Assessing the potential of low-cost drilling in meeting the MDGs for water supply in Nigeria

By

Adedotun Adekile

A research project submitted in partial fulfilment of the requirements for the award of the degree of Master of Science of

Loughborough University

December 2009

Supervisor: Brian Reed BSc, MSc, MICE, MCIWEM, CEng, CEnv

Water, Engineeing and Development Centre

Department of Civil and Building Engineering

Certificate of Authorship

I certify that:

i I am responsible for the work submitted in this project and that the original work is my own

ii I have not submitted this work to any other institution for the award of a degree

iii all field work was carried out by me with no outside assistance except as noted below.

iv all information (including diagrams and tables) or other information that is copied from or based on the work of others has its source clearly acknowledged in the text in the place where it appears.

Signed…………………………………………………………………………………………………

Name…………………………………………………………………………………………………

Date……………………………………………………………………………………………………

To the best of my knowledge, I believe that the above declaration is true.

Signed..…………………………………………………………………………………………………

Name of local guarantor…………………………………………………………………………….

Date……………………………………………………………………………………………

N.B. The data and information on locally fabricated rigs and hand drilling from Lagos and River States in this report were collected along with Olasola Olabode of the National Water Resources Institute, Kaduna, Nigeria when, he and the author carried out the 'Study of Public and Private Drilling In Nigeria' for UNICEF in 2008.

Table of Contents

Certificate of Authorship ii

Table of Contents iii

List of Figures vi

List of Tables........ vi

List of Abbreviations and Acronyms vii

Acknowledgement viii

Abstract ix

Executive Summary........ x

Executive Summary........ x

Chapter 1 Introduction 1

1.1 Background to the study........ 1
1.2 Aims and objectives of the research 1
1.3 Country context 2
1.4 Report structure........ 3

Chapter 2 Literature review 5

2.1 The literature review process 5
2.1.1 Aims of the review........ 5
2.1.2 Methodology of the literature search 5
2.1.3 Verification of documents 6
2.1.4 Structure of the review........ 6
2.2 Outcome of the literature review........ 6
2.2.1 The groundwater option........ 6
2.2.2 Groundwater abstraction techniques........ 7
2.2.3 Groundwater development in Nigeria 10
2.2.4 The groundwater resources of Nigeria 11
2.2.5 Borehole Drilling in Nigeria 16
2.2.6 Borehole cost and price 17
2.2.7 Achieving cost reduction in borehole construction 20
2.3 Summary of the literature review........ 22

Chapter 3 Methodology........ 25

3.1 Introduction........ 25

3.2 Desk study 26
3.2.1 Estimating the number of boreholes that are required to meet the MDGs 26
3.2.2 Identification of areas with hand drilling potential in the country 26
3.3 Field work 26
3.3.1 Sample size 28
3.3.2 Evaluation of locally fabricated rigs 28
3.3.3 Evaluation of the potential of hand drillers to contribute to water supply targets 29
3.4 Data analysis 29
Chapter 4 Research Findings 31
4.1 Introduction 31
4.2 An overview of the national rural water supply framework 31
4.3 Sector structure 32
4.4 Rural water supply coverage and borehole drilling in Nigeria 34
4.5 Estimating the number of boreholes to meet the MDGs in Nigeria 34
4.6 Locally made rigs – the beginnings 36
4.6.1 Drilling rig fabricators' background 37
4.6.2 Business structure 38
4.6.4 Prices of locally fabricated rigs 43
4.6.5 Rig performance 44
4.6.6 Impact of locally fabricated rigs on borehole prices 47
4.7 Case study of a locally fabricated rig 48
4.8 Hand drilling 50
4.8.1 Identification of potential areas of hand drilling 51
4.8.2 Hand drilling technique 54
4.8.3 Hand drillers background 54
4.8.4 Hand drillers entrepreneurial skills 56
4.8.6 Prices of hand drilled boreholes 58
4.8.7 Hand drillers capability 59
4.9 Case study of a hand drilling operation 60
Chapter 5 Discussion 63
5.1 Definitions 63
5.1.1 Fabrication versus manufacturing 63
5.1.2 Low cost drilling 63
5.2 Low cost drilling and economies of scale 63
5.3 Promoting low cost drilling for livelihoods 63
5.4 Government projects and low cost drilling 64
5.5 Bringing hand drillers within the purview of government projects. 64

5.6 Ground water monitoring 65
5.7 Borehole sustainability and the MDGs 65
Chapter 6 Conclusion 67
6.1 Introduction 67
6.2 Institutional Issues 67
6.3 Present water supply coverage 67
6.4 Locally fabricated rigs 67
6.5 Locally fabricated rigs and cost effective boreholes 68
6.6 Hand drilling 68
Chapter 7 Recommendation 69
7.1 Introduction 69
7.2 The Federal Government 69
7.3 State Government 69
7.4 Local Government level 70
7.5 External Support Agencies and Non Governmental Organisations 70
References 71

List of Boxes

Box 1 Summary of the Hydrogeology of Nigeria 14
Box 2 Sustainability of water points in Nigeria – Keast (2007)........ 35
Box 3 Case study of a locally fabricated rig 49
Box 4 Case study of hand drilling operation........ 61

List of Figures

Figure 1 Administrative map of Nigeria 3
Figure 2 Hand Drilling Tree (From Danert and Gaya, 2009)........ 9
Figure 3 Relief Map of Nigeria (From Iloeje, 1996) 12
Figure 4 Geology of Nigeria (From Iloeje, 1996)........ 15
Figure 5 *RWSN* Conceptual Framework for Cost-Effective Boreholes........ 21
Figure 6 Map of the Project States........ 27
Figure 7 Map of Areas with hand drilling potential 53

List of Tables

Table 1 Prices of Boreholes from different Projects in Nigeria........ 18
Table 2 Cost sharing for capital investment 32
Table 3 Summary of Information on Rig Fabricators........ 36
Table 4 Prices of locally fabricated rigs........ 43
Table 5 Summary of feedback from locally fabricated rig users 46
Table 6 Historic borehole Prices (Adenle and Beale, 1989) 48
Table 7 Summary of boreholes drilled with the Terraqua rig 50
Table 8 Geology of States where hand drilling is going on........ 52
Table 9 Hand drillers background........ 55
Table 10 Hand drilled borehole prices........ 58
Table 11 Hand drillers capability 59

List of Pictures

Picture 1 Trailer rig from A.U Drilling in Kaduna........ 40
Picture 2 Truck mounted medium duty rig from A.U. Drilling in Kaduna........ 41
Picture 3 A 4wheel trailer on a drilling site with some of the parts labelled 42
Picture 4 Ready made rig in Gombe 42
Picture 5 A five-man hand “turning” party........ 54
Picture 6 Hand drilling equipment........ 54
Picture 7 Water selling point........ 62
Picture 8 Ehigiamusoe’s water business........ 62

Photo Credits

All the photographs in this report were taken by the author.

Exchange rate

At the time of the report the exchange rate was Nigerian Naira 150 to US$1.

List of Abbreviations and Acronyms

ADP	Agricultural Development Program
CEO	Chief Executive Officer
DFID	Department for International Development
DW	Deep Well
EMAS	Escuela Movil de Agua y Saneamiento (Mobile School for Water and Sanitation)
ESA	External Support Agency
EU	European Union
FMWR	Federal Ministry of Water Resources
hp	horse power
IDWSSD	International Drinking Water Supply and Sanitation Decade
JICA	Japan International Cooperation Agency
JMP	Joint Monitoring Program
km	kilometre
l	litres
LGA	Local government authority
m	meter
mm	millimetre
MDGs	Millennium Development Goals
NEEDS	National Economic Empowerment Development Strategy
NGO	Non Governmental Organisation
NPC	National Planning Commission
NRWSSPSF	National Rural Water Supply and Sanitation Programme Strategic Framework
OSSAP-MDGS	Office of the Senior Special Assistant to the President on MDGs
RUWASSA	Rural Water and Sanitation Agency
RWSN	Rural Water Supply Network
UNICEF	United Nations Children’s Fund
uPVC	Ultra polyvinyl chloride
WASH	Water, Sanitation and Hygiene
WEDC	Water Engineering and Development Centre
WHO	World Health Organisation

Acknowledgement

The author gratefully acknowledges the advice, support, and encouragement of the supervisor, Brian Reed in the course of the project work presented in this report. Thanks to Mohammed El Fatih former WASH Chief, UNICEF Nigeria who provided the author the opportunity to carry out a drilling study of Nigeria during which some of the data for this project were collected. Thanks also to Kerstin Danert of the Rural Water Supply Network for providing several useful references and directing the author to other sources. And to all the drilling rig fabricators, conventional and hand drillers and government officials who contributed to this report by granting interviews and providing data. Thanks also to Olusola Olabode of the National Water Resources Institute Nigeria, my co-consultant on the drilling study of Nigeria.

Finally thanks to my family for their support and understanding even when they had to go through privations brought about by spending scarce family resources on this project. And special thanks to my daughters Adesewa and Moyo Adekile, for proof reading the several drafts of the report and making corrections.

Abstract

There has been some concern amongst sector practitioners that Nigeria may not meet the Millennium Development Goals for water supply. According to the WHO/UNICEF Joint Monitoring Programme (2008) rural water supply coverage in Nigeria decreased from 34 per cent in 1990 to 30 per cent in 2006 and urban drinking water supply declined from 80 per cent in 1990 to 65 per cent in 2006. Nigeria with an estimated population of over 140 million is the most populous nation in Africa and if Nigeria does not meet the MDGs it is unlikely that Sub-Saharan Africa will meet them.

In order to be on track thousands of boreholes will need to be drilled in the country particularly in the rural areas. To achieve this, radically different approaches are needed that will incorporate a variety of solutions. Emphasis has to be placed on solutions that are affordable and which will allow households and communities to satisfy their need for potable water. In Nigeria, drilling rigs are being fabricated locally by small enterprises. Boreholes are also being drilled manually at a fraction of the cost of machine drilled holes. This research assesses the potential of locally fabricated rigs and hand drilling to contribute to meeting the MDG for water supply.

Key words: hand drilling, rig fabrication

Executive Summary

1 Introduction

The Millennium Development Goal (MDG) No. 7, ensuring environmental sustainability, has the target of reducing by half the number of people without access to safe drinking water and sanitation by 2015. There is some concern that Nigeria will not make the MDGs for water supply and sanitation (Keast, 2007). Water and sanitation coverage in the country decreased between 1990 and 2006 (JMP, 2008). If Nigeria with a population of over 140 million (NPC, 2006), and by far the most populous country in Africa does not make the MDGs then Africa is not likely to attain them.

The United Nations Children's Fund (UNICEF) Nigeria in 2008, out of concern for the cost and quality of borehole drilling in the country carried out a 'Study of Public and Private Borehole Drilling in Nigeria" (Adekile and Olabode, 2008). The study was concerned with the cost effectiveness of borehole drilling in the country. It identified locally fabricated rigs and hand drilling as means of reducing borehole costs and thereby reaching more people particularly in the rural areas. The study however did not

- look in detail at the performance of the rigs
- identify and quantify those areas of the country where hand drilling can be successfully practised
- suggest the mode of bringing hand drilling and hand drillers into the mainstream of government projects to meet the MDG targets for water supply

1.2 Research aim

The aim of the research project was to fill some of the gaps in the UNICEF 2008 report i.e.

- evaluate the potential of locally manufactured drilling rigs to contribute to increased water coverage
- evaluate the potential of hand drilling operators to contribute to increased water coverage.

2 Literature review

The literature review showed that groundwater sources are easier to develop than surface water sources particularly in rural areas but the quality of the water should not be taken for granted. Both machine and hand drilling have applications in borehole provision but hand drilling works only in particular environments where the hydrogeology is favourable. Where hard rock is encountered during drilling, the borehole may have to be abandoned.

Most of the drilling in Nigeria is done by the private sector. The drillers number in their hundreds. Their ranks include both conventional drillers with mechanical drilling equipment and manual drillers.

Borehole costs in the country are variable due to the varying geological terrains and contractual demands which in turn necessitate variable designs. In general, hand drilled boreholes are much cheaper than machine drilled boreholes. However, hand drillers are only patronized by householders and small scale enterprises and have not been brought into the mainstream of government projects.

It has been proposed by several workers that light duty and smaller drilling rigs are likely to produce cheaper boreholes than heavy duty drilling rigs. Light and medium duty drilling rigs are being fabricated locally in Nigeria. It is also proposed that these may produce more cost effective boreholes.

Gaps in the literature

Gaps found in the literature were

- no documentation or literature on locally fabricated drilling rigs
- no information on actual drilling capacity in the country in terms of number of equipment and personnel
- no information on why government agencies and other institutions do not patronise hand drillers since a hand drilled borehole costs only a fraction of machine drilled boreholes

3 Methodology

A mixed strategy was used in carrying out the research involving both a survey approach and case studies. The methods used involved document review, structured interviews, and field observations. A desk study was used to collate and review existing data and literature on drilling in Nigeria. Based on field interviews, the geology of Nigeria and borehole records, a map of those areas of the country that could benefit from hand drilling was produced. These are areas where hand drilling has been reported successfully carried out, with water level within 50 m and of unconsolidated sediments and weathered crystalline rocks.

Field visits were made to interview drilling rig fabricators, locally made rig users, hand drilling operators and employers of drillers. The field surveys and observation covered 9 states of the country.

The validity of the data collected was based on the various strategies and methods used in collecting the data such that some triangulation was achieved. There was close correlation between interviewee responses and field observations. Case studies provided further validation of the data collected. The data collected are presented in this report in the form of tables, as a narrative of the work carried out, the findings and the conclusion derived from them.

4 Findings

Institutional set up to meet the MDGs

The low water supply coverage in Nigeria is attributed to facility provision not keeping pace with population growth (UNDP/FGN, 2008) and installed facilities breaking down (Keast, 2007). The Nigerian government has set up relevant institutions to carry out reforms in the water supply sector to address the low water coverage and the MDGs.

Estimating the number of boreholes to meet the MDGs

Boreholes are often the technology of first choice in meeting rural water supply requirements. It is estimated in this research that about 10,000 boreholes need to be drilled annually to meet the water supply target. Thus in the 9 years between 2006 and 2015, 90,000 boreholes will be required. A saving of just 10% on borehole cost means about 2-3 million additional people could be provided with water for the same investment.

Reducing borehole costs

For many years, several workers have advocated or sought ways to reduce the cost of drilling by designing simple and low cost rigs which will translate to more people having access to safe water supplies. In Nigeria, light and medium duty rigs capable of drilling down to 100 m and 200 m depths respectively are being fabricated by small enterprises from refurbished engines and discarded vehicle parts. The trend started in 1984.

Rig fabricators' background

The drilling rig fabricators are of diverse backgrounds, from university graduates to those with little formal education but they had all been exposed to drilling in one way or the other either as drillers, engineers, mechanics, or welders. In the course of the research, 10 rig fabricators were interviewed.

Business structure

All the fabricators are legally registered as limited liability companies or trading enterprises. They cannot survive on rig fabrication alone as patronage is low so they engage in other businesses such as drilling contracts, repairs of drilling rigs and fabrication of other pieces of equipment.

The clientele is mainly local, although 2 of them based in Kano and Gombe in the northern part of the country have clients coming from Niger, Chad and Cameroon Republics.

Most buyers pay in instalments until the fabrication is completed. This makes it possible for young drilling enterprises to acquire a rig whilst hiring equipment from others initially.

Types of rigs

The rigs are either trailers or truck mounted. The prime movers are refurbished engines. The mast and drive heads are hydraulically controlled. All the components are procured locally from local scrap yards. Sometimes new valves, hoses, engines are used if the prospective owner so desires.

Rig performance

Depending on the time of construction, each rig has drilled 50 to 500 boreholes. Drilling time on the basement to an average depth of 40 m is 2 days. Spare parts are readily available from the same sources from which the original components were obtained. Parts that often break down are the hydraulic pump, hydraulic hoses, and the swivel. The main complaints of the rig users are that parts have no specification, the rigs are not standardised so that spare parts are used on trial and error basis.

None of the interviewees has experienced an accident due to a rig malfunctioning. Rig performance is validated by users going back to the same fabricators for other rigs.

Drilling rig prices

The prices range from N1.7 million ($11,000) to N3.5 million ($23,000) for the trailer mounted rigs and from N3.3 million ($22,000) to N3.7 million ($24,000) for the truck mounted rigs excluding the truck. In comparison to the fabricated rigs, a brand new trailer rig imported from Thailand of the same drilling capacity costs N6 million (US$40,000) on the Nigerian market.

Impact of locally fabricated rigs on borehole cost

Borehole prices drilled using locally made rigs for private individuals vary between N300,000 and N400,000 (US$2000 – 2700) whereas on government sponsored projects the price of a similar borehole is about N650,000 (US$4,300). Several of the drillers interviewed find it difficult to get government contracts directly as they said the process is not always transparent and there are delays in payment. The reduced cost, which makes it possible to reduce the price on private boreholes, is not passed on to government projects. But the reduced cost has made it affordable for many householders to drill their own borehole.

Hand drilling

Hand drilling is currently going on in 18 of the 36 states of the country. The technique used by hand drillers in the country is jetting. The ranks of the hand drilling operators include farmers, artisans, university graduates, retired government workers and conventional drillers.

The price of a hand drilled borehole varies between N180,000 and N350,000 (US$1200 – 2300) depending on the location and whether it is inclusive of the price of the pump. This is 30-50% lower than on government projects.

The patrons are mainly the private sector. Hand drillers have not been brought into the mainstream of government contracts.

5 Conclusions

The research concludes that both locally fabricated rigs and hand drilling have been employed for the provision of water supply boreholes for some years in the country and have the potential to lower the prices of boreholes so that the water coverage gap can be bridged. The potential for lower borehole prices has been manifested in the prices of private boreholes but not yet on government projects. The benefit of the technologies is yet to be tapped by government projects. Hand drillers are not patronised by the government.

The research showed that some of the hand drillers have a high level of entrepreneurial skills and have been working as conventional drillers on government projects and should be able to execute government projects.

About 10,000 boreholes need to be drilled annually in the country to meet the MDGs. This is a challenge necessitating innovative alternatives. All options available to reduce cost and thereby reach more people should be considered.

The different state governments need to go into partnership with the Water Well Drillers Association of Nigeria and hold dialogue with its members for a more cost effective pricing and drilling of boreholes in the light of locally fabricated rigs and prevailing borehole prices in the private sector.

To encourage as many drillers as possible to participate in government projects governments need to ensure that drilling contract award process is timely, transparent and equitable.

Government's attitude to hand drilling is not likely to change easily. The effectiveness of hand drilling has to be demonstrated by external support agencies and NGOs, setting up pilot projects in those states with hand drilling potential. The results of such pilot projects should be well documented and widely disseminated.

References:

Keast, G (2007) *The Way Forward for UNICEF WASH in Nigeria: Programme Recommendation* UNICEF Nigeria

National Population Commission (2007) *National Census Figures.* Federal Government of Nigeria

WHO/UNICEF (2008) *Progress in drinking water and sanitation* Joint Monitoring Programme available at http://documents.wssin.org/resources/documents.html Accessed 24.3.09

Chapter 1 Introduction

In September 2000, the United Nations Millennium Summit agreed 8 time-bound and measurable goals to reduce poverty, hunger, illiteracy, environmental degradation and discrimination against women globally by the year 2015 (WELL, 2004). The Millennium Development Goal (MDG) No. 7, ensuring environmental sustainability has the target of reducing by half the number of people without access to safe drinking water and sanitation. There are only six years left to the target date and there is some concern that Nigeria will not make the MDGs for water and sanitation. Water and sanitation coverage in the country has decreased between 1990 and 2006 (JMP, 2008). If Nigeria, with a population of over 140 million (NPC, 2006), and by far the most populous country in Africa does not make the MDGs then Africa is not likely to attain them.

1.1 Background to the study

The United Nations Children's Fund (UNICEF) Nigeria in 2008, out of concern for the cost and quality of borehole drilling in the country carried out a 'Study of Public and Private Borehole Drilling in Nigeria" (Adekile and Olabode, 2008). The study was mostly concerned with the cost effectiveness of borehole drilling in the country. It identified locally fabricated rigs and hand drilling as means of reducing borehole costs and thereby reaching more people particularly in the rural areas. However there were some gaps in the study. The study did not

- look in detail at the process of construction of the rigs, their viability and safety
- identify and quantify those areas of the country where hand drilling can be successfully practiced
- suggest the mode of bringing hand drilling and hand drillers into the mainstream of government projects to meet the MDG targets for water supply

1.2 Aims and objectives of the research

The aim of the research is to fill some of the gaps in the UNICEF study. The objectives are to:

- evaluate the potential of locally fabricated drilling rigs to contribute to increased water coverage
- evaluate the potential of hand drilling operators to contribute to increased water coverage.

To achieve the objectives an attempt has been made at estimating the number of boreholes that will be required in the country to meet the MDGs and to produce a map of those areas where hand drilling may be feasible.

The focus is on increasing the rural water supply coverage as this is the area with lower coverage. It is hoped that the research will provide information that will enable decision makers to develop an understanding of the potential contribution of locally fabricated rigs and hand drilling in meeting the water supply targets.

1.3 Country context

Nigeria occupies an area of 924,000 km^2, between latitudes $4^o1'$ N and $13^o9'$ N and longitudes 2^o 2' E and 14^o 30' E. It shares borders with 4 countries: the Republic of Niger to the north, the Republics of Chad and Cameroon to the east and Benin Republic to the west. The country is bounded to the south by the Atlantic Ocean and a coastline which measures approximately 800 km.

The country operates a federal constitution and a 3-tier government structure i.e. Federal, State and Local Government. There are presently 36 States and 774 Local Governments constituting the federation. Figure 1 shows the 36 states of the country. Out of its 49 years as an independent nation, the country was ruled by military governments for 30 years. The country returned to full democratic government in 1999. According to the 2006 census figures the population of the country is 140 million. Approximately half of the population live in rural areas. The main economic activities in the rural areas are agriculture and livestock rearing with about two thirds of the population engaged in small holdings. (FMWR, 2004).

Crude oil accounts for 95% of the foreign exchange earnings of the country. Nigeria has an estimated proven reserve of 32 billion barrels of crude oil and is the 6^{th} largest producer in OPEC. In spite of the huge earnings from the sale of crude oil the country remains essentially poor with inadequate infrastructure. According to the UNDP Human Development Report 2006 the country is rated 159^{th} out of 177 countries on the human development index. The Gross Domestic Product per capita is $1,154 whilst life expectancy is put at 43.4 years and adult literacy is 67%.

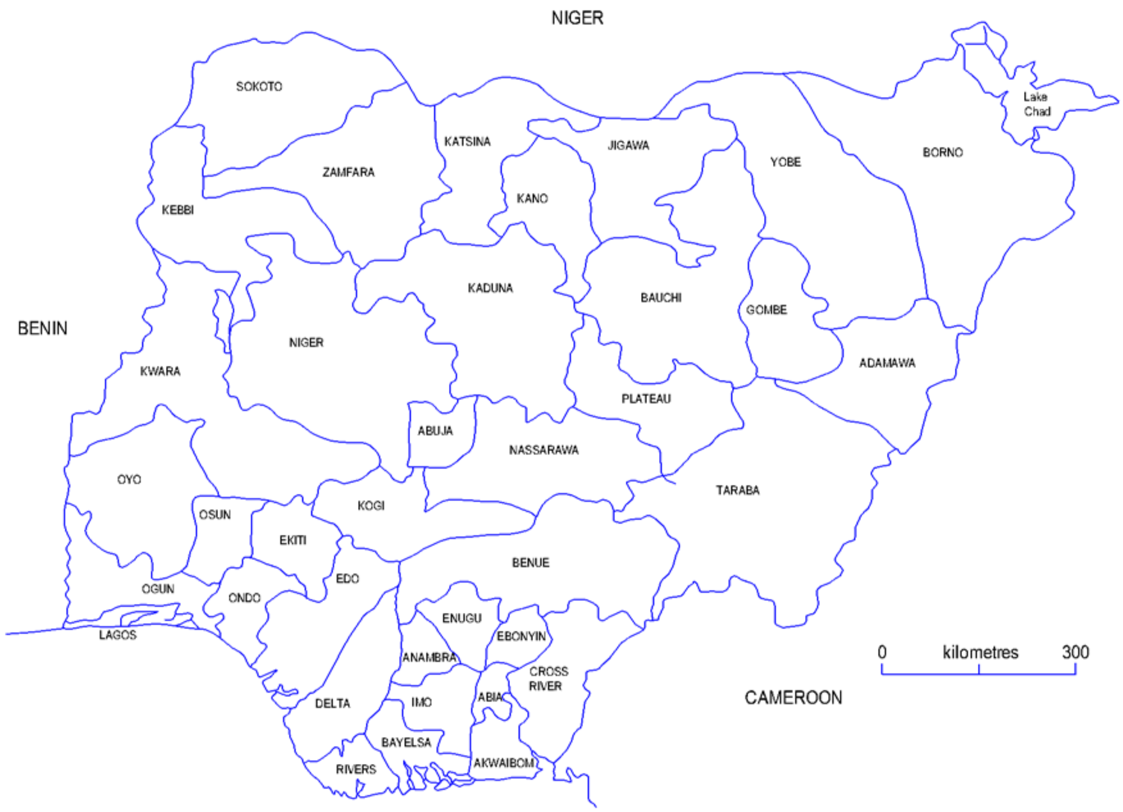


Figure 1 Administrative map of Nigeria

1.4 Report structure

Chapter 1 provides the background to the research, the aims and objectives and the country context.

Chapter 2 gives an account of the literature review with comments on some of the outcomes of the review and gaps in the existing knowledge.

Chapter 3 gives the detail of the methodology used in carrying out the research, analysing the data and information gathered.

Chapter 4 provides the findings of the research both from the desk study and field survey. It gives an estimate of the number of boreholes required in the country, the areas of the country where hand drilling might be feasible, evaluates the potential the locally fabricated rigs and hand drilling to contribute to increased water coverage.

Chapter 5 provides the authors comment and discussion of the outcomes of the research.

Chapter 6 gives the conclusion from the work done.

Chapter 7 provides the recommendation.

Chapter 2 Literature review

The methodology of the literature search, verification of documents and the structure of the review and the outcome are presented below.

2.1 The literature review process

2.1.1 Aims of the review

The aims of the review are to:

- gain an understanding of the research topic i.e. low cost drilling in relation to meeting the MDGs in Nigeria
- understand the current state of low cost drilling in general and in Nigeria in particular
- identify the gaps in the current knowledge
- establish links between the current research and other research on the subject (Jones, 2008:4.5).

The sources of the documents and books reviewed were the internet, libraries and offices of government, non governmental organizations (NGOs) and external support agencies (ESAs).

2.1.2 Methodology of the literature search

The methodology of carrying out the literature search on the internet was based on reducing the research concepts to key words and phrases, using Boolean operators, in search engines such as Google, Yahoo, and Teoma to find relevant documents.

Library catalogues and publication databases were used in searching for information. The Aqualine database on MetaLib was used to search for appropriate titles and abstracts, as well as on http://www.ingentacontact.com/itpib/wti. Electronic copies of relevant papers were then requested from the WEDC information officer.

The World Bank Public Information Centre, Abuja and the National Water Resources Institute Library, Kaduna, Nigeria also provided sources of information.

The reference list of some of the publications consulted indicated other sources of information, as well as providing names of authors active in the field of research. Experienced sector practitioners, and colleagues also provided or pointed to relevant documents.

2.1.3 Verification of documents

The documents consulted were selected after a careful evaluation of their credibility and authority particularly those from internet sources as well as the presentation, relevance, objectivity, method, provenance, and timeliness to ensure that they meet the standards of serious academic publication (Northedge, 2005:237).

2.1.4 Structure of the review

The information gathered from the different sources has been collated to bring out the salient points in thematic subheadings in 2.2 below. A summary of the outcome of the literature review is provided at the end, with comments on some of the findings and gaps in the literature.

2.2 Outcome of the literature review

2.2.1 The groundwater option

Groundwater sources are often the first choice of technology for water supply, particularly in rural areas. They are easy and cheap to install and the water needs little or no treatment.They can also be located close to the point of use and lend themselves to the principles of community participation and can be developed incrementally. Surface water if available is prone to contamination and seasonal fluctuation. Rainwater harvesting can be expensive and is dependent on adequate rainfall. In the contrary, groundwater can be found in most environments if one looks hard enough with the right expertise (MacDonald et al, 2005:1). In large parts of Africa, South America and Asia, groundwater is the only realistic water supply option to meet the demands of dispersed rural communities (Forster et al, 2000).

However it should not be taken for granted that groundwater is always potable. It may contain contaminants which render it unsuitable for domestic use without treatment. The contamination could be due to minerals dissolved into it from the rocks through which it flows but could be due to human activities - bacteria and viruses leaking into shallow aquifers from excreta in nearby septic tanks, latrines, cesspits, and open defecation areas (Skinner, 2003:19).

A consequence of assuming that groundwater is always safe is the occurrence of endemic fluorosis in many countries from people drinking water with high fluoride content. In India alone 62 million people are affected (Susheela, 2001) quoted by Smet and Wijk (eds.) (2002:500). Arsenic levels in groundwater beyond safe limit (which can cause cancer) have also been found in many countries. The worst is Bangladesh where out of approximately 8 million boreholes, 3 million are contaminated with arsenic and 20 million people are at risk

(Smet and Wijk (eds.) (2002:516). In a survey in Benue State of Nigeria between 2006 and 2007, higher levels of arsenic than the safe limit were found in 11% per cent of borehole samples tested and fluoride levels above the safe limit were found in 13% of the borehole samples (WaterAid, undated).

2.2.2 Groundwater abstraction techniques

Groundwater abstraction may either be by horizontal or vertical structures. Horizontal structures are galleries which can be springs, adits, qanats, ditches, infiltration drains or tunnels or horizontal boreholes. Galleries are suitable where the water has to be abstracted from shallow aquifers with small saturated thickness. Ditches, which are open dug channels are easy to construct, have a large capacity and long useful life but being open the water collected is prone to contamination. Infiltration drain and tunnels are installed with horizontal screens to allow water into a sump or collector well. They could be expensive to design and construct but the water is underground and protected from contamination (Smet and Wijk (ed.) 2002:208).

Vertical modes of groundwater abstraction involve the construction of either large diameter dug wells or small diameter boreholes or tubewells. Dug wells usually have limited capacity so their use is restricted to individual household consumption and other small scale water supplies. The large diameter shaft acts as a storage reservoir and thus provides for peak withdrawals but where aquifers occur at great depth boreholes are more suitable (Smet and Wijk (ed.) 2002: 210).

A borehole is a well drilled into the ground to reach an aquifer. Boreholes have several advantages:

- they are quick to construct if the equipment is available
- they can be drilled deep and can therefore tap deeper, often more sustainable groundwater
- they can be drilled in very hard rock
- effective sanitary seals can easily be constructed.

However they can be expensive to construct and since the borehole is a narrow tube a bucket and rope cannot be used to lift the water. A pump has to be used which requires proper use and maintenance (MacDonald et al, 2005:27). The borehole could be drilled by a machine or manually by hand (Skinner, 2003:22). All drilling techniques must be able to

- penetrate, break or cut the formation to be drilled
- remove the loose material from the hole

- support the hole to prevent collapse during, or immediately after drilling (Carter,2005)

Machine drilled boreholes

There are several methods of machine drilling but the most common for groundwater abstraction are the percussion drilling and rotary drilling (Wurzel, 2001).

The principle of the percussion drilling involves lifting and dropping a cutting tool suspended at the end of a rope or a string of rods into the hole. The method was used by the Chinese over 3000 years ago. The dropping force is provided by an engine and the drilling rig can be attached to an air-driven reciprocating piston. The cuttings from the drilled hole are removed by a bailer lowered into the hole periodically as the drilling progresses (Smet and Wijk (ed.) 2002:236). Air percussion drilling also called down-the-hole hammer, is used to construct holes in hard formations. It drills at a fast rate and air is used as the flushing medium to remove the cuttings from the hole (Smet and Wijk (ed.) 2002:237).

Rotary drilling relies on the breaking up of rock material by abrasion and crushing action. A drilling bit is rotated which applies considerable force that grinds down and breaks up the formation. Continuous circulation of a drilling fluid removes the cuttings from the hole. Rotary drilling is particularly suitable in loose formations and soft rock and can be used to drill large diameter holes to considerable depth (Smet and Wijk (ed.) 2002:239).

Hand drilling

There are basically four hand drilling techniques;

- augering, - drilling a small diameter hole with a hand rotated cutting tool which is then withdrawn to remove excavated material. This is repeated until the desired depth is attained. It is suitable only for unconsolidated sediments
- hand percussion involves manually lifting and dropping a cutting tool suspended at the end of a rope or string of rods into the hole.
- jetting involves loosening and removing the material from a hole by the washing action of a water jet, hence it is sometimes called washboring. This is only practicable in shallow loose sandy formation
- sludging is a continuous drilling method that allows the drilling fluid to flow down the annulus and carry the cuttings up through the drill pipe.

(Shaw, 1999:41)

Several adaptations of the four basic techniques in different countries have led to a myriad of terminologies which Danert and Gaya (2009) have tried to resolve by classifying the different adaptations under the four basic techniques. This is presented in the hand drilling tree, figure

2. For example, the tree shows that EMAS[1] drilling is a form of jetting combined with a percussion action. Drilling mud is pumped down through the drill stem using a hand operated mud pump. The mud flows back up around the drill stem, carrying up the drill cuttings. Sand and small stones are decanted, and the drilling mud is recycled through the pump. A percussion action is performed by lifting and dropping the drill using a lever, mounted on a drilling tower. In addition, the drill stem is rotated in half-turns in both directions, enhancing the grinding action of the bit.

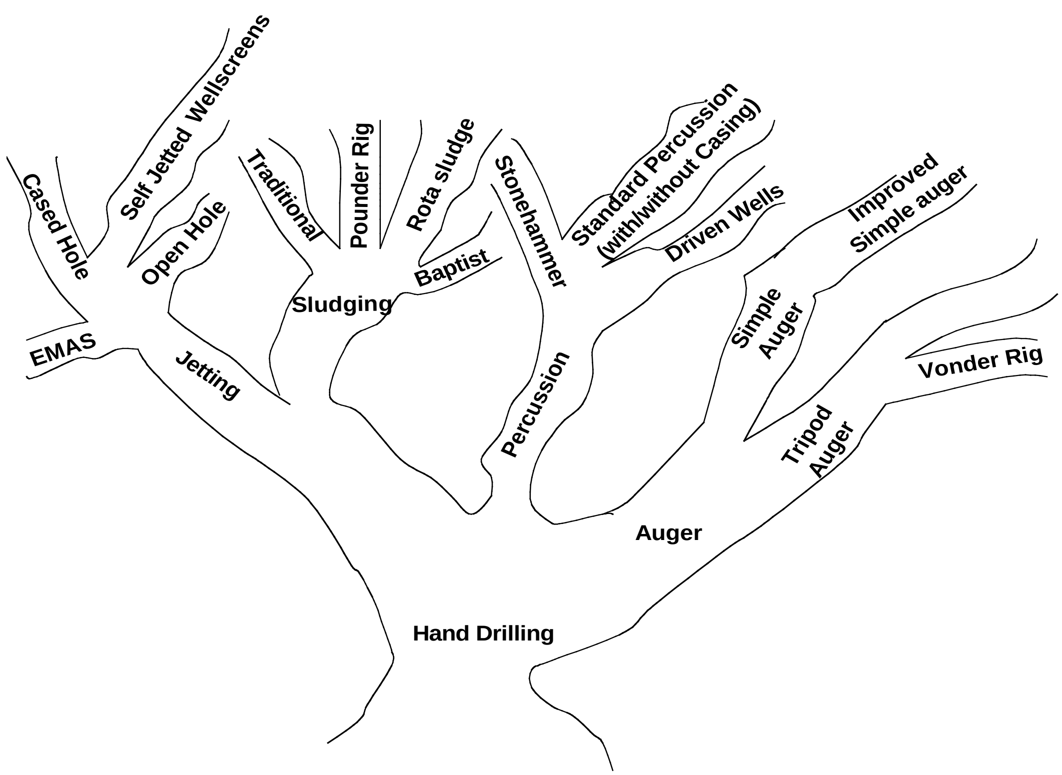


Figure 2 Hand Drilling Tree (From Danert and Gaya, 2009**)**

Hand drilling has long been practiced in Bangladesh, and along the Ganges plain of India. They have recently been introduced to parts of Latin America and Africa (Danert and Gaya, 2009).

[1] EMAS stands for Escuela Movil de Agua Saneameento meaning Mobile School for Water and Sanitation

Hand drilling, promoted by World Bank supported projects, started in northern Nigeria in the early1980s from the need to provide water for irrigation through tubewells. From irrigation the practice has been extended to water supply. Over 10,000 tubewells have been constructed by hand drilling in the country for irrigation and an estimated 20,000 boreholes for water supply. Out of the 36 states of the country, hand drilling is presently being carried out in 17 states (Adekile and Olabode ,2009).

Hand drilling only works where the formation is not too hard and the depth to the aquifer is not very great. It can provide low cost water supplies in those areas where it is feasible. It is not considered a panacea for rural water supplies, but one of many technical options that can be considered (Danert and Gaya, 2009).

2.2.3 Groundwater development in Nigeria

Historically and up till about 1930 in Nigeria groundwater abstraction was through unlined hand dug wells protected at the top by timber frames. However in 1947 the Public Works Department took over the construction of rural water supplies. A cable tool rig was purchased and the first rural boreholes were constructed. Rotary water drilling by a contractor began in 1951 when a British drilling company Balakhany Chad was registered. The first major water supply drilling program was between 1956 and 1962 when 280 boreholes were drilled in the north eastern part of the country to explore the artesian aquifers of the Chad basin (Hazell, 2004).

Balakkany Chad dominated the sector for several years with some competition from another British company, George Stow and an Israeli Company, Nigeria Water Resources and Engineering Company. Between independence and the beginning of the Water and Sanitation Decade in 1980 several other operators came into the country from Italy, Germany, Britain and Greece.

In the 1980s others came in from China, Japan and Canada through the international competitive bidding of the World Bank supported ADPs. Through the ADPs about 8000 boreholes fitted with handpumps were drilled in the northern parts of the country. All the companies employed and trained Nigerians as rig operators, mechanics, welders and drivers. Thus in the mid 80s when the Nigerian economy went into a recession and the expatriate drilling firms found it difficult to operate and had to close down, there was already a crop of trained Nigerian drillers. Some of the companies left their equipment on lease to their local employees. Some of the employees who were laid off set up their own companies such that by 1996 when the government embarked on another large scale borehole drilling programme under the Petroleum Trust Fund, 800 prequalification applications were received from which 167 contractors were appointed. Only 3 were foreign companies (Adekile and Olabode, 2008).

2.2.4 The groundwater resources of Nigeria

Groundwater occurrence relates to the physical terrain i.e. relief, climate, geology and drainage. The relief, drainage and climate of the Nigeria as described by Iloeje (1996) are summarized as follows.

Relief

The relief consists of the high plateaux where the land is generally over 300 m above sea level, and the lowlands which can be less than 5 m above sea level in the coastal areas (figure 3). The highlands are dissected into three blocks by the three trunks of the Niger-Benue river system:

- the Central Plateaux in the north
- the Eastern and North eastern highland in the east
- the Western uplands in the west

The lowlands lie in the basins of the major rivers along the Atlantic Coast and in the Chad basin.

Drainage

Figure 3 also illustrates the drainage. The rivers in the south are arranged in almost parallel north-south direction because the land slopes to the south whilst the rivers in the north radiate from the Central Plateau and flow in all directions. There are five major hydrological basins – the Niger, Benue, Chad, Cross River and South Atlantic drainage basins.

Climate

The climate is tropical with two distinct seasons – the rainy season from around April to October and the dry season from November to March. The country is divided into three climate zones

- the Sahel in the north (on the southern fringes of the Sahara Desert) characterised by a mean annual rainfall of 75 mm and rainy days of 60-40 northwards
- the Savannah in the middle belt with mean annual rainfall of 1000 -1250 mm with rainy days of 80-60 days northwards
- the Tropical rain forest in the south with mean annual rainfall of 1250 mm to over 4000 mm and the number of rainy days is 80-120 southwards

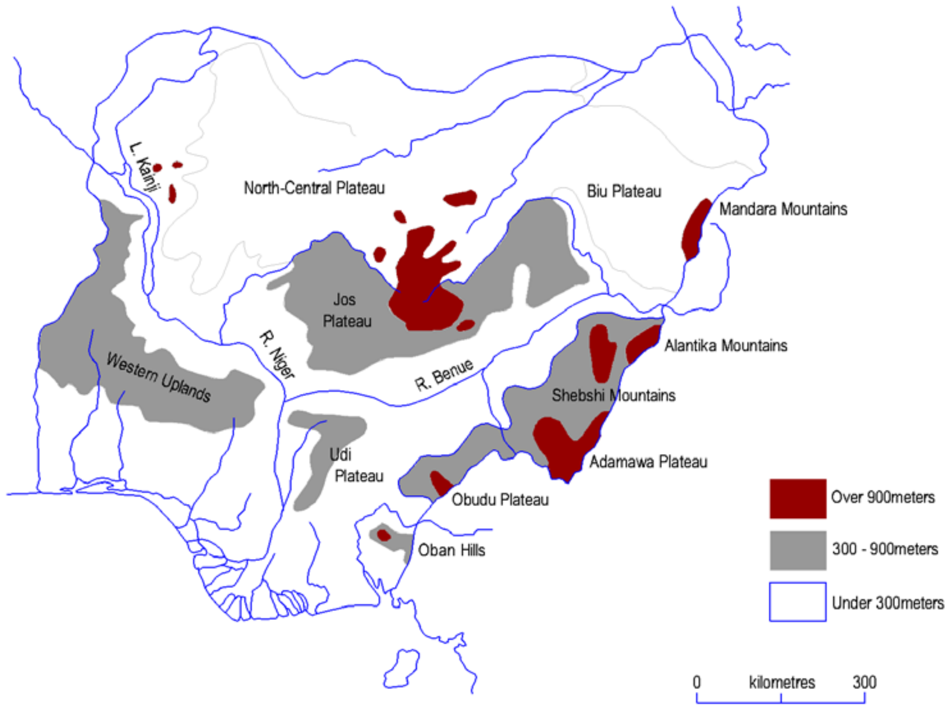


Figure 3 Relief Map of Nigeria (From Iloeje, 1996)

Geology

The accounts of the geology of Nigeria are scattered in several published and unpublished papers, bulletins, and journals as well as official and unofficial reports (Kogbe, 1975).

Raeburn and Jones (1934) published the first regional hydrogeological study in the country in their account of the geology and water resources of the Chad Basin. Recent accounts include consultant's reports reviewing State or local hydrogeology for various projects, and academic publications. The reports of the drilling accounts of several World Bank funded Agricultural Development Program (ADP) rural water supply projects also provide a lot of information on the groundwater resources of the country. The ADP projects which were carried out in present day Bauchi, Gombe, Jigawa, Kaduna, Kano, Katsina, Kebbi, Kwara, Sokoto and Zamfara States probably generated logs of about 8000 boreholes. Refer to figure 1. Also consultants' reports of the investigation of the irrigation potential of shallow alluvial aquifers in most of the northern states for the ADPs provide excellent information on the groundwater resources of the floodplains (Adekile and Olabode, 2008).

Offodile (2002) attempts a synthesis of existing knowledge on the groundwater resources of the country. He recognises the interplay between rainfall, climate and geology and describes the groundwater resources of the country according to thirteen river basins, accepting the river basin/catchment as the unit of water resources management. He attributes the droughts that occur almost on a ten yearly cycle, and the southward movement of the Sahel and its effects on groundwater recharge to global climate change. He also discusses the issues of poor quality groundwater, contamination and over abstraction in some parts of the country.

Akujieze et al (2003) divide the country into two major geological units, the crystalline basement complex and the Cretaceous - Tertiary sedimentary rocks. They classify the aquifers according to depositional basins rather than river basins as done by Offodile (2002). They recognize eight regional aquifers (which they call “giant” aquifers) and thirty local and minor aquifers. They estimate the surface water resources of the country as 224 trillion l/year and the groundwater potential as 50 million trillion l/annum against an estimated demand for domestic consumption of 60 billion l/year in 2001 and therefore conclude that there is abundant water resources potential within the country.

Adekile and Olabode (2008) as most workers, recognize the basement complex as one hydrogeological unit and subdivide the sedimentary rocks into two units: the consolidated sediments and the unconsolidated sediments. A summary of the hydrogeology of the country based on Adekile and Olabode (2008) is presented in box 1 and a geological map of Nigeria (from Iloeje, 1996) is shown in figure 4.

Some of the aquifers in Nigeria lie at great depth and some are of poor water quality (Offodile, 2002). Eduvie (2008) identifies the areas of difficult groundwater terrain in the country as those relating to

- geological environments e.g. the compacted sediments of the Benue trough and lack of fractures and regolith in the basement complex of the Katsina/Zamfara area
- deep water levels and aquifer zones being over 300 m e.g. parts of Enugu, Borno and Yobe States
- poor water quality e.g. salinity in most of the shallow coastal aquifers and some sediments of the Benue trough
- poor access to drilling sites especially in the swamps of the Niger Delta area

Cases of groundwater mining caused by over-abstraction have been reported in the Lagos and Maiduguri areas (Adekile and Olabode, 2008). In Lagos the water level decline has not resulted in the dewatering of the aquifer and it remains confined. It however created flow reversals leading to saline intrusion into boreholes at the coast (Parkman Consultants, 1996).

Box 1 Summary of the Hydrogeology of Nigeria

The Basement Complex rocks are mainly granitic in composition and in different stages of metamorphism. They are found in the higher parts of Nigeria. See figure 3.They comprise Precambrian gneisses, migmatites, schists, phyllites and quartzites. There are also Older and Younger Granites. The Younger Granites are intrusive masses, confined mainly to the Jos Plateau area whilst the Older Granites are batholitic and are disperse.

The Basement Complex also includes metasediments and volcanic rocks of different ages. About 55 % of the country is underlain by the Basement Complex. This includes the entire area of Kaduna, Kano, Katsina, Bauchi, Plateau, Oyo, Oshun and Ekiti States and parts of Zamfara, Adamawa, Kwara and Taraba States (See figure 1 – map of Nigeria showing the 36 states).

The rocks in the fresh state possess no primary porosity and therefore do not hold water but where weathered or fractured they incorporate many isolated minor aquifers. Much of the weathered mantle which developed in the Tertiary has survived to present times, and in areas of fracturing where the mantle is thicker than average there is sufficient storage for domestic and rural community requirements. The aquifers are very often the only source of water close to rural settlements but have to be located using a combination of remote sensing, geological analysis and geophysical survey.

In most cases during exploration, sites for successful boreholes are located within reach of the nominated villages. Depth of drilling hardly exceeds 60 m. Borehole yield is of the order of 1 m^3/hour and a handpump will provide a basic supply for about 300 people. Thousands of boreholes have been drilled in the country to provide rural water supply from the aquifers.

The consolidated sediments were laid down in Cretaceous seas. They comprise limestones, shales, sandstones and mudstones. They are usually gently inclined, locally fractured and gently folded. They cover about 20% of the country. This includes most of Sokoto State, the northern parts of Katsina State, the Niger-Benue trough and the south eastern parts of the country. The consolidated sediments contain only minor aquifers. As a result of repeated episodes of folding, the rocks have been compacted and cemented and all primary porosity lost. Groundwater is stored in fractures and in the weathered mantle overlying the rocks. Due to the small particle size of the weathering product the permeability is limited. Borehole yields are in the range 0.5 to 1.2 m^3/hour and borehole depth of about 10 - 60 m. Exploration of the aquifers is similar to that on the basement complex .

Box 1 Continued

.

The unconsolidated sediments

These are mainly loose sands and clays deposited in the Tertiary. They occupy about 25% of the country and are to be found in Sokoto, Borno, Yobe, Jigawa States and most of southern Nigeria. The unconsolidated sediments also include the Quaternary deposits laid down along the floodplains and deltas of rivers and the wind blown sediments of northern Nigeria. The sediments incorporate sandy horizons which constitute viable aquifers. They have been exploited for industrial, municipal and private water supply for more than half a century in the major population centres of Lagos, Benin, Port Harcourt, Maiduguri and Sokoto. Where the water level and the sands occur at reasonable depths they have been utilised for handpump supplies.

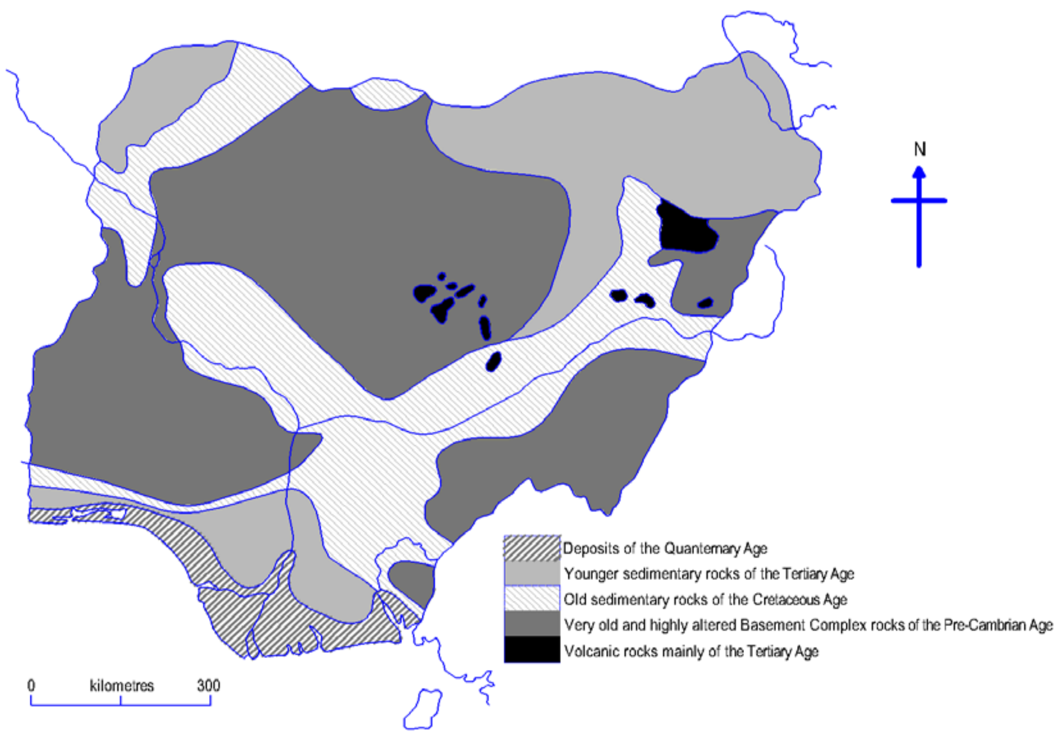


Figure 4 Geology of Nigeria (From Iloeje, 1996**)**

Offodile (2002) reports that In the Chad basin around Maiduguri, several of the artesian boreholes have lost the initial head and are no more free-flowing which he attributes to overdevelopment of the aquifers.

2.2.5 Borehole Drilling in Nigeria

Presently most of the borehole drilling in Nigeria is carried out by the private sector (Adekile, 2007). In the past, some public sector agencies were involved in drilling but they were unable to overcome the restrictions imposed by having to conform to civil service conditions and were inefficient and therefore became defunct (Adenle and Beale, 1989). Apart from a few agencies like the Kano State Rural Water and Sanitation Agency, most government agencies in the country have disengaged from borehole drilling (Adekile and Olabode, 2008). This is in contrast to other African countries such as Ethiopia where public sector agencies are more active than the private sector and NGOs in borehole provision (Carter et al, 2006).

Adenle and Beale (1989) identified only 25 competent and committed local drilling contractors out of the estimated 400 drilling companies operating in the country at the time. Currently the Federal Ministry of Water Resources (FMWR) has 230 pre-qualified contractors on its list (Adekile, 2007). The Water Well Drilling Association of Nigeria founded in 2008, has a directory of 350 drilling contractors (WSP/RWSN, 2009). Adekile and Olabode (2008) estimate that there may be up to 1000 drilling contractors in the country and they classify them into three groups:

- conventional drilling contractors with equipment and a management structure usually headed by trained hydrogeologists
- drillers engaged in manual drilling or using locally fabricated rigs. These include farmers, artisan drillers, university graduates and retired government hydrogeologists
- contractors with some interest in drilling but no equipment whatsoever.

Drilling rigs used by Nigerian drillers

Adekile and Olabode (2008) classify drilling rigs into light, medium and heavy duty rigs. Light duty rigs are those capable of drilling down to 100 m, medium duty rigs between 100 m and 300 m and heavy duty rigs greater than 300 m. They report that 30% of the rigs in their project area are light to medium rigs and are fabricated locally. The rest tend to be heavy duty rigs imported from China, Europe, USA, etc.

The locally fabricated rigs are made from scraps and fitted with refurbished engines. Rigs have been made locally as far back as 1985. The prices range from N1.5 million (US$10,000) for a light duty trailer rig to N3.5 million (US$22,000) truck mounted medium duty rig (Onashile, 2008). In contrast, the medium duty trailer, PAT 301 rig imported from

Thailand cost N6 million (US$40,000) (PAT Nigeria, 2009) and the Ingersoll Rand TH60 that UNICEF used to assist the Rural Water and Sanitation Agencies to procure cost US$600,000 per unit exclusive of the accessories (Wurzel, 2001).

2.2.6 Borehole cost and price

The borehole price is what the government or the project pays for the borehole and the cost is what the contractor incurs to deliver the product. The difference between the cost and the price is due to the need to add percentages to the cost for profit, overhead, taxes and risks to arrive at the price (Carter et al, 2006).

A common assertion is that the cost of borehole drilling in Sub-Saharan Africa is high and construction quality is regularly compromised (Danert et al, 2008). Similar concern has been raised in respect to drilling in Nigeria (Adekile and Olabode, 2008).

Danert et al (2008) give a comparison of borehole prices in several African countries which range from $120 to $500 per meter whilst Wurzel (2001) put drilling cost at an average of $15 per meter in India. However, Carter et al (2006) reject the simplistic comparison of borehole costs between countries, particularly the often cited comparison between drilling costs in Africa and India. They point out that India is a subcontinent with huge markets, developed infrastructure, widespread competition, and relatively easy drilling. Whilst Africa is a continent of 52 nations, relatively small markets, vast distances, poor roads, and relatively little drilling activity.

Adekile and Olabode (2008) also aver that it is difficult to compare borehole prices because they are governed by several factors such as

- geology which determines depth to the aquifer and the drilling technique and lining material
- the expected output of the borehole which determines the casing size and the length of the screen
- distance to the project site for the contractor to move his equipment
- contractual demands such as project sign boards, services to the engineer etc
- operational costs, overheads, insurances, taxes and risks which vary from country to country and even from project to project within the same country.

The time taken for borehole completion also affects the basic drilling costs. Antea (2007), reports that the average completion time for a borehole in Burkina Faso is 2 days whilst it may take 45 days in Senegal.

Because of so many variables that are likely to affect the drilling cost, Carter et al (2006) in trying to analyse the cost of boreholes on various projects in Ethiopia concentrate on 4 main components of drilling costs common to all boreholes i.e.

- mobilisation/demobilization cost for transporting men and equipment to a site and back
- drilling cost includes equipment depreciation, labour, fuel, lubricants and drill fluids
- casing and completion cost includes supply and installation of casing and screen, gravel pack , sanitary seal and well head construction
- development refers to the cleaning of the borehole following construction, pumping test, for an assessment of the borehole and aquifer parameters

Using the same 4 components, Adekile and Olabode (2008) estimate the cost of a machine drilled borehole on the basement complex of Nigeria, 110mm diameter uPVC lined, 50 m deep as N500,000 (US$4,000). For a machine drilled borehole, 150mm diameter steel lined borehole to 150 m depth the cost is calculated as N2.24 million (US$19,000). By the time 30 % is added for overhead, and profit and 10% for taxes and other costs, the price comes to about N637,000 (US$5400) for the borehole on the basement and N3.2 million (US$27,000) on the sediments which are comparable with current prices for such boreholes on most projects (Adekile and Olabode ,2008). Table 1 gives the prices of boreholes from different projects in Nigeria and illustrates the variability of prices between projects due to the various factors mentioned above (Adekile and Olabode, 2008).

Table 1 Prices of Boreholes from different Projects in Nigeria

Project	Geology	Price Naira	Price US$	Remarks
FMWR	Basement Complex	723,016	6,127	Contract price for drilling 60 m hole but reduced to 50m for comparison. Total contract price is N1,404,000 inclusive of services to the engineer & supply of pumps
Hadejia Jamaare RBDA Kano	Basement Complex	673,000	5,700	Contract price for drilling a 50 m deep borehole lined with 110mm uPVC casing
Kano State RUWASSA	Basement Complex	667,000	5,650	Contract price for drilling a 50 m deep borehole lined with 110 mm uPVC casing
Kano State RUWASSA	Basement Complex	400,000-500,000	3,390-4,237	Charge for drilling borehole for private householders
Kaduna State RUWASSA	Basement Complex	657,000	5,567	Contractors payment certificate for drilling a 50 m deep borehole, lined with 110 mm uPVC casing
Kaduna RUWASSA	Basement Complex	635,000	5,381	Contractors payment certificate for a 40 m deep borehole lined with 110 mm uPVC casing

Project	Geology	Price Naira	Price US$	Remarks
Niger State RUWASSA	Basement Complex	621,000	5,262	Contractors payment certificate for a 40 m deep borehole lined with
Private driller Ibadan	Basement Complex	400,000	3,390	Charge for drilling a 35 m borehole for private householders using a locally made rig. Cost to driller is N240,000
Hadejia Jamaare RBDA, Kano	Sedimentary	1,315,050	11,144	Engineers estimate for 150 mm diameter uPVC lined, 75 m deep borehole
Niger State RUWASSA	Sedimentary	840,000	7,118	Payment records for an 80 m deep uPVc lined borehole
Niger State RUWASSA	Sedimentary	740,000	6,271	Payment records for a 60 m deep borehole
Lagos RUWASSA	Sedimentary	6,562,500	55,614	Contract price for a 300mm diameter borehole to 250 m lined with steel without the pump
Lagos RUWASSA	Sedimentary	900,000	7,627	Contract price for 150 mm diameter uPVC lined borehole to 80 m depth
Lagos State Water Corporation	Sedimentary	7,111,300	60,265	Contract price for a 225 mm diameter borehole 130 m deep lined with steel, 48 hour development and 36 hour pump test
Lagos State Private driller	Sedimentary	120,000,000	1,016,949	Contract price for drilling an 800 m deep borehole
EU Project Enugu State	Sedimentary	3,303,900	28,000	Contract price for 350 mm diameter steel lined borehole to 60 m
EU Project Adamawa State	Sedimentary	2,177,000	18,449	Contract price for 250 mm diameter steel lined borehole 120 m deep at Demsa
EU Project Adamawa	Sedimentary	2,451,665	20,776	Contract price for 250 mm diameter steel lined borehole 120 m deep at Banjiram
FMWR	Sedimentary	3,110,000	26,355	Contract price for drilling 150 mm diameter borehole 150 m deep lined with steel
FMWR	Sedimentary	5,889,500	49,906	Contract price for drilling 150 mm diameter borehole to 300 m deep lined with steel
River State RUWASSA	Sedimentary	450,000-740,000	3,813-6271	Hand drilled borehole 150 mm diameter to 60 m by direct labour
River State Private driller	Sedimentary	60,000,000	508,474	Contract price for 200 m deep borehole in Escravos

N.B. At the time of compilation the prices exchange rate was N118 to the US$1.

Cost of hand drilled boreholes

Sutton (2007) puts the cost of drilling a tubewell in Malawi at 65 Euro (6.5 m deep and 90 mm diameter). Danert (2006) puts the price of hand drilled tubewells in Niger republic between US$50 and US$300. Adekile and Olabode (2009) put the cost of hand drilled water supply boreholes at approximately N153,400 (US$1300) and that of irrigation tubewells[2] as N2,400 (US$20) to N6,000 (US$50) depending on the depth. In spite of the relative lower cost of hand drilling, hand drillers in Nigeria have not been brought into the mainstream of government contracts although some conventional drillers do sublet government contracts to hand drillers (Adekile and Olabode, 2009).

2.2.7 Achieving cost reduction in borehole construction

Several workers have lent their voices to means of reduction of cost and prices in borehole drilling in Africa. Water Surveys Nigeria Limited (1986) in the Bauchi State Shallow Aquifer Study argues that ‘rural boreholes do not need a big rig and if urgency is not paramount such boreholes do not need high tech rigs. Smaller rigs are very much cheaper and simple rigs need less expert operation – so boreholes produced are much cheaper”.

Wurzel (2001) argues for depths and borehole designs which are best suited to handpumps rate of abstraction, construction techniques to fit the context, and short periods of pumping test. He queries the use of expensive geophysics for low yielding boreholes, suggesting that an experienced eye may be able to site a borehole without geophysics.

Ball (2001) provides a practical description of machine-drilled borehole construction, borehole designs for handpumps, development and test-pumping. His emphasis is on light and portable rigs which he argues are more appropriate to the context of developing countries.

Ball (2004) suggests that cost reduction can be achieved by reducing drilling diameter for handpump boreholes from 110 mm to 75 mm. He reminds the readers that the convention of 110 mm diameter cased hole arose from the need to accommodate the cylinder of the India Mark II pump and that the new modifications of the India Mark III and Afridev can fit into a 75 mm hole. He demonstrates that a 75 mm hole requires 25% of the inputs of a 150 mm hole and all the savings. He also asserts that 90% of the boreholes in Africa do not need lining to depth. Apart from increasing the drilling cost, complete lining blocks water from flowing freely into the hole. However according to Adekile and Olabode (2008) Nigerian drillers reject the idea of an open hole because it is never certain that the material from the weathered mantle will not migrate down and block the hole. Better the extra cost of lining material than the loss of the entire hole. The Community Water and Sanitation Agency in Ghana for the same

[2] A tubewell is also a borehole but most times it is shallower than a borehole because it has been jetted into the formation usually alluvial deposits and meant for irrigation.

reason also stipulates that all boreholes in the country are lined completely (CWSA, Ghana, 2007).

Water Surveys (1986), Wurzel (2001), Ball (2001) and Ball (2004) emphasize technological change in achieving cost reduction in borehole drilling whilst Carter et al (2006) find non functional boreholes, which can impose an all inclusive cost of up to 50% on a productive borehole a major source of wastage and conclude that reducing failure rate will have a major impact on reducing cost but this will require investment in capacity development of both the private drillers and the drilling supervisors in government agencies.

From previous works on borehole cost the Rural Water Supply Network (RWSN)[3] has developed a conceptual frame work for cost effective borehole provision. See figure 5.

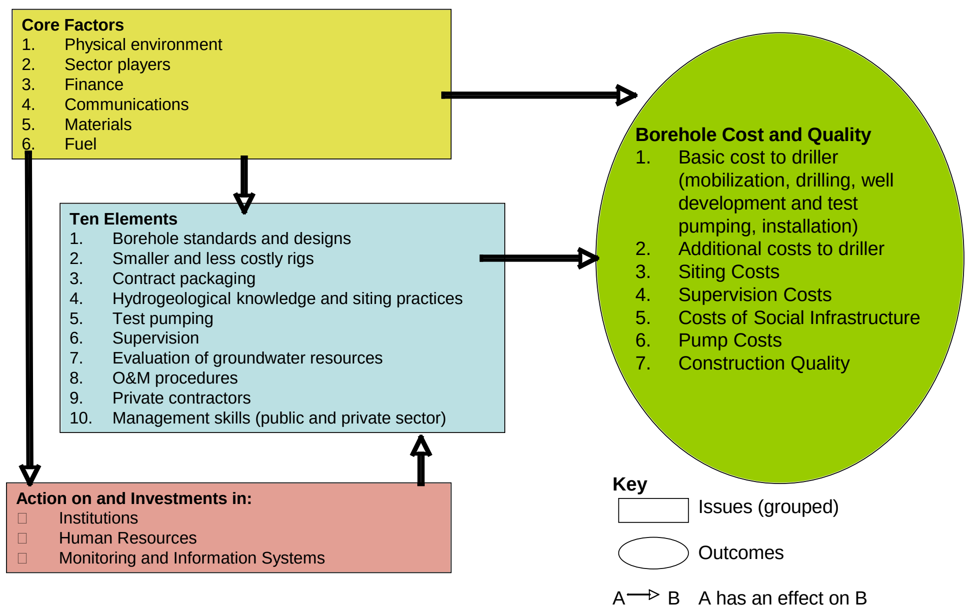


Figure 5 *RWSN* Conceptual Framework for Cost-Effective Boreholes

The framework recognizes that borehole costs and quality are influenced by six core factors and ten elements which need to be analysed to determine the most effective ways to bring about improvements in a particular context or country. The core factors are independent variables such as the geology, climate, communication network, sector players and programmes, availability of finance for sector investment, cost and availability of material.

[3]*RWSN* is a global network promoting sound practices in rural water supply and is committed to the development of cost effective boreholes in Sub Saharan Africa.

The core factors cannot be easily influenced but have a bearing on the cost and quality of boreholes.

The ten elements are policies and practices which can be influenced and changed more easily than the core factors. These include borehole designs, appropriate rigs, contract sizes, effective supervision etc. The ten elements can be improved upon by action and investment in human resources, institutional framework and monitoring and information systems.

There is a general consensus in the literature that lighter, smaller rigs are cheaper and therefore mobilization and drilling cost for each borehole will be cheaper than using bigger rigs as demonstrated by Rowles (1995). Adekile and Olabode (2008) for the same reasons suggest that the use of locally made rigs in Nigeria may be more cost effective than using big imported rigs and where hand drilling is feasible this may also contribute to lower costs. However Sutton (2007) studying hand drilling in Malawi is of the opinion that donor programs can diminish public and private incentives to promote lower cost drilling. Where large donor programs, such as those supported by the World Bank are willing to pay up to US$15,000 per borehole in Malawi (Mthunzi, 1999) there is little incentive to take up lower cost drilling options as long as such donations continue.

2.3 Summary of the literature review

Groundwater sources are easier to develop than surface water sources particularly in rural areas but the quality of the water should not be taken for granted. Abstraction by vertical structures may be cheaper and easier than by horizontal structures except where the aquifers are shallow and thin. Both machine and hand drilling have applications in borehole provision but hand drilling works only in particular environments where the hydrogeology is favourable. Where hard rock is encountered during drilling the borehole may have to be abandoned.

In Nigeria some effort has been put into developing the groundwater resources through borehole provision for water supply but water supply coverage remains poor particularly in the rural areas and is even declining.

Most of the drilling in Nigeria is done by the private sector. The drillers number in their hundreds. Their ranks include both conventional drillers with mechanical drilling equipment and manual drillers.

Borehole costs in the country are variable due to the varying geological terrains and contractual demands which in turn necessitate variable designs. In general hand drilled boreholes are much cheaper than machine drilled boreholes. However hand drillers are only patronized by householders and small scale enterprises and have not been brought into the mainstream of government projects.

It has been proposed by several workers that light duty and smaller drilling rigs are likely to produce cheaper boreholes than heavy duty drilling rigs. Light to medium duty drilling rigs are being produced locally in Nigeria and it is also proposed that this may produce more cost effective boreholes.

Comments on some of the themes of the literature review

The use of light rigs has been proposed for cost reduction but it has to be remembered that there are areas of the country with deep aquifers (>300 m depth) which require heavy duty rigs. So there is a market and need for such rigs.

Wurzel (2001) suggests that where there are experienced field personnel, geophysics could be dispensed with in siting boreholes on the basement complex. This is debatable and may be counter productive leading to a greater number of failed boreholes. Another question is how many such experienced people are available. It may be more cost effective to reduce the amount of geophysical data collected. The current practice is to specify the use of electromagnetic conductivity metering combined with resistivity sounding when in actual fact one of the techniques could suffice.

Ball (2004) suggests partial lining of boreholes on the basement complex of Africa. This may be feasible in areas of poorly developed weathered zone. In Nigeria the overburden is usually more than 20 m thick, sometimes up to 40 m i.e. no hard rocks are encountered to this depth and the boreholes have to be cased. This is why most Nigerian drillers reject the idea of an open hole.

Ball (2004) also suggests that some modification of the India Mark III cylinder will go down a 75 mm casing. The author, in the current research measured the outer diameter of the cylinder of the India Mark III available on the Nigerian market and it was found to be 71 mm. It may just go down a 75 mm diameter hole but if there is a slight deviation in the verticality of the hole it is not likely to go down the hole.

Adekile & Olabode (2008) identified 3 categories of drillers in Nigeria including “contractors with some interest in drilling but no equipment whatsoever”. This category of drillers is likely to comprise opportunistic middle men and should not be considered as drillers.

Gaps in the literature

Whereas small rigs such as the Eureka Port-a-Rig have been studied and well documented (Mthunzi, 1999), in discussion with colleagues and senior sector practitioners in Nigeria none is aware of any documentation or literature on the locally fabricated drilling rigs except for the brief mention in Adekile and Olabode (2008).

Also it has not been possible to find information on the actual drilling capacity in the country in terms of number of equipment and personnel. It seems no such survey has been carried out since Adenle and Beale (1989). This is in contrast with Ethiopia where Carter et al (2006) state that there are 23 private drillers who own 40 % of an estimated 150 drilling rigs in the country.

Another unanswered question is why government agencies and other institutions do not patronise hand drillers if a hand drilled borehole costs only a fraction of a machine drilled borehole.

Chapter 3 Methodology

3.1 Introduction

This chapter describes the methodology of the research. The methodology was aimed at addressing the objectives of the research and to fill some of the gaps identified in the course of the literature review. Specifically it was aimed at

- evaluating the potential of locally manufactured drilling rigs to contribute to increasing water supply coverage
- evaluating the potential of hand drilling operators to contribute to increasing water supply coverage.

To meet the objectives it was necessary to

- understand the rural water supply sector in the country as the focus of the required acceleration should be in the rural areas with the lower coverage
- roughly estimate the number of boreholes that are required in the country to meet the MDGs
- understand the operation and disposition of locally fabricated drilling rigs
- identify those parts of the country where hand drilling is presently going on and where it is feasible and work out a modality for the engagement of hand drillers by the government

A mixed strategy was adopted in carrying out the research. Both survey and case study approaches were employed. The survey approach was used to document the current status of locally fabricated drilling rigs and hand drilling in 9 states of the federation. The methodology involved the collection of qualitative data for in-depth understanding of the research objectives through interviews, review of documents and observation of the rig making process and drilling.

The case study strategy was adopted to evaluate the performance of one locally fabricated rig and one hand drilling operator. The rig belonging to Terraqua Nigeria Limited was chosen for the case study on locally fabricated rig because it was being assembled at the time of the research and it provided an opportunity to witness the making of a rig. Also the owner had just won a contract for the drilling of 10 boreholes in Zaria city which he intended to drill with the rig which provided an opportunity to evaluate the performance of a locally made rig in the field. It was convenient that the rig maker, the rig user and the location of the drilling contract were all within 60 km radius of the base of the researcher.

The choice of the activity of Water Hope Nigeria Limited for the hand drilling case study was also informed by the proximity of its location to other activities on the research. Also its main operator is one of those few hand drilling operators with entrepreneurial skills who do not aspire to own a conventional rig but wants to continue as a hand drilling operator as a service to his community.

3.2 Desk study

At the desk study stage, secondary data were collected from existing documents and literature. A literature review was carried out as reported in chapter 2. A review of the rural water supply sector in Nigeria in relation to borehole provision was also carried out.

3.2.1 Estimating the number of boreholes that are required to meet the MDGs

An estimate of the number of boreholes that will be required to meet the MDGs was estimated bearing in mind the current population figures and growth rate, existing water supply coverage figures, other potential sources of water such as piped water systems, hand dug wells, spring collection and rain water harvesting.

3.2.2 Identification of areas with hand drilling potential in the country

The main criteria for the identification of areas with hand drilling potential are

- areas of unconsolidated sediments
- areas where water level and aquifers are known to exist within 100 m depth
- areas where hand drilling was reported to have been successfully carried out

Hand drilling operators were asked to indicate those areas of the country where they had successfully drilled boreholes manually. Existing maps and hydrogeological data of the country were analysed to identify those areas where environmental and hydrogeological situations could make hand drilling a potentially suitable low cost and sustainable solution to increasing water supply coverage.

3.3 Field work

The field work was carried out between August and October 2009 during which key sector practitioners were interviewed and the drilling rig fabricating process and hand drilling operation were studied. The selection of the states of the federation for field data collection was purposive. The states were selected based on the known level of activity of rig fabrication and hand drilling operation. The states where data were collected were

- Bauchi
- Edo
- Rivers
- Gombe

- Kaduna
- Oyo
- Lagos
- Kano
- Niger

They are shown in figure 6, Map of the Project states.

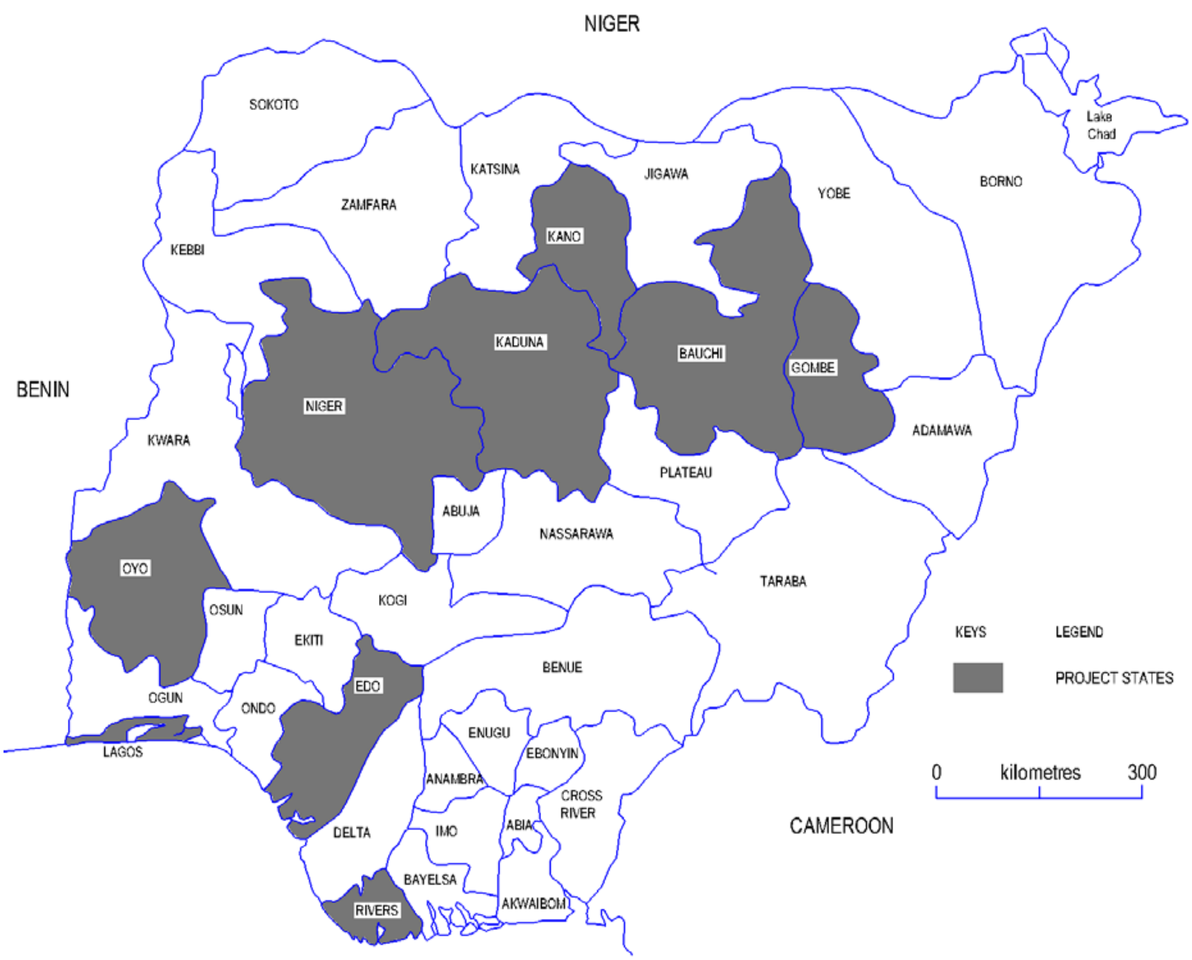


Figure 6 Map of the Project States

Government water agencies, local rig fabricators, drillers using locally made rigs, and hand drillers were interviewed. Structured interviews were used to ensure that same questions were asked from different participants and for ease of triangulation. This was more expensive and more time consuming than questionnaires but past experience of similar studies had shown that the use of questionnaires generated a very low response rate.

Permission of the interviewees to disclose their identities and use their company or organization names in the report was sought and all of them granted the permission.

3.3.1 Sample size

Local rig fabricators

The local rig fabricators tend to be located in areas of high population density in the country i.e. Lagos, Kano, Kaduna, Ibadan, and Port Harcourt, although 2 were found based in Gombe and Ilorin, which are not particularly areas of dense population but centres of some commercial activity. In Kaduna city, 4 such fabricators were located and in Kano city 2. In Lagos there may be up to 10. Across the country the author estimates that there may be up to 40 such enterprises. Thus interviewing 10 local rig fabricators in six cities represents a fair sample size.

Locally fabricated rig users

The locally fabricated rigs are scattered all over the country. 30% of the rigs surveyed by Adekile and Olabode (2008) were made locally. In the present research, the help of the fabricators was sought to locate the users of rigs made by them such that feedbacks from interviewing the rig users can be passed to the fabricators if necessary. Thus most of the drillers interviewed were in the same locality as the fabricators. Eventually 12 locally fabricated rigs users were interviewed.

Hand drilling operators

There may be up 50 hand drilling parties in Lagos state alone (Adekile and Olabode 2008) and probably over 200 across the country. 18 hand drilling operators were interviewed in 9 states.

3.3.2 Evaluation of locally fabricated rigs

The evaluation of local locally fabricated rigs involved

- Interviewing the fabricators
- observation of the process of rig making
- monitoring rig performance in the field
- getting feedback from locally made rig users.

The rig fabricating process was monitored in the workshop of A.U. Drilling Kaduna. A case study of the operation and performance of a newly assembled rig belonging to Terraqua Drillers Nigeria Limited was made by monitoring the drilling of 16 boreholes with the rig.

3.3.3 Evaluation of the potential of hand drillers to contribute to water supply targets

Hand drillers in each state were identified and interviewed to assess their

- potential output capacity in terms of number of drilled boreholes per annum
- patrons/customers and types of contract agreement
- technical skills and experience
- level of education
- entrepreneurial skills

The process of drilling and the techniques used were observed in the field.

3.4 Data analysis

Five steps were taken in analysing the data analysis. These were:

- preparation of the data
- familiarity with the data
- interpreting the data
- verifying the data
- representing the data

(Denscombe, 2007:288)

In preparing the data, the responses to the structured questions were recorded in the computer in the same format for each of the respondents. Case study field notes were typed out and duplicate copies made and stored away. The field data were then studied and scrutinised until the author became familiar with them.

The analysis of the data and the conclusions derived from them were grounded in the evidence that was collected. A conscious attempt was made not to introduce any preconceptions from previous research into the data analysis. And in the process of the analysis care was taken to repeatedly check the data collected with the emerging themes and categories.

The validity of the data collected is based on the various strategies and methods used in collecting the data such that some triangulation was achieved. Several respondents were interviewed and field observations were made and there was some correlation between the interviewee responses and field observations. Case studies provided further validation of the data collected. The data have been presented as simple narrative of the work carried out, with tables, figures and pictures.

3.5 Limitation

The major limitation to the research was the size of the country. Nigeria occupies a huge land area. Travelling distances are quite great. Trying to collect data from a representative sample for the whole country was a challenge within the resources available for the research.

Another limitation was the author's little knowledge of mechanical engineering and the inability of the rig fabricators to explain the engineering or specification of the different rig components adequately so the report could not delve deeply into the rig making process.

Chapter 4 Research Findings

4.1 Introduction

This chapter presents the findings of the research. It gives an overview of the rural water sector in Nigeria, estimates the numbers of boreholes that will be required to meet the MDG for water supply, describes the current status of low cost drilling techniques i.e. locally fabricated rigs and hand drilling, and evaluates their potential to contribute to meet the MDG for water supply.

4.2 An overview of the national rural water supply framework

Rural water supply in Nigeria is governed by the

- National Economic Empowerment and Development Strategy (NEEDS)
- National Water Supply and Sanitation Policy
- National Rural Water Supply and Sanitation Programme Strategic Framework

The National Economic Empowerment and Development Strategy (NEEDS), Nigeria's poverty reduction strategy paper, recognises that water supply and sanitation are central to many aspects of human development – health, education, urban and rural development (NPC, 2004). NEEDS was designed to achieve the various MDG targets by setting out reform programmes that will lay a foundation for sustainable poverty reduction.

The National Water Supply and Sanitation Policy proposes a strategy for the water supply and sanitation sector in four sub-sectors: urban, small towns, rural areas and water resources management. The policy defines a rural water supply scheme in Nigeria as a simple scheme serving a population of less than 5,000 people with a guaranteed minimum level of service of 30 litres per capita per day, within 250 meters of the community and serving about 250-500 persons per water point. It defines a small town as one with a population of 5,000 – 20,000 and urban as over 20,000 people.

The National Rural Water Supply and Sanitation Programme Strategic Framework (NRWSSPSF) is aimed at the provision of safe water and sanitation services in a cost effective manner through a cost sharing arrangement between the three tiers of government (Federal, State, and Local Government) and the benefiting communities. The supply is owned and managed by the communities. It stipulates that government has the responsibility for capital investment for rural water supply, with token contribution from the communities to foster a sense of ownership and promote sustainability. The Federal, State, Local

Governments and beneficiary communities are required to share the cost of capital investment in water supply and wastewater projects as shown in Table 2.

Table 2 Cost sharing for capital investment

Stakeholder	Rural WS	Small Towns WS	Urban WS
Federal Government	50%	50%	30%
State Government	25%	30%	60%
Local Government	20%	15%	10%
Community	5%	5%	Nil

The framework also guides the establishment of water supply and sanitation systems so as to ensure sustainable access to and hygienic use of safe water and improved sanitation services (Iliyas and Eneh, 2007).

4.3 Sector structure

The Federal Ministry of Water Resources (FMWR) has the responsibility to formulate policies, collect data, monitor and co-ordinate water resources development at the national level.

The State Governments are responsible for the provision of water supply at state level. They usually operate through the State Water Agency (sometimes called a board, corporation, or agency depending on the state) and the State Rural Water Supply and Sanitation Agency (RUWASSA) both of which are under the State Ministry of Water Resources.

The State Water Agencies are responsible for urban water supply. They are supposed to be financially self sustaining by charging commercial rates for the water supplied but none of the agencies in the country has been able to achieve this. They therefore depend on subvention from the government.

The RUWASSAs are responsible for water supply and sanitation in rural areas. The RUWASSAs are often supported by UNICEF and other external support agencies. The technology used is mainly boreholes fitted with handpumps.

The Local Government Authorities are constitutionally responsible for the provision of potable water to rural communities in their areas of jurisdiction as well as sanitation.

However, due to lack of funds, autonomy and shortage of manpower these functions are not effectively carried out by the local government authorities (Iliyas and Eneh, 2007).

External Support Agencies Apart from UNICEF, other external support agencies involved in rural water supply are the

- European Union (EU)
- Department for International Development (DFID)
- Japan International Cooperation Agency (JICA)
- WaterAid

The Office of the Senior Special Assistant to the President on the MDGs

In June 2005, following several rounds of negotiation between the Government of Nigeria and the Paris Club of creditor-countries, Nigeria was granted a debt relief of about $18 billion or about 51% of Nigeria's total external debts to the Club. The debt relief gain was used by the government to establish a Virtual Poverty Fund to ensure that monies released from the debt relief are channelled towards initiatives to reduce poverty. This fund is controlled and disbursed by the Office of the Senior Special Assistant to the President on MDGs (OSSAP-MDGs). Since 2006, on an annual basis approximately $1 billion has been allocated to support progress in health, education, water and sanitation, environment, energy, housing, women rights, HIV&Aids and social safety nets aimed at meeting the MDGs (YaracNigeria, 2009). OSSAP-MDGs under the water and sanitation programme has been awarding contracts for the construction of boreholes and giving grants to state governments in borehole construction. It has not been possible in the course of this research to establish the percentage of the total disbursement that goes to the rural water supply sector.

The National Water Resources Institute

The National Water Resources Institute is responsible for conducting training courses for all cadres of manpower development for the water industry. There is a component of groundwater development in all the programmes. Apart from the regular programmes leading to a diploma or certificate there are also short courses of 1 or 2 week duration designed for the particular needs of the participants.

The Private Sector provides services to the water industry as suppliers, consultants and contractors.

4.4 Rural water supply coverage and borehole drilling in Nigeria

Several rural water supply interventions involving borehole drilling have been embarked upon by the Federal Government or its agencies since the water and sanitation decade, 1981-1990. Some of these are:

- National Borehole Programme (1981-1985)
- Department of Food, Roads and Rural Infrastructure (DFRRI) RUWATSAN Programme (1986-1992)
- Petroleum Trust Fund (PTF) Water Supply Project (1996-1999)
- Improved National Access to Water Supply and Sanitation (2000-2001)
- The Presidential Water Initiative (2003 – to the present)
- Millennium Development Goals Water and Sanitation Projects (On going)

Apart from the interventions listed above, there are others sponsored by external support agencies, State and Local Governments (Habila, 2002). However, in spite of the several interventions, rural water supply coverage decreased from 34 per cent in 1990 to 30 per cent in 2006 and urban drinking water supply declined from 80 per cent in 1990 to 65 per cent in 2006 (JMP, 2008). The Mid Point Assessment of the MDGs in Nigeria 2000 - 2007 accepts the decline in coverage, which it attributes to rising population outstripping facility provision and the failure of most water provision programmes (UNDP/FGN, (2008). The Mid Point Assessment also accepts that the chances of meeting the MDG target for water supply are slim. Keast (2007) is categorical in stating that Nigeria is not on track to meet the MDGs for water supply which he relates to non sustainability of installed water points. See Box 2.

4.5 Estimating the number of boreholes to meet the MDGs in Nigeria

Several estimates have been put forward for the required number of boreholes to meet the MDGs in Africa. Danert et al (2008) estimate the number of boreholes required to be drilled in Sub-Saharan Africa to meet the MDGs as 35,000 per annum. This is based on the data from JMP 2004 i.e. 12 million people served in 2004, MDG of 701 million people served in 2015 and full overage of 1625 million served. The estimates assumes that 50% of the people will be served with hand dug wells, treated surface water or spring sources, 37.5% of the people will be served with a handpump (300 persons per pump) and 12.5% with a mechanised borehole (2000 people per system). As a rough guide, if according to Wikkipedia (2009) the population of Nigeria represents one fifth the population of Sub-Saharan Africa then about 7000 boreholes are required to be drilled in Nigeria annually.

However, another way to estimate the number of boreholes required is to proceed from the recent coverage figures and using the same assumptions in JMP 2004.

Box 2 Sustainability of water points in Nigeria – Keast (2007)

> Sustainability of water points is a major problem in Nigeria. Handpump breakdown rates are typically above 50% and are often much higher – for example in Zamfara State, where current estimates are that 62% of handpumps installed are non-operational. Other water extraction technologies – such as diesel or solar pumping systems – have even higher breakdown rates. The problem is so serious and widespread that it has been identified as a significant issue by senior decision-makers, including President Obasanjo, who mentioned it during a speech at the National Water Supply and Sanitation Forum in 2006. Some participants at the forum went so far as to suggest that the entire government sector budget for 2007 should be earmarked for repairs and maintenance instead of drilling new water points. Poor sustainability of water points is due to three main factors: a top-down approach to rural water supply common in government programmes, poor initial quality of boreholes and handpump installations, and lack of a viable maintenance system and spare parts supply chain.

According to the 2006 census figures, the population of Nigeria was 140,000 million and coverage for water supply according to JMP 2008 was 50% that means to halve the number of people without water supply by 2015, provision had to be made in 2006 for 35 million people. At a population growth rate of 2.8% per annum (UNDP/FGN 2008) and using the equation

$$N = N_0 \times (1 + r)^T$$

where
N = future population
N_0 = initial population
r = rate of population growth
T = years of growth

to project the 2015 population means making provision for 45 million people. Assuming that 37.5% of the 45 million will be served with handpumps at the rate of one handpump per 300 people means 16.8 million people served with 56,000 boreholes between 2006 and 2015. Thus the number of handpump fitted boreholes required is at least 6,000 per annum. Assuming that another 12.5 % will be served with motorised boreholes at the rate of one borehole per 2000 means, an additional 2750 boreholes or 305 per annum are required. This means a total of 6303 boreholes per annum. If it is allowed that 3% of the existing boreholes may have to be re-drilled brings the figure to 6500. Allowing a 20 % margin for error due to assumptions means 7800 boreholes are required. However in a situation where up to 30 - 50% of the installation may be out of work at a particular time means this figure may be doubled. Thus at least 10,000 boreholes are required per annum for domestic water supply. In the 9 years between 2006 and 2015, 90,000 boreholes will be required. A saving of just 10% on borehole cost will mean about 2 to 3 million additional people could provided with improved water supply sources within the same budget.

4.6 Locally made rigs – the beginnings

For many years several workers have advocated or sought ways to reduce the cost of drilling by designing simple and low cost rigs which will translate to more people having access to safe water supplies. A new trend in Nigeria is the fabrication of drilling rigs from discarded material. In many of the big towns in Nigeria there are small enterprises fabricating light and medium drilling rigs. In the course of the research 10 rig fabricators were interviewed in Ibadan, Ilorin, Lagos, Kano, Kaduna and Gombe. Table 3 provides some background information on the rig fabricators interviewed.

Table 3 Summary of Information on Rig Fabricators

Rig Fabricators name	Location	Background of CEO	Year since operation	No. of rigs sold in 2008
A.U. Drilling	Kaduna	Mechanic	2003	15
Speo Group of Companies	Kaduna	HND Mechanical Engineering	2001	11
Yemdem Nigeria Limited	Kaduna	Fitter machinist	2007	3
Unique Metal Fittings and Fabrication	Gombe	HND Mechanical Engineering	2002	6
Deep Well Hydraulics	Lagos	B.Sc. Chemistry. Worked in an engineering company	1990	14
Heatom Borehole Drilling	Ibadan	Machinist	2000	12
Frilucson	Ibadan	Driller	1994	4
Unisteel Construction and Furniture Company	Kano	Mechanic/Welder	2002	5
J.I.B Technical Service	Ilorin	Mechanic	2003	7
Gbolahan Ogunwuyi	Ilorin	Mechanic	2006	5

Drilling rig fabrication has actually been going on in Nigeria, undocumented, for quite some time, at least as far back as 1984. The managing director of Deep Well Hydraulics, Lagos stated that he copied a drilling rig his then employers bought from the USA in 1984 and in 1990 decided to concentrate on building rigs for a living. Similarly, Friday Ojikeri of Frilucson, Ibadan said he copied a rig his company bought in 1993 and made two other rigs. Simon Opara of Speo Group of Companies, Kaduna said he started experimenting with rig fabrication in 1988. However of the 12 drilling contractors using locally made rigs interviewed only one actually bought his rig in the 1990s. All the others bought their first rigs after 2000.

The beginning of locally fabricated rigs in the mid 1980s coincided with the period of the Structural Adjustment Programme of the military regime of General Babangida which caused economic hardships and devaluation of the currency. Hard currency was difficult to obtain. Several expatriate companies including drilling contractors found it difficult to operate and left the country. This was also the time of the emergence of the local drilling contractors. Thus the economic hardship provided an impetus for some individuals to look inwards to develop some coping strategies to the prevailing situation.

4.6.1 Drilling rig fabricators' background

The drilling fabricators are of diverse backgrounds, from university graduates to those with little formal education. Of the 10 interviewed, 3 had tertiary level education (university and polytechnic) the others had little formal education but could communicate in English. All the fabricators developed an interest in rig fabrication having worked with established drilling companies as drillers, machinists, mechanics and welders. 2 had a family background in metal works. Simon Opara said his family i.e. father, brothers and sisters are all fabricators of one type of equipment or the other. Throughout his growing up years and school days, Hassan Abubakar of Unique Metal Fittings and Fabrication Gombe, worked in his father's workshop and took over the business when his father died.

Tobi Oluwatimehin of Heatom Borehole Drilling, Ibadan after primary school worked as an apprentice machinist in Frilucson before setting up his own drilling and rig fabricating company.

Unisteel Construction and Furniture Company, Kano started as a mechanic workshop repairing trucks and drilling rigs and later ventured into building rigs from local materials.

A.U.Drilling Ltd, Kaduna and J.I.B Technical Ilorin also started as mechanics repairing drilling rigs and trucks. About 5 years ago A.U. Drilling started fabricating rigs. At the time of the visit to their workshop there were 8 rigs under construction.

4.6.2 Business structure

All the fabricators are legally registered as either limited liability companies or as trading enterprises. Apart from Deep Well Hydraulics and Frilucson which were established in the 1990s all the others were registered in the 2000s. The head of the organisation often carries the title of chairman or managing director. He is assisted by a workshop manager or engineer.

They all have workshops with basic tools like welding machines, oxy acetylene gas cutting equipment, drilling machines. Four of them, Speo, Unique Metal Fittings and Deep Well Hydraulics possess lathe machines. However those that lack particular equipment have access to the services of other machine shops as all the companies are located in areas of high commercial activity. The workshop spaces of the fabricators in Lagos and Ibadan are small, less than 600 m^2 and crammed. Unique Metal Fittings and Fabricators, Gombe have the biggest workshop, about 0.5 of a hectare and employ over a hundred staff and apprentices.

The rig fabricator’s clientele is mainly local. However Unisteel Construction and Furniture Works, Kano have clients who come in from neighbouring Niger Republic. Similarly Unique Metal Fittings and Fabricators, Gombe sell rigs to clients based in Niger, Chad and Cameroon Republics.

All the 10 fabricators stated that they could not survive on rig fabrication alone as patronage is low. They therefore engage in other lines of business akin to fabrication or drilling. All the 10 engage in the business of repairing rigs. All of them also carry on business as drilling contractors where they use rigs made by themselves except Unique Metal Fittings and Fabricators. Unique Metal Fittings and Fabricators do not engage in drilling contracts but are involved in the fabrication of other metal equipment such as water tanks, wheel barrows, milling machines, vegetable oil extractors, block moulding machines, threshing machines, gates, window frames and doors.

Time taken to complete the fabrication of a rig could be 3 weeks but payment often delays the job as most buyers pay in instalments. Speo, Yemdem and J.I.B. make the chassis of the trailer rigs, mount them on wheels and wait for the customers to specify drilling depth required and other components. Unique Metal Fittings makes the rigs complete and ready for the buyers. All the others make them as ordered and start work when an advance payment has been paid. There is an advantage in the latter arrangement in that for a deposit as small as 10% of the negotiated price of the rig by the prospective rig owner, work can begin on the rig and continues as further instalments are made. Several of the drillers using local rigs acquired them this way. If as much as 75 % payment has been made A.U. Drilling allows the owner to start work with the rig and pay the balance as work comes in. It also allows the fabricator to correct possible defects on the rig.

A major short coming of all the fabricators interviewed is that they do not keep proper records of their activities. In trying to find out how many rigs they had made since starting business and from that extrapolate how many such rigs are in the country, none could give an accurate answer, only guesses. When asked if the receipt books and invoices would not provide the information, the answer usually given was that it would be incomplete since a lot of the business is done verbally and on mutual trust. Thus fairly accurate answers for the number of rigs produced and sold could only be obtained for the previous year only, 2008. The number of rigs sold by each fabricator in 2008 ranged between 3 and 15.

Apart from inadequate patronage and recording keeping, other challenges faced by the fabricators are:

- lack of a sustainable source for the rig components; sometimes they have to go all over the country looking for components
- lack of standard specification for components and materials resulting in non compatibility of some of the components
- lack of standard means of determining properties of material, capacity and efficiency of hydraulic components
- negative criticism or cynicism from the public such as comments like ‘can this toy rig work’

The National Water Resources Institute has initiated a project for the ‘Development of Standardized Rig Fabrication Models’ to address some of the challenges facing the fabricators (Alayande, 2009).

4.6.3 Types of rigs

The light rigs are capable of drilling to 100 m and are usually mounted on trailers and referred to locally as ‘towing” rigs. The trailers are sometimes fitted with 2 wheels and sometimes with 4 wheels. The chassis are made from steel beams and the mast from steel rails. They are fitted with manual jerks or hydraulic jerks. The engines are refurbished engines from old trucks. The mast and the drill stem are hydraulically controlled. The hydraulic rams are from old tipper trucks. Picture 1 shows a light medium rig in Kaduna and Picture 2 shows a medium duty rig from the same workshop. Pictures 3 and 4 are labelled to show some of the components of the rig.

The medium duty rigs are mounted on trucks and are capable of drilling to about 200 m. Customers buy their trucks and the rigs are then mounted on them but Unique Metal Fittings and Fabrication do buy trucks and mount the rigs on them.

The materials used in the fabrication from the hydraulic pumps, to the control valves, rams, engines, mast, and chassis are all procured locally from scrap yards. However new valves, hoses and engines can be fitted on the rig if the prospective owner so wishes.

The rigs can be fitted with a hammer and compressor to drill through hard crystalline or compacted sedimentary rocks.

The capacity of the rig in terms of depth and lifting capacity depends mainly on the combination of the capacity of the hydraulic pump, the engine and the power head. But none of the fabricators could accurately give the ratings of these components on the rigs. The choice of components is mainly done by a rule of the thumb albeit based on experience.

Picture 1 Trailer rig from A.U Drilling in Kaduna

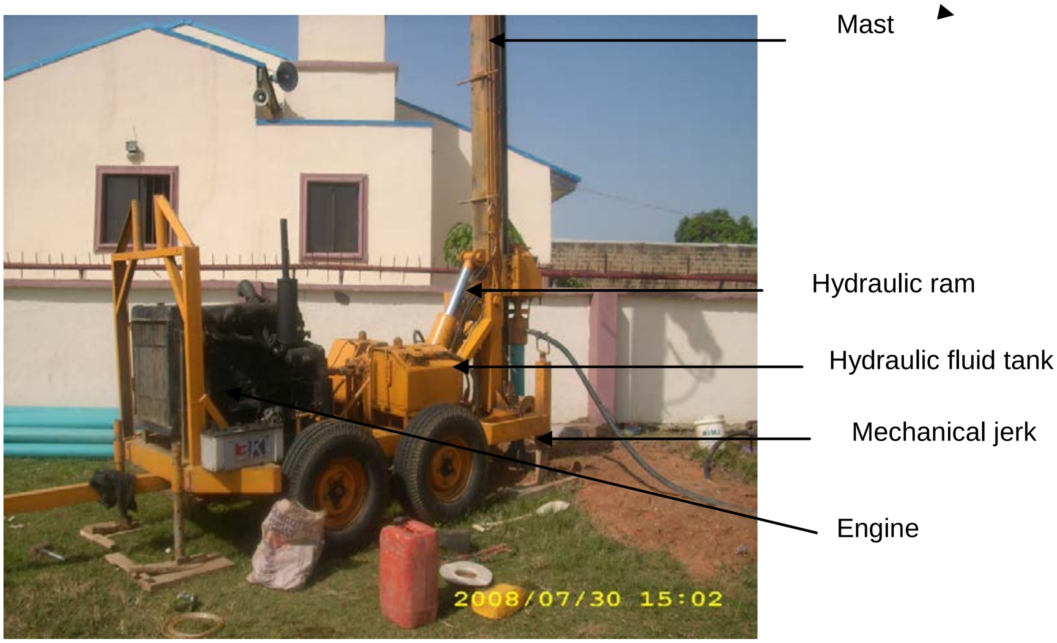
Picture 2 Truck mounted medium duty rig from A.U. Drilling in Kaduna

Deep Well Hydraulics, Lagos have standardized on four types of rigs as follows:

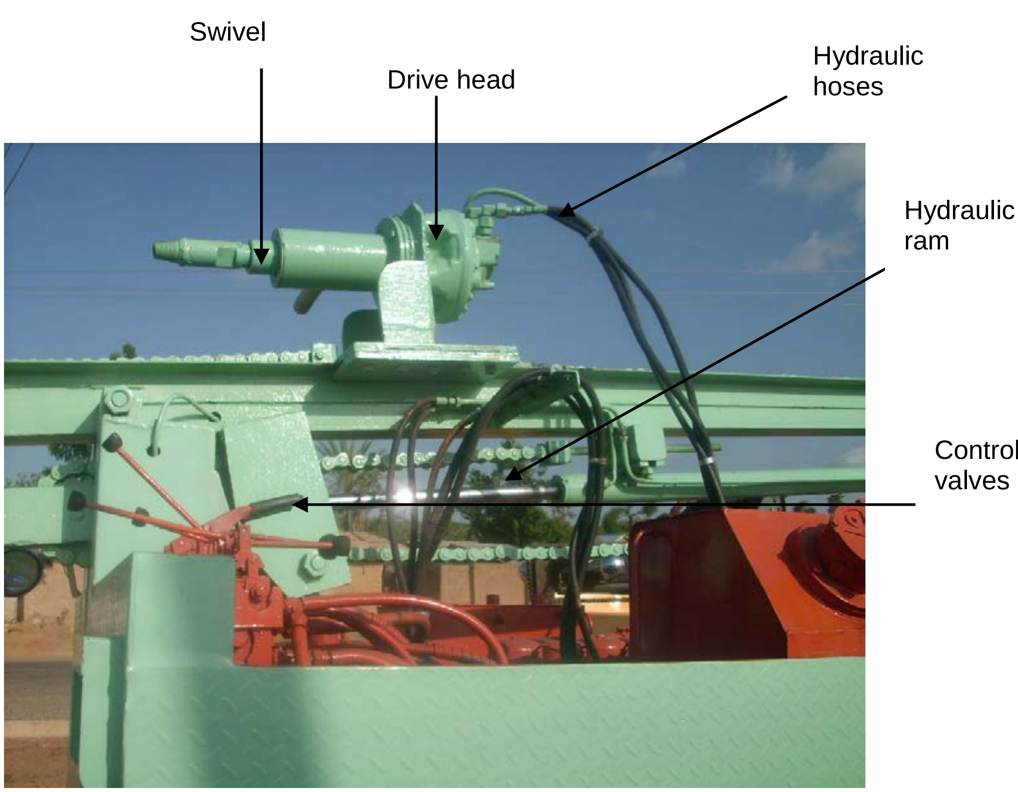
- DW 1000, trailer mounted capable of drilling to 100 m depth, 40 hp engine, with no mud pump
- DW 2000, trailer mounted also capable of drilling to 00 m depth, 40 hp engine but with a mud pump
- DW 3000, trailer mounted capable of drilling to 150 m depth, 60 hp engine with a mud pump
- DW 4000, truck mounted capable of drilling to 220 m depth, 80 hp engine with a mud pump

The mud pumps are 5 hp petrol driven pumps. The engines are reconditioned Deutz engines. The trailer-mounted rigs are fitted with manual jerks and the truck mounted ones with 4 hydraulic jerks. Deep Well Hydraulics give a one year warranty on their products.

Deep Well Hydraulics explained that they use only Deutz engine because they are air-cooled and no problem of radiator leaking. Unique Metal, Gombe also use Deutz engine for the same reason. Speo, Kaduna have standardized on Ford engines because they are readily available in the market.



Picture 3 A 4wheel trailer on a drilling site with some of the parts labelled



Picture 4 Ready made rig in Gombe

4.6.4 Prices of locally fabricated rigs

Although the prices of the rigs depend on negotiation between the fabricator and the buyer, customer specification and preferences, the prices given by the fabricators were fairly uniform for particular classes of rigs. Table 4 gives a summary of drilling rig prices from several sources. The prices range from N1.7 million (US$11,000) to N3.5 million (US$23,000) for the trailer mounted rigs and from N3.3 million (US$22,000) to N3.7 million (US$24,000). The prices of the rigs from the southern parts are slightly lower than those from the northern parts probably because they are closer to the scrap markets of Lagos from which most of the components are sourced. In comparison to the local rigs the medium duty PAT 301 trailer rig imported from Thailand which performs the same operation cost N6 million (US$40,000) on the Nigerian market (PAT Nigeria, 2009). This is however a factory made rig with all the components new.

When asked why they do not use new components such as new engines, drive heads, mud swivel, hydraulic hoses and control valves, all the fabricators responded that it would take the price beyond what is affordable by the drilling contractors.

They all agreed that the trailers rigs are more popular than truck mounted rigs because apart from being cheaper and more affordable, drillers have realised that it is better to have the pieces of drilling equipment as separate components i.e. the rig, the compressor, the mud pump and the truck each on its own rather than all mounted on one truck. Once a trailer rig is towed to the site, the towing vehicle is available for other purposes such as getting people, fuel, pipe and water to the site instead of just standing on the hole. Also as most of the young drilling companies are patronised by householders involved in self supply, it is easier to manoeuvre a trailer rig into a corner of the compound than a truck mounted rig. Other components such as the compressor can be brought to site when required or could be used on other jobs.

Table 4 Prices of locally fabricated rigs

Rig Fabricator's Name	Location	Prices			
		Trailer		Truck mounted	
		Naira	US$	Naira	US$
A.U. Drilling	Kaduna	2.5 million	17,000	3.7 million	24,000
Speo Group of Companies	Kaduna	2.2 million	14,600	3.5 million	23,000
Yemdem Nigeria Limited	Kaduna	2.2 million	14,600	3.3 million	22,000
Unique Metal Fittings and Fabrication	Gombe	3.5 million	23,000	5.5 million*	37,000

Rig Fabricator's Name	Location	Prices			
		Trailer		Truck mounted	
		Naira	US$	Naira	US$
Deep Well Hydraulics	Lagos				
DW 1000		1.7 million	11,000		
DW 2000		2.2 million	14,600		
DW 3000		2.7 million	18,000		
DW 4000				3.2 million	21,300
Heatom Borehole Drilling	Ibadan	2.5 million	17,000	3.2 million	21,300
Frilucson	Ibadan	3.0 million			
Unisteel Construction and Furniture Company	Kano	2.5 million	17,000	3.5 million	23,000
J.I.B. Technical Service	Ilorin	2.2 million	14,600		
Gbolahan Ogunwuyi	Ilorin	2.2 million	14,600		

*N.B. Price is inclusive of the cost of the truck (used)

4.6.5 Rig performance

12 drilling rig users were interviewed to find out their experiences on the performance of the rigs, parts that quickly wear out or need to be replaced often and the safety of the rigs.

WED Nigeria Limited, bought a trailer rig in 2004 from Speo, Kaduna. According to their records by the end of 2008 they had drilled 300 boreholes with the rig. In 2006 they bought a truck mounted rig from the same outfit. The author witnessed the rig drilling a borehole at the British High Commission residential village in Abuja. The 35 m hole was completed in 2 days. And to date they have drilled 170 boreholes with the rig. In 2008 WED decided to build another rig themselves and not go back to Speo because from the use of the 2 rigs and supervision of the fabrication they had acquired enough experience to build their own rig and save some money. When WED was asked if they could afford to buy a new rig from abroad would they do so, the answer was a firm no as it would be an unnecessary expense considering the terrain they work in. For the maximum depth of 60 m they usual drill on the basement complex, the local rigs are adequate and make them competitive.

Devteck Contractors', attitude was similar to that of WED. After buying the first rig from Frilucson, they decided to build the second rig themselves whilst retaining Frilucson as a consultant.

The first rig bought by Dumson Nigeria Limited was a German made rig but the second rig was bought from Deep Well Hydraulics in Lagos. Mba Onwuka, M.Sc Hydrogeology, managing director of Dumson Nigeria Limited said for any drilling below 100 m his Nigerian made rig is far more cost effective than the German rig. For the same cost effectiveness, Mba also engages in hand drilling where he considers it more effective than machine drilling. See 4.8.2. Dumson's operation is mainly on the sedimentary terrain around Lagos. He deploys each of his equipment depending on the proposed depth of the borehole to be drilled.

Machika Drilling Company, Kaduna is probably the largest drilling outfit in Kaduna city with 4 truck mounted rigs. Apart from the first Ingersol Rand T60 rig bought from the United States, the 3 other rigs were made locally.

The advantages of the locally fabricated rig identified by all the users interviewed are:

- Affordability. The lower prices make it possible for new drilling companies to acquire a rig. There is no need for import licences and duties. The possibility of paying in instalments means whilst most drillers start by hiring drilling equipment they could plough back some of the profit to eventually acquire their own rig.
- Cost effective borehole provision. The lower cost of the rig compared to imported rig makes the users to be competitive. Although several of the local rig users tend to charge the same price for boreholes as those with the imported rigs on most government jobs because everybody has an idea of government rates, they however do lower their prices considerably when drilling for private households. Whilst the price of a 100 mm diameter uPVC lined borehole to a depth 40 m on a government project could be N650,000 (US$4300) the same borehole for a private owner could be N300,000 to N400,000 (US$2000 – 27000). Waterworkx Borehole Services, Ibadan said he would charge N400,000 (US$2700) for a private borehole on the basement complex and his cost would be roughly N240,000 (US$1600) giving him a 40% profit margin.
- Availability of spare parts. The local rig users do not suffer much down time due to lack of spare parts. The spare parts for the rigs are available from the same sources as the original components. Both Dumson and Machika said they could suffer rig down time as much as 2 months whilst waiting for spare parts to arrive from abroad for their imported rigs. This would only be a matter of days for the locally fabricated rigs.

None of the rig users has recorded an accident due to the rig malfunctioning. They are not discriminated against by employers because they are using locally fabricated rigs. Not many employers know the difference between two.

A major constraint mentioned by the users is lack of specification for the rig components so that spare parts are bought on trial and error basis until one is found that fits or works with the equipment. They identified the hydraulic pump as the weak link in the whole assemblage. It has to be replaced quite often. The National Water Resources Institute has also identified this problem and in association with the National Hydraulic Equipment Institute is now looking for ways to design hydraulic pumps for the required torque to drill through most terrains in Nigeria (Alayande, 2009).

Another component that poses a problem is the mud swivel which often leaks. But both rig fabricators and users agreed that the swivel head will always leak due to the wearing away of the rubber seal. The seals need to be replaced on average after every 10 boreholes drilled on the basement but they are cheap; each seal costs about N3000 (US$20).

Apart from Deep Well Hydraulics who have names for models of the rigs produced by them, with some definition of the components of each model, none of the other rig makers have given names to their rigs. Table 5 summarises the feedback from the rig users.

Table 5 Summary of feedback from locally fabricated rig users

Name of rig user	Rig Fabricator's name	Year of fabrication		No of Boreholes drilled to date	Frequently changed parts
Geo-Afrik Consultants	A.U. Drilling, Kaduna	Rig 1	2005	220	Swivel head, hydraulic pump
		Rig 2	2008	53	Hydraulic hoses and pumps
WED Nigeria Ltd	Speo, Kaduna	Rig 1	2004	300	Hydraulic pumps
		Rig 2	2006	170	Hydraulic pumps
	WED Nigeria, Kaduna	Rig 3	2008	80	Hydraulic pumps
Machika Drilling Company	A.U. Drilling, Kaduna	Rig 1	2002	400	Engine sleeves and rings, hydraulic pump
		Rig 2	2004	350	Hydraulic pumps

Name of rig user	Rig Fabricator's name	Year of fabrication		No of Boreholes drilled to date	Frequently changed parts
		Rig 3	2006		
Teraaqua Nigeria Limited	A.U. Drilling,Kaduna		2009	16	Non so far
Devtek Contractors	Frilucson, Lagos	Rig 1	2003	300	Hydraulic hoses and pumps
	Devtek Contractors/Frilucson	Rig 3	2007	60	Hydraulic hoses
MALE Integrated Service	Heatom Technical, Ibadan		2004	250	Hydraulic pump
Waterworkx Borehole Service	Heatom, Technical Ibadan		2007	100	Hydraulic pump, control valves
Aqua Ventures	Frilucson, Ibadan		2003	45	Hydraulic pump, valves
Nugget Wells , C6 Unity	Deep Well Hydraulics, Lagos		1994	800	Hydraulic pump
Meek Engineers Nigeria Limited	Deep Well Hydraulics, Lagos		2004	230	Hydraulic pump
Dumson Nigeria Limited	Deep Well Hydraulics, Lagos		2004	600	Hydraulic pump, control valves
Garada Water Engineering and construction	Unique Metal Fittings, Gombe		2008	23	Non so far

4.6.6 Impact of locally fabricated rigs on borehole prices

Borehole prices for a 100 mm uPVC lined 60 m deep borehole given by Adenle and Beale (1989) are as in table 6.

Table 6 Historic borehole Prices (Adenle and Beale, 1989)

Organisation	Price US$
Local contractors	4600 – 5700
UNCEF Projects	5100 – 6900
ADP projects using international contractors	9000 – 12000

UNICEF boreholes were drilled in-house and ADP projects went for international competitive bidding.

If the inflation that would have taken in place in 20 years is factored into the prices in table 6, one would expect present prices to be at least doubled. Yet the prices given by the local contractors then and now (in table 1) are comparable, at least on government projects. However, as shown in 4.6.5 the prices of private boreholes are lower than that on government projects. This reduction may not be attributed to the use of locally fabricated rigs only. Although the market has grown (as population and demand grow), more drilling companies have come into field and the competition greater than before. Private owners will probably also negotiate better rates than government officials.

Several of the drilling contractors interviewed concentrate on private sector work because they find it difficult to get government jobs directly as they claim that the process is not always transparent, contracts are given as party patronage and there are delays in payment. With private sector work there is no delay in payment and a substantial advance payment is obtained so the risk is lower. Some drillers wait for third parties with the right connection to get and finance government projects, to hire their services. Then the driller also has to reduce the price to the private sector rate but ask for a substantial advance payment.

Another factor influencing the price of government borehole projects is that in awarding the contract a bench mark for the contract price is set by the evaluating committee, based on the engineer's estimate and all the bidders below this price are awarded a contract. Giving the contract to the lowest bidder could actually force prices down but it may not build local capacity on the scale required. The borehole which the government pays N650,000 (US$4300) could actually be obtained for N400,000 (US$2700) or thereabout with proper negotiation bringing a saving of almost 40%.

4.7 Case study of a locally fabricated rig

A case study of a locally fabricated rig was made by witnessing some of the stages of the construction of the rig and its performance in the field through the drilling of 16 boreholes.

Box 3 Case study of a locally fabricated rig

Terraqua Limited was established in 2007. The main promoter and managing director, Tunde Ajobiewe had worked as a technician, supervising borehole drilling for a groundwater consultancy. He bought a used truck for N750,000 (US$5000) and asked A.U. Drilling Kaduna to mount a drilling rig on the truck. The agreed price for the construction of the rig was N3.5 million (US$23,000). Tunde made a deposit of 30% of the agreed price. No contract was signed but receipts were issued for the payments. He specified a Deutz engine, new hoses and 50 m length of new drilling rods. He felt a truck mounted rig will be quicker to move around than a trailer rig and more impressive to the clients.

The truck carriage was reduced to 4 m to fit the usual design by A.U. Drilling. A 5 m mast was constructed on the ground by welding together 2 steel rails with cross braces. Whilst this was being done, the fabricator went to Lagos to buy all the parts – engine, hydraulic pumps, diesel tank, hydraulic oil tank, rams, lifting chain, drive head, mud swivel, control valves and hoses. These were then assembled on the truck. Construction took a month. Tunde made another 30% deposit. By this time the rig was ready for testing. The rig was released and a test hole drilled in a field outside the fabricators workshop. No problem was encountered with the rig, only with the engine and brakes of the truck. Once these were fixed the rig was ready for a contract. Terraqua got the down payment for the 10 borehole contract in Zaria LGA and mobilised. Tunde made another 20% down payment for the rig and bought a Honda mud pump.

The writer witnessed the drilling of 16 boreholes with the rig. Terraqua hired a compressor as the terrain was on the basement complex. Table 6 summarized the result of the drilling with the rig. No major problem was encountered with the rig. Maximum depth drilled was 45 m on a hole where rock was encountered at 2 m depth and from where hammering started. After 45 m and no sign of water the hole was declared abortive. Once the rig was on site, borehole completion time was usually 2 days.

Table 7 Summary of boreholes drilled with the Terraqua rig

Location	Completion time (days)	Depth drilled (m)	Hammer used from depth (m)	Problems encountered
Zaria Bh 1	2	42	12	None
Zaria Bh 2	2	43	Not used	None
Zaria Bh 3	2	30	8	None
Zaria Bh 4	2	26	Not used	Mud swivel leaking, rubber seal changed
Zaria Bh 5	3	34	22	None
Zaria Bh 6	2	32	18	None
Zaria Bh 7	3	42	10	Abortive borehole: dry
Zaria Bh 8	2	33	20	None
Zaria Bh 9	2	34	16	None
Zaria Bh 10	3			None
Hammadiyah Mosque Kaduna	2	35	Not used	Gravel pack running into the hole. Had to be re-drilled. No mechanical problem with the rig
Nigerian Army Barracks, Jaji	2	38	Not used	None
Private house, Kawo New Extention, Kaduna	4	45	2	Abortive. Unable to carry out geophysics because of surrounding buildings
Hamza Zayaad Building, Kaduna	4	38	Not used	Caving in due to loose formation
Engr. Dikkos Residence, Kaduna	4	20	18	Hard rock, lack of penetration

4.8 Hand drilling

As shown in the literature review hand drilling has been well documented in several countries. It has been going on in Nigeria at least since 1982, when the World Bank assisted ADPs in northern Nigeria trained some of their staff in washboring techniques to construct tubewells in the shallow alluvial aquifers along the flood plains of the major rivers as a source of water for irrigation. The initiative survives till today. From irrigation, the technique has been adapted to water supply.

4.8.1 Identification of potential areas of hand drilling

The areas with the potential for hand drilling were identified by asking the hand drillers interviewed to list the states of the country where they had successfully drilled holes in the past. This was then compared to the existing geological maps, and borehole logs of the country to determine the geology of the area. When a state is mentioned by a driller, care was taken to ascertain the part of the state as in some states the geology is not uniform and favourable throughout for hand drilling. Table 8 shows the states where hand drilling is presently going on and the geology of the states. The areas can be classified into three categories:

- alluvial deposits along the flood plains of the major rivers
- discontinuous weathered basement aquifers
- continuous porous sedimentary aquifers

The alluvial aquifers are usually developed by hand drilled tubewells for irrigation. But there are several communities and settlements bordering or underlain by alluvial deposits where hand-drilled boreholes are providing water supply.

There are zones of fairly deep weathering on the basement complex which are reached by hand drilling. Geophysics is required to locate such aquifers but they have been reached by hand drilling at depths up to 40 m. In the northern states of Bauchi, Kano, and Kaduna and Zamfara states, underlain by basement complex, hand drilling is being carried out successfully whereas in the southern states of Oyo, Osun and Kwara on the basement complex no hand drilling is reported.

Most of the hand drilling is going on in the southern coastal plains. The shallow Coastal Plains Sands aquifer comprising sand and clays runs from the west to the east of the country. It is also an area of high population density. Lagos, Benin, Port Harcourt and Calabar cities are underlain by the Coastal Plains Sands. In Port Harcourt, Rivers State it was reported that all the drilling is by hand because of the shallow sand aquifer. Similarly in Benin, Edo State, the conventional drillers said they could not compete with the hand drillers and look for work elsewhere.

In the northern parts, the porous sands and sandstones of the Chad, Niger, Sokoto and Gongola basins incorporate aquifers that are being reached by hand drilling.

The investigation showed that hand drilling is going on and is feasible in 18 states of the 36 states of the country. Figure 7 shows the map of the areas with hand drilling potential produced from the data collected.

Table 8 Geology of States where hand drilling is going on

State	Geology		
	Age	Formation	Rock type
Akwa Ibom	Quaternary/Tertiary	Alluvium/ Coastal Plains Sands	Sands, gravels and clays
Anambra	Quaternary	Alluvium	Sands, gravels and clays
Bauchi	Precambrian	Basement Complex	Weathered granites
Bayelsa	Quaternary	Deltaic deposit	Sands, gravels and clays
Borno	Quaternary	Chad Formation	Sands, gravels and clays
Cross River	Quaternary/Tertiary	Alluvium/ Coastal Plains Sands	Sands, gravels and clays
Edo	Tertiary	Coastal Plains Sands	Sands, gravels and clays
Delta	Quaternary	Deltaic Deposit	Sands, gravels, mud,
Gombe	Quaternary/Tertiary	Alluvium/Kerri Kerri Formation	Sandstone
Imo	Tertiary	Coastal Plains Sands	Sands, gravels and clays
Kaduna	Precambrian	Basement Complex	Weathered granites
Kano	Precambrian	Basement Complex	Weathered granites
Lagos	Quaternary/Tertiary	Littoral and Lagoonal deposits/ Coastal Plains Sands	Sands, gravels, mud, clays
Niger	Quaternary/Cretaceous	Alluvium/Nupe Sandstones	Sands, gravels, sandstones
Rivers	Quaternary/Tertiary	Alluvium/Coastal Plains Sands	Sands, gravels and clays
Sokoto	Tertiary	Gwandu	Sands and clays
Yobe	Quaternary	Chad	Sands
Zamfara	Precambrian	Basement Complex	Weathered granite and gneisses

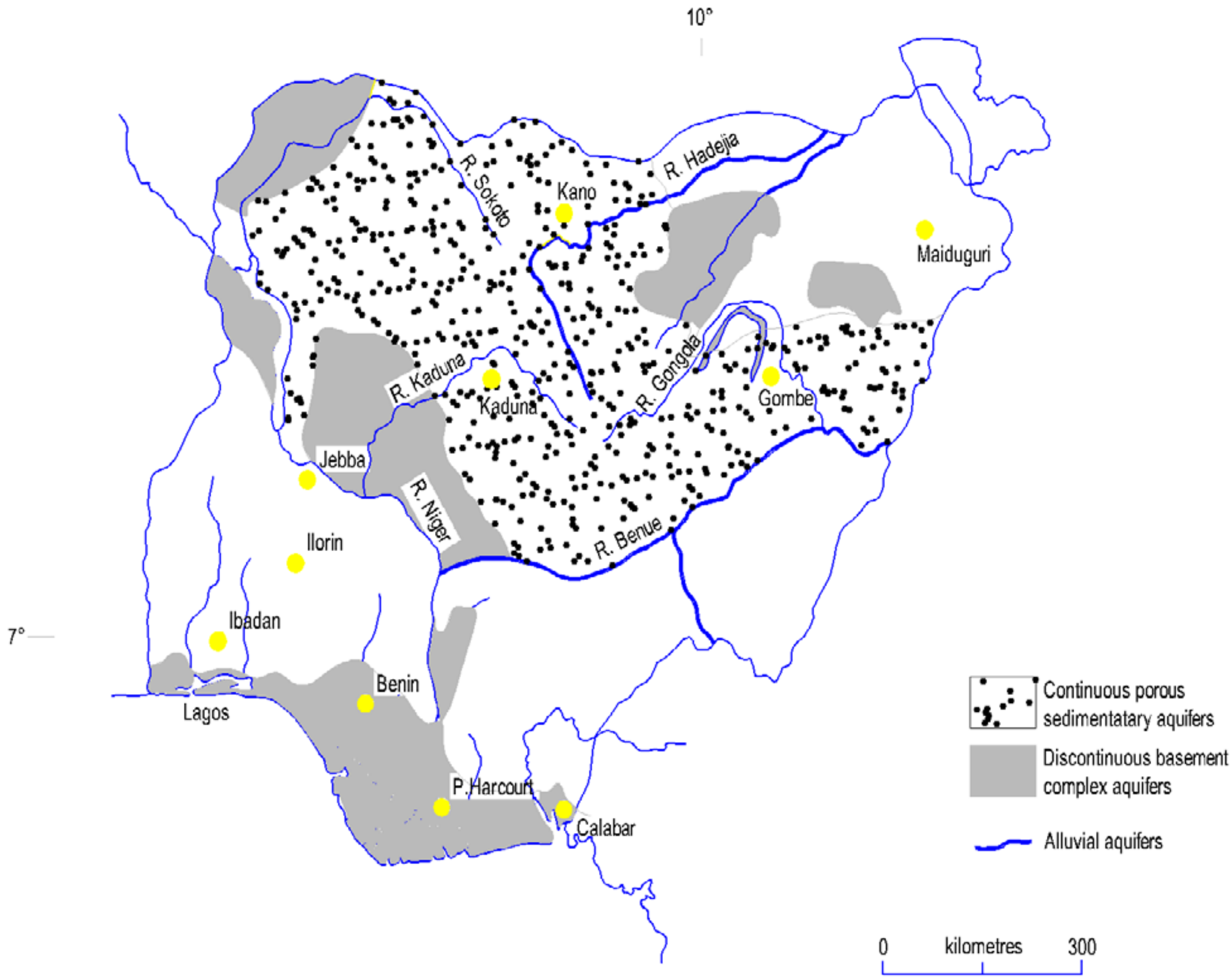


Figure 7 Map of Areas with hand drilling potential

4.8.2 Hand drilling technique

The technique used by all the hand drillers interviewed is the jetting method. Water, sometimes mixed with a drilling mud such as bentonite is pumped from a circulation pit through a hose attached to a 50 mm galvanised iron drill stem with a drilling bit at its end. The water flows back up through the well and brings the cuttings to the surface.

Hand drillers operate in parties of 5 men, who have bonded together and developed a rhythm and synchrony of turning the drill pipe. The drill stem is continuously rotated by four of the men to break the formation whilst the water hose is held in place by the fifth man. This is why hand drilling is locally referred to as “hand turning”.

The jetting equipment is fabricated locally. Usually the hole is opened up by augering to a few meters depth or to the water table before jetting starts. The hole is lined with plastic casings, and the screens made on site by cutting slots into the bottom casing. The mud pump (usually petrol driven Honda pump) is also used for developing the hole by pumping until the water is clear. Because the mud pump is designed to handle water and not sand and mud, it has to be replaced quite often may be after every ten hole. It costs about N20,000 (US$1333). See pictures 5 and 6.

Picture 5 A five-man hand “turning” party

Picture 6 Hand drilling equipment

4.8.3 Hand drillers background

Like the local rig fabricators, hand drillers are also of diverse background, from farmers without any formal education to university graduates, religious leaders, retired government hydrogeologists and former salesmen. The ranks also include conventional drillers like Mba Onwuka mentioned in 4.6.5 who justified his use of hand drilling by saying “*why kill an ant with a sledge hammer?”* i.e. where the aquifer is shallow and sandy why use a mechanised rig. Since several of his customers are private householders, the equipment is light and can be manoeuvred into a corner of a small property. Drilling time is usually 2 days and only a 5 man crew required.

33 year old Olumide Bamisaiye a hand driller in Lagos, took a degree in geology 6 years ago. On finishing the national service he could not find a regular job. He took a loan of N700,000 (US$4700) from his parents to start a hand drilling operation. In the past five years he has drilled 150 boreholes. His clients are private industries and householders. He would like a regular job but if he can build his operation to two boreholes per week he will continue with drilling.

Similarly, Mohammed Izzah of Dangarba Engineering, with a diploma in marketing, borrowed money from his parents to start a hand drilling operation when he could not find regular employment. He started drilling in December 2006. By June 2008 he reckoned he had drilled 250 boreholes. In 2009 he bought a brand new Dando rig and compressor from the UK but he intends to keep on with his hand drilling line as he feels there is a market for it and quite profitable to him.

Table 9 gives a summary of the background of the 18 hand drillers interviewed.

Table 9 Hand drillers background

Name of company	Location (state)	Name of CEO	Educational background	Professional background	Year of starting business as hand driller
Jobio drilling	Akwa Ibom	Joe Akpabio	B.Sc Geology	Retired geologist	2002
Soles and Sons	Edo	Solomon Ekairia	School certificate	Head driller	1998
Podery Ventures	Edo	Okpodu Onoriede	B.Sc, Geology	Drilling	1996
Itohan Mercy Enterprises	Edo	Desmond Obinyan	College diploma	Drilling	2005
C.D.A Drilling and Construction Com	Edo	Isibor Emmanuel	B.Sc Business education	Sales man, drilling	1989
Vinsmond Drilling Company	Edo	Vincent Okifo	B.Sc Engineering	Mechanical engineering	1996
None	Gombe	Ali Adamu	No formal education	Small contract job	2004
Albarka Water Venture	Gombe	Al Amin Mohammed	Trained as hand driller by Borno State	Hand drilling	2001

Name of company	Location (state)	Name of CEO	Educational background	Professional background	Year of starting business as hand driller
			Water Board		
Nasara Drilling Company	Gombe	Mohamed Usman	No formal education	Farming	1995
Water Hope Nigeria Ltd	Kaduna	Kingsley Ojianelo	B.Sc Business Administration	Drilling, church pastoral work	1992
Dangarba Engineering Ltd	Kaduna	Mohamed Izzah	HND Marketing	Drilling	2006
Neat Drilling Ltd	Kano	Joseph Osigbeevo	School certificate	Plumbing	2001
Dumson Nigeria Ltd	Lagos	Mba Onwuka	M.Sc Hydrogeology	Drilling and geology	2000
Links Hydroengineering Ltd	Lagos	Olumide Bamisaiye	B.Sc Geology	Geology	2004
Abdul driller	Niger	Abdul Dimba	Trained in washboring by ADP	Wasbore driller	2000
Rich drill	Rivers	Sylvanus N.Ike	B.Sc Petroleum Engineering	Oil well driller	1986
McTonis Technical company	Rivers	Martins Ekpo	Technical school certificate	Plumber	1998

4.8.4 Hand drillers entrepreneurial skills

The entrepreneurial skills of the hand drillers were evaluated on the criteria of

- company registration
- level of education or technical competence
- professional background
- organisational skill

Of the 18 hand drillers interviewed only one is not formally registered either as a limited liability company or a trading business. 9 of them have university degrees or polytechnic diplomas. Only 2 had no formal education but they were able to communicate in English.

They all have an office address, business cards, bank accounts and are able to prepare quotations and proposals. There is an evidence of commitment to the profession in that many of the drillers have been in the business for a long time.

Rich Drill, Dangarba Engineering and Dumson have conventional drilling rigs but consider that hand drilling is more cost effective in some terrains than conventional drilling. Dumson stated that hand drilling represents 40% of his turnover.

Thus all the hand drillers interviewed had some entrepreneurial skills.

4.8.5 The hand drillers' clientele

The hand drillers' clients are mainly the private sector, mostly householders because the borehole prices are affordable. Their clientele also includes fish farmers, car wash owners, bottled water and sachet water manufacturers, and conventional drillers. The hand drillers are not usually patronised by government projects. Only one occasion of a government agency employing hand drillers was encountered. This was in the creeks of Rivers State when the Rivers State Rural Water Supply and Sanitation Agency (RUWASSA) engaged a hand driller to construct boreholes in some of their communities. As there was no access for big rigs in the creeks, hand drilling was the appropriate option.

Mogammed Izzah drilled six boreholes manually for the Nigeria National Petroleum Company (a government owned company) in their host communities but he said he got the job because he had actually drilled in the private residences of some of the managers and had thereby demonstrated the potential of hand drilling and gained their confidence.

Kingsley Ojianelo said he drilled 23 boreholes manually as a subcontractor to a conventional driller who had got the job from the Kachia LGA of Niger State. It was also reported that in Yobe state several hand drillers work as subcontractors to conventional drillers or middle men who had secured contracts from the government.

The question then arises why government projects are not tapping the potential provided by hand drilling technology with its lower prices, as one of the options to bridge the water supply gap. One reason that can be adduced is that most of the public institutions involved in borehole drilling contracts in Nigeria tend to follow the same contract procedure and set similar conditions. There is some reluctance by individual civil servants or agencies to break from the mold and try new innovations. The Federal Ministry of Water Resources asking for tenders for a borehole contract required that interested parties should have

- an average annual turnover of N 150,000,000 (US$ 1 million) over the previous 5 years
- □2 no drilling rigs

- 2 no compressors
- 1 no geophysical equipment
- 2 truck mounted cranes

(FMWR, 2006). These conditions automatically precluded the hand drilling operators.

Asked why her agency does not use hand drillers, the response of the secretary to the Gombe State RUWASSA was that they could not guarantee the quality of the product as hand drillers use a water pump for development instead of a compressor and therefore the water may remain cloudy for a long time. The response from the Director of the Kaduna State RUWASSA was similar. He said that as Kaduna state is underlain by the basement complex, if hard rocks are encountered at a shallow depth the borehole would have to be abandoned. The response of the Director of Lagos State RUWASSA was simply that it was not the agency's policy to use hand drilling. Apart from the obvious reluctance of civil servants to change, there also seems to be a lack of understanding of the technology and its potential.

4.8.6 Prices of hand drilled boreholes

All the hand drillers charge per hole rather than per meter drilled. They do not go into elaborate contract agreements but a quotation is presented to the prospective client and an advance payment requested, usually 75% before work starts. In case of a dry borehole 50% of the advance payment is refunded or another point tried. The writer witnessed Mohammed Izzah drilling a second hole in a residence when some mica flakes were found in the water from the first hole, at no extra cost. Dry holes were only reported on the basement complex. All the drillers working in the sedimentary and regional aquifers of Edo, Lagos, Rivers, and Gombe States said they had never encountered a dry hole.

The prices of boreholes obtained from the drillers are presented in table 10. The prices vary between N180,000 to N300,000 (US$1200 - 2000) depending on location and whether a submersible pump is supplied and the type.

Table 10 Hand drilled borehole prices

Driller	Location (State)	Price Naira	Price US$	Remarks
Soles and sons	Edo	250,000	1666	60 m deep. Inclusive of pump. 60% advance payment
Podery Ventures	Edo	250,000	1666	60 m deep. 75% advance payment
Itohan-Mercy	Edo	300,000	2000	60 m deep. 60% advance payment

Driller	Location (State)	Price Naira	Price US$	Remarks
Enterprises				
C.D.A Drilling and Construction Co.	Edo	270,000	1800	75% advance payment
Albarka Ventures	Gombe	300,000	2000	Including a submersible pump
Nasara Drilling Company	Gombe	300,000	2000	Including a submersible pump
Water Hope	Kaduna	180,000-200,000	1200-1333	30 m deep borehole
Dangarba Engineering	Kaduna	260,000	1700	35 m deep on the basement
Neat Drilling Limited	Kano	210,000	1400	35 m deep on the basement
Links Engineering	Lagos	220,000	1470	Without the pump
McTonis	Rivers	240,000	1600	Without the pump

4.8.7 Hand drillers capability

The research enquired into the capability of the hand drillers in terms of number of boreholes drilled per annum and maximum depth ever attained. The results are presented in table 11. Most could only give figures for the previous two years, 2007 and 2008. It shows that some drill as little as 5 boreholes per annum whilst the more established ones drill over 100.

Maximum drilling depth ever attained also varies. The drillers operating on the sediments have drilled over a hundred meters whilst those operating on the basement complex recorded about 45 m.

Table 11 Hand drillers capability

Driller	Location (State)	Deepest hole ever drilled (m)	No of boreholes drilled per annum	
			2007	2008
Soles and sons	Edo	120	27	38
Podery Ventures	Edo	100	68	52
Itohan-Mercy Enterprises	Edo	107	13	22

Driller	Location (State)	Deepest hole ever drilled (m)	No of boreholes drilled per annum	
			2007	2008
C.D.A Drilling and Construction Co.	Edo	100	86	107
Vinsmond	Edo	125	17	18
Albarka Ventures	Gombe	75	20	20
Nasara Drilling Company	Gombe	50	20	40
Ali Adamu	Gombe	40	10	5
Water Hope	Kaduna	45	98	110
Dangarba Engineering	Kaduna	40	121	132
Dumson Nigeria Limited	Lagos	100	70	58
Neat Drilling Limited	Kano	100	-	10
Links Engineering	Lagos	80	44	60
McTonis	Rivers	80	23	40

4.9 Case study of a hand drilling operation

The operation of Water Hope Nigeria limited has been used as a case study of hand drilling operation and is reported in box 4.

Box 4 Case study of a hand drilling operation

Water hope Nigeria Limited was registered in 1992. The owner, Kingley Ojianelo has a degree in business studies from the UK, and had worked with a drilling company in Kaduna in the 80s. When the company folded up in the 1992 he relocated to his native Edo State and started a hand drilling company. He and his wife are the directors of the company. He has two hand drilling parties and they drill on average one borehole a week, although drilling time per borehole is usually two days on site. The equipment consists of

- 1 pickup vehicle
- 2 x 40 m length of 50 mm diameter G.I. drill pipe
- 4 No clamps
- A petrol driven mud pump
- Drag bits (125, 150 and 200 mm diameter)
- Water tank

The clamps and bits are made by the company. Other pieces of equipment are bought locally. The mud pumps wear out quickly because they are actually water pumps and have to be replaced after 5 or 10 boreholes but the cost only N20,000 (US$167).

Kingsley Ojianelo is also a pastor of his church and sees hand drilling as part of his ministry and a means to empower members of his congregation. He charges N180,000 – N200,000 (US$1200 -1666) per borehole depending on the location. This includes the casing and an electrical submersible pump. He allows a profit margin of 30% in his price. For his congregation members, he will drill a borehole for anybody with a small scale industry who can make a deposit of N100,000 (US$800). They can then pay the balance gradually from the sale of their products. Mrs Olagunju, a former bank employee was on forced leave from the bank when she set up a sachet water making business with the part payment arrangement offered by Water Hope. When she was recalled back by the bank, she found the business viable enough that she did not go.

Pictures 7 and 8 show Elder Ehigiamusoe's water selling business. The retired school teacher set up the business to augment his pension with the part payment arrangement with Water Hope. He says in the dry season the queue for water may mean a waiting time of 30 minutes. He has bought a generator to ensure regular power supply for the pump.

Kingsley Ojianelo says he does not aspire to owning a drilling rig as he thinks it is unnecessary hassle since he can make a living from hand drilling and help his congregation at the same time. Within the Mando area of Kaduna city there are at least 20 small enterprises which have benefited from the part payment arrangement.

Picture 7 Water selling point

Picture 8 Ehigiamusoe's water business

Chapter 5 Discussion

This chapter discusses some of the issues and findings of the research.

5.1 Definitions

5.1.1 Fabrication versus manufacturing

Throughout the report, the act of making rigs locally in Nigeria is referred to as fabrication rather than manufacturing even though Chambers Dictionary (1998 edition) defines manufacturing as “ making on a large scale, fabricating, concoct or event”. The word manufacturing, particularly when referring to a piece of equipment like a drilling rig suggests that the equipment is made repeatedly to the same specification and standard, with all the components new and the quality of the product assured; the product has a brand name and probably covered with a patent. This is not the case with the rigs described in this document. Thus the word fabrication has been found to be more appropriate than manufacturing.

5.1.2 Low cost drilling

It could be argued that fabricating rigs by copying existing imported ones and drilling with them is not low cost drilling. However the fabricated rigs provide an opportunity for some cost reduction such that small scale enterprises and households interested in self supply can afford a borehole. It is therefore low cost drilling.

5.2 Low cost drilling and economies of scale

The research has shown that low cost drilling using locally fabricated rigs and hand drilling could reduce the borehole cost by as much as 40%. This is under the present condition where the drillers go from one borehole to the other and in a year may drill between 50 and 100 boreholes. However, if large contract packages of about 20 and 50 borehole lots, in contiguous locations are available to each driller, mobilisation cost will be reduced and the contract will enjoy the economies of scale and therefore further reduction in price is possible.

5.3 Promoting low cost drilling for livelihoods

Apart from providing improved domestic water supply sources, low cost drilling provides employment opportunities for several people. Besides the people directly employed in drilling, the water from the boreholes drilled is providing means of livelihood. Several small scale enterprises, such as private water selling, sachet water making, car wash centres, flower garden centres, brick making, as well as irrigation and livestock watering derive water from low cost boreholes. Thus, promoting low cost drilling could also be a poverty alleviation strategy.

5.4 Government projects and low cost drilling

Government projects are not deriving the maximum benefits from the low cost drilling technologies available. One of the reasons is lack of transparency and delays in the contract award process which discourages some conventional drillers from participating in government projects. Where jobs go through middle men, apart from the possibility of standards being compromised there is also an increased cost to cover the middle man. A Water Well Drillers Association of Nigeria was formed in 2008. It will be of benefit to government projects if the different governments in the country go into partnership with the association. Drilling contracts are then given to only those identified as professional drillers by being members of the association. Contracts can be classified according to the level of complexity and awarded to drilling contractors with the level of capability required. Over specification of boreholes should be avoided. Contracts can be packaged in larger lots and lower prices negotiated in the light of prevailing borehole prices in the private sector.

Government agencies and projects need to be more flexible in contract specification, to try new and cheaper alternatives to the existing ones.

5.5 Bringing hand drillers within the purview of government projects.

The research has shown that there are vast areas of the country where hand drilling is feasible. It has also shown that there are hand drillers with the entrepreneurial skill to carry out government projects. There is thus an opportunity to meet the demands of millions of people using hand drilling technique. This is presently not being done by the government for reasons already explained elsewhere in this report. A change in attitude is required. Yet it is the nature of government structure to resist change. To get the hand drillers in to the purview of government project will require the assistance of external support agencies such as the UNICEF and NGOs such as WaterAid to demonstrate the effectiveness of hand drilling.

UNICEF or WaterAid as partners to the government in the rural water supply sector could set up pilot projects lasting a year or two in some of the states. Those states initially could be those underlain by continuous porous sedimentary aquifers, such as Rivers, Bayelsa, or Delta. A cluster of hand drillers are identified in those states. Negotiation is entered into with each one of the drillers and a contract to drill a number of boreholes in particular LGAs is agreed. The promoter could assist the drillers in terms of equipment or capacity development if required. A criticism mentioned against hand drilling is that the quality of the product cannot be assured as hand drillers use a water pump for development rather than a compressor. A compressor could be provided for the use of a cluster of hand drillers in particular states.

The drilling should be closely supervised, ensuring that lining materials are of the required standard and that sanitary seals are properly placed. The results of the pilot projects should be properly documented and disseminated to all stakeholders and government staff. If the projects are successful, then they may be replicated on government projects.

5.6 Ground water monitoring

There is need for groundwater level and quality monitoring to avoid over abstraction and pollution of the sources. The abstraction from rural community supply boreholes fitted with handpumps is low and poses no threat to environmental sustainability so long as they are well constructed.

In most of the urban areas as population increases and the public water systems are unable to cope with the demand, and with increasing wealth, more and more households are drilling their own boreholes. The abstraction points are often close together and there is not enough space to locate them at the adequate distance from potential sources of pollution such as a soak-away. If the sanitary seals are not properly placed there may be some contamination.

There is also some concern of over abstraction particularly in the densely populated urban areas. In the course of the research, households were encountered in Kano and Kaduna where their traditional wells had dried up due to being surrounded by households with boreholes with submersible pumps, lowering the water table. During the industrial boom of the 1970s groundwater level decline was observed in the Lagos area. This has stabilised over the years but it may reoccur if the rate of abstraction continues to increase.

Some farmers also use the irrigation boreholes as a source of drinking water. As the boreholes tend to be shallow, in some cases not more than 3 m deep, there is some risk of contamination from poor excreta disposal, fertiliser and pesticides.

5.7 Borehole sustainability and the MDGs

The country is not likely to meet the MDGs for water supply if 30-50% of the installed facilities is broken down at any particular time. Apart from depriving the communities it is meant to serve, a non productive borehole or non functional borehole imposes additional costs on the productive borehole. A borehole may fail for several reasons, such as

- the borehole may prove dry or unproductive
- the borehole may fail after construction perhaps years later because of construction faults, corrosion or clogging of borehole screen
- the borehole may fail sometime later due to over abstraction
- the pump may fail

The failure may be due to poor siting or poor construction and supervision. Even when a competent company is used, the staff on site may result to sharp practices which reduce the quality of the work. Thus supervision is always required. Yet the resources for supervision may be limited. Even where competent supervising staffs are available the resources to keep them on site and with the drilling rig at all times may be lacking.

Carter et al (2006) showed that if the impacts of both the short term and the long term failure are taken into account then the all inclusive cost of borehole failure can be illustrated by the formula

$$\mathbf{F = (a+(1 - a)f / (a(1-b))}$$

Where

F = cost multiplier to apply to base cost of a productive borehole

a = drilling success rate

b = post construction failure rate

f = cost of construction of a dry borehole as a fraction of productive borehole cost.

For a drilling success rate of 80% and post construction failure rate of say 25% and cost ratio of dry to productive holes of about 0.60 the equation shows that the real (all inclusive) cost of drilling is 53% higher than that of a productive sustainable borehole (F =1.53). If drilling were to improve to a success rate of 90% and post construction failure rate reduced to 15%, for example, the factor F would reduce to 1.25. i.e. the all inclusive cost of a productive sustainable borehole would reduce from 1.53 times the productive borehole base cost to 1.25, a saving of 18%. Drilling success rate and post construction failure therefore have a significant impact on borehole cost. Thus another way to reduce drilling cost is to reduce failure rate and this will require investment in capacity development of both the private drillers and the drilling supervisors in government agencies.

Chapter 6 Conclusion

6.1 Introduction

The research set out to

- evaluate the potential of locally fabricated drilling rigs to contribute to increasing water supply coverage
- evaluate the potential of hand drilling operators to contribute to increasing water supply coverage

It achieved the two aims and concludes that both locally fabricated rigs and hand drilling have been employed for the provision of water supply boreholes for some years in the country. The two techniques have the potential to lower the prices of boreholes so that the water coverage gap can be bridged. The full potential of the technologies is yet to be tapped by the various government projects in the country. The conclusion is elaborated upon below.

The research also tried as much as possible within its limitation to fill two of the three gaps identified in the literature review i.e. lack of information on locally fabricated rigs and why government agencies do not use hand drillers.

6.2 Institutional Issues

Nigeria has set up institutional arrangements to meet the MDG targets. The country's poverty reduction strategy paper, NEEDSs is designed to address the MDGs. A virtual fund for poverty reduction has been set up using the gains from the debt relief granted the country by the Paris club of creditors. The fund totalling $18 billion dollars is administered by the office of the Office of the Senior Special Assistant to the President on the MDGs. Whether the fund is adequate to meet the MDGs or not has not been determined.

6.3 Present water supply coverage

Rural water supply coverage declined from 34 per cent in 1990 to 30 per cent on 2006 and urban water from 80 per cent to 65 per cent in 2006. The decline is attributed to facility provision not keeping pace with population growth and installed facilities breaking down.

Boreholes are often the technology of first choice in rural water supply. The research estimates that about 10,000 boreholes need to be drilled annually in the country to meet the MDGs. A saving on cost, as little as 10 % means that a lot more people will be reached.

6.4 Locally fabricated rigs

Light and medium duty drilling rigs are being fabricated locally in Nigeria. They have been used to drill water supply boreholes for more than 20 years both on government projects and for private businesses and householders. The cost of the rigs is less than that of an imported rig of the same capacity. Spare parts are readily available. Not much down time is incurred waiting for spares parts as is experienced on imported rigs. None of the interviewees has recorded an accident due to rig malfunctioning. A major constraint of the rigs is that there is no specification for the components thus spares are bought on trial and error basis.

6.5 Locally fabricated rigs and cost effective boreholes

Due to the lower cost of the rigs, mobilisation and drilling cost of a borehole drilled with one are lower than that of an equivalent imported rig and therefore the rigs have the potential of reducing borehole prices in the country. This potential is already manifested in the price of private household boreholes. However it has not been manifested in government borehole projects.

6.6 Hand drilling

Hand drilling has been going on for a long time in the country both for agriculture and water supply. The price of hand drilled boreholes is presently about a third of that of machine drilled boreholes. The prices are fairly uniform throughout the country. Thus, where hand drilling is feasible more people could be reached.

The hand drillers' clientele comprise householders and owners of small scale industries. As the population increases and public supplies are not meeting the demand, several households are engaging in self supply and the lower cost of hand drilling makes it affordable.

Hand drillers have not been brought into the mainstream of government projects. The main reason given is lack of quality assurance for hand drilled boreholes. The research showed that some of the hand drillers have a high level of entrepreneurial skills and have been working as conventional drillers on government projects and should be brought within the purview of government projects.

The areas of the country where hand drilling is going on and where it is feasible have been identified. The potential of hand drilling needs to be demonstrated by pilot projects at local government level and state level by the likes of UNICEF and WaterAid. This could then be replicated and scaled up on government projects.

Chapter 7 Recommendation

7.1 Introduction

This chapter makes some recommendation based on the outcomes of the research for the different tiers of government, the external support agencies and NGOs on how to accelerate the provision of water supply and bridge the gap.

7.2 The Federal Government

The Federal Government and its agencies should concentrate on policy formulation and coordination whilst providing financial support to the states and local governments to implement borehole drilling projects. The national rural water policy should be reviewed with emphasis put on considering all available options for bridging the water supply deficit including hand drilling where it is feasible.

The Federal Government should spearhead a national borehole programme involving all stakeholders and determine the number of boreholes required in each state to meet the MDGs. The investment required, the available financing options and the responsibility of each stakeholder should be identified.

The Federal Government should instigate actions to determine the available drilling capacity in the country i.e. the number of drilling contractors, the number of rigs and their location so that if there is a shortfall in meeting the targets, options to bridge the gap can be identified and mobilised.

The Federal Government should go into partnership with the Water Well Drillers Association of Nigeria so as to derive maximum benefit from the aggregate knowledge and expertise of its members and to develop a more realistic and cost effective pricing of boreholes.

7.3 State Government

The State Governments should identify the manpower and capacity development requirements of their staff for effective supervision of borehole drilling and provide the training, tools and enabling environment.

The State Governments and the RUWASSAs should ensure that borehole contract award process is timely, transparent and equitable. They should also associate with the Water Well Drillers Association of Nigeria and hold dialogues with the members for a more cost effective pricing and drilling of boreholes in the light of locally fabricated rigs and prevailing borehole prices in the private sector.

The State Governments should work with the local governments and develop guidelines for continuous monitoring of water sources, both quality and output, and operation and maintenance. They should also provide training and technical support for LGA staff to be able to continue the training of community members in operation and maintenance of their facilities.

State Governments should identify those areas in their states where hand drilling is feasible and hand drilling operators with entrepreneurial skills who can be engaged to drill low cost boreholes.

7.4 Local Government level

Local governments should keep an inventory of the boreholes within their area and monitor their functionality and support the communities in the maintenance of the facilities.

7.5 External Support Agencies and Non Governmental Organisations

ESAs and NGOs should set up pilot borehole projects to demonstrate the effectiveness of hand drilling. They are also to support federal and state governments in sector and institutional reforms including the development of policy, strategy and regulatory frameworks, and building capacity of government institutions at all levels to monitor and drive progress. They should support other processes that promote equity, transparency and good governance.

References

Adekile, D. (2007) *Nigeria Drilling Study Background Report*. Consultancy Report RWSN/WSP

Adekile, D. and Olabode, O. (2008) *Study of Public and Private Borehole Drilling in Nigeria.* Consultancy Report to UNICEF Nigeria

Adekile, Dotun.and Olabode, Olusola (2009) *Hand drilling in Nig*eria *why kill and ant with a sledge hammer.* RWSN Community Site available at <http://www.rwsn.ch/documnetation/skatdocumentation.2009-02-27.7138623246 (Accessed 08/05/09)

Adenle, O.A. and Beale, D. (1989) *Borehole Drilling in Africa, Nigeria Case Study.* Water and Sanitation Division, Infrastructure and Urban Development Department, The World Bank.

Akujieze, Christopher, N, Coker, S.J.L and Oteze, G.E. (2003) *Groundwater in Nigeria – a millennium experience – distribution, practice, problems and solutions.* Hydrogeology Journal, Volume 11 – *Number* 2. April 2003

Alayande W. (2009) *Youth Empowerment Initiative of the National Water Resources Institute, Kaduna*. Workshop Proceedings

Antea. (2007). *Etude sur l'optimisation du coût des forages en Afrique de l'Ouest Rapport de Synthèse.* Banque Mondiale Programme Pout L'Eau et L'Assainissement – Afrique (PEA-AF)

Ball, Peter (2001) *Drilled Wells. SKAT Working Papers on Water Supply and Sanitation.* No. 2, SKAT, St Gallen, Switzerland.

Ball, Peter (2004) *Solutions for Reducing Borehole Costs in Africa*. WSP/RWSN/Skat Field note

Carter, Richard (2005) *Human Powered Drilling Technologies.* Cranfield University

Carter, Richard (2006) *Ten-step Guide Towards Cost Effective Boreholes, Case Study of drilling costs in Ethiopia* WSP/RWSN Field Note

Carter, Richard, Desta, Horecha, Etsegenet Berhe, Eyob Belete, Yetnayet Negussie, Belete Muluneh and Danert, Kerstin (2006) *Drilling for Water In Ethiopia: A country case study by the Cost Effective Borehole Flagship of the Rural Water Supply Network.* Federal Democratic Republic of Ethiopia/WSP/RWSN

Community Water and Sanitation Agency (2007) *National Water Policy, Ghana.* Ministry of Water Resources Works and Housing

Danert, Kerstin (2006) *A Brief History of Hand Drilled Wells in Niger – Only the beginning.* WSP/RWSN Field Note

Danert, K. Carter, R.C. Adekile, D. MacDonald, A. (2008) *Cost Effective Boreholes in sub-Saharan Africa* 33rd WEDC International Conference, Accra Ghana. Available at www.rwsn.ch/documentation/skatdocumentation.2008-04-19.5002404274/file (Accessed 08/05/09)

Danert, Kerstin (2009) *Realising the potential of hand drilled wells for Rural Water Supplies.* Waterlines, April 2009 Volume 28 Number 2.

Danert, Kerstin and Gaya, Silvia (2009) *Hand Drilling Directory.* (Draft) RWSN Hand Drilling Cluster Group

Denscombe, Martyn (2007) *The Good Research Guide for small-scale social research projects.* Third Edition Open University Press, McGraw Hill House, Maidenhead, Berkshire, England

Eduvie, Martin, (2008) *Difficult Groundwater Terrains of Nigeria in relation to Drilling Cost* Paper presented at the stakeholders workshop for developing the Study of Public and Private borehole Drilling in Nigeria, Minna, 2008

Federal Ministry of Water Resources Nigeria (2004) *National Rural water Supply and Programme, A Strategic Framework* Department of Water Supply and Quality Control

Federal Ministry of Water Resources Nigeria (2006) *Bidding Document for Borehole Construction* Federal Government of Nigeria

Forster, S.S.D., Chilton, J. Moench, M. Cardy, F. and Schiller, M.(2000) *Groundwater in Rural Development.* World Bank Technical Paper N. 463, World Bank Washington D.C, Available at http://www-wds.worldbank.org (Accessed: 20.05.09)

Habila, O.N. (2002) *Rural Water and Sanitation Development in Nigeria*. In Proceedings of the 28thWEDC International Conferenece, KOlkata, India

Hazell, Robin (2004) *British Hydrogeologists in West Africa – an historical evaluation of their role and contribution.* In Mather, J.D. ed. 200 years of British Hydrogeology, Geological Society London special publication

Iloeje N.P. (1996) *A New Geography of Nigeria*. Longman Nigeria Limited

Iliyas M.and Eneh D. (2007) *Report on Public Expenditure Review in the Rural Water and Sanitation Sector for Kaduna State.* Nigeria World Bank Nigeria

Keast, G (2007) *The Way Forward for UNICEF WASH in Nigeria: Programme Recommendation.* UNICEF Nigeria

Jones, Hazel (2008) *Individual Research Project. A WEDC Post graduate module.* Loughborough Univeristy

Kogbe, C.A ed. (1976) *The Geology of Nigeria.* Elizabethan Publishing Co., Lagos, Nigeria

MacDonald, Allan, Davies, Jeff, Carlow, Roger and Chilton, John (2005) *Developing Groundwater – A guide for Rural Water Supply.* ITDG Publishing, Shumacher Centre for Technology and Development, Borton Hall, Bourton-on-Dunsmore, Warwickshire, Uk

Mthunzi, Mazauko (1999) *Introduction of low cost borehole.* In Integrated Development for Water Supply and Sanitation. Available at http://www.lboro.ac.uk/wedc//papers/25/188.pdf . (Accessed 18 May 2009)

National Planning Commission (2005) *National Economic Empowerment and Development Strategy.* Federal Government of Nigeria

National Population Commission (2007) *National Census Figures.* Federal Government of Nigeria

National Water Policy Ghana (2007) Ministry of Water Resources, Works and Housing,

Northedge, Andrew (2005) *The Good Study Guide.* The Open University, Walton Hall, Milton Keynes UK

Offodile, Matthew (2002) *Ground Water Study and Development in Nigeria* Mecon Geology and Engineering Services Limited Jos, Nigeria

Onashile, O. (2008) Managing Director Deep well Hydraulics, Personal Communication (Interview).

Parkman Consultant, (1996) *Review of Lagos State Water Resources Masterplan.* Consultant's report to the Lagos State Government

PAT Nigeria (2009) *Quotation for a PAT 301 rig and accessories*

Raeburn C. and Jones, Brynmor (1934). *The Geology and Water Supply of the Chad Basin.* Geological Surveys of Nigeria, Bulletin 15

Rowles, R, (1995) *Drilling for Water: a Practical Manual.* 2nd Ed. Avebury press Aldershot

Shaw, Rod ed. (1999) *RUNNING WATER More technical Briefs on health, water and sanitation*. IT Publications, London, UK

Skinner, Brian (2003) *Small Scale Water Supply: A Review of Technologies.* ITDG Publishing, London

Smet, Jo and Wijk Christine eds. (2002) *Small Community Water Supplies.* IRC Technical Paper Series 40

Sutton, Ian (2007) *An Assessment of Hand Drilling Potential in Upland and Lowland Dambo Environments of Malawi*. M.Sc. Thesis, School of Applied Sciences, Cranfield University

WaterAid (undated) *Ensuring Acceptable Water Quality in Rural Communities.* Briefing Note

Water Surveys (1986) *Bauchi State Shallow Aquifer Study.* Consultants Report to the Bauchi State Agricultural Development Project

WELL (2004*) Will it cost the earth? An overview of cost estimates for achieving the water and sanitation targets of the Millennium Development Goals.* Briefing note 9 WEDC Loughborough University

WHO/UNICEF (2008) *Progress in drinking water and sanitation.* Joint Monitoring Programme available at http://documents.wssin.org/resources/documents.html (Accessed 24.03.09)

Wikkipedia (2009) *Demographics of Nigeria*

Wurzel, Peter (2001) *DRILLING RIGS IN NIGERIA-UNICEF AND A RATIONAL PROCUREMENT POLICY-an argument for a greater focus on manual drills and procurement of smaller, less expensive, more maneuverable mechanical rigs. UNICEF Nigeria*

Wurzel, Peter (2001) *Drilling Boreholes for Hand pumps.* Swiss Centre for Development Cooperation in Technology and Management

WSP/RWSN (2009) Consultant's report on the Water Well Drilling Association of Nigeria

YaracNigeria (2009). *Nigeria and the MD*Gs available at www.yaracnigeria.org/node/335 (Accessed on 12.12.09)