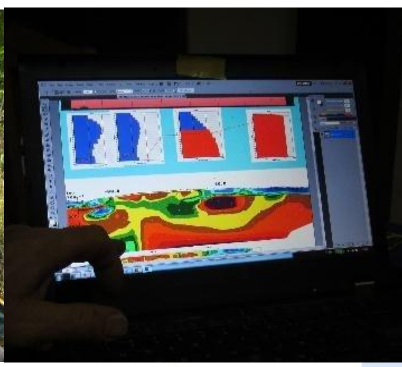
May 22, 2019

ISGEAG Final (End term) Report

Improving Sustainable Groundwater Exploration with Amended Geophysics (ISGEAG), L16019 vw011

Final report

VIA Water



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Executive summary

This is the End Term report of the 'Improving Sustainable Groundwater Exploration with Amended Geophysics' (ISGEAG), a partnership between Amref Health Africa, Kenya Electricity Generating Company Limited (KenGen Ltd.), Acacia Water, SamSam Water Foundation and Wiertsema & Partner. ISGEAG is funded by the Dutch innovation program VIA Water. VIA Water is executed by Aqua for All (A4A) and funded by the Dutch Ministry of Foreign Affairs.

ISGEAG applied different existing and new geophysical methods in three reasonably well-researched areas (Kajiado, Kwale and Naivasha) to show the limitations of the different geophysical methods, study their best combination for each different context and improve the interpretation of the measurements. An on-the-job training trajectory did run parallel to the research program.

The goal of ISGEAG was that by improving the geophysical surveys and groundwater exploration this would lead to better drilling results and more sustainable abstraction of groundwater. Despite the fact that this direct impact by ISGEAG has not been demonstrated, the knowledge-sharing between Dutch, Kenyan and other international partners on geophysics, groundwater exploration and borehole drilling, both public and private partners, has been stimulated and improved. Valuable lessons and increased understanding of the benefits of improved geophysics, most notably the WalkTEM of partner ABEM/Guideline Geo Sweden, in a hydrogeological and water availability context have been realized, and the business opportunities with it.

Colophon

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1 General information

Type of report	End term		*Reference date*	31-03-2019	
Project number	L16019/vw011				
Country	Kenya				
Title	Improving Sustainable Groundwater Exploration with Amended Geophysics (ISGEAG)				
Contract Organisation	Acacia Water B.V.				
Project period, including extension if given	01-08-2016 till 31-12-2018, after extension				
Project budget	*Contract:*	€ 255,510	*Spent*	€ 253,861	
Subsidy amount VIA Water	*Contract:*	€ 195,310	*Spent*	€ 182,261	
			Received	€ 177,960	
Project partners	*Contract:*	€ 60,200	*Received/spent*	€ 71,600	

1.1 Innovation Summary

Gravity, magnetic, electrical and magnetic methods to study the Earth (geophysics) are widely used for groundwater exploration. To be effective, efficient and sustainable these methods should be weighed and integrated, supported by hydrogeological assessments and followed by the appropriate data analyses techniques. In Kenya, poor application of geophysics currently results in a low cost-efficiency, poor estimates of sustainable yields and non-discovered new water resources. The Improving Groundwater Exploration with Amended Geophysics (ISGEAG) project aimed to address these shortcomings with a research and capacity building program.

ISGEAG aimed to improve access to safe water in Kenya through improved hydrogeological assessment practices. The project applied traditional, existing and new geophysical methods in three (3) reasonably well researched areas in Kenya (Kajiado, Kwale/Mombasa, and Naivasha – in the original project proposal Mombasa, Kajiado and Kakuma were anticipated, red.). The project introduced 'new' geophysical methods such as: Time domain Electromagnetic soundings (TDEM), Electrical Resistance Tomography (ERT), Audio Frequency Magneto Telluric soundings (AMT).

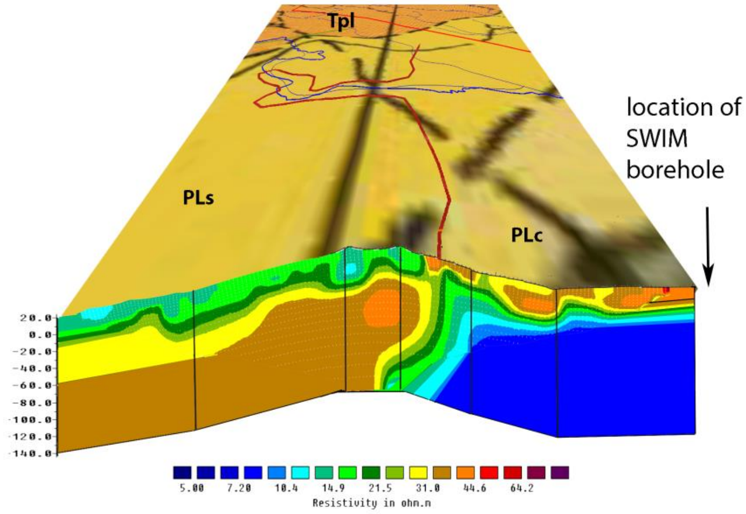

Figure 1. Example of a geophysical cross-section showing saline groundwater intrusion in Kwale coastal zone, Kenya

The assumption was that comparison and combination of 'new' and conventional methods, like VES soundings and HEP profiling, will lead to better understanding of Kenyan aquifers. A brief explanation of these geophysical methods is given in Box 1 on the next page.

Which geophysics can best be used to study the characterization of an aquifer is dependent on the hydrogeological characteristics of the subsoil. Basically, there are three features that are fundamental to assess the potential for groundwater exploration in Kenya: 1) the presence of saline water, 2) the characterization and interconnection of fractured aquifers, and/or 3) the water-holding potential of shallow river sediment aquifers. To study these features three hydrogeological representative areas were selected:

1. **Kajiado Town**, as its surroundings are characterized by relative deep (decreasing) groundwater levels in fractured zones. Methods proposed: depending on the depth of the aquifer either CVES (ERT) for deep systems or TDEM (incl. ABEM's WalkTEM), AMT, borehole logging for shallow systems;
2. **Mombasa**, as it is characterized by a coastal aquifer which has a relative deep fresh and salt groundwater interface. Methods proposed: CVES (ERT), TDEM (incl. WalkTEM), AMT, logging in new wells. Based on more reliable geophysical survey and borehole data from a close local contact the research location changed later on to **Kwale County**, which is south of Mombasa;
3. **Kakuma**, in north-western Kenya, was chosen because of the presence of volcanic type of aquifers. Methods proposed: TDEM, VES, HEP and CVES (ERT). Due to security issues at and near Kakuma refugee camp, this research site was later changed to **Naivasha**, with is geology of volcanic origin belonging to the Eastern Rift Valley system.

Box 1: Brief explanation of used geophysical methods

Abbreviation	Description
AMT	Audio-Magneto Telluric (AMT) Sounding is a one-dimensional (1D) electro-magnetic (EM) method, using a natural source, low frequency EM field induced by thunderstorm lighting and Cosmic radiation (solar wind). The AMT receiver antenna should be exactly oriented according to the true magnetic north. Investigation depths up to 300m or more below ground can be achieved depending on the recorded frequencies. In urbanized areas AMT measurements are not possible due to artificial EM noise. The apparent resistivity can be calculated from the measurements. Layered models can be calculated with special software from a combination of TDEM and AMT.
VES	Vertical Electrical Sounding (VES) is a widely used, one-dimensional sounding based on direct current (DC). With 2 current electrodes a DC current is induced. Two potential electrodes measure the potential induced by this DC electrical field. Apparent resistivity is calculated with depth by increasing electrode distances. Typical depth of investigation of a VES is approximately one-sixth (1/6) of the electrode range AB. Layered, true resistivity (horizontal) layered models can be derived with special software. This process is called 'geophysical inversion'.
HEP	Horizontal Electric Profiling (HEP) is typically used for rapid location or delineation of lateral variations in apparent resistivity of the medium and usually involves moving an electrode array of constant separation horizontally along the surface. Exact depth of the anomalies is typically difficult to establish. A layered inversion is not possible.
ERT	Electrical Resistivity Tomography (ERT) is a two-dimensional (2D) direct current method. Basically, it is a combination of many HEP and VES measurements in one single, integrated data set, and is therefore alternatively referred to as a CVES (Continuous VES). Long cables with many electrodes are in use. With repetition the method can be scaled up to a 3D model. Exploration depth is the basically the same as with VES. 2D layered models can be calculated ('inverted') with special software.
TDEM	Time Domain Electro-Magnetic (TDEM) is based on an intermitting primary electrical electric field in a transmitter antenna (or loop). The secondary field (so-called 'Eddy Currents') is induced due to the change of this primary field to zero (shutdown). This decreasing secondary field over time (micro seconds) is measured in a receiver loop after each shut down of the primary field. The time versus magnitude (Nano-micro Volts) graph is calculated into an apparent resistivity depth graph. With special software a layer model can be derived (inversion). The method is more sensitive to relative conductive (low resistivity) layers. ZONGE, WalkTEM and airborne TDEM (e.g. SkyTEM) are specific TDEM instruments.

The research will show the limitations of different geophysical methods, study their best combination for each different context and improve the interpretation of the measurements. It includes an on-the-job research and capacity training trajectory for a group of over 25 Kenyan experts and students (men and women) in the field of hydrogeology, geology and geophysics on:

- the suitability of the different geophysical methods, as there is no such thing as one single instrument which fits all needs;
- the use of proven geophysical methods that are new to the Kenyan context;
- the assessment, integration and appropriation of traditional water exploration techniques, such as water searching with a divining rod, standard geophysical methods and new geophysical methods; and
- the interpretation of geophysical data.

The knowledge build and data collected during the project will be made available freely online but shall also be disseminated with participants and other stakeholders through open participatory (field) discussions. Hence the insights and products developed can be integrated in future projects, when implementation is done without the support of the international experts involved in this project. Knowledge dissemination and widespread capacity building are central to the project. Specific attention will be paid to the added value of female experts in the water and groundwater exploration sector.

Achieving the goals and aims of the ISGEAG project will result in better interpreted, consistent and well-founded assessment of geophysical survey results, leading to better drilling results and a more sustainable abstraction of groundwater. Hence, the burden of fetching water is alleviated and occurrence of water-related diseases reduced. This particularly benefits the urban population, the poorest, women and children.

1.2 Planning versus realization

In the final ISGEAG project proposal (September 2016) submitted to VIA Water it was already stated that “the planning is indicative and highly dependent on the availability of Kenyan partners and stakeholders.” This was especially dependent on the availability geophysical equipment (AMT, ERT and TDEM) of project partner Kenya Electricity Generating Company (KenGen), and having good and reliable geophysical survey reports and borehole drilling logs of existing boreholes of a selected location available. Furthermore, local climatic conditions in Kenya throughout the year had to be taken into account, since heavy rains and saturated soils make executing geophysical surveys nearly impossible.

Therefore, originally the three two-week geophysical field experiments were scheduled for:

1. **10 – 20 of February and 18 – 28 of April, 2017, Kajiado**;
2. 9 –20 of October, 2017, Mombasa;
3. 13 – 24 of November, 2017, Kakuma.

Nevertheless, due to unavailability of geophysical equipment (of KenGen), lack of reliable geophysical survey and borehole data, or anticipated rainy seasons, both the period and location of the last two geophysical field experiments changed during the project period. Perhaps the biggest stumbling block turned out to be the Kenyan presidential elections of August 2017, and the noisy aftermath that continued until late 2017. Based on new information and new local contacts and partnerships that came along during the project period, the last two research sites and dates changed to:

2. **19 – 30 of March, 2018, Kwale** (near Mombasa), geology: typical coastal setting (fresh-salt water intrusion and sandstones);
3. **28 October – 9 November, 2018, Naivasha**, geology: volcanic rock belonging to the Eastern Rift Valley system.

It should also be said that planning with five primary project partners and additional sub-partners, taking into account the availability of people and the required geophysical equipment, made it challenging to come to quick agreements on dates that suited all. This has certainly also caused delays, and even led to the application for postponement of the final project deadline with donor VIA Water from 31st of July, 2018, to 31st of December, 2018.

What the planning made more complicated too, but brought the innovation to a next level, was the hiring of ABEM/Guideline Geo Sweden's WalkTEM. More about ABEM/Guideline Geo and performances and results of their WalkTEM equipment can be read in Chapter 2. The two times hiring and transport from Sweden via Netherlands to Kenya of the WalkTEM equipment requested for additional planning capacity from multiple partners.

Additionally, multiple efforts were made to get the Water Resources Authority (WRA) of Kenya involved in the project, since WRA is the policy maker and regulator of groundwater resources and its exploitation in Kenya, and could potentially be the 'game changers' in groundwater exploration and exploitation. Despite the established contacts on different levels, attending a WRA official at one of ISGEAG's innovative geophysical field experiments was not high enough on their priority list.

Lessons learned

The first geophysical experiment in Kajiado Town was besides the technical challenges, also very much logistically and planning wise a test. From this first field experiment we learnt that:

- Managing the project, contracts and logistics by lead organization Acacia Water all from the Netherlands proved to be difficult, and would've been better and more effective if there was more face-to-face interaction with our Kenyan partners to have a good, common understanding, and a trustworthy relationship. The project budget, however, did not allow for frequent visits to Kenya, especially not prior to the field experiments. Luckily there was a kick-off meeting with all partners at the AMREF Health Africa office in Nairobi. Conference or Skype calls later on were less successful, while phone calls were often not answered. Communication via e-mail or deployment of a Young Expert of YEP located in Nairobi, Kenya, proved to be more successful;
- Planning and coordination with local partners should start at least 4 – 6 months prior to the actual field experiment dates, in order to get the agendas and expectations of all partners involved aligned;
- In order to ensure that strategy, outcomes and deliverables are being met and promised geophysical equipment and personnel was being made available, as defined in the project proposal, it was necessary to establish memorandum of understandings (MOUs) or even contracts with the project partners;
- The project plan did not allow or at least underestimated the required time for mutual data interpretation and reporting at the end of each two-week geophysical

field experiments, in particular between experts of KenGen, SamSam Water (Mr. Harry Rolf) and Acacia Water/Wiertsema & Partners (Mr. Michel Groen). The time during the two-weeks was already filled with measuring in the field, logistics, data quality analysis and building a database. This meant data interpretation and reporting most of the time still had to be done after the visits to Kenya, often in the own-time of people. The subsequent communication over e-mail proved not to be effective. For the third geophysical field experiment the project team received extra funding from VIA Water for an extra week, which provided ample time for mutual interpretation, comparison and discussion, thereby improving the results and reporting, and enforcing the role and knowledge of the local partners.

2 Results

2.1 Results

In this chapter and paragraphs the main results per research location as well as the overall results and findings will be presented.

2.1.1 Main activities & overall findings

The main activities executed during the ISGEAG project were the three (3) geophysical field experiments at three (hydro)geologically representative areas, as explained in paragraph 0. The comparative, hands-on and on-the-job research and training trajectory to a big group of Kenyan experts in the field of hydrogeology, geology and geophysics at each research site, aimed to:

i. Conceptual approach, start with a concept what to expect (forward models)
ii. showcase the suitability of different geophysical methods;
iii. introduce proven geophysical methods that are new to the Kenyan context;
iv. assess, integrate and appropriate conventional water exploration techniques and standard geophysical methods; and
v. the interpretation of geophysical data of these various methods to test the concept.

Overall findings

Some general findings that were identified during all three geophysical field experiments:

- The ABEM WalkTEM system proved to be very successful and often even superior compared to the other geophysical methods. The electromagnetic system provides an intuitive user interface and built-in software that enables head starts because first inversions can be performed in the field. The WalkTEM is especially effective in areas with a high resistive top layer and low resistivities in the subsoil, such as coastal and volcanic areas, with a relative high resolution from the surface to great depths (~200 m bgl) when using a relatively small transmitter loop (spread). It also provides very exact measurements sometimes even within 1-metre accuracy on (sharp) changes in resistivity, such as the change between fresh-salt water boundaries in coastal areas and deep, water-bearing fractures in basement rock. This is absolutely new and very important for Kenya;
- ERT gave excellent results for locating fractures in the basement area. When the top layer has a high resistance (dry sand) the execution of the method will be harsh and results will be poor;
- In respect to conventional VES methods the current practice is bad. Execution of VES is done routinely and without consideration for the quality and significance for understanding the hydrogeological situation;
- The applicability of one-dimensional method as VES soundings and HEP profiling is limited, because of inherent limitation of the long electrode distance, compared to its exploration depth. The experts of ISGEAG suggest to use 1/6 of total AB length as ‘rule of thumb’. Typically, an AB-spread of 2x 200m is used, which would mean that

the exploration depth is not deeper than 70 m bgl. Many Kenyan consultants' reports wrongly assume a much deeper exploration depth, and suggest and present to their clients an exploration depth of 100m or more is reached when using an AB-spread of 2x 200m;

- HEP profiling results can be misleading because anomalies are mostly the effect of superficial (top 25m) layers and are therefore not an indication for deeper structures. Many Consultants' survey reports wrongly assume that a HEP profile measures the resistivity changes at a specific 'probing depth' of AB/2. This is not the case: each HEP measurement gives the apparent resistivity of a subsurface 'block' of roughly 1/6 of the AB in use;
- Single and isolated VES measurements will not give the required insight for prospecting drilling locations, especially where the geophysics is not compared to borehole logs and not guided by wider hydro-geological insights from existing information;
- Survey 'borehole siting' reports encountered in Kenya often lack essential information and proper argumentation of the advised drilling location and drilling depth.

Table 1. Indications of the depth of investigation (DOI) and vertical resolution accuracy per method

Method	Approximate probing depth / depth of interaction (DOI) [m bgl]	Accuracy of vertical resolution	limitations	Labour
VES (ABEM LS, SAS 1000/SAS 4000/siscall)	~ 70	Moderate to poor	Equivalence Resolution decrease with depth, high resistive top layer.	3 - 4 persons, relative simple lay out, simple instrument operation, 2 – 3 hours (dep. Field circ)
ERT (CVES, ABEM LS)	~ 140 (or more depending length of the cables)	Excellent vertical and lateral resolution	High resistive top layer Resolution decreases with depth,	4 – 5 persons, more complex lay out and instrument operation, 2 – 4 hours dep. lay out
TDEM (WalkTEM)	From 5 up to 300 standard or more (even 800) especially with bigger transmitter loop and heavy transmitter	Good, due to dual moment and many time windows (data points)	Culture Noise fences, powerlines, can "see" low resistivity, and less high resistivity layers, Resolution decreases with depth. Skills are needed with adequate Inversion software	1 – 2 persons, with standard, simple lyout, simple instrument operation, inversion direct on instrument Less than 1 hour
TDEM (Zonge)	From 20 up to 800, depending lood size and transmitter	Moderate - poor due to limited amount of time windows (data points)	Culture Noise fences, powerlines, can "see" low resistivity not high resistivity layers, Resolution decreases with depth. Skills are needed with adequate Inversion software	2 – 3 persons depending loop size and transmitter, relative complex lay out and instrument operation, 1 – 3 hours
AMT	From 50 up to great depth of >500	Poor, resolution will increased with acombined use of TDEM	Culture Noise fences, powerlines, can "see" low resistivity, and less high resistivity layers, Resolution decreases with depth. Complicated inversion software, good skills are needed	2 persons, relative complex lay out and operation, 1 – 3 hours, Calibration is needed

Note: The final results (data quality and interpretation) depends highly on:

i. the quality of the instrumentation in use;
ii. the experience of the operators;
iii. quality of the field layout;
iv. the software in use; and
v. the skills and experience of the geophysicist.

For all methods counts that both the depth of investigation (DOI) and the resolution are dependent on the field conditions and the geology. With VES and ERT the DOI is limited in areas with a high resistive (dry) topsoil. When using long AB lines with VES, often lateral geological chances are being passed, making it difficult to interpret the soundings according to the 1-D assumption.

The typing of 'reasonable' for the accuracy of resolution must be considered relatively; the resolution of discerning layers as such is very low when compared to the actual changes in lithology (or e.g. the resolution in electrical borehole logging). For example in a VES model one can seldomly distinguish more than 5 layers. Moreover, in all methods the resolution decreases with depth.

2.1.2 Kajiado Town

The geophysical field experiments in Kajiado town were executed from 10 – 20 of February and 18 – 28 of April, 2017. The methods used in Kajiado were: conventional HEP and VES (applied by Earth Water Consultants Ltd and AMREF, partly to support VIA Water project Sponge City Kajiado), more advanced ERT, AMT, TDEM on two selected profiles northwest of Kajiado, and 4 additional TDEM soundings with the new ABEM WalkTEM equipment.

The organizations of KenGen, AMREF Health Africa, Earth Water Ltd, Kajiado County Government, the local implementing NGO Neighbours Initiative Alliance (NIA), students of KEWI and University of Nairobi as well as casual workers, sent participants to the ISGEAG on-the-job training trajectory. Out of 36 participants, 4 were women. The complete participant list can be found in Annex 1A.

This Kajiado experiment shows how skilled applications and integrated interpretation of multiple soundings and methods can help to a better insight in the groundwater system, leading to a likely increased borehole drilling success rate. Lack of documented information from existing boreholes and previous surveys and the quality of survey reports is a main hinderance to fully understand the system.

This is why we urgently advise to pay more attention to the quality and availability of consultant survey and borehole completion reports. These technical documents should be easy to acquire, while the information of the reports should be complete, correct and reproducible in a way that the data can be of use in future programs and help to get more insight in the hydrogeology of a certain area. This ongoing process of gaining and increasing knowledge is fundamental for the way forward to a sustainable groundwater exploration.

Main results of Kajiado experiment

The main results of the Kajiado geophysical fieldwork campaign can be summarized as follows:

- For the geological basement context of Kajiado with deep fractures, the ERT method (2D electrical resistivity tomography) gave the best results, especially in lateral resolution;

- The exploration depth of TDEM is potentially much deeper than ERT. The exploration depth and the (both vertical and lateral) resolution of TDEM is however limited in areas like Kajiado where the resistivity increases with depth;
  Standard TDEM instrumentation and AMT methodology lack information of the first tenth of meters and are poor in resolution compared to ERT. However new developments in instrumentation (ABEM WalkTem) can achieve a much higher vertical resolution even than ERT. This was confirmed by the four (4) additional TDEM soundings with the new WalkTem equipment executed inside the fracture zone at the Kajado River, which confirmed the low resistivity up to 200 meters below ground level. The results are consistent with ERT results. See also Figure 2 on the next page.
  The most evident advantages of the WalkTem instrument over conventional TDEM (of Zonge) are:
  - The positive effect of the smaller WalkTem loop size on the influence of lateral change;
  - Increased resolution, because more datapoints are available for inversion with WalkTEM:less points need to be skipped and more 'time windows' are measured);
  - A better estimation of the depth to the basement (based on unconstrained 'smooth' inversions);
  - A better location of anomalies and its lateral extend, and a better indication of the anomaly depth (e.g. fractures).
- To derive proper resistivity information from AMT measurements, AMT has to be combined with TDEM soundings;
- Single TDEM and AMT require less labor than VES soundings and (under favorable conditions) also ERT. On the other hand, TDEM and AMT are less straightforward, while instrumentation and interpretation are more complex. Due to the recent development of instruments like WalkTem and software like SPIA this is changing rapidly and becoming more user-friendly;
- Interpretation based on one dimensional individual soundings (VES, TDEM, and AMT) assumes horizontal layering. This assumption is not valid when the geology changes within the 'spread' of the measurement. Therefore, detailed information on the location and geometry of faults cannot be obtained in complex geology when lateral changes are within the size of the (transmitter) spread. With VES, due to its relatively large electrode spread, this effect is most severe.

Synergy with VIA Water's Sponge City Kajiado project

The ISGEAG proposal already indicated that there will be a linkage to the VIA Water Sponge City proposal. It was foreseen that the knowledge on hydrogeological surveys that will be gained through ISGEAG could be used to enrich the Sponge City project interventions, while the information gathered from Sponge City can assist in the proper application of hydrogeological surveys.

Because of the hydrogeological reconnaissance survey under Sponge City, the activities under ISGEAG could commence faster and better in Kajiado. This was also due to the preliminary investigation and social grounding that Mr. Harry Rolf conducted under the Sponge City project in February 2017.

The geophysical surveys under ISGEAG, have provided a lot of information as to where you could implement rainwater harvesting and buffering interventions. Especially in regard to the investigated "Gully C". It provided a better foundation and validation of what is possible and where. Results of ISGEAG's geophysical survey results in relation to the Kajiado River profile can be found in Figure 2 on the next page.

It also resulted in a better contact and relation between Acacia Water, SamSam Water and NIA, because of a better common understanding of the local context and what hydrogeological and technically is possible. That alone was special that NIA – in the name of the Sponge City project – contacted the ISGEAG project partners themselves concerning hydrogeological questions.

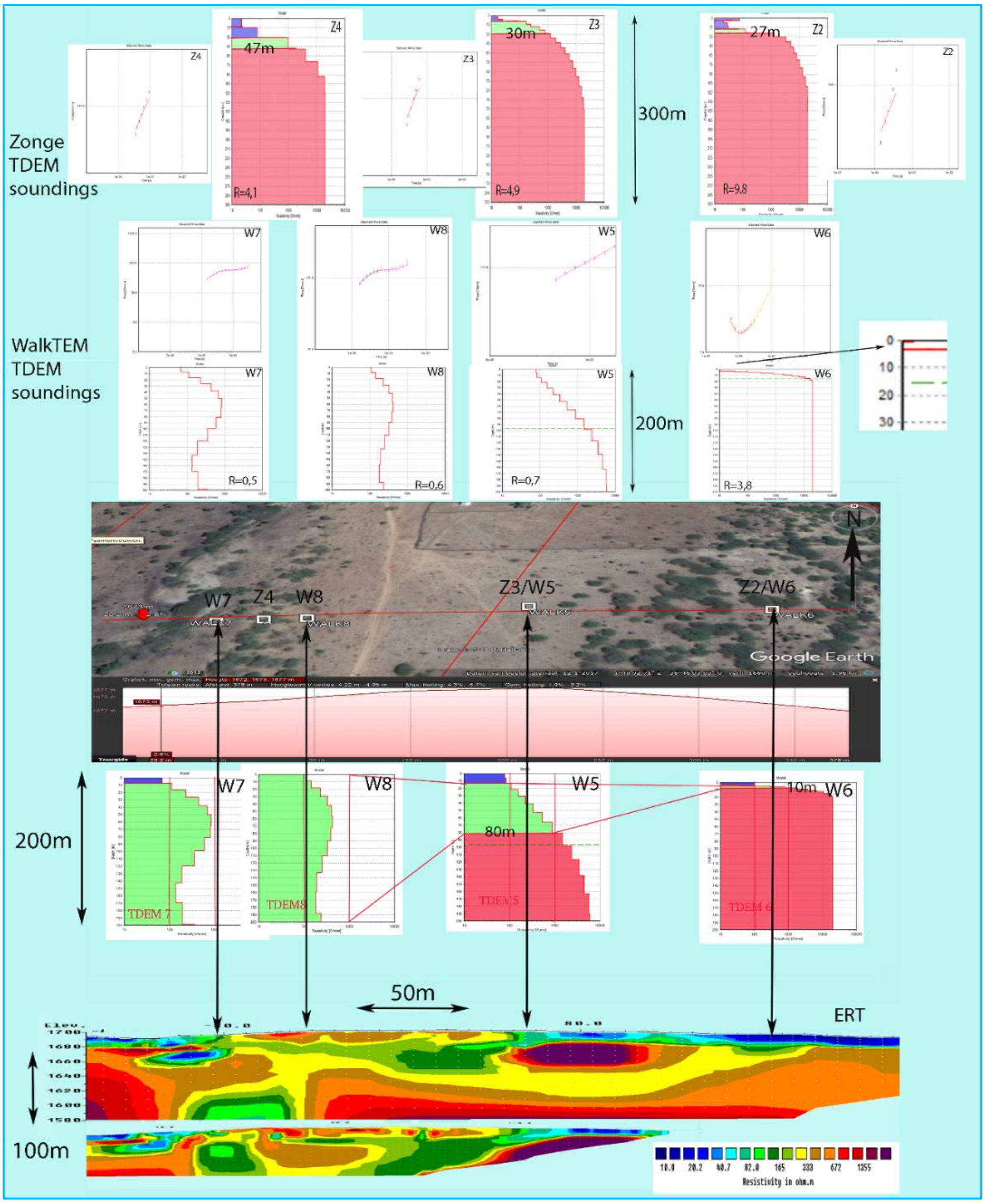

Figure 2. Kajiado River profile. Results of 4 additional ABEM WalkTEM inversions (above) compared with ERT results (below). The fracture zone (deep green zones in the ERT profile results) is confirmed by low resistivity of the WalkTEM soundings W7 and W8 (green, low resistivity zone). The buried river valley (yellow in the ERT profile results) is confirmed by the 80 m bgl basement depth of WalkTEM results W5 (red, high resistivity zone).

2.1.3 Kwale

The geophysical field experiment was executed between March 19 and 30, 2018, in the typical coastal setting of Kwale County, at the southern coast of Kenya. It aimed at determining the saline water intrusion and the identification of deep Jurassic sandstone aquifers in the typical coastal geological setting of Kwale County. Thanks to the good reference data of BASE Titanium Ltd it is shown that new geophysical methods such as TDEM, AMT and ERT are important improvements to explore the substrate on larger depths than 70 meters below ground level. Especially the WalkTEM of ABEM appears to be very useful for practice. The device is simple and convenient to use, and especially the built-in software enables users head starts because first inversions can already be performed in the field.

The involved organizations in Kwale consisted of BASE Titanium Ltd, Rural Focus, theGro for GooD project, KenGen, Amref Health Africa, Jos Hansen & Soehne, Earth Water Ltd, students and researchers of KEWI and University of Nairobi (UoN), Oxford University, Manken GeoConsultants Ltd. as well as casual workers. This ISGEAG on-the-job training trajectory consisted of 35 participants, of which three were women The complete participants list can be found in Annex 1B.

Comparison of the resistivity methods

The aim of the ISGEAG project was also to introduce 'new' geophysical methods for groundwater exploration and compare them with the more conventional methods to discriminate the advantages and limitations of each method. In Kwale, VES soundings, ERT tomography, TDEM and AMT soundings were applied on 3 transects. The location of the transects was based on the information provided by BASE Titanium Ltd. VES soundings were carried out near borehole 3 (BH3), borehole 5 (BH5) and close to the SWIM borehole.

Because of the information that is available at 2 boreholes (both geological and electrical logs) and because these methods are independent from the geophysics done within ISGEAG, the evaluation of the applicability of the various methods (VES, ERT, TDEM and AMT) is mainly focused at the BH5 transect. A general conceptual profile is presented in Figure 3 and Figure 4 on the next pages. The profile is compared with the existing conceptual hydrogeology. It is clear that the resistivity profile generally agrees with the existing concepts, but there are also differences and new issues.

Geology related conclusions

The first, shallow clay layer in Kwale, which seemed discontinuous, can locally prevent shallow aquifer recharge. The second, Jurassic confining layer seems to be more or less continuous. Recharge of the second (deeper) aquifer will mainly be indirect, from the outcrop area to the west. The deeper (Mazeras sandstone) aquifer seems to be discharging fresh groundwater to the ocean, so saline groundwater intrusion is not yet an issue at this location. The shallow aquifer may be particularly vulnerable to increased saline groundwater intrusion, because of over-abstraction from the shallow aquifer, although currently limited evidence is available that this is occurring in this location. Fresh groundwater water in the deep Karoo sandstones is expected to depths of >200m; deeper layers may contain saline water.

The surprisingly low resistivity of the Mazeras aquifer is not what would be expected of sandstone containing fresh groundwater. The reason for this could be due to a matrix consisting of conductive minerals within the sandstone; or that water bearing layers are restricted to thin layers which are beyond the resolution capabilities of the methods. Borehole logging seems to point to a combination of these two. The low resistivities of the Mazeras formation could also be related to a NNE-SSW oriented paleo channel associated with and connected to other paleo channels as referred in a recent STOTEN paper (Ferrer *et al*, 2019).

Although this could also be a coral type of reef that have become fractured and karstified, at Kwale there is no indication that there is massive limestone that could be karstified. In Kwale the presence of limestone is limited and it is mainly corals. According to the borehole water samples the water is fresh in this part of the aquifer indicating the presence of a paleo channel.

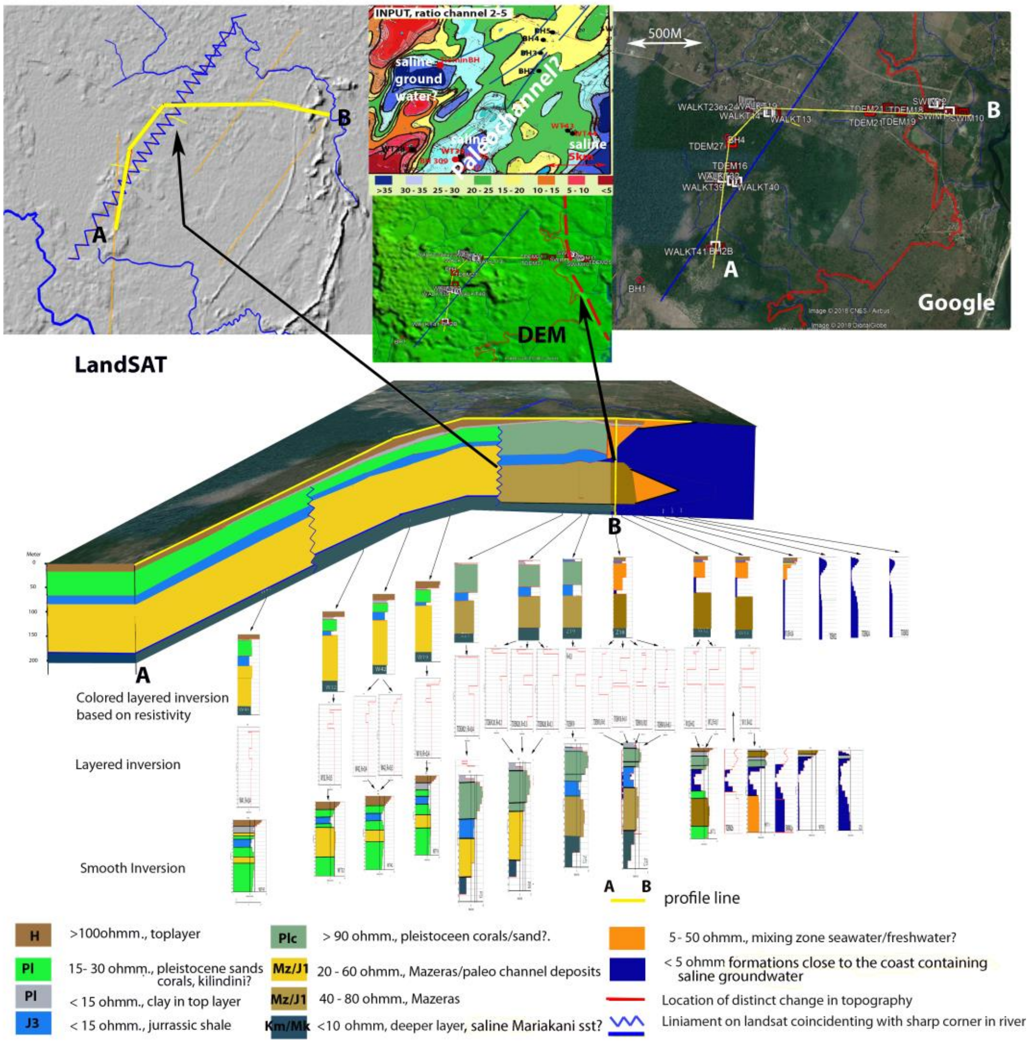

Figure 3. Tentative hydrogeological cross-section along the BASE Titanium boreholes and from Borehole 5 towards the coast (SWIM borehole)

A new interpretation of airborne TDEM (Astromineral, 1978, discussed by Carruthers, 1985) in combination of the ISGEAG geophysics seems to consolidate this but also reveals other consequences. If these are true, groundwater exploration in relation to the distribution of saline groundwater needs to be reviewed in this area. It really shows the urgency for extra WALKTEM soundings and a solid monitoring network. The socio economic consequences of salinization of the groundwater is enormous. Groundwater is essential for local households, hotels for tourism along the coast, mining industry an irrigated agriculture (especially sugar cane).

In this respect, extra TDEM WalkTem soundings south of the study area, showed clear evidence for saline groundwater intrusion in at least one area (Vingujini), probably due to extensive groundwater exploitation. Once again more (saline) groundwater mapping with the WalkTem, or even airborne TDEM (SkyTem) is strongly recommended. Near Gazi (SWIM borehole), at least one additional dual-piezometer monitoring site is recommended further inland from the current SWIM location, 350 m due-west of the main road, opposite the SWIM, to monitor saltwater intrusion more effectively.

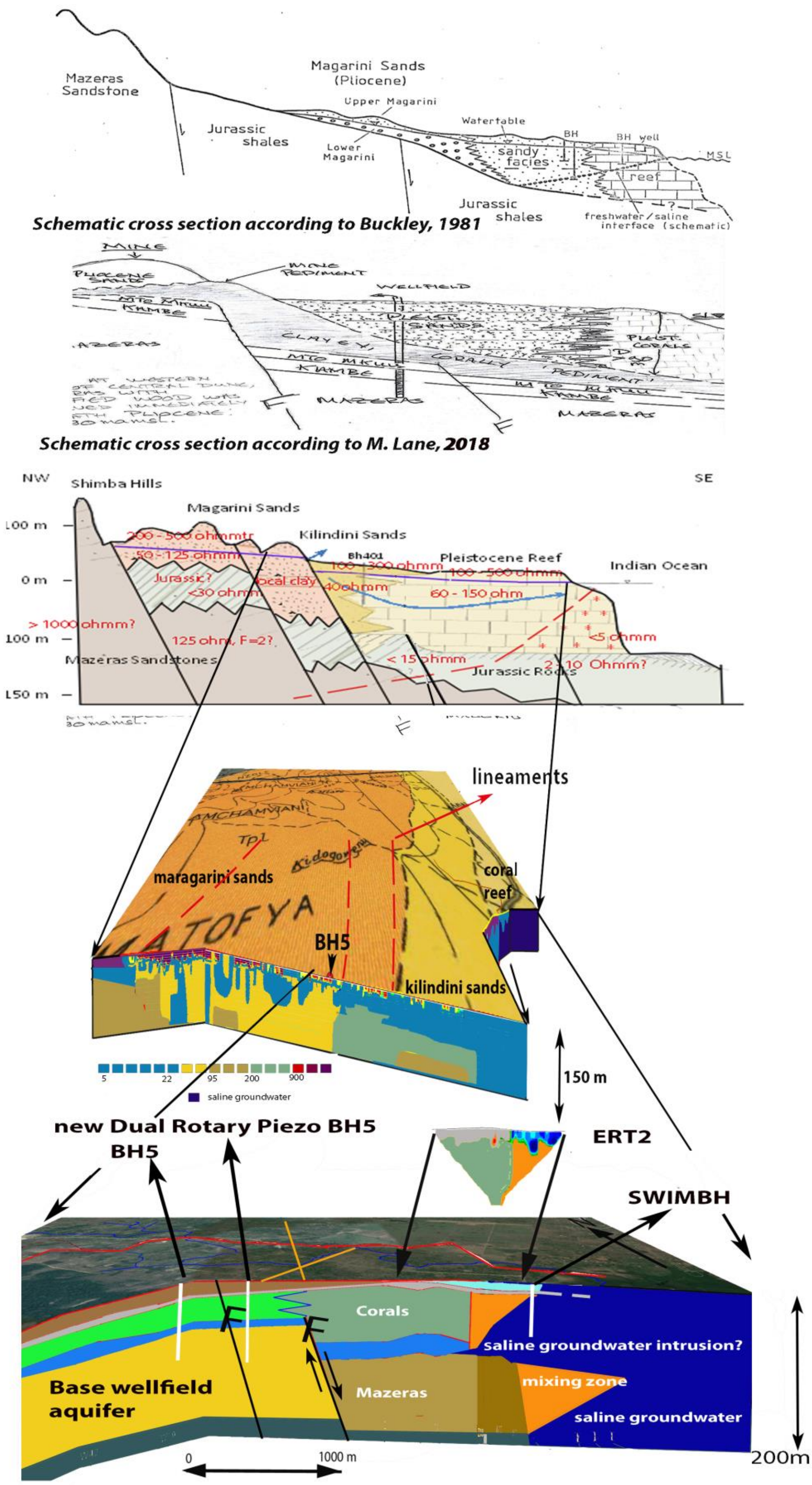

Figure 4. Conceptual cross-section compared with existing conceptual models

Main results of Kwale experiment

Summarizing the main results of the geophysical field experiment in Kwale:

1) Borehole siting reports often lack essential information; sometimes they even contain miss-interpretations that conflict with methodological assumptions. In general, reports (even the proper ones) are extremely difficult to obtain and do not contribute to understanding the (local) hydrogeological concept, which is needed to achieve sustainable groundwater exploration. It is therefore advised to develop and improve the standard model report for any hydrogeological related assessment. Some advice and recommendations towards "minimal" reporting standards for consultants are provided in Annex 2 of this report;
2) Due to the good reference data of BASE Titanium it has been demonstrated that new geophysical methods to Kenya, such as TDEM, AMT and ERT, provide an important improvement to explore the subsurface at greater depths compared to the conventional HEP and VES methods;
3) First analysis shows that the vertical resolution and the exploration depth of TDEM WalkTEM is better than ERT Wenner in this area due to the high contact resistance of the top layer. Even with small transmitter loops of 40m x 40m, the WalkTEM goes to depths of 150 m bgl with a high resolution because of its so called '*dual-moment*' wherein deep and shallow resistivity is measured at the same time. A third instrument setting is the *'high-moment'* with which very high current strength can applied for exploring the deeper layers. All these 3 measurements can be combined in an inversion leading to the high resolution;
4) Especially the new TDEM WalkTem appears to be very useful for practice and application in coastal zones. The WalkTem equipment is easy and convenient to use (user-friendly). In a day approximately at least 6 - 8 measurements can be done, depending on field circumstances (obstacles, no cables, etc.). Especially the built-in software which can generate a first inversion in the field is very important to adjust the concept during the measurement and, if necessary, change the measurement strategy;
5) The TDEM Zonge and AMT approaches were poor in terms of resolution but gave useful information about the deeper layers, especially the Zonge 4Hz soundings. With the WalkTEM, deeper soundings can be made as well when the loop size is increased. With an extra transmitter, depths of interpretation up to 800 m deep should be possible. This was not, however, experimented within the Kwale case;
6) A combination of several transmitter loops with TDEM instruments like the WalkTem, combined with the right software (SPIA), can give a combination of both shallow and deep inversion results at high resolution. Application of AMT would not be not necessary in this case. The quality of inversion of AMT resistivity data is strongly dependent on the quality of the TDEM data;
7) The execution of ERT, VES and HEP is difficult because of the high resistivities of the dry sandy top layers, directly on top of low resistivity layers. Due to the problem with electrode contacts (because of high resistivity top layer), high resolution ERT protocols (i.e. Dipole-Dipole and Gradient arrays) could not be applied. Even with the Wenner array, a lot of 'bad' data points had to be deleted in the Kwale case;
8) For the TDEM and AMT methods, less labor is required compared to VES soundings and ERT profiles. However, the interpretation of the data is less straightforward and instrumentation is more complex (especially the older generations of instruments) and expensive.
9) Coastal areas with low resistivities in the subsurface lends itself very well for the application of TDEM, whilst the limitations of VES just come more to light (on top of

the limited exploration depth of 1/6 of the AB, typically not more 50 - 70 m bgl), making it a less suitable method for coastal areas.

2.1.4 Naivasha

The geophysical field experiment in Naivasha was executed in the geological volcanic sediments on the premises of the Kenya Agricultural and Livestock Research Organization (KALRO) Dairy Research Institute farm, near Lake Naivasha, from 28 October until 9 November, 2018. The geology is a deep sedimentary basin of re-worked volcanic and lacustrine sediments. The geophysical methods were: i) conventional VES soundings and HEP profiling, ii) ERT, iii) TDEM, with two instruments: Zonge (of KenGen) and WalkTEM (ABEM Sweden), and iv) AMT. See also Figure 5 below.

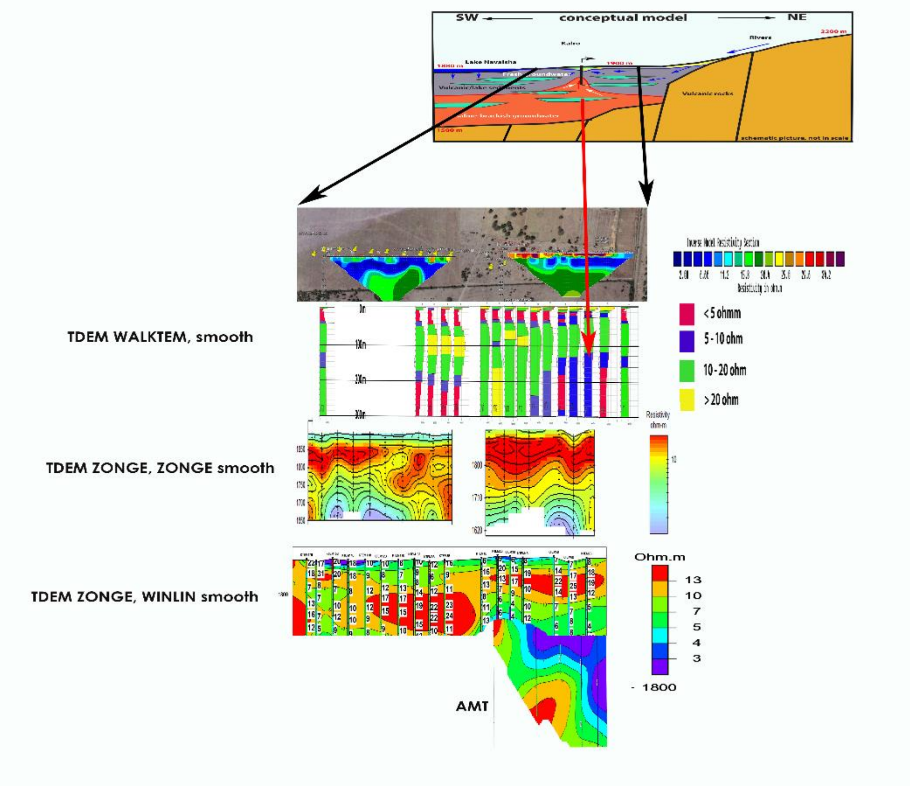

Figure 5. Proving of the conceptual model in Naivasha

A number of organizations were involved in the Naivasha experiment, including: Amref, Guideline Geo Ltd/ABEM, IRD/NOEVA Benin, Jos Hansen & Soenne Ltd, KALRO, KenGen, Ministry of Mines, NIA, Tullow Oil Plc., students and researchers of KEWI, UoN and University of Eldoret and World Vision Kenya. Together they sent 39 participants to the on-the-job training trajectory in Naivasha, of which 5 were women. The complete participants list of Naivasha can be found in Annex 1C.

Main results of Naivasha experiment

Main findings from the field experiments in Naivasha are as follows:

1) Integration of and between the different geophysical methods, and combining this with existing borehole and geophysical survey data (so called ‘conceptual puzzling’) introduces spectacularly better results;
2) VES (one-dimensional; 1D), reasonable resolution to approximately 60 – 70 m bgl. Increased risk is when a long spread of the AB (>400 m) is being applied, which leads to blurring of the lateral changes in the geology;

3) HEP profiling is only appropriate to identify lateral changes in the top 30m of the soil. HEP profiling is, thus, dominated by the top soil layers (lithology), depending on presence of clays, and rarely says anything about deeper structures (as often mistakenly thought). That is why HEP is only interesting for shallow boreholes (up to 30 m bgl);
4) ERT (or CVES; 2D) can provide reasonable insight up to approximately 100 - 15000 m depth depending the cables and set up in use, if correctly applied and interpreted, itcan provide good indication of possible anomalies, such as fracture zones and salt water intrusion;
5) TDEM (especially WalkTEM)(1D) gives a good resolution up to 150 to 200 m bgl (when a loop size of 40 x 40m is being applied). When applying a larger loop size depths of 350 to 400 m bgl or more can be reached, but results in a decrease of the resolution. From the two instruments used (Zonge and WalkTEM), the WalkTEM was exceptional in its use. It is practical to use, and easy to learn to work with by operators without the need for specialized knowledge or experience of TDEM and geophysics. First inversions (interpretation of the raw data to a layer-model) is directly visible on the screen while being in the field; this is an important advantage of the WalkTEM;
6) AMT (1D).because of the use of low frequency natural sources (solar wind and lightning) the exploration depth is over 500 meter, however the resolution is poor. The setup is small but complicated, calibration is needed as well as good skills. Inversion can be improved in respect to true resistivity and layer depth with TDEM soundings, with the so-called 'shifts' When also additional information is available (borehole logs) the inversion can be constraint and further improved with dedicated software.

2.1.5 Final Workshop

At the end of the field work period in Navaisha the hydrogeologist and geophysicist experts of SamSam Water, Wiertsema & Partners and KenGen spend five days to evaluate and, if necessary, to re-interpret the measurements data as well to prepare the final workshop.

This final workshop was held at the KenGen office in Naivasha and attracted a variety of persons from several disciplines (water consultancy's, mining consultancy's, university's, etc). It was proved to be very successful and profound discussions on geophysical prospecting as well as the groundwater exploration in general were held. ABEM / Guideline Geo was available and gave a presentation focused on their geophysical solutions. The ABEM representative in Kenya (Jos Hansen) really helped us to increase the amount of attendants. Also, Fabrice Lawson, a geophysicist of NOEVA Benin, another VIA water project, attended and gave his presentation on his experience with the Magnetic Resonance Sounding (MRS) method in the coastal zone of Greater-Cotonou, Benin.

One very clear message that came from this workshop was the all participants established that more research and education is needed in the field of geophysics and groundwater exploration, since there is a profound lack of quality education and curricula in these fields in Kenya.

Despite the urge we put on their invitations, it was really a pity that representatives of the Kenyan Water Resources Authority (WRA) did not attend this workshop,

2.1.6 Lessons learned

Some other lessons that are learned during the ISGEAG period:

1) During the project it appeared difficult to get the Kenya Water Resources Authority (WRA) involved into the ISGEAG project. Being the regulatory body and potential 'game changers' in groundwater exploration and exploitation, they play a pivotal role in groundwater management. It was learned that (financial) incentives are needed to get WRA and their technical officers involved. The project plan should have incorporated WRA involvement and renumeration for this from the beginning. It has been difficult to contact WRA officials and get the right persons involved;
2) The same goes for University of Nairobi, who could and should play an important role in the dissemination of the newly gained knowledge;
3) In kind contributions are not to expect from local partners due to the socio-economic state of Kenya and most of these organizations (no budget). Project budgets needs to anticipate more on this;
4) Memorandums of Understanding (MOUs) with project and involved partners should be signed well in advance of starting the fieldwork mission, to avoid discussion points about input and fees;
5) The three geophysical field experiments provided training to a total of 110 participants. Out of this 110 only 11 were women (10%), ranging from managerial positions at Kenyan national companies to hydrogeology or geophysicist students. This low percentage can partly be explained by the fact that this is still a very technical and male dominated field of work;
6) The project plan did unfortunately not allow the required time for mutual interpretation and reporting, in particular between KenGen and Dutch experts. Mission time is mainly spent on measuring in the field, logistics, data quality analysis and building a database. For combining inversions and mutual interpretation of all the data into a hydrogeological concept really lacked time. Afterwards email communication proves not to be effective. There should be ample time for mutual interpretation, comparison, discussion. Realize this process together in Kenya will improve the results and the reporting and it will enforce the role and knowledge of the local partners. The inserted third 'analysis week' after the geophysical experiments of Naivasha with KenGen and Dutch experts proved very effective;
7) File names, stations names and numbers should be unambiguous, and same goes for GPS coordinates, which should be from the start according to international standards and reciprocal with Google-Earth. In Kenyan water projects there is often confusion on these coordinates, the mostly used local system is the ARC1960 grid, while others are using WGS84. The problem is that the used system is often not mentioned;
8) Before the start of the fieldwork, the field location should be visited for reconnaissance and social grounding by a field hydrologist, a social worker and local community leaders;
9) With the WalkTEM system it is proved that a higher resolution can be achieved. The system was used in Kajiado before going to Kwale. The ABEM WalkTEM system proved to be very successful, especially in Kwale but also in Kajiado and Naivasha, it is an easy to use sounding system with a high resolution combined with a relative small transmitter loop (spread).

2.2 Impacts

The exact impact – direct or indirect, and now or in 5 years' time – of the ISGEAG project is hard to estimate. There are, however, some signs indicating that a change has been brought about:

1) Growth in hydrogeological conceptual thinking of ISGEAG participants;
2) Urgency and better understanding of (coastal) fresh-salt situation created;
3) Naivasha study outcomes contributing to more effective hydrogeological advice;
4) Successful demonstration of ABEM/Guideline Geo Sweden's WalkTEM and its purchase by various VIA Water partners.

2.2.1 Growth in hydrogeological conceptual thinking

Growth in hydrogeological conceptual thinking of ISGEAG participants and partners. During the on-the-job training trajectory, the participants have been exposed to a learned to make better linkages between the use of different geophysical equipment and measurements, the interpretation of the geophysical data, and on this basis improve the hydrogeological interpretation of a location. This is per geological location summarized in the reports through step-by-step plans per discussed geophysical method (VES, ERT, TDEM and AMT), instructions and standard model reporting (Annex 2 of this report) which the Kenyan partners can use as a guideline.

2.2.2 Urgency and better understanding of fresh-salt situation created

Extra WalkTEM soundings south of the Kwale study area showed clear evidence for saline groundwater intrusion in at least one area (Vingujini), probably due to extensive groundwater exploitation. More (saline) groundwater mapping with the WalkTEM or even airborne TDEM (SkyTEM) is strongly recommended. Judging by the reactions of and co-operation with Rural Focus/Gro for GooD and KenGen that a better understanding of the fresh-salt situation has arisen, especially in Kwale, and that these organizations would like to do something with this with regard to groundwater mapping, monitoring and enforcement. This relates to the 'Mapping of Coastal zone Kwale', which was written as addendum to the project proposal. Nevertheless, regulatory agencies (WRA, national or county governments) have not shown any interest yet, while concrete contacts have not yet been established. Also interest of potential financers (e.g. World Bank, UNICEF) are not yet in the picture.

2.2.3 Naivasha study outcomes contributing to more effective advice

Geophysical and hydrogeological outcomes of the Naivasha study and the resulting new insights can be used by Naivasha County Government, WRA and/or other consultants can be used to provide more effective hydrogeological advice to KALRO in regard to groundwater abstractions and monitoring on their premises.

2.2.4 Successful demonstration of WalkTEM and purchase by VIA Water partners

The successful use and demonstration of ABEM/Guideline Geo's WalkTEM during the ISGEAG research weeks and its added value in the field of strong fresh-salt and geological boundaries, especially on greater depths (>100m bgl), has resulted in the actual purchase of this device by NOEVA Benin/IRD France for geophysical research in Benin and by Wiertsema & Partners (The Netherlands).

2.3 Scaling perspective

Geophysics and groundwater exploration are very specialized fields of work. For an outsider it is often hard to comprehend which methods are being used and how indications and characterization of underground water are being established. The Kenyan groundwater exploration sector and geophysical consultants make good use of this fact, and use the basic amount of information and tools to provide the minimum of hydrogeological indications. Something that is hard to verify by any other layman anyway. To say blunt, it appears that this system has made them lazy, sloppy and inaccurate, while using outdated geophysical methods and interpretation of it. For them, there is no need to change their current approach, since it currently also works (for them), providing them with a good income.

This current system and mindset can only change when the 'rules of the game' are radically changed. It is therefore advised to develop and improve the standard model report for any hydrogeological related assessment. An attempt in the form of advices and recommendations to introduce "minimal" reporting standards for consultants are provided in Annex 2 of this report.

According to the experts of ISGEAG, the Kenya Water Resources Authority (WRA), or otherwise the Kenyan Ministry of Water and Sanitation (MoWS), would be the principal authority to change this situation. Unfortunately, during the ISGEAG project process WRA seemed not interested in professionalization and improvement of current procedures regarding groundwater exploration. Or at least there was insufficient compensation for this from the ISGEAG project side, while their interest and intrinsic motivation to improve the system was lacking.

A bottom up approach seems to be the only solution, by getting young students involved, enthusiastic professors and establish long-term educational programs was one of the outcomes of the workshop. Through learning on the job, universities and commercial parties (such as ABEM / Guideline Geo) who see the added value to be involved would be one of the solutions. At the same time building a community of reliable experts that can help each other and overrule the consultancies who do not want to invest in knowledge and sustainability. With or without the Water Resources Authority (WRA), although in the end they have to join at some point.

The "job" itself could partly be financed by private organizations such as BASE Titanium, KISCOL and KALRO. The proved outcomes of ISGEAG will directly benefit them in a much more sustainable groundwater exploration.

2.3.1 Establishing a sustainable groundwater exploration in Kajiado

In Kajiado, ISGEAG found evidence for a high potential groundwater aquifer in a paleochannel combined fracture. See also Figure 6 on the next page.

In the report suggestions were made for sustainable groundwater exploration. In combination with the VIA Water project Sponge City Kajiado, which is led by the RAIN Foundation, aquifer recharge, groundwater protection and monitoring, and soil erosion prevention could be easily implemented based on the ISGEAG results.

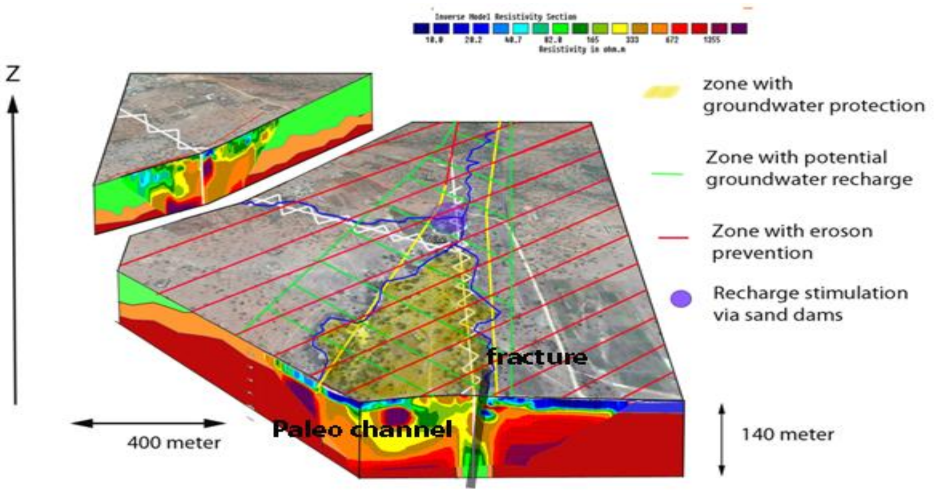

Figure 6. Final hydrogeological conceptual model of Kajiado

2.3.2 Over abstraction of groundwater in Kwale County

The amount of groundwater abstraction in the two main Kwale wellfields (Tiwi and Msambweni) is substantial and growing, but are currently not properly monitored and managed on quantity and quality. At various locations salinization of boreholes have been confirmed with the TDEM/WalkTEM measurements.

Therefore, further hydrogeological mapping and monitoring of Kwale County groundwater is advised. The results of the WalkTEM, in particular for mapping of salt water intrusion were a real eye-opener for Kwale geologists. There is a good opportunity to better identify and locate locations which pose a risky situation of saltwater intrusion along the coast. Picking up this recommendation and action point should, however be demand-driven and lies with the responsible Kenyan water resources authorities (e.g. WRA, MoWS and County Governments).

If this is going to be picked up, then it is advised to setup a measurement campaign for the entire coastal area as quickly as possible, starting with the geophysical mapping of the coastal zone around Kwale with SkyTEM (an airborne TDEM technique related to WalkTEM). Based on the results, deep probing will have to be carried out at specific locations (TDEM / AMT) as well as investigation of possible deep groundwater exploration (e.g. the Neogene aquifer). Following the results, a monitoring program will have to be set up in the salinization areas. The area otherwise runs great social and economic risks. ISGEAG experts have tried to address these issues at local authorities (WRA), the local companies BASE Titanium and KISCOL, and explore (funding) opportunities for this with international organizations, such as WorldBank, the Netherlands Embassy in Nairobi (EKN), and with Vitens Evides International (VEI), but this has not led to concrete signs and approaches of interest, let alone financing.

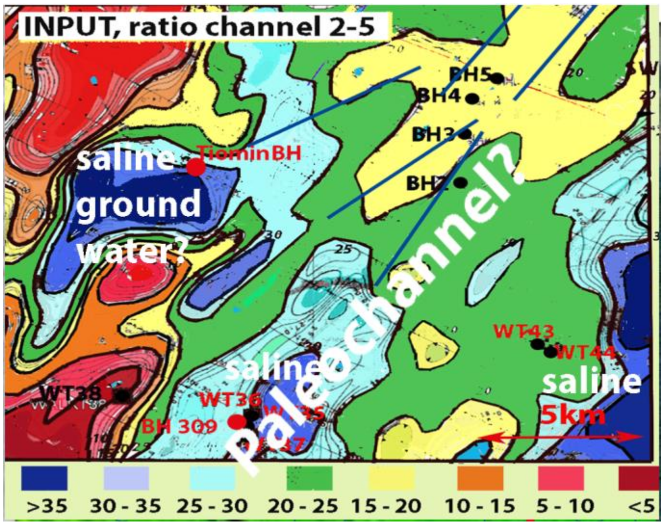

Figure 7. Based on new interpretation of Airborne TDEM (Astromineral 1978) and the locations of the wellfield, extra WalkTEM soundings and new borehole information giving evidence to the new concept and showing the vulnerability of the groundwater situation.

2.3.3 Establishing the source of salinization at the KALRO wellfield

In Navaisha, the ISGEAG program gave evidence to the source of salinization of the wells of the Kenya Agricultural & Livestock Research Organization (KALRO) and came up with a strategy to avoid this in the future. See also Figure 8 below.

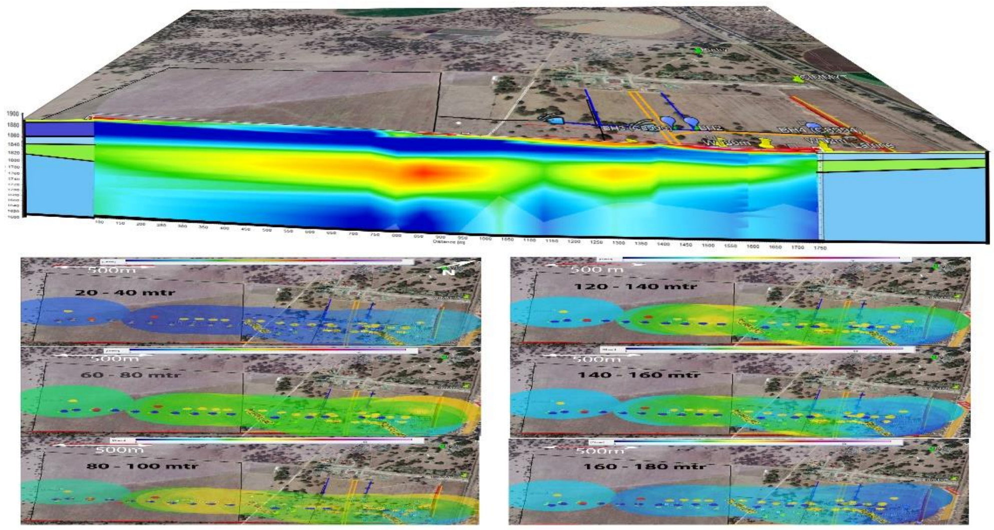

Figure 8. 2D cross-section and lateral extension with depth of resistivity at KALRO. From yellow to red the resistivity increases giving better prospects for groundwater abstraction. The light blue in the shallow zones are mostly clays while the deep blue zones indicate salty/brackish groundwater

2.4 Organization & Partnerships

In this paragraph the project partners and key involved stakeholders are being discussed.

2.4.1 Project team & partners

Acacia Water (lead)

Acacia Water provides consultancy services on groundwater exploration, artificial groundwater recharge, development and management of water resources in general, environmental-friendly development plans, and water infrastructure design. The company is a research-oriented consultancy firm that distinguishes itself by a close collaboration with universities and research institutes. Within ISGEAG, Acacia Water was responsible for the overall project management, partner communication and final reporting through Mr. Stefan de Wildt, while Mr. Michel Groen was the main geophysicist and hydrogeological expert within the project, having extensive experience in these fields, including data collection, fieldwork and analysis.

During the ISGEAG project period Mr. Groen has switched to Wiertsema & Partners, a leading geotechnical engineering company in the Netherlands working worldwide in the fields of soil mechanics, environment, hydrogeology and geotechnics. Due to the good cooperation between Acacia Water and Wiertsema & Partners Mr. Groen could continue his activities for ISGEAG successfully.

SamSam Water

SamSam Water Foundation is a Dutch Foundation that aims to increase the number of people in developing countries with sustainable and reliable access to water and sanitation. 'SamSam' means 'together'. SamSam works together to reach our goal: safe and reliable water to all! SamSam Water believes in practical solutions, realized in close collaboration with partners and beneficiary communities. As one of their activities, SamSam Water makes information on water and sanitation easy to find and accessible for all. For example, all the reports of projects like ISGEAG are made readily available on the SamSam Water website. SamSamWater was represented by Mr. Harry Rolf of Rolf Groundwater Services (RGS), a hydrologist with over 30-years of experience in (ground)water projects in developing countries. Mr. Rolf was an important pivot in the contact with Kenyan partners, social grounding at each research location and taking on a leading role in regard to the more conventional geophysical methods (HEP and VES).

KenGen

Kenya Electricity Generating Company (KenGen) is a leading electrical power generation company in Kenya. KenGen experts are often hired to assess the potential for groundwater abstraction in a certain region. The company holds a lot of knowledge on the subsurface and geotherm, has well-trained geophysics teams and has access to advanced geophysical equipment unique to Kenya, such as: AMT, ERT (CVES) and TDEM (Zonge), which were used at all three research locations. Albeit a very professional and dedicated organization, there appeared to be a significant gap from an operational and knowledge perspective between the operational teams and management, which sometimes slowed down and clouded the cooperation with the other partners in the project.

AMREF Health Africa

AMREF Health Africa in Kenya was a reliable partner throughout this project, providing very valuable and essential logistical support (transport), social grounding at each of the three research locations, and providing a dedicated water and sanitation expert during all three geophysical field experiments.

2.4.2 Other partners & stakeholders

During the project period and each of the three research locations ISGEAG received significant and valuable support from a number of organizations and people. Below, the main organizations are mentioned:

- **ABEM/Guideline Geo**[1], Sweden, seized the opportunity to introduce the new and groundbreaking TDEM instrumentation WalkTEM, which could be the new standard in TDEM soundings. ISGEAG could hire the new WalkTEM from ABEM twice against a significant discount price to promote its application and functioning in Eastern Africa. ABEM is very much interested in the results and introduction of WalkTEM in Kenya/Eastern Africa, and want to be involved in for example seminars given in the region. Cooperation and communication with ABEM/Guideline Geo was very good and swift. The representative of ABEM in Kenya, **Jos. Hansen & Soehne (East Africa) Ltd.** through Mr. Mohammed Sikander were very supporting in logistics, instrumentation and contributing in the fieldwork and workshop. ABEM/Guideline Geo Sweden was also involved with the workshop;
- **AGS Aarhus GeoSoftware**[2], Denmark. Due to the research and educational aims of ISGEAG, AGS Aarhus let the project team make use, for free, their user-friendly and very efficient inversion software for TDEM and WalkTEM;
- **Earth Water Ltd.** – a groundwater consultancy from Nairobi, Kenya, provided field teams for the execution of HEP and VES resistivity measurements in the Kajiado field campaign. The consultant showed however more interest in financial gain of this project than willingness to innovate and learn from new displayed geophysical methods;
- **University of Nairobi** (UoN), Department of Geology, and **Kenya Water Institute** (KEWI), providing motivated students and the future geophysicists and hydrogeologists of Kenya. Capacity and skills of the students were, however, sometimes limited. They also clearly had difficulties linking the theoretical to practical application, something that is close to absent in their educational training. Nevertheless, it was very good that a number of students have been given the time and space for this exposure and enrichment of their curriculum. The engagement of universities on the other hand showed the importance and need to change Kenyan groundwater practices through education of young professionals. In the Naivasha training and workshop there was a very active role of the **University of Eldoret** (UoE), represented by professor Mr. Daniel Mogata. UoE is very interested in any activities to improve their curriculum and to enforce better education of future groundwater experts;
- **Rural Focus Ltd** was a direct partner for the geophysical experiment in Kwale County. Rural Focus is an independent consultancy, seconded to BASE Titanium. BASE Titanium's wellfield was the main study area in the Kwale research. Mr. Mike Lane and Mr. Willy Sasaka of Rural Focus provided ISGEAG with essential information and logistical arrangements, while they knew the ins and outs of the area, geology, and existing boreholes and piezometers. Mr. Sasaka was ISGEAG's indispensable liaison with BASE and the Kenya Forest Service (KFS) in Kwale;
- **Gro for GooD**[3] is a multiple-year program active in the coastal area of Kwale County, including the areas around the BASE Titanium quarry and the KISCOL (sugar cane plantations) estates. Gro for GooD is part of the UpGro (Unlocking the Potential of GROundwater for the poor) programme that is managed by the University of Oxford

[1] https://www.guidelinegeo.com/
[2] https://www.aarhusgeosoftware.dk/
[3] https://upgro.org/consortium/gro-for-good/

(UO), University of Nairobi (UoN) and Rural Focus Ltd. UPGro is a social and natural science approach to enabling sustainable use of groundwater for the benefit of the poor, has similarly to ISGEAG a strong research focus, and supports WRA on setting up better code of practices (CoPs) guidelines together with a variety of Kenyan governmental departments for hydrogeological assessments, groundwater and borehole exploration, water infrastructure functionality as well as for the surface water sector to the design and construction of, for example, dams. One of the UO researchers, Mr. Patrick Thomson, joined ISGEAG with the fieldwork in Kwale.

2.5 Communication

During the project period different means of communication and communications itself have been made, including the use of websites and social media. The VIA Water program bureau also utilized several communication platforms to reach out to its project partners and funders, including their own Twitter account (@viawater) and the online VIA Water Community (https://www.viawater.nl/community).

2.5.1 Twitter messages during VIA Water 'drop the mic' event at AIWW 2017

Both Acacia Water and YEP Programmes sent twitter messages into the world on Monday 30th of October, 2017, during the VIA Water 'drop the mic' event at the Amsterdam International Water Week (AIWW) 2017 conference week. Some footage of this can be seen in Figure 9 below.

Figure 9. Twitter messages of Acacia Water and YEP programmes during the VIA Water 'drop the mic' event at the 2017 AIWW

2.5.2 VIA Water Community posts

During the project period two VIA Water Community (https://www.viawater.nl/community) posts have been shared online.

This first one was posted on 19 May, 2017, and gave a summary of the ISGEAG 1st geophysical field experiment in Kajiado (https://www.viawater.nl/community/isgeag-1stgeophysical-field-experiment-in-kajiado). This resulted in two reactions, of which one was representing a project partner of our joint ISGEAG/SpongeCity Kajiado projects.

The second post was posted on 13 August, 2018, after exceptional results with ABEM/Guideline Geo's WalkTem were achieved during the 2nd field campaign in Kwale (https://www.viawater.nl/community/exceptional-results-walktem-after-2nd-field-campaign-kwale). This post resulted in one reaction by someone of the VIA Water program bureau itself.

2.5.3 SamSam Water database

SamSam Water Foundation dedicated a page under its 'Projects' tab on their website (www.samsamwater.com) to the ISGEAG project, and thereby making all produced technical reports written under the ISGEAG project available to everyone – truly *Open Source*! The webpage currently contains 6 published ISGEAG documents and can be accessed via the following link:
https://www.samsamwater.com/projectdata.php?projectid=81

2.5.4 UPGro – Unlocking the Potential of Groundwater for the Poor

As said, the UpGro (Unlocking the Potential of GROundwater for the poor) programme is managed by the University of Oxford (UO), University of Nairobi (UoN) and Rural Focus Ltd. UPGro is active on Twitter (@UPGroResearch) and shares publications & papers, news and webinars on their website (www.upgro.org).

2.5.5 Communication lessons learned

Communication and sharing experiences, in any project, is key. Although reactions to ISGEAG posts on the VIA Water Community where perhaps little, it does not say they are not read. This is something that perhaps has been underestimated by the ISGEAG partners. Due to the spread of work and non-continuous involvement of any partner it was difficult to keep the external communication going. Genuinely speaking, in the day-to-day activities of the partners this activity was a bit left behind. Which is a shame in view of the results achieved.

2.6 Innovation

2.6.1 Modifications on the innovation

The original innovation did not need much adaptation, except for the major improvements and impact resulting from the application of ABEM/Guideline Geo's WalkTEM during the 2nd field experiment in Kwale, which was greater than expected. This led to the conclusion that this specific geophysical equipment and technique should also be tested in Kajiado (1st field experiment) and in the 3rd and last field experiment of Naivasha. This also made WalkTEM's share in dissemination, training, results and reporting much larger than anticipated. Since WalkTEM is technically speaking a TDEM technique, it was consequently described as part of the TDEM geophysical results in the geophysical technical reports per location.

Something else that has been observed during the execution of the project is the importance of good geophysical and hydrogeological reporting according to well set and verified standards. Recommendations for improvements to the existing system are suggested in Annex 2: "Reporting standards for consultants", wherein "minimal" reporting standards for consultants are introduced. This, however, did not lead to major adaptations of the ISGEAG innovation or its approach.

2.6.2 Appropriateness for the target group

In terms of capacity building and hands-on training on integrating the geophysical methods, originally especially supervisors of drilling projects were targeted to be trained.

The training was to include how to write or execute:

- quantified sensitivity analyses of inversion;
- exploration depth analyses;
- the evaluation of electrode distances;
- the interpretation of profiling graphs;
- the search for fractured aquifers;
- the incorporation of the results into GIS systems.;
- location of the measurements and drilling locations;
- log descriptions and borehole (completion) reports.

The larger ISGEAG project also aimed improving knowledge-sharing between the local Kenyan partners on geophysics, groundwater exploration and borehole drilling. Thereby focusing toward building the capacity of experts, consultants, students, water managers and NGO-officers on groundwater exploration.

Looking back on the project, we can say that a large part of this target group has been reached, of which the participants can be sub-divided as follows:

1. Geophysicists & geologists (KenGen, Tuwoil Plc., ABEM/Guideline Geo);
2. Hydrogeologists & consultants (EarthWater Ltd, Rural Focus Ltd, UPGro/Gro for gooD, Manken Geo Consultants Ltd.);
3. Students and lecturers of educational institutions (University of Nairobi, University of Eldoret, KEWI); and
4. NGO-officers on groundwater exploration (AMREF Health Africa, NIA, CESPAD)

See also Annex 1 of this report. From the geophysicists & geologist group we can see that, especially KenGen, understands the benefits of improved geophysics in a hydrogeological and water availability context, and the business opportunities within it.

Similar observations go for the Hydrogeologists & consultants group, although being true professionals they can also lose themselves faster in details and limitations of the demonstrated methods, rather than seeing the improvements and opportunities of it. Students and, in lesser extent, lectures of educational institutions were generally highly motivated in participating in the ISGEAG field experiments. Their capacity and knowledge, however, often lagged somewhat, which is mainly due to the outdated curriculum in which they are taught.

NGO-officers on groundwater exploration were very interested since they see the added value of using improved geophysics for higher success rates on borehole drilling and groundwater exploration. It remains to be seen, however, if these more technical and lower-ranked officers have the influence and persuasiveness for investments in more advanced geophysical equipment at NGOs. To bring about change, advocacy and lobby at senior management level must therefore be initiated too in order to convince them and let them see the added value of this.

Striking absent parties include:

- Borehole drilling companies and supervisors of drilling projects. The latter, however, can also be found among abovementioned hydrogeology and consultant parties;
- Other NGO-officers and WASH experts from organizations outside the ISGEAG contract partners;
- Lastly, and most importantly, water managers, especially those of the Kenyan Water Resources Authority (WRA), Ministry of Water and Sanitation (MoWS) and drinking water utilities were missing. Despite various invitations and efforts to involve these parties in the project, the requests from ISGEAG were never accepted. As ISGEAG partners we feel that there was not sufficient financial compensation for these parties against their participation.

Nevertheless, involvement and adoption of improved geophysics as well as setting minimal and improved reporting standards for consultants by, especially, the Water Resources Authority (WRA) as regulatory body is of key importance for improving the groundwater exploration situation in Kenya.

Also, knowledge-sharing between the Kenyan partners on geophysics, groundwater exploration and borehole drilling, both public and private partners, should be stimulated and continued, preferably on a national level and platform.
In future, this should lead to a Kenyan-based expert team that can further develop the knowledge base and support other parties. UKAID's UPGro/Gro for gooD and REACH programs have made some extensive efforts together with technical officers from a variety of Kenyan Governmental departments and other Kenyan experts, to improve the Code of Practice (CoP) for all kind of groundwater exploration related development and construction works.

The larger aim is that a Government Guideline on water resources development will get developed and published to entrench nationwide understanding. If aforementioned issues and urgency could be (better) addressed this will result in more sustainable, effective and efficient use of groundwater resources, and will reverse the unsustainable and unacceptable failure rates of dry and non-functional boreholes and handpumps. Such improvements would allow improving water provision to those current without or with poor access to water, most notably the poorest, women, children and elders.

3 Learning opportunities

The learning opportunities in the ISGEAG project is subdivided in: i) ISGEAG learning agenda, ii) learning within VIA Water, iii) learning from others and iv) suggestions to VIA Water.

3.1 Learning agenda

The learning agenda for the ISGEAG project was defined and implemented as:

1. Bringing Kenyan hydrogeological and geophysical partners and students together;
2. Mutual learning from practical field experiments, building of a hydrogeological concept with various geophysical methods at three geologically distinctively different areas; and
3. Knowledge and experience sharing during mid-term and wrap-up discussion days per geophysical field experiment.

At the end of the third and last geophysical field experiment in Naivasha, a two-day workshop was held, wherein many and wide variety stakeholders participated (see also Annex 1c). In the context of the ISGEAG project and Kenya a lot was learned on the applicability of new geophysical technologies and how they could add value to groundwater exploration in Kenya. Another conclusion from ISGEAG is that the present groundwater practices in Kenya, and current hydrogeological assessment system and mindset, are insufficient and that the 'rules of the game' need to be changed radically by WRA and MoWS (e.g. in the form of a standard model report), as suggested in paragraph 0 and Annex 2.

As said earlier, one very clear message that came from this workshop was the all participants established that more research and education is needed in the field of geophysics and groundwater exploration, since there is a profound lack of quality education and curricula in these fields in Kenya. One of the main outcomes of the final workshop was that a bottom up approach seems to be the only solution, targeting getting young students involved, enthusiastic professors in front of the classroom and establish long term educational programs. By learning on the job through internship placements, requests for universities and the private sector to cooperate even more. At the same time building a community of reliable experts that can help each other and overrule the consultancies who do not want to invest in knowledge and sustainability.

It was also learned that the curricula of relevant Kenyan educational institutions (Geological Department of University of Nairobi, University of Eldoret and the Kenyan Water Institute (KEWI) in Eldoret) in a parallel trajectory need to be improved both in theory and in the practice of geophysics, hydrogeological assessments and groundwater exploration, aligned with new insights, the latest techniques and according to contemporary standards.

Throughout the ISGEAG project and especially around the organization and execution of the three geophysical field campaigns it proved difficult to get the Kenyan Water Resources Authority (WRA) involved and engaged in the project. As executive power, regulator and policy enforcer, WRA plays a pivotal role in changing the current practices. Whether it was her passivity, lack of capacity or different expectations of reimbursements, WRA was seemingly not active in its role to change the groundwater exploration situation in Kenya and to learn from the ISGEAG project outputs. With the result that universities, consultants and other stakeholders also feel less pressure and urgency to change things and improve their practices.

Nevertheless, most (Kenyan) partners involved in ISGEAG are aware of the institutionalized and organizational problems currently playing around geophysics and hydrogeological assessments, but rarely does anyone dare to criticize this (even in a positive or polite way). In Kenya, providing a livelihood (subsistence) and financial gain seems a more dominant interest than professional quality of work.

3.2 Learning within VIA Water

The VIA Water programme offered ISGEAG the opportunity to test and compare various conventional and newer groundwater exploration technologies and geophysical methods. Such a comparative and highly practical research would never have been possible in a regular WRM program. The geophysical possibilities and opportunities are now known and well-reported. It is, however, now still up to the Kenyan (educational) institutions, experts and consultants and to take it up the advices and recommendations being made, to implement it and to embed it into national policies and guidelines.

Also, the VIA Water Sharing Skills Seminar week at Maanzoni Lodge, Athi River in Kenya, in November 2016, was a very valuable seminar for sharing experiences and to give a kick-start to our ISGEAG project. The seminar, organized by the VIA Water program bureau and facilitated by MDF Training & Consultancy, assembled 30 project leaders from 9 African countries from all VIA Water projects at that time. From ISGEAG this seminar week was represented by someone from Acacia Water (Mr. Stefan de Wildt) and someone of AMREF Health Africa (Mr. Kenneth Ochieng). The week facilitated the representatives in working on their project management and leadership skills, while knowledge got enriched by sharing it with others, which ultimately leads to better innovations and a higher level of development.

Valuable contacts were established through the VIA Water program bureau too, such as:

1. linkage with Sponge City Kajiado project – on initiative of VIA Water – and its partners (RAIN Foundation, Acacia Water, AMREF Kenya, MTTI, NIA, SASOL Foundation). This was an excellent match between the two projects and the joined forces are still on-going. It genuinely supported both ISGEAG and Sponge City Kajiado in developing a combined approach and gave inspiration and new ideas for combining groundwater monitoring, protection, recharge and exploration for safe drinking water supply as well as for irrigation water;
2. knowledge exchange with NOEVA Benin. The contacts with the NOEVA project worked well to both sides: both projects came to similar conclusions on ‘conventional techniques’ (VES, ERT), while NOEVA Benin and its partner IRD France now purchased the ABEM/Guideline Geo WalkTEM technique for application in Benin. On the other hand, ISGEAG learned from the opportunities of the Magnetic Resonance Sounding (MRS) method as tested in the coastal zone of Cotonou, Benin.

3.3 Learning from others

ISGEAG learned from different partners, persons and sources to improve its research performances and results. A detailed list is given below:

- **NOEVA Benin/Mr. Fabrice Lawson:** The independent research in Benin – executed within VIA Water project NOEVA: HydroGeophysics in Coastal zone of Benin – came to similar conclusions as ISGEAG with respect to the limitations of conventional geophysical techniques (VES/HEP);
- **Rural Focus Ltd/Mr. Mike Lane:** this collaboration showed the importance of working with professionals and experts who value commitment and high quality of work. As an advisor to BASE Titanium Ltd, Rural Focus also showed the positive difference in working with a commercial Kenyan company, and knowing and valuing the importance of good groundwater research, reliable data and acting accordingly;
- Lessons from **Rural Focus Ltd/Gro for gooD:** the importance of a multi-year relationship, joint vision and commitment, which is managed and guided by an international group of experienced and renowned senior hydrogeologists;
- **KenGen:** roughly the opposite of Rural Focus, where an apparent gap exists between the operational teams and management. It must be stressed that the operational teams are very skilled, practical, resourceful and fast in the field. Their focus and experience is mainly on geothermal but they are also participating and gaining experience in groundwater. In communications with the management level of KenGen it seems that financial gain is a major driver, and this approach trickles down and influences and hinder the delivery of quality work and developing knowledge by the operational teams;
- A very good and conducive relationship is realized with **ABEM/ Guideline Geo** Sweden and their East African Region representative **Jos. Hansen & Soehne (East Africa) Ltd.** Besides the leasing of geophysical equipment, the collaboration is exploring opportunities for the organization of user-trainings and seminars;
- A good working relationship was also built with **University of Eldoret** (UoE). UoE was represented by lecturers who showed real interest to learn more and are willing to partner in future education projects (e.g. NUFFIC Niche proposals);
- Getting hands on technical information and documents in Kenya is extremely difficult, which is a great worry. Most of the useful data are from (British) studies in the eighties or even older. These documents are often readily available on the Internet. It was very positive to find that many of these reports were digitized copies made available by Wageningen University (WUR) and ITC/TU Twente, both Dutch universities.

3.4 Suggestions to VIA Water

Overall the support of VIA Water, its program bureau and their extensive network both in Kenya as well as in other African countries proved very valuable and well appreciated, of which the collaborations with the Sponge City Kajiado and NOEVA Benin are good examples. Nevertheless, some project experiences also identified issues that could have received some more support or can be points for improvement for future projects:

- VIA Water could anticipate more on potential project management issues by adding a project checklist. Especially in relation to the importance of having a MoU or contract with your project partners. With some partners MoU's were established during the project after it was determined that a relative loose approach did not work. Nevertheless, even with MoU's communication and project agreements with some project partners were still difficult and rough. Suggestion to VIA Water is that more attention and support could be provided on how to manage and deal with such issues, for example during the Shared Skills Seminars;

- VIA Water could also provide a more training and sensitization about in-kind contributions and the rationale behind it, especially towards independent entrepreneurs and local partners. Within ISGEAG this remained somewhat unclear to some project partners and staff, and this issue continued being a recurring discussion throughout the project, claiming dismissal of the in-kind contribution or being entitled to other (higher) rates or more days as a result of double employment or being sub-contractor for example. Secondly, it was also a practical administrative struggle sometimes. The lead party had most of the times prepared ready-made invoice templates for partners and then incorrect invoice overviews were still sent back and without the in-kind contributions. It is merely a suggestion that VIA Water – besides the negotiations among the partners themselves - could also pay more attention to this;
- VIA Water's flexibility towards supplementary budgets and with regard to timing was well appreciated. Nevertheless, in ISGEAG's experience fairly interpretable proposals were approved, while there was less flexibility in contract and budget spending, which made it difficult sometimes to justify deviations and overtime within existing reporting framework. Stricter selection in advance can prevent projects and alliances from making it themselves difficult to account for project activities and expenditures. On balance, this means that ISGEAG now has to pay back a part of the allocated budget. Admittedly, Acacia Water also could have looked up consultation with VIA Water more often too in this regard;
- VIA Water could give guidelines and give room for more financial space for budgeting the educational part of projects (daily subsistence allowances (DSAs), travel and lodging of participants, etc.);
- As partners of ISGEAG we feel that VIA Water and considering its extensive network, especially in relation to education institutions such as IHE Delft, could give more guidance, advice and think of collaboration with local active educational institutes to establish long-term education programs at a practical level (learning on the job). This was currently unfortunately insufficiently included and accounted for in the ISGEAG project, and which could be seen as negligent on our part, but is something that could also have been noticed by VIA Water;
- Preparation for and sharing of experiences on how to deal with passive and aloof partners, personnel conflicts within organizations and the loss of key personnel in your project, are some of subjects which could get more attention. For example during the annual multi-day VIA Water Sharing Skills Seminars;
- The renting and (temporarily) importing of geophysical equipment from Netherlands and Sweden to Kenya required some significant planning, time and costs, and then it still caused some custom issues upon arrival in Kenya. In a later stage we requested for and received assistance from the Dutch Embassy in Nairobi (EKN) with regard to custom clearance. In future projects, VIA Water could mediate more in this and stimulate the exchange of experiences between VIA Water project owners.

4 Finances

An overview of expenses and revenues against original and adjusted budgets, including the Addendum to the original budget (L16021, VW011) is presented in Annex 3: Financial End Report. The finances for the ISGEAG project were fully funded by VIA Water through Aqua for All, in addition to the own contributions of the ISGEAG project partners. This funding consisted of two parts:

1. Funding of the original ISGEAG project (project nr.: L16021, VW011). The total contract sum is € 224,050 and includes the contribution of contract partners of € 50,200 as specified in the original budget. The remaining amount of € 173,850 is considered as a grant of Aqua for All/VIA Water;
2. Addendum to the original ISGEAG budget (proposal date 16-05-2018), with an up topping of the contract by € 31,460, being a subsidy for € 21,460 and a co-funding contribution of € 10,000.

Together this amounts to a total (potential) funding by VIA Water/Aqua for All of € 195,310.

4.1 Expenses

Starting with the expenses under the ISGEAG project, there are some deviations from the original budget and other explanations in regard to project spending that are noteworthy reporting.

4.1.1 Acacia Water

Starting with the lead partner, Acacia Water, the actual costs incurred largely correspond with what was budgeted. It should be mentioned that the project expenses made by Mr. Michel Groen after his transfer to Wiertsema & Partners (Spring 2017) is included under the budget of Acacia Water since there was a kind of subcontractor contract with them (budget worth € 20,950). Same goes for the knowledge exchange with NOEVA Benin in Kenya as part of the Addendum to the ISGEAG contract, which has been placed under the Acacia Water budget. The main deviations under the budget of Acacia Water are the fact that:

- actual international flight costs were in some occasions slightly higher than budgeted, while once a ticket for SamSam Water/RGS has been booked from the budget of Acacia Water;
- Daily subsistence allowance (DSA) and accommodation costs for all three fieldwork locations together proved lower than anticipated;
- Combined insurance and transport costs of ABEM/Guideline Geo's WalkTEM equipment proved lower than anticipated, partly because the WalkTEM was purchased by Wiertsema & Partners still during the project time;
- deployment of a Senior consultant (Mr. Albert Tuinhof was proposed) for investigating (financing) possibilities for mapping of Kwale coastal zone under the

Addendum has not been utilized, mainly due to lack of time as well as sufficient perspective towards implementation of this project idea.

This all results in a positive balance of € 4,501 which has not been spent according to the two budgets (original budget and Addendum to it).

4.1.2 SamSam Water

The activities under the budget of SamSam Water are completely executed by Mr. Harry Rolf of Rolf Groundwater Services (RGS). Below the major explanations and deviations:

- RGS has executed more work than anticipated, preliminary because there were much more days needed in the project for i) preliminary data collection and analysis, ii) fieldwork preparations and iii) reporting. In the end a total of 24 days have been spent more by RGS in the ISGEAG project than budgeted for. This explains the higher costs being made (€ 16,559 more than budgeted) as well as the higher in-kind contributions under this part of the budget;
- Extra costs on rental and purchase of additional equipment, tools and utensils to execute the fieldwork;
- Paying of DSAs and participation costs (e.g. venue, lunch) of voluntarily participating students and professors of universities (Nairobi, Eldoret) and KEWI, which proved higher than budgeted;
- A financially negative deviation under the budget of SamSam Water are higher expenses as a result of higher travel costs and insurances, which were advanced by SamSam Water (through Rolf Groundwater Services).

This resulted in a negative balance of € 16,559 under the SamSam Water budget, which was spent more compared to the two budgets (original budget and Addendum to it).

4.1.3 KenGen

The actual costs incurred by contract partner KenGen largely correspond with what was budgeted. Extra and higher costs can be justified because the hiring of geophysics teams was only for the TDEM equipment, and not for the deployment of AMT and ERT. This agreement was overlooked during the writing of the project proposal and the signing of the contract and new arrangements had to be made afterwards regarding the deployment of AMT and ERT. Relatively smoothly it has been agreed that AMT and ERT can be deployed for a total of 12 team days, including executive teams, for a total amount of € 9,250, which has been partially financed from the contract budget part intended for 'hiring of geophysics/Earth Water Ltd.'. See also the next paragraph.

Under the Addendum the deployment of 1 Senior hydrogeologist for 5 days has not been utilized and invoiced by KenGen. The two mentioned deviations to the budget results in a negative balance of € 6,250, which was higher than budgeted.

4.1.4 Hiring of geophysics/Earth Water

This budget remained largely untouched throughout the project, also because of unclarity if this could be used by other contract partners than Earth Water or for the (additional) hiring of geophysical equipment. In the end, Earth Water has only been deployed for 5 days during the Kajiado fieldwork campaign, compared to the total 30 days available. During this first geophysical field experiment it proved, however, that i) they wanted to recover transport costs from the other contract partners, ii) that application of HEP/VES was not relevant at all fieldwork locations and iii) that Earth Water Ltd is not interested and willing to learn from other geophysical methods, and was not participating and contributing to the mutual learning aspect of the ISGEAG project.

Part of the 'rental additional equipment' budget was used for the hiring of AMT and ERT equipment including the operation teams of KenGen, as explained in the previous paragraph.
The two times renting costs of ABEM/Guideline Geo's WalkTEM are also included under this budget, and amount to € 9,832, which is € 5,168 less than the actual budget of € 15,000.

In total only € 12,832 has been spent from this budget part of originally €33,000, resulting in a positive balance of € 20,168.

4.1.5 AMREF Health Africa

Contract partner AMREF Health Africa is the only partner who have carried out all project activities exactly according to budget. Nothing more or less has been spent.

4.1.6 Overall Expenses

From the overall expenses we see that especially from the original budget more has been done than budgeted; €254,361 spent versus €255,510 budgeted (difference: € -1,149). This comprises spending from subsidy amount of VIA Water as well as in-kind contributions and discount on rates. When only looking to expenses from the VIA Water subsidy, actual costs have been incurred that amount to €182,461. While from the Addendum financing the budget has not been fully utilized; only €23,874 was spent of the €31,460 total available budget (difference: € 7,586, and both VIA Water subsidy and in-kind contributions).

Explanations for these differences have been provided in the paragraphs above. The 'underspending' of the Addendum budget can largely be attributed to the non-execution of investigating the opportunities for regional groundwater mapping of the Kwale coastal zone due to lack of time and sufficient perspective. This activity included the deployment of Senior external consultants and hydrogeologists of Acacia Water (Mr. Albert Tuinhof), SamSam Water and KenGen for 5 days and international travel.

Putting the original budget and Addendum to it together it can be seen that € 255,510 was budgeted, but that the actual costs incurred remained at € 254,361, of which in-kind contribution (or discount on rates) was budgeted at € 60,200. However, in the end an own-kind contribution of € 71,900 was provided by the contract partners. This higher amount can be explained by the considerable number of extra days that have been made and invoiced by SamSam Water (through RGS).

4.2 Revenues

From the funding disbursements as presented in Table 2 on the next page it can be seen too that the total invoiced amounts to € 182,461 instead of the theoretical € 195,310 budgeted funding by Aqua for All as explained in the introduction of this chapter. This can be explained by lower project expenses actually incurred, which was explained in the previous paragraph.

Based on the available project funding a final payment request of € 17,350 to Aqua for All was allowed. However, based on actually incurred project expenses, only a final amount of €4,501 will be invoiced in July 2019.

Table 2: Contractual funding disbursements as received by Aqua for All

Description	Invoice date	Invoice amount
Disbursement schedule 08/2016, first payment	15-07-2016	€ 100,000
Disbursement schedule 04.2017, 1st part second payment	08-12-2017	€ 26,500
2nd part third disbursement, preparation 3rd mission	21-06-2018	€ 30,000
Disbursement according to addendum contract L16021	21-06-2018	€ 21,460
Sub total amount:		**€ 177,960**
Receivable final invoice	March 2019	€ 4,501
Total amount:		**€ 182,461**

4.3 Verification of accounts

Incoming invoices are checked by Acacia Water's administration on project number, budget and accuracy, then entered in the Exact package, to the project administration. The project administration has a comprehensive time administration and the invoices entered are displayed. The incoming invoices go to the project manager for approval, control takes place on basis of delivery and agreements made. This financial statement has been prepared by Ingrid van Geloven and audited by Kees Dorland Financial Manager, both employees of Acacia Water. If a financial audit is needed the financial statement can and will be audited with the administration by a certified independent external auditor.

Annexes

Annex 1: Participants lists

A: Participant list of Kajiado

B: Participant list of Kwale

C: Participant list of Naivasha

Annex 1A: Participant list of Kajiado

Participation list ISGEAG on-the-job training trajectory Kajiado

No.	Name	Organization	Role / function	E-mail address	Telephone number
1	Omiti, Amon	KenGen	Geophysicist	aomiti@kengen.co.ke	0725921886
2	Cosmas, Rutto	KenGen	Geophysicist	crutto@kengen.co.ke	0721664234
3	Kuhura, Elias	KenGen	Geophysicist		0798196186
4	Oduong, Elvis O	KenGen	Technician	e.oduong@kengen.co.ke	0712120119
5	Waweru Nganga, Paul	KenGen	Technician	p.waweru@kengen.co.ke	0721780860
6	Mogunde Motaro, Enock	KenGen	Technician	enock.motaro@kengen.co.ke	0723436372
7	Kimani, Peter K	KenGen	Technician	petersonwitz@kengen.co.ke	0712318313
8	Kimata, Junior	KenGen	Geophysicist	jkimata@kengen.co.ke	0728855805
9	Omollo, Philip	KenGen	Geophysicist	pomollo@kengen.co.ke	071977882
10	Murilla, Colvin	KenGen	Technician	cmurilla@kengen.co.ke	0720521369
11	Kangethe, Henry K	KenGen	Technician	kkangette@kengen.co.ke	0723437258
12	Maina, Paul M	KenGen	Technician	pmuchiri@kengen.co.ke	0725739399
13	Maina, James K	KenGen	Technician	jkamai@kengen.co.ke	0726445340
14	Ochieng, Kenneth	AMREF	Technical	kenneth_ochieng@yahoo.co.uk	0721962440
15	Makomba, Pendo	AMREF	intern	pendosamson@yahoo.com	0717113410
16	Omwaka, Kennedy	AMREF	intern	omwakaken@gmail.com	0726321071
17	Zioka. Joy M	Earth Water Consultants	Ass. Hydrogeologist	joynzioka.m@gmail.com	
18	Konicoru, Kiarie, Ian	Earth Water Consultants	Ass. Hydrogeologist	iankiari@yahoo.com	
19	Maina, Charles	Earth Water Consultants	Ass. Hydrogeologist	charlesmaina@rocketmail.com	
20	Musoma, Amos	KEWI	Student	amosmusoma@gmail.com	0707011494
21	Kangutu, Michael	University of Nairobi	Student	mk.geomike@gmail.com	0725177493
22	Kimata P	Kajiado County	Water	pkimata@gmail.com	
23	Njoroge , Dorcas	Kajiado County	Water	dorcasnini@yahoo.com	
24	Waiganjo, Florence	Kajiado County	Water	fwainganjo@gmail.com	
25	Baraza, Jacob	CESPAD NGO		jacobbaraza@yahoo.com	0725409960
26	Maripel, Stephen	Edukaya Olkeju	social worker, pastor		0720279457
27	Matampash Kenny	NIA (NGO)	Technical coordinator	kennymatampash@yahoo.co.uk	
28	Jakinda Samwel	NIA	Hydrogeologist	sjakinda@yahoo.com	
29	Teketi Paul	NIA	technical	teketip@yahoo.co.uk	
30	Leikishon, John	NIA	technical	johnyienky@yahoo.com	0727720296
31	Mogoj. Samuel	Casual	VES soundings		0717559196
32	Gichana, Saul	Casual	VES soundings		0700173752
33	Mulwa, John	Casual	VES soundings		0721275035
34	Mwaura, Geoffrey	Casual	VES soundings		0789257449
35	Muruthi, Elias	Casual	VES soundings		0798196186
36	Mogetho, Job	Casual	VES soundings		0725302043

Annex 1B: Participant list of Kwale

Participation list ISGEAG on-the-job training trajectory Kwale					
No.	Name	Organization	Role / function	E-mail address	Phone nr.
1	Jones, Georgina	BASE Titanium Ltd	Manager Environment	GJones@basetitanium.com	
2	Mike Lane	Rural Focus/ Gro for gooD	senior Geologist	lanemike01@gmail.com	
3	Willy Sasaka	Rural Focus/ Gro for gooD	hydrogeologist	willy.sasaka@ruralfocus.com	722853838
4	Thomas, Mike	Rural Focus	hydrogeologist	mthomas@yahoo.com	
5	Mwakurya, Suleiman	Rural Focuse	geologist	mwakurya@gmail.com	
6	Wara, Calvince	Rural Focus/ Gro for gooD	research operations	calvince.wara@ruralfocus.com	
7	Alfan, Nanga	Rural Focus	driver		
8	Cosmas, Rutto	KenGen	Geophysicist	crutto@kengen.co.ke	0721664234
9	Omollo, Philip	KenGen	Geophysicist	pomollo@kengen.co.ke	071977882
10	Oduong, Elvis O	KenGen	Technician	e.oduong@kengen.co.ke	0712120119
11	Kimani, Peter K	KenGen	Technician	petersonwitz@kengen.co.ke	0712318313
12	Okota, Martin	KenGen	Technician		
13	Kariuki, Lilian	KenGen			
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Annex 1C: Participant list of Naivasha

Participation list ISGEAG on-the-job training trajectory Naivasha *)					
*) kindly note that not all (e-mail) addresses may be correct due to participant's handwriting					
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Annex 2: Reporting standards for consultants

Reporting standards for consultants

In this *standard model report* the "minimal" reporting standards for consultants involved in geophysics and groundwater exploration are being introduced.

The ISGEAG partners provide their observations on the current execution of hydrogeological assessments in Kenya and provide suggestions and recommendations on how to improve the quality of hydrogeological assessment reporting and investigation practices. It entails the scientific and practical implementation requirements of determining a drilling location which is assessed to have the highest potential/greatest chance of success to tap underground water. This is mostly assessed during a hydrogeological assessment, preferably in combination with a geophysical survey.

Contextual background

To increase the chance for successful borehole drilling and tapping of groundwater a proper hydrogeological survey is required in which a maximum of relevant data is collected and combined, giving better understanding of the hydrogeological system, thereby enabling a well-argued decision on drilling a borehole at a specific location to a specific depth.

At the completion of the siting investigations a Hydrogeological Assessment Report shall be written, describing the investigation and presenting recommendations as appropriate[4]. For permitting, the report has to be submitted to the Water Resources Authority (WRA). The Second Schedule of the Water Resources Management rules (2007)[5] prescribes the guidelines, format and compilers for Technical Reports which should show the consultant's professional judgment in including important and appropriate information in the Technical Report. The reader is also referred to the Kenyan Code of Practice (CoP) for Borehole Siting (MoWS/WRA, 2018[6]), which have been developed with support of UKAID's UPGro/Gro for GooD programme. CoPs for the construction of boreholes, the supervision of construction of boreholes and the test pumping of boreholes have been recently developed too.

Observations and recommendations from ISGEAG

During the three ISGEAG fields campaigns (Kajiado, Kwale and Naivasha), many 'hydrogeological' or 'geophysical' survey reports were encountered which varied greatly in quality. See also Box 2 as example on the next page. Well-documented reports will not only be useful for the Kenya Water Resources Authority (WRA) but will also be a crucial source of information for any future investigations by other organizations, landowners and developers in the same area.

The availability of and access to reports in Kenya on the other hand is a major challenge: reports of preliminary and geophysical surveys, actual borehole drilling and borehole completion are often not readily available, while hydrogeological investigations are seriously hampered (and unnecessarily costly) by the lack of available technical information of these preliminary investigations.

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4 Depending on the purpose and scale of the investigations the names and contents of the report may be different: "Borehole Siting", "Hydrogeological Survey", "Geophysical Survey", "Hydrogeological Assessment", "Aquifer Study", "Water Resources Assessment"

5 Kenya Water Resources Management Rules, 2007 [L.N. 171/2007, L.N. 93/2011, L.N. 105/2012], of which Rules 27, 64, 66, 68, 72, 85, 120, 121 apply for the second schedule.

6 Kenya Ministry of Water and Sanitation/Water Resources Authority (2018). The Code of Practice for Borehole Siting (Draft). Nairobi, Kenya.

Box 2: Drilling beyond exploration depth

Although an integrated hydrogeological assessment is recommended, only three Vertical Electrical Soundings (VESs) are usually carried out by most hydrogeologist to determine the location of a new borehole in Kenya. VES is a geo-electrical methods that provides information about the characterization of the subsurface and the presence of groundwater up to a depth of 50 to 70 meters. Local experts, however, often recommend drilling depths beyond the assessment capacity of VES without using additional research methods

The fragment below was copied from a report for borehole siting. The VES was executed with the maximum electrode distance of 500 meter. This corresponds to an exploration depth of less than 100 meter (1/6th of AB). As can be read at the bottom of the figure drilling is recommended to an approximate depth of 220 meter. The collected data does neither provide any information on the characterization of the subsurface at that depth nor on the presence of groundwater for abstraction. Moreover, the location of the VES, coordinates and topography, considered crucial for proper an hydrogeological assessment is not included in the report.

Interpretations of VES 3

Depth (m)	Resistivity (Ohmm)	Interpretation
0.0 – 2.1	330.0	Sandy top soils
2.1 – 6.1	428.9	Weathered sub-srufface soils
6.1 – 26.0	1020.0	Compact regolith
26 – 80.0	375.4	Weathered basement
80 - 150	340.0	Highly weathered/ fractured basement
Below 150.0	682.0	Weathered to fresh basement

The results of VES 3 measurements show that the site is covered at the surface by sandy loam top soils to a depth of about 2.1m. These are underlain by weathered sub-surface soils to a depth of 6.1m and are in-turn underlain by compact regolith to a depth of about 26m. This is underlain by highly weathered/ fractured basement to a depth of about 150m and it's aquiferous. Beyond 150m is weathered to fresh basement layer with increasing resistivity is Aquiferous on the upper zones

Drilling is recommended at this site to an approximate depth of about 220m.

As such, WRA prescribes that the format of abovementioned reports should be adequate. In addition that this needs to be clearer and better defined, the requirements per part must be improved and better defined as well such that it provides grounded information on the understanding of the geological and groundwater system ('the concept'). In such a way that it is not only useful for the recommended borehole location at hand, but also benefits any future investigations by any interested person or party in the area.

Minimal Reporting Standards per subject

The following sections give the main advices and recommendations of the ISGEAG partners for the "minimal" reporting standards for consultants. The paragraphs follow chronologically the main subjects, and can also be traced to the Geophysical technical report chapters (Geophysical Technical Reports Kajiado (2018) and Kwale (2019)).

1. Project background information

The standard brief report should state at least substantiated information in regard to the:

1. Applicant
2. Location
3. Proposed activity
4. Water demand (current and future)
5. Existing water resources and infrastructure

This project background information should be supported by a proper digital map of the study area including:

- Geographical coordinates;
- Relevant names of locations
- Main roads
- Locations of the main water sources (boreholes, shallow wells, springs, piped water supply systems)

In Kenya, the Arc1960 coordinate system is still being used, being convenient for topographical maps. However, worldwide use of Google Earth and thereby the use of UTM WGS84 for geographical positions and locations is nowadays more commonly used. It therefore is advised to use WGS84 for GPS locations and to make "minimally" use of Google Earth for mapping (although GIS software such as ArcGIS or Q GIS are used as well). Always indicate the datum and coordinate system (e.g. WGS84 or ARC1960) that is being used.

2. Biophysical context

Provide a comprehensive and thorough area or landscape background of the biophysical context, which typically includes a factual and verified description of the:

1. Administrative boundaries;
2. Census data; current and forecast (if available);
3. Existing water resources and water supply infrastructure (if available);
4. Topography, based on digital elevation model (DEM, e.g. based on SRTM satellite imagery);
5. Precipitation (P; ARC2 and/or GPCC satellite data verified with local meteorological data)
6. Evapotranspiration (ET; based on MODIS-17 satellite data);
7. Soils (e.g. based on ESDAC Soil Atlas of Africa, 2013);
8. Land use (Landcover MODIS-12 product, current land use and change over time);
9. Vegetation changes, based on NDVI (MODIS-13 product data sets);
10. Geology & hydrogeology;
11. Surface water bodies, including drainage patterns (based on DEM)

Although a desk study is often prescribed in the scope of work, the results are not always presented or reflected in the reports, nor the references of where the information was found.

It is important to not just collect and report the collected information, but to conduct a professional interpretation of all data sets and sources combined. Under the ISGEAG mantrum "Groundwater is a Puzzle", the (fun) professional challenge should be to combine all pieces of information to get an improved idea of the concept: the likely geology, where are the water bearing formations (aquifers), the likely water quality, fracture zones, possible relations with river patterns, elevation, water quality, structural lineaments, geology maps, etc.

Remote sensing based interpretations[7] can be very helpful to provide conceptual ideas:

- Digital Elevation Maps (DEM) based calculations of drainage patterns (e.g. by using QGIS or Global Mapper free software);
- 3D views in Google Earth combined with lineaments from LandSat (US Geological Survery; USGS) and geological maps ;
- Old topography maps revealing information on boreholes, rivers, swamps, etc.

3. Geology and Hydrogeology

Introduce and describe the regional and local (hydro)geology situation and its characteristics based on existing studies and reports. Be as specific as possible on remaining questions and data gaps that did not become clear enough during the desk study (Step 1. and 2.). Topics that could be further – but are not limited to – investigated include:

- Other fracture zones in the vicinity of the research location;
- Deep geological weathering near lineaments or landscape features (e.g. pronounced depressions, geological transition or contact zones, such as foot of a hill);
- The likely recharge concept, including rate, zones and extent (temporal and spatial).

These topics and questions should guide determining the research location and type of fieldwork to be executed. In other words, is it or is it not useful to carry out geophysical investigations and what type of geophysical method is then most adequate, for example. Copying geological descriptions of other reports is allowed, as long as credits and references to these data sources are correctly provided. See also Box 3 below.

Box 3: Credit and referencing of copied geological descriptions

There is nothing wrong with (no harm in) copying geology chapters from existing literature of (other consultant's) reports. Do provide, however, proper credits and references to these literature and data sources, also for reference and verification of these sources. More importantly, copy correctly. During the ISGEAG project a borehole siting report was encountered for a village just 2 km from Mazeras Township, which is obviously underlain by coastal sediments and/or sandstones. The consultant, however, wrongly copied a description of another report and dared to claim that the geology is Basement rock.

4. Reconnaissance Fieldwork

The consultants' report should reflect the results of a thorough field reconnaissance, a crucial step in filling in missing pieces/parts of the 'Groundwater Puzzle'. During ISGEAG the reconnaissance activities were even called 'Forensic Hydrology' on existing water sources and thorough reconnaissance of the physical field situation.

Visit existing boreholes and other water sources within a radius of at least 1 km of the project site. Interview the owners on any relevant piece of information, including: current status and yield, construction details like depth, yield, quality and drawdown. If the borehole has an airline and can be pumped: measure water levels, and measure indicative

[7] *For tools and maps see also: https://www.samsamwater.com/tools.php*

water quality from a water sample, at least on indicative EC, pH and Nitrates (NO_3^-). Try to find out where survey and drilling reports may be found (often this is the only way to lay hands on those crucial reports). The location of unsuccessful "dry" boreholes can provide invaluable information as well. The GPS location of the borehole should be noted (in WGS84).

While traveling (walking) through the area, mark relevant field features: rock outcrops, stones at surface, in river banks, changes in soil cover and vegetation, water indicators like trees, excessive erosion, stagnant water pools, unnatural features like (electrified) fences, powerlines and underground (metal) pipes (e.g. oil pipes) that may interfere with geophysics.

The reconnaissance findings should be analyzed and combined, mapped and verified to existing (WRA database) information, leading to conclusions on where the findings do confirm the hydrogeological concept (e.g. confirmation of the highest yielding borehole) as well as features that seem to reject the concept (e.g. certain geological rock types that contradict the hydrogeological concept).

The reconnaissance should be reported in a '*Hydrogeology of the investigated area'* chapter, giving specific (!) conclusions (and questions) on the revealing concepts of aquifers and groundwater potential, recharge, groundwater flow, likely recharge and water quality and calculated hydraulic characteristics. Include maps and tables combining existing and newly required information. All raw data and GPS locations should be reported in (annex) tables.

In some cases, the report just gives a copied table of the existing MoWS-WRA borehole database. In the first place these borehole data should at least be verified in the reconnaissance campaign. And, rather than just repeating what the database table indicates, the data should be discussed and substantiated. For example, by discussing and substantiating why the highest yielding borehole is the highest, how this compares to other boreholes and how this relates to local geology and the hydrogeological concept. Realize that borehole characteristics may also be negatively influenced because of bad construction.

The results of the reconnaissance phase should give specific ideas on prospecting target locations and should give direction on the set-up of the geophysical fieldwork (technique, location, size).

5. Geophysical fieldwork preparation (Introduction)

Geophysics can be another important piece of the 'Groundwater Puzzle' that may support and increase the chance of successful borehole drilling. Without serious study(ing) of existing and reconnaissance data, isolated application of geophysics is not very useful.

In Kenya most of the geophysics is commonly done by 1D resistivity VES soundings and HEP profiling. The reader should be aware that alternative methods exist, e.g. as researched in this ISGEAG project (AMT, ERT, TDEM (e.g. with Zonge or WalkTEM equipment)). The introduction of new techniques (like TDEM) is hampered by the high purchase costs of the equipment. The technique of 2D electrical imaging (ERT, Electrical Resistivity Tomography) is however starting off in its use in Kenya, now its added value and payback model are being more and more recognized.

On the VES soundings and HEP profiling the reader should be aware of the following major limitations:

- The depth of exploration of VES is limited to 100 m or (in dry areas) even less;
- The long reach of the VES line often passes nonhorizontal (lateral) geologic structures, conflicting the 1D assumptions of the method, visible by off-sets and distortions in the sounding curve. Interpretation based on automatically-smoothed field data may easily give incorrect results;
- HEP profiling frequently give misleading results when the HEP exploration depth is not properly understood. The HEP exploration depth is limited to around 25 m. HEP anomalies therefor just represent lateral changes in the shallow subsoil, often dominated by the presence of shallow clays;
- Both HEP and VES are not appropriate to delineate deep (sub)vertical structures like fracture zones;
- The 2D ERT method (which is actually multiple VESes carried out simultaneously and in series) is able to indicate lateral structural changes such as weathered fractures, preferably done in dipole-dipole array mode in a roll-along procedure. As in VES, in the execution of ERT in dry sandy areas it is extremely difficult to get good readings and proper interpretation of ERT (avoiding to just getting a 'nice colour picture') requires a lot of experience and time.

See also Box 4 below. For more details, see the respective chapters in the ISGEAG Technical Geophysical reports per research location.

Box 4: Misunderstandings on HEP probing depth

A very serious misunderstanding on horizontal electrical profiling (HEP) encountered in siting reports is that HEP profiling gives the lateral structural resistivity changes at one specific depth, whereby the '*probing depth*' is commonly wrongly assumed at half of the electrode reach or spread AB. In reality, this probing depth is not deeper than 1/3rd and more often around 1/6th of the chosen electrode spread AB. Considering an electrode spread AB of 100m, the probing depth lies somewhere between 17 and 33 m bgl.

6. Introduction to Geophysical Fieldwork

The fieldwork set-up should be done with care, depending on the conceptual insight on the target location, whereby a number of important considerations must be taken into account:

- Consider to do the soundings in a matrix or square array;
- Under NO circumstances will a single vertical sounding (VES) be sufficient;
- If HEP profiling is considered, define the expected target: what do you expect to see as HEP-anomalies (which (range of) resistivity values)?
- Good practice is to carry out soundings ('control soundings') close to a borehole with a known (and reliably reported) drillers log;
- To understand the geophysics of good and bad prospects, it may also be very beneficial to conduct geophysics near the best yielding borehole as well as near an unsuccessful 'dry' borehole.

7. Geophysical Fieldwork

The technical interpretation (inversion) of geophysical soundings should be done with care. For details on best practices and pitfalls in the inversion procedure the reader is referred to the Kajiado ISGEAG reports[8]. On VES inversion, the (most) important issues are:

- Restrict the number of model layers to the very minimum giving a good RMSE fit on the data. The model will seldom have more than 4 layers, unless one has specific information to constrain a certain layer as known, for example for nearby boreholes;
- Take into account the statistical uncertainty range and the correlation between layer parameter values;
- Any layers beyond a depth of 100 m (or even less) will be uncertain in both depth and resistivity;
- (Automatic) shifting or '*smoothing*' of the sounding curve is not recommended, unless there is clear information on a consistent displacement of the sounding curve segments and realize that discontinuities in the data can as well be caused by bad electrode contacts, passing powerlines, pipes, river beds, etc. The unshifted raw data should at least be included in the report;
- Apply sensitivity analysis on depth and resistivity of deep layers.

Troublesome is that some of the survey reports show a model and inversion data fit that don't correspond to the measurements as given in the report's raw data table (see next paragraph). This shows that (automatic) shifting or '*smoothing*' of the sounding curve has been done prior to the technical interpretation (inversion) of the geophysical soundings.

Most striking was a case where the data and re-interpretation clearly showed shallow clay overlying fresh basement rock at a depth of 15 m bgl, while the result in the report claims that fresh basement was at 100 m bgl. The greatest danger and problem with this is that these statements are assumed to be truthful, where wrong groundwater exploration decisions are being based on.

The enforcement system should go to a point where the client or Kenyan Water Resources Authority (WRA) verifies the inversion results, or at least let it verify by independent experts.

8. Reporting Geophysics

The geophysics raw data should always be reported and tabulated, at least as an annex to the main report, and must meet the following minimum conditions:

- Sounding GPS coordinates noted;
- Orientation of the VES lines;
- Sounding array type (Schlumberger, Werner, Dipole-Dipole, etc.)
- Inversion software program used and which version;
- Raw measured, unshifted data;
- RMSE fit of the model;
- Verification of the layer model inversion;
- Digital map (preferably developed in QGIS or Google Earth) giving locations and direction of soundings and profiles;
- Inversion results explained in a hydrogeological context.

[8] Groen, M., Rolf, H., Omiti, A., Cosmas, R. (2018). ISGEAG, 1st Technical Report, Geophysics near Kajiado Town, Acacia Water, SAMSAMwater, Wiertsema&Partners funded by VIA Water
Rolf, H. (2017). VES soundings Kajiado Town, SamSam Water, funded by VIA Water

9. Conclusions and Recommendations

Be complete and specific in your groundwater exploration and development advice, and substantiate it elaboratively. Provide sufficient reasoning and discussion on the chosen and advised drilling location(s) and depth(s). This is currently often a major lack, while the main advice is only based on one or two executed Vertical Electrical Soundings (VESes). Advice and recommendations should, however, be based on all chronological steps and subjects of the process as described in the previous 8 paragraphs.

Locally this can be confirmed or supported by geophysical fieldwork which is a logical indication within the system to identify the most promising groundwater exploration location. At the same time, a consultancy report would also be stronger if the not promising areas were indicated too, though you see this (unfortunately) very little.

Certainly in situations where there is still a lot of uncertainty, it is advisable to indicate to the client to first drill a small-diameter exploratory borehole. Always advice to the client to periodically monitor – preferably on a daily basis – the borehole and its water levels, manually or automatized/telemetrically, in order to monitor the performance of the pump and borehole and the characteristics of the aquifer after construction and during operation.

Annex 3: Financial End Report

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