Report No:

Rationalization of Drilling Operations in Tanzania

Review of the Borehole Drilling Sector in Tanzania

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Abbreviations and Acronyms

BoQ	Bill of Quantities
BWO	Basin Water Office
DAWASA	Dar es Salaam Water and Sanitation Authority
DCG	District Conditional Grants
DDCA	Drilling and Dam Construction Agency
DRA	Demand Responsive Approaches
DTH	Down the Hole Hammer
DWE	District Water Engineer
DWO	District Water Office
DWR	Directorate of Water Resources
GIS	Geographic Information System
GoT	Government of Tanzania
GPS	Global Positioning Systems
ID	Internal Diameter
IWRM	Integrated Water Resources Management
Km	Kilometre
MDG	Millennium Development Goal
MIS	Management Information System
MOU	Memorandum of Understanding
MWLD	Ministry of Water and Livestock Development
NAWAPO	National Water Policy
NGO	Non-Governmental Organisation
NRWSSP	National Rural Water Supply and Sanitation Programme
NWSDS	National Water Sector Development Strategy
O&M	Operation and Maintenance
OD	Outside Diameter
PO-RALG	Presidents Office, Regional Administration and Local Government
RWS	Rural Water Supply
RWSD	Rural Water Supply Division
RWSN	Rural Water Supply Network
RWSSP	Rural Water Supply and Sanitation Project
SWAP	Sector-Wide Approach to Planning
TOR	Terms of Reference
TSP	Technical Service Provider
TZS	Tanzanian Shilling
USD	US Dollar
VES	Vertical Electrical Sounding

Executive Summary

Tanzania has a vibrant growing economy – business opportunities are emerging in all sectors. This growth is also reflected in the drilling industry. The country has formulated ambitious MDG for rural water. The private sector drilling industry represents one of the supply-side bottlenecks. To meet the MDG, development of sufficient local capacity for borehole drilling is critical. This study reviews the situation in the drilling sector, assesses options, and identifies support areas.

Drilling Industry

The drilling sector in Tanzania can be characterised by:

- **Sufficient human capacity**; DDCA employs a large number of well-trained drillers and hydrogeologists. This skills base is underutilised because of the way DDCA operates. With a transition of DDCA into a regulatory body, the present employees could take this opportunity to start their own private businesses. The majority of trained drillers come from government services; they are now employed by contractors.

- **Lack of equipment:** drilling operators have not been able to make sufficient investments into new equipment. The equipment is ancient and unreliable. Frequent breakdowns slow down the performance. Some of the DDCA equipment could be sold into the private industries.

- **Lack of private sector consultants:** The market for Technical Service Providers and private consulting companies is still very young. It will take some time before a consulting capacity emerges that meets the demands and needs of District Water Engineers.

- **Lack of capital:** Nearly all drillers have not enough cash and not enough confidence into the market to invest in new equipment.

Tanzania has a high potential for groundwater use. The borehole database maintained by the MWLD records 9,242 boreholes. The NRWSSP aims to provide access to safe water to an additional 14.5 million people by 2015 at a cost of USD 533 million. This provides a substantial market for drilling of about 1,600 boreholes annually. The capacity needs to be doubled to meet the targets. The private sector has to invest USD 4-6 million in equipment; a mixture of about 40 rigs from small to large capacity is needed. The predicted turnover of USD 80-100 million over 10 years provides the basis for this investment.

Public Sector Drilling

In the past, the government drilled most boreholes; private sector participation had been minimal. Since 1997, when DDCA was formed, the agency drilled 3,161 boreholes. The agency has 296 highly qualified skilled and experienced employees. It covers about 60% of the present market. DDCA is under capitalised, no government investments, old equipment (25 functional rigs). The implementation rate is low due to old and obsolete equipment. However, the JICA project brought some new drill rigs and compressors. In the long run, DDCA could not become viable institution, as a para-statal agency it is excluded from bidding for World Bank financed projects. The current operation level with old equipment does not allow making sufficient profits to replace the old equipment.

DDCA's way of operating needs to be changed. The reform of government structure calls for the line ministries to solely concentrate on policy formulation, monitoring and regulatory activities and to be completely de-linked from executing implementation.

Private Sector Drilling

Some private sector companies were formed by ex-MWLD staff. They try to expand but lack the capital. Even moderate expansion is difficult. Credits from commercial banks require a security of 125% and the assurance of continual government work. The interest rate is 18%, repayment rates are 3 yrs.

One foreign company (Chinese corporation) operates in the country.

The drilling sector is distorted by the water supply situation in Dar es Salaam. In town, about 1,000 boreholes (registered and not registered) are drilled each year. Several drillers operate

only in town. About 9,000 boreholes extract 50,000 to 70,000 m^3 per day from the aquifer. This excessive use may cause salt-water intrusion and damage to the aquifer. Unregulated abstraction should stop.

Market

The technical range of groundwater abstraction is quite wide. A high percentage of sites are suitable for dug-wells and hand-augered boreholes. The borehole data in Dodoma reveals that the average depth of all boreholes drilled is 62.3m, the average static water level is 16.5m, and the average yield is 10.6 m^3 per hour.

Drilling equipment ranges from very lightweight rigs to large truck mounted rigs. Most of the equipment is old and in poor state of repair.

Of the approximately 16,000 boreholes that need to be drilled in the next 10 years, 25% would be in unconsolidated formations, 60% unconsolidated up to a depth of 20-30 meters and consolidated with greater depth, and 15% entirely consolidated. Where significant local deposits of sediments overlay the Plutonic-Metamorphic rocks, they might constitute an isolated aquifer system.

Contracts and Cost

In RWSSP, drilling work was tendered without pre-qualification of bidders. The tender evaluation did not dedicate sufficient importance to full and comprehensive information about the capabilities of the bidders and it did not reveal considerable inconsistencies. The costs were high (considerably higher than the estimated unit costs). It will be a challenge for the NRWSSP to keep cost down. The following aspects have a positive impact on cost: a) Productivity, depreciation of equipment is a large cost factor, b) Procurement, economies of scale and packaging, and c) Low cost technologies, optimising well design and reducing borehole diameter.

However, cost considerations are not the only aspects. Quality and sustainability of works need to be taken into account as well. The challenge will be to strive for low cost without jeopardising quality.

Specifications

The Government Circular No: 3 specifies the boreholes, however the specifications are imprecise. In practice, the drillers and consultants follow the guidelines only loosely. The need to establish an effective regulatory framework is evident.

For site selection, the consultants are required to undertake a geophysical survey using at least two methods, of which one should be a VES resistivity survey. An optimised siting procedure would require that the hydrogeologists make a professional judgement where only the bare minimum of surveying is required and where more work and input are required.

All boreholes are cased and gravel packed to 150mm ID (deep wells) or 117mm ID (shallow wells). For handpumps, 4-inch casing 102mm ID would be sufficient. A 24-hours pumping test as specified is not always necessary. For shallow handpump boreholes, a 12-hours test would be sufficient.

Matching the borehole diameter to the extraction method would provide a potential for cost savings. Similarly, unlined boreholes (in crystalline rock) could be piloted and tried out. Mechanisms have to be defined for the introduction of new and innovative drilling techniques and borehole designs. The regulator might have to work together with selected NGOs.

Regulations

RWSD is responsible for supervisory and advisory services and for monitoring performance. For water resources management the NWSDS restructuring gives the regulatory role to Basin Water Offices. The Basin Water Office is not mandated to regulate rural water supply. This function will remain within MWLD.

Prequalification and drilling permits are issued, however they are not based on consistent professional assessments of the companies. Permits should be renewed at regular intervals based on performance data, and physical inspection of equipment.

Quality is not monitored constantly. Based on completion records and performance assessments from the DWE, the performance of drillers and consultants should be observed.

Enforced borehole specifications, production guidelines, and safety measures should be established and up-dated continuously. This includes also the preparation of model documents for tendering, tender evaluation, and contracts. Contract management guidelines have to be drawn up that will allow district implementation.

The interfaces with the river basin offices have to be clearly defined and the regulatory body has to work closely with these offices to ensure to ensure ground water protection.

Recommendations

Action plan for transition of DDCA into a Regulatory Body

In the processes of reorganizing DDCA, a transition period of at least three years is required to make the necessary changes. The formulation of a vision and mission for the agency will take some time. The change to DDCA performing mainly regulatory functions would have an effect on other departments and sections of RWSD, e.g. Design Supervision Section, Construction Monitoring Section, Directorate of Water Resources, and the River Basin Offices. The interfaces between future-DDCA, the Directorate of Water Resources, and the river basin authorities need to be clearly defined. A national workshop with all stakeholders should be held to define all the tasks and authorities. Once the duties and tasks are defined, it will be important to assess the resources available within DDCA. This would entail human skills as well as equipment. The identification and separation of the personnel and assets to be retained should be given a priority.

The institutional setting would need to be considered carefully. DDCA might become a government department or agency within the MWLD (could be added to an existing directorate or (better) be a separate unit.

The transition should take place in stages to allow a smooth changeover. To create a strong regulatory and monitoring body that sets rules and monitors implementation, a core staff will have be retained from the DDCA and accorded appropriate incentive and back ups. This

includes the equipment, materials, and vehicles necessary for regulatory and monitoring activities.

DDCA would need to gradually cease the commercial drilling operations and dispose of unneeded staff and equipment.

The future tasks should be regulation, setting of standards, enforcement of standards, issuance of permits, quality control, data collection, MIS, and limited non-commercial drilling. DDCA should:

- issue recommendations for drilling permits to the Ministry of Trade for applicants after scrutiny of personnel resources, and physical inspection of equipment. and renew of permits at regular intervals
- prepare borehole specifications, production guidelines, and safety measures (including model documents for tendering, tender evaluation, and contracts)
- vet and approve dam construction projects and dam designs; this has to be done in close cooperation between DDCA and the river basin offices
- monitor the performance of drillers and TSPs. Spot checks on drilling sites to inspect the actual work execution can be used for on site advice to enhance capacity.
- establish effective data on boreholes together with the river basin offices, analyse the data on a regular basis
- train DWE, TSP, and private sector on new equipments and methods as well as on quality control and certification audits
- advise districts in technology choice
- drill (restricted to non-commercial work) wells for emergencies, hydrogeological studies, exploration, and training purposes.

The large number of skilled DDCA employees represents a great human asset in the country. The transitional plan has to make sure that this asset is not lost to the rural water sector. DDCA would retain a core staff of about 30 highly qualified, skilled drillers and hydro geologists (more academically oriented DDCA staff). The team should be equipped with a small number (2) of efficient and new drilling rigs and auxiliary equipment.

The employees that cannot be retained should be notified as early as possible. These staff members would be motivated to form private sector drilling companies or consulting companies, and to purchase the drill rigs, equipment, materials, and vehicles when they are disposed. Training should be offered to workers that would want to leave government services and start their own business. They would need training in economics, management, business administration, sales, equipment management, and financial issues.

The process should be carried out with highest transparency and it should include coordination with all involved stakeholders. It is absolutely essential that the plans are properly communicated to the workers and that the chances that these changes offer are explained. The emerging drilling market needs these workers operating as new private sector companies and utilising the equipment they know well.

Procurement

To promote local private drillers, procurement processes should provide a steady stream of smaller contracts. The challenge in the NRWSSP will be to create an environment in which the administrative burden is as small as possible and in which economies of scale are achieved. Other mechanism than tendering at district level are required.

Uniform rates procurement fits best to the Tanzanian environment. It makes best use of the limited capacity and assists district authorities in letting out contracts quickly. In a national tendering process for fictive boreholes, unit charges are established. MWLD negotiates with pre-qualified contractors the applicable unit prices per activity. The rates are renewed annually. This pricelist is used in contracting drilling firms. Contracting is done based on capacity and

availability. The system provides a simple mechanism for districts to package borehole drilling. Districts can jointly contract the same drilling company thus achieving economy of scale.

To achieve accountability it is desirable when the same contractor is employed over several years. Satisfactory execution of the work should lead to down-stream work. Extended contracts give an incentive to do a good job and create a long-term relationship with DWE. Mechanisms need to be worked out for concessions to contract down-stream work. Uniform rate approaches are a useful pre-condition for such approaches.

District administrations prepare the district development plans on a three-year rolling basis. Such plans can be approved in principle at central level. This would allow the districts to make long-term commitments. Accordingly, the contract period could also be extended to 3 years. This again would create market security and bigger size contracts.

Regional coordination between districts would allow packaging contracts with sizable lots.

Database

A well-maintained database is a prerequisite for water resources management. Current borehole records have essential elements, but miss GIS. The attributes need to be standardised for ease of data entry. When the network is sufficiently expanded data sharing between districts and higher administrative echelons will be made easy.

MIS are tools for data processing, helping to support informed decision-making. Several attempts to create MIS exist in Tanzania. Any new data collection and setting up of databases would need to be integrated with ongoing MIS systems. Emphasis has to be on the quality and usefulness of the data and not on the technical opportunities. Districts need to collect up-to-date and accurate data to generate useful reports.

Technology

The use of ***reduced diameter screen boreholes*** should be piloted***.*** The borehole has a 2-inch continuous slot type screen. Since the screen is fitted between 2 pieces of 4-inch casing a positive annulus exists which always provides an annulus of minimum 20mm thickness for the gravel pack. The real cost saving effects are in the drilling as the borehole can be 150mm (6-inch) diameter instead of 225mm (9-inch).

A NGO in cooperation with MWLD could carry out a pilot project to test this option as an alternative design.

Many countries specify ***unlined boreholes*** in hard rock formations. The drilling diameter can be smaller, casing and the screen can be saved, and no gravel pack is used. To gain in-country experience and skills it would be best to introduce the technology through a pilot project.

NGOs have the best flexible structures to conduct pilot projects to carry out action research on new designs or methods. Such pilots have to be executed under controlled and supervised conditions in conjunction with MWLD. When a method proves successful, it can be included it into the specifications.

1 Introduction

The development of a local capacity for cost-effective borehole drilling in the private sector is a critical factor for large-scale progress in rural water supply. If Tanzania wants to meet the millennium development goals (MDG), it needs to drill 14,000 boreholes with handpumps and 1,500 boreholes for motorised small-piped systems[1]. Cost for boreholes in Tanzania are rather high, USD 6,000 for handpumps and USD 12,000 for mechanised systems[2].

As an input activity towards the World Bank, Water Sector Support Project the review team carried out an analytical study on the drilling industry in Tanzania. This industry represents one of the supply-side bottlenecks (lack of drilling capacity) for accelerated rural water supply services in Tanzania. The study aims at gaining a better understanding of the problems associated with the industry, assessing options, and identifying support areas.

Many inter-related factors affected the emergence of local drilling capacity. In the past, drilling was done by the government through the regional offices of MWLD. This approach created a government owned drilling fleet. The rigs were typically purchased under projects and often used by foreign contractors. At the end of the projects period, they were handed to the ministry. To centralise the regional drilling capacity, a public agency - Drilling and Dam Construction Agency (DDCA) was formed in 1997. As a para-statal drilling organisation, DDCA suffers from the inefficiencies inherent to the public sector; low utilization of equipment due to disrepair and lack of supplies. Despite these set backs DDCA remained the BIG PLAYER in the drilling sector.

Lately, under the drive for structural reform and re-focus of the public sector DDCA was excluded from competing for World Bank financed drilling contracts. The National Water Policy (NAWAPO) states that in future the provision of services has to be done mostly by private operators. Establishing a thriving drilling industry has been complicated by the small size of the market relying mostly on public contracts. Private operators were reluctant to reach out to isolated rural areas where risks and costs are high.

SWAP, decentralisation, and community driven principles have been adopted in the NAWAPO. These approaches bring the risk of fragmenting the market with inherent higher cost. They need to be reconciled with the requirement to plan drilling campaigns, which offer economies of scale by packaging sufficient number of boreholes. Consultant driven implementation often leads to over specified boreholes requiring expensive siting, drilling, and development techniques.

Drilling costs account typically for 80 % of the hardware investment costs for boreholes, the rest consisting of the handpump and the apron. The potential for cost saving in drilling is tremendous, the stakes are considerable; an average cost reduction of more than 10% is easily realistic, which, if realised, would result in savings of USD 10 million. In order to achieve these savings it will be necessary to create a favourable environment for the private sector drilling industry to grow and invest in equipment and human skills. The public sector needs to be structured to make use of the opportunities the emerging market offers. Factors like productivity and costs for obtaining contracts have a bigger impact on drilling cost than diameter of wells and yield criteria. The young emerging drilling industry needs a steady stream of smaller contracts and mechanisms are required to help local drillers entering into the market.

However, that does not mean that the saving potential lying in technology should be neglected; smaller diameter boreholes require smaller rigs, realistic acceptance criteria help to bring cost down for well development and siting. Low-cost drilling technologies provide a significant potential for helping the local drilling industry being established. The investment costs are clearly less and the price per borehole can be reduced. The issue is not to develop new technologies but to transfer and adapt existing ones.

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[1] National Rural Water Supply and Sanitation Programme (NRWSSP), Main Report Volume 1, September 2004

[2] NRWSSP Investment Plan Budget, 2004

2 Findings

2.1 Assessment of the drilling sector

2.1.1 Market in the past few years

Boreholes have been constructed in Tanzania since at least 1930 up until the present day. The borehole database maintained by the MWLD, Directorate of Water Resources in Dodoma lists 9,242 boreholes. The data entry is not consistent; many boreholes have no data recorded and for others the data are incomplete. It is therefore difficult to establish how many of these boreholes are actually used to provide water. It appears that the shallow boreholes drilled by hand drilling methods were not recorded or only partially recorded.

The below chart gives the numbers of boreholes that were recorded in Dodoma over the last 25 years

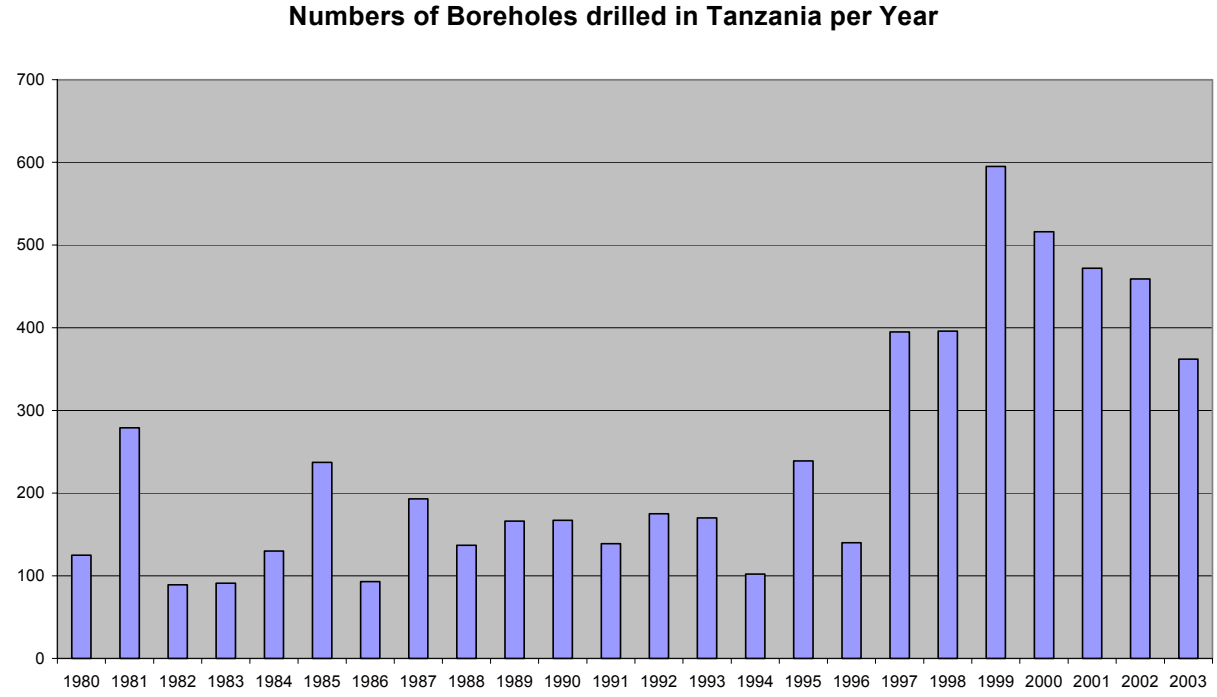


Chart 1: Boreholes drilled in Tanzania

2.1.2 The potential Market

Tanzania has a high potential for boreholes in terms of hydrology. Boreholes drilled for domestic water supplies indicate variable yields. Some boreholes in the Dodoma plain have exceptionally high yields of about 460m^3/hr. The average yield of boreholes (excluding Dar es Salaam and dry boreholes) is 11m^3/hr. The average static water level of productive boreholes is about 17 metres and the average total depth 62 metres[3].

The scope of the drilling market in Tanzania can be projected to include domestic water supply, industrial use, irrigation, recreational use, etc. However, domestic water supply remains the single most important market.

Improved drinking water sources are considered to be all piped water, protected wells, boreholes/tubewells, medium/shallow wells equipped with handpumps, and covered springs. On this basis, the overall percentage of households using improved water in 2000/2001 was found

[3] Calculated from the data provided in the Borehole Database, Dodoma

to be 56% (46% in rural areas and 88% in the urban). This overall coverage was observed to have risen 10% from 46% in 1991[4]. To meet the MDG the NRWSSP aims to provide access to safe water for 74% of the rural population by mid-2015. The Rural Water Supply Investment Requirements were calculated.

This implies an increase in water supply coverage to an additional 14.5 million people by 2015 at a cost of USD 533 million[5]. Obviously, this provides a substantial market for drilling in Tanzania.

Under the assumption that 30% of the shallow wells for handpumps are machine drilled, the investment plan estimates that the following numbers of machined drilled boreholes are needed until 2015 in the various regions.

Region	Handpump & Shallow Well	Handpump & Borehole	Electric / Diesel Pumped & Piped System	Windmills	Total BH
Dodoma	32	399	84	226	741
Arusha	120	175	87	0	382
Kilimanjaro	53	126	18	0	197
Tanga	130	259	59	62	510
Morogoro	249	360	66	0	675
Coast	262	101	39	0	402
Lindi	45	39	85	0	169
Mtwara	146	362	37	0	545
Ruvuma	73	533	61	0	667
Iringa	15	543	13	0	571
Mbeya	131	767	88	0	986
Singida	169	483	50	155	857
Tabora	434	822	143	0	1399
Rukwa	80	567	43	0	690
Kigoma	129	790	63	0	982
Shinyanga	862	1008	167	32	2069
Kagera	525	0	108	0	633
Mwanza	960	1142	106	0	2208
Mara	310	379	75	0	764
Manyara	146	426	105	0	677
Total Tanzania	**4,871**	**9,281**	**1,497**	**475**	**16,124**

Table 1: Boreholes in NRWSSP per region[6]

The below chart shows where the biggest demand is estimated.

[4] MWLD, WaterAID, East African Statistical Training Centre and the National Bureau of Statistics (2002), "Water and Sanitation in Tanzania" , Dar es Salaam, Tanzania

[5] NRWSSP Investment Plan Budget, 2004

[6] NRWSSP Investment Plan Budget, 2004

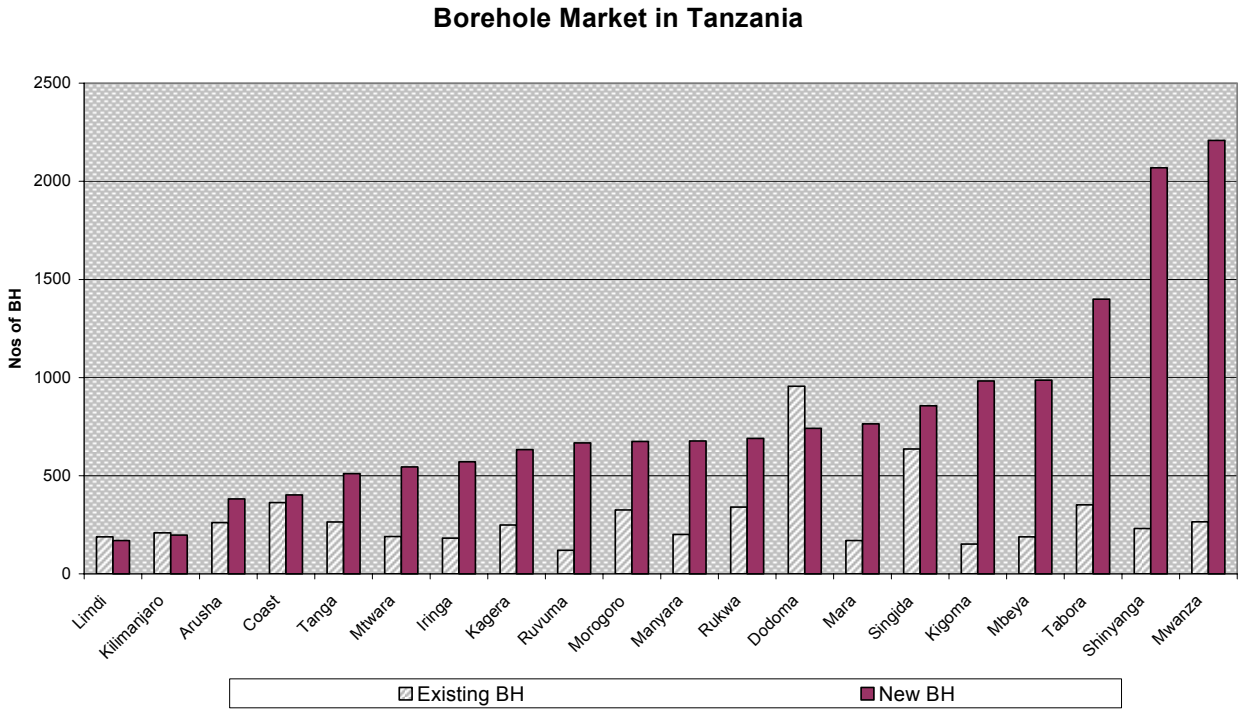


Chart 2: Borehole market[7]

In the next 10 years, about 1,600 boreholes have to be drilled in rural Tanzania annually. Presently, the drilling industry produces about 900 licensed boreholes in rural areas. The capacity needs to be doubled to meet the targets set by the NRWSSP.

The increase of the capacity has to be looked before the background that DDCA, which takes up about 60% of the market, is likely to drop out of the market as a competitor.

The private sector has to make an effort investing in equipment to meet the emerging additional demand. Of the 40 registered companies only about 25% are fully active in rural Tanzania. Assuming a production rate of one borehole in six days (including mobilisation) a well-equipped rig can drill 40 to 60 boreholes per year, a mixture of about 40 rigs from small to large capacity is needed. To bring the drilling industry to a level where they can operate comfortably in all kinds of formation (hard and soft) will require major inputs. The capital investment in this sector amounts to say some USD 4-6 million.

Assuming an average cost of USD 5,000 to 6,000 per borehole, the production of 16,000 boreholes over 10 years provides a turnover of USD 80 to 100 million. With this potential income, the private drilling sector can be expected to investment in better equipment, which would be required for the expanded production needed to meet the MDG. If DDCA stops commercial drilling and sells out its equipment it will probably help five or six companies to be established and to strengthen four or five of the existing ones. Eventually about ten companies might be able to build the capacity for wining contracts in the different regions. Through such reorganisation of the sector, about 50% of the boreholes could be drilled with the available equipment and capacity. The private sector would have to invest in additional equipment and manpower to build up the capacity for drilling the other 50%.

2.1.3 Monitoring Database in Dodoma

In order to obtain a drilling permit it is necessary to apply to the offices of MWLD, Directorate of Water Resources in Dodoma. The WRD of the MWLD has highly qualified personnel and basic facilities. However, the centrally kept borehole data seem to be a legacy from the past that requires updating in content, data entry, and designing a format. The data lacks basic information like coordinates, aquifer test parameters such as transmissivity. The geologic description shows inconsistencies in which similar field conditions are described differently, e.g.

[7] Calculated for drinking water Boreholes only

some qualifiers like decomposed and weathered granite are used interchangeably. This is an example, which indicates a disconnection between the description and the physical condition. The term 'weathered' would be sufficient to describe the state of the rock type.

The office issues a serial number for the borehole and in turn, the drilling company has to submit the borehole data to the office. Presently, the database includes records of 9,242 boreholes. The borehole data collected from the twenty regions of Tanzania (excluding Dar es Salaam's 1,389 boreholes) lists 7,853 boreholes. The records include different level of information for each borehole. Most of the boreholes have incomplete information, normally the district name, location name, total depth, static water level, yield and limited information is available on drawdown, formation, and the quality of water.

The records are full of inconsistencies and inclusions, which make it difficult to process the data. For example some borehole depths are given in meters and others in feet, some unnecessary abbreviation like blg (below ground level) and underscores are included in the columns. Four decimal places after the comma for water levels or depth does not seem to reflect real observations; also two static levels for the same borehole were recorded. In general, when the field data is transferred it would be useful to make the entries with a view of making them suitable for handling and processing with any tabular processing software.

Up until the late nineties, most of the boreholes were drilled by the Government, the regional water office. The Drilling and Dam Construction Agency (DDCA) was officially launched on 26th March 1999. DDCA took over the drilling operations from the regions. DDCA as an 'agency' has been the dominant player in Tanzania – typically averaging 400 boreholes a year. In the last two years, the production of DDCA has gone up to over 500 holes. Since 1999, the boreholes drilled by DDCA are about 60% to 70% of the boreholes that are registered in MWLD central database.
However, it is evident that a large number of boreholes are not registered. Especially the boreholes drilled in Dar es Salaam do not find their way into the database. For instance, the DDCA records from June 2003 to date show that DDCA has drilled 857 boreholes. Of this number, 415 boreholes were drilled in Dar es Salaam. This indicates that 48.4% of all drilling attempts actually were in Dar es Salaam.

Table 2 compares the DDCA records with the data from Dodoma. It shows that in some years DDCA drilled more holes than were recorded at the MWLD. This can be explained; the boreholes drilled for industry and mining are not recorded, but also a large number of non-registered boreholes are drilled in Dar es Salaam (and possibly in the country).

	1998/1999	1999/2000	2000/2001	2001/2002	2002/2003
DDCA	505	583	404	390	422
MWLD	496	556	494	466	411

Table 2: Boreholes drilled by DDCA and registered at MWLD[8]

2.1.4 Drilling in Dar es Salaam

Production of both official and unofficial holes is distorted by the water supply situation in Dar es Salaam urban- and peri-urban areas. The DAWASA, city water supply, has by no means the capacity to meet the current needs and it can not at all keep pace with the population expansion of the city. In 1997, severe drought affected the surface water supply. The worst effects on the population were averted by an emergency programme of drilling boreholes. Dar es Salaam is situated largely on a medium shallow sand aquifer, which easily allows sinking of 30-80m deep holes that normally provide a decent groundwater supply.

This aquifer has been extensively exploited by private house owners and small businesses since 1998. This new market has spawned a number of specialist 'urban only' drilling contractors who only drill in the city and make a good profit from the urban demands. Dar es Salaam drilling work is also undertaken by most other Tanzanian contractors. It is estimated

[8] DDCA records and WRD records

that annually about 1,000 boreholes are drilled. This market provides a sound economic base or workload of perennial commercially available work to the Tanzanian drilling industry.

However, the potential environmental shortcomings if allowed to continue without monitoring and unregulated could be grave.

2.2 The Quality and Status of the Drilling Industry in Tanzania

The Tanzanian drilling industry at present is an emerging industry. In the past until 1999, the government drilled most boreholes. Private sector participation has been minimal. When DDCA was formed, the agency still covered the largest part of the market. The market has been heavily distorted by the extraordinary situation in Dar es Salaam. The present drilling capacity in the private sector was mostly created to meet the demand for sedimentary drilling in the town. The overall capacity to drill is limited. Old and unreliable equipment slow down the implementation rate. The status of the drilling industry will have to be considerably strengthened to cope with the demand foreseen in the NRWSSP that aims to meet the MDG.

The Ministry of Water and Livestock Development (MWLD) has issued three circulars (guidelines), which outlines the basic requirements in groundwater:

- Guidelines on procedures for groundwater exploration in Tanzania mainland
- Government regulations and guidelines on groundwater exploration in Tanzania mainland
- Government specifications and regulations applicable to water well drilling and installation in Tanzania mainland

All firms interested in drilling have to apply for a “Permit for Water Well Drilling and Installation” from the Assistant Director, Hydrogeology Section, Water Resources Division. A list of equipment, drill rigs and accessories as well as CV’s of personnel should be attached to the application. Officers from the Water Resources Division should physically inspect and scrutinise the listed items. These procedures are not strictly followed. Thirty-nine drilling contractors are registered with the MWLD, Directorate of Water Resources. Out of these about 16 are equipped with drilling rigs and can complete borehole on their own. About half of the registered companies hire rigs or compressors and other essential components to drill and complete boreholes. The human resource-, equipment-, material-, and capital capacities in the individual companies vary widely.

The principal players are not more than four or five companies including DDCA. They operate in Arusha, Mwanza, Dodoma, and the Coast regions. The World Bank financed Rural Water Supply and Sanitation Project (RWSSP) attracted nine companies, which participated in the tenders floated by the districts supported under the RWSSP. Most of the companies are equipped to drill in soft formation, and mainly concentrate on the Dar es Salaam area, where there are neither rigorous field conditions nor contractual complexities.

2.2.1 DDCA

Drilling and Dam Construction Agency (DDCA) was formed to develop safe and sustainable water sources through drilling of deep and shallow wells and construction of surface dams for domestic use, irrigation, industrial use, etc.

DDCA operates in the whole country; the agency is the largest drilling contractor in Tanzania. It provides services such as groundwater prospecting, drilling, construction of dams, on a profit basis. Institutionally the agency is as it looks: *“An old government department that has been divided off as an ‘Agency’ with the remains of the drilling fleet of equipment dating back some 70 years”*. With minimal investments in new equipment and limited resources to meet recurrent maintenance costs DDCA has remained an effective borehole drilling organisation: Indeed since the creation of the agency, DDCA has ‘by hook or crook’ maintained an annual production about 500 boreholes.

Since its establishment, DDCA drilled a total of 3,161 boreholes. Implementation of activities is generally satisfactory though the implementation rate is low. This is caused by the poor performance of equipment. The machinery and equipment currently used by DDCA is old and obsolete.

DDCA is excluded from bidding for World Bank financed projects. Despite this exclusion, DDCA gets some part of this market. Successful contractors that do not have the necessary equipment to drill the boreholes specified in the contract tend to "lease" equipment from DDCA. In reality, this leasing is subcontracting DDCA to drill for the contractor. DDCA sometimes coerces the clients to buy them spare parts for repairing an old rig before they start work.

A DDCA client gets the full package; there are no shortcuts to service. The drilling of a borehole includes a competent site survey including geophysics and this is backed up with access to existing borehole logs. The drilled hole is cased with good materials, gravel packed and then developed by a different specialist crew. Once developed, the borehole is test pumped by separate crew. The whole construction process is recorded; a full report is produced with drill log, test pump log, well completion details, and borehole drawing. Unfortunately, DDCA keeps these records for internal use and they are not transferred into a national database.

DDCA has a variety of equipment for different activities. They include 63 drilling rigs (25 functional), 47 heavy plants for dam construction, 20 compressors, and 13 generators as well as a number of vehicles, and survey- and soil laboratory-equipment. Most of the equipment is aged; many rigs are between 30 and 70 years old. To keep them operational is expensive; they frequently break down and require uneconomical repairs. Equipment is grounded due to lack of spare parts and need for major repairs. Verification, registration, and valuation of DDCA's assets were carried out in the year 2001 to establish the depreciated value of the assets. The valuation indicated that only 5% of the drilling rigs and 9% of the vehicles were worth to continue working for the next 5 years[9].

DDCA is under capitalised and no government investments were made. Since its establishment, DDCA did not buy any heavy drilling equipment. Government regulations do not allow purchasing second hand equipment. However, the JICA financed project brought some new drill rigs and compressors to DDCA.

According to DDCA implementation report covering the period from mid 1998 to June 2003 the agency has made a total revenue of TZS 9,881,345,000 against a total expenditure of TZS 8,932,364,000 this leaves a surplus of TZS 948,981,000 (equals roughly USD one million). However, none of the earnings have been allocated to capital expenditure. Over the last years in Dar es Salaam alone, DDCA drilled roughly about 400 boreholes per year, representing an annual turnover of 1 million USD. This income should yield them a margin of about USD 300,000. Why DDCA has not been able to purchase new equipment with these earnings is not clear.

DDCA has a number of skilled and experienced crews, even though many of the staff members are quite young (at least in Dar es Salaam). The DDCA staff is highly qualified (drillers and hydro geologists; Ministry Employees = 88; DDCA Employees = 154; Daily Paid = 54, Total = 296). They also have specific teams for the siting, drilling, development, and construction. The way they operate is (at least in Dar es Salaam) more cost effective than the small drillers that have no specialised teams. DDCA implements projects all over the country. Staff are sometimes underutilised due to lack of modern equipment and poor condition of existing equipment.

The teams met by the review team are enthusiastic and engaged in doing the best possible work.

Some examples:

- DDCA rig yard, George Bernard – has several apparent 'lost causes' to repair. E.g., a 20-year-old Atlas Copco compressor with 10,000 hours needs an extensive engine re-build and reconditioning of the air end. Trucks have been converted with odd alternative engines, cannibalised from other trucks. The sketchy contact he has with original suppliers provides tales of superseded engines and parts, hardly anymore available.
- PAT 201 rig – this light partly hand operated machine is 8 years old. Its purchase cost was about USD 5,000. It is used to drill shallow holes in Dar es Salaam and still generates handsome revenue. The rig is operational but bears witness of several repairs and shows

[9] DDCA Implementation Report 1998 - 2003

considerable wear. The drill crew who uses the rig are well organised and have the skills to construct boreholes of an acceptable standard.

- Schramm rig – this huge machine was deployed to drill an 80m hole. Despite its size, the rig has effectively little more capacity than the PAT 201 as the main mud pump on this huge rig is a small 5 x 4 duplex. The machine functions, but requires considerable innovation to keep it operational. Pipe work is sealed off with wrapped rubber inner tube. Suction flanges without effective gaskets are packed with clay to prevent air leaks. The crew works very professionally and the workers are well organised and disciplined.
- PAT 301 Skid hydraulic rig. This rig is 8 years old and has been used to drill sedimentary holes. Holes are now appearing in the drill pipes. They have drilled so many metres in the often-abrasive drill fluid that they are completely worn through. The steel pipe bends that direct mudflow around the rig have similarly been worn completely away. Once more a well-organised and professional drill crew.

Figure 1 Schramm Rig

2.2.2 Private sector Drilling Companies

KADET Drilling, Onesmo Karumba

The company is managed by the owner. Onesmo Karumba is an ex-MWLD staff member, a Geologist. He is literate and capable. He has invested little capital. He owns a low cost PAT 301 drill rig and couple of second hand trucks. Has an old Compair compressor (175CFM x 6 bar, more than 30 years old) for development. When the review team visited the company, the compressor was down with a defect water pump and a radiator leak.

The quality of the work is not beyond doubts. Last year he drilled in Rufiji and encountered big problems. The geological conditions are sedimentary soil, sand, and clay. The surveying was done with Schlumberger resistivity soundings, based on these the depth to be drilled was determined. Mud drilling to the given depth was done and then the borehole was lined with a 100 mm ID casing. Two to three lengths of slotted screens were placed and gravel packed. The wells were developed with airlifting only. The pump testing revealed in 19 out of 26 cases that the yield was less than 500 litres per hour, below acceptance criteria. Karumba's team did not seem to be very resourceful. Neither the driller nor the supervisor seemed to have any notion of changing their method of working and were just satisfied telling the review team: "Topographic misjudgement, drilling at too high altitude." It appears that all boreholes were drilled and developed before the pump testing took place thus, leaving no room for remedial action.

This year the specifications were changed to 117mm ID casing and the drilling sites were selected at lower altitude. The success rate is definitely better.

The PAT rig is in reasonable condition but the mud pump has a low flow. Drilling of 8-inch diameter holes in sedimentary soil is achievable but slow, due to the poor hole cleaning capacity.

Karumba does not use biodegradable polymer as an alternative to bentonite. This year the driller suggested using a polymers to get better performance and potentially improve well development and well yield. This was rejected by the consultant, immediately seeking a full 'chemical hazard sheet' for the polymer to be deployed to confirm and record its suitability for use in the construction of a drinking water supply.

Karumba is trying to expand his operations but lacks the capital to buy bigger rig. He obtained a quotation for a second hand Schramm Rig with a capacity to drill to 300m. Such a rig with the necessary compressor and trucks would cost about USD 600,000. Even moderate expansion is difficult. In order to get a credit from a commercial bank he would need to have a 125% guarantee and the assurance that he would win further contracts for continual government work.

When the review team asked: "What could be done to improve his position?" He answered: "A lease contract from the World Bank, where the rig could only be used for their work. About 50% of the drilling cost is margin that could be used for equipment repayment."

Hydrotech Ltd

Owner/Manager is Wilson Mgombela. He is ex-MWLD; he left MWLD in 1992 to step out into private sector. When he started his own business, he bought scrap machines and battled them into serviceable condition. The management of Hydrotech has a very positive outlook. Wilson Mgombela is a knowledgeable, intelligent, and committed individual. The total workforce employed is about 20 staff.

Hydrotech has the following equipment:

Rigs	Rockdrill, truck mounted, capacity 200m	
	B80, trailer mounted, capacity 200m	
	Failing, truck mounted, capacity 200m	
	MM, Russian, truck mounted, capacity 200m	
Compressors	2 Atlas Copco	20bar@750CFM
	1 Ingersoll Rand	20bar@1150CFM
	1 Aarzen	14bar@500CFM
	1 XA-XR	13bar@850CFM
Vehicles	2 Trucks	
	5 4WD Pick-ups	

The equipment is old and subject to frequent breakdowns

They are awaiting delivery of an 850CFM x 20 Bar Sullair Air compressor. This was a strategic investment of approximately USD 70 – 80,000, which enables them to perform effective rock drilling, where the compressor capacity effectively determines the rig performance.

Hydrotech works for MWLD (World Bank project), NGOs, and private individuals.

The turnover in the last years was:

1999	TZS 105,000,000	USD 105,000
2000	TZS 124,000,000	USD 124,000
2001	TZS 180,000,000	USD 180,000
2002	TZS 204,000,000	USD 204,000
2003	TZS 256,000,000	USD 256,000

The income is low for a company of this size. Accordingly, the amount available for upgrading equipment or human skills is very limited.

Hydrotech is still quite close to DDCA; the two organisations have a good relationship, and are helping each other out (spare parts repairs). However, Hydrotech finds it unfair competition that DDCA is able to take on work at below commercial rates, due to the special status of the agency (DDCA does not depreciate the equipment or charge for capital cost). The low quotes from DDCA push the prices down.

Working for RWSSP, they were not completely confident with the siting and supervision ability of the TSPs. TSP used inexperienced supervisors who would need additional training. A further aspect that is of concern, when contract variation occurs, the administrative procedures effect that payment are long outstanding (six to twelve months) despite TSP approval.

If DDCA would sell off some of its equipment, Hydrotech would be very interested to participate in the bidding for it.

Jiangsu Geology and Engineering Co. Ltd. (Chinese Contractors)

Jiangsu was visited at the drill site in Mpwapwa district. They are operating a Chinese built table drive rig, which according to the crew can drill a 500mm diameter hole down to 300m. The rig is in good condition including a large mud pump, and the 12bar@750CFM Ingersoll Rand compressor.

A Chinese crew runs the equipment, only some helpers are local. Their operation does little to assist capacity building in the country. The crew gives the impression of being competent however, only one member speaks English.

Jiangsu is a huge multinational Chinese corporation operating in several African countries. The capital equipment is amortised during the Tanzania activities. In the event that this is not possible, the whole operation is moved to a different country.

While working for RWSSP the company produced good work.

The visited drill site was a 40m hole cased with 6-inch casing. The borehole log showed hard material at 8m and substantial water was encountered between 11 to 14m. The estimated yield was 17 m^3 per hour. A second water strike took place at 32m in harder veined basement. This could be a convenient way of explanation to justify why the driller kept on down to 40m drilling depth.

Don Consult's site engineer and the supervising hydrogeologist were not really aware of this construction detail. Eight resistivity surveys were done in this location. The hydrogeologist initially recommended drilling to 55m depths where he expected a water-bearing fissure in consolidated rock. In the actual case, the hole is taking most water from the weathered top layer between 11-14m depth and very little water from underlying fissures. This raises the question why the resistivity survey was interpreted to expect water available at 55m depth and not in a relatively shallow permeable weathered layer.

There is some doubt about the environmental sustainability of the aquifer. The water drawn from this well is rainwater, which falls in this restricted location and soaks into an underground reservoir. The village needs about 350 m^3 per day, the 24 hour test pumping may not give sufficient data to determine the safe production limits and the aquifer storage parameters.

Commercial Drillers in Dar es Salaam

The review team came across some small drilling operations working in built up areas of Dar es Salaam. These drilling operators are presumably working without licenses. The boreholes are not registered with the central database and formal drill logs are not completed. The operators had relatively new PAT 301 type equipment, which was in good working order.

The interviewed drilling crews stated that they are busy and had continued work. The practiced drilling methodology was not quite as professional as DDCA. They are using smaller mud pits. However, they have a better back up with vehicles bringing water and materials.

In addition, the equipment in these units does not include air compressors or tools to drill harder rock holes away from the coastal formation. The indicative cost of a domestic borehole complete with a fitted submersible pump was reported to be USD 3,000 to 4,000.

2.2.3 Supervision, Consultants

Open competitive tendering for drilling and test pumping using indigenous drilling firms' needs strong supervision as such firms might exhibit poor performance coupled with delays due to numerous logistical problems including break down of machines, lack of spares and fuel. Drillers are often reluctant to take instructions from a supervisor. The RWSSP experience piloting procurements through the DWE letting contracts showed that very precise preparation of BoQs is necessary to produce comprehensive tender documents. It also underscored the need for close supervision of the contractors.

In general, the boreholes are drilled, developed, lined, and completed according to the outlined drilling standards. However, borehole or aquifer test results and geological logs are not properly interpreted in most cases. One reason could be that when boreholes are drilled for handpumps, the relevance of data collection and interpretation is reduced. Given the minimum yield criteria, sufficient water is thought to be available for abstraction with handpumps any way.

A present a competent core group of consultants or hydrogeologists exists within the MWLD/DDCA. A few private consulting firms (TSP) conduct hydrogeological/geophysical surveys and supervise the drilling of boreholes. However, with the increased demand for boreholes to be drilled the need for more competent consultants is apparent. The consultants work on behalf of the owner or the district administration. They are responsible for the quality of the borehole drilling, pump testing and completion, etc. However, in some places the review team observed that the contractors were enjoining a free hand and loose supervision.

The production of an appropriately drilled and completed borehole, and the generation of quality borehole data is a shared responsibility between the regulators, consultants, contractors, and owners. Thus, the competence of the respective actors is important. The full realization of the value of the borehole data, as basis for the evaluation of ground water potential, can greatly assist development and management of aquifer systems and defend against impending damages.

Don Consult

Don Consult are one of the private sector technical service providers (TSP) as employed by the RWSSP. TSP consultants are contracted to help in the choice of technology under DRA, to site and design the boreholes, to supervise the drilling contractors, to monitor the drilling operation and to advise on the final borehole construction and completion. The TSP are contracted for a lump sum price (per district) to deliver work against a defined specification on a commercial basis. This model throws up some anomalies that are likely to be noted in the review process of RWSSP.

The review team found that Don Consult had competent staff and reasonable management skills at the headquarters in Dar es Salaam. However, in the field the capacity of the TSP's resident engineers and especially the site supervisors is definitely drawn out quite thin. These engineers are often young and inexperienced. According to the manager, young graduates are employed who have to get two years of employment before the can be accredited as certified engineers. They are very cheap as the employment gives them the opportunity to reach the 2 years required. They are however no match to supervise an experienced driller and they have the responsibility to make assessments and to take decisions about additional work or when to stop. The above example of Rufiji drilling gives way to the belief that a site engineer on the ball could have averted the unsatisfactory situation. In Mpwapwa, the site supervisor was clearly not in control of the drilling operation. The drilling contractor was in charge and related directly to the resident engineer.

With the rapid expansion to the national NRWSSP covering all the 100 rural districts, the capacity in the private sector to provide the specified TSP services could well be overstretched, leading to bad quality work.

2.2.4 Training

The Rewegarulila Water Resources Institute (WRI) is affiliated to DDCA. The government-run training institute provides the core of the training for middle level technicians through this local "technical training school'. School leavers with good academic passes in Maths and Science are

inducted into 3-year training courses. Whilst providing limited field experience the school provides a solid base of knowledge to build field experience.

2.3 Technology

2.3.1 Hydrogeological/Geophysical Survey

The guidelines specify that at least two geophysical methods should be used for choosing a site. Each new water well must be assigned an identification number, and its geographical position given in UTM co-ordinates, all boreholes should be cased and screened to the bottom of the borehole and plugged properly. These guidelines serve as a general guidance. They will be incorporated into the upcoming water law. Presently the guidelines are not fully adhered to. Complete observation of these guidelines could only be effected when a regulating authority fully enforces adherence.

The players in the game are the regulatory body, which issues the guidelines and specifications, the consultant- hydrogeologist involved in siting and supervisory work, the drilling companies, and the owners.

2.3.2 Specifications

The technical range of groundwater abstraction is quite wide.

Hand dugs wells are viable constructions maximising very small water producing zones with underground storage

Hand augered wells, as promoted by the Dutch rural water projects, are a viable method to access water. They are drilled typically into the weathered layers on the wide flat plains.

Drilled Wells

The Government Circular No: 3 Government specifications and regulations applicable to water well drilling and installation in Tanzania, (see Annex III) states: *"All boreholes should be well cased and screened to bottom of the borehole and plugged properly. No open boreholes will be allowed",* and *"Internationally accepted methods of well cleaning, developing and step-drawdown pumping test of at least 24 hours depending on the yield of the borehole shall be followed."*

This instruction, however meagre it might be, seems to be followed mostly. The internal diameter is usually specified at 117mm or 150mm for handpump installations and 150mm for mechanised extraction. This requires according to the tender specifications and BoQ the drilling of 225mm respectively 300mm boreholes.

Most drillers agree, that especially for handpumps, also 4-inch casing (113mm OD x 102mm ID, according to British Standard dies) would be sufficient. It appears that in the past 4-inch casings (110mm OD x 98mm ID, according to ISO Standard dies) were used. Problems were encountered when a submersible pump was inserted for pump testing. The 4mm difference in bore means that a 4-inch submersible pump has sufficient clearance to slide inside the imperial 4-inch pipe but does not fit into the metric pipe. Thus, the use of 4-inch pipes was discontinued.

The borehole diameter has a significant impact on the volume of material that has to be removed when drilling. The volume determines the type and size of the drilling equipment that can be used. It is the diameter that will determine the flow of the drill mud or compressed air, which is required to clean, i.e. to remove debris from a borehole. A 300mm diameter hole needs twice the flow of mud or air than a 225mm hole. This translates into significantly higher capital costs to purchase construction equipment and increases the recurrent operating costs for drilling boreholes, transporting heavier items, fuelling larger engines, and hauling more water to fill mud pits all cost more.

The well development and pump testing practices vary. Even though a 24-hour test is specified for all wells, this is practice is not followed consistently for shallow boreholes. The RWSSP specifies 12-hours tests for shallow wells (in the view of the review team this is a sensible practice). It appears that the authorities are more concerned about sufficient yield than about cost savings. At the same time the practice in the field shows that contractors want to save money and follow the guidelines only loosely.

Similarly, the use of unlined boreholes (in crystalline rock) is not practiced. The risks are considered too big.

Drilling depth

Out of 850 holes drilled by DDCA in all of Tanzania during the last 20 months[10], the deepest hole (dry) is 150m in depth. Only 26 boreholes were drilled deeper than 100m and a total of 50 boreholes were deeper than 80m.

From the data available in the Dodoma Borehole database, 5,848 boreholes were processed to get the average depth, 3,935 boreholes were processed to get the static water level, and 3,533 boreholes were processed to get the yield in the respective different regions. This basic information can be combined with the regional geology to provide an idea of the drilling depth, type of formation and the expected yield. These factors have a direct bearing on the drilling technology to be employed and on the cost implications. The figures below show the results from the survey.

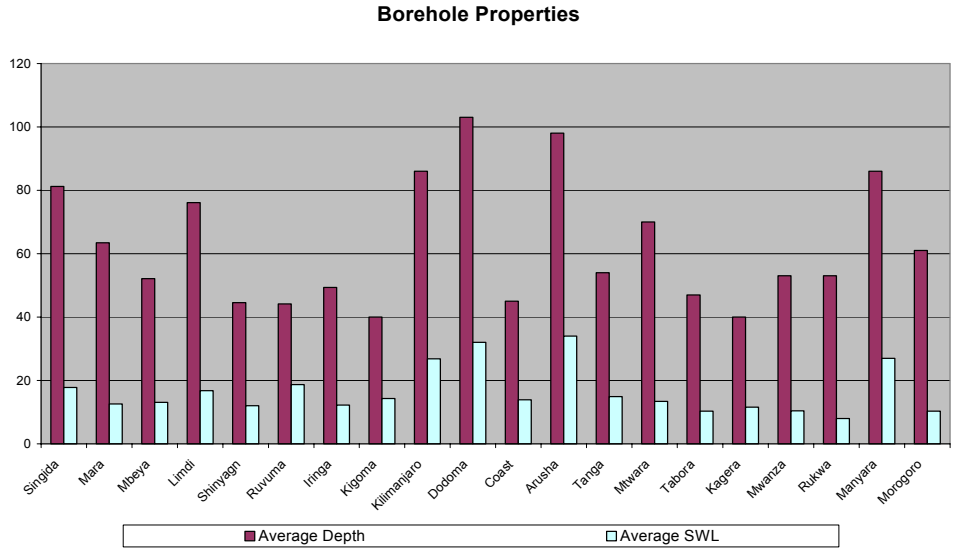


Chart 3: Borehole properties by Region

The average depth of all boreholes drilled in the 20 regions is 62.3m

The average static water level of all boreholes drilled in the 20 regions is 16.5m

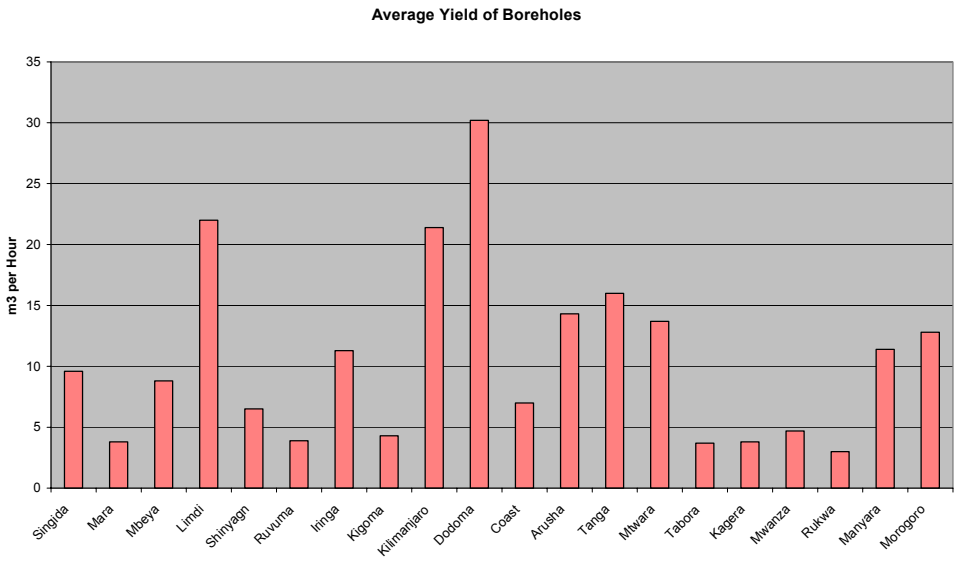


Chart 4: Yield by Region

[10] DDCA Database, Visima Vilivyochimbwa Mwaka, 2003-2004 and 2004-2005

The average yield of all boreholes is 10.6 m^3 per hour. It should be noted that a handpump requires a yield of 0.5 m^3 per hour.

2.4 Equipment, Present Capacity

Mechanised drilling equipment in Tanzania ranges from very lightweight part hand/ part engine operated rigs for mud drilling in the coastal sediments, to examples of still working 1940's Rushton Bucyrus cable tool rigs, through to generally large truck mounted rigs with a mixed selection of mud drilling and compressed air drilling technology. Apart from some isolated examples, most of the equipment is of a considerable age and whilst it is operable, it is in poor state of repair. There is a definite shortage of quality replacement parts. Locally makeshift repairs keep the equipment barely serviceable.

The coastal plains and often deep weathering require drillers to practice and be familiar with mud drilling techniques this requires use and knowledge of water pumps both piston and centrifugal impeller type. Use of mud additives is limited – bentonite is locally available and is used – polymer mud systems are known of but not commonly used. The requirement to haul water for construction with mud is reflected in the equipment lists of the contractors with water bowsers and tankers.

DDCA are possibly the only remaining operator of cable-tool percussion rigs in Tanzania. The review team visited a machine being used close to the sea. It was penetrating first through a consolidated layer of coral/ limestone and then into softer sand, which was hoped to be a fresh water aquifer. The ability of these cable-tool machines to penetrate slowly and to allow the sampling and testing of any water located makes this drilling method still a viable option. The visited Rushton Bucyrus model 22 is an 80-years old classic drill rig design. The rig visited being about 60 to 70 years old. Despite its age, the rig was still operational but bore witness to countless interventions of re-worked components that kept it in its working condition. The review team observed the DDCA operating crew. These were younger-generation drillers, who had recently been passed on the required skills and ability to operate this type of equipment. Worldwide, the skills required for good productive cable tool drilling have largely disappeared in recent years. The lack of skill and expertise for using this method effectively has an effect on the viability of this technique. Modern rotary drilling techniques have replaced percussion drilling. Tanzania has resisted this trend and has maintained a skill base in this area.

Figure 2 Chinese Drill Rig

Tanzania requires a combination of drilling techniques. Like in most of Africa[11], away from the coastal areas, in the middle belt the predominant formation is crystalline rock. Tanzania is characterised by wide, open plains with occasional intrusive rock out crops. Indeed the crystalline rock is in common with most drilling in Africa. However, generally in Tanzania the depth of the weathered mantle over fresh hard crystalline rock is deeper than other countries. This deep weathered layer provides the bulk of the groundwater storage, and this potentially allows for greater well yields than would be typical in this type of rock formations. In certain plains this allows using hand augers penetrating deep enough to the water bearing layer and locating a weathered band of material permeable, which permits to install a screen for abstraction.

However, the weathered layers are a greater challenge to the drillers. Characteristic to this deep weathering layers are that they are unstable and loose. They require permanent or temporary casing during the drilling.

Deeper machine boreholes typically pass through deep layers of weathered rock and into hard rock. DTH (Down the hole hammer) powered by an air compressor need to be used. The air compressor mainly delivers the energy to smash and break the rock. An additional advantage of DTH and compressor method is that any 'water strikes' are immediately noticed and qualitative and quantitative judgements can be made by the drillers. In hard, consolidated rock, DTH hammer drilling typically provides the lowest cost of drilling per metre and the fastest drilling rate. However, this is accomplished with the highest cost capital of equipment. The numbers of metres drilled by a rig per year determine the amortisation cost for the capital investment. To keep the depreciation cost low, DTH rigs need to be productive and to drill many metres.

Both the required 'top hole' techniques of setting working casings and the use of DTH and air compressors are well-established techniques with both DDCA and private drillers.

2.5 Regulation

The Rural Water Supply Division (RWSD) has been assigned the overall responsibility to provide supervisory and advisory services in the development of rural water supply and sanitation services, and to monitor the installation and performance of those services.

However, the National Water Sector Development Strategy (NWSDS) restructuring plan indicates the creation of Basin Water Board and Central Water Board with an advisory role and Basin Water Office (BWO) and a Directorate of Water Resources (DWR) as executive bodies respectively. The creation of a new institutional framework following the Integrated Water Resources Management (IWRM) anticipates the role of the MWLD to shift to policy formulation, monitoring and regulating through the DWR. The DWR will then be responsible for the overall formulation of water resources management policies, development of guidelines and standards.

At the middle level of the organisational structure the Basin Water Office will eventually be responsible for the coordination of all nine river basins, provide advise on policy, legislation and best practices, ownership, rights and distribution of benefits etc. Currently, the Basin Water Office is in charge of only few river basins and has limited resources. Until each basin is sufficiently organised, the nationals Basin Water Office will remain to be very important focal point. The Basin Water Office is not mandated to regulate rural water supply. This function will remain within MWLD.

Already, the BWO are coordinating the Pangani and Rufiji rivers and three river basin offices exist as pilot projects. The aim is to replicate the experience gained to rest of the river basins. The BWO has a big task of expanding and building the river basin offices in all the remaining river basins. DDCA can provide technical assistance to BWO in developing formats and guidelines for assessing and collecting point water sources such as boreholes, dug wells, springs etc. The senior staffs of the DDCA can closely work on ad hoc basis for the facilitation of strengthening of the BWO and building its sub-offices.

The present set up is as follows:

[11] The Hydrogeology of Cristalline Basement Aquifers in Africa, Wright E.P and Burgess W.G, 1992

2.5.1 Prequalification, Drilling Permits

The Ministry of Trade registers companies. The registered company has to apply using appropriate forms for "Application for Permit for Water Well Drilling and Installation in Tanzania Mainland". List of equipment, drill rigs and accessories as well as CVs of personnel are to be attached and a fee paid. Presently when a company applies for a permit, they are registered when the registration fee has been paid. In theory, the Directorate of Water Resources should make an assessment of applicants. The assessment includes vetting of human resources, equipment, and financial capability. This is not done and permits are also not renewed at regular intervals (e.g. 2 years).

No guidelines for pre-qualification exist in the major projects. Only the World Bank project RWSSP has an exclusion rule for government organisations (like DDCA).

2.5.2 Quality assurance

The Construction Monitoring Section of RWSD is tasked with reviewing consultants' TOR; monitoring construction progress; and preparing progress reports.

There is a clear lack of capacity to monitor constantly the performance of drillers and consultants. Contractors are not pre-qualified and do not have to fear consequences for bad work. Contractors showing weak performance should be warned that they might loose the license if the quality of work is not improved. This performance monitoring should be even more rigid when a new contractor tries to get into the market.

2.5.3 Guidelines, Specifications

The Design Supervision Section of RWSD is responsible for policy preparation; reviewing and updating designs and standards (codes of practice); coordinating the operation and financing of pre-feasibility studies. As such, this section together with Directorate of Water Resources would be in charge of the preparation of borehole specifications, production guidelines, and safety measures. The guidelines in use are not specific and have not been revised. Because of the ambiguous guidelines, each project created individual rules. These rules are not consistent or coordinated.

2.6 Procurement

2.6.1 Procurement in RWSSP

Drilling work, like all other contracts in RWSSP, are tendered out. The competitive tendering process takes six months and more before drilling can start.

The RWWSP did not follow a process of pre-qualification. Tenders were published in the newspaper and everybody was invited to tender. According to World Bank regulations, DDCA was not eligible to participate. The bids were opened and reviewed by a tender evaluation team consisting of the Project Coordination Unit. The tender evaluation would not give sufficient importance to full and comprehensive information about the capabilities of the bidders. Post qualification as done in the project did not always reveal the true picture of capacities. For instance, the document for drilling in Rufiji specified 3 deep boreholes and 15 shallow boreholes. The contract was awarded to KADET (Karumba) despite the fact that KADET does not have a drill rig that can drill to the specified depth. During the execution of the contract, Karumba sub-contracted DDCA to drill those three holes.

The review team reviewed tenders that were submitted. Close scrutiny showed that considerable inconsistencies occurred in some of the submission, e.g. the item water sampling was priced in the same document at one place with TZS 200,000 per unit and in an other place with TZS 5,000 per unit and the cost for drilling 300mm dia alluvial varies from TZS 700/m to 60,000/m. These inconsistencies appear to have gone unnoticed during the tender evaluation. The bidding documents (Karumba) contained several calculation errors, which were corrected by the evaluators.

Review Bids									
Bidder	Hydrotech			Karumba			Karumba		
Type of BH	3BH ~70m			3BH ~100m			15BH ~50m		
	Hard Rock			Sedimentary			Sedimentary		
District	Mpwapwa			Rufiji			Rufiji		
Cost Components		per BH	%		per BH			per BH	
Bid cost and overheads	2,640	880	7.2%	1,891	630	4.7%	4,629	309	6.2%
Mobilisation	3,000	1,000	8.2%	1,450	483	3.6%	3,550	237	4.7%
Transport between Sites	648	216	1.8%	1,189	396	3.0%	2,911	194	3.9%
Setting up on Site	600	200	1.6%	157	52	0.4%	383	26	0.5%
Drilling and temp. Casing, Overburden	1,725	575	4.7%	171	57	0.4%	294	20	0.4%
Hard Rock Drilling	6,250	2,083	17.0%		-	0.0%		-	0.0%
Drilling Unconsolidated Formations	2,875	958	7.8%	12,450	4,150	31.1%	7,545	503	10.1%
Air Flushing	360	120	1.0%	60	20	0.1%	300	20	0.4%
Sampling and Borehole Logging.	38	13	0.1%	900	300	2.2%	2,070	138	2.8%
Casing	2,992	997	8.1%	5,100	1,700	12.7%	10,920	728	14.6%
Screen	1,628	543	4.4%	2,800	933	7.0%	5,980	399	8.0%
Gravel Packing, Sealing and Backfilling	1,119	373	3.0%	2,100	700	5.2%	5,510	367	7.3%
Well Development	1,440	480	3.9%	1,920	640	4.8%	9,600	640	12.8%
Pump Testing	1,622	541	4.4%	4,212	1,404	10.5%	8,279	552	11.0%
Water Sampling/disinfection	350	117	1.0%	579	193	1.4%	2,650	177	3.5%
Provisional Sum	6,100	2,033	16.6%	1,450	483	3.6%	3,550	237	4.7%
Sub Total	**33,387**	**11,129**		**36,428**	**12,143**		**68,171**	**4,545**	
Contingencies 10%	3,339	1,113	9.1%	3,643	1,214	9.1%	6,817	454	9.1%
Total	**36,726**	**12,242**	**100%**	**40,071**	**13,357**	**100%**	**74,988**	**4,999**	**100%**
Price per metre	*193.29*	*USD*		*133.57*	*USD*		*99.98*	*USD*	

Table 3: Review bids from RWSSP

- The example of Mpwapwa shows that mobilization and transport between sites make up 10% of the cost, or USD 1,000 per borehole. This is clearly due to the small contract of three boreholes only.
- Screens for the same dia boreholes are USD 543 per hole in the Mpwapwa bid and USD 933 per hole in the Rufiji bid.
- Well development and pump testing is USD 1,021 per hole in the Mpwapwa bid and USD 2,044 per hole in the Rufiji bid.

A systematic review of submitted tenders would give an overall picture of unit costs. When such inconsistencies are discussed with the drillers considerable cost savings could be achieved. However, decentralised procurement makes such an analysis more difficult. An independent regulatory body could take such a task on.

Cost

The analysis of the drilling cost as experienced in the RWSSP shows that the cost was high. The investment plan for the NRWSSP is based on the following unit costs:

	NRWSSP	RWSSP
Shallow well with Handpump	USD 2,490 (incl. Handpump, siting and construction work)	
Borehole with Handpump	USD 7,700 (incl. Handpump, siting and construction work)	USD 5,000 (excl. Handpump, siting and construction work)
Mechanised Borehole	USD 12,500 (incl. siting and construction work)	USD 12,500 (excl. siting and construction work)

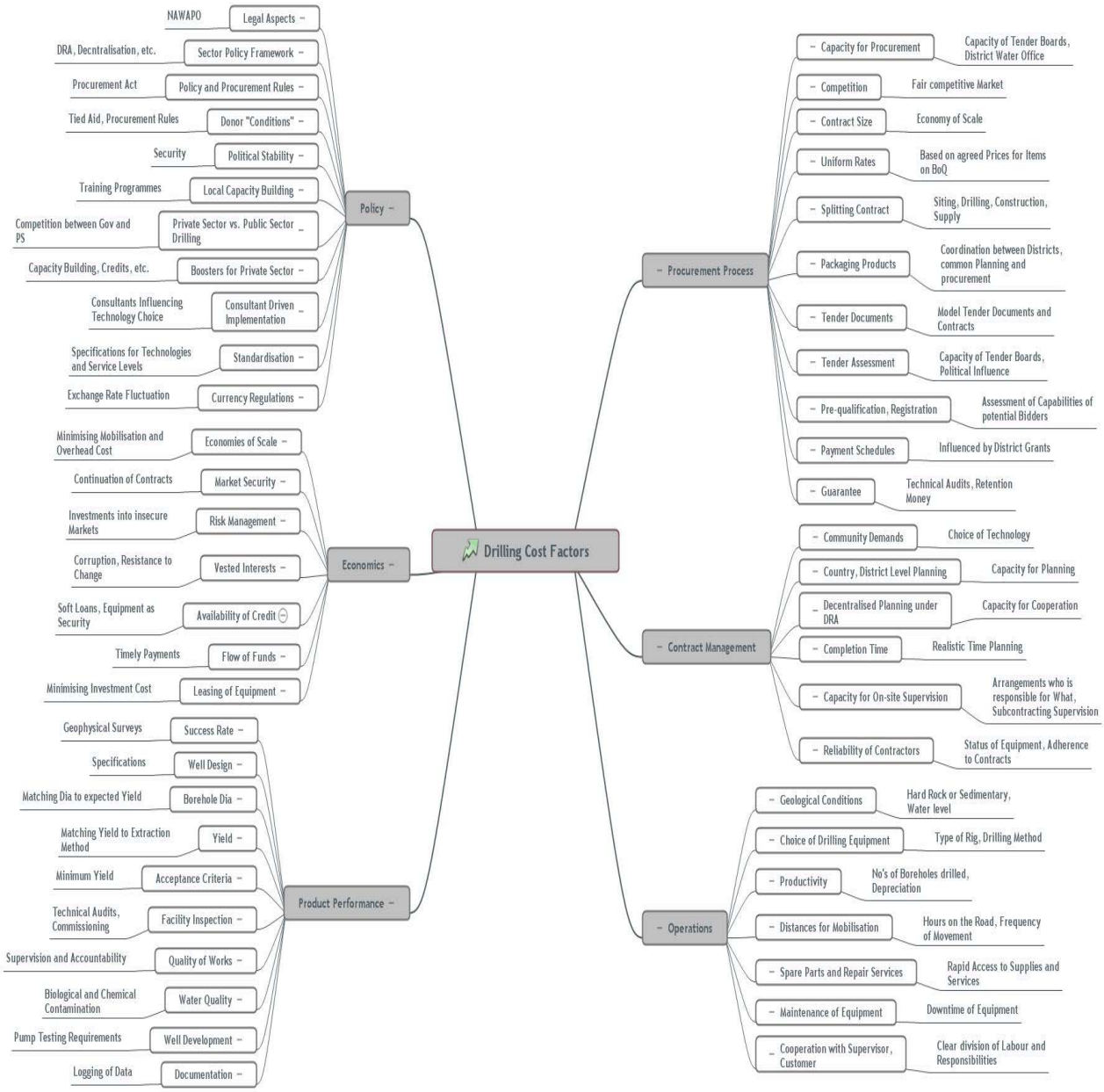
Table 4: Cost comparison NRWSSP vs. RWSSP

These costs include the full facility, i.e. Siting, design, drilling, supervision, construction, and supply of equipment. The drilling cost contributes to only about 50% of the full facility cost. The actual costs in RWSSP were clearly above the expected typical cost for the facilities.

Type of BH	3BH ~70m		3BH ~100m		15BH ~50m	
	Hard Rock		Sedimentary		Sedimentary	
District	Mpwapwa		Rufiji		Rufiji	
Materials	2,030	16.6%	3,526	26.4%	1,671	33.4%
Fuel	1,275	10.4%	817	6.1%	223	4.5%
Labour charges	4,911	40.1%	6,686	50.1%	2,105	42.1%
Overheads	4,026	32.9%	2,328	17.4%	1,000	20.0%
	12,242		**13,357**		**4,999**	

Table 5: Actual Cost from Tenders in RWSSP

It will be a challenge for the NRWSSP to keep cost down. Considering the financial resource stress, it will be essential to keep cost down otherwise meeting the MDG might be just a dream.



The Chart 5: Factors that influence drilling cost

Many of these aspects and factors are closely interlinked, therefore interventions to reduce cost need to weighed against their negative effects. However, the following aspects, which can be influenced in the rural water sector, have a clear positive impact to bring cost down:

- Productivity is key. The investment for a fully equipped drill rig varies between USD 25,000 to 600,000. Depreciation for such equipment is an important cost factor (especially for the higher investment range). Economically, the rigs need to be depreciated over 5 to 7 years. If a rig costs USD 600,000 and drills 20 boreholes a year, it drills 140 boreholes in 7 years. The capital depreciation is about USD 4,300 per borehole. If the productivity goes up to 50 boreholes a year, the capital depreciation is reduced to USD 1,700 per borehole[12].
- Procurement, economies of scale and packaging; (creating an environment in which the drilling industry can use the full capacity of its equipment). Large contract of 200 boreholes and more can effect a reduction in the unit cost due to economies of scale, reduced mobilisation cost and minimised overhead costs. Experience elsewhere (Uganda, Nigeria) showed that small contract of up to 40 boreholes are the most expensive solution. In the RUWASA project in Uganda, the cost for drilling boreholes were for small contracts up to 40 boreholes 33% higher than large contracts of >200 boreholes. The use of uniform rates approach was 26% more costly than large contracts[13].
- Technology; striving towards the optimum value for money, i.e. low cost technologies and optimising the well design (matching well to the pumping devise, reducing borehole diameter).

However, cost considerations are not the only aspects. Quality and sustainability of works need to be taken into account as well. The challenge will be to strive for low cost without jeopardising quality.

2.6.2 Decentralised Procurement under Conditional Grants

When the RWSSP closes and the NRWSSP will be executed throughout the country, the authority of the World Bank to overlook the individual contracts ceases. In this case, the DWE will have to make decisions based on the availability of DCG (District Conditional Grants). This might impede the possibility to make easy changes in subproject design, as they are now quite common in RWSSP. It is unlikely that the provisional sum can be increased to cover all eventualities. Because the districts have a work plan and a budget that has been approved by the MWLD, the total amount approved amount per year is fixed and cannot be exceeded.

From the practical point of view, this might lead to a trend towards low cost solutions and more predictable facility planning, i.e. where a high yield is required for a mechanised borehole the planning bears more risks. That means that the programme should start thinking how such situations are handled.

If the trend goes to shallow wells, the drilling industry might be faced with a slump in orders for a while and the NRWSSP will concentrate first on shallow wells leaving the more difficult options to the end of the planning period (2010 onwards) with consequences for cost and technical issues.

On one hand, a trend towards low cost solutions would be good as the present capacity for planning, design, and construction is not sufficient to meet the potential demand. The drilling industry would have time to adjust to the increasing demand and can grow slowly. On the other hand, there is a risk that the drop in orders is so massive that the industry collapses and will not recover in time. The threat is aggravated especially before the background of an unnatural situation in Dar es Salaam and a highly under capitalised industry.

2.6.3 Working Capital

In RWSSP the private sector contactors have to give a performance bond of 5% of the contract value when they submit the bid. Once they are awarded the contract, drillers are paid a 20% advance.

The contract documents follow standard World Bank format. They are comprehensive and complete. In some cases, they might even be a bit too complicated for the drillers.

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12 Field Note, Solutions for Reducing Borehole Cost in Rural Africa, WSP/RWSN, 2004
13 RUWASA II, Experiences and Lessons learnt, Uganda 2002

Payment takes place after the completion certificates are issued. Retention of 10% is deducted. It is possible to replace the retention with a bank guarantee. Payment of the retention will be at the end of the guarantee period.

If the contract is executed as per plan, this procedure does not hurt the contractors. If a problem arises (like a dry borehole) and the design of the facility needs to be changed, the consultant has to come up with a remedial action plan. In theory, the communities would now need to be consulted again and a new community contribution would need to be negotiated. This is however not practical. After consultation with the DWE and his consent, the consultant goes on with the changes based. Should the variation be bigger than the 15% margin (provisional sum) in the contract, the DWE will need to get approval from the RWSSP project manager. The project management in turn needs a “no objection” from the World Bank procurement department. The World Bank is (naturally) restrictive in issuing “no objections” to variations. Thus, when the changes are substantial the contractor might have to wait for several months before the additional work or material has been accepted as a compensation item. Common sense in the execution of the work dictates that the work continues in the way as if all changes had been approved. Thus, the contractor acts as a bank to the project with consequences to his cash flow situation.

2.7 Disposal of GOT equipment

It was mentioned that DDCA might sell off some of its equipment. The review team looked into this possibility and found that it is quite possible to dispose of equipment. The law recently has changed. It was some years ago possible to the transform government agencies through in-house bidding into private companies. The transition of Plants and Equipment Hiring Company (PEMCO state owned) into TANPLANT is such an example. Today, this is not any longer possible. However, if equipment is auctioned off, everybody (including GoT employees) has the right to bid for the items. That means the DDCA rigs and machinery could be sold off. If DDCA is not directly dissolved, the sales can take place in a staggered manner.

2.7.1 Plant hiring

It appears that plant hiring in Tanzania is a tricky business. PEMCO actually collapsed because the government owned company had to follow government rules and was not flexible enough to respond to the needs of the market. In addition, GoT regulations prohibit the purchase of second hand equipment.

In terms of drilling equipment, the plant hire is even more complicated. When the sector talks about DDCA leasing equipment to private sector contractors, the reality is that the contractor subcontracts DDCA to do the work. This is sensible, especially as with old and vulnerable equipment there is need for a crew that knows how to operate the machine. DDCA on the other hand insists that private contractors, which want to subcontract work, have to pay for repairs and spare parts to make the rented equipment functional. The private contractors complain that when DDCA has the machines running again they will take them back and use them for their own work. There is a clear friction between the two parties, and not all is rosy and cosy. However all encountered drillers come from government service and have therefore a certain loyalty to DCCA.

2.8 Commercial Credit Availability, for working capital and new investment

In order to establish a sound drilling industry a considerable injection of capital is needed. The private sector drillers will need to revert to taking credits from commercial banks. The review team tried to find out the conditions for taking out a credit.

2.8.1 Banks

Discussion with ABC, African Banking Corporation and Eurafrica Bank (EAB) gave the following result:

Private contractors can get credit for the purchase of equipment, however the security needed is 125%, and the interest rate is 18% for TZS and 10% for USD. Land property, houses or capital that is invested n other business are accepted as security. Eurafrica Bank also accepts the equipment as security. Normal repayment rates are 3 years.

An under capitalised contractor has no chance getting any credit. Eurafrica said they would consider a credit based on a good business plan if the creditor had a firm order of the equivalent value from a reputable purchaser. They left it open whether the GoT would be considered trustworthy, they would trust the World Bank. Ideally, the customer should pay the instalments for repayment directly to the bank without going through the creditor.

The bank could retain the ownership of the equipment until it is paid. EAB would allow second-hand equipment as security. They would however insist that the equipment comes from an approved source (mentioned would not accept an Indian rig).

2.8.2 Equipment supplier (MACS)

MACS is the representative of Ingersoll Rand and Atlas Copco. Their terms are absolutely Cash on Delivery. No credit is given. MACS do not see the drilling equipment market as substantial enough to make an effort. They do not stock any spare parts.

2.9 Environmental Concerns in and around Dar es Salaam

Dar es Salaam and the Coast region are heavily populated. Dar es Salaam has about 3 million inhabitants. DAWASA the municipal water supply has not the capacity to supply all households with sufficient water. The people depend on private boreholes for their daily consumption. Dar es Salaam is situated on unconsolidated quaternary sediments with a good potential for ground water with high hydraulic conductivity in the overlaying quaternary sediments. The depth of the water table is very shallow. A sample of 919 boreholes analysed showed a static water level of 12m. Drilling is usually not very deep, records of 1386 boreholes show that they were drilled to an average depth of 49m.

Most boreholes are drilled on a private property, which confines the site selection to limited areas. In Dar Salaam alone there are an about 4000 reported boreholes. It is estimated that an equal amount of not registered boreholes exist. Such huge numbers of boreholes would extract about 50,000 to 70,000 m^3 per day from the aquifer. This corresponds to about 5,000 to 10,000 water tankers.

With such huge numbers of boreholes being in use, they can:

- interfere with one an other
- be contaminated from surface and near surface wastes and latrines. The water table being very shallow, the boreholes are prone to contamination from surface and near surface sources.
- cause salt-water intrusion in case of excessive use

With the impending health hazard and possible damage to the aquifer there is a great need for the citywide study of the ground water quality and potential. Where it is necessary to drill individual boreholes a case-by-case study should be made to weigh their merit in respect of the impending danger. Existing boreholes need to be regularly monitored and inspected and their continued use approved.

When fresh water overlies salt-water aquifer, a judicial use of the aquifer must be exercised. It is an established fact that the salt water rises six metres when the fresh water aquifer is lowered by one metre. Once the saltwater intrusion is widely spread, it becomes very difficult to push the salt water back and restore the aquifer to its original condition. Hence, unregulated abstraction of water should stop and the concerned government health and water authorities need to be authorised to control the situation.

2.10 Victoria Lake Development Project

Lake Victoria has a surface area of 68,800 km2 and a shoreline of 3,500 km. The catchment area is 184,000 km2. It is shared between Kenya, Uganda, and Tanzania 6, 45 and 49 percent respectively.

Current threats to the ecosystem include biodiversity losses, lack of oxygen, increased in algal concentration, wetland damage, water pollution, land degradation and forest loses. The lake water body, the wetland, and the rest of the catchment area are an integrated system that

requires multi-disciplinary and comprehensive approach to plan and execute different development activities compatible with promoting a sustainable ecosystem.

The two phases of the Lake Victoria Environmental Management Project and the East African Community, the broad based regional intergovernmental organization of Kenya, Uganda and Tanzania, have outlined comprehensive plans which invite broad spectrum of investments in fishery, cleaning the lake, reducing pollution, controlling soil degradation, promoting forestry, rural water development and sanitation.

In the Tanzanian sector the Kagera, Mwanza and Mara occupy the southern part of the Lake Victoria catchment. The major towns such as Bukoba, Musoma, and Mwanza are found within the catchment area. The government of Tanzania and Sweden implemented a project known as Health through Sanitation and Water (HESAWA). The program covered health education, environmental sanitation, and water supply in 15 districts of the three regions. The program was carried out for about 15 years and had a significant impact in the improvement of the social and economic welfare of the lake zone population of 4 million. Currently there are no visible NGOs or ESAs presence in the rural water supply and sanitation activities.

In future, the Lake Victoria Environmental Management Project might provide a further market opportunity for the Tanzanian drilling sector.

3 Conclusions

The drilling sector in Tanzania can be characterised by:

- **Sufficient human capacity;** DDCA employs a large number of well-trained drillers and hydrogeologists. This skills base is underutilised because of the way DDCA is forced to operate. Indeed DDCA has produced the majority of a new generation of trained drillers that is now employed by the emerging private contractors. With a transition of DDCA into a regulatory body, the present employees could take this opportunity to start their own private businesses.
- **Lack of equipment:** not all drilling operators have been able to make sufficient investments into new equipment. The equipment is ancient and unreliable. Frequent breakdowns and difficulties obtaining spare parts slow down the performance of the sector. Some of the equipment owned by DDCA could be sold into the private industries. The above-mentioned small private companies (formed by ex-DDCA staff) could purchase the rigs and equipment and keep this operational.
- **Lack of private sector consultants:** The market for TSP and private consulting companies is still very young. It will take some time before a consulting capacity emerges that meets the demands and needs of DWE.
- **Lack of capital:** Nearly all drillers have not enough cash (and outside Dar es Salaam also not enough confidence into the market) to invest in new equipment.

To drill 16,000 boreholes over the next ten years the drilling sector has to develop in the above, but especially in the latter three fields.

3.1 Potential for Private Drilling and Well Construction Industry

Presently, Tanzania has a vibrant growing economy – business opportunities are emerging in all sectors. This growth is also reflected in the drilling industry.

The market opportunities for drilling and exploiting private water supplies in Dar es Salaam leads to a continual, indeed expanding investment in drilling equipment. Dar es Salaam generates enough cash for this expansion. The newest rigs in the country are operating in Dar es Salaam.

PVC pipes for well casings and screens are produced by several local manufacturers. Several stockists import well casing and screen from at Dubai and India – materials arriving by the container loads. Similarly, bentonite, mud pumps, and submersible pumps are available from numerous sources.

The Dar es Salaam market is based on the conditions in the coastal plains (sand aquifers, holes 30-80m deep). The equipment used and the skill base deployed is attuned to this drilling. Therefore, if the Dar es Salaam “drilling bubble” bursts and the contractors are forced to find work in rural areas they are only equipped to drill in the sedimentary deposits of the coastal plains. To move inland onto the basement the drilling industry would need to invest in air compressors, DTH hammers, and probably new larger drilling rigs.

3.2 Scope of market nationally and regionally (by drilling technology)

The deployment of an appropriate drilling rig and the choice of an appropriate drilling method (percussion, rotary percussion, rotary and hydraulic) or technique (the way each method is used) requires the understanding of the geology. Thus, the market availability is divided to correspond to the anticipated technology choice.

To have an overview of the stratigraphic sequence or the depth-wise variation, the existing broad classification of the aquifer formations, and the geologic data of the boreholes in the Dodoma database were analysed[14]. In most regions and notably in Mtwara, Coast, Morogoro, Ruvuma, Shinyanga, Kilimanjaro, Kagera, Lindi, Mwanza and Mebya the dominant water

[14] See also Annex IV, Hydrogeological Map of Tanzania

bearing formations are unconsolidated sand and gravels. In region such as Singida, Mara, Irringa, Kigoma, Dodoma, Rukwa and Manyara the water bearing formations are predominantly weathered and/or fractured Granites/Gneisses. Arusha is dominated by igneous rocks and the water bearing zones are mostly in weathered and fractured lava flows. In Tanga region, the semi-consolidated marine sediments and the Karoo sandstones are mostly the water bearing zones.

The aquifer formation in the country can be generalised into

Category	Aquifer Type	Area %
1	Old, Paleogene, Neogene and Quaternary sediments	20%
2	Volcano-Plutonic/granite	15%
3	Plutonic-Metamorphic/Gneiss rocks	65%

Table 6: Aquifer Categories

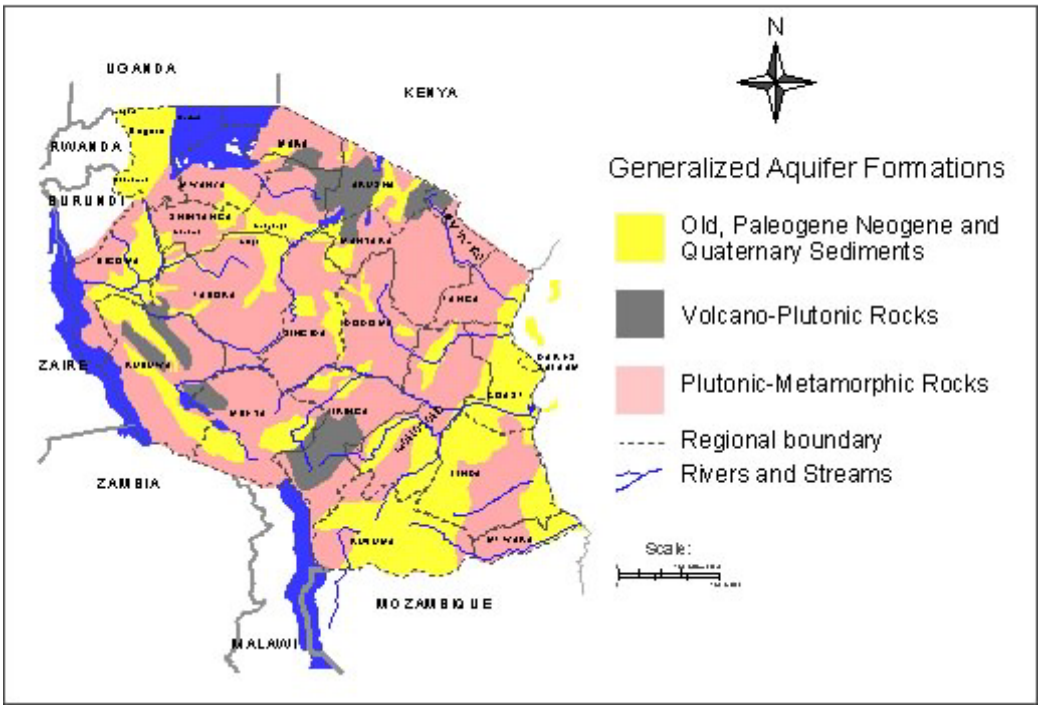

Fig 1: Aquifer Formations

The Old, Paleogene, Neogene and Quaternary sediments are mostly unconsolidated and semi-consolidated where the Old sediments occur. The Volcano-Plutonic are mostly consolidated and the Plutonic-Metamorphic are also consolidated except when weathered.

Boreholes drilled in the 1st and 2nd category are expected to be fairly homogenous depth-wise, mostly sediments in the first and volcanic and granites in the latter. In the 3rd category, typical sections usually include unconsolidated superficial deposits, weathered granites/gneiss, fractured granite/gneiss and solid bedrock.

As a first approximation of the 16,000 borehole expected to be drilled,

- 25% would be in entirely unconsolidated formation (comprising areas that belong to 1st category, and some loose ash flows and pyroclastic material from the 2nd category),
- 60% unconsolidated up to a depth of 20-30 meters and consolidated with greater depth (overburden covering partly weathered Plutonic-Metamorphic rocks 3rd category),
- 15% entirely consolidated (Plutonic-metamorphic rocks, covered by a veneer of dry superficial deposit, and lava flows).

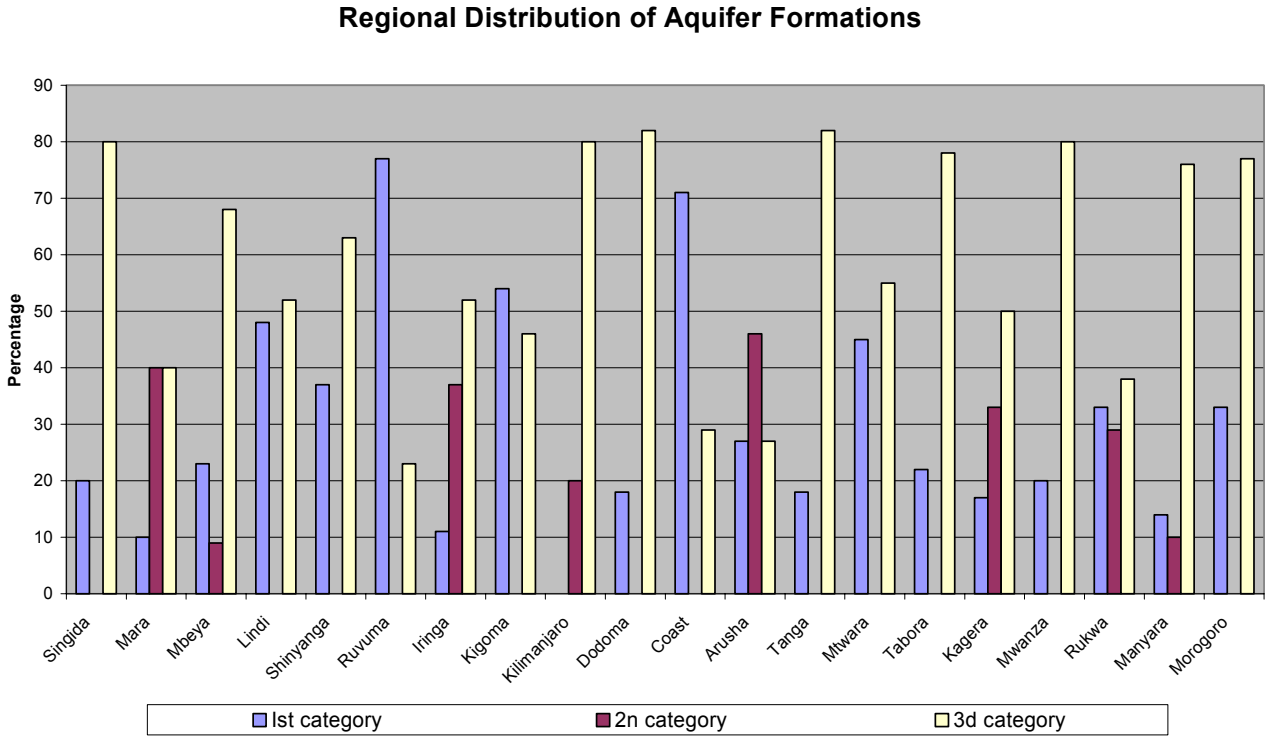

Chart 6: Distribution of Aquifers by Region

Where significant local deposits of sediments overlay the Plutonic-Metamorphic rocks, they constitute an isolated aquifer system. Therefore, while the generalised map could be used as a first approximation for an overall planning borehole siting remains a-case-by-case issue. The above estimate also corresponds agreeably with the numbers of boreholes assumed for the national investment plan (see Table1)

In the common phraseology, boreholes are classified as shallow (0-30m), medium (31-50m), deep (51-80m), and very deep (>80m). The graph below indicates the percentage according to the depth in the regions

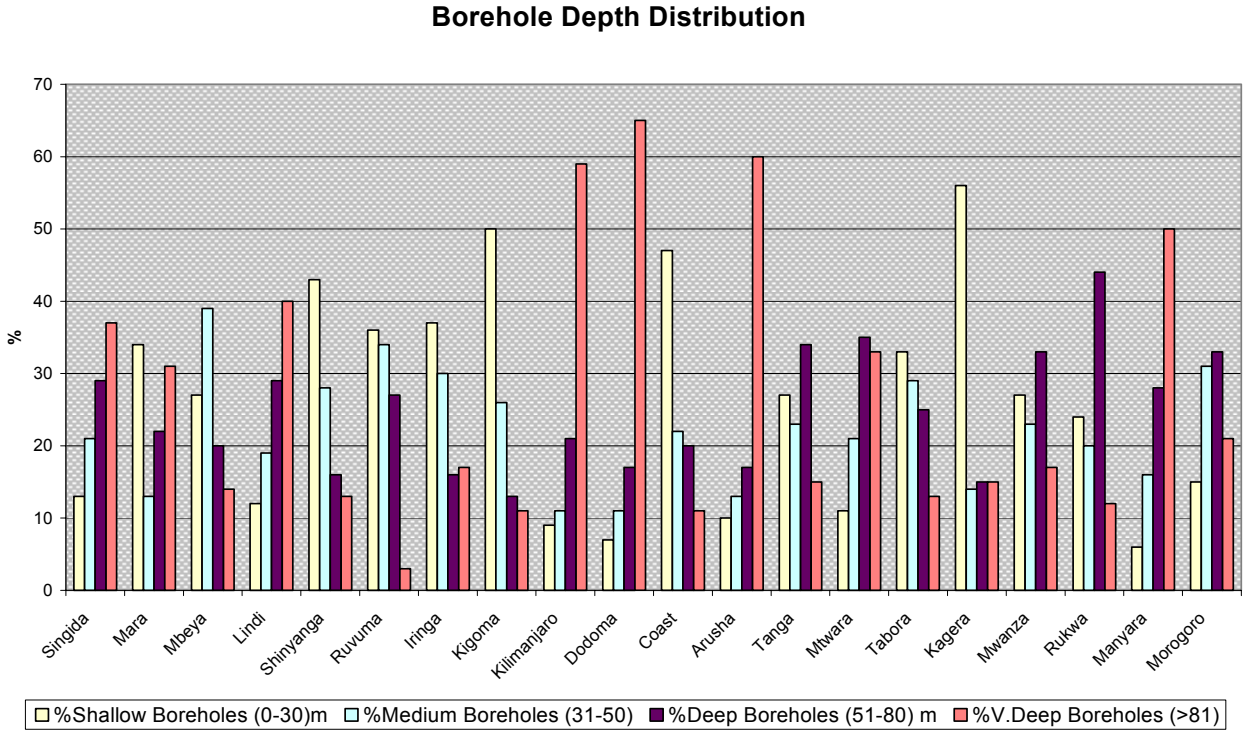

Chart 7: Depth Distribution by Region

The above classifications represent the groundwater conditions of the regions. The number of boreholes to be drilled, the aquifer distribution, and the borehole depth distribution can indicate the type of technology to be used in the different regions.

3.2.1 Boreholes and dug well potential

To corroborate the groundwater condition the boreholes database kept in Dodoma was analysed. In areas where the static water level is less than 8 meters shallow hand dug well fitted with handpumps might be feasible. A quick review of the static water levels reveals that a high percentage of dug wells are possible.

Regions:	Percentage of sites suitable for dug wells
Ruvuma, Dodoma, Arusha, Manyara	20-30%
Tanga	31-40%
Singida, Mara, Iringa, Kigoma, Kilimanjaro,	41-50%
Shinyanga, Coast, Morogoro	51-60%
Mebeya, Mtwara, Kagera, Mwanza, Rukwa	60-70%

Table 7: Suitability for Dug wells

3.3 Technology

3.3.1 Site selection, Surveys

On the specifics of site selection, the consultants are required to undertake a geophysical survey using at least two methods and of which one should be a VES resistivity survey. The data is recorded and plotted on paper or software to come up with a justification or indication of a viable drilling site. This activity does not necessarily guarantee good drill sites. Depending on the hydrogeological conditions, the investigation might be too much or too little. The site engineers query the siting methodology.

In some locations in Tanzania, it certainly should be possible to locate a borehole for a handpump yield just where the community want to peg it. Laying out resistivity wires and data recording are an unnecessary undertaking.

However, in more demanding locations, situated on difficult topography and geology, finding a viable borehole site will require the full deployment of hydrogeological tools, including extensive research of existing abstractions, local mapping, and aerials photograph analysis and satellite imagery. The fieldwork toward the location of the best site can consist of heavy geophysical survey for several days and of repeated data collection.

An optimised siting procedure would require that the hydrogeologists would have to make a judgement on a professional basis where to do the bare minimum and where more work and input is required to achieve the best result.

3.3.2 Borehole Specifications

For handpumps, also 4-inch casing (imperial standard: 113mm OD x 102mm ID but also ISO standard: 110mm OD x 99.6mm ID) would be sufficient. This would allow wells to be test pumped with commonly available 4-inch electric submersible pumps (Nominal OD 95mm). It should be noted that at least three major pump manufactures (one Grundfos with SQ range) are now producing ranges of 3-inch electric submersible pumps that will insert inside casings 90mm OD x 76mm bore.

A 24-hours pumping test is not always necessary. For shallow handpump boreholes, a 12-hours test would be sufficient. In practice, the drillers and consultants follow the guidelines only loosely.

Matching the borehole diameter to the extraction method would provide a savings potential. Similarly, unlined boreholes (in crystalline rock) could be piloted and tried out.

Drilling bigger diameter holes requires bigger drilling equipment. Big rigs cost a huge amount of money to buy and operate. They cost at least three times as much as smaller rigs. If the drilling specifications were optimised, small, lightweight rigs could tackle 90% of the drilling targets in Tanzania.

It needs to be noted that the structural weaknesses in the drilling operations have more influence on cost than the specification. Regardless the potential should be fully exploited and not blocked out by inflexible borehole specifications.

3.4 Regulation

The policy stipulating that all drilling needs to be done through the private sector affects that an emerging drilling industry will be operating in Tanzania. The need to establish an effective regulatory framework is evident.

Prequalification and drilling permits need to be issued based on professional scrutiny of the companies. Permits need to be renewed at regular intervals (e.g. 2 years) based on performance data, and physical inspection of equipment.

Quality has to be monitored constantly. Based on completion records and performance assessments from the DWE, the performance of drillers and consultants needs to be observed. The regulator should carry out spot checks on drilling sites inspecting the actual work execution.

Borehole specifications, production guidelines, and safety measures need to be established and up-dated continuously. This includes also the preparation of model documents for tendering, tender evaluation, and contracts. Contract management guidelines have to be drawn up that will allow the district implementation and help the DWST and DWE to execute the planned work.

The interfaces with the river basin offices have to be clearly defined and the regulatory body has to work closely with these offices to ensure that the borehole designs are made to give the best protection to the ground water resources in terms of quality and aquifer depletion.

Mechanisms have to be defined for the introduction of new and innovative drilling techniques and borehole designs. The regulator might have to work together with selected NGOs. NGOs have the best flexible structures to conduct pilot projects that could represent action research on new designs or methods. Such pilots have to be carried out under controlled and supervised conditions. When a method proves successful, it can be included it into the specifications.

3.4.1 Transformation of the DDCA into Regulatory Body

Present situation:

- DDCA is under capitalised, no government investments, old equipment (25 functional rigs), highly qualified staff (drillers and hydro geologists; Ministry Employees = 88; DDCA Employees = 154; Daily Paid = 54, Total = 296)

Activity:

- Drilling and construction work, are not eligible to tender for WB projects. Drills about 500 boreholes per year (50% in Dar es Salaam and 50% in the country). Customers: Government, NGOs, private
- Not counting Dar es Salaam, DDCA drills about 50 to 60% of all wells in Tanzania.

DDCA structure and way of operating needs to be changed for the following main reason:

- The reform of government structure calls for the line ministries solely concentrate on policy formulation, monitoring and regulatory activities and be completely de-linked from executing implementation,
- Lack of versatility associated with the government regulations and procedures to run and make a profit making agency,
- The DDCA as a para-statal agency, in the long run, could not become viable institution with out the current support rendered in the form of zero capital cost, tax exemption, subsidy in the form of salaries etc and subsequent need for external help,

- The current operation level with old equipment does not enable to earn sufficient profit to allow for equipment replacement. Hence, the DDCA will eventually have less and less equipment to work with.

The review team in discussion with DDCA management formulated an outline how DDCA could be transformed into a regulator body with limited, non-commercial drilling activities. (see chapter 4.1)

4 Recommendations

4.1 Action plan to for transition of DDCA into a Regulatory Body

4.1.1 DDCA Proposal for future:

DDCA prepared a proposal to take on in the future a regulatory and Quality Control function as well as playing a role in equipment leasing. In addition, the proposal includes that DDCA would keep on drilling.

This proposal was discussed between DDCA and the review team, and the result form this deliberations were:

DDCA agrees that the leasing part would not be practical as a government agency could not organise themselves in the necessary flexible manner to effectively manage a plant hiring operation.

The proposed role of a restructured DDCA in future would be:

- **Regulation** (Including definition of interfaces with River basin Organisations)
    - Setting standards and specifications for drilling,
    - Issuing licenses and drilling permits,
    - Monitoring wells for ground water resource evaluations,
    - Collecting and analyzing logs and aquifer test data,
    - Keeping borehole database, which at presented are collected by different offices of the MWLD.
- **Quality assurance** (supervision)
    - Inspecting and supervising
    - arbitration
    - support to DWE and TSP
- **Training** and expert advice
- **Drilling,** non-commercial work

In the processes of reorganizing the MWLD, the DDCA transformation would take place in a three-year period. During the process of the transition, operational functions of the DDCA should be transferred to the private sector. A core group of staff still committed to the public service would be retained. Other technical staff members, who want to venture out into the private sector, would have ample time to do so. Until the private drilling industry is strong enough to take jobs wherever required, DDCA would still be engaged in drilling activities in government priority areas. However, with time emphasis should be shifted to drilling for exploratory and training purposes.

A change over into a mainly regulatory function would effect some other departments and sections of RWSD, e.g. Design Supervision Section, Construction Monitoring Section, Directorate of Water Resources, and the River Basin Offices.

It would be good the hold a national workshop with all stakeholders to define all the tasks and authorities that DDCA will have to perform. Especially the interfaces with BWO and/or DWR need to be clearly outlined. A process of consultation and consensus building should precede the workshop. It might be useful to set up a task force that prepares the institutional changes.

Once the duties and tasks are defined, it will be important to assess the resources available within DDCA. This would entail human skills as well as equipment.

To create a strong regulatory and monitoring agency that can set rules and monitor implementation, a core staff will have be retained from the DDCA and accorded appropriate

incentive and back ups. This includes the equipment, materials, and vehicles necessary for regulatory and monitoring activities.

Thus DDCA would need to gradually cease the commercial drilling operations and work out a plan how it can dispose of staff and equipment not needed for its new function. The present staff comprising of a large number of skilled professionals represents a great human asset in the country. The transitional plan has to make sure that this asset is not lost to the rural water sector. Staff members should be motivated to form their own drilling companies and purchase the drill rigs, equipment, material, and vehicles when they are disposed. Since a management buy-out or in-house biding is not allowed by the procurement act of the government, the DDCA will have to sell out its assets through an open auction or competitive bidding. The privatization should be implemented in stages to allow smooth transition of the DDCA into a regulatory and monitoring body.

The disposition of asset is the responsibly of the accounting office of the MWLD and as and when the dissolution of the DDCA is decided by the relevant office the, privatization of the DDCA can proceed in accordance with government regulations. The privatization processes can be outlined by the MWLD and mandated to the privatization agency for implementation.

4.1.2 Regulation

It is recommended that DDCA is the key agency to establish an effective regulatory framework for the private sector drilling industry operating in Tanzania. It could have the following functions and structure.

Activities: Regulation, setting of standards, enforcement of standards, issuance of permits, quality control, data collection, and MIS

Institutional: Government department or agency within the MWLD (could be added to an existing directorate or (better) be a separate unit. The interfaces between future DDCA, the Directorate of Water Resources, Regional Administrative Secretariats, and the River Basin Authorities need to be clearly defined. The work should be complementary with clearly defined authorizations (the new DDCA should rub shoulders with the other departments but not stand on their toes).

Tasks:

Regulation Private Sector Drillers

The registration of companies is by the Ministry of Trade and drilling permits are issued through DWR. Presently when a company applies for a permit, they are registered when the registration fee has been paid. In future DDCA would have the duty to make an assessment of such applicants. The assessment includes vetting of human resources, equipment, managerial and financial capability. Only if DDCA issued a recommendation the DWR should give the permits. Permits need to be renewed at regular intervals (e.g. 2 years). The renewal has to follow the same pattern as new permits; scrutiny of personnel resources, physical inspection of equipment,

Quality assurance

DDCA role would be to monitor constantly the performance of drillers and TSPs (based on the feedback from the DWE who sends the completion records and performance assessments to DDCA whenever a job is completed). DDCA would have to collect this data and to analyse it on an annual basis. When a contractor shows weak performance, he should be warned that he might loose the license if the quality of work is not improved. This performance monitoring should be even more rigid when a new contractor tries to get into the market.

DDCA should carry out spot checks on drilling sites inspecting the actual work execution.

DDCA having years of drilling experience, could lend support to the TSPs (Consultants or Contractors) by conducting periodic performance monitoring and issuing guidelines and on site advice to enhance their capacity. The capability of the drilling industry is highly variable and some contracts are bound to end up in poor service delivery, which might call for arbitration between the communities and/or DWE, and contractors. DDCA could be called in to provide support in clarifying a situation and offering an experts opinion.

For a greater flexibility, and the in interest of speedy operation the consultant and DWE need to incorporate contingency plans (provisional work) and be adept enough to suggest quick remedial actions. Such practice can be useful especially in situations where package contracts are made and progress on any one borehole affects the overall progress.

Guidelines, Specifications

DDCA would be responsible for the preparation of borehole specifications, production guidelines, and safety measures. This includes also the preparation of model documents for tendering, tender evaluation, and contracts. Contract management guidelines have to be drawn up that will allow the district implementation and help the DWO to execute the planned work. Over time DDCA should also come up with guidelines how to tackle unexpected (but common) problems.

The interfaces with the river basin offices would have to be clearly defined and DDCA is to work closely with these offices to ensure that the borehole designs give the best protection to the ground water resources in terms of quality and aquifer depletion.

For new and innovative drilling techniques and borehole designs, the DDCA would have to work together with selected NGOs. NGOs have normally flexible structures that allow conducting pilot project for action research on new designs or methods. Such pilots would have to be carried out under controlled and supervised conditions. When a method proves successful, DCCA can include it into its specifications. DDCA would also the Tanzanian body that keeps in contact with international developments and should be an active member of technical groundwater organisations such as RWSN. These international contacts will benefit Tanzania and at the same time allow letting others have part in lessons learnt and best practices developed in the country.

Dam construction: the role of DDCA is to vet and approve projects and dam designs; this has to be done in close cooperation between DDCA and the river basin offices.

Database

Presently the database of boreholes kept in the directorate of water resources in Dodoma is incomplete and not up to date. In addition, the data collected is insufficient. For the holes drilled by DDCA it keeps a more comprehensive database.

DDCA together with the river basin offices would need to establish effective data collection on all boreholes in the country. The design of such a database should be governed by the desire to collect all necessary data but not to overload it with unnecessary data. The data has to be analysed on a regular basis. Databases that are in a computer and nobody uses the data for planning purposes or for monitoring O&M efficiency are useless.

Geologic description of the collected samples should reflect the hydraulic properties rather than a random description of what meets the eye. The geologic logs need to be recorded to reflect the entire section as the non-water bearing zones are also important to understand the hydraulic connectivity and correlate with nearby borehole data. Hence, the field data collection and the data entry should be modified, with the processing and ultimate use of the data in mind. The database should provide a complete and consistent description of the field conditions.

Borehole data recording format should be comprehensive enough to include data from all sources and should at least include the coordinate, consistent sample descriptions, borehole and aquifer test results, and the quality of water. Other data such borehole siting details, geophysical logging, gravel packing, pump installation and borehole completion data should be collected and recorded as well. To ensure that the proper data is generated, collected and processed, a formalised or standardised format should be provided and periodic evaluation of processed data should be put in place.

Training

DDCA's new role would, among other things, include training. DDCA should be tasked with the training of DWE, TSP as well the private sector engaged in NRWSSP. New equipment, new innovative drilling techniques, and borehole designs (after being tested as described above) need to be passed on when they go from pilot action research to large-scale dissemination.

DWO personnel need training on quality control and on how to execute certification audits. DDCA as the agency that sets to standards should train the DWE so that these standards are utilised uniformly in the country. Specially, DDCA would have the unique position of training, devising control procedures, monitoring and evaluating the quality of works. The experience gained could then be perfected and integrated in to the future role of the BWO and ultimately to WRD.

Periodic short term courses should be organised to highlight the need of inventory of existing point source hydrogeological data; and the importance of geophysical survey (electrical resistivity, seismic refraction and electromagnetic profiling); and exploratory drilling. Each workshop needs to be accompanied by field demonstrations. On-the-job training given to TSPs will have two fold advantages. Firstly, it will help solve practical field problems, and secondly, replicate and standardise methods of operation. DWE participation in workshops would create awareness in other aspects of source development besides the contractual agreements.

The DCCA should play a role in giving advice to districts in technology choice and work in close cooperation with the departments responsible for the regulation pumping equipment and construction work.

A further field of training could be capacity building of workers that would want to leave government services and start their own business. Such staff members need training in economics, management, business administration, sales, equipment management, and financial issues.

Drilling

DDCA's role in water well drilling should be restricted to non-commercial work. The river basin offices and water resources departments need wells drilled for hydrogeological studies, exploration, and water quality and water table measurement. These boreholes are in their design specific and need to be drilled by experienced crews. In addition, boreholes might be drilled for training purposes. In case of a bottleneck in the private drilling capacity, DDCA could be contracted on a sole source basis for drilling a few boreholes under a project. DDCA would be paid on the same unit price basis as wells that were competitively bid.

DDCA should retain a core staff of well skilled drillers and hydrogeologists to perform this kind of work. To execute it operational functions the core team should be equipped with a small number (2) of efficient and new drilling rigs and auxiliary equipment. Such equipment should be kept constantly in good working order and if necessary replaced at regular intervals. These resources in material and human skills should also be kept ready for the case of emergencies. A new influx of refugees or a drought would need a quick response by a ready and efficient unit. This includes that the MWLD would have to provide a specific budget line for upkeep (maintenance and renewal) of a basic stock of equipment (rigs) within DDCA. .

4.1.3 Transitional Arrangement (Implementation Plan)

A transition period of at least 3 years is required to make the necessary changes in DDCA. The formulation of a vision and mission for the agency will take some time. The process should be carried out with highest transparency and it should include coordination with all involved stakeholders. AS mentioned above a task force carrying out the process should be formed. The identification and separation of the personnel and assets to be retained should be given a priority.

Personnel: Highly qualified technical staff, about 30 to 50 persons (retain more academically oriented DDCA staff). The personnel that cannot be absorbed in to the drilling and training teams should be notified as early as possible. These employees would be motivated to form private sector drilling companies or consulting companies.

The assets to be retained need to be identified jointly by the DDCA technical staff and the agency responsible for the privatisation. Once the identification and valuation is completed, all assets not required by the DDCA should be transferred to the privatising agency for disposal.

The not needed equipment would be auctioned off; with the specific aim that employees could purchase the rigs, which they know and had been working on. The drilling crews of DDCA could

set up independent private drilling companies. This would be the basis of a future expanded drilling industry. The drill crews have good professional skills and little capital. Technical (training) and financial (credit) assistance will be necessary to get these companies started.

Technical staff of DDCA (hyrdogeologists, engineers, etc.) not anymore needed in the new function of DDCA could be motivated to form new companies that functions as a TSP and provides technical services such as siting, supervision, and design. A further option could be that this type of DDCA staff is absorbed in the presently operating TSP.

Similarly, the heavy machinery for dam construction would be sold and again the workers should be motivated to form their own construction companies.

4.1.4 Communications

It is absolutely essential that the plans for transforming DDCA are properly communicated to the workers and that the chances that these changes offer are explained.

The drilling market in Tanzania would need these workers. They will have to found new private sector companies and should be utilising the equipment that is in the country.

4.2 Planning Process in the Districts

(DRA, Conditional Grants, 3 yrs rolling plans,)

Tanzania has taken the decision to move towards decentralisation and the SWAP approach. This approach has several advantages. Instead of executing projects, all major stakeholders (national institutions, local governments, donors, NGOs, and communities) follow a common approach, based on best practices. Planning and budgeting are done in one combined planning process. In Tanzania 100 rural districts will be planning water systems. This means that the theoretical market for borehole drilling of about 1,600 boreholes per annum will be fragmented in to 100 individual contracts of about 15 boreholes each. Every one of these contracts needs a tender documents, bid-evaluation, and order. The time and energy needed to handle this administrative load is in an unfavourable relationship to the value of the contracts. A drawback coming from the fragmentation of the market is that the economies of scales are lost. The drilling bids submitted to RWSSP show very high cost for “Bid and Overheads” and for “Mobilisation” due to the small lot sizes.

Mechanisms have to be found under which NGOs can be integrated into the district planning process and the drilling operation (if they operate a drill rig) without necessarily taking away their autonomy in sub-project execution.

Private sector driller who are willing and able to invest in the improvement of the operations (training of personnel and new equipment) need to have a predictable market forecast. Especially when credits for investment are needed commercial banks devise their credit conditions on the business plans with realistic and predictable order books.

4.3 Procurement

Procurement processes would need to be focused on creating a future market for the drilling industry. If deemed effective and suitable, they should allow contract packaging and contract provisions that encourage the entry of international drillers through larger contracts. But primarily, they should promote local drillers with a steady stream of smaller contracts. It will be very important to find ways of helping local drilling companies to enter into the market by providing finance for suitable lower-cost rigs, perhaps technical assistance, and supply chain support.

The medium term budget framework under SWAP requires swift planning and execution of the work. The competitive tendering process is very time consuming it takes six months before drilling can start. District Tender Boards are subject to political changes. After elections, many new District Councils may want to appoint new district tender boards and old ones are either dissolved or suspended. New boards need time to become effective and thus districts tendering for works can come to a stand still or is very time consuming.

The RWSSP experience with free invitation for tendering and post-qualification showed that this approach should not be norm in district tendering. As a regulator, DDCA provides specifications of acceptable equipment and after equipment inspections approves firms as pre-qualified contractors for drilling contracts. For proper pre-qualification procedures, the type of drilling rig/equipment to use needs to be inspected and it needs to be verified that the contractor has skilled staff on site. If old and obsolete equipment is used such as cable tool rigs or very old rotary rig progress of work is slow. Additional time for completing the contracts can jeopardise the execution of planned work in the expenditure framework. And it has cost implications for the districts in terms of additional supervisory costs. A solution might be that for extensions the contractor has to bear the extra supervision costs. At an agreed rate, the additional supervisory cost for the extra days is deducted from the contractor's payment.

The challenge in the NRWSSP will be to create an environment in which the administrative burden is as small as possible and in which economies of scale are achieved. Other mechanism than district level tendering will be required. Tanzania has set an important example that such deviations from the norm are possible by using a pragmatic approach to handpump supply chains. The review team therefore recommends that other options than the presently practised bidding for small contracts are used and implemented.

4.3.1 Uniform rates

The below outlined system with uniform rates would be the procurement option that appears to fit best to the Tanzanian environment. It has the big advantage to make best use of the limited capacity available in the private sector drilling industry. Further, very important, it assists the district authorities in letting out contracts quickly. Locally based drilling companies have an advantage over those from far away. They can offer their services do the district repetitively and it is hoped that this continuity of using the same contractor would create familiarity on both sides and would enhance the accountability.

To speed up the contracting process the use of uniform rates for drilling can be adopted. That means in a national tendering process for fictive boreholes (conducted for instance by the regulatory body, MWLD in conjunction with a central tender board or contracts committees in the ministry) unit charges are established. After tendering, MWLD negotiates with pre-qualified contractors the applicable unit price per activity specified in the bills of quantities (BoQ). They are approved by the Contracts Committees in the ministry on an annual basis. The pricelist is used for contracting drilling firms. With this uniform rates approach, the districts award contracts to pre-qualified firms based on their capacities and availability. The approach simplifies and shortens the contracting process. It results in speeding up drilling rates, However, it does not promote direct competition for each individual contract.

Under DCG where the achievement of outputs in a short time is important, the 'uniform rates' approach appreciably reduces the length of the tendering process. Further, it would provide a simple mechanism for districts, which decide combined planning and packaging of their borehole drilling. These districts could jointly contract the same drilling company thus achieving an economy of scale.

As mentioned before, experience elsewhere showed that despite uniform rates do not put into effect direct competition, the cost saving due to more efficient planning and better utilisation of available capacity outweighs the gains from direct tendering.

Recently the TZS has been fairly stable against the USD. However, a problem could be caused if there are significant changes in the currency exchange rates affecting the unit costs of inputs. To overcome such complications it would be necessary to adopt a foreign currency and convert all rates. Invoicing can be done in the foreign currency, but payments are made TZS equivalent based on the actual exchange rates.

4.3.2 Concessions, Down-stream Work, Rolling Contracts

In order to achieve accountability and long-term responsibility for work done in one area it is desirable when the same contractor is employed over several years. Assumed that a drilling contractor has worked satisfactory during the execution of the work it would make sense to give the next lot of work again to the same contractor. This would create an incentive for the

contractor to do a good job. It would also create a long-term relationship with the supervisor and the DWE.

Mechanism how concessions could be granted to contract down-stream work would need to be worked out. Uniform rate approaches would be a useful pre-condition for such approaches.

Market security for a driller would allow him to invest in equipment and human resources. Contract packaging and business models should be considered in which local start-up companies are supported with a lease-purchase arrangements that allows them to pay back the investment over a number of boreholes. Technical assistance should be provided to ensure the local contractor is operating and maintaining the rig properly.

4.3.3 Three years budget guarantee

The district administrations prepare the district development plans on a three-year rolling basis.

Projects like mechanised systems with a distribution network for a small town require a longer planning horizon then one year. A piped system requires easily a total construction time of two years. The work not only involves the design and the physical construction. The management system and the financing mechanism for operating the facility need to be put in place as well. This requires considerable social inputs and training. All this has to go in parallel with the physical construction work. Therefore, a decision to build a mechanised system entails a commitment by the districts that extends over a period of more than one year.

It is recommended that the three-year rolling plans be approved in principle at central level. Once a plan is approved, it includes the commitment from central government and from the local government to execute the plan as close as possible. It is obvious that such long-term commitments cannot be made right down to the last shilling. The security of the long-term funding could be around 80% for the second year and 70% for the third year. This would allow the district to make long-term commitments for bigger projects. Accordingly, the contract period could also be extended to 3 years. This again would create market security and bigger contract sizes.

Three-year plan approval would allow districts to alternate their development projects. With a longer planning cycle, instead of implementing a mix of technologies every year (e.g., 20 shallow boreholes, 11 deep boreholes, etc.); in year one, they could do all the siting and design and in year two the drilling and construction would take place. An implementation pattern could than be:

- year one: drilling 40 shallow boreholes, siting 22 deep boreholes
- year two: 0 shallow boreholes, drilling and construction 22 deep boreholes

The total achievements would be the same but it would be possible to utilise economies of scale and concentrate on one technology during the year. Depending on the technologies used, the amount of funding needed per year would be about the same, and be the number of additional persons served would also remain about steady.

However, with the present practice the district authorities only know how much funding will be allocated for rural water and sanitation when the annual budget is approved.

4.3.4 Regional Coordination between Districts

If planning for RWS facilities were done in a coordinated way in the regions, it would be possible to package the drilling contracts together. Such contracts covering several districts would create sizable lots that could attract also international companies.

4.3.5 Letting out big contracts

The probably most cost effective solution would be to divide the 16,000 boreholes into (let us says) four lots and tender out all borehole drilling to 3 or 4 big drilling companies. They would drill 4,000 boreholes over 10 years. The quality of the holes would be acceptable since a big company can put in place the adequate quality control procedures. This approach is not very practicable, as it does not fit in with DRA principles. Big companies would need to have long-term work plans that cannot be changed. In addition, the likelihood that such contracts would be

won by international companies is very high. Such companies would do very little to build local capacities. The profits are taken out of the country. Therefore, this approach cannot be recommended.

4.4 Monitoring, database for boreholes

A well-maintained database is a prerequisite for water resources assessment and evaluation. Current borehole records have the essential elements. However, to transfer the information to GIS system at least the coordinates of every borehole must be re-established. Finding a position to high accuracy is easily done by using Global Positioning Systems (GPS). The attributes or the borehole data need to be standardised for ease of data entry. Once the necessary data is established data analysis, representing and reporting can be generated as and when required. The GIS practiced at Dodoma can be applied at the districts level provided the necessary training is given. When the network is sufficiently expanded data sharing between districts and higher administrative echelons will be made easy. With the use of GIS updating, producing accurately referenced map and desktop publishing becomes routine. The consistency of input data can be monitored and tested periodically to ensure quality data collection and storage.

Management Information Systems (MIS) are tools for data processing helping to organise and support informed decision-making. Several attempts to create MIS have taken place or are in the process of being implemented by different projects, e.g. the GTZ supported project and the RWSSP. Any new data collection and setting up of databases would need to be integrated with ongoing MIS systems. All these endeavours rely on computer-based MIS. An important pre-requisite for the establishment of an effective MIS is to define input data in view of the eventual use of the output. The output is only as good as the input. Collection of data should be as much as necessary and as little as possible. The emphasis should be on the quality and usefulness of the data and not on the technical opportunities. The districts need to collect up-to-date and accurate data to generate useful reports.

Systematic monitoring and reporting at district level would allow collecting data that could be transferred in to the national MIS system. Such data would be the basis for decisions like district allocations and distribution of grants in an equitable way.

4.5 Technologies Borehole Specifications

- The use of plastics as well lining is well established for groundwater abstractions. PVC pipes: are lightweight and flexible to carry and install over steel.
- are corrosion free
- allow cheap production of well screens. A plastic pipe can be easily slit with saw blades to slot sizes as small as 0.25mm.

However, conventional well design does not make use of the full potential of this material.

4.5.1 Reduced Screen Diameter, an example of potential innovation

- In Tanzania, the convention requires a sedimentary hole for handpump abstraction to be screened and gravel packed, using a uniform diameter of casing and screen of 150mm bore. In some cases casing with 102mm ID are used.
- To place the 4-inch (113mm) screen good drilling practice would require gravel pack of 50-75mm thickness. Actually, a fully effective gravel pack needs to be only 12mm thick (Groundwater & Wells). However, the practical issue is how to ensure this minimal thickness is maintained in hole unlikely to be straight with pipe that equally is not straight.
- Given the ease of producing highly efficient well screen from plastic pipe by slotting, most low yielding boreholes need very short lengths of well screen. One metre has enough open area to be safely considered adequate for the required flow for a handpump. Certainly, no harm is done in over specifying the screen to ensure good yields.

- Good borehole design places the well screen towards the base of the aquifer and allows the water to rest and flow upwards into the plain cased part of the borehole. This promotes less turbulent flow at the well screen.

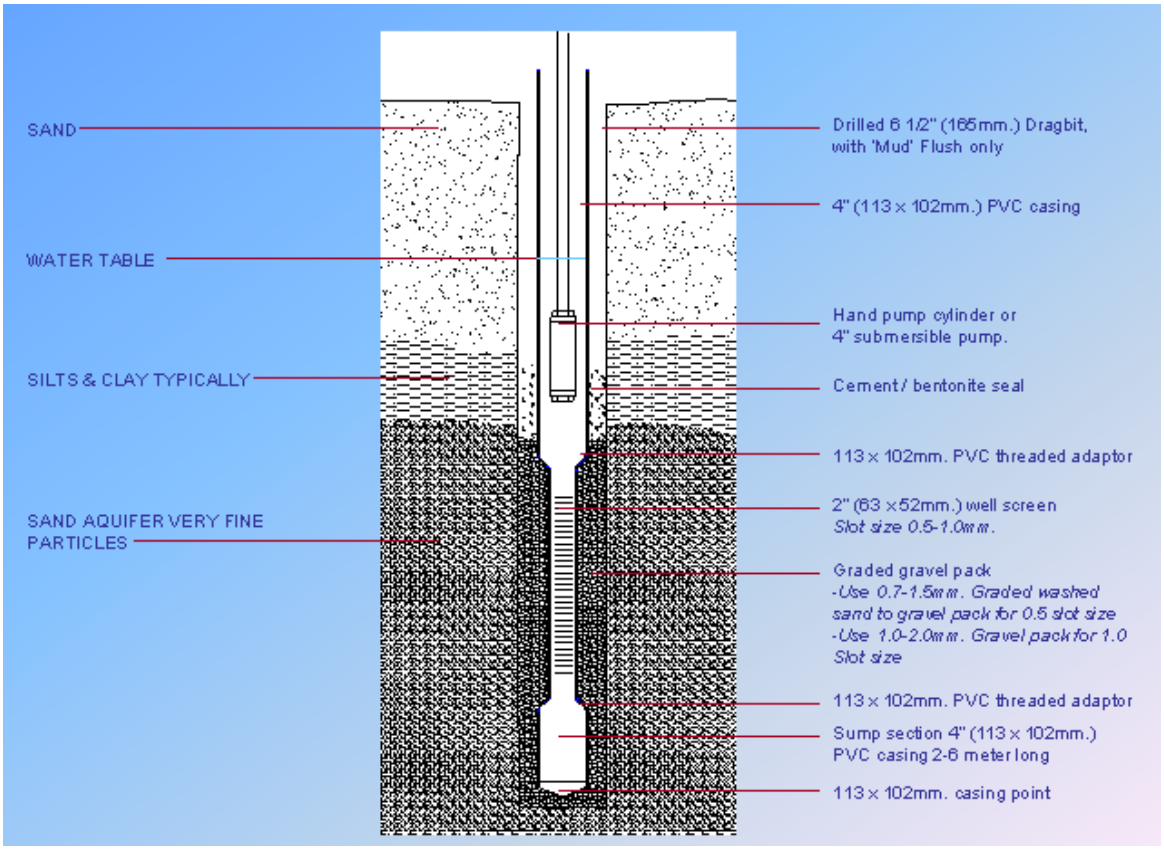

Fig 2: reduced Diameter Well Screen

The reduced diameter screen solution takes advantage of each of the suppositions above.

- The 2-inch screen section can be a high capacity continuous slot type screen equal to a normal 4-inch plain slotted screen pipe. Although, the use of this design screen is actually unnecessary for an inflow velocity required for a handpump or even modest submersible pump. Since the screen is fitted between 2 pieces of 4-inch casing a positive annulus exists it will always provide an annulus of minimum 20mm thickness for the gravel pack. The pump cylinder is placed in its desired location for intake, above the screen. In fact, it becomes impossible to put the pump in the wrong place.

What is the significance of this design? Is it purely a few dollar cost saving on three metres of 2-inch screen vs. 4-inch screen? The real cost saving effects are in the drilling. The borehole required to accept this design need only be drilled a 150mm (6-inch) diameter and not the current specified of 225mm (9-inch).

The effects on drilling operations would be for a hole drilled with mud circulation:

Operation	**150mm (6-inch) diameter hole**	**225mm (9-inch) diameter hole**
Mud Pump Flow, To lift debris from bottom of borehole	200/400 litres minute	800/900 litres/min
Water to Fill mud pits – carried to site – 3 times borehole volume – 50m hole	2700 litres	7500 litres
Volume of spoil removed 50m hole	.85 m cube	2.5m cube

The effects on drilling operations would be for a hole drilled with compressed air and down-the-hole hammer:

Operation	150mm (6-inch) diameter hole	225mm (9-inch) diameter hole
Air Compressor flow. To lift debris from bottom of borehole	11/13m cube/min 400/450 CFM	20/30 m cube min 750/1000 CFM
Capital Cost of Unit	$40,000	$90,000
Fuel Consumption estimated for 50m hole	200 litres	600 litres

Pilot Project to establish viability

This type of borehole design is not used in Tanzania. Even though, the theory and practice of such design holds up experience has to be made in the field in Tanzania. Only if the design has been properly tested this option could be recommended as an alternative design.

To introduce such a novel idea it would ideally require a pilot project to make some trial installations. The well performance of these boreholes would then need to be monitored over a safe period to establish whether this design it is a working option that can be considered as a recommended option.

Since such a test needs additional resources and special attention, it is recommended that the MWLD cooperates with an NGO to conduct such a pilot project.

4.5.2 Unlined Boreholes in Hard Rock

Many countries (India, Sudan, etc.) specify the boreholes to be unlined in hard rock formations. Many million boreholes have been drilled to this design. Such unlined boreholes represent a considerable potential for cost saving. The drilling diameter can be smaller, casing and the screen can be saved, and no gravel pack is used.

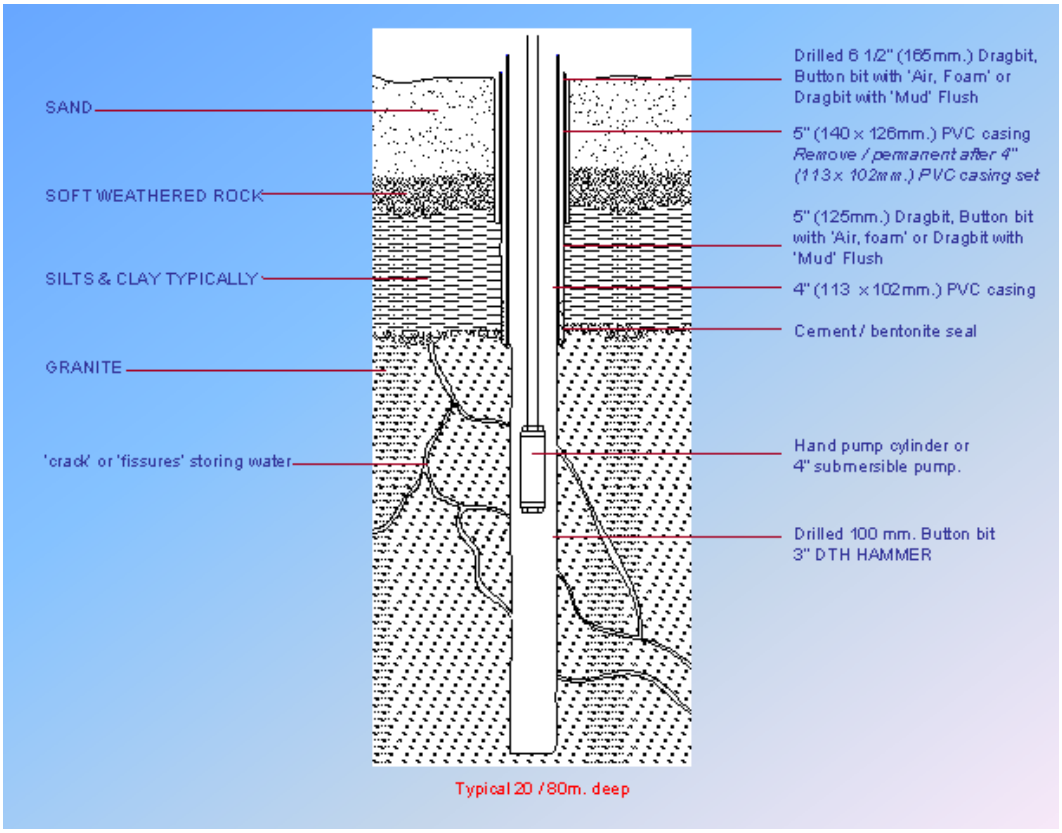

Fig 3: Unlined Borehole

In Tanzania, this design is not used and a considerable potential for cost reduction lies idle.

However, it would be useful to gain some in-country experience and skills to deploy such a technology successful. As with the reduced screen diameter option it would be best to introduce the technology through a pilot project. It is recommended that the MWLD cooperates with an NGO to conduct such a pilot project.