61.0	Grey sand and clay
61.0- 70.1	Sand and grey clay, some wood fragments
70.1- 73.2	Grey sand
73.2- 97.5	Sand and clay with abundant wood fragments in some zones
97.5- 99.1	Sand and wood fragments
99.1-102.1	Sand, clay and wood fragments
102.1-106.7	Sand, clay and abundant wood fragments
106.7-108.2	Sand and wood fragments
108.2-109.7	Sand, clay and wood fragments
109.7-132.6	Mainly sand, some clay, wood fragments abundant at some levels
132.6-144.8	Abundant wood fragments, sand and clay
144.8-153.0	Sandy clay

Standing water level above the ground surface and the bore flowed at 38 *l*/min. 24.4 m of slotted casing installed over intervals to a depth of 61 m. Hole pumped at a rate of 296 *l*/min with a drawdown to 16.4 m from the surface after 5 hours of pumping.

Hole 40 [*EP234937*]

Location;	5.5 km south-east of Evandale	*Commenced;*	17. 2.70
Elevation;	157.6 m	*Completed;*	24. 2.70

Depth (m)	*Description*
0- 1.5	Brown clayey sand
1.5- 6.1	Coarse sand and grit
6.1- 10.7	Brown clay and occasional quartz gravel fragments
10.7- 35.1	Dark grey and brown plastic clay with occasional conglomerate fragments at beginning
35.1- 44.2	Brown plastic clay
44.2- 45.7	Weathered dolerite fragments

46.3 m of casing installed, some slotted. Standing water level was one metre below the surface. A bailing test over 2 hours indicated a rate of 19 *l*/min was being produced with the maximum drawdown.

Appendix 1 (continued)

Hole 41 [*EP209845*]

Location;	2 km west of Powranna	*Commenced;*	17. 2.70
Elevation;	187.2 m	*Completed;*	24. 2.70

Depth (m)	*Description*
0- 4.6	Brown sandy clay
4.6- 16.8	Gravel and gravelly clay
16.8- 21.3	Grey sandy clay, some gravel fragments
21.3- 45.7	Grey and brown clay, a little silty material, occasional wood fragments
45.7-116.4	Brown and grey clay (45.7-∿54.9 m some very fine sand grains in clay), some wood fragments
116.4-117.3	Conglomerate with quartzite pebbles (only top 0.3 m of run recovered)

45.7 m of casing installed, some slotted. Standing water level was at 7.6 m from the surface. The hole was bailed for 2 hours and produced at a rate of about 4 *l*/min with a drawdown of 45.7 m.

Hole 42 [*EP172874*]

Location;	6 km north-west of Powranna	*Commenced;*	24. 2.70
Elevation;	170.7 m	*Completed;*	14. 3.70

Depth (m)	*Description*
0- 3.1	Brown clayey sand, occasional quartz pebbles
3.1- 4.6	Grey sandy clay
4.6- 6.1	Light brown sandy clay
6.1- 24.4	Light brown to grey clay
24.4- 42.7	Grey plastic clay
42.7- 91.4	Grey-brown clay
91.4- 96.0	Grey-brown clay
96.0- 99.1	Brown sandy clay
99.1-102.1	Gravel, rounded quartzite up to 75 mm diameter
102.1-153.0	Brown clay, mainly light coloured with little or no sand. Occasional wood fragments

Slotted casing installed from 76.2 to 91.4 m. Standing water level was at 20.1 m. Hole pumped at 248 *l*/min for 6 hours, which produced a drawdown to 53.6 m.

Hole 43 [*EP223885*]

Location;	Symmons Plains	*Commenced;*	16. 3.70
Elevation;	162.2 m	*Completed;*	12. 5.70

Depth (m)	*Description*
0- 1.5	Reddish brown clayey soil
1.5- 4.6	Clayey grit
4.6- 6.1	Grit
6.1- 10.7	Grit and coarse sand grading down to gravelly grit. Gravel fragments throughout with a maximum size of about 25 mm of rounded and angular quartz

Appendix 1 (continued)

Hole 43 [*EP223885*] *(continued)*

Depth (m)	*Description*
10.7- 39.6	Grey-brown silty clay, a few angular quartz fragments
39.6- 79.2	Brown clay (mainly dry - probably plastic when wet)
79.2- 80.8	Boulders of quartzite, sandstone (wood fragments? baked in rock)
80.8- 91.4	Rock fragments - dark material and quartz
91.4- 97.5	Rock fragments, some clay
97.5-100.6	No sample
100.6-115.8	Gravelly fragments (quartz fragments abundant), some clay and wood fragments
115.8-141.7	Brown clay with gravel and wood fragments, clay content increases towards end

Slotted casing installed at 42.7-48.8 m and 88.4-103.6 m. Hole pumped at 265 *l*/min over a period of 5½ hours and this produced a drawdown to 47.5 m from a standing water level of 4.9 m below the surface.

Hole 44 [*EP196928*]

Location; 5 km south of Evandale — *Commenced;* 12. 5.70
Elevation; 156.7 m — *Completed;* 22. 6.70

Depth (m)	*Description*
0- 1.5	Brown clay soil
1.5- 4.8	Brown clayey sand
4.8- 6.1	Brown sand
6.1- 9.1	Fine gravel, up to 13 mm
9.1- 24.4	Brown-grey plastic clay
24.4- 27.4	Dark grey rock fragments with clay (basalt fragments)
27.4- 35.1	Gravel fragments (quartz up to 4 mm)
35.1- 48.8	Mainly brown-grey clay, a few gravel fragments
48.8- 54.9	Mainly conglomerate? Core from 51.5-52.4 m showed quartzite, dolerite boulders, rounded, up to 75 mm. Calcite abundant in areas
54.9- 86.9	Light grey-brown clay, a few gravel fragments, some wood fragments
86.9-112.8	Light blue-grey-brown plastic clay
112.8-167.6	Light grey plastic clay, occasional wood fragments
169.2-169.8	0.6 m conglomerate

Slotted casing installed at 21.3-33.5 m and 45.7-48.8 m. Standing water level was 3.8 m. After pumping at 281 *l*/min for 3 hours, the level was 23 m.

Appendix 1 (continued)

Hole 45 [*EP208969*]

Location;	One kilometre south of Evandale	*Commenced;*	22. 6.70
Elevation;	157.3 m	*Completed;*	29. 6.70

Depth (m)	*Description*
0- 1.5	Soil and brown clay
1.5- 3.1	Light brown clay
3.1- 6.1	Weathered rock fragments
6.1- 12.2	Rock fragments - basalt
12.2- 13.0	Conglomerate with rounded quartz fragments, final section coarse basalt
13.0- 14.0	Basalt

Slotted casing installed at 3.1-6.1 m and 9.1-12.2 m. The hole was pumped at 95 *l*/min for 2 hours which lowered the water level from a standing level of 1.6 m to a final level of 10.6 m.

Hole 46 [*EP249986*]

Location;	4.5 km east of Evandale	*Commenced;*	29. 6.70
Elevation;	178.0 m	*Completed;*	9. 7.70

Depth (m)	*Description*
0- 1.5	Soil and clay
1.5- 3.0	Clay with concentrations of iron oxide
3.0- 12.0	Light brown sandy clay (less sand with depth)
12.0- 26.0	Light brown plastic clay
26.0- 30.5	Brown plastic clay, some wood fragments
30.5- 52.0	Brown plastic clay, some wood fragments
52.0- 52.5	Conglomerate grading down to dolerite

Slotted casing installed between 30.5-52.4 m. Standing water level was 10.6 m. The bore was pumped at 68 *l*/min for 4½ hours and the water level fell to 49.2 m below the surface.

Hole 47 [*EP271954*]

Location;	7 km south-east of Evandale	*Commenced;*	9. 7.70
Elevation;	180.1 m	*Completed;*	13. 7.70

Depth (m)	*Description*
0- 6.0	Brown shale fragments
6.0- 21.3	Grey shale fragments

No appreciable water

Appendix 1 (continued)

Hole 48 [*EP259959*]

Location;	6 km south-east of Evandale	*Commenced;*	14. 7.70
Elevation;	171.6 m	*Completed;*	20. 7.70

Depth (m)	*Description*
0- 1.5	Dark brown soil and clay with iron nodules
1.5- 7.6	Brown clayey gravel (fragments up to 8 mm)
7.6- 19.8	Light brown plastic clay with occasional gravel fragments
19.8- 24.4	Plastic light grey-brown clay
24.4- 57.9	Dark grey-brown plastic clay
57.9- 61.0	Light grey-green siltstone fragments
61.0- 62.8	Baked shale and sandstone

61.3 m of casing installed, some slotted. The hole was bailed for 2 hours at 11 *l*/min which drew the water level down to the maximum drawdown. The standing water level was at 4.7 m.

Hole 49 [*EP184953*]

Location;	3.5 km south-west of Evandale	*Commenced;*	21. 7.70
Elevation;	163.7 m	*Completed;*	29. 7.70

Depth (m)	*Description*
0- 6.1	Gravel, rounded quartzite, quartz and a little clay
6.1- 36.6	Weathered basalt? becoming harder and finer towards end. Some gravel fragments (fallen in?). From 27.4-30.5 m some sedimentary-like material, clay or weathered zeolite?
36.6- 37.7	Unweathered vesicular basalt

Slotted casing installed at 27.4-39 m. Standing water level was at 16.2 m below the surface. Pumping at 296 *l*/min for 4 hours produced a draw-down to 22.3 m.

Hole 50 [*EQ236010*]

Location;	4.5 km north-east of Evandale	*Commenced;*	30. 7.70
Elevation;	145.9 m	*Completed;*	20. 8.70

Depth (m)	*Description*
0- 1.5	Brown sand
1.5- 12.2	Dolerite fragments from boulder beds
12.2- 21.3	Light brown clay
21.3- 24.4	Brown clay with dolerite fragments
24.4- 42.7	Dark brown-grey clay and sandy clay
42.7- 59.4	Dark brown sandy clay with wood fragments
59.4- 91.4	Light grey clay, some wood fragments, very little sand
91.4- 96.0	Grey clayey sand, a little wood
96.0- 99.1	Grey sand
99.1-109.7	Sandy clay, some wood fragments

Appendix 1 (continued)

Hole 50 [*EQ236010*] *(continued)*

Depth (m)	*Description*
109.7-131.1	Grey sandy clay
131.1-140.2	Grey sand
140.2-143.0	2.8 m of light grey-brown sandy mudstone, some grit fragments. At about 2.6 m, mottled area near dolerite contact?

Slotted casing installed at 88.4-106.7 m. Standing water level was 18.9 m below surface. Hole pumped for 4 hours at 265 *l*/min with a draw-down to 54.9 m.

Hole 51 [*EQ206016*]

Location; 4 km north of Evandale *Commenced;* 20. 8.70
Elevation; 69.8 m *Completed;* 21. 9.70

Depth (m)	*Description*
0- 1.5	Soil and brown clay
1.5- 7.6	Light brown clay
7.6- 15.2	Light grey-brown sandy clay
15.2- 19.8	Sand with wood fragments
19.8- 22.9	Mainly wood fragments
22.9- 36.6	Wood fragments and clay, a little sand
36.6- 42.7	Sand and wood fragments
42.7- 50.3	Clay and wood fragments
50.3- 54.9	Sand, clay and wood fragments
54.9- 62.5	Clay and wood fragments
62.5- 67.1	Rock fragments (hard section about one metre thick)
67.1- 74.7	Clay and wood fragments
74.7- 76.2	Brownish grey clay
76.2- 86.9	Wood fragments mainly, some clay
86.9-106.7	Grey clay with some fine sand, some wood fragments
106.7-112.8	Sand, clay and wood fragments
112.8-117.4	Mainly wood fragments, some clay
117.4-121.9	Sand, some clay, wood fragments
121.9-125.0	Wood fragments, some clay
125.0-134.1	Sand (varying amounts) in clay, some brownish with wood fragments
134.1-135.6	Sand
135.6-152.4	Mainly wood, clay, a little sand

Bore is artesian and flows at the rate of 46 *l*/min. Slotted casing installed at 76.2-106.7 m. Hole pumped at 108 *l*/min and the drawdown was to 37.9 m.

Appendix 1 (continued)

Hole 52 [EQ185052]

Location; 1.5 km east of Relbia — *Commenced;* 21. 9.70
Elevation; 59.1 m — *Completed;* 7.10.70

Depth (m)	*Description*
0- 1.5	Soil and limonite nodules
1.5- 7.6	Brown clay
7.6- 13.7	Brown sand
13.7- 41.2	Brown clay and sand
41.2- 45.7	Rock and wood fragments
45.7- 47.9	Conglomerate containing dolerite boulders
47.9- 61.0	Dark rock fragments
61.0- 82.3	Mainly rock fragments, becoming more brown
82.3- 83.8	Conglomerate, dolerite fragments and brown mudstone? matrix
83.8- 94.5	Mainly rock fragments and wood fragments
94.5- 96.0	Conglomerate with dolerite fragments

48.8 m of casing installed, some slotted. Standing water level was 17.7 m below the surface. The hole was bailed at 15 *l*/min for four hours which produced a drawdown to 93.9 m.

Hole 53 [EP351710]

Location; 2.5 km north-west of Conara — *Commenced;* 8.10.70
Elevation; 207 m — *Completed;* 18.11.70

Log same as for Hole 57.

Hole 54 [EP274876]

Location; 2 km south of Nile — *Commenced;* 19.11.70
Elevation; about 180 m — *Completed;* 7.12.70

Depth (m)	*Description*
0- 1.5	Brown soil
1.5- 6.1	Brown sand and gravel (dolerite)
6.1- 9.1	Gravel, up to 6 mm, vein quartz and dolerite?
9.1- 10.7	Brown clay
10.7- 12.2	Brownish sand
12.2- 13.7	Brown clayey sand
13.7- 19.8	Brownish grey clayey sand, some coarse sand
19.8- 21.3	Brown clay, some sand
21.3- 25.9	Light blue clay, some wood fragments
25.9- 42.7	Grey to light brown sand, some clay
42.7- 51.8	Grey sand, some clay
51.8- 65.5	Dark brown clay with increasing amounts of rock fragments (some quartz, some igneous fragments)
65.5- 73.2	Light brown clay, some rock fragments
73.2- 73.5	Conglomerate with dolerite fragments

Some slotted casing was included in the 39.6 m of casing installed. Standing water level was at 5.6 m. The hole was pumped at 136 *l*/min. The water level after four hours of pumping was at 13.5 m.

Appendix 1 (continued)

Holes 55, 56 [EP060850]

Location; Cressy
Elevation; about 160 m

Depth (m)	*Description*
0- 1.5	Mid brown clay, some small iron oxide pellets
1.5- 3.0	Light grey-brown silty clay
3.0- 9.1	Light grey and red mottled clay
9.1- 38.1	Dark grey clay, some silty material, occasional brown clay pellets
38.1- 45.7	Dark grey clay with zones of light grey silty clay
45.7- 64.0	Light grey clay and silty clay, some iron oxide nodules
64.0- 71.6	Clay, becoming more sandy and silty with occasional grit fragments, some lignite fragments
71.6- 77.7	Grey clayey sand
77.7- 85.3	Grey silty clay with a few grit fragments, some lignite fragments
85.3- 97.5	Grey sandy and silty clay, some lignite fragments
97.5-103.6	Mainly grey clay, some small iron oxide? pellets
103.6-115.8	Grey-brown clay and silty clay, some probable siderite fragments
115.8-146.3	Grey sandy clay and clayey sand, some lignite fragments

Hole 57 [EP352712]

Location; 2.5 km north-west of Conara *Commenced;* 24. 5.68
Elevation; 207 m *Completed;* 10. 6.68

Depth (m)	*Description*
0- 1.5	Brown iron stained sand
1.5- 4.6	Lateritic material (iron nodules in clay)
4.6- 6.1	Brown clay
6.1- 18.3	Clayey sand
18.3- 22.9	Coarse angular sand with fragments of vein quartz, clear quartz, and fossil wood
22.9- 25.9	Fine grey sand with a few grit fragments
25.9- 27.4	Coarse material, vein quartz up to 25 mm, angular clear quartz up to 6 mm in sandy material. Silicified wood up to 25 mm. Larger grains mainly rounded, others angular
27.4- 33.5	Grit and fine gravel, vein quartz and clear quartz with sand (some heavy black mineral)
33.5- 44.2	Grey sandy clay with occasional grit and gravel
44.2- 45.7	Grey clay, some grit fragments
45.7- 47.2	Dark brown clay with fine gravel and grit fragments
47.2- 50.3	Dark brown clay, nodule of pyrite
50.3- 51.8	Brown stained sand
51.8- 53.3	Dark brown clay
53.3- 54.9	Gritty material
54.9- 61.0	Brown clay with a little sand

Samples may have been mixed up.

Appendix 1 (continued)

Hole 57 [EP352712] (continued)

Water struck at 25.9 m, some water entering between 45.7-47.2 m. Hole pumped at 170 *l*/min for 2.5 hours with a drawdown of one metre. Further hole was later drilled nearby and pumped at 1140 *l*/min for a drawdown of about 1.3 m.

Hole 58 [EP331701]

Location;	3 km north-west of Conara	*Commenced;*	12. 6.68
Elevation;	210.0 m	*Completed;*	5. 7.68

Depth (m)	*Description*
0- 1.5	Brown clay
1.5- 7.6	Light brown-grey sandy clay, a few iron nodules
7.6- 9.1	Light grey clay
9.1- 10.7	Light grey sandy clay
10.7- 15.2	Light brown sandy clay
15.2- 21.3	Sand with grit and fine gravel fragments, becoming coarser
21.3- 22.9	Mainly grit, angular fragments of quartz
22.9- 27.4	Fine gravel, fragments of vein quartz up to 13 mm and often rounded, clear quartz, angular. Coarsest at top
27.4- 30.5	Light brown sandy clay
30.5- 33.5	Grit and gravel
33.5- 38.1	Grit to fine gravel, mainly angular fragments
38.1- 45.7	Dark grey sand, occasional wood fragments
45.7- 47.2	Grit, fine gravel, some fragments cemented with pyrite
47.2- 53.3	Grey sandy clay
53.3- 57.9	Sandy clay, becoming more sandy

Standing water level 25.3 m. Hole pumped at 108 *l*/min for 2.25 hours with the pump foot valve placed at 36.6 m. Hole pumped dry after this period.

Hole 59 [EP396688]

Location;	3.5 km east of Conara	*Commenced;*	No.1 12.8.68	No.2 16.8.68
Elevation;	200.9 m	*Completed;*	No.1 15.8.68	No.2 13.9.68

Depth (m) *Description*

Hole 1

0- 1.5	Brown clay
1.5- 16.8	Weathered basalt, mainly clay
16.8- 18.3	Weathered basalt, becoming harder

Hole 2 (box collapsed, samples mixed up: 24 samples)

0- 16.8	Small fragments of basalt, weathered but fairly hard
16.8- 21.3	Brown weathered vesicular basalt, large fragments
21.3- 30.5	Grey sandy clay, sand becoming more abundant
30.5- 35.1	Grey clayey sand
35.1- 36.6	Coarse sand, grit with some 12 mm diameter pebbles

Appendix 1 (continued)

Hole 59 [EP396688] (continued)

Unable to get casing down because of irregularly shaped hole. Abundant water, unable to lower with bailer. Water entered hole between 13.7 and 15.2 m, but a much larger amount could be withdrawn from the pebbly coarse sand bed.

Hole 60 [EP394636]

Location;	6 km south-east of Conara	*Commenced;*	13. 9.68
Elevation;	201.5 m	*Completed;*	14.10.68

Depth (m)	*Description*
0- 10.7	Weathered basalt, becoming less weathered
10.7- 19.8	Basalt, fairly hard
19.8- 20.4	Some sand with basalt fragments

Water in large quantities entered hole at 9.1-13.7 m from the surface. It was bailed for one hour at 53 *l*/min. Water level stabilised at 2.1 m from the surface.

Hole 61 [EP393723]

Location;	6 km east of Cleveland	*Commenced;*	17.10.68
Elevation;	194.2 m	*Completed;*	30.10.68

Depth (m)	*Description*
0- 1.5	Weathered basalt fragments
1.5- 3.1	Clayey sand
3.1- 4.6	Brown clay
4.6- 19.8	Grey-light brown clay
19.8- 21.3	Dark brown clay
21.3- 24.4	Brown clayey sand
24.4- 27.4	Grey clay with wood fragments
27.4- 30.5	Dark grey sand with coarse gravel, some clay
30.5- 53.3	Grey and brown clay, a little sand

Water entered hole from 27.4-30.5 m. The standing water level was at 6.1 m. The hole was bailed at 27 *l*/min for two hours with a drawdown to about 28.5 m.

Hole 62 [EP307735]

Location;	3.5 km south-east of Epping Forest	*Commenced;*	31.10.68
Elevation;	205.4 m	*Completed;*	19.11.68

Depth (m)	*Description*
0- 4.6	Lateritic material
4.6- 7.6	Brown clay
7.6- 15.2	Grey clayey sand
15.2- 16.8	Brown clay
16.8- 18.3	Sand
18.3- 22.9	Gravel, sand and grit, fragments up to 25 mm in diameter (no water)
22.9- 25.9	Grey sandy clay

Appendix 1 (continued)

Hole 62 [*EP307735*] *(continued)*

Depth (m)	*Description*
25.9- 27.4	Gritty material
27.4- 30.5	Grey clayey sand with pebbles up to 40 mm diameter
30.5- 35.1	Sandy clay, clayey sand
35.1- 38.1	Grit
38.1- 41.2	Fine gravel (granite size quartz), some large 25 mm diameter vein quartz, even grained apart from these, otherwise fairly angular
41.2- 45.7	Coarse sand, some grit and fine conglomerate fragments
45.7- 46.6	Sandy clay

Good supply of water in gravel from 38.1 m onwards. Very little water in gravel from 18.3-27.4 m. Standing water level was at 27.4 m and the hole was bailed at a rate of 38 *l*/min for one hour with a drawdown to 32 m.

Hole 63 [*EP275757*]

Location;	2 km south-west of Epping Forest	*Commenced;*	2.12.68
Elevation;	198.4 m	*Completed;*	14.12.68

Depth (m)	*Description*
0- 4.6	Gravel, grit, and clay (fragments up to 13 mm)
4.6- 6.1	Grey sandy clay
6.1- 15.2	Grey and brown even grained clayey sand
15.2- 19.8	Coarse sand
19.8- 21.3	Coarse sand and grit
21.3- 29.0	Coarse grey very clayey sand
29.0- 30.5	Dark grey-brown clay
30.5- 33.5	Fine grey clayey sand
33.5- 42.7	Grey and brown sandy clay
42.7- 45.7	Coarse angular sand
45.7- 51.8	Fine clayey sand
51.8- 53.3	Fine grit with abundant clay

Standing water level was about 22.9 m. Water was struck at about 15.2 m. The hole was bailed for about two hours at about 19 *l*/min with a large drawdown.

Hole 64 [*EP299780*]

Location;	1 km north-east of Epping Forest	*Commenced;*	16.12.68
Elevation;	181.4 m	*Completed;*	23. 1.69

Depth (m)	*Description*
0- 1.5	Red clay with laterite nodules
1.5- 3.1	Red clay, few iron nodules
3.1- 13.7	Light grey to brown plastic clay
13.7- 15.2	Clayey sand
15.2- 18.3	Clayey grit to fine gravel
18.3- 19.8	Grit to fine gravel
19.8- 21.3	Clayey sand with grit fragments

Appendix 1 (continued)

Hole 64 [EP299780] (continued)

Depth (m)	*Description*
21.3- 24.4	Coarse angular sand, some wood
24.4- 25.9	Clayey sand
25.9- 38.1	Grey sand, some clay
38.1- 39.6	Dark sandy clay
39.6- 48.8	Dark brown clayey sand and sandy clay, some wood fragments
48.8- 53.3	Very fine sand

Water was struck within the interval of 21.3-30.5 m. The hole was bailed with slotted casing only in the bottom section of the hole at a rate of 30 *l*/min. The slotted casing was then pulled back to the interval above 30.5 m. The standing water level was 8.5 m. The hole was bailed at the maximum rate for a drawdown of only one metre.

Hole later pump tested when the standing water level was 4.2 m. It was pumped at 163 *l*/min for a period of over two hours for a drawdown to 15.1 m.

Hole 65 [EP269809]

Location; 4 km north-west of Epping Forest *Commenced;* 23.1.69-6.2.69, then 21.5.69
Elevation; 169.8 m *Completed;* 28.5.69

Depth (m)	*Description*
0- 4.6	Gravelly and sandy brown clay
4.6- 6.1	Brown clay
6.1- 9.1	Clayey grit and fine gravel
9.1- 10.7	Gravel, grit, and sand
10.7- 12.2	Coarse sand and grit
12.2- 18.3	Clayey sand
18.3- 33.5	Grey-brown clayey sand
33.5- 41.2	Grey-brown sandy clay
41.2- 54.9	Brown sandy clay

Water struck between 6.1-12.2 m. A pump test was conducted over a period of more than two hours at a rate of 160 *l*/min with a drawdown from a standing water level of 4.8 m to 8.9 m.

Hole 66 [EP247835]

Location; 2.5 km south-east of Powranna *Commenced;* 28. 5.69
Elevation; 161.3 m *Completed;* 13. 6.69

Depth (m)	*Description*
0- 1.5	Brown clayey sand with gravel
1.5- 3.1	Grey-brown sandy clay with angular grit
3.1- 7.6	Angular coarse sand, grit gravel (large fragments rounded)
7.6- 16.8	Grey-brown clay, wood fragments, a little sand, some grit fragments

Hole 66 [EP247835] (continued)

Depth (m)	*Description*
16.8- 30.5	Brown clay, a little sand, some grit fragments
30.5- 32.0	Brown clay and gravel, mainly vein quartz
32.0- 33.5	Brown clay, a few gravel fragments
33.5- 35.1	Clay and gravel
35.1- 38.1	Brown clay, some gravel
38.1- 47.2	Brown clay, some grit fragments
47.2- 62.5	Brown clay, a few gravel fragments
62.5- 64.0	Brown clay

Water was struck at 6.1-9.1 m and at 47.3 m. The standing water level was one metre and a pump test at the rate of 163 *l*/min over a period of about three hours drew the level down to 4.6 m from the surface.

Hole 67 [EP234791]

Location; 6 km north-west of Epping Forest *Commenced;* 18. 6.69
Elevation; 206.1 m *Completed;* 15. 7.69

Depth (m)	*Description*
0- 6.1	Red and grey clay (with iron staining) and iron nodules
6.1- 15.2	Light grey clay with pink and red staining
15.2- 16.8	Grey clay
16.8- 18.3	Brown clayey sand, some grit fragments
18.3- 19.8	Light grey sandy clay
19.8- 24.4	Coarse sand with grit and fine gravel fragments
24.4- 25.9	Coarse sand, grit, and fine gravel fragments
25.9- 27.4	Dark brown sandy clay
27.4- 42.7	Dark brown clay
42.7- 48.8	Dark brown-grey clay
48.8- 56.4	Dark grey clay
56.4- 57.9	Blue and green clay

No significant water obtained.

Hole 68 [EP318808]

Location; 5 km north-east of Epping Forest *Commenced;* 16. 7.69
Elevation; 176.2 m *Completed;* 31. 7.69

Depth (m)	*Description*
0- 4.6	Brown clay
4.6- 10.7	Brown coarse sand with grit and gravel fragments up to 40 mm
10.7- 13.7	Angular sand and grit with gravel fragments becoming more common towards bottom
13.7- 16.8	Grey clayey sand with mica
16.8- 25.9	Dark brown clay, some sand
25.9- 47.2	Dark brown clay, some sandy clay at beginning. Large fragments of silicified(?) material towards end

Appendix 1 (continued)

Hole 68 [*EP318808*] *(continued)*

Hole drilled to 54.9 m; driller reported stiff grey clay 15.2-54.9 m.

Water struck at about 7.6 m. The standing water level was 4.8 m. A pump test over a period of just greater than two hours at a rate of 159 *l*/min drew the level down to 6.6 m.

Hole 69 [*EP297844*]

Location;	7 km east of Powranna	*Commenced;*	1. 8.69
Elevation;	173.4 m	*Completed;*	15. 8.69

Depth (m)	*Description*
0- 4.6	Brown sandy clay
4.6- 12.2	Gritty sand with some fine angular gravel fragments (first 3.0 m of section clayey, final 1.5 m clean)
12.2- 18.3	Grey clayey sand
18.3- 35.1	Grey clayey sand (even grained)
35.1- 50.3	Grey and brown sandy clay

Log from 0-12.2 m may be out of order. Driller reported final depth as 41.2 m. Water struck at 6.1 m. Standing water level was 5.6 m from the surface. A pump test lasting about two hours at a rate of about 30 *l*/min drew the water level down to 16.6 m.

Hole 70 [*EP284886*]

Location;	1 km south-east of Nile	*Commenced;*	19. 8.69
Elevation;	181.7 m	*Completed;*	6. 9.69

Depth (m)	*Description*
0- 1.5	Brown clay
1.5- 7.6	Brown sand with dolerite boulders
7.6- 9.1	Brown to grey sandy clay
9.1- 12.2	Grey clay, a little sand
12.2- 15.2	Grey to brown clay
15.2- 16.8	Brown clay with dolerite(?) fragments
16.8- 22.9	Dark brown plastic clay
22.9- 27.4	Dark brown to grey clay
27.4- 32.0	Grey clayey sand
32.0- 36.6	Grey sandy clay

Driller reported final depth as 54.9 m with 5.2-54.9 m clay, changing from dark grey to brown and light grey in some sections. No significant water supplies obtained to the depth drilled.

Appendix 1 (continued)

Hole 71 [EP264920]

Location;	3 km east of Clarendon	*Commenced;*	9. 9.69
Elevation;	173.4 m	*Completed;*	8.10.69

Depth (m)	*Description*
0- 1.5	Grey clayey sand
1.5- 7.6	Brown clay
7.6- 10.7	Brown clay with iron nodules
10.7- 13.7	Brown clay
13.7- 16.8	Light grey clay with wood fragments
16.8- 18.3	Dark grey-brown clay
18.3- 21.3	Grey sandy clay
21.3- 22.9	Brown clay
22.9- 25.9	Grey sandy clay
25.9- 41.2	Grey clay and sandy clay with wood fragments
41.2- 53.3	Grey clay and sandy clay with wood fragments

No significant amounts of water obtained to the depth drilled.

Hole A [DP972955]

Location;	Oaks Siding	*Commenced;*	16. 6.66
Elevation;	179.5 m	*Completed;*	1. 7.66

Depth (m)	*Description*
0- 0.3	Blue metal screenings
0.3- 0.9	Red surface soil
0.9- 11.6	Basaltic clay
11.6- 17.7	Clay with laterite
17.7- 61.0	Sticky dark grey clay
61.0- 73.2	About 100 mm hard and 0.6 m thick soft bands
73.2-106.7	Very soft sandy clay
106.7-118.9	Soft with occasional 0.6 m thick hard band
118.9-128.0	Mostly hard bands
128.0-137.2	Soft bands about 0.9 m thick, hard bands about 1.5 m thick
137.2-146.3	Soft and hard sandy clay
146.3-148.0	2 m core
148.0-163.1	Soft sedimentary clay with wood pieces

Hole B [DP978975]

Location;	2 km north-east of Oaks Siding	*Commenced;*	4. 7.66
Elevation;	168.3 m	*Completed;*	18. 7.66

Depth (m)	*Description*
0- 0.6	Red surface soil
0.6- 2.1	Basalt clay and ironstone
2.1- 16.8	Basalt clay with laterite
16.8- 30.5	Sticky grey clay
30.5- 37.2	Very soft clay 1.5 m, hard clay 50 mm
37.2- 48.8	Hard sandy clay
48.8- 64.0	Soft and hard sandy clay
64.0- 76.2	Sedimentary clay with wood

Appendix 1 (continued)

Hole B [DP978975] (continued)

Depth (m)	*Description*
76.2- 88.4	Sedimentary clay
88.4-134.1	Very soft sedimentary clay
134.1-140.2	Harder sedimentary clay
140.2-144.8	Very soft sedimentary clay
144.8-149.4	Harder sedimentary clay
149.4-155.4	Soft mudstone
155.4-160.0	Soft and hard, 1.8 m soft, 0.9 m hard
160.0-163.1	Soft brown coal

Attempt made to clean out hole to get logger down, 24.1.67-27.1.67.

Hole C [DP981981]

Location; 2.5 km north-east of Oaks Siding *Commenced;* 18. 7.66
Completed; 28. 7.66

Depth (m)	*Description*
0- 0.6	Black surface soil
0.6- 1.5	Gravelly clay
1.5- 18.3	Basaltic clay
18.3- 27.4	Sand
27.4- 61.0	Sandy clay
61.0- 76.2	Hard and soft sandy clay, 1.5 m seams
76.2- 77.7	Soft mudstone
77.7-112.8	Hard and soft lignite and clay
112.8-158.5	Hard and soft lignite and clay
158.5-163.7	Sand and sandy clay

1.2.67-10.2.67 Hole cleaned out for logger, screen and casing installed and hole bailed; unsuccessful.

15.2.67-17.2.67 Further hole drilled 1.5 m from first hole to 24.4 m. Cased and bailed.

Hole D [DP989003]

Location; 5 km north-east of Oaks Siding *Commenced;* 29. 7.66
Completed; 31. 8.66

Depth (m)	*Description*
0- 0.9	Black surface soil
0.9- 4.6	Ironstone and clay
4.6- 21.3	Basaltic clay
21.3- 32.0	Decomposed dolerite
32.0- 67.1	Dolerite

Further work 12.12.66-22.12.66. Screening put down hole and further tests showed the hole to be dry.

Appendix 1 (continued)

Hole E [DP985990]

Location; 3.7 km north-east of Oaks Siding *Commenced;* 20. 2.67
Completed; 14. 3.67

Depth (m)	*Description*
0- 0.5	Metal screenings
0.5- 7.6	Red clay
7.6- 12.2	Silty clay
12.2- 15.2	Sandy clay
15.2-103.6	Sticky clay
103.6-138.7	Sticky clay and wood
138.7-143.3	Limestone(?) (driller thinks limestone)
143.3-152.1	Blue clay

Hole cased to 13.9 m, 6 *l*/min good quality water. Further work 1.11.67-9.11.67.

APPENDIX 2

Results of contract bores

	Owner and locality	AMG Reference[1] (approximate)	Completed	Driller[2]	Standing water level (m)	Depth water struck (m)
1	Eastoe Brothers, Longford	EP053987	18/ 6/51	D.O.M.	5.5	21.3
2	C. Sealey, Longford	EP059983	17/ 1/51	D.O.M.	4.5	21.3
3	R.J. Eastoe, Longford	EP056986	8/ 8/67	A.G.P.	flowing	18.3-19.8
4	M.J. O'Toole, Carrick	EQ038005	10/ 8/67	A.G.P.		55
5	R.K.A. Terry and Sons, Longford	EQ097006	5/12/50	D.O.M.	10.4	25.9
6	H. Nevin, Longford	EQ099000	12/ 2/51	D.O.M.		10.1
7	H. Nevin, Longford	EP102998	7/ 2/51	D.O.M.		
8	H. Nevin, Longford	EP099997	8/ 2/51	D.O.M.		
9	C. Sealey, Longford	EP062984	2/ 4/51	D.O.M.		21.3

Total depth (m)	Output (l/min)	Quality (mg/l TDS)	Status[3]	Drillers Log (Depths in metres)
21.3	23	1232†	O	0-6.1 clay, 6.1-12.2 clay and ironstone, 12.2-15.2 black pug, 15.2-21.3 sandstone
21.3	19	corrosive	O	0-4.6 clay, 4.6-12.2 stiff pug, 12.2-21.3 pug mixed with dolerite boulders and gravel followed by fine sand.
24.7	190	560†	C	0-0.6 soil, 0.6-1.2 decomposed rock, 1.2-17.1 brown and yellow clay layers and ironstone, 17.1-18.9 sandstone, 18.9-22.9 white sand, 22.9-24.7 clay and carbonaceous shale.
33.9	4		A	0-0.9 soil, 0.9-9.8 brown and yellow clay, 9.8-22.6 grey and white clay, 22.6-33.9 sandstone and hard layers of dolerite.
31.2	9		C	0-24.4 clay, 24.4-31.4 dolerite
12.8	2	good	A	0-12.8 (bottomed on dolerite?)) individual location of these bores is unknown
4.6			A	0-4.6 clay (bottomed on dolerite?)) individual location of these bores is unknown
7.9			A	0-7.9 clay (bottomed on dolerite?)) individual location of these bores is unknown
22.3	23		F	0-15.9 clay, 15.9-18.6 clay mixed with shingle, 18.6-21.3 mudstone, 21.3-22.3 sand. (Exact location unknown).

Appendix 2 (continued)

	Owner and locality	AMG Reference[1] (approximate)	Completed	Driller[2]	Standing water level (m)	Depth water struck (m)
10	B. Cox, Longford	EP084945	30/ 1/51	D.O.M.		24.4
11	S. Cox, Longford	EP085946	6/ 2/51	D.O.M.	13.1	23.8
12	Walsh, Longford	EP083961	18/12/50	D.O.M.	0.24	17.1
13	Walsh, Longford	EP080963	11/ 1/51	D.O.M.	0.24	27.4
14	F. Murfett, Cressy	EP050847	3/ 7/51	D.O.M.	2.7	29.9
15	C.R. Field, Cressy	EP026815	16/ 8/51	D.O.M.		
16	Wallace, Cressy	EP046819	26/ 6/51	D.O.M.	9.8	24.4
17	B.A. Youl, Symmons Plains	EP208872	pre Feb. 1968	I.B.C.	2.4	
18	B.A. Youl, Symmons Plains	EP190974	pre Feb. 1968	I.B.C.		
19	C. Butter-worth and Son, Cressy	EP032826?	24/ 7/51	D.O.M.		

Total depth (m)	Output (l/min)	Quality (mg/l TDS)	Status[3]	Drillers Log (Depths in metres)
25.9	15		F	0-3.1 clay, 3.1-12.2 gravel, 12.2-13.7 pug, 13.7-25.9 pug and gravel (exact location unknown).
26.1	19	900†	O	0-3.1 clay, 3.1-12.2 gravel, 12.2-19.8 black pug, 19.8-23.2 gravelly pug, 23.2-26.1 gravel and silt.
21.3	23	480†	O	0-6.1 gravel and clay, 6.1-17.1 pug and silt, 17.1-19.8 sandstone, 19.8-21.3 dolerite and quartz gravel.
29.9	23	545†	O	0-11.3 gravel and clay, 11.3-13.7 pug and gravel, 13.7-21.3 pug, 21.3-28.4 pug and silt, 28.4-29.9
29.9	23		C	0-0.3 soil, 0.3-5.8 clay and pug, 5.8-7.6 ironstone, 7.6-16.8 grey pug, 16.8-29.9 black pug.
56.4			A	0-0.3 soil, 0.3-9.1 clay and grey pug, 9.1-19.8 grey pug, 19.8-56.4 black pug.
25.9	20	1810†	O	0-0.6 soil, 0.6-8.5 clay and pug, 8.5-15.2 pug and clay, 15.2-16.8 ironstone, 16.8-19.5 black pug, 19.5-25.9 ironstone gravel.
13.7	46	2755†	C	
33.6	dry		A	
27.4	dry		A	0-0.3 soil, 0.3-18.3 pug and clay, 18.3-27.4 black pug.

Appendix 2 (continued)

	Owner and locality	AMG Reference[1] (approximate)	Completed	Driller[2]	Standing water level (m)	Depth water struck (m)
20	C.Butter-worth and Son, Cressy	EP026825?	13/ 7/51	D.O.M.		
21	C. Butter-worth and Son, Cressy	EP026830?	2/ 8/51	D.O.M.		
22	Mason, Pateena Road	EQ088016	16/ 2/51	D.O.M.		
23	D.M. Redburn, Evandale	EP211981	23/10/69	Mono	9.1	17.1
24	Bell, Oaks	DP970974	1967	I.B.C.	1.8	
25	Bell, Oaks	DP968973	1967	I.B.C.	2.7	
26	L.A. Stuart, Whitemore	DP940940	1967	I.B.C.	3.4	
27	E. Shaw, Whitemore	DP908978	11/ 9/51	D.O.M.		9.1
28	H.W. Bramich, Hagley	DP920977	1967	I.B.C.		
29	F.H. Badcock, Hagley	DP913998	30/ 8/51	D.O.M.		
30	F.H. Badcock, Hagley	DQ911001	6/ 9/51	D.O.M.		
30A	F.H. Badcock, Hagley	DP916999	28/ 8/51	D.O.M.		
31	Z. Pearn, Hagley	DP911991		Z. Pearn		

Total depth (m)	Output (l/min)	Quality (mg/l TDS)	Status[3]	Drillers Log (Depths in metres)
39	dry		A	0-0.3 soil, 0.3-6.1 pug and clay, 6.1-19.5 grey pug, 19.5-39 black pug
39.6	dry		A	0-0.3 soil, 0.3-4.6 grey pug, 4.6-12.2 grey pug and clay, 12.2-19.8 grey pug, 19.8-39.6 black pug.
31.1	dry		A	0-6.1 clay and gravel, 6.1-31.1 clay (bottomed on dolerite).
33.6	53	good	O	0-19.8 clay, 19.8-24.4 coal, 24.4-33.6 mudstone, soft mudstone, quartz, mudstone.
12.2	4	715†	O	0-12.2 mainly clay, some gravelly material to about 9.1.
24.4	4	620	C	0-24.4 mainly clay, some gravelly material to about 9.1.
11.0	46+	250†	O	0-3.1 clay, 3.1-5.5 sandy clay, 5.5-11.0 weathered basalt.
10.1	23	570	O	0-0.5 soil, 0.5-4.6 not recorded, 4.6-10.1 sandstone.
18.3	8		O	
15.2			A	0-0.3 soil, 0.3-9.1 clay, 9.1-15.2 black pug.
12.2			A	0-0.3 soil, 0.3-9.1 clay, 9.1-12.2 black pug.
36.6			A	0-0.3 soil, 0.3-9.1 clay, 9.1-18.3 clay and black pug, 18.3-36.6 black pug.
45.7?	dry		A	

Appendix 2 (continued)

	Owner and locality	AMG Reference[1] (approximate)	Completed	Driller[2]	Standing water level (m)	Depth water struck (m)
32	L.C. Clark, Hagley	DP894989	19/ 9/51	D.O.M.	0	32
33	Gibson, Westwood	DQ968064	1967	I.B.C.?	3.3	
34	W. Reynolds, Epping Forest	EP315742	22/11/68	D.O.M.		
35	W. Reynolds, Epping Forest	EP313744	27/11/68	D.O.M.	12.2	27.4-29
36	J. Reynolds, Cleveland	EP335718	1967	Sides & Co.		
37	Tasmanian Government Railways, Conara	EP359687	June 1928	D.O.M.		30.5-33.6
38	Tasmanian Government Railways, Conara	EP361686	June 1928	D.O.M.		30.5-33.6
39	Gibson, Conara	EP388607	9/11/51	D.O.M.		20.7

Total depth (m)	Output (l/min)	Quality (mg/l TDS)	Status[3]	Drillers Log (Depths in metres)
33.6	30	500	O	0-0.3 soil, 0.3-13.7 clay, 13.7-33.6 sandstone.
12.2	8	240	C	Mainly hard basalt.
			F	0-13.7 soil, clay with ironstone pebbles ranging to decomposed basalt, then gravel and grey sand.
29	19+	2795†	O	0-15.2 soil, ironstone gravel, weathered basalt, 15.2-29.9 sand with small gravel, 25.9-29 gravel, then dark clay.
28.7	227	2370†	O	0-12.2 clay, 12.2-18.3 fine sand, 18.3-22 fine sand, gravel with clay, 22-27.4 coarse sand with gravel, 27.4-28.4 ironstone gravel, 28.4-28.7 clay.
39.6	15		F	0-14.6 soil and decomposed basalt, 14.6-20.1 hard basalt, 20.1-22.6 hard white sandstone, 22.6-37.5 fine sandy grit, 37.5-39.6 mudstone.
36.6	15	884†	F	0-14.6 soil and decomposed basalt, 14.6-20.1 hard basalt, 20.1-22.6 hard white sandstone, 22.6-36.6 fine sandy grit.
22.9	23	1480†	O	0-0.6 soil, 0.6-7.6 clay, 7.6-15.2 soft sandstone, 15.2-16.5 dolerite?(or basalt) 16.5-20.7 unknown, 20.7-22.9 decomposed sandstone.

Appendix 2 (continued)

	Owner and locality	AMG Reference[1] (approximate)	Completed	Driller[2]	Standing water level (m)	Depth water struck (m)
40	A.MacKinnon, Campbell Town	EP385637	16/10/68	D.O.M.	1.2	
41	A.MacKinnon, Campbell Town	EP401634	4/ 5/66	T.D.		9.1
42	A. Taylor, Campbell Town	EP280670	19/ 3/63	D.O.M.		12.2
43	A. Taylor, Campbell Town	EP285658	27/ 3/63	D.O.M.		36.6
44	A. Taylor, Campbell Town	EP286657	5/ 3/65	D.O.M.		3.1, 38.1
45	A. Taylor, Campbell Town	EP307675	25/ 5/69	W.L.	5.4	19.8, 20.4, 39.6, 52.5, 67.1
46	J.M.Taylor, Campbell Town	EP358642	28/ 5/69	W.L.	5.2	6.7
47	J.M.Taylor, Campbell Town	EP370651	25/ 5/69	W.L.		

Total depth (m)	Output (*l*/min)	Quality (mg/*l* TDS)	Status[3]	Drillers Log (Depths in metres)
11.3	76		C	0-4.6 brown soil changing to brown clay, 4.6-10.7 decomposed basalt, 10.7-11.3 decomposed basalt with unweathered basalt at end.
12.2	53	1985†	O	0-0.6 sand, 0.6-5.5 clay, 5.5-12.2 basalt.
29	19		O	0-2.4 sand, 2.4-28.7 sandstone, 28.7-29 dolerite.
39	19-23	1140	F	0-6.1 sand, clay and gravel, 6.1-12.2 soft clay, 12.2-36.6 hard grey clay, 36.6-39 sandstone.
42.7	23	1400	O	0-0.6 sand, 0.6-1.8 clay, 1.8-4.9 ironstone gravel, 4.9-18.3 grey clay and sand, 18.3-36.6 grey clay, 36.6-39.6 clay and ironstone gravel, 39.6-42.7 clayey sandstone with rounded pebbles.
80.8	91	1230†	O	0-0.6 soil, 0.6-2.4 clay, 2.4-5.2 coloured sand, 5.2-6.1 ironstone, 6.1-7.6 decomposed dolerite, 7.6-80.8 dolerite.
22.9	6	6990†	O	0-2.1 dark clay, 2.1-6.7 clayey sand, 6.7-8.5 soft sandstone, 8.5-22.9 conglomerate? (probably dolerite for most of depth after 6.7 m).
74.7	poor		C?	0-1.2 soil, 1.2-4.9 honeycombed lava, 4.9-6.7 sandy clay, 6.7-9.1 tuff, 9.1-19.8 decomposed basalt with bands of sandy clay, 19.8-21.3 feldspar, 21.3-28.4 basalt with some quartz, 28.4-33.6 clay,

Appendix 2 (continued)

	Owner and locality	AMG Reference[1] (approximate)	Completed	Driller[2]	Standing water level (m)	Depth water struck (m)
48	K. Headlam, Epping Forest	EP178675	28/ 8/67	T.D.		
49	Gibson, Campbell Town	EP391594	14/11/51	D.O.M.		6.1
50	R.R. Taylor, Cleveland	EP301708	8/ 6/67	T.D.	4.6	13.4
51	A. Taylor, Cleveland	EP307707	8/ 6/67	T.D.	5.2	16.8-22.9
52	A. Taylor, Campbell Town	EP293671	21/ 3/63	D.O.M.		
53	A. Taylor, Campbell Town	EP291672	23/ 3/63	D.O.M.		
54	P. Chilvers, Cleveland	EP336713	13/11/63	D.O.M.	21.3	
55	L. D'Antoine, Epping Forest	EP322758	5/ 6/67	Sides and Co.	8.5	10.7

Total depth (m)	Output (*l*/min)	Quality (mg/*l* TDS)	Status[3]	Drillers Log (Depths in metres)
				33.6-36 basalt and mica, 36-37.5 sandstone, 37.5-59.5 basalt, 59.5-61.3 clay, 61.3-74.7 broken basalt, mica and sand seams (basalt mentioned probably all or nearly all dolerite).
44.2			A	0-0.3 soil, 0.3-44.2 sandy clay, 44.2 dolerite boulders
15.2	27		O	0-0.3 soil, 0.3-4.6 clay, 4.6-15.4 soft sandstone.
18.3	227	1035†	O	0-0.3 soil, 0.3-13.4 clay, 13.4-18.3 coarse sand.
22.9	190	1480†	O	0-0.6 soil, 0.6-16.8 clay, 16.8-22.9 coarse sand.
8.2	dry		A	0-7.6 sand, 7.6-8.2 dolerite
25.9	dry		A	0-3.1 sand, 3.1-9.1 basalt, 9.1-18.3 sandstone, 18.3-25.6 basalt and mudstone, 25.6-25.9 dolerite.
44.2	46+	1011†	O	0-18.3 clay and sand, 18.3-27.4 clay with bands of quartz gravel, 27.4-29 clay with decomposed wood fragments, 29-35.1 gravel, 35.1-44.2 sand and clay, 44.2 dolerite?
16.2	46+	1805†	O	0-4.3 firm clay, 4.3-7.3 fine yellow sand, 7.3-10.7 white sandy clay, 10.7-15.9 coarse producing sand with large wash stones, 15.9-16.2 light brown clay

Appendix 2 (continued)

	Owner and locality	AMG Reference[1] (approximate)	Completed	Driller[2]	Standing water level (m)	Depth water struck (m)
56	W.V. Jones, Campbell Town	EP411560	19/11/70	Mono	0	31
57	T. Woolnough, Hagley	DQ914034	21/ 8/73	Mono	1.2	18.3, 21
58	T.C. French, Hagley	DQ916046	20/ 8/73	Mono	flowing	0.9, 9.8, 14.0
59	J. Badcock, Hagley	DQ904041	23/ 8/73	Mono	0.3	12.1, 16.8, 17.7, 18.3
60	P. Beveridge, Hagley	DQ900043	1/ 3/73	Mono	3.1	6.1, 12, 31.7, 37.2

Total depth (m)	Output (l/min)	Quality (mg/l TDS)	Status[3]	Drillers Log (Depths in metres)
15.2	1515	1980†	C	0-0.3 soil, 0.3-1.2 sandy clay, 1.2-1.8 vesicular basalt, 1.8-2.4 sandy clay and vesicular basalt boulders, 2.4-5.5 vesicular basalt, 5.5-6.1 basalt, 6.1-6.4 broken basalt, 6.4-13.1 basalt, 13.1-15.2 vesicular basalt.
24.4	46	290†	O	0-0.3 soil, 0.3-1.2 brown clay, 1.2-2.4 clay and gravel, 2.4-3.7 yellow clay, 3.7-4.3 grey hardpan, 4.3-11.6 yellow hardpan, 11.6-18.0 basalt, 18.0-18.9 decomposed basalt, 18.9-19.5 red decomposed material, 19.5-21 basalt, 21.-24.4 decomposed basalt.
18.3	46	490†	O	0-0.3 soil, 0.3-1.5 decomposed material, 1.5-2.4 grey clay, 2.4-9.8 decomposed material, 9.8-10.7 broken basalt, 10.7-14.0 basalt, 14.0-18.3 decomposed basalt.
24.4	46	1440†	O	0-0.3 soil, 0.3-1.2 brown clay, 1.2-3.7 decomposed material, 3.7-15.2 decomposed rock, 15.2-16.8 basalt, 16.8-17.4 conglomerate, 17.4-17.7 light grey clay, 17.7-24.4 conglomerate.
44.2	83	120†	O	0-0.2 soil, 0.2-1.5 brown clay, 1.5-4.3 yellow clay with hard bands, 4.3-6.1 grey clay, 6.1-8.2 decomposed yellow material, 8.2-11.9 decomposed rock, 11.9-22.0 basalt, 22.0-31.7 grey clay with decomposed material, 31.7-37.2 basalt, 37.2-44.2 decomposed material with bands of hard clay.

Appendix 2 (continued)

	Owner and locality	AMG Reference[1] (approximate)	Completed	Driller[2]	Standing water level (m)	Depth water struck (m)
61	P. Beveridge, Hagley	DQ902045	2/ 3/73	Mono	3.1	5.5, 8.8, 10.7, 23.8
62	D. Gibson, Cluan	DP883934	18/ 9/73	Mono	9.1	
63	E. Dobson, Bracknell	DP942920	11/ 9/73	Mono	2.1	6.1, 12.2, 21.3, 35
64	E. Dobson, Bracknell (Cluan Road)	DP926889	13/ 9/75	Mono		
65	T. Keach, Poatina	DP925759	23/ 3/73	Mono		33.5, 45.7
66	M. O'Toole, Carrick	EQ038006	6/ 9/73	Mono		22.9

Total depth (m)	Output (l/min)	Quality (mg/l TDS)	Status[3]	Drillers Log (Depths in metres)
30.5	190	260†	O	0-0.3 soil, 0.3-5.5 brown clay, 5.5-7.6 mudstone, 7.6-8.5 blue clay, 8.5-15.2 mudstone, 15.2-20.7 basalt, 20.7-23.8 decomposed grey material with bands of clay, 23.8-28.0 basalt honeycombed with feldspar, 28.0-30.5 basalt.
29.5	46	580†	O	0-0.3 soil, 0.3-6.1 sandy yellow clay (wet), 6.1-7.0 sandy grey clay, 7.0-7.6 hard grey clay, 7.6-9.8 grey sandy clay, 9.8-12.2 yellow sandy clay (wet), 12.2-29.6 mudstone.
29.0	341	760†	O	0-0.3 soil, 0.3-0.9 brown clay, 0.9-29.0 decomposed material (basalt?).
11.0			C	0-0.3 soil, 0.3-0.6 brown clay, 0.6-4.6 decomposed material with dolerite boulders, 4.6-5.8 dolerite boulders, 5.8-9.1 decomposed material with dolerite boulders, 9.1-11.0 dolerite.
58.9	76	420†	O	0-0.3 soil, 0.3-3.4 clay and boulders, 3.4-4.6 dolerite, 4.6-33.5 grey shale, 33.5-34.4 black mudstone, 34.4-39.6 grey mudstone, 39.6-58.9 green rock.
?			S	0-0.2 soil, 0.2-0.6 light brown sandy clay, 0.6-1.8 yellow clay, 1.8-13.7 light grey clay, 13.7-22.9 yellow sandy clay with some water, 22.9-48.8 sandy grey clay.

Appendix 2 (continued)

	Owner and locality	AMG Reference[1] (approximate)	Completed	Driller[2]	Standing water level (m)	Depth water struck (m)
67	M. O'Toole, Carrick	EQ035008	3/ 9/73	Mono		33.5
68	R. Reid, Cleveland	EP334715	1/74	Stacpoole	22.9	22.9
69	H.F. Foster, Campbell Town	EP387566	8/ 4/73	Mono	4.8	4.9, 9.5
70	E. Flood, 'Isis Vale', Campbell Town	EP207665	Feb. 1973	Stacpoole		8.2
71	E. Flood, 'Stone Quarry', Cressy	EP130734	Feb. 1973	Stacpoole		
72	E. Flood, 'Stone Quarry' Cressy	EP131728	Feb. 1973	Stacpoole	1.8	3.1
73	R. Lynch, Hagley	DQ906064	31/ 5/76	Mono	3.1	5.5

Total depth (m)	Output (l/min)	Quality (mg/l TDS)	Status[3]	Drillers Log (Depths in metres)
			S	0-0.2 soil, 0.2-1.2 brown clay, 1.2-2.1 grey clay, 2.1-2.4 red clay, 2.4-14.6 yellow clay with sand bands, 14.6-15.4 basalt boulder, 15.4-26.2 yellow clay with decomposed material, 26.2-27.4 dolerite, 27.4-28.0 soft patch, 28.0-29.6 dolerite, 29.6-30.5 soft patch, 30.5-32 dolerite, 32-32.6 soft patch, 32.6-33.5 dolerite.
32.3	38	880†	O	0-18.0 clay, 18.0-24.4 clay with occasional pebbles, 24.4-32.0 gravel and clay (gravel to 25 mm but average 6 mm), 32.3 brown sandstone.
14.6	76	salty	A	0-0.3 soil, 0.3-2.4 sand, 2.4-4.9 grey sandy clay, 4.9-8.2 decomposed material, 8.2-8.9 gravel, 8.9-14.6 dolerite.
34.1	8	sandy	A	0-0.3 soil, 0.3-4.9 clay and wash, 4.9-8.2 grey drift, 8.2-12.2 fine wet sand, 12.2-15.9 grey drift, 15.9-19.8 black drift, 19.8-34.1 brown drift.
34.4			A	0-0.6 soil, 0.6-6.7 soft clay and sandstone, 6.7-9.1 black clay, 9.1-24.4 brown clay, 24.4-34.4 grey mudstone.
15.9	8	100	C	0.0-3 soil, 0.3-3.1 clay, 3.1-15.9 mudstone.
29.9	380	370†	O	0-0.6 soil, 0.6-5.5 clay, 5.5-9.1 decomposed basalt, 9.1-16.8 soft basalt, 16.8-29.9 vesicular basalt.

Appendix 2 (continued)

	Owner and locality	AMG Reference[1] (approximate)	Completed	Driller[2]	Standing water level (m)	Depth water struck (m)
74	F.B. Hingston, Whitemore	DP938963	20/ 9/76	Mono		
75	Jones, Cressy	EP012886	25/10/78	Mono		
76	Jones, Cressy	EP012885	25/10/78	Mono		
77	Burford, Cressy	EP013888	26/10/78	Mono		
78	V. Adams, Symmons Plains	EP224860	24/10/78	Mono		
79	H. Watmore, Westbury	DQ841030	25/ 9/78	Mono		
80	R. Blazely, Hagley	DQ977063	16/ 2/78	Mono	3.1	4.3
81	S. Herbert, Carrick	DQ988021	22/ 9/78	Mono	3.1	30.5
82	L. Allen, Carrick	EQ031030	7/ 2/79		12.2, 18.3	9.1
83	V. Adams	EP225862		Mono		

Notes:

1 All holes are shown on Figure 3.

2 D.O.M. = Department of Mines
Mono = Mono Pumps (Aust.) Pty Ltd
T.D. = Tasmanian Drillers
W.L. = Waterland
A.G.P. = Austral Geoprospectors
I.B.C. = Intercolonial Boring Company

Total depth (m)	Output (l/min)	Quality (mg/l TDS)	Status[3]	Drillers Log (Depths in metres)
51.8			A	0-10.7 soil and clay (yellow), 10.7-51.8 light blue clay.
10.7			A	0-0.3 soil, 0.3-10.7 clay.
10.7			A	0-0.3 soil, 0.3-10.7 clay.
21.3			A	0-0.3 soil, 0.3-21.3 clay.
38.1			A	0-0.3 soil, 0.3-15.2 clay, 15.2-21.3 coarse sand, 21.3-38.1 clay.
15.2			A	0-1.8 soil and clay, 1.8-15.2 dolerite and clay.
11.6	27	760†	O	0-0.3 soil, 0.3-4.3 loose basalt, 4.3-11.6 dolerite (basalt?).
35.4	114		O	0-3.1 clay, 3.1-4.6 gravel, 4.6-27.4 sand and clay, 27.4-29.0 clay, 29.0-35.4 sand (coarse).
19.8	106	730†	O	0-0.3 soil, 0.3-0.6 rounded stone, 0.6-12.2 clay, 12.2-16.8 loose basalt and clay, 16.8-19.8 basalt (dol-erite?).
				0-0.3 soil, 0.3-7.6 clay 7.6-10.7 sand and gravel, 10.7-88.4 silty clay.

3 O = operating
A = abandoned
F = filled in
C = capped
S = collapsed

† = chemical analysis available.

APPENDIX 3

Geological logs of diamond drill holes

DH 1, Longford area

Two diamond drill holes were drilled in 1885-86 at Belmont near Longford. The actual location of these holes is unknown, the position shown on Figure 3 being that shown on the Longford one mile sheet (Blake, 1959). The site of the first hole was on Mr Ritchies Belmont Estate, while Johnston (1888) described the deeper bore (Belmont Bore 2) as being one mile south-west of Longford (at Belmont), approximately the position shown on Figure 3.

Belmont Bore 1

Depth (m)	*Description*
0 - 4.2	surface shaft
4.2- 16.9	clay with veins of ironstone
16.9- 19.1	drift with quartz stones
19.1- 27.8	sandy clay
27.8- 57.7	clay with lignite
57.7- 78.7	clay and sandy drift
78.7- 86.3	concretionary drift with lignite
86.3- 92.7	sandy clay with lignite
92.7-104.8	drift
104.8-122.5	drift with sandy clay and wood
122.5-139.2	red clay
139.2-145.3	sandstone
145.3-152.0	sandstone with seams of lignite and red clay
152.0-161.6	hard mud shale
161.6-164.7	mud shale and sandstone
164.7-168.3	shale showing fossils
168.3-176.2	shale and sandstone
176.2-177.8	hard brittle slate
177.8-183.7	slate
183.7-186.0	shale with veins of carbonate of lime
186.0-189.5	shale and sandstone
189.5-191.6	shale with veins of concretionary sand and lignite
191.6-194.8	mud shale and sandstone
194.8-197.4	concretionary sand and lignite
197.4-210.3	layers of mud shale and soft mullocky sand and wood

Belmont Bore 2

Depth (m)	*Description*
0 - 5.0	surface shaft
5.0- 12.2	brown clay
12.2- 13.1	wash
13.1- 29.3	black clay
29.3- 39.6	stones and drift
39.6- 53.0	black clay and wood
53.0- 74.4	white clay and wood

Belmont Bore 2 (continued)

Depth (m)	*Description*
74.4-152.8	white sandy clay and drift
152.8-198.6	sandy clay and drift with decayed wood
198.6-215.8	mottled clay
215.8-217.9	red clay
217.9-236.5	sand clay with wood
236.5-267.6	light blue clay with wood (including 1.2 m of wood at 243.8 m)
267.6-272.6	mottled clay and wood

DH 2, Carr Villa Estate, Launceston

This hole was drilled in 1886. The location shown on Figure 3 is only approximate.

Depth (m)	*Description*
0 - 1.8	surface shaft
1.8- 25.6	variegated clay
25.6- 25.7	lignite
25.7- 26.3	red clay
26.3- 33.9	blue sandy clay
33.9- 49.1	sandy clay with lignite
49.1- 49.7	black clay and lignite
49.7- 61.7	blue clay with sandstone pebbles
61.7- 70.1	brown clay
70.1- 96.3	blue and black clay with lignite
96.3- 96.6	black clay and lignite
96.6- 97.8	blue sandy clay
97.8- 97.9	lignite
97.9-101.8	sandstone
101.8-105.8	blue clay
105.8-106.6	black clay and lignite
106.6-115.5	fossiliferous sandstone
115.5-115.6	lignite
115.6-137.9	soft blue sandstone and lignite and leaf beds
137.9-143.9	blue sandy drift and lignite
143.9-146.7	brown clay
146.7-149.6	brown clay and pebbles
149.6-154.5	blue clay with gravel and lignite
154.5-157.0	greenish sandstone
157.0-159.5	white sandstone
159.5-161.0	greenish sandstone
161.0-174.0	hard blue sandstone gradually into greenstone or diabase of a soft to a very sense description

DH 3, Green Rises Road, Cressy [EP046867]

Depth (m)	*Recovery (m)*	*Recovery (%)*	*Description*
0 - 6.1	3.40	56	brown soil, brown clay with limonite pisoliths, light grey and brown mottled clay. Occasional slip surfaces on clay.
6.1 - 12.85	3.35	50	brown and grey mottled clay, a few limonite pisoliths near top.
12.85- 14.53	0.38	23	light brown clay. Thin vertical iron-rich seams (about 0.5 mm diameter)
15.53- 16.08	0.28	51	light brown clay
16.08- 16.69	0.61	100	light brown clay followed by dark grey clay
16.69- 17.30	0.51	84	brown to grey clay
17.30- 17.98	0.58	85	brown clay
17.98- 18.49	0.53	100	grey brown clay, some carbonaceous material
18.49- 19.15	0.38	73	grey-brown clay, thin band of siderite at beginning
19.15- 19.66	0.61	100	brownish clay with vivianite nodules
19.66- 20.32	0.61	100	brown clay, occasional vivianite nodules
20.32- 20.63	0.38	100	brown clay, a few carbonaceous fragments, some mica
20.63- 21.26	0.64	100	1.5 m thick band of siderite followed by brown clay with occasional vivianite nodules
21.26- 21.87	0.14	23	hard sandstone (siderite?) with a little brown clay at end of run
21.87- 22.43	0.58	100	brown clay with iron staining and vivianite nodules
22.43- 23.09	0.56	85	brown clay
23.09- 23.77	0.05	7	brown clay
23.77- 24.53	0.64	84	fragmented brown clay
24.53- 25.43	0.76	84	fragmented brown clay
25.43- 25.55	0.13	100	brown clay, 12 mm siderite band
25.55- 26.16	0.61	100	25 mm siderite band followed by fragmented brown clay
26.16- 26.70	0.46	85	brown clay
26.70- 26.87	0.18	100	brown clay
26.87- 27.58	0.71	100	35 mm siderite band followed by brown clay
27.58- 28.22	0.41	64	brown clay with 10 mm siderite band
28.22- 28.45	0.25	100	fragmented brown to grey clay
28.45- 29.08	0.76	100	brown clay, 25 mm siderite band 150 mm from end of run
29.08- 30.66	1.45	92	75 mm brown clay, 0.6 m brown sandy clay, 0.8 m brown clay. Slip plane at 0.7 m.
30.66- 32.26	1.42	89	brown clay, 25 mm siderite band 1 m from start of run
32.26- 33.83	1.50	96	brown clay, final 100 mm sandy clay
33.83- 35.13	?		brown clay and silt with mica fragments

DH 3, Green Rises Road, Cressy [EP046867] (continued)

Depth (m)	Recovery (m)	Recovery (%)	Description
35.13- 36.70	1.09	82	brown clay, sandy clay for final 500 mm, some plant fragments
36.70- 37.92	1.42	100	brown clay and sandy clay inter-bedded with plant fragments
37.92- 39.78	1.30	70	light brown clay with some sandy horizons, a little mica
39.78- 40.97	1.22	100	dark and light grey-brown clay and silt with some mica
40.97- 41.99	1.42	100	brown silty clay, some mica and plant fragments
41.99- 43.51	1.42	93	brown clay with horizons showing varying degrees of consolidation
43.51- 44.81	1.27	98	brown silty clay, a few mica frag-ments
44.81- 44.93	0.11	92	brown clay
44.93- 46.51	1.45	92	brown clay, some plant fragments
46.51- 47.98	1.32	98	brown clay, a few plant stems
47.98- 49.23	1.37	100	light brown and darker brown clay, plant fragments
49.23- 50.83	1.42	89	brown clay with plant fragments
50.83- 52.12	1.35	100	0.5 m light grey brown compact silty clay
52.12- 52.55	0.33	76	brown clay
52.55- 54.08	1.02	75	brown clay with slip surfaces
54.08- 55.32	1.37	100	brown clay and silty clay, some plant fragments
55.32- 58.37	2.46	100	brown clay with plant fragments
58.37- 58.55	0.74	100	brown clay
58.55- 60.07	1.40	92	brown clay and silt
60.07- 66.80	6.10	91	brown clay with plant fragments, siderite bands at 63.1 m, 65.4 m
66.80- 67.79	0.94	95	brown clay and silty clay
67.79- 75.13	6.81	93	dark grey-brown clay with siderite bands; 150 mm at 68.48 m, 40 mm at 69.29 m, 15 mm at 69.93 m, 25 mm at 70.31 m, 25 mm at 70.82 m, 200 mm at 71.93 m, 25 mm at 72.54 m, 50 mm at 73.08 m, 75 mm at 73.33 m, 25 mm at 73.48 m and 25 mm at 74.37 m.
75.13- 79.66	3.99	88	mainly light grey sandy clay, a little brown clay, siderite band at 75.29 m
79.66- 81.13	0.56	38	light grey and dark grey clay, 230 mm fine sandstone at end of run
81.13- 82.78	no recovery		
82.78- 83.24	0.38	83	light grey sand, some clay
83.24- 86.08	no recovery		
86.08- 87.61	1.25	82	coarse grey sand, a little clay
87.61- 89.26	0.81	49	coarse sand with plant fragments
89.26- 91.59	1.32	57	sand with plant fragments, 150 mm gravel at 90.07 m

DH 3, Green Rises Road, Cressy [EP046867] (continued)

Depth (m)	*Recovery (m)*	*Recovery (%)*	*Description*
91.59- 91.87	0.33	100	sand with gravel band (fragments up to 25 mm diameter)
91.87-101.42	4.70	49	grey and brown sand, some plant fragments, mica, a little clay
101.42-108.31	5.61	81	sand and sandy clay interbedded with mica and plant fragments, minor clay beds
108.31-109.02	0.66	93	coarse sand, clayey sand, plant fragments
109.02-110.57	0.18	12	sandy clay, some wood fragments
110.57-112.09	no recovery		
112.09-120.50	5.51	66	mainly loose grey sand, minor clay bands and a few plant fragments.
120.50-129.77	4.19	45	grey sandy clay with plant fragments and leaf impressions, some mica
129.77-131.90	2.21	100	light grey clay, some sandy horizons
131.90-133.43	1.63	100	light grey sandy clay with plant fossils, final 300 mm of dark grey-brown clay
133.43-133.61	0.13	72	dark grey-brown clay with shear surfaces
133.61-137.72	3.45	84	light grey clay with sand size siderite crystals
137.72-141.05	3.35	100	light grey clay with sand size siderite crystals. Red stain on broken surfaces

DH 4, Egerton Road, White Hills [EQ221024]

Depth (m)	*Recovery (m)*	*Recovery (%)*	*Description*
0 - 1.6	0.23	14	black sandy soil passing into sandy clay
1.6 - 3.02	0.53	37	occasional dolerite pebbles in spotted blue-grey clay
3.02- 4.00	0.46	47	light grey spotted brown clay with unweathered basalt boulders, one dolerite fragment
4.00- 5.5	0.18	12	dolerite boulders
5.5 - 6.8	0.11	9	dolerite boulders and travertine
6.8 - 7.29	0.26	53	dolerite and basalt boulders
7.29- 8.53	0.32	26	as above
8.53- 9.73	0.12	6	one dolerite boulder
9.73- 9.88	0.12	80	dolerite and basalt fragments
9.88- 10.31	0.26	61	basalt fragments
10.31- 10.68	0.23	62	basalt boulders, one coarse tuff fragment
10.68- 11.06	0.08	21	basalt fragments, a little weathered
11.06- 12.1	0.33	32	basalt fragments
12.1 - 12.2	0.14	140	basalt boulders, one small dolerite fragment

Depth (m)	*Recovery (m)*	*Recovery (%)*	*Description*
12.2 - 13.16	0.14	15	basalt fragments followed by one fragment of basalt welded in contact with a conglomerate containing dolerite and basalt boulders
13.16- 14.08	0.48	52	mainly basalt fragments, some vesicular, two dolerite fragments up to 70 mm diameter, some sandy material
14.08- 15.64	0.15	10	tuffaceous sandstone containing calcite seams
15.64- 17.66	0.95	47	sand and conglomerate, containing weathered dolerite fragments followed by weathered vesicular basalt and occasional dolerite boulders
17.66- 19.25	0.53	33	conglomerate with dolerite boulders
19.25- 19.86	0.63	103	as above
19.86- 20.16	0.30	100	as above
20.16- 20.46	0.24	80	as above
20.46- 20.76	0.42	140	as above with one quartzite boulder
20.76- 21.06	0.25	83	conglomerate
21.06- 21.36	0.30	100	conglomerate with one basalt fragment
21.36- 21.76	0.30	75	as above with calcite veining
21.76- 21.98	0.16	73	conglomerate with basalt fragments
21.98- 22.28	0.25	83	as above, mainly dolerite boulders
22.28- 22.58	0.22	73	conglomerate with zeolite veins
22.58- 22.88	0.20	67	conglomerate of dolerite, a few basalt fragments with sandy matrix
22.88- 23.18	0.26	87	as above
23.18- 23.48	0.42	140	as above
23.48- 23.78	0.23	77	conglomerate
23.78- 24.08	0.23	77	finer grained conglomerate
24.08- 24.38	0.22	73	as above, small dolerite fragments
24.38- 24.78	0.4	100	tuffaceous sand
24.78- 25.08	0.30	100	fine even grained tuffaceous sandstone
25.08- 25.38	0.20	67	fine sand passing into silty clay
25.38- 26.90	0.18	12	conglomerate mainly dolerite fragments, gritty matrix
26.90- 28.42	0.47	31	as above with clay zones
28.42- 29.03	0.56	92	fine conglomerate, occasional 50 mm dolerite fragments
29.03- 30.25	-	-	one small pebble recovered
30.25- 31.77	1.30	86	fine conglomerate with dolerite and quartzite, final 180 mm passing into laminated tuffaceous sandstone
31.77- 32.20	0.5	116	conglomerate with coarse sand matrix, mainly dolerite, occasional quartzite fragments
32.20- 32.60	0.37	93	as above

DH 4, Egerton Road, White Hills [EQ221024] (continued)

Depth (m)	*Recovery (m)*	*Recovery (%)*	*Description*
32.60- 33.00	0.40	100	conglomerate with some basalt fragments
33.00- 33.30	0.45	150	conglomerate mainly with dolerite fragments
33.30- 33.8	-	-	no recovery
33.8 - 34.10	0.4	133	as above with occasional clay pellet areas
34.10- 34.6	0.38	76	conglomerate-dolerite with occasional vesicular basalt fragments
34.6 - 35.5	0.52	58	begins with conglomerate followed by silty light brown clay with mica fragments
35.5 - 37.02	0.20	13	two conglomerate fragments followed by light brown disturbed sandy clay
37.02- 37.52	0.40	80	50 mm of conglomerate fragments followed by clay and deeply weathered vesicular basalt
37.52- 38.02	0.36	72	weathered basalt
38.02- 38.52	0.48	96	variably weathered basalt, calcite seams
38.52- 39.02	0.35	70	weathered vesicular basalt
39.02- 39.52	0.34	68	weathered basalt (one dolerite fragment may have fallen down from above)
39.52- 39.93	0.34	83	weathered basalt
39.93- 40.45	0.38	73	deeply weathered basalt with zones of calcite seams 15 mm thick
40.45- 40.95	0.33	66	weathered basalt
40.95- 42.97	1.98	98	weathered basalt, becomes less weathered towards end, final 30 mm is conglomerate
42.97- 44.49	0.48	32	conglomerate-basalt and dolerite fragments for 200 mm then vesi-cular basalt to end
44.49- 46.01	0.73	48	420 mm of light brown clay followed by possibly very deeply weathered vesicular basalt
46.01- 48.18	2.1	101	grey sandy clay passing into green-ish silty clay, 150 mm carbon-aceous grey clay 600 mm before end, then green sand
48.18- 49.05	0.9	103	sandy and silty light grey clay passing into light grey clay, some carbonaceous
49.05- 50.57	1.55	102	silty grey clay
50.57- 52.09	1.57	103	silty grey clay, plant stems abun-dant one iron oxide replaced stem.
52.09- 52.74	0.50	77	grey silty clay
52.74- 53.61	0.95	109	light grey and grey-brown clay with plant stems, concentration of carbonaceous material at end

DH 4, Egerton Road, White Hills [*EQ221024*] *(continued)*

Depth (m)	*Recovery (m)*	*Recovery (%)*	*Description*
53.61- 55.13	1.58	104	as above, coaly matter and carbonaceous clay for 500 mm in middle
55.13- 56.65	0.52	34	sandy clay (feldspathic or tuff?)
56.65- 58.17	1.01	66	disturbed silty clay
58.17- 59.69	0.82	54	light grey silty and sandy clay
59.69- 61.61	1.28	67	first 600 mm disturbed clay, final part fine sand
61.61- 63.13	1.20	79	fine sand, final 100 mm silty clay
63.13- 64.65	0.68	45	light grey silty clay
64.65- 66.17	0.87	57	light grey clay

APPENDIX 4

Logs of proline auger holes

Hole	Location	Depth water struck (m)	Total depth (m)	Salinity (mg/*l*)	Log (Depths in metres)
1	Parknook Road, Cressy	1.2	2.7	3500	0-0.9 soil, passing into brown clay; 0.9-2.7 brown clay with Permian tillite at bottom.
2	Parknook Road, Cressy	1.5	15.2	6750	0-0.9 soil and brown clay; 0.9-5.5 brown clay with pebbles; 5.5-15.2 grey mudstone (Permian).
3	Cressy	1.8	7.3	900	0-0.9 soil and brown clay; 0.9-4.6 brown clay with pebbles; 4.6-7.3 grey sand.
4	Cressy	1.5	6.4	1250	0-0.9 soil and brown clay; 0.9-2.7 brown clay with pebbles; 2.7-6.4 grey sand.
5	Cressy	-	7.3		0-0.9 soil and brown clay; 0.9-1.8 brown pebbly clay; 1.8-2.7 grey clay; 2.7-3.7 brown pebbly clay; 3.7-7.3 brown and grey clay.
6	Cressy	1.5	11.9	750	0-4.6 red clay, some gravel fragments; 4.6-11.9 alternating red and grey clay.
7	Cressy	1.8	13.1	2100	0-1.8 pebbly clay; 1.8-3.7 brown clay; 3.7-13.1 white clayey sand.
8	Cressy	2.4	13.1	3200	0-1.8 brown lateritic soil; 1.8-8.2 grey and iron-stained clay; 8.2-13.1 brown and grey clay.
9	Cressy	2.1	10.1	3200	0-10.1 silt, grey clay, sandy clay with a few pebbles.
10	Cressy	1.1	12.8	7000	0-4.6 iron-stained light grey clay; 4.6-12.8 light brown to grey clay.
11	Cressy	4.6	12.8	6800	0-0.9 brown clay; 0.9-5.5 iron-stained light grey clay; 5.5-12.8 grey and light brown clay.

Appendix 4 (continued)

Hole	Location	Depth water struck (m)	Total depth (m)	Salinity (mg/*l*)	Log (Depths in metres)
12	Cressy	2.7	13.1	6800	0-0.9 dark brown clay; 0.9-1.8 reddish clay; 1.8-4.6 light grey clay; 4.6-8.2 iron-stained light grey clay; 8.2-13.1 light grey clay.
13	Cressy	4.9	4.9+	1100	Sandy silt, brown clay with a few pebbles, mudstone fragments and white clay.
14	Cressy	3.1	3.1+	1200	Silty soil, brown clay, sandy clay.
15	Cressy	3.1	3.1+	1350	Silty soil, brown clay, grey clay with pebbles.
16	Poatina	-	0.8	-	0-0.8 pebbly sandy silt (Permian tillite?).
17	Poatina	-	2.7	-	0-0.9 silty soil; 0.9-1.8 brown clay; 1.8-2.7 pebbly sandy clay.
18	Poatina	-	1.2	-	0-1.2 sandy clay, occasionaly dolerite pebbles.
19	Poatina	-	2.1	-	0-0.9 black sandy soil; 0.9-2.1 light brown clayey sand.
20	Poatina	2.1	2.7	300	0-0.9 black clay; 0.9-1.6 clayey sand; 1.6-2.7 pebbly clayey sand.
21	Poatina	-	4.6	-	0-2.7 dark coloured clay; 2.7-4.6 clay with sand and silt.
22	Poatina	2.1	3.1	700	0-0.9 dark coloured clay; 0.9-1.8 pebbly sandy silt; 1.8-3.1 dark grey mudstone (Permian).
23	Poatina	2.4	5.5	1220	0-0.9 silty soil; 0.9-3.7 pebbly clay (some dolerite fragments); 3.7-5.5 dark grey mudstone (Permian).
24	Macquarie Settlement	2.7	6.4	870	0-4.6 sandy clay; 4.6-6.4 sandy clay with pebbles.
25	Macquarie Settlement	4.9	10.1	3700	0-1.8 gravelly silty soil; 1.8-3.7 brown sand; 3.7-10.1 sandy clay and clayey sand with pebbles.

Appendix 4 (continued)

Hole	Location	Depth water struck (m)	Total depth (m)	Salinity (mg/l)	Log (Depths in metres)
26	Macquarie Settlement	1.5	13.1	12 000	0-0.9 silty soil; 0.9-4.6 sand; 4.6-13.1 light grey sandy silt becoming finer with increasing depth.
27	Macquarie Settlement	2.4	12.8	2300	0-1.8 sandy soil; 1.8-3.7 iron-stained clay with sand and pebbles; 3.7-12.8 fine sand.
28	Macquarie Settlement	-	1.8	-	0-1.8 silt with sand and pebbles.
29	Macquarie Settlement	4.3	13.1	13 820	0-1.8 silty soil; 1.8-6.4 iron-stained light grey clay; 6.4-13.1 brown clay.
30	Macquarie Settlement	2.1	13.1	very saline	0-0.9 silty soil; 0.9-5.5 iron-stained light grey clay; 5.5-13.1 light brown to grey clay.
31	Macquarie Settlement	9.8	19.2	11 730	0-5.5 sand and sandy silt; 5.5-7.3 silt; 7.3-19.2 clay and silty clay.
32	Macquarie Settlement	4.6	7.0	1100	0-7.0 sand and clayey sand.
33	Macquarie Settlement	-	1.8	-	0-1.8 gravel (pisolitic limonite).
34	Macquarie Settlement	4.0	19.2	1250	0-19.2 sand and clayey sand with lignite fragments towards bottom.
35	Macquarie Settlement	2.4	17.4	1330	0-15.6 sand; 15.6-17.4 sandy clay.
36	Macquarie Settlement	7.0	14.6	very saline	0-0.9 silty soil; 0.9-1.8 clay with silt and pebbles; 1.8-5.5 sandy silt; 5.5-14.6 silty clay.

Appendix 4 (continued)

Hole	Location	Depth water struck (m)	Total depth (m)	Salinity (mg/l)	Log (Depths in metres)
37	Connorville	1.8	11.0	2500	0-0.9 silty soil; 0.9-2.7 silty clay; 2.7-11.0 pebbly sandy silt (Permian tillite?).
38	Connorville	2.1	4.3	1400	0-0.9 silty soil; 0.9-4.3 sandy and clayey silt with pebbles towards bottom of hole.
39	Connorville	2.7	3.1	900	0-0.9 pebbly silt; 0.9-3.1 weathered phyllite (Cambrian).
40	Connorville	2.1	18.3	1500	0-0.9 silt; 0.9-14.6 brown and red clay, silty clay with occasional pebbles; 14.6-18.3 green clay.
41	Connorville	-	2.4	-	0-0.9 clayey soil; 0.9-2.4 clay with gravel.
42	Connorville	-	1.2	-	0-1.2 gravelly silt.
43	Connorville	-	8.2	-	0-0.9 pebbly silt; 0.9-5.5 pebbly sand; 5.5-8.2 pebbly clay.
44	Connorville	-	0.9	-	0-0.9 gravelly silt.
45	Connorville	-	1.2	-	0-1.2 pebbly clay.
46	McRaes Hills	-	2.4	1200	0-2.4 brown sandy clay (one dolerite boulder).
47	McRaes Hills	-	1.2	-	0-0.9 brown sandy clay; 0.9-1.2 pebbly clay (mainly quartzite, some dolerite fragments).
48	McRaes Hills	-	0.9	-	0-0.9 clay and dolerite boulders.
49	Blackwood Creek	-	0.9	-	0-0.6 dolerite boulders; 0.6-0.9 Permian mudstone?
50	Blackwood Creek	3.4	4.6	410	0-0.9 dark clay and small dolerite fragments; 0.9-1.8 dark clay; 1.8-4.6 pebbly clay (Permian).
51	Blackwood Creek	-	0.9	-	0-0.9 sandy clay with quartzite fragments (bottomed on Permian?)

Appendix 4 (continued)

Hole	Location	Depth water struck (m)	Total depth (m)	Salinity (mg/l)	Log (Depths in metres)
52	Blackwood Creek	1.5	15.2	870	0-0.9 brown clay; 0.9-1.8 brown clay with lime nodules; 1.8-2.7 brown clay with iron oxide nodules and occasional dolerite boulders; 2.7-15.2 pebbly blue clay (mostly Permian).
53	Blackwood Creek	-	0.6	-	0-0.6 brown clay, a few dolerite fragments and a few brown sandstone fragments.
54	Blackwood Creek	-	0.6	-	0-0.6 sandy clay, some Permian? sandstone fragments.
55	Blackwood Creek	-	1.5	-	0-0.9 brown clay and occasional dolerite pebbles; 0.9-1.5 clay with quartzite pebbles (Permian).
56	Blackwood Creek	-	1.8	-	0-1.8 brown clay (bottomed on Permian?)
57	Blackwood Creek	-	1.5	-	0-1.5 clay and pebbles.
58	Blackwood Creek	-	1.5	-	0-1.5 brown sandy clay.
59	Blackwood Creek	1.5	5.5	1800	0-1.8 brown clay; 1.8-5.5 blue clay and mudstone fragments (Permian).
60	Bracknell	3.1	15.2	170	0-0.9 brown clay; 0.9-2.7 blue sandy clay; 2.7-12.2 light brown sandy clay; 12.2-15.2 dark grey clay.
61	Bracknell	2.4	4.0	420	0-0.9 brown clay; 0.9-1.8 grey brown clay; 1.8-2.7 blue grey clay with mudstone fragments; 2.7-4.0 grey brown clay.
62	Bracknell	0.3	4.3	240	0-1.8 brown sandy clay; 1.8-4.3 dark grey mudstone.
63	Bracknell	-	3.4	-	0-1.8 brown sandy clay; 1.8-3.4 grey clay, some sand with pebbles (mainly quartzite, some dolerite).
64	Bracknell	0.6	3.7	950	0-1.8 brown clayey sand; 1.8-2.7 clayey sand and sandstone fragments; 2.7-3.7 sand with rounded quartz fragments.
65	Bracknell	-	2.4	-	0-0.9 sandy clay; 0.9-2.4 sand, clay and gravel.

Appendix 4 (continued)

Hole	Location	Depth water struck (m)	Total depth (m)	Salinity (mg/l)	Log (Depths in metres)
66	Bracknell	2.4	6.1	2250	0-2.7 clayey sand; 2.7-4.6 sandy clay; 4.6-6.1 clay, sand and gravel (mainly quartz and quartzite up to 60 mm diameter).
67	Bracknell	1.5	7.3	800	0-0.9 brown sandy clay; 0.9-2.7 blue-grey sandy clay; 2.7-7.3 dark blue-grey clay with fragments of blue mudstone and sandy mudstone.
68	Bracknell	-	6.4	-	0-0.9 grey-brown clayey sand; 0.9-1.8 brown clayey sand with a few quartz pebbles; 1.8-6.4 brown clayey sand.
69	Cluan	2.4	8.5	320	0-3.7 brown clayey sand; 3.7-4.6 blue sandy clay; 4.6-5.5 light grey clay; 5.5-8.5 grey-blue micaceous mudstone fragments.
70	Cluan	1.2	6.7	880	0-3.7 clay, sandy clay with occasional quartz pebbles; 3.7-6.7 white and brownish sand (Triassic?).
71	Cluan	2.4	9.8	240	0-3.7 grey and brown sandy clay; 3.7-6.4 reddish brown clay, some sandstone fragments, some pebbles; 6.4-7.3 brown sand; 7.3-9.8 light grey and dark grey-banded micaceous sandstone (Triassic?)
72	Cluan	8.2	11.0	1050	0-1.8 clay and sand; 1.8-11 grey micaceous shale and bluish sandstone (Triassic).
73	Cluan	4.9	6.4	800	0-0.9 sandy clay; 0.9-6.4 sand, sandstone fragments with mica (Triassic).
74	Cluan	4.0	5.8	950	0-2.7 sandy clay; 2.7-3.7 yellow sand with sandstone fragments; 3.7-5.8 blue sandy clay with blue mudstone and sandy mudstone flakes.
75	Western Lagoon	2.4	6.4	600	0-1.8 brown clay, some sand; 1.8-4.6 grey-brown sand with clay and pebbles; 4.6-6.4 light brown clay some sandstone fragments and chert(?) fragments (Triassic?)

Appendix 4 (continued)

Hole	Location	Depth water struck (m)	Total depth (m)	Salinity (mg/*l*)	Log (Depths in metres)
76	Western Lagoon	2.1	6.4	1100	0-0.9 green to brown clay; 0.9-1.8 clayey sand; 1.8-5.5 clayey sand; 5.5-6.4 sand (on sandstone?, Triassic?)
77	Conara	1.2	6.4	3500	0-2.7 grey clay; 2.7-3.7 dark grey clay; 3.7-6.4 brown clay with weathered basalt fragments.
78	Conara		15.2	9000	0-1.8 grey-brown clay; 1.8-3.7 dark grey clay, some sandy clay; 3.7-10.1 brown clayey sand with basalt and dolerite(?) fragments up to 10 mm diameter; 10.1-11.9 light grey clay; 11.9-15.2 light grey sandy clay.
79	Conara	2.4	6.4	7000	0-0.9 brown sandy clay with fine angular gravel (granitic quartz fragments?); 0.9-2.7 brown clayey sand; 2.7-4.6 grey clayey sand; 4.6-6.4 grey clayey sand with gravel fragments up to 10 mm.
80	Conara	1.2	5.5	1650	0-0.9 pisolitic iron nodules in clay; 0.9-3.7 sandy clay, a few pisolitic iron nodules; 3.7-5.5 clay with abundant pisolitic iron nodules.
81	Conara	-	2.4	-	0-2.4 red clay with pisolitic iron nodules.
82	Conara	-	6.4	-	0-4.6 orange-red clay; 4.6-6.4 yellowish white clay.
83	Conara	-	6.1	-	0-0.9 brown clay; 0.9-2.7 iron-stained grey clay; 2.7-4.6 brown and grey clay with abundant limonite pisolites; 4.6-5.5 brown clay with occasional limonite pisolites; 5.5-6.1 brown clay with abundant limonite pisolites.
84	Cleveland	-	5.2	-	0-1.8 red clay; 1.8-5.2 yellow-brown clay.
85	Cleveland	0.9	6.1	4500	0-2.7 orange-red clay, some quartz gravel; 2.7-6.1 light yellowish grey clay.
86	Cleveland	-	6.4	-	0-1.8 brown clayey sand; 1.8-2.7 brown to red clay with limonite pisolites; 2.7-6.4 light grey-brown clay.

Appendix 4 (continued)

Hole	Location	Depth water struck (m)	Total depth (m)	Salinity (mg/l)	Log (Depths in metres)
87	Cleveland	-	6.4	-	0-0.9 grey clayey sand, some grit; 0.9-1.8 red sandy clay with limonite pisolites; 1.8-4.6 light brown sandy clay; 4.6-6.4 grey-brown sand.
88	Cleveland	-	6.4	-	0-2.7 brown clay and sand, a few gravel fragments; 2.7-3.7 grey-brown sand; 3.7-4.6 brown clay; 4.6-6.4 light grey-brown sandy clay.
89	Cleveland	-	2.4	-	0-2.4 red clay with limonite pisolites.
90	Cleveland	-	2.4	-	0-1.8 brown clay with limonite pisolites; 1.8-2.4 iron-stained grey clay with limonite pisolites.
91	Cleveland	-	1.5	-	0-1.5 iron-stained clay with limonite pisolites.
92	Epping Forest	-	2.7	-	0-0.9 brown clay with limonite pisolites; 0.9-1.8 limonite stained grey clay; 1.8-2.7 red clay with massive laterite fragments.
93	Epping Forest	-	6.4	-	0-0.9 brown clay with limonite pisolites, some sand; 0.9-1.8 iron stained grey clay, abundant limonite; 1.8-2.7 grey sandy clay; 2.7-3.7 grey sand, sandstone fragments; 3.7-6.4 yellow sand.
94	Epping Forest	-	6.4	-	0-0.9 light brown clay with limonite pisolites; 0.9-2.7 iron stained grey clay with limonite pisolites; 2.7-6.4 light grey-brown clay with limonite fragments.
95	Epping Forest	-	6.4	-	0-0.9 brown clay, abundant limonite pisolites; 0.9-1.8 iron stained grey clay with limonite pisolites; 1.8-4.6 light grey clay; 4.6-6.4 light grey sand.
96	Epping Forest	2.7	6.4	1250	0-1.8 iron-stained brown and grey clay; 1.8-2.7 cream clay; 2.7-6.4 grey and yellow clayey sand.

Appendix 4 (continued)

Hole	Location	Depth water struck (m)	Total depth (m)	Salinity (mg/l)	Log (Depths in metres)
97	Epping Forest	2.4	5.2	1000	0-1.8 grey iron-stained clay, limonite pisolites; 1.8-3.7 yellow grey clayey sand; 3.7-5.2 chocolate brown clay (some weathered basalt?)
98	Epping Forest	-	1.5	-	0-1.5 limonite pisolites and iron-stained grey clay.
99	Epping Forest	-	6.4	-	0-0.9 grey-brown clay, some limonite pisolites; 0.9-4.6 grey-brown clay; 4.6-6.4 light brown clay.
100	Epping Forest	-	6.4	-	0-0.9 grey-brown clay, some limonite pisolites; 0.9-4.6 grey-brown clay; 4.6-6.4 light brown clay.
101	Epping Forest	-	12.8	-	0-8.2 red-orange-grey and brown clay; 8.2-12.8 white, grey and brown gravelly clay (quartz and quartzite gravel).
102	Barton area	-	4.6	-	0-2.7 brown clayey sand, a few limonite pisolites; 2.7-4.6 brown sand, a few limonite pisolites.
103	Barton area	1.8	4.6	6500	0-0.9 brown clayey sand; 0.9-2.7 grey clayey sand; 2.7-4.6 yellow sand, some sandstone fragments (Triassic?)
104	Barton area	2.1	4.6	2250	0-0.9 dark brown sandy clay, a few limonite pisolites; 0.9-4.6 light brown sandy clay.
105	Kenilworth area	-	3.4	-	0-1.8 brown sand; 1.8-3.4 grey-brown sand, some sandstone fragments.
106	Stockwell area	-	4.6	-	0-0.9 brown sand; 0.9-2.7 clayey brown sand; 2.7-4.6 brown sand with sandstone fragments.
107	Kenilworth area	-	1.5	-	0-1.5 brown clayey sand with some limonite pisolites.
108	Kenilworth area	2.1	4.6	2700	0-4.6 brown gravel with sand and clay (gravel fragments of dolerite, quartz, chert, silicified wood and limonite pisolites).

Appendix 4 (continued)

Hole	Location	Depth water struck (m)	Total depth (m)	Salinity (mg/l)	Log (Depths in metres)
109	Winton area	3.4	4.6	2250	0-0.9 brown sand; 0.9-2.7 dark brownish grey clay, some sand, some limonite pisolites; 2.7-4.6 clayey sand with gravel (limonite pisolites and quartzite up to 25 mm diameter).
110	Barton area	-	2.7	-	0-0.9 brown sandy clay with limonite pisolites; 0.9-2.7 sand and sandstone (Triassic).
111	Barton area	-	4.6	-	0-0.9 orange clay; 0.9-2.7 white clay; 2.7-3.7 yellow clay; 3.7-4.6 grey clay.
112	Barton area	-	1.5	-	0-1.5 yellow sand with sandstone fragments.
113	Kenilworth area	1.2	4.6	4300	0-0.9 brown sandy clay; 0.9-2.7 light brown and dark pink shale; 2.7-4.6 brown shale and sand.
114	Stockwell area	-	1.5	-	0-1.5 brown sandy clay (bottomed on dolerite).
115	Kenilworth area	-	2.7	-	0-0.9 brown sand; 0.9-2.7 brown clayey sand.
116	Winton area	3.4	4.6	1100	0-0.9 brown sand; 0.9-2.7 orange-brown sandy clay; 2.7-4.6 yellow clay, some limonite pisolites.
117	Winton area	1.5	4.6	5400	0-1.8 clayey sand, some fine gravel; 1.8-2.7 chocolate sandy clay with abundant gravel (limonite pisolites, quartz and chert fragments up to 25 mm diameter); 2.7-4.6 brown-grey clayey sand.
118	Valleyfield	-	4.6	-	0-3.7 brown sandy clay with limonite pisolites; 3.7-4.6 light brown sand with sandstone fragments (Triassic?).
119	Stockwell	2.4	3.4	14 000	0-0.9 dark yellow sand; 0.9-3.4 yellow sand, some sandstone fragments (Triassic?)
120	Quarry Hill	-	2.4	-	0-0.9 clayey sand; 0.9-2.4 yellow sand and sandstone fragments.

Appendix 4 (continued)

Hole	Location	Depth water struck (m)	Total depth (m)	Salinity (mg/l)	Log (Depths in metres)
121	Quarry Hill	-	4.6	-	0-2.7 orange-red sand; 2.7-4.6 grey-white sand, some sandstone fragments.
122	Stockwell	-	3.7	-	0-2.7 brown sand (some clay from 1.8-2.7); 2.7-3.7 cream sand with sandstone fragments (Triassic?)
123	Kenilworth	-	4.6	-	0-0.9 brown sand; 0.9-1.8 brown sand with some limonite pisolites; 1.8-4.6 clayey sand with some gravel (chert and limonite pisolites up to 25 mm diameter).
124	Kenilworth	-	4.6	-	0-0.9 brown clay with abundant limonite nodules; 0.9-4.6 gravelly sand (quartz, chert silicified wood, limonite nodules and dolerite up to 40 mm diameter).
125	Winton	-	4.6	-	0-1.8 brown sand; 1.8-2.7 sand and dark grey clay; 2.7-3.7 dark grey clay; 3.7-4.6 brown sandy clay, some gravel (including agate and dolerite fragments).
126	Stockwell	-	2.1	-	0-0.9 brown sandy clay; 0.9-2.1 sand and sandstone fragments.
127	Stockwell	-	1.2	-	0-1.2 sand and sandstone fragments.
128	Powranna area	-	5.3	-	0-1.2 iron oxide pisolitic gravel (up to 25 mm diameter) and silt; 1.2-1.8 hard brown clay; 1.8-2.7 white indurated? silty clay; 2.7-3.7 angular coarse light brown quartz sand, some pebbles; 3.7-4.6 becoming coarser with fragments of quartz often 6 mm and occasionally up to 15 mm diameter, milky and dark granite-like quartz; 4.6-5.3 sandy gravel, with quartz fragments up to 50 mm diameter some clayey sand. At 5.3 m drilling stopped by hard material - large gravel fragment?

Appendix 4 (continued)

Hole	Location	Depth water struck (m)	Total depth (m)	Salinity (mg/l)	Log (Depths in metres)
129	Powranna area	-	8.1	-	0-0.3 iron oxide pisolitic gravel; 0.3-1.8 red iron oxide stained grey clay; 1.8-2.7 brown clay, some iron oxide fragments, some quartz fragments; 2.7-7.3 red-brown, brown and light brown clayey sand and clayey gravel, mainly milky quartz fragments; 7.3-8.1 fine red clayey gravel with fragments about 4 mm diameter, but some larger quartzite fragments up to 30 mm.
130	Stinking Springs	-	2.7	-	0-1.2 limestone; 1.2-1.8 clay with nodules of limestone; 1.8-2.7 blue clay with pyrite.
131	Stinking Springs (30 m west of spring)	-	2.7	-	0-0.6 clay; 0.6-2.4 clay with limestone nodules; 2.4-2.7 clay with quartzite pebbles.
132	Stinking Springs (180 m west of spring)	-	2.7	-	0-0.6 sand; 0.6-0.9 brown clay; 0.9-1.8 clay with some limonite nodules; 1.8-2.1 sand; 2.1-2.7 clay with some gravel fragments (quartz).

APPENDIX 5

Summary logs of uranium prospecting holes

The following are abridged versions of logs prepared by Getty Oil Development Co. for the uranium prospecting holes. The interpretations of the electric logs have been made from those supplied with the report (Middleton, 1973). The more distinct features of these logs have been selected; *e.g.* the zones which probably represent sand or gravel which may be water-bearing as opposed to the clay and silty clay horizons. Another distinct feature of the electric logs, particularly in the western part of the basin, are narrow sharp peaks which probably represent siderite seams ('carbonate' bands).

In some holes the standing water level is given, but mostly it is the fluid level that is recorded. This latter figure may be about the same value as the standing water value in many cases. In holes where good aquifers were penetrated, the mud level from the drilling would be expected to progress fairly quickly towards the standing water level. Where poor aquifers or no water-bearing horizons were intersected, the fluid level and the standing water level are likely to be markedly different.

B1

This hole is shown on one of Getty Oil's location plans, but there is no record of the hole being drilled.

B2 (elevation 218.5 m; hole depth 29.5 m)

0-0.3 m sandy soil; 0.3-2.4 m grey and light brown clay, red streaks; 2.4-5.5 m red iron oxide stained sand; 5.5-15.2 m grey, light brown, brown, and yellow-brown clay; 15.2-29.6 m basalt, weathered at top becoming less weathered till too hard to drill.

Remarks: Hole dry, cuttings air flushed 0-29.5 m. At 29.0 m water was brought up with cuttings. Electric logs - only gamma ray (good). Significant constant decrease in this at 11.6 m - beginning of basalt?

B3 (elevation 208.8 m; hole depth 6.1 m)

0-1.5 m clay - grey to brown, infrequent limonite nodules grading into weathered basalt; 1.5-6.1 m basalt - weathered to 3.1 m, then unweathered.

Remarks: Cuttings air flushed.

B4 (elevation 215.5 m; hole depth 33.5 m)

0-0.6 m ironstone gravel (up to 25 mm), concretions, sandy silty matrix; 0.6-4.6 m grey ferruginous clay; 4.6-18.3 m grey clay, some limonite staining, thin beds of gritty ferruginous gravel (9.1-12.2 m); 18.3-21.3 m clay, probably weathered basalt; 21.3-33.5 m basalt - weathered to fresh.

Remarks: Air flushed 0-4.6 m, water flushed 4.6-33.5 m.

B5 (elevation 214.3 m; hole depth 32.0 m)

0-0.2 m sand, fine grey quartz, occasional limonite nodules; 0.2-12.2 m clay, grey to buff-yellow-brown, some ironstone nodules; 12.2-13.7 m clay, grey passing into green clay with igneous texture; 13.7-32.0 m basalt, weathered at top, becoming less weathered, vesicular. Cavity 30.2-31.4 m.

Remarks: Air flushed 0-3.1 m, water flushed 3.1-32.0 m, loss of water 30.2 m - unable to regain - lack of sufficient casing.

Electric logs: Water level at 26.2 m - thus only γ which is irregular to 12.2 m then decreases to fairly uniform level to bottom.

B6 (elevation 205.7 m; hole depth 109.7 m)

0-0.5 m clay, brown and reddish, limonite nodules; 1.5-15.2 m weathered basalt, less weathered at end; 15.2-24.4 m sandy silt, brown to orange-brown; 24.4-27.4 m clay, grey, some carbonised wood; 27.4-28.3 m sandy silt grey-green, some wood fragments; 28.3-29.0 m clay - weathered basalt; 29.0-38.1 m sandy silt and silty sand, some wood fragments; 38.1-47.2 m silty clay, brown to black, wood fragments; 47.2-48.8 m pebbly gravel, poorly sorted with silt and clay; 48.8-64.0 m silty clay dark brown, wood fragments; 64.0-67.1 m silty sand, quartz and feldspar; 67.1-70.1 m coarse sand and pebbly gravel some silt; 70.1-97.5 m sandy silty, dark brown to grey-black and silty clay, light grey with black and yellow areas; 97.5-109.7 m weathered dolerite.

Remarks: Air flushed to 15.2 m where water table was struck.

Electric logs: R, SP and gamma ray to 51.8 m. Water level at 9.8 m. Low fairly stable γ to 13.7 then increases and is very variable. SP featureless; R - small uninterpretable variations.

C1 (elevation 188.1 m; hole depth 64.6 m)

0-1.5 m sandy silty clay, orange-brown, limonite nodules; 1.5-5.5 m weathered basalt - mainly clay with igneous texture; 5.5-11.6 m sandy silty clay, orange-brown, grey, cream-white; 11.6-30.5 m gritty sand, pebbly sand some feldspar, silty sand and clay with wood; 30.5-31.7 m gravel; 31.7-50.3 m sandy silt and sand, some wood fragments; 50.3-56.4 m gravel, occasional dolerite boulder; 56.4-64.0 m sand, coarse and gritty, sandy silt a little pyrite, wood fragments; 64.0-64.6 m weathered and fresh dolerite?

Electric logs: Little apparent correspondence to lithology apart from about 30.5-39.6 m where SP and γ high, R low.

C2 (elevation 210.3 m; hole depth 86.9 m)

0-6.1 m ferruginous silty clay with limonitic bands; 6.1-18.3 m silty and fine sand, limonite nodules; 18.3-27.4 m basalt very weathered - 24.4-27.4 m slightly vesicular; 27.4-36.6 m sandy silt and silty sand, yellow to brown; 36.6-42.7 m gravel coarse, poorly sorted, clear quartz, a little feldspar, chalcedony? some wood fragments towards end, rounded to subangular; 42.7-48.8 m silt and silty clay, gravel (contamination?) wood fragments; 48.8-51.8 m gravel, as above; 51.8-64.0 m silt, silty clay, a little sand, wood fragments; 64.0-68.6 m pebbly sand, coarse, some silt; 68.6-83.8 m silt, silty clay, minor pebbly coarse sand, wood fragments; 83.8-86.9 m dolerite weathered to less weathered.

Remarks: Cuttings water flushed for whole depth. Water level 9.8 m for logging.

Electric logs: 18.3-24.4 m distinct low on γ, high SP, relatively low R - basalt? Gravel zones reasonably distinct from 36.6-51.8 m on SP and R, but not on γ.

C3 (elevation 213.4 m; hole depth 18.9 m)

0-4.6 m clay, iron staining, limonite nodules; 4.6-6.1 m clay (weathered basalt) grey and brown; 6.1-18.9 m weathered basalt, hardness increasing with depth.

C4 (elevation 212.1 m; hole depth 16.2 m)

0-1.5 m ferruginous top soil, then orange-brown clay; 1.5-16.2 m basalt - weathered with zones of abundant vesicles, limonite filled passing into unweathered basalt.

C5 (elevation 213.4 m; hole depth 26.8 m)

0-7.6 m clay - orange, brown-fawn, red, minor grey, limonite nodules; 7.6-13.7 m clay - creamy grey, purple-orange, igneous texture; 13.7-19.8 m clay - light grey, some orange-brown patches (basalt?); 19.8-26.8 m basalt, weathered to unweathered.

Remarks: Air flushed - no record on water.

C6 (elevation 201.2 m; hole depth 12.2 m)

0-1.5 m clay with limonite nodules; 1.5-11.6 m gravel - some ironstone at 1.5-3.1 m, followed by mainly quartz, a little feldspar, basalt fragments, chalcedony. Some fine sand - silty sand above 9.1 m; 11.6-12.2 m hard basalt.

Remarks: Samples water flushed.

C7 (elevation 197.2 m; hole depth 6.7 m)

0-1.5 m silty clay, mottled brown; 1.5-3.7 m sandy silt, light grey; 3.7-6.7 m basalt, weathering decreasing with depth.

Remarks: Water flushed samples.

C8 (elevation 196.3 m; hole depth 8.2 m)

0-0.6 m soil and silty clay; 3.1-6.1 m gravel, poorly sorted, quartz ironstone, petrified wood, basalt, sandstone; 6.1-8.2 m basalt, relatively fresh.

Remarks: Cuttings water flushed.

C9 (elevation 196.3 m; hole depth 8.2 m)

0-0.3 m top soil - clay; 0.3-5.5 m pebbly gravel, pebbly clayey sand, rounded, subrounded quartz, quartzite, siltstone, granite, detritus? 5.5-8.2 m basalt, fresh from 7.3-8.2 m.

C10 (elevation 195.1 m; hole depth 36.6 m)

0-1.5 m sandy, pebbly clay, brown, few quartz pebbles, limonite; 1.5-4.6 m sandy, clay - brown and orange, and sandy pebbly clay; 4.6-12.2 m gravel - quartz, quartzite, sandstone with matrix of clay and silt; 12.2-13.7 m basalt, soft and weathered; 13.7-18.3 m gravel and clay interbedded, pebbles quartz, quartzite; 18.3-30.5 m clayey silt and clay, light grey, orange-brown, wood fragments; 30.5-32.0 m decomposed dolerite and quartz pebbles (contamination?); 32.0-36.6 m decomposed dolerite (contamination to 35.1 m).

Remarks: Water level 3.4 m.

Electric logs: Logs not very useful. Gamma just below basalt is low, *i.e.* 'gravel' for about 1.5 m. All three logs indicate 'sand or gravel'-like bed, 0.5-1.5 m thick at 29 m.

C11 (elevation 192.0 m; hole depth 3.7 m)

0-1.5 m clay, dark brown to black; 1.5-3.1 m sand, fine with some silt; 3.1-3.7 m basalt, unweathered.

Remarks: Cuttings air flushed.

C12 (elevation not known; hole depth 34.8 m)

0-1.5 m gravel, recent, poorly sorted, quartz, basalt; 1.5-6.1 m basalt, little weathered apart from top and bottom; 6.1-13.7 m clay and silty clay?, possibly weathered basalt; 13.7-18.3 m sandy silt, silty sand, gravel, quartz, quartzite; 18.3-25.0 m silty clay, dark brown, wood fragments; 25.0-32.9 m sandy silt 25.0-26.5 m, silty clay, clay, with almost entirely wood fragments 29.9-32.9 m; 32.9-34.8 m dolerite, weathered passing into unweathered.

Remarks: Cuttings water flushed.

C13 (elevation not known; hole depth 3.7 m)

0-0.6 m top soil, grey clay; 0.6-3.7 m basalt, relatively fresh.

D1 (elevation 205.1 m; hole depth 22.3 m)

0-3.1 m gravel up to 6 mm. Quartz predominantly subrounded; 3.1-9.1 m clay, variable and brown colour, gravel contamination, some iron nodules; 9.1-21.3 m clay after dolerite, igneous texture.

Remarks: Cuttings water flushed.

D2 (elevation 197.2 m; hole depth 22.9 m)

0-3.1 m sandy clay, brown and mottled; 3.1-10.7 m clay, beginning with grey to white with ferruginous patches, then ferruginous patches absent; 10.7-22.9 m clay after dolerite, igneous texture distinct.

Remarks: Water flushed, dry hole.

Electric logs: γ - rather featureless.

D2(ii) (elevation 197.2 m; hole depth 33.5 m)

0-3.1 m silty clay and silty sand, orange-brown; 3.1-4.0 m silty clay, yellow-brown, plastic; 4.0-7.0 m clay and silty clay, light grey to red-brown; 7.9-8.5 m sandy clay, light grey, plastic; 8.5-10.1 m clay, chalky white; 10.1-25.9 m clay after basalt, (may be 8.5-10.1 m also) becoming less weathered towards end; 25.9-33.5 m basalt, weathered becoming unweathered at end (dolerite also mentioned in log).

D3(i) (elevation not known; hole depth 9.1 m)

0-1.5 m silty clay, brown, ferruginous hard patches; 1.5-3.1 m clay, mottled grey and brick red, limonite nodules; 3.1-9.1 m silty clay, brown.

Remarks: Cuttings water flushed. Water loss too great to continue hole.

Electric logs: Logs of little interest - dry hole.

D3(ii) (elevation 204.5 m; hole depth 18.3 m)

0-3.7 m clay, brown and mottled grey, some iron nodules; 3.7-9.1 m silty clay, rare iron nodules, some carbonaceous material towards end; 9.1-18.3 m grey clay after dolerite, igneous texture.

Remarks: Cuttings water flushed.

D3(iii) (elevation 204.5 m; hole depth 128.0 m)

0-1.5 m clay, light to dark grey with brown and yellow staining; 1.5-6.1 m sandy silty clay, light to dark grey, some iron nodules; 6.1-29.9 m clay after basalt, grey to brown; 29.9-38.1 m sandy silt and silty sand; 38.1-40.5 m gritty sand, angular to subrounded quartz, some lithics; 40.5-45.7 m sandy silt some carbonaceous matter; 45.7-51.2 m gritty and pebbly sand, clear quartz, white quartzite; 51.2-71.6 m sandy and clayey silt, some wood fragments; 71.6-79.3 m sand, clear quartz, some feldspar; 79.3-120.4 m sandy silt with bands of sand and wood fragments; 120.4-128.0 m clay after dolerite.

Remarks: Water level during logging 17.4 m.

Electric logs: Coarse sand and pebbly beds show up on all three logs (R and SP had to be rebased). Basalt shows on γ as steady low value. Below 52 m all logs are rather flat and featureless.

D4 (elevation 211.8 m; hole depth 29.0 m)

0-4.6 m clay with some silty clay, limonite nodules; 4.6-9.1 m sandy and silty clay, limonite nodules; 9.1-21.3 m sandy silt, orange stain to 18.3 m then decreases; 21.3-23.8 m pebbly gravel - colourless quartz 80% 3-5 mm, some feldspar; 23.8-30.5 m basalt, weathered at first, then fresh.

Remarks: Water level 5.5 m.

Electric logs: Basalt shows flat and low on γ, gravel very distinct on SP, many rebases further up.

F1 (elevation 204.2 m; hole depth 36.6 m)

0-2.1 silty clay, orange with limonite nodules; 2.1-4.6 m sandy silt, mottled red, orange to grey; 4.6-7.0 m coarse silty sand, up to 2 mm; 7.0-10.7 pebbly silty clay, pebble size increases with depth; 10.7-22.9 m pebbly gravel, poorly sorted pebbles up to 25 mm; 22.9-24.4 silty clay, dark brown with abundant carbonaceous matter; 24.4-30.5 sandy silt, abundant peaty fragments; 30.5-36.6 weathered dolerite.

Remarks: Water level at 4.0 m for logging.

Electric logs: Gravel at 10.7-21.3 shows fairly well on all three logs (may be series of bands of gravel). Dolerite is low and fairly flat on γ, high on SP, low on R.

F2 (elevation 211.5 m; hole depth 68.6 m)

0-7.6 m silty clay and sandy silt, limonite nodules, grain size increases with depth; 7.6-15.2 m silty sand, grey, yellow-grey; 15.2-18.3 m pebbly silty sand, brown to grey pebbles up to 12 mm; 18.3-36.6 m pebbly gravel, poorly sorted - predominantly quartz up to >6 mm; 36.6-47.2 m silty clay and sandy clay, becomes coarser with depth, grey; 47.2-61.0 m coarse sand with silt, grey, poorly sorted, clear quartz 70-80%, feldspar 20-30%; 61.0-68.6 m sandy silt with carbonaceous matter, grey-brown to black-green weathered mineral (mafic?).

Remarks: Water level for logging 11.6 m.

Electric logs: 47.2-61.0 m SP and R indicate bands of sand, γ flat from bottom to gravel at 18.3-36.6 m. All logs show this zone, best section appears to be 21.3-35.7 m.

F3 (elevation 207.3; hole depth 86.9 m)

0-14.3 m silty clay and clay, which grades into below, some iron nodules at top; 14.3-17.1 m silty sand; 17.1-22.3 m pebbly gravel, poorly sorted up to 15 mm diameter; 22.3-38.1 m silty sand and silty clay, some lignite fragments; 38.1-39.6 m pebbly gravel, poorly sorted up to 15 mm diameter; 39.6-56.4 m sandy silt and silty sand, some wood fragments; 56.4-62.5 m coarse sand up to 2 mm, 80% quartz 20% feldspar; 62.5-86.9 m silty sand, grey-green to brown, some carbonaceous material.

Remarks: Fluid level 14.3 m.

Electric logs: γ flat from bottom to 39.6 m, SP and R peaks at 66.1-73.2 m, 53.3-62.2 m. γ, SP and R all show peaks in interval 36.6-38.4 m. Main peak is 18.3-22.9 m although γ is rather subdued. It may extend to 25.6 m but peaks are lower.

F4 (elevation 198.1 m; hole depth 100.6 m)

0-12.2 m gritty sand and sandy silt, grey and brown; 12.2-16.8 m clay, light grey; 16.8-24.4 m silty clay and sandy silt, grey-green, abundant wood fragments; 24.4-25.9 m pebbly gravel, poorly sorted; 25.9-93.0 m sandy silt and silty sand with wood fragments; 93.0-100.6 m weathered dolerite.

Remarks: Fluid level 8.8 m.

Electric logs: All logs rather featureless (flat) apart from small peaks at 45.4-49.7 m and about 21.3-24.4 m.

F5 (elevation 207.3 m; hole depth 64.0 m)

0-1.5 m sandy silt, brown with limonite nodules; 1.5-7.6 m weathered dolerite; 7.6-10.7 m clay, brown, grey to black; 10.7-18.3 m sandy silt and silt, some 3 mm fragments; 18.3-22.9 m pebbly silt, fragments up to 25 mm;

22.9-25.9 m gravel, fairly well sorted - some pebbles up to 12 mm, usually 3-6 mm; 25.9-32.0 m silty clay, grey to light brown, some carbonaceous fragments; 32.0-36.6 m sand, coarse, decrease in size with depth, carbonaceous matter; 36.6-57.9 m sandy silt and silty sand, grey-green and brown; 57.9-64.0 m clay after dolerite.

Remarks: Fluid level 11.9 m.

Electric logs: Small rise in SP 30.5-43.3 m, peaks in all 16.8-21.3 m - R very insensitive scale. Logger may not be working for SP and R?

F6 (elevation 200.0 m; hole depth 40.2 m)

0-6.1 m silty sand, brown, a few limonite nodules, some large pebbles of basalt 1.5-3.1 m; 6.1-7.6 m silty clay, cream with mica flakes; 7.6-10.7 m fine sand, quartz; 10.7-15.2 m silty clay and silty sand; 15.2-16.8 m pebbly sand, up to 15 mm; 16.8-25.3 m silty clay, light to dark brown, wood fragments abundant at end; 25.3-26.5 m coarse sand, quartz, white, poorly sorted; 26.5-36.6 m sandy silt, wood fragments common at end; 36.6-40.2 m clay after dolerite.

Remarks: Fluid level 7.6 m.

Electric logs: γ in dolerite is low and flat from 36.6-39.6 m. Peak in γ at 22.9-27.4 m, strong peak in γ at 6.7-11.6 m, log repeated to confirm. Shows on R particularly and SP moderately. Peaks (-ve) on SP from 18.3 m to water level.

F7 (elevation 200.0 m; hole depth 64.0 m)

0-6.1 m silty clay and sandy silt, grey and brown; 6.1-10.7 m fine sand, orange to grey-brown; 10.7-13.7 m silty clay, grey; 13.7-15.2 m pebbly sand, pebbles to 6 mm, poorly sorted; 15.2-16.8 m pebbly silt, light brown to dark grey; 16.8-25.9 m silty clay, dark grey to brown, carbonaceous material; 25.9-30.5 m coarse sand, predominantly quartz, well sorted; 30.5-59.4 m sandy silt, fine sand, silty sand with carbonaceous material, fine sand 32.0-33.5 m, 36.6-38.1 m; 59.4-64.0 m sandstone, relatively consolidated pale green - Triassic?

Remarks: Fluid level 13.1 m.

Electric logs: 'Sand' type peaks at about 4-10.1 m?, 26-39.6 m, 45.7-47.2 m, 48.5-51.2 m, 53.3-55.8 m.

H1(ii) (elevation 176.5 m; hole depth 112.8 m)

0-2.1 m ironstone gravel, up to 6 mm, some quartz up to 12 mm; 2.1-7.6 m silty sand, light yellow-grey; 7.6-10.7 m coarse sand, some pebbles up to 3 mm; 10.7-17.4 m sand, clay and silt, grey, yellow; 17.4-22.0 m coarse sand; 22.0-102.0 m sandy silt, sandy clayey silt, and silty clay with carbonaceous fragments; 102.0-112.2 m clay after dolerite; 112.2-112.8 m fresh dolerite.

Remarks: Fluid level 7.3 m.

Electric logs: 105.2-108.2 m low peak on all three logs (lowest on γ). 100.6-101.2 m sharp peak on R, moderate on SP and γ. Logs are flat to 22.9 m. 11.6-22.9 m strong peak on R and SP (1.2 m low zone at 18.3 m)

7.6-22.9 m irregular peak on γ. The log for H1, an earlier bore which went to 54.9 m, almost repeats that for H1(ii).

H2 (elevation 174.7 m; hole depth 73.2 m)

0-3.1 m pebbly, silty sand, brown, pebbles 1.5 mm diameter - 20-30%; 3.1-15.2 m silty coarse sand and coarse sand, pebbles up to 12 mm at top; 15.2-18.3 m silty clay, yellow-brown to grey; 18.3-73.2 m sandy silt with clay bands, grey to dark brown, carbonaceous fragments.

Remarks: Fluid level 6.4 m.

Electric logs: Apart from 0.6 m wide peak at 60.1 m in SP and R and 1 m peak at 35.1 m, logs are fairly flat to 16.5 m. Then 'sand' band shows on SP and R not obvious on γ.

H3 (elevation 178.9 m; hole depth 36.6 m)

0-1.5 m pebbly silty sand, quartz and iron nodules; 1.5-3.1 m gravel, quartz and ironstone; 3.1-6.1 m sandy silt, grey and red-brown; 6.1-18.3 m coarse sand with some silt, brown and grey; 18.3-19.8 m silty sand, grey to greenish grey; 19.8-36.6 m sandy silt, dark grey to brown, carbonaceous matter.

Remarks: Water level 9.1 m.

Electric logs: Logs flat to 17.4 m (from bottom up). 'Sand' peaks 9.1-17.4 m (with 1.2 m 'clay' zone from 13.7-14.9 m) on R and SP. 6.1-17.4 on γ.

H4(i) (elevation unknown; hole depth 13.7 m)

0-3.1 m sandy silt; 3.1-4.6 m pebbly sandy silt, poorly sorted; 4.6-6.1 m gravel, poorly sorted, rare large pebbles; 6.1-7.6 m sandy silt, mottled grey and brown; 7.6-9.1 m coarse sand; 9.1-12.2 m gravel; 12.2-13.7 m boulder gravel.

Remarks: Cuttings water flushed. Hole stopped because of consistent caving in - apparently at this depth there were large boulders.

H4(ii) (elevation 169.8 m; hole depth 117.4 m)

0-3.1 m sandy silt, mottled red, brown, grey; 3.1-13.7 m gravel in silty sand matrix, quartz - colourless and grey, quartzite, chalcedony (agate), feldspar; 13.7-33.5 m silty sand, greenish grey, some carbonaceous matter; 33.5-112.8 m sandy silt with lenses of silty sand and clay bands, carbonaceous matter; 112.8-117.4 m weathered dolerite, becoming less weathered.

Remarks: Cuttings water flushed, fluid level 4.9 m.

Electric logs: Nothing particularly significant on logs.

H5 (elevation 167.3 m; hole depth 80.8 m)

0-10.1 m pebbly gravel, quartz, quartzite, dolerite up to 25 mm (rare amethyst); 10.1-80.8 m carbonaceous silty sand and sandy silt. Peaty band 51.8-54.9 m.

Remarks: Fluid level 3.1 m.

Electric logs: Logs featureless from bottom to 12.8 m then there are peaks in R and SP, γ is lower from about 9.1 m.

H6(ii) (elevation 167.6 m; hole depth 64.0 m)

0-3.1 m silty sand, brown poorly sorted; 3.1-9.1 m pebbly gravel, poorly sorted - quartz, feldspar, dolerite, occasional wood fragments; 9.1-64.0 m silty sand with carbonaceous fragments.

Remarks: Fluid level 3.1 m.

Electric logs: Peaks (+ve) in R from 54.6-57.0, 51.2-52.1, 40.8-36.3 m which are reflected to some extent in γ and SP (as -ve peaks). Peaks in SP and R 19.8-21.6 m and 9.5-12.5 m with some signs in γ. Strong peaks in SP and R 3.7-6.4 m, absent in γ.

J1 (elevation 171.6 m; hole depth 59.4 m)

0-6.1 m sandy gravel - coarse sand, quartz, quartzite, dolerite, and basalt up to 3 mm; 6.1-10.7 m fine sand with silt, grey to brown; 10.7-51.8 m silty sand, sandy silt, grey and brown carbonaceous material; 51.8-59.4 m siliceous mud? silicified silty clay.

Remarks: Fluid level at 1.8 m.

Electric logs: Logs possibly not reliable. SP nearly flat, R very irregular. Strongest peak in R at 3.7-5.5 m.

M1 (elevation 159.1 m; hole depth 27.4 m)

0-3.7 m silty sand, grey to orange; 3.7-15.2 m silty clay, light brown and grey; 15.2-27.4 m clay after dolerite.

Remarks: Fluid level 3.4 m.

Electric logs: Distinct drop in R and SP 14.6-23.5 m and in γ 14.6-24.4 m.

M2 (elevation 159.1 m; hole depth 77.7 m)

0-1.2 m silty sand, red; 1.2-54.9 m silty clay, light grey to 15.9 m with some black bands, then mainly dark grey; 54.9-77.7 m sandy silt, light grey to grey-green, carbonaceous and dark from 61.0 m. Water leaked up on to road, stopped at 77.7 m.

Remarks: Fluid level 7.3 m.

Electric logs: R featureless, SP very irregular, -ve peak from 57.9-69.5 m. Sharp 0.3-0.6 m wide peaks for most of log. γ shows a -ve peak from 51.8-67.1 m.

M3 (elevation 164.6 m; hole depth 64.0 m)

0-15.2 m sandy silty clay, dark brown-grey, followed by mottled grey and yellow-brown; 15.2-64 m silty clay, dark brown to dark grey, carbonaceous matter.

Remarks: Fluid level 4.9 m, samples water flushed.

Electric logs: Logs all rather flat and featureless.

M4 (elevation 170.7 m; hole depth 173.7 m)

No written log is available for this hole. The following log is derived from diagrammatic sections.

0-1.2 m silt; 1.2-2.1 m ironstone gravel; 2.1-22.9 m silty clay; 22.9-36.6 m silt with carbonaceous matter; 36.6-82.3 m silty clay; 82.3-88.4 m silty sand; 88.4-157.0 m silty clayey gravel 88.4-103.6 m, then clay, carbonaceous matter; 157.0-160.0 m silt with carbonaceous matter; 160.0-161.5 m carbonaceous matter; 161.5-173.7 m silty clay with carbonaceous matter.

M5 (elevation 170.7 m; hole depth 61.0 m)

0-1.2 m silty sand, grey to orange-brown; 1.2-22.9 m sandy silty clay and silty clay, orange-brown to grey, rare wood fragments; 22.9-61.0 m silty clay, dark brown, carbonaceous.

Remarks: Fluid level 2.1 m.

Electric logs: Graphs of logs rather featureless.

O1 (elevation 152.4 m; hole depth 143.3 m)

0-3.1 m silty sand; 3.1-6.1 m sandy clay, grey, some orange stain; 6.1-9.1 m clayey sand, whitish to grey, some orange stain; 9.1-16.8 m sand with sandy clay bands, quartz, medium to fine-grained; 16.8-25.9 m sandy silty clay, orange-brown; 25.9-38.1 m clayey sand with pebble bands, light grey to grey; 38.1-120.4 m sand with carbonaceous fragments - poor return of cuttings. Hard layers 80.8-82.3 m, 89.9-90.5 m - silcrete? Increase in quartz medium to coarse-grained 114.3-120.4 m; 120.4-137.2 m carbonaceous sandy silt, dark brown; 137.2-143.3 m pebbly sand, (5% quartz fragments up to 5 mm).

Remarks: Air flushed to 38.1 m, hit water at 17.7 m, fluid level 14.6 m.

Electric logs: Possible 'sand' bands 135.6-136.6, 104.9-117.0, 77.7-82.3, 45.7-56.7, 22.9-31.1 m. 'Carbonate' peak 81.1-81.4 m. Strong peak on γ from 10.7-15.9 m, absent on other logs.

O2 (elevation 152.4 m; hole depth 19.8 m)

0-3.1 m silty sand with gravel, quartz, quartzite 5-10 mm; 3.1-9.1 m clay, light to dark grey, light brown; 9.1-19.8 m clay after dolerite, grey-fawn to orange-brown, light yellow fresh dolerite at 19.8 m.

O3 (elevation 152.4 m; hole depth 73.2 m)

0-1.5 m pebbly silty sand; 1.5-3.1 m pebbly silty clay, quartz, lithics, limonite nodules, chalcedony; 3.1-4.6 m sandy gravel; 4.6-15.9 m silty clay, ferruginous stain; 15.9-38.1 m silty clay, carbonaceous, dark brown to dark grey; 38.1-47.2 m silty clay with sandy silt, gravel and siliceous bands; 47.2-73.2 m silty clay, abundant lignite.

Remarks: Cuttings air flushed, fluid level 6.4 m.

Electric logs: 63.1 m to 73.2 m a low irregular (+ve) peak on R and γ (-ve). Series of small peaks (-ve) on R to 44.8 m (carbonate bands?). From 36.6-44.5 m there is a strong peak on R, shows on γ, absent SP. 12.2-25 m rounded low peak on R. SP uninterpretable throughout.

04 (elevation 150.3 m; hole depth 91.4 m)

0-4.6 m sandy pebbly clay, limonite and quartz up to 12 mm; 6.1-10.7 m clay, some silt, light grey-brown, yellow-orange, iron stain; 10.7-21.3 m clay silt and sand, 12.2-13.7 m silty sand, light grey and brownish, carbonaceous towards end; 21.3-38.1 m sandy silt, carbonaceous fragments; 38.1-50.3 m pebbly silty sand, some clay - pebbles to 30 mm, quartz, quartzite; 50.3-71.6 m sandy clayey silt with wood fragments; 71.6-79.3 m silty clay, wood fragments; 79.3-88.4 m clay with wood fragments; 88.4-91.4 m decomposed dolerite.

Remarks: Water flushed samples, fluid level 8.8 m.

Electric logs: 'Sand' bands 82.3-88.4, 66.1-70.7, 50.3-51.8, 33.5-38.4, 28.7-31.4, 18.3-21.3, 12.2-13.4 m. 'Carbonate' peak? 74.1-74.4 m.

05 (elevation 154.2 m; hole depth 44.2 m)

0-3.1 m silty gravel, rounded quartz 12 mm, limonite nodules, chalcedony, quartzite; 3.1-6.7 m gravel, quartz, limonite nodules; 6.7-18.9 m silty sand and sandy silt, yellow-brown to grey - oxidation boundary; 18.9-29.0 m silty clay, dark grey to brown, carbonaceous; 29.0-39.6 m silty sand, grey to bluish grey, possibly Triassic sediments (cuttings lithified); 39.6-44.2 m consolidated rock (dolerite?).

Remarks: Cuttings water flushed, fluid level 5.5 m.

Electric logs: SP and R not working, -ve peak on γ from 12.2 m to surface.

06 (elevation 155.5 m; hole depth 97.5 m)

0-3.1 m pebbly silty sand, quartz up to 3 mm, rare limonite nodules; 3.1-6.1 m silty clay, some silty sand and ironstone gravel; 6.1-13.7 m silty sand and sandy silt, brown-yellow and grey; 13.7-20.7 m silty clay, iron stain, 18.3-19.8 m limonite bands; 20.7-26.8 m silty clay, carbonaceous, dark grey to dark brown; 26.8-35.1 m silty sand, sand increases with depth; 35.1-54.9 m sandy silt, carbonaceous - bluish grey to brown, some pebbles; 54.9-59.4 m carbonaceous matter dominant; 54.9-71.6 m clayey silt, sandy clayey silt with bands almost entirely of peat 61.0-64.0, 70.1-71.6 m; 71.6-85.3 m dolerite and brown organic silty clay fragments - boulder beds?; 85.3-97.5 m dolerite.

Remarks: Cuttings water flushed, fluid level 11.3 m.

Electric logs: SP and R very irregular to 84.7 m - out of order? γ flat and low to 72.2 m (dolerite in this section?). R peaks (+ve) 71.6-73.2, 64.3-65.8, 47.9-48.2, 33.5-34.8 m. Small peaks above this include 18.6-18.9 m, 20.7-21.0 m. Some of these may be sand bands, others carbonate.

07 (elevation 139.3 m; hole depth 69.5 m)

0-4.6 m silty sand, ferruginous; 4.6-7.6 m pebbly sandy silty clay, up to 20 mm, quartz, quartzite, limonite; 7.6-22.9 m clay, mainly carbonaceous, a little silty (15.2-16.8 m), dark brown, light brown, grey; 22.9-27.4 m clay, after dolerite?, some with faint igneous texture; 27.4-65.5 m sand or Triassic sandstone?, fairly compact, carbonaceous matter, some peaty, some bituminous?, 62.5-65.5 m gradation to shale; 65.5-69.5 m shale, hard, very compacted.

Remarks: Fluid level 4.0 m.

Electric logs: Peak in R (+) 42.7-57.9 m (not on γ or SP). Peak on γ (+) 31.1-32.3 m.

P1 (elevation 159.7 m; hole depth 152.4 m)

0-0.6 m silty clay, light to dark grey; 0.6-17.7 m clay and silty clay, fawn-brown to grey; 17.7-79.2 m clay, dark grey to chocolate-brown, carbonaceous, vivianite occasionally. 45.7-79.2 m thin bands silcrete (siderite?) silt increases towards end; 79.2-86.9 m silty clay, sandy silt, carbonaceous; 86.9-88.4 m sand; 88.4-91.4 m pebbly gravel, quartz and dolerite, average size 10 mm; 91.4-102.1 m silty sand, silty clay with carbonaceous matter, occasional pebbles; 102.1-134.1 m bands of sand and silty clay, carbonaceous matter; 134.1-152.4 m silty sand with silty clay lenses, carbonaceous matter.

Remarks: Fluid level 9.1 m.

Electric logs: Flat and 'clay'-like to 121.9 m; 'sand' bands 110.0-121.3 m, 83.8-92.1 m; 'carbonate' bands 0.3-0.6 m thick at 75.3, 72.9, 71, 70.4, 69.8, 68.9, 68.3, 67.4 (very high) 63.7 m.

P2 (elevation 154.5 m; hole depth 150.9 m)

0-1.5 m top soil, red-brown, abundant limonite nodules; 1.5-15.2 m clay with limonite bands, yellow-brown; 15.2-50.3 m clay, carbonaceous, predominantly dark brown to grey, plastic; 50.3-65.5 m clay, a little silty, shale silcrete or siderite?, carbonaceous; 65.5-73.2 m sandy silt, some clay, coarse sand, carbonaceous; 73.2-94.5 m pebbly silty clayey sand, 10-15 mm mainly quartz, possible dolerite, feldspathic sandstone, carbonaceous; 94.5-115.8 m silty clayey sand, carbonaceous; 115.8-128.0 m sandy silt, silty clay, carbonaceous; 128.0-150.9 m clayey, clayey silt with carbonaceous material.

Electric logs: All logs flat to 121.0 m; 'sand' bands 116.7-121.0, 106.1-107.9, 89.9-104.2, 77.4-79.2, 65.5-71.9 m; 'carbonate' bands 0.3-0.6 mm thick at 58.8, 57.9, 56.7, 56.1, 54.6 (very prominent) 50.9, 48.8 m.

P3 (elevation 160.6 m; hole depth 152.4 m)

0-0.9 m sandy silty clay; 0.9-15.5 m clay, silty clay, orange-brown; 15.5-70.1 m clay, carbonaceous, dark grey to brown, occasional vivianite, silt increasing at 33.5 m. 48.8-59.4 m hard brown silcrete, rare at first but frequency increases with depth. 59.4-68.6 m occurs every 1-1.5 m; 70.1-78.6 m sandy silt and silty sand, carbonaceous, coarse sand band at about 76.2-78.6 m; 78.6-81.4 m pebbly gravel, angular to subrounded quartz and dolerite, 15-20 mm quartz colourless; 81.4-89.9 m sandy silty clay, grey-blue; 89.9-97.5 m silty sand, coarse with carbonaceous matter; 97.5-131.1 m silty clay and sand, brown with carbonaceous matter; 131.1-146.3 m silty sand, carbonaceous, silcrete band 140.2-141.7 m; 146.3-148.4 m silcrete band(s?) and coarse sand; 148.4-152.4 m silty sand, carbonaceous.

Remarks: Fluid level 7.6 m.

Electric logs: 'Sand' bands 91.4-115.8, 73.5-79.6, 65.2-66.5 m; 'carbonate' seams 139.6, 140.5, 88.1, 89.6, 65.2, 64.3, 63.7, 63.4, 62.5, 61.9, 61.3, 60.7, 59.7, 57.6, 56.4, 54.6, 53.4, 50.6 m.

P4 (elevation 156.7 m; hole depth 152.4 m)

0-2.4 m silty clay, yellow-orange; 2.4-18.9 m clay and silty clay, orange-brown; 18.9-56.4 m clay, carbonaceous dark grey to chocolate brown, vivianite, 45.7-56.4 m thin bands silcrete; 56.4-62.5 m clay, grey-blue to grey, no carbonaceous matter; 62.5-70.1 m sandy silt grey-blue; 70.1-80.8 m pebbly gravel, quartz, quartzite (70-80%), dolerite (20-30%) average 5 mm diameter; 80.8-115.8 m sand, silty sand, some clay, carbonaceous; 115.8-149.4 m silty clay, light blue-grey and brown, 147.8-149.4 m vivianite, carbonaceous; 149.4-152.4 m thin pebble bands, silcrete band 149.4 m, white quartz, quartzite and dolerite pebbles.

Remarks: Fluid level 4.3 m.

Electric logs: 'Sand' bands 134.7-135.6, 130.5-131.4, 124.7-126.5, 64.6-93.9 m (some clay seams in this section); 'carbonate' bands 149.1, 147.8, 57.3, 54.3, 53.0, 51.8, 51.2, 50.6, 49.7, 46.0 m.

P5 (elevation 152.7 m; hole depth 152.4 m)

0-1.5 m sandy, silty clay; 1.5-19.2 m clay and silty clay, fawn-orange, light grey; 19.2-51.8 m clay, carbonaceous, dark grey to chocolate-brown, some minor silt, silcrete bands 38.1-51.8 m; 51.8-59.4 m silty clay, carbonaceous; 59.4-61.0 m sandy silt, carbonaceous; 61.0-65.5 m pebbly gravel, quartz, quartzite, dolerite; 65.5-106.7 m silty clay and sandy silty clay, carbonaceous, dominantly grey-blue-brown; 106.7-108.2 m sand, carbonaceous; 108.2-121.9 m silty clay, carbonaceous; 121.9-131.1 m silty clay and sandy silt; 131.1-152.4 m lignite bands and sandy silty clay, light grey-dark brown.

Remarks: Fluid level 5.5 m.

Electric logs: 'Sand' bands 145.4-147.5, 121.0-125.0, 89.0-92.4, 60.4-65.8 m. 'Carbonate' bands 91.1, 52.4, 44.5 m.

P6 (elevation 143.6 m; hole depth 155.5 m)

0-1.5 m top soil, red-brown; 1.5-13.7 m clay with limonitic bands, yellow-brown-grey, red, plastic; 13.7-16.8 m clay, carbonaceous, dark brown-grey, carbonaceous; 16.8-18.3 m silt, grey-brown; 18.3-38.7 m clay with hard silty bands, dark grey-brown, carbonaceous; 38.7-50.3 m sandy silt and silty sand; 50.3-54.9 m pebbly sand (coarse) and gravel, abundant pebbles >3 mm, quartz, quartzite; 54.9-114.3 m clay, carbonaceous, a little silt at beginning, dark brown to dark grey non-plastic fragments. Peat abundant from 61.0-82.3 m; 114.3-134.1 m silty clay, carbonaceous; 134.1-155.5 m silt and silty sand, some clay, carbonaceous.

Remarks: Fluid level 3.1 m.

Electric logs: 'Sand' bands - 149.4-150.6, 131.1-138.7, 114.3-115.8, 92.4-101.5, 86-86.6, 59.4-61, 42.7-54.9 m. 'Carbonate' bands at 82.9, 34.1?, 33.2?, 31.4 m.

P7 (elevation 139.6 m; hole depth 150.9 m)

0-1.5 m gravel, limonite nodules; 1.5-10.7 m clay, with limonitic bands, yellow-brown; 10.7-38.1 m clay, carbonaceous fragments, dark brown-grey, some silt; 38.1-45.7 m silt, carbonaceous, some sand towards base; 45.7-48.8 m pebbly coarse sand, some silt, carbonaceous; 48.8-54.9 m peat; 54.9-77.7 m clay and silt, some sand, carbonaceous; 77.7-83.8 m pebbly coarse sand with clay, silt; 83.8-91.4 m clay and sandy silt, carbonaceous; 91.4-111.3 m silt and coarse pebbly sand bands, carbonaceous; 111.3-150.9 m silt, clay, and sandy silt interbedded, some zones of abundant carbonaceous matter.

Remarks: Fluid depth 4 m.

Electric logs: 'Sand' bands 142.7-144.2, 121.6-125, 104.6-105.5, 79.3-84.4, 71.6-74.4, 65.8-66.8, 62.5-64 m; 'carbonate' bands 40.2, 39.3, 31.7, 31.1, 28.7, 27.4, 26.5, 25.9, 25.0 m.

Q1 (elevation 143 m; hole depth 30.5 m)

0-3.1 m sandy ironstone gravel; 3.1-9.1 m silty clay, brown and grey mottled; 9.1-19.8 m silty clay, dark brown to grey, carbonaceous; 19.8-27.4 m sandy silt, to 22.9 m forams??, then carbonaceous; 27.4-30.5 m clay after dolerite.

Remarks: Cuttings water flushed, fluid level 0.3 m.

Electric logs: Dolerite on γ is low.

Q2 (elevation 156.1 m; hole depth 152.4 m)

0-19.8 m silty clay, clay, a little sand 1.5-4.0 m - orange-brown to red; 19.8-38.1 m silty clay, carbonaceous, dark brown; 38.1-47.2 m fine silty sand, some clay, some wood material; 47.2-50.9 m silty clay, grey-blue; 50.9-57.3 m dolerite and quartz pebbles, carbonate cement (acid tested); 57.3-79.3 m sandy silt, some coarse and silty sand, carbonaceous; 79.3-83.8 m sandy silty clay; 83.8-138.7 m silty sand, some coarse, carbonaceous to 100.6 m; 138.7-140.2 m pebbly silty sand, pebbles to 8 mm; 140.2-145.4 m very coarse silty sand, carbonaceous; 145.4-152.4 m silty clay, brown and carbonaceous.

Remarks: Fluid level 11.0 m.

Electric logs: Not very good. 'Sand' bands 131.1-146.3, 108.2-125.6, 70.1-79.3 m (it could be largely sand from 61-146.3 m) 48.8-52.7 m. 'Dolerite' boulder bed shows as a 'clay'-type layer.

Q3(i) (elevation not known; hole depth 21.3 m)

0-18.3 m silty clay, yellow-brown, plastic; 18.3-21.3 m silty clay, dark grey to dark brown, plastic. Drilling difficulties - loss of return.

Q3(ii) (elevation not known; hole depth 57.0 m)

0-22.9 m silty clay with limonitic bands, yellow-brown and grey; 22.9-53.3 m silty clay, carbonaceous, dark brown to dark grey; 53.3-57.0 m clay after dolerite. Dolerite basement.

Remarks: Fluid level 3.7 m.

Electric logs: Fairly featureless. Dolerite area - γ low, R and SP high.

R1 (elevation 179.8 m; hole depth 36.6 m)

0-10.7 m silty clay, grey, red, and yellow-brown; 10.7-29.0 m silty clay, carbonaceous, dark brown to dark grey, plastic; 29.0-32.0 m fragments of decomposed dolerite common; 32.0-36.6 m clay after dolerite.

Remarks: Fluid level 3.4 m.

Electric logs: No distinct features on logs.

R2 (elevation 176.8 m; hole depth 152.4 m)

0-1.5 m sandy silt; 1.5-19.8 m clay and silty clay, grey to orange-brown to brick red; 19.8-73.2 m silty clay, carbonaceous; 73.2-82.3 m sandy silt, grey-blue; 82.3-91.4 m coarse silty sand, carbonaceous; 91.4-103.6 m sandy silt, grey-blue, some orange iron stain; 103.6-108.2 m silty clay; 108.2-148.7 m coarse sand, carbonaceous fragments up to 3 mm, nodules green weathered dolerite?, subangular to subrounded up to 5 mm; 148.7-152.4 m silty clay, brown, carbonaceous.

Remarks: Fluid level 15.9 m.

Electric logs: 'Sand' bands common below 76.2 m *e.g.* 138.4-144.5, 111-135.6, 103-109.1, 77.4-88.4 m. Another peak (mainly in R) 65.5-70.1 m.

R2b (approximately 400 m north of R2; hole depth 137.2 m)

0-20.7 m clay, brown to yellow-brown, grey, lower plastic; 20.7-67.1 m clay, carbonaceous, dark brown to grey, a little silt; 67.1-74.7 m sandy silt, clay and gravel (6-3 mm), peat; 74.7-77.7 m silty clay, peaty, brown; 77.7-89.9 m clay, carbonaceous (brown), non-carbonaceous (grey), ferruginous (yellow-orange); 89.9-92.1 m sandy silt; 92.1-111.3 m silt and sandy silt, carbonaceous; 111.3-137.2 m sand, some silty, some coarse, carbonaceous.

Remarks: Fluid level 19.8 m.

Electric logs: Apparently almost continuous 'sand' from 91.4-137.2 m. ('Clay' bands 97.5-99.7, 109.7-112.2 m). Other 'sand' bands within range of 64.0-71.9 m. 'Carbonate' bands at 64.6, 61.0, 58.5-59.4, 57.6, 54.6 m.

R3 (elevation 183.8 m; hole depth 123.4 m)

0-12.8 m silty clay, yellow-brown, grey, plastic; 12.8-71.6 m silty clay, carbonaceous, dark brown-dark grey, plastic; 71.6-79.3 m silty sand, minor greybilly (74.7-76.2 m), coarse sand, carbonaceous; 79.3-85.3 m coarse sand, carbonaceous; 85.3-123.4 m silty clay, carbonaceous, dark brown to dark grey, non-plastic.

Remarks: Fluid level 12.8 m.

Electric logs: 'Sand' beds 106.7-121.9, 93.0-105.2, 81.4-85.3, 75.0-80.5, 68.6-70.4, 64.3-65.5 m. Some of these may be partly clayey or silty sand. 'Carbonate' peaks at 94.5, 90.2, 75.0, 64.6 m. High γ peaks (off scale) 76.2-77.4, 103.6-104.6 m.

R4 (elevation 175.9 m; hole depth 150.9 m)

0-22.9 m silty clay, grey, yellow-brown, most plastic, limonite bands?; 22.9-51.8 m silty clay, carbonaceous, dark brown to dark grey, largely plastic; 51.8-77.7 m silty sand, sandy silt, silty clay interbedded, carbonaceous; 77.7-94.5 m silty clay, some sandy clay; 94.5-114.3 m silty sand, top 9 m carbonaceous, greenish grey to light brown; 114.3-129.5 m sand, medium to coarse, grey; 129.5-135.6 m sandy silt, carbonaceous, grey; 135.6-150.9 m silty clay, lenses silty sand, light grey-orange patches.

Remarks: Fluid level 2.7 m.

Electric logs: 'Sand' beds 88.1-123.8 m (best peak at 88.1-93.9 m), 66.8-69.8, 50.6-56.4 m ('clay' 51.8-54.3 m). 'Carbonate' peaks 87.2, 83.5, 82.6, 48.8, 47.2, 46.0, 45.4, 42.1 m. γ fairly high 141.1-141.7 m.

R5 (elevation 173.7 m; hole depth 137.2 m)

0-22.9 m silty clay, brown and grey patches - plastic, orange patches less plastic. Most plastic 8.2-22.9 m; 22.9-71.6 m clay, carbonaceous, dark grey to dark brown, fine-grained, plastic; 71.6-77.7 m sandy silt, common brown-grey spherical hard fragments - forams?; 77.7-99.1 m silty clay, sandy silt, forams? carbonaceous after 91.4 m, light grey clay before; 99.1-129.5 m sand - fine to coarse, grey, carbonaceous; 129.5-137.2 m silty clay, light brown and yellow-brown, hard angular fragments - greybilly.

Remarks: Fluid level 3.4 m.

Electric logs: Only logged to 131.1 m. 'Sand' band generally from 94.8-123.8 m with best peaks at 94.8-98.2 and 119.5-123.8 m. Also low peak 82.6-84.3 m. 'Carbonate' seams at 128.9, 100.0, 83.2, 67.7, 58.2, 52.7 m. γ high 71.0-71.6 m.

R6 (location of this hole is not known; hole depth 152.4 m)

0-3.1 m sandy silty clay; 3.1-15.2 m clay with thin silty clay bands, reddish and fawn-brown; 15.2-54.6 m clay, carbonaceous and light blue-grey, mainly dark grey to chocolate-brown, rare vivianite inclusions; 54.6-57.9 m sandy silt, yellowish grey to blue-grey, silcrete 56.4-59.4 m; 57.9-63.4 m sandy silty clay, carbonaceous, silcrete 61.0-62.5 m; 63.4-100.6 m silty sand, sandy silt, lenses of light blue grey-orange clay, carbonaceous sections, silcrete 73.2-74.7 m; 100.6-117.4 m silty clay, bands of sand; 117.4-141.7 m sand and wood fragments, brown silty clay, carbonaceous; 141.7-152.4 m wood fragments, silty clay, sand bands.

Remarks: Fluid level 3.4 m.

Electric logs: 'Sand' bands 126.8-143.6, 115.8-121.9, 105.2-109.7, 91.4-93.3, 82.0-86.9, 75.6-77.1, 64.3-70.4, 54.9-57.9 m. 'Carbonate' bands 103.6, 99.4, 72.5, 71.9, 60.1, 56.4, 53.3 m.

R7 (elevation 161.5 m; hole depth 164.6 m)

0-3.1 m sandy silt and silty clay with limonite pebbles; 3.1-18.3 m silty clay, light grey-yellow-brown, mainly plastic; 18.3-54.9 m clay, dark brown to dark grey, mainly plastic, carbonaceous; 54.9-57.9 m sandy silt, carbonaceous; 57.9-100.6 m silty clay, bluish grey, light brown, rare peat, forams? 96.0-99.1 m; 100.6-106.7 m sandy silt, light brown to yellow-brown, forams?; 106.7-121.9 m silty sand and sand, some wood fragments and forams?; 121.9-134.1 m sandy silt, grey to light brown; 134.1-164.6 m silty sand, medium to coarse-grained, grey, some wood pieces.

Remarks: Fluid level 3.7 m.

Electric logs: 'Sand' bands 131.1-141.7 m (and possibly to 162.2 with clay seams at 158.5-160.6, 151.5-153, 148.7-149.7, 144.7-146.0, 141.7-142.7 m) 106.7-119.8 m (with 'clay' band at 111.9-115.8 m) 104.2-105.2, 79.3-84.1, 61.9-63.4, 52.7-55.2 m. 'Carbonate' bands 101.5, 83.8, 64.9, 64.0, 54.3, 50.9, 49.7, 46.6 m.

R8 (elevation 170.7 m; hole depth 164.6 m)

0-13.7 m silty clay, reddish brown - grey - yellow-brown; 13.7-41.3 m silty clay, carbonaceous, dark brown to grey; 41.2-56.4 m silty clay, lenses of silty sand, clay carbonaceous; 56.4-102.1 m silty clay, rare sandy silt, some carbonaceous matter, silty clay blue-grey, very plastic; 102.1-155.4 m sand, medium to coarse (106.7-115.8 m considerable silt); 155.4-164.6 m sandy silt, grey.

Remarks: Fluid level 18.3 m.

Electric logs: 'Sand' beds 114.6-126.5 m (below this SP very high and fairly flat. R peaks at 135.6-139.3 m plus several broad low peaks to bottom of hole) 106.7-108.8, 98.5-102.1, 89.6-91.4, 55.5-56.7, 48.2-51.2, 43.0-45.7 m. 'Carbonate' seams 114.9, 101.5, 98.5, 93.6, 88.7, 79.9, 76.5, 75.3, 71.4, 65.2, 55.6, 45.4 m. High γ 118-119.2, 155.5-156.1 m.

R8a (elevation 170.7 m; hole depth 138.7 m)

0-15.2 m clay with silty clay bands, light grey to fawny brown, orange-brown; 15.2-41.8 m clay, carbonaceous, chocolate-brown to dark grey, plastic; 41.8-48.8 m sandy silt, light grey; 48.8-59.4 m clayey silt and sandy silt, carbonaceous; 59.4-91.4 m clay and sand bands, clay grey, forams? 68.6-85.3 m; 91.4-100.6 m sand, silty sand, some wood fragments; 100.6-118.9 m grey clay, carbonaceous silty clay, grey-blue iron stain 106.7-118.9 m, abundant forams?; 118.9-125.0 m sand, coarse, angular-subrounded, wood fragments; 125.0-136.3 m sandy silt and silty clay; 136.3-138.7 m sand, very coarse angular.

Remarks: Fluid level at 6.7 m.

Electric logs: 'Sand' bands 132.6-137.2, 112.8-122.5, 88.4-96.9, 85.3-86.6, 69.8-70.7, 43.9-45.1 (weak on SP), 40.5-42.1 m. 'Carbonate' seams 121.3, 112.5, 72.5, 70.4, 68.3, 61.0, 44.8, 41.2, 40.5 m. High γ 103.3-103.9 m.

R8b (elevation 170.7 m; hole depth 147.8 m)

0-22.3 m clay, silty clay, grey to orange-brown 0-1.5 m limonite nodules, poorly compacted generally; 22.3-47.2 m silty clay, carbonaceous chocolate brown - dark grey. Silcrete? bands 30.5-30.8, 36.6-38.1, 41.2-42.7, 45.7-47.2 m; 47.2-76.2 m silty clay, light grey often poorly compacted, some wood fragments. 67.0-68.6 m thin silcrete band, 68.6-76.2 m abundant fawny brown silcrete beds; 76.2-86.9 m silty clay and sandy silty clay, carbonaceous; 86.9-88.4 m sandy silt; 88.4-97.5 m sandy silty clay, silty clay, carbonaceous; 97.5-107.6 m ferruginous silty clay, carbonaceous silty clay, red-brown, yellow; 107.6-147.8 m sandy silt, sand, silty clay, carbonacoues.

Remarks: Fluid level 8.5 m.

Electric logs: 'Sand' bands possible from 107.6-139.6 m (definite 107.6-112.2 m) 76.2-94.5 m (possible total of about 6.1 m in several small peaks in this zone). 'Carbonate' seams 75.0, 73.2, 72.2, 71.6, 69.5, 71.3, 64.6, 41.8, 38.7, 36.0, 31.4, 30.2 m. High γ 108.5-109.1, 110.3-111.6 m.

R9 (elevation 161.2 m; hole depth 152.4 m)

0-19.8 m soil and silty? clay, light grey to mottled yellow-brown; 19.8-76.2 m clay, carbonaceous, dark chocolate-brown, dark greyish-brown; 76.2-109.7 m sandy silt, carbonaceous; 109.7-123.4 m coarse sand, carbonaceous; 123.4-138.7 m silty sand, some wood, 131.1-138.7 m feldspathic grey-blue to grey-green; 138.7-143.3 m sand, medium to coarse; 143.3-152.4 m silty sand, feldspathic.

Remarks: Fluid level 3.1 m.

Electric logs: 'Sand' band 139.0-143.0, 143.6-144.2, 147.2-148.4 (all low peaks) 125-137.8 (moderate peak) 106.7-123.4 (high peak) 91.4-93.0, 86.0-86.9, 82.3-83.5 m. 'Carbonate' peaks 77.4, 71.0, 72.9, 72.2, 67.4, 66.5 m. High γ 109.4-110.3 m.

R10 (elevation 162.8 m; hole depth 184.4 m)

0-1.5 m limonite grains in orange-brown silty clay; 1.5-17.7 m orange brown and grey clay; 17.7-80.8 m brown to grey, carbonaceous silty clay and clay; 80.8-88.4 m grey-blue sandy silt; 88.4-94.5 m silty sand, some wood; 94.5-97.5 coarse and carbonaceous silty sand; 97.5-149.4 m silty clay, sandy at beginning, occasional carbonaceous horizons but usually iron stained red-brown; 149.4-155.5 m grey to white clayey silty sand; 155.5-178.3 m silty clay, increase in carbonaceous matter, red-brown stain; 178.3-182.9 m silty - coarse sand; 182.9-184.4 m silty sand.

Remarks: Fluid level 10.4 m.

Electric logs: 'Sand' bands 173.7-180.1, 164.9-166.7, 144.2-163.1 (low peak on R and SP) 115.8-118.9, 121.3-122.5, 88.4-95.7, 78.0-86.3 m (low peak on R). 'Carbonate' bands 80.5, 78.9, 75.6, 75.3, 74.7, 74.1, 73.5, 71.0, 70.4, 68.0, 64.9 m. High γ 136.6-137.5, 113.4-114.9, 95.1-96.0 m. High SP (alone) 154.5-155.1 m.

R11 (elevation 156.7 m; hole depth 189.0 m)

0-1.5 m silty clay, limonite nodules; 1.5-13.1 m grey to orange-brown clay; 13.1-68.6 m carbonaceous brown to grey clay; 68.6-87.8 m sandy silty clay, sandy silt, dominantly carbonaceous; 87.8-97.5 m coarse silty sand, lower ferruginous, occasional dolerite fragments 2-3 mm; 97.5-109.7 m clay, predominantly ferruginous; 109.7-128.6 m coarse carbonaceous silty sand, top ferruginous; 128.6-138.7 m light milky grey sandy silty clay; 138.7-161.5 m coarse-medium silty sand; 161.5-180.4 m light grey-brown moderately compact clay; 180.4-189.0 coarse carbonaceous sand up to 2 mm.

Remarks: Fluid level 6.1 m.

Electric logs: only to 183.8 m. 'Sand' bands 180.8-183.8, 174.7-178.9, 172.8-174, 171.9-172.5, 170.1-171.3, 139.6-152.7, 122.5-124.1, 106.7-118.3, 84.7-89.9, 80.8-81.7, 76.8-77.7 m. 'Carbonate' bands 105.8, 73.8, 64, 63.4, 61.9, 59.4, 50.3 m. High γ 163.4, 103.9, 89.3 m.

R12 (elevation 174.7 m; hole depth 150.9 m)

0-19.8 m clay with limonite band; 19.8-91.4 m dark greyish brown clay but occasional pellets of brown reddish clay. Silcrete 40.2, 46.0, 51.8, 53.3-54.9, 68.9-82.3 m. Carbonaceous and grey-white to grey-brown, plastic 68.9-91.4 m; 91.4-106.7 m ferruginous, grey-orange to bright orange-red clay, some silt; 106.7-118.9 m ferruginous silt; 118.9-129.5 m fine to coarse sand, feldspar common, quartz subrounded to subangular; 129.5-137.2 m grey to grey-brown sandy silt; 137.2-150.9 m grey to grey-brown silty clay, extensive forams?

Remarks: Fluid level 11.9 m.

Electric logs: 'Sand' bands 116.1-126.5 m (some possible sand beds at at 128-143.5 m and 146.6-150.0 m) 110.6-112.2, 98.5-100.6 m. 'Carbonate' bands 110.0, 73.5, 68.6, 66.1, 62.2, 62.8, 60.4, 59.7, 57.9, 55.8, 54.9, 53.0, 50.9, 50.3, 48.8, 48.2, 46.9, 44.2, 41.2 m. High γ 129.5-130.2, 84.7-85.7 m.

R13 (elevation 180.8 m; hole depth 155.5 m)

0-3.1 m clay soil; 3.1-14.6 m yellow-brown, plastic clay with limonite bands; 14.6-22.9 m carbonaceous clay; 22.9-24.4 m light grey sandy silt; 24.4-30.5 m light grey-light greyish brown silty clay; 30.5-35.1 m white-light grey sandy silt, forams?; 35.1-44.2 m carbonaceous silt; 44.2-53.3 m carbonaceous silty sand; 53.3-65.5 m carbonaceous clay, a little silty clay; 65.5-68.6 m carbonaceous sandy silt; 68.6-105.2 m clay, carbonaceous to 82.3 m, ferruginous 82.3-105.2, forams 94.5-105.2 m; 105.2-109.7 m sandy silt; 109.7-126.5 m sand and silty clay, ferruginous, forams; 126.5-132.6 m clay, foram bearing sand; 132.6-155.5 m silty sand, some carbonaceous, sandy silt towards end.

Remarks: Fluid level 16.8 m.

Electric logs: 'Sand' bands 100.6-115.2 m (relatively high R and γ to bottom of hole high SP to 136.6 m), 65.5-68.6, 44.8-51.8 m. 'Carbonate' bands 140.5, 61.0, 53.3, 48.2, 28.0, 23.2 m. High γ 75.0-76.2, 46.3-47.9 m.

R14 (elevation 180.8 m; hole depth 152.4 m)

0-14.6 m silty clay, clay, sandy clay with limonite nodules (0-1.5 m); 14.6-54.9 m carbonaceous clay, a little silt, dark grey-brown plastic, vivianite. Sandy silt band 53.3-54.9 m silcrete 50.3-51.8 m; 54.9-65.5 m sandy silt, carbonaceous clay, sand in bands, light to dark brown; 65.5-80.7 carbonaceous blue-grey to grey-brown sandy clayey silt; 80.7-91.4 m sand, some coarse bands of clay, sandy silt towards end; 91.4-114.3 m grey-blue silty clay to clay, some orange clay some carbonaceous matter towards end. Sand band 105.2-106.7 m; 114.3-147.8 m grey-blue clay and silty clay, some carbonaceous, two thin bands silcrete 141.7-147.8 m; 147.8-152.4 m carbonaceous grey-brown sandy silt.

Remarks: Fluid level at 6.1 m.

Electric logs: 'Sand' bands 89.9-90.8, 75.3-87.7 m ('clay' bands towards end) 54.0-58.5 m (weak on γ). 'Carbonate' bands 112.5, 98.8?, 72.2, 69.5, 66.8, 64.9, 45.1 m. High γ 78.0-78.9 m.

S1 (elevation 175.9 m; hole depth 166.1 m)

0-14.3 m orange-brown, fawny brown clay and silty clay; 14.3-20.1 m carbonaceous, dark grey-brown silty clay; 20.1-45.7 m carbonaceous sandy silt; 45.7-50.3 m dolerite detritus? silcrete; 50.3-67.1 m sandy silt, some carbonaceous, silcrete 47.5-50.3, 59.4-61.0 m; 67.1-111.3 m ferruginous sandy silt, sand bands, some carbonaceous material; 111.3-144.8 m ferruginous and carbonaceous silty clay, yellow-brown, red, chocolate-brown; 144.8-162.5 m carbonaceous sand, gritty sand up to 5 mm; 162.5-166.1 m light grey-blue sandy silt.

Remarks: Fluid level at 7.9 m.

Electric logs: 'Sand' bands 155.5-163.7, 140.8-152.4, 128.9-130.2, 120.4-121.9 (weak), 67.1-111.3 m (may be some sand bands here - log peaks weak), 58.8-61.0, 54.0-55.8, 43.3-47.9 m (weak on SP for last three), 33.5-36.0 m weak on γ. 'Carbonate' bands 47.6, 44.5, 40.0 m.

S2 (elevation 167.6 m; hole depth 161.5 m)

0-14.6 m soil, clay, silty clay, light grey, yellow-brown, plastic; 14.6-71.6 m carbonaceous, dark grey - brown clay, some silt; 71.6-88.4 m light grey, brownish, carbonaceous sandy silty clay; 88.4-144.8 m ferruginous clay, some silty, sandy horizons, sand 135.6-137.2 m; 144.8-161.5 m carbonaceous sand and silty sand.

Electric logs: 'Sand' bands 140.2-160.0 m (some 'clay' bands) 129.5-130.8, 120.1-122.2 m (low peaks). 'Carbonate' bands 137.5, 103.9 m. High γ 147.8-148.4, 146.3-147.2 m.

S3 (elevation 175.0 m; hole depth 150.9 m)

0-22.9 m clay with limonitic bands, dominantly plastic; 22.9-112.8 m carbonaceous clay, dark brown - dark grey, vivianite? 24.4-36.6 m; 112.8-120.4 m grey and brown carbonaceous silt and clay; 120.4-135.6 m carbonaceous sandy silt and clay; 135.6-150.9 m clay and silty clay, ferruginous, carbonaceous, forams?

Remarks: Fluid level 9.5 m.

Electric logs: Fairly featureless. 'Sand' band 128-130.5 m. 'Carbonate' bands 101.2, 99.1, 95.7, 94.8 m.

S4 (elevation 179.8 m ; hole depth 150.9 m)

0-25.9 m clay with limonite bands, dominantly plastic; 25.9-123.4 m carbonaceous, brown to dark grey clay, vivianite 27.4-39.6 m; 123.4-137.2 m coarse sand, minor clay; 137.2-141.7 m carbonaceous silt, clay, silty sand; 141.7-149.4 m light grey clay and silty clay, forams?; 149.9-150.9 m sandy silt, carbonaceous clay.

Remarks: Fluid level 4.9 m.

Electric logs: 'Sand' band 123.4-138.7 m ('clay' 128-130.5, 134.1-135.3 m) 146.6-147.8 m. 'Carbonate' bands 119.8, 118.6, 115.8, 112.2, 104.6 m.

S5 (elevation 182.0 m; hole depth 150.9 m)

0-13.7 m yellow-brown to grey clay with limonite bands, often plastic;

123.4-141.7 m coarse sand, carbonaceous clay; 141.7-150.9 m carbonaceous clay, sandy silt.

Remarks: Fluid level at 7.6 m.

Electric logs: 'Sand' bands 148.1-149.4, 146.6-147.8, 143.3-144.2, 121.3-140.8 m ('clay' beds 126.5-128, 129.8-131.1, 132.9-133.9, 135.0-135.9 m). 'Carbonate' bands 116.7, 116.1, 115.5, 114.0, 113.7, 113.4, 111.0, 110.0, 107.6, 105.5, 103.6 m.

S6 (elevation 182.9 m; hole depth 150.9 m)

0-16.8 m grey, yellow-brown clay, limonite bands; 16.8-118.9 m carbonaceous - dark brown to dark grey clay, often plastic, vivianite 27.4-45.7 m; 118.9-129.5 m carbonaceous clay and sandy silt; 129.5-137.2 m silty clay and sand, forams?; 137.2-150.9 m carbonaceous, ferruginous clay, forams?

Remarks: Fluid level 10.1 m.

Electric logs: 'Sand' bands 123.4-141.7 m (not strong overall, strong peaks 131.1-132.3 m), 116.1-117.3 m. 'Carbonate' bands 147.2, 146, 110.0, 109.1, 107.3, 103.9 m.

S7 (elevation 163.7 m; hole depth 152.4 m)

0-21.3 m soil, brown to light grey, orange-brown clay; 21.3-91.4 m carbonaceous - dark grey-brown clay, vivianite 27.4-59.9 m, laminated and silcrete bands 68.6-73.2 m; 91.4-105.2 m carbonaceous clay, sandy and clayey silt; 105.2-108.2 m coarse to medium sand; 108.2-152.4 m carbonaceous sandy silty clay and clay.

Remarks: Fluid level at 5.9 m.

Electric logs: 'Sand' bands 140.2-144.2, 135.3-136.6, 115.5-119.8, 102.1-104.6, 88.4-94.5 m. 'Carbonate' bands 126.8, 119.5, 117.4, 100.6, 88.4, 85.0, 81.4, 82.0 m.

S8 (elevation 159.7 m; hole depth 152.4 m)

0-18.3 m grey, orange-brown, fawn plastic clay, a little silty; 18.3-47.2 m carbonaceous clay, a little silt, silcrete bands 41.2-47.2 m; 47.2-56.4 m blue-grey sandy silt, some carbonaceous; 56.4-83.8 m carbonaceous, blue-grey silty clay, clay; 83.8-105.2 m silty sand, clay, sandy clay; 105.2-114.3 m sand, some sandy silt; 114.3-152.4 m carbonaceous and grey-blue silty clay, sandy silt.

Remarks: Fluid level at 3.1 m

Electric logs: 'Sand' bands 128-129.8, 123.8-126.8, 93.9-114.3 m ('clay' from 96.0-97.5 m) 79.3-80.5, 49.4-51.8 m. 'Carbonate' bands 80.5, 63.4 m some weaker zones. High γ 96.9-97.5 m.

S9(i and ii) (elevation 165.8 m; hole depth 155.5 m)

0-10.7 m clay with limonite bands, minor silt, yellow-brown, grey, plastic; 10.7-38.1 m carbonaceous dark brown-grey clay, dominantly plastic; 38.1-73.2 m carbonaceous sandy silt, silty clay, silcrete 68.6-73.2 m; 73.2-88.4 m sand, some silty sand, some clay, silcrete; 88.4-91.4 m carbonaceous sandy silt, clay; 91.4-98.2 m carbonaceous sand, silty sand; 98.2-118.9 m carbonaceous sand, silty clay, silty sand; 118.9-137.2 m clay, some forams, some ferruginous and carbonaceous zones; 137.2-152.4 m sandy silt, clay, some ferruginous and carbonaceous zones.

Remarks: Fluid level 18.6 m.

Electric logs: 'Sand' bands 147.2-151.2, 133.8-141.7, 125-125.9, 105.2-108.8, 97.5-98.2, 87.8-96.0, 67.1-74.7, 39.9-41.2 m. 'Carbonate' bands 81?, 69.5, 68.3, 53.3 m, between 43.6-51.8 m there are 10 bands. Around 32.3 m there are several weak bands.

S10 (elevation 175.9 m; hole depth 152.4 m)

0-14.3 m clay and silty clay, light grey orange-brown, plastic; 14.3-53.3 m carbonaceous brown to dark grey plastic clay, vivianite, silcrete every 1-2 m 44.8-53.3 m; 53.3-86.9 m clay, silty clay, sandy silt and clay, some carbonaceous, some ferruginous; 86.9-97.5 m sand, some silty clay, carbonaceous; 97.5-118.9 m carbonaceous silty clay, silty sand, sand; 118.9-131.1 m silty clay, clay, some carbonaceous, ferruginous 126.5-131.1 m; 131.1-149.4 m sand, some silty clay lenses, ferruginous clay; 149.4-152.4 m ferruginous clay and sand.

Remarks: Fluid level 10.1 m.

Electric logs: 'Sand' bands 145.4-147.8, 138.1-143.0, 129.8-136.6, 113.4-114.6, 104.6-107.9 m (only high (-ve) on SP) 84.4-94.5, 61.0-61.6 m. 'Carbonate' bands 86.6, 86.0, 85.0, 80.5, 61.0, 58.8, 51.2, 50.0, 49.1, 48.8, 47.6, 46.9, 46.3, 42.7, 40.5 m. γ ray 74.4-75.3, 62.8-63.4 m.

S11 (elevation 177.7 m; hole depth 150.9 m)

0-15.2 m clay, limonite bands, ferruginous staining, some plastic; 15.2-24.0 m clay, some carbonaceous, some ferruginous; 24.0-32.0 m grey sandy silt; 32.0-36.6 m carbonaceous and ferruginous silt and clay; 36.6-64.0 carbonaceous and ferruginous clay and silty clay; 64.0-77.7 m medium to coarse sand; 77.7-91.4 m sand, clay, silty clay, some carbonaceous, some ferruginous; 91.4-97.5 m medium to coarse sand; 97.5-150.9 m some sand (at start), clay sandy silty clay, carbonaceous and ferruginous.

Remarks: Fluid depth 0.6 m.

Electric logs: 'Sand' bands 129.5-133.2, 96.3-97.5, 85.3-92.1, 67.3-75.6, 26.8-30.8 m. 'Carbonate' bands 106.1, 103.9, 33.2 m.

S12 (elevation 182.9 m; hole depth 150.9 m)

0-18.3 m clay with limonitic bands, grey, brown-yellow, some plastic; 18.3-39.6 m carbonaceous dark brown to dark grey clay, laminated hard angular silty clay 33.5-39.6 m (silcrete); 39.6-45.7 m carbonaceous clay and sandy silt; 45.7-67.1 m silt, clay, silty clay, some carbonaceous; 67.1-76.2 m sandy silt; 76.2-77.7 m pebbly coarse sand, 20% >6 mm - quartz clear to grey; 77.7-150.9 m silty clay, clay, sandy silty clay, some ferruginous, some carbonaceous, rich in wood fragments 91.4-100.6 m.

Remarks: Fluid level 18.3 m.

Electric logs: 'Sand' bands 103.6-106.7 m (weak on γ), 80.2-82.0, 66.8-75.3 m. 'Carbonate' bands 119.5, 106.4, 63.7, 55.8, 37.8, 37.2, 34.1, 30.4 m.

S13 (elevation 171.9 m; hole depth 152.4 m)

0-1.5 m light to dark grey clay; 1.5-19.8 m orange-brown sandy and silty clay; 19.8-39.6 carbonaceous dark grey-brown plastic clay, vivianite; 39.6-57.9 m carbonaceous sandy silt, silty clay; 57.9-61.0 m pebbly gravel, average size 5 mm - white to smoky black, <5% dolerite; 61.0-79.3 m sandy silty clay, often ferruginous, some carbonaceous; 79.3-89.9 m sand bands, clay, carbonaceous; 89.9-105.2 m dominantly wood fragments; 105.2-106.7 m sand, carbonaceous fragments; 106.7-144.8 m wood fragments, silty clay, silcrete band 123.4-125.0 m; 144.8-150.9 m brown sandy silt, silty clay; 150.9-152.4 m silty clay, carbonaceous matter.

Remarks: Fluid level 3.7 m.

Electric logs: 'Sand' bands 140.5-145.1 m (not on γ), 113.4-115.8 m (mainly on γ, slight peak on R), 100.3-101.5, 54.9-62.2 m. 'Carbonate' bands 123.8, 55.8, 51.2, 39.9, 21 m.

S14 (elevation 181.1 m; hole depth 138.7 m)

0-16.2 m brown-yellow orange clay, silty clay; 16.2-33.2 m carbonaceous dark grey to brown clay, plastic; 33.2-40.5 m carbonaceous sandy silt; 40.5-46.6 m carbonaceous, plastic silty clay; 46.6-62.5 m carbonaceous sandy silt, 50.3-51.8 m silcrete; 62.5-138.7 m wood fragments, silty clay - brown to light grey, 91.4-94.5 m - 0.3-0.9 m of silcrete.

Remarks: Fluid level 0.9 m.

Electric logs: 'Sand' bands - poor peaks 91.4-92.4, 80.5-83.2, 36.6-57.9 m (low peaks on SP and R, not on γ), 3.4-14.9 m (high peaks on SP and R, not on γ - oxidation zone of clay).

S15 (elevation 171.9 m; hole depth 131.1 m)

0-10.7 m clay, limonite bands; 10.7-15.2 m carbonaceous dark brown-grey clay; 15.2-26.8 m carbonaceous silt; 26.8-44.2 m carbonaceous grey pebbly coarse sand, sand, silt, quartz - clear to grey pebbles > 3 mm; 44.2-83.8 m carbonaceous sand and silt, silty sand; 83.8-108.2 m wood fragments, silty clay, silcrete bands 102.1-108.2 m; 108.2-125.0 m clay, silt, dolerite pebbles - dolerite weathered at 120.4-125.0 m forams? particularly 115.8-125 m; 125.0-131.1 m dolerite.

Remarks: Fluid level 4.6 m.

Electric logs: Dolerite possible from 111.3 m. Peak (-ve) on γ 92.1-98.2 m not on other logs. 'Sand' bands 63.7-78.3, 43.3-54.9, 32.9-39.6, 25.0-27.7 m. 'Carbonate' bands 107.6, 102.4, 100.3, 18.0 m.

S16 (elevation 172.8 m; hole depth 123.4 m)

0-7.6 m brown silty clay, some plastic; 7.6-9.1 m yellow-brown sandy silt; 9.1-29.0 m silty sand, sand, some silty, mainly ferruginous; 29.0-68.6 m carbonaceous sandy silt, sand (near top); 68.6-85.3 m medium-fine carbonaceous sand; 85.3-106.7 m carbonaceous sand, sandy silt beds; 106.7-109.7 m medium-grained grey sand; 109.7-115.8 m carbonaceous sand, silty clay, clay; 115.8-123.4 m dolerite (118.9-123.4 m hardness increases with depth).

Remarks: Fluid level 12.2 m.

Electric logs: R very irregular and little use. Dolerite possibly at 106.7 m? 'Sand' bands 93.0-97.5, 57.9-91.4, 49.7-82.3, 39.6-42.7, 35.4-38.7, 9.1-27.4 m. High γ 29.0-8.8 m.

S17 (elevation 185.0 m; hole depth 137.2 m)

0-13.2 m clay, ferruginous staining, limonitic bands, plastic; 13.2-41.2 m carbonaceous dark brown-grey clay, mainly plastic; 41.2-53.3 m carbonaceous brown, sandy silt, silty clay, silcrete bands 42.7-45.7, 41.2-42.7 m; 53.3-64.6 m carbonaceous grey clay, silty, often plastic, silcrete 61.0-62.5 m; 64.6-68.6 m medium to coarse grey sand; 68.6-77.7 m silty and carbonaceous clay, some plastic, some silcrete; 77.7-88.4 m medium to fine carbonaceous sand; 88.4-105.2 m carbonaceous interbedded clay and sandy silt; 105.2-123.4 m ferruginous, carbonaceous orange-brown clay, forams? 117.4 m; 123.4-137.2 m clay, sandy silt, coarse sand, clay ferruginous, silcrete 135.6-137.2 m.

Remarks: Fluid level 15.9 m.

Electric logs: 'Sand' bands 127.4-133.5, 115.5-123.4, 77.7-83.5, 62.5-65.5, 43.3-45.1 m. 'Carbonate' bands 90.5, 60.1, 58.5, 57.0, 56.1, 55.2, 39.6, 38.4, 37.2, 35.4, 34.4, 33.5 m.

T1

This hole is shown on one of Getty Oil's location plans, but there is no record of the hole being drilled.

T2 (elevation 187.8 m; hole depth 114.3 m)

0-3.1 m soil and sandy silty clay; 3.1-16.8 m light grey and brown clay; 16.8-32.0 m sandy silt and clay, carbonaceous and ferruginous; 32.0-36.6 m light blue-grey pebbly silty sand, some pebbles 2-3 mm; 36.6-68.6 m sandy silty clay, light bluish, light brown dark brown carbonaceous; 68.6-103.6 m carbonaceous sand, sandy silt, clay (sand 80.8-86.9 m); 103.6-105.2 m decomposed dolerite boulder; 105.2-111.3 m bluish grey sandy clayey silt; 111.3-114.3 m partly weathered dolerite.

Remarks: Fluid level at 4.0 m.

Electric logs: 'Sand' bands 108.5-109.7, 103.9-105.5, 96.6-97.5, 78.6-85.3, 68.6-70.7 m (γ high, +ve) 29.3-32.9 m. High γ 102.7 m.

T3 (elevation 176.8 m; hole depth 137.2 m)

0-15.2 m light grey, reddish brown silty clay, some plastic; 15.2-67.1 m carbonaceous dark grey-dark brown silty clay, mainly plastic; 67.1-80.8 m carbonaceous sandy silt, silty clay; 80.8-99.1 m carbonaceous silty sand, coarse sand; 99.1-106.7 m carbonaceous silty sand and silty clay; 106.7-109.7 m medium-grained sand; 109.7-137.2 m carbonaceous sandy silt, silty sand, silty clay.

T4 (elevation 175.5 m; hole depth 137.2 m)

0-17.7 m grey and yellow-brown silty clay, often plastic; 17.7-99.1 m carbonaceous dark brown-dark grey silty clay, plastic; 99.1-103.6 m carbonaceous silty sand, silty clay; 103.6-106.7 m coarse sand; 106.7-137.2 m silty clay, silty sand, sandy silt, some plastic.

Remarks: Fluid level at 3.1 m.

Electric logs: 'Sand' bands 132.0-133.2, 121.9-125.9, 118.3-119.5, 114.0-116.1, 97.8-104.6 m. 'Carbonate' peaks 88.7, 83.2, 79.9, 73.5 m (& four small peaks between 75.9 and 78.0 m)

T5 (elevation 177.7 m; hole depth 137.2 m)

0-18.3 m light grey to yellow-brown clay; 18.3-88.4 m a little carbonaceous dark brown clay, mainly plastic; 88.4-94.5 m plastic light grey and yellow clay, silty clay; 94.5-103.6 m silty sand, coarse sand, (coarse 100.6-103.6 m); 103.6-125.0 m sandy silt, silty clay, some carbonaceous, some green-grey-brown; 125.0-137.2 m carbonaceous silty sand, silty clay, some plastic.

Remarks: Fluid level 7.6 m.

Electric logs: 'Sand' bands 132.3-133.5, 121.9-122.8, 109.1-110.3, 94.5-101.8 m. High γ 97.2-97.8, 98.5-99.4 m.

T5a (elevation 177.7 m; hole depth 137.2 m)

0-16.8 m grey-red and yellow-brown clay with limonitic bands, plastic; 16.8-82.3 m carbonaceous dark grey-brown clay, vivianite to 61.0 m; 82.3-83.8 m grey silty clay, 5-10% vivianite; 83.8-94.5 m carbonaceous brown clay, vivianite; 94.5-99.1 m carbonaceous silty clay, clay; 99.1-106.7 m carbonaceous sandy silt; 106.7-111.3 m carbonaceous coarse sand, some quartz pebbles >2 mm; 111.3-115.8 m carbonaceous brown clay, silty clay; 115.8-137.2 m carbonaceous clay, silty clay.

Remarks: Fluid level 3.4 m.

Electric logs: 'Sand' bands 119.8-125.0, 99.4-107.3 m. 'Carbonate' bands 91.4, 85.7, 84.7, 86.5, 76.5 m. High γ 99.1-100.0 m.

T5b (elevation 177.7 m; hole depth 138.7 m)

0-18.9 m light grey, orange brown clay, silty clay; 18.9-91.4 m carbonaceous brown-dark grey clay, vivianite to 32.0 m, 83.8-91.4 m hard bands of silcrete; 91.4-105.2 m carbonaceous sandy silt, clay; 105.2-109.7 m sand and sandy silt, some wood fragments; 109.7-121.9 m grey-blue carbonaceous silty clay; 121.9-126.5 m sandy silt; 126.5-129.5 m carbonaceous sand; 129.5-135.6 m sandy silt and silty clay, wood fragments; 135.6-138.7 m sand, sandy silt, wood fragments.

Remarks: Fluid level at 2.7 m.

Electric logs: 'Sand' bands 134.1-135.3, 130.8-132.3, 119.5-125.9, 103.6-106.4, 95.4-97.8, 90.2-91.4 m. 'Carbonate' bands 119.8, 88.1, 86.5, 86.6, 85.0, 84.7, 81.7, 80.2 m. High γ 103.6-104.2 m.

T6 (elevation 173.7 m; hole depth 121.9 m)

0-3.1 m silty clayey top soil, limonite nodules 1.5-3.1 m; 3.1-16.2 m orange to light grey clay; 16.2-79.3 m carbonaceous brown to grey clay, some silty; 79.3-83.8 m sandy silt, blue-grey matrix; 83.8-88.4 m silty sand, some carbonaceous matter; 88.4-89.3 m coarse sand, feldspar about 20%; 89.3-97.5 m carbonaceous silty sand, coarse at first; 97.5-121.9 m carbonaceous sandy silty clay, clay.

Remarks: Fluid level at 3.7 m.

Electric logs: 'Sand' bands 118.6-122.8, 103-103.9, 92.7-123.1, 87.8-89.9, 82.0-85.0 m. 'Carbonate' bands 75.3, 75.0, 74.1, 73.2, 72.2, 70.1 m. Strong γ 82.6-83.2 m.

T7 (elevation 175.3 m; hole depth 152.4 m)

0-3.1 m medium-fine, orange-brown sandy silt; 3.1-18.9 m light grey to yellow-orange clay; 18.9-77.7 m brown-chocolate-grey carbonaceous clay, some silty; 77.7-99.1 m silty sand, some carbonaceous; 99.1-106.7 m carbonaceous sandy silt; 106.7-108.2 m coarse silty sand, some forams?; 108.2-152.4 m clay, sandy silt, some carbonaceous, some blue-grey.

Remarks: Fluid level 4.0 m.

Electric logs: 'Sand' bands 147.8-149 m, low peak 126.5-144.8 m - silt? 120.1-121.9, 105.2-112.2, 95.4-97.2, 76.2-93 m (strong series of peaks). 'Carbonate' bands 107.6, 56.4, 54.0 m.

T8 (elevation 171.9 m; hole depth 141.7 m)

0-2.4 m sandy, silty clay, occasional pebbles 10-15 mm; 2.4-15.9 m orange-brown-fawn clay; 15.9-60.1 m carbonaceous grey, chocolate-brown clay, some silty; 60.1-70.1 m carbonaceous sandy silty clay; 70.1-72.5 m carbonaceous silty sand; 72.5-81.7 m feldspathic coarse-fine sand, wood fragments; 81.7-141.7 m sandy silt, silty sand.

Remarks: No electric logs located.

V1 (elevation 145.4 m; hole depth 97.5 m)

0-1.5 m sand; 1.5-4.6 m greenish-blue sandy silty clay; 4.6-12.2 m iron stained silty sand; 12.2-13.7 m medium to fine sand, limonite nodules 9.1-12.2 m; 13.7-21.3 m ferruginous sandy silt, silty sand; 21.3-23.8 m silty clay, orange stain; 23.8-29.0 m carbonaceous silty sand; 29.0-51.8 m carbonaceous sand, bands silty clay 45.7-51.8; 51.8-56.4 m carbonaceous sandy silty clay; 56.4-59.4 m sand; 59.4-64.0 m carbonaceous silty sand and clay; 64.0-85.3 m coarse sand, silty 71.6-73.2 m gritty, carbonaceous 83.8-85.3; 85.3-88.4 m silty clay, sandy silty clay; 88.4-91.4 m carbonaceous sand; 91.4-94.5 m silty sand and silty clay; 94.5-97.5 m hard siliceous dark grey to greenish greywacke? Permian or Triassic.

Remarks: Fluid level 5.5 m.

Electric logs: No SP and fairly indefinite logs. 'Sand' bands 89.6-91.8, 72.9-82.6, 66.8-70.1, 54.9-61.6, 26.8-49.7, 11.9-14.9 m.

V2 (elevation 150.3 m; hole depth 100.6 m)

0-6.1 m medium to mainly fine ferruginous sand; 6.1-15.2 m silty sand, sandy silt, some clay; 15.2-18.3 m carbonaceous sandy silt, silty sand; 18.3-24.4 m silty clay, clayey silt; 24.4-41.2 m sandy silt, silty sand, some clayey, carbonaceous; 41.2-64.0 m sand and silty sand interbedded, some clay, carbonaceous; 64.0-68.6 m silty clay, some sand, clay blue-grey; 68.6-97.5 m mainly sand, some silty clay and sand particularly towards end, carbonaceous; 97.5-100.6 m hard silicified grey-green quartz sand to greywacke with lithic fragments; silicified pebbly gravel bed.

Remarks: Fluid level 9.1 m.

Electric logs: SP very irregular and 'sand' bands difficult to detect; 88.4-90.8, 82.6-84.1, 77.1-80.2, 52.4-59.7, 37.5-45.7, 26.8-28.3 m.

V3 (elevation 172.8 m; hole depth 160.0 m)

0-4.6 m ferruginous silty sand; 4.6-8.5 m ferruginous coarse gravel; 8.5-18.9 m silty sand, silt oxidation boundary at 8.5 m, below carbonaceous silt, plastic; 18.9-22.9 m pebbly sand, sandy gravel; 22.9-36.6 m silt, coarse sand beds, silty sand, sandy silt, silty clay (much contamination from above); 36.6-73.2 m carbonaceous silty clay, peat to 56.4 m; 73.2-79.3 m silty sand, peat chips, abundant wood fragments; 79.3-129.5 m silty clay, clay, some carbonaceous, some ferruginous? some plastic clay; 129.5-150.9 m medium to coarse sand, carbonaceous silt 135.6-137.2, 138.7-140.2 m; 150.9-160.0 m carbonaceous sandy silt, peat 153.9-155.5 m.

Remarks: Fluid level at 3.7 m.

Electric logs: 'Sand' bands 153.9-154.5, 146.3-147.2, 139.6-145.1, 126.2-138.1, 71.0-73.2, 68.3-69.8, 23.2-30.5 (not on SP) 17.1-22.6 (not on SP), 9.8-12.8, 4.9-6.7 m. 'Carbonate' bands 103.3, 97.5, 87.2, 85.7, 72.9, 67.7, 66.1, 64.9 m.

V4(i, ii, iii) (elevation 123.4 m; hole depth 13.7 m)

0-7.6 m medium to fine sand; 7.6-12.2 m Recent gravel, coarser with depth; 12.2-13.7 m silty sand.

Remarks: Unable to continue because of gravel in all holes.

V4b (elevation 142.3 m; hole depth 150.9 m)

0-4.6 m ferruginous sandy clayey silt; 4.6-8.5 m Recent gravel, ferruginous; 8.5-94.5 m carbonaceous silty clay, clay, silt. Mainly peat 8.5-16.8, 42.7-48.8, 59.4-62.5 m; 94.5-150.9 m grey-brownish sandy silt, some carbonaceous, some coarse sand content 121.9-135.6 m.

Remarks: Fluid level 2.4 m.

Electric logs: 'Sand' bands 141.4-143.0 m (weak peaks), 135.0-138.7, 124.1-133.5 m (weak peaks), 118.3-121.9, 113.1-113.4, 115.2-116.1, 98.5-104.6, 96.9-97.2, 93.3-94.5, 58.5-59.1, 52.1-53.7, 3.7-7.6 m.

V5 (elevation 148.4 m; hole depth 64.0 m)

0-3.1 m ferruginous soil and silty clay; 3.1-10.7 m ferruginous gravel; 10.7-32.0 m silty sand, ferruginous to 16.8 m, carbonaceous after; 32.0-48.8 m brown and grey silt; 48.8-54.9 m light brown-grey silty clay; 54.9-61.0 m compact brown and black shale? baked Permian on dolerite?; 61.0-64.0 m clay after dolerite, igneous texture.

V6 (elevation 153.3 m; hole depth 70.1 m)

0-2.1 m sandy silty clay; 2.1-10.1 m clay with pebble bands; 10.1-13.1 m carbonaceous clay; 13.1-14.6 m silty sand; 14.6-15.9 m coarse quartz sand; 15.9-24.4 m blue grey to grey silty sand; 24.4-27.4 m grey to blue-grey sandy silty clay; 27.4-55.8 m carbonaceous silty clay; 55.8-70.1 m clay after dolerite, hard bands creamy 'white' rock, hard dolerite at end.

Remarks: Fluid level 3.1 m.

Electric logs: From γ dolerite may start at 53.0 m. 'Sand' bands 13.1-23.2, 3.1-6.1 m (only on R).

V7 (elevation 157.2 m; hole depth 64.0 m)

0-8.5 m silty clay and clay; 8.5-11.3 m carbonaceous clay; 11.3-19.8 m carbonaceous sandy silt, silty sand; 19.8-26.2 m sand, wood fragments, becoming pebbly at 24.4-26.2 m; 26.2-29.3 m detritus bed, quartz, quartzite; 29.3-57.9 m carbonaceous sand, silcrete 32.0-33.5, 54.9-56.4 m; 57.9-64.0 m sandy silty clay, grey to brown.

Remarks: Fluid level 3.4 m.

Electric logs: Not very distinctive. 'Sand' bands 12.8-55.8 m not strong (16.8-21.3 m 'clay'?).

V8 (elevation 153.3 m; hole depth 134.1 m)

0-12.8 m clay and silty clay bands, mainly grey to orange-brown; 12.8-21.3 m carbonaceous clay, silty clay; 21.3-24.4 m carbonaceous silty sand; 24.4-32.0 m carbonaceous sand, gritty 27.4-29.0 m, pebbly 29.0-32.0 m; 32.0-36.6 m carbonaceous sandy silty clay; 36.6-68.6 m sand and thin bands sandy silty clay, silcrete 67.1-68.6 m; 68.6-99.1 m carbonaceous silty sand, sand band 74.7-77.7 m; 99.1-111.3 m carbonaceous sandy silty clay and silty clay; 111.3-123.4 m detritus bed, quartz, quartzite, occasional dolerite; 123.4-134.1 m clay after dolerite(?), red-brown stain through samples.

Remarks: Fluid level 4.0 m.

Electric logs: From γ dolerite may start at 116.4 m. 'Sand' bands 109.7-115.8, 92.4-94.5, 70.1-87.8, 34.1-62.5, 23.8-30.5 m. 'Carbonate' bands 69.5, 66.8, 14.6, 13.1, 11.9, 11.3 m.

V9 (elevation 150.3 m; hole depth 36.6 m)

0-1.5 m top soil; 1.5-11.6 m clay with limonite bands; 11.6-18.3 m sandy silt, light grey to grey-brown, carbonaceous towards end; 18.3-24.4 m sand and gravel, 18.3-19.8 m fine sand, 19.8-21.3 coarse sand, 21.3-24.4 m gravel quartz clear, grey-white, 22.9-24.4 m some clay after dolerite; 24.4-36.6 m clay after dolerite, strong igneous texture 30.5-36.6 m.

Remarks: Fluid level 0.6 m.

Electric logs: Dolerite probably from about 22.9 m from γ log.

V10 (elevation 160.3 m; hole depth 155.5 m)

0-9.1 m silty clay, clay with limonite bands, grey to yellow-brown; 9.1-17.4 m carbonaceous plastic dark brown-dark grey clay; 17.4-19.8 m bluish-grey sandy silt; 19.8-21.3 m carbonaceous silty clay; 21.3-29.0 m sandy silt and silty sand; 29.0-32.0 m quartz gravel up to >12 mm, white to colourless grey; 32.0-39.6 m carbonaceous light brown-grey sandy silt; 39.6-47.2 m medium to coarse sand; 47.2-70.1 m carbonaceous silty sand, some silty clay; 70.1-73.2 m medium to coarse grained sand; 73.2-86.9 m sandy silt, silty sand, carbonaceous to 82.3 m; 86.9-91.4 m sand; 91.4-102.1 m silty sand, sandy silt, silty clay towards end; 102.1-150.0 m silty clay, clay, carbonaceous 146.3-150.0 m Jdl fragments; 150.0-155.5 m decomposed dolerite.

Remarks: Fluid level 4.3 m.

Electric logs: R and SP very irregular, interpretation mainly from γ. 'Sand' bands 139.9-142.7, 60.4-78.8?, 37.5-46.3, 28.4-31.4 m.

V11 (elevation 168.6 m; hole depth 125.6 m)

0-13.7 m soil, clay with limonitic bands; 13.7-24.4 m carbonaceous dark brown-grey clay, mainly plastic; 24.4-32.0 m carbonaceous sandy silt, some pebbles towards end; 32.0-41.2 m quartz gravel up to >12 mm, minor quartzite, subangular-rounded; 41.2-100.6 m carbonaceous - greenish grey silty sand, coarse sand 91.4-93.0 m, weathered dolerite 97.5-100.6 m; 100.6-102.1 m coarse sand; 102.1-105.2 m dolerite-quartz gravel in fine grey silty matrix; 105.2-111.3 m grey silty sand; 111.3-112.8 m peat in silt; 112.8-117.4 m light grey-dark grey sandy silty clay; 117.4-120.4 m dolerite boulder bed; 120.4-125.6 m clay after dolerite, hardness increasing.

Remarks: Fluid level 14.0 m.

Electric logs: Dolerite from 115.2 m? (γ log interpretation). 'Sand' bands 110.0-111.9, 100-103.0, 95.1-98.8, 82.6-90.2, 60.4-70.7, 50.3-57.0, 46.7-48.8, 42.4-44.5, 37.2-38.7, 30.8-33.2, 34.1-36.3 m.

V12 (elevation 170.7 m; hole depth 88.4 m)

0-4.6 m grey-yellow-orange silty clay, clay; 4.6-7.6 m sandy silt; 7.6-12.2 m gritty sand, 12.2-15.2 m carbonaceous silty clay; 15.2-22.9 m medium to very fine silty sand; 22.9-32.9 m coarse to fine sand, silty sand; 32.9-38.1 m carbonaceous sandy silty clay; 38.1-42.7 m carbonaceous sand; 42.7-74.7 m carbonaceous silty sand, sand 54.7-56.4 m; 74.7-76.2 m sand; 76.2-77.7 m silty sand; 77.7-88.4 m clay after dolerite, fairly fresh fragments at 86.9 m.

Remarks: Fluid level at 6.4 m.

Electric logs: SP very irregular, all logs not easy to interpret. 'Sand' bands 61.6-71.9, 45.7-56.4, 33.5-41.2, 21.6-30.5, 14.3-24.1 m.

V13 (elevation 173.4 m; hole depth 147.8 m)

0-0.9 m sandy silt; 0.9-3.4 m ferruginous gravel; 3.4-4.6 m pebbly sand; 4.6-15.2 m clay, sandy silt, sandy silty clay, ferruginous; 15.2-22.9 m carbonaceous - grey silty sand; 22.9-29.0 m sand, wood fragments; 29.0-77.7 m carbonaceous silty sand, sand 35.1-36.6, 50.3-51.8 m; 77.7-138.7 m sand, wood fragments, some silty horizons (103.6-105.2, 118.9-121.9 m); 138.7-143.3 m carbonaceous silty sand; 143.3-147.8 m clay after dolerite, hard, fresh dolerite 147.2-147.8 m.

Remarks: Fluid level at 5.8 m.

Electric logs: Not easy to interpret, many R rebases. 'Sand' bands 128.3-131.1, 119.5-126.5, 100.3-115.2, 96.0-97.5, 89.9-92.4, 85.7-88.1, 82.0-83.2, 63.4-76.8, 49.7-57.3, 41.2-45.1, 30.8-35.7, 1.2-4.3 m.

V14 (elevation 159.4 m; hole depth 21.3 m)

0-7.0 m sandy silty clay, clay, grey to yellow-orange; 7.0-21.3 m clay after dolerite, fresh dolerite 20.7-21.3 m.

Remarks: Fluid level 1.7 m.

Electric logs: From γ log, dolerite may extend from 6.7 m.

W1 (elevation 153.3 m; hole depth 44.8 m)

0-0.9 m carbonaceous silty sand; 0.9-1.5 m ferruginous silty sand; 1.5-4.6 m pebbly gravel, angular-subrounded quartz, quartzite; 4.6-13.1 m grey-orange clay and sandy silty clay; 13.1-36.6 m carbonaceous silty plastic dark brown-grey clay; 36.6-41.2 m carbonaceous sandy clayey silt; 41.2-42.7 m carbonaceous silty clay; 42.7-43.6 m hard siliceous sand; 43.6-44.8 m dark greenish black basalt, fresh and hard.

Remarks: Fluid level 1.5 m.

Electric logs: Difficult to interpret distinct beds.

W2 (elevation 166.4 m; hole depth 25.3 m)

0-2.4 m gravel; 2.4-7.6 m orange-brown sandy silty clay; 7.6-16.8 m clay after basalt; 16.8-25.3 m fresh and competent basalt.

Remarks: Fluid level 3.1 m.

Electric logs: Small peak 3.7-12.5 m.

W3 (elevation 170.4 m; hole depth 27.7 m)

0-1.5 m pebbly silty clay; 1.5-3.1 m silty clay; 3.1-4.6 m gravel; 4.6-7.6 basalt and boulders; 7.6-27.7 m basalt, decomposed on top.

Remarks: Fluid level 2.1 m.

Electric logs: Little can be interpreted from log.

W4 (elevation 170.4 m; hole depth 34.8 m)

0-1.5 m pebbly clayey silt; 1.5-4.6 m silty clay; 4.6-19.8 m weathered basalt; 19.8-22.9 m tuff?? 22.9-27.4 m basalt; 27.4-32.0 m brown and grey clay; 32.0-33.5 m fine-grained greenish-grey to grey silicified gravel?; 33.5-35.1 m basalt.

Electric logs: Difficult to interpret any lithologic boundaries.

W5 (elevation 155.1 m; hole depth 10.7 m)

0-3.1 m silty sand and sandy silt; 3.1-10.7 m basalt, fresh after 6.1 m.

W6 (elevation 161.2 m; hole depth 7.6 m)

0-1.5 m silty clay; 1.5-7.6 m basalt, only slightly weathered.

APPENDIX 6

Logs of oil prospecting holes

OP 1, Green Rises Road, Bracknell [*DP999885*]

Depth (m)	*Description*
0- 29.0	clay
29.0- 73.2	gritty clay
73.2- 94.5	no sample
94.5-137.2	no sample, trouble with many changes in formation (clay and sand?)
137.2-274.3	no sample
274.3-277.4	core; 76 mm light brown sandy clay
277.4-317.0	no sample
317.0-356.6	mainly sand and sandstone
356.6-365.8	no sample
365.8-368.8	core; 75 mm light brown sandy clay, some mica and wood fragments
368.8-435.9	no sample
435.9-442.0	coarse sand, some grit fragments
442.0-445.0	core; even grained fairly fine sand
445.0-454.2	sand?
454.2-487.7	coarse angular sand, a little clay, some wood fragments
487.7-500.0	fine sand, some coarse particles
500.0-512.1	coarse angular sand
512.1-518.2	fine sand and clay
518.2-524.3	coarse sand with clay
524.3-554.7	coarse angular sand, some grit fragments
554.7-556.0	core; siltstone and sandy siltstone, some carbonate in matrix and plant remains
556.0-566.9	coarse sand, some clay
566.9-576.1	coarse sand, abundant plant fragments
576.1-588.3	plant fragments, some clay
588.3-600.5	fine sand, some clay
600.5-615.7	coaly matter and clay
615.7-618.8	core; 100 mm fine sandy clay, some coaly matter
618.8-634.0	mainly coaly matter in sample return
634.0-640.1	clay, coaly matter, some coarse sand
640.1-658.4	mainly coaly matter, some clay
658.4-670.6	coarse sand, clay and plant remains
670.6-685.8	shale fragments
685.8-687.6	dolerite

OP 2, Hagley [*DQ908024*]

Depth (m)	*Description*
0- 27.4	mudstone
27.4- 36.6	soft dolerite (basalt?)
36.6- 45.7	mudstone
45.7- 64.0	sandstone
64.0- 82.3	fine sand
82.3-140.2	fine sand
140.2-144.8	even grained angular sand
144.8-155.5	clay and wood fragments

Appendix 6 (continued)

Depth (m)	*Description*
155.5-158.5	angular coarse sand to fine grit, some wood fragments
158.5-161.5	clay, some sand and wood fragments
161.5-182.9	clay with wood fragments and sand diminishing in quantity
182.9-189.0	clay, wood and some sand
189.0-213.4	mainly wood fragments, a little sand and clay
213.4-219.5	wood fragments and angular fine to coarse sand
219.5-240.8	mainly wood fragments, a little sand
240.8-253.0	mainly wood fragments, a little clay
253.0-256.0	angular sand and wood fragments
256.0-268.2	mainly wood fragments
268.2-271.3	angular, even grained sand, wood fragments, some clay
271.3-274.3	core; 100 - 50 mm light brown clay, 50 mm mainly lignite with clay seams
274.3-279.4	even grained angular sand, a few wood fragments
279.4-320.0	clay and wood fragments, sand becoming less abundant towards end
320.0-347.5	clay and wood fragments, a little sand
347.5-353.6	mainly wood fragments, a little clay
353.6-374.9	clay and wood fragments, wood becoming more abundant towards finish of section
374.9-402.3	clay and wood fragments, a reddish stain in some samples
402.3-478.5	clay and wood fragments
478.5-484.6	clay, wood fragments and abundant fine sand
484.6-490.7	mainly wood fragments
490.7-496.8	wood fragments, fine sand, some clay
496.8-502.9	clay and wood fragments
502.9-512.1	mainly wood fragments, some clay
512.1-518.2	clay and wood fragments
518.2-521.2	core; 40 mm clayey sand, carbonate matrix
521.2-536.5	wood fragments and angular sand
536.5-557.8	clay and wood fragments
557.8-560.8	clay, wood fragments, some sand
560.8-570.0	clay and wood fragments
570.0-573.0	wood fragments, clay, some sand
573.0-582.2	wood fragments, sand becoming more abundant, some clay
582.2-591.3	sand abundant, some wood fragments
591.3-606.6	wood fragments, sand and clay
606.6-627.9	clay, wood fragments, some sand
627.9-646.2	mainly angular sand, some wood fragments, a little clay
646.2-649.2	core; 40 mm friable sandstone
649.2-650.2	core; 120 mm mudstone with zones of sand
650.2-652.3	clay, sand and wood fragments
652.3-673.6	clay and wood fragments
673.6-676.7	clay and fragments of wood mainly, some shale fragments?
676.7-682.8	mainly carbonaceous material, some clay, a little sand
682.8-688.9	shale fragments and clay
688.9-695.0	wood fragments and shale fragments
695.0-698.0	sand, wood fragments and clay

Appendix 6 (continued)

Depth (m)	*Description*
698.0-704.1	clay and wood fragments
704.1-759.0	clay, sand, wood fragments and shale fragments
759.0-792.5	shale fragments, clay, wood fragments and sand
792.5-831.5	dolerite

Both holes were drilled by C.G. Sulzberger. The logs are a combination of the drillers log and the logs of samples where collected.

APPENDIX 7

Details of wells

	Owner and locality	Top. pos.[1]	Status[2]	Total depth (m)	Water level (m)	Yield[3] (*l*/day)	Quality (mg/*l* TDS)	Use[4]	Pump[5] type	Remarks
1	M. Gee, Relbia		O*	3.7	0	2 000	300	d,s		
2	E.C. Bligh, Breadalbane	vf	O	4.3	1.2	1 000	728†	s		Currently unused.
3	Raeburn, Breadalbane	vf	C		6.7		602†		W	
4	Cameron, Evandale	s	C	∿18.3	∿15.2					
5	Cameron Evandale	vf	C*	∿18.3						
6	H.G. Hart, Evandale	vf	O	∿12.2	10.7	9 000	548†	s	W	
7	Perth		C	1.8	1.2	30 000	700			
8	M.J. O'Toole, Longford	vf	C*	4.3	1.8		1134†			
9	R.M. Bertram, Longford	vf	C*	5.0-6.1	1.8		274†		W	
10	R.M. Bertram, Longford	vf	C*	6.1	4.0		1368†			
11	A.J. MacKinnon, Longford	vf	C	∿7.6	4.2		292†			
12	A.E. Wilks, Evandale		C*	3.5	3.1		258†			

Appendix 7 (continued)

	Owner and locality	Top[1] pos.	Status[2]	Total depth (m)	Water level (m)	Yield[3] (l/day)	Quality (mg/l TDS)	Use[4]	Pump[5] type	Remarks
13	I.M.V. Jones, Evandale		C*	18.3	7.6		242†			
14	G. Newton, Longford		C	11.0	2.7		234			
15	'Entally House', Hadspen		C*	3.7			193†			
16	R. Hughes, Longford	vf	O	∿21.3	4.0		422†	g	E	
17	H.J. Nevin & Son, Longford	vf	C	∿15.2	7.9	2 000	446†			
18	Cox, Longford		O**	6.7	4.9	11 000	894†	s,d	E	
19	Cox, Longford	vf	O*		4.0		326†	g	D	Sited by diviner
20	J.A. Dumaresq, Pateena Road		O**	∿4.6	1.8		326†	d	E	Poor summer yield
21	R.J. Peters, Pateena Road	vf	C	20.1	18	180		d	E	
22	M.J. O'Toole, Longford		C*	36.6			414†	s	D	
23	P. Whishaw, Carrick	s	C*	9.0-12.0	1.8					
24	'Crichton', Longford		O*				830†	d	E	
25	L. & M. Walker, Longford		O*	8.8	4.6		500†	g,s	E	

Appendix 7 (continued)

	Owner and locality	Top.[1] pos.	Status[2]	Total depth (m)	Water level (m)	Yield[3] (l/day)	Quality (mg/l TDS)	Use[4]	Pump[5] type	Remarks
26	S.H. Pitt, Longford		C*	6.1	3.4		1440†			
27	'Richmond Park', Longford	vf	C*	3.4	1.8		190†			
28	'Thornleigh', Longford	vf	C*	14.3	4.3		405†			
29	K. & A. Buttery, Longford		C*	9.1	4.0		510			
30	K. & A. Buttery, Longford		C*	5.2	2.4		110			
31	K. & A. Buttery, Longford		C*	4.3	2.1		145†			
32	L.R. Hughes, Longford	vf	A	9.1	6.7				W	
33	'Maldon', Longford	vf	O*	13.1	6.1		250†	d,s	W	Brown water with metallic odour
34	T.H. Bertram, Longford	vf	O*	4.6	3.1		380†	d,s	E	Used for drinking water
35	T.H. Bertram, Longford	vf	O*	3.7	1.2	11 000	565†	d,s	E	
36	A. Murgatroyd, Carrick	vf	O	6.7			1480†	d,s	E	
37	M. & L. Goss, Bishopsbourne	vf	O*	5.5	1.8		700†	d,s	E	

Appendix 7 (continued)

	Owner and locality	Top.[1] pos.	Status[2]	Total depth (m)	Water level (m)	Yield[3] (l/day)	Quality (mg/l TDS)	Use[4]	Pump[5] type	Remarks
38	A.C. Sherwood, Bishopsbourne	vf	C	4.6	1.8	9 000	555†			
39	D.R. Murfet, Toiberry	vf	O*	13.4	7.9	4 500	395†	d,s	E	
40	G.A. Freeman & Son, Toiberry	vf	O*	10.4	10.1		1485†	d,s	E	
41	G.A. Freeman & Son, Toiberry		O*	4.6	0.3		440†	s	E	
42	T. Badcock, Toiberry		O*	>30.5		1 100	1400†	s	E	
43	T. Badcock, Toiberry		C	11.0	4.3				W	
44	D. & A. Brooks, Toiberry		O*	7.9	3.1		465†	s	T	
45	I.L. Reid, Toiberry	vf	O*	7.9		13 500	755†	d,s	E	
46	H.G. Shipp, Toiberry	vf	O				1390†	d,s	W	Water corrosive
47	N.A. Eeles & Son, Toiberry	vf	C	7.3	2.4	900	670†			Water corrosive
48	J.I. Badcock, Toiberry		O*	10.1	5.2		680†	s	T	
49	T. Badcock, Toiberry	vf	O*	7.3	4.3		365†	s	H	Divined

Appendix 7 (continued)

	Owner and locality	Top.[1] pos.	Status[2]	Total depth (m)	Water level (m)	Yield[3] (l/day)	Quality (mg/l TDS)	Use[4]	Pump[5] type	Remarks
50	Lagoon Farm, Toiberry		O*			1 800	680†	d	W	
51	R.H. Manson, Longford	vf	C*	12.2	1.2	4 500	2575†	d,s	W	
52	B. Murfett, Longford		O*	33.6	12.2		1400†	d,s	W	
53	T.S. Murray, Longford		O*,N	15.6	11.3		990†	s	W	
54	G. Cox, Longford		O,N				515†	d,s	W	
55	'Fair Banks', Cressy	vf	O*	11.3	7.9		895†	d,s	W	
56	C.F. Targett, Cressy	vf	O*	9.1	6.1	50 000	670	d,s	E	
57	J.D. Casey, Cressy		C*	11.3	4.0		310†			
58	J. Humphries, Cressy		C*	7.3	4.3	65 000	380†	d,s	W	Windmill out of order
59	G.C. Freeland, Cressy		C*	11.6	7.3		350†	d,s	W	Windmill out of order
60	C.H. Exton & Son, Longford	vf	C*	5.5	1.5		600†			
61	E.A. Fyfe, Cressy		O*	10.1	6.4		210	s	W	Windmill not working

Appendix 7 (continued)

	Owner and locality	Top.[1] pos.	Status[2]	Total depth (m)	Water level (m)	Yield[3] (*l*/day)	Quality (mg/*l* TDS)	Use[4]	Pump[5] type	Remarks
62	'Rose Mount', Cressy	vf	C	12.5	3.7		170†			
63	G.W. Scurr, Cressy	vf	O*	10.7		600		d,s	E	60°F.
64	F.H. Howard, Cressy	vf	O*	5.8	3.1		1840†	s	T	60°F.
65	Murfett, Cressy	vf	C	4.9	2.4		870†			60°F.
66	F.D. Howard, Cressy	vf	O*		5.2		540†	d,s	W	59°F.
67	D.R. Brooks, Cressy	vf	O*	6.1	2.4	600	900†	s	W	56°F.
68	M.J. Smith, Cressy	vf	O*	8.5	5.2	1 000	430†	d,s	E	58°F.
69	C. Peltzer, Evandale	vf	C	7.6	2.7		260†	s	W	Windmill inoperative
70	'Eskleigh', Perth	vf	C	2.4	0.3		100†			
71	B. Youl, Symmons Plains	vf	C							
72	D. Cameron, Nile	vf	C*	9.1	6.1		1220†			60°F.
73	C.R. Field, 'Woodfield', Cressy	sv	C	7.6	0.3		1600			Makes little water in summer

Appendix 7 (continued)

	Owner and locality	Top.[1] pos.	Status[2]	Total depth (m)	Water level (m)	Yield[3] (l/day)	Quality (mg/l TDS)	Use[4]	Pump[5] type	Remarks
74	M. & T. Gatenby, Creekton, Cressy	v	A*	9.8	0.6		320	n		Used pre 1930
75	J.M. Bovill, Bracknell	vf	C*	7.3	0.3		640			
76	L. McKinnon, Bracknell	f	O	8.2	1.8	1 800	315†	d	E	Dug about 1908
77	L. McKinnon, Bracknell	s	O	14.3		2300-4500	1600	s	W	
78	L. McKinnon, Bracknell	vf	C	6.85	0		640			
79	L. McKinnon, Bracknell	ht	C*	8.8	4.0		175			
80	B. Barnett, McRaes Hills	ht	N*	22.3	14.9		480		W	
81	S.K. Wilson, Bracknell	vf	N	8.2	0.6		510		W	
82	S.K. Wilson, Bracknell	vf	C*	16.2	0.6		125			
83	S.K. Wilson, Bracknell		C	7.0	0.6		210			
84	J.M. Gatehouse, Bracknell	f	C*	9.8	2.1		200			Makes little water in summer
85	J.M. Gatehouse, Bracknell	vf	C	7.3	0		1150			Not pumped since 1950

Appendix 7 (continued)

	Owner and locality	Top.[1] pos.	Status[2]	Total depth (m)	Water level (m)	Yield[3] (*l*/day)	Quality (mg/*l* TDS)	Use[4]	Pump[5] type	Remarks
86	J. Masters, Cressy	gs	O*	8.2	1.2	1 100	270	s,d	E	Dug pre 1922
87	V. Spencer, Bishopsbourne	f	F	8.35						
88	V. Spencer, Bishopsbourne		F	24.4						
89	V. Spencer, Bishopsbourne	f	F	4.6						
90	D.W. Field, Bishopsbourne	vf	F							
91	D.W. Field, Bishopsbourne		F							
92	D.W. Field, Bishopsbourne	s	O*	13.4	4.6	4 500	2265†	s	E	Edge of terrace
93	D.W. Field, Bishopsbourne		C	6.4	0.3		160			Edge of terrace
94	D.W. Field, Bishopsbourne		F							
95	D.W. Field, Bishopsbourne	f	C	7.0	0.6		140			Not used for about 2 years
96	J.R. Green, Bishopsbourne	f	C	12.2?	0.9	no estimate				Stock water when used
97	L.J. Spencer, Bishopsbourne		S	9.1			hard			

Appendix 7 (continued)

	Owner and locality	Top.[1] pos.	Status[2]	Total depth (m)	Water level (m)	Yield[3] (*l*/day)	Quality (mg/*l* TDS)	Use[4]	Pump[5] type	Remarks
98	L.J. Spencer, Bishopsbourne		F	6.1		700	hard			
99	N.J. Prewer, Bracknell	vf	C	?	0					
100	J. Smith, Bracknell	s	C*	3.7	0.3		400			
101	Leonard, Bracknell		O*	5.5	0.3		1420		E	Used in summer
102	Towns, Bracknell	ht	F							
103	Towns, Bracknell	sv	O*	5.5	1.5	4 500	740†	s		Basalt
104	Towns, Bracknell	s	F							
105	H.R. Dobson, Bracknell		N	11.0	10.7		380		W	Basalt
106	V.H. Prewer & Sons, Whitemore	g	F	18.3						
107	V.H. Prewer & Sons, Whitemore	g	C	5.8	0.6		60			Was 20 m deep
108	V.H. Prewer & Sons, Whitemore	ht	F	27.4						Good supply when used
109	V.H. Prewer & Sons, Whitemore	g	O	3.7	0	4500-8800	700	s	W	

Appendix 7 (continued)

	Owner and locality	Top.[1] pos.	Status[2]	Total depth (m)	Water level (m)	Yield[3] (l/day)	Quality (mg/l TDS)	Use[4]	Pump[5] type	Remarks
110	V.H. Prewer & Sons, Whitemore		F							
111	V.H. Prewer & Sons, Whitemore		F	7.0						
112	H.W. Prewer, Whitemore	gs	O	5.8	0.6		190	s	W	
113	K. & E. Walker, Bishopsbourne	gs	C	~18.3	1	450-900				
114	K. & E. Walker, Bishopsbourne	f	C*	6.1	0.3	900	60			
115	R.R. Field, Bishopsbourne	f	F	shallow						No water in dry
116	T.G. Spencer, Bishopsbourne	s	S	16.8		900	good			
117	T.G. Spencer, Bishopsbourne		C	6.4		1 400	110			Not used
118	T.G. Spencer, Bishopsbourne	f	C	6.7	0.9	unknown	140			
119	E. Badcock, Bishopsbourne	f	O			450	550	s	W	
120	E. Badcock, Bishopsbourne	f	C*	6.4	5.2	small	53			
121	E. Badcock, Bishopsbourne	s	C	6.1	1.2	unknown	90			

Appendix 7 (continued)

	Owner and locality	Top.[1] pos.	Status[2]	Total depth (m)	Water level (m)	Yield[3] (l/day)	Quality (mg/l TDS)	Use[4]	Pump[5] type	Remarks
122	Smith, Bishopsbourne	ht	C*	9.8	4.2		350	d	H	Used in summer
123	W. Preece, Bishopsbourne	f	C*	5.2	0.3	100	220	d		
124	Hayes, Bishopsbourne	f	C	5.8	1.2	100	315			
125	W. Preece, Bishopsbourne	f	C*	7.0	0.9		50	s		Used in summer
126	Hayes, Bishopsbourne	gs	O	8.8	2.1		615†	d,s	E	
127	Hayes, Bishopsbourne		C*	8.2	2.1		125			
128	Gatenby, Bishopsbourne	f	F	3.7						
129	Gatenby, Bishopsbourne		C	2.7						Being filled
130	Gatenby, Bishopsbourne		C	4	1.2		200			
131	Gatenby, Bishopsbourne	ht	F							
132	Ollington, Bishopsbourne	f	C*	6.7	2.4		140			Used sometimes in summer
133	R.C. Steele, Bishopsbourne		C*	5.5	3		250			

Appendix 7 (continued)

	Owner and locality	Top. pos.[1]	Status[2]	Total depth (m)	Water level (m)	Yield[3] (l/day)	Quality (mg/l TDS)	Use[4]	Pump[5] type	Remarks
134	F.R. Hall, Bishopsbourne	s	O*	7.0	3.4	18 000	160	s	W	
135	M. Page, Bishopsbourne	f	C							Inaccessible
136	M. Page, Bishopsbourne	f	F							
137	Cresswell, Oaks		F	∿9.1						
138	K.W. Badcock, Oaks	f	C	4.6	0.6	poor	190			
139	K.W. Badcock, Oaks	gs	C	4.6	0.3		700	s		
140	K.W. Badcock, Oaks	f	O	6.4	0.3	unknown	310	s	E	
141	J. French, Oaks	vf	C	3.7	0		40			Not used
142	J. French, Oaks	gs	C	6.7	0.3		55		H	
143	J. French, Oaks	sv	N	1.8			105	s	W	Brackish when used
144	L.W. Stubbs, Oaks	s	O*	4.6	0	9000-12000	220	f	E	
145	L.W. Stubbs, Oaks	s	F	∿21.3						

Appendix 7 (continued)

	Owner and locality	Top.[1] pos.	Status[2]	Total depth (m)	Water level (m)	Yield[3] (l/day)	Quality (mg/l TDS)	Use[4]	Pump[5] type	Remarks
146	I. Heazlewood, Oaks		O	9.1		1400-2300			W	
147	Bell, Oaks	s	O*	8.2	0.9	2 300	420	s	E	
148	Bell, Oaks		C	6.4	0.5		350			
149	Bell, Oaks	s	C	3.4	0		100			
150	M.G. Patterson, Oaks	s	F	9.1						
151	W. Denne, Oaks	gs	F	18.3+						Low water level when used
152	W. Denne, Oaks	vf	O		1.5	6 800	640	s	E	
153	W. Denne, Oaks	s	O	$\sim$12.2					W	Inaccessible
154	M. Denne, Oaks	gs	C*	6.7	0.3		90			
155	Walker, Oaks	sv	C	4.9	0.3		90			
156	Archer, Carrick	gs	O	7.3	0.6		150	s	W	No water in dry summer
157	A.W. Hill, Carrick	sv	O	4.3	0.6		1250		H	No water in dry summer
158	J.A. French, Whitemore	gs	N*	7.3	0.6	450-2300	1050			Partly filled in
159	J.A. French, Whitemore	gs	C*	10.4	1.5		65			Not used for 40 years
160	J.A. French, Whitemore	gs	O	12.2	3.1		750	s,f	E	

Appendix 7 (continued)

	Owner and locality	Top.[1] pos.	Status[2]	Total depth (m)	Water level (m)	Yield[3] (*l*/day)	Quality (mg/*l* TDS)	Use[4]	Pump[5] type	Remarks
161	E.H. Heazlewood, Whitemore	sv	O	4.0	0		190		W	
162	French, Whitemore	sv	O	8.2	1.5	2 300	330		W	
163	French, Whitemore	sv	O	3.7	0					Used in combination with 162
164	French, Whitemore		A	6.1						Not successful
165	E.H. Heazlewood, Whitemore	gs	O	3.7	0	4500-9000	1300			
166	Windus, Whitemore		O*		0.6	poor				
167	I. Heazlewood, Whitemore	f	C*	4.3	0.5		125			
168	I. Heazlewood, Whitemore	v	C	6.7	1.8	1400-2300	55		W	Not used
169	I. Heazlewood, Whitemore	gs	O	5.2	0	4 500	620		W	
170	J.K. Heazlewood, Whitemore	gs	O	5.8	0	9 000	970		E	
171	J.K. Heazlewood, Whitemore	f	O*	4.3	0.6	4 500	1400		W	
172	J.K. Heazlewood, Whitemore	gs	C	5.2	0.6	1 400	400			Not used

Appendix 7 (continued)

	Owner and locality	Top.[1] pos.	Status[2]	Total depth (m)	Water level (m)	Yield[3] (*l*/day)	Quality (mg/*l* TDS)	Use[4]	Pump[5] type	Remarks
173	J.K. Heazlewood, Whitemore	vf	N	5.2	0		700			Virtually never used
174	B.R. Heazlewood, Whitemore	vf	C*	4.6	0.6	poor	970			
175 to 177	B.R. Heazlewood, Whitemore	f	F							
178	K.J. Heazlewood, Whitemore		C	12.2	0.3	poor	65		W	Only open to 600mm below surface
179	E. Shaw, Whitemore	ht	C	3.7						
180	E. Shaw, Whitemore		C							Inaccessible
181	L.G. French, Whitemore		O	5.2	6.7		200	s,t		
182	L.A. Stuart, Whitemore	f	N*	8.2	6.7	2 300	700		W	
183	R. Gray, Whitemore	ht	O	11.0	7.3	<225	400			Not used much
184	L.A. Stuart, Whitemore	f	O*	7.6	3.1	~45	180		W	
185	L.A. Stuart, Whitemore		O*	9.5	4.3	4 500	490		W	

Appendix 7 (continued)

	Owner and locality	Top.[1] pos.	Status[2]	Total depth (m)	Water level (m)	Yield[3] (*l*/day)	Quality (mg/*l* TDS)	Use[4]	Pump[5] type	Remarks
186	L.A. Stuart, Whitemore	f	C*	10.4	0.3		125		W	
187	L.A. Stuart, Whitemore	f	O*	9.8	7.0	>9 000	220		W	Capacity greater than windmill pump
188	A.J. French, Whitemore	f	O*	6.7	4.0	9 000	250		E	
189	A.J. French, Whitemore		F	6.1			brackish			
190	A.J. French, Whitemore		F	7.6						
191	A.H. McCulloch, Whitemore		C	6.1	1.2	18 000				
192	A.H. McCulloch, Whitemore	f	C	6.1	1.2	18 000	brackish			Used in summer
193	A.H. McCulloch, Whitemore	f	O	6.1	2.7	18 000	750		E	
194	M.E. Hillier, Whitemore	v	F							
195	M.E. Hillier, Whitemore	s	F							
196	M.E. Hillier, Whitemore	gs	N*	8.8	0.3		820		W	
197	Dobson, Whitemore	f	O	3.1	0		520		W	

Appendix 7 (continued)

	Owner and locality	Top.[1] pos.	Status[2]	Total depth (m)	Water level (m)	Yield[3] (*l*/day)	Quality (mg/*l* TDS)	Use[4]	Pump[5] type	Remarks
198	Dobson, Whitemore	gs	O	7.6	3.4		390	d	E	
199	Dobson, Whitemore		S							
200	Dobson, Whitemore	vf	O*	4.3	1.8		1430		W	
201	F.M. & D.G. Pearn, Whitemore	f	C*	7.3	2.7	<900	370		E	
202	F.M. & D.G. Pearn, Whitemore	f	C	5.2	0.6		300		W	
203	F.M. & D.G. Pearn, Whitemore		S							Used to be siphoned into 329
204	F.M. & D.G. Pearn, Whitemore	gs	O**	5.2	0		1360	d	E	Supplies two houses
205	F.M. & D.G. Pearn, Whitemore	f	C*	3.4	0		420		W	
206	B. Hingston, Whitemore	f	O	15.6	3.4	~2 300	970		W	
207	J. & M. Gilham, Whitemore	f	O*	7.0	0.3	2300-4500	2650		E	Dolerite area
208	J. & M. Gilham, Whitemore	gs	C*		0.3	poor			W	Inaccessible
209	J. & M. Gilham, Whitemore	gs	O*	3.7	0	2300-4500	1100		W	

Appendix 7 (continued)

	Owner and locality	Top. pos.[1]	Status[2]	Total depth (m)	Water level (m)	Yield[3] (*l*/day)	Quality (mg/*l* TDS)	Use[4]	Pump[5] type	Remarks
210	C. & A. Badcock, Whitemore		C			6 800				Edge of low plateau
211	C. & A. Badcock, Whitemore	s	O*	6.1	1.8	6 800	260		E	
212	R.G. Scott, Whitemore	f	O*	5.5	2.4		260		W	
213	R.G. Scott, Whitemore	f	O*	6.7	1.2		250		E	Pressure system pumps well dry basalt area
214	T.G. Scott, Whitemore	sv	O*	4.6	0.3	4 500	280		E	
215	S.J. Hingston, Whitemore	sv	O*	2.7	0		20		W	
216	S.J. Hingston, Whitemore	h	O	18.3?	?	good			E	Inaccessible
217	A. French, Whitemore		O	12.8	11.0	22 500	330		E	Terrace edge
218	T.G. Scott, Whitemore		C	deep		poor				
219	L.C. McCulloch, Whitemore	f	O	16.8	1.2		260	s	E	
220	L.C. McCulloch, Whitemore	sv	O*	7.6	2.4		265	s	W	
221	L.C. McCulloch, Whitemore	sv	O*	6.1	0.5	5 500	520	s	W	

Appendix 7 (continued)

	Owner and locality	Top.[1] pos.	Status[2]	Total depth (m)	Water level (m)	Yield[3] (l/day)	Quality (mg/l TDS)	Use[4]	Pump[5] type	Remarks
222	H. McCullagh, Whitemore	sv	O*	5.8		2300-4500	1160	s	W	
223	H. McCullagh, Whitemore	sv	O*	5.5		2300-4500	700	s	W	
224	A.J. Lindsay, Whitemore	ht	O*	13.1	0.3	450	700		E	
225	A.J. Lindsay, Whitemore		F							
226	A.J. Lindsay, Whitemore	v	O							Some water siphoned in summer
227	A.L.J. Badcock, Whitemore	gs	O*	5.8	0.9		560		W	
228	E. Shaw, Whitemore	ht	O	12.2	1.5	3600	310	s	W	
229	L.J. McCulloch, Whitemore	gs	O*	5.2	0	900	300	s	E	
230	L.J. McCulloch, Whitemore	gs	O	8.8	0.3	900	340	s	W	
231	L.J. McCulloch, Whitemore		A			no water				
232	H.W. Bramich, Hagley	sv	O*	3.4	0	>9000	125	s	W	
233	H.W. Bramich, Hagley	sv	O*	5.2	0	2300	95	s	W	

Appendix 7 (continued)

	Owner and locality	Top. pos.[1]	Status[2]	Total depth (m)	Water level (m)	Yield[3] (l/day)	Quality (mg/l TDS)	Use[4]	Pump[5] type	Remarks
234	H.W. Bramich, Hagley	gs	C*	4.3	0	2300	295			
235	H.W. Bramich, Hagley		C	∿9.1						Not used
236	H.W. Bramich, Hagley		C	∿6.1						Not used
237	V.E. Pearn, Hagley	ht	O*	11.6	0.6	900	415	s		Not used very much
238	Z. Pearn, Hagley	f	O*	10.7	3.1	900	180	s	E	
239	H.F. & V. Bad-cock, Hagley	sv	O*	6.4	0.3	900	85		W	
240	H.F. & V. Bad-cock, Hagley		C*	2.4		fair supply			W	Windmill broken
241	H.F. & V. Bad-cock, Hagley		O*	12.8	0	900	110		W	
242	J.M. Pearn, Hagley	sv	O*	7.3	0.6	1400	65		W	
243	J.M. Pearn, Hagley	ht	O	9.1		1400			E	Inaccessible - cement cover
244	J.M. Pearn, Hagley	sv	O*	3.7	0.3	4500	900		W	
245	M. & R. French, Hagley	gs	C	4.9	0	1400	130			

Appendix 7 (continued)

	Owner and locality	Top.[1] pos.	Status[2]	Total depth (m)	Water level (m)	Yield[3] (*l*/day)	Quality (mg/*l* TDS)	Use[4]	Pump[5] type	Remarks
246	G. & R. French, Hagley	ht	O*	9.1	0.6	450	95			
247	H.W. Bramich, Hagley		O						W	No access to property
248	L. French, Hagley	gs	O?*	4.3	0.6		150		H	) All wells on this property have a small yield except for 253 which intersected gravel. 253 dug with large auger. (248–253)
249	L. French, Hagley	gs	O*	4.3	0.3		40	s	W	)
250	L. French, Hagley	f	C*	5.8	0.9		300			)
251	L. French, Hagley	f	O*	7.9	0.3		140	s	W	)
252	L. French, Hagley		O					s	H	)
253	L. French, Hagley	f	O	6.7	0		inaccessible			)
254	H.W. May, Hagley	f	C*	7.9	0.3		195			
255	H.W. May, Hagley		C							
256	H.W. May, Hagley		F							
257	H.W. May, Hagley		F							

Appendix 7 (continued)

	Owner and locality	Top.[1] pos.	Status[2]	Total depth (m)	Water level (m)	Yield[3] (*l*/day)	Quality (mg/*l* TDS)	Use[4]	Pump[5] type	Remarks
258	G.W. French, Whitemore	ht	O*	8.2	3.4	20 000	230		E	
259	G.W. French, Whitemore	sv	O*	4.6	0.3	9000	150	s	W	
260	G.W. French, Whitemore	sv	O*	4.6	?	32 000	inaccess-ible	s	P	
261	H. Smith, Westbury	s	O	3.7	0.6	3600		s		
262	L.G. Clarke, Hagley	f	O	15.6	1.2	3200	200		E	
263	L.G. Clarke, Hagley	sv	N*	5.8	0		260		W	
264	L.G. Clarke, Hagley	f	N*	3.1	0.3		970		W	
265	S.M. Scott, Westbury	s	O*	2.7	0.9	6800	270		W	
266	L.L. Dobson, Hagley	v	A							
267	L.L. Dobson, Hagley	s	A							
268	L.L. Dobson, Hagley	v	A							
269	S.M. Scott, Westbury		N*	5.2	0		400		W	

Appendix 7 (continued)

	Owner and locality	Top.[1] pos.	Status[2]	Total depth (m)	Water level (m)	Yield[3] (l/day)	Quality (mg/l TDS)	Use[4]	Pump[5] type	Remarks
270	V.E. Pearn, Hagley	f	C*	2.7	0		75			
271	V.E. Pearn, Hagley	sv	N*	10.1	0		290			
272	V.E. Pearn, Hagley	v	N*	9.5	0.6		270		H	
273	V.E. Pearn, Hagley	sv	C*	9.5	0.6		150			
274	R.H. Heazlewood, Hagley	f	O	4.6	0	4500	110		W	
275	R.H. Heazlewood, Hagley	gs	O	7.9	0	450	110		E	
276	H.C. Gibson, Hagley	sv	O	4.3	0.9	1400	320		E	
277	M.F. Gorringe, Hagley	f	O*	3.0	0.3	small flow	195		W	
278	M.F. Gorringe, Hagley		F							
279	A.C. Cowan, Hagley	f	O*	4.6	0		130	s	W	
280	A.C. Cowan, Hagley	ht	C*	8.2			inaccess-ible			Never dry
281	V. Smith, Hagley	sv	C	6.1	0		100			No water in summer

Appendix 7 (continued)

	Owner and locality	Top.[1] pos.	Status[2]	Total depth (m)	Water level (m)	Yield[3] (l/day)	Quality (mg/l TDS)	Use[4]	Pump[5] type	Remarks
282	E.G. Scott, Hagley		C	6.4	0		450			Little water in summer
283	E.G. Scott, Hagley		C	8.2	0	small flow	460			
284	E.G. Scott, Hagley	f	O	5.5	0	4500	260		W	
285	E. Lindsay, Westbury	s	O	5.5	0.6		280	s	H	
286	S.L. Clarke, Westbury	s	C	6.1	0.3		520			
287	R. Gibson, Westbury		O	5.5	0.3	225	2000		H	
288	G.E. Walters, Westbury	s	O*	8.8	1.5	450	220	d	H	
289	Zeeman, Westbury	s	O			540		d		Inaccessible
290	H. Howell, Westbury	gs	O*	9.8	0.9		125		H	
291	R. King, Westbury	gs	C	5.5	0.6		75			
292	F.A. Richards, Westbury	gs	C	5.2	0.6		1300			
293	F.A. Richards, Westbury	f	N*	7.3	0.6	4500	270		W	

Appendix 7 (continued)

	Owner and locality	Top.[1] pos.	Status[2]	Total depth (m)	Water level (m)	Yield[3] (l/day)	Quality (mg/l TDS)	Use[4]	Pump[5] type	Remarks
294	Burns, Westbury	v	C	5.2	0		90			Too hard?
295	I. Walker, Westbury	f	O*	7.0	0.9		430	s	E	
296	D. Phelps, Westbury	gs	O*		7.6	300	95		H	
297	D. Phelps, Westbury	v								Creek water flowing into well
298	J.K. Bell, Carrick		C	2.7						
299	A. Boutcher, Hagley		C*	5.8		1400-1800	320		W	
300	A. Boutcher, Hagley		C*	2.4	no water					
301	A. Boutcher, Hagley		C*	13.1	11.3		230			
302	A. Boutcher, Hagley		C*	4.9	1.2	900	200			
303	J. Barnett, Hagley	s	F							
304	J. Barnett, Hagley	s								) Dam built over wells
305	R.C. & N.A. Richardson, Hagley	f								)

Appendix 7 (continued)

	Owner and locality	Top.[1] pos.	Status[2]	Total depth (m)	Water level (m)	Yield[3] (l/day)	Quality (mg/l TDS)	Use[4]	Pump[5] type	Remarks
306	W. French, Hagley	f	O*	9.8	2.7	>4500	460		E	
307	W. French, Hagley	gs	C*	5.8	2.4		200			
308	W. French, Hagley	f	F							
309	W. French, Hagley	f	F							
310	W. French, Hagley	gs	N*	5.5	3.1	2300	360		W	
311	French Bros, Hagley	sv	C*	4.0	0		290			
312	French Bros, Hagley	gs	F							
313	French Bros, Hagley	ht	F							
314	French Bros, Hagley	f	N			poor	polluted			
315	French Bros, Hagley	f	N			poor	polluted			
316	French Bros, Hagley	gs	N	6.1			polluted			
317	French Bros, Hagley	f	C							

Appendix 7 (continued)

	Owner and locality	Top.[1] pos.	Status[2]	Total depth (m)	Water level (m)	Yield[3] (l/day)	Quality (mg/l TDS)	Use[4]	Pump[5] type	Remarks
318	French Bros, Hagley									Dam built over well
319	Hagley,	ht	O	11.0	7.6		215		E	
319A	T. Woolnough, Hagley	sv		1.8			170			
319B	P.A. Windred, Hagley	ht	O*	11.3	4.6		350		P	
320	M.A. Scott, Westbury	f	C*	2.7	0.6		150			
321	A.O. Nichols, Westbury	f	C*	2.1	0.3		190			
322	A.O. Nichols, Westbury	gs	C	11.6	1.8		380			
323	R.G. Bratton, Westbury	ht	O*	18.3	14.6	1400	180		W	
324	R.G. Bratton, Westbury	v	O	2.1	2.0	450	450		H	
325	R.G. Bratton, Westbury	gs	O*	5.5	4.3	1400	150		W	
326	D. Scott, Hagley		F							
327	D. Scott, Hagley		F							

Appendix 7 (continued)

	Owner and locality	Top.[1] pos.	Status[2]	Total depth (m)	Water level (m)	Yield[3] (l/day)	Quality (mg/l TDS)	Use[4]	Pump[5] type	Remarks
328	D. Scott, Hagley		F							
329	D. Scott, Hagley		F							
330	D. Scott, Hagley		F							
331	D. Scott, Hagley		F							
332	D. Scott, Hagley		F							
333	D. Scott, Hagley		F							
334	L.E. Donovan & Son, Westbury	ht	N*	7.0	2.4	200	190		H	
335	L.E. Donovan & Son, Westbury	gs	O*	7.9	6.6	900	460	s	E	
336	L.E. Donovan & Son, Westbury	f	O*	3.9	1.5	2300	210		W	
337	L.E. Donovan & Son		F	4.9						
338	W.R. Scott, Westbury	sv	O*	3.7	1.8		200		E	
339	W.R. Scott, Westbury	f	O*	4.9	0.61	11 000	350		W	

Appendix 7 (continued)

	Owner and locality	Top.[1] pos.	Status[2]	Total depth (m)	Water level (m)	Yield[3] (*l*/day)	Quality (mg/*l* TDS)	Use[4]	Pump[5] type	Remarks
340	W.R. Scott, Westbury	gs	O*	6.7	1.8	900	50		W	Not used much
341	W.R. Scott, Westbury	ht	O*	7.3	2.4	450	60		W	
342	R. Lynch, Hagley	f	O*	7.3	0.9	9000	130		E	
343	R. Lynch, Hagley	f	O*	4.9	2.4	4500	320		W	
344	R. Lynch, Hagley	f	C*	3.4	1.4	3600	150			
345	J. Cresswell, Hagley		F		∿1.2					Water polluted
346	J. Cresswell, Hagley		F							
347	J. Cresswell, Hagley		F							
348	G.W. Pitt & Son, Westbury	f	O*	6.1	0.9	23 000–45 000	350		E	
349	G.W. Pitt & Son, Westbury	gs	O*	6.0	4.3	4500	95		E	
350	W. McGee, Westbury		F							Was good supply
351	Michelson, Westbury		A			no water				

Appendix 7 (continued)

	Owner and locality	Top.[1] pos.	Status[2]	Total depth (m)	Water level (m)	Yield[3] (l/day)	Quality (mg/l TDS)	Use[4]	Pump[5] type	Remarks
352	G.W. Pitt & Son Westbury		A			no water				
353	W. McGee, Westbury		F							
354	R.W.G. Hutton, Hagley	gs	O*	5.2	3.7	4500	200		E	
355	L.A. Williams, Hagley	sv	C*	7.0	2.4	360	180			
356	R. & J. Donovan & Son, Hagley		C	∿9.1		poor				To be filled in
357	R. & J. Donovan & Son, Hagley		F			very poor				
358	K.W. Allen, Hagley	gs	O*	7.5	2.7	9000	110	s,g	E	
359	Messrs Selby, Hagley	ht	O*	10.7	7.6	4500	100	d,s	E	
360	Badcock, Hagley			∿8.2		none in summer				
361	Greenhill, Westbury		C*	6.4	3.7		100	d,s		Not used
362	G. Hills, Selbourne	f	C*	2.9	1.8		115	s		
363	G. Eyles, Selbourne		F			poor				

Appendix 7 (continued)

	Owner and locality	Top.[1] pos.	Status[2]	Total depth (m)	Water level (m)	Yield[3] (l/day)	Quality (mg/l TDS)	Use[4]	Pump[5] type	Remarks
364	G. Eyles, Selbourne		F			poor				
365	E. Heazlewood, Selbourne		F	4.9						
366	E. Heazlewood, Selbourne	f	O*	3.0	1.2	4500	330	d,s	E	
367	Lindsay, Selbourne		S	5.5		poor in summer				
368	A. Eyles, Selbourne		F			poor				
369	A. Eyles, Selbourne		F							
370	V.A. French, Selbourne		F							
371	V.A. French, Selbourne		F							
372	C. Smith, Selbourne		F							
373	D.I. Viney, Westwood		F							
374	Kilby, Westwood		F							
375	Gibson, Westwood	f	C	7.6	3.0		240			

Appendix 7 (continued)

	Owner and locality	Top.[1] pos.	Status[2]	Total depth (m)	Water level (m)	Yield[3] (l/day)	Quality (mg/l TDS)	Use[4]	Pump[5] type	Remarks
376	B.L. Heazlewood & Sons, Westwood	gs	N	3.7	0.6		380			
377	B.L. Heazlewood & Sons, Westwood	gs	N	3.7	0.3				W	
378	D.I. Viney, Westwood	f	O	3.7	2.7	4500	1500	s	H	
379	J. Lyon, Westwood	gs	O	1.5	0.6	14 000-18 000	230	g	E	
380	G.W. Butler, Selbourne	s	F	∿7.3	2.7					
381	G.W. Butler, Selbourne	f	N*	5.5	4.4		500		W	
382	K. Hendley, Rosevale		S	1.8						
383	Cuthbertson, Rosevale	v	S				180			
384	D. Towns, Rosevale	gs		1.2	0		650			
385	Smith, Westwood	f	O	2.7	1.4	23 000	410	s	E	
386	Smith, Westwood	sv	F							
387	H.T. Johnston, Westwood		O	3.3	1.4	23 000-45 000	260	s,g,d	E	

Appendix 7 (continued)

	Owner and locality	Top.[1] pos.	Status[2]	Total depth (m)	Water level (m)	Yield[3] (l/day)	Quality (mg/l TDS)	Use[4]	Pump[5] type	Remarks
388	H.T. Johnston, Westwood		F							
389	Fletcher, Epping Forest	f	C	4.3		2300	good	g		Fish in well
390	K. Payne, Epping Forest	f	C	4.3		2300				
391	K. Payne, Epping Forest	f	F							
392	Reynolds, Cleveland	f								Dam built over well
393	Mrs Gibson, Conara	ht	O*	4.5	1.4	22 000-32 000	2250	s	W	
394	D. Gibson, Campbell Town	s	F							
395	D. Gibson, Campbell Town	f	O	4.0	1.8	2300-4500	930	s	W	
396	D. Gibson, Campbell Town	f	O*	3.7	1.8	2300-4500	1300	s	E	
397	D. Gibson, Campbell Town	v	O*	3.7	1.8	2300-4500	2000	s	W	
398	D. Gibson, Campbell Town		F							
399	D. Gibson, Campbell Town		F							

Appendix 7 (continued)

	Owner and locality	Top.[1] pos.	Status[2]	Total depth (m)	Water level (m)	Yield[3] (l/day)	Quality (mg/l TDS)	Use[4]	Pump[5] type	Remarks
400	A. McKinnon, Campbell Town	f	O	2.4	0.9		1650	s	E	
401	No well									
402	Mrs Gibson, Conara	v	O	12.2	4.9	900-1400	470	s	W	
403	R.R. Taylor, Epping Forest		F	7.6			salty			
404	Muirhead, Campbell Town		F	6.1			salty			
405	Foster, Rosedale	f	O	2.7	2.4	2300	1650	s	W	Not used for several years
406	A. Nicholson, Campbell Town	v	F							
407	J.M. Taylor, Campbell Town	ht	O	4.3			3300	s	H	127 mm auger hole
408	J.M. Taylor, Campbell Town	f	C*	9.1	2.3		520			Part collapsed
409	J.M. Taylor, Campbell Town	f	C*	$\sim$8.2	$\sim$2.1	45 000				Inaccessible
410	J.M. Taylor, Campbell Town		F	9.1						
411	J.M. Taylor, Campbell Town	ht	O**	7.0		54 000	2350	s	E	Inaccessible

Appendix 7 (continued)

	Owner and locality	Top.[1] pos.	Status[2]	Total depth (m)	Water level (m)	Yield[3] (*l*/day)	Quality (mg/*l* TDS)	Use[4]	Pump[5] type	Remarks
412	J.M. Taylor, Campbell Town	sv	F							
413	D. Taylor, Campbell Town	v	N*	3.4	0.6		6200		W	
414	J.M. Taylor, Campbell Town	sv		1.1	0.5	22 000	320	s		Hole dug on spring
415	J.M. Taylor, Campbell Town	v	O	3.4	2.4		300	s	W	
416	J.M. Taylor, Campbell Town	v	O**	3.6	1.8		1600	s	W	300 mm auger hole
417	J.M. Taylor, Campbell Town	f	O	3.7	2.4		2250	s	W	
418	J.M. Taylor, Campbell Town	f	O	5.2?	3.7?		1650	s	W	
419	J.M. Taylor, Campbell Town	v	O				1200			Inaccessible
420	J.M. Taylor, Campbell Town	f	O						W	Inaccessible
421	R. Gatenby, Cressy	s	F	6.1		poor				
422	R. Gatenby, Cressy	s	F			poor				
423	Casey, Delmont	f	N	10.7	0.6		2850			

Appendix 7 (continued)

	Owner and locality	Top.[1] pos.	Status[2]	Total depth (m)	Water level (m)	Yield[3] (l/day)	Quality (mg/l TDS)	Use[4]	Pump[5] type	Remarks
424	E.D. Mills, Cressy	v	C*	6.6	1.7		900			
425	E.D. Mills, Cressy		F							Position approximate
426	E.D. Mills, Cressy		F							Position approximate
427	Saddler, Campbell Town	sv	N	2.1	0		250			Creek running into well
428	Saddler, Campbell Town	f	O*	3.4	1.2	23 000	700	s,d	W	
429	Saddler, Campbell Town	gs	O*	10.1	5.8	2300	1100	s	W	
430	Saddler, Campbell Town	f	O*	3.7	1.4	9000	3300	s	W	
431	Saddler, Campbell Town	f	O*	5.5	2.4	450	3200	s	W	
432	Gibson, Campbell Town	ht	O	24.4			1000	s	W	Inaccessible
433	Gibson, Campbell Town	v	O	4.3	2.3		1000	s	W	

1. Topographic position; vf = valley flat, s = slope, gs = gentle slope, g = gully, v = valley, sv = shallow valley, f = flat, te = terrace edge, ht = hill top or small hill.

2. Status; O = operating, C = capped, N = not used, A = abandoned, F = filled in, S = collapsed.

3. Estimated yield only.

4. Use; d = domestic, s = stock, g = garden, f = dairy, t = toilet, n = not used

5. Pump type; W = windmill, E = electric, D = diesel motor, T = tractor driven, P = petrol motor, H = hand operated.

* = brick lined, ** = concrete pipe.

For location of wells see Figure 3.

† = chemical analysis available.

APPENDIX 8

Chemical analyses of water from wells

Item	Well number 2		3		6		8		9		10		11		12		13	
pH	7.8		7.0		7.6		6.6		7.0		6.6		6.9		7.0		7.0	
	mg/l	epm	mg/l	epm	mg/l	epm	mg/l	epm	mg/l	epm	mg/l	epm	mg/l	epm	mg/l	epm	mg/l	epm
CO_3	1.2	0.04	-	-	0.9	0.03	-	-	-	-	0.6	0.02	0.6	0.02	0.6	0.02	-	-
HCO_3	25.5	0.43	11	0.18	17	0.28	2.4	0.04	6.1	0.1	1.2	0.02	11	0.18	7.3	0.12	6.1	0.10
Cl	122	3.4	442	12.5	153	4.3	473	13.3	88	2.5	671	18.9	140	3.9	290*	8.2	37	1.0
SO_4	47	0.98	33	0.69	16	0.33	12	0.25	nil		13	0.27	trace		25	0.52	23	0.48
F	0.4		0.2		0.3		0.2		0.1		0.3		0.2		0.3		0.3	
SiO_2	34		47		36		25		18		26		23		13		19	
Ca	40	2.0	13	0.7	28	1.4	3	0.15	2	0.1	7	0.35	1	0.05	26	1.6	6	0.3
Mg	49	4.03	34	2.80	105	8.65	45	3.7	12	0.99	74	6.08	15	1.23	5	0.41	5	0.41
Fe					0.5				7		0.5		2				4	
Al	nil		nil		nil		nil		nil		nil		nil		nil		nil	
K	7	0.18	2.6	0.06	3	0.07	3.5	0.09	7	0.18	7	0.18	4	0.10	9	0.23	6	0.15
Na	70	3.04	50	2.2	75	3.3	230	10.0	55	2.4	365	15.9	105	4.6	22	0.9	24	1.0
TDS	728		602		548		1134		274		1368		292		258		242	
Total ions	330		633		398		566		305		1166		196		398		130	
Hardness	302		173		502		193		55		321		65		86		36	
- permanent	275		164		484		191		50		317		53		77		31	
- temporary	27		9		18		2		5		4		12		9		5	
Alkalinity	27		9		18		2		5		4		12		9		5	
Na%	54.3		40.4		25.1		72.4		63.7		71.3		77.2		36.0		55.6	
S.A.R.	2.2		1.7		1.5		7.2		3.3		8.9		5.8		0.9		1.7	
E.S.P.	2.0		1.2		0.9		8.6		3.5		10.6		6.8		0.07		1.2	
R.S.C.																		

* Cl 29.0?

Appendix 8 (continued)

Item	Well number																	
	14		15		16		17		18		19		20		22		24	
pH	7.0		7.1		7.5		6.9		7.5		7.1		7.5		6.7		6.1	
	mg/l	epm	mg/l	epm	mg/l	epm	mg/l	epm	mg/l	epm	mg/l	epm	mg/l	epm	mg/l	epm	mg/l	epm
CO_3	0.6	0.02	0.6	0.02	-	-	0.6	0.02	0.6	0.02			0.6	0.02			nil	
HCO_3	7.3	0.12	7.3	0.12	16	0.26	10	0.16	16	0.26	10	0.16	14.6	0.24	2.4	0.04	1.2	0.02
Cl	244*	6.9	214*	6	76	2.1	52	1.5	305	8.6	61	1.7	40	1.1	311	8.8	370	10.4
SO_4	trace		5	0.10	18	0.37	44	0.92	22	0.46	28	0.58	15	0.31	7	0.15	27	0.56
F	0.3		0.1		0.3		0.2		0.1		0.2		0.3		0.2		0.6	0.03
SiO_2	17		13		37		24		31		32		84		12		86	
Ca	3	0.5	24	1.2	9	0.5	19	0.9	28	1.4	14	0.7	6	0.3	21	1.04	4	0.2
Mg	10	0.82	4	0.39	13	1.07	27	2.22	90	7.4	16	1.32	16	1.32	39	3.21	16	1.3
Fe	5	0.03													1	0.04		
Al	nil		nil		nil		nil		nil		nil		nil		nil			
K	7	0.18	10	0.26	3	0.07	5	0.13	1	0.03	1	0.03	0.5	0.01	8	0.20	1	0.02
Na	22	0.9	8	0.3	120	5.2	50	2.2	160	7.0	35	1.5	50	2.2	120	5.2	214	9.3
TDS	234		193		422		446		894		326		326		414		830	
Total ions	316		286	8.39	622		232		654		197	5.99	227		501		728	
Hardness	49		76		75		158		440		101		81		212		76	
- permanent	40		67		62		147		425		93		63		210		75	
- temporary	9		9		13		11		16		8		15		2		1	
Alkalinity	9		9		13		11		16		8		15		2		1	
Na%	51.9		26.1		77.1		42.8		44.4		43.1		57.7		55.7		86.1	
S.A.R.	1.3		0.3		5.9		1.8		3.3		1.5		2.4		3.6		10.7	
E.S.P.	0.7		- 0.8		6.9		1.4		3.5		0.9		2.2		3.9		12.7	
R.S.C.																		

*Cl 24.4? *Cl 21.4?

Appendix 8 (continued)

Item	Well number																	
	25		26		27		28		31		33		34		35		36	
pH	6.0		7.0		7.4		6.4		5.7		6.3		6.6		6.3		6.0	
	mg/*l*	epm	mg/*l*	epm	mg/*l*	epm	mg/*l*	epm	mg/*l*	epm	mg/*l*	epm	mg/*l*	epm	mg/*l*	epm	mg/*l*	epm
CO_3	nil		nil		nil		nil		nil		nil		nil		nil		nil	
HCO_3	3.1		9.5	0.16	6.1		12	0.20	3.7	0.06	6.7	0.11	14.6	0.02	6.7	0.11	3.7	0.06
Cl	195	5.5	240	6.8	65	1.8	105	3.0	55	1.6	70	2.0	125	3.5	265	7.5	830	23.4
SO_4	77	1.60	103	2.15	3	0.06	7	0.15	3	0.06	34	0.71	9	0.19	21	0.44	1	0.02
F	nil		1.6	0.08	0.1		0.4	0.02	0.1		0.9	0.03	nil		nil		0.9	0.03
SiO_2	30		12		15		11		17		13		43		50		25	
Ca	15	0.7	84	4.2	8	0.4	14	0.7	6	0.3	10	0.5	40	2.0	19	1.0	35	1.9
Mg	20	1.6	76	6.2	12	1.0	18	1.5	5	0.4	14	1.1	50	4.1	22	1.8	52	4.3
Fe	-		-		-		-		-		-		-		-		trace	
Al	-		-		-		-		-		-		-		-		-	
K	8	0.2	60	1.50	2	0.05	8	0.16	2	0.04	9	0.2	2	0.05	6	0.13	3	0.07
Na	110	4.8	140	6.1	92	4.0	80	3.5	15	0.6	37	1.6	34	1.5	120	5.2	440	19.1
TDS	500		1440		190		405		145		250		380		565		1480	
Total ions	468		726		204		255		107		195		317		510		1394	
Hardness	118		523		70		109		35		83		306		137		309	
- permanent	115.5																	
- temporary	2.5																	
Alkalinity	2.5		7.5		5.0		10.0		3.0		5.5		12.0		5.5		3.0	
Na%	68.5		42.2		74.3		62.6		47.8		52.5		20.3		65.6		75.6	
S.A.R.	4.8		2.7		4.8		3.3		1.0		1.8		0.9		4.4		10.9	
E.S.P.	5.5		2.7		5.5		3.5		0.2		1.4		0.07		5.0		12.9	
R.S.C.																		

Appendix 8 (continued)

Item	Well number																	
	37		38		39		40		41		42		44		45		46	
pH	6.6		7.2		5.6		4.6		5.2		6.4		6.6		6.9		6.6	
	mg/l	epm	mg/l	epm	mg/l	epm	mg/l	epm	mg/l	epm	mg/l	epm	mg/l	epm	mg/l	epm	mg/l	epm
CO_3	nil		nil		nil		nil		nil		nil		nil		nil		nil	
HCO_3	4.9	0.07	15.9	0.02	1.2		1.8	0.03	1.8	0.03	1.2	<0.02	1.2	0.02	2.4		4.3	0.07
Cl	370	10.4	160	4.5	160	4.5	810	22.8	210	5.9	915	25.8	210	5.9	440	12.4	810	22.8
SO_4	100	2.08	2	0.04	11	0.23	18	0.37	1	0.02	2	0.04	58	1.21	15	0.31	-	
F	nil		nil		0.1		0.4	0.02	0.2	0.01	0.2	0.01	nil		nil		nil	
SiO_2	36		9		27		26		27		15		26		14		10	
Ca	52	2.6	42	2.1	3	0.1	16	0.8	2	0.1	20	1.0	6	0.3	18	0.9	24	1.2
Mg	30	2.5	34	2.8	13	1.1	70	5.8	12	1.0	102	8.4	24	2.0	48	4.0	82	6.7
Fe	-		-		-		-		-		-		-		trace		-	
Al	-		-		-		-		-		-		-		-		-	
K	2	0.05	25	0.64	2	0.05	5	0.10	1	0.02	9	0.20	3	0.07	8	0.20	14	0.30
Na	174	7.6	52	2.3	98	4.3	350	15.2	118	5.1	360	15.7	116	5.1	164	7.1	360	15.7
TDS	700		555		395		1485		440		1400		465		755		1390	
Total ions	769		340		315		1287		373		1424		444		709		1304	
Hardness	247?		245		60		328		54		470		114		242		397	
- permanent																		
- temporary																		
Alkalinity	4.0		13.0		1.0		1.5		1.5		1.0		1.0		2.0		3.5	
Na%	60.0		1.5		80.0		70.0		82.2		62.9		69.2		59.8		67.0	
S.A.R.	4.8		0.9		5.6		8.4		6.9		7.2		4.8		4.5		7.9	
E.S.P.	5.5		37.5		6.5		10.0		8.2		8.6		5.5		5.1		9.4	
R.S.C.																		

Appendix 8 (continued)

Item	Well number																	
	47		48		49		50		51		52		53		54		55	
pH	5.5		4.1		6.7		6.6		5.9		7.0		6.5		6.3		4.2	
	mg/*l*	epm	mg/*l*	epm	mg/*l*	epm	mg/*l*	epm	mg/*l*	epm	mg/*l*	epm	mg/*l*	epm	mg/*l*	epm	mg/*l*	epm
CO_3	nil		nil		nil		nil		nil		nil		nil		nil		nil	
HCO_3	0.6		1.2	0.02	1.8	0.03	2.4		1.2	0.02	1.8	0.02	1.8	0.02	1.2	0.02	nil	
Cl	275	7.8	370	10.4	125	3.5	140	3.9	1720	48.5	775	21.9	510	14.4	160	4.5	420	11.8
SO_4	7	0.15	6	0.06	2	0.04	3	0.06	17	0.35	7	0.15	28	0.58	6	0.12	5	0.10
F	nil		0.3	0.02	0.5	0.02	nil		0.4	0.02	0.5	0.02	0.02		0.1		nil	
SiO_2	62		35		40		40		25		30		29		50		66	
Ca	2	0.1	7	0.3	4	0.2	22	1.1	28	1.4	26	1.3	15	0.9	10	0.5	3	0.1
Mg	20	1.6	26	2.1	12	1.0	36	3.0	178	14.6	78	6.4	42	3.5	14	1.1	42	3.5
Fe	1		-		10	0.5	-		trace				-		-		-	
Al	-		-		-		-		-		-		-		-		-	
K	1	0.02	5	0.10	4	0.08	1	0.01	10	0.25	5	0.10	8	0.20	4	0.10	2	0.05
Na	166	7.2	170	7.4	62	2.7	100	4.5	680	29.6	340	14.8	220	9.6	100	4.5	196	8.5
TDS	670		680		365		680		2575		1400		990		515		895	
Total ions	535		620		261		354		2659		1263		854		345		734	
Hardness	87		124		59		203		802		386		211		82		253	
- permanent																		
- temporary																		
Alkalinity	0.5		1.0		1.5		2.0		1.0		1.5		1.5		1.0		nil	
Na%	80.9		75.8		62.1		52.4		65.1		65.9		70.0		74.2		70.4	
S.A.R.	7.8		6.8		3.5		3.1		10.5		7.5		6.6		5.0		6.3	
E.S.P.	9.3		8.1		3.8		3.2		12.5		8.9		7.8		5.7		7.4	
R.S.C.																		

Appendix 8 (continued)

Item	Well number																	
	57		58		59		60		62		64		65		66		67	
pH	6.5		6.5		6.4		6.2		6.4		4.2		7.9		5.2		7.0	
	mg/l	epm	mg/l	epm	mg/l	epm	mg/l	epm	mg/l	epm	mg/l	epm	mg/l	epm	mg/l	epm	mg/l	epm
CO_3	nil		nil		nil		nil		nil		nil		nil		nil		nil	
HCO_3	3.7		1.2		3.7	0.06	1.2	0.02	1.8	0.02	1.2	0.02	18.3	0.3	1.2	0.02	3.7	<0.01
Cl	105	3.0	175	4.9	125	3.5	320	9.0	70	2.0	970	27.4	320	9.0	210	5.9	365	15.9
SO_4	8	0.17	nil		17	0.35	6	0.12	4	0.08	76	1.60	44	0.92	27	0.56	11	0.23
F	0.4		nil		nil		nil		0.2	0.01	0.5	0.02	0.6	0.03	0.3	0.02	nil	
SiO_2	19		44		19		17		12		50		15		35		26	
Ca	9	0.5	5	0.2	7	0.3	10	0.5	2	0.1	15	0.7	14	0.7	7	0.03	34	1.7
Mg	22	1.8	15	1.2	12	1.0	20	1.6	5	0.4	100	8.2	20	1.6	20	1.6	66	5.4
Fe	-		-		-		-		3		trace		-		-		-	
Al	-		-		-		-		-		-		-		-		-	
K	13	0.33	2	0.05	9	0.22	4	0.10	2	0.04	1	0.02	52	1.33	3	0.06	14	0.30
Na	56	2.4	100	4.3	72	3.1	150	6.5	26	1.1	416	18.1	230	10.0	108	4.7	206	8.9
TDS	310		380		350		600		170		1840		870		540		900	
Total ions	234		342		265		528		126		1629		714		412		926	
Hardness	127?		73		66		77		25		449		158		100		357	
- permanent																		
- temporary																		
Alkalinity	3.0		1.0		3.0		1.0		1.5		1.0		15.0		1.0		3.0	
Na%	54.3		75.7		71.9		75.9		69.5		67.1		83.1		74.5		56.4	
S.A.R.	2.2		5.1		3.9		6.3		2.2		8.9		9.3		5.2		4.7	
E.S.P.	2.0		5.9		4.3		7.4		1.9		10.6		11.1		6.0		5.4	
R.S.C.																		

Appendix 8 (continued)

Item	Well number															
	68		69		70		72		76		92		103		126	
pH	6.2		6.0		6.3		6.2		5.8		5.7		7.2		6.8	
	mg/*l*	epm	mg/*l*	epm	mg/*l*	epm	mg/*l*	epm	mg/*l*	epm	mg/*l*	epm	mg/*l*	epm	mg/*l*	epm
CO_3	nil		nil		nil		nil									
HCO_3	1.2		4.3	0.07	2.4	0.04	7.9	0.13	9	0.15	27	0.44	170	2.79	60	0.98
Cl	230	6.5	70	2.0	10	0.3	70	2.0	91	2.57	1270	35.82	236	6.65	253	7.14
SO_4	3	0.06	24	0.5	4	0.08	5	0.10	3	0.06	90	1.87	5	0.10	28	0.58
F	0.2		0.9	0.03	0.1		0.2	0.01								
SiO_2	60		12		2		22		31		34		46		14	
Ca	2	0.1	6	0.3	6	0.3	4	0.2	3	0.15	25	1.25	41	2.05	21	1.05
Mg	13	1.1	6	0.5	1	0.08	14	1.1	22	1.81	95	7.81	65	5.34	29	2.38
Fe	trace		trace		-		200*		trace		trace		trace		trace	
Al	-		-		-		-		-		-		-		-	
K	1	0.02	3	0.06	1	0.02	7	0.14	1	0.03	5	0.15	4	0.13	30	0.76
Na	130	5.7	68	2.9	5	0.2	60	2.6	80	3.48	620	220	44	1.91	90	3.92
TDS	430		260		100		1220		315		2265		740		615	
Total ions	440		194		31		390		240		2166		611		525	
Hardness	57		40		19		68		99							
- permanent									92		3950		230		123	
- temporary									7		22		140		49	
Alkalinity	1.0		3.5		2.0		6.5		7		22		140		49	
Na%	82.7		78.7		36.7		67.8		64.2		75.0		21.6		57.7	
S.A.R.	7.4		4.6		0.5		3.2		3.5		12.7		1.0		3.0	
E.S.P.	8.8		5.2		- 0.5		3.3		3.7		14.9		0.2		3.1	
R.S.C.																

*colloidal suspension present

APPENDIX 9

Chemical analyses of groundwater from investigation holes

Item	Hole number																	
	3		4		5		6		7		8		9		10		11	
pH	8.1		6.8		5.3		6.4		6.6				7.8		6.8		6.2	
	mg/l	epm	mg/l	epm	mg/l	epm	mg/l	epm	mg/l	epm	mg/l	epm	mg/l	epm	mg/l	epm	mg/l	epm
CO_3													1	0.01	173	5.8		
HCO_3			126	2.06	10	1.6	2.5	0.04	10	0.16			18	0.29	nil	nil	2	0.03
Cl	586	16.53	1280	36.10	1037	29.25	3000	84	475	13.4	528	14.9	366	10.3	301	8.5	2430	68.5
SO_4	25	0.52	85	1.77	62	1.29	241	4.8	5	0.1	11	0.2	14	0.29	10	0.21	175	3.6
F			0.1		0.2	0.01	0.4		0.5		nil		trace		0.25	0.01		
SiO_2	53		21.2		52		350		40		23		14		52		12	
Ca	80	3.99	142	7.09	15	0.75	120	6.0	82	4.1	62	3.1	48	2.4	53	2.7	100	5.0
Mg	75	6.17	158	13.0	76	6.25	312	25.7	58	48	52	4.3	42	3.4	36.5	3.0	244	20.1
Fe	nil		1		15		1.0		trace		-		trace		0.05		trace	
Al	nil		nil		nil		nil				-		nil		nil		nil	
K	15	0.38	8	0.2	2	0.03	6	0.15	11	0.3	8	0.2	8	0.21	6.4	0.16	4	0.01
Na	275	11.96	640	27.8	620	27	840	36.5	145	6.3	408	17.8	160	6.9	174	7.57	1020	44.4
TDS	1440		2765		2274		4582		858		934		920		836		3800	
Total ions					1889								657		806		3987	
Hardness	509		1004		440		1583		444		369				282			
- permanent	315		901		432		1580		434		358		276				1253	
- temporary	194		103		8		3		10		9		17				1	
Alkalinity	194		103		8		3		10		9		17		227		1	
Na%	54.8		58.2		79.4		54.3		42.6		70.9		55.1		57.6		63.9	
S.A.R.	5.3		8.6		14.4		9.2		3.0		9.3		4		4.5		12.5	
E.S.P.	6.2		10.3		16.7		11.0		3.1		11.1		4.4		5.1		14.7	
R.S.C.	nil		nil		nil													

Appendix 9 (continued)

Item	Hole number																	
	12		13		15		16		17		18		19		20		21	
pH	7.8		8.0		6.8		8.0		6.2		6.8		6.0		4.4*		7.2	
	mg/l	epm	mg/l	epm	mg/l	epm	mg/l	epm	mg/l	epm	mg/l	epm	mg/l	epm	mg/l	epm	mg/l	epm
CO_3	1	0.01	nil		-													
HCO_3	11	0.18	14	0.02	206	3.5	161	2.6	77	1.3	103	1.7	72	1.2	nil		148	2.43
Cl	460	13.0	665	18.8	211	6.0	295	8.3	197	5.6	490	13.9	105	3.0	106	3.0	141	3.98
SO_4	3	0.06	20	0.4	28	0.6			8	0.16	3	0.06	11	0.23	9	0.19	5	0.10
F			0.8										trace					
SiO_2	11		17		8		5		15		2		13		5.5		9	
Ca	73	3.6	76	3.8	13	0.7	45	2.2	19	0.9	62	3.1	6	0.3	2	0.1	28	1.4
Mg	50	4.1	84	6.9	15	1.2	32	2.6	20	1.6	59	4.6	5	0.4	5	0.4	24	1.97
Fe	trace		-		trace		trace		nil		nil		trace		0.1		0.2	
Al																		
K	10	0.26	22	0.5	14	0.4	8	0.2	5	0.1	14	0.4	3	0.07	2	0.05	6	0.15
Na	158	6.87	210	9.3	175	7.6	125	5.4	90	3.9	155	6.7	78	3.4	34	1.48	105	4.57
TDS	857		1665		574		716		410		1090		341		150		409	
Total ions	777		1110		670		673		431		888		293					
Hardness			536		94		244		130		343		95		211		168	
- permanent	377						83		34		215		36		211		47	
- temporary	11				94		161		79		105		59		0		121	
Alkalinity	11		12.5		169		161		79		105		59		0		121	
Na%	48.4		47.8		80.8		53.8		61.5		48.0		83.2		75.4		58.4	
S.A.R.	3.5		4		7.8		3.5		3.5		3.4		5.8		3		3.5	
E.S.P.	3.8		4.4		9.3		3.8		3.8		3.6		6.8		3.1		3.8	
R.S.C.													0.5					

*HCl bottle, not washed out?

Appendix 9 (continued)

Item	Hole number																	
	22		23		23A		24		25		26		27		28		29	
pH	6.0		6.0		6.0		5.3		7.5		8.0		7.3		6.8		7.8	
	mg/l	epm	mg/l	epm	mg/l	epm	mg/l	epm	mg/l	epm	mg/l	epm	mg/l	epm	mg/l	epm	mg/l	epm
CO_3	nil		nil		nil		nil		nil		6	0.18	nil		nil		11	0.6
HCO_3	29	0.47	57	0.94	46	0.75	5	0.1	38	0.62	161	2.6	238	3.9	7.9	1.3	199	3.26
Cl	376	10.6	1620	45.5	1760	49.5	1070	30.2	338	9.53	123	3.47	88	2.48	92	2.6	246	6.94
SO_4	39	0.81	34	0.71	27	0.56	77	1.6	46	0.92	10	0.2	3	0.07	4	0.08	nil	
F	nil		nil		2.5	0.12												
SiO_2	31		10		11		12		1		38		13		10		12	
Ca	8	0.4	215	10.7	215	10.7	56	2.8	34	1.7	15	0.7	12	0.6	9	0.45	46	2.3
Mg	26	2.1	204	16.8	220	18.1	135	11.1	45	3.7	45	3.7	29	2.4	20	1.64	42	3.5
Fe	nil		nil		trace		15		trace		trace		trace		trace		trace	
Al	nil		nil		nil		nil		nil		nil		nil		nil		nil	
K	4	0.01	27	0.69	27	0.69	12	0.3	18	0.5	4	0.1	16	0.4	7	0.15	17	0.43
Na	218	9.5	704	30.6	726	31.6	440	19.1	148	6.4	59	2.6	92	4.0	62	2.7	136	5.9
TDS	705		2815		3000		2040		763		501		376		199		680	
Total ions									668		461		491					
Hardness	127		1376		1541		695		270		222		149				288	
- permanent	103		1330		1503		690		239		74		149		31		107	
- temporary	24		46		38		5		31		148		nil		65		181	
Alkalinity	24		46				5		31		148		174		65		181	
Na%	79.2		53.3		52.8		58.3		56.1		38.0		59.5		57.7		52.1	
S.A.R.	8.5		8.3		8.3		7.3		3.9		1.8		3.3		2.6		3.5	
E.S.P.	10.1		9.9		9.9		8.7		4.3		1.4		3.5		2.5		3.8	
R.S.C.													0.9					

Appendix 9 (continued)

Item	Hole number																	
	30		31		32		33		34		36		37		38		39	
pH	8.0		7.8		7.9		8		6.2		8.4		8.4		7.8		8.4	
	mg/l	epm	mg/l	epm	mg/l	epm	mg/l	epm	mg/l	epm	mg/l	epm	mg/l	epm	mg/l	epm	mg/l	epm
CO_3	22	0.73	nil		nil		nil		nil		4	0.13	4	0.13			2.5	0.083
HCO_3	406	6.66	125	2.05	205	3.26	89	1.46	63	1.03	150	2.46	220	3.61	115	1.88	87	1.43
Cl	70	1.97	239	6.74	109	3.07	21	0.59	392	11.05	1300	36.67	350	9.87	205	5.78	305	8.60
SO_4	3	0.07	77	1.60	2.5	0.05	2.5	0.05	nil		65	1.35	63	1.31	17	0.35	16	0.33
F									nil		trace		0.2					
SiO_2	26		9		44		43		14		9		30		28		18	
Ca	29	1.49	29	1.45	29	1.45	12	0.60	28	1.3	240	11.98	39	1.95	30	1.50	38	1.90
Mg	56	4.60	30	2.50	44	3.60	14	1.15	46	3.78	140	11.52	53	4.36	22	1.81	33	2.71
Fe	trace		trace		trace		trace		trace		nil		nil		trace		trace	
Al	nil		nil		nil		nil		nil		nil		nil		nil		nil	
K	8	0.2	6	0.16	5	0.12	1	0.03	11	0.28	23	0.59	1.2	0.03	5	0.12	8	0.20
Na	106	4.6	178	7.70	50	2.20	24	1.04	170	7.40	410	17.84	190	8.27	106	4.61	126	5.48
TDS	518		643		470		208		770		2500		900		535		730	
Total ions	736						163+ SiO_2		722		2330		920					
Hardness	355										1140		320		175		230	
- permanent	nil		93		85		15		223		1010		130		71		151	
- temporary	355		102		168		73		32		130		190		94		79	
Alkalinity	355		102		168		73		32		130		190		94		79	
Na%	44.2		66.6		31.5		38.0		60.2		44.0		56.8		58.8		55.2	
S.A.R.	2.7		5.5		1.4		1.1		4.6		5.2		4.7		3.6		3.6	
E.S.P.	2.7		6.4		0.8		0.4		5.2		6.0		5.4		3.6		3.9	
R.S.C.	1.34																	

Appendix 9 (continued)

Item	Hole number																	
	40		42		43		44		45		46		48		49		50	
pH	7.6		7.6		7.2		8.3		8.3		5.1		9.5		8.5		8.8	
	mg/*l*	epm	mg/*l*	epm	mg/*l*	epm	mg/*l*	epm	mg/*l*	epm	mg/*l*	epm	mg/*l*	epm	mg/*l*	epm	mg/*l*	epm
CO_3	nil		nil		nil				81.5	2.72								
HCO_3	118	1.93	412	6.75	231	3.79	91	1.49	91	1.49	348	5.70	23.2	0.38	273	4.47	331	5.43
Cl	2715	76.59	353	9.96	371	10.47	1100	31.03	460	12.98	1610	45.42	3880	109.46	1880	53.04	860	24.26
SO_4	97	2.02	7	0.15	5	0.10	135	2.81	7	0.15	114	2.37	115	2.39	77	1.6	3	0.06
F																		
SiO_2	10		18		17		11		15		21		80		30		6	
Ca	220	10.98	60	2.99	60	2.99	215	10.73	19	0.95	125	6.24	125	6.24	272	13.57	130	6.49
Mg	324	26.65	50	4.11	50	4.11	125	10.28	45	3.70	232	19.08	*	2.06	448	36.85	94	7.73
Fe	0.1		0.2		0.4		0.3		0.8				25		0.2		0.3	
Al			nil		nil		0.4		1.5		0.2		9.5		0.2		0.2	
K	7	0.18	12	0.31	12	0.31	11	0.28	8.5	0.22	15	0.38	9	0.23	11	0.28	13	0.33
Na	1190	51.77	174	7.57	164	7.13	372	16.18	304	13.22	728	31.67	1585	68.95	212	9.22	212	19.14
TDS	4940		1000		1010		2150		1030		3390		7340		3640		1950	
Total ions																		
Hardness	1879		360		360		1052		232		1267		2485		2576		714	
- permanent	1782		22		171		977		22		982		2466		2352		443	
- temporary	97		338		189		75		210		285		19		224		271	
Alkalinity	96.5		338		189		75		210		285		19		224		271	
Na%	58.0		49.2		51.2		44.0		74.3		55.9		88.8		15.9		58.8	
S.A.R.	11.9		4.0		3.8		5.0		8.7		8.9		33.9		1.8		7.2	
E.S.P.	14.0		4.4		4.2		5.8		10.4		10.6		32.8		1.4		8.6	
R.S.C.																		

* No Mg reported in analysis. Possibly 25 mg/*l* Mg and 9.5 mg/*l* Fe

Appendix 9 (continued)

Item	Hole number																	
	51		53		54		56		57		58		59		60		61	
pH	7.0		6.7		7.4		7.1		8.0		8.0		6.2		6.9		7.1	
	mg/l	epm	mg/l	epm	mg/l	epm	mg/l	epm	mg/l	epm	mg/l	epm	mg/l	epm	mg/l	epm	mg/l	epm
CO_3	nil				nil		nil				nil				nil			
HCO_3	190	3.11	130	2.13	140	2.30	220		11	0.02	11	0.02	18	0.29	582	9.5	189	3.1
Cl	804	22.68	1600	45.14	36	1.02	590		1740	49.1	790	22.3	176	4.98	2430	68.5	423	12.0
SO_4	61	1.27	150	3.12	3	0.06	nil		33	0.71	40	0.81	31	0.64	122	2.5	41	0.85
F									0.2	0.01	0.5	0.2			nil			
SiO_2	10		38		28		20		34		38		31.6		52		12.5	
Ca	146	7.29	78	3.89	8	0.40	92	4.59	45	2.1	11	0.55	trace		165	8.2	50	2.49
Mg	52	4.28	200	16.45	17	1.40	70	5.76	190	15.6	96	7.9	0.8	0.07	385	31.7	60	4.93
Fe	0.4		nil		trace		trace		nil		-		4		nil		0.1	
Al	nil		N.D.								-		116†		nil			
K	13	0.33	10	0.26	2	0.05	19	0.49	15	0.3	14	0.3	4	0.1	8	0.2	8	0.2
Na	400	17.40	760	33.06	30	1.31	14	6.09	740	32.4	380	16.2	143	6.22	915	31.7	250	10.9
TDS	1760		3340		180		1200		3485		1830		1815		5120		1077	
Total ions							1150		2810		1380							
Hardness	578		1020		88		518		894		422		3.3				372	
- permanent	422		910				406								1690		217	
- temporary	156		110				112						15		480		155	
Alkalinity	156		110		117		112		8		11.5		15				155	
Na%	60.5		62.1		43.1		38.9		64.9		66.2		98.9		44.5		60.0	
S.A.R.	7.2		10.4		1.4		2.7		10.9		7.9		33.2		7.1		5.7	
E.S.P.	8.6		12.3		0.8		2.7		12.9		9.4		32.3		8.4		6.7	
R.S.C.					0.5								0.22					

† Suspension infilterable, giving high Al and Fe and apparently high TDS

Appendix 9 (continued)

Item	Hole number														Proline holes			
	62		63		64		65		66		68		69		PH29		PH31	
pH	7.8		6.7		5.2		3.8		6.1		8.6		8.4		4.3		4.2	
	mg/*l*	epm	mg/*l*	epm	mg/*l*	epm	mg/*l*	epm	mg/*l*	epm	mg/*l*	epm	mg/*l*	epm	mg/*l*	epm	mg/*l*	epm
CO_3	nil		nil		nil		nil		nil		7	0.23	8	0.27				
HCO_3	12.4	0.2	18	0.3	43	0.7	nil		32	0.52	590	9.67	250	4.09				
Cl	352	9.9	317	8.9	3200	90.2	1990	56.14	1450	40.9	2080	58.68	1460	41.19	5855	165.2	3855	108.8
SO_4	13	0.3	37	0.8	186	3.9	20	0.42	4	0.08	210	4.37	56	1.17	716	14.9	29	0.6
F							0.7		0.1		0.2		trace					
SiO_2	28		18		19		58		29		49		31					
Ca	23	1.15	23	1.15	260	13	84	4.19	108	5.39	130	6.49	190	9.48	190	9.48	260	12.97
Mg	32	2.6	22	1.8	294	24.2	202	16.61	170	13.98	230	18.92	200	16.45	820	67.45	1000	82.26
Fe	trace		trace		14	0.75	19		0.7		nil		nil		1		20	
Al	nil		nil		nil		10		nil		nil		nil		nil		nil	
K	8	0.2	9	0.2	12	0.3	15	0.38	7.2	0.18	12	0.31	5	0.13	22	0.56	28	0.72
Na	192	8.3	124	5.4	1210	57.8	960	41.76	620	26.97	1110	48.29	480	20.88	3450	150.06	2040	88.47
TDS	725		580		5645		3560		2465		4370		3030		13820		11730	
Total ions	772		568		5595		3359		2421				2650					
Hardness	189		148		1860						1260		1300		3449		4764	
- permanent	87		133		1825		1040		954		760		1080		3443		4758	
- temporary	102		15		35		nil		16		500		220		6		6	
Alkalinity	102		15		35		acidic		16		500		220		6		6	
Na%	69.4		64.5		58.1		67.0		58.4		57.9		44.8		66.3		48.4	
S.A.R.	6.1		4.5		12.2		13		8.7		13.6		5.8		24.2		12.8	
E.S.P.	7.2		5.1		14.3		15.2		10.4		15.8		6.8		25.6		15.0	
R.S.C.																		

APPENDIX 10

Chemical analyses of groundwater from contract holes

Item	Hole number																	
	1		3		11		12		13		16		17		24		26	
pH	6.7		7.4		6.4		6.4		6.5		6.8		5.6		8.2		7.2	
	mg/*l*	epm	mg/*l*	epm	mg/*l*	epm	mg/*l*	epm	mg/*l*	epm	mg/*l*	epm	mg/*l*	epm	mg/*l*	epm	mg/*l*	epm
CO_3			0.6	0.02	nil				nil		nil		nil		trace			
HCO_3	24	0.4	17	0.28	15.9	0.26	8.5	0.14	9.8	0.16	11	0.18	1.8	<0.01	112	1.84	97	1.59
Cl	488	13.8	125	3.5	440	12.4	230	6.5	210	5.9	985	27.8	1565	44.1	340	9.59	46	1.30
SO_4	8	0.17	30	0.62			21	0.44	25	0.5	3	0.06	3	0.06	1	0.02	1	0.02
F	nil		0.2		0.2		nil		nil		0.1		1.4	0.07				
SiO_2	15		81		11		40		25		2		53		27		19	
Ca	39	1.95	12	0.6	26	1.3	20	1.0	26	1.3	20	1.0	90	4.5	43	2.15	9	0.5
Mg	85	6.99	32	2.63	36	3.0	22	1.8	24	2.0	102	8.4	220	18.1	25	2.06	15	1.23
Fe	10		0.5										trace		trace		trace	
Al	nil		nil															
K	8	0.20	2	0.06	9	0.2	7	0.15	8	0.20	26	0.66	7	0.15	18	0.46	2	0.06
Na	185	8.0	63	2.7	236	10.3	110	4.8	120	5.2	424	18.4	510	23.2	140	6.09	17	0.74
TDS	1232		560		900		480		545		1810		2755		715		250	
Total ions	840		363		774		439		448		1573		2451		706		206	
Hardness	447		162		214		140		164		47		1130					
- permanent	445		145												118		nil	
- temporary	2		17												92		80	
Alkalinity	2		17		13		7		8		9		1.5		92		80	
Na%	46.9		68.7		71.0		63.9		62.1		67.0		50.8		60.9		38.5	
S.A.R.	3.8		2.1		7.0		4.1		4.1		8.5		6.9		4.2		0.8	
E.S.P.	4.2		1.8		8.3		4.6		4.6		10.2		8.2		4.7		- 0.08	
R.S.C.																		

Appendix 10 (continued)

Item	Hole number																	
	35		36		38		39		41		45		46		50		51	
pH	7.1		7.3				6.9		7.6		7.9		7.9		7.9		6.9	
	mg/*l*	epm	mg/*l*	epm	mg/*l*	epm	mg/*l*	epm	mg/*l*	epm	mg/*l*	epm	mg/*l*	epm	mg/*l*	epm	mg/*l*	epm
CO_3	nil		nil		77.57		nil		nil		nil		nil		nil		nil	
HCO_3	396	6.49	443	7.26			223	3.65	331	5.43	547	8.97	687	11.26	380	6.23	356	5.83
Cl	1210	24.13	1150	32.44	391.52		789	22.51	928	26.18	557	15.71	3600	101.56	353	9.96	631	17.8
SO_4	nil		133	2.77	20.53		35	0.73	35	0.73	17	0.35	133		9	0.19	38	0.79
F																		
SiO_2	17		42		67.88		82		36		53		71		33		30	
Ca	85	4.24	65	3.24	18.42		80	3.99	110	5.49	80	3.99	440	21.96	70	3.49	65	3.24
Mg	180	14.81	95	7.81	30.23		140	11.52	120	9.87	50	4.11	540	44.42	65	5.35	40	3.29
Fe	41		0.3		)9.98		0.3		0.4		0.7		0.4		0.4		0.8	
Al					)		nil		nil		nil		nil		nil		nil	
K	12	0.31	16	0.41			8	0.20	2	0.05	3.5	0.09	15		2	0.05	15	0.38
Na	515	22.4	785	34.15	229.3		275	11.96	460	20.01	420	18.27	1290	56.12	190	8.27	405	17.62
TDS	2795		2370		884.12		1480		1985		1230		6990		1035		1480	
Total ions													6776					
Hardness																		
- permanent	416		28				593		498		nil		2800		129		35	
- temporary	325		363				183		271		448		563		311		292	
Alkalinity	325		363				183		271		448		563		311		292	
Na%	54.3		75.8				43.9		56.6		69.4		46.0		48.5		73.4	
S.A.R.	7.3		14.5				4.3		7.2		9.1		9.7		3.9		9.8	
E.S.P.	8.7		16.8				4.8		8.6		10.8		11.5		4.3		11.7	
R.S.C.											0.87							

Appendix 10 (continued)

Item	Hole number																	
	54		55		56		57		58		59		60		61		62	
pH			7.3		8.0		7.2		7.7		7.3		7.4		7.2		7.0	
	mg/*l*	epm	mg/*l*	epm	mg/*l*	epm	mg/*l*	epm	mg/*l*	epm	mg/*l*	epm	mg/*l*	epm	mg/*l*	epm	mg/*l*	epm
CO_3	104.6	3.49	nil				nil		nil		nil		nil		nil		nil	
HCO_3			252	4.13	430	7.05	210	3.44	240	3.93	660	10.80	83	1.36	170	2.79	170	2.79
Cl	450	12.69	482	13.60	800	22.57	58	1.64	135	3.81	430	12.13	25	0.71	48	1.35	190	5.36
SO_4	21.4	0.45	29	0.60	42	0.87	<5	<0.10	<5	<0.10	<5	<0.10	<5	<0.10	<5	<0.10	17	0.35
F																		
SiO_2	28		47		50		32		25		18		2		32		19	
Ca	57.2	2.85	18	0.90	79	3.94	26	1.30	43	2.15	84	4.19	10	0.50	20	1.00	41	2.05
Mg	42.2	3.47	75	6.17	160	13.16	29	2.39	48	3.95	170	13.98	8	0.66	17	1.40	28	2.30
Fe	4.0		0.3		0.4		<0.1		<0.1		<0.1		<0.1		<0.1		<0.1	
Al			nil		<0.2		<0.2		0.3		<0.2		0.3		<0.2		<0.2	
K			5	0.13	13	0.33	1.4	0.04	3	0.08	8	0.21	2	0.05	1.3	0.03	2.3	0.06
Na	237	10.31	250	10.88	320	13.92	30	1.31	32	1.39	120	5.22	20	0.87	34	1.48	86	3.74
TDS	1011		1805		1980		290		490		1440		120		260		580	
Total ions																		
Hardness																		
- permanent			102		510		14		100		370		nil		nil		78	
- temporary			207		350		170		200		540		58		120		140	
Alkalinity			207		350		170		200		540		68 ?		140 ?		140	
Na%	62.0		60.9		45.5		26.8		19.5		23.0		44.2		38.7		46.6	
S.A.R.	7.8		5.8		4.8		1.0		0.8		1.7		1.1		1.4		2.5	
E.S.P.	9.3		6.8		5.5		0.2		- 0.8		1.2		0.2		0.8		2.4	
R.S.C.													0.2		0.39			

Appendix 10 (continued)

Item	Hole number											
	63		65		68		73		80		82	
pH	6.8		7.2		7.1		7.1		7.6		7.1	
	mg/l	epm	mg/l	epm	mg/l	epm	mg/l	epm	mg/l	epm	mg/l	epm
CO_3	nil		nil		nil		nil		nil		nil	
HCO_3	130	2.13	340	5.57	290	4.75	170	2.79	370	6.07	180	2.95
Cl	330	9.31	44	1.24	370	10.44	95	2.68	240	6.77	270	7.61
SO_4	<5	<0.1	35	0.73	23	0.48	<5	<0.1	<5	0.1	10	0.21
F												
SiO_2	5		21		28		40		44		54	
Ca	39	1.95	55	2.75	32	1.60	20	1.00	34	1.7	72	3.59
Mg	90	7.40	24	1.97	42	3.45	32	2.63	45	3.7	42	3.45
Fe	<0.1		<0.1		<0.1		<0.1		<0.1		<0.1	
Al	<0.2		<0.2		<0.2		<0.2		<0.2		<0.2	
K	4.4	0.11	1.4	0.04	0.6	0.02	1.4	0.036	0.8	0.02	3.7	0.1
Na	45	1.96	48	2.09	260	11.31	42	1.83	180	7.83	90	3.92
TDS	760		420		880		370		760		730	
Total ions												
Hardness							190					
- permanent	370		nil		13		1		nil		200	
- temporary	100		240		240				270		150	
Alkalinity	100		280		240		140		300		150	
Na%	18.2		31.1		69.2		34		59		36.3	
S.A.R.	0.9		1.4		7.1		1.4		4.8		2.1	
E.S.P.	0.07		0.8		8.4		1.8		5.5		1.8	
R.S.C.			0.85						0.67		0.57	

APPENDIX 11

Descriptions of aquifer materials

The following are brief descriptions of material making up the aquifers from some of the boreholes. The size range and angularity, together with the dominant composition, are the main factors that have been considered. Detailed examination and identification of minor constituents has not been undertaken.

INVESTIGATION HOLES - WESTERN SUB-BASIN

IH 3 (128-146 m); grey-brown sample

Clayey sand angular grains of mainly clear quartz up to 0.75 mm, but usually much smaller.

IH 7 (88.4-91.4 m); grey sample

Clayey sand, clear angular quartz grains fairly even grained. Average size about 0.3 mm but up to 0.7 mm in diameter.

One very small sphere in magnetic fraction included in a quartz fragment.

IH 16 (85-104 m); grey sample

Fairly even grained fine angular quartz sand. Mainly clear quartz with some milky fragments. Average size about 0.3 mm.

Some nearly spherical shaped material in magnetic fraction.

IH 18 (79-88 m); brown sample

Angular fragments of mainly clear quartz with about 5% milky quartz fragments up to 1.5 mm diameter, with average size about 0.5 mm.

Flattened sphere in magnetic fraction.

IH 20 (85-91 m)

Clayey sand with angular clear quartz fragments up to 0.5 mm diameter. Some milky quartz.

IH 21 (91-108 m); light grey-brown sample

Mainly clear angular quartz, some of the larger particles are milky quartz. Particles up to 1.75 mm diameter with an average size of about 0.75 mm and a wide size range.

One spherical particle in magnetic fraction.

IH 27 (34-37 m); brown sample

Coarse sand, mainly angular. Clear quartz with particles up to 3.25 mm diameter, most fragments much smaller. Occasional fragments show some rounding.

Appendix 11 (continued)

IH 36 (79.2-82.3 m); grey sample

Angular clear quartz fragments covered with clay. Fragments up to 1 mm diameter.

IH 39 (70-73 m); grey sample

Clayey sand with clear quartz fragments up to 2.5 mm with an average size of about 0.9 mm.

Some vitreous material in magnetic fraction.

IH 50 (131-140 m); brown sand

Uneven grained sand mainly of clear angular quartz fragments. Pink garnet fairly common; up to 1 mm diameter. Average particle size about 0.3 mm.

Large magnetic fraction (includes garnet), no spheres observed.

INVESTIGATION HOLES - EASTERN SUB-BASIN

IH 58 (21-38 m)

Iron oxide stained coarse fraction (≯5 mm). Contains angular to subrounded, and occasionally rounded quartz fragments; about 50% are clear or smoky clear quartz and are probably derived from granite or other igneous rocks. The remainder are milky vein-like quartz. Size ranges up to 18 mm diameter but average is a little over 5 mm. About 25% of aquifer material is in this size range.

Fine fraction. Nearly all angular clear quartz, grades down to material only a few microns diameter. Occasional magnetic fragments.

IH 59 (36.6 m); grey sample

Coarse fraction. Several fragments 12-22 mm diameter, angular to subrounded, consisting of milky vein-like quartz and quartzite, and making up about 10% of the sample. Smoky quartz and milky vein-like quartz (5-7 mm diameter) in about equal proportions make up about 15% of the sample; they are angular to subrounded.

Fine fraction. Dominantly clear angular quartz, a little milky quartz.

A small percentage of a strongly magnetic material present - magnetite?

IH 62 (16.8-26 m)

Coarse fraction. About 10% of sample (5-8 mm diameter) of about equal proportions of smoky granite-like quartz and vein-like quartz, angular to subrounded.

Fine fraction. Mainly angular clear quartz. Small magnetic fractions included black sphere 50 μm diameter.

Appendix 11 (continued)

IH 63 (15.2-21.3 m); brown sample

Coarse fraction. 5-10 mm diameter, mainly milky vein-like quartz, a few smoky granite-like quartz fragments.

Fine fraction. Mainly clear angular quartz.

IH 63 (42.7-53.3 m); grey sample

Fine fraction. Mainly clear angular quartz up to 1 mm diameter. No coarse fraction.

IH 65 (6.1-18.3 m); brown sample

Coarse fraction. Mainly made up of milky quartz ranging from 5-20 mm diameter with a few smoky granite-like quartz fragments around the 5 mm size range. One large 40 mm piece of quartzite. This fraction makes up about 30% of sample.

Fine fraction. Angular clear quartz mainly with some milky quartz. A small magnetic fraction - magnetite?

IH 66 (3.1-7.6 m); brown sample

Coarse fraction. Ranges in size from 5-15 mm of mainly angular milky quartz. Some larger pieces are rounded.

Fine fraction. Mainly angular clear quartz. Magnetic fraction contains black spheres with vitreous lustre; 0.125 mm diameter.

IH 67 (18.3-25.9 m); brown sample

Coarse fraction. Mainly milky quartz in this size range (5-15 mm) with some smoky quartz in lower part of range. Coarser fragments are subrounded, smaller fragments are angular.

Fine fraction. Mainly angular clear and milky quartz, with occasional coarser grained subrounded particles. Magnetic fraction contains black sphere.

IH 68 (4.6-13.7 m); brown sample

Coarse material. Fragments 5-45 mm diameter with the coarser grains rounded. Consists of dolerite, milky quartz and one Permian fragment with bryozoan. Some smoky granite-like quartz in lower part of size range.

Fine fraction. Angular clear and milky fraction. A large magnetic fraction.

IH 69 (4.6-12.2 m); brown sample

Coarse fraction. Larger fragments up to 20 mm diameter are rounded quartzite, while those down to 5 mm diameter are angular milky quartz.

Fine fraction. Clear and milky quartz, usually angular, occasionally subrounded.

Fairly large magnetic fraction.

OIL PROSPECTING HOLE 2

145-158 m; grey sample

Fairly even grained sand average size about 1.25 mm, angular fragments, mainly clear, some milky. Magnetic fraction contains numerous black spheres 0.125-0.375 mm diameter.

436 m; grey sample

Fairly even grained coarse sand, a few fragments up to 5 mm but average size about 1 mm diameter. Mainly clear angular to subrounded quartz.

Magnetic fraction contains small dark spheres.

537 m; grey-brown sample

Even grained angular sand, average size about 0.9 mm, mainly clear quartz. No spheres seen in magnetic fraction.

585 m; grey sample

Even grained sand with lignite fragments. Mainly clear angular quartz, some milky quartz. Average size about 0.8 mm. One broken sphere in magnetic fraction.

698 m; grey sample

Clayey fine grained sand, average size 0.5 mm diameter. Dominantly angular clear quartz. Magnetic fraction contains spheres 0.125 mm to 0.25 mm diameter.

APPENDIX 12

Tertiary palynology of the Longford Basin

S.M. Forsyth

Petroleum exploration in the Gippsland Basin has led to the erection of spore-pollen zones spanning the Late Cretaceous to late Miocene interval (Stover and Evans, 1973; Stover and Partridge, 1973). These zones have, with modifications, been recognised in the Bass Basin (Partridge, 1973) and form a basis on which to interpret Tasmanian palynological data. With the exception of the more marine sections of the Gippsland Basin sequence where foraminifera are present, the ages of the zones have been determined by spore-pollen and microplankton correlation with sequences containing planktonic foraminifera, primarily in the Otway Basin and New Zealand.

There has been a divergence of opinion regarding the position of the Palaeocene-Eocene boundary in the Otway Basin. The Rivernook Member of the Dilwyn Clay has variably been regarded as of Palaeocene age (McGowran, 1970) and Early Eocene (Abele *et al.*, 1976). The Rivernook Member certainly post dates the *Pseudohastigerina* Datum. However, uncommon occurrences of *P. wilcoxensis* are known from the Palaeocene *Globorotalia velascoensis* Zone and probably from the *G. pseudomenardii* Zone (Stainforth *et al.*, 1975; McGowran, 1970).

Partridge (1976) depicted revisions of the Gippsland Basin spore-pollen zone ages and extended the base of the lower *Malvacipollis diversus* Zone down into the latest Palaeocene and presented evidence for a hiatus in the lower *M. diversus* Zone below the *Wetzeliella hyperacantha* dinoflagellate Zone. Partridge maintained the *W. hyperacantha* Zone, as developed in the Rivernook Member and Gippsland Basin in the Early Eocene, and noted reworking of *Lygistepollenites balmei* Zone species into the *W. hyperacantha* Zone during transgression, perhaps overcoming difficulties pointed out by Abele *et al.* (1976) regarding the range of *Gambierina edwardsii*.

The lower *Malvacipollis diversus* Zone thus is considered to range in age from latest Palaeocene into Early Eocene.

From palynological examination, Harris (1968) suggested correlation of sediments from Rose Rivulet, Legana, and Legana Cliffs with the upper units of the Dilwyn Clay, and in following McGowran (1970) suggested a Palaeocene age. In the interests of consistency with the Gippsland Basin zones, an Eocene age for some of these samples may be more appropriate. Of the palynomorphs listed by Harris (1968) from the Tasmanian 'Palaeocene' only *Triorites edwardsii* = *Gambierina edwardsii* (Cookson and Pike) Harris does not range into the *Malvacipollis diversus* Zone and Harris noted this species to be rare. In addition Harris noted the presence of *Tiliapollenites notabilis* = *Intratriporopollenites notabis* (Harris) Stover which appears first in the lower *M. diversus* Zone. It is therefore probable that some of the samples examined by Harris may be as young as Early Eocene, although a latest Palaeocene age cannot be ruled out. Others belong to the *L. balmei* Zone as indicated by 'rather rare *Triorites edwardsii*' and are therefore Palaeocene in age.

The Rose Rivulet sequence has recently been resampled close to Harris' (1968) sample sites, but to date only one new sample has been studied. This yielded a *M. diversus* Zone assemblage. In addition Esso gives Eocene determinations for a nearby bore (IH 44) including one sample from below sea level. Eocene sediments also occur on the north side of Rose Rivulet in DH 4 at White Hills. These sediments range from Early? to Middle-Late Eocene with an abrupt change in the microfloral composition, possibly suggesting a hiatus prior to *Nothofagidites asperus* Zone (Middle to Late Eocene) sedimentation. Further Palaeocene and Early Eocene determinations are listed in Table 7.

Late Early Eocene to Middle Eocene palynofloras containing *Proteacidites pachypolus* have also been recorded from various parts of the basin. Dettmann (1966) noted similar Middle Eocene palynofloras from about sea level from two holes drilled south of Carrick, and suggested conformity with the *Proteacidites pachypolus* Zone of 'Middle Eocene' age. In particular, the co-occurrence of *P. pachypolus, P. grandis, Santalumidites cainozoicus, Nothofagidites asperus* and other abundant *Nothofagidites spp.* in Longford Hole 2 indicates an assemblage from close to the *Proteacidites asperapolus/ Nothofagidites asperus* Zone boundary of Middle Eocene age.

From Spring Bay, Harris (1968) reported similar Middle Eocene microfloras containing common *Nothofagidites* and an abundance of two morphotypes of *P. pachypolus*, presumably including *P. asperopolus* Stover and Evans (1973). Both *P. pachypolus* and *P. asperopolus* appear first in the Upper *Malvacipollus* Zone and the shorter ranged *P. asperopolus* does not extend into the late Eocene Upper *Nothofagidites asperus* Zone. In the Bass Basin, the range of *P. asperopolus* is further restricted as its first appearance marks the base of the *P. asperopolus* Zone (Partridge, 1973). The abundance of the two morphotypes suggests that the assemblage is as young as the *P. asperopolus* Zone or slightly younger (Partridge, 1973, p.10). The common occurrence of *Nothofagidites* may indicate an age as young as the base of the *N. asperus* Zone.

P. pachypolus is a very common up-hole contaminant of Palaeocene chip samples examined from the Hagley oil prospecting hole (OP 2) and indicates that rocks of similar age are developed in this section of the basin.

A palynoflora in DH 4 at White Hills immediately beneath rocks bearing a *Nothofagidites asperus* Zone assemblage is probably close to the *P. asperopolus/N. asperus* Zone boundary if no hiatus occurs in the sequence. Should a hiatus be present, then this palynoflora may be as old as late Early Eocene.

Younger assemblages assignable to the lower or middle *Nothofagidites asperus* Zone (Middle to Late Eocene) are widespread. *P. pachypolus* appears to be generally absent. This palynoflora has recently been detected in seven bore holes, whilst previous analysis by Esso has indicated Middle-Late Eocene rocks are present in four other holes. These occurrences extend from Westbury south to Cleveland and from Bracknell east to Evandale, and lie 80 m to 150 m above present sea level.

No assemblages assignable to the Upper *Nothofagidites asperus* Zone or younger zones have as yet been recorded from the basin, although the *Proteacidites tuberculatus* Zone has been detected commonly outside of this area, including from the neighbouring Port Sorell Basin and the lower Tamar (Sutherland, 1971). Many extra basinal occurrences are in rocks protected from erosion by basalt cappings.

The palynological evidence suggests basin subsidence continued through the Early Eocene and that the Tamar and Cressy sub-basins at times subsided independently. This is indicated particularly by *Gambierina edwardsii* bearing rocks above sea level in the general Launceston area, and the occurrence of the *Malvacipollis diversus/Lygistepollenites balmei* Zone boundary (in part based on the first downhole occurrence of *Gambierina rudata*) below 300 m and most likely at 500 m below sea level at Hagley.

The occurrence of assemblages close to the *P. asperopolus/Nothofagidites asperus* Zone boundary near sea level at Spring Bay and Longford is consistent with relative subsidence coming to an end during the *P. asperopolus* Zone. No evidence has been found of large scale relative movement of *N. asperus* Zone sediments in the basin.

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APPENDIX 13

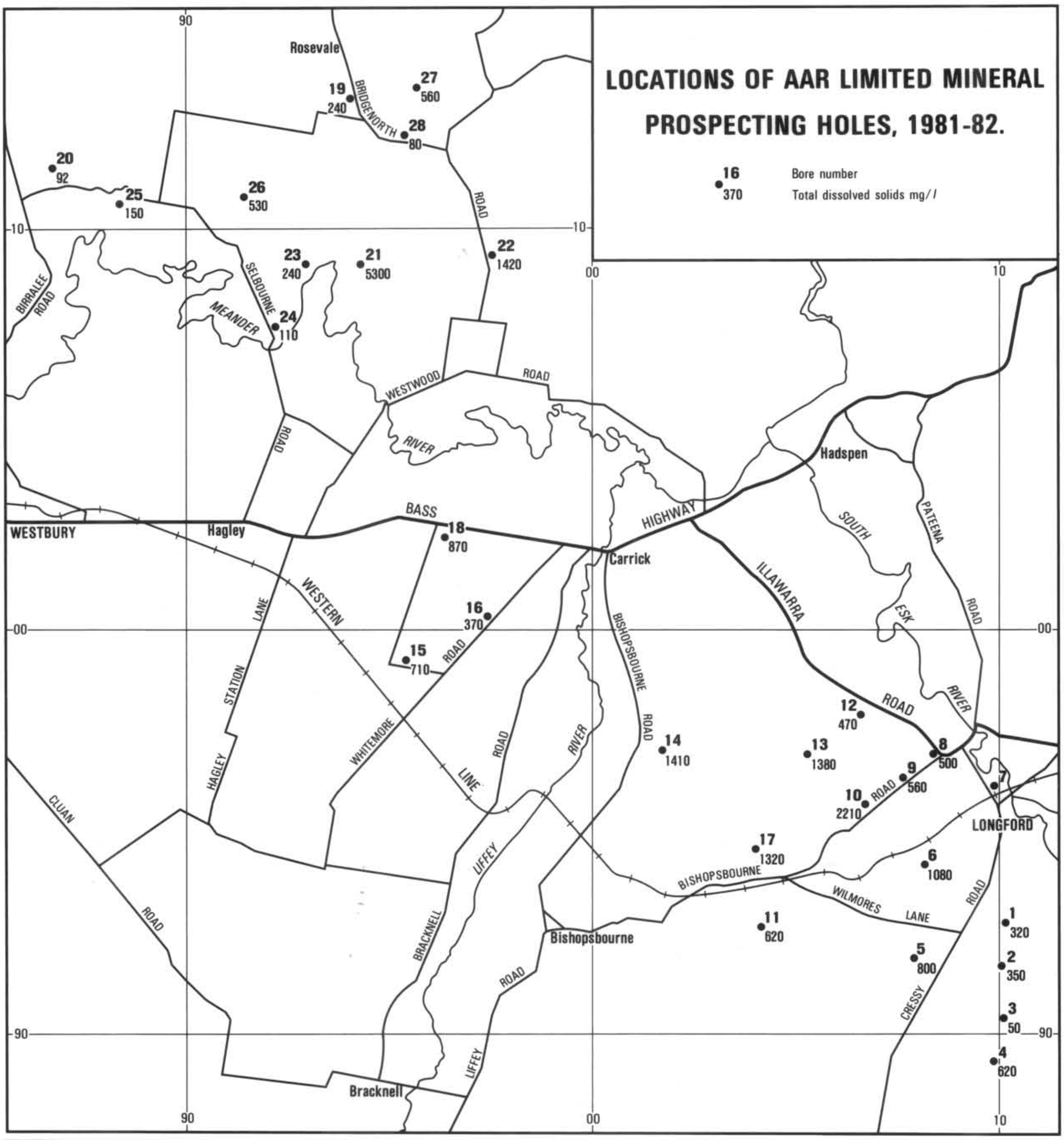
Groundwater information from mineral prospecting holes, 1981-82

During 1981 and early 1982, AAR Limited and associated company CSR Limited undertook two periods of exploration drilling within the Tertiary basin area. The geologists involved, R. Osborne and P. Ellis, collected water samples for analysis from some of the holes drilled, as well as recording some other information. Appreciation is expressed to them for undertaking this work.

The first series of holes was drilled from six kilometres south of Longford to Whitemore (Holes 1-18, fig. 33), and water samples were analysed from all holes excepting Hole 7. The results of these analyses are given in this appendix, together with standing water levels.

It is of interest to note that Holes 4, 5, 6, and 9 were artesian, Holes 4 and 9 being near previous holes that were artesian. The total dissolved solids values from the chemical analyses fit reasonably well with the contours of salinity in Figure 2, although there are exceptions, with water from Holes 10 and 13 being the most notable. None of these holes was pumped (except for the naturally flowing holes) and it may be some time before an equilibrium is reached between circulation water used in drilling and aquifer water. In addition, some of the holes would not have penetrated the same aquifers or the same number of aquifers as the investigation holes, and this could account for some variation in the total salinity between the holes.

The second series of holes (Holes 19-28, fig. 33) was drilled north of the Meander River, in an area where there were no test holes drilled and other information on groundwater is fairly scattered. These holes provide new information on the chemical quality of the water, although the same comments apply to this series as the first series with regard to equilibrium being reached between circulation and aquifer water. The low pH in some samples is probably due to some contamination, either in the sample collecting bottles or in the circulation mud.



LOCATIONS OF AAR LIMITED MINERAL PROSPECTING HOLES, 1981-82.
16 370
Bore number
Total dissolved solids mg/l
Rosevale
Hadspen
Carrick
Hagley
WESTBURY
LONGFORD
Bishopsbourne
Bracknell
BASS HIGHWAY
ILLAWARRA ROAD
WESTERN LINE
MEANDER RIVER
SOUTH ESK RIVER
LIFFEY RIVER
BIRRALEE ROAD
SELBOURNE ROAD
BRIDGENORTH ROAD
WESTWOOD ROAD
HAGLEY STATION LANE
WHITEMORE ROAD
BISHOPSBOURNE ROAD
BRACKNELL ROAD
LIFFEY ROAD
CLUAN ROAD
PATEENA ROAD
WILMORES LANE
CRESSY ROAD
1 320
2 350
3 50
4 620
5 800
6 1080
7
8 500
9 560
10 2210
11 620
12 470
13 1380
14 1410
15 710
16 370
17 1320
18 870
19 240
20 92
21 5300
22 1420
23 240
24 110
25 150
26 530
27 560
28 80
90
00
10
5 cm

Figure 33.

Chemical analyses of water from mineral prospecting holes, 1981-82

Item	Hole number													
	1		2		3		4		5		6		8	
pH	5.7		6.4		5.9		6.7		5.3		7.3		6.9	
Conductivity (μS/cm)	450		490		50		850		1170		1480		480	
	mg/l	*epm*	*mg/l*	*epm*	*mg/l*	*epm*	*mg/l*	*epm*	*mg/l*	*epm*	*mg/l*	*epm*	*mg/l*	*epm*
CO_3	nil		nil		nil		nil		nil		nil		nil	
HCO_3	51	0.84	120	1.97	14	0.23	215	3.53	16	0.26	305	5.00	165	2.71
Cl	110	3.10	120	3.38	3	0.09	190	5.36	425	11.99	510	14.38	58	1.64
SO_4	32	0.67	17	0.35	<5	0.10	59	1.23	<5	<0.10	<5	<0.10	27	0.56
SiO_2	23		7.4		<5		13		13		10		21	
Ca	4.4	0.22	5.9	0.29	3.0	0.15	16	0.80	15	0.75	37	1.85	8.3	0.41
Mg	7.2	0.59	5.7	0.47	1.2	0.10	14	1.15	21	1.73	61	5.01	3.5	0.29
Fe	0.1		<0.1		<0.1		<0.1		<0.1		<0.1		0.2	
Al	<0.2		<0.2		<0.2		<0.2		<0.2		<0.2		0.7	
K	3.2	0.08	5.7	0.15	0.7	0.02	6.0	0.15	1.0	0.03	15	0.28	2.8	0.07
Na	100	4.35	115	5.00	5.9	0.26	205	8.92	250	10.88	265	11.53	130	5.66
TDS	370		350		50		620		800		1080		500	
Hardness														
- permanent	nil		nil		1		nil		110		94		nil	
- temporary	41		38		11		98		13		250		39	
Alkalinity (as $CaCO_3$)	42		97		11		180		13		250		135	
Na%	84.5		87.1		52.8		82.3		81.5		63.3		89.1	
S.A.R.	6.84		8.11		0.74		9.03		12.65		6.23		9.57	
E.S.P.	8.11		9.67		-0.17		10.76		14.82		7.35		11.39	
R.S.C.														
Standing water level (m)	2.4		7		1.8		flowing		flowing		flowing		2.7	

For location of holes see Figure 33.

Item	Hole number													
	9		10		11		12		13		14		15	
pH	6.3		4.4		5.7		5.3		3.7		3.5		3.6	
Conductivity (μS/cm)	890		3700		960		720		2250		2150		1030	
	mg/l	*epm*	*mg/l*	*epm*	*mg/l*	*epm*	*mg/l*	*epm*	*mg/l*	*epm*	*mg/l*	*epm*	*mg/l*	*epm*
CO_3	nil		nil		nil		nil		nil		nil		nil	
HCO_3	140	2.30	nil		49	0.80	18	0.30	nil		nil		nil	
Cl	245	6.91	1320	37.22	305	8.60	210	5.92	780	22.0	800	22.56	350	9.87
SO_4	25	0.52	70	1.46	10	0.21	27	0.56	15	0.31	19	0.40	15	0.31
SiO_2	32		42		34		12		42		15		82	
Ca	20	1.00	16	0.80	14	0.70	13	0.65	6.6	0.33	15	0.75	4.2	0.21
Mg	28	2.30	87	7.15	12	0.99	14	1.15	82	6.74	52	4.27	19	1.56
Fe	<0.1		4.1		<0.1		<0.1		0.2		11		0.2	
Al	<0.2		1.1		0.6		<0.2		2.5		0.9		0.4	
K	6.7	0.17	2.2	0.06	0.9	0.02	2.0	0.05	2.0	0.05	2.6	0.07	0.9	0.02
Na	135	5.87	675	29.36	175	7.61	115	5.00	320	13.92	380	16.53	180	7.83
TDS	560		2210		620		470		1380		1410		710	
Hardness														
- permanent	50		410		48		67		370		275		91	
- temporary	115		nil		40		23		nil		nil		nil	
Alkalinity (as $CaCO_3$)	115		nil		40		23		nil		nil		nil	
Na%	64.7		78.7		81.9		73.7		66.4		76.8		81.6	
S.A.R.	4.57		14.73		8.28		5.27		7.40		10.2		8.32	
E.S.P.	5.20		16.99		9.87		6.12		8.80		12.11		9.92	
R.S.C.														
Standing water level (m)	flowing		2.3		4.6		1.4		2.4		2.7		4.9	

For location of holes see Figure 33.

Item	Hole number													
	16		17		18		19		20		21		22	
pH	6.2		5.0		5.8		5.8		5.9		4.0		3.6	
Conductivity (μS/cm)	440		2300		1350		470		150		8600		2500	
	mg/l	*epm*	*mg/l*	*epm*	*mg/l*	*epm*	*mg/l*	*epm*	*mg/l*	*epm*	*mg/l*	*epm*	*mg/l*	*epm*
CO_3	nil		nil		nil		nil		nil		nil		nil	
HCO_3	140	2.30	9.6	0.16	19	0.31	42	0.69	17	0.28	nil		nil	
Cl	55	1.55	820	23.12	490	13.82	100	2.82	30	0.85	3000	84.60	820	23.12
SO_4	37	0.77	44	0.92	12	0.25	13	0.27	<5	0.10	125	2.60	7	0.15
SiO_2	11		29		12		14		6.4		6.6		17	
Ca	4.8	0.24	22	1.10	24	1.20	7.9	0.39	2.6	0.13	61	3.04	21	1.05
Mg	2.8	0.23	65	5.01	39	3.21	4.2	0.35	1.9	0.16	280	23.03	57	4.69
Fe	0.2		<0.1		<0.1		<0.1		<0.1		6.7		0.1	
Al	1.4		0.5		<0.2		<0.2		<0.2		3.2		10	
K	3.2	0.08	5.8	0.15	5.7	0.15	1.8	0.05	0.8	0.02	4.1	0.11	2.7	0.07
Na	95	4.13	360	15.66	220	9.57	73	3.17	23	1.00	1325	57.61	320	13.91
TDS	370		1320		870		240		92		5300		1420	
Hardness														
- permanent	nil		315		205		2		nil		1335		345	
- temporary	32		7.9		16		35		14		nil		nil	
Alkalinity (as $CaCO_3$)	115		7.9		16		35		14		nil		nil	
Na%	90.0		72.1		68.8		81.3		77.9		68.9		70.9	
S.A.R.	8.52		8.96		6.44		5.2		2.6		16.0		8.2	
E.S.P.	10.16		10.68		7.61		6.0		2.5		18.3		9.8	
R.S.C.														
Standing water level (m)	15.6		2.4		1.5									

For location of holes see Figure 33.

Item	Hole number											
	23		24		25		26		27		28	
pH	5.3		6.0		6.4		8.2		6.3		5.6	
Conductivity (µS/cm)	300		140		260		920		850		140	
	mg/l	*epm*	*mg/l*	*epm*	*mg/l*	*epm*	*mg/l*	*epm*	*mg/l*	*epm*	*mg/l*	*epm*
CO_3	nil		nil		nil		nil		nil		nil	
HCO_3	2.6	0.04	8.5	0.14	65	1.07	440	7.21	19	0.31	5.9	0.01
Cl	91	2.57	19	0.54	45	1.27	91	2.57	235	6.63	33	0.93
SO_4	<5	0.01	<5	0.10	<5	0.10	<5	0.10	10	0.20	<5	0.10
SiO_2	8.5		7.4		9.4		29		24		6.4	
Ca	3.3	0.17	3.3	0.17	8.6	0.43	32	1.60	23	1.15	1.9	0.10
Mg	5.4	0.44	4.8	0.40	5.7	0.47	42	3.45	18	1.48	1.9	0.16
Fe	<0.1		<0.1		<0.1		<0.1		<0.1		<0.1	
Al	<0.2		<0.2		<0.2		<0.2		<0.2		<0.2	
K	2.4	0.06	2.3	0.06	1.5	0.04	1.3	0.03	1.4	0.04	0.4	0.01
Na	43	1.87	13	0.57	32	1.40	63	2.74	110	4.78	19	0.83
TDS	240		110		150		530		560		80	
Hardness												
- permanent	28		21		nil		nil		115		8	
- temporary	2.1		6.9		45		255		16		4.8	
Alkalinity (as $CaCO_3$)	2.1		6.9		53		360		16		4.8	
Na%	82.5		52.5		61.5		35.4		64.7		76.4	
S.A.R.	3.4		1.1		2.1		1.7		4.1		2.3	
E.S.P.	3.6		0.4		1.8		1.2		4.6		2.1	
R.S.C.					0.17		2.16					
Standing water level (m)												

For location of holes see Figure 33.