HYROLOGICAL & HYDROGEOLOGICAL SURVEY REPORT

BOREHOLE SITE INVESTIGATION

AT

L.R. NO. MN/IV/292/02 & OTHERS

VIPINGO AREA, KILIFI COUNTY

VIPINGO DEVELOPMENT LTD.

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GLOSSARY

Alluvium - sediments deposited by or in conjunction with running water in rivers, streams, or sheet wash and in alluvial fans

Apparent resistivity - the resistance [Ω] per length [L] of a surface area [L2], in essence the resistance of a cube to the one-way passage of electricity. Apparent resistivity is used in a number of geophysical and hydrogeological applications

Aquifer - a consolidated or unconsolidated geologic unit (material, stratum, or formation) or set of connected units that yields water of suitable quality to wells or springs in economically usable amounts

Auger – rotary drilling equipment, used in soils or poorly-consolidated materials, that removes cuttings from a borehole by mechanical means without the use of drilling fluids. Augers operate on the inclined plane or screw principle

Borehole - a hole drilled into the earth into which well casings or piezometers may be installed

Brackish water - water with a salinity ⊂ (103, 104 mg/L]

Breccia – a clastic deposit consisting of angular clasts (fragments), commonly embedded in finer material

Casing - a pipe that is in a well or borehole. More specifically, a casing is a tubular, water-tight structure installed in the excavated or drilled hole to maintain the well opening and, along with cementing, to confine the groundwaters to their zones of origin and to prevent the entrance of surface contaminants.

Catchment **–** the area of land drained by a single stream or river or, in the case of karst, drained by a single doline or group of dolines. Catchment and watershed are equivalent terms.

Caving - materials that erodes (caves) from a borehole in response to upward-flowing fluid within the annulus of a well or borehole while being drilled.

Clastic - a term describing sediments or rocks composed of mineral or rock fragments (e.g., sand, sandstone, shale, conglomerate, etc.)

Cone of depression – a curved water table or potentiometric surface that forms around a pumping well

Domestic use – water used by and connected to a household for personal needs or for household purposes, such as drinking, bathing, heating, cooking, sanitation or cleaning, and landscape irrigation. Ancillary use may include water of domestic animals.

Drawdown - the drop in head from the initial head caused by pumping from a well or set of wells.

Evaporation - the process by which liquid water at or near the Earth's surface turns into vapor at temperatures less than boiling.

Evapotranspiration - the combination of evaporation and transpiration, generally measured in units of $[L^3/t/L^2]$.

Fault - a fracture which has experienced translation or movement of the fracture walls parallel to the plane of the fracture.

Filter pack – coarse sand packed around the screen of a well.

Fluvial - referring to processes occurring in a river.

Formation - a body of rock strata that consists of a certain lithology or combination of lithologies; a lithologically mappable unit

Fracture - a subplanar discontinuity in a rock or soil formed by mechanical stresses. A fracture is visible to the naked eye and is open (i.e., not filled with minerals),
Fresh water - water with salinity < 1000 mg/l; drinkable or potable water is implied.
Gravel pack - gravel or sand used to fill the annulus between the well screen/casing and the rock or soil of the well bore.
Hydraulic gradient (i or ∇h)- the change in hydraulic head with direction.
Impermeable – (1) impervious to a fluid; (2) a material with zero permeability
Interface - the zone or surface separating waters of different salinities or separating different fluids (e.g., oil and water or water and air).
Isopleths - lines or surfaces of constant composition
Lacustrine - relating to processes occurring in a lake
Loam - a soil that is a mixture of sand, silt, and clay-sized particles.
Optimal yield- the rate of extraction of groundwater from an aquifer, aquifer system, or groundwater basin for various uses that maximizes the time discounted rate of return.
Outcrop - where a formation is present at the Earth's surface
Piezometer - a pressure-measuring device. This typically is an instrument that measures fluid pressure at a given point rather than integrating pressures over a well.
Pump or pumping test - one of a series of techniques to evaluate the hydraulic properties of an aquifer by observing how water levels change with space and time when water is pumped from the aquifer
Recharge - the process by which water enters the groundwater system or, more precisely, enters the phreatic zone
Recharge zone – the area of an aquifer or aquifer system where water enters the subsurface and, eventually, the phreatic zone.
Runoff –

- water from precipitation, snowmelt, or irrigation running over the surface of the Earth;
- surface water entering rivers, lakes, or reservoirs;
- a component of stream flow.

Safe yield- the volume of water that can be annually withdrawn from an aquifer (or groundwater basin or system) without:1) Exceeding average annual recharge; 2) Violating water rights; 3) Creating uneconomic conditions for water use; or 4) Creating undesirable side effects, such as subsidence or saline water intrusion
Saline – the condition of containing dissolved or soluble salts;
Saline water – water with over 10,000 ppm total dissolved solids;
Salinity - the amount of solutes (dissolved materials) in water [ppm, mg/l, or millimoles/l]; total dissolved solids (TDS)
Yield – generically, the amount of water pumped from a well (or bore). The units of yield are volume per time [$L^3 t^{-1}$].

- Mining yield- the appropriate rate of pumping from an aquifer that is receiving no or little recharge.
- Sustainable yield- the volume of water that can be extracted annually from an aquifer or groundwater basin that can, in conjunction with other available water resources, sustain a

reasonable human population indefinitely at an acceptable standard of living and maintain critical natural habitats indefinitely.

1 PHYSICAL DESCRIPTION

1.1 Location and climate

Vipingo is located some 35 kilometres from Mombasa and 23 kilometres form Kilifi town. The site is located north of Vipingo centre between Shauri Moyo and Takaungu which makes it even nearer to Kilifi. The area extends from the seaboard to the Chonyi hills that separate the coastal plain from the hinterland. Being part of the coastal belt, the area is climatically a semi-humid zone with mean annual temperatures between 24-30°C. Rainfall ranges between 800 -1400mm annually. Within the vicinity of Vipingo, the Chonyi rainfall station records an annual average of 1210mm.

Rainfall peaks in May, but is more or less uniformly distributed throughout the rainy season; the dry months are January to March.

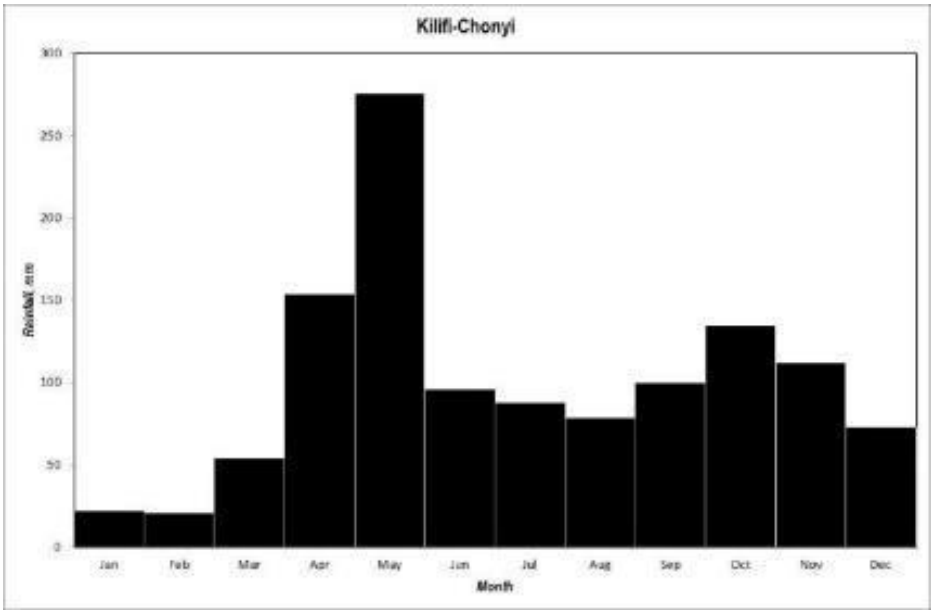

Figure 1. Rainfall hydrographs for Kilifi Chonyi (KMD 93338085).

1.2 Geology of the Area

The northern Kenya coast is defined by sedimentary geology that comprises sandstones, limestones and wind-blown sediments. The full succession of rock units that otherwise are of hydrogeological interest is as follows:

Triassic

Mariakani Sandstone

Discontinuity

Mazeras Sandstone

Jurassic
Kambe Limestone

Tertiary
Magarini Sands

Quaternary
Lagoonal sands/ Coral and coral breccia
Wind-blown superficial sands
Alluvium

Recent
Alluvium

Based on the location, tectonic events and lithology, the basin lithological sequence can be divided into the following seven units:-

1. Metamorphic basement (Precambrian);
2. Karroo syn-rift unit (Upper Carboniferous/Lower Permian to Triassic);
3. Late syn-rift and Transitional unit (Liassic);
4. East Gondwana break-up unit (Middle Jurassic to Lower Cretaceous);
5. Passive margin unit I (Upper Cretaceous-Lower Paleocene);
6. Passive margin unit II (Eocene to Upper Oligocene);
7. Passive margin unit III (Upper Oligocene to Recent).

The geology of the Vipingo area of current hydrogeological interest begins in the Karroo (i.e., the sandstones see Figure 2). The various geological units are described in greater detail.

1.2.1 Mazeras Sandstone

This sandstone outcrops west of the study area and is shown in the cross-section to underlie the area at depth. During their continental deposition, the sandstones were intercalated with carbonates and other salts.

1.2.2 Kambe Limestone

The Kambe Limestone crops out along the entire coast as a 120 km elongated strip wider in the north and narrows the south. The limestone is represented mainly by carbonate facies (Caswell 1953, 1956); except in the Mombasa area, where the occurrence of clay and marly levels has been reported (Westermann 1975). According to Caswell (1953, 1956), from Mazeras to the north the lithological succession becomes entirely calcareous, showing features of a carbonate platform. The thickness of the formation increases northwards, passing from 150 to 600 m. Its thickness in the

Vipingo areas is not certain, but in geological section it could be thicker than 300 metres.

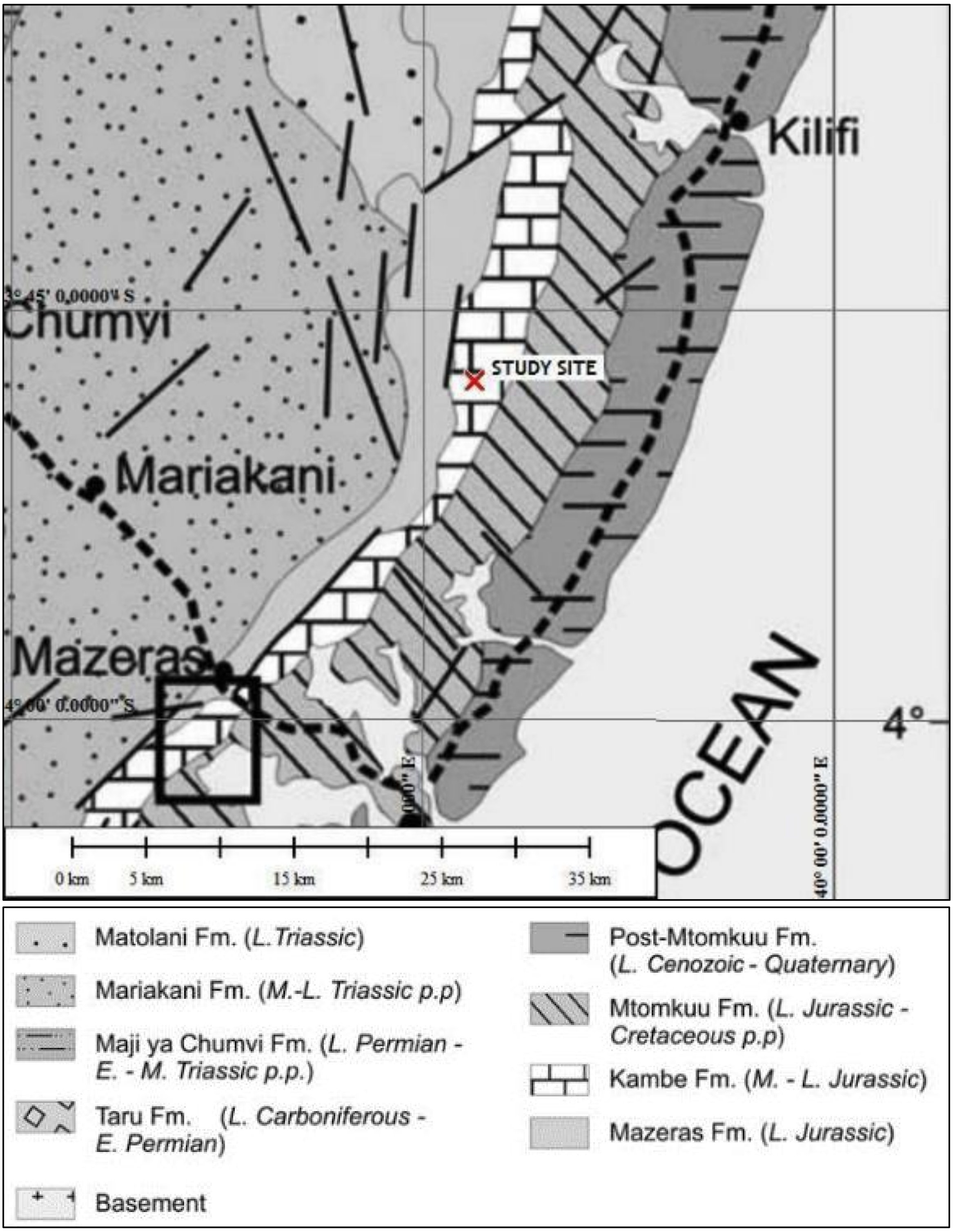

Figure 2. Geology of the study area

The formation was formed under two events, the Bajocian and Bathonian. The basal Bajocian sediments of the Kambe formation were deposited under near shore neritic and estuarine conditions. Basal transgression conglomerates, largely composed of

Duruma detritus, are overlain by impure micritic limestones, occasionally with small bioherms, and near-shore oolitic limestones, which were deposited in a shallow shelf environment with only moderate terrigeneous contamination.

The Kibiongoni formation is the Bathonian member and comprises shales, sandy siltstones, impure sandstones and grits, representing a partly contemporary estuarine facies with strong terrigeneous influence. Apparently seaward drainage was restricted by coastal ranges, probably resulting from up-doming prior to rifting. Clastic detritus was thus transported into estuaries just by a few rivers breaching this coastal range whilst the limestones of the Kambe formation formed in the clean, agitated sea between the estuaries. With increasing denudation of the coastal range, they were partly later covered by estuarine Kibiongoni sediments.

1.2.3 Upper Jurassic Shales

This monotonous sequence of fossiliferous Upper Jurassic calcareous shales and mudstones with occasional thin lenses of impure or oolitic limestones overlies the Kambe Limestone. Four formations of these shales are recognized on a biostratigraphical basis extending from the Calloway into the Kimmeridgian (Caswell 1953 & 1956). The fauna of the basal shales is characteristic of muddy deeper water deposits. This facies, however, did not persist and Argovian sediments again include oolithic limestones and even a horizon with gypsum concretions, indicating the return of shallow-water conditions. Sedimentation apparently continued without a break into the middle Kimmeridgian.

1.2.4 Magarini Formation

Erosion prevailed during the Tertiary until the Upper Pliocene, when tectonic reactivation resulted in increased erosion from structural highs. Fluviatile pebble beds, gravels and sands of the Magarini formation were deposited on down-faulted and eroded Jurassic and Duruma sediments. After a regression during the lowest Pleistocene, dunes which form the bulk of the Magarini formation were blown-up.

The younger Pleistocene was marked by eustatic fluctuations of the sea level, by the erosion of the Magarini sediments, the growth of a coral reef and the deposition of the associated lagoonal sands and back reef deposits of the Kilindini formation.

1.2.5 Lagoonal deposits

The lagoonal sands and clays deposited on the edge of a Pleistocene sea appear to be sparsely fossiliferous, consisting of poorly consolidated grey, pale grey brown and rusty brown clayey sands, sandy clays and marls with intercalations of reddish to pale brown sands, very likely similar to those formations occurring in the Mombasa and Malindi areas. Mineralogical analysis of the latter reveal that the sands are poorly cemented by gyp sum, limonite and clays and mainly comprise quartz with scattered grains of magnetite, ilmenite and pale pink garnet (Caswell et al, 1953).

1.2.6 Windblown and alluvial deposits

Most prominent of the recent deposits are the Aeolian sands composed of predominantly white, unconsolidated sands, distinguishable from the fossil dunes by less cementation and colouring. Because of their unconsolidated nature porosity and permeability are high, suggesting a favourable environment for perched fresh water aquifers. The elevation of the dunes favours the formation of a perched, unconfined aquifer system above the salt water interface, most likely at sufficient depth below surface to limit evapotranspiration losses. As fresh water has a lower density (1000 kg/m^3) than seawater (1025 kg/m^3), the fresh water will form a floating lens and depress the interface to below mean sea level. The actual hydro static level to which the groundwater table reaches above sea level will also be a function of the permeability of the sand, natural recharge, and lateral sub surface outflow to the sea and the lowlands inland of the dunes.

Other recent fluvial, lacustrine and marine deposits, consisting of sands, mud, and silt have accumulated in and around the ephemeral streams.

2 HYDROGEOLOGY

2.1 Concepts of a Deep-seated Aquifer

The stratigraphic column shows major unconformities between the Kambe Limestone and the Mazeras Formation (Karroo sandstone) and Mazeras and Mariakani sandstones (Figure 3). These unconformities are natural zones of groundwater accumulation. The sandstones are of continental origin, which means that groundwater found in them is likely to be fresh, unless secondary mineralisation induces formation of salts.

The Kambe and Mtomkuu formations are shelf limestone facies deposited during the Jurassic marine transgression hence groundwater that occurs in them would most likely be brackish to saline. The only other units within which freshwater aquifers can be located are the younger sand deposits that include the Magarini Sands, lagoonal sand deposits and wind-blown superficial sands. By nature of their occurrence, these units are shallow and thin hence they are host to shallow limited fresh water aquifers.

It is this stratigraphic arrangement that leads to occurrence of brackish aquifers below the shallow fresh water aquifers even where saltwater intrusion is unlikely due to the distance from the shoreline.

When targeting deep aquifers therefore, the investigator will have to look for a ground layering model where a low resistivity layer occurs at depth (representing weathered limestone/saline aquifer). Where the model ends in the low resistivity layer it will be interpreted to have ended in limestones/ unconformity, but where there is a deeper layer with higher resistivity the model will be interpreted to have terminated in sandstone.

The geological section A-A′ (Figure 5), from Simba Hill across Vipingo Ridge to the sea (see map Figure 6) shows that the Kambe Limestone is quite thick in the project area hence its contact with the Mazeras sandstone is possibly over 400 metres deep.

Furthermore, part of the Lower Kambe is known to be conglomeratic (Chiocchini et al., 2005). This raises the prospect that aquifer zones may be found near the contact with the Mazeras sandstone.

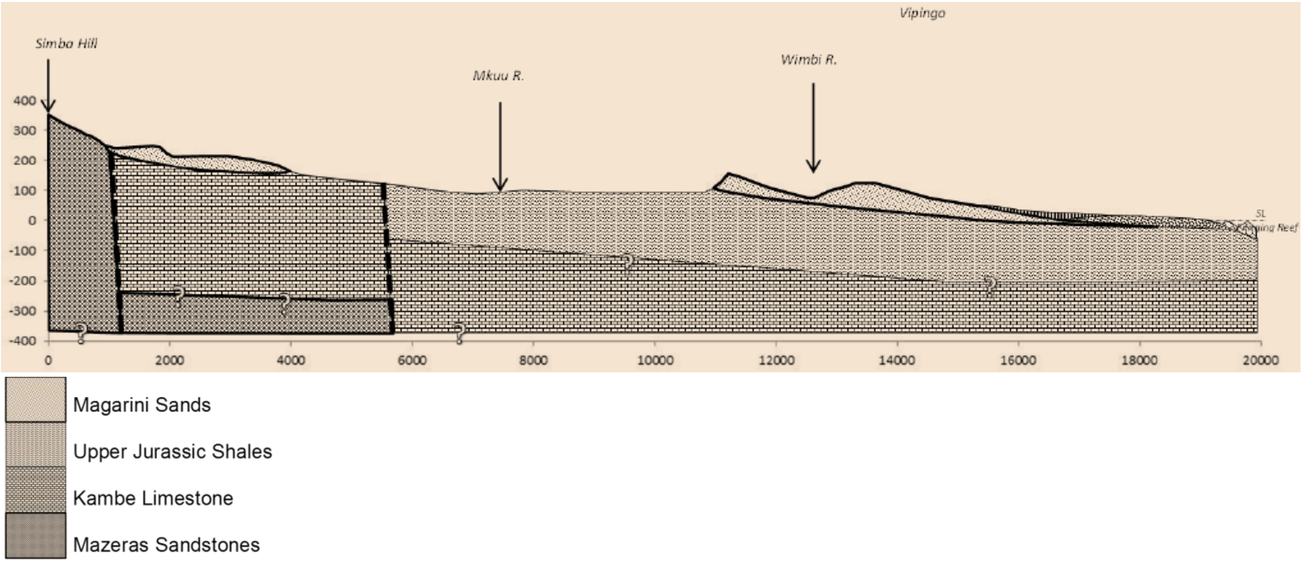

Figure 3. Geological section A-A′

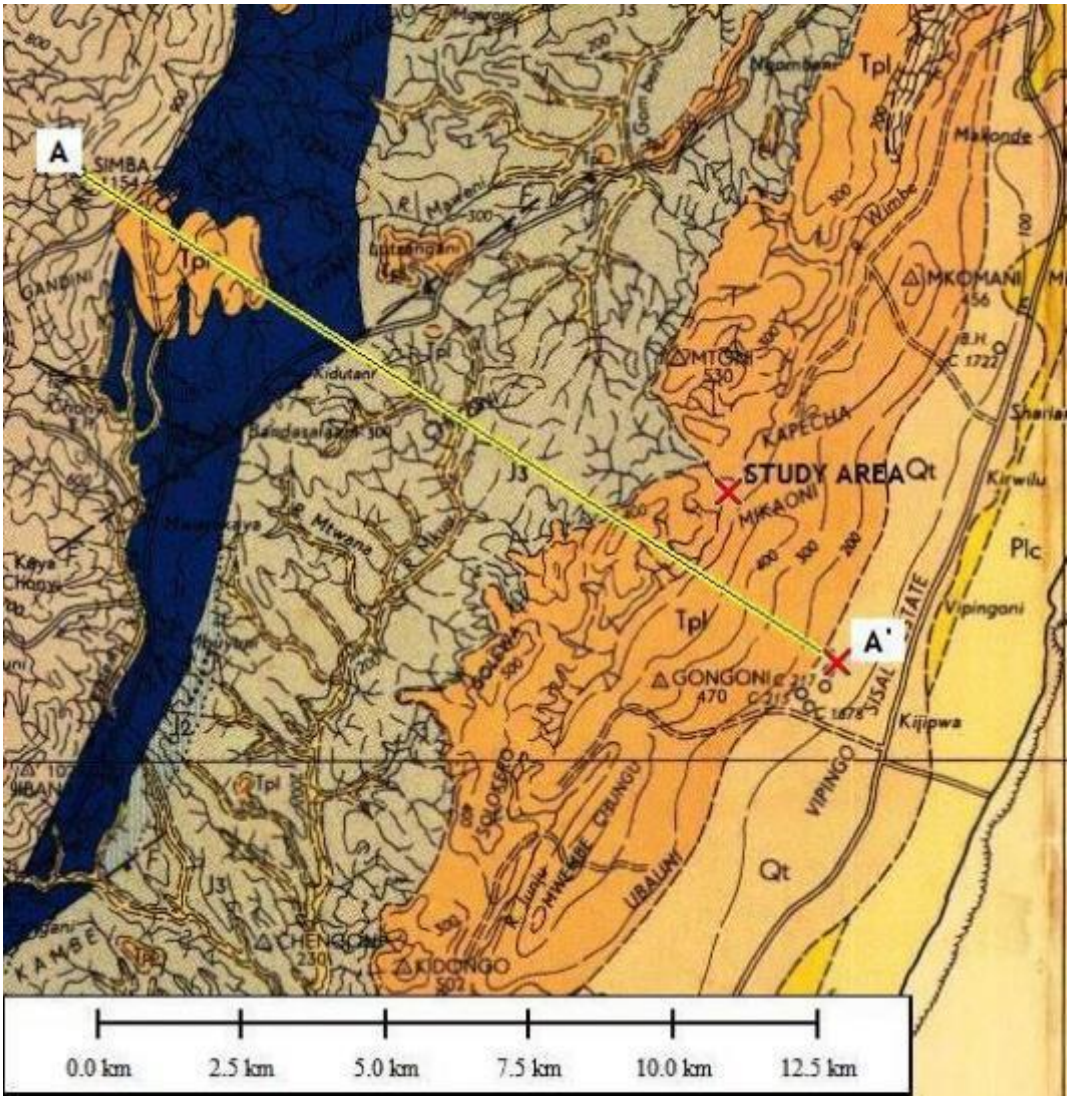

Figure 4. Geological map extract of the Kilifi-Mazeras area showing section A-A′.

2.2 Structures

Apart from the unconformities tectonic structures like faults play an important role in groundwater occurrence. Faults tend to induce deep circulation of groundwater, especially so in the coastal belt where the Karroo faulting and continental shelf faulting caused displacement of hundreds, even thousands of metres. They are hydraulic conduits, a kind of underground pipeline than can be tapped for groundwater when ab boreholes is located in the rigt place.

At the Vipingo Development site no major faulting is evident; the nearest fault runs NNE-SSW about 4 kilometres west of the area. However, there are hidden fractures that can be detected only by detailed study. For this work, longitudinal surface elevation profiles were taken to prove location of the fractured segments.

Fractured zones were picked by drawing parallel longitudinal sections along the ridge and on the coastal plain.

These fractured zones were hence investigated on the ground through horizontal electric profiling followed by vertical electrical soundings at precise points where the fracture anomalies were located.

2.3 Aquifer recharge

The present source of greatest recharge in the hinterland of the north coast occurs on the Mazeras and Mariakani sandstones outcrop. This suggests that where faults occur, there is a chance for groundwater throughflow to the shoreline. It is such flux that was targeted by the hydrogeological investigations conducted.

The occurrence of regional faults striking parallel to the coastline means groundwater moving along the faults is dispersed along the fault system. In the event that there is a cross-cutting NW-SE fault, such a system forms a formidable flux path because it provides an exit route for groundwater along the regional fault system.

It is this possibility that makes the fractures picked by the horizontal profiling study significant.

2.4 Water quality

Groundwater from the shallow aquifer (less than 60m) in Vipingo area is regarded as marginally fresh to brackish (EC here being 1000 – 3000 μS/cm). This means there are some chemical parameters that are found in higher concentration than is permissible for drinking water quality or irrigation water quality. It is therefore important that water from new boreholes be tested to assess suitability for intended use or to evaluate the cost of improving it to be suitable for intended use.

For the proposed deep groundwater exploration, its quality is not assured and there is no evidence yet of the quality of deep water from this area. This aspect will therefore be treated as an experimental case where once the borehole is drilled the water quality will be tested.

During the field survey a hydro census was conducted in which 6 groundwater sources were mapped and their well head physico-chemical parameters analysed as follows:

Table 2-1. Wellhead quality data

Name	pH	EC(@25^0 C)	TDS	Easting, WGS84	Northing
Timboni S/Moyo Factory	7.39	1740	870	591648	9583413
BH 7- Corona S/Moyo Factory	7.23	1580	800	591750	9584267
BH 8-Duka S/Moyo	7.22	2030	1020	591777	9584933
BH 9	No test	No test	No test	591476	9582603
BH 1-Head office Corona	7.51	920	460	588051	9577159
BH 21 -Head Office Factory Gate	7.78	798	400	588197	9577239
Hand dug well	7.45	1530	760	591613	9582679

The data shows that the water is basically potable. Nonetheless, detailed drinking water quality analyses will show if there are any parameters that individually exceed permissible levels.

3 GEOPHYSICAL SURVEYS

Horizontal electric profiling (HE) and vertical electrical sounding (VES) were used for the geophysical investigations, the former for discretising fracture anomalies and the latter for investigating the groundwater prospects at the particular anomaly and depth to water if potentially existent.

A SYSCAL R1 48 Plus resistivity instrument was deployed for the geophysical ata collection. It has the advantage over other instruments of having 200 Watt power output compared to 100W for similar range of instruments.

3.1 Basic principles and measuring techniques in geo-electric survey

The method selected for the survey was electrical resistivity profiling and sounding. The method was used to acquire field data about the underlying geology, and more especially factors that would be conducive to groundwater occurrence. Since resistivity is a function of the state of weathering of the rock strata, which is influenced by the occurrence of pore water, the observed variations are used to determine the water-bearing zones underground. However, clay layers often produce similar responses to the geo-electric probe current as groundwater does. The investigator must be aware of this when performing data interpretation and while making decisions in the field.

In conventional resistance, a specified current is injected into the ground using probes connected to a DC power source. The resulting measured voltage is used to calculate the ground's resistance to current flow by Ohm's Law:

$$R = V/I,$$

where *R = resistance, V = voltage, and I = current*

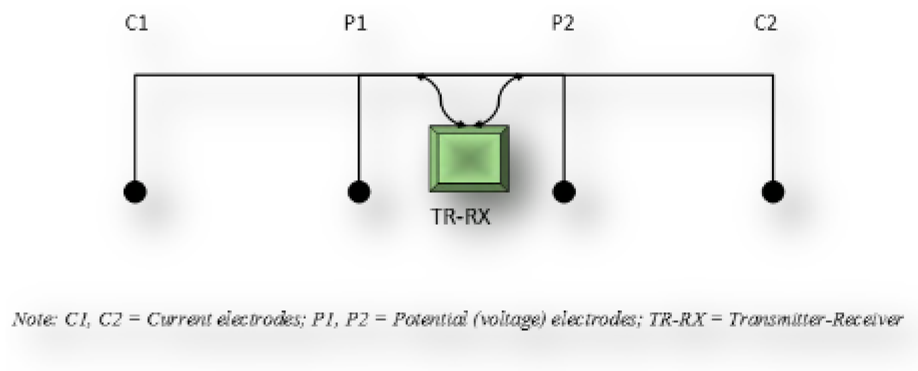

Figure 5. Illustration of the theory behind field resistivity survey

Resistance will vary depending on the distance and geometry between the probes so it is normalized with the addition of a geometric factor that converts the measurement to apparent resistivity, ρa, (expressed in ohm-meters):

$\rho a = 2\pi\ a\ V/I$, for equally spaced galvanic electrodes (Wenner array)

3.1.1 Horizontal electric profiling (HEP)

In HEP, the distance between the current and potential electrodes is kept the same, in an arrangement called the Wenner array. Strictly speaking, what was done in the field was a mixture of Wenner-Schlumberger, where the station interval (distance between potential electrodes) is constant, and similarly the distance between current electrodes, though different form that between potential electrodes, is also kept constant. Orientation of the HEP lines was determined by the major regional lineaments in the area.

It was observed that lineaments influencing groundwater flow run due NW-SE, so the horizontal electric profiles (HEP) lines would be orientated SE-NW in order to increase chances of picking low-resistivity anomalies. Some lineaments run approximately E-W.

Figure 6. Lineaments identified around the project site

Once the fracture traces were picked, the data was transferred and georeferenced to the site layout plan. This was so as to locate common purpose land use parcels that fall along the fracture traces. It is these sites that would then be investigated in detail on the ground to find out suitable borehole sites that do not conflict with the land use plan.

Figure 7. Fracture traces georeferenced onto the layout plan

What the superimposed fracture traces provide is information that the 'empty' spaces along these lines are the most likely sites to get the maximum yields from boreholes. As a result, most of the boreholes have to be located along these lines to ensure maximum potential yields.

3.1.2 *Data interpretation principles*

The quantitative interpretation of the data is conventionally accomplished with the help of one-dimensional models consisting of horizontal, infinitely extending homogeneous layers each with a different resistivity. The adjustment of measured data and model responses is usually performed using inversion methods.

The data collected was interpreted using *Interpex IX1D* software which is used for forward and inverse modelling of resistivity data. The software approximates the ground characteristics that would give the kind of resistivity signal delivered by the instrument during the data acquisition process. It relates ground strata resistivity and their thickness to derive a best-approximation model of the ground layering.

The following table illustrates the forward models of the ground depth-resistivity relationship from the site. Detailed VES data are included in this report in Appendix 1.

3.2.1 *Analysis of VES data for Borehole Site 1*

The site shows a 4-layer ground model, with the main strata being sands, coral breccia and coral limestone. The fourth layer is the weathered form of the coral limestone – the Kibiongoni beds – which as a result forms the main aquifer at this locality. Analysing the 3 VESes, VES 1 aquifer has the least rate of change between the third and fourth (aquifer) layer. This means it has the lowest gradient hence it has the better chance of striking fresh water. It is therefore the preferred drill site. VES 2 was considered outright poor and not included in the analysis.

<u>Table 1. Interpretation of VES data, Site 1</u>

Depth (m)	Resistivity (Ωm)	Interpretation	Remarks
SITE 1, VES 1 GR			
0 - 1.6	101	Sands	
1.6 - 5.5	395	Coral breccia	
5.5 - 15.3	111	Coral limestone, weathered	
>15.3	10	Ditto, deeply weathered	Aquifer, fresh
SITE 1, VES 3			
0 - 1.9	161	Sands	
1.9 - 6.4	504	Coral breccia	
6.4 - 20.9	125	Coral limestone, weathered	
>20.9	11	Ditto, deeply weathered	Aquifer, fresh
SITE 1, VES 4			
0 - 1.6	83	Sands	
1.6 - 8.0	227	Coral breccia	
8 - 21.5	144	Coral limestone, weathered	
>21.5	13	Ditto, deeply weathered	Aquifer, fresh

3.2.2 *Analysis of VES data for Borehole Site 2*

Site 2 presents 5-layer models; this is because of the presence of lagoonal sands, which do not appear at Site 1. VES 2 shows a steep gradient between the fourth confining layer and the bottom which is the aquifer layer. The gradient is more gentle for VES 5. Consequently, VES 5 is the better drill choice.

Table 2. Interpretation of VES data, Site 2

SITE 2 VES 2			
0 - 1.6	140	Sands	
0.6 - 4.9	335	Coral breccia	
4.9 - 12.2	169	Lagoonal sands	
12.2 - 26.4	254	Coral limestone	
>26.4	8	Deeply weathered/saline	Aquifer, brackish
SITE 2 VES 5			
0 - 0.5	212	Sandy soil	
0.5 - 2.2	143	Sands	
2.2 - 5.4	386	Coral breccia	
5.4 - 19.7	113	Coral lst, weathered	
>19.7	17	Coral, lst, deeply weath'd	Aquifer, fresh

3.2.3 *Analysis of VES data for Borehole Site 3*

At the proposed borehole Site 3 the two soundings show and aquifer that is fresh at 30 meters and less, but gets brackish if drilled too deep. Since the client is interested in adequate water even if slightly brackish, the site can be drilled to a maximum 40 meters.

Table 3. Interpretation of VES data, Site 3

SITE 3, VES 1			
0 - 0.5	262	Sandy soil	
0.5 - 1.5	605	Sands	
1.5 - 4.9	386	Coral breccia	
4.9 -30.0	120	Coral limestone	
>30.0	5	Deeply weathered/saline	Aquifer, brackish
SITE 3 VES 2			
0 - 1.6	456	Sands	
1.6 - 3.8	907	Coral breccia	
3.8 - 7.3	142	Lagoonal sands	
7.3 - 12.9	358	Coral limestone	
12.9 - 32.0	26	Deeply weathered lst	Aquifer, fresh
>32.0	393	Coral limestone	

3.2.4 *Analysis of VES data for Borehole Site 4*

At the proposed borehole site #4 a total of 3 soundings were executed, all of which show groundwater presence. Two of the sites indicate occurrence of brackish water, but one site shows presence of fresh water hence it was selected as the most suitable drill site.

Table 4. Numerical inverse resistivity model for Site 4

SITE 4, VES 1			
0 - 1.5	33	Sands	
1.5 - 3.5	50	Coral breccia	
3.5 - 8.9	19	Lagoonal sands	
8.9 - 26.1	149	Coral limestone	
>26.1	3	Deeply weathered lst	Aquifer, brackish
SITE 4 VES 2			
0 - 1.7	46	Sands	
1.7 - 5.3	58	Coral breccia	
5.3 - 11.6	23	Lagoonal sands	
11.6 - 25.5	160	Coral limestone	
>25.5	3	Deeply weathered lst	Aquifer, brackish
SIE 4, VES 3			
0 - 1.4	109	Sands	
1.4 - 4.7	656	Coral breccia	
4.7 - 16.1	29	Lagoonal sands	
16.1 - 36.7	87	Coral limestone	
>36.7	23	Deeply weathered lst	Aquifer, fresh

3.2.5 *Analysis of VES data for Borehole Site 4*

Table 5. Numerical inverse resistivity model for Site 5

SITE 5, VES 2			
0 - 0.5	1135	Sandy soil	
0.5 - 1.2	58	Clayey sands	
1.2 - 2.7	529	Coral breccia	
2.7 - 6.5	59	Coral limestone, weathered	
6.5 - 16.7	350	Coral lst	
>16.7	10	Deeply weathered coral lst	Aquifer, fresh
SITE 5, VES 3			
0 - 0.5	349	Sandy soil	
0.5 - 1.3	664	Clayey sands	

1.3 - 6.2	430	Coral breccia	
6.2 - 13.6	92	Coral limestone, weathered	
13.6 - 30.3	319	Coral lst	
>30.3	10	Deeply weathered coral lst	Aquifer, fresh
SITE 5, VES 4			
0 - 1.8	353	Sands	
1.8 - 3.9	939	Coral breccia	
3.9 - 9.5	88	Lagoonal sands	
9.5 - 20.8	803	Coral limestone	
>20.8	15	Deeply weathered lst	Aquifer, fresh
SITE 6, VES 1			
0 - 0.8	85	Sandy soil	
0.8 - 2.2	198	Clayey sands	
2.2 - 5.7	110	Coral breccia	
5.7 - 12.4	139	Coral limestone	
12.4 - 38.2	82	Coral lst, weathered	Aquifer, fresh
>38.2	111	Coral lst	
SITE 6, VES 2			
0 - 1.8	146	Sands	
1.8 - 23.5	174	Coral breccia	
>23.5	63	Limestone	
SITE 6, VES 3			
0 - 0.7	94	Sandy soil	
0.7 - 2.0	54	Clayey sands	
2.0 - 4.8	130	Coral breccia	
4.8 - 10.5	82	Coral limestone, weathered	
10.5 - 25.8	398	Coral lst	
>25.8	2	Coral lst, brackish water	Aquifer, brackish
SITE 7, VES 1			
0 - 0.4	372	Sandy soil	
0.4 - 6.0	260	Coral breccia	
6.0 - 13.4	85	Lagoonal sands	
13.4 - 24.4	160	Coral limestone	
>24.4	5	Deeply weathered lst	Aquifer, brackish
SITE 7, VES 2			
0 - 0.4	372	Sandy soil	
0.4 - 6.0	260	Coral breccia	
6.0 - 13.4	85	Lagoonal sands	
13.4 - 24.4	160	Coral limestone	
>24.4	5	Deeply weathered lst	Aquifer, brackish
SITE 7, VES 3			
0 - 0.7	72	Sandy soil	
0.7 - 2.0	377	Coral breccia	
2.0 - 13.5	153	Lagoonal sands	

13.5 - 34.9	66	Coral limestone	
>34.9	8	Deeply weathered lst	Aquifer, brackish
SITE 8, VES 1			
0 - 0.6	175	Sandy soil	
0.6 - 1.8	88	Clayey sands	
1.8 - 3.8	247	Coral breccia	
3.8 - 10.0	59	Coral limestone, weathered	
10.0 - 21.6	247	Coral lst	
>21.6	6	Coral lst, brackish water	Aquifer, brackish
SITE 8, VES 2			
0 - 3.2	113	Sands	
3.2 - 14.5	1019	Coral breccia	
>14.5	62	Limestone	Non-aquifer
SITE 9, VES 1			
0 - 1.3	164	Sands	
1.3 - 4.3	942	Coral breccia	
4.3 - 9.5	95	Lagoonal sands	
9.5 - 22.4	263	Coral limestone	
>22.4	5	Deeply weathered lst	Aquifer, brackish
SITE 9, VES 2			
0 - 0.6	100	Sandy soil	
0.6 - 1.6	340	Coral breccia	
1.6 - 4.4	111	Lagoonal sands	
4.4 - 17.0	922	Coral limestone	
>17.0	11	Deeply weathered lst	Aquifer, fresh
SITE 9, VES 3			
0 - 0.5	271	Sandy soil	
0.5 - 1.9	597	Coral breccia	
1.9 - 6.4	517	Lagoonal sands	
6.4 - 28.3	640	Coral limestone	
>28.3	13	Deeply weathered lst	Aquifer, fresh
SITE 10 VES, 1			
0 - 0.6	65	Sandy soil	
0.6 - 3.0	180	Coral breccia	
3.0 - 16.1	77	Lagoonal sands	
16.1 - 41.6	146	Coral limestone	
>41.6	36	Deeply weathered lst	Aquifer, fresh
SITE 10, VES 2			
0 - 0.7	68	Sandy soil	
0.7 - 2.9	185	Coral breccia	
2.9 - 16.7	77	Lagoonal sands	
16.7 - 37.6	160	Coral limestone	
>37.6	41	Weathered lst	Aquifer, fresh
SITE 10, VES 3			

0 - 1.5	45	Sands	
1.5 - 4.0	96	Coral breccia	
4.0 - 11.6	30	Lagoonal sands	
11.6 - 32.7	53	Coral limestone	
>32.7	17	Deeply weathered lst	Aquifer, fresh

4 CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

The study was designed to investigate occurrence of brackish groundwater aquifers beneath Vipingo Development site. Through application of structural studies, horizontal electrical resistivity profiles and vertical electrical sounding, at least 15 suitable drilling sites have been located, of which 10 are recommended for immediate development. Although the project aim is location of brackish water, some of the sites show presence of a lens o fresh water. The ultimate drilling depth will therefore have to be monitored so as to limit the level of brackishness.

The investigations show that the groundwater aquifer occurs in the coral limestone below the coral breccia and varies in depth between 20 and 40 meters below ground level, depending on the elevation above mean sea level.

Expansive use of brackish water is within the Vipingo area aquifer is uncharted territory, and, just like with other ground-breaking work, there is need for monitoring program with the establishment of the wells. This will endure that there is adequate information to study the impact of withdrawing brackish water on the whole aquifer system, especially the movement of the freshwater lens.

4.2 Recommendations

Drilling is recommended at the following tabulated locations, to the recommended depths.

SITE ID	VES No.	Depth, m	Easting, m	Northing, m
BH 1	VES 1	40	591640	9585083
BH 2	VES	50	591715,	9586754
BH 3	VES 1	50	592169	9585339
BH 4	VES 1	60	591792	9587499
BH 5	VES 2	60	591686	9586493
BH 6	VES 1	60	592208	9586108
BH 7	VES 2	45	593295	9588955
BH 8	VES 1	60	591945	9589109
BH 9	VES 1	55	592559	9586397
BH 10	VES 3	50	591879	9587247

The following minimum specifications will apply to the borehole site development:

1. Depth: the borehole shall be drilled to the recommended depth, subject to monitoring with an EC meter during drilling to determine the suitable depth to stop drilling.
2. Diameter: the boreholes shall be drilled at the open-hole diameter of 10 ¼" and installed with 168mm PVC casing and screens.
3. Drilling method: direct rotary fluid assisted air-flush drilling is recommended; however, the driller may propose other effective method to achieve the desired depth.
4. Each borehole shall be tested at a constant rate for 24 hrs and recovery measurements taken to at least 90% of full recovery, unless otherwise stopped by the supervisor.
5. A permanent dipper tube in the borehole and a master meter shall be fitted in each well for abstraction monitoring.

Figure 8. Selected drilling sites shown on layout plan

5 REFERENCES

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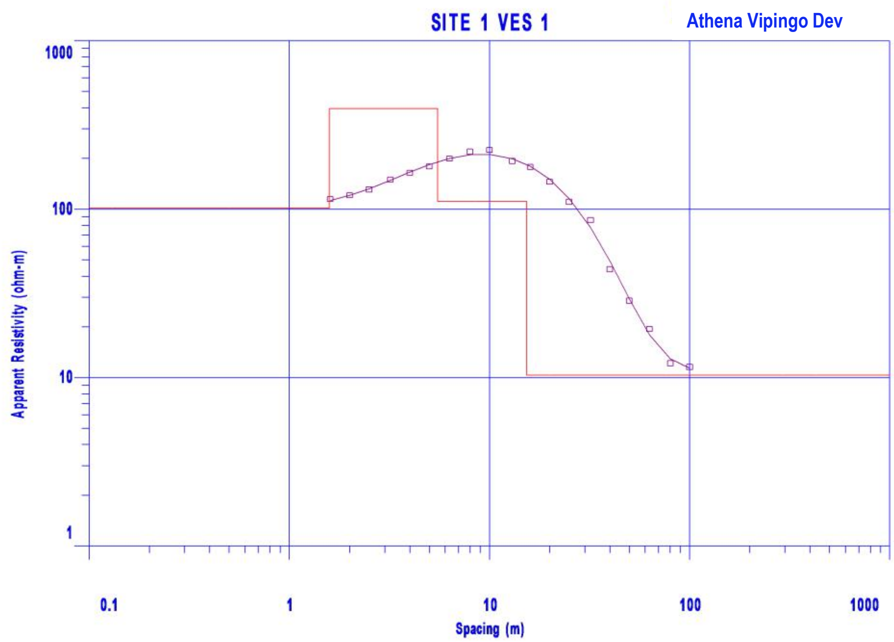
Westermann G.E.G. (1975). Bajocian Ammonoid Fauna of Tethyan affinities from the Kambe Limestone Series of Kenya and implication to plate tectonics. Newsletter Stratigr., 4: 23-48, Berlin*

Chiocchini, M., Fazzuoli, M. and Reale, V. (2005). The mid-Jurassic marine transgression in East Africa: New data on the depositional environment and age of the Lower Kambe Formation (Aalenian to Bajocian) In the Mombasa area (S.E Kenya).

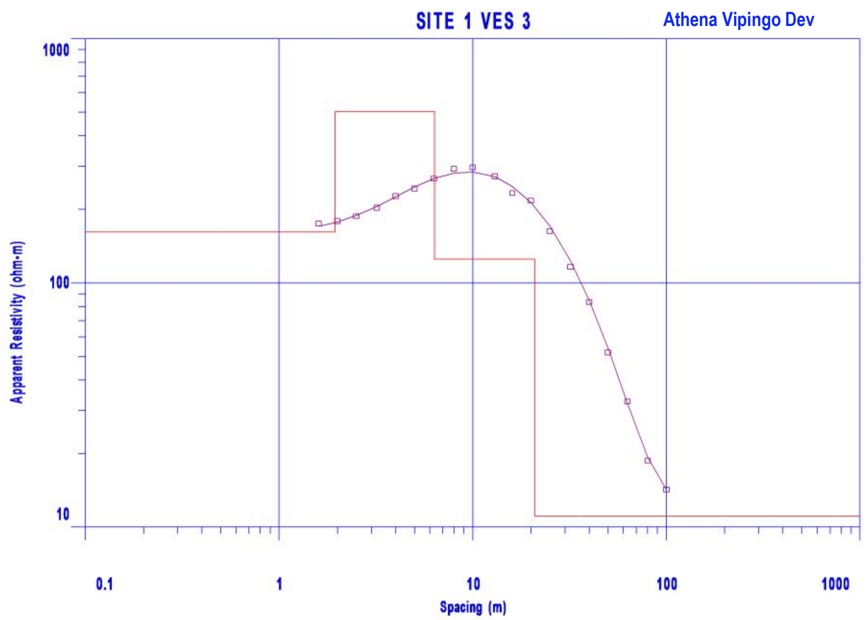
APPENDIX 1: MODELLED VES DATA



MODEL

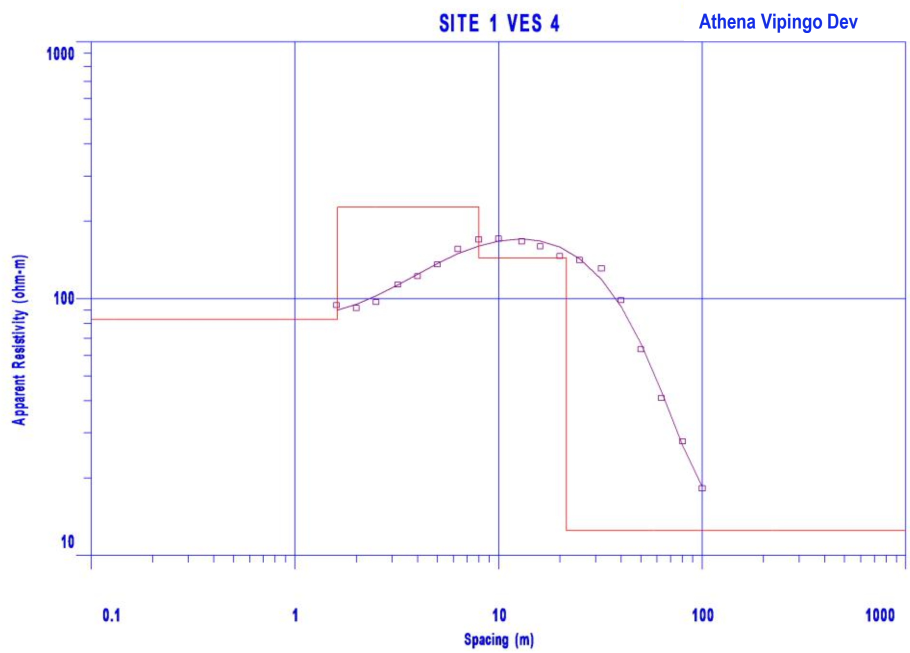
AB/2 (m)	MN (m)	App. Resistivity (ohm-m)
1.6	0.5	115.00
2	0.5	121.00
2.5	0.5	131.00
3.2	0.5	150.00
4	0.5	164.30
5	0.5	179.10
6.3	0.5	199.40
8	0.5	219.40
10	0.5	224.40
13	0.5	193.00
16	0.5	178.00
20	0.5	145.30
25	0.5	110.40
32	0.5	86.30
40	10	44.01
50	10	28.60
63	10	19.47
80	10	12.17
100	10	11.56

Calc. Res (ohm-m)	Depth (m)
101	1.6
395	5.5
111	15.3
10	>10.3



MODEL

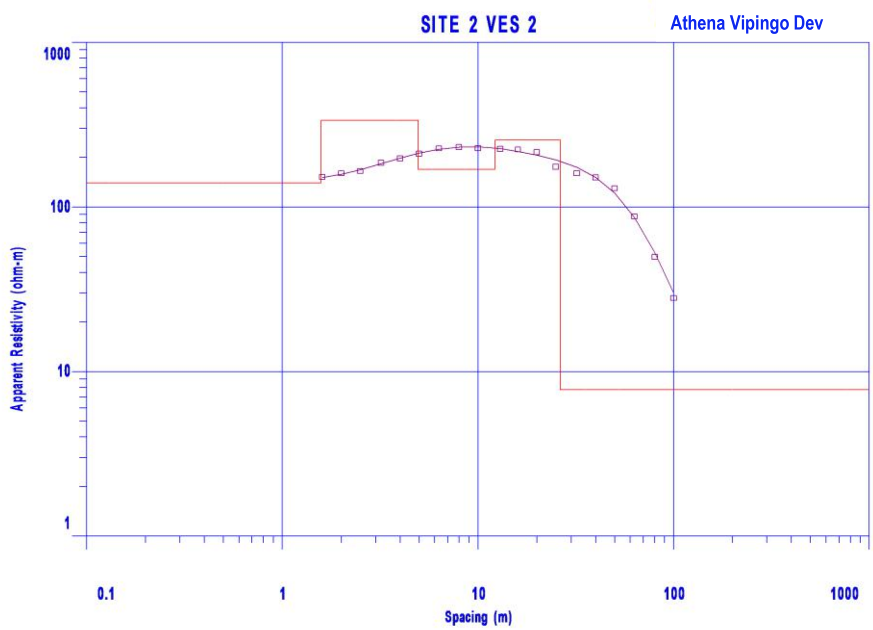
AB/2 (m)	MN (m)	App. Resistivity (ohm-m)		Calc. Res (ohm-m)	Depth (m)
1.6	0.5	175.00		161	1.9
2	0.5	179.00		504	6.4
2.5	0.5	187.40		125	20.9
3.2	0.5	203.00		11	>20.9
4	0.5	226.30			
5	0.5	243.10			
6.3	0.5	267.00			
8	0.5	293.00			
10	0.5	297.00			
13	0.5	273.20			
16	0.5	233.10			
20	0.5	217.10			
25	0.5	163.00			
32	0.5	116.30			
40	10	83.43			
50	10	51.89			
63	10	32.66			
80	10	18.72			
100	10	14.24			



MODEL

AB/2 (m)	MN (m)	App. Resistivity (ohm-m)
1.6	0.5	94.40
2	0.5	92.00
2.5	0.5	97.00
3.2	0.5	113.40
	0.5	122.30
5	0.5	136.00
6.3	0.5	156.10
8	0.5	170.00
10	0.5	171.20
13	0.5	167.00
16	0.5	160.00
20	0.5	146.60
25	0.5	141.40
32	0.5	131.10
40	10	94.40
50	10	63.50
63	10	41.04
80	10	27.82
100	10	18.24

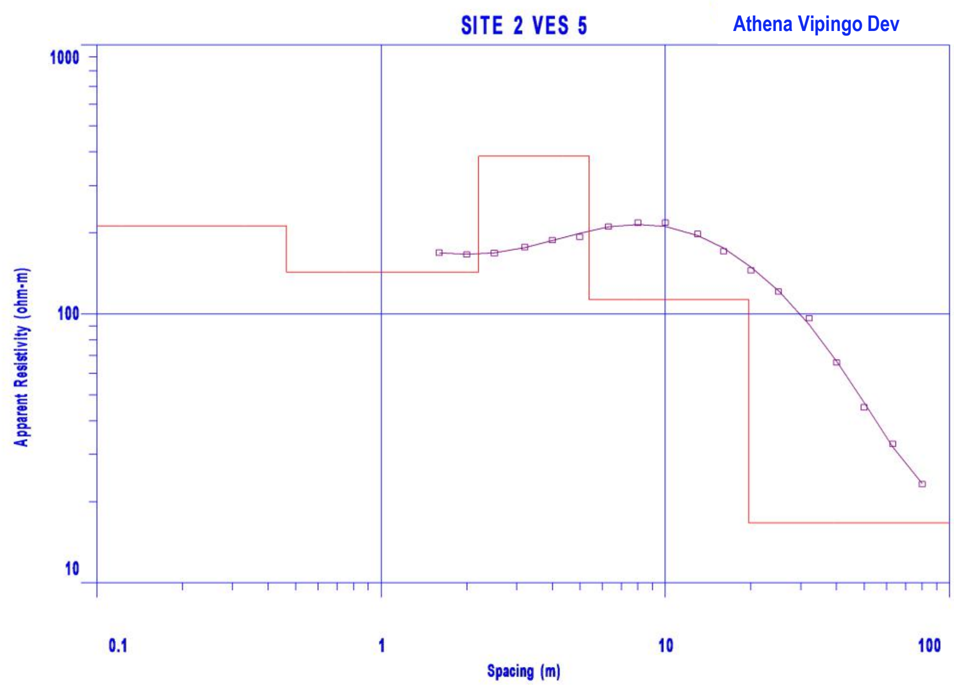
Calc. Res (ohm-m)	Depth (m)
83	1.6
227	8.0
144	21.5
13	>21.5



MODEL

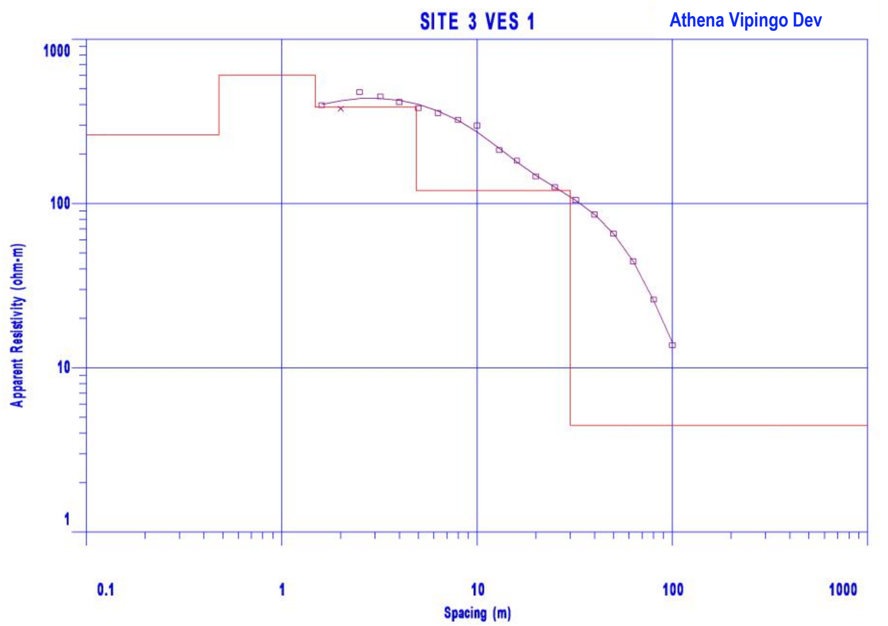
AB/2 (m)	MN (m)	App. Resistivity (ohm-m)
1.6	0.5	105.30
2	0.5	123.00
2.5	0.5	138.00
3.2	0.5	165.00
	0.5	193.10
5	0.5	207.00
6.3	0.5	218.00
8	0.5	216.00
10	0.5	193.40
13	0.5	165.22
16	0.5	134.15
20	0.5	110.39
25	0.5	82.48
32	0.5	77.20
40	10	88.89
50	10	81.75
63	10	59.82
80	10	71.64
100	10	88.37
130	10	129.50
160	10	145.62
200	10	168.20
250	10	239.49

Calc. Res (ohm-m)	Depth (m)
140	1.6
335	4.9
169	12.2
254	26.4
8	>26.4



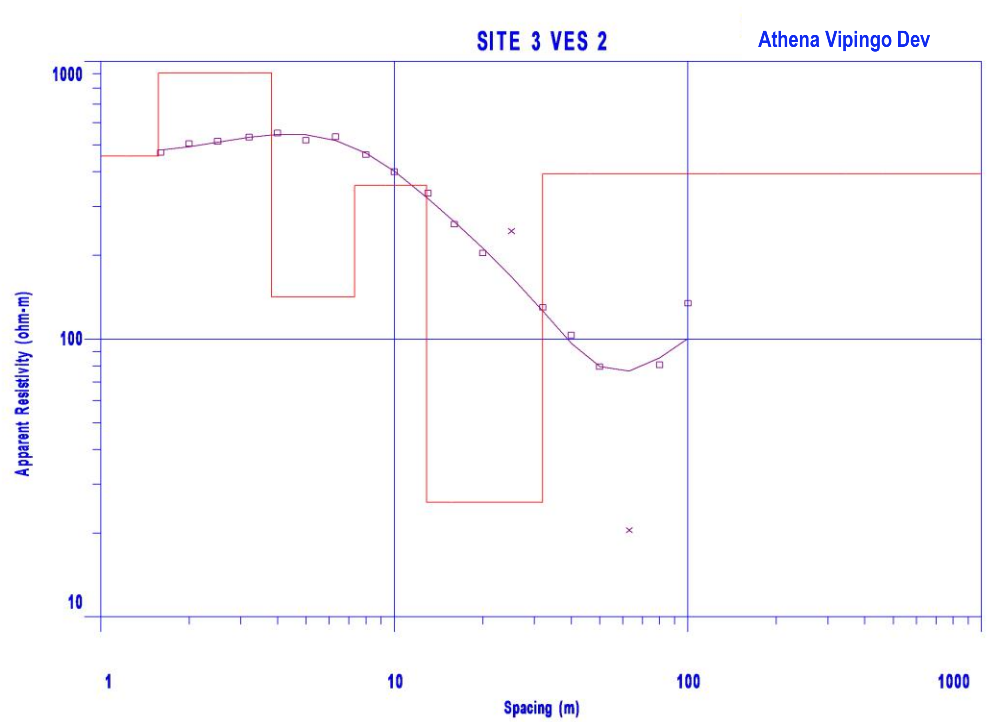
MODEL

AB/2 (m)	MN (m)	App. Resistivity (ohm-m)		Calc. Res (ohm-m)	Depth (m)
1.6	0.5	169.00		212	0.5
2	0.5	166.40		143	2.2
2.5	0.5	168.30		386	5.4
3.2	0.5	177.20		113	19.7
	0.5	188.00		17	19.7
5	0.5	193.20			>19.7
6.3	0.5	211.30			
8	0.5	218.20			
10	0.5	218.60			
13	0.5	198.10			
16	0.5	171.00			
20	0.5	145.20			
25	0.5	121.00			
32	0.5	96.30			
40	10	66.01			
50	10	44.92			
63	10	32.87			
80	10	23.28			



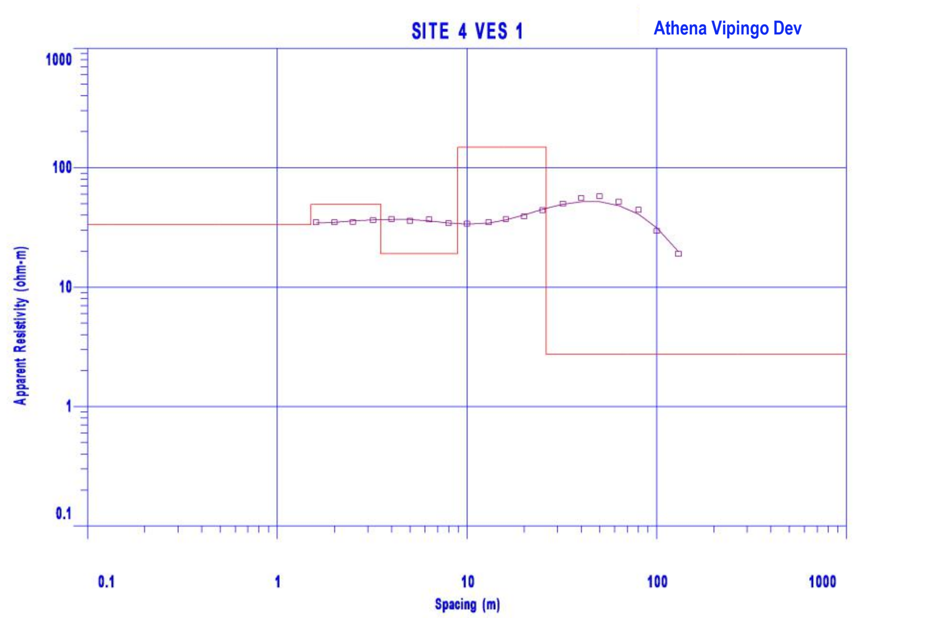
MODEL

AB/2 (m)	MN (m)	App. Resistivity (ohm-m)		Calc. Res (ohm-m)	Depth (m)
1.6	0.5	396.00		262	0.5
2	0.5	377.20		605	1.5
2.5	0.5	477.00		386	4.9
3.2	0.5	448.00		120	30.0
	0.5	414.00		5	>30.0
5	0.5	380.00			
6.3	0.5	355.00			
8	0.5	323.00			
10	0.5	298.00			
13	0.5	211.00			
16	0.5	182.00			
20	0.5	146.00			
25	0.5	126.00			
32	0.5	105.00			
40	10	85.48			
50	10	65.54			
63	10	44.45			
80	10	26.07			
100	10	13.75			



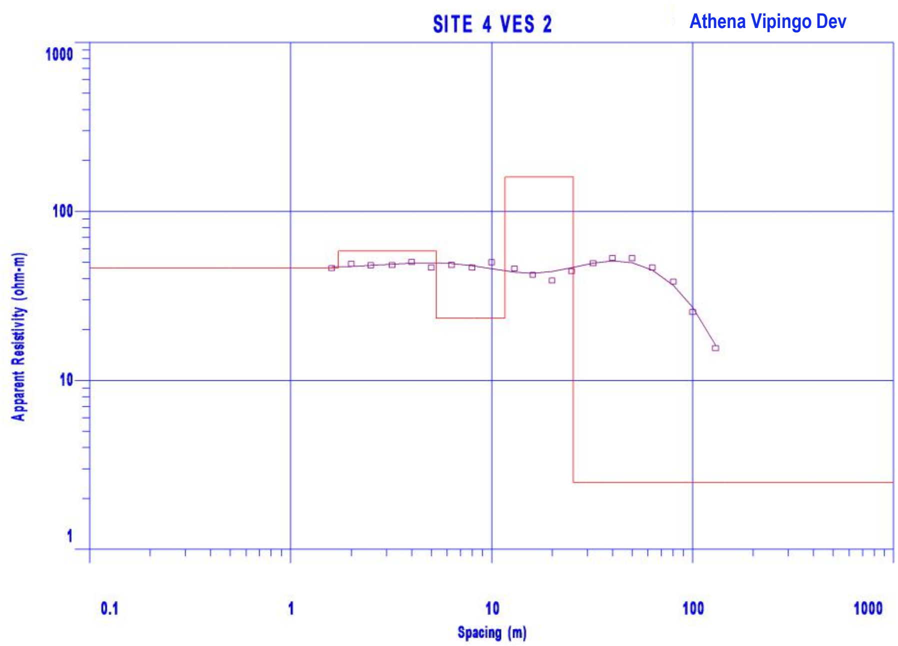
MODEL

AB/2 (m)	MN (m)	App. Resistivity (ohm-m)		Calc. Res (ohm-m)	Depth (m)
1.6	0.5	469.00		456	1.6
2	0.5	506.00		907	3.8
2.5	0.5	515.00		142	7.3
3.2	0.5	533.20		358	12.9
	0.5	552.00		26	32.0
5	0.5	519.40		393	>32.0
6.3	0.5	535.00			
8	0.5	461.20			
10	0.5	400.00			
13	0.5	335.00			
16	0.5	259.00			
20	0.5	204.00			
25	0.5	245.10			
32	0.5	130.00			
40	10	103.25			
50	10	79.65			
63	10	20.51			
80	10	80.78			
100	10	134.51			



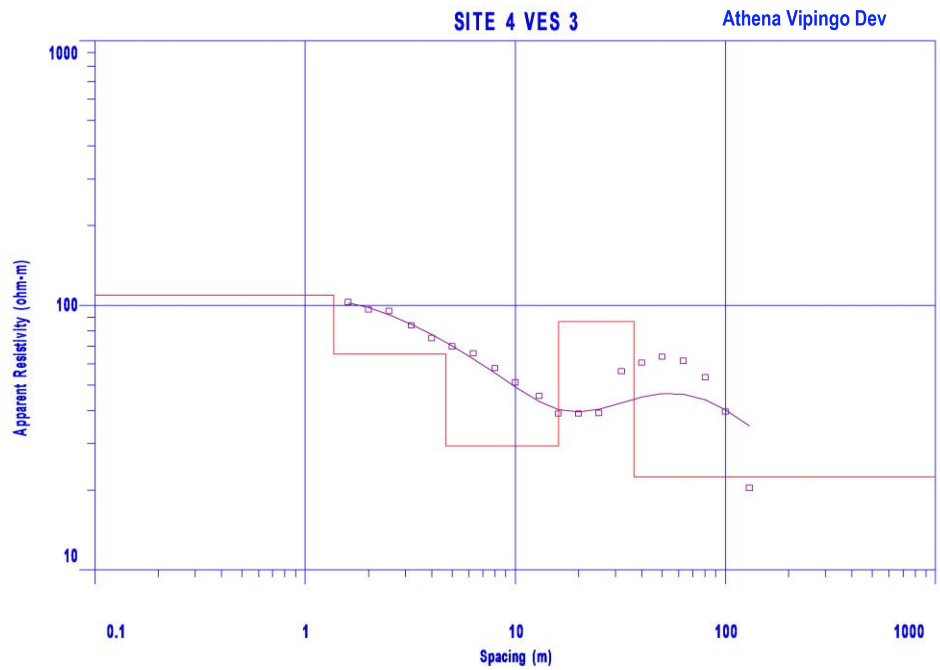
MODEL

AB/2 (m)	MN (m)	App. Resistivity (ohm-m)	Calc. Res (ohm-m)	Depth (m)
1.6	0.5	105.30	33	1.5
2	0.5	123.00	50	3.5
2.5	0.5	138.00	19	8.9
3.2	0.5	165.00	149	26.1
	0.5	193.10	3	>26.1
5	0.5	207.00		
6.3	0.5	218.00		
8	0.5	216.00		
10	0.5	193.40		
13	0.5	165.22		
16	0.5	134.15		
20	0.5	110.39		
25	0.5	82.48		
32	0.5	77.20		
40	10	88.89		
50	10	81.75		
63	10	59.82		
80	10	71.64		
100	10	88.37		
130	10	129.50		
160	10	145.62		
200	10	168.20		
250	10	239.49		



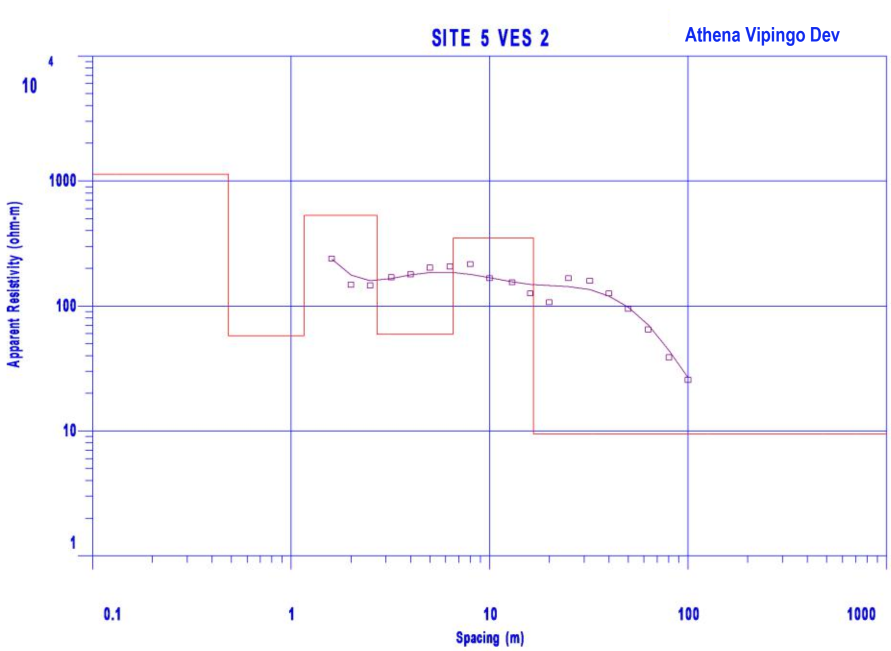
MODEL

AB/2 (m)	MN (m)	App. Resistivity (ohm-m)	Calc. Res (ohm-m)	Depth (m)
1.6	0.5	46.20	46	1.7
2	0.5	49.00	58	5.3
2.5	0.5	48.00	23	11.6
3.2	0.5	48.10	160	25.5
	0.5	50.30	3	>25.5
5	0.5	46.60		
6.3	0.5	48.30		
8	0.5	46.60		
10	0.5	50.00		
13	0.5	46.00		
16	0.5	42.10		
20	0.5	39.00		
25	0.5	44.30		
32	0.5	49.40		
40	10	53.10		
50	10	52.95		
63	10	46.57		
80	10	38.45		
100	10	25.39		
130	10	15.52		



MODEL

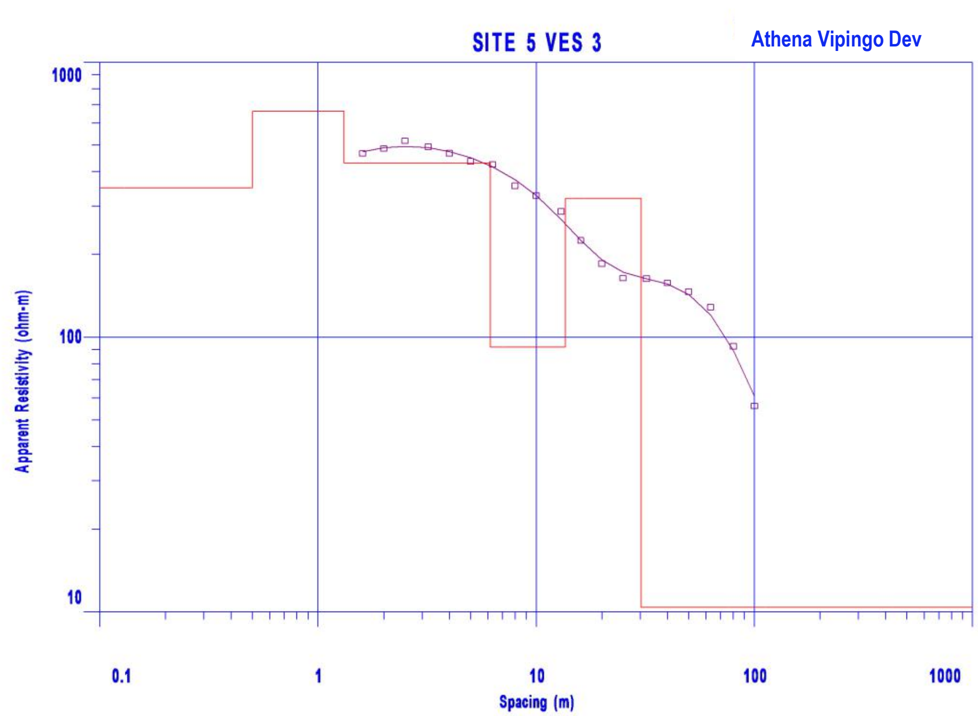
AB/2 (m)	MN (m)	App. Resistivity (ohm-m)		Calc. Res (ohm-m)	Depth (m)
1.6	0.5	103.00		109	1.34
2	0.5	96.40		656	4.7
2.5	0.5	95.20		29	16.1
3.2	0.5	84.00		87	36.7
	0.5	75.20		23	>36.7
5	0.5	70.00			
6.3	0.5	66.00			
8	0.5	58.00			
10	0.5	51.20			
13	0.5	45.40			
16	0.5	39.00			
20	0.5	39.00			
25	0.5	39.20			
32	0.5	56.40			
40	10	60.78			
50	10	63.94			
63	10	61.75			
80	10	53.48			
100	10	39.63			
130	10	20.42			



MODEL

AB/2 (m)	MN (m)	App. Resistivity (ohm-m)	
1.6	0.5	239.40	
2	0.5	148.00	
2.5	0.5	146.10	
3.2	0.5	170.00	
	0.5	179.40	
5	0.5	203.00	
6.3	0.5	207.00	
8	0.5	216.10	
10	0.5	167.00	
13	0.5	155.00	
16	0.5	126.20	
20	0.5	107.30	
25	0.5	167.00	
32	0.5	159.20	
40	10	126.19	
50	10	94.59	
63	10	64.82	
80	10	38.85	
100	10	25.62	

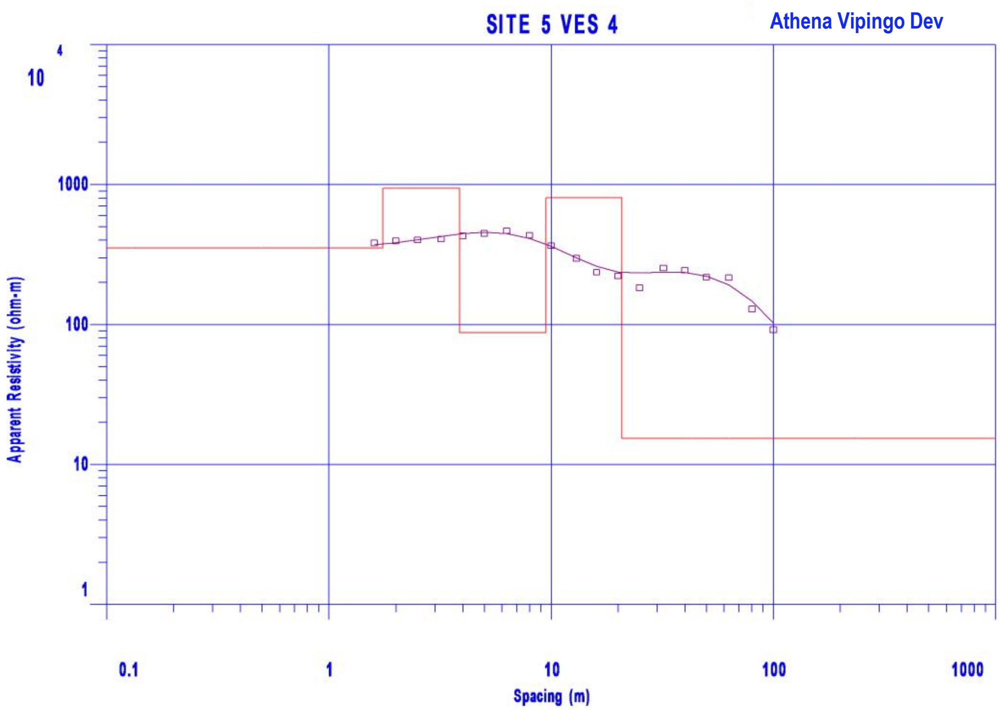
Calc. Res (ohm-m)	Depth (m)
1135	0.5
58	1.2
5289	2.7
59	6.5
350	16.7
10	>16.7



AB/2 (m)	MN (m)	App. Resistivity (ohm-m)
1.6	0.5	466.00
2	0.5	485.00
2.5	0.5	518.00
3.2	0.5	493.20
	0.5	466.30
5	0.5	436.00
6.3	0.5	425.00
8	0.5	355.00
10	0.5	327.10
13	0.5	286.30
16	0.5	225.00
20	0.5	185.10
25	0.5	164.00
32	0.5	163.10
40	10	157.48
50	10	146.23
63	10	128.57
80	10	92.69
100	10	56.24

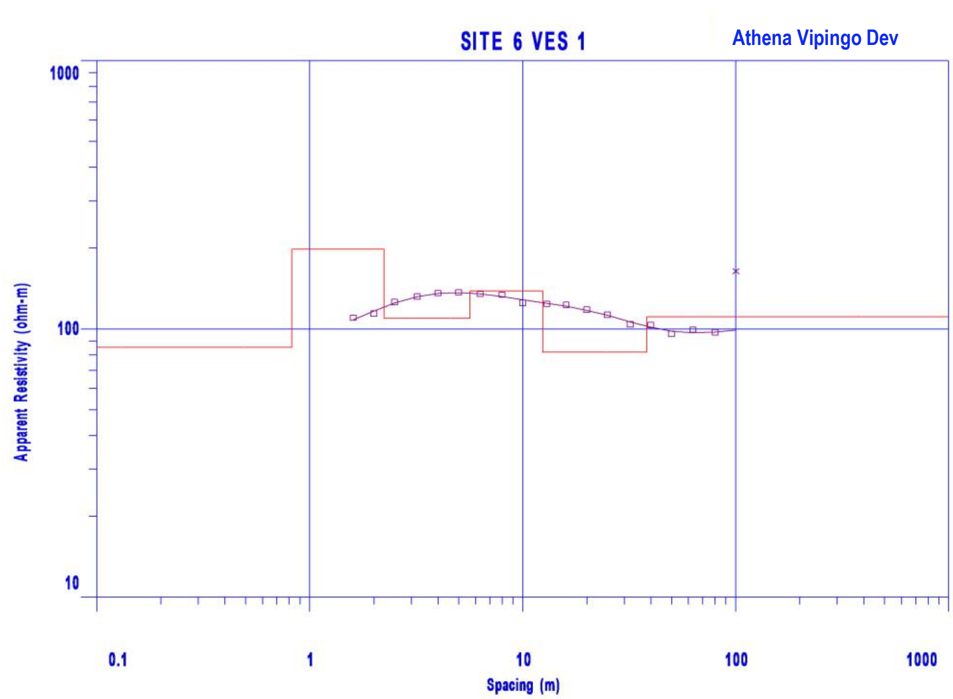
MODEL

Calc. Res (ohm-m)	Depth (m)
349	0.5
664	1.3
430	6.2
92	13.6
319	30.3
10	>30.3



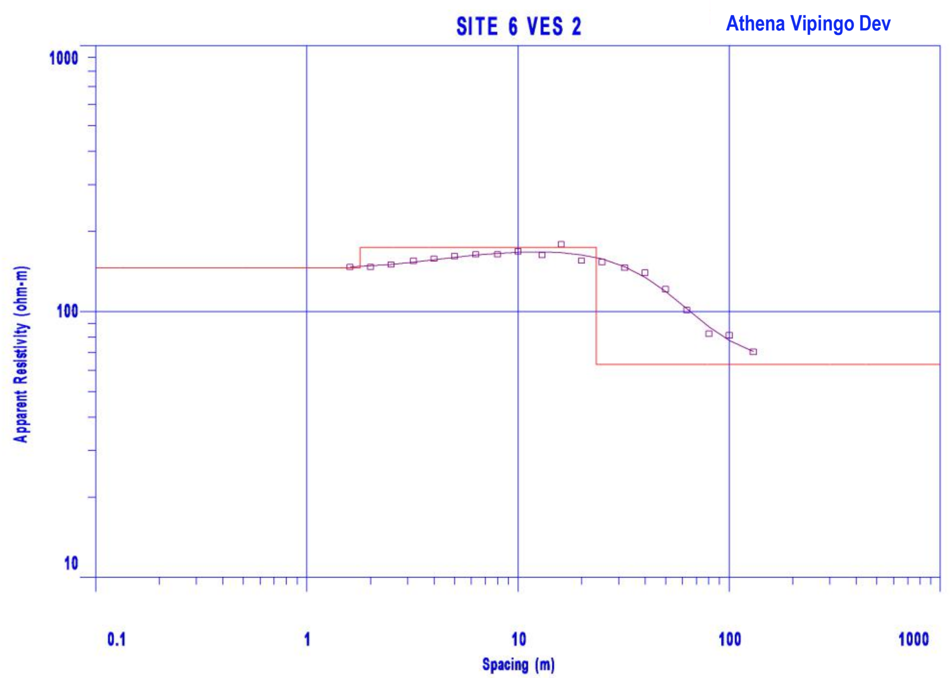
MODEL

AB/2 (m)	MN (m)	App. Resistivity (ohm-m)		Calc. Res (ohm-m)	Depth (m)
1.6	0.5	382.10		353	1.8
2	0.5	396.00		939	3.9
2.5	0.5	402.30		88	9.5
3.2	0.5	407.50		803	20.8
	0.5	429.40		15	>20.8
5	0.5	447.00			
6.3	0.5	468.00			
8	0.5	434.00			
10	0.5	365.40			
13	0.5	297.20			
16	0.5	236.00			
20	0.5	222.00			
25	0.5	183.10			
32	0.5	253.00			
40	10	244.15			
50	10	218.15			
63	10	216.20			
80	10	129.15			
100	10	92.00			



MODEL

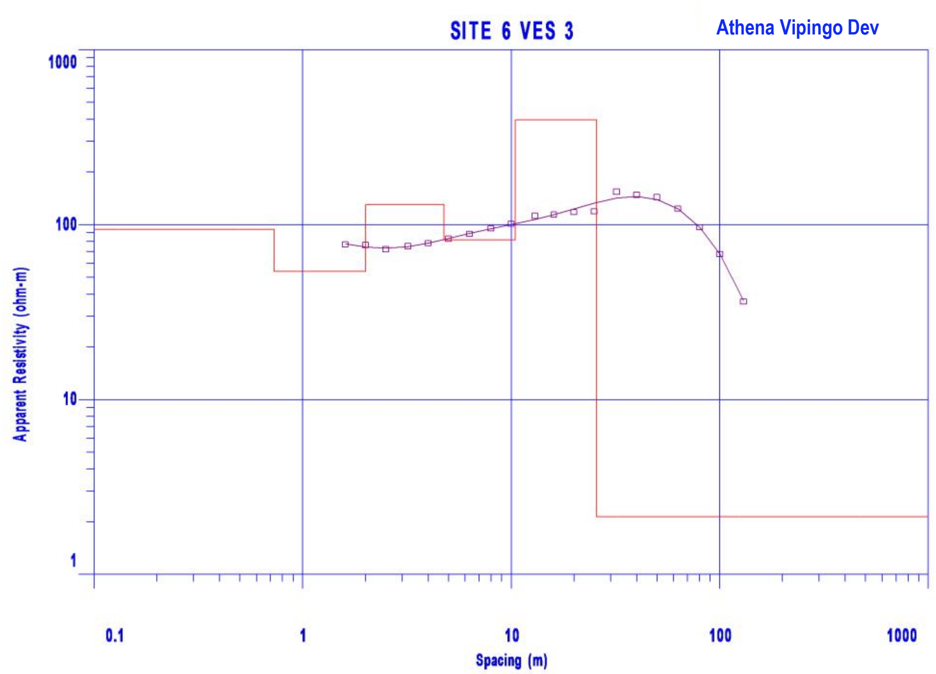
AB/2 (m)	MN (m)	App. Resistivity (ohm-m)		Calc. Res (ohm-m)	Depth (m)
1.6	0.5	110.10		85	0.8
2	0.5	114.10		198	2.2
2.5	0.5	126.00		110	5.67
3.2	0.5	132.00		139	12.4
	0.5	136.00		82	38.2
5	0.5	137.00		111	>38.2
6.3	0.5	135.00			
8	0.5	134.20			
10	0.5	125.10			
13	0.5	124.00			
16	0.5	123.00			
20	0.5	118.00			
25	0.5	113.00			
32	0.5	104.00			
40	10	103.24			
50	10	95.82			
63	10	99.41			
80	10	97.19			
100	10	164.41			



AB/2 (m)	MN (m)	App. Resistivity (ohm-m)
1.6	0.5	147.00
2	0.5	147.00
2.5	0.5	150.10
3.2	0.5	155.00
	0.5	158.10
5	0.5	161.40
6.3	0.5	164.00
8	0.5	164.10
10	0.5	168.20
13	0.5	163.00
16	0.5	179.00
20	0.5	155.40
25	0.5	153.40
32	0.5	146.00
40	10	140.04
50	10	121.37
63	10	101.31
80	10	82.44
100	10	81.44
130	10	70.52

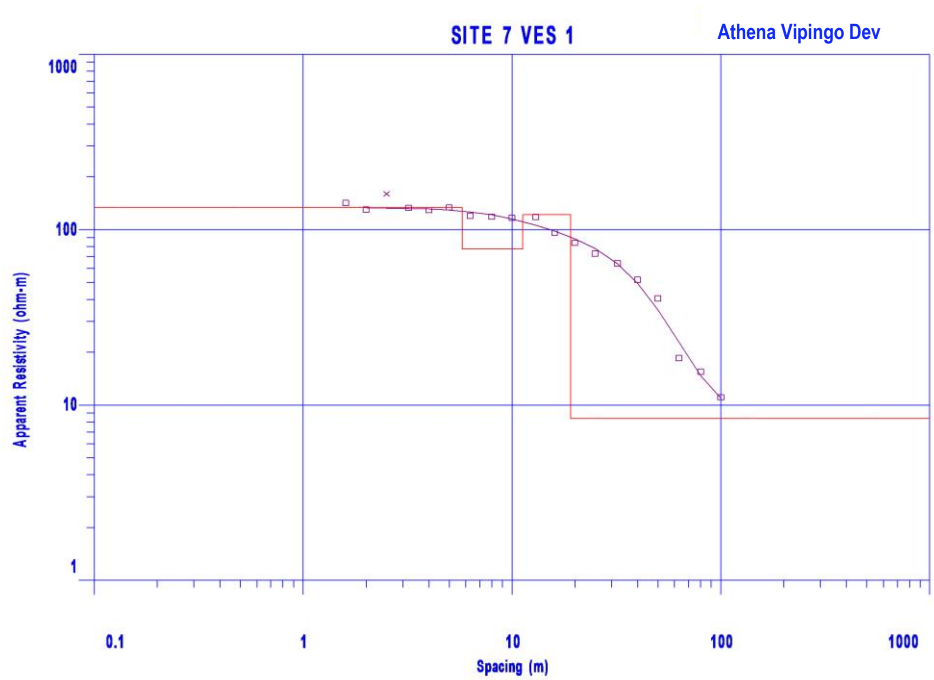
MODEL

Calc. Res (ohm-m)	Depth (m)
146	1.8
174	23.5
63	>23.5



MODEL

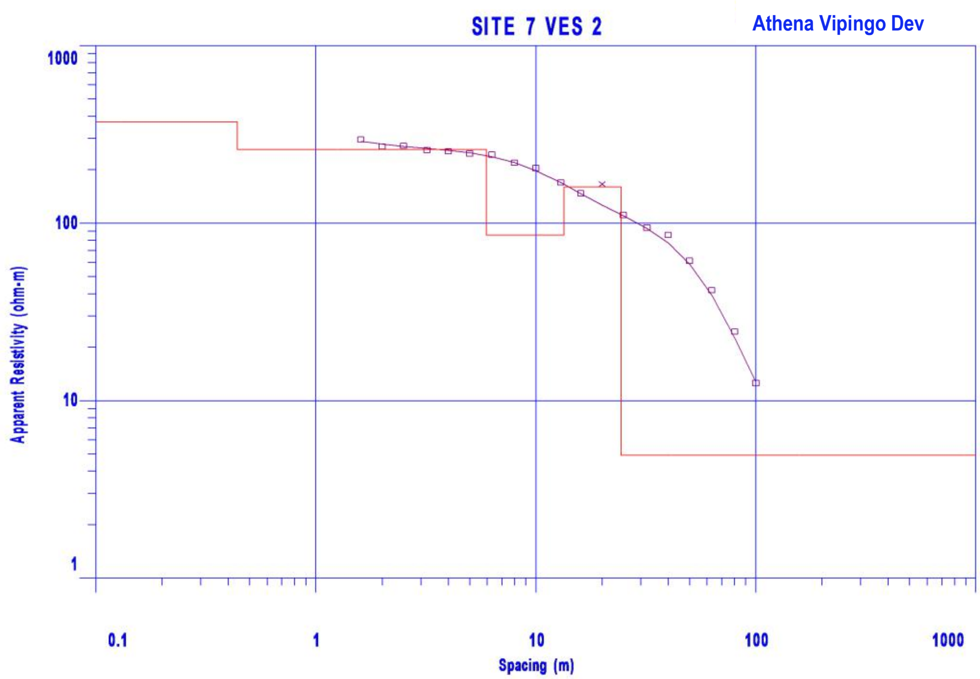
AB/2 (m)	MN (m)	App. Resistivity (ohm-m)		Calc. Res (ohm-m)	Depth (m)
1.6	0.5	105.30		94	0.7
2	0.5	123.00		54	2.0
2.5	0.5	138.00		130	4.8
3.2	0.5	165.00		82	10.5
	0.5	193.10		398	25.8
5	0.5	207.00		2	>25.8
6.3	0.5	218.00			
8	0.5	216.00			
10	0.5	193.40			
13	0.5	165.22			
16	0.5	134.15			
20	0.5	110.39			
25	0.5	82.48			
32	0.5	77.20			
40	10	88.89			
50	10	81.75			
63	10	59.82			
80	10	71.64			
100	10	88.37			
130	10	129.50			
160	10	145.62			
200	10	168.20			
250	10	239.49			



MODEL

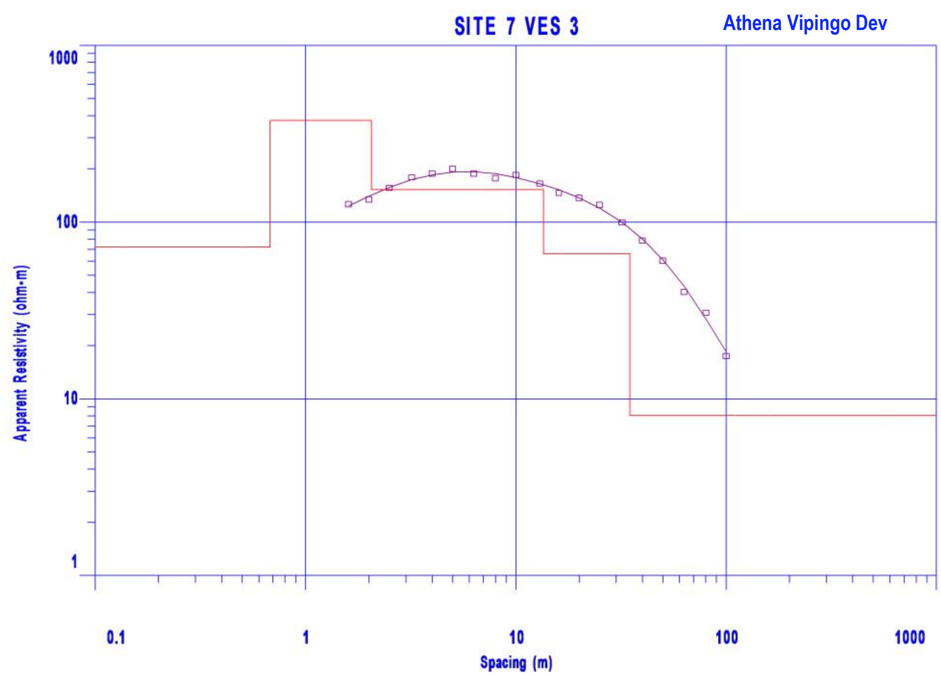
AB/2 (m)	MN (m)	App. Resistivity (ohm-m)
1.6	0.5	296.10
2	0.5	270.00
2.5	0.5	272.40
3.2	0.5	258.00
	0.5	254.00
5	0.5	247.00
6.3	0.5	243.00
8	0.5	219.00
10	0.5	204.20
13	0.5	169.40
16	0.5	147.20
20	0.5	166.20
25	0.5	111.00
32	0.5	94.40
40	10	85.82
50	10	61.30
63	10	41.89
80	10	24.52
100	10	12.57

Calc. Res (ohm-m)	Depth (m)
372	0.4
260	6.0
85	13.4
160	24.4
5	>24.4



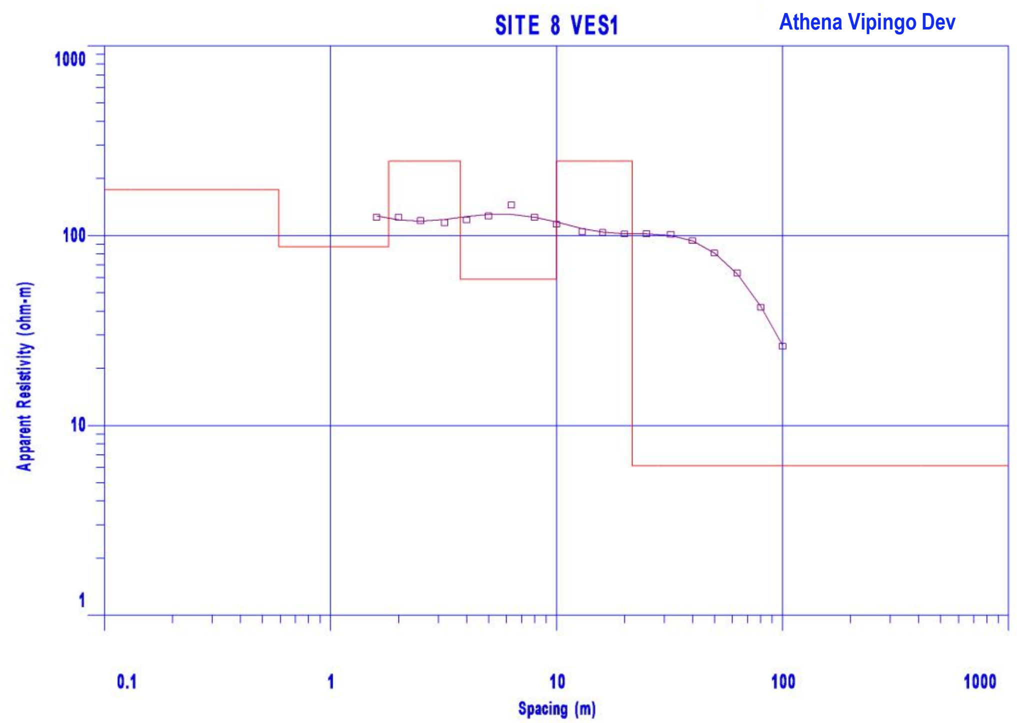
MODEL

AB/2 (m)	MN (m)	App. Resistivity (ohm-m)	Calc. Res (ohm-m)	Depth (m)
1.6	0.5	296.10	372	0.4
2	0.5	270.00	260	6.0
2.5	0.5	272.40	85	13.4
3.2	0.5	258.00	160	24.4
	0.5	254.00	5	>24.4
5	0.5	247.00		
6.3	0.5	243.00		
8	0.5	219.00		
10	0.5	204.20		
13	0.5	169.40		
16	0.5	147.20		
20	0.5	166.20		
25	0.5	111.00		
32	0.5	94.40		
40	10	85.82		
50	10	61.30		
63	10	41.89		
80	10	24.52		
100	10	12.57		



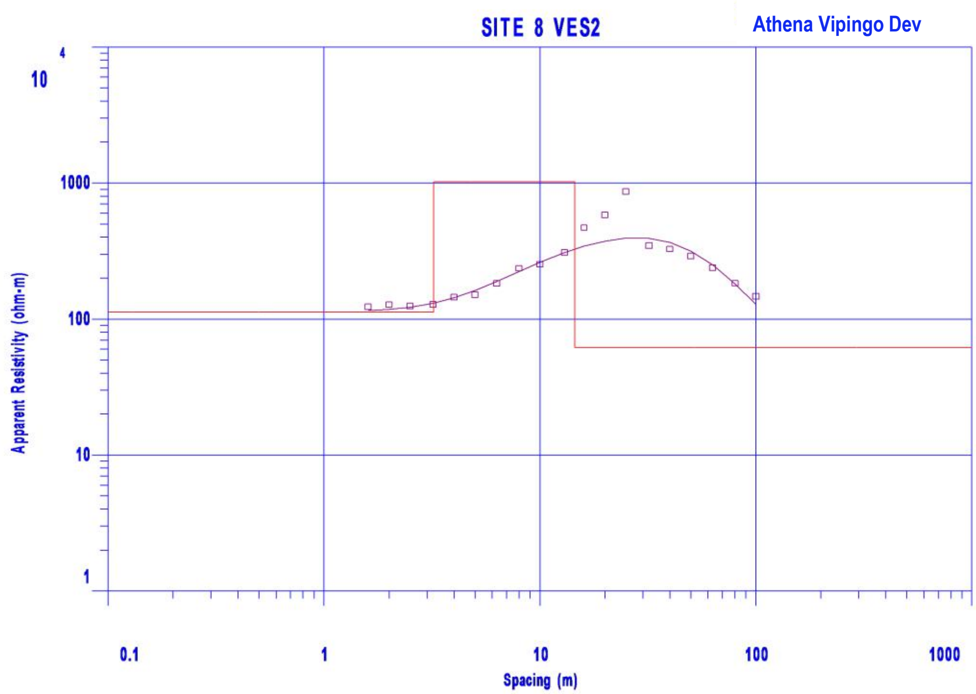
MODEL

AB/2 (m)	MN (m)	App. Resistivity (ohm-m)		Calc. Res (ohm-m)	Depth (m)
1.6	0.5	126.30		72	0.7
2	0.5	134.30		377	2.0
2.5	0.5	156.30		153	13.5
3.2	0.5	179.30		66	34.9
	0.5	188.00		8	>34.9
5	0.5	200.00			
6.3	0.5	188.00			
8	0.5	177.20			
10	0.5	185.00			
13	0.5	165.00			
16	0.5	146.00			
20	0.5	137.20			
25	0.5	125.00			
32	0.5	99.50			
40	10	78.66			
50	10	60.37			
63	10	40.25			
80	10	30.65			
100	10	17.47			



MODEL

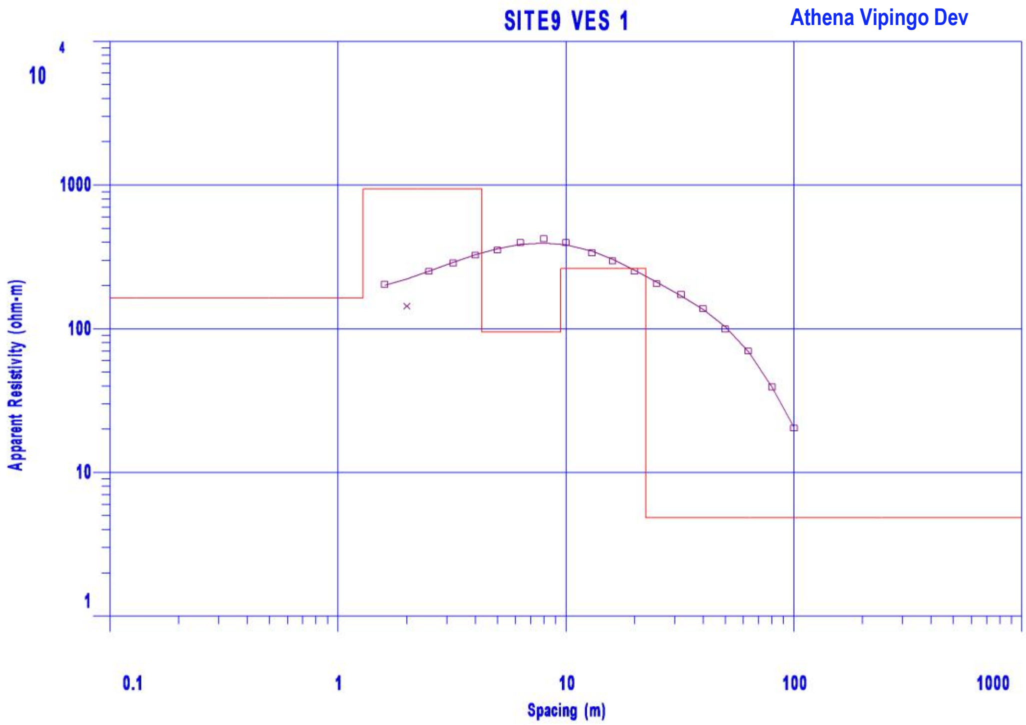
AB/2 (m)	MN (m)	App. Resistivity (ohm-m)		Calc. Res (ohm-m)	Depth (m)
1.6	0.5	105.30		175	0.6
2	0.5	123.00		88	1.8
2.5	0.5	138.00		247	3.8
3.2	0.5	165.00		59	10.0
	0.5	193.10		247	21.6
5	0.5	207.00		6	>21.6
6.3	0.5	218.00			
8	0.5	216.00			
10	0.5	193.40			
13	0.5	165.22			
16	0.5	134.15			
20	0.5	110.39			
25	0.5	82.48			
32	0.5	77.20			
40	10	88.89			
50	10	81.75			
63	10	59.82			
80	10	71.64			
100	10	88.37			
130	10	129.50			
160	10	145.62			
200	10	168.20			
250	10	239.49			



MODEL

AB/2 (m)	MN (m)	App. Resistivity (ohm-m)
1.6	0.5	123.00
2	0.5	128.00
2.5	0.5	125.10
3.2	0.5	128.40
	0.5	145.00
5	0.5	151.00
6.3	0.5	183.10
8	0.5	236.00
10	0.5	253.00
13	0.5	309.00
16	0.5	471.20
20	0.5	584.00
25	0.5	868.00
32	0.5	347.00
40	10	327.99
50	10	291.21
63	10	239.10
80	10	183.92
100	10	147.14

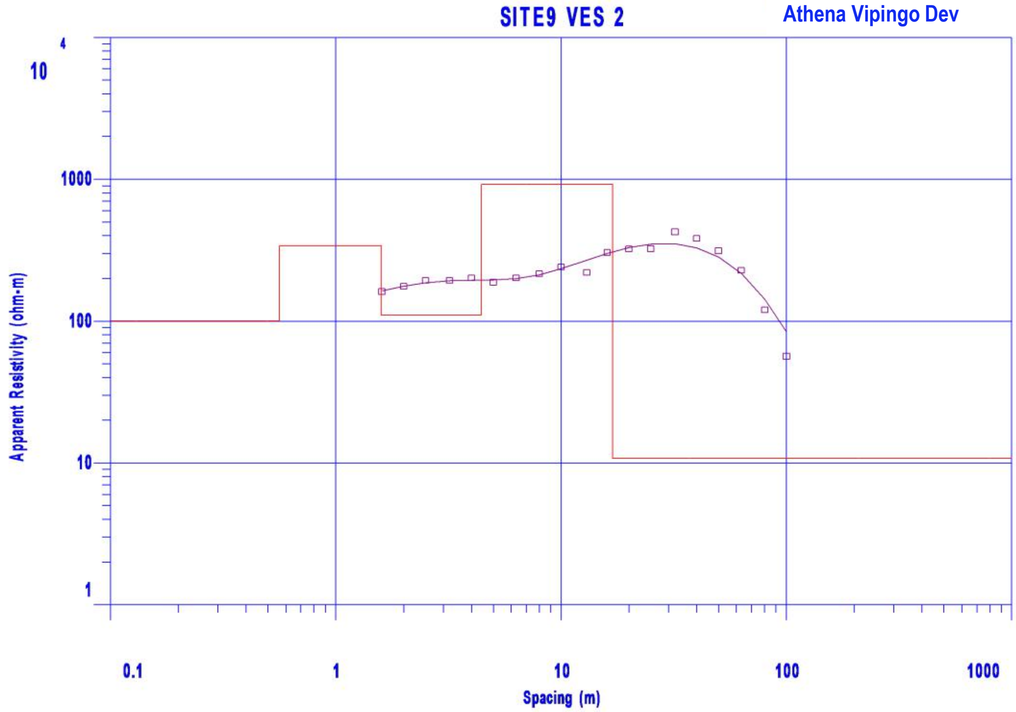
Calc. Res (ohm-m)	Depth (m)
113	3.2
1019	14.5
62	>14.5



MODEL

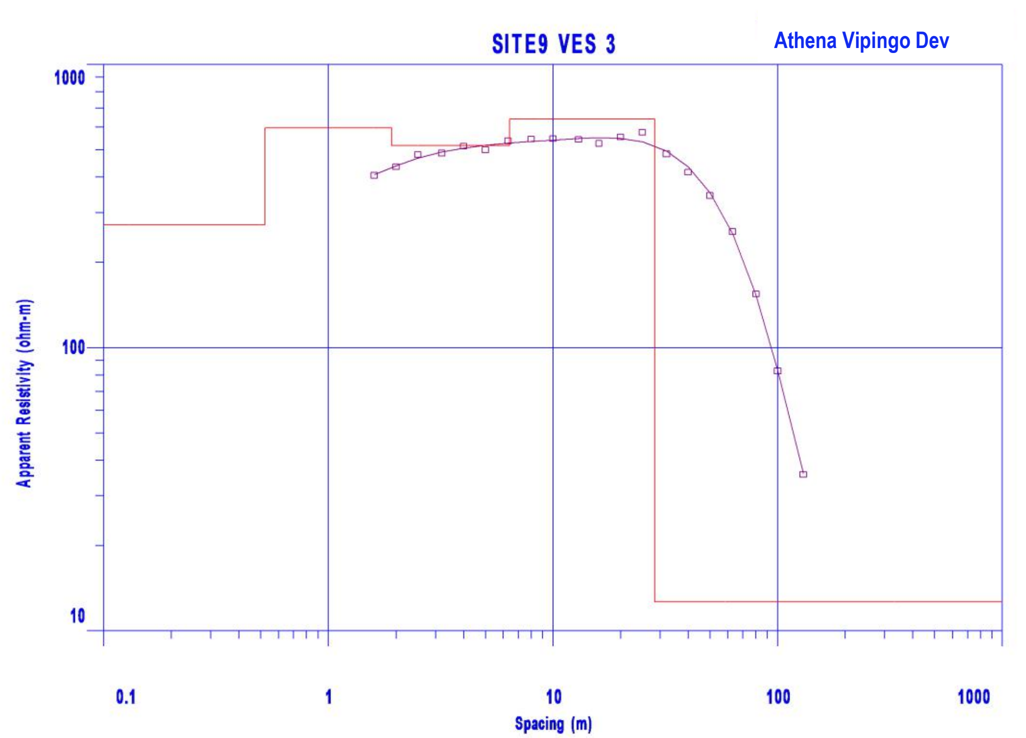
AB/2 (m)	MN (m)	App. Resistivity (ohm-m)
1.6	0.5	105.30
2	0.5	123.00
2.5	0.5	138.00
3.2	0.5	165.00
	0.5	193.10
5	0.5	207.00
6.3	0.5	218.00
8	0.5	216.00
10	0.5	193.40
13	0.5	165.22
16	0.5	134.15
20	0.5	110.39
25	0.5	82.48
32	0.5	77.20
40	10	88.89
50	10	81.75
63	10	59.82
80	10	71.64
100	10	88.37
130	10	129.50
160	10	145.62
200	10	168.20
250	10	239.49

Calc. Res (ohm-m)	Depth (m)
164	1.33
942	4.3
95	9.5
263	22.4
5	>22.4



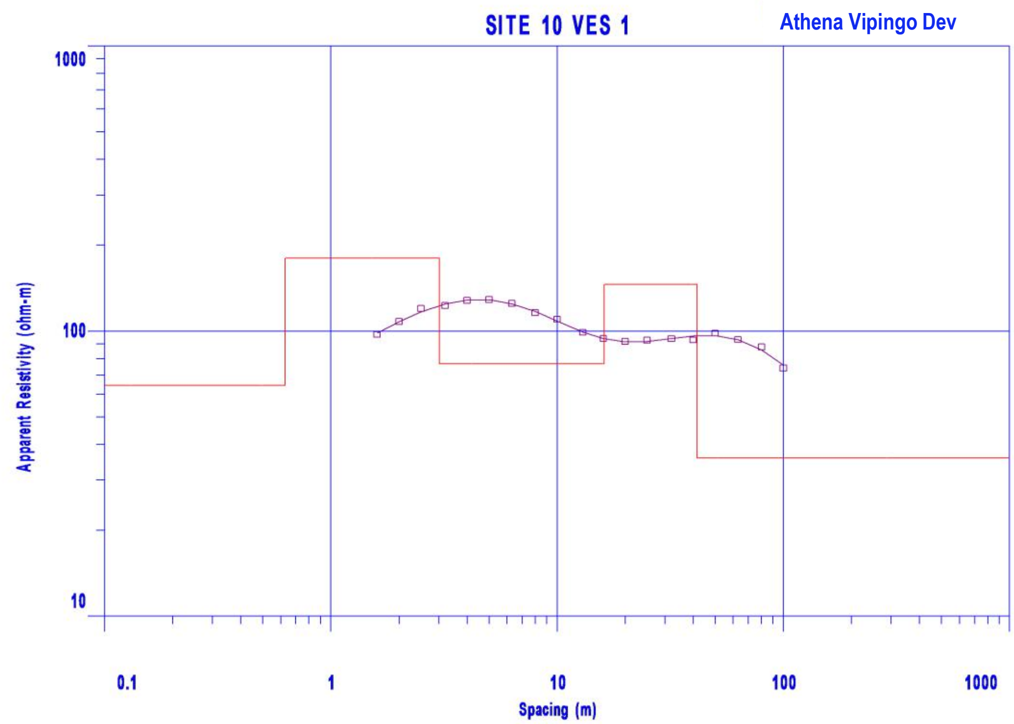
MODEL

AB/2 (m)	MN (m)	App. Resistivity (ohm-m)	Calc. Res (ohm-m)	Depth (m)
1.6	0.5	162.10	100	0.6
2	0.5	176.00	340	1.6
2.5	0.5	194.20	111	4.4
3.2	0.5	194.20	922	17.0
	0.5	202.00	11	>17.0
5	0.5	188.00		
6.3	0.5	202.00		
8	0.5	216.00		
10	0.5	241.00		
13	0.5	221.00		
16	0.5	305.40		
20	0.5	323.00		
25	0.5	324.10		
32	0.5	426.40		
40	10	383.51		
50	10	313.61		
63	10	228.60		
80	10	120.34		
100	10	56.68		



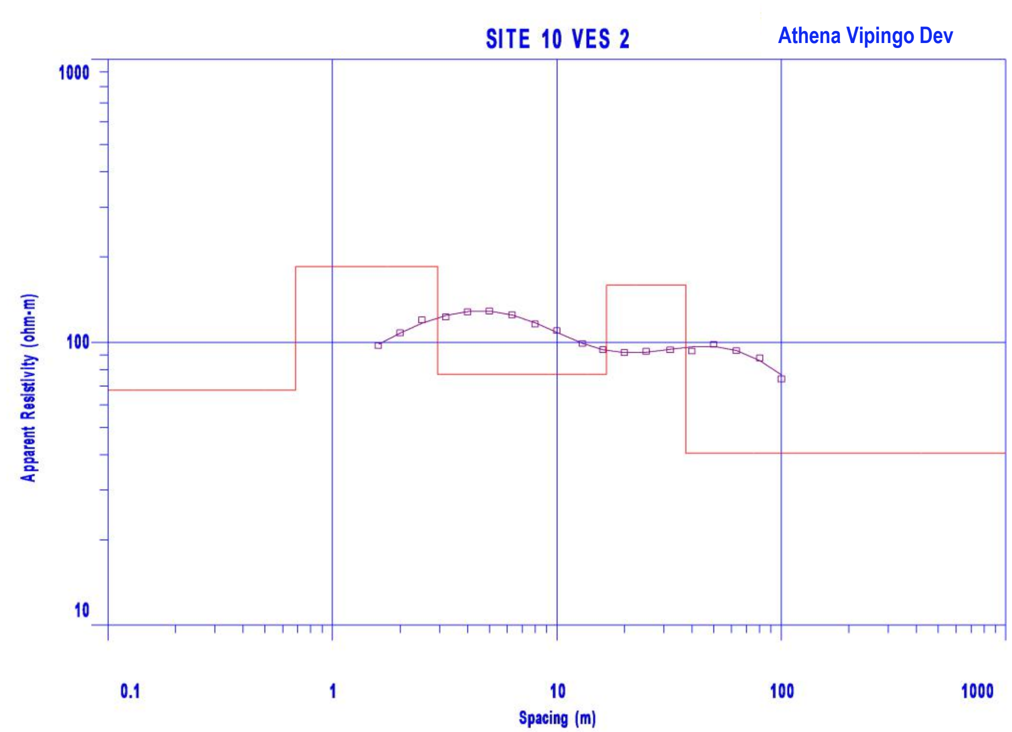
MODEL

AB/2 (m)	MN (m)	App. Resistivity (ohm-m)		Calc. Res (ohm-m)	Depth (m)
1.6	0.5	406.00		271	0.5
2	0.5	435.30		597	1.9
2.5	0.5	480.30		517	6.4
3.2	0.5	486.00		640	28.3
	0.5	514.00		13	>28.3
5	0.5	500.00			
6.3	0.5	537.00			
8	0.5	545.00			
10	0.5	547.00			
13	0.5	543.10			
16	0.5	526.20			
20	0.5	554.30			
25	0.5	576.00			
32	0.5	483.00			
40	10	415.97			
50	10	344.41			
63	10	256.68			
80	10	154.86			
100	10	82.80			
130	10	35.68			



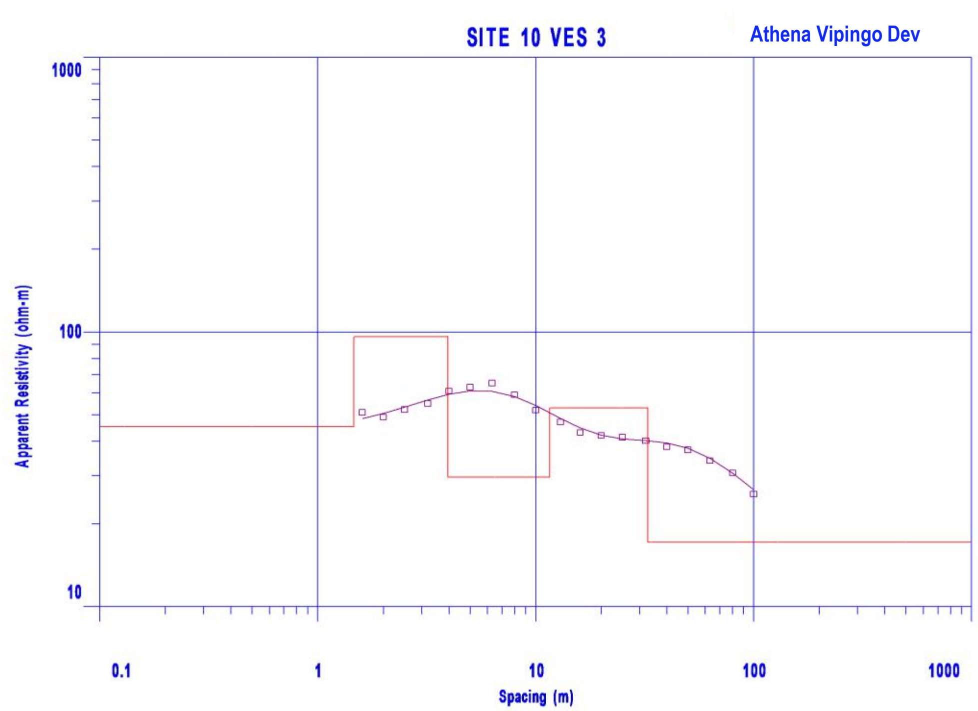
MODEL

AB/2 (m)	MN (m)	App. Resistivity (ohm-m)		Calc. Res (ohm-m)	Depth (m)
1.6	0.5	97.40		65	0.6
2	0.5	108.00		180	3.0
2.5	0.5	120.00		77	16.1
3.2	0.5	123.00		146	41.6
	0.5	128.00		36	>41.6
5	0.5	129.00			
6.3	0.5	125.00			
8	0.5	116.00			
10	0.5	110.00			
13	0.5	99.00			
16	0.5	94.20			
20	0.5	92.00			
25	0.5	93.00			
32	0.5	94.00			
40	10	93.11			
50	10	98.35			
63	10	93.41			
80	10	88.06			
100	10	74.21			



MODEL

AB/2 (m)	MN (m)	App. Resistivity (ohm-m)		Calc. Res (ohm-m)	Depth (m)
1.6	0.5	97.40		68	0.7
2	0.5	108.00		185	2.9
2.5	0.5	120.00		77	16.7
3.2	0.5	123.00		160	37.6
	0.5	128.00		41	>37.6
5	0.5	129.00			
6.3	0.5	125.00			
8	0.5	116.00			
10	0.5	110.00			
13	0.5	99.00			
16	0.5	94.20			
20	0.5	92.00			
25	0.5	93.00			
32	0.5	94.00			
40	10	93.11			
50	10	98.35			
63	10	93.41			
80	10	88.06			
100	10	74.21			



MODEL

AB/2 (m)	MN (m)	App. Resistivity (ohm-m)		Calc. Res (ohm-m)	Depth (m)
1.6	0.5	51.00		45	1.4628
2	0.5	49.00		96	3.9487
2.5	0.5	52.20		30	11.601
3.2	0.5	55.00		53	32.686
	0.5	61.00		17	Over 32.7
5	0.5	63.00			
6.3	0.5	65.20			
8	0.5	59.20			
10	0.5	52.00			
13	0.5	47.00			
16	0.5	43.00			
20	0.5	42.00			
25	0.5	41.40			
32	0.5	40.20			
40	10	38.20			
50	10	37.22			
63	10	34.01			
80	10	30.71			
100	10	25.68			