

INKOMATI-USUTHU WATER MANAGMENT AREA GEOHYDROLOCAL DESKTOP STUDY



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GEOHYDROLOCAL DESKTOP STUDY

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1. INTRODUCTION

1.1. BACKGROUND

Inkomati-Usuthu Catchment Management Agency (IUCMA) has in the past provided assistance to the Department of Water and Sanitation (DWS) with the Drilling and Testing of boreholes in the Inkomati Water Management Area. The purpose of the project was to get information regarding the groundwater scenario at the particular locations to feed into the Groundwater Resource Information Project of the DWS. Therefore DWS has again requested the IUCMA to provide assistance with the drilling of at least 7 boreholes within the Usuthu Catchment Area.

1.2. GENERAL

Thoka Geosciences was commissioned by the Inkomati-Usuthu Water Catchment Management Agency (IUCMA) to conduct Siting, Drilling and Testing of 7 Groundwater Monitoring Boreholes within the Usuthu Water Management Area. This report serves as a geohydrological interpretation for all scientific determinations conducted for the borehole sites under the scope of works highlighted above.

Following instruction from the IUCMA representatives, 9 borehole sites were initially planned, but only 6 borehole sites were advanced and equipped with groundwater monitoring boreholes. A total of 11 boreholes were drilled throughout the project with 4 boreholes regarded non successful. The focus of this report will primarily focus on all the work conducted from the initial stages of borehole siting at every borehole site, borehole site selections process, borehole drilling process and borehole specifications, pump testing of every borehole regarded successful, and discussion of all pump testing data retrieved and discussion of all data to achieve a geohydrological concept.

1.3. AIM & OBJECTIVES

The geohydrological report serves the purpose of providing geohydrological information of all borehole sites identified and to highlight regional scientific features of the sites that will serve as informative features for the purpose of developing a groundwater understanding of the Inkomati-Usuthu Catchment Management Agency.

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2. REGIONAL LOCALITY DESCRIPTION AND CHARACTERISTICS

2.1. GENERAL LOCALITY

The Inkomati-Usuthu Water Catchment Management Agency identified nine borehole sites which all fall under the Usuthu Sub-Catchment Area which is south of the Inkomati Catchment Area. The borehole localities are namely Athalia Borehol Site, Empuluzi Borehole Site, Amsterdam Borehole Site, Cangaza Borehole Site, Hartebeesfontein Borehole Site, Mayflower Borehole Site, Belfast Borehole Site, KwaGadlanga Borehole Site, Mayershoop Borehole Site. The spatial relationship and localities of all nine proposed groundwater monitoring boreholes is indicated by Figure 1 & Figure 2.

2.2. REGIONAL PRECIPITATION

The mean annual rainfall within the Usuthu Water Catchment Area is about 700 - 1000 mm. (Review, Evaluation and Optimisation of the South African Water Resources Monitoring Network, Volume 2: Map Book, March 2015).

2.3. VEGETATION TYPES

Vast portions of the Usuthu Water Management area is planted with Pines, other softwood species and Eucalyptus Species (Report on commercial timber resources and primary round wood processing in South Africa, 2007). But the table below describes the regional natural vegetation cover of the proposed monitoring borehole sites. Please see Table 1.

2.4. AQUIFER CLASSIFICATION

The Inkomati-Usuthu Water Managment Area is within the North-Eastern Middelveld Hydrogeological Region. The aquifer properties within this region are mapped as having medium development potential and consist of intergranular and fractured aquifer types (Department of Water Affairs and Forestry, 2008).

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Table 1: Shows the different vegetation types of the borehole sites, (South African National Biodiversity Institute, 2012).

Monitoring Borehole Site	Vegetation Type
Athalia	Sub-Escarpment Grassland Bioregion, Ithala Quartzite Sourveld
Empuluzi	Mesic Highveld Grassland Bioregion, KaNgwane Montane Grassland
Amsterdam	Mesic Highveld Grassland Bioregion, KaNgwane Montane Grassland
Cangaza Primary School	Mesic Highveld Grassland Bioregion, KaNgwane Montane Grassland
Hartebeesfontein	Mesic highveld Grassland Bioregion, Eastern Highveld Grassland,
Mayflower	Mesic Highveld Grassland Bioregion, KaNgwane Montane Grassland
Belfast	Mesic Highveld Grassland Bioregion, KaNgwane Montane Grassland
KwaGadlanga	Mesic Highveld Grassland Bioregion, KaNgwane Montane Grassland
Meyershoop	Mesic Highveld Grassland Bioregion, KaNgwane Montane Grassland

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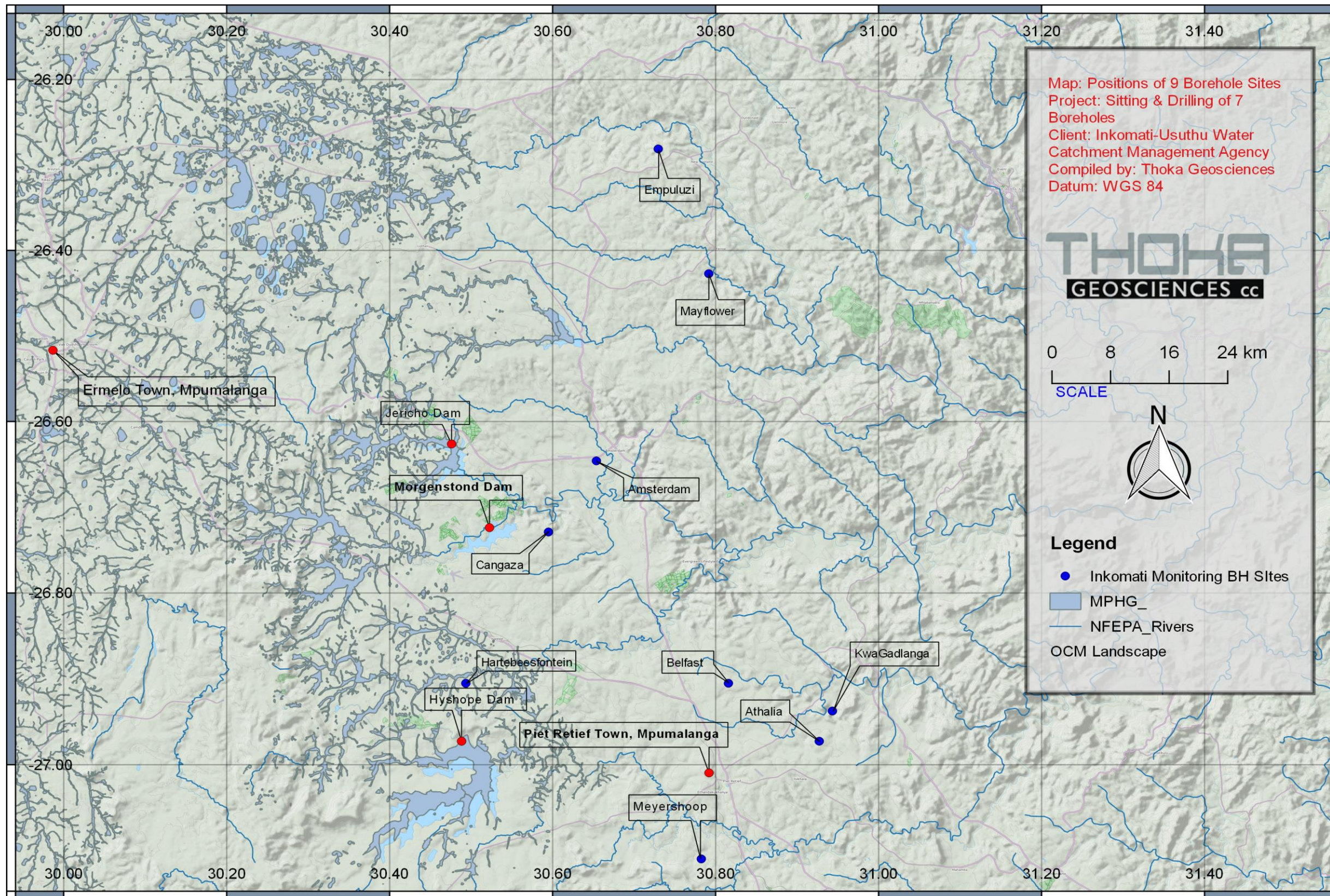


Figure 1: Shows the landscape and localities of all monitoring borehole sites proposed by Inkomati-Usuthu Water Catchment Management Agency

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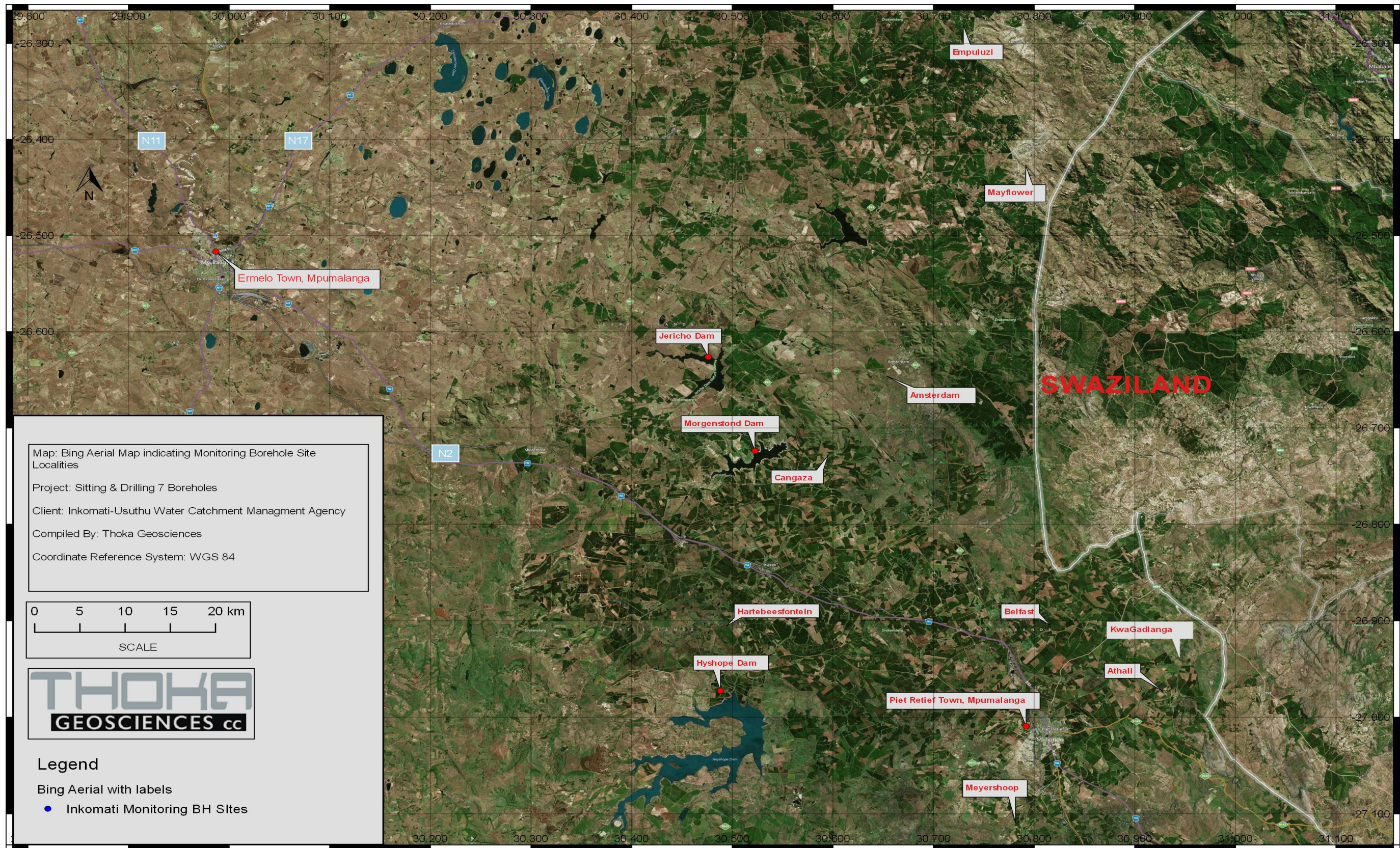


Figure 2: Shows a satellite image indicating the Localities of the proposed borehole sites

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3. SITE DESCRIPTIONS

3.1. AMSTERDAM MONITORING BOREHOLE SITE

3.1.1. Amsterdam Borehole Site Description

The study area is located approximately 2 km from Amsterdam Town and the central coordinate of the site is -26.644854°S 30.652185°E. The site area is elevated to about 1250 m above mean sea level. There is no formal primary usage of the land within proximity of the site but grazing cattle and rubble dumping have been identified.

The study area is also approximately 18 km east of the Jericho Dam and 14 km east of Morgenstond Dam. Jericho dam is an earth fill type of dam located on the Mpama River, it was established in 1966 and its primary purpose is to serve for municipal and industrial use. Jericho Dam is 21.3m high and 1167.8m wide. It has a catchment area of 218 km² and 982.5 ha surface area.

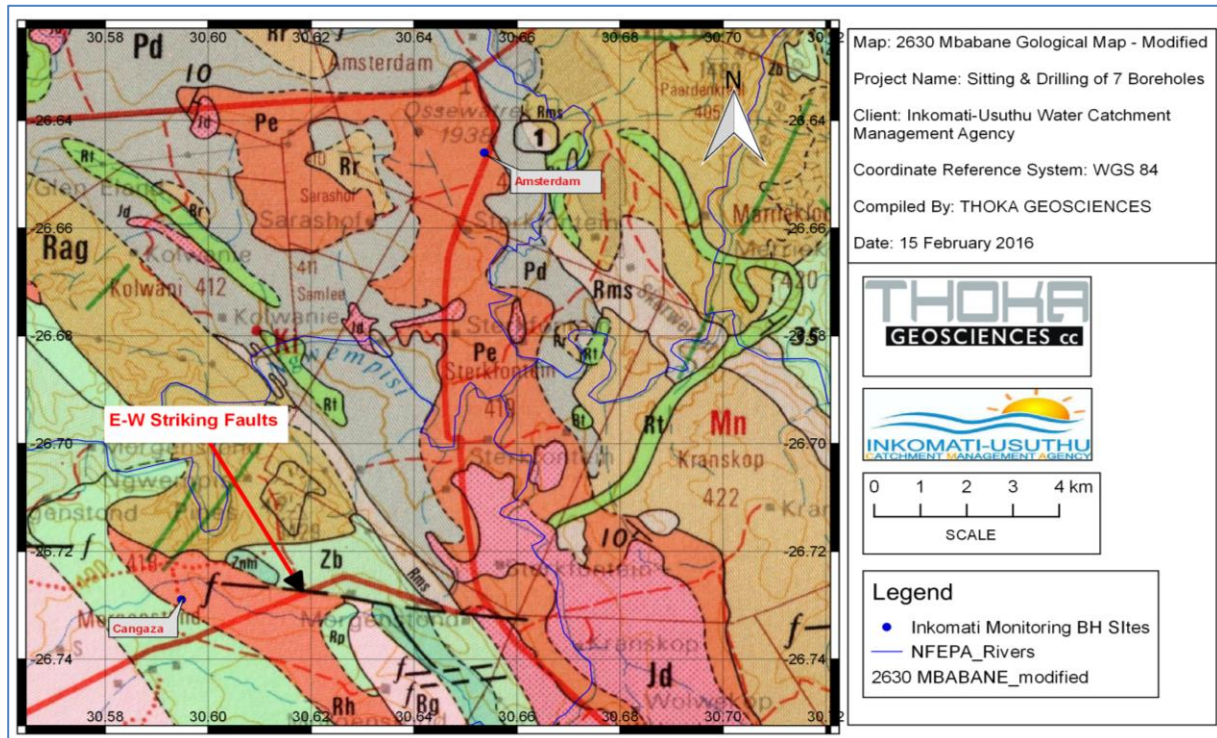
3.1.2. Local Topography

Local topography in the area is depicted by an average slope of about 1.6% slopping towards the western direction. The far eastern side of the site has outcropping shale rocks dipping towards the eastern direction.

3.1.3. Local Geology

According to the geological map sheet 2630 Mbabane at a scale of 1: 250 000. The site is located within the proximity of ECCA Group rocks, and the Dwyka Formation rocks. The ECCA Group rocks include Micaceous Shales, grit, sandstone, shale and coal seams, mudstones and subordinate coal. The Dwyka Formation rocks mainly consist of glacial sediments and shale. Shale outcrops are visible on the eastern portion of the site (Figure 4) and Figure 3 shows the regional geology of the Amsterdam Groundwater Borehole Area.

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Pvo	Pe	Pp: Micaceous Shale
Pv		Pv: Grit, sandstone, shale, coal seam
Pp		
Pd		Pvo: Shale

Figure 3: Portrays the regional geology of the Amsterdam Groundwater Monitoring Borehole Area.

3.1.4. Local Aquifer Characteristics

Groundwater in the area is expected to be primarily hosted by fractured and contact rock features. Site observation and the analysis of the regional geological map covering the site indicates possible geological contact zones within proximity of the boreholes site. Site conditions indicated shale rocks dipping towards the eastern direction outcropping on the eastern parts of the site. The far western portion of the site indicated no outcrops.

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Figure 4: Shows outcropping shale rocks at the Amsterdam Borehole Site.

3.2. ATHALIA MONITORING BOREHOLE SITE

3.2.1. Athalia Borehole Site Description

The borehole site is located within the Mkondo Local Municipality in the Gert Sibande District Municipality and in the Usuthu Water Management Area. The site is located about 15 Km north east of Piet Retief Town, Mpumalanga and falls south of the Blesbokspruit River. The central coordinate for the borehole site is $-26.972750^{\circ}\text{S } 30.927161^{\circ}\text{E}$ with a mean elevation above sea level of about 1220 m. The immediate proximity of the site is used for residential purposes and open fields are used for grazing. The main land usage in the area is for the Mondi Plantations which mainly comprises of Pines, other softwood species and Eucalyptus Species (Report on commercial timber resources and primary round wood processing in South Africa, 2007).

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3.2.2. Local Topography

The local topography of the Athalia borehole site is characterised by a Valley like topography stimulated by the surrounding stream features within vicinity of the borehole site. The slope of the valley deep towards the water streams and forms general slope of about 4.5%. The groundwater occurrence is presumed to be highly influenced by the topographical characteristics of the area and the groundwater flow direction is presumed to be linked to the topography.

3.2.3. Local Geology

According to the Geological Map Sheet 2630 Mbabane at a scale of 1: 250 000. The site locality is underlain by rocks falling under the Pongola Sequence of the Randian Era. The local rocks are of the Nsuze and Mozaan Subgroup rocks. These rocks include rocks of the Mantonga, Bivane, Skurwerant, and Redcliff Formations. These formations chronologically consist of quartzite, inter layered andesitic lava, basaltic and andesitic lava with ash layer, quartzite with inter layered shale and Ferruginous shale with banded iron formation as the youngest rocks.

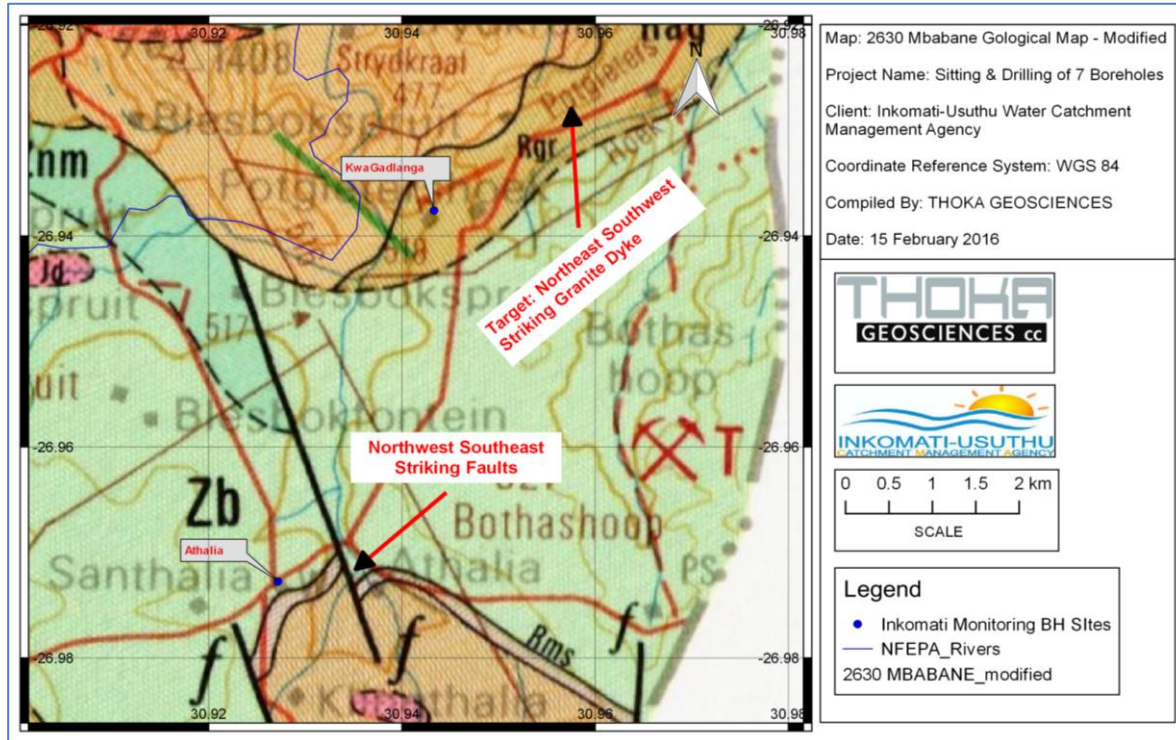
The locality of Athalia is also characterised by faults striking in the north westerly direction. The faults are a family of the Mahamba Shear Zone and evidently show displacement of the Skurwerant Formation and the Redcliff Formation (

Figure 5).

3.2.4. Local Aquifer Characteristics

The site is located on mapped geological faults and contact zones of different geological formations (Figure 5). The faulting and geological contacts are expected to be spots of increased potential fracturing and act as preferential pathways for erosive activity within the rock structures.

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Geological Legend

Zb

Basaltic and andesitic lava with ash layer

Znm

Quartzite, interlayered andesitic lava

Rav

Micrographic and felsic rhyolite

Rag

Pyroclastic rocks, ash-flow tuff; rhyolitic tuff

Rms

Quartzite with inter-layered shale

Figure 5: Portrays the regional geology of the Athalia & Kwagadlanga Groundwater Monitoring Borehole Site.

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3.3. KWAGADLANGA MONITORING BOREHOLE SITE

3.3.1. Kwagadlanga Borehole Site Description

The borehole site is located about 16 Km north east of the Piet Retief Town in Mpumalanga and is within the Mkondo Local Municipality in the Gert Sibande District Municipality and in the Usuthu Water Management Area. The site is bounded by the Blesbokspruit River on the east with a distinct tributary stream flowing west feeding into the Blesbokspruit. The central coordinate of the site is - 26.937901°S 30.940387°E with an elevation above mean sea level of about 1220 m. The site is occupied by dwelling houses east of the site and the main land usage in the area is for the Mondi Plantations which mainly comprises of Pines, other softwood species and Eucalyptus Species (Report on commercial timber resources and primary round wood processing in South Africa, 2007).

The site is also equipped with a groundwater borehole equipped with a hand pump. Assessment of the borehole indicated low yields. The depth, static groundwater level and other information regarding the borehole are not known.

3.3.2. Local Topography

The site is characterised by ~7% average slope towards the western direction draining into the Blesbokspruit River.

3.3.3. Local Geology

According to the Geological Map Sheet 2630 Mbabane at a scale of 1: 250 000. The site locality is underlain by the Amsterdam Formation of the Randian Era and the Mantonga Formation of the Nzuze Group. Pyroclastic rocks, ash-flow tuff, rhyolitic tuff and pyroclastic breccia are the typical rock types encountered within the region (

Figure 5). The locality of the area is also within the proximity of a granite dyke striking in the north eastern south western direction. A walk through survey of the area revealed an outcrop of jointed quartzite rocks belonging to the Mantonga Formation rocks. The joint structures were striking on north east south west direction depicting the strike direction of the granite dyke mapped on the 2630 Mbabane Geological Map Sheet. The joint is also striking in similar direction as the tributary stream feeding into the Blesbokspruit River.

3.3.4. Local Aquifer Characteristics

The site is located on geological structures associated with intrusive dykes and regional faulting extending towards the site. The intrusive granite dyke is expected to poses preferable groundwater

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flow features. The faulting is also expected to increase potential fracturing and act as preferential pathways for erosive activity within the rock structures. The occurrence of jointed quartzite also arise the precedence of fractured intergranular aquifer types. Therefore the aquifers within vicinity of the KwaGadlanga Borehole Site are expected to poses properties of intergranular and fracturing properties.

3.4. MEYERSHOOP MONITORING BOREHOLE SITE

3.4.1. Meyershoop Monitoring Borehole Site Description

The borehole site is located about 12 Km south of Piet Retief Town, Mpumalanga within the Mkondo Local Municipality in the Gert Sibande District Municipality and in the Usuthu Water Management Area. The locality of the site is bounded by the Assengaa River on the north, the Klein Assengaa River on the south and the Swartwater River in the east. The site central coordinate is -27.109669°S 30.782411°E with an elevation above mean sea level of about 1280 m. The main land usage in the area is for the Mondi Plantations which mainly comprises of Pines, other softwood species and Eucalyptus Species (Report on commercial timber resources and primary round wood processing in South Africa, 2007).

3.4.2. Local Topography

Local topography in the area is depicted by an average slope of about 0.5% slopping towards the north eastern direction.

3.4.3. Local Geology

According to the Geological Map Sheet 2730 Vryheid at a scale of 1: 250 000, the proximity of the Meyershoop Borehole Site is underlain by rocks of the Pongola Sequence mainly consisting of medium to coarse grained biotite granite, porphyritic biotite granite, and coarse grained hornblende granites (Figure 6). Older Barberton Sequence rocks occur mainly comprising of amphibolite, talc carbonate schist and serpentine bearing schist. The area is also intruded by younger dolerite rocks.

There is no evidence of faulting indicated by the Geological Map Sheet 2730 Vryheid, but the occurrence of dolerite intrusive rocks does suggest sharp contacts between the older granite rocks of the Pongola Sequence and the dolerites.

3.4.4. Local Aquifer Characteristics

Groundwater in the area is expected to be hosted by fractured and weathered rock features. The intrusion of earlier dolerite rocks within the vicinity of the site is also expected to enhance fracturing

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and weathering of the older granite rocks. Thus geophysical survey of the area was setup to target the above mentioned features.

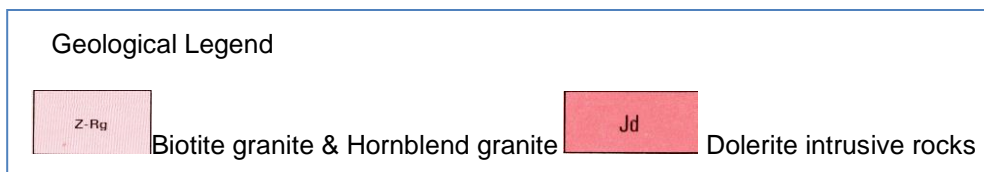
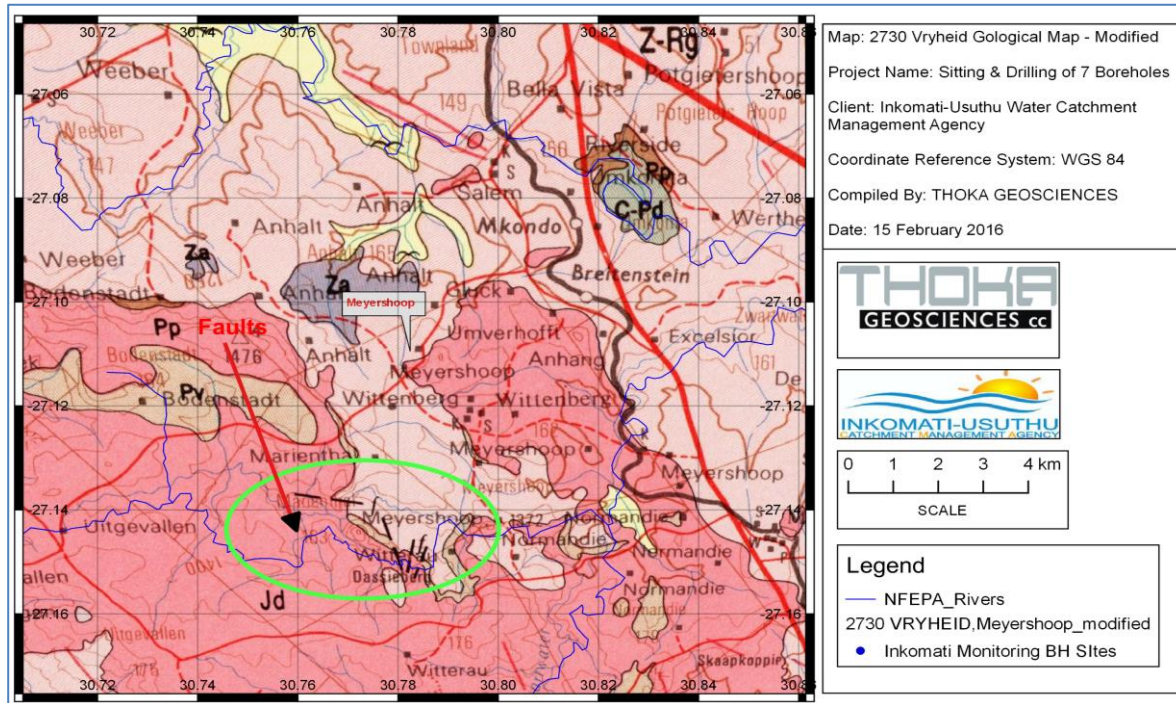


Figure 6: Portrays the regional geology of the Mayershoop Groundwater Monitoring Borehole Area.

3.5. MAYFLOWER GROUNDWATER MONITORING BOREHOLE AREA DESCRIPTION

3.5.1. Mayflower Monitoring Borehole Site Description

The site is located in the Mpumalanga Province, Albert Luthuli Local Municipality in the Usuthu Water Management Area. The site is positioned within the Magoqo Township. The borehole site is located about 1.2 Km south of the Metula River and within the proximity of a tributary river feeding into the Metula River. The site has an elevation above mean sea level of about 1400 m and the central coordinate to the site is -26.434425 S 30.789572 E.

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The site is currently being used as vacant land but the nearby surrounding areas are used for residential purposes.

3.5.2. Local Topography

Steep topography characterises the site with an average slope of about 3% sloping towards the south east direction converging into the Metula River Valley.

3.5.3. Local Geology

According to the geological map sheet 2630 Mbabane at a scale of 1: 250 000. The regional geology is made up of intrusive rocks mainly consisting of leucocratic potassic granite, porphyritic and veined with granodiorite (

Figure 7). There are no dykes or geological contact features indicated on the regional scale. The local geology at the site consists of outcropping potassic granite rocks and weathered rounded boulders on the surface.

3.5.4. Local Aquifer Characteristics

The site is underlain by granite rocks. The aquifer type is thus inferred to be primarily intergranular and fractured aquifer.

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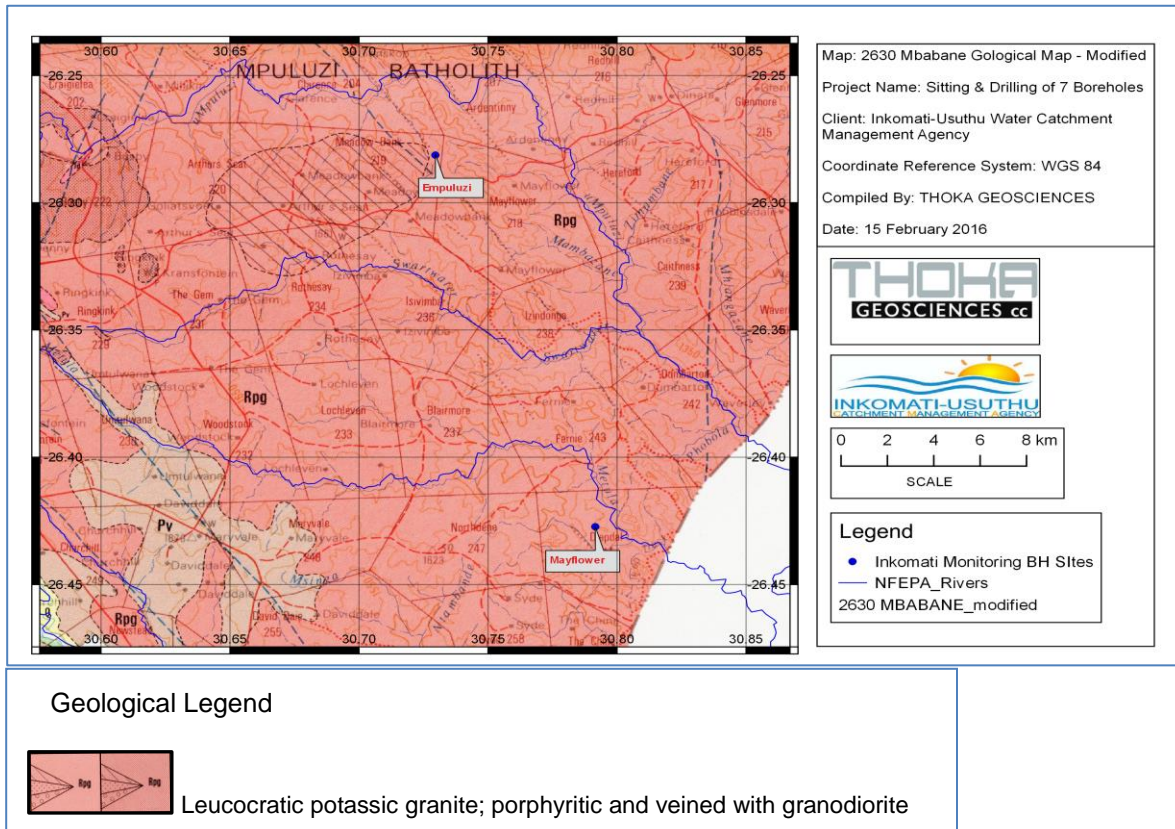


Figure 7: Portrays the regional geology of the Mayflower Groundwater Monitoring Borehole Area.

3.6. CANGAZA GROUNDWATER MONITORING BOREHOLE SITE

3.6.1. Cangaza Monitoring Borehole Site Description

The study area is located in the Mpumalanga province approximately 13 km south west of Amsterdam Town and approximately 36 km northwest of Piet Ritief Town within the proximity of the Cangaza Primary School. The area is also characterized by channeled wetlands surrounding the area and the central coordinates are -26.728647°S 30.593998°E. The main land usage in the area is for the Mondi Plantations which mainly comprises of Pines, other softwood species and Eucalyptus Species (Report on commercial timber resources and primary round wood processing in South Africa, 2007). Two parts within the vicinity were selected by Inkomati-Usuthu Catchment Management Agency representatives as potential areas. The Cangaza School is equipped with a borehole supplying water to water tanks within the school. The details of the borehole depth yield and recharge rates are unknown.

The area is also approximately 7 km north east of the Morgenstond Dam. The Morgenstond Dam is an earth-fill type dam located on the Ngwempisi River, approximately 18 km west south of

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Amsterdam, Mpumalanga Province. It was established in 1978 and has been renovated in 1991. The dam's main purpose is to serve for municipal and industrial use. Morgenstond dam is 45.3 meters high and 600 meters wide. It has a catchment area of 548 km² and a surface area of 977.2 hectares.

3.6.2. Local Topography

The site is characterised by ~4% average slope towards the eastern direction draining into the channelled wetlands.

3.6.3. Local Geology

According to the geological map sheet 2630 Mbabane at a scale of 1: 250 000. On the regional scale, site area is characterised by the intrusive rocks of the Usushwana Complex specifically the Hlelo and Piet Retief Suite rocks. The Hlelo Suite comprises of microgranites and aplite and granodiorites and the Piet Retief Suite consists of gabbro, and ferrogabbro with magnetite outcrop, Amsterdam Formation Volcanics and rocks of the Pongola Sequence occur in the vicinity of the site.

A walk through survey of the area indicated occurrence of reddish brown ferricrete outcropping on the surface. This is evidence of pedogenesis associated with dropping and rising of the water table resulting in the formation of a pedogenic layer.

The region of the site has significant faulting occurring. The faults have a general strike direction of south south east-west west north. Although this is evident on the Geological Map Sheet 2630 Mbabane, the local survey of the area showed no evidence of deformation or structural movements related to the faults on the surface.

3.6.4. Local Aquifer Characteristics

The site is located on complex geological structures associated with intrusives of the Usushwana Complex and the regional faulting occurring. The intrusives are expected to poses intergranular and fractured aquifers. The faulting is also expected to increase potential fracturing and act as preferential pathways for erosive activity within the rock structures. Therefore the aquifers within vicinity of the Cangaza Borehole Site are expected to poses properties of intergranular and fracturing properties.

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4. BOREHOLE SITING FOR BOREHOLES DRILLED

4.1. GEOPHYSICAL TECHNIQUES & METHODS

Geonics EM 34-3 and a Magnetometer were used to conduct geophysical investigation of the proposed sites to site for preferable groundwater features within the allocated areas. Geophysical traverse lines were setup to dissect linear structures, faults and rivers or any form of geological or geomorphologic structure which depicts preferred groundwater flow structures.

The magnetic survey was used to measure the total magnetic field component of the earth's magnetic field. The different magnetic susceptibility of the different rock types give contrasting magnetic signatures which were examined to detect geological contacts, dykes and faults. These features again are indicators of potential groundwater occurrence.

The electromagnetic survey measures the apparent conductivity of the underlying rocks. The apparent conductivity changes throughout site indicate the geological changes depicting contacts, faults, dykes and weathering.

Numerous traverse lines were conducted for both electromagnetic and magnetic survey on examined directions presumed to dissect geological structures which are associated with groundwater occurrence. The survey stations were setup at intervals of 10 meters along the traverse lines. A vertical and horizontal survey of the apparent conductivity was conducted respectively using 20 meter coil spacing. The reading of the magnetometer and the EM 34-3 were recorded on every survey station together with the coordinates of the survey point.

The Electromagnetic and Magnetic Survey data was plotted as line graphs of Distance vs Conductivity for the electromagnetic survey and Distance vs Total Magnetic Field for the Magnetic Survey.

Unaltered, unfractured igneous and sedimentary rocks (potassic granite) are normally very resistive (typically a few hundred to thousands of ohm-m) depending upon their fluid content, porosity, fracture characteristics, and impurities. Metamorphic rocks (that do not contain graphite) are moderately to highly resistive (hundreds to thousands of ohms per meter). Resistivity may be low (less than 100 ohm-m) along fault zones that were fractured enough to have once hosted fluids (generally water or brine) from which conductive minerals were deposited (D Briant *et al*, 2006)

Therefore the aim was to identify conductivity and total magnetic changes along the traverse lines. Sharp rises or drops in conductivity and total magnetic field are the primary detectors of geological discrepancies. Therefore several points on the plotted graphs were marked as potential groundwater occurrence spots. The geophysical interpretation from the traverse lines was integrated with physical

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site conditions and understanding of the site topography and geology to mark the most suitable borehole drilling points.

The discussed borehole siting is relevant to the sites where successful boreholes were drilled. Thus a total of 6 sites namely Amsterdam, Athalia, kwagadlanga, Meyershoop, Mayflower and Cangaza Monitoring Borehole Siting are discussed below.

4.2. AMSTERDAM MONITORING BOREHOLE SITING

Two traverse lines were setup for both the Magnetic Survey and Electromagnetic Survey. The survey stations were setup at every 10 m interval along the traverse lines unless there was obstruction (e.g. pits/ground holes). Both Horizontal and Vertical Readings were recorded for the electromagnetic survey on every survey station. Figure 9 portrays the traverse lines taken. The primary aim of the traverse lines was to detect/cross zones of weathered, fractured rock within the area and on the interim detect contacts between older granites with earlier dolerite intrusions. The fractured and weathered zones were targeted as potential groundwater host features. It should be noted that some traverse lines are longer than others due to site conditions interfering with the geophysical instruments i.e. shale quarries were avoided at certain instances resulting in shorter traverse lines and non parallel traverses. Thus traverse line directions were also chosen with consideration of available traversing space and the consideration of obstruction.

The analysis of the traverse lines at Amsterdam monitoring borehole site shows a clearly defined anomaly (Figure 9). The anomaly is caused by a geological contact of a dike nature (Figure 3) causing a drop in apparent conductivity and rise in total magnetic field along the feature. Thus the drilling points were selected to take advantage of the geological characteristics discussed.

4.3. ATHALIA MONITORING BOREHOLE SITING

A couple of traverse lines using EM 34-3 and a Magnetometer were conducted at various areas within the vicinity of the Athalia Monitoring Borehole Site. Due to site constraints such as power lines, fences, rubble, water lines and other services installed within the site area, total magnetic field and conductivity methods were regarded as non-reliable sources of deducing potential groundwater points. Thus the siting processes were dependent on geological structures and existing borehole information.

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4.4. KWAGADLANGA MONITORING BOREHOLE SITING

The analysis of Traverse Line 1 total magnetic field and electromagnetic indicates significant total magnetic field drop from 10 - 50 m traverse distance (Figure 11). The drop in total magnetic field records 274 nT change in the total magnetic field. The apparent conductivity on the same distance does not register any corresponding change that may suggest higher conductivity of the underlying material. Further analysis of Traverse Line 1 shows rapid rise in apparent conductivity from 150 - 170 m traverse distance for both the horizontal and vertical dipole. The sharp rise in apparent conductivity is mirrored by the gradual drop of the total magnetic field on the same traverse distance. Therefore point 170 m on traverse Line 1 depicts the highest apparent conductivity with lower total magnetic field indicating material with low resistivity thus suggesting weathered/fractured formations for potential groundwater occurrence. This point was regarded as a significant point for groundwater occurrence.

Traverse Line 2 moving in the northwest direction indicates an isolated anomaly depicted by the total magnetic field drop between 120 and 130 m traverse distance. The apparent conductivity also indicates an isolated rise in conductivity from 140 - 200 m traverse distance for the horizontal dipole. But the total magnetic field on the same points does not indicate any correspondence. The points of isolated significant change in apparent conductivity and total magnetic field depicted by Traverse Line 2 are considered as low-medium potential groundwater occurrence indicators. Figure 11 portrays the traverse lines conducted for Kwagadlanga Monitoring Borehole Siting.

4.5. MEYERSHOOP MONITORING & COMMUNITY BOREHOLE SITING

Analysis of the electromagnetic and magnetic survey of the Meyershoop Borehole site indicates a possible contact between a more resistive and less resistive rock. The more resistive material is depicted by the reduced apparent conductivity readings on the EM 34-3. The reduced apparent conductivity is mirrored by a rise in total magnetic field which is a possible signature of an intrusive material such as a dolerite (Figure 12). As the regional geology of the area shows random outcrop of dolerite, it may be inferred that the interrelationship between the dolerite and the older granites in the area was intercepted by the geophysical traverse lines thus indicated by the form of an anomaly. The contact between the older granites and the earlier dolerite may raise potential groundwater hosting features. Thus the contact point between the two is inferred as potential points for borehole drilling.

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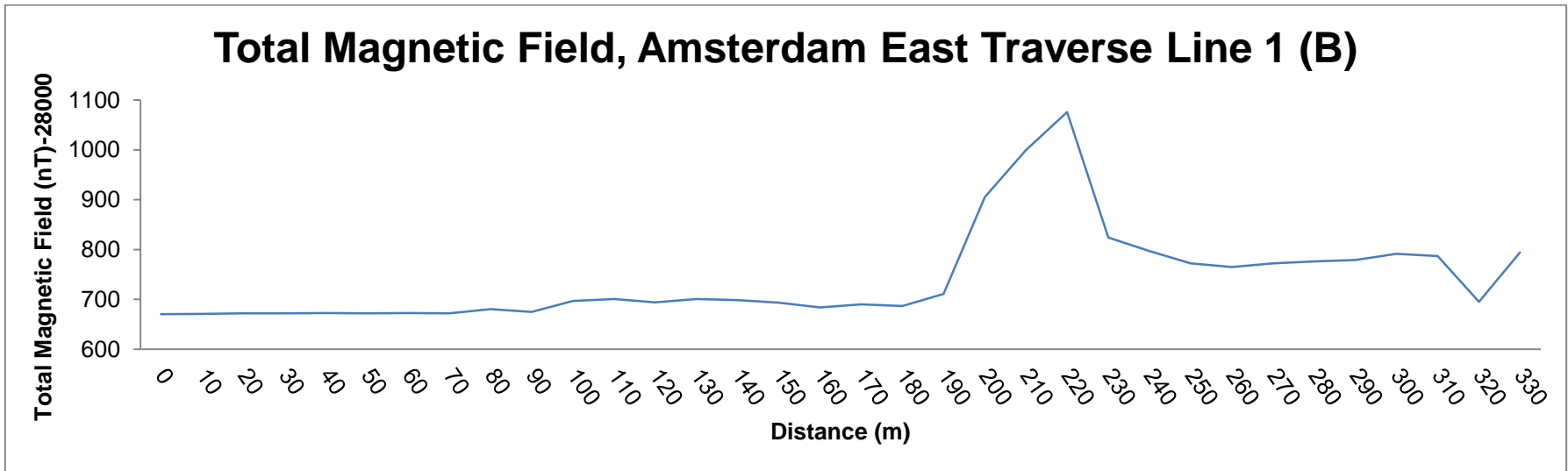
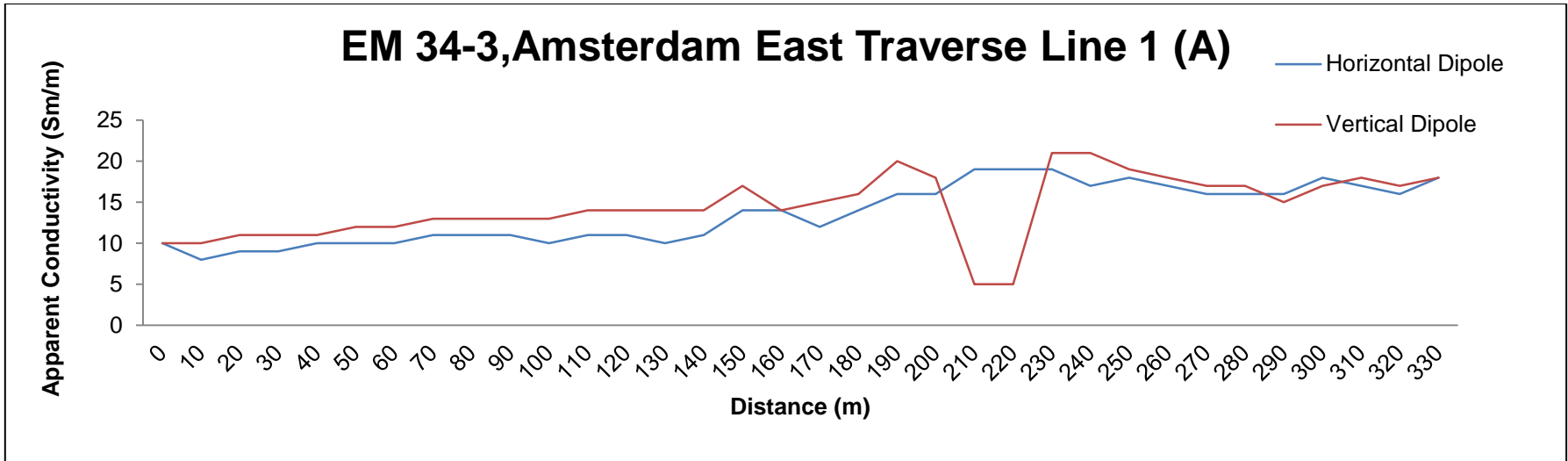
4.6. MAYFLOWER MONITORING BOREHOLE SITING

Analysis of the total magnetic field showed minor gradual increase with no clearly defined anomaly. The selection of a borehole point considered the topographic and geomorphologic properties instead.

4.7. CANGAZA MONITORING BOREHOLE SITING

Traverse Line 1 transgressing towards the SSE direction results indicated a sharp rise in apparent conductivity for the vertical dipole readings between 50 - 70 m traverse distances. The sharp rise was also mirrored by the continuous gradual drop in total magnetic field. The horizontal dipole reading on the other hand indicated a steady rise in apparent conductivity from 30 m traverse distance until 100 m traverse distance whereby the apparent conductivity levelled up. In relation to the horizontal dipole, the total magnetic field experienced a drop of about 200 nT until 110 m traverse distance whereby total magnetic field started rising again. A potential drilling point is inferred from the relationship between the horizontal dipole and total magnetic field readings. Thus a potential drilling point is selected to be at 100 m traverse distance for Traverse Line 1 and a secondary drilling point at 70 m traverse distance (Figure 13).

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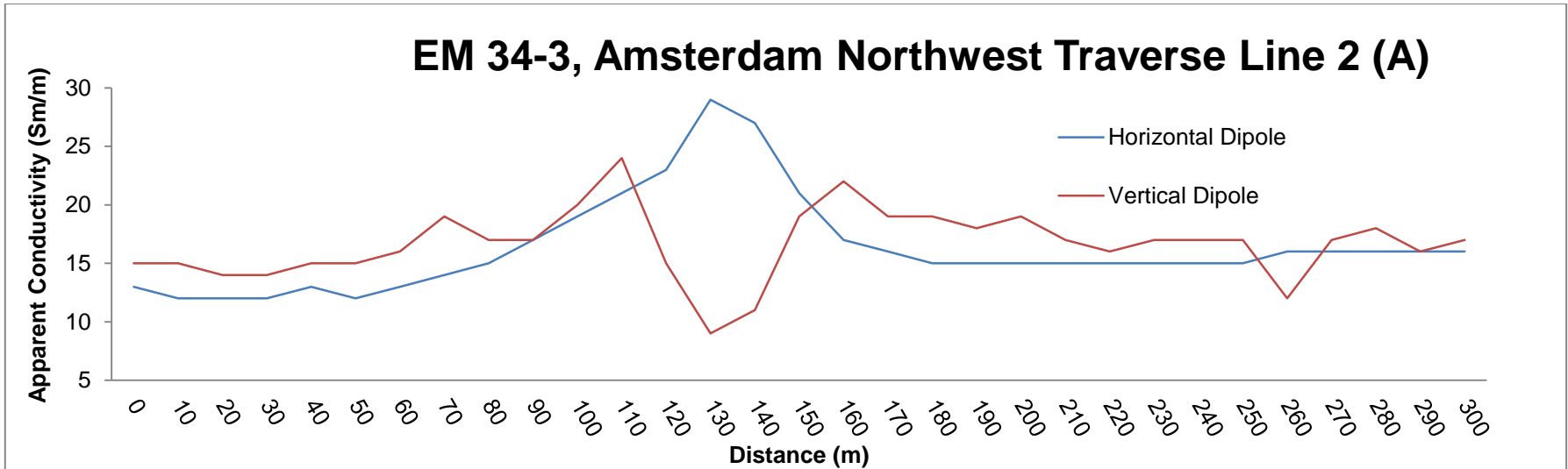
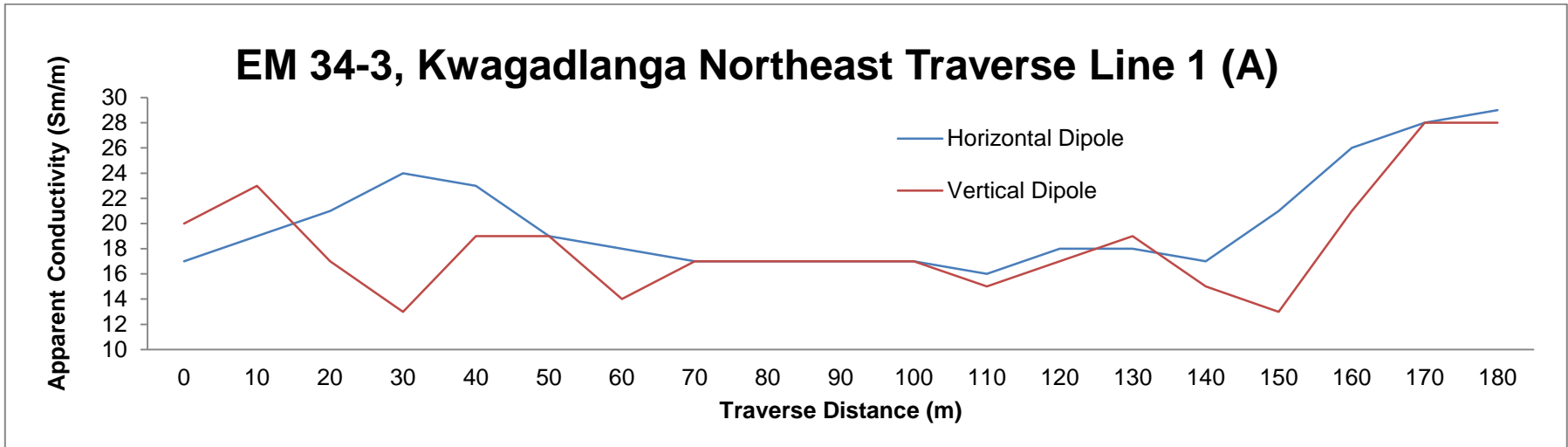


Figure 9: shows the plotted graphs of the EM 34-3 and Magnetic Survey for Travers Line 1 (A&B) & Line 2 (A) in Amsterdam



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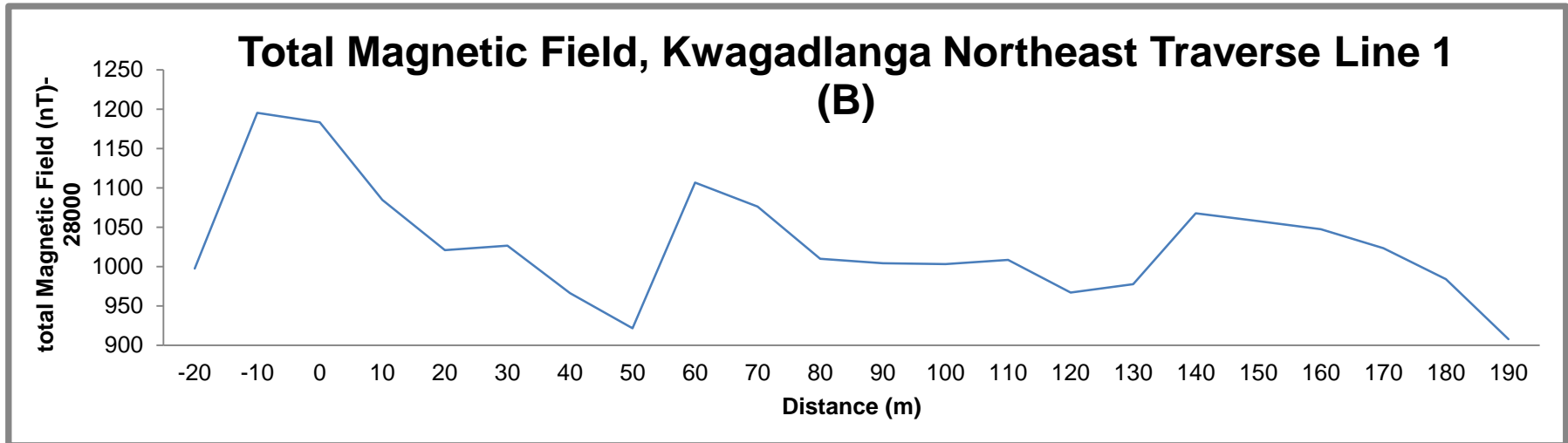
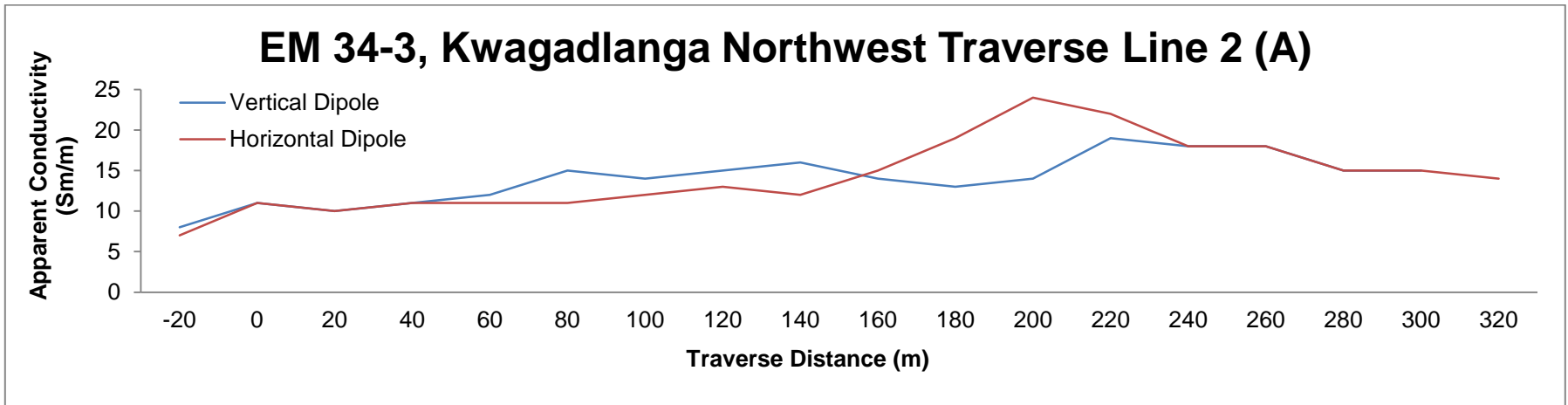


Figure 10: shows the plotted graphs of the EM 34-3 and Magnetic Survey for Travers Line 1 (A & B) in KwaGadlanga



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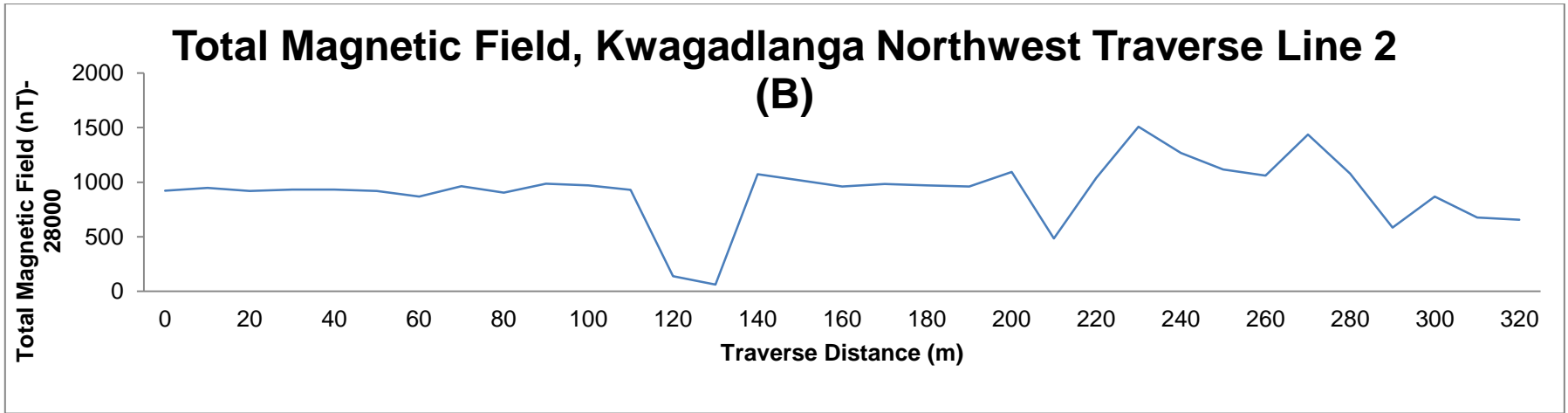
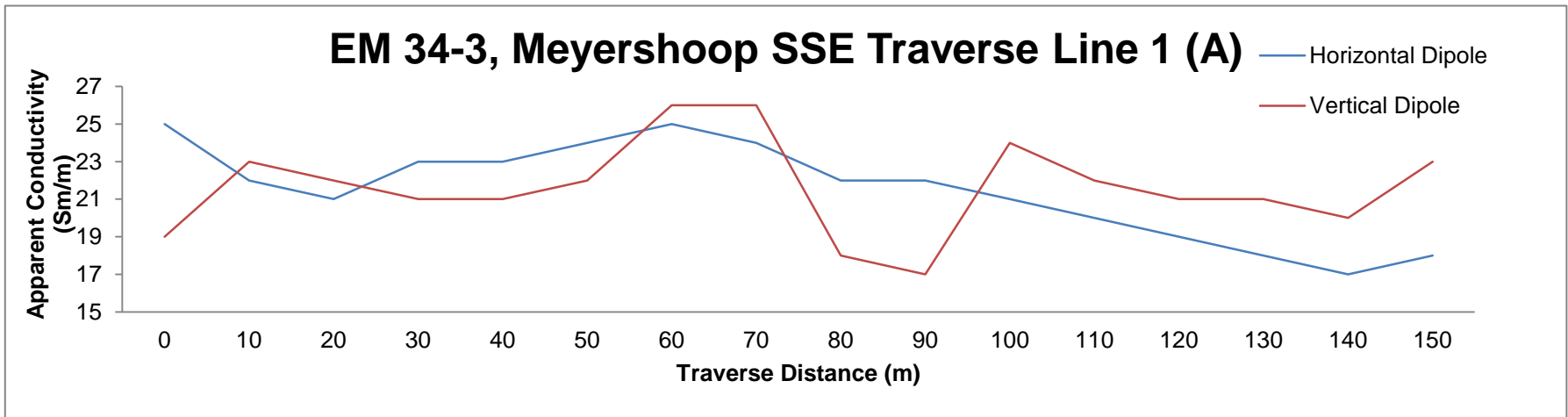


Figure 11: shows the plotted graphs of the EM 34-3 and Magnetic Survey for Travers Line 2 (A & B) in KwaGadlanga



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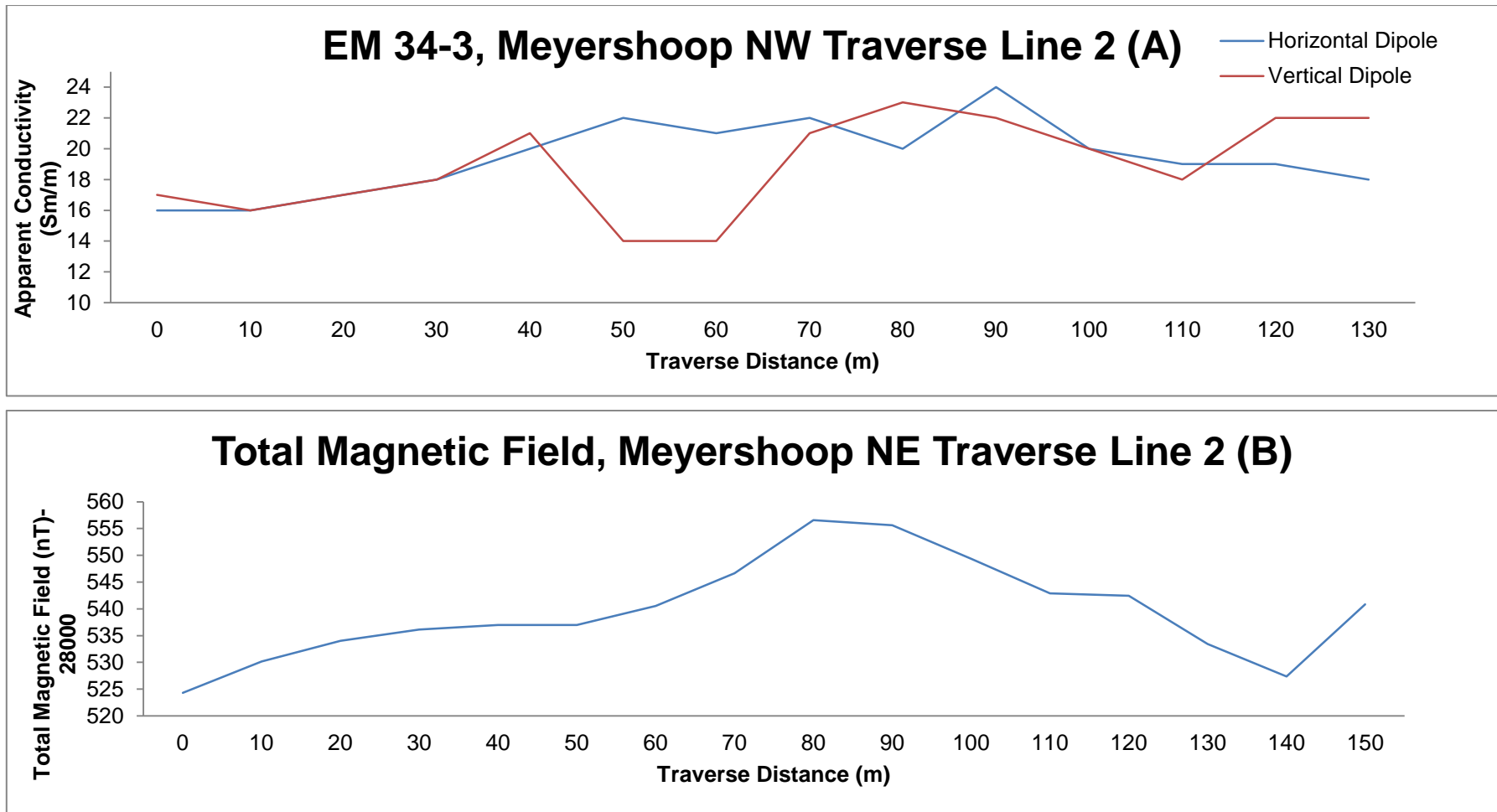
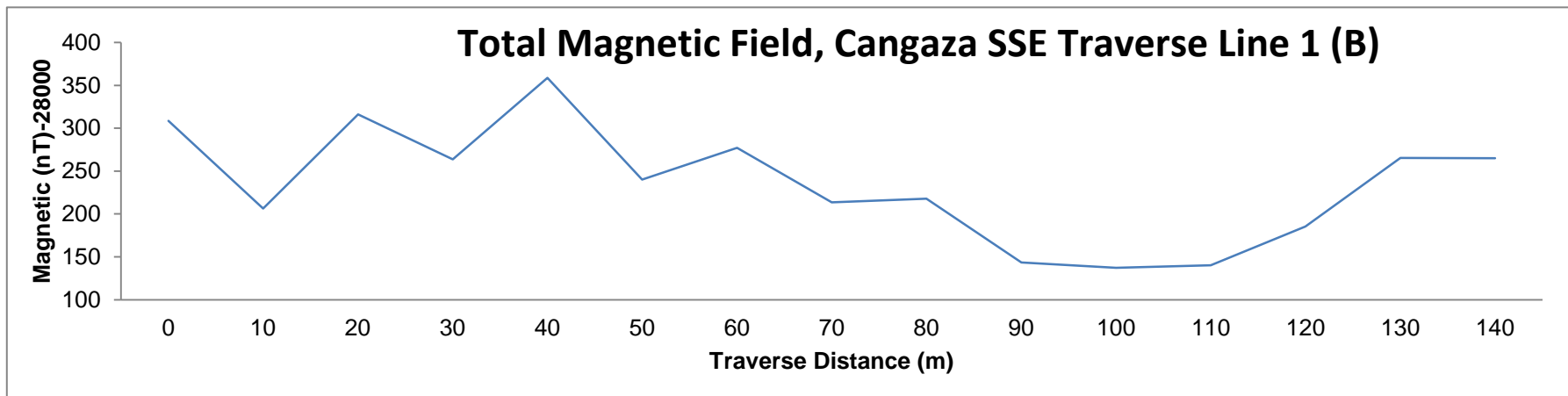
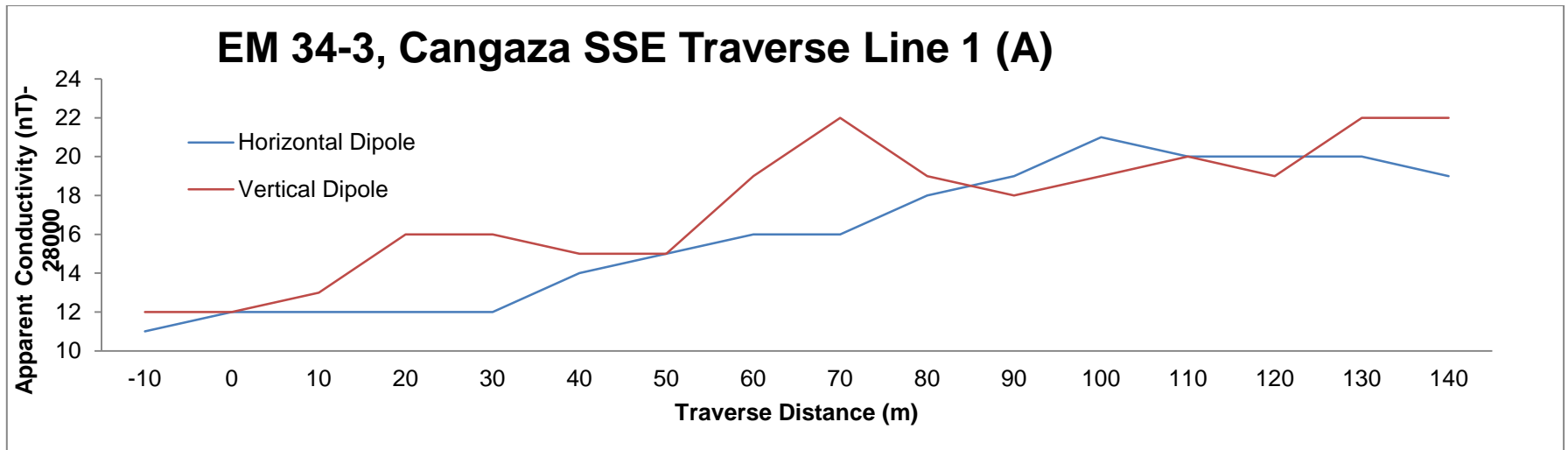


Figure 12: Shows the plotted graphs of EM 34-3 and Magnetic Survey for Traverse Lines 1 (A) & 2 (A & B) in Meyershoop

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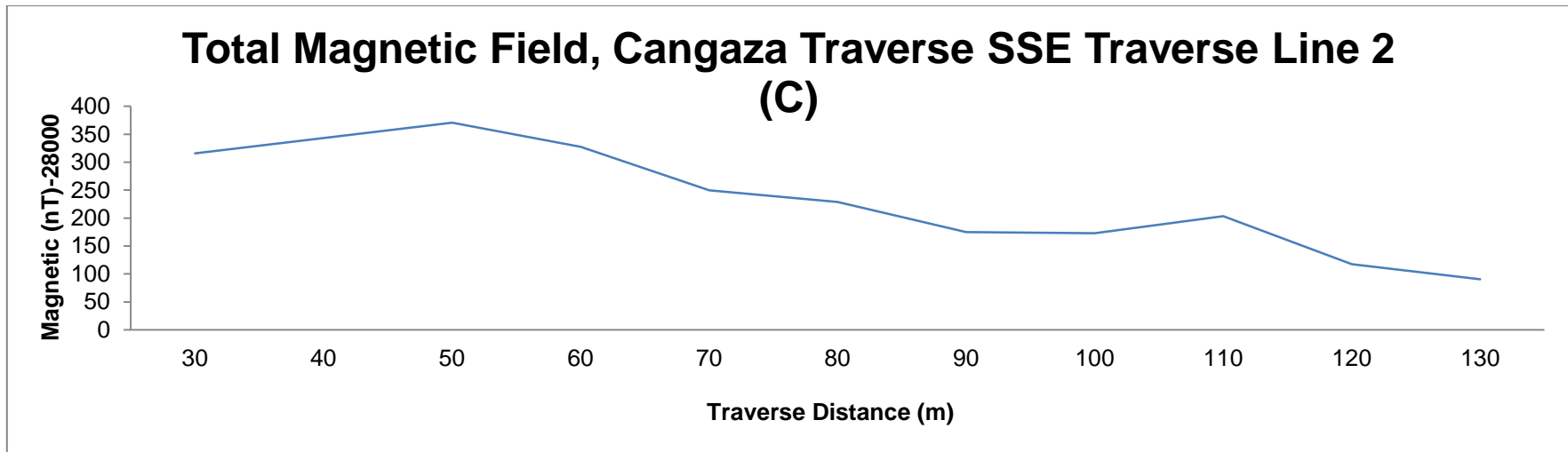


Figure 13: shows the plotted graphs of the EM 34-3 and Magnetic Survey for Traverse Lines 1 (A&B) and Line 2 (C)

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5. BOREHOLE DETAILS

5.1. BOREHOLE DRILLING

A total of 11 boreholes were drilled with nine boreholes striking water and two boreholes resulting as dry boreholes. Two of the boreholes striking water were abandoned after one at Cangaza was regarded to have insufficient groundwater yield and one abandoned due to collapsing profile.

All the drilling was conducted using a percussion drilling rig with a 24 bar compressor capacity. The boreholes were drilled with a 203 mm bit through unconsolidated horizons and stabilized with solid steel casing within the respective horizons. The more stable horizons of the boreholes were drilled using a 165 mm bit to depth. Three of the boreholes were further secured with 110 mm pvc casing to total depth as these boreholes had a high potential for collapsing. A summary of the boreholes drilled and their respective properties is shown in Table 2. The profile logs for the boreholes are attached in Appendix I.

Information such as drilling penetration rate, formation hardness, sample recovery, water strikes and other information was captured for every borehole. Appendix II shows the drillers logs for the respective eleven boreholes drilled.

Samples were collected per meter drilled and logged by a geologist to produce profile logs of the boreholes drilled (please see Appendix I).

Table 2: Shows the summary of the properties and specifications of all boreholes drilled

COORDINATES	BOREHOLE DEPTH	COLLAR LEVEL	WATER STRIKE	STEEL CASING & PVC CASING
Mayflower 1				
26.434260S 30.789580 E	54 m	1406 m	None	None
Mayflower 2				
26.426 22 S 30.791 66 E	80 m	1397 m	42m	15.6 m
Mayflower 3				
26.429 74 S 30.798 07 E	60 m	1374 m	26m	36 m & 60 m

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COORDINATES	BOREHOLE DEPTH	COLLAR LEVEL	WATER STRIKE	STEEL CASING & PVC CASING
Cangaza 1				
26.730 70 S 30.593 06 E	79 m	1368 m	None	None
Cangaza 2				
26.728 85 S 30.593 97 E	60 m	1368 m	21m	15 m
Belfast				
26.908 40 S 30.803 37 E	49 m	1295 m	None	None
KwaGadlanga				
26.938 95 S 30.938 79 E	60 m	1187 m	15m	9 m
Amsterdam				
26.644 48 S 30.653 64 E	55 m	1261 m	46m	15 m
Athalia				
26.970 97 S 30.924 89 E	60 m	1198 m	43m	47 m
Meyershoop 1				
27.097 7 S 30.783 40 E	60 m	1185 m	26m	28 m & 60 m
Meyershoop Community Borehole				
27.063 23 S 30.465 97 E	75 m	1262 m	31m	19 m & 75 m

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6. PUMP TESTING PROCESSES

6.1. PUMPING TESTS

The pumping test of the aquifer is conducted to estimate sustainable yield in accordance to the guidelines by Van Tonder *et al.* (2001a) and these guidelines include guidelines for:

- Choosing of pump size, possibly with high discharge rate,
- Calibration test,
- Determining length of Constant Rate test (24 hours in this case),
- Measuring of drawdown during the pumping period,

6.1.1. Measuring Recovery on Step Drawdown Test

Step drawdown tests were conducted as a calibration procedure to determine the appropriate abstraction rate for the constant rate test. A table showing the results of the step drawdown test can be found in appendix III.

6.1.2. Constant Rate Test

The constant rate test was conducted to fully stress the aquifer of the boreholes at an average abstraction rate that was determined from calibration tests. The selection of the constant pumping rate was estimated taking consideration the geological information extracted from the borehole profile logs to assure that the groundwater level drops but does not exceed the main water strike level. Drawdown was measured during the 24 hour pumping test period in intervals using a water level deep meter (See appendix IV for the water drawdown measured during pumping period). After switching off the pump, groundwater level recovery was monitored until the boreholes were at least 95% recovered to the original groundwater static level (See appendix V for the residual water levels measured).

6.1.3. Long Term Sustainable Borehole Yield Estimation

Flow Characteristic (FC) Basic method (Van Tonder et al. 1998b) was used to estimate sustainable borehole yield from the time drawdown data. The basic method uses derivatives and subjective or generalised information about boundaries and does not require determination of storativity. Derivative and diagnostic plots were also used to characterize the flow and understand drawdown time trends which are used to determine some of the input parameters to FC.

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6.2. PUMP TESTING RESULTS

6.2.1. Meyershoop Community Borehole

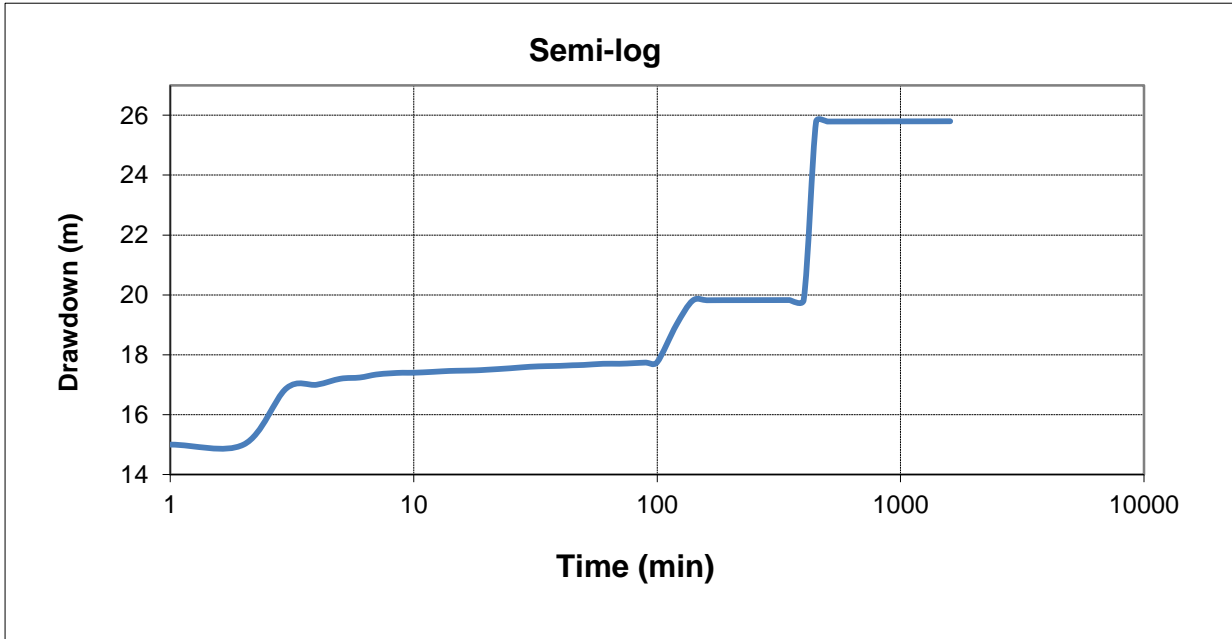


Figure 14: Semi-log plot of drawdown against time for Meyershoop Community Borehole

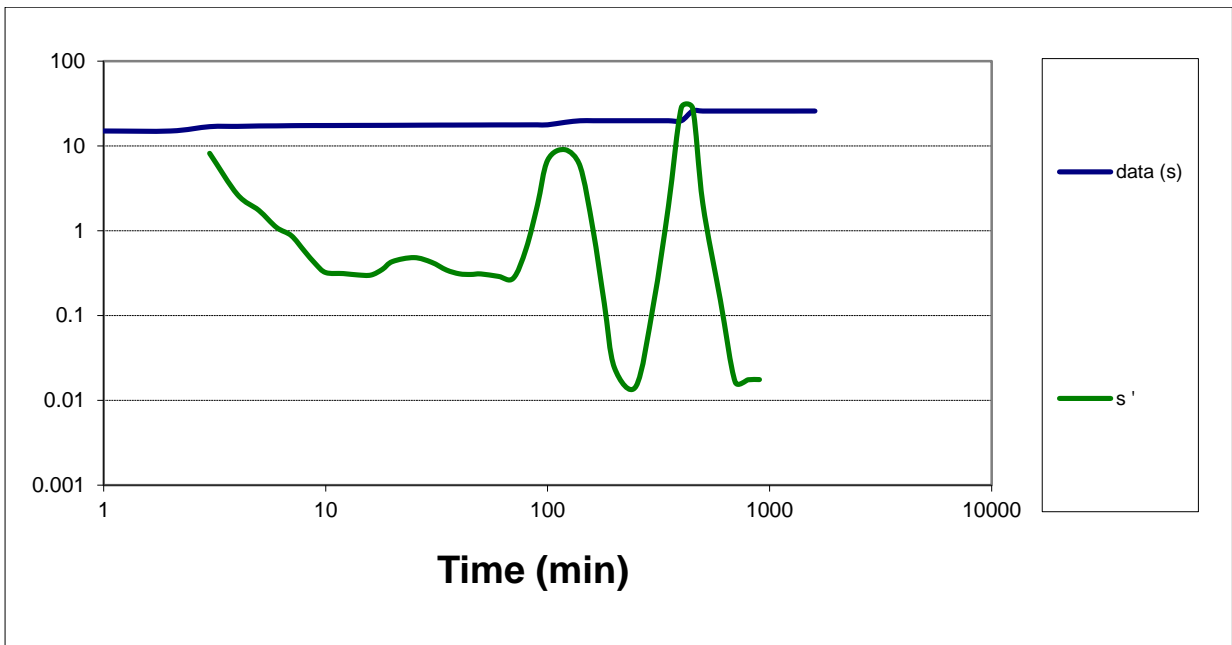


Figure 15: Log-log plot of drawdown derivative against time for Meyershoop Community Borehole

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6.2.2. Meyershoop Monitoring Borehole

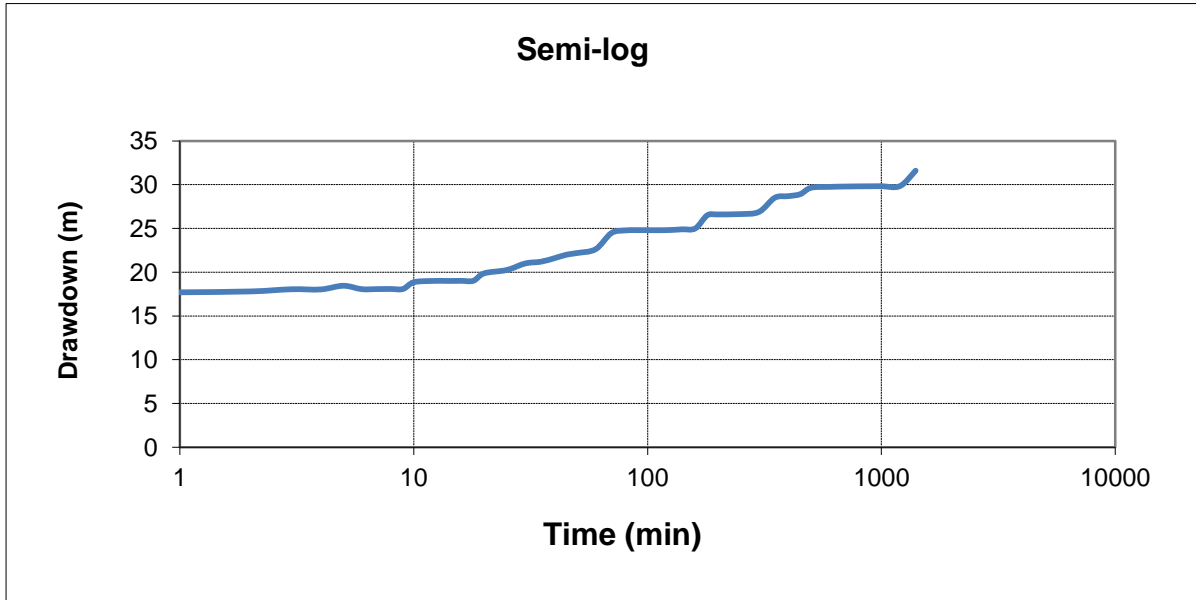


Figure 16: Semi-log plot of drawdown against time for Meyershoop Monitoring Borehole

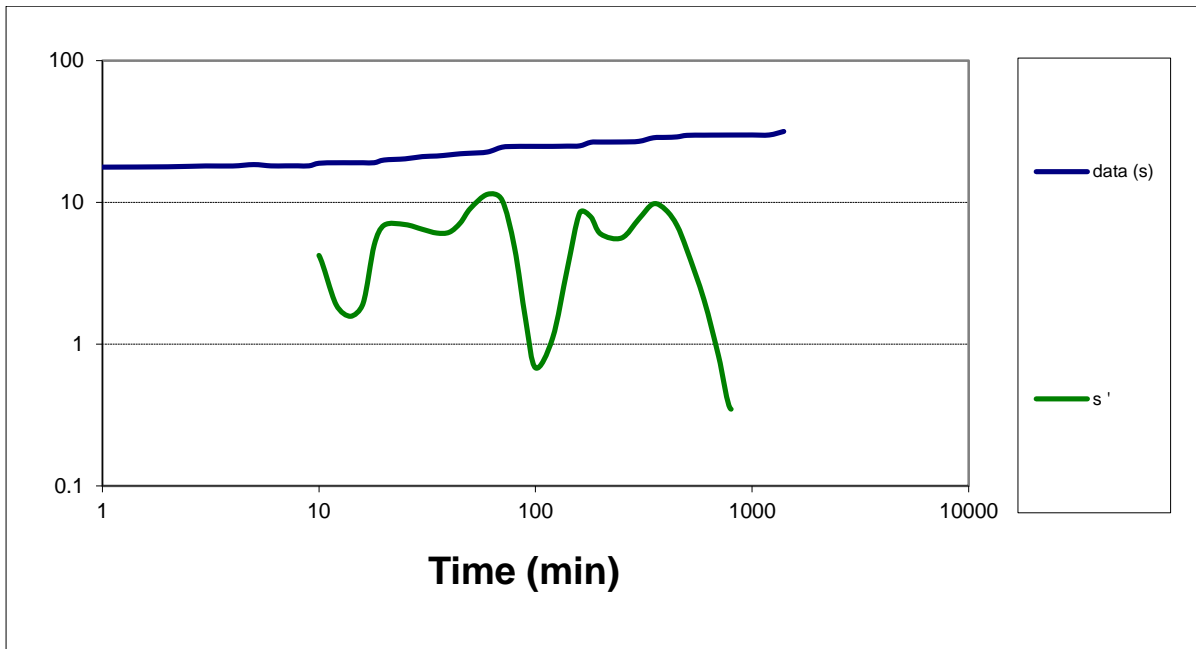


Figure 17: Log-log plot of drawdown derivative against time for Meyershoop Monitoring Borehole

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6.2.3. Kwagadlanga Monitoring Borehole

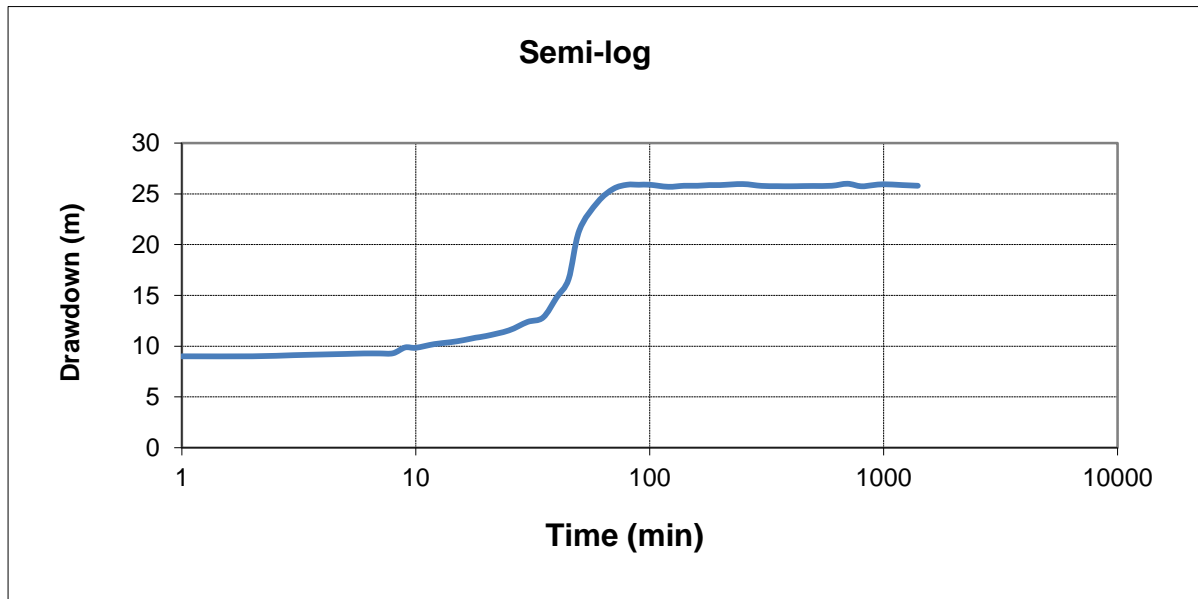


Figure 18: Semi-log plot of drawdown against time for Kwagadlanga Monitoring Borehole

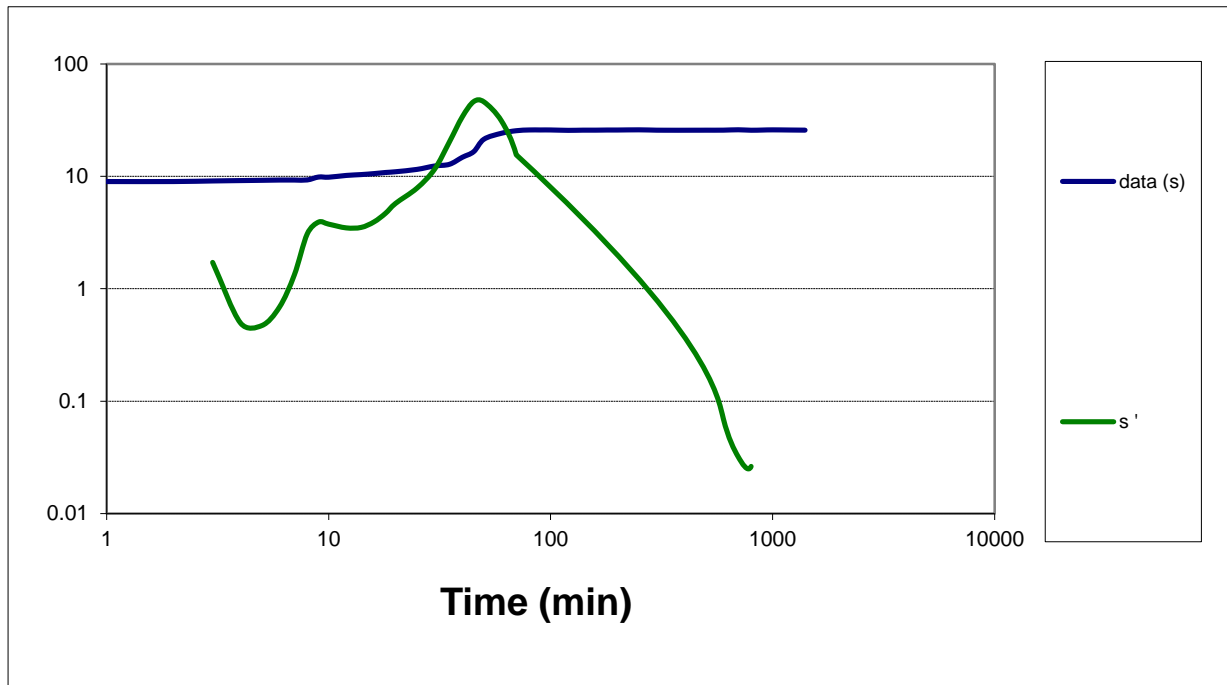


Figure 19: Log-log plot of drawdown derivative against time for Kwagadlanga Monitoring Borehole

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6.2.4. Athalia Monitoring Borehole

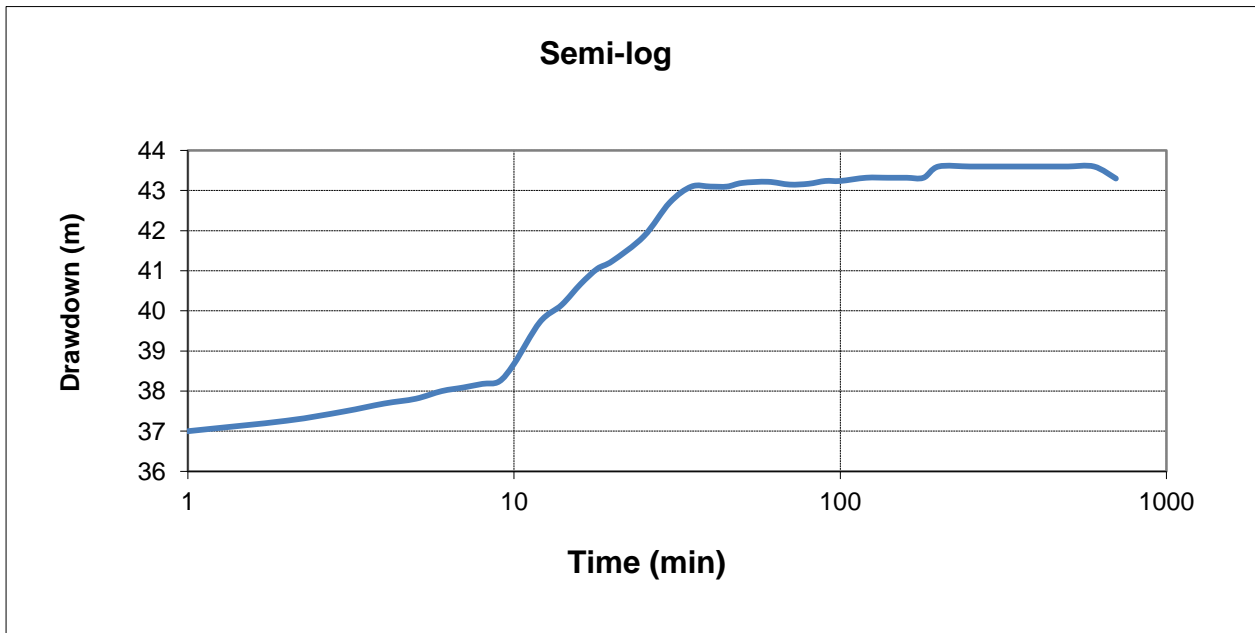


Figure 20: Semi-log plot of drawdown against time for Athalia Monitoring Borehole

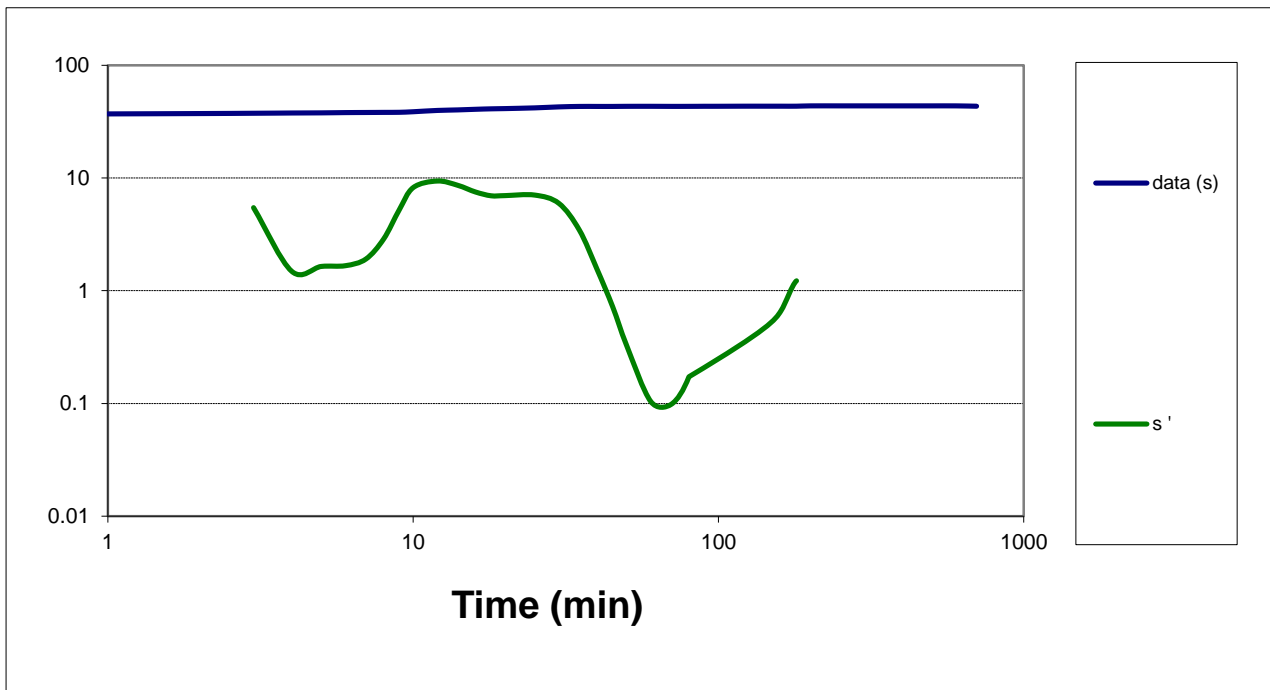


Figure 21: Log-log plot of drawdown derivative against time for Athalia Monitoring Borehole

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6.2.5. Cangaza Monitoring Borehole

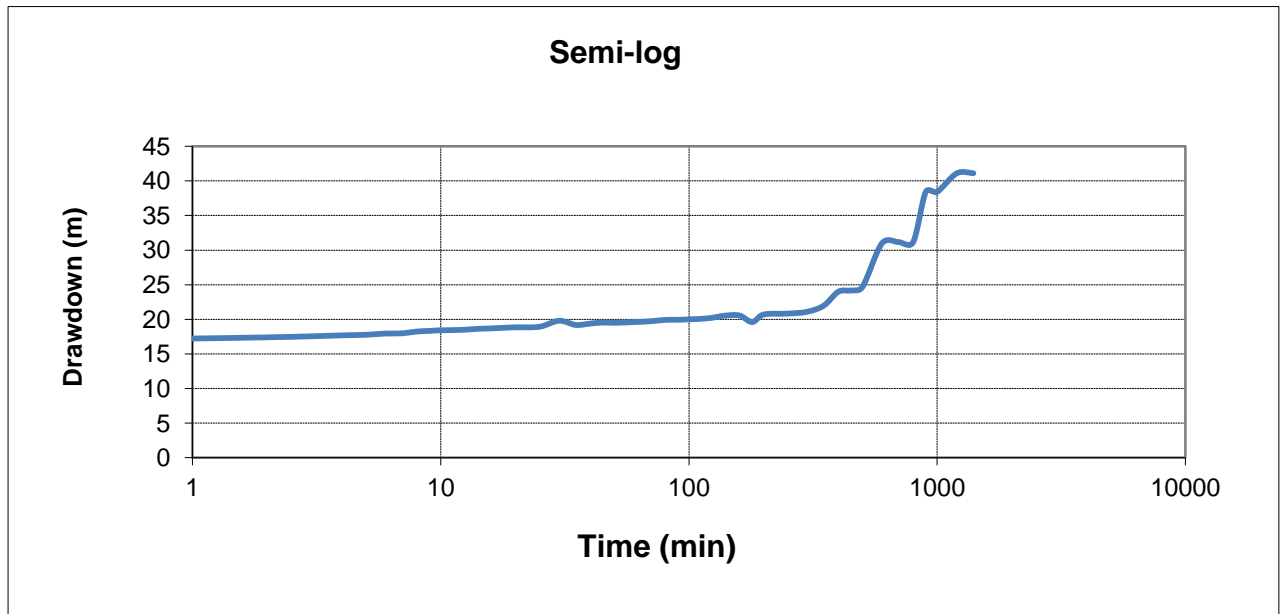


Figure 22: Semi-log plot of drawdown against time for Cangaza Monitoring Borehole

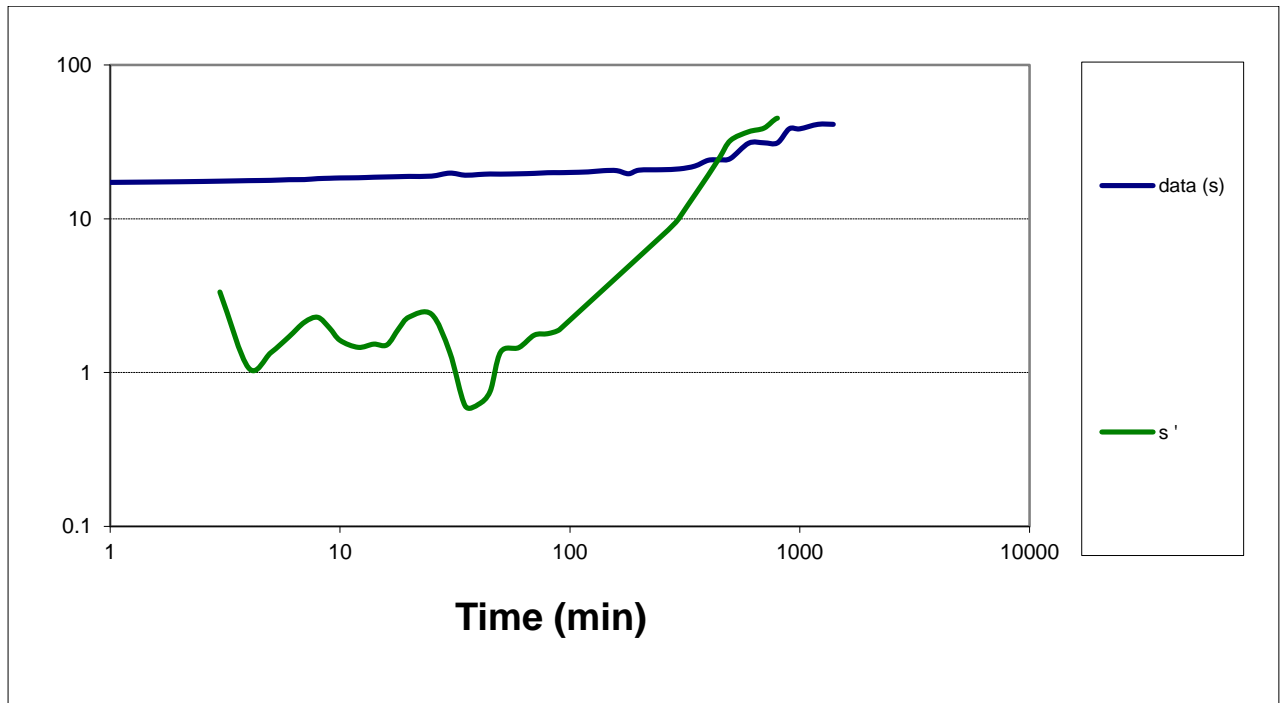


Figure 23: Log-log plot of drawdown derivative against time for Cangaza Monitoring Borehole

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6.2.6. Amsterdam Monitoring Borehole

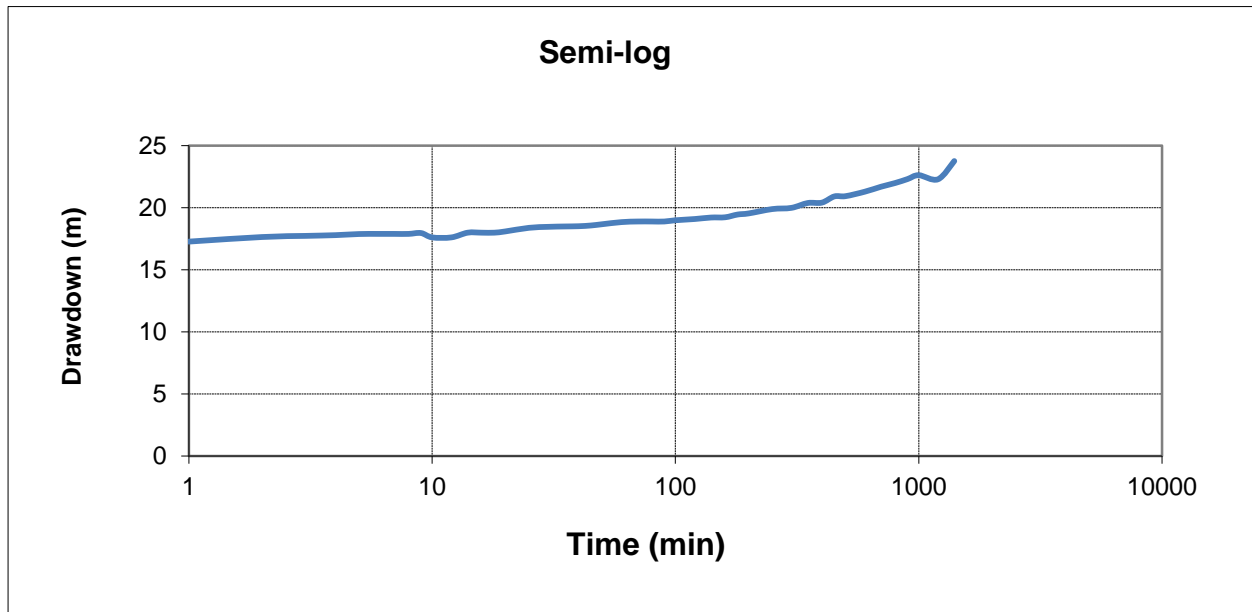


Figure 24: Semi-log plot of drawdown against time for Amsterdam Monitoring Borehole

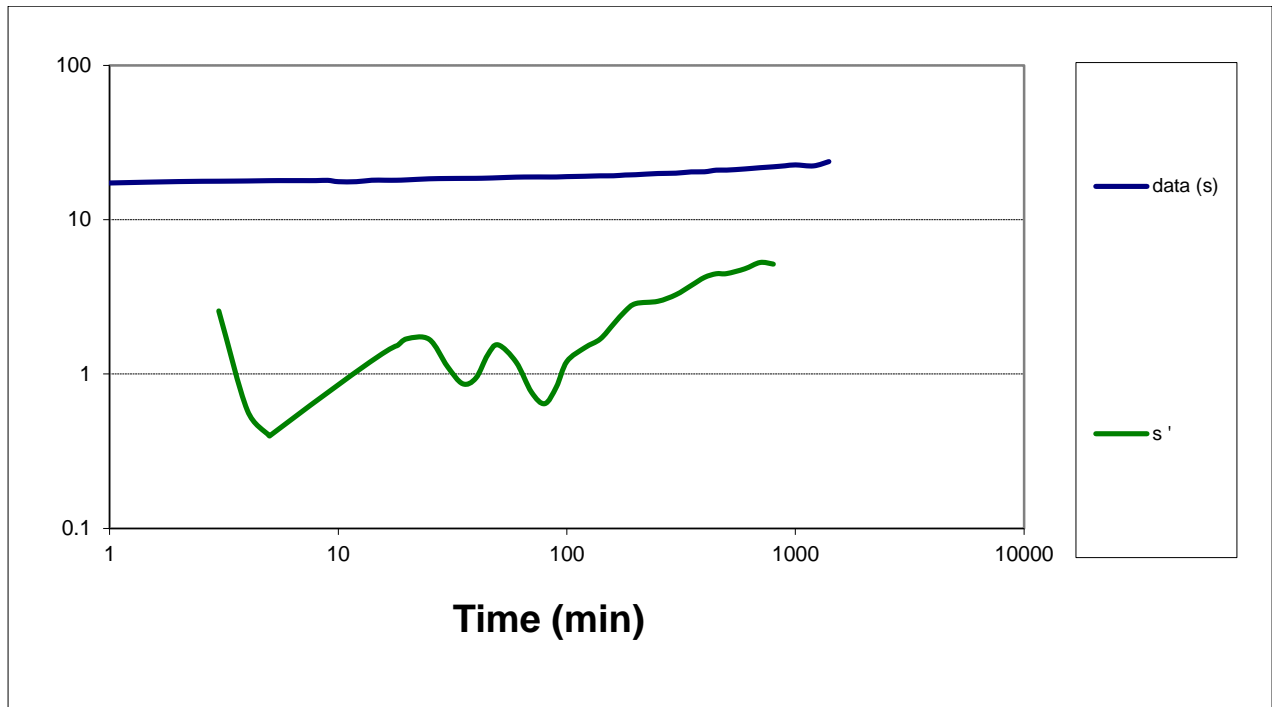


Figure 25: Log-log plot of drawdown derivative against time for Amsterdam Monitoring Borehole

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6.2.7. Mayflower Monitoring Borehole

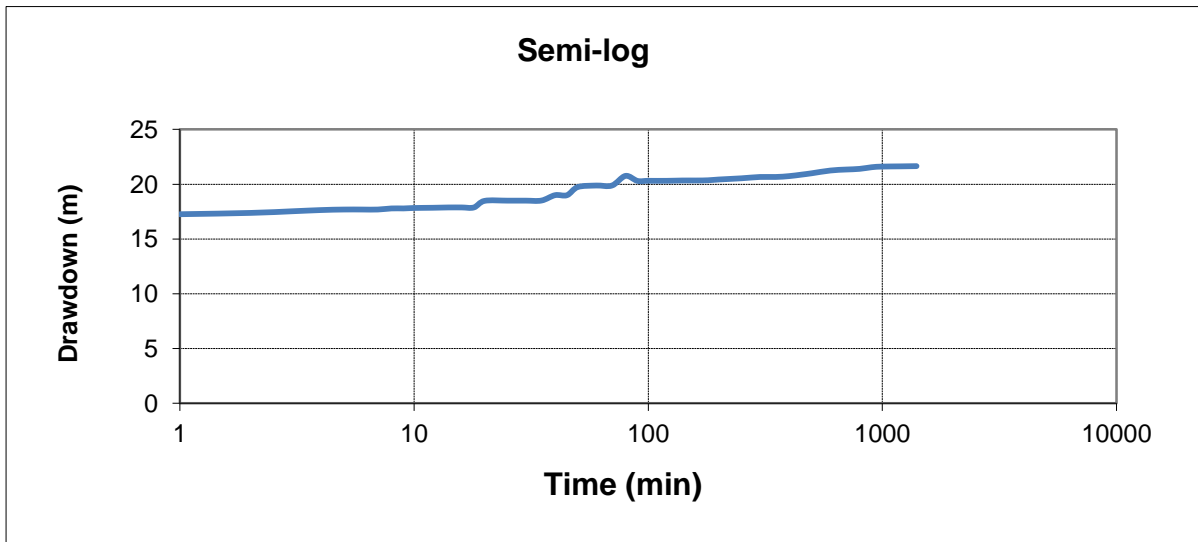


Figure 26: Semi-log plot of drawdown against time for Mayflower Monitoring Borehole

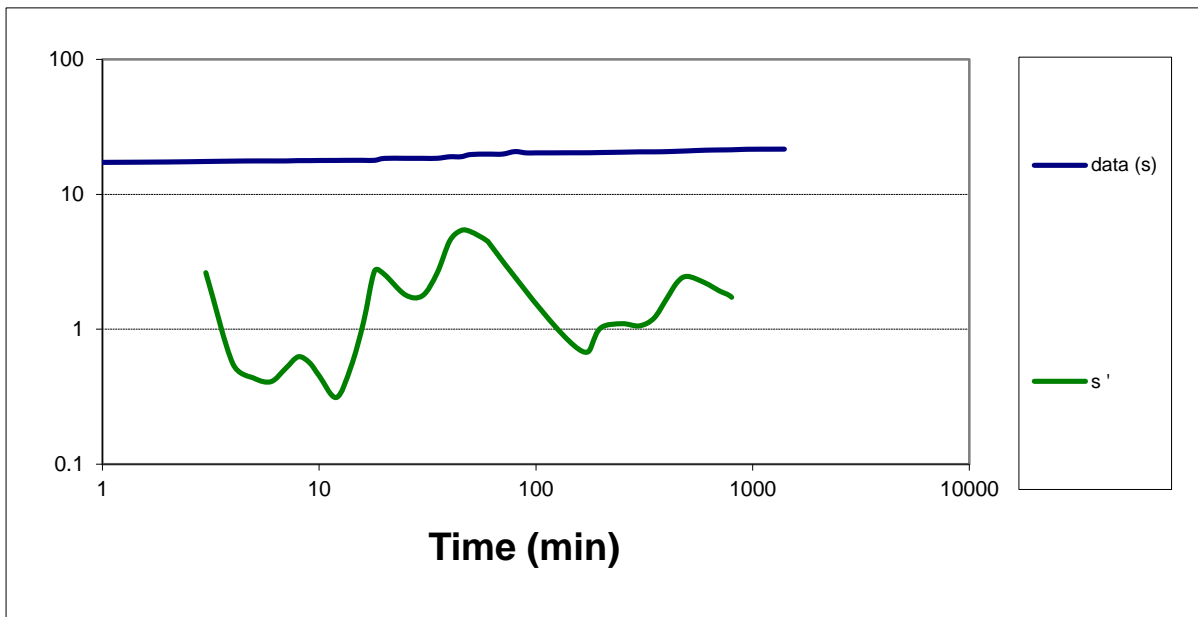


Figure 27: Log-log plot of drawdown derivative against time for Mayflower Monitoring Borehole

7. GROUNDWATER QUALITY ANALYSIS

The groundwater samples were collected during the calibration pumping phase. The samples were analysed for major and minor ions to determine the chemical content of the groundwater

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The samples in the entire above mentioned place i.e. Meyershoop, Cangaza Primary School, Athalia, KwaGadlanga, Amsterdam and Mayflower comply with all of SANS, 2006 parameters except for turbidity which is extremely high due to the fact that the samples were taken during the calibration pumping phase. It was observed that the groundwater turbidity cleared with time during the constant pumping phase. Microbiological analysis of the groundwater was not taken due to the time constraints and logistical challenges linked with the spatial distribution of boreholes as it required that microbiological analysis be conducted at no longer than 24 hours after sampling. Table 3 below shows the groundwater analysis results for all the successful boreholes drilled.

Table 3: Shows the groundwater sample analysis conducted and the comparison with SANS 241

MEYERSHOOP				
Analysis	Unit	Method	Results	SANS 241
Cadmium	µg/L Cd	CMP 33	<0.20	<3
Calcium	mg/l Ca	CMP 33	6.5	150
Chloride	mg/l Cl	CMP 27 A	6.0	<300
Colour	mg/l Pt	CMP 12 A	<5.0	<15
Copper	µg/L Cu	CMP 33	<0.44	<2.0
Electrical conductivity	mS/m [25°C]	CMP 31	11.7	<170
Fluoride	mg/l F	CMP 27 A	<0.20	<1.5
Iron	µg/L Fe	CMP 33	<0.88	<300
Lead	µg/L Pb	CMP 33	<0.11	<10
Magnesium	mg/l Mg	CMP 33	3.2	70
Manganese	µg/L Mn	CMP 33	23	<100
Nitrate Nitrogen	mg/l N	CMP 27 A	2.5	<11
PH	pH units [25°C]	CMP 31	5.83	5-9.7
Sodium	mg/l Na	CMP 33	14	<200
Sulphate	mg/l SO4	CMP 27 A	<5.0	<250
Total Hardness	mg/l	CMP 4	29	<1200
Turbidity	NTU	CMP 13 A	401	<1
Zinc as Zn	µg/L Zn	CMP 33	<0.57	<5
KWAGADLANGA				
Analysis	Unit	Method	Results	SANS 241
Cadmium	µg/L Cd	CMP 33	<2.0	<3
Calcium	mg/l Ca	CMP 33	13	150
Chloride	mg/l Cl	CMP 27 A	3.0	<300
Colour	mg/l Pt	CMP 12 A	<5.0	<15
Copper	µg/L Cu	CMP 33	<0.44	<2.0
Electrical conductivity	mS/m [25°C]	CMP 31	17.2	<170
Fluoride	mg/l F	CMP 27 A	<0.20	<1.5
Iron	µg/L Fe	CMP 33	21	<300
Lead	µg/L Pb	CMP 33	<0.11	<10
Magnesium	mg/l Mg	CMP 33	7.8	70
Manganese	µg/L Mn	CMP 33	122	<100
Nitrate Nitrogen	mg/l N	CMP 27 A	1.9	<11
PH	pH units [25°C]	CMP 31	6.04	5-9.7
Sodium	mg/l Na	CMP 33	9.7	<200
Sulphate	mg/l SO4	CMP 27 A	<5.0	<250

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Total Hardness	mg/l	CMP 4	65	<1200
Turbidity	NTU	CMP 13 A	412	<1
Zinc as Zn	µg/L Zn	CMP 33	<0.57	<5
MEYERSHOOP 2				
Analysis	Unit	Method	Results	SANS 241
Cadmium	µg/L Cd	CMP 33	<0.20	<3
Calcium	mg/l Ca	CMP 33	6.2	150
Chloride	mg/l Cl	CMP 27 A	6.2	<300
Colour	mg/l Pt	CMP 12 A	<5.0	<15
Copper	µg/L Cu	CMP 33	<0.44	<2.0
Electrical conductivity	mS/m [25°C]	CMP 31	11.7	<170
Fluoride	mg/l F	CMP 27 A	<0.20	<1.5
Iron	µg/L Fe	CMP 33	<0.88	<300
Lead	µg/L Pb	CMP 33	<0.11	<10
Magnesium	mg/l Mg	CMP 33	3.1	70
Manganese	µg/L Mn	CMP 33	22	<100
Nitrate Nitrogen	mg/l N	CMP 27 A	2.5	<11
PH	pH units [25°C]	CMP 31	5.88	5-9.7
Sodium	mg/l Na	CMP 33	13	<200
Sulphate	mg/l SO4	CMP 27 A	<5.0	<250
Total Hardness	mg/l	CMP 4	28	<1200
Turbidity	NTU	CMP 13 A	386	<1
Zinc as Zn	µg/L Zn	CMP 33	<0.57	<5
MAYFLOWER				
Analysis	Unit	Method	Results	SANS 241
Cadmium	µg/L Cd	CMP 33	<0.20	<3
Calcium	mg/l Ca	CMP 33	13	150
Chloride	mg/l Cl	CMP 27 A	3.2	<300
Colour	mg/l Pt	CMP 12 A	<5.0	<15
Copper	µg/L Cu	CMP 33	<0.44	<2.0
Electrical conductivity	mS/m [25°C]	CMP 31	17.5	<170
Fluoride	mg/l F	CMP 27 A	<0.20	<1.5
Iron	µg/L Fe	CMP 33	10	<300
Lead	µg/L Pb	CMP 33	<0.11	<10
Magnesium	mg/l Mg	CMP 33	8.0	70
Manganese	µg/L Mn	CMP 33	48	<100
Nitrate Nitrogen	mg/l N	CMP 27 A	2.4	<11
PH	pH units [25°C]	CMP 31	6.05	5-9.7
Sodium	mg/l Na	CMP 33	10	<200
Sulphate	mg/l SO4	CMP 27 A	<5.0	<250
Total Hardness	mg/l	CMP 4	65	<1200
Turbidity	NTU	CMP 13 A	375	<1
Zinc as Zn	µg/L Zn	CMP 33	<0.57	<5
ATHALIA				
Analysis	Unit	Method	Results	SANS 241
Cadmium	µg/L Cd	CMP 33	<0.20	<3
Calcium	mg/l Ca	CMP 33	6.1	150
Chloride	mg/l Cl	CMP 27 A	6.6	<300
Colour	mg/l Pt	CMP 12 A	<5.0	<15
Copper	µg/L Cu	CMP 33	<0.44	<2.0
Electrical conductivity	mS/m [25°C]	CMP 31	12.3	<170

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Fluoride	mg/l F	CMP 27 A	<0.20	<1.5
Iron	µg/L Fe	CMP 33	<0.88	<300
Lead	µg/L Pb	CMP 33	<0.11	<10
Magnesium	mg/l Mg	CMP 33	3.2	70
Manganese	µg/L Mn	CMP 33	16	<100
Nitrate Nitrogen	mg/l N	CMP 27 A	2.7	<11
PH	pH units [25°C]	CMP 31	5.86	5-9.7
Sodium	mg/l Na	CMP 33	13	<200
Sulphate	mg/l SO4	CMP 27 A	6.5	<250
Total Hardness	mg/l	CMP 4	28	<1200
Turbidity	NTU	CMP 13 A	96	<1
Zinc as Zn	µg/L Zn	CMP 33	<0.57	<5

CANGAZA

Analysis	Unit	Method	Results	SANS 241
Cadmium	µg/L Cd	CMP 33	<0.20	<3
Calcium	mg/l Ca	CMP 33	15	150
Chloride	mg/l Cl	CMP 27 A	1.4	<300
Colour	mg/l Pt	CMP 12 A	<5.0	<15
Copper	µg/L Cu	CMP 33	<0.44	<2.0
Electrical conductivity	mS/m [25°C]	CMP 31	16.2	<170
Fluoride	mg/l F	CMP 27 A	<0.20	<1.5
Iron	µg/L Fe	CMP 33	7.0	<300
Lead	µg/L Pb	CMP 33	<0.11	<10
Magnesium	mg/l Mg	CMP 33	5.6	70
Manganese	µg/L Mn	CMP 33	70	<100
Nitrate Nitrogen	mg/l N	CMP 27 A	0.35	<11
PH	pH units [25°C]	CMP 31	6.07	5-9.7
Sodium	mg/l Na	CMP 33	12	<200
Sulphate	mg/l SO4	CMP 27 A	7.3	<250
Total Hardness	mg/l	CMP 4	61	<1200
Turbidity	NTU	CMP 13 A	132	<1
Zinc as Zn	µg/L Zn	CMP 33	<0.57	<5

AMSTERDAM

Analysis	Unit	Method	Results	SANS 241
Cadmium	µg/L Cd	CMP 33	<0.20	<3
Calcium	mg/l Ca	CMP 33	15	150
Chloride	mg/l Cl	CMP 27 A	0.51	<300
Colour	mg/l Pt	CMP 12 A	<5.0	<15
Copper	µg/L Cu	CMP 33	<0.44	<2.0
Electrical conductivity	mS/m [25°C]	CMP 31	19.4	<170
Fluoride	mg/l F	CMP 27 A	<0.20	<1.5
Iron	µg/L Fe	CMP 33	53	<300
Lead	µg/L Pb	CMP 33	<0.11	<10
Magnesium	mg/l Mg	CMP 33	8.4	70
Manganese	µg/L Mn	CMP 33	71	<100
Nitrate Nitrogen	mg/l N	CMP 27 A	0.21	<11
PH	pH units [25°C]	CMP 31	6.19	5-9.7
Sodium	mg/l Na	CMP 33	16	<200
Sulphate	mg/l SO4	CMP 27 A	10	<250
Total Hardness	mg/l	CMP 4	72	<1200
Turbidity	NTU	CMP 13 A	120	<1
Zinc as Zn	µg/L Zn	CMP 33	<0.57	<5

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APPENDICES

Appendix I: Borehole Logs

Appendix II: Drillers Logs

Appendix III: Step-Drawdown Tests

Appendix IV: Constant Pump Tests

Appendix V: Residual Water Level

Appendix VI: Geological Legend for Map Sheet 2630 Mbabane 1:250 000

Appendix VII: Geological Legend for Map Sheet 2730 Vryheid 1: 250 000

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Appendix VI: Geological Map & Legend for Map Sheet 2630 Mbabane 1:250 000

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Appendix VII: Geological Map & Legend for Map Sheet 2730 Vryheid 1: 250 000