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EVALUATION OF A LIGHTWEIGHT DRILL FOR INVESTIGATION OF GROUNDWATER CONDITIONS ON FLOOD PLAINS

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1 Introduction

1.1 A lightweight drilling machine and auxilliary sub-surface investigation equipment has been used in order to evaluate groundwater conditions with general application to siting and designing flood embankments. The aquifer investigated was Lower Greensand of Cretaceous origin overlying Kimmeridge Clay. The aquifer is overlain by clay and gravel deposits. Geological information available prior to the investigation had shown variation in the thickness of the aquifer between 2.5m and 12.5m and the depth to the aquifer between 1m and 5m below ground level.

1.2 Nine boreholes were drilled by powered auger and well points installed for assessing and monitoring of the piezometric level of the aquifer across the 0.6 km^2 site. A further four boreholes were drilled by powered auger and well screens installed for bulk sampling of the groundwater and permeability testing of the aquifer.

1.3 A more detailed investigation of a $1200m^2$ area of the site was also carried out. This involved the drilling of three boreholes by powered auger to prove the depth and thickness of the aquifer. Further small diameter bores were made by a rapid flow through sampling technique, to 3m depths and piezometer tips installed through these into the top of the aquifer to give detailed information on piezometric levels.

2 Description of equipment

2.1 The drilling system comprises :

(a) The Marlow Prospectorpac - hydraulic power generator.

(b) Mole DD2 drill.

(c) Augers and auger bits.

(d) Flow through sampling bit with extension rods and hydraulically powered hammer assembly.

(e) Hydraulic jack.

(f) Drill casing.

2.2 (a) The 'Prospectorpac' is a portable hydraulic power pack which provides on site hydraulic power to drilling equipment. A gear type pump is driven by an 11 hp petrol driven engine. Hydraulic fluid is drawn from a reservoir and pumped to a control valve. Manual movement of the valve lever directs fluid to the equipment in use via high pressure hydraulic hoses.

(b) The 'Mole DD2' is a multi-purpose lightweight portable drill powered hydraulically by the 'Prospectorpac'. The top-head drive drill has hydraulic operation for rotation, feed and pulldown. The operator has fingertip control of speed of rotation, coarse to fine feed,and forward and reverse rotation. In the vertical drilling position, the rig measures 2.25m high by 0.85m wide by 1.90m long and weighs 143kg, see Fig 1 and Plate 1. The drill may be manoeuvred and operated by a two-man team.

(c) The augers are 75mm diameter and 3 feet in length, see Plate 2. However, the drill may be modified to accept 100mm and 150mm diameter augers. Various auger bits are available including fish-tail bits for soft strata and tungsten-carbide mining bits for harder strata.

(d) Flow through sampling equipment has also been used in the investigation. The sample bit consists of a robust 35mm. OD tube with a cutting edge which is driven into the ground to the required depth using 35mm OD, 1m. length, extension rods and a hydraulically powered hammer assembly, see plates 3 and 4. The sample bit is fashioned in such a way that soil is driven into the tube and then through a side port and compressed onto the side of the hole.

(e) A hydraulically powered jack is used to extract the sample bit and extension rods. A 35mm nominal ball clamp is used to effect upward movement of the rods during extraction. By interchanging the clamp and guides, the jack may also be used to pull back the casing, (f) below.

(f) Casing may be run to prevent collapse of the augered holes. The casing is nominally 90mm OD, 75mm ID and of 1m lengths. The casing may be driven behind the lead auger, ahead of it or after drilling and then cleaned out (redrilled). The casing is driven by the hydraulic hammer assembly mentioned in (d) above.

3 Geological logging and sampling

3.1 A total of sixteen boreholes were drilled by powered auger to depths between 3.0m and 8.0m. Bulk samples of the spoil were taken at least every 1.0m. Very little gravel was encountered and that which was, found to be discontinuous and clay bound. The strata above the aquifer may therefore be described as semi-permeable overburden.

3.2 The boundary between the overburden and the Lower Greensand aquifer was very distinct during drilling and characterised by a brief cessation of spoil transported up the auger flights followed by the production of water, then silty water, then sandy water (see plate 5). Another indication that the aquifer had been encountered was a reduction in the rate of drilling. If this was noticed, the auger was allowed to rotate with no downward feed until the production of spoil verified the boundary.

3.3 The boundary between the base of the aquifer and the Kimmeridge Clay was difficult to define during drilling. Of the boreholes which penetrated the Kimmeridge Clay, extraction of the augers proved clay packed onto the flights of the lower augers so the position of the boundary could be measured from this (Plate 6).

3.4 Analysis of samples taken while augering the Lower Greensand aquifer shows a high content of fine material. This is in agreement with the results of subsequent permeability tests and is thought to signify a negligible loss of fines or sorting of the sample due to the disruption of augering.

3.5 An opportunity to verify the reliability of geological logging arose when a 2.75m deep trench was to be constructed in an area where the aquifer was known to be fairly close to the ground surface. A borehole was drilled at either end of a proposed trench, 20m apart. The following stratigraphy was logged from inspections of the spoil whilst drilling :-

Depth below ground level m.	Western borehole	Depth below ground level m.	Eastern borehole
0		0	
	clayey topsoil		clayey topsoil
0.9		0.6	
	orange-brown sandy clay with some gravel		orange-brown sandy clay with some gravel
1.8		1.8	
	green clayey sand		green clayey sand
2.5		2.4	
	Lower Greensand aquifer		Lower Greensand aquifer
3.0		3.5	
	end of borehole		end of borehole

These logs compare favourably with the profile exposed by the trench excavation as shown in Fig 2.

4. Installation of well points

4.1 Boreholes were drilled for the well points by power augering to a depth of about 2m below the top of the aquifer. The augers were then removed. The slotted stainless steel, 50 mm nominal, well drive point (Plate 7) was then connected to the required length of extension tubes (generally 5m). The assembly was then lowered into the borehole manually and pushed through any material that may have slumped in until reaching the firm base of the borehole. No difficulty was experienced in doing this. A small amount of silting up inside the well points occurred but this is not necessarily undesirable as it is in hydraulic continuity with the aquifer and minimises distortion of groundwater flow due to the well point. The position of the water level inside the extension tubes (piezometric level) may be measured by electrical contact probe.

4.2 It was found that the water levels inside the extension tubes rose rapidly to between 0.5m and 2.3m above the top of the Lower Greensand. This indicated a confined aquifer and verified the semi-permeable character of the overburden.

5 Installation of well screens and permeability tests.

5.1 In order to carry out representative permeability tests on the aquifer, it was necessary to screen a fairly large thickness of the Lower Greensand. This was achieved by utilisation of a 3m length of 50mm nominal diameter 'Hydrotec' well screen with two 250mm filter fabrics to screen the high proportion of fine material present (Plate 8). Because of the close tolerance between the diameters of the augered hole and the screen, it was necessary to run casing down the borehole and then redrill inside the casing to produce a clean hole (Plate 9). The screen was then inserted manually and the casing jacked out around it allowing the formation to collapse onto the screen.

5.2 Some difficulty was experienced at first with drilling inside the casing, probably due to the presence of cohesive material and also of stones becoming snagged between the augers and the casing wall which caused the casing to rotate or for sections to unscrew. However, it was possible to place the screens within 1m of the planned position in every case and this was considered satisfactory. The well construction is shown in Fig 3.

5.3 A mini submersible pump was used to discharge from each well until a constant pumping rate and constant drawdown were achieved. The yield from a well with a constant rate of pumping which is not sufficient to cause dewatering of the aquifer along the screen is expressed by the radial flow equation :

$$Q = \frac{2\pi K\ l\ s_w}{\ln\ (R/r_w)}$$

where

Q = pumping rate from the well
s_w = drawdown of water level in the well
l = effective length of screen
r_w = radius of the filter
K = permeability of the aquifer
R = radius of zero drawdown

5.4 The mean value of permeability for the screened sections of aquifer were estimated by assuming a value of R and using measured values of discharge and drawdown after 1 hour of steady pumping. The results were as follows :-

Borehole No	Effective Screen Length m.	Discharge m^3/s	Drawdown m	Permeability m/s
S1	2.1	5.6 10^{-5}	4.4	6.1 10^{-6}
S2	2.3	6.9 10^{-5}	3.4	9.1 10^{-6}
S3	2.8	2.8 10^{-5}	3.7	2.7 10^{-6}
S4	1.9*	8.3 10^{-5}	3.0	1.5 10^{-5}

* total thickness of aquifer

5.5 These values of permeability agreed well with those derived from falling head tests in the open boreholes drilled before the trench was excavated.

6 Installation of piezometer tips

6.1 A detailed piezometric investigation was carried out by installing piezometer tips in an area where the aquifer was known to be thin and shallow. The small bore (35mm dia) flow through sampling technique was used to provide undisturbed samples of the Lower Greensand and of the top of the Kimmeridge Clay. The condition of the samples was very good and 100 per cent retrieval was achieved. These proved the Lower Greensand to be variably cemented and the top of the Kimmeridge Clay to be highly indurated in places. These are difficult strata to sample by most rapid methods.

6.2 Due to the nature of the sampler bit, the hole produced stands up well, especially in cohesive material. This enabled flush fitting piezometer drive tips (Plate 7) to be installed manually in the top of the aquifer in the holes bored by the sampler. The results of piezometric monitoring enabled the variation in magnitude and direction of the local hydraulic gradient to be studied in relation to effective rainfall and changes in absolute hydraulic head.

7 Summary of results obtained by use of lightweight drill

7.1 Prior to the investigation, collation of existing data indicated that the groundwater flow was characterised by an unconfined two-layer aquifer of gravel upon sand and occasionally overlain by some clay. The permeabilities were assumed to be typical for these types of deposits. Some piezometric data was previously available though antiquated and sparse.

7.2 Subsequent to the investigation the groundwater flow is found to be characterised by a confined one-layer aquifer of variably cemented sand overlain by a sandy clay, with some gravel present. The gravel is not in hydraulic continuity with the aquifer. The permeability of the sand is very low due to a high fines content. Piezometric data has been updated and detailed maps of groundwater flow may be compiled.

7.3 The drilling equipment used has proved capable of evaluating sub-surface conditions for the type of economical groundwater investigation required for flood embankment schemes.

Acknowledgements

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The study was carried out and reported by Mr D C Watkins of the Groundwater Section of the River Engineering Department. The study formed part of a research commission by the Ministry of Agriculture Fisheries and Food to provide a guide for the investigation and design of flood embankments with respect to groundwater effects.

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The views expressed in this report do not necessarily reflect either the policies or the opinions of the commissioning agency.

FIGURES

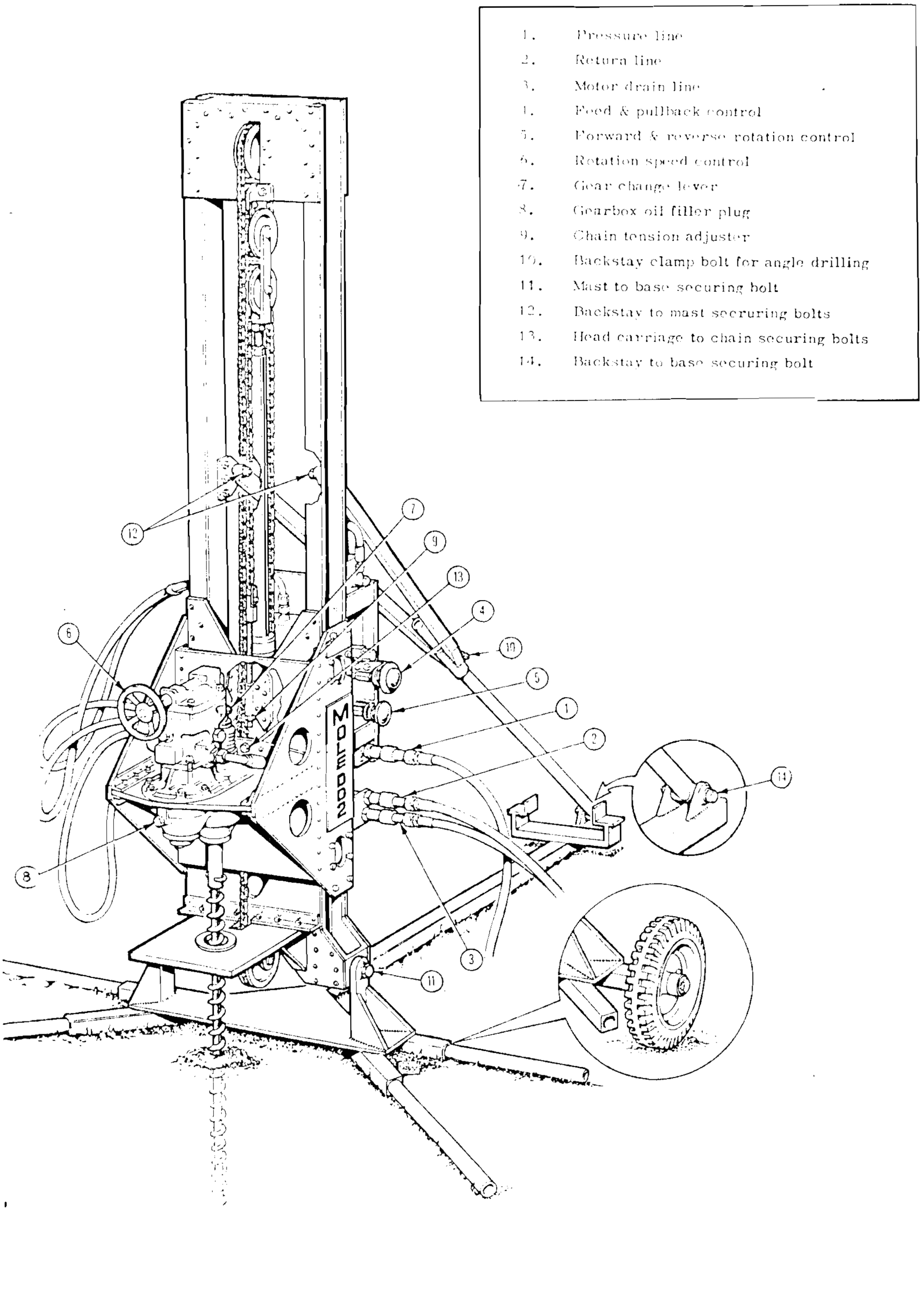

Fig 1 Mole DD2 drill

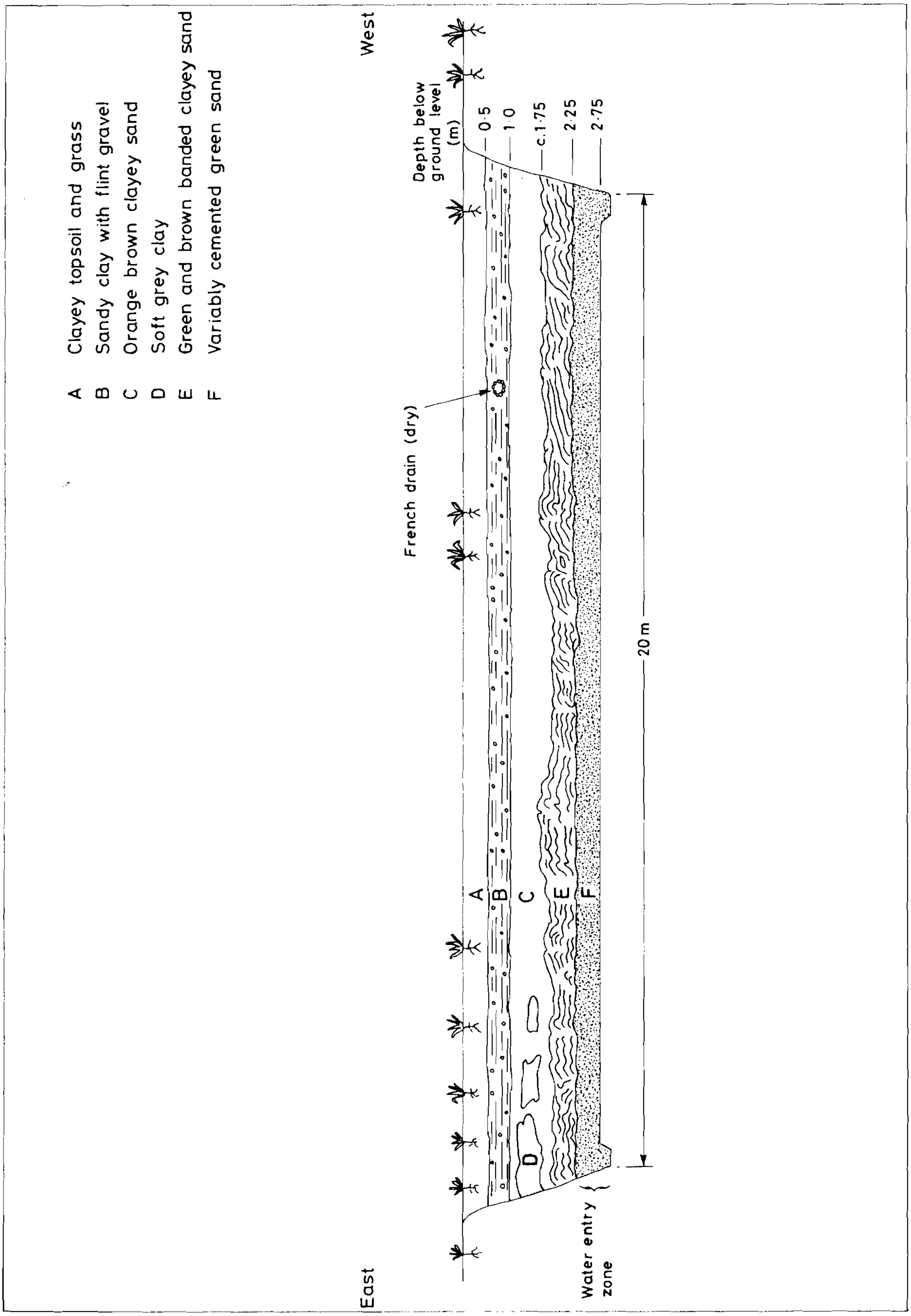

Fig 2 Sketch of exposed side of trench excavation

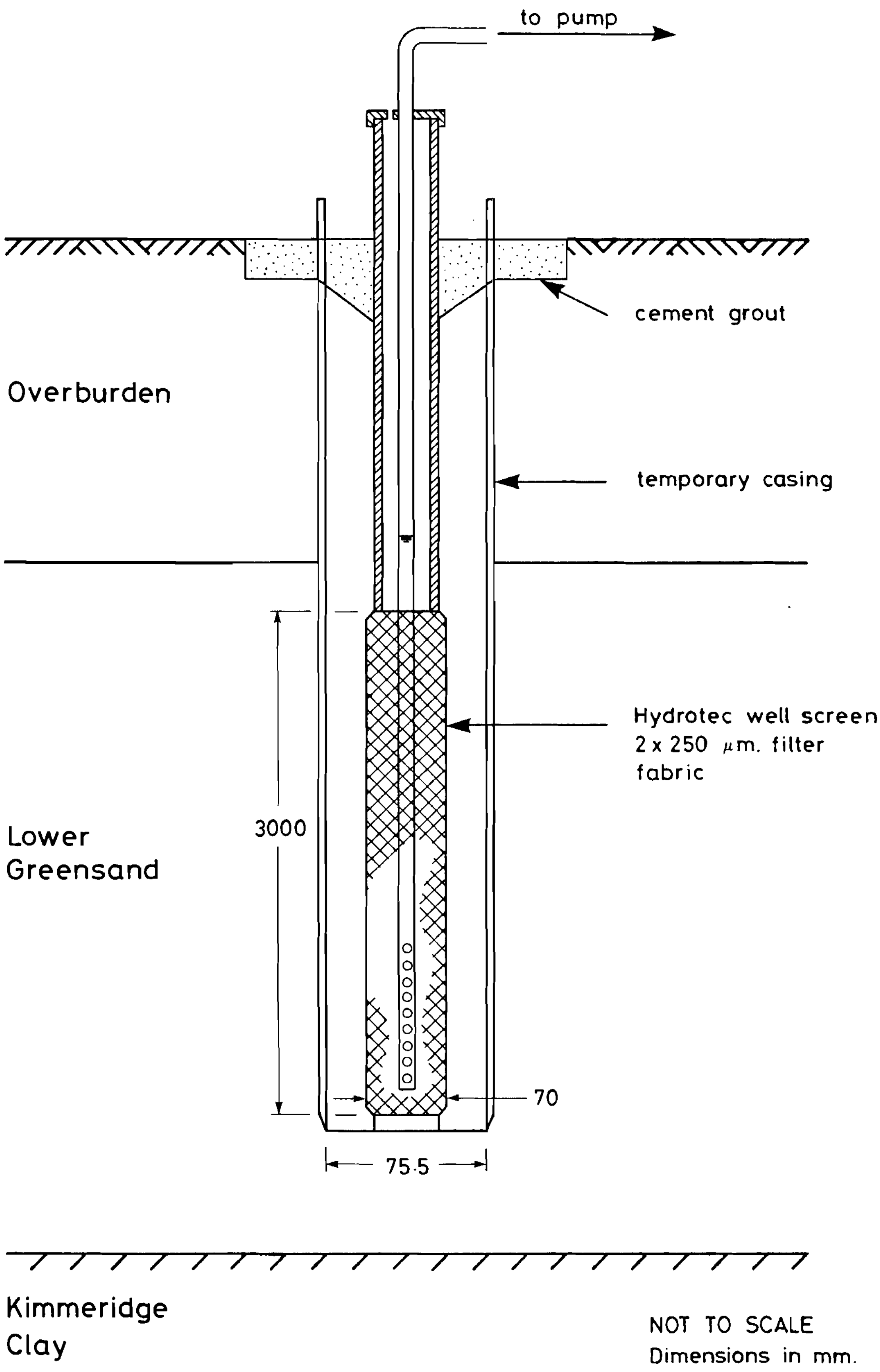

Fig 3 Well construction

PLATES

Plate 1.   Mole DD2 drill

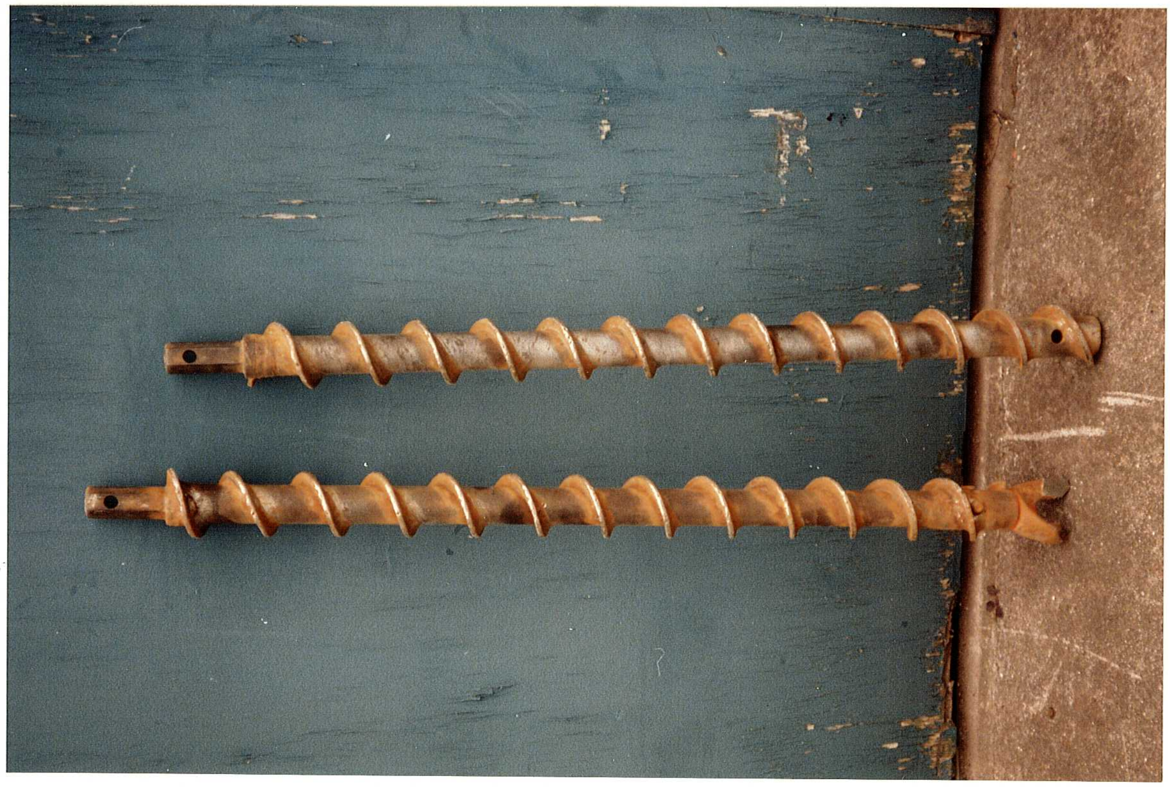

Plate 2.   75 mm diameter augers

Plate 3. Sample bit

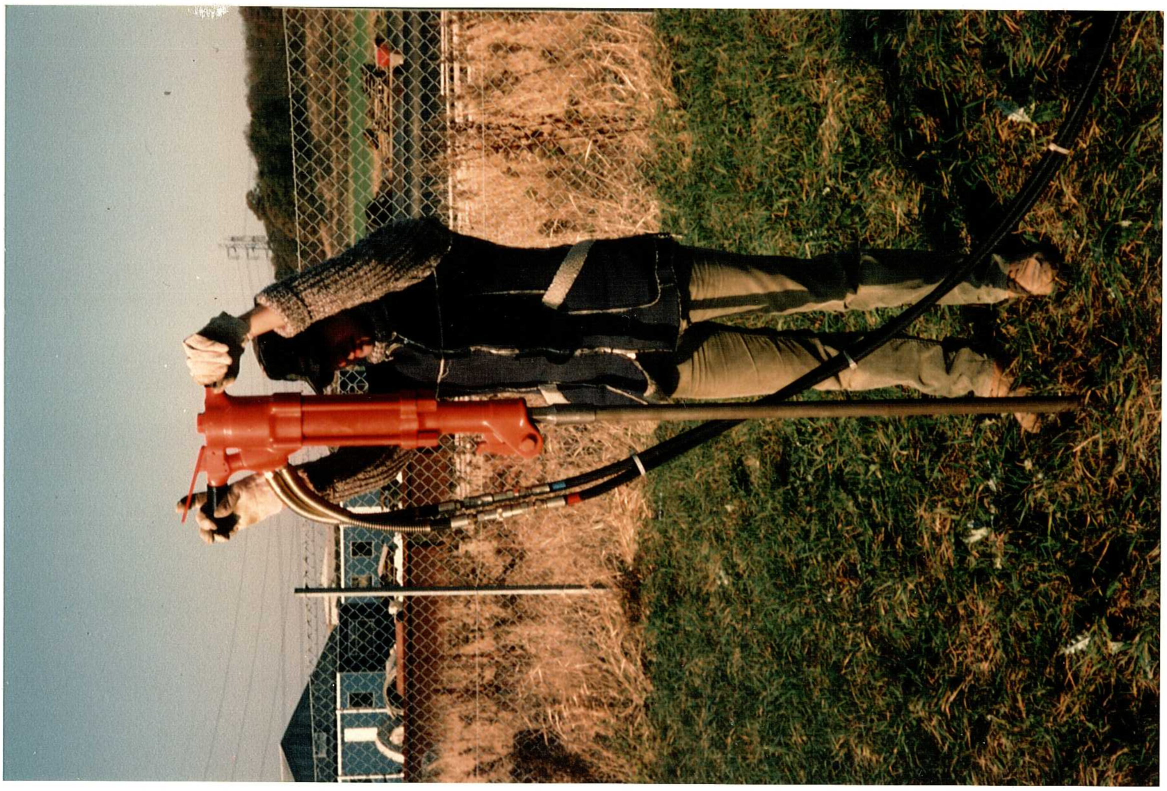

Plate 4. Flow through sampling

Plate 5. Lower Greensand spoil

Plate 6. Kimmeridge Clay spoil

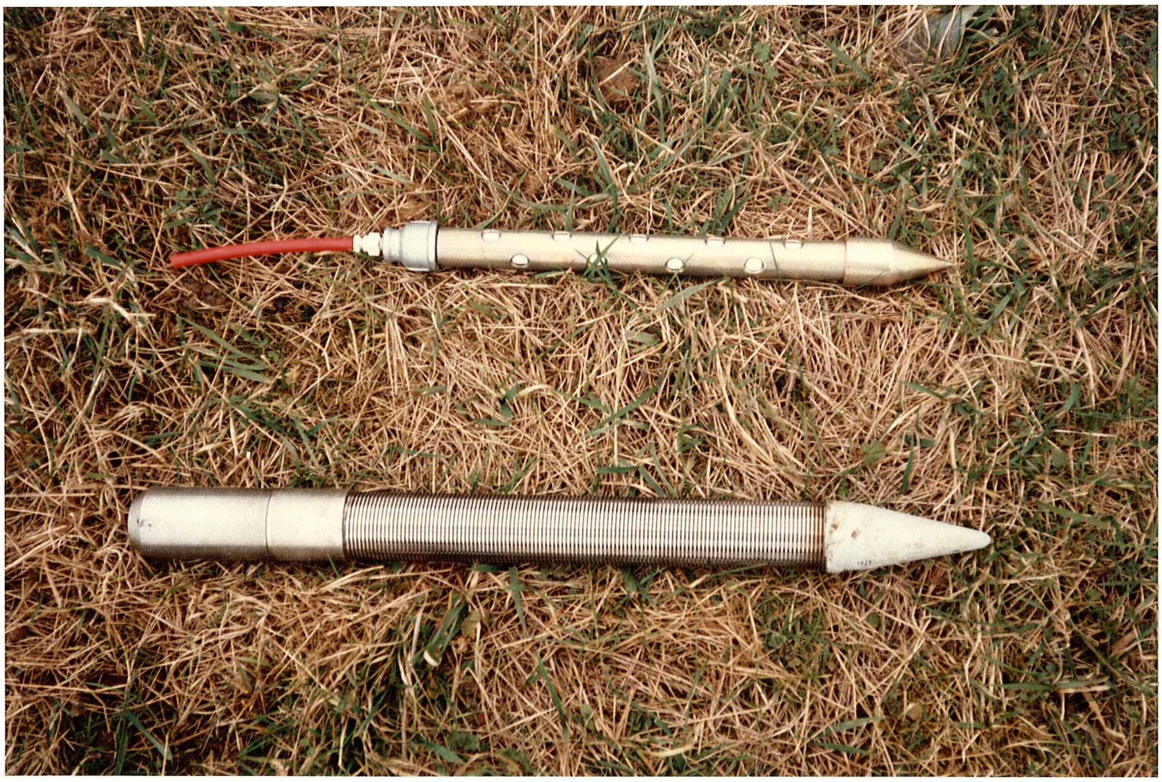

Plate 7. Piezometer tip (top) and well point (bottom)

Plate 8. Well screen

Plate 9. Casing of augered hole