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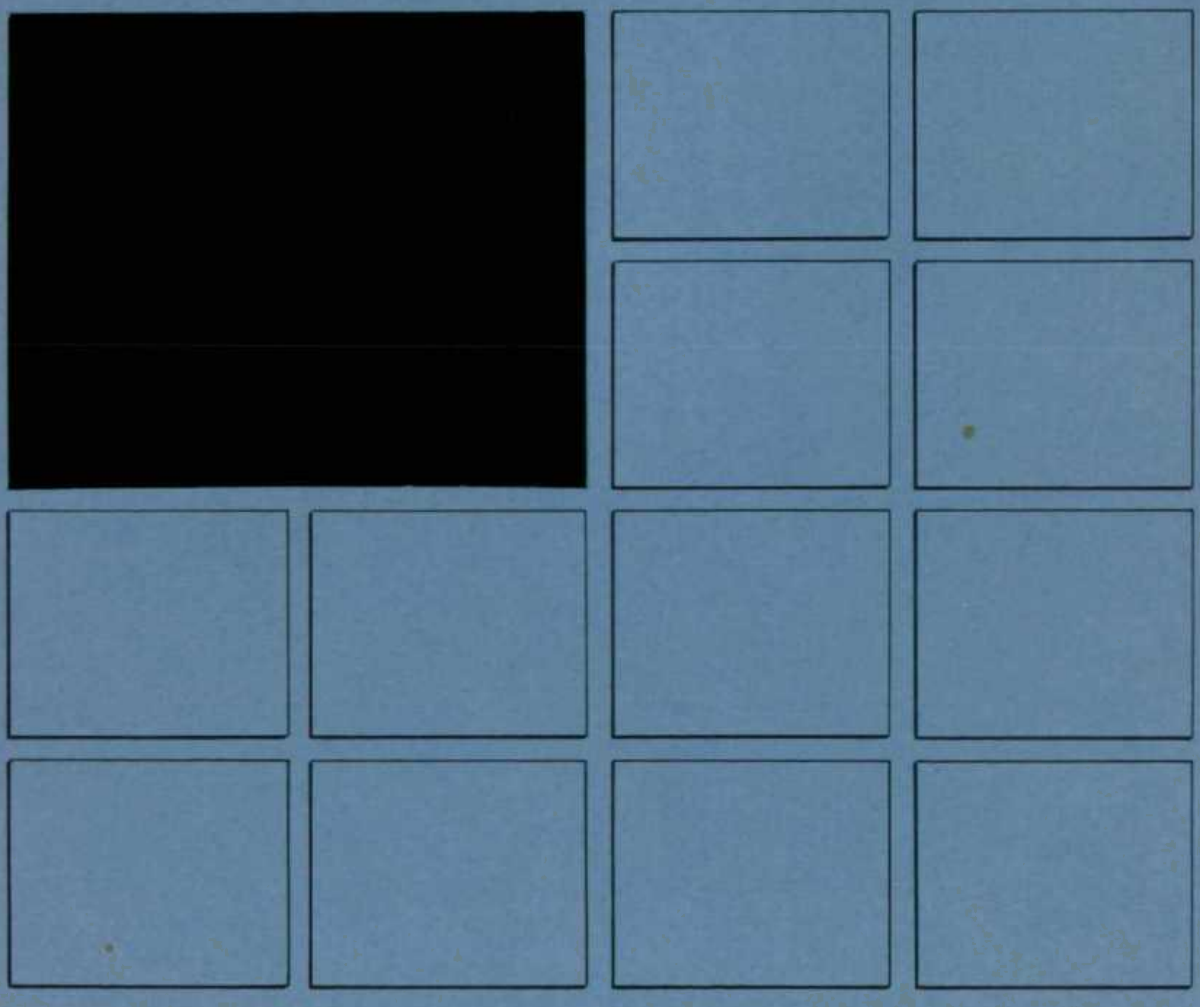

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SEARLE PLANT, MORPETH

RECONNAISSANCE SURVEY

REPORT ON PHASE I

May 1987

Institute of Hydrology

Wallingford, Oxon

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1. INTRODUCTION

1.1 General

The Searle Pharmaceutical site near Morpeth extends over an area of some 20 ha. Four chemical production plants, covering an area of about 1 ha, are situated in the north eastern part of the site (Figure 1A)

The toxic chemical waste from the chemical plants and adjacent laboratory is conveyed through a separate effluent drain system to a treatment works just north of the chemical plants. At least 75% of this system failed pressure-tests during a survey in October 1985. It was therefore highly probable that leakage of toxic wastes would have contaminated the underlying deposits. Subsequently, engineering works near Chemical Plant 4 encountered groundwater containing acetone at shallow depth.

The Institute of Hydrology have undertaken a reconnaissance survey of an area of some 2 ha in and around the chemical plant area. This study was arranged to be undertaken in two main phases:

Phase A: an initial drilling and sampling programme to determine the extent of pollution and the environmental risk arising from such pollution.

Phase B: a period of monitoring of a network of sampling points leading to proposals for any remedial action required.

This report summarises the results from Phase A.

The site is underlain by Millstone Grit and Coal Measures. The nearest potential groundwater supply at risk is a borehole located about one kilometre southwest of the site. However, it is believed that this borehole is not in use.

A shallow stream follows the northern boundary of the site about 220 m north of the chemical plants. A drain leading from the western part of the site discharges into this stream. The stream itself passs beneath the Morpeth by-pass to join the R. Wansbeck about 1.3 km north of the

site. Although ephemeral, the stream is downgradient of the chemical plant area and could therefore be at risk. A grassed area, the North Field, occurs between the chemical plants and the stream.

1.2 Programme Outline

Six shallow and two deep wells were drilled by the Institute of Hydrology at separate locations in the North East area of the site between 16 and 27 February 1987. One of the deep boreholes was drilled upslope of the chemical plant area for lithological control.

The first site to locate any contaminants was drilled in the North Field with the intention that if contaminants were not located within the boulder clay horizons or weathered bedrock at this site then subsequent sites would be drilled towards the chemical plants in an arc extending East and South East from the initial site. Drilling would consist of shallow wells at first to avoid cross-contamination of the underlying sandstone if shallow contaminants were found. If contaminants were identified at the initial site then the investigation would extend North and North East to locate its extent (within the site boundary only). If contaminants were not found at the shallow sites then some initial investigation of the chemical plant area itself would begin in order to prove that contaminants were definitely present.

Polluted groundwater was encountered at only 2 locations:

- at MP6, about 10 m North East of the effluent plant, where high levels of sodium chloride were found

- at MP8, about 8 m North of Chemical Plant 2, where volatile organics were found in high concentrations.

At this stage it was decided to appraise the results of this initial programme prior to further investigation within the chemical plant area itself. The initial results, which were presented as a preliminary report in March 1987, strongly suggested that contamination had not spread beyond the site and could even be restricted to the immediate area of the chemical plants. Between 2 and 9 April 1987 five shallow and one deep borehole were drilled specifically in the area of the chemical plants to

define the pollution in this area in more detail. The locations of the IH boreholes are shown in Figure 1B.

1.3 Methodology

A total of 11 shallow and 3 deeper wells were constructed using a shell and auger rig. Great care was taken during the drilling to seal off the upper layers in the borehole using casing. No water was added to the boreholes to assist drilling which made it easier to check the seals were preventing water from entering the borehole.

A 50 mm galvanised steel pipe with a 0.5 m perforated tip was placed in the hole and supported at the surface. The perforated tip was wrapped in Terram to prevent ingress of fine material.

After the wells had been completed water was pumped out to both purge the well and to assist in development of it; the water in the well is then more representative of the water present in the sequence. Water samples were taken in some wells during normal drilling operations to assist with the planning of the programme; but in all cases except MP14 the wells were resamples after purging. The water samples were taken using a syringe sampling system modified by the Institute of Hydrology; the sample was decanted immediately into a clean airtight bottle.

To estimate the permeability values of the formation simple recovery tests were carried out. These involved pumping out a known volume of water and measuring the water level in the well as it returned to its original level.

1.4 Geology

1.4.1. Regional Setting

The geology of the Morpeth area described on Sheet 14 and the accompanying memoirs suggested that the whole site is underlain by the Millstone Grit. The area has recently been resurveyed by the British Geological Survey and the boundary between the Millstone Grit and the overlying Coal Measures is now thought to cross the site in an east west direction near the northern end of the buildings.

The Millstone Grit, in the Morpeth area, is characterised by thick coarse grained sandstones as found in MP4 together with fine grained sandstones (MP14) and mudstones. The Coal Measures comprise of cyclic sequence of shale, mudstone, sandstone, seat earth and coal with each unit up to a few metres thick. There are no known faults in the factory area and the Millstone Grit-Coal Measures contact is conformable. The depth to bedrock for the whole site is shown in Figure 2.

We have found 3 main lithological units that overlie the bedrock:

Brown till
Silt
Grey till

The lithological logs for the 14 boreholes we drilled are given in Appendix A.

1.4.2 The Brown Till Sequence

The brown till sequence occurs over the whole site with thickness in general up to 2.0 m. In the north the sequence thickens to over 6 m in the North Field area. The sequence is variable comprising of brown silty and very silty clays with some clayey silts. The consistency is generally firm but soft-firm and firm-stiff were encountered. The clays contain variable amounts of pebbles mainly of sandstone, limestone, mudstone and coal.

Within the brown till sequence in the North Field there are interlayered fine-medium silty sands. In MP2 these sands contain gravel between 2.6 m and 3.3 m below ground level. The sands pinch out towards the south and are not present around the chemical plants.

1.4.3 The Silt

The IH and previous boreholes in the northeast part of the site have proved up to 2.0 m of soft clayey silt with a distinctive olive colour. In some places the olive silt is sandy, for example 0.3 m of very silty sand is found in MP5. At MP7 laboratory analysis of a sample taken between 5.4 m and 5.9 m below ground level gave a result of 50% sand, 42% silt and

8% clay. The upper boundary with the brown till is transitional with the consistency changing from firm to firm-soft to soft over a thickness of up to 1 m.

The greatest thickness of silt (1.9 m) was encountered at MP11 underlying a silty clay. The upper and lower soft layers are separated by 0.5 m of a stiff silt. As all the silt layers are olive grey and are classified as clayey silt we have assigned the whole thickness of silt to the main silt layer. Consequently the normally overlying brown till sequence is absent. In MP4, in the North Field, the silt layer was proved between 3.8 and 4.9 m below ground level as interlaminated silts and sands.

1.4.4 The Grey Till

The grey till is a stiff dark grey silty clay with sandstone, limestone and occasional dolerite pebbles. This clay, which overlies the bedrock in all boreholes, varies in thickness between about 1.5 m in the south at MP1 to about 3.5 m in the north at MP14. The grey till generally is thickest where contamination has been found. The boundary with the overlying soft silt layer is usually sharp, but at some locations the top of the grey till is a stiff dark grey brown silt.

In October 1985 site investigation borehole BH2 was drilled in the area of the west drum store. The log states that only 0.3 m of stiff dark brown sandy clay separated waterbearing sands from sandstone bedrock. We believe this log to be incorrect and that the bedrock was a sandstone boulder in the till.

1.5 Piezometry

During drilling water inflow was usually slow due to the low permeability of the sequence; consequently water levels may have taken several days to reach equilibrium. Water level elevations, for the silt layer, are shown in Figure 7 for the 16 April 1987, one week after completion of the drilling programme. The elevations vary from about 81 m OD in the south to 76 m OD in the north east at MP6. The average gradient towards the northeast is 0.06 but in the southeast the gradient is less at about 0.03 with the flow in a more easterly direction.

The silt layer in the south is confined with the piezometric surface at or above the top of the silt layer. Away from the chemical plants the piezometric head increases until at MP6 it is about 2 m above the silt layer.

Between the chemical plants a shallow water table was found within the dolerite fill at MP8 and in the dolomite fill at MP14. At all the other sites where the dolomite/ dolerite fill is present no water was found in it. As water was only found within the fill at these two sites any water bearing layers are discontinuous and that water is only present because of local lateral and vertical variations in the fill material or degree of compaction of it.

A separate shallow water table is present in MP3 in the North Field indicating that the water bearing formation is isolated from the more continous deeper sands and silts.

The weathered sandstone at MP4 was found to contain water. This water bearing zone is fully confined by the overlying boulder clay. The sandstone located at MP14 was found to be dry, but it was also found to be a finer grained sandstone and less weathered.

1.6 Permeability

Estimates of permeability have been made from short recovery tests, and for the sands from grain size analysis. Table I summarises the results of these tests.

The permeability estimate derived from grain size is the mean from 5 samples. The permeability was calculated using a technique derived by Boonstra and de Ridder.

As a general indication of permeabilities for these sequences we would expect values in the range of 10^{-2} to 10^{-4} m/d for mixed sands, silts and clays such as the brown till sequence and about 10^{-6} m/d for massive clays such as the grey clay. The occurrence of groundwater in the silt horizon overlying the grey clay would seem due to the higher permeability of the silt compared with the very low permeability of the denser more compact grey clay which restricts further downward movement of

Table I Derived permeability values

	permeability K m/d	layer
MP2	7.0	silty sand
MP3	40.0	sand
MP4	5×10^{-4}	sandstone
MP5	5×10^{-4}	silt
MP6	0.4	silt
MP7	0.4	silt
MP8	1.4	silt
MP9	0.7	silt
MP10	3.0	silt
MP11D	1.0	silt
MP2	5.0	sand (grain size analysis)

groundwater.

The permeability estimates we obtained for the silt layer are, in general, considerably higher than might be expected for silts. The method we used for constructing the wells resulted in an annulus around the 50 mm casing. This annulus would have the effect of forming a reservoir which could dampen the effects of the pumping. A greater effect is the uncertainty of the thickness of the contributing water bearing layers. This is because of the transitional nature of the brown till-silt junction which may be up to a metre thick compared to the average thickness of the silt layer of 0.5 m. The mean derived permeability value for the silt layer in the chemical plant layer is 1.3 m/d. This permeability estimate has a large degree of uncertainty because of the annulus and the thickness of the water bearing layers. We estimate that these could be as high as an order of magnitude and as such we have chosen the lower value of 0.1 m/d; we consider that this is a conservative estimate for the permeability.

2. SAMPLING RESULTS

2.1 Organic contamination

We were informed by Searle that methanol and acetone were the most commonly discharged organic compounds in the complex effluent produced by the plants; and we decided to use them as markers for contamination. The analyses were performed by Analytical and Technical Services of Newcastle using gas chromatography. Since we were trying to locate gross contamination we decided that a detection limit of 1 mg/ℓ would give sufficiently sensitive. The drilling samples were analysed on site by Searle staff, also using gas chromatography, to guide the drilling programme. Initially only methanol and acetone were analysed for but tetra-hydrofuran (THF) was found to be present in MP8 and subsequently this was included in the analysis. With the exception of MP2, 3 and 4 all boreholes were resampled during April and analysed for the three compounds. As methanol and acetone and THF, although less dense than water, are fully miscible, there will probably be uniform vertical contamination. At the time of sampling temperature, electrical conductivity and pH were also measured. The results of the analysis are shown in Tables II, III and IV and on Figure 8.

During April several trenches were being dug along the eastern boundary. We took the opportunity of sampling water that collected in the trenches. Unfortunately heavy rainfall made the trench samples of dubious value. Because of the rain we felt that any samples taken of surface water would also be of limited value.

Those samples indicated as drilling samples were taken during normal drilling operations. Less emphasis should be placed on the drilling samples. The drilling equipment was washed between sites but there still may have been some slight cross contamination such as at MP12 where acetone was found in the drilling sample but not in the purged sample; MP12 was drilled after MP11, a heavily contaminated site.

Methanol has only been found in samples taken from MP11. It may be that biological degradation is taking place which converts the methanol to methane.

TABLE II Water sample analysis - boreholes

Sample No.		Date	Time	Methanol (mg/ℓ)	Acetone (mg/ℓ)	THF (mg/ℓ)	
4	N3	21.2.87	1130	0	0	–	purged
65	NE3	8.4.87	1710	0	0	0	purged
8	NE4	24.2.87	1000	0	0	–	
13	MP1	27.4.87	1130	0	0	–	
14	MP2	27.2.87	1140	0	0	–	purged
15	MP3	27.2.87	1140	0	0	–	purged
16	MP4	27.2.87	1140	0	0	–	purged
9	MP5	25.2.87	0930	0	0	–	purged
66	MP5	8.4.87	1720	0	0	0	purged
10	MP6	25.2.87	1005	0	0	–	purged
67	MP6	8.4.87	1730	0	0	0	purged
68	MP7	8.4.87	1740	0	0	0	
17	MP8	27.2.87	1230	0	0	–	upper (not purged)
11	MP8	26.2.87	1830	0	8	700	lower (not purged)
69	MP8	8.4.87	1750	0	0	1432	* purged
45	MP9	7.4.87	1340	Tr	<1	<1	purged
46	MP9	7.4.87	1340	0	0	0	duplicate
35	MP10	6.4.87	1340	<1	<1	0	purged
36	MP10	6.4.87	1340	Tr	Tr	Tr	duplicate
28	MP11S	6.4.87	1300	48	58	65	not purged
53	MP11S	8.4.87	0910	71	318	151	purged
54	MP11S	8.4.87	0910	103	217	119	duplicate
30	MP11D	6.4.87	1305	110	133	125	not purged
55	MP11D	8.4.87	0915	62	261	140	purged
56	MP11D	8.4.87	0915	180	337	182	duplicate
32	MP12	6.4.87	1315	0	31	0	not purged
57	MP12	8.4.87	0925	0	0	0	purged
58	MP12	8.4.87	0925	0	0	0	duplicate
34	MP13	6.4.87	1325	0	17	0	not purged
59	MP13	8.4.87	0920	0	8	0	purged
60	MP13	8.4.87	0920	0	0	0	duplicate
37	MP14	6.4.87	1500	0	249	60	top+
38	MP14	6.4.87	1500	0	150	67	duplicate
–	MP14	6.4.87	2200	0	0	0	middle+

* also 1000 mg/ℓ of unidentified organic
\+ drilling sample

TABLE III Water sample analysis - trenches

Sample No.		Date	Time	Methanol (mg/ℓ)	Acetone (mg/ℓ)	THF (mg/ℓ)	
50	SE of MP1	7.4.87	1735	0	0	0	
48	East of MP14	7.4.87	1730	0	0	0	
61	East of MP14/NE3	8.4.87	1000	0	0	0	
62	MP14/NE3	8.4.87	1000	0	0	0	duplicate
63	at NE3	8.4.87	1350	Tr	Tr	0	
64	at NE3	8.4.87	1350	0	0	0	duplicate
	Effluent plant	6.4.87	1500	0	9	0	before rain
52	Effluent plant	7.4.87	1740	0	0	0	after rain

TABLE IV Water sample analysis

	Date	Time	EC(S)	pH	Temp (°C)	
MP1	6.4.87	1725	520	7.72	10.2	
MP2	4.4.87	0925	770	7.16	6.5	
MP3	4.4.87	1655	480	6.91	6.2	
MP4	5.4.87	1055	730	8.18	7.3	
MP5	25.2.87	0930	1820	6.7	6.5	
MP5	3.4.87	1430	2950	7.16	7.1	
MP6	23.2.87	1800	3160	6.7	6.5	
MP6	25.2.87	1000	5910	6.85	6.4	
MP6	2.4.87	1530	6620	7.00	8.1	
MP6	3.4.87	1330	7180	7.33	7.1	
MP7	4.4.87	1515	1930	7.05	6.9	
MP8	27.2.87	1230	630	7.4	-	
MP8	26.2.87	1830	4570	6.3	-	
MP8	5.4.87	1610	5390	6.61	6.5	
MP9	7.4.87	1350	1670	7.1	9.4	
MP10	6.4.87	1540	1850	6.89	10.5	
MP11S	8.4.87	1750	1800	7.14	9.8	upper
MP11D	8.4.87	1420	1820	7.08	8.4	lower
MP12	7.4.87	1710	820	7.63	6.8	
MP13	7.4.87	1550	2440	7.54	7.9	
MP14	6.4.87	1500	1060	9.10	7.1	upper (drilling)
MP14	6.4.87	2200	2110	7.12	8.1	middle (drilling)
NE3	3.4.87	1745	2880	7.27	6.6	
NE4	24.2.87	0930	1575	6.9	-	
NE4	5.4.87	1705	1650	7.14	8.2	
Trench near MP14	7.4.87	1730	1100	7.69	6.9	
Trench near MP1	7.4.87	1735	730	7.87	6.8	
Trench near MP14/NE3	8.4.87	1000	480	7.56	5.6	
Trench at effluent plant	7.4.87	1800	880	7.60	7.0	

2.2 Inorganic contamination

In February 1987 we found high sodium and chloride levels present in MP6. In April we resampled MP6 and sampled MP5 and NE3; the samples were analysed for inorganic ions. The analysis, using standard techniques, were carried out by the Institute of Hydrology. The results are given in Table V.

Table V Inorganic analysis Results

		MP5	MP6	MP6	NE3
Cations	Na	214	875	830 +	89
	Ca	295	440	440	395
	Mg	53	90	80	29
	K	3	4	1	1
Anions	HCO3	244	251	-	205
	SO4	490	345	360	12
	Cl	590	2150	2200	850
	NO3	3.3	0.1	-	0.4
Ionic balance		-4.1%	-3.2%		-3.0%
Minor ions	Fe	0.1	3.6	8	2.9
	Zn	36	15	28	0.6
	Al	-	-	2	-

All units are mg/ℓ
+ partial analysis sample collected 25.2.87

The high levels of zinc in boreholes MP5 and MP6 could be derived from the galvanised steel casing; NE3 has a plastic casing.

The high sodium and chloride levels indicate that the source of contamination is probably the road salt which has been stored in the effluent plant area for several years. A storm water drain passes within two metres of MP6 which may be leaking and been acting as the source of contamination.

3. DISCUSSION

3.1 Sources of contamination

Toxic waste is conveyed from the laboratory and the chemical plants to the effluent plant for treatment through the network of drains shown in Figure 8. There are two systems of effluent drains, at different depths, which join near the north east corner of Chemical Plant 4:

(i) a shallow system of drains, located at less than 1.5 m below ground level, beneath and immediately east of Chemical Plant 4.

(ii) the other effluent drains run north from the laboratory to the effluent plant, linking with Chemical Plant 1, 2 and 3. The depth varies but in general is between 1.4 and 2.5 m below ground level.

The shallow system and the drains on the north side of Chemical Plant 3 are located within the fill.

3.2 Contamination of fill material

The fill extends under and around all the chemical plants and was also observed in the trenches along the east fence line. The fill comprises of variably compacted crushed dolerite around Chemical Plants 1 and 2, the dolerite is replaced with dolomite at the other sites. The thickness of the crushed material varies from 0.3 m dolomite at MP12 and MP14 to 1.3 m of dolerite at MP8. Beneath the rock fill there is a clay fill with some silt layers; this part of the fill is not present at sites MP12 and 13.

A shallow water table was encountered in the dolerite fill at MP8. The source of the water is probably a combination of direct rainfall and runoff from the surrounding paved areas and buildings. This was found to be uncontaminated.

While drilling MP10 the fill between 1.3 to 1.5 m below ground level there was an odour of contaminants but the sequence was not damp. In MP14 at 1.0 m below ground level water was struck at the base of the crushed dolomite fill. It was possible to obtain a water sample which contained

about 200 mg/ℓ of acetone and 65 mg/ℓ of THF (MP14 top). As both MP10 and MP14 are close to Chemical Plant 4 which has shallow drains (less than 1.4 m deep) it would appear likely that the source of contamination within the fill at these sites is solely from the shallow drains associated with Chemical Plant 4 and the north side of Chemical Plant 3.

The permeability of the more open textured crushed fill is higher than that of the silt layer. If an estimated permeability of only twice the silt is assumed then the groundwater velocity within the upper fill would be approximately 25 m/yr. This is about the distance to the fence from Chemical Plant 4. The reason no contamination was found at MP12 or in the holes dug close to the fence could be that the velocity figure is high, the contaminant plume passes between the holes or the contamination is infiltrating to a greater depth. The last possibility is the least likely of the three considering the presence of the lower fill and brown clay in boreholes MP7, 10, 12 and 14.

The eastward extent of the fill is not known but as dolomite is present in the trenches near the boundary fence it can be assumed to extend to the fence. The dolomite is underlain by 1.1 m of clay in MP12 which will restrict the downward movement of water; this will allow the creation of a separate shallow water table. The general movement of water within the crushed fill would then be expected to follow the surface topography and be parallel to the fence flowing towards the north east corner.

3.3 Contamination of the silt layer

The silt layer at the base of the brown till sequence was encountered in all the boreholes we drilled and is probably a continuous horizon. The thickness varies from 0.3 m in MP10 to 1.9 m in MP11 with an average thickness of about 0.5 m. The grey clay till, at least 2 m thick near the chemical plants, separates the silt layer from the underlying bedrock.

The silt layer is confined by the overlying brown till at all boreholes. At MP11 the rest water level is about at the junction of the lower fill and the silt. Moving towards the North Field the piezometric head increases until at MP6 it is over two metres above the top of the silt. The head differences in the overall sequence would result in upward

movement of water down dip as well as downward movement towards the bedrock if there is any vertical continuity. The clays above and below the silt layer would make this unlikely.

Water from the silt layer is unlikely to emerge at the surface. However there may be a preferential path along the line of the effluent drain as it passes down the slope north of Chemical Plant 4. Near MP7 the drain is about 3.3 m below ground level but at the trench dug near the effluent plant the top of the concrete surround was within the clay fill at about 0.5 m. A water sample taken from the trench contained some acetone but a sample taken the following day after heavy rain was uncontaminated.

The main area of pollution located is in the silt layer south of Chemical Plants 3 and 4, in boreholes MP8, MP11 and MP13. Using the permeability estimate of 0.1 m/d the contaminant plume would have an approximate velocity of 2 m/yr and would take about 15 years to cover the 30 metres to the nearest site boundary east of Chemical Plant 2. However no contaminant was found in any of the down dip boreholes stretching from MP9 in the south through MP10 to MP5 in the north.

If we assume an average thickness of 0.5 m for the silt layer and a quoted porosity for silt of 40% then the storage volume of silt beneath Chemical Plant 1 and 2 is 670 m^3 and beneath Chemical Plant 3 and 4 about 450 m^3. These figures represent the approximate maximum value of polluted groundwater in the silt layer present within the site if little or no lateral movement has taken place.

During drilling the underlaying grey till was logged as a stiff clay containing rock fragments. There was no indication of water ingress. The relatively low permeability of the clay will effectively prevent downward movement of water.

3.4 Contamination of the bedrock

Three deep boreholes were drilled to bedrock. These were MP1, east of the warehouse, MP4 in the North Field and MP14 east of Chemical Plant 4. The bedrock under most of the site are the mudstones penetrated in MP1, which were found to be dry. The sandstones, north of Chemical

Plants 3 and 4, were found to be dry in MP14 but water bearing in MP4. The depth at which water was struck in MP4 coincided with the top of the sandstone and as such seems to be associated with the bedrock rather than entering the borehole, through a leaking seal, from a higher horizon. No contamination in the bedrock was found but in order to investigate deeper into the sandstone different drilling techniques will have to be used.

3.5 Areas at risk from contamination

The risk of contamination of the crushed fill is greatly reduced if the shallow effluent drains lie in the lower fill which comprises mainly of clay. Similarly if the deeper drains are not in contact with, or in close proximity to, the silt layer, the risk of contamination is much less. Figure 9 shows those areas that we consider to be at the greatest risk of contamination from the effluent drians.

We have taken into account all the available lithological data to determine the areas at greatest risk. However, the variable thickness of the crushed fill and the variable depth and thickness of the silt layer make it impossible to accurately define the areas. We have chosen a value of 0.5 m as the maximum distance that leakage from a drain can cause contamination in the silt layer.

The source of contamination, at MP11, is the relatively shallow drains south of Chemical Plant 3 but because of the greater thickness of silt present at the site the contamination is present in the silt layer and not in the fill.

We have not attempted to show the extent of the contaminated areas because of the uncertainty of the groundwater velocities in the silts and fill. However, the map does show the areas which would allow effluent leaking from the drains to enter a relatively permeable water bearing horizon.

4. CONCLUSIONS

The recent survey has proved the presence of contamination by toxic organic chemicals in the deposits underlying the chemical plant area due to leakage from the effluent drain system. This has neither extended

beyond the immediate area of the chemical plants nor has it penetrated to the underlying bedrock. As such, the area contaminated is localised in extent and does not present any immediate threat to the area outside the Searle site; even though the contamination may have been taking place for up to 15 years.

The extent of the contamination beneath the chemical plant area has not yet been fully defined. Our work shows that the pollution occurs at two levels: in the fill beneath Chemical Plants 3 and 4 and in the silt layer beneath Chemical Plants 1 and 2 and between the chemical plants.

Contamination of the fill material is due to the shallow effluent drains associated with Chemical Plant 4 and the north side of Chemical Plant 3. A saturated zone in the fill has not developed due to the shorter period of leakage and the recent repairs to the shallow drains which suggests that the volume of effluent that has leaked is small.

The effluent drains beneath Chemical Plants 1 and 2 occur either close to the base of the lower fill or below it and consequently the more permeable upper fill has not been contaminated. Instead the drains are mainly either in contact with or in close proximity to the silt layer at the base of the brown till sequence. The risk of pollution northwards along the eastern side of Chemical Plant 4 from the drains is reduced due to the shallow slope of the drains compared to that of the silt layer. It is possible that water may follow a preferential path along the drains themselves. However trench samples taken, while perhaps not wholly representative, near the exit point of the drains close to the collector tank at the effluent plant do not suggest a preferential pathway.

The silt layer is saturated, confined and has a low permeability. The underlying grey till, with a much lower permeability, separates the silt from the bedrock. The contaminated area is underlain by mudstones rather than sandstones which further reduces the risk of deeper contamination. The contamination of the silt layer is still apparently restricted to the area of Chemical Plants 1 and 2 despite the probability that leakage has occurred from the drains associated with those plants since they were built over 15 years ago.

A thicker sequence of silt occurs near the cooling tower between Chemical Plants 1 and 3. The shallow drains, associated with Chemical

Plant 3, in this probably localised area, are in contact with the silts. As a result a recharge mound, not yet fully defined, appears to have developed. Since these silts are in hydraulic continuity with the main silt layer leakage from the shallow drains can be transmitted to the silt layer.

A contaminated area has also been identified just north of the effluent plant. This is caused by direct pollution from nearby stockpiles of road salt and/or leakage from the adjacent storm drain. Ask such this is considered to be a separate and less important problem than that associated with the chemical plant area. No toxic organic chemicals are associated with this pollution.

5. RECOMMENDATIONS

1. A network of observation wells has now been installed in the north eastern part of the site which can be used to monitor the contamination. We suggest that this network is supplemented by:

(a) three additional boreholes penetrating the grey till:
- close to the north side of Chemical Plant 3 where information is still lacking
- at the western end of Chemical Plant 3 to provide additional information on water level elevations and contamination. It would also extend our knowledge of the shallow silts encountered at MP11
- near the boundary fence east of Chemical Plant 2 to clarify the direction of groundwater flow in the silt layer.

(b) a series of shallow pits around the peripheral parts of the fill.

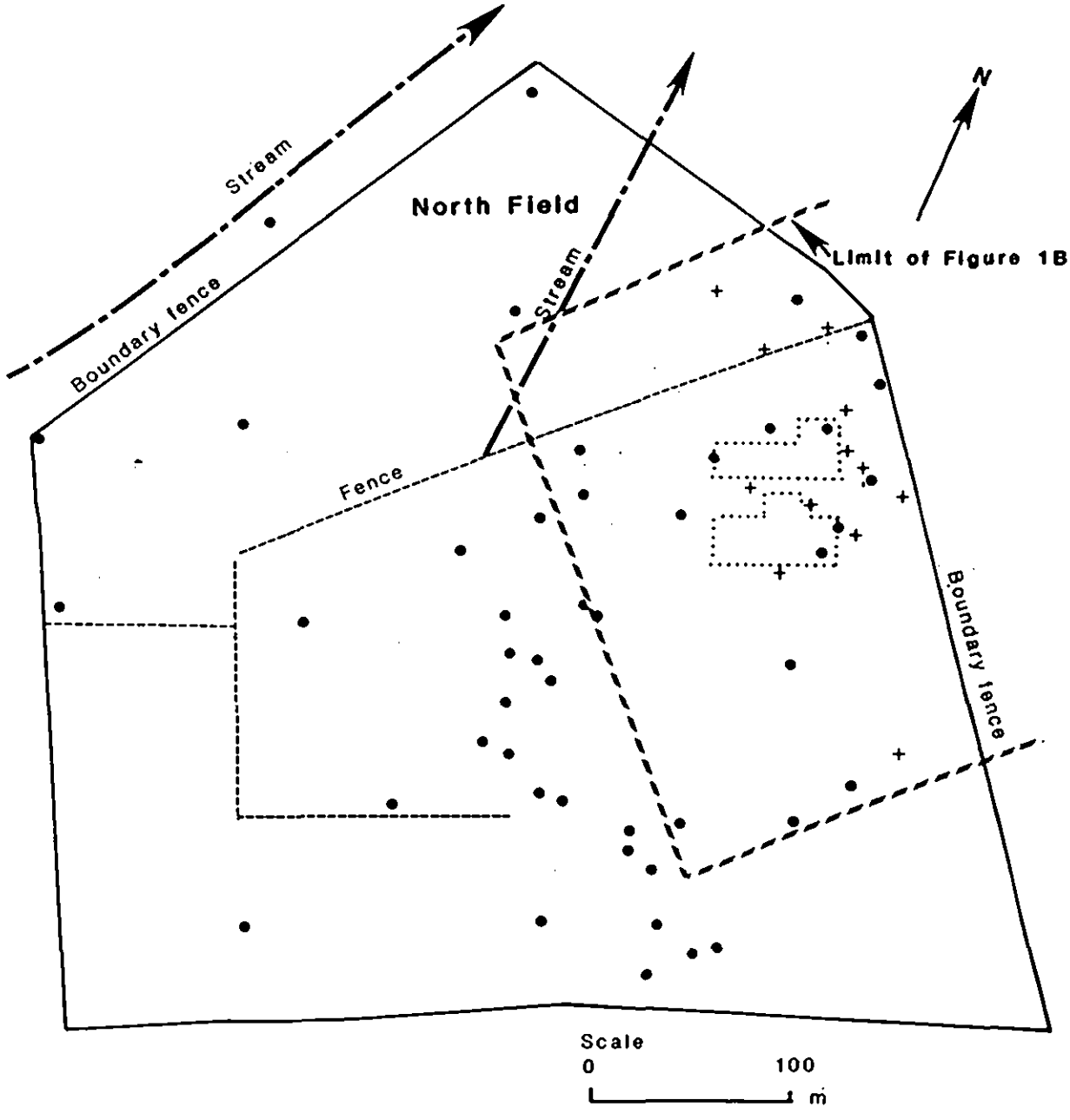
Routine measurements of water levels should be made at each site at fortnightly intervals for the next six months to indicate the response of the system to natural recharge as well as contaminant leakage. The monitoring requirements should be reviewed after three and six months of monitoring.

Water samples for organic analysis should be taken from the monitoring network, initially at monthly intervals, for the next six months. These would also include the two surface streams in and close to the North Field. All monitoring points which have concentrations of organic compounds of less than 1.0 mg/ℓ should be analysed, at least once, using a detection limit of 10 µg/ℓ.

2. Remedial measures should be implemented in order to ensure that the contaminants do not spread further. The highest concentrations of pollutants are found in the silt layer between the chemical plants. The clean up operations should commence with abstraction from the silt layer in that area.

3. The road salt should be stockpiled in such a way as to prevent further contamination of the area just north of the effluent plant. The stormwater drains in the same area should be inspected for possible leakage.

Location map



- Previous site investigation boreholes
+ I.H. boreholes

Chemical plants

Figure 1A

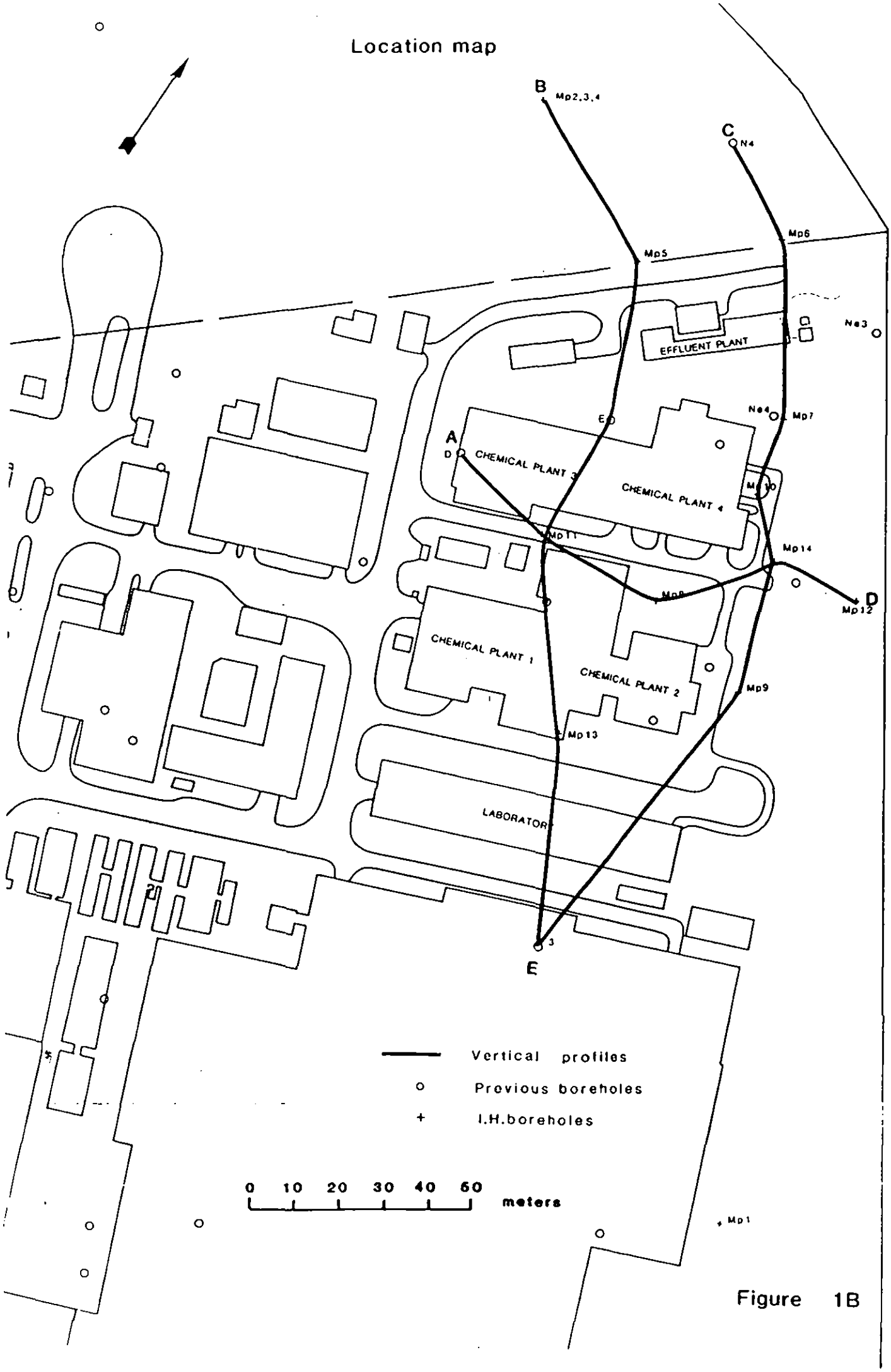
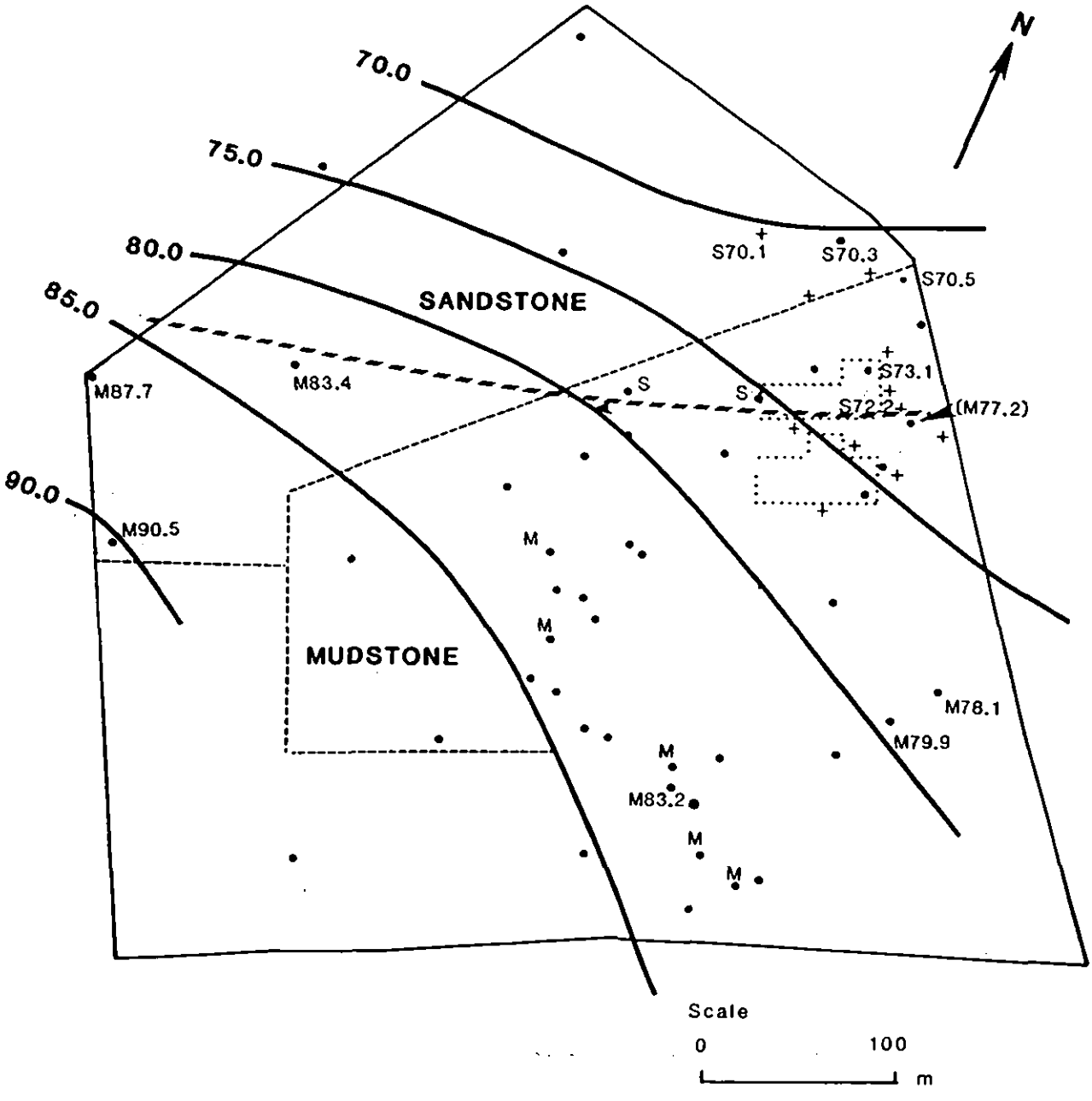

Location map
B
Mp2,3,4
C
N4
Mp6
Mp5
Ne3
EFFLUENT PLANT
Ne4
Mp7
A
D
CHEMICAL PLANT 3
CHEMICAL PLANT 4
Mp10
Mp11
Mp14
Mp8
D
Mp12
CHEMICAL PLANT 1
CHEMICAL PLANT 2
Mp9
Mp13
LABORATORY
3
E
Vertical profiles
Previous boreholes
I.H.boreholes
0 10 20 30 40 60
meters
Mp1

Figure 1B

Elevation of bedrock (m.O.D.)



M Mudstone

S Sandstone

• Previous boreholes

\+ I.H. boreholes

– – – – Sandstone / mudstone junction

Figure 2

Elevation of top of grey clay (m.O.D)

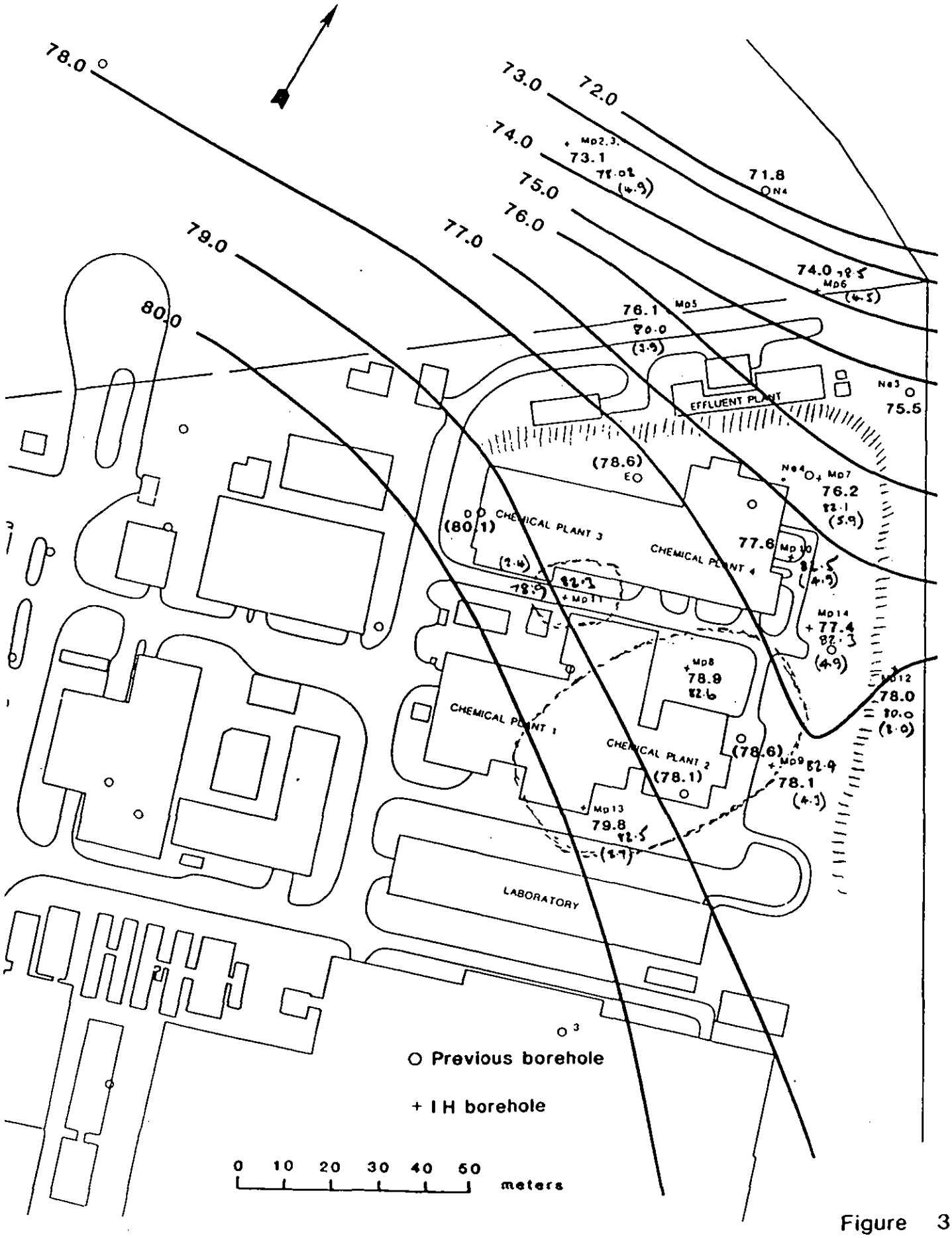


Figure 3

Geological cross section C-E

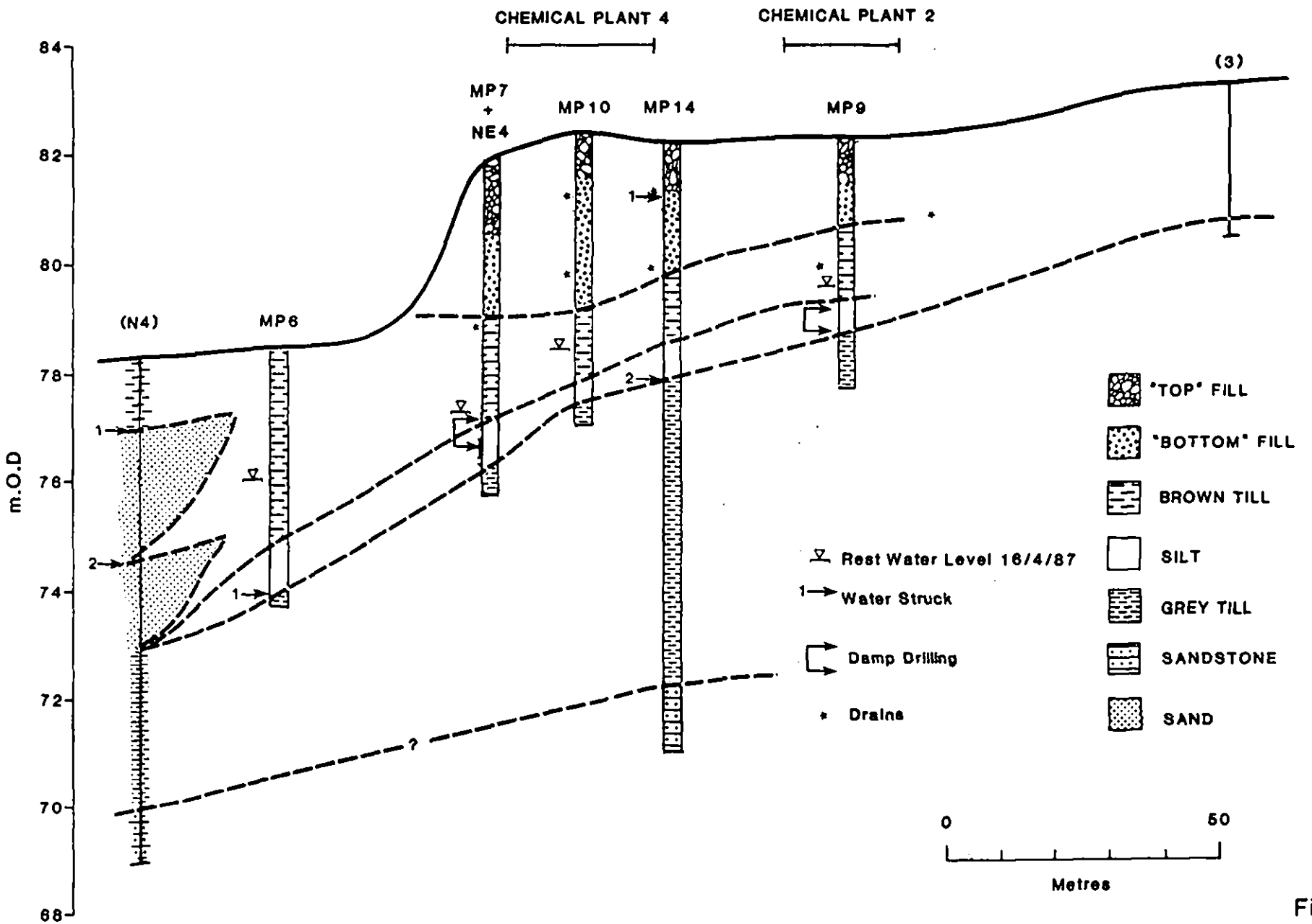


Figure 4

Geological cross section B-E

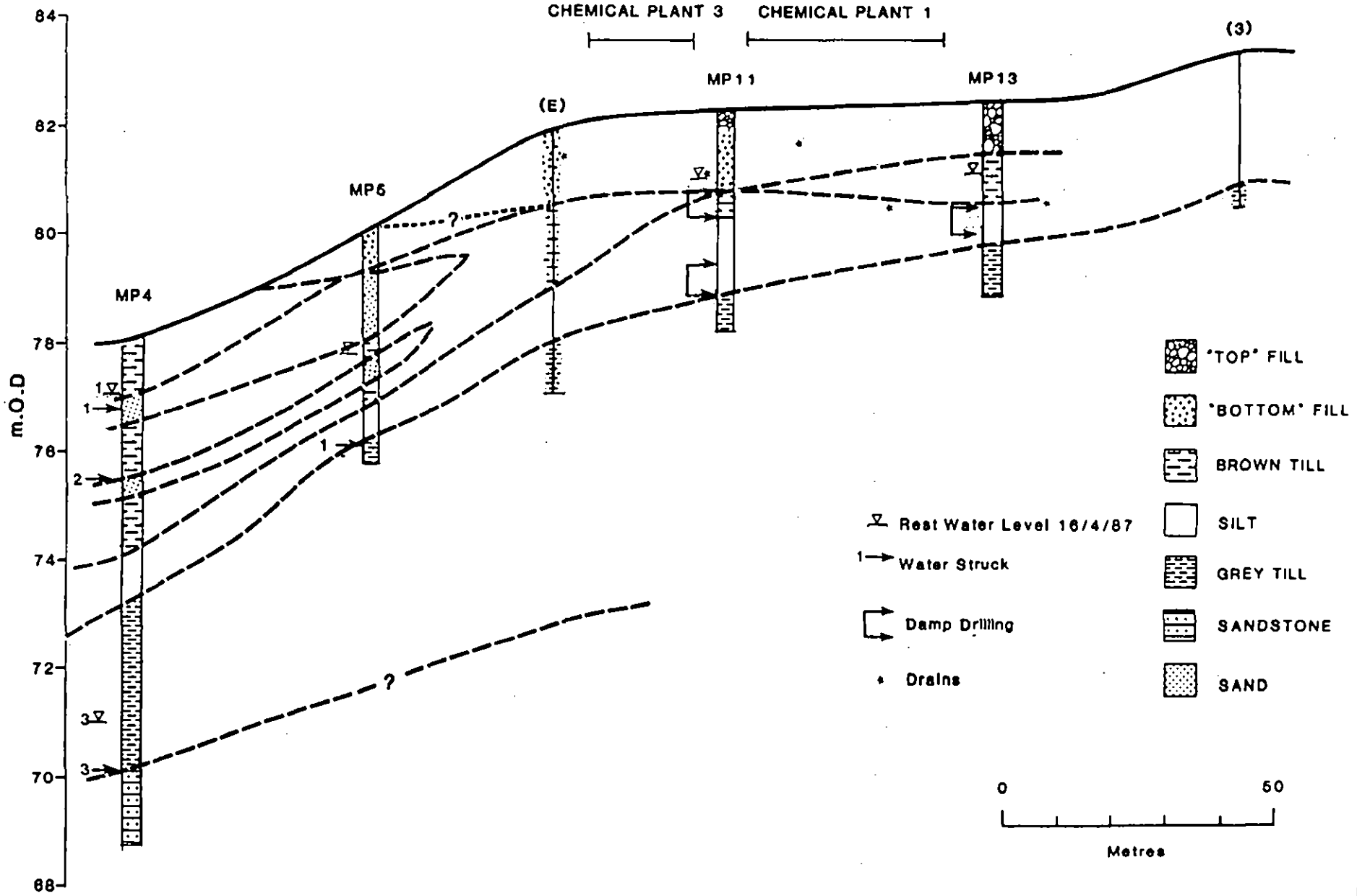


Figure 5

Geological cross section A–D

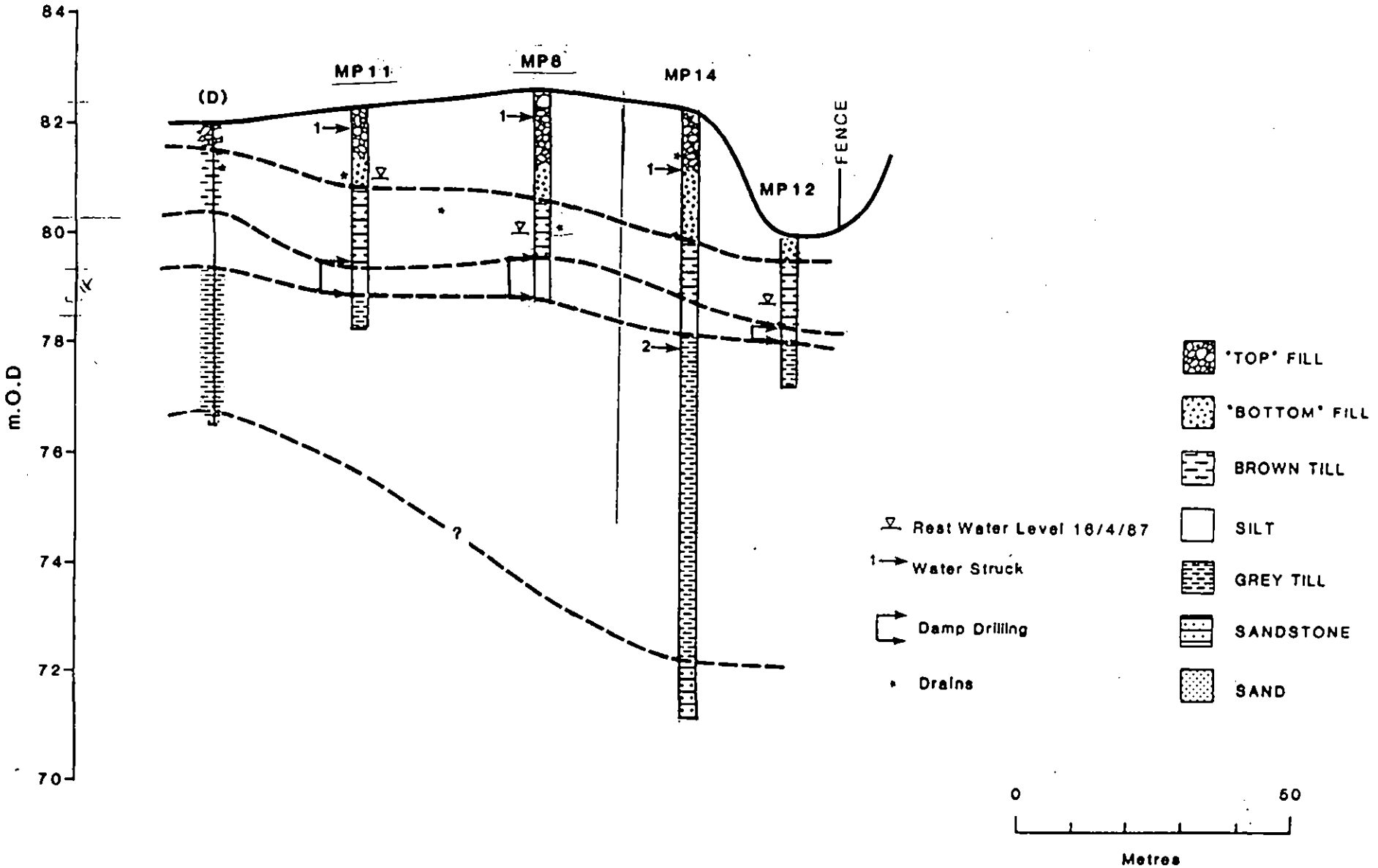


Figure 6

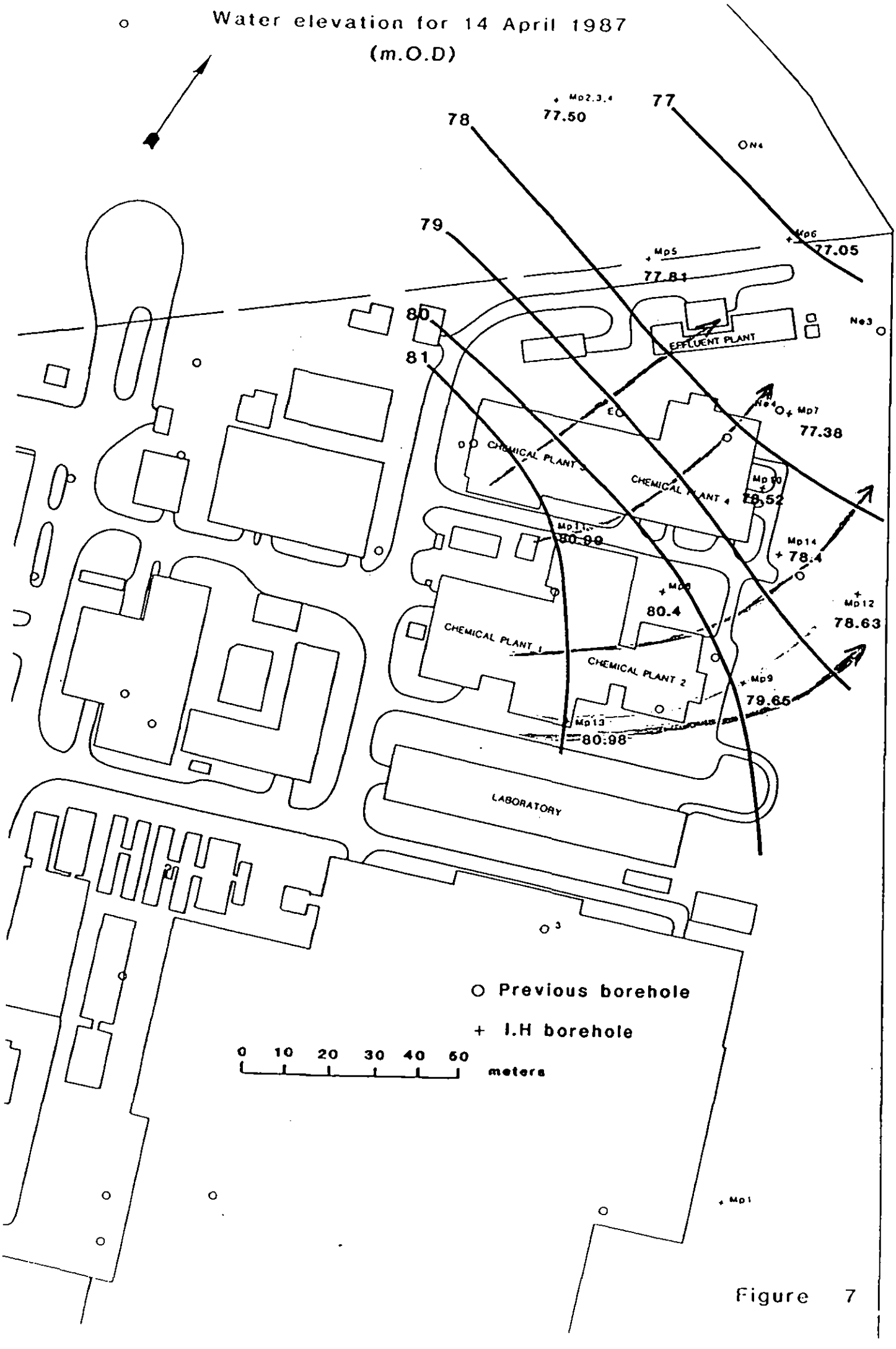

Water elevation for 14 April 1987
(m.O.D)
77
78
79
80
81
Md2.3.4
77.50
ON4
Md6
77.05
Md5
77.81
No3
EFFLUENT PLANT
No4
Md7
77.38
CHEMICAL PLANT 3
CHEMICAL PLANT 4
Md10
78.52
Md11
80.99
Md14
78.4
Md8
80.4
Md12
78.63
CHEMICAL PLANT 1
CHEMICAL PLANT 2
Md9
79.65
Md13
80.98
LABORATORY
Md1
O Previous borehole
+ I.H borehole
0 10 20 30 40 50
meters

Figure 7

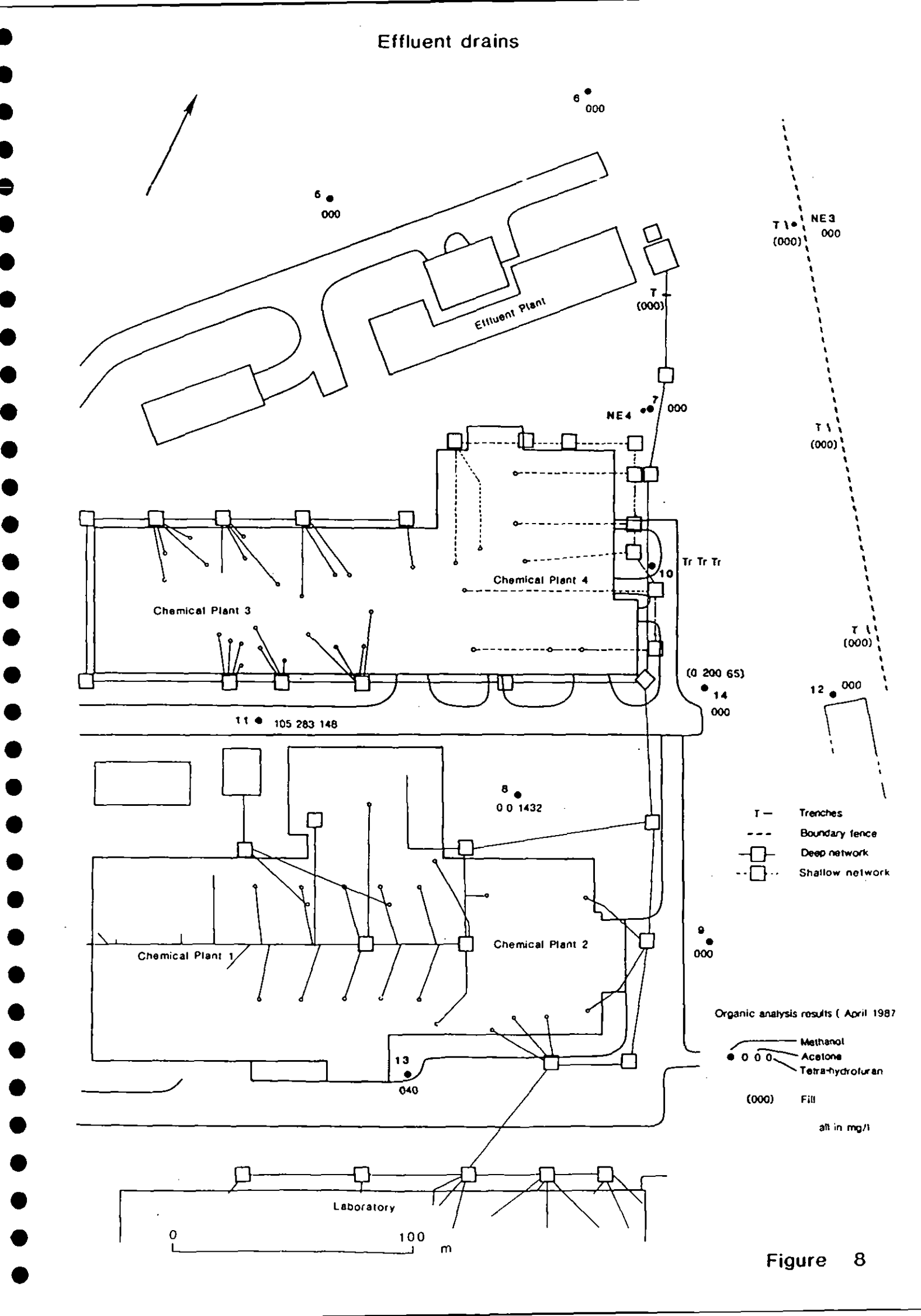

Effluent drains
6
000
6
000
Effluent Plant
T
(000)
T 1
(000)
NE3
000
NE4
7
000
T 1
(000)
Tr Tr Tr
10
Chemical Plant 4
Chemical Plant 3
T 1
(000)
(0 200 65)
14
000
12
000
11
105 283 148
8
0 0 1432
T — Trenches
Boundary fence
Deep network
Shallow network
Chemical Plant 1
Chemical Plant 2
9
000
Organic analysis results (April 1987
Methanol
0 0 0
Acetone
Tetra-hydrofuran
13
040
(000) Fill
all in mg/l
Laboratory
0
100
m

Figure 8

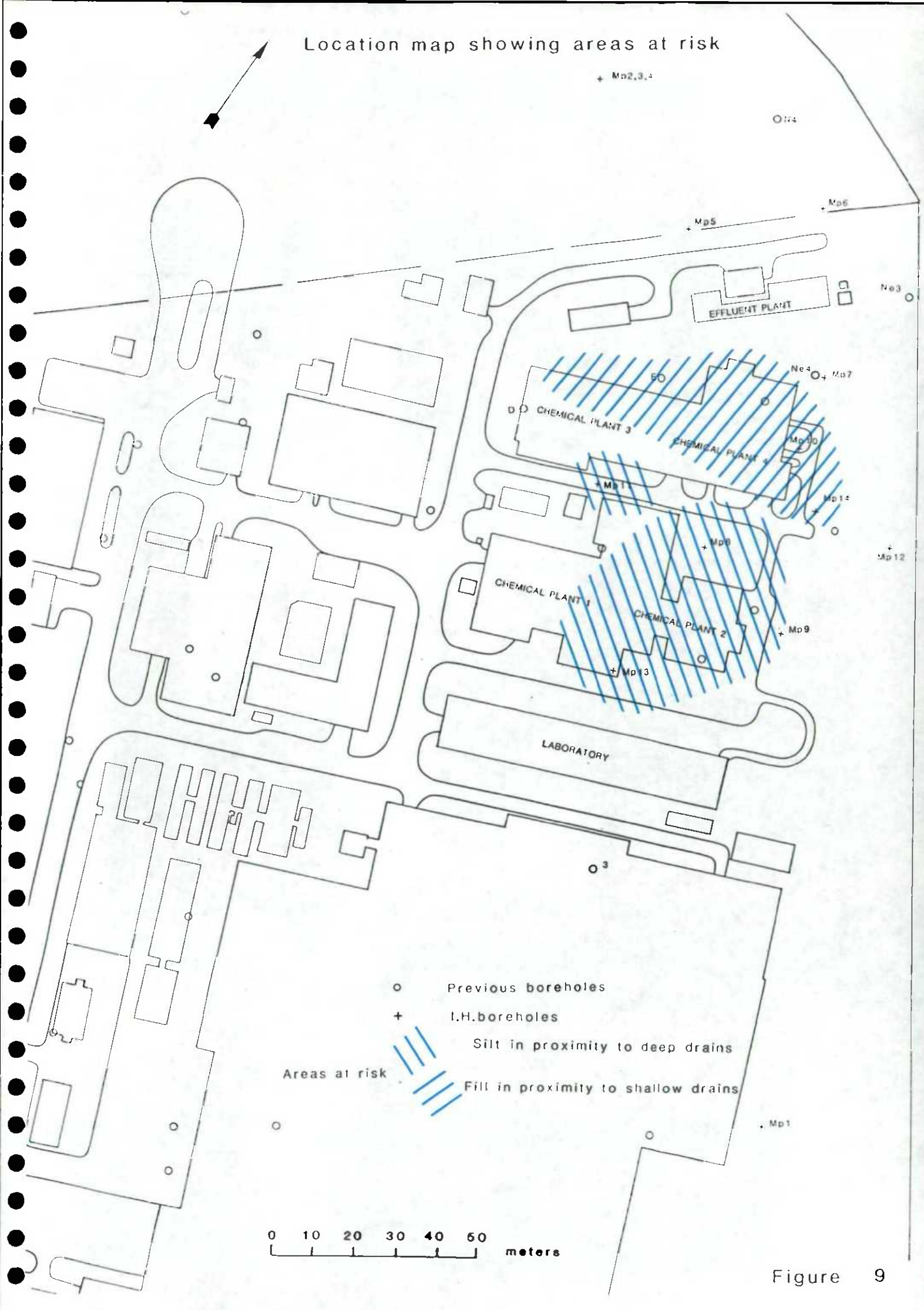

Location map showing areas at risk
Mp2,3,4
Mp5
Mp6
Ne3
EFFLUENT PLANT
Ne4
Mp7
CHEMICAL PLANT 3
CHEMICAL PLANT 4
Mp10
Mp11
Mp14
Mp8
Mp12
CHEMICAL PLANT 1
CHEMICAL PLANT 2
Mp9
Mp13
LABORATORY
Mp1
Previous boreholes
I.H.boreholes
Areas at risk
Silt in proximity to deep drains
Fill in proximity to shallow drains
0 10 20 30 40 60
meters

Figure 9

APPENDIX A

BOREHOLE LOGS

PROJECT: SEARLE

BOREHOLE NO: MP1

DRILLING METHOD - SHELL & AUGER
CROSS BLADED CLAY CUTTER FROM 0 M. TO 6.3 M.
SHELL & HAMMER FROM 6.8 M. TO 6.8 M.

LOCATION: MORPETH

G. REP.: .....

START DATE: 13/2/87

COMPLETION DATE: 18/2/87

CONTRACTOR: IH

WATER STRUCK. NOT STRUCK. M.BGL. ..... M.BGL.

ROSE TO. 5.55 (26/2/87) M.BGL. ..... M.BGL.

TOTAL DEPTH: 6.8 M.

CASING DIAMETER/TYPE:
..... MM FROM ..... M. TO ..... M., TYPE .....
..... MM FROM ..... M. TO ..... M., TYPE .....

DRILLED DIAMETER
200 MM. FROM 0 M. TO 6.8 M.
..... MM. FROM .... M. TO .... M.

SCREEN DIAMETER/TYPE:
..... MM FROM ..... M. TO ..... M; TYPE/SLOT(MM) .....
..... MM FROM ..... M. TO ..... M; TYPE/SLOT(MM) .....

DEPTH (M.BGL)	GRAIN SIZE ANALYSES (Sample No. and location)	SUMMARY OF AQUIFER CONDITIONS / LITHOLOGY	DEPTH (M.BGL)	BOREHOLE CONSTRUCTION (Casing/screen / gr. pack)	ELEVATION OF WATER M.AOD	DEPTH TO WATER M.BG L.	SYMBOLIC LOG	ELEVATION M. AOD	DEPTH M. BGL.	STRATIGRAPHIC UNITS
1	MP/1 0.0-1.0	ELEVATION OF TOP OF WOOD COVER AOD = 84.37 MADE GROUND (Clay with rubble fill)								
	MP/1 0.5-1.0									
	MP/1 1.5-2.0									
2	MP/1 2.0-2.5									
	MP/1 2.5-3.0									
3	MP/1 3.0-3.5							81.4	3.0	
		Firm, weathered, variegated yellowish brown (10YR5/8) and gray (10YR5/1) CLAY with occasional sandstone pebbles.						80.9	3.5	BOULDER CLAY

BOREHOLE NO. MP1

DEPTH (M. BGL)	GRAIN SIZE ANALYSES (Sample No. and location)			DEPTH (M. BGL)	BOREHOLE CONSTRUCTION (casing/screen/gr. pack)	ELEVATION OF WATER M. AOD	DEPTH TO WATER M. BGL	SYMBOLIC LOG	ELEVATION M. AOD	DEPTH M. BGL	STRATIGRAPHIC UNITS		
4	MP1/9 3.5-4.0		Firm, yellowish brown (10YR5/6) and greyish brown (2.5Y5/2) CLAY with small 0.01–0.02 m patches of grey muddy sand						80.4	4.0			
	MP1/10 4.0-4.5		Firm, greyish brown (2.5Y5/2) sandy CLAY with mainly sandstone pebbles, with some coal fragments and occasional dolerite and limestone pebbles						79.7	4.7			
5	MP1/10 4.5-5.0		Firm–stiff, ~~silty~~ greyish brown (2.5Y5/2) silty CLAY with some sandstone pebbles						79.4	5.0			
	MP1/11 5.0-5.5		Stiff, dark greyish-brown (2.5Y4/2) silty CLAY with some sandstone pebbles and occasional coal fragments			78.82 ▽	5.55 ▽		78.9	5.5	BOULDER CLAY		
6	MP1/12 5.5-6.0		Stiff, dark grey (5Y4/1) slightly sandy, silty CLAY with sandstone pebbles.										
	MP1/13 6.0-6.5								78.1	6.3			
	14		Hard, grey (N3) sandstone and limestone bandlets.						78.0	6.4			
	15		Medium weathered, very dark grey mudstone (N3)						77.9	6.5			
	16		Mod. weak, ~~gre~~ finely lam. grey (N5) mudstone						77.8	6.6			
	17		Mod. weak, black (N2) thickly lam. mudstone						77.6	6.8	COAL MEASURES		
7			End of borehole										

34, 26

PROJECT: SEAHLE

BOREHOLE NO: MP2

DRILLING METHOD SHELL&AUGER

CLAYCUTTER ..FROM 0..M. TO 2.6. M.

AUGER .....FROM 2.6.M. TO 3.6. M.

LOCATION

MORPETH

G. REP.:.....

START DATE: 18/2/87.

COMPLETION DATE: 20/2/87

CONTRACTOR IH

WATER STRUCK. ROSE TO.

1.2...M.BGL. SEALED OFF...M.BGL.

2.6...M.BGL. (26/2/87) 0.77..M.BGL.

TOTAL DEPTH: 3.6 M.

CASING DIAMETER/TYPE:

200.....MM FROM ....0..... M.TO..~~2.6~~ 1.7 M., TYPE 8" BSP WATER WELL .203 .057

50.....MM FROM ....0..... M.TO.....2.6 M., TYPE 2" BSP

DRILLED DIAMETER

200.....MM. FROM 0...M. TO 1.7. M.

150.....MM. FROM 1.7.M. TO 3.6 M.

SCREEN DIAMETER/TYPE:

50 MM FROM 2.6 M. TO 3.1 M: TYPE/SLOT(MM) 2" BSP (PERF) WITH 700 TERRAM

..... MM FROM ..... M. TO ..... M: TYPE/SLOT(MM) .....

SUMMARY OF AQUIFER CONDITIONS

HEIGHT OF 2" BSP ABOVE GROUND LEVEL = 0.70

" " 8" WATER WELL CASING ACL = 0.76

ELEVATION OF TOP OF 2" BSP AOD = 78.724

Elevation of gl = 78.02m OD

WL IN 2" BSP 10.30 ON 20/2/87 = 1.21 BGL

" " 8" " " " = 0.81 BGL.

DEPTH (M.BGL)	GRAIN SIZE ANALYSES (Sample No. and location)	LITHOLOGY	DEPTH (MBGL)	BOREHOLE CONSTRUCTION (Casing/screen/ gr. pack)	ELEVATION OF WATER M.AOD	DEPTH TO WATER M.BG L.	SYMBOLIC LOG	ELEVATION M. AOD	DEPTH M. BGL.	STRATIGRAPHIC UNITS
0	MP2/1 0-0.3	Soft, dark brown (10YR3/3) silty clay loam						77.7	0.3	TOP SOIL
1	MP2/2 0.3-1.0	Firm, variegated yellowish red (5YR5/8) and light brownish grey (10YR6/2) sandy silty CLAY with sandstone and quartzite pebbles and coal fragments			77.25 ▽	0.77 ▽		77.0	1.0	
	MP2/3 1.0-1.2	Soft-firm, yellowish brown (10YR5/4) silty CLAY becoming sandy with depth						76.8	1.2	
	MP2/4 1.2-1.5	Soft Loose, variegated grey (10YR5/1) and yellowish brown (10YR5/8) silty fine-medium quartz SAND						76.5	1.5	
2	MP2/5 1.5-2.3	Firm, greyish brown (2.5Y5/2) silty CLAY with occasional fine sandstone pebbles.	1.7					76.3	1.7	BOULDER CLAY.
	MP2/6 2.3-2.6	Firm to stiff, brown (7.5YR4/2) silty CLAY, becoming more pebbley with depth	2.6					75.4	2.6	
3	MP2/7 2.6-3.1	Dense, brown (7.5YR5/4) muddy, gravelly, fine-med quartz SAND with coarse coal sand fragments and coarse limestone and sandstone pebbles, becoming more gravelly towards base	3.1					74.9	3.1	
	MP2/8 3.1-3.3	Dense, brown (7.5YR5/4) muddy fine-med. quartz SAND	3.3					74.7	3.3	
	MP2/9 3.3-3.6	Soft-firm, greyish-brown (2.5Y5/2) CLAY End of borehole.						74.4	3.6	

PROJECT: SEALE

BOREHOLE NO: MP3

DRILLING METHOD SHELL&AUGER

CLAY CUTTER FROM 0 M. TO 2.2 M.

.....FROM ....M. TO ..... M.

LOCATION

MORPETH.

G. REF.:.....

START DATE: 26/2/87.

COMPLETION DATE: 20/2/97.

CONTRACTOR HA

WATER STRUCK. ROSE TO.

1.3 M.BGL. (26/2/87) 0.51 M.BGL.

.....M.BGL. .....M.BGL.

TOTAL DEPTH: 2.2 M.

CASING DIAMETER/TYPE:

200 MM FROM 0 M.TO 1.1 M., TYPE 8" WATER WELL .203

50 MM FROM 0 M.TO 1.25 M., TYPE 2" BSP

DRILLED DIAMETER

200 MM. FROM 0 M. TO 2.2 M.

.....MM. FROM ....M. TO .... M.

SCREEN DIAMETER/TYPE:

50 MM FROM 1.25 M. TO 1.75 M: TYPE/SLOT(MM) 2" BSP PERF .051 NOT TO TERRAM.

..... MM FROM ..... M. TO ..... M: TYPE/SLOT(MM) .....

SUMMARY OF AQUIFER CONDITIONS

HEIGHT of 2" BSP AGL = 1.0

" " 8" WATER WELL CASING AGL = 0.50

ELEVATION OF TOP of 2" BSP AOD = 79.02

Elevation of gl = 78.02 m OD

WL in 2" BSP 15.30 on 20/2/87 = 0.84 BGL

DEPTH (M.BGL)	GRAIN SIZE ANALYSES (Sample No. and location)	LITHOLOGY	DEPTH (MGL)	BOREHOLE CONSTRUCTION (Casing/screen/gr. pack)	ELEVATION OF WATER M.AOD	DEPTH TO WATER M.BG.L.	SYMBOLIC LOG	ELEVATION M. ADD	DEPTH M. BGL.	STRATIGRAPHIC UNITS
		As MP2.						77.7	0.3	Soil
1		As MP2			77.51 ▽	0.51 ▽				
			1.25					76.7	1.3	
		As MP2						76.3	1.7	
2			1.75					75.8	2.2	
		End of borehole.								

PROJECT: SEALE

BOREHOLE NO: MP4

DRILLING METHOD SHELL & AUGER

CRM RAISED CLAYCUTTER FROM 0 M. TO 2.6 M.

BAILER FROM 2.6 M. TO 3.5 M.

CLAYCUTTER 3.5 7.9

BAILER WATER STRUCK. 7.9 9.2 ROSE TO.

1.0 M.BGL. 11.14 - 21/2/87 1.07 M.BGL.

2.6 M.BGL. 24/2/87 7.74 M.BGL.

TOTAL DEPTH: 9.2 M.

LOCATION: MORPETH.

C. REP.:

START DATE: 20/2/87

COMPLETION DATE: 22/2/87.

CONTRACTOR IH

CASING DIAMETER/TYPE:

250 MM FROM 0 M. TO 1.7 M., TYPE 10" WATER WELL CASING .254

200 MM FROM 0 M. TO 6.25 M., TYPE 8" " .203

DRILLED DIAMETER

250 MM. FROM 0 M. TO 2.6 M.

200 MM. FROM 2.6 M. TO 3.5 M.

SCREEN DIAMETER/TYPE:

50 MM FROM 8.65 M. TO 9.15 M; TYPE/SLOT(MM) 2" BSP .051

..... MM FROM ..... M. TO ..... M; TYPE/SLOT(MM) .....

SUMMARY OF AQUIFER CONDITIONS

HEIGHT OF 2" BSP AGL = 1.14
HEIGHT OF 8" WATER WELL CASING = 0.6
HEIGHT OF 10" WATER WELL CASING = 0.6
ELEVATION OF TOP OF 2" BSP AOD = 79.157

Elevation of gl = 78.02 m OD

DEPTH (M.BGL)	GRAIN SIZE ANALYSES (Sample No. and location)	LITHOLOGY	DEPTH (M GL)	BOREHOLE CONSTRUCTION (Casing/screen gr. pack)	ELEVATION OF WATER M.AOD	DEPTH TO WATER M.BG L.	SYMBOLIC LOG	ELEVATION M. A.O.D	DEPTH M. BGL.	STRATIGRAPHIC UNITS
		As MP2.						77.7	0.3	
		Sandy CLAY (As MP2)								
1		CLAY. (As MP2).						77.1	0.9	
								77.0	1.0	
		SAND (As MP2)						76.5	1.5	
2		CLAY (As MP2)	1.7							
								75.4	2.6	
3		SAND (As MP2)						75.0	3.0	
	MP4/1 3.0-3.9	Soft to firm, dark grey (N4) very silty CLAY with sandstone, and limestone pebbles and coal fragments.								

BOREHOLE NO. MP4

DEPTH (M.BGL)	GRAIN SIZE ANALYSES (Sample No. and location)			DEPTH (M. BGL)	BOREHOLE CONSTRUCTION (casing/screen/gr. pack.)	ELEVATION OF WATER M. AOD	DEPTH TO WATER M. BGL	SYMBOLIC LOG	ELEVATION M. AOD	DEPTH M. BGL	STRATIGRAPHIC UNITS
4	MP4/1 3.8-4.0		Soft dark greyish brown (2.5Y4/2) muddy, fine-med sand with some gravel						74.2	3.8	
	MP4/2 4.0-4.2		Soft-firm, dark grey (N4) clayey SILT with silty clay laminae.						74.1	3.9	
	MP4/3 4.2-4.3		Soft, olive yellow (2.5Y6/6) very silty fine-med SAND with dark grey (N4) clay laminae.						73.9	4.1	
	MP4/4 4.3-4.9		Soft, dark grey (10YR4/1) clayey SILT with sand laminae and occasional dolerite and limestone pebbles.						73.7	4.3	
5	MP4/5 4.9-5.9		Stiff, very dark grey (N3) silty CLAY with sandstone and limestone pebbles						73.1	4.9	
6	MP4/6 5.9-6.8		Firm, very dark grey (N3) very silty CLAY with limestone and sandstone pebbles						72.1	5.9	
7	MP4/7 6.8-7.5		Stiff, very dark grey (N3) silty CLAY with mainly weak yellow (10YR8/8) fine-coarse gritstone pebbles.			70.83	7.19		71.2	6.8	BOULDER CLAY
	MP4/8 7.5-7.9		Stiff, dark brown (7.5YR4/4) silty CLAY with reddish yellow (7.5YR7/8) sandstone pebbles						70.5	7.5	
8	MP4/9 7.9-8.1		Mod. strong, yellow (10YR7/6) med-coarse SANDSTONE						70.1	7.9	
	MP4/10 8.1-8.6		Weak, weathered yellowish brown (10YR5/4) SANDSTONE						69.9	8.1	
	MP4/11 8.6-9.2		Mod weak, weathered, brownish yellow (10YR6/8) SANDSTONE						69.4	8.6	MILLSTONE GRIT
9			End of borehole (9.2)						68.8	9.2	

PROJECT: SEARLE

BOREHOLE NO: MP5

DRILLING METHOD SHELL&AUGER

CLAYCUTTER ..... FROM 0.0 M. TO 4.1 M.

..... FROM .... M. TO ..... M.

LOCATION

MORPETH

G. REF.: .....

START DATE: 23/2/87

COMPLETION DATE: 23/2/87

CONTRACTOR IH

WATER STRUCK. ROSE TO.

3.9 M.BGL. (25/2/87) 2.40 M.BGL.

..... M.BGL. ..... M.BGL.

TOTAL DEPTH: 4.1 M.

CASING DIAMETER/TYPE:

200 MM FROM 0 M. TO 1.7 M., TYPE 8" WATER WELL CASING

50 MM FROM 0 M. TO 3.6 M., TYPE 2" BSP

DRILLED DIAMETER

200 MM. FROM 0 M. TO 4.1 M.

..... MM. FROM .... M. TO .... M.

SCREEN DIAMETER/TYPE:

50 MM FROM 3.6 M. TO 4.1 M; TYPE/SLOT(MM) 2" BSP PERF WITH TERRAM .051

..... MM FROM ..... M. TO ..... M; TYPE/SLOT(MM) .....

SUMMARY OF AQUIFER CONDITIONS:

Elevation of gl = 79.96m OD
ELEVATION OF TOP OF 2" BSP AOD = 80.709
TOP OF 8" CASING = 0.05 AGL
TOP OF 2" BSP ← 0.75 AGL.

DEPTH (M.BGL)	GRAIN SIZE ANALYSES (Sample No. and location)	LITHOLOGY	DEPTH (MBGL)	BOREHOLE CONSTRUCTION (Casing/screen / gr. pack)	ELEVATION OF WATER M.AOD	DEPTH TO WATER M.BG L.	SYMBOLIC LOG	ELEVATION M. AOD	DEPTH M. BGL.	STRATIGRAPHIC UNITS
0		Made Ground						79.3	0.7	
1	MP5/1 0.9–1.2	Loose, yellowish red (5YR5/8) silty fine SAND						78.8	1.2	
2	MP5/2 1.2–2.0	Loose, reddish yellow (7.5YR6/8) silty fine SAND	1.7					78.0	2.0	
	MP5/3 2.0–2.4	Soft, brown, (7.5YR5/2) thinly laminated sandy clayey SILT			77.56	2.40		77.6	2.4	
	MP5/4 2.4–2.7	Loose, strong brown (7.5YR5/6) silty fine SAND						77.3	2.7	
	MP5/5 2.7–3.6	Soft, dark greyish brown (10YR4/2) very clayey sandy SILT	3.6					76.4	3.6	BOULDER CLAY

BOREHOLE NO. MP 5.

DEPTH (M. BGL)	GRAIN SIZE ANALYSES (Sample No. and location)			DEPTH (M. BGL)	BOREHOLE CONSTRUCTION (casing/screen/gr. pack)	ELEVATION OF WATER M. AOD	DEPTH TO WATER M. BGL	SYMBOLIC LOG	ELEVATION M. AOD	DEPTH M. BGL	STRATIGRAPHIC UNITS		
4	MP2 3.8-3.9		Loose, light olive brown (2.5Y5/4) very silty fine SAND						76.1	3.9			
			Stiff, dark grey (N4) very silty CLAY with sandstone and limestone pebbles.	4.1					75.9	4.1			
			End of borehole.										

PROJECT: SEARLE

BOREHOLE NO: MP6

DRILLING METHOD SHELL&AUGER

CLAY CUTTER FROM 0 M. TO 4.5 M.

BAILER FROM 4.5 M. TO 4.7 M.

LOCATION

MORPETH

G. REP.:

START DATE: 23/2/87

COMPLETION DATE: 24/2/87

CONTRACTOR IH

WATER STRUCK. ROSE TO.

4.5 M.BGL. (25/2/87) 1.65 M.BGL.

.....M.BGL. .....M.BGL.

TOTAL DEPTH: 4.7 M.

CASING DIAMETER/TYPE:

.200 MM FROM 0 M. TO 1.6 M., TYPE 8" .203 NAT. WELL CASING

50 MM FROM 0 M. TO 4.2 M., TYPE 2" BSP

DRILLED DIAMETER

.200 MM. FROM .0 M. TO 4.5 M.

.150 MM. FROM 4.5 M. TO 4.7 M.

SCREEN DIAMETER/TYPE:

.50 MM FROM 4.2 M. TO 4.7 M; TYPE/SLOT(MM) 2" BSP PEFC WITH SCREEN .051

..... MM FROM ..... M. TO ..... M; TYPE/SLOT(MM) .....

SUMMARY OF AQUIFER CONDITIONS

Elevation_gl = 78.53 mOD

ELEVATION OF TOP OF 2" BSP AOD = 78.648

TOP OF 8" CASING = 0.12 AGL

TOP OF 2" BSP = 0.12 AGL

DEPTH (M.BGL)	GRAIN SIZE ANALYSES (Sample No. and location)	LITHOLOGY	DEPTH (MBGL)	BOREHOLE CONSTRUCTION (Casing/screen / gr. pack)	ELEVATION OF WATER M.AOD	DEPTH TO WATER M.BG L.	SYMBOLIC LOG	ELEVATION M. AOD	DEPTH M. BGL.	STRATIGRAPHIC UNITS
		Topsoil						78.2	0.3	
1	MP6/1 0.3-0.9	Stiff, strong brown (7.5YR5/6) silty CLAY with sandstone and limestone pebbles and coal fragments						77.6	0.9	
	MP6/2 0.9-1.3	As above becoming strong brown (7.5YR4/6)						77.2	1.3	
	MP6/3 1.3-1.8	Stiff, brown (7.5YR 4/2) CLAY			76.88	1.65		76.7	1.8	
2	MP6/4 1.8-2.5	As above, with some sandstone pebbles and coal fragments.						76.0	2.5	BOULDER CLAY
3	MP6/5 2.5-3.0	Firm, dark grey (N4) silty CLAY						75.5	3.0	
	MP6/6 3.0-3.6	Soft, dark grey (N4) very silty CLAY with occasional sandstone pebbles						74.9	3.6	

BOREHOLE NO. MP6

DEPTH (M. BGL)	GRAIN SIZE ANALYSES (Sample No. and location)			DEPTH (M. BGL)	BOREHOLE CONSTRUCTION (casing/screen/gr. pack)	ELEVATION OF WATER M. AOD	DEPTH TO WATER M. BGL	SYMBOLIC LOG	ELEVATION M. AOD	DEPTH M. BGL	STRATIGRAPHIC UNITS		
4	MP6 3.5-4.5		Soft, dark greyish brown (2.5Y4/2) clayey SILT	4.2					74.0	4.5			
	MP6 4.5-4.7		stiff, dark grey (N4) sandy CLAY.	4.7					73.8	4.7			
5			End of borehole										

PROJECT: SEARLE

BOREHOLE NO: MP7

DRILLING METHOD: HEAD & AUGER

CUTTER FROM 0 M. TO 0.67 (2.14) M. (6.3)

CHISELLING FROM 0.6 M. TO 1.5 M.

LOCATION: MORPETH.

G. REP.:

START DATE: 24/2/87.

COMPLETION DATE: 24/2/87

CONTRACTOR: H.

WATER STRUCK. ROSE TO.

DAMP. 4.8-5.3. (25/2/87) 5.77 M.BGL.

M.BGL. M.BGL.

M.BGL. M.BGL.

CASING DIAMETER/TYPE:

.200 MM FROM 0 M. TO 1.6 M., TYPE 8" WATER WELL CASING (.05)

50 MM FROM 0 M. TO 5.8 M., TYPE 2" BSP

TOTAL DEPTH: 6.3 M.

DRILLED DIAMETER

200 MM. FROM 0 M. TO 6.3 M.

MM. FROM M. TO M.

SCREEN DIAMETER/TYPE:

50 MM FROM 5.8 M. TO 6.3 M; TYPE/SLOT(MM) 2" BSP PERF (.05) & 1/2" PERFATEX.

MM FROM M. TO M: TYPE/SLOT(MM)

SUMMARY OF AQUIFER CONDITIONS

HEIGHT OF 2" BSP ACIL = 0.83

ELEVATION OF TOP OF 2" BSP = 82.936.

Elevation of gl = 82.11 - OD

DEPTH (M.BGL)	GRAIN SIZE ANALYSES (Sample No. and location)	LITHOLOGY	DEPTH (MBGL)	BOREHOLE CONSTRUCTION (Casing/screen / gr. pack)	ELEVATION OF WATER M.AOD	DEPTH TO WATER M.BG L.	SYMBOLIC LOG	ELEVATION M. AOD	DEPTH M. BGL.	STRATIGRAPHIC UNITS
		Topsoil								
1	MP7/1 0.2-0.6	Made Ground (Soft-firm, very dark grayish brown very silty CLAY)						81.5	0.6	
	MP7/2 0.6-1.4	Made Ground (Strong, very pale yellow (10YR7/4) crushed dolomite)						80.7	1.4	
2	MP7/3 1.4-2.2	Made Ground (Firm, very dark grey (N3) very silty CLAY)	1.6					79.9	2.2	
	MP7/4 2.2-3.0	Made Ground (Soft, very dark grey (N3) very clay SILT)						79.0	3.1	
3	MP7/5 3.1-4.0	Firm, yellowish red (5YR5/8) silty CLAY with grey (N6) mottles.								

BOREHOLE NO. MP7

DEPTH (M.BGL)	GRAIN SIZE ANALYSES (Sample No. and location)			DEPTH (M. BGL)	BOREHOLE CONSTRUCTION (casing/screen/gr. pack)	ELEVATION OF WATER M. AOD	DEPTH TO WATER M. BGL	SYMBOLIC LOG	ELEVATION M. AOD	DEPTH M. BGL	STRATIGRAPHIC UNITS
4	MP7/6 4.1-4.5		Soft-firm, dark brown (7.5YR 4/2) CLAY						78.1	4.0	
									77.3	4.8	
5	MP7/7 4.8-5.2		Soft dark greyish brown (2.5Y 4/2) sandy clayey SILT						76.8	5.3	
	5.5-5.6		Soft-firm very dark grey (N4) very silty CLAY						76.7	5.4	
	MP7/9 5.4-5.9		Soft, dark greyish brown (2.5Y 4/2) sandy clayey SILT			76.24 ▽	5.27 ▽		76.2	5.9	
6	MP7/10 5.9-6.3		Stiff, very dark grey (N3) sandy very silty CLAY. End of borehole.						75.8	6.3	

PROJECT: SEARLE

BOREHOLE NO: MP9

DRILLING METHOD SHELL & HAMMER / CRAB BLADED CLAY CUTTER

SHELL & HAMMER FROM .?..M. TO 2.5.. M.

CRAB BLADED CLAY CUTTER FROM ....M. TO ..... M. /

LOCATION: MORPETH

G. REP.: .....

START DATE: 26/2/87

COMPLETION DATE: 26/2/87

CONTRACTOR 14

WATER STRUCK. ROSE TO.

0.5 M.BGL. 0.5 M.BGL.

damp 3.0-3.7M.BGL. (26/2/86) 3.13 M.BGL.

TOTAL DEPTH: 3.9 M.

CASING DIAMETER/TYPE: .203

200 MM FROM 0 M. TO 2.3 M., TYPE 8" WATER WELL

50 MM FROM 0 M. TO 3.1 M., TYPE 2" BSP

DRILLED DIAMETER

200 MM. FROM 0 M. TO 3.9 M.

..... MM. FROM .... M. TO .... M.

SCREEN DIAMETER/TYPE: .051

50 MM FROM 3.15 M. TO 3.65 M; TYPE/SLOT(MM) 2" BSP PERF WITH TERRAM

..... MM FROM ..... M. TO ..... M; TYPE/SLOT(MM) .....

SUMMARY OF AQUIFER CONDITIONS

HEIGHT OF 2" BSP AGL = 0.26

HEIGHT OF 8" WATERWELL CASING AGL = 0.20

ELEVATION OF TOP OF 2" BSP AOD = 82.82

Elevation of GL = 82.56 m OD

DEPTH (M.BGL)	GRAIN SIZE ANALYSES (Sample No. and location)		LITHOLOGY	DEPTH (MBGL)	BOREHOLE CONSTRUCTION (Casing/screen / gr. pack)	ELEVATION OF WATER M.AOD	DEPTH TO WATER M.BG.L.	SYMBOLIC LOG	ELEVATION M. AOD	DEPTH M. BGL.	STRATIGRAPHIC UNITS
			Top soil						82.4	0.2	
1	MP9/1 0.2-0.5		Made round. (crushed dolerite).								
2	MP9/2 1.5-2.0		Made Ground (firm, greyish brown (2.5Y5/2) silty CLAY and crushed dolerite)						81.1	1.5	
									80.6	2.0	
	MP9/3 2.0-2.5		Stiff, brown (7.5YR5/4) and grey (N5) mottled silty CLAY with sandstone pebbles	2.3					80.1	2.5	Boulder Clay
3	MP9/4 2.5-3.0		Soft-firm, olive grey (5Y5/2) very silty CLAY						79.6	3.0	
	MP9/5 3.0-3.5		Soft, olive (5Y4/3) sandy clayey SILT with acetone odour	3.5		79.46 ▽	3.13 ▽				

BOREHOLE NO. MP8

DEPTH (M. BGL)	GRAIN SIZE ANALYSES (Sample No. and location)			DEPTH (M. BGL)	BOREHOLE CONSTRUCTION (casing/screen/gr. pack)	ELEVATION OF WATER M. AOD	DEPTH TO WATER M. BGL	SYMBOLIC LOG	ELEVATION M. AOD	DEPTH M. BGL	STRATIGRAPHIC UNITS		
									78.9	3.7			
3.7	MP8/6 3.7-3.9		Firm, dark grey (5Y4/1) and yellowish brown (10YR5/6) very clayey SILT						78.7	3.9			
			End of borehole										

PROJECT: SEARLE

BOREHOLE NO: MP9

DRILLING METHOD SHELL & AUGER

SHELL HAMMER FROM 0 M. TO 1.0 M.

CRM GRADED CLAY/GRAVEL FROM 1.0 M. TO 4.6 M.

LOCATION: MORPETH

G. REF.:

START DATE: 3/4/87

COMPLETION DATE: 3/4/87

CONTRACTOR IH

WATER STRUCK. DAMP 3.3-3.7 M.BGL. ROSE TO 2.71 (14/4/87) M.BGL.

3.9 M.BGL. ROSE TO 2.71 (14/4/87) M.BGL.

CASING DIAMETER/TYPE: .200

200 MM FROM 0 M. TO 1.7 M., TYPE 8" WATER WELL CASING

50 MM FROM 0 M. TO 3.15 M., TYPE 2" BSP

TOTAL DEPTH: 4.6 M.

DRILLED DIAMETER

200 MM. FROM 0 M. TO 4.6 M.

MM. FROM M. TO M.

SCREEN DIAMETER/TYPE: .051

50 MM FROM 3.15 M. TO 3.65 M; TYPE/SLOT(MM) 2" BSP PERF WITH TERRAM

MM FROM M. TO M; TYPE/SLOT(MM)

SUMMARY OF AQUIFER CONDITIONS

HEIGHT OF 2" BSP AGL = 1.20

HEIGHT OF 8" WATERWELL CASING BGL = 0.04

ELEVATION OF 2" BSP AOD = 83.56

ELEVATION OF GROUND LEVEL = 82.36

DEPTH (M.BGL)	GRAIN SIZE ANALYSES (Sample No. and location)	LITHOLOGY	DEPTH (MBGL)	BOREHOLE CONSTRUCTION (Casing/screen / gr. pack)	ELEVATION OF WATER M.AOD	DEPTH TO WATER M.BG L.	SYMBOLIC LOG	ELEVATION M. AOD	DEPTH M. BGL.	STRATIGRAPHIC UNITS
		Topsoil						82.3	0.1	
1	MP9/1 0.1-0.9	Made Ground (Crushed dolerite)						81.5	0.9	
	MP9/2 0.9-1.7	Made Ground (Firm, dark yellowish brown (10YR4/6) silty CLAY with limestone, brick and coal fragments	1.7					80.7	1.7	
2	MP9/3 1.7-2.2	Firm, very dark grey (5Y3/1) clayey SILT with limestone pebbles						80.2	2.2	
	MP9/4 2.2-2.4	Firm, variegated, yellowish brown (10YR5/6) sandy very silty CLAY with pink sandstone pebbles and coal.						80.0	2.4	
3	MP9/5 2.4-3.1	Soft-Firm, laminated, variegated, dark yellowish brown (10YR4/4) very clayey SILT with pink streaks and sandstone & limestone pebbles and coal fragments			79.65 ▽	2.71 ▽		79.3	3.1	Boulder Clay
	MP9/6 3.1-3.3	Soft, dark greyish brown (2.5Y4/2) clayey SILT	3.15					79.1	3.3	
	MP9/7 3.3-3.7	Soft, olive grey (5Y4/2) clayey SILT								

BOREHOLE NO. MP9

DEPTH (M.BGL)	GRAIN SIZE ANALYSES (Sample No. and location)			DEPTH (M. BGL)	BOREHOLE CONSTRUCTION (casing/screen/gr. pack)	ELEVATION OF WATER M. AOD	DEPTH TO WATER M. BGL	SYMBOLIC LOG	ELEVATION M. AOD	DEPTH M. BGL	STRATIGRAPHIC UNITS		
	MP9/P 3.7-4.1		Firm, dark greyish brown (2.5Y4/2) clayey SILT with olive yellow (2.5Y6/6) silty SAND pockets	3.65					78.7	3.7			
	MP9/B 4.3-4.6		Stiff, dark greyish brown (2.5Y4/2) clayey SILT with occasional sandstone pebbles						78.4	4.0			
	MP9/10 4.3-4.6		Stiff, very dark grey (N3) silty CLAY with sandstone and limestone pebbles						78.1	4.3			
			End of borehole.						77.8	4.6			

PROJECT: SEARLE

BOREHOLE NO: MP10

DRILLING METHOD: SHELL & AUGER

SHELL & HAMMER FROM 0 M. TO 1.5 / 3.0 M. TO 3.4 M.

CROW BLADED CLAW CUTTER FROM 1.5 / 3.4 M. TO 3.0 / 5.4 M.

LOCATION: MARPET

G. REP.:

START DATE: 4/4/87

COMPLETION DATE: 5/4/87

CONTRACTOR: IH

WATER STRUCK. DAMP 4.6-4.9 M.BGL. ROSE TO. 3.95 (14/4/87) M.BGL.

M.BGL. M.BGL.

TOTAL DEPTH: 5.4 M.

CASING DIAMETER/TYPE:

200 MM FROM 0 M. TO 1.7 M., TYPE 8" WATERWELL CASING .202

50 MM FROM 0 M. TO 4.4 M., TYPE 2" BSP

DRILLED DIAMETER

200 MM. FROM 0 M. TO 5.4 M.

MM. FROM M. TO M.

SCREEN DIAMETER/TYPE:

50 MM FROM 4.4 M. TO 4.9 M: TYPE/SLOT(MM) 2" BSP PERF WITH TERRAM .051

MM FROM M. TO M: TYPE/SLOT(MM)

SUMMARY OF AQUIFER CONDITIONS

HEIGHT OF 2" BSP AGL = 1.00
HEIGHT OF 8" WATERWELL CASING AGL = 0
ELEVATION OF 2" BSP AOD = 83.47
ELEVATION OF GL AOD = 82.47

DEPTH (M.BGL)	GRAIN SIZE ANALYSES (Sample No. and location)	LITHOLOGY	DEPTH (MBGL)	BOREHOLE CONSTRUCTION (Casing/screen / gr. pack)	ELEVATION OF WATER M.AOD	DEPTH TO WATER M.BG L.	SYMBOLIC LOG	ELEVATION M. AOD	DEPTH M. BGL.	STRATIGRAPHIC UNITS
	MP1/1 0-0.9	Made Ground (crushed dolomite)						81.6	0.9	
1	MP10/2 0.9-1.3	Made Ground (Firm, dark reddish brown (5YR3/3) silty CLAY with abundant small mudstone & limestone pebbles						81.2	1.3	
	MP10/3 1.3-2.0	Made Ground (Soft-firm, very dark grey (5Y3/1) very clayey SILT with contaminant odour between 1.3-1.5						80.5	2.0	
2	MP10/4 2.0-2.4	Made Ground (Soft-firm, very dark greyish brown (10YR3/2) clayey SILT / silty CLAY with abundant mudstone and brick fragments						80.1	2.4	
	MP10/5 2.4-2.9	Made Ground (Soft, very dark grey (5Y3/1) clayey SILT with sandstone & brick fragments.						79.5	3.0	
3	MP10/6 2.9-3.4	Made Ground Concrete						79.1	3.4	

BOREHOLE NO. MP10

DEPTH (M.BGL)	GRAIN SIZE ANALYSES (Sample No. and location)			DEPTH (M. BGL)	BOREHOLE CONSTRUCTION (casing/screen/gt. pack)	ELEVATION OF WATER M. AOD	DEPTH TO WATER M. BGL	SYMBOLIC LOG	ELEVATION M. AOD	DEPTH M. BGL	STRATIGRAPHIC UNITS		
4	MP10/8 3.4-4.6		Soft-firm, dark yellowish brown (10YR4/4) silty CLAY with some sandstone fragments	4.6		78.52	3.95		77.9	4.6	Boulder Clay		
5	MP10/9 4.6-4.9		Soft, olive brown (2.5Y4/4) angey SILT, slightly sandy in parts. Damp	4.9					77.6	4.9			
	MP10/10 4.9-5.4		Stiff, very dark grey (N3) with olive brown mottling very silty CLAY with Limestone and Sandstone Pebbles						77.1	5.4			
			End of borehole										

PROJECT: SEARLE

BOREHOLE NO: MP11

DRILLING METHOD	LOCATION	
SHELL & HAMMER FROM 0 M. TO 0.7 M.	MORPETH	G. REP.:
CROSS BLADED CLAMCUTTER FROM 0.7 M. TO 4.0 M.		START DATE: 4/4/87
		COMPLETION DATE: 4/4/87
		CONTRACTOR IH

WATER STRUCK.	ROSE TO.
DAMP 1.5-2.0 M.BGL.	1.28 (14/4/87) (IN BOTH WELLS) M.BGL.
DAMP 2.9-3.4 M.BGL.	M.BGL.

TOTAL DEPTH: 4.0 M.

CASING DIAMETER/TYPE:

200 MM FROM 0 M. TO 1.75 M., TYPE 8" WATERWELL .203
50 MM FROM 0 M. TO 2.3 M., TYPE 2" BSP
50 MM FROM 0 M. TO 3.4 M., TYPE 2" BSP

DRILLED DIAMETER

200 MM. FROM 0 M. TO 4.0 M.
MM. FROM M. TO M.

SCREEN DIAMETER/TYPE:

50 MM FROM 1.7 M. TO 2.3 M: TYPE/SLOT(MM) 2" BSP PERF ~~ITERRAM~~ .051
50 MM FROM 2.9 M. TO 3.4 M: TYPE/SLOT(MM) 2" BSP PERF ~~ITERRAM~~

SUMMARY OF AQUIFER CONDITIONS

DEPTH OF 8" WATERWELL CASING TOP BGL = 0.05
DEPTH OF SHALLOW 2" BSP BGL = 0.04 (COUPLING)
DEPTH OF DEEP 2" BSP BGL = 0.04 (COUPLING)
ELEVATION OF SHALLOW 2" BSP AOD = 82.27
ELEVATION OF DEEP 2" BSP AOD = 82.27
ELEVATION OF GROUND LEVEL = 82.31.

DEPTH (M.BGL)	GRAIN SIZE ANALYSES (Sample No. and location)	LITHOLOGY	DEPTH (MBGL)	BOREHOLE CONSTRUCTION (Casing/screen / gr. pack)	ELEVATION OF WATER M.AOD	DEPTH TO WATER M.BG L.	SYMBOLIC LOG	ELEVATION M. AOD	DEPTH M. BGL.	STRATIGRAPHIC UNITS
		Tarmac	0.1					82.2	0.1	
0-0.4	MP11/1	Made Ground (crushed dolomite)						81.9	0.4	
0.4-1.5	MP11/2	Made Ground ? (Firm, yellowish brown (10YR5/6) silty CLAY with some coal and sandstone fragments.			80.99 ▽	1.32 ▽		80.8	1.5	
1.5-2.0	MP11/3	Soft, olive gray (5Y4/2) clayey sandy SILT with contaminant odour	1.7 / 2.3					80.3	2.0	
2.0-2.4	MP11/4	Soft-firm, olive gray (5Y4/2) clayey SILT with slight contaminant odour	2.3					79.9	2.4	
2.4-2.9	MP11/5	Stiff, olive grey (5Y4/2) clayey SILT with some sandstone and limestone pebbles	2.9					79.4	2.9	Boulder Clay
2.5-3.4	MP11/6	Soft, dive gray (5Y4/2) clayey sandy SILT	3.4					78.9	3.4	
3.4+	MP11/7	Stiff, very dark grey (N3) silty CLAY with limestone and sandstone						78.3	4.0	

End of borehole.

PROJECT: SEACLE

BOREHOLE NO: MPR

DRILLING METHOD	LOCATION	
STEEL HAMMER FROM 0 M. TO 0.7 M.	MORPETH	G. REF.:
CROSS BLADED CLAY CUTTER FROM 0.7 M. TO 2.8 M.		START DATE: 4/4/87
		COMPLETION DATE: 5/4/87
		CONTRACTOR IH

WATER STRUCK.	ROSE TO.
Damp 1.5-1.7	1.37 (4/4/87)
.....M.BGL.	.....M.BGL.
.....M.BGL.	.....M.BGL.

TOTAL DEPTH: 2.8 M.

CASING DIAMETER/TYPE:

200 MM FROM 0 M. TO 1.7 M., TYPE 8" WATERWELL CASING .202

50 MM FROM 0 M. TO 2.15 M., TYPE 2" BSP .051

DRILLED DIAMETER

200 MM. FROM 0 M. TO 2.8 M.

..... MM. FROM .... M. TO .... M.

SCREEN DIAMETER/TYPE:

50 MM FROM 2.15 M. TO 2.65 M; TYPE/SLOT(MM) 2" BSP PERF HAND SLOTTED

..... MM FROM ..... M. TO ..... M; TYPE/SLOT(MM) .....

SUMMARY OF AQUIFER CONDITIONS

HEIGHT OF 2" BSP AGL = 1.06

HEIGHT OF 8" WATERWELL CASING AGL = 0

ELEVATION OF 2" BSP AOD = 81.06

ELEVATION OF GL AOD = 80.00

DEPTH (M.BGL)	GRAIN SIZE ANALYSES (Sample No. and location)	LITHOLOGY	DEPTH (MBGL)	BOREHOLE CONSTRUCTION (Casing/screen / gr. pack)	ELEVATION OF WATER M.AOD	DEPTH TO WATER M.BG L.	SYMBOLIC LOG	ELEVATION M. AOD	DEPTH M. BGL.	STRATIGRAPHIC UNITS
		Topsoil						79.9	0.1	
	MPR2 MAR/1 0.05-0.1-04	Made Ground (crushed dolomite)						79.6	0.4	
		Firm - stiff, very dark grey (5Y3/1) very clayey SILT						79.4	0.6	
1	MPR2/3 0.6-1.5	Firm, brown (7.5YR4/4), silty CLAY with some limestone and sandstone pebbles			78.63 ▽	1.37 ▽		78.5	1.5	
	MAR/4 MPR2 1.2-1.3	Soft, light olive brown (2.5Y5/4) clayey SILT	1.7					78.3	1.7	
2		Firm, brown (10YR4/3) silty CLAY with some sandstone pebbles						78.0	2.0	Boulder Clay
	MPR2/6 2.0-2.8	Firm - stiff, very dark grey (5Y3/1) silty CLAY with limestone and sandstone pebbles	2.15 2.65					77.2	2.8	
3		End of borehole								

PROJECT: SEARLE

BOREHOLE NO: MP 13

DRILLING METHOD
SHELL HAMMER ..... FROM 0 M. TO 1.5 M.
C209 BLADE/CLAYCUTTER ..... FROM 1.5 M. TO 3.6 M.

LOCATION
MORPETH

G. REP.: .....
START DATE: 5/4/87
COMPLETION DATE: 5/4/87
CONTRACTOR IH.

WATER STRUCK.
Damp 19-25 ..... M.BGL.
..... M.BGL.

ROSE TO.
1.51 (14/4/87) ..... M.BGL.
..... M.BGL.

TOTAL DEPTH: 3.6 M.

CASING DIAMETER/TYPE: .203
200 MM FROM 0 M. TO 1.7 M., TYPE 8" WATERWELL CASING
60 MM FROM 0 M. TO 2.4 M., TYPE 2" BSP

DRILLED DIAMETER
200 MM. FROM 0 M. TO 3.6 M.
..... MM. FROM .... M. TO .... M.

SCREEN DIAMETER/TYPE: .051
50 MM FROM 24 M. TO 2.9 M; TYPE/SLOT(MM) 2" BSP PERF + TERRAM
..... MM FROM ..... M. TO ..... M: TYPE/SLOT(MM) .....

SUMMARY OF AQUIFER CONDITIONS

HEIGHT of 2" BSP AGL = 0.89
HEIGHT of 8" WATERWELL CASING AGL = 0
ELEVATION of 2" BSP AOD = 83.38
ELEVATION of GL. AOD = 82.49

DEPTH (M.BGL)	GRAIN SIZE ANALYSES (Sample No. and location)	LITHOLOGY	DEPTH (M.GL)	BOREHOLE CONSTRUCTION (Casing/screen / gr. pack)	ELEVATION OF WATER M.AOD	DEPTH TO WATER M.BG L.	SYMBOLIC LOG	ELEVATION M. AOD	DEPTH M. BGL.	STRATIGRAPHIC UNITS
		Shingle						82.4	0.1	
1	MP13/1 0.1-1.0	Made Ground (crushed dolomite)						81.5	1.0	
2	MP13/2 1.0-1.9	Soft-firm, dark greyish brown (10YR 4/2) very silty CLAY with some limestone and sandstone pebbles			80.98	1.51		80.6	1.9	
	MP13/3 1.9-2.5	Soft, dark greyish brown (2.5Y 4/2) sandy clayey SILT	2.4					80.0	2.5	
	MP13/4 2.5-2.7	Soft-firm, dark greyish brown (2.5Y 4/2) sandy clayey SILT with some sandstone pebbles						79.8	2.7	Boulder Clay
3	MP13/5 2.7-3.6	Stiff, very dark grey (N3) very silty CLAY with abundant sandstone and limestone pebbles.	2.9					78.9	3.6	

End of borehole

PROJECT: SEARLE

BOREHOLE NO: MP14

DRILLING METHOD	LOCATION	
CROSS BLADED CAT. AUGER FROM 0 M. TO 10.2 M.	MARPENT.	G. REP.:
SHELL & HAMMER FROM 10.2 M. TO 11.2 M.		START DATE: 6/4/87
		COMPLETION DATE: 8/4/87
		CONTRACTOR IH.

WATER STRUCK.	ROSE TO. (IMMEDIATELY)
1.0 M.BGL.	0.9 M.BGL.
4.4 M.BGL.	3.9 M.BGL. (AFTER 1 HOUR)

TOTAL DEPTH: 11.2 M.

CASING DIAMETER/TYPE:

250 MM FROM 0 M.TO 1.7 M., TYPE 10" WATER WELL CASING .254

200 MM FROM 0 M.TO 5.6 M., TYPE 8" WATER WELL CASING

DRILLED DIAMETER

250 MM. FROM 0 M. TO 5.0 M.

200 MM. FROM 5.0 M. TO 10.2 M.

150 10.2 11.2

SCREEN DIAMETER/TYPE:

— MM FROM — M. TO — M; TYPE/SLOT(MM) —

..... MM FROM ..... M. TO ..... M; TYPE/SLOT(MM) .....

.203

SUMMARY OF AQUIPER CONDITIONS

HEIGHT OF 10" WATER WELL CASING AGL = 0

HEIGHT OF 8" WATER WELL CASING AGL = 0.69

ELEVATION OF GROUND LEVEL = 82.29

ELEVATION OF TOP OF 8" WATER WELL CASING = 82.98

1. Drove 10" casing to 1.7 and drilled open hole to 5.0 Water struck 5 hours — no evidence of leakage.
2. No water struck in Sandstone.

DEPTH (M.BGL)	GRAIN SIZE ANALYSES (Sample No. and location)	LITHOLOGY	DEPTH (MBGL)	BOREHOLE CONSTRUCTION (Casing/screen / gr. pack)	ELEVATION OF WATER M.AOD	DEPTH TO WATER M.BG L.	SYMBOLIC LOG	ELEVATION M. AOD	DEPTH M. BGL.	STRATIGRAPHIC UNITS
		Topsoil							0.2	
	MP14/1 0.2-0.5	Made Ground (crushed dolomite, in firm, yellowish brown (10YR5/4) clayey matrix						81.8	0.5	
	MP14/2 0.5-0.6	Made Ground (firm, dark greyish brown (10YR4/2) clayey SILT						81.7	0.6	
1	MP14/3 0.6-1.0	Made Ground (crushed dolomite)						81.3	1.0	
	MP14/4 1.3-1.5	Made Ground (firm, dark greyish brown (2.5Y4/2) clayey SILT						81.0	1.3	
	MP14/5 1.5-1.7	Made Ground (stiff, grey (N5) clayey SILT with pink sandstone pebbles						80.8	1.5	
	MP14/6 1.7-1.9	Made Ground (firm, dark brown (7.5YR4/2) clayey SILT with mudstone and coal fragments	1.7					80.4	1.9	
2	MP14/7 1.7-2.4	Made Ground (soft-firm soil with wood, polystyrene and mudstone fragments						79.9	2.4	
	MP14/8 2.4-2.6	Firm, very dark greyish brown (2.5Y3/2) clayey SILT						79.7	2.6	
	MP14/9 2.6-2.9	Firm, variegated dark grey (5Y4/1) and strong brown (7.5YR5/8) very clayey SILT						79.4	2.9	
3	MP14/10 2.9-3.1	Firm, brown (7.5YR4/2) very clayey SILT						79.2	3.1	
	MP14/11 3.1-3.6	Firm, dark greyish brown (10YR4/3) very silty CLAY						78.7	3.6	Boulder Clay

BOREHOLE NO. MP14

DEPTH (M.BGL)	GRAIN SIZE ANALYSES (Sample No. and location)			DEPTH (M. BGL)	BOREHOLE CONSTRUCTION (casing/screen/gr. pack)	ELEVATION OF WATER M. AOD	DEPTH TO WATER M. BGL	SYMBOLIC LOG	ELEVATION M. AOD	DEPTH M. BGL	STRATIGRAPHIC UNITS		
4	MP14/12 3.6-4.0		Soft-firm, dark greyish brown (2.5Y 4/2) sandy clayey SILT						78.3	4.0			
	MP14/13 4.0-4.4		Soft, olive brown (2.5Y4/4) sandy clayey SILT						77.9	4.4			
	MP14/14 4.4-4.7; MP14/15 [illegible]		Stiff, very dark greyish brown (2.5Y 3/2) with very dark grey (N3) mottles clayey SILT						77.4	4.9			
5	MP14/16 4.9-5.8		Stiff, very dark grey (N3) silty CLAY with abundant limestone and sandstone pebbles	5.0; 5.6					76.5	5.8			
6	MP14/17 [illegible]		Firm, dark grey (5Y4/1) sandy, very clayey SILT						76.3	6.0			
	MP14/18 6.0-6.5		Stiff, very dark grey (N3) silty CLAY with abundant limestone and sandstone pebbles								Boulder Clay		
	MP14/19 6.5-6.9												
7	MP14/20 6.9-7.2												
	MP14/21 7.2-7.6												
8	MP14/22 7.6-8.2												
	MP14/23 8.2-8.8												

BOREHOLE NO. MP14

DEPTH (M.BGL)	GRAIN SIZE ANALYSES (Sample No. and location)			DEPTH (M. BGL)	BOREHOLE CONSTRUCTION (casing/screen/gt. pack)	ELEVATION OF WATER M. AOD	DEPTH TO WATER M. BGL	SYMBOLIC LOG	ELEVATION M. AOD	DEPTH M. BGL	STRATIGRAPHIC UNITS		
9	MP14/24 8.8-9.5								72.8	9.5			
10	MP14/25 9.5-10.1		Stiff, dark grey (5Y4/1) silty CLAY with abundant limestone and sandstone pebbles						72.2	10.1			
11	MP14/26 10.1-11.2		Hard, light yellowish brown (10YR 6/4) fine-medium grained SANDSTONE	11.2					71.1	11.2	Millstone Grit		
			End of borehole										

APPENDIX B

WATER LEVEL DATA

Searle, Morpeth

Water levels

Station No	Date	Time	Depth to water (m below datum level)	Elevation of water table (m above sea level)
MP1	26 Feb 87	1110	5.548	78.822
	27 Feb 87	1130	4.582	79.788
	6 Apr 87	1717	0.028	84.342
	7 Apr 87	1353	0.497	83.873
	16 Apr 87		0.750	83.620
MP10	4 Apr 87	1559	5.223	78.247
	5 Apr 87	1154	4.966	78.504
	6 Apr 87	1110	5.000	78.470
	6 Apr 87	1521	4.963	78.507
	7 Apr 87	1044	4.923	78.547
	8 Apr 87	1132	4.898	78.572
	14 Apr 87		4.952	78.518
	16 Apr 87		4.930	78.540
MP11D	5 Apr 87	846	2.252	80.017
	6 Apr 87	1125	1.401	80.868
	7 Apr 87	1527	1.317	80.952
	8 Apr 87	906	1.369	80.900
	8 Apr 87	1110	1.337	80.932
	14 Apr 87		1.280	80.989
	16 Apr 87		1.320	80.949
MP11S	7 Apr 87	1528	1.320	80.949
	8 Apr 87	905	1.344	80.925
	14 Apr 87		1.280	80.989
	16 Apr 87		1.320	80.949
MP12	5 Apr 87	1942	2.728	78.331
	6 Apr 87	1151	2.515	78.544
	7 Apr 87	1039	2.276	78.783
	8 Apr 87	923	2.085	78.974
	8 Apr 87	1138	3.030	78.029
	14 Apr 87		2.432	78.627
	16 Apr 87		2.370	78.689
MP13	6 Apr 87	1127	3.006	80.373
	7 Apr 87	1037	2.836	80.543
	7 Apr 87	1544	3.193	80.186
	8 Apr 87	914	3.122	80.257
	14 Apr 87		2.400	80.979
	16 Apr 87		2.390	80.989

Searle, Morpeth

Water levels

Station No	Date	Time	Depth to water (m below datum level)	Elevation of water table (m above sea level)
MP2	23 Feb 87	1215	1.570	77.248
	26 Feb 87	1700	1.564	77.254
	27 Feb 87	1130	1.553	77.265
	2 Apr 87	1126	1.318	77.500
	3 Apr 87	1142	1.342	77.476
	4 Apr 87	914	1.352	77.466
	5 Apr 87	1048	1.349	77.469
	6 Apr 87	1913	1.322	77.496
	7 Apr 87	1716	1.277	77.541
	8 Apr 87	1656	1.211	77.607
	14 Apr 87		1.320	77.498
	16 Apr 87		1.340	77.478
MP3	23 Feb 87	1215	1.644	77.375
	26 Feb 87	1700	1.509	77.510
	27 Feb 87	1130	1.427	77.592
	2 Apr 87	1132	1.249	77.770
	3 Apr 87	1140	1.263	77.756
	4 Apr 87	927	1.282	77.737
	5 Apr 87	1051	1.269	77.750
	6 Apr 87	1914	1.282	77.737
	7 Apr 87	1717	1.229	77.790
	8 Apr 87	1657	1.153	77.866
	14 Apr 87		1.270	77.749
	16 Apr 87		1.250	77.769
MP4	23 Feb 87	1215	9.070	70.090
	26 Feb 87	1700	8.330	70.830
	27 Feb 87	1130	8.133	71.027
	2 Apr 87	1133	7.665	71.495
	3 Apr 87	1138	7.769	71.391
	4 Apr 87	950	7.817	71.343
	5 Apr 87	1024	7.845	71.315
	6 Apr 87	1914	8.069	71.091
	7 Apr 87	1718	8.163	70.997
	8 Apr 87	1659	8.126	71.034
	14 Apr 87		8.360	70.800
	16 Apr 87		8.180	70.980

Searle, Morpeth

Water levels

Station No	Date	Time	Depth to water (m below datum level)	Elevation of water table (m above sea level)
MP5	24 Feb 87	1430	3.296	77.413
	24 Feb 87	920	3.172	77.537
	25 Feb 87	925	3.146	77.563
	2 Apr 87	1136	2.932	77.777
	3 Apr 87	1136	2.974	77.735
	3 Apr 87	1405	2.972	77.737
	4 Apr 87	953	2.985	77.724
	5 Apr 87	1146	2.967	77.742
	6 Apr 87	1916	2.947	77.762
	7 Apr 87	1714	2.869	77.840
	8 Apr 87	1653	2.787	77.922
	14 Apr 87		2.895	77.814
	16 Apr 87		2.890	77.819
MP6	24 Feb 87	1130	2.873	76.777
	24 Feb 87	1815	2.797	76.853
	25 Feb 87	1000	2.775	76.875
	27 Feb 87	1230	2.770	76.880
	2 Apr 87	1139	2.696	76.954
	3 Apr 87	1144	2.596	77.054
	4 Apr 87	955	2.606	77.044
	5 Apr 87	1148	2.596	77.054
	6 Apr 87	1918	2.584	77.066
	7 Apr 87	1719	2.552	77.098
	8 Apr 87	1651	2.494	77.156
	14 Apr 87		2.600	77.050
	16 Apr 87		2.590	77.060
MP7	25 Feb 87	810	6.598	76.342
	2 Apr 87	1141	5.681	77.259
	3 Apr 87	1147	5.675	77.265
	4 Apr 87	1002	5.675	77.265
	4 Apr 87	1426	5.680	77.260
	5 Apr 87	1150	5.679	77.261
	6 Apr 87	1209	5.657	77.283
	7 Apr 87	1046	5.657	77.283
	8 Apr 87	1647	5.620	77.320
	14 Apr 87		5.560	77.380
	16 Apr 87		5.690	77.250

Searle, Morpeth

Water levels

Station No	Date	Time	Depth to water (m below datum level)	Elevation of water table (m above sea level)
MP8	26 Feb 87	1530	3.385	79.434
	2 Apr 87	1434	2.814	80.005
	3 Apr 87	1200	2.818	80.001
	4 Apr 87	1728	2.832	79.987
	5 Apr 87	1157	2.825	79.994
	5 Apr 87	1552	2.822	79.997
	6 Apr 87	1129	2.848	79.971
	7 Apr 87	1051	2.815	80.004
	8 Apr 87	1120	2.778	80.041
	14 Apr 87		2.280	80.539
	16 Apr 87		2.830	79.989
MP9	4 Apr 87	819	3.736	79.823
	5 Apr 87	1155	3.167	80.392
	6 Apr 87	1112	3.021	80.538
	7 Apr 87	1042	3.879	79.680
	7 Apr 87	1337	3.892	79.667
	8 Apr 87	1126	3.783	79.776
	14 Apr 87		3.912 ?.?	79.647
	16 Apr 87		3.910	79.649
NE3	26 Feb 87	1430	2.633	*
	27 Feb 87	1115	2.431	*
	2 Apr 87	1450	2.418	*
	3 Apr 87	1158	2.297	*
	3 Apr 87	1718	2.298	*
	4 Apr 87	957	2.315	*
	5 Apr 87	1258	2.317	*
	6 Apr 87	1910	2.308	*
	7 Apr 87	1048	2.280	*
	8 Apr 87	1645	2.253	*
	16 Apr 87		2.330	*
NE4	24 Feb 87	900	5.343	*
	2 Apr 87	1142	5.367	*
	3 Apr 87	1149	5.274	*
	4 Apr 87	1004	5.262	*
	5 Apr 87	1152	5.282	*
	5 Apr 87	1646	5.285	*
	6 Apr 87	1210	5.539	*
	7 Apr 87	1047	5.459	*
	8 Apr 87	1649	5.430	*