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Reconnaissance visit to assess the hydrogeology of the Oku area, Sekyere West District, Ashanti Region, Ghana.

DfID KaR Programme

Internal Report IR/01/153

BRITISH GEOLOGICAL SURVEY

INTERNAL REPORT IR/01/153

Reconnaissance visit to assess the hydrogeology of the Oku area, Sekyere West District, Ashanti Region, Ghana

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Front cover

Borehole site under large trees, Oku, Ghana.

Bibliographical reference

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Foreword

This report is the published product of a study by the British Geological Survey (BGS) carried out in Ghana during April 2001.

Acknowledgements

Many thanks to Father Patrick Lynch of Oku Mission for his warm hospitality during the BGS visit. Thank you also to WaterAid (Ghana) for support and for supplying a vehicle and driver, and to Mr. Kurt Klitten of the Danish Embassy in Accra for advice and information on the Oku area.

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Summary

The Oku area of central Ghana experiences severe water shortages during the October to March dry season. Surface water in the form of rivers and ponds is widely available in the wet season, but tends to dry up during the remainder of the year. Diseases associated with contaminated drinking water are prevalent. A large proportion of boreholes drilled into the well-lithified low permeability sandstones fail after two or three years, because despite the high seasonal rainfall, rates of recharge to the aquifer are very low. Boreholes typically yield only a few basins of water a day, and need to be left overnight to recharge. This leads to long queues, and forces some people to turn to potentially contaminated surface water sources. Successful boreholes have been sited along shallow river valleys and on structural lineations, but these boreholes are often not near settlements. Several options exist for improving the water supply in the Oku area, including the following:

1. Small dams or bunded ponds.
2. Large diameter shallow wells constructed in alluvium.
3. Further boreholes.
4. Rainwater harvesting.
5. The artificial recharge of existing boreholes using rainwater or filtered surface water.

The last option would allow existing water points to be used, and would contribute towards avoiding the problems of contaminated surface water. However, the permeability of the aquifer may be so low that recharge rates would not be able to meet the water needs of the community. It is likely that a system of seasonal conjunctive use involving some or all of the above options will prove to be most effective.

1 Introduction

Rural water supply is difficult in the Oku area where distinct seasonal wet and dry periods are experienced. Attempts made by World Vision to supply the area with groundwater have met with mixed results. Some user communities feel that groundwater alone does not provide a sustainable year round form of supply. During 11-13 April 2001 two BGS hydrogeologists visited the Oku Catholic Mission at the request of Mr G Mumbo, Country Representative, WaterAid (Ghana). The Oku area's water supply problems were described by Father Patrick Lynch, head of the Catholic Mission at Oku, who introduced the BGS team to the area and showed them boreholes and prospective dam sites. His information was used as the basis for a groundwater development map of the area (Figure 1).

2 Location

Oku is located at lat N7°20'/ long W1°00' within Sekyere West District of Ashanti Region. This area is located north of Kumasi, some 40km east of Ejura within the south-western quadrant of the Afram Plains. The access track to the Oku area from Ejuri is some 45km long. Only the western half of this track as far as Odumase is shown on the 1:50 000 topographic maps of the area. Locations of boreholes, rock outcrops and the track between Oku and Ejura (at 1 km intervals) were accurately determined using a hand held Global Positioning System (GPS).

3 Topography and Climate

The Oku area is located upon the north-west – south-east trending watershed between the south-easterly flowing Afram River to the south and the northerly flowing Sene River to the north. The northern side of the Afram River valley is formed by a 60 m high scarp of hard sandstones. These sandstones underlie much of the Oku area, gently dipping away to the north from 180 m above mean sea level at the scarp to less than 120 m, the surface being dissected by a series of fairly wide ephemeral river valleys. The Afram river occupies a wide valley that runs along the outcrop of softer mudstones and sandstones. This river rises along the southern slopes of a 340 m high north-west - south-east striking sandstone ridge south of Ejura.

Average rainfall of 1200 mm occurs during the April to October wet season, when short term flooding can occur, rendering access to and travel within the area very difficult. The visit took place at the start of the wet season. The first heavy rains of the wet season were experienced during both nights of the visit. Surface drainage is mainly ephemeral, rainwater from heavy storm events draining away as sheet surface flow. During the November to March dry season the area is affected by hot and dust laden Harmattan winds blowing south from the Sahara.

The Afram Plains supports a savannah type vegetation of dense bush and larger trees. The surface is thinly mantled by ferruginous tropical soils through which some outcrops of country rocks occur.

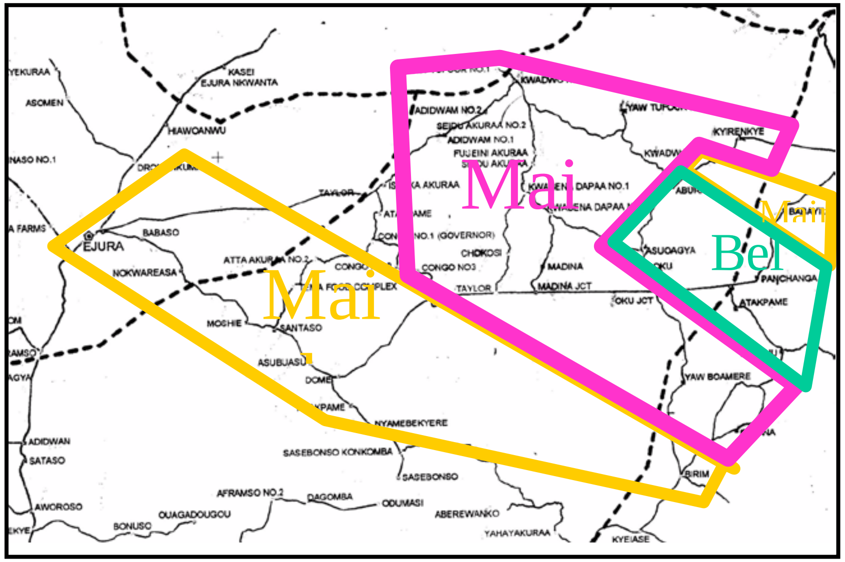

Figure 1 Oku Area Reported Groundwater Development

4 Map Coverage

The area is covered by 1:50 000 scale topographic maps Nos. 0701C1/3, and 0702D1/2/4 published in 1973, copies of which were obtained from the Survey Department in Accra. The basic geology of the area is shown on the National Geology Map of Ghana at a scale of 1:1 000 000, published by the Geological Survey of Ghana in 1988. Copies of village location and borehole location maps were provided by Father Patrick who also provided some indication of the distribution of successful and unsuccessful boreholes.

5 Rock types and groundwater availability

Given the short time span of the visit study of the rocks present in the area was limited to those found at the surface in the Oku area and those noted along the road traverse between Oku and Ejura. The regional geology of the area is shown on Figure 2 (Geological Survey of Ghana, 1988). The Oku area is located within the south-western quadrant of the Voltaian Basin in which are found well-lithified early Palaeozoic sandstones, conglomerates and mudstones. Reference to this map shows that the Oku Area occurs on the north-western extension of the Voltaian sedimentary strata that underlie the Afram Plains area to the east. The Oku area is apparently underlain by homogeneous sandstones as seen further to the east in the Afram Plains between Maame Krobo, Bonkrom and Nyamebekyere (Davies, 2000)(Plate 1). The hydrogeological nature of these sandstones is poorly understood.

Plate 1. Sandstones of the Obosum Formation, Voltaian Series cropping out near Bonkrom, eastern Afram Plains

These sandstones have been subjected to long term tropical weathering to depths in excess of 40 m. This has resulted in the cementation of fine-to-medium sandstones with a mixture of red iron oxide and black manganese oxide cements resulting in loss of any primary permeability. The main water bearing targets appear to be fracture zones but although much work has been done on the location of such fracture zones using remote sensing techniques little has been done to characterise the geo-hydraulic nature of these fractures (World Vision, 1995). Studies using data derived from production boreholes to the east indicate that the upper weathered zone may form a very low permeability layer that halts rapid recharge of infiltrating rainwater to the underlying fracture zones. A series of boreholes has been drilled by World Vision in the Oku area. No data are available from these boreholes other than informal data gathered from the community following borehole installation.

West of Oku along the track to Ejura several boreholes with good yields installed by World Vision were noted at Dome. There, mid-way between Oku and Ejura in the valley of the Afram River, micaceous flaggy sandstones were seen to crop out at several localities. South of Ejura similar flaggy sandstones with mudstones are noted cropping-out in a major south facing scarp (Plate 2). Several high yielding boreholes have been installed in this formation as a wellfield designed to supply Ejura township.

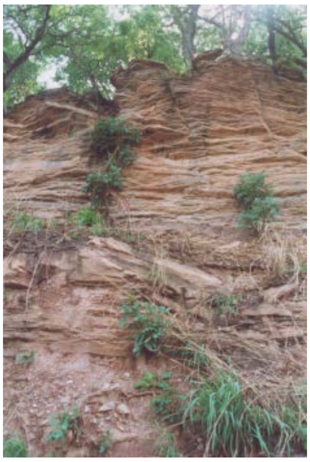

Plate 2. Micaceous flaggy sandstones and mudstones of the Obossum Formation, Voltaian Series cropping out in a scarp south of Ejura

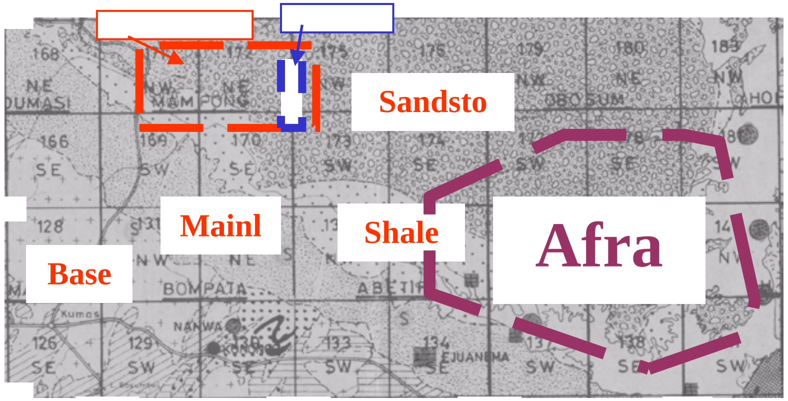

Figure 2 Afram Plains Geology and Area Location Map

6 Sites visited at Oku

At Oku the BGS team visited a series of seven boreholes drilled by World Vision in the vicinity of Oku mission. The yield characteristics of each borehole were discussed with Father Patrick and women from the local communities. All boreholes are equipped with India Mark II hand pumps. Some consideration was given to worn pump seals being the cause of low yields, but Father Patrick reported that the seals had been replaced and that yields had not improved. There are only 2 good boreholes within a 20 km radius of Oku, so the water supply situation during the dry season is critical for the local communities.

No geological logs or test pumping details were available for any of these boreholes. Father Patrick suggested that data from these boreholes may be held at the World Vision offices in Kumasi. The date of borehole completion and its reference number are usually inscribed on the concrete borehole top plinth (Plate 3).

Plate 3. Details of World Vision (WV) Bh 1502 on well head plinth

At the first site to the north of the village a group of three boreholes were seen (Plates 4-6). These boreholes were drilled more than 4 years ago. Each had a good yield for about the first three years, during which unrestricted pumping took place. In each case the borehole began to fail after this time. Although the surrounding area and stream flood regularly for prolonged periods during the wet season, there is no parallel increase in borehole yield, indicating that little or no recharge reaches the aquifer. Sandstone was noted cropping out in an adjacent stream section.

Plate 4. WV Bh 681, poor yield, no recharge - formerly the best yielding pump in the area.

(lat N7°21.514'/ long W1°0.462')

Plate 5. WV Bh 497, poor yield, no recharge

(lat N7°21.49'/ long W1°0.46')

Plate 6. WV Bh no number, poor yield, no recharge

(lat N7°21.504'/ long W1°0.44')

A similar history of yield decline followed the drilling of a fourth borehole (Plate 7) at the second site. Here the borehole yield was initially so good that Father Patrick and the local community considered equipping the borehole with a motorised pump with the aim of reticulating water to other parts of the village. Unfortunately the yield declined to 10-20 basins per day after a single year of use. The aquifer does not receive active recharge from floods or rainwaters.

Plate 7. WV Bh 1502 completed 23/8/2000

**(lat N07°22.311'/
long W01°00.545')**

At the third site yet another poorly yielding borehole was viewed which initially had good yield (Plate 8). Seepage water accumulates within the borehole over night to provide some 5-6 basins of water in the morning. Following this abstraction it takes more than one hour to fill a basin with water at the reduced yield which presumably equates with the rate of seepage inflow. Again there is no improvement in rate of yield during the wet season indicating little or no recharge to the underlying fractured aquifer system.

Plate 8. WV Bh 1506, poor yield

**(lat N07°20.697'/
long W01°00.020')**

At the fourth site the team viewed the 'Macho Pump', so called because it requires several people to operate it (Plate 9). This borehole, according to Father Patrick, has been low yielding and difficult to operate since installation. This borehole was located adjacent to a stream course on a lineation but still has a poor yield of 5-6 basins per day and receives little or no wet season recharge.

Plate 9. WV Bh (no plate) ('Macho Pump')

(lat N07°20.659'/ long W01°00.295')

A second borehole at the fourth site (Plate 10), located further away from the stream course than the 'Macho Pump' was also inspected. Again this borehole has had a poor yield since it was installed. Little or no improvement in yield is noticed during the wet season implying little or no recharge to the underlying aquifer system.

Plate 10. WV Bh 498, poor yield, no recharge. (N7°20.659'/W1°0.195') Children have to wait up to 30 minutes before additional water can be pumped from this borehole

World Vision tend to drill groups of boreholes at nominally successful sites located on what are perceived to be structural lineations, frequently within 50-100 m of each other. Successful boreholes tend to have moderate to high yields on drilling (1-3l/sec). Some yields have been sufficient for some user groups to consider equipping those boreholes with engine powered pumps to supply water reticulation schemes. Although these boreholes produce water at good discharge rates for up to 3 years, during which time an unlimited number of basins may be filled each day, discharge rates can decline markedly so that only 10-20 basins can be filled daily. It may also take up to one hour to fill a basin after an initial 3-5 basins are filled with the water that has accumulated overnight. Often little or no improvement in yield characteristics is apparent during or after the annual wet season implying very limited or no recharge to the fractured aquifer systems. As shown above, these characteristics are common to most if not all of the boreholes located in Oku. Similar characteristics are apparent in boreholes drilled into similar sandstone formations in the eastern Afram Plains area. However, those boreholes drilled into the micaceous flaggy sandstones to the south along the Afram Valley have not shown a decline in yield after several years of use.

Borehole water levels can be measured by passing an electrical dipper through an access hole normally covered by a metal plate (Plate 11).

Plate 11. Borehole access hole located on an India Mark II hand pump

7 Discussion

The total population of the area and hence the likely water demand is unknown. UNICEF recommend that one borehole be sufficient to supply 250 people with 25 litres of water per person. Therefore the seven boreholes drilled at Oku should have been capable of supplying a nominal population of 1750 persons when first drilled with water at a combined rate of 43.7 m^3/day. Most of the boreholes had good yields, presumably about 1 l/sec or greater, when first drilled. The user population of each borehole would have been able to collect their water needs of 6.2 m^3/day with a minimum of 4 hours of pumping per day. At the present time each borehole yields sufficient water to fill 10-20 basins per day. If a basin holds 50 litres then this equates to 0.5 to 1 m^3/day, 8 to 16 % of total water demand. The water requirement per person per year is 91 m^3, a total of about 16 000 m^3/year for the nominal population of the area.

Members of the local community and Father Patrick stressed the problems caused by the lack of an adequate water supply especially during the dry season. These problems were demonstrated at each of the boreholes by the low borehole yields and queues of empty basins. Gastro enteric illnesses become prevalent when villagers use contaminated waters from streams and puddles at the onset of the heavy rains. During discussions about the water supply options Father Patrick informed the team that he has approximately £15,000 to spend on a water source, donated by a New Zealand organisation, Water for Survival.

The area is underlain by a consolidated sandstone formation of unknown thickness that appears to dip to the north-east (Figure 3). This formation may be underlain by a flaggy sandstone formation that crops out along the valley of the Afram River to the south-west. The boundary between the two formations is marked by a scarp some 30-60m high. The consolidated sandstone formation forms a poor aquifer, water being found mainly along fracture zones, but there are no borehole data to substantiate this assumption which is based upon experience drawn from the APDO area to the east. That the flaggy sandstone formation forms a good aquifer is shown by the incidence of productive boreholes along the track to Ejura, particularly at Dome. The productive borehole at Berem has probably been drilled into this formation through the lower part of the consolidated sandstone formation. Therefore a deep borehole could be drilled in the southern part of the Oku area to intercept the flaggy sandstone at depth as a trial.

From the limited data available the consolidated sandstone appears to have a permeability of about $3x10^{-7}$ to $1x10^{-6}$ m/s, which is typical for fractured consolidated cemented sandstones. Given the decline in pumping yield experienced since borehole installation the water resources of the system appear to have been successively mined over the years with little active recharge by seasonal rainfall reaching the system. Presumably any fractures and permeable horizons within the sandstone would have been dewatered over the years. Water now enters the system by seepage from the low permeability rock alone. Presumably in such a consolidated sandstone formation the emptied void space may still be open to receive water injected by artificial recharge. In the short term a falling head test should be undertaken upon one of the formerly high yielding boreholes to see if this is still the case. If there is scope for artificial recharge, consideration should be given to the seasonal recharge of rainwater to the underlying aquifer to provide a dry season resource. This may be done using water collected in roof-top catchments and/or filtered stream water collected in ponds (Figure 4).

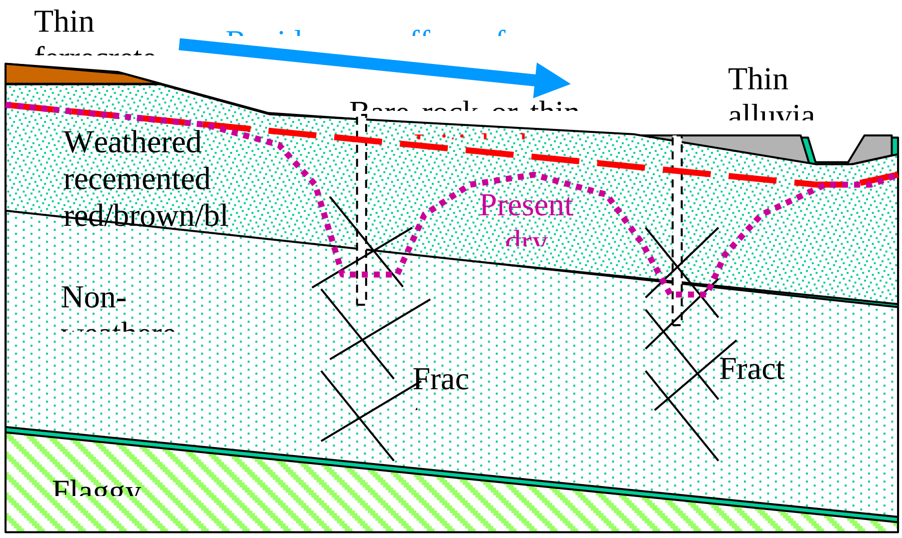

Figure 3 Cross-section showing possible geology and hydrogeology of the Oku area

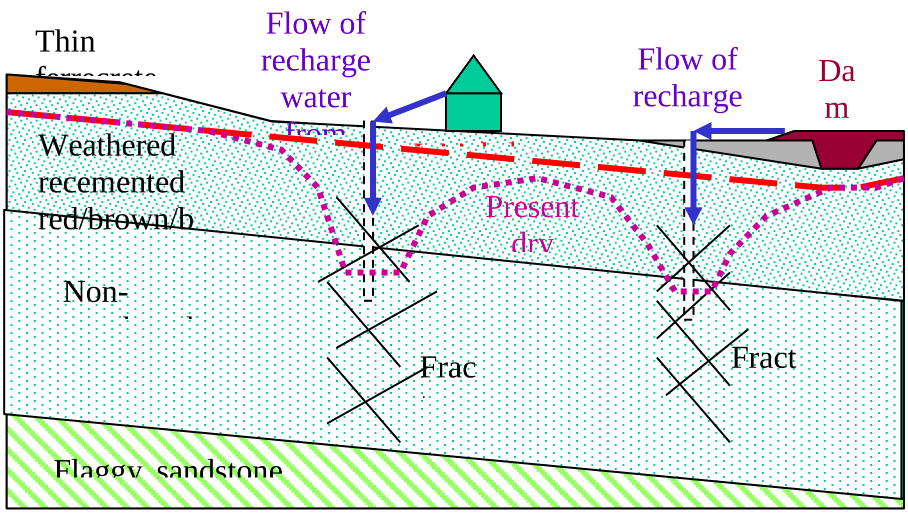

Figure 4 Cross-section showing possible methods of artificial recharge of rainwater to the underlying fractured consolidated sandstone aquifer

8 Options for water supply in Oku

The following five options for water supply in the Oku area can be considered:-

8.1 SMALL DAMS/BUNDED PONDS

A small dam that contains water all the year round was inspected at Berem some 10km to the south of Oku (Plate 12).

Plate 12. Berem Pond

Within the Oku area the team were shown two further sites where small dams or bunded ponds could be constructed to store water for use during the dry season (Plates 13 and 14). Local logging companies have the necessary bulldozers for such work.

The first site (Plate 13) is located in a small valley north of Oku village where shallow pits were excavated to obtain water from the alluvium during the dry season. The stream course could be dammed to increase the amount of water stored in the shallow pits in the dry season.

Plate 13. Oku dam site 1

(lat N7°21.937'/ long W1°0.64')

Plate 14. Dam site 2
(lat N7°20.529'/ long W0°59.744')

The second site, an old dam located east of Oku Junction, was excavated by a logging company and has fallen into disuse (Plate 14). It could be re-excavated using a logging company bulldozer.

Small dams can effectively store large quantities of water obtained during the wet season and can remain viable throughout the dry season. They can be relatively easily constructed using a bulldozer. However, they are liable to surface contamination and can transmit various water-borne diseases if the water is used untreated.

8.2 LARGE DIAMETER DUG WELLS

A large diameter dug well, possibly with radial collecting laterals to increase the yield, could be constructed in one of the thicker areas of alluvium in a shallow valley, such as the first site mentioned above (Plate 13). The river and rainfall in the rainy season would recharge the alluvium, which would act as a storage medium and potentially constitute a source of water throughout the dry season. The success of such a well would partly depend on the thickness of alluvium in which it was constructed. A survey using trenches or a hand auger would need to be conducted to identify the thickest part of the alluvium. The well could be dug by hand at a diameter of around two metres, and it is advisable that a ferrocement or similar lining be used to reinforce the top two or three metres. Such a lining should project above the surface of the ground to provide some protection from flooding and contamination. The laterals could be constructed by trenching radially from the well, below the water table, then filling the trenches partially with some coarser, permeable material such as gravel before completely backfilling with alluvium. A dug well would be less vulnerable to surface contamination than a pond, as the natural filtering effect of the alluvium would remove impurities. A dug well could be constructed almost entirely with local materials and labour, although it is potentially vulnerable to flooding and is also dependent on the thickness of the alluvium.

8.3 ADDITIONAL DEEP BOREHOLES

The failure of deep boreholes in the Oku area provided the impetus for the BGS visit. It is likely that further boreholes in the immediate vicinity of Oku will suffer from the same problems of low recharge, leading to failure after two or three years of use. Since boreholes are relatively expensive to drill, this option may not be cost effective. There is a possibility that deeper boreholes may intersect the more permeable flaggy sandstones at depth, but this needs further research.

8.4 RAINWATER HARVESTING

The rainfall in the Oku region is relatively high, and the roofs of four buildings each measuring 10 x 20 metres could potentially collect enough water to supply 44 basins every day of the year, if the water could be adequately stored. Such a system could supply water to 88 persons for the whole year, 176 persons for half of a year or 352 persons for a quarter of a year, if distribution was managed. Rainwater harvesting has the obvious advantages of low cost and of avoiding the contamination problems to which surface water is vulnerable, and is particularly viable where large areas of roofing are available.

8.5 ARTIFICIAL RECHARGE SYSTEMS

Consideration was given to increasing the dry season yield of a currently low yielding (but formerly high yielding) World Vision borehole by channelling rainfall collected from roofs into the aquifer via that borehole. Presumably, within the well consolidated sandstone formations, voids that formerly contained water would still be open and available to accept recharge water. The artificial recharge scheme has the advantage of not requiring a tank or similar storage device, and stored water could be obtained from the borehole in the normal way using the pump. A test collection system (Figure 3) could be cheaply constructed and monitored to assess the viability of such a system. It is possible that a borehole would not be able to accept water at the rate at which it falls during heavy rain, and some storage facility would be needed to hold the water so that it could be fed into the borehole at a suitable rate. A combination of above ground storage and borehole recharge would probably prove to be the most practical solution.

9 Conclusions

There are distinct water resource and supply management problems in the Oku area which is underlain by a series of low yielding well consolidated sandstones. Groundwater occurs within infrequent discontinuous confined fractured aquifers of limited extent that receive little to no recharge of rain water during the wet season. Unfortunately, boreholes only provide sufficient water for up to three years, long enough for the establishment of village communities but insufficient to sustain them in the long term. Although there is significant annual rainfall much of this rapidly flows away by surface runoff to ephemeral streams.

The best water supply management option for the Oku and areas in similar environments appears to be the conjunctive use of water from surface and groundwater sources. During the wet season water should be drawn from streams with water collected for dry season use in small dams, shallow wells and rainfall catchment systems. During the dry season water should be drawn for domestic purposes from small dams and for drinking purposes from rainfall catchment systems. Water should be drawn from boreholes only towards the end of the dry season when all other sources have been emptied. Such a system whereby the different sources are used together (stepped conjunctive use) may be the most effective.

To enhance the above supply system consideration should be given to the drilling of some deeper test boreholes to a depth of 150 m to 200 m to assess whether or not the further drilling of boreholes into the relatively impermeable sandstones in the area is cost-effective.

An artificial recharge system by the injection of rainfall into the underlying aquifer via low yielding boreholes would offer a simple means of cheaply storing large quantities of water for dry season use. A trial system could be constructed fairly easily and cheaply. Above ground storage of rainwater may well be necessary as the rate at which boreholes can be recharged will probably be low, based on estimates of aquifer permeability.

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