



British Geological Survey



DFID Department For
International
Development

TECHNICAL REPORT WC/00/07
Overseas Geology Series

Communicating groundwater research: the example of Oju and Obi, eastern Nigeria

A M MacDonald and J Davies



BGS International™
British Geological Survey
Keyworth
Nottingham
United Kingdom NG12 5GG

Executive Summary

The British Geological Survey has been working with WaterAid to improve water supplies for poor communities in rural Nigeria. Oju and Obi are two adjacent local government areas in Benue State, Nigeria. During the annual dry season (November to April) there is an acute water shortage and much of the population of 300 000 have to rely on unprotected ponds and seepages which are often far from communities. If available, groundwater would offer the safest, easiest and least expensive solution to the water supply problem. The area is underlain by mudstones. Prior to the BGS study, little was known about the potential for finding groundwater in mudstone environments. After a two year study, involving 75 km of geophysical surveys and 54 exploratory boreholes, BGS concluded that sustainable groundwater resources do exist in the mudstone environment of Oju and Obi. Simple geophysical techniques could be used to identify good sites for boreholes or wells, if interpreted carefully. This information could be used to improve the quality of life of 300 000 people.

Communication and partnership were essential aspects of the research. Various organisations had an interest in the outcome of the research. The degree of detail required by the different users varied considerably, so the research had to be effectively communicated in a number of ways.

BGS worked closely with WaterAid's local partner, the Water and Sanitation Unit (WASU) of the local government. Every aspect of the research was discussed with the WASU, from choosing where research sites should be located to designing the form the outputs of the research should take. The partnership was facilitated by several participatory workshops, substantial field training and involvement in the WASU's weekly planning meetings. Although it was time consuming keeping the WASU fully informed of the methods, rationale and progress of the research, there were many beneficial impacts. Firstly, it meant that the WASU could confidently prepare communities that were used as test sites. Consequently, relations with the local communities were excellent and research activities could proceed rapidly with few misunderstandings. Secondly, the WASU were in a much better position to accept and understand the results of the research, since they were involved in its design. Thirdly, continual dialogue with the WASU kept the research from heading off on tangents that may not have had direct relevance to community water supply. Finally, close co-operation with the WASU meant that the results of the research were communicated in ways that were relevant to their needs and skills, for example in simple maps, visual aids and workshops.

Although the WASU are implementing the project at community level, the complexity of the groundwater resources require geologists and engineers to help choose optimum sites for boreholes or wells, and to carry out drilling and testing. Capacity to carry out these surveys is found within the state rural water supply agency (BERWASSA) and within WaterAid. BERWASSA staff were involved in the research process in several ways: BERWASSA staff contributed to the design of the research; two substantial workshops were organised to discuss the findings of the study, and geologists from BERWASSA worked with BGS for several months in the field. Detailed reports and guidelines have been written for BERWASSA to help them to develop the groundwater resources of Oju and Obi.

In addition to WASU, BERWASSA and WaterAid, BGS developed relations with several other organisations in the water sector of Nigeria. The difficult hydrogeological conditions encountered in Oju and Obi are found throughout several other states in south-east Nigeria, so there was much interest in the study from water engineers and geologists working in these areas. In response, BGS organised a three day workshop to discuss the results of the investigations in Oju and Obi. Twelve UNICEF water engineers for the Eastern Zone attended, two professors from University of Nigeria Nsukka and two geologists from the Nigerian Geological Survey. Many comparisons were drawn between the experiences of participants in their areas and those found in Oju and Obi.

Contents

1.	INTRODUCTION	1
2	REASONS FOR GROUNDWATER STUDY	1
3.	SUMMARY OF HYDROGEOLOGICAL RESEARCH IN OJU AND OBI	2
4.	PATERNERSHIPS	5
4.1	WaterAid	5
4.2	The local government WASU	5
4.2.1	Working with the WASU	5
4.2.2	WASU Workshops	6
4.3	Communities	8
4.4	BERWASSA and WaterAid Engineers	9
4.5	Links with other organisations	10
5.	SUMMARY	11
	APPENDIX 1	
	APPENDIX 2	

LIST OF FIGURES

Figure 1	Women collecting water from a pond in Obi.
Figure 2	Diagram show that only wells that penetrate water-bearing rocks below the laterite maintain a high yield all year round.
Figure 3	A simplified map showing the groundwater potential of Oju and Obi.
Figure 4	A WASU member examining rocks during a workshop in Obi.
Figure 5	BERWASSA geologist learning to use the techniques required to find water in Obi.

LIST OF BOXES

Box 1	Reasons why the groundwater potential of mudstones have escaped serious study.
Box 2	How groundwater occurs in the mudstones of Oju and Obi.
Box 3	Geological triangulation.
Box 4	Guidelines for developing groundwater in Oju and Obi.

Acronyms and Abbreviations

BERWASSA	Benue Rural Water Supply and Sanitation Agency
BGS	British Geological Survey
DFID	Department for International Development
LGA	Local Government Area
RUSAFIYA	UNDP assisted rural water Supply and Sanitation Project NIR/87/011
UNICEF	United Nations Children Fund
WASU	Water and Sanitation Unit.

1. Introduction

The British Geological Survey (BGS) has been working with WaterAid to help improve water supplies for poor communities in rural Nigeria. The BGS was commissioned to investigate the groundwater potential of two local government areas in Benue State, Eastern Nigeria. Although the investigations have demanded scientific rigour, a large component of BGS's work has been communicating both the methods and results of the research to various stakeholders. The results of the investigations are detailed in two reports: MacDonald and Davies (1998) and Davies and MacDonald (1999).

The focus of this short report is to discuss the transfer to partners of the knowledge and skill developed during the study. To put this in context, the rationale for the groundwater investigations and a summary of the conclusions of the study are also given.

2. Reasons for the groundwater study

Oju and Obi are two adjacent local government areas (LGAs) in a remote part of eastern Nigeria. During the annual dry season (November to April) both LGAs experience severe water shortage and families have to rely on unprotected ponds and seepages for their drinking water. Consequently, much of the population (approximately 300 000 people) is badly affected by various water related illnesses.

There have been several previous attempts to solve the water supply problems in Oju and Obi. Speculative borehole drilling in the 1980s and 1990s proved largely unsuccessful, leading a World Bank project (RUSAFIYA) to conclude that groundwater should be abandoned in favour of large reticulated systems. However, the technical and institutional capacity required for reticulated systems is much higher than for local groundwater sources. For this reason, the one reticulated system within the area has not functioned for more than a few months since it was installed over ten years ago.

If available, groundwater would offer the safest, easiest and least expensive water supply to the communities of Oju and Obi. Other community options such as rainwater harvesting are possible, but expensive and difficult to manage over the five month dry season. Against this background, the UK Department for International Development (DFID) commissioned BGS to carry out a thorough investigation of the available groundwater resources within the area and devise appropriate methods for siting wells and boreholes. The information gathered from the study would be used by WaterAid and others to help communities develop sustainable water supplies.

Oju and Obi are underlain by low permeability mudstones and shales. These sedimentary rocks are composed of clay particles and only store water in fractures or thin sandstone layers contained within the mudstone. The geology is complicated and highly variable; the rock type can change significantly with a few metres. Prior to this study, little was known about the potential of mudstones to supply groundwater to rural communities. Box 1 gives reasons why mudstone environments have escaped significant hydrogeological research.



Figure 1. Women collecting water from a pond in Obi.

Box 1. Reasons why the groundwater potential of mudstones have escaped serious study

1. Mudstones are not an important groundwater resource in the northern developed world. Alternative sources are developed and reticulated to customers in both urban and rural areas.
2. The limited groundwater research budgets available for the southern, developing world have been targeted to understanding aquifers with greater groundwater potential, such as unconsolidated sedimentary rocks and crystalline basement rocks.
3. During the 1960s and 1980s, the complex hydrogeology of mudstone environments resulted in groundwater being written off for rural water supply in favour of large reticulated systems.

However, the main lesson learned from projects over the past 20 years is that rural water supply is best managed by the local communities who will use the water. For this approach to work, safe and sustainable water resources have to exist within walking distance of communities. Hence the importance of rocks, such as mudstone, that contain relatively small amounts of groundwater.

3. Summary of hydrogeological research in Oju and Obi

The problem in Oju and Obi is simple: there is plenty of water in the wet season (wells and boreholes are generally full) but as the dry season progresses most of the wells and many of the boreholes dry out. However, a few boreholes and wells do contain groundwater all year round. BGS set out to understand why this was the case and to develop techniques to identify areas that contain groundwater throughout the year.

To meet the research objectives, the following work was carried out: a base map was created from satellite images and published maps; more than 75 km of geophysical surveys were undertaken; 54 exploration boreholes were drilled and the rocks examined; pumping tests were performed on 30 boreholes; and 150 water samples taken for analysis. A full account of the groundwater investigation is given in Davies and MacDonald (1999).

The studies show that sustainable groundwater resources do exist within Oju and Obi. However, the presence and chemistry of the groundwater is highly dependent on the geology. The thick laterite soil found throughout the area is highly permeable and full of water in the rainy season. As the rains end however, water stored within the laterite soil rapidly drains away. As a result, only wells or boreholes that penetrate water bearing rocks below the laterite contain significant water in the dry season (see Figure 2).

Some rock units contain much groundwater, and boreholes could be successful if drilled anywhere. Other rock units contain groundwater only where the rocks have been significantly faulted and fractured, so boreholes have to be carefully sited on fracture zones. Only one rock unit, the Awgu Shale, contains little or no usable groundwater. Box 2 describes how groundwater occurs in the

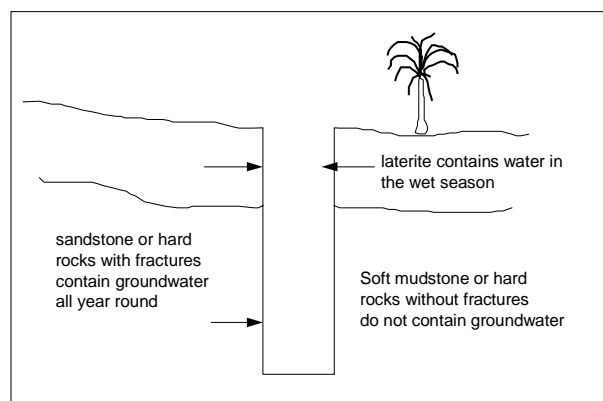
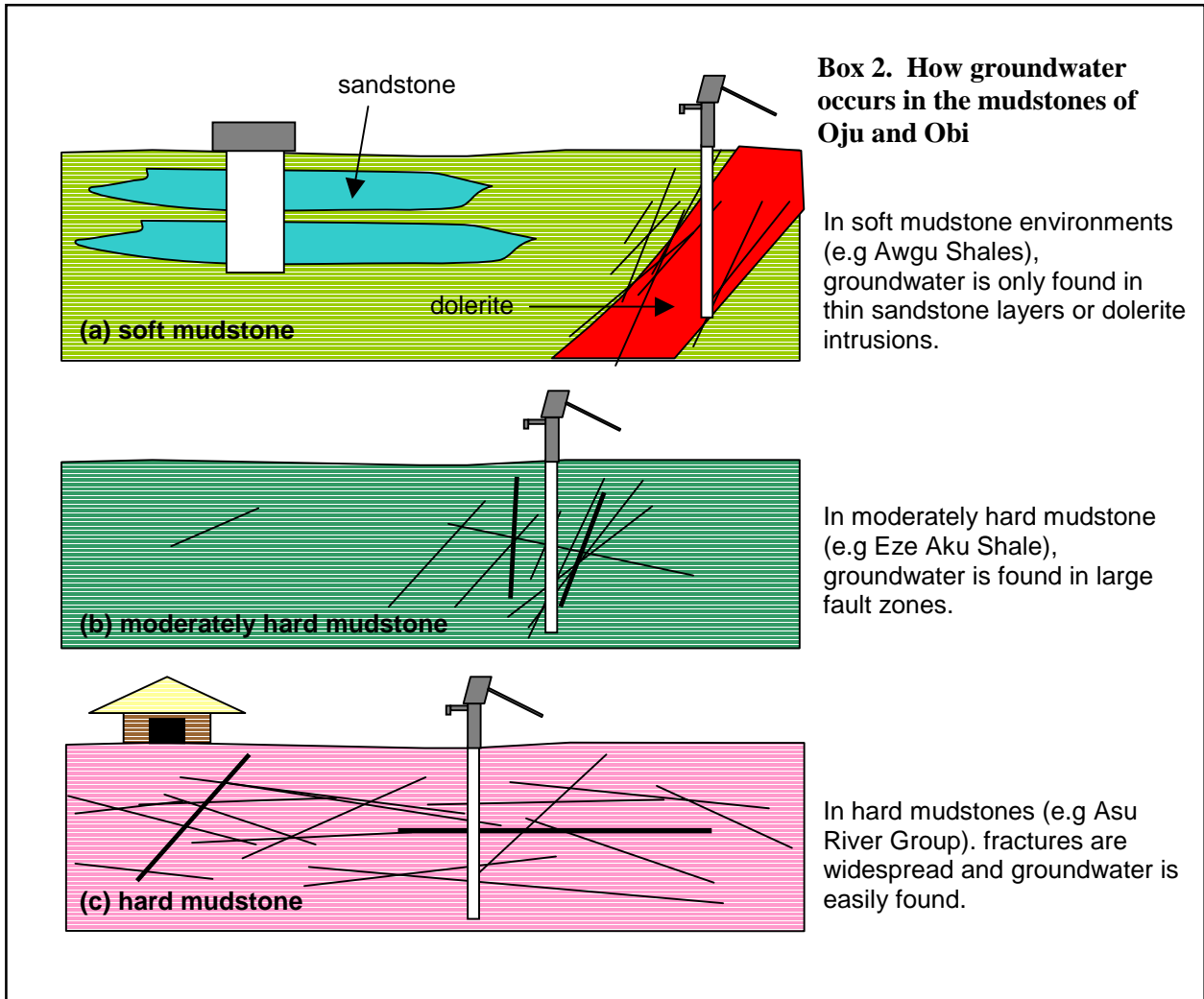


Figure 2. Only wells that penetrate water-bearing rocks below the laterite maintain a high yield all year round.



various mudstones found throughout Oju and Obi. The groundwater potential map for the area is shown in Figure 3.

Simple geophysical techniques are required to locate groundwater in much of Oju and Obi. Standard methods commonly used in Africa, such as EM34 and resistivity, can identify fracture zones or distinguish sandstone from mudstone. However, the data need to be interpreted carefully using rules and techniques that are specific to the rock type. The best method for locating dolerite intrusions (the most important water bearing rock in Obi) is magnetic profiling. This technique is seldom applied in water projects, but is nonetheless simple and easy to use.

The information provided by BGS is directly applicable to about 250 villages. This would contribute to improving the quality of life of over 200 000 people. The guidelines may be applicable to another 80 villages (100 000 people) in Oju and Obi. These are in poorly accessible areas and therefore not investigated during the study. However, information from maps suggest the geology is roughly similar to the study area.

The geology throughout much of Benue State, and surrounding states in south-eastern Nigeria, is similar to Oju and Obi. The knowledge and exploratory techniques developed during this study could be readily applied to other parts of Benue and adjacent states.

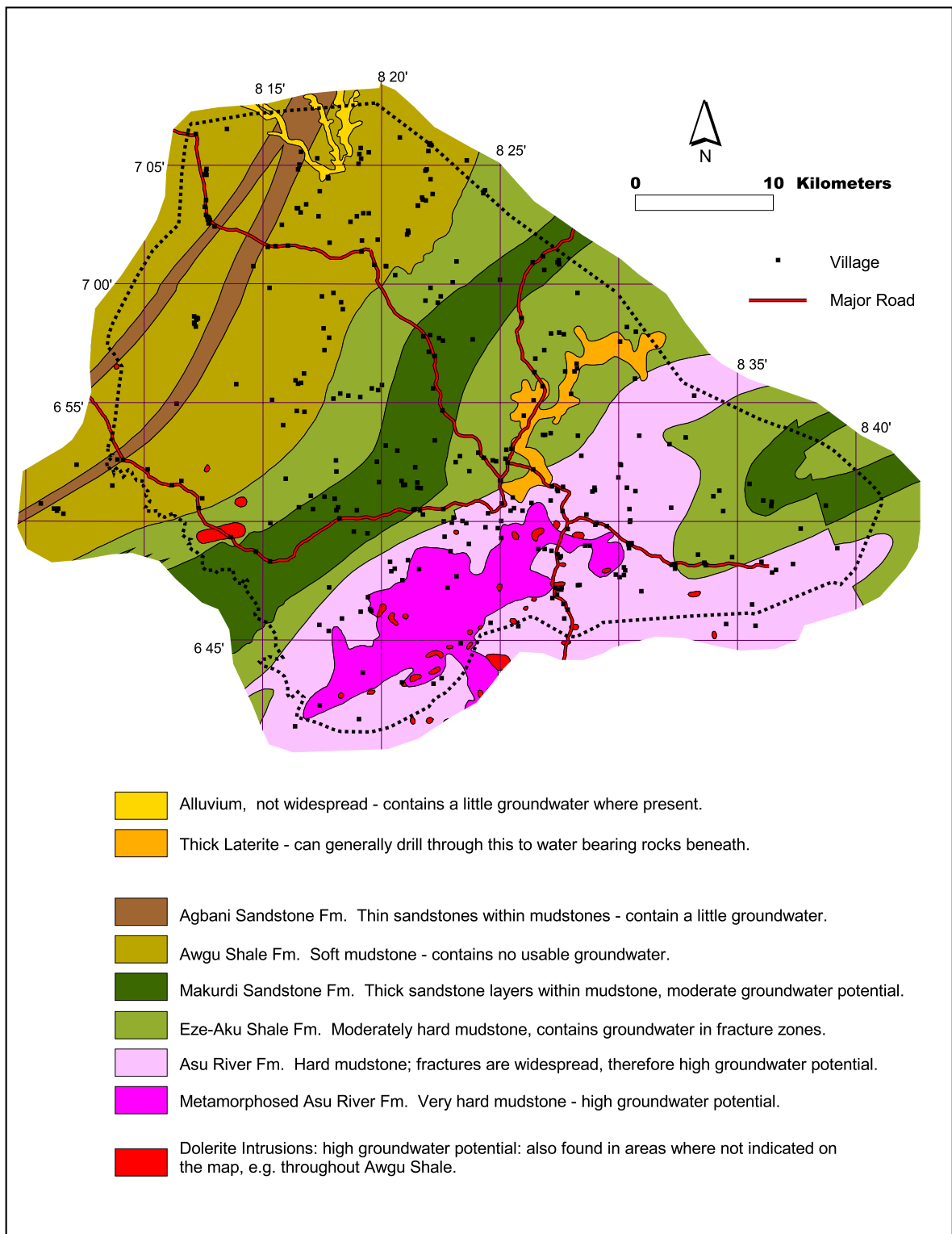


Figure 3. A simplified groundwater potential map of Oju and Obi (MacDonald and Davies 1998).

4. Partnerships

An essential aspect of this research was partnership. Many organisations had an interest in the research, either directly or indirectly. The research was carried out for WaterAid and their Nigerian partners, the local government WASU, and funded by DFID. Benue State Rural Water and Sanitation Agency (BERWASSA) are currently contracted by WaterAid and the WASU to site and drill boreholes in Oju and Obi using the guidelines developed by BGS. UNICEF-assisted rural water supply agencies from other states with similar geology were also interested in the outcome of the research, as was the Geology Department of the closest university (University of Nigeria Nsukka). The working relationships that BGS developed with the various stakeholders in the groundwater research are discussed below.

4.1 WaterAid

Although the project was funded entirely by DFID, BGS were subcontracted by WaterAid to carry out the groundwater investigations of Oju and Obi. Seldom has this level of research been undertaken with local government or NGOs as partners. Such work has usually been carried out with regional or national water authorities or regulatory bodies, where most water expertise is concentrated.

This partnership has proved fruitful. WaterAid has considerable strengths in participatory development, and long experience in demand responsive community water supply. However, these strengths only come into play once groundwater has been found. The expertise provided by BGS in developing techniques for finding and developing groundwater has allowed WaterAid to develop a community water supply project in a difficult area with poor health statistics. Without this expertise, such a project would have been much more difficult. Working closely with WaterAid has allowed BGS to focus their research to the needs of those working most closely with the problems of community water supply. The relationship with WaterAid has also helped BGS communicate the results of the research more appropriately and effectively.

4.2 The local government WASU

4.2.1 Working with the WASU

WaterAid's main partners for the Water Supply and Sanitation project in Obi and Oju were the local government WASU. The WASU work with communities to provide water and sanitation facilities that are appropriate for the community *and* the hydrogeological environment. Because of their close links with communities, and their need for the information provided by the research, WASU were integral to the research process. In particular:

1. WASU staff were instrumental in choosing sites for groundwater investigations. Test sites were identified using a methodology developed with WASU based on community vulnerability (a measure of poverty), geology and access for the drilling rig. Vulnerable communities received priority.
2. WASU staff introduced the BGS team to villages and helped explain to community members the reasons for research. A member of the WASU team would visit the village every day to check on work progress. To undertake this successfully, the WASU had to be well briefed about the geology of the area and research methods.

3. One of the BGS team attended weekly WASU management meetings to discuss progress and any issues arising from the previous weeks work.
4. WASU team members were familiarised with various equipment that the BGS team were using. All had opportunities to use the geophysical techniques, and to see how pumping tests were carried out and chemistry samples taken. Interaction with the drilling process was more difficult. Although WASU members could watch the drilling in progress, the danger posed by the rig and the delicacy of the drilling operation meant they could not gain 'hands-on' experience. This problem was exacerbated in the first year by the possessiveness of the driller. More emphasis was placed on engaging the WASU team during the second year's drilling: a more flexible driller was employed and the WASU team were invited to watch and interact more closely.
5. More formal training was conducted with the WASU to increase their knowledge and skills throughout the project. Training occurred through participatory workshops (see below).
6. If a trial borehole was successful, the WASU would integrate the community within the water supply and sanitation program. Communities that had benefited from trial drilling were not given financial advantage over those that had not. If none of the BGS trial boreholes in a village were successful, the community would be reassessed by WASU using the guidelines produced from the research.

The full participation of the WASU in the research had various implications. Every aspect of the research was discussed with the WASU, who helped to design the geophysical surveys and choose the test sites. Much effort was spent keeping the WASU informed, and making sure that they understood the rationale and methods of research. Although this was time consuming, it had many benefits. Firstly, it meant that the WASU could confidently prepare those communities used as test sites. As a result, there were few misunderstandings and relations with the local communities were excellent. Secondly, the WASU were in a much better position to accept and understand the results of the research, since they were involved in its design. Thirdly, continual dialogue with the WASU kept the research from heading off on tangents that may not have had direct relevance to community water supply. Finally, close co-operation with the WASU meant that results of the research were communicated in ways that were relevant to their needs and skills, for example through workshops using simple maps and visual aids.

4.2.2 WASU workshops

During the course of the project, BGS ran several participatory workshops with WASU staff. The workshops provided an important forum for discussing groundwater in general and the peculiarities of groundwater occurrence in Oju and Obi. BGS has considerable experience running training courses and workshops, and has an international reputation for training geoscientists. However, BGS has little experience training non-scientists. Therefore, in designing the workshops, WaterAid staff helped ensure that the workshops contained an appropriate level of information and were conducted in an inclusive and participatory manner. There were three main workshops; these took place in October 97, October 98 and January 2000. Appendix 1 contains an example of the content, methods and participants of the workshop.



Figure 4. A WASU member examining rocks during a workshop in Obi.

Workshop 1: introduction to groundwater and the need for research

The first workshop took place prior to the drilling. There were several aims:

- to discuss how groundwater fits into the wider hydrologic cycle and how water is stored and moves through the ground;
- to discuss the particular difficulties of finding groundwater in Oju and Obi;
- to describe the methods and techniques required to investigate the groundwater potential of the area;
- to decide on an appropriate system for identifying research sites and agree on the best way of approaching and informing communities.

The issues discussed at the workshop were also raised during the day to day interaction between the WASU and BGS teams. At the beginning of the research, when little was known about the hydrogeology of the area, the uncertainty surrounding the investigations was often a problem for the WASU team. Prior to drilling at a test site there was generally little indication as to whether drilling would be successful. However, confidence increased as more information was collected.

Workshop 2: guidelines for developing groundwater in Oju and Obi (see Appendix 1)

After the bulk of the research had been undertaken, a second major workshop was held. This workshop comprised two days of discussions followed by two days of field trips. All WASU members attended the workshop along with two members from the WASU management committee. The aims of the workshop were:

- to reinforce basic geological and hydrogeological principles;
- to present the results of the investigations and discuss the geological limitations on groundwater development in Oju and Obi;
- to understand and use the geological triangulation method designed to help assess the groundwater potential of a site (see Box 3);
- to become familiar with the guidelines for developing water supply systems in different rock types;
- to develop tools to help explain the groundwater problems to community water committees.

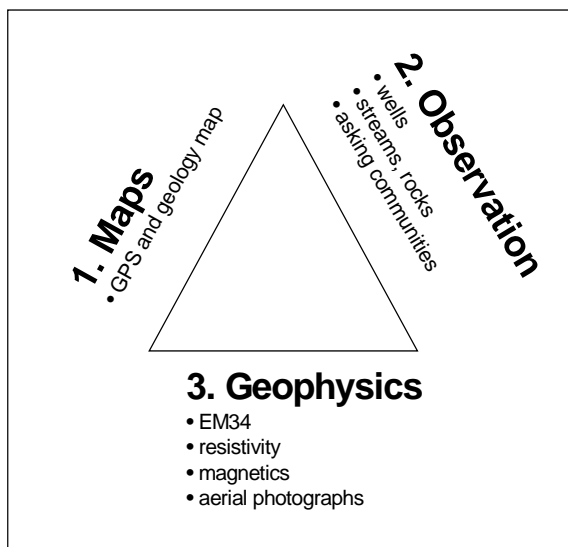
A report detailing the material covered in the workshop was written and distributed to all participants. All members participated enthusiastically and most became adept at the field geology and mapping techniques. Participants' knowledge and practical skills were tested at the end of the workshop with an examination; everybody passed and some did exceedingly well.

Workshop 3: feedback from the WASU after using the guidelines

This workshop was held with the WASU after they had been using the geological triangulation procedures and water development guidelines for one year. The aims of the workshop were:

- to refresh WASU members on the hydrogeology of Oju and Obi;
- to give the WASU an opportunity to provide feedback on their experience using the geological triangulation procedures and water development guidelines; and
- to identify and address any hydrogeological problems that had arisen over the year.

Box 3. Geological triangulation



An approach that BGS found particularly useful in Oju and Obi is “geological triangulation”. WASU members apply the concept of triangulation (substantiating information from various sources) to the sociological and health aspects of the project. Using the same approach to estimate the groundwater potential of a site, helped bridge the gap between the sociological and technical components of the project.

Prior to drilling, information about the groundwater potential of a village can be gained from three different sources: maps, field observation and geophysics. Taken separately, each source of information is uncertain. Taken together however, they provide a powerful tool for assessing the groundwater potential at a site. The WASU can undertake the first two components of triangulation themselves, and can call on expertise within WaterAid or BERWASSA to carry out the geophysics.

This was a particularly useful workshop, since it provided an opportunity for feedback after WASU had spent a year on their own applying the results the investigations. WASU had competently used the geological triangulation methods, although some difficulties had arisen in areas where the research had been inconclusive and the guidelines sketchy. Box 4 gives a summary of the guidelines used by the WASU teams.

4.3 Communities

Much of the time spent by BGS staff in Oju and Obi was in communities, undertaking surveys and drilling or testing boreholes. The good relationship between BGS and the communities was important, not only for the smooth operation of the research, but for the profile of the project generally. The success of the project relies heavily on the trust that develops between communities and the project. Understandably, trust is not easily given, and depends heavily on communities being fully informed of all activities carried out within their land, and the relations built up between project staff and community members. For this reason, BGS-community relations were given a high priority and guidelines were established with WASU and WaterAid on how to conduct the research without compromising community trust.

BGS were introduced to the community by WASU staff, who then remained in contact with the community throughout the investigations. Volunteers from each community worked alongside BGS, helping with the geophysics, drilling and pumping tests. These volunteers also acted as a bridge between the community and the investigations. Community members were fully consulted about the location of the geophysical surveys and the position of the test boreholes. It was not possible for a WASU member to remain with BGS throughout the investigations, as there was pressure on them to carry out other activities. However, a WASU member would try to visit the research sites every day.

Rock samples were generally shown to the community and their implication for water supply discussed. Communities were very interested in the surveys; often more than a hundred people would come to watch the test drilling or test pumping! In most communities there were no misunderstandings as the nature of

Box 4. Guidelines for developing groundwater in Oju and Obi.

Simple guidelines have been set down outlining the appropriate methods for water supply in the different areas of Oju and Obi. These guidelines have been produced on an A4 table and are used in conjunction with the groundwater development map (Figure 3). The guidelines describe, for each rock type, the potential for finding groundwater, what geophysical techniques are required to site wells or boreholes, how to interpret the geophysics, the necessary depth for a borehole or well, and any other relevant information.



A small, laminated A4 version of the map has been produced for the WASU with the guidelines printed on the back for quick reference.

the BGS research was clear. Occasionally, however, problems arose, where it was rumoured that BGS were searching for minerals or oil, rather than water. These suspicions generally arose when rock samples were being carefully examined. Why would we look so carefully at the rocks, when looking for water? These suspicions were compounded by the poor image of oil exploration in Nigeria during the 1990s. However, these misunderstandings were resolved, once the WASU had time to sit with community leaders to answer their questions.

4.4 BERWASSA and WaterAid engineers

Although WASU are implementing the project at community level, the complexity of the groundwater resources require geologists and engineers to help choose optimum sites for boreholes or wells, and to carry out drilling and testing. Capacity to carry out these surveys is found within the state rural water supply agency (BERWASSA) and within WaterAid. The success of boreholes and wells depends largely on how well these geologists and engineers perform their job.

The detailed investigations carried out by BGS provide the techniques that BERWASSA and WaterAid geologists require to find and develop groundwater in Oju and Obi. A significant component of the project was to transfer this knowledge and skill from BGS to BERWASSA and WaterAid. This was done in a variety of ways: involving the engineers in the research process; detailed workshops discussing the research results; substantial field training and detailed reports. These are discussed in detail below.

Involving BERWASSA in the research process

From the outset, BERWASSA personnel had an input to the direction of the hydrogeological research. They were consulted during the project preparation, and it was largely in response to the problems that they had encountered trying to find groundwater in Oju and Obi that the hydrogeological research programme was drawn up. Unfortunately, due to the common position of the EU member states after Nigeria's expulsion from the Commonwealth, it was not possible for DFID to have direct links with BERWASSA (a state organisation). Informal links were kept during this period, and as the situation

changed, they were integrated more fully into the project. There were regular meetings with BERWASSA geologists to discuss project progress.

Workshops

Two participatory workshops were held with BERWASSA and WaterAid staff to discuss the findings of the hydrogeological research. The workshops focussed on where groundwater occurs in Oju and Obi, and which techniques are appropriate for finding and developing groundwater. These workshops were more technical than those WASU attended. There was a large practical component within the workshops, and participants learned how to use and interpret geophysical methods in the context of Oju and Obi. Pumping tests have been discussed, with participants learning how to carry out and correctly interpret pumping tests in completed boreholes. Appendix 2 gives details of one of these workshops.

Field Training

Much emphasis has been placed on working alongside BERWASSA and WaterAid engineers in the field. WaterAid and BERWASSA engineers have spent two to three months working directly with BGS, carrying out geophysical surveys, pumping tests, or supervising drilling. This has allowed them to learn field procedures and put theory into practice.

Reports and Manuals

It has been a priority of BGS to document all the groundwater studies carried out in Oju and Obi for use by Nigerian water engineers and geologists. Personnel within BERWASSA and WaterAid are mobile, and so the benefits of training received may not be realised in Oju and Obi. By providing detailed reports and manuals however, new personnel can rapidly learn how to exploit groundwater in Oju and Obi. The maps and final report have been reviewed and edited to ensure that they are in a format useful for engineers working in Nigeria. Detailed reports showing all the data collected during the investigations have also been produced, allowing future engineers or geologists to access the original data on which the BGS interpretations are based.

4.5 Links with other organisations

In addition to WASU, BERWASSA and WaterAid, BGS developed relations with several other organisations in the water sector of Nigeria. The difficult hydrogeological conditions encountered in Oju and Obi are found throughout several other states in south-east Nigeria, therefore there was much interest in the study from water engineers and geologists working in these areas. Informal links were made with the Geology Department at the University of Nigeria Nsukka, the geological survey of Nigeria and with Eastern Zone Office of UNICEF.

UNICEF

UNICEF geologists and water engineers in states with similar geology (12 staff) attended one of the technical workshops organised by BGS to discuss the results of the investigations in Oju and Obi (see Appendix 2). Many comparisons were drawn between their experiences and those of WASU and



Figure 5. BERWASSA geologist learning to use the techniques required to find water in Obi.

WaterAid staff in Oju and Obi. Participants were reassured to learn that the problems they are facing in developing groundwater in the low permeability sediments of Eastern Nigeria are not insurmountable. Some of the techniques discussed in the workshop could be immediately applied to their situation; other techniques, however, would require further training, additional equipment, or in some cases, more detailed investigation. The co-ordinator for UNICEF's activities in the Eastern Zone was kept informed of progress during regular meetings with WaterAid.

University of Nigeria, Nsukka (UNN)

Various meetings were held with the Head of the Department of Geology and the Professor of Hydrogeology at UNN to discuss problems they had encountered in developing groundwater. Three of their students worked with BGS for several months learning about groundwater investigation techniques. The professors attended the technical workshop organised by BGS and attended by UNICEF and BERWASSA staff.

Wider Academic Community

Little research has been carried out on the groundwater potential of mudstone environments like Oju and Obi. There is a duty therefore, for BGS to publish their findings, to help others who are trying to set up groundwater projects in similar areas. Aspects of the investigations have been presented to several university and academic bodies, and submitted to various journals for publication. This should help build collective knowledge of how groundwater occurs in these rocks and lead to more focussed research in future.

5. Summary

The BGS study of the groundwater potential of the Oju and Obi areas proved that usable groundwater resources exist within the area. This was one of the first detailed studies of the groundwater potential of mudstone environments; hitherto, mudstones were dismissed as containing no groundwater. The guidelines and simple techniques provided by BGS have allowed WaterAid to develop a community water supply programme in an area where only large scale reticulated water supply was thought feasible.

Throughout the investigations, BGS has worked closely with various partners. WaterAid's local partners, the WASU, were integral to the research process. They are currently using simple methods developed during the study to assess the potential for groundwater at a community. The state drilling agency (BERWASSA) were involved in many aspects of the study, and are using the techniques developed by BGS to help the WASU site and drill boreholes. Other stakeholders such as UNICEF, local universities and the wider academic community have been kept informed of the progress of the groundwater investigations.

Further Reading

Davies, J and MacDonald, A M, 1999. Final report: the groundwater potential of the Oju/Obi area, eastern Nigeria. British Geological Survey Technical Report WC/99/32.

MacDonald, A M and Davies, J, 1998. Groundwater development maps for Oju and Obi Local Government Areas, eastern Nigeria. British Geological Survey Technical Report WC/98/53.

Appendix 1: WASU workshop 6-9 October 1998

Participants (14):	Oju WASU: 2 engineers, 2 health workers, 2 community development officers Obi WASU: 2 engineers, 1 health worker, 1 community development officer 2 members from Oju management committee 2 members from Obi management committee.
Duration:	4 days
Workshop methods	Group work, discussing issues and questions with occasional lectures. Various learning aids were used such as working models and exercises. Two days of field work examining rocks and wells. Comprehensive notes of the workshop were distributed.

Workshop outline

Day 1

The hydrological cycle: in three groups, participants considered the hydrogeological cycle by following the path of a raindrop after it hit the ground.

Geological Principles (1) the process of sedimentation was introduced by experimenting with a fishtank filled with water and two types of sand.
(2) folding and erosion were discussed using a model with different colours of plastocine
(3) in three groups the participants discussed soil formation using the following questions as aids: define soil? What is soil made from? How does soil form?

Geological triangulation In three groups participants discussed the various methods available for trying to find out the rock type under a village (e.g drilling, geophysics, digging holes etc.). The concept of geological triangulation arose from the discussion.

Maps A brief lecture was given on how to use maps. In groups participants then did a series of exercises using maps.

Day 2

Observation In groups participants discussed what information they would need to collect during a baseline survey to characterise the geology of a site. This was combined into a checklist.

Geophysics In a short lecture, the main concepts of geophysics were introduced as used by BERWASSA and WaterAid.

Hydrogeology of Oju/Obi Two models were used to illustrate the hydrogeology of Oju and Obi: one showed laterite underlain by soft clay, the other laterite underlain by sandstone. A discussion followed on the main controls of groundwater occurrence in Oju and Obi.

Guidelines In three groups, participants examined several rocks samples. After describing the rocks, they each suggested whether the rock was good for a borehole, well or neither. A general discussion followed where the guidelines produced by BGS were introduced.

Day 3 - 4

Field trips Various sites were visited in Oju and Obi. At each sites, participants had to examine the rocks and comment on their suitability for groundwater development. Prior to going into the field, each of the communities were plotted on a map.

Appendix 2: technical workshop 20-22 October 1998.

Participants (17):	3 BERWASSA geologists; 10 UNICEF geologists from other states; 2 geology professors from University of Nigeria, Nsukka, 2 geologists from the Geological Survey of Nigeria; the WaterAid Engineer.
Duration:	3 days
Workshop methods	Lectures, discussions, group work, exercises and field trips. Reports and maps were distributed, along with notes from the workshop.

Workshop outline

Day 1

Introduction	Participants introduced themselves and stated their aspirations for the workshop
Setting the Scene	A series of slides were shown to put in context the hydrogeological investigations in Oju/Obi.
Other States	Five participants had prepared short informal presentations describing an aspect of groundwater development in their state. Each lasted about 10 minutes and was followed by lively debate.
Geology of Oju/Obi	Slides of rocks samples for each of the geological units in Oju and Obi were shown and discussed. Participants were particularly interested in the core samples, which show the rocks in an unweathered state; much discussion followed.
Maps	Participants discussed what elements they considered essential for a 'perfect' map. This lead on to a discussion of what useful parameters can be collected in a cost-effective manner. The hydrogeology maps for Oju and Obi were then introduced and discussed.
Survey methods	Using overheads, the different geophysical methods used in Oju and Obi were described with examples of interpretation from various hydrogeological environments. This was followed by a discussion of the techniques used by participants in other areas.
Test pumping	Slides were shown of the different equipment and techniques used for test pumping. Overheads were then used to describe the principles of carrying out and analysing pumping tests.

Day 2

Field visit to Oju	The participants were divided into two groups. Group 1 examined all the core samples and discussed the occurrence of groundwater. Group 2 carried out an
--------------------	--

exercise in a community. They had experience using the GPS and maps, and then carried out a geophysical survey and analysed and interpreted the results.

Day 3

Field visit to Obi Dolerite was examined and described by participants. Hands on experience with pumping tests was given with two exercises involving bailer tests and the whale pumps. Pumping tests were undertaken and then analysed. Visits were also made to a collapsed well and a thick sequence of laterite.

Evaluation Participants divided into three groups and considered four questions:

1. What new technique or information did you find most interesting?
2. What are the largest problems that you face in your work?
3. How can you apply what you have learnt during workshop to your work?
4. What would you like to see happen in the future?

The groups reported back, and prioritised their replies to the four questions.