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SUSTAINABILITY OF WATER AND SANITATION SYSTEMS

Exploration of sustainable water sources

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EXPLORATION OF GROUNDWATER sources in Tanzania is vested in the Hydrogeology Section of the Department of Water Research which is one of the Directorates forming the Ministry of Water, Energy and Minerals. The Commissioner for Water Affairs is a link between the Water Directorates and the Principal Secretary of the Ministry. The Head of Hydrogeology services is the topmost boss of the section and stays in Dodoma which is centrally situated lying within a semi-arid region. At Dodoma, the Head is assisted by five professionals in different fields of geological Sciences and a number of supporting staff. In each of the 20 regions in Mainland Tanzania, there is a Hydrogeologist who carries out all hydrogeological/ geophysical investigations, monitors drilling activities and carries general groundwater management. There is at least a functioning resistivity meter in each region. The Head office co-ordinates and carries out all national projects and controls the overall movement and development of various geophysical equipment available from Dodoma. However EM systems are available from donor-assisted regions:

UNICEF in Kagera and UNDP in Arusha. Seismic refraction system has recently been bought by UNICEF in Mtwara.

Tanzania has a long history of exploration of water sources as the first borehole was drilled in Morogoro almost 65 years back (in 1931) where resistivity method in form of Wenner configuration was used for siting.

Hydrogeological investigations

Hydrogeological investigations begin with desk study at the office. This comprises of the following:

- study of existing boreholes and their parameters near or within a place of investigation. This informations is available from up-to-date borehole catalogues prepared for each region. At Dodoma it is possible to relog actual borehole samples collected throughout the country which are carefully packed and stored at this office. With the acquisition of desk top computers a process of copying all information from the borehole catalogues in diskettes has already been started.
- study and analysis of hydrogeological factors controlling movement and occurrence of groundwater for an area under investigation. This will usually cover study of geological maps available for over ¾ of Tanzania as Quarter Degree Sheets 9QDS) with scale 1:125,000. QDS are published by the Tanzania Geological Survey of Dodoma.
- Topographical maps at 1:50,000 also have information on drainage and general geomorphological features. Topo maps have been prepared by the Directorate of Surveys and Mapping in Dar es Salaam. Some of these maps are out of date due to various human activities which has taken place but then up-to-date information must be extracted from analysis of relevant air photographs.
- Analysis of satellite imageries and aerial photographs for delineation of regional and local lineaments. The commonly studied satellite imageries are both Landsat and SPOT. The imageries are available through the Institute of Rural Assessment (IRA) of the University of Dar es Salaam. Aerial photos used have been taken at various times but still have very valuable information.

Geophysical investigations

The following are main geophysical methods deployed in Tanzania for exploration of water sources:

a) Magnetic-cheap, rapid and effective in delineating dikes and sometimes faults and fractures. In the water sector we use Geometrics G 816 proton magnetometers. Interpretation is manually done.

b) Vertical electric sounding (VES) VES is done using ABEM AC resistivity meters, ABEM SAS - 300 terrameters and Japanese McOhm resistivity meters deploying exclusively Schlumberger array. Manual interpretation is emphasized so as to have a prior model before one used software programs for interpretation.

c) Seismic refraction - is done by using explosives to generate seismic waves. It is carried out in particularly difficult areas in the basement places of Mtwara, Dodoma and Singida. The seismograph currently used is a Japanese OYO which is quite modern featuring both analogue and digital recording. Interpretation is mainly manually done but recently the Hydrogeology Section has acquired software for Seismic refraction analysis.

d) EM is done by Geonics EM 34-3 equipment and sometimes by Genie which is borrowed from the Mineral Sector.

Minor methods include the following:

e) VLF WADI (Singida TCRS program) which proved to be ineffective due to existence of considerable thickness of overburden.

f) Geophysical well - logging (SP, temperature and resistivity) were recorded in two wells during the EEC Drilling program for Mtwara town water supply (1986)
g) Electric profiling - this was done in Kapunga, Mbeya when attempting to map sandy aquifers within a formation consisting of succession of thick clays and thin sandy layers. The method recorded little success.

Besides, the whole country is covered with aerogeophysical surveys. The Government contracted Geosurvey International to do this job (1976-1980) and the survey included magnetics, radiometrics and EM-VLF. More than one million kilometres were flown at a spacing of 1.0km and flight altitude of 120m above the ground. Detailed surveys were also conducted in some areas with a line spacing of 250m and at an altitude of 90m above the ground. The direction of survey line was E-W (Marobhe, 1989). Therefore regional structures can be studied from the various maps prepare out of this survey.

Case studies

Basement areas

a) The most and unique success of using VES in borehole siting is noted at Makutupora, which is a well-field for capital of Tanzania - Dodoma.

VES No.6 was probed on May 5, 1978 using an ABEM AC terrameter (Schlumberger array). Interpretation by 3 layer master curves and auxiliary charts gave the 5-layer model as shown below.

Borehole 119/75 drilled to 123m at that site has a tested yield of over 460m^3/hr with a drawdown of only 5.00 meters; and static water level of 29.42m. Water struck is from 38.10 meters and the aquifer is sand plus weathered and highly fractured granite. Water quality is good and the borehole forms a major groundwater source for the city.

b) Seismic refraction method has been successful in Dakawa, Morogoro where surveys for the then ANC camp was done as part of the Norwegian peoples Aid (NPA) project. (Kasonta - 1989). The surveys were done using an ABEM SX-24 channel seismograph which records analogue data on Kodak photographic paper. Manual interpretation using the mean-minus-T method indicated low velocities (2000 m/s to 3067m/s) within the bedrock (velocities 5000-6000 m/s) which are fractures or faulted zones where secondary permeability is high. Borehole 36/90 drilled in 1990 over a lower zone with 3067 m/s on profile 1 to a depth of 37.5m has a yield of 97m^3/hr with no drawdown. Borehole 38/90 drilled to 65.4m over a low zone with 2000 m/s on profile 3 gave a yield over 70 m^3/hr with drawdown of 1.73m only.

In both cases the aquifer is coarse sand and weathered gneiss. Both of these groundwater sources are now used for the newly established Local Government Institution at Wami-Dakawa.

c) A combination of EM, seismic and VES has recently (1994) been carried out in Songea as part of the EEC financed Urban Water Supply project. The geology of the area around Songea is dominantly a cover of superficial deposits of Quaternary age overlying granites and granitic gneisses of the Basement complex. Thirty four transverses (total length 39.5km) were made using a Geonics EM 34 - 3 equipment and a Seintrex instrument which was used in its Genie mode. The traverses were run only at a constant 40m separation. Date obtained was manually plotted on graph paper. The plots show distances from the point of origin along the x-axis and apparent ground conductivities as measured using horizontal and vertical dipole configurations on the y-axis.

One hundred forty eight VES were carried out within a radius of 20km of Songea town using a Japanese Oyo Markohm II unit resistivity meter. In order to provide an indication of local calibration, soundings were made in the vicinity of the only existing borehole in Songea area. The sounding made at Msamala borehole was interpreted as shown below.

According to the geologic log, most permeable zone encountered was between 40 and 50m.

A resistivity value of 220 Ohm. meters has been interpreted for this zone.

Basing on this eight sites have been selected for exploratory cum production drilling and the boreholes are expected to be successful.

Five seismic profiles were carried out in Songea area, one close to the existing borehole 53/89 at Msamala. A Japanese OYO seismograph was used with explosive charges providing the source of energy for generating seismic waves. Manual interpretation of seismic data using the mean-minus-T method indicated that the aquifer has an average low velocity of 1800 m/s.

Volcanic areas

The highest yielding borehole in the country is located within the volcanic areas at the Tanganyika Planting

Depth m	Resistivity Ohm.m	Interpreted geology
0 to 1.0	280	Sand with clay
1.0 to 2.1	40	Clay whitish and silt
2.1 to 12.2	15	Silt and sand medium grained
12 to 50	8	Sand coarse grained and weathered granite
50 to depth	infinity	Weathered becoming fesh rock

Depth m	Resistivity Ohm.m	Interpreted geology
0 to 1.2	575	Sand with clay
1.2 to 7.2	1500	coarse sand with clay (highly weathered rock)
7.2 to 52.2	220	Clay to coarse sand (moderately weathered rock)
52 to depth	5500	Poorly weathered becoming fresh rock

Company (TPC) in Moshi District. VES using Wenner configuration was carried out in late 60's at a site where borehole has been drilled. The exact yield of the borehole is not known but exceeds 500 m^3/hr. The aquifer is weathered pyroclastics and Water is obtained under-sub-artesian conditions.

Coastal areas

VES has normally been the main geophysical method in exploration of groundwater in coastal areas. One of the notable advantages of this method is that it is easier to determine the saline conditions prior to drilling, depicted from extremely low Values of resistivities.

Authors have successfully carried out VES at the Fahari Bottlers Company (FBL) premises in Dar es Salaam to locate a site for drilling a borehole. Seven VES were probed and the recommended drilling site (VES 4) has the following interpreted data:

Depth m	Resistivity Ohm.m	Interpreted geology
0 to 1.3	700	Dry sand
1.3 to 13	65	Coarse sand
13 to depth	17	Coarse sand

Borehole No.165/90 drilled at that site to a depth of 45m gave enough fresh water of 3000 litres/hours with maximum drawdown of 10m.

The site has been selected on basis of the relatively high resistivity value of 17 ohm meters for the potential aquifer.

A typical site where saline water is encountered is VES 6 with a resistivity of 7.5 ohm.m for the third layer as shown below.

Layer	Apparent resistivity ohm.m	VES 6 Thickness m.
1	3000	1.4
2	30	2.8
3	7.5	

Summary

From the case studies, it is evident that the outlined hydrogeological and geophysical methods have been quite effective in locating sustainable water sources despite the fact that most data processing is manually done. This is due to having field data of high quality collected from sound and effective methodologies and equipment. However with the advancement of modern interpretation packages which involve software, it is necessary that key professional staff is trained on this subject. Though the rate at which the PCs are being made available in regions is low it is encouraging as the they
are seven regions now equipped with personal computers. The use of the software, however does not replace manual interpretation as experience has shown that model creation without prior determined parameters gives out extremely ambiguous results.

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