INSTITUTE OF GEOLOGICAL SCIENCES

HYDROGEOLOGICAL DEPARTMENT

MINISTRY OF OVERSEAS DEVELOPMENT RESEARCH CONTRACT FOR THE DEVELOPMENT OF PLASTIC (FIBREGLASS) WELL LININGS ('MINIPUITS')

FINAL REPORT

J B W Day, B Sc

May 1974

Exhibition Road
London SW7 2DE

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F I N A L   R E P O R T

J.B.W. DAY, B.Sc.

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FOREWORD

Prototypes of 'Minipuits' - sectional prefabricated well casings - have been designed in detail and manufactured by Bristol Composite Materials Engineering Ltd to a concept originated by the Hydrogeological Department of the Institute of Geological Sciences as a result of field studies in the Sahelian zone of West Africa. The Institute has also carried out the tests which are described in this report. A research grant of £1000 awarded by the Ministry of Overseas Development to the Institute has assisted with the costs of testing and manufacture, but the greater part of the manufacturing expense has been borne by Bristol Composite Minerals Engineering Ltd, to whom due acknowledgement is made.

A patent application has been made in respect of the design of the second prototype.

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8. Two men using buckets and ropes can abstract simultaneously from the same well without difficulty.

9. The costs to a prospective purchaser of the linings and slotted screens are at present:

Outer slotted screen, length 2 metres, diameter 36 inches (in 2 halves), complete with base plates and locking bar	£195
Inner slotted screen, length 2 metres, diameter 30 inches (in 2 halves), complete with base plate and locking bar	£171
Annular deflector plate	£ 20
Casing section, length 1 metre, diameter 36 inches (in two longitudinal halves)	£120.20
Nylon nuts	£ 4
Assembly tool	£ 5

Thus a typical installation to a total depth of 7 metres would cost £996 at today's prices.

The above costs reflect labour-intensive, hand lay-up manufacturing methods. Costs may be substantially reduced if modules were to be mass produced by press moulding, but the necessary capital outlay on moulds is unlikely to be made unless the numbers of orders justify it.

10. Field trials under overseas conditions are desirable. Twenty-five sets of minipuits are at present being manufactured for possible implementation of an ODM project in Tchad, but their principle, construction and performance need to be tested and demonstrated more widely if these wells are to be generally accepted.

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Ministry of Overseas Development Research Contract for the Development

of Plastic (Fibreglass) Well Linings ('Minipuits')

CONCLUSIONS OF THE FINAL REPORT

1. The 'minipuits', a light, strong, durable, corrosion-free, prefabricated, sectional well casing and slotted screen, has now been tested in the UK. It is considered to have worldwide potential in developing countries for use as domestic, village or stock wells. Although primarily designed for bucket abstraction by 1-2 men, small hand or mechanical pumps can be fitted if desired. The modules are easily transportable and can be emplaced by village labour. Local costs are thus limited to light transport, direct labour, and that of a small concrete surface platform and coping.

2. Minipuits are suitable for use in unconsolidated shallow aquifers such as desert sands or river alluvia in situations where suitable cheap local lining and screen materials are not readily available. In particular, they offer a ready alternative to the massive concrete construction, favoured by so many governments and organisations, and which normally requires heavy transport and skilled or semi-skilled labour for installation. They also provide a more hygienic and durable substitute for the primitive unlined holes-in-the-ground which all too often provide the sole water supply for remote rural populations.

In Wadi (dry river bed) situations subject to seasonal floods, traditional wells have to be re-excavated every year. A minipuits, covered by a steel plate bolted to the topmost casing flange, could simply be cleared and reopened after floods eliminating the need for expensive and time-consuming re-excavation. Once installed, maintenance at any site is simple and can be carried out by the villagers themselves.

3. Because of their more limited penetration of the saturated aquifer, yields of individual minipuits are likely to be less than those of conventional concrete wells. However a substitute group of 2 or 3 minipuits is likely to equal or exceed the yield of a large conventional well, with the added advantages of spreading groundwater abstraction and reducing the risk of pollution by avoiding large concentrations of animals around well heads.

4 UK field emplacement trials on two prototypes, the second a modified and improved version of the first, have shown that this type of well can successfully be sunk by hand using minimal simple equipment. Two or three men can easily handly, assemble and sink the prefabricated modules all of which will fit into or onto a Landrover or similar transport. To date a total depth of 6 metres has been achieved without serious problems, but it is obvious that much greater depths could be achieved.

5. The second prototype has demonstrated the dual purpose facility offered by the slotted well screens. Outer and inner screens can if necessary be used to exclude silt by enclosing an annular, removable sand or gravel pack - this configuration gives 2 metres penetration of the water table - or the inner screen can be used as a telescopic downward extension of the outer to give 4 metres penetration of the saturated aquifer. Much narrower slot widths can be achieved in fibreglass than in concrete. Only in exceptional conditions of fine running sands is siltation likely to occur in the absence of the sandpack - nominal slot width of 0.045 inch (1.14 mm) should prevent appreciable siltation, bearing in mind the low entrance velocity of the water.

6. Tests have indicated yields of the order of 2.5 litres per minute (about 800 gallons per day) from $1\frac{1}{2}$ metres of saturated, poorly transmissive aquifer. Under more favourable conditions (say 4 metres penetration of a moderately transmissive aquifer) yields in the range 2000-4000 gallons per day can confidently be expected. Larger yields are likely from installations sunk in highly transmissive aquifers such as coarse sands or gravels.

7. The slotted screens could if necessary be used below the water table in conjunction with an upper lining of other suitable material if

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FINAL REPORT

Introduction

An interim progress report (attached as Appendix 1) has already been issued (October 1973) and the present report complements the previous report and should be read in conjunction with it. The earlier report described the background to the Research Contract, the design and manufacture of the first prototype and the results of field tests.

Certain modifications to the design of prototype 1 were then suggested, and as sufficient ODM funds remained available it was decided to manufacture and test a second prototype. This not only was to incorporate an improved cutting edge but also a 2-metre inner slotted screen section of 30-inch diameter designed to serve the dual purpose of either an inner lining of an annular gravel pack, or (after dismantling and extracting the gravel pack) as a downward telescopic extension of the slotted screen to give a total penetration of the saturated portion of the aquifer (below the water table) of 4 metres, double the penetration of the first prototype. Other minor modifications were to include nuts bonded to the underside of the upper flanges of casing sections and slight changes in the design of both vertical and horizontal flanges.

Construction of Second Prototype

The basic module of the outer casing remains the same size as in the first prototype, namely 1 metre long by 36 inches (914 mm) diameter, in flanged vertical half-sections connected by nylon bolts. In one section nylon nuts are bonded to the underside of the upper flange to enable assembly from inside the cylinder using a special assembly tool (see Plate 3a). Three complete casing sections were ordered.

The outer screen with base plate and locking bar also remains similar in size and form, except that the lower inward-facing flange is mounted several inches above the lower edge. The arrangement of slots and their width (0.045 inches or 1.14 mm) remains similar as does the ratio of slotted to unslotted area (7%). An innovation is the addition of a second, inner screen of similar form but smaller diameter (30 inches or 762 mm) to the outer screen in order to accommodate a gravel pack if desired. It too is fitted with removable baseplate (not slotted) and locking bar, but the rim below the lower inward facing flange is a little longer and has cutaway portions to enable subsequent extraction of the gravel pack from within the screen at its base (see Plate 2b). The total length of the inner screen is a little more than 2 metres; it is also designed, when not used to line the gravel pack, to telescope through the inner flange at the base of the outer screen. It is then loosely fitted to the outer screen at its top by an annular dished plate which acts partly as a spacer, but principally as a plate to deflect descending buckets (see Plates 2a and 4b).

Site Conditions

The geological succession at the IGS Longmoor test site is described on page 2 of the interim report (Appendix 1); at the time of the original test of the first prototype in September 1973 only 0.3 metre of the Folkestone Sands aquifer was saturated. As a result of the dry autumn and winter, groundwater levels throughout much of the country remained abnormally low until the heavy rains of late January and February 1974, after which levels more nearly approached their seasonal normal. By the middle of March the groundwater level at the site was about $3\frac{1}{2}$ metres below surface. Since the base of the Folkestone Sands lay at 4.9 metres, there was thus 1.4 metres of saturated sand aquifer above the underlying silts of the Sandgate Beds.

Tests on 2nd Prototype, 12th-14th March 1974

1. Sinking of outer screen

A site 5 yards east of the 1st prototype was chosen where surface and groundwater levels were similar. A pit was dug by mechanical digger to water table at $3\frac{1}{2}$ metres, backfilled to 3 metres, and flooded by pumping from prototype 1. This effectively and temporarily increased the thickness of saturated aquifer to 2 metres, and the outer screen section was lowered to the bottom of the pit and sunk 1 metre below the raised water level, by hand excavation from within the screen, in order to test the modified lower cutting edge. The new design was found to facilitate greatly the sinking process and no particular problems were encountered. Every effort was taken to maintain verticality. Water and mud were removed by rope and bucket in the usual way. Sinking the outer screen to a depth of 1 metre below water level took 2-3 hours; at the end of this time the base plate and locking bar were positioned.

2. Sandpack assembly

The inner screen was then lowered into position for assembly with sandpack. Three 3-inch-by-3-inch wooden blocks fitted with lanyards and wire hooks were spaced at 120° intervals in the upper part of the annulus to keep the inner screen centrally positioned, and during the next hour 50 buckets of sand were poured into the annulus completely filling it. No appreciable distortion of the screens occurred and the upper dished annular deflector plate was positioned without difficulty.

Next day the well contained about ½ metre of water, which was taken out with buckets. The annular dish plate was removed, and removal of the annular sandpack was attempted by excavation and loosening through the castellations at the base of the inner screen, after the inner baseplate had been taken out. Attempts to hoist the inner screen straight out by rope failed to move it. Careful excavation of the sandpack from below combined with flushing with water from above and prodding with rods succeeded in removing all the pack in about 3 hours.

3. Sinking of inner screen

The inner screen was then lifted out, the baseplate of the outer screen removed, the inner screen replaced together with the spacer blocks as before, and downward excavation by hand of the inner screen through the outer screen was started. None of these operations resulted in any damage to the screens, which stood up perfectly to (deliberately) heavy-handed treatment. Excavation proceeded as before with one man inside the screen excavating and one on the planks above hauling and emptying spoil buckets. It proved possible (though uncomfortable) for a 6-ft-tall man to work effectively inside the 30-inch-diameter tube, although men of shorter stature are obviously better suited to this work.

Before excavation started, it had been anticipated that trouble might be experienced with the extended portion of the castellations, and so it proved. There was a marked tendency for these relatively poorly supported portions to 'pinch' inwards as sinking proceeded, and in future operations the castellations should be removed by hammer and chisel before attempting to sink the inner screen.

Sinking continued in stages of about 0.1 metre; excavation was followed by hitting a short plank laid across the top of the inner screen with a 10-cm-by-10-cm baulk of timber; by which means verticality (or near verticality) could be maintained fairly easily, the screen sinking eventually to a level about 0.3 metre below the base of the saturated Folkestone Sands and within the Sandgate silts. At this level serious pinching of the castellations occurred in the much harder material and no further excavation was carried out. After removing the spacer blocks, the baseplate, locking bar and annular deflector plate were positioned, the masking tape stripped from the screen slots, two upper casing sections positioned and attached, and the well left to fill with water (Plate 4b).

Thus the total depth of the completed well was 5.2 metres, the base of the outer casing being at 4 metres.

It was found that the casing sections could be bolted up without difficulty from within the cylinder using the new 'assembly tool' (see Plate 3a).

4. Yield tests on prototypes 1 & 2

Whilst excavation of prototype 2 continued, the opportunity was taken to carry out a further yield test on prototype 1 under the prevailing hydrogeological conditions. From the previous interim report it will be remembered that the top of the slotted screen lay at 3.90 metres below surface i.e. now 0.4 metres below static groundwater level. It will also be recalled that the lowermost metre of screen was sunk in impermeable Sandgate silts and was thus acting as a sump.

Water was abstracted by bucket until the water level in the well lay 0.3 metre below the base of the aquifer, and the time taken for the level to recover to the base of the sand was measured. The data thus obtained indicated a yield under the prevailing groundwater conditions, and at extreme drawdown, of 2.5 litres per minute or about 800 gallons per day. The water remained clear and silt-free throughout.

A subsequent yield test on prototype 2, with the static groundwater level 0.19 metre below the top of the inner screen, indicated a yield in this well (with the inner screen not fully extended) of 1½ litres per minute (about 500 gallons per day) for a depression in water level of 1 metre only. Again, the water remained clear. Extrapolation of the data indicates a yield of about 800 gallons per day (similar to that obtained for the first prototype) had the water level been depressed to the base of the aquifer - the condition under which prototype 1 was tested. It should be again emphasised that the transmissivity of this aquifer is low and much higher yields could normally be obtained - probably of the order of 20 cubic metres (about 4½ thousand gallons) per day from an installation penetrating 4 metres (both screens fully extended) of moderately transmissive saturated aquifer, and even greater yields from highly transmissive grits or gravels. In the latter cases it is likely that a de-watering pump would be necessary during sinking, particularly of the inner screen.

Yields of 10 cubic metres (about 2000 gallons) per day should easily be obtainable from installations fitted with a sandpack and penetrating 2 metres of moderately transmissive saturated aquifer.

ODA Research Contract for Development of Plastic Well Linings ('Minipuits')

INTERIM PROGRESS REPORT

Background

A field appraisal of groundwater requirements of the trade cattle routes (pistes a betail) in Tchad indicated that there was a need there for light, strong, durable linings for shallow wells (depths envisaged 5-7 metres) to replace open wells conventionally constructed in expensive concrete, with deep filters requiring regular maintenance. A group of 4-5 'minipuits' emplaced by direct village labour should provide an acceptable substitute for a single large conventional well at far less cost; additional advantages would be ease of maintenance, the spreading of both water abstraction and of the animals to be watered over an area instead of their concentration at a single point, leading to insanitary conditions. Single 'minipuits' in suitable hydrogeological situations should be ideal for small village domestic supplies; a small concrete rim and platform would ensure a reasonable standard of hygiene. In most cases abstraction would be by means of ropes and buckets, but hand-pumps could be fitted if desired. If successful, 'minipuits' could be used anywhere in the world where cheaper alternatives could not be provided and where hydrogeological conditions, i.e. mainly an unconsolidated aquifer with a relatively shallow water table, were suitable.

Research Contract

In March 1973 ODA awarded a research contract to IGS for the design, development and testing in the UK of prototype minipuits.

Design and Manufacture of prototype

An order for the detailed design and manufacture of a prototype in suitable plastic was given by IGS to Bristol Composite Materials Engineering Ltd (BCME). After discussion of various proposed designs, one was selected for development, the material being fibreglass, bonded with epoxy resin. BCME offered to fund at least half the design and manufacturing costs then estimated (by the company) at £1500, but later decided to make no charge for the manufacture of the first prototype, which was delivered on 24th August.

This "Mark 1" model consisted of 12 hemi-cylindrical casing sections each 36 inches (0.9144 metres) diameter, 10 of which were 1 metre in depth and unslotted, whilst the remaining two half sections were 2 metres in depth and slotted (nominal slot width 0.040 inch) to the extent of approximately 7% of the surface area. The slotted sections were, of course, designed to function as a well screen. A flat, circular, baseplate, also of fibreglass and consisting of two semicircular halves which fitted beneath fixed retaining lugs at the base of the lowermost casing section, was locked in place by means of a stout holding bar. The base plate was slotted in similar fashion to the lowermost casing section.

Each half-section of the casing was flanged vertically and the flanges drilled to receive nylon bolts. Each section was flanged horizontally at both ends, and the flanges of adjacent sections could be bolted together in the same way. At the bottom of the lowermost 2-metre slotted section was an internal 5-cm strengthening flange; no external flanges were present except at the top of the section. Two streamlined thickened strengthening hoops were incorporated circumferentially in the casing wall at 1/3-metre spacings between top and bottom flanges in each 1-metre section, and four such hoops in the basal section, interrupting the vertical rows of horizontal slots. Nominal wall thickness of the sections was about 4 mm.

Test of first prototype

(i) Site Conditions

It was decided to sink the first prototype at the IGS Inflitration Research Site at Longmoor, near Petersfield, Hampshire, because this site was readily available and the depth of the water table known to be suitable. However as a result of abnormal drought conditions, water levels in the ground were at least 1 metre lower than normal for the time of year and it was realised that it would not be possible to test the full yield potential of the installation under the prevailing conditions.

The geological sequence at the site (proved in the excavation) is as follows:

	Thickness m	Depth m
Recent		
Black peaty sandy soil, grading into	0.30	0.30
Folkestone Sands		
Soft, weathered, brown iron-stained sands with occasional small chert pebbles	3.80	4.10
Brownish-grey fine sands becoming increasingly silty downward	0.80	4.90
Sandgate Beds		
Dark grey compact sandy silt, sand content decreasing downwards	1.00+	5.90

The strata were unsaturated to 4.60 metres at which depth water started to enter the pit. By 4.90 metres there was little further increment of water and the underlying silts were virtually dry. Thus the thickness of the saturated Folkestone Sands aquifer at the time of sinking was only 0.30 metre, but records of water level fluctuations elsewhere on the site indicated a seasonal fluctuation in response to rainfall of up to 2 metres.

(ii) Installation of the casings

A pit, approximately 3 m x 4 m at the surface, was mechanically excavated to a depth of 4.80 metres. The top of the pit was subsequently widened, to a depth of about 1 metre, to provide a foundation for scaffold planks and to remove some of the topweight from the sides of the pit. This and a previous pit dug nearby showed no tendency to cave above the water table. The two lowermost (slotted) half-sections were bolted together on the surface and then lowered by rope sling around the top flange to the base of the pit. One man then descended the casing and began to excavate beneath and within the basal inward-turned flange; spoil and water were hauled to the surface by a second man on the planks above. Progress was slow in the harder silts of the Sandgate Beds but by the end of the first day the base of the cylinder has descended about 0.25 metre below the base of the pit.

The following morning there was about 0.5 metre of water in the casing and surrounding pit, and about 100 gallons (just under ½ cubic metre) were removed by bucket. Despite the lack of water in the silts beneath 4.90 metres, it was decided to continue to sink the casing to prove the feasibility of the method of sinking. After adding and bolting up two casing sections to the lowermost section (in order to add weight) excavation continued from within the cylinder. It was found that the 5-cm flat inturned basal flange made undercutting difficult, and when the cylinder descended the amount of travel was restricted as the flange tended to compress rather than cut through the silt. Rocking from within the cylinder, and jumping on a plank laid across the top of the cylinder were found to be effective aids to downward penetration; at first verticality presented no problems.

The best excavating tools were found to be an ordinary garden fork which could be used to partially undercut by inserting at a slight angle beneath the rim and then using the rim as a fulcrum, after first making a sump in the centre. Final undercutting was then achieved with the blade end of a geological hammer, and the spoil - largely liquid mud and sand (water and mud leaked continually behind the casing and beneath the flange) - was bailed into the bucket with a stout saucepan. The slots in the casing had been taped over beforehand with contact adhesive masking tape which effectively prevented ingress of water through the casing sides during sinking; there was no difficulty evacuating water and spoil by bucket.

Excavation continued in 1-hour shifts until the base of the casing had reached 5.90 metres late in the afternoon. After positioning the base plates and locking bar the masking tape was then stripped from the slots, when small quantities of silt were found to have accumulated in 'bubbles' behind the tape on the inner side of the slots. During the final shift the cylinder had become slightly out of vertical, but as circumstances prevented further deepening it was decided to try to straighten the column by pulling on a rope after two more sections had been bolted on to add leverage and to bring the top of the casing above ground level. However suction in the silts surrounding the lower casing prevented it being pulled upright, and the threads of the lowermost nylon flange bolts were stripped in the attempt. Verticality could have been restored by further selective excavation, but time did not allow this to be done as the pit had to be backfilled by dark. The broken bolts were replaced and backfilling proceeded; on completion the site was temporarily fence

(iii) Preliminary yield tests

A subsequent test by two men using buckets indicated an approximate daily yield of 2/3 cubic metre (147 gallons) per day under the prevailing conditions i. e. only 0.30 metre of saturated aquifer. If the well had penetrated two metres (i. e. the full length of the slotted section) of saturated aquifer of similar transmissivity, a yield of at least 4 cubic metres per day could reasonably be expected at this site. However, the lower part of the Folkestone Sands is silty, and the transmissivity (not precisely determined) evidently low; the yield in sands of moderate transmissivity is likely to be in the range 5-10 cubic metres per day.

Further yield tests will be carried out when the hydrogeological conditions on site become more favourable i. e. after groundwater levels have been raised by seasonal infiltration.

Further prototype development

A second ("Mark 2") prototype, for which funds remain available, is under construction by Bristol Composite Materials Engineering Ltd. Planned modifications include a narrow chisel-edged flange beneath the lower cylinder to facilitate downward movement, and an additional inner slotted cylinder of 30 inches (0.762 m) diameter to fit inside the lowest slotted section so as to accommodate a gravel pack within the 3-inch (0.0762 m) annulus, the latter being covered and protected by a stout, sloping dish-plate. The inner casing would be designed for subsequent installation should significent silting occur. Improved assembly techniques are also planned; the casing sections must be capable of being bolted together from within the linings as assembly proceeds - it is unlikely, in the field situation, that the dug pit would be large enough to permit bolting from the outside.

It is hoped to complete installation and testing of "Mark 2" this year, but full yield tests may have to await the return of more normal hydrogeological conditions.

Conclusions

1. The first prototype 'minipuits' - sectional shallow well lining, incorporating a slotted screen, all prefabricated in durable epoxy resin-bonded fibreglass, has been successfully installed in sands and silts at the IGS Infiltration Research Site at Longmoor, near Petersfield, Hampshire.

2. The linings were emplaced in a mechanically excavated pit to a total depth of almost six metres, the lowermost metre being excavated below the water table by hand within the bottom section of casing.

3. The method of sinking proved satisfactory, and it should be possible to install minipuits in hand-dug pits through unconsolidated sediments to depths greater than originally envisaged i. e. to about 12 metres (10 metres to water table, and 2 metres below) without much difficulty.

4. The bottom edge of the lowermost casing section requires redesign to form a chisel edge.

5. Silting troubles are likely to be minimal except in very fine loose sands or silts, because the entry velocity of water is low. The addition of an inner slotted cylinder below the water table, with gravel-packed annulus, should effectively prevent the entry of silt.

6. Simple yeild and recovery tests on the completed installation indicate an actual yield under unfavourable prevailing hydrogeological conditions (30 cm of saturated silty sand aquifer) of 2/3 cubic metre (147 gallons) per day. Full penetration by the 2-metre well screen of a moderately transmissive sand aquifer should give yeilds in the range 5-10 cubic metres (1100-2200 gallons) per day.

7. The strength of the casings proved adequate for the purpose and no breakages (except nylon bolts) resulted from transport or installation. The casings proved light (14.5 kg per 1 metre half-section) and sinking and assembly were easily handled by 3 men with simple implements.

8. It was found that one man can reasonably be expected to lift water by conventional bucket from a depth of 5 metres at the rate of 130-150 gallons per hour. Using primitive buckets (goatskins or calabashes) of smaller capacity the rate is more likely to approximate to 110 gallons ($\frac{1}{2}$ cubic metre) per hour. The 36 inch (0.914 metre) diameter linings can easily accommodate 2 abstractors simultaneously, in which case the constraint on use is likely to be the yield of the well.

9. A small concrete coping and platform around the wellhead is essential if pollution by animals and sand on wet ropes is to be avoided.

John B W Day
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3 October 1973

Plate 1a (above)

Lowering the outer screen to the bottom of the pit.

Plate 1b (left)

Emplacing the outer screen below the water table. The slots are covered by masking tape to exclude water during sinking.

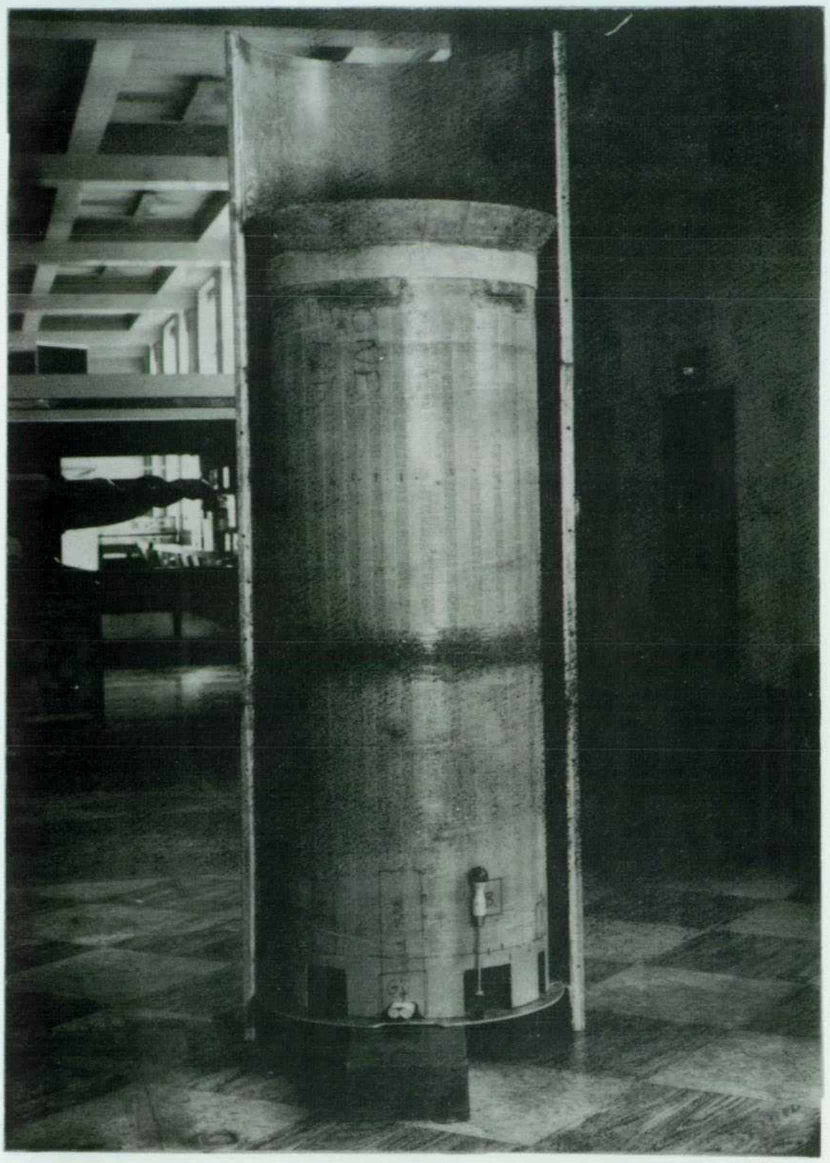

Plate 2a (left)

Inner and outer slotted screen sections assembled for use with annular sandpack. The castellations at the base of the inner screen assist subsequent removal of the sandpack.

Plate 2b (below)

Detail of base of inner screen showing removable baseplate and locking bar. The outer screen has a similar arrangement.

Plate 3a (left)

Assembling the upper lining sections from within the well. Nylon nuts are bonded to the undersides of the upper flanges of each section; the bolts are held by the assembly tool.

Plate 3b (below)

Some of the simple tools used for assembly and emplacement. They include ladder, tape measure, spacer blocks, garden fork, paint scraper, bailer, hammer, screwdriver/assembly tool, ropes, buckets and planks.

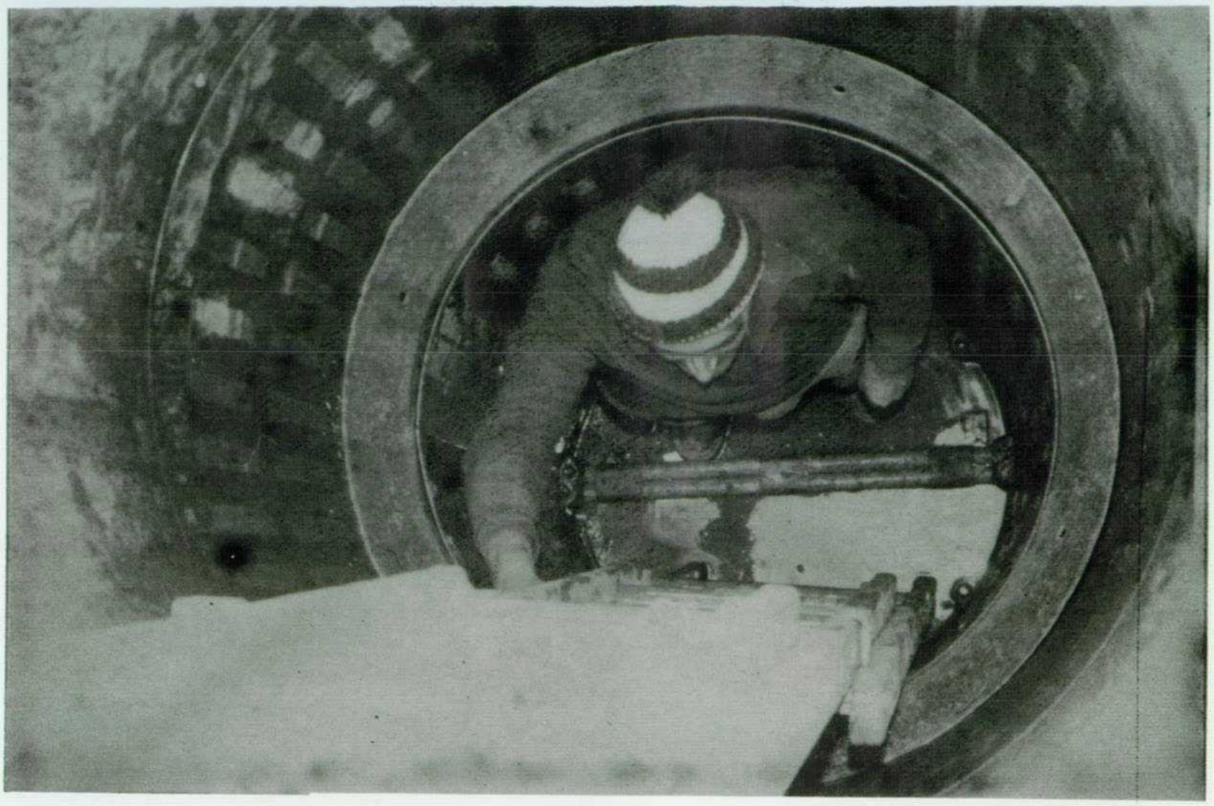

Plate 4a

Emplacement of inner screen showing wooden spacer blocks in position and hooked to top of screen. Masking tape covers the slots during sinking.

Plate 4b

The completed well with inner screen sunk through and below the outer screen. The annular deflector plate and the base plates with wedged locking bar are in position. The masking tape has been stripped from the slots.