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A Review of Borehole Construction, Development and Maintenance Techniques Around Owerri and its Environs, Southeastern Nigeria.

Olasehinde, P.I. and Amadi, A. N.
Department of Geology, Federal University of Technology,
P. M. B. 65, Minna, Niger State.
akoamadi @ yahoo.com

Abstract
Borehole construction and development are techniques employed in the exploitation and management of groundwater. A review of the design, construction, development and maintenance of boreholes around Owerri was undertaken with the aim of finding a lasting solution to problems associated with borehole drilling in the area. Groundwater occurs abundantly in the coastal plain sands (Benin Formation) which outcrop in the area with static water level (SWL) ranging from 8-65 meters depending on the location and the period of the year. The groundwater flow direction is north-south. The lithologic-log of boreholes in the area revealed that 0-5 meters are lateritic-sand followed by medium to coarse grained sand with clay bands occurring at greater depth. Well yield and drawdown vary from 54.24–231.50 m^3/hr and 0.9–13.5 meters respectively, while the hydraulic conductivity is approximately 3.55×10^{-12}m/sec. All these values indicate high specific yield and good aquifer performance. Groundwater from boreholes is the main source of water supply in the area, yet there are many failures. Some of the identified causes of borehole failure in the area include: poor geophysical survey, poor knowledge of the local geology, insufficient funding, improper borehole drilling supervision, unprofessional and inexperienced delivery of borehole drilling and post borehole completion problems. These problems can be remedied through proper geophysical survey, adequate funding, employment of professional and experienced drillers, proper well supervision and development as well as regular borehole maintenance.

Keywords.
Development, Maintenance, Owerri, Groundwater, Causes of Borehole Failures and Remediation Techniques.

Introduction

Water is the elixir of life; without it, life is not possible. A person requires three liters of portable water per day to maintain the essential fluids of the body. Civilization have flourished with the development of reliable water supplies, hence the saying when the well is dry, we know the worth of water (Benjamin Franklin). A borehole (water well) is a hole drilled for the principal purpose of obtaining water supply (Lewis, 1998). In recent times, borehole has become the main source of water supply in rural, semi-urban and urban areas (Offodile, 2002). This is attributed to the fact that borehole water derives its source from groundwater, which is not easily contaminated like the surface water and less costly than surface water harnessing.

This work focuses on the techniques involved in explorations design, construction, development and maintenance of boreholes with emphasis on Owerri and its environs, (southeastern Nigeria). It also intends to serve as a practical guide to the principles involved in the drilling of future boreholes in the area.

Study area description.

The study area is Owerri (Southeastern Nigeria). It Lies between Latitudes 5°20'N to 5°40'N and longitudes 6°50'E to 7°10'E (fig.1). It is a low lying terrain with a good road network. The area is drained by three main rivers (Otamiri, Oramiriukwa and Nworie). The rivers flow in the north-south direction except Njaba River which flows from west to east to join Oramiriukwa River (fig.1).

Original

General geology of the area.

Stratigraphic succession of rocks in the study area consists of Nsukka, Imo-Shale, Ameki, Ogwashi-Asaba and Benin Formations (Hazel, 1971) as shown in Table1. The coastal plain sand belonging to the Benin formation extends to a considerable depth in the area and is favourable for ground water development. The formation consists predominantly of very thick coastal sand, sandstone, clays and sandy clays occur in lenses. North of Owerri towards Orlu and Okigwe, the thickness of the Benin Formation decreases drastically and starts to overlap the Ogwashi-Asaba Formation which is mainly clayey sand with lignite seams (fig.1). The Ameki Formation which is mainly sandstone unconformably underlies the Ogwashi Asaba Formation. The Imo Shale unconformably underlies the Ameki Formation while the Nsukka Formation underlies all the formations (Uma and Egboka, 1984; Short and Stauble, 1967). Groundwater occurs abundantly in the coastal plain sands (Benin formation) and the static water level (SWL) ranges from 8-65 meters depending on the location and the time of the year. The Benin formation also overlies the petroleum bearing Agbada and Akata formations in the southern (Niger Delta) area (Table 2). It is a good aquifer with an average annual replenishment of about 2.5 billion cubic meters per year (Onyegocha, 1980). In most areas, the sandy components forms more than 90% of the sequence of the layers therefore permeability, transmissivity and storage coefficient are very high. Inspite of these favourable conditions for groundwater accumulation, cases of borehole failures abound in Owerri area. This is what led to the present study.

Climate and Physiography of the Area.

The study area lies within the tropical rainforest belt of Nigeria and the climate has distinct wet (March-October) and dry (November-February) seasons. The average annual rainfall is approximately 2,250 mm. The humidity is generally high throughout the year and the rates of evapotrauspiration far exceed that of precipitation during the dry seasons (Uma and Egboka, 1986). The topography is characterized by gently undulating lowlands and plains.

Borehole Design and Constructional Methods.

The design of a water well must be proceeded by well executed predrilling feasibility studies which most of the time rely on geophysical studies of the subsurface geology (Olasehinde, 1999). The design of a water well depends on the type of aquifer system to be exploited and the discharge rate required (or supply demand) must be decided before a borehole can be properly designed (Anderson, 1973). It will determine the size of pump to be installed, which, in turn, will govern the minimum internal diameter (ID) of the pump-chamber casing. The cardinal rule of well design is that the ID of pump chamber must be large enough to accommodate the pump-shroud, cable and risers. An average design will incorporate the following features: total drill depth (TDD), drilled diameter, casing selection, screen selection, casing/ screening installation and gravel pack design fig.2. The drilling method commonly used in Owerri area is the rotary drilling. A rotary rig comprises of a floor on which is mounted a diesel engine power unit, a mud pump for circulating the fluid, a winch for raising or lowering the drill string and a mast from which the drill string is suspended fig.3. The drill string is made up of lengths of heavy-duty steel tubing or drill pipe, with the drill-bit assembly attached to the bottom. The drilling fluid or mud is mixed in a mud pit and is pumped by mud pump through the kelly hose to a water swivel at the top of the

 April 2009
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kelly. This swivel is the unit from which the entire drilling string is suspended and allows the mud to pass while the drill string rotates. The mud passes down the drill string to the bit which it leaves by ports in the bit faces, and then returns up the annulus around the drill string to the mud pits (Fig.3).

The mud pit has two chambers: the first and the smaller allows cuttings to settle from the mud (settlement pit) before it passes to the second chamber which acts as a sump for the mud pump (Driscoll, 1986). The mud removes cuttings from the bit, carries them out into the mud pits. It cleans, cools and lubricates the drill-bit and drill-string. It exerts a supportive mud cake on the borehole walls to prevent caving of the formation. It also retains cuttings in suspension while the drilling stops to add extra lengths of drill-pipe. The rate of penetration (ROP) is a function of lithology. It is faster in sandy formation than in clayey formation. Similarly, the colour of the mud is a reflection of the immediate drilling environment. Drilling mud appears dark in lignite formation and reddish in lateritic formation (fig.4).

After drilling has been completed, the drill-strings are carefully pulled out of the borehole; this is followed by casing of the borehole (fig.5) which consists of blind casings and screens, back-flushing and gravel-packing (British Standard). After 24 hours, a compressor is used to flush the well in order to clean the borehole annulus before the installation of submersible pump as illustrated in fig.5.

Borehole Failure and Remediation

Inability of a water well to yield the required quantity of water at a given time interval is termed borehole failure (Driscoll, 1986 and Lewis, 1998). The major cause of this failure is the lack of understanding of the local geology of the area. Other causes of borehole failures include:

1. Faulty or lack of geophysical survey
2. Unprofessional delivery of borehole drilling
3. Inadequate funding.
4. Inefficient supervision of borehole while drilling.
5. Post borehole completion problems such as:
    - i. Non back flushing of the well before gravel packing
    - ii. Improper borehole development
    - iii. Incomplete gravel packing
    - iv. Absence of well logging
    - v. Blockage of aquifer/ gravel pack
    - vi. Incrustation of the screen
    - vii. Wrong positioning of the screen
    - viii. Absence of pumping test
    - ix. Siltation
    - x. Corrosion

The remediation measures are outlined below:

1. Thorough predrilling geophysical survey leading to understanding the subsurface geology.
2. Employing professional and experienced drillers
3. Adequate borehole funding and regular borehole maintenance
4. Proper borehole drilling supervision by competent hydrogeologist.
5. Proper back flushing of borehole before gravel packing.
6. Using appropriate screen slot size for a given aquifer.
7. Proper position of the screen.
8. Installation of corrosion resistant casing material.
9. Regular pump testing and well logging

April 2009
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Discussions

In the Owerri area, it is common experience to have loss of circulation. This is due to the loose formation sometimes encountered during drilling. A fore knowledge of such formation during the exploration stages would prepare the well developer to choose appropriate chemicals to prevent loss of circulation.

Around Owerri, borehole collapse is another common phenomenon. The drilling stems get stuck readily. The solution has been to put adequate chemicals (bentonite and antisol) and to case immediately after drilling.

Towards Nkwerre-Orlu in the northwest, most boreholes are dry. This is due to lack of extensive aquifers in the Ameki formation where aquifers are in lenses within the formation. Therefore the location of prolific sand lenses here will solve the problem of drilling abortive wells. The boreholes need careful logging and screening not to miss the prolific sand lenses.

Conclusion.

A borehole design around Owerri varies with the number of aquifers to be exploited and the depth of the aquifer. Each design will include: Borehole depth, borehole size, borehole constructional material and gravel packing. Boreholes deteriorate over time and needs periodic maintenance. The local geology of the area to be drilled, determines the type of construction design and technique to be used. Geophysical survey should be carried out before drilling operations starts. Corrosion resistant casing pipes are recommendable.

Boreholes should be thoroughly backwashed to remove all chemicals used in drilling before and after gravel packing. Success of the construction also depends on the kind of rig used and the availability of suitable tools. The remediation procedures outlined should be adhered to. Adequate drilling chemicals should be made available during drilling to avoid wall collapse/ caving in and prevent loss of circulation.

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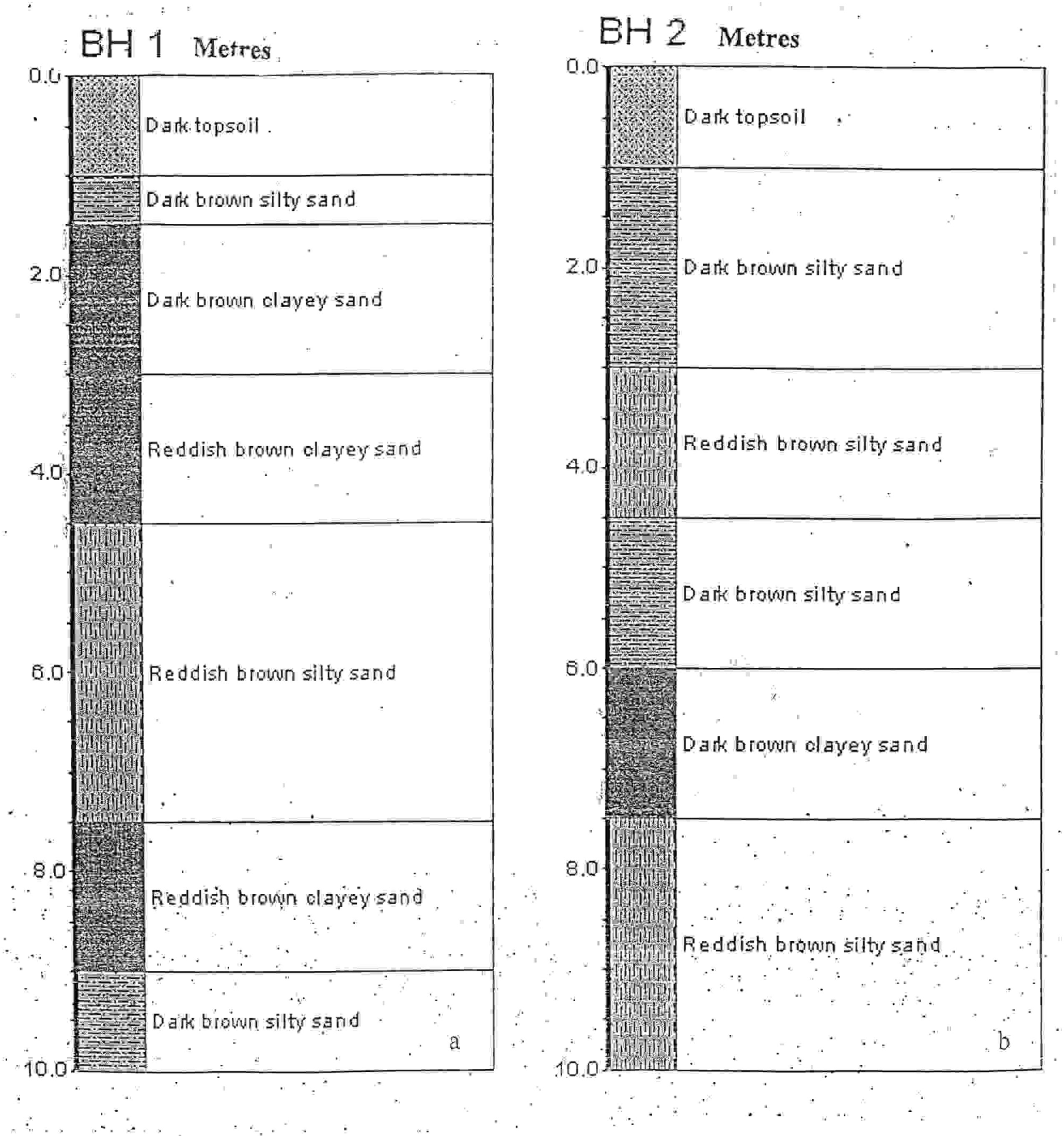

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Table 1. Stratigraphic Succession of Rocks in Owerri Area (After Uma and Egboka, 1985).

	Age	Formation	Lithology
Tertiary	Miocene-Recent	Benin Formation (Afam Member)	Medium to coarse grained, poorly consolidated sand with clay lenses and stringers
	Oligocene-Miocene	Ogwashi-Asaba Formation	Unconsolidated sand with lignite seams at various layers
	Eocene	Ameki Formation Nanaka Sand	Grey clayey-sandstone and sandy- claystone
	Paleocene	Imo Shale	Laminated clayey-shale
Upper Cretaceous	Maastrichian	Nsukka Formation	Sandstone intercalated with shale and coal beds

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Table 2. Correlation of Subsurface and Surface Formations of Niger Delta Basin (After Whiteman, 1982)

Youngest Age		Oldest Known Age	Youngest Age		Oldest Known Age
Recent	Benin Formation	Oligocene	Pleistocene	Benin Formation	Miocene
Recent	Agbada Formation	Eocene	Miocene Eocene	Ogwashi-AsabaFormation Ameki Formation	Oligocene Eocene
Recent	Akata Formation	Eocene	Late Eocene Paleocene	Imo Shale Nsukka Formation	Paleocene Maastrichian
			Maastrichian	Ajali Formation	Maastrichian
			Campanian	Mamo Formation	Campanian
			Campanian	Nkporo Shale	Santonian
			Coniacian	Agwu Shale	Turonian
			Turonian	Eze-Aku Shale	Turonian
			Albian	Asu River Group	Albian

Subsurface **Surface**

Original

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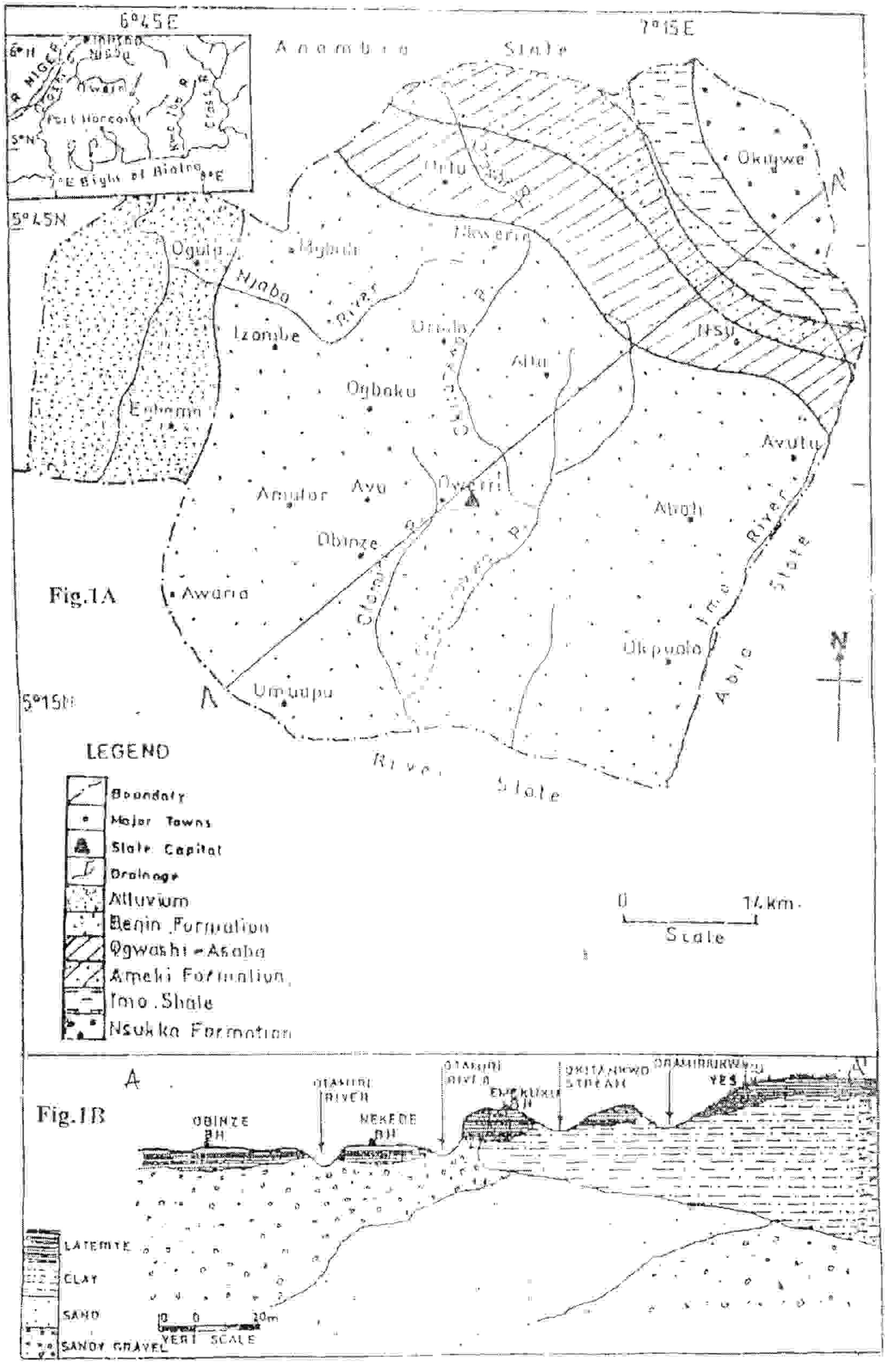

Fig.1A. Location of Owerri on a geological map of the study Area.
Fig.1B. Cross-Section from SW to NE through Owerri Area.

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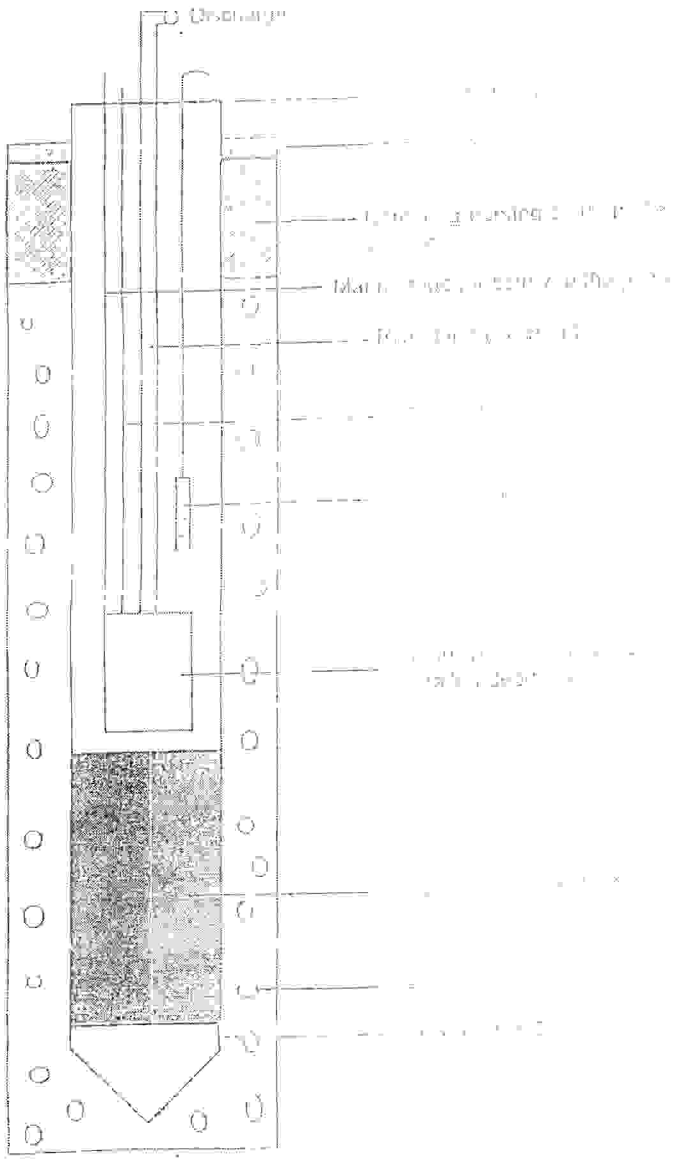

Fig.2A. Borehole Design before Drilling

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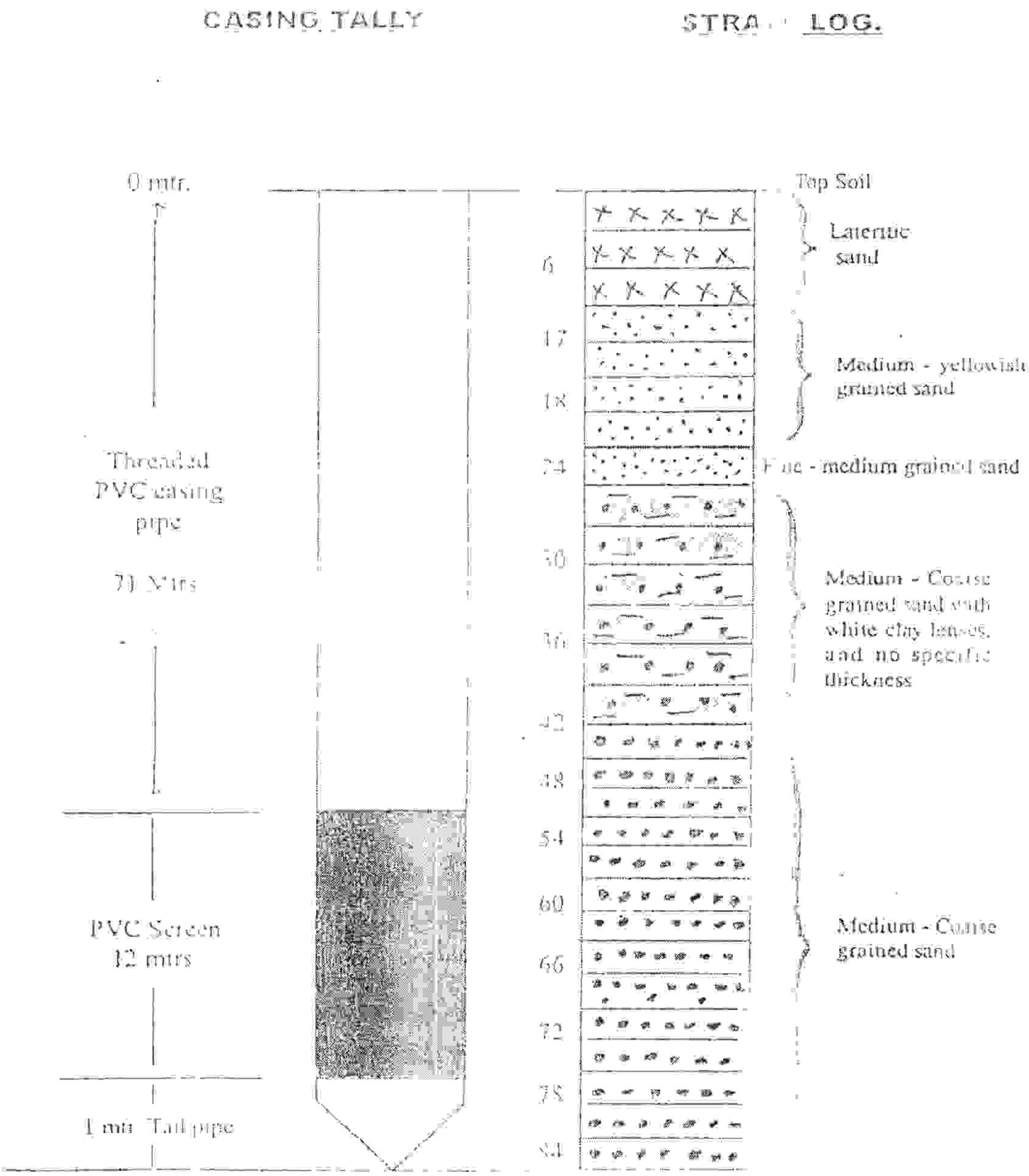

Fig.2B. Borehole Strata-log at Owerri after Drillin

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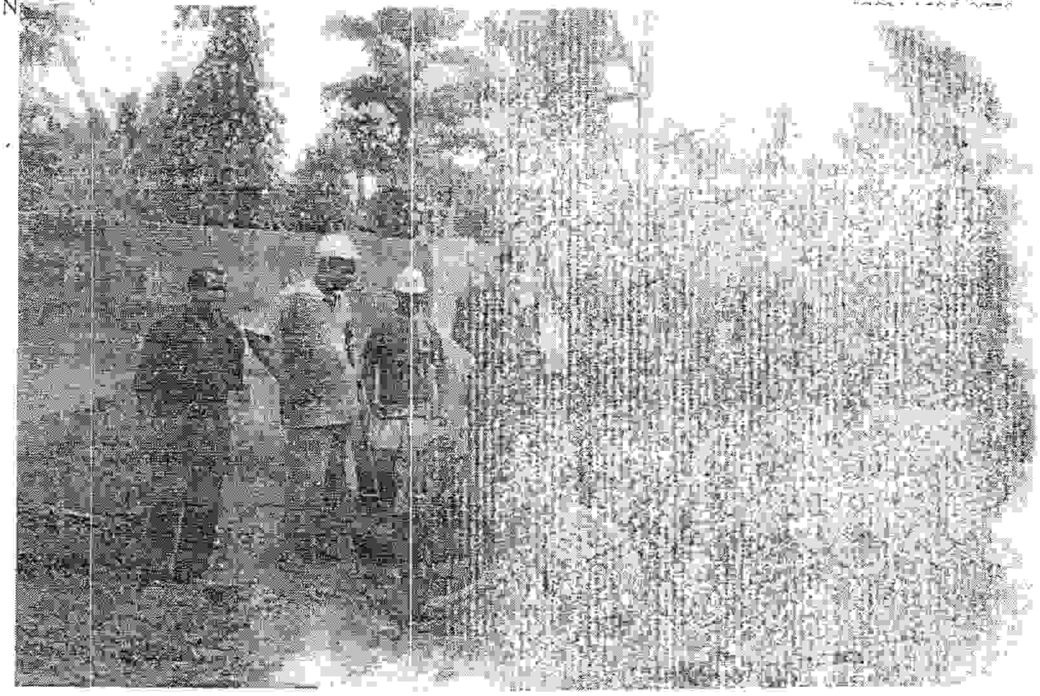

Fig.3. Borehole Drilling Using a Rotary Rig at Owerri.

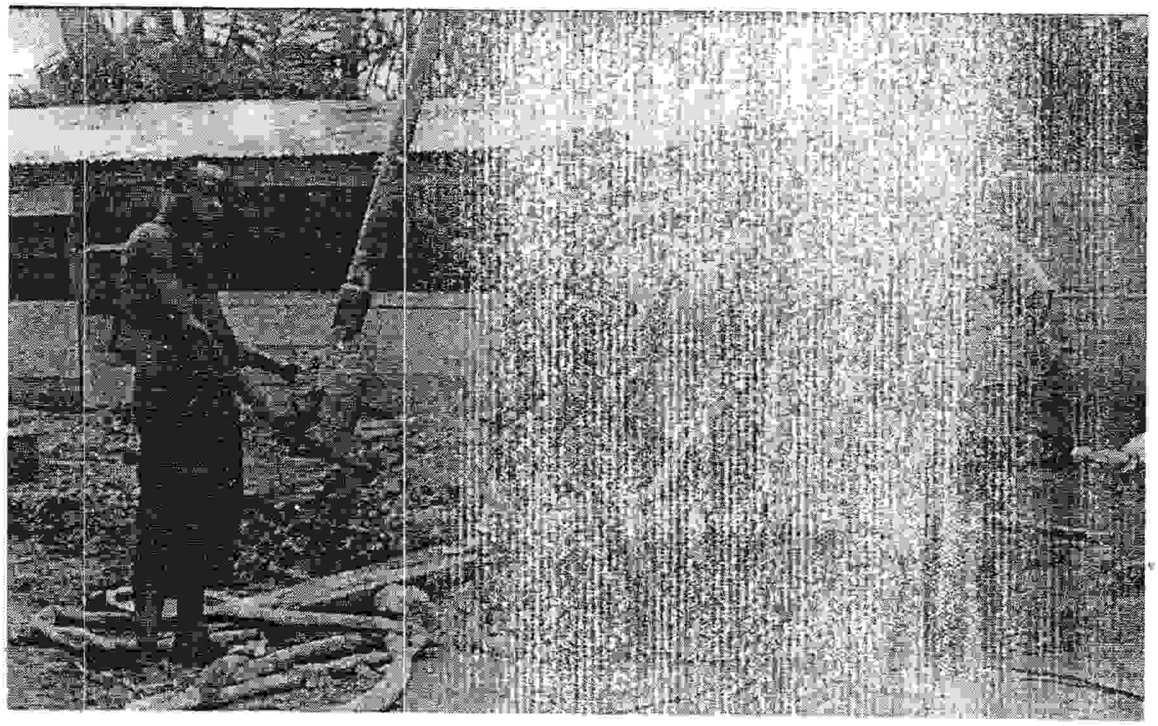

Fig.4. Sampling from the Mudpit (X).

April 2009
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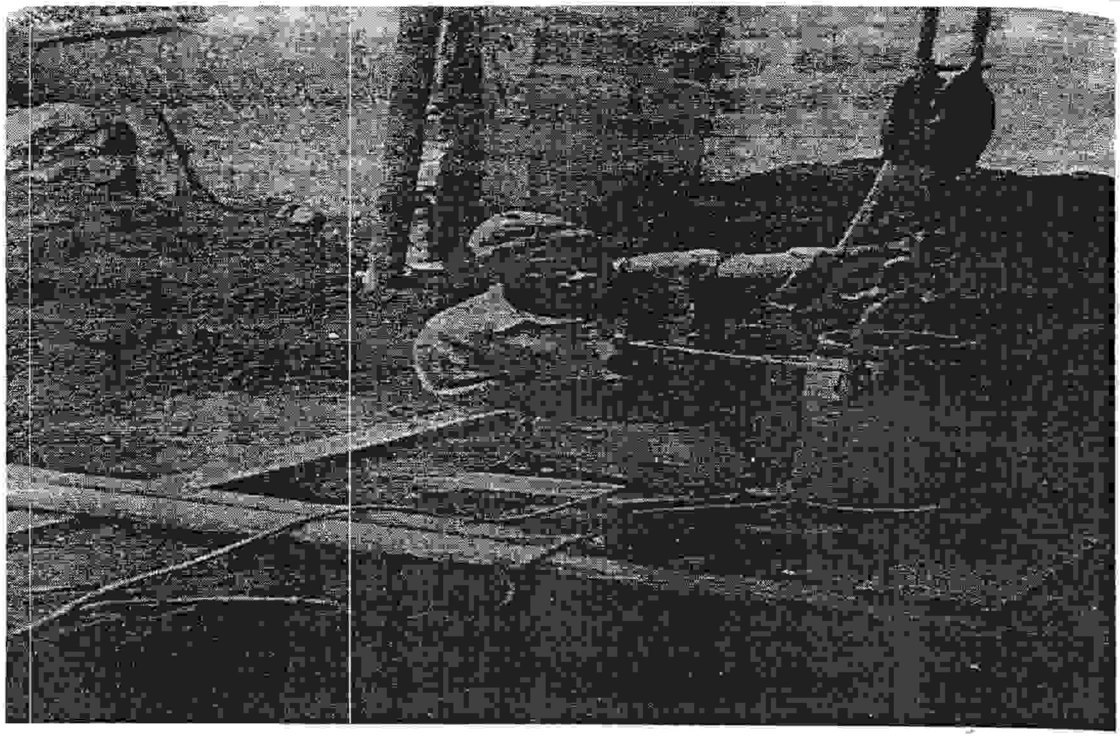

Fig.5. Casing of Borehole (Stainless Casing). The Welder was inside the Mudpit during welding.

Fig.6. Surging of Borehole Water By Compressing

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