FORUM FOR GROUNDWATER

ISSUE THREE

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Welcome to the third issue of the Forum, a newsletter about groundwater development in Africa. It is available to download from the following websites, together with back issues:

http://burdon.wwgw.org/
http://www.waternet.co.za/groundwater/

In this issue Callist Tindimugaya discusses groundwater mapping and other tools for improving groundwater services, with an emphasis on Uganda but with many lessons for other countries. Jeff Davies continues his discussions of African hydrogeological environments with an article on basement rocks in Zimbabwe, and his experiences working on drought alleviation in that country. Ralf Klingbeil of BGR (German Federal Institute for Geosciences and Natural Resources) provides three articles detailing groundwater related work they are or have been involved in recently. The first focuses on a project in which BGR is cooperating with WA-Net and WaterNet to identify and assess skills and capacity needs related to groundwater in Western and Southern Africa. The second describes joint Namibian-German groundwater exploration using some sophisticated geophysical techniques, whilst the third describes a Zambian-German groundwater cooperation project.

An issue which seems to tie all five articles together is the importance of collecting, interpreting and using groundwater data in the best way possible. Correctly used, groundwater data makes drilling much more successful, helps to ensure that supplies are sustainable, and reduces costs. This is an issue which is understood by groundwater experts the world over, but is not always well communicated to planners, funders and other project partners. As groundwater professionals we have a responsibility to make sure that groundwater data is valued – since ultimately, this is the only way we can "see" this hidden but exceptionally valuable resource.

"Forum for Groundwater" is coordinated by the IAH Burdon Network and the CSIR Water Resources Competence Area. Views and opinions expressed in this Forum are those of the individual authors. It is intended to be a discussion forum for those interested in groundwater, with an emphasis on African groundwater.

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If you would like to contribute to the Forum, please contact Jude (above). We are always looking for material on aspects of groundwater in Africa, particularly by those working in or interested in Africa. Letters, emails and general comments are also most welcome.

CONTENTS

GROUNDWATER MAPPING AND ITS IMPLICATIONS FOR RURAL WATER SUPPLY COVERAGE IN UGANDA

– Callist Tindimugaya

Introduction

Groundwater plays a significant role in domestic water supply in Uganda with its development commencing in the early part of this century. Groundwater development, based on deep boreholes, shallow wells and protection of springs is however greatly influenced by the varied geological conditions, which consist of very old Precambrian rocks that underlie over 90% of the country. Thus, aquifers occur in the weathered overburden (regolith) and in the fractured bedrock.

Groundwater development plans at both the national and district (local government) levels have been made with very little information on the hydrogeological conditions and groundwater potential of various areas. This has not only resulted in unsuccessful water sources but also in resources being spent on very expensive water supply technologies when cheaper and more sustainable ones are possible. Water sources have sometimes also been constructed in areas with poor water quality leading to abandonment while others have been constructed too deep making them very expensive to construct, operate and maintain.

The current national rural water supply coverage is estimated at 61 percent and is to be significantly improved to at least 95 percent by 2015. The focus is on groundwater development using low-cost, simple water-supply technologies. Assessment and mapping of groundwater resources in the country is therefore essential in order to guide planning of groundwater development activities thereby targeting poorly served areas.

Groundwater mapping

Groundwater Mapping Programme was initiated in 2001, on a small scale pilot level, with the aim of assessing and mapping groundwater resources at district, regional and national level in order to guide efficient and cost-effective groundwater resources planning and development. The maps prepared represent groundwater resources in terms of their quantity and quality and summarize this information spatially.

So far groundwater maps have been prepared for 17 districts out of 81 districts in the country and upscaling of activities is planned to start in 2007. Six types of maps are prepared for each district namely:

- Water supply coverage maps
- Hydrochemical characteristics maps
- Water quality maps
- Hydrogeological characteristics maps
- Groundwater potential maps
- Groundwater supply technology options maps

Groundwater maps and their usefulness in improvement of water supply coverage

Some of the groundwater maps prepared are very useful in improvement of water supply coverage as discussed below:

Hydrogeological Characteristics Map

The hydrogeological characteristics of an aquifer in an area are illustrated by means of parameters measured during the drilling process. These measured parameters are then presented as separate insert maps, namely Overburden Depth, First Water Strike, Main Water Strike, and Static Water Level. The Overburden Thickness Map is useful when planning future drilling campaigns, as it enables estimates of the amount of casing that will be required, as well as assisting in defining the drilling method that may be most appropriate in order to develop a successful water source. The Water Strike Maps assist in planning drilling contracts as they give indications of the likely depths that should be drilled to encounter groundwater. The Static Water Level Map assists in planning future pumping equipment requirements as it indicates the level at which the groundwater will stand in the well, and hence the minimum depth that the pump has to be installed. The Hydrogeological Parameter Maps are also used in preparation of the Water Supply Technology Map. Use of the above maps will result in groundwater development being carried out in a cost effective manner leading to construction of more water sources using the same resources thereby increasing accessing to safe drinking water to the population.

Groundwater Potential Map

Groundwater potential is a very broad term and may be influenced by many factors but the definition of 'groundwater potential' used in the development of this map is the simplest possible and may be stated as "the ability of a particular area to supply an adequate quantity of groundwater of potable quality to satisfy the demand of that area."

In order to categorise 'groundwater potential' it is necessary to categorise the principal factors that influence it i.e. well yield and water quality. Well yield is measured with the aim of assessing the ability of the source to sustain a handpump whose maximum capacity is 1 m^3/hr and satisfy the minimum yield requirements of 0.5 m^3/hr for a rural water supply source. For map preparation purposes well yield is thus classified into four categories namely >1 m^3/hr, 0.7-1 m^3/hr, 0.5 – 0.7 m^3/hr and <0.5 m^3/hr. Water quality is also grouped into three categories of Potable water, above Guideline Value (GV) and above Maximum Acceptable Value (MAV).

The final map is a categorization of 'groundwater potential' that combines both the yield and the water quality factors. Groundwater potential is depicted on the map by a colour designation of a range of yields, overlain by hatched areas relating to the water quality characteristics. It is thus

possible to have a particular area that has 'good potential' with respect to yield, but 'poor potential' with respect to water quality.

The Groundwater Potential Map is useful when planning future water supply activities in an area to indicate the zones of lower potential in which more investigation efforts will be required in order to develop a successful water source or where groundwater development should be avoided altogether. Use of this map will not only reduce the number of unsuccessful water sources but will also ensure that areas with unacceptable water quality are not targeted for groundwater development.

Water Supply Technology Options Map

This map demonstrates the suitability of different areas for different possible technical options for groundwater development. This map is the most important map with respect to groundwater development planning as it serves to indicate the type of technology that may be appropriate in different areas. The map is prepared by considering the distribution of the first and the main water strikes, the estimated well yields during drilling and whether they occur in the overburden or in the bedrock. If water strikes occur shallower than 15 m below ground level in the overburden and minimum yield of 0.5 m^3/hr was estimated, such an area would be suitable for shallow dug wells. If the water strikes with minimum yield of 0.5 m^3/hr occur between 15 and 30 m in the overburden then the area would be suitable for shallow drilled wells while if they occur deeper than 30 m whether in the overburden or bedrock, then the area would be suitable for deep boreholes. In financial planning terms the choice of technical option will also clearly have a very significant influence on the overall cost of water source provision in an area and hence water supply coverage.

Conclusions

Groundwater mapping is very important in supporting groundwater development programmes in hard rock areas through providing information on the distribution of groundwater resources and the feasible water supply technology options. This will not only result in sustainable groundwater development plans but will also lead to cost effectiveness and hence rapid increase in water supply coverage. Groundwater maps are currently guiding district (local governments) political and technical officials in Uganda on the feasible water supply technology options to consider in various areas and are also providing indications of areas with low water supply coverage which require more attention. The districts are now exclusively constructing shallow wells in areas where they are indicated as feasible as opposed to the past practice of constructing deep boreholes everywhere. The communities with the lowest water supply coverages, through their elected leaders, are also using the maps to bargain for their equitable share of government resources. Although an evaluation of the usefulness and impact of the groundwater maps has not yet been carried out, there is no doubt that the maps have provided an overview of the groundwater resources and water supply situation in the various districts for use in planning future water supply projects. It is expected that with the availability of groundwater maps there will be a significant reduction in failure of wells, and cost of water supply systems in terms of initial investments, and operation and maintenance costs. Fund saved would be used to construct additional water sources, which would lead to increase in water supply coverages and hence more benefits to the people. The success of groundwater mapping however depends on availability of good quality groundwater data, which is currently not readily available and will require a big effort to collect.

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Hydrogeological Environment: Basement Aquifers – *Jeff Davies, BGS*

Case Study - Basement Aquifers in Zimbabwe

In 1984 the British Geological Survey assisted in the supply of water to refugee resettlement schemes in Zimbabwe; in 1992 it advised on groundwater supply during the drought there.

The Sabi Valley of eastern Zimbabwe in 1984 a year of normal rainfall with acacia trees in leaf.

Exactly the same area in 1992 after no rainfall for 1.5 years with sand drifting across the road

During both periods water was primarily obtained from Precambrian age crystalline basement aquifers of limited groundwater resources. These aquifers underlie much of Zimbabwe where they have been developed to supply much of the basic water needs of the rural population. Although large numbers of boreholes have been drilled into these rocks, especially for drought relief purposes, their aquifer characteristics are poorly understood. It is likely that researchers could usefully revisit the results of projects undertaken in the pre computer days to gain information that will better inform today's hydrogeologists about these aquifers.

In 1984 the Government of Zimbabwe, through its agency AGRITEX, undertook the settlement of returning refugees on former commercial farms. Water was supplied through the rehabilitation of old and provision of new boreholes. The Inyamazura area west of Mutare was one such site. This area is underlain by Precambrian crystalline basement of granites and gneiss with intruded dolerites. Potential drilling sites were located on zones of weathering and fracture using topographic and geological maps, aerial photograph interpretation and geophysical survey methods – electrical resistivity depth probing with the ABEM Terrameter and electro-magnetic traversing with the EM-34 systems. Boreholes were drilled using cable tool percussion and down the hole hammer air flush drilling with rock chip samples being obtained at 0.5m intervals. The boreholes were test pumped either using a reciprocating pump for a 3 hour discharge followed by a recovery test, or by bailing water for 30 minutes and recording the rate of water level recovery. Water samples were obtained for hydrochemical analysis during the test pumping. The boreholes were generally equipped with Zimbabwean manufactured 'Bush' pumps.

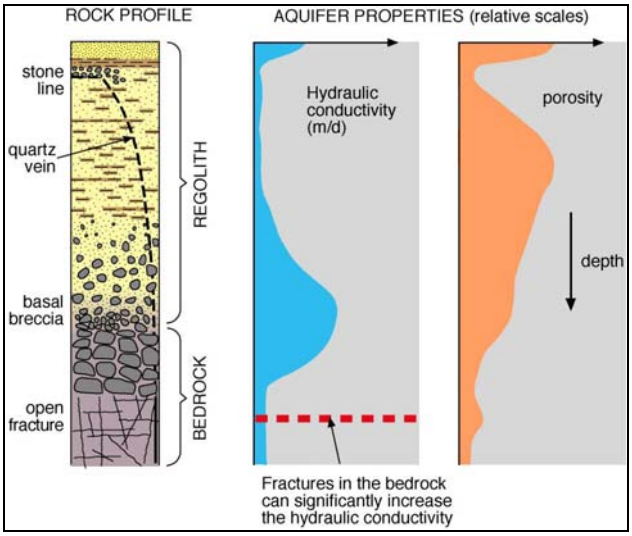
Resistivity surveying using an ABEM Terrameter (left), and test pumping borehole drilled by a Land Rover-mounted DHD rig (right).

Drought relief borehole equipped with a Bush pump.

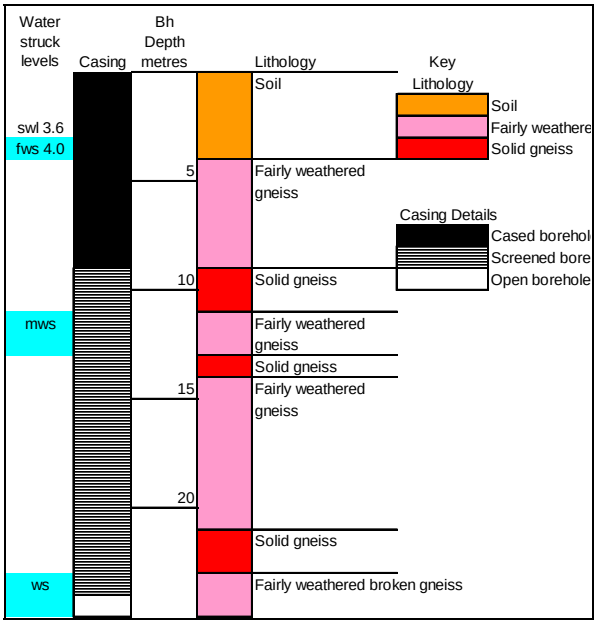
All of these are standard techniques still in use today – or are they? They may be in use but how often have even large well funded borehole drilling projects been undertaken without collection of the basic data that these methods can provide? Hence the general understanding of crystalline basement aquifer systems in southern Africa remains poor.

So what information can be derived from past projects, and can such information be used to inform programmes undertaken today?

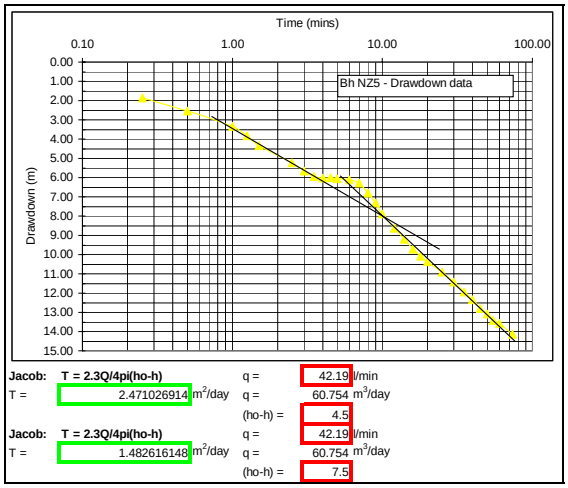
Geological data from 20 boreholes drilled west of Mutare in 1984 were used to construct a shallow weathering profile within the crystalline basement rocks. In deeper boreholes thinner zones of weathering related to regional groundwater base levels were also recognised. Simple pumping tests conducted on these boreholes provided hydraulic information needed to understand groundwater occurrence in these weathered zones and associated fracture zones. These tests were conducted at discharge rates of 0.25-1.0 l/sec producing aquifer transmissivities of 1-10 m^2/day. These data can be used to understand groundwater flow patterns and the resources in basement aquifers.



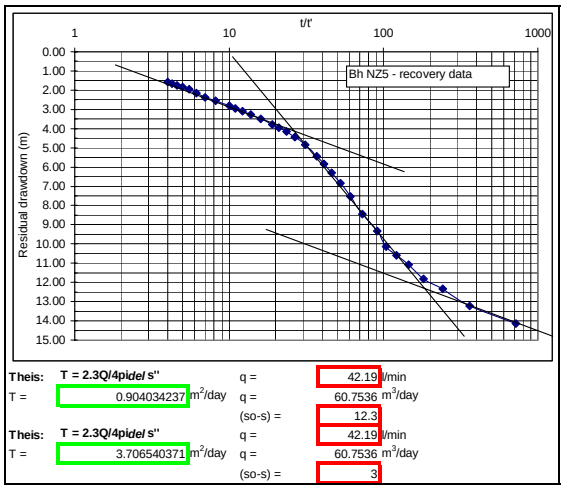
Log of a 1984 borehole showing deep weathered zones



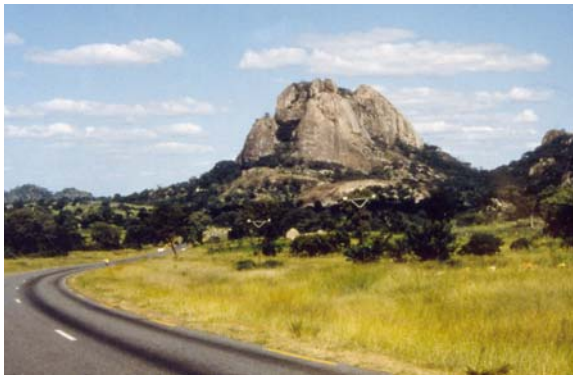
Shallow weathered zone showing permeability and porosity variations



Plot and analysis of yield/drawdown test pumping data



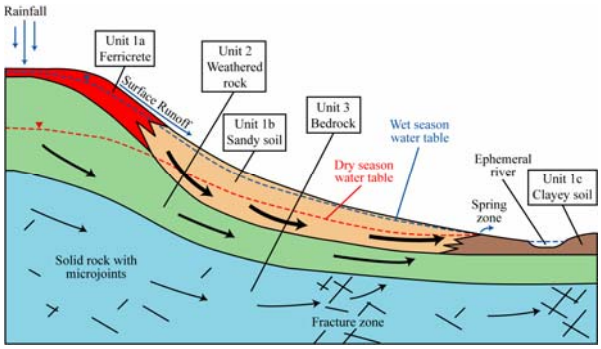
Plot and analysis of yield/recovery test pumping data



Typical granite 'kopjie' in north-eastern Zimbabwe

During the 1980s the British Geological Survey undertook detailed studies of Crystalline Basement rock aquifers in Zimbabwe and Malawi. The results of this work were published in Wright, E P and Burgess, W G (eds), 1992. Hydrogeology of Crystalline Basement Aquifers in Africa, Geological Society Special Publication No 66. The hydrogeology of Zimbabwe is described in Interconsult, 1985: National Master Plan for Rural Water Supply and Sanitatio, Volume 2/2 Hydrogeology. Prepared for the Ministry of Energy and Water Resources and Development, Republic of Zimbabwe, these reports are now out of print.

Unfortunately, although many borehole drilling projects have been undertaken in Zimbabwe and adjacent countries, usually in response to prolonged drought, little effort has been made to collect and collate hydrogeological data from them. Consequently our knowledge of how these aquifers behave and their resources remain poorly understood.



Typical patterns of weathering and groundwater flow that develop under a semi-arid to sub-tropical environment.

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Groundwater Capacity Building Initiative for Africa (GW-CB Africa)

- Themba Gumbo, Kojo Kpordze, Mathias Polak, Ralf Klingbeil

This initiative aims at identifying urgent capacity needs in Africa regarding groundwater management in its wider sense. The rational behind this is that many African water managers and hydrogeologists are convinced that there is a lack of capacity in their country's groundwater management, but it is often more difficult to clearly state what the specific deficit is, nor how to overcome it. This initiative intends to help clarifying what kind of capacity building is needed and to identify appropriate trigger points for capacity building measures.

GW-CB Africa was initiated by two regional capacity building networks, WaterNet and WA-Net, together with the Federal Institute for Geosciences and Natural Resources (BGR), Germany. The two networks are partners of Cap-Net, the capacity building network for IWRM, an associated programme of Global Water Partnership (GWP). WaterNet and WA-Net are composed of research and training institutions from Southern (WaterNet) and Western Africa (WA-Net). BGR, as the German geological survey, has long-standing experience in development cooperation in the groundwater sector.

Due to this institutional structure, the initiative first focuses on two regions: one in Southern and the other in Western Africa. If the results from the two regions will allow for it, an extension towards other regions is envisaged.

The initiative is composed of two major components. The first one is a survey to find out which are the major capacity gaps with regard to groundwater management. In a second step the survey results have to be analysed and discussed with stakeholders in order to prepare the ground for appropriate capacity building measures.

At the moment, the first component (survey) is proceeding. For this purpose, the regional networks and BGR have been contracting two consultants (one for each region) to gather the necessary data from water managers, scientists and other experts. This is to be done with a comprehensive questionnaire which asks for a detailed picture of groundwater management in the respective countries. Major components of the questionnaire include:

- Institutional management
- Legal status of resources and enforcement of rules
- Resource assessment and how information is used in water management
- Resource use
- Maintenance of infrastructure
- Integrated Water Resources Management
- Groundwater development
- Groundwater and environmental protection
- Groundwater education and training
- Economic aspects and demand management

From this wide range of groundwater management aspects it should be possible to identify the largest capacity deficits. In each of the two regions data is gathered from a number of countries. While analysing the replies it will be a major task to ascertain if there are capacity needs with regional importance, i.e. that matter in most of the countries. The discussion of these aspects will be the starting point for the second phase of the initiative which should bring the survey results into implementation.

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Groundwater Exploration in Northeastern Namibia and Airborne Geophysical Investigations on Selected Mineral Targets

- Greg Christelis, Frieder Schildknecht, Fritz Rainer Haut

From November 2002 to March 2005 the Department of Water Affairs of Namibia (DWA) and the Federal Institute for Geosciences and Natural Resources (BGR), Germany conducted a joint groundwater project concerning the investigation of groundwater resources in three areas in northeastern Namibia. The three investigation zones were identified by the DWA as areas with predominant importance for water supply from groundwater:

- the Oshivelo Area east of the Etosha Pan
- the southern part of Eastern Caprivi
- the Eiseb-Graben Area in the Eastern Kalahari

The climate in northeastern Namibia is semi-arid, being characterised by variable and spatially uneven distributed summer rainfall with mean annual precipitation differing from about 300 mm per annum in the western and southern parts to more than 600 mm in the most easterly part of Caprivi. The limited rainfall is strongly overbalanced by a potential evaporation of up to 3000 mm per annum. Furthermore this rainfall is not reliable and highly variable, particularly in the areas with low annual precipitation.

Growing population and climatic changes with fewer and less intensive flood events place severe stress on the already strained natural resources of the country. Increasing competition for water among users requires proper management of the groundwater resources which is therefore of critical importance for the sustainable development of the country. Groundwater resource management is particularly relevant when developing vulnerable fresh groundwater resources that are located near brackish or saline resources, as is often the case in northern Namibia. The most important prerequisite for a sustainable use of the fresh groundwater is therefore a detailed evaluation of its availability and its characterisation in terms of quality and vulnerability, particularly with respect to adjacent saltwater occurrences.

DWA and BGR designed programs of hydrogeological and geophysical investigations to meet the particular natural conditions in the different areas. The joint project incorporated helicopter based EM-profiling in the eastern Caprivi and the Oshivelo area for subsurface resistivity determinations within moderate depths, but with high horizontal resolution. The EM-measurements were accompanied by airborne magnetic and radiometric profiles. All measurements were carried out by DWA and BGR experts and with the DWA- and BGR-owned equipment.

The airborne measurements were of particular importance for the delineation of near surface freshwater lenses in an area of predominantly high mineralised groundwater in the Eastern Caprivi. In order to investigate deeper layers, VES- and TEM-soundings were conducted. Because of deep water tables prevailing in the Kalahari project area, airborne measurements were omitted here in favour of a more detailed program with classical geophysical sounding techniques. The results of the geophysical measurements were validated in every area of investigation by a series of exploration boreholes. In these exploration wells a comprehensive programme of hydrogeological surveys was run: pumping tests, chemical and isotopic analysis of water samples as well as geophysical borehole logging. The collected data were compared with existing information and hydrogeological conceptual models for the different investigation areas were developed.

For an optimal utilisation of the sophisticated airborne equipment the groundwater investigation program was completed by additional helicopter surveys on mineral targets, defined by the Geological Survey of Namibia, and a comprehensive study on the fracture system of the Windhoek Aquifer around the capital of Namibia, sponsored by the city of Windhoek. The results of the latter investigation are of particular importance for the capital's future drinking water supply. The city of Windhoek intends to use the overexploited Windhoek Aquifer as subsurface storage by injection of processed rainwater from the reservoirs around Windhoek. A large part of the collected rainwater in reservoirs is lost every year during the dry season by evaporation. Artificial recharge to the Windhoek Aquifer will reduce evaporation losses and hence contributes to the safeguarding of the water supply of Windhoek city.

Drilling rig and down-hole borehole geophysical logging in Nambia

Results:

In the Oshivelo area the extent of the already known Oshivelo Artesian Aquifer was delineated and its quality was described. The aquifer turned out to be less extensive than expected. The results are important for the future planning of the water supply for the fastest developing area of Namibia, the Cuvelai Basin.

In eastern Caprivi, a formerly unknown freshwater aquifer of large horizontal extent was detected with TEM-soundings and later verified by exploration wells. The findings are of particular importance as the area is planned to be supplied with drinking water from the Zambezi River via a costly pipeline. An information campaign addressing local stakeholders aroused significant public interest in the new findings.

In the Kalahari, the tectonic Eiseb-Graben was delineated in detail. In certain areas inside the graben, near its northwestern shoulder, freshwater bearing structures were detected with TEM-soundings at depths below 170 m. Exploration boreholes drilled on this structure revealed yields of probably more than 120 m^3/h. Compared with the values of 1.0 m^3/h to 3.5 m^3/h from previously drilled boreholes, these outcomes are highly promising and may contribute to a better water supply and a change of the perspective of land-use in this remote area. The result of this investigation is indicating the existence of an important transboundary groundwater resource.

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Groundwater Resources for Southern Province Zambia (GReSP) - *Simon Kang'omba, Roland Baeumle*

The Government of the Republic of Zambia has identified an urgent need for investigation of the groundwater resources of the country. To ensure sustainable development and use of the country's water resources, the increasing demand for groundwater in agriculture, commercial and domestic use needs to be regulated. The basis is a countrywide assessment of the available quantities and qualities of groundwater. In Zambia the use of groundwater is not regulated, in contrast to surface water. This poses a risk to the sustainable development, management and use of the resource.

Pump equipped borehole in Zambia

The Southern Province is drought prone and therefore an area of particular concern. The knowledge base on the availability and quality of groundwater is scanty and hampers an effective management of this vulnerable resource. The increasing demand of groundwater for agricultural, commercial and domestic use is creating tension amongst stakeholders. In view of this, comprehensive hydrogeological investigations are urgently needed in order to facilitate a sustainable development.

Within the framework of the Zambian-German Technical Cooperation with Zambia a joint project of the Department of Water Affairs (DWA) and the Federal Institute for Geosciences and Natural Resources (BGR), Germany started in May 2005. The project team comprises experts in the fields of hydrogeology, water quality, GIS/database applications and groundwater resource management from both countries. The activity is closely connected to a GTZ-project supporting the political reform process in the water sector.

The project intends to fulfil the urgent need for groundwater resource assessment in the Southern Province. It is envisaged to strengthen the understanding and capacities of the Zambian Scientists and Engineers in groundwater resources mapping, exploration, groundwater protection and data provision. This will contribute to building up an efficient institutional framework to solve hydrogeological problems with an emphasis on groundwater resource planning and management. The overall goal of the project is a better water supply for the Zambian people, thus contributing to reducing poverty in the long term.

The main activity during Phase I is to assess the available data of the Southern Province (analogue and digital) for the compilation of a database and hydrogeological maps of the study area. The maps will show the location of boreholes and distinguish between aquifers with poor and high groundwater potential. They will also delineate areas characterised by poor groundwater quality as well as areas that are exceptionally vulnerable to pollution.

Other activities comprise the interpretation of aerial photographs and satellite images, recharge area investigations, groundwater sampling, laboratory work and data processing

Individual tasks during the project include:

- To collect, collate and digitise all relevant hydrogeological data and information on the Southern Province.
- To build up and continuously update a hydrogeological database introducing the software package GeODin.
- To assess the groundwater quantity and quality of the aquifer systems.
- To train scientists, engineers and technicians in hydrogeological field investigation and resource management.
- To advise regulation and planning authorities on future monitoring and regulation of groundwater resources.
- To regularly inform all relevant stakeholders on the project activities and achievements.
- To produce and distribute hydrogeological maps for management purposes using ArcGIS complemented by explanatory reports.

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