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Cost-effective boreholes in sub-Saharan Africa

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The paper sets out a conceptual framework for Cost-Effective Boreholes (CEB) in sub-Saharan Africa. Using examples from the literature, it sets out six key factors and discusses thirteen elements that affect CEB. The elements are: operation and maintenance procedures; preference for local private sector drilling; borehole standards and designs; drilling equipment; procurement processes; contract packaging; programme and contract management; siting; construction supervision; test pumping requirements; evaluation of groundwater resources, hydrogeological data collection and storage; and regulation and private sector professionalism. Adherence to basic principles with respect to these elements can improve CEB provision. However more investment in human resource development, institutional strengthening, better monitoring and more transparent reporting is required. The thirteen elements of the CEB conceptual framework could be used to benchmark the drilling sector in a particular country and thus raise incentives to make improvements but this requires international as well as national endorsement.

Introduction

If current trends continue Sub-Saharan Africa will reach the MDG water target in 2040 (UNDP, 2006). For Sub-Saharan Africa to get on track to the targets, connection rates for water will have to rise from 10 million a year in the past decade to 23 million a year in the next decade. It has been estimated that about 35,000 boreholes per year need to be drilled in sub-Saharan Africa to meet the MDG target for domestic water supply¹ If one considers full coverage by 2050, and water for irrigation as well as industrial supply, at least 50,000 boreholes per year are required. It is well known that drilling costs in sub-Saharan Africa are considerably higher than in India. Whereas the cost of drilling a borehole in India is about US\$1,000, comparable costs in sub-Saharan Africa are US\$ 6,000 to US\$20,000 (UNICEF, 1998).

Concerns regarding the disparity between the relatively low costs of handpumps and the high costs of drilled wells were raised at the UNDP-World Bank International Handpump Workshop in 1992 (Doyen, 2003). Stakeholders have also raised concern about variable construction quality. The Cost-Effective Boreholes (CEB) flagship of the Rural Water Supply Network (RWSN) was set up to improve the health of the borehole drilling sector in sub-Saharan Africa so high-quality boreholes are constructed and that enterprises are profitable as well as efficient.

This paper sets out a conceptual framework for CEB in sub-Saharan Africa and uses it to compare the policies and practices of several countries. The paper makes recommendations on how the key challenges facing the sector could be addressed.

Methodology

The conceptual framework builds on previous work by Wurzel (2001), Smith (2003), Ball (2004), Carter (2006), Carter et al (2006), the 5th RWSN Forum in Accra (RWSN, 2006), Danert (2008) and Adekile and Olabode (2008). It also draws on an ongoing project by UNICEF to develop a generic code of practice for cost-effective boreholes which can be tailored to suit specific county contexts. The analysis set out in is

paper draws on numerous studies undertaken over the last 20 years in more than ten countries (see references).

Assertions, information and evidence

One cannot readily make simplistic cost comparisons as every borehole is unique (e.g. Table 1). Accurate information on drilling prices or costs in sub-Saharan Africa is not easy to access due to poor, fragmented and non-standardized record keeping of many projects and programmes as well as concerns over release of data (ANTEA, 2007). National, or even programme averages can hide more than they reveal and there are huge differences in what is included and left out. Simple league tables of average national drilling costs as an incentive to improve cost-effectiveness are thus not very helpful. More in-depth analysis is required.

Country, year (reference)	Price per well	Price Per meter	Comments
Kenya, 1996 (Doyen, 2003)	\$8,400	\$120	Price estimated for 70m well in specific programme (includes drilling, testing but not siting, supervision or failure)
Nigeria, 2006 (Adekile, 2007)	\$11,700	\$195	Federal Ministry of Water Resources 2006 borehole price. PVC lined, 60 m depth fitted with handpump.
Tanzania, 2004 (Baumann et al, 2005)	\$6,000	-	Budget for borehole with a handpump, as in the National Rural Water Supply and Sanitation Programme (2004), Main Report V 1.
Uganda, 2007 (MWE, 2007b)	\$8,700	-	Average price of private sector drilled deep boreholes (with handpumps) paid for by district local governments in F/Y 2006/7.
Malawi, 2001 (Mthunzi, 2004)	\$2,730	-	Estimated average well cost including capital, recurrent, personnel & materials; assuming 45 wells drilled per year with small rig by NGO.
Burkina Faso, 06 (ANTEA 2007)		\$152	Average cost of drilling and installation of casing and screen (PVC) but not the pump, as established by study of drilling costs.
Senegal, 2006 (ANTEA, 2007)	-	\$500	Average cost of drilling and installation of casing and screen (stainless steel) but not the pump, as established by study of drilling costs.

Conceptual framework

ANTEA (2007) and Carter et al (2006) point to the need to address the parameters that affect drilling cost-effectiveness. Borehole costs and quality are primarily influenced by six core factors and thirteen elements as set out in Figure 1.

Borehole costs and quality

It is essential to note that 'price' refers to the amount paid by a programme for the successfully completed borehole, whereas 'cost' is borne by the driller and consultant(s). The cost of a borehole comprise:

1. The basic costs to the driller, ie:
 - **Mobilisation** – all costs involved in transporting equipment to site and back to base.
 - **Drilling** – allows for the per-hour (converted to per-meter) costs of equipment depreciation, labour consumption of fuel, lubricants and drill fluids and replacement of drilling tools. Affected by depth; diameter; drilling and standby, or waiting time.
 - **Installation** – includes the supply and installation of plain casing and screen, gravel pack, sanitary seal and well-head construction.
 - **Well development** refers to the cleaning of the borehole after construction and **test pumping** is the post-construction assessment of borehole and aquifer performance.

The time taken to undertake these activities affects the basic drilling costs. While savings on one item such as casing can have a considerable effect on the installation cost, the proportion saved on the total cost depends on how much the installation component affects the total construction cost.

2. Additional costs to the driller include VAT, tax, overheads and kickbacks (where common practice). Some of these are hidden within the Bill of Quantities. An astute driller will assess the requirements for a particular tender, consider the risks involved and load particular items accordingly.
3. Pump costs vary considerably and are in some cases included in quoted borehole prices.
4. Siting costs - borne by the Government /programme, driller or consultant. Where consultants undertake this, the costs are clear and visible but these costs are often concealed within programme overheads.
5. Supervision costs are generally borne by the Government or programme, or consultants.
6. Costs of Social Infrastructure, i.e. mobilising and training communities and forming management groups. These costs are also sometimes hidden within programme expenditure.
7. Construction quality refers to the degree to which the borehole is straight; the quality of well development and gravel packing; the casing/screen quality including its installation; the permeable backfill material and placement; the quality of the sanitary seal and headworks. From the user perspective, turbid water, low flow rates, seasonal functionality all represent compromises on quality of service.
8. Post-construction failure increases actual borehole costs significantly. A 50% failure rate effectively doubles the well price.

The core factors and thirteen elements of CEB

The core factors are independent variables that do not change at all or cannot easily be influenced from within the sector but have a bearing on the cost, and quality of boreholes. It is important to understand what they are, and be realistic about the extent to which they can be changed in a given time frame. Given this, it is essential to pay due attention to the 13 elements. Box 1 outlines the basic principles that the authors consider should be adhered to with respect to these elements.

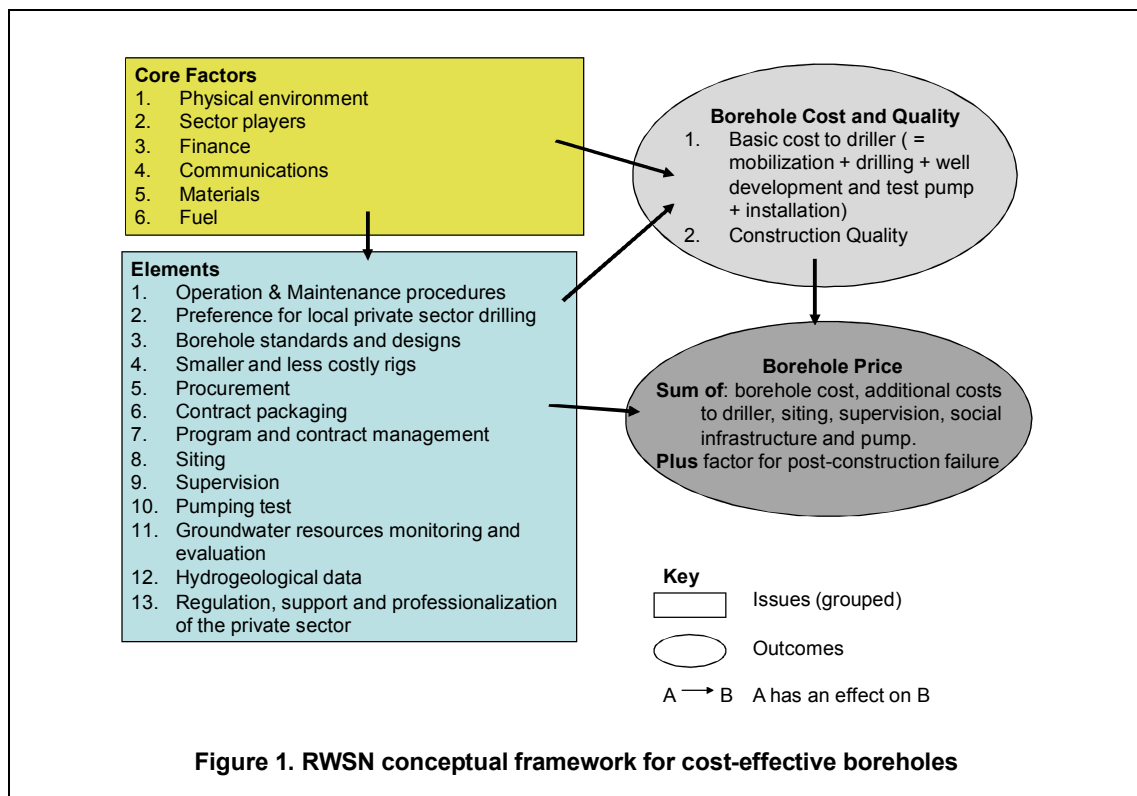


Figure 1. RWSN conceptual framework for cost-effective boreholes

Analysis of the thirteen elements of cost-effective boreholes

1. Operation and maintenance (O&M) procedures

Unfortunately broken down handpumps and abandoned boreholes are a frequent site across the continent. An estimated 30% to 50% of installed facilities in Nigeria are broken down at any one time (Adekile and Olabode, 2008). Comparable figures for Malawi and Uganda are 30% and 20% respectively. Reliable and comprehensive data in this regard is lacking, but water point mapping work is capturing more information.

Unless initial construction quality is high, water is of an acceptable quality and long term operation and maintenance procedures are established and adhered to, CEB provision will never be realized. Drilling programmes often neglect the much-needed community sensitisation and mobilisation aspects. Water users rarely contribute more than a small proportion of the capital cost towards construction, if anything, and ownership tends to be unclear. The development of and support to social infrastructure is often neglected and spare parts are frequently not available. These, combined with lack of follow-up support (e.g. to retrain committees and mechanics; ensure spares are available) contribute to poor operation and maintenance and thus broken down sources.

Box 1: Key elements for cost-effective boreholes

- *Operation and maintenance (O&M) procedures* to ensure the sustainability of pumped groundwater sources for the expected lifetime of the facility should be established, adhered to and monitored.
- *Who drills?* The preferred option is that local private sector enterprises undertake construction of water wells and pump installation. This should encourage in-county capacity to grow and foster competition.
- *Standards and design:* Boreholes should be designed and constructed so that they are fit for their intended purpose in terms of diameter, depth, casing and screen.
- *Drilling equipment:* Smaller and less costly rigs should be utilized to provide boreholes that are fit for their designed purpose. Manual drilling should be brought into the mainstream of water supply programmes, with appropriate quality control.
- *Procurement:* Systematic, transparent and timely processes of advertising, pre-qualification, tendering, evaluation and award need to be established and followed.
- *Contract Packaging:* Contracts should be packaged for multiple boreholes in close proximity and for boreholes with similar geology.
- *Programme and contract management.* It is essential that drilling programmes have sufficient skills to design and manage the programmes or bring in expertise. Payment for works must be timely.
- Appropriate *siting* practices should be utilized.
- High quality, timely *construction supervision* should be emphasized.
- *Test pumping requirements* should be matched to borehole purpose while taking into account the importance of data to improve the understanding of hydrogeology and water resources.
- Rigorous evaluation of groundwater resources should be undertaken and information made available.
- *Hydrogeological data* collection and storage should be undertaken.
- *Regulation and private sector professionalism:* A strong public sector is needed to oversee and regulate the private sector. The private sector needs better access to credit and should professionalize.

2. Preference for local private sector drilling

In order to keep drilling costs down, a rig should be used for about 220 days per year (60% of the time) and be subject to regular maintenance and repair. This equates to drilling 20,000 hours over a ten year period. Unfortunately such high usage is rarely achieved within state-owned equipment. There are numerous rigs lying idle in Government yards, broken down or rarely used. There is a growing consensus (by the World Bank, several bilateral donors and African Governments) that private sector drilling tends to be more efficient and effective than direct implementation by the State. Governments and donor support agencies are encouraged to provide support so that the private sector can be built up rather than supporting the purchase of State-owned drilling rigs. Moves towards more private sector drilling, as part of wider policy reforms vary widely. It may be desirable for Government to retain at some minimum drilling capacity to deal with emergency situations. There are questions with respect to NGOs drilling wells directly as this reduces the market for private drilling and is subject to unfair competition.

3. Borehole standards and designs

Wells should be designed so that they are *fit for their intended purpose* (Carter et al, 2006), which means that the diameter, depth, lining and backfill materials, screen open area and other design features should be

well-matched to need (expressed as water demand, longevity, hydraulic efficiency and cost). Differentiating between different magnitudes of abstraction requirements is particularly important.

Doyen (2003) points out that often, wells drilled for rural handpump are being constructed to give high yields, and are forced to conform to higher standards necessary. Well yields of 0.25l/s are adequate for hand pump wells. Handpump boreholes diameter requirements and the small diameter submersible pumps that are now on the market mean that 4" (~100mm) internal diameter boreholes are usually sufficient. Diameter requirements vary considerably between countries. In Mozambique 4" casing is installed, (WE Consult, 2006); in Uganda 4-5" casing is specified (MWE, 2007a); and 6" casing is used in Ethiopia. In Kenya, the high drilling specifications (152 mm diameter) are apparently due to plans to upgrade sources to motorised pumps with small piped distribution systems later. However, given the enormous challenge of meeting the MDGs, and difficulty in maintaining existing rural water supplies, such thinking may not be realistic for many countries.

In countries where boreholes are drilled into stable basement formation, savings can be made by casing the collapsing formation only and not casing the hole drilled into the basement, as is the standard in Uganda (MWE, 2007a). In Tanzania and Nigeria all boreholes are fully lined.

Drilling beyond the optimum yield depth is common, with examples documented in Ethiopia (Carter et al, 2006), Kenya (Doyen, 2003) and Nigeria (Adekile and Olabode, 2008). In the basement complex, a geophysical survey can provide a good indication of depth requirements and for sedimentary formation; existing drilling records can be used to determine realistic drilling depths. It is essential that seasonal fluctuations are taken into consideration where necessary.

4. Equipment - smaller and less costly rigs

Borehole costs are affected by the type of equipment used, with cheaper and lighter equipment resulting in lower mobilization costs. Ball (2004) compared drilling with equipment costing US\$ 470,000 and US\$ 95,000 and estimated that the price per borehole (including overheads) for the larger rig is \$8,837, while boreholes with the smaller rig cost US\$ 2,652 (a factor of 3.3). There is a tendency to overestimate required well depth and over-drill, or specify large rigs which have a bearing on the equipment that drilling enterprises decide to buy (Carter et al, 2006). If a contractor can only invest in one rig, he may purchase the largest possible rig, to provide flexibility.

In many countries (eg Kenya, Ethiopia, Mozambique, Niger), the rigs in use are oversized for the purpose of drilling rural handpump boreholes (Doyen, 2003; Carter et al, 2006; WE consult, 2006; Danert 2007). In Nigeria, half of the rigs encountered on a study by Adekile and Olabode (2008) were classified as light to medium. Discussions with Government stakeholders and drillers in Niger (Danert, 2005) and Ethiopia revealed a lack of awareness of new light conventional rigs on the international market.

Use of old equipment, with the result that breakdowns are frequent, maintenance difficult and performance is slow is common Tanzania (Baumann et al, 2005), as well as in Senegal, Burkina Faso, Mali and Mauritania (ANTEA, 2007). 68% of drilling rigs in Ethiopia are older than 15 years (Carter et al, 2006). However, lack of initial capital limits options with respect to equipment purchase.

Manual (or hand) drilling techniques provide a viable alternative in particular environments (soft formation and shallow groundwater). Adekile and Olabode (2008) found that the cost of a manually drilled hole in Nigeria was about one third of a conventionally drilled hole. In Chad they cost a tenth of machine-drilled wells (Practica, 2005). Manual drilling techniques are used in Niger, Benin, Burkina Faso, Nigeria, Chad, Ethiopia, Mozambique, Malawi, Madagascar, South Africa, Senegal and Tanzania. In Nigeria, an estimated 30,000 hand drilled wells are in existence (Adekile and Olabode, 2009).

5. Procurement

Tendering procedures in many countries are still weak and procedures can take a long time, which is not good for business and unnecessarily increases costs, affecting the price or quality. Adekile (2007) found that in Nigeria, contracts are often awarded to non-professionals who then sub-contract to the drilling contractor, lowering the profit margin and sometimes compromising technical standards. In Nigeria, numerous drillers complain of not being able to tender for Government projects as they do not stand a chance (Adekile and Olabode, 2008).

In other countries (eg Malawi and Uganda), there are companies which will not tender for work with certain District Governments (Danert, 2008a). Baumann et al (2005) found that there was no pre-qualification of bidders in Tanzania and that tender evaluations did not find out inconsistencies in the capabilities of different bidders. In Ethiopia, considerable procurement is "unplanned", which means that it

is rather sudden, and driven by the availability of funds. In such cases the sequence of steps followed for open and limited tenders are not adhered to (Carter et al, 2006).

6. Contract packaging

Transport is a major cost component for borehole drilling, which can be reduced by clustering wells to limit expenditure. Unfortunately, small contract packages are common in many countries. Not only do these raise costs (and hence prices), but they do not allow for long term planning and investment by private enterprises.

Decentralisation in its current form works against this. In the case of Uganda, each of 79 Districts annually contracts out its own boreholes, and the numbers of wells drilled are small (ranging from 1 to 20 in 2007; average 9.5 in 2008 (MWE, 2007b; MWE, 2008). There are cases in Tanzania where a contractor had to enter five or six contracts to drill nine or ten wells (Baumann et al, 2005). In Nigeria, many contracts are packaged as one or two boreholes (Adekile, 2007). Doyen (2003) states that in Kenya, costs could rise by as much as 25% if drilling campaigns are not in economic lots of 50 wells or more. Community mobilisation efforts and response to the demand driven approach by end users should be reconciled with clustering of wells to achieve economies of scale, which is not always easy.

7. Programme and contract management

As more countries move over to national programmes, or adhere to sector wide approaches, there is a danger that expertise with respect to programme management as well as drilling contract is insufficient. Where governments are changing role from implementer to that of planner and regulator, or as more responsibilities are given to District level, skills may be lacking. In Tanzania, for example, model documents for tendering, evaluation and contracts were lacking and there were no contract management guidelines (Baumann et al, 2005). Although poorly documented, anecdotal evidence suggests that this is an area which is particularly weak in many countries. To make matters worse, understaffed ministries and local Government offices are not uncommon.

Payment systems for water well drilling vary considerably. In Nigeria, Malawi and Mozambique it is common for drilling contractors to be paid for a geophysical survey and only to be paid for successful wells. In Uganda, payment is theoretically against a bill of quantities, but this is not always followed (Danert, 2008a). It has been strongly argued that such a mechanism increases prices, as drillers take the risk into account. In Mozambique, payment delays of three months are common in Government projects but there are examples where delays have been for several years (WE Consult, 2006).

8. Siting practices

Improvements in knowledge of hydrogeology (see section 4.11 and 4.12) and enhanced experience in site survey can increase drilling success rates, and reduce the disparity between anticipated and actual drilling depths. Professional siting involves desk and field reconnaissance, but does not always require the use of geophysics (MacDonald et al, 2005). In many countries in the region, drillers themselves undertake the siting, and are subsequently only paid for a successful well.

In many countries there is a tendency to specify geophysics on drilling sites, even where it is not necessary. Adekile and Olabode (2008) point out that on some of the unconsolidated sediments in Nigeria, a review of existing borehole data would be more applicable in determining depths than geophysics. In Tanzania, consultants are required to undertake a geophysical survey using at least two methods, including a VES resistivity survey, which is not always necessary (Baumann, 2005). However when trying to locate water in fractured bedrock, geophysical techniques may significantly improve success rates. In the challenging hydrogeological conditions of Mauritania, there are between two and three reconnaissance wells drilled per successful well (ANTEA, 2007).

9. Supervision

Doyen (2003) states: “*over-drilling is roughly inversely proportional to the degree of supervision of drilling operations*”. Both the quality of drilling supervision and on-site authority are important. Degree courses in geology and hydrogeology do not provide graduates with a solid foundation in drilling supervision. It is not uncommon for drillers to complain about being supervised by inexperienced hydrogeologists, straight out of university. Other drillers use their monopoly on knowledge and exploit this. Unfortunately, supervision capacity is extremely limited in much of sub-Saharan Africa and is a key reason for borehole failure.

In Nigeria the capacity for proper supervision, in terms of experienced personnel and equipment is limited at State level (Adekile and Olabode, 2008). Kaduna State Ministry of Water Resources realised that they did not have sufficient competence to supervise their drilling programmes and invested in training (Adekile,

2007). The Nigerian Federal Government and external support agencies engage consultants to carry out drilling supervision (Adekile and Olabode, 2008). In Malawi, there are only a handful of hydrogeologists in the country. Supervision of test pumping is often the only professional supervision that takes place. Communities are expected to undertake a certain amount of drilling supervision (for which they are given no more than two days training) (Baumann and Danert, 2008). In Uganda supervision is either undertaken by private consultants or by District Government depending on who is financing the work. In Ethiopia, supervision is undertaken directly by the Water Bureaux or through hired consultants with variation regarding the level of supervision and strictness. Contractors cite lack of timely decision-making by supervisors as a frequent problem (Carter, 2006).

There is need for close on-site supervision, with the supervisor having the confidence and authority to decide when depth is sufficient. It is envisaged that the increased cost of better supervision would ultimately be offset by reduced drilling costs and improved construction quality.

10. Pumping test

Doyen (2003) estimates that 7% savings would be possible in Kenya if a 3-hour, rather than a 24-hour discharge and 12 hour recovery was used to test pump rural handpump wells. The high standards test pumping requirements are intended to obtain as much hydrogeological information about the aquifer in the vicinity of the borehole as possible. Doyen (2003) states that although per meter drilling costs in Kenya fell by 35% between 1988 and 1996, the increased standards for well development, pump testing and well design increased costs by as much as 36% with the result that there were no net savings. Tanzania specifies a 24-hour pumping test (Baumann, 2005). In Nigeria, pumping tests have been matched to borehole purpose for several years. The Federal Ministry of Water Resource and State project usually specify pumping tests of 2 to 6 hours for handpumps and 8 to 24 hours for motorised schemes.

The bailer test (MacDonald et al, 2005) provides a very low cost pumping test alternative.

11. Groundwater resources monitoring and evaluation

MacDonald and Davies (2000) point out that: sustainability of groundwater supplies; overexploitation in sedimentary basins; variations in natural water quality and contamination of groundwater demand more attention. There is an urgent need for improved groundwater resources monitoring and better water quality testing. Groundwater levels appear to have fallen in some parts of Nigeria and it has been suggested that intensive drilling in the urban areas of Lagos and Kano State could lead to water level decline (Adekile, 2007; Adekile and Olabode, 2008). Arsenic has been reported in some parts of Nigeria but it is not tested for in water supply projects.

12. Hydrogeological data

Hydrogeological data is extremely important and insufficient attention to the storage, analysis and utilisation of drilling data is a lost opportunity. Unfortunately coordinated research and data collection on groundwater in sub-Saharan Africa has become increasingly difficult. Mistakes are repeated, while information from thousands of boreholes is not collected. In Tanzania, only 60% to 70% of boreholes drilled by the Parastatal are recorded in the central database and records from industry and mining are not included at all (Baumann et al, 2005). Meanwhile knowledge of hydrogeology in Nigeria has improved considerably over the years and data has been collected with a view to publishing hydrogeological maps (Adekile and Olabode, 2008) and hydrogeological mapping is underway in Ethiopia and Uganda.

Simple techniques for the collection and analysis of high value data from drilling programmes exist, but are inadequately used. This is a missed opportunity for significantly enhancing the knowledge base of groundwater in Africa, and enabling issues for specific research to be identified and targeted. MacDonald and Davies (2000) advocate for the dissemination of simple techniques on groundwater resource assessment to stakeholders involved in rural water supply.

13. Regulation and professionalism of the private sector

The public sector in many sub-Saharan countries is still struggling to fulfil its emerging regulatory role. Regulation of number of employees and equipment is demanding in some countries, eg Ethiopia (Carter et al, 2006) and lacking in others, eg Nigeria (Adekile, 2007). Although drilling permits are issued in Tanzania, they are not based on consistent professional assessments of the companies, and quality is not monitored on a regular basis (Baumann et al, 2005). The private sector has nowhere near the capacity required to meet the required MDG targets and training opportunities are rare. Some countries (e.g. Nigeria and Uganda) have considerable national expertise while others are still heavily reliant on foreign companies. Costs of

expatriate staff are four to eight times as much as local staff in Burkina Faso, Senegal, Mali and Mauritania (ANTEA, 2007).

Obtaining regular work is essential to enable enterprises to remain in business and be cost-effective but contractors generally have to submit tenders for work to many projects every year. Only one documented case of a drilling concession, running over several years in Nigeria has been documented (Robinson, 2006).

Setting up in business can be extremely difficult. There are cases in Mozambique where it has taken three years for a company to establish itself (WE Consult, 2006). There are many people with the skills, but not the finances to invest in drilling enterprises. Interest rates on loans are high, eg 20-40% in Mozambique (WE Consult 2006); 18% in Tanzania (Baumann et al, 2005), repayment periods tend to be short and securities unrealistic. In Nigeria, people generally use their own savings and those of relatives as start-up capital.

Importation of equipment and spares can be very difficult if contractors do not have foreign connections (Carter et al, 2006; Robinson, 2006; Adekile, 2007).

Networking, collaboration and lobbying are recognised as important mechanisms to professionalize organisations and bring about policy shifts. Drillers Associations in Mozambique and Nigeria have recently been established, initially with donor support. In Mozambique, the association successfully lobbied for more realistic contract terms and conditions. The Uganda Drillers Association had collapsed by 2003, although drillers have collaborated to demystify tax procedures. The Medic Project Management Unit in South Sudan provides an interesting example of drilling enterprises which are collaborating with each other. Documentation and analysis of the success of networking and collaboration of drillers is lacking, but evidence from other sectors indicates that it could be instrumental in bringing about positive change.

Conclusions and recommendations

There are numerous ways through which the cost-effectiveness of borehole provision can be improved. Adherence to the 13 basic principles set out in this paper (Box 1) would do much to improve the drilling sector. However, in order to bring about such a change there is need for much more investment in human resource development, institutional strengthening, improved monitoring and more transparent reporting mechanisms. Such investment is not going to be made overnight and needs the full backing of key decision-makers. The Conceptual Framework for CEB provides a solid foundation for identifying strengths and weaknesses of the borehole drilling sector, and for making cross-county comparisons. However, action by policy makers and the private sector is required, for which better incentives seem to be required than those that currently exist.

A simple model of borehole costs would demystify drilling costs and provide a tool for sensitivity analysis regarding depth, rig amortization, distance and drilling time. It would be prudent to utilise the thirteen elements as a basis for benchmarking the drilling sector in a particular country or for a particular programme. Such benchmarking could be undertaken under the umbrella of a generic and national code of practice for CEB. However, there is need for political buy-in at international as well as national level to enable such benchmarking to have an impact on policies and practices.

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Note

1. Based on Joint Monitoring Programme (2004) data of 412 million people served in 2004: MDG of 701 million people served in 2015 and full coverage of 1625 million served. Assumption made that 37.5% of people will be served with a handpump (300 people per pump) and 12.5% will be served with a mechanised borehole (2,000 people per system). Assumes that 3% of existing boreholes need to be re-drilled annually.

Keywords

Boreholes, drilling, cost-effectiveness, private sector, groundwater, wells.

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