

Geology and Hydrogeology Report

Report Prepared for

Gulf Power Ltd.

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Prepared By:

**Mr. Eliud Wamwangi – Reg.
Geologist**

P. O. Box 667 – 00517

Nairobi, Kenya



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1 Introduction

1.1 Objective

This report is part of an Environmental Impact Assessment (EIA) report being prepared for the proposed Diesel Power Plant site in Athi River area. Its main objective is to present the geological, hydro-geological and soil conditions that pertain to the site. The vulnerability to pollution as a consequence of the proposed plant and mitigation measures necessary has also been considered.

To undertake a desk study of soil, geological and hydro-geological information

1.2 Terms of Reference

The Consultant was commissioned by the Client to carry out a geological and hydro-geological survey of the project area and subsequently present a report under the following terms:

- (i) Undertake a desk study of the geological and hydro-geological information available of the project area.
- (ii) Carry out fieldwork involving observation of the topography and drainage pattern of the project area; carry out a geophysical survey to check on the sub-surface geological conditions of the project site.
- (iii) Analyze all the data in order to assess the vulnerability to pollution of the groundwater in the area and also to Stony Athi River nearby.
- (iv) Compile and submit to the Client a report which shall include all the details of the above investigations and the Consultants recommendations.

2 Geology

2.1 Regional Geology

The Athi River area is located in the outskirts of Nairobi city to the south east. Geologically, the Athi River area lies on Cenozoic volcanic material overlying Basement System rocks at a depth.

Before the volcanic episode, this area was made up of Pre-Cambrian Basement System crystalline rocks of the Mozambique Belt. These very old rocks were laid down, metamorphosed, exposed and eroded and were, in Pre-Tertiary times, an ancient land-surface.

The volcanic materials resulting from eruption owing to the formation of the Great Rift extensively and widely covered much of Kenya. This activity in turn covered the old land surface. This geology is comparable to the geology of the city of Nairobi which was characterized by volcanic periodicity. That is, periods of extrusive activity followed by periods of relative calm activity during which erosion by wind and water occurred. In the early Tertiary period, during a period of substantial moisture climate, numerous river systems deposited erosion debris in extensive lakes. The resulting deposits are known as the Athi tuffs and lake beds, which today form a very important Aquifer system (Athi Series). This is however the top most layer in Athi River area.

This intermittent volcanic and erosive activity in Nairobi continued throughout the Tertiary period and into the Pleistocene Epoch of the Quaternary period. The combined volcanic and sedimentary series locally reach a thickness of five to seven hundred meters. The Athi River geology is not as thick as that of many areas in Nairobi due to the missing of some layers attributed to spreading capacity during the deposition period.

2.2 Geology of the Project Area

The volcanic rocks in the area are represented by Upper Athi Series consisting of sediments and Lake Beds, Athi Tuffs and Kapiti phonolite. The thickness of these volcanics varies but generally decreases towards the south and southeast as they reach the limit of the lava flows.

Below the volcanics are the undifferentiated crystalline rocks of the Mozambique Belt that is the Basements System rocks consisting mainly of gneisses and schists. These are shallow seated and have been encountered by several of the numerous Boreholes drilled in the vicinity of the area.

The geological succession underlying the project area consists of the Cenozoic volcanics which, in geo-chronological order, consists of the following formations:

- Upper Athi Series
- Kapiti Phonolites
- Basement System

2.3 Upper Athi Series

The Upper Athi Series forms part of the extensive Athi tuffs and lake beds. Its occurrence is as a result of consolidation of fragmental volcanic material which was deposited shallowly into water after eruption. Geaverts, 1964, classify the series as all the sediments and tuffs lying between the Nairobi and the Kapiti phonolite. They are taken to include beds of the Kerichwa Valley series where the phonolite and trachytes are absent.

The extensive occurrence of the series in the area indicates the former presence of an extensive swampy country. The presence of chert deposits indicate periods of quiescence during deposition while the contorted bands and slump structures may be due to tremors and movements during the same period.

The Athi series is sub-divided into Upper, Middle and Lower Athi series. The three groups do not necessarily occur together in all areas where Athi series is present. Their physical characteristics are different. The Upper Athi series consists mainly of sandy sediments, tuffs and welded tuffs, with clays being subordinate.

2.4 Kapiti Phonolite

Wherever the contacts of the Kapiti Phonolite are present, the unit underlies associated volcanic rocks and is consequently the oldest lava of the succession. This has been confirmed by numerous borehole sections, which reveal that the sub-volcanic floor over which the Kapiti Phonolite was extruded was irregular and cut in Precambrian rocks. The lava was laid down on an eroded surface covered in places by Tertiary conglomerates and grits (Fairburn, 1963), formed part of the first Miocene flood eruptions. The rock is distinctive in hand specimens by its large white crystals of feldspar and waxy-looking nephelines which are set in a fine grained dark green to black or dark bluish-grey groundmass.

This is the oldest lava flow in the area and lies directly on the Basement. The Kapiti phonolite is exposed in the south-eastern corner of the area in Athi River Township. The outcrops are not extensive and are confined mainly to the valley of Athi River, Stony Athi and along Kitengela River.

2.5 Rocks of Mozambique Belt

These are crystalline rocks of Precambrian age which are exposed in the south west of Kitengela where the volcanic cover has been removed by erosion. They are predominantly biotite gneisses, frequently migmatitic and rich in hornblende.

3 Hydrogeology

3.1 Groundwater Occurrence

Groundwater normally occurs in pores and interstices of various rock formations depending on the geological conditions and physiography of the area, the permeability and porosity of the rock formations, the degree and depth of weathering, fracturing of the rock formation and the historical tectonic conditions of the area. The recharge conditions are also very important factors.

3.2 Regional hydrogeology

In general groundwater in volcanic rocks is limited to fractures and erosion levels within the volcanic succession. Fresh lavas are usually not water bearing because of their massive and impervious nature. The most significant aquifer system west of the project area is the Upper Athi Series aquifer system. This is the main aquifer for boreholes in Nairobi and Kiambu areas and is composed of tuffs, lakebeds and sediments. Other aquifers in this area are found in the weathered inter-lava layers and in fractured zones. In the eastern part of the project area the volcanic rocks thin out exposing the metamorphic Basement System rocks where aquifers are predominantly found in fractured or deeply weathered zones. The Lukenya Range east and northeast of the project area is basically metamorphic Basement rocks composed mainly of granitic gneiss. The groundwater potential in the Basement System east of the project area is generally lower than that of the volcanic areas to the west.

3.3 Hydrogeology of the Project Area

The hydrogeology of the project area is variable as indicated by the interpreted Vertical Electrical Sounding (VES) data obtained at the site and carried out at three different points on the project plot. The volcanic layer on the Basement rocks was typically deposited on an uneven eroded surface and the depth to the Basement rocks will therefore vary from one area to another. At the site of VES I the Basement is indicated to be at about 29 metres while at VES II and III it is at 10.7 and 100 metres, respectively. The site of the best aquifer is at VES III where it indicates an aquifer at between 70 and 100 metres. This is expected to be at the contact of the Kapiti Phonolites and the Basement rocks. Below is data of some of the boreholes in the vicinity of the project area.

Table 1: Boreholes located within 3 km of the proposed project site

Owner	Borehole No. 'C'	Distance/ Direction (km)	Total Depth (m)	Water Struck Levels (m)	Water Rest Level (m)	Tested Yield (m ³ /hour)
	2301	1.8/SSW	127	33, 125	24	11.55
	2303	2.0/SSW	140	61, 76, 131	19	9.09
BAT	4001	1.3/NW	200	109, 132	33.7	103.2
KMC	4053	2.7/NW	143.3	5.2, 54.9	24.7	10.9
Athi Leather Works	4734	2.3/NW	110	8, 94	4.5	30
Bawazir Tanneries	10533	3.2/NW	152	4-6, 92	68	12
	10724	3.0/NW	106	10, 89	58	12.8
Youth for Christ	11719	2.8/ENE	101	26,32,38-50	20	1.6
Devki Steel	12473	2.5/NW	100.6	24.4-36.6, 47-79	55.1	7.2
Athi River Steel	13717	1.1/NW	175	138, 170	46.3	2.16
Superior Homes	New BH	1.1/E	110	-	26.4	24
BH opp. AR Steel	New BH	1.0/NNW	160	70, 130, 150	63.2	11

Source: Ministry of Water and Irrigation Database

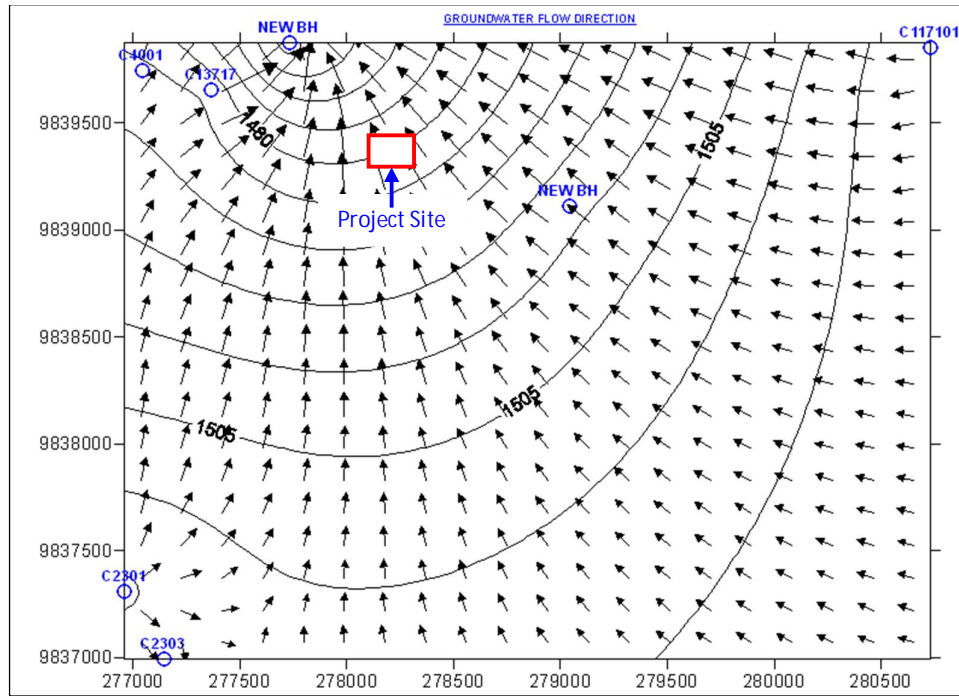
From the borehole data shown in Table 1 and especially the new boreholes near the project plot, a borehole drilled at VES III would be expected to yield between 10 and 20 m³ of water per hour.

3.4 Groundwater Flow and Recharge

The recharge of groundwater in the project area is expected to be good as a result of the influence of the permanent Stony Athi River located around two hundred metres away. Rivers have typically groundwater regimes flowing adjacent to the river. The nearby Kiima kya Mbiti and Lukenya Hills also serve as a catchment and source of groundwater recharge. The Ngong Hills located further to the west of the project area are also expected to be a source of recharge especially along the Kitengela River basin.

Figure 1 below shows the groundwater flow in the project area interpolated from the borehole data given in Table 1. The flow is generally in a northerly and northwesterly direction. This is towards the Athi River basin which is the main drainage system in the area. Stony Athi River is a tributary of the Athi and joins about 3.5 km north of the project area. In the project area the Stony Athi River generally flows in a northerly direction which is also consistent with the inferred groundwater flow direction also to the north.

Figure 1: Inferred groundwater flow around the proposed project site



Source: Consultant (2010)

3.5 Potential Pollution of Groundwater

The potential of pollution to groundwater in the area from the proposed Power Generation Plant is expected to be minimal due to the Kapiti Phonolite confining layer. The only way pollutants can reach the aquifer system below is through fractures or breaches in the Kapiti Phonolite. These were not identified in the area.

The greater risk of pollution is to surface water mainly from surface runoff. Migration through the top soil is also a possibility but would greatly be reduced by the clayey black cotton soil.

APPENDIX

General Location of the Project Site

Topographical map extract [Mapsheet 148/4 & 149/3 - 1:50,000]

Geological Map of the Project area

HEP Graph, VES Graph and Field Data

Figure 2: General location map of Project Site Indicating HEP and VES Location

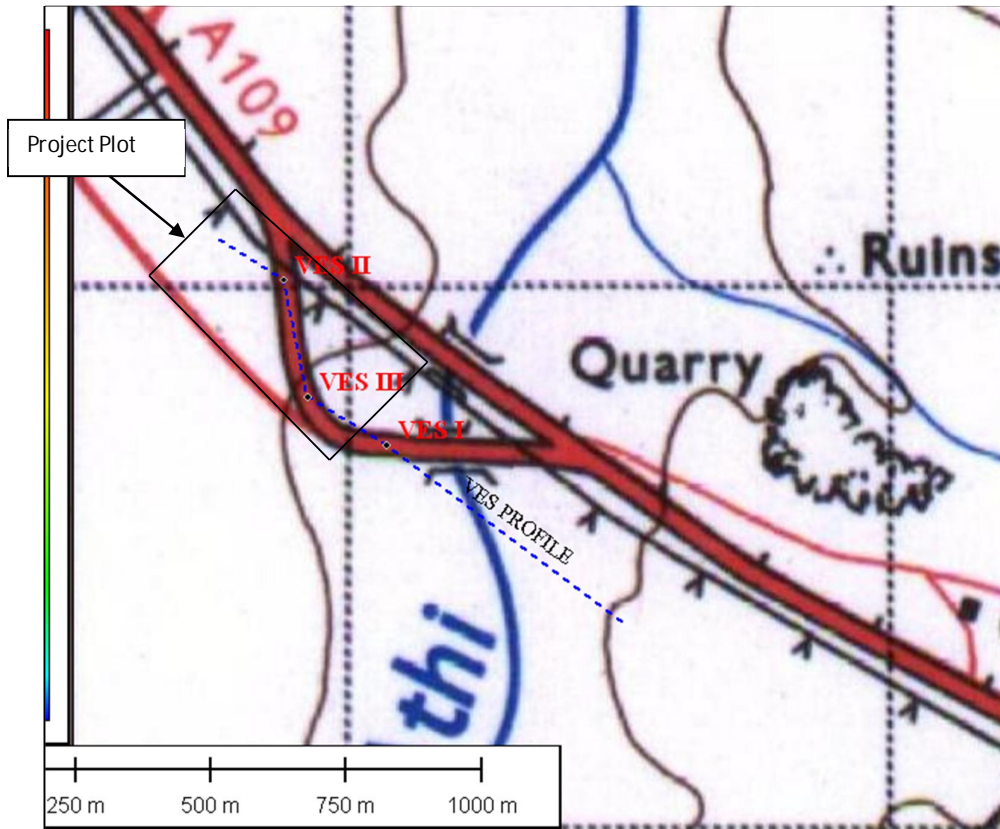
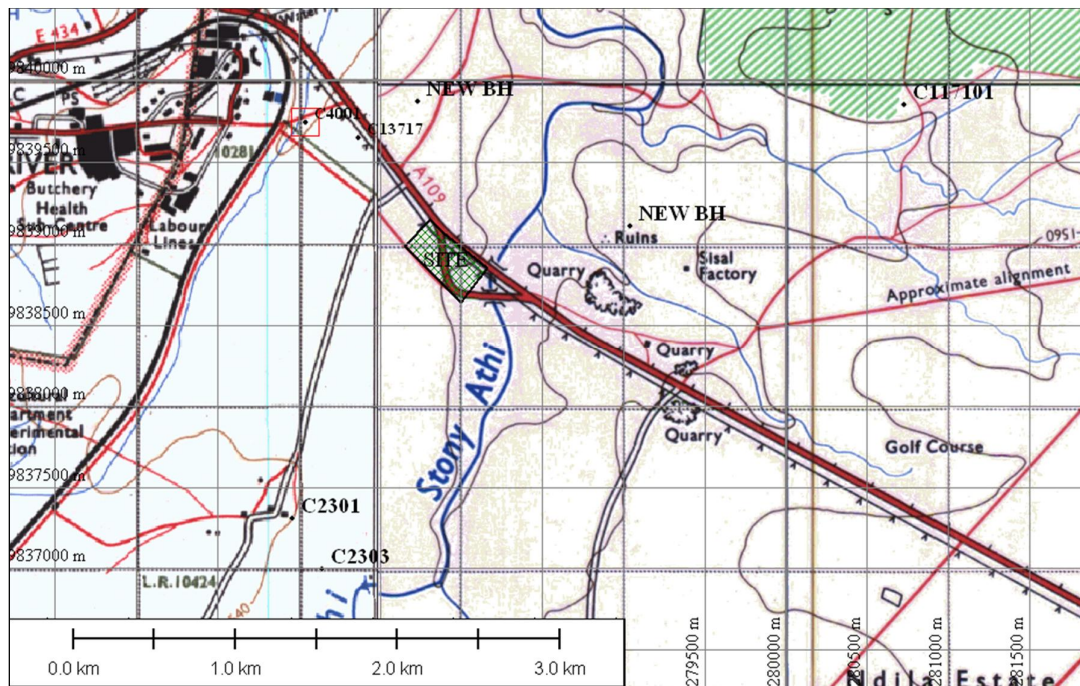


Figure 3: Topographic map sheet indicating the existing borehole sites in the vicinity of the project plot



Mapsheet 148/4 – NAIROBI & 149/3 MUA HILLS

Figure 4: Graph of the Horizontal Electrical Profile (HEP I)

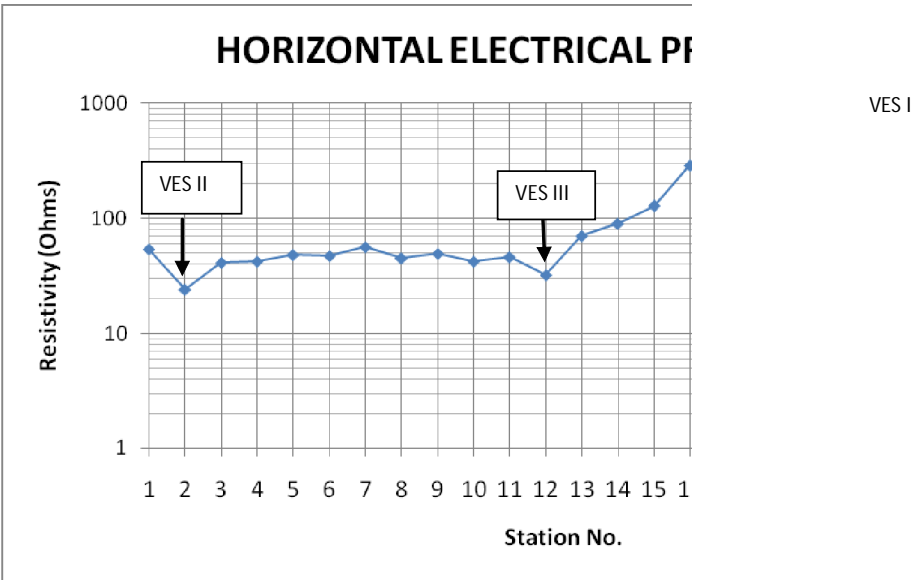


Figure 5: Graph of VES I

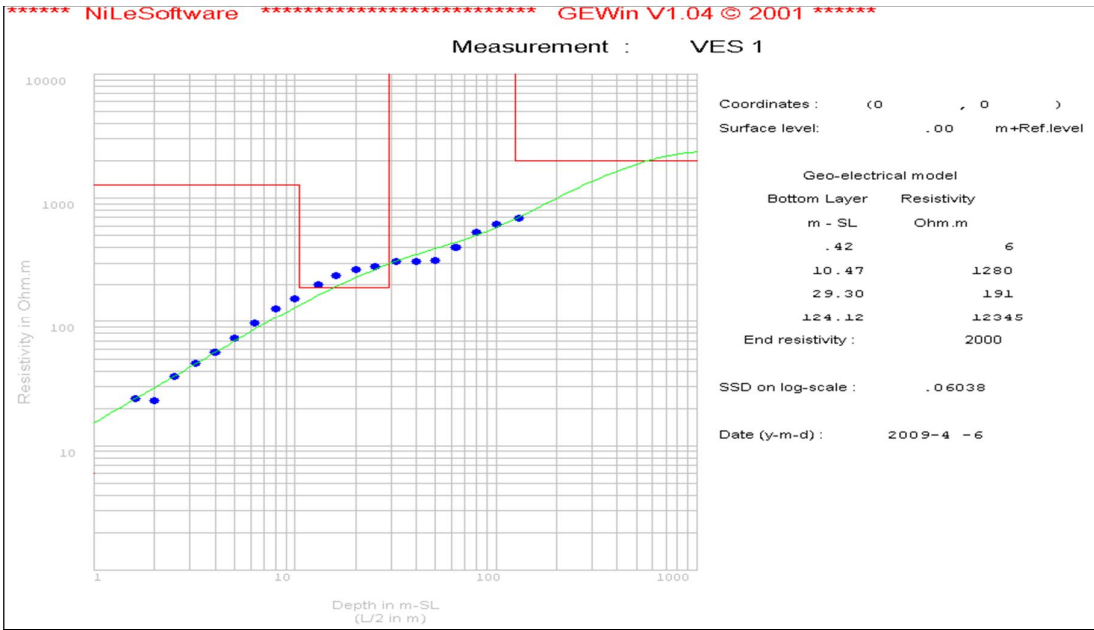


Figure 6: Graph of VES II

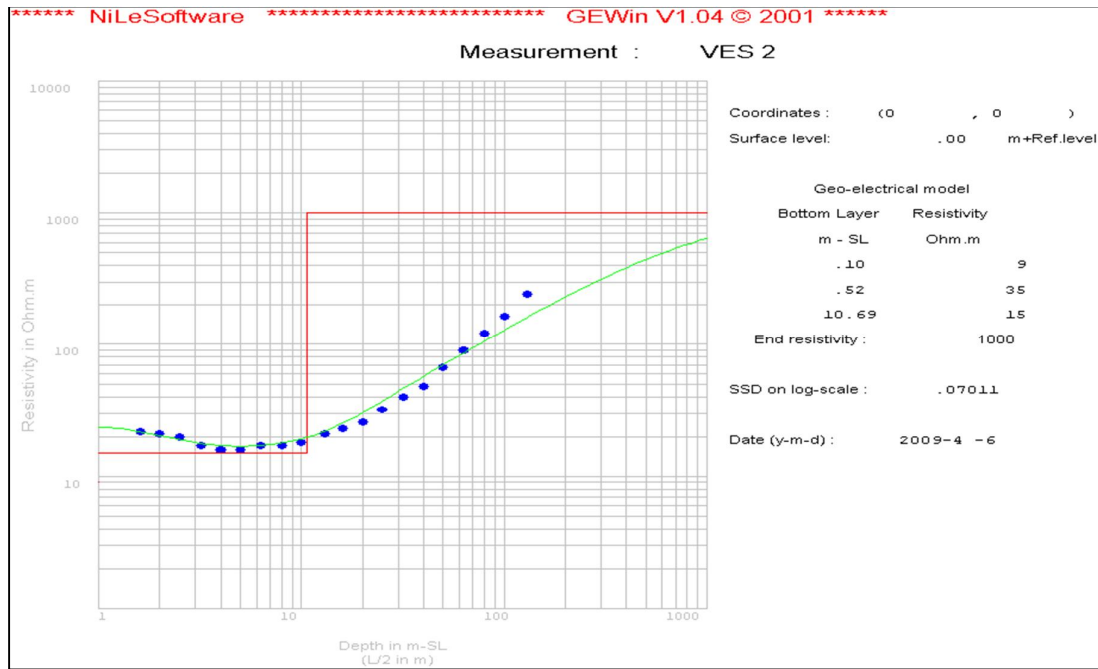


Figure 7: Graph of VES III

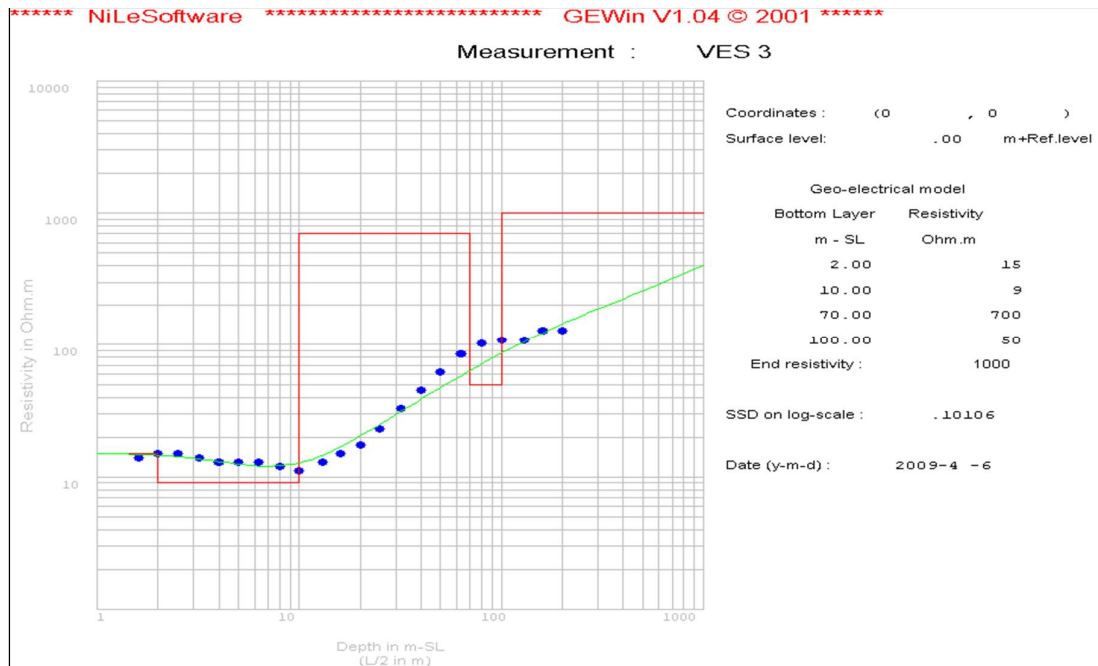


Table 2: Field Data for VES I, II and III

AB/2	VES I	VES II	VES III	AB/2	VES I	VES II	VES III
1.6	24	22	14	25	281	32	23
2.0	23	21	15	32	315	44	33
2.5	36	20	15	32	302	35	31
3.2	46	17	14	40	312	48	45
4.0	57	16	13	50	313	67	62
5.0	74	16	13	63	404	91	86
6.3	97	17	13	80	531	122	103
8.0	128	17	12	100	616	165	109
10	155	18	12.2	130	697	243	108
13	201	21	13	160			128
16	238	23	15	200			
20	266	26	17.3				

Figure 8: Map showing Geology of the Project Area

