1,050MW Coal Fired Power Plant

Hydrogeology Study

Report Prepared for

Amu Power Company Limited

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10 July 2016

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1 Executive Summary

This Report presents the results of a baseline study of the hydrogeological environment of Kwasasi, Lamu area where a 1,050MW coal fired power project is proposed for construction. The project site is located in Kwasasi sub-location, about 30 kilometres north of the proposed Lamu port. The relatively low altitude of the area 0-14m (amsl) makes it ideal for a coal power project due to the good accessibility to demand area, cheap labour, nearness to a seaport harbor, sea water for steam generation and cooling as well as availability of land that prevail there. The project targets to produce about 1,050 megawatts of electricity power at the project's maturity development.

Kwasasi project area is predominantly covered by fine sandy soils, with black cotton soil in low lying and flood plains/mud flats, which are in turn underlain by highly weathered coral limestones and clay. The area has low seismic activity and is therefore geologically stable for long term development of major infrastructures.

This report outlines the baseline hydrogeological environment, the sensitivity of this baseline environment in relation to the proposed project and the potential impacts that may emanate due to the development of the coal power project. Mitigation measures are recommended in order to ensure that the potential adverse impacts of the proposed project on this environment are mitigated.

The report concludes that the greatest disturbance and risk to the hydrogeological environment is expected during the construction and the operation phases of the project as this is when there will be a lot of excavation for the coal power project foundations, access of heavy construction tracks, trenching for underground cables, and construction of a substation, boiler site, coal ash yard, stoke pile yard, generator rooms, administration and residential block among other infrastructure development. It will also be the time when there will be a lot of vehicles and heavy machinery at the site that may be sources of hydro-carbon substance leaks. Operation phase will involve cleaningand crushing of coal to enhance efficient combustion and steam generation. The coal cleaning will produce sulfur dioxide and mineral matter such as coal ash, heavy metals (mercury and arsenic), while heat from the generated steam will may lead to elevated surface and ground water temperatures.

Mitigation measures recommended include construction of access tracks with tarmac, stone and laterite (murram) that are well compacted to carry the weight of expected heavy vehicles. The tracks should also be constructed in such a way as to allow for easy drainage of surface run-off on either side of the track to minimize the potential for water-logging, erosion and land slippage around the track. In steeply sloped areas the side drainage trenches of the tracks should have concrete barriers at intervals of around 30 to 50 metres (depending on the slope) to check erosion and deep cutting of the trench. Stockpiles of excavated materials will be stored in designated areas at minimum distance of 20m from any nearby watercourses or drains to minimize risk of silt laden surface water runoff entering water courses.

Other mitigation measures include offsite refueling of vehicles/machinery. This will consequently decrease risk of spillage and leakage of oils, fuels and other contaminants as the only vehicles expected will be those bringing the operators and the management of the facility. It is however, recommended that the management and site Engineer should ensure routine checks and documentation are carried out around the facility sites and that appropriate monitoring tool kits are located within and around the facility to ensure that any water level, temperature, sedimentation, tidal levels and water quality changes are immediately detected and mitigated.

2 Introduction

2.1 Description of the project area

Lamu County is generally flat and lies between altitude zero and 20m above sea level, making it prone to flooding/water logging during the rainy seasons and periods of high tides. The main topographical features include coastal Island and Dudol plains, sand dunes and the Indian Ocean. The county has four major catchment areas categorized as Dodori coastal zone, Dudol, Lamu bay drainage and Tana River Delta.

The hydrology of the project area is governed by the climate, geology, soils and drainage system. Climatic data is obtained from Lamu Meteorological Station No. 9240001. Lamu area has a wet and humid tropical maritime type of climate. This type of climate is responsible for the dense forests cover as well as the mangrove forest near the ocean.

Average annual rainfall data for the period from 1993 to date is about 1000mm. The lowest rainfall observed was 684mm in 2012 and the highest was 2242mm in 1996. Monthly variation has the typical bi-modal distribution with mean long rains depth of 250mm in May and the short rains depth of about 100mm in November. The months in between have minimal rainfall and are drier.

Figure 2-1: Climatology of Mean Monthly Rainfall

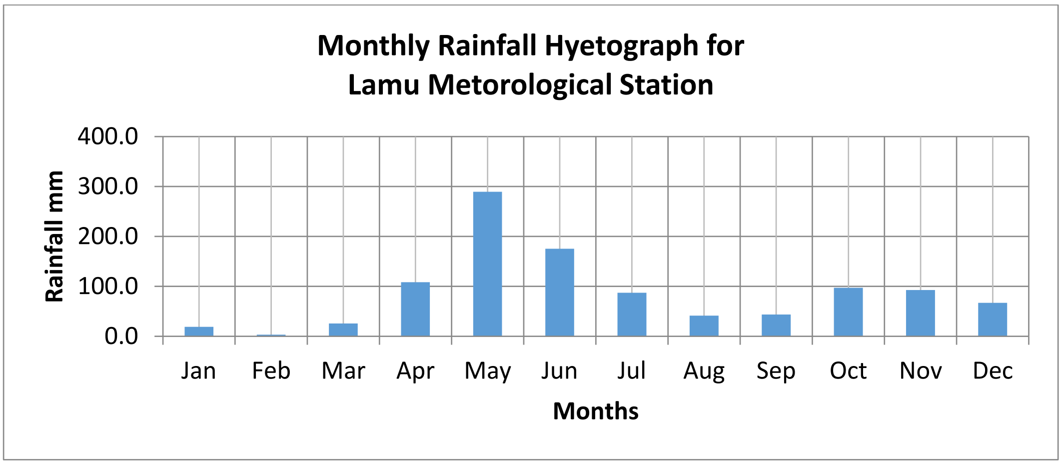
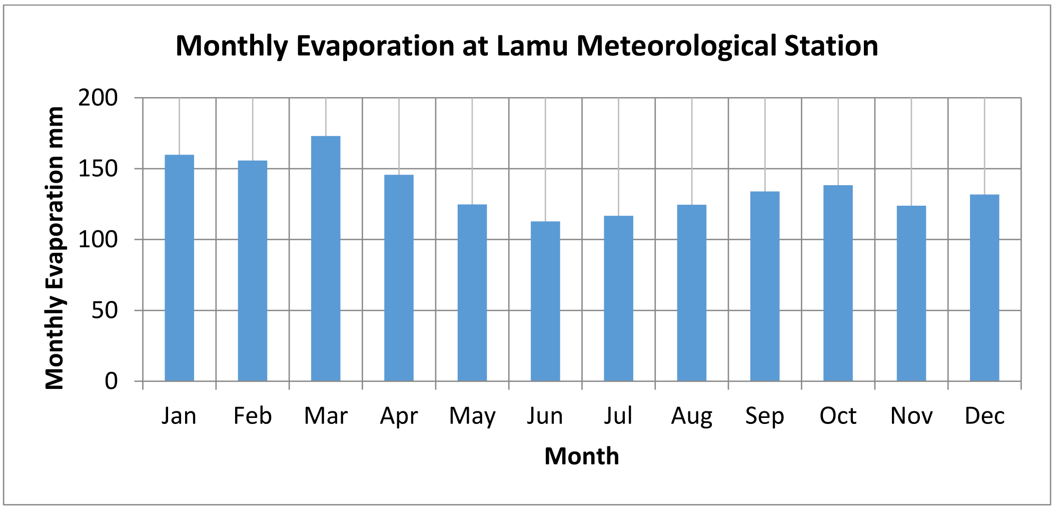


Figure 2-2: Monthly Evaporation



Relative humidity is high ranging from about 65% in the rain seasons to above 80% in the drier months and annual mean evaporation exceeds 1600mm. Mean annual evaporation is therefore higher than mean annual rainfall.

Seasonal storms have high intensity and are often accompanied by thunderstorms. The outcome of such heavy rainfall is localized water logging and flooding of the floodplain. Pools of standing water and ponds are left after rains. These make up for the limited drainage system comprising mainly seasonal streams and shallow but intermittently flowing water into the Indian Ocean. There are no perennial rivers in the area.

Due to the physiographic climate and other natural conditions, the county is made of two broad economic zones covering the mainland for agriculture and livestock keeping and Islands for marine activities. The Lamu county is made of cosmopolitan population composed of indigenous communities made of Swahili's, Arabs, Korei, Boni and Ormas and migrant communities from the rest of the country.

The LAPSSET project will require water supply, electricity supply among others and will also attract huge migrant population estimated to be over one million (CIDP 2013-2017). This will certainly overstretch the county's social services necessitating development planning for adequate service provision.

A consortium of investors (Amu Power, Gulf, Centum and Kenya Power) has planned to spend Kenya Shs 174 billion on developing a 1,050 megawatts coal fired power plant project. The coal powered facility will consist of the coal power plant, cooling systems, electric power transmission, coal ash yard and waste management facilities.

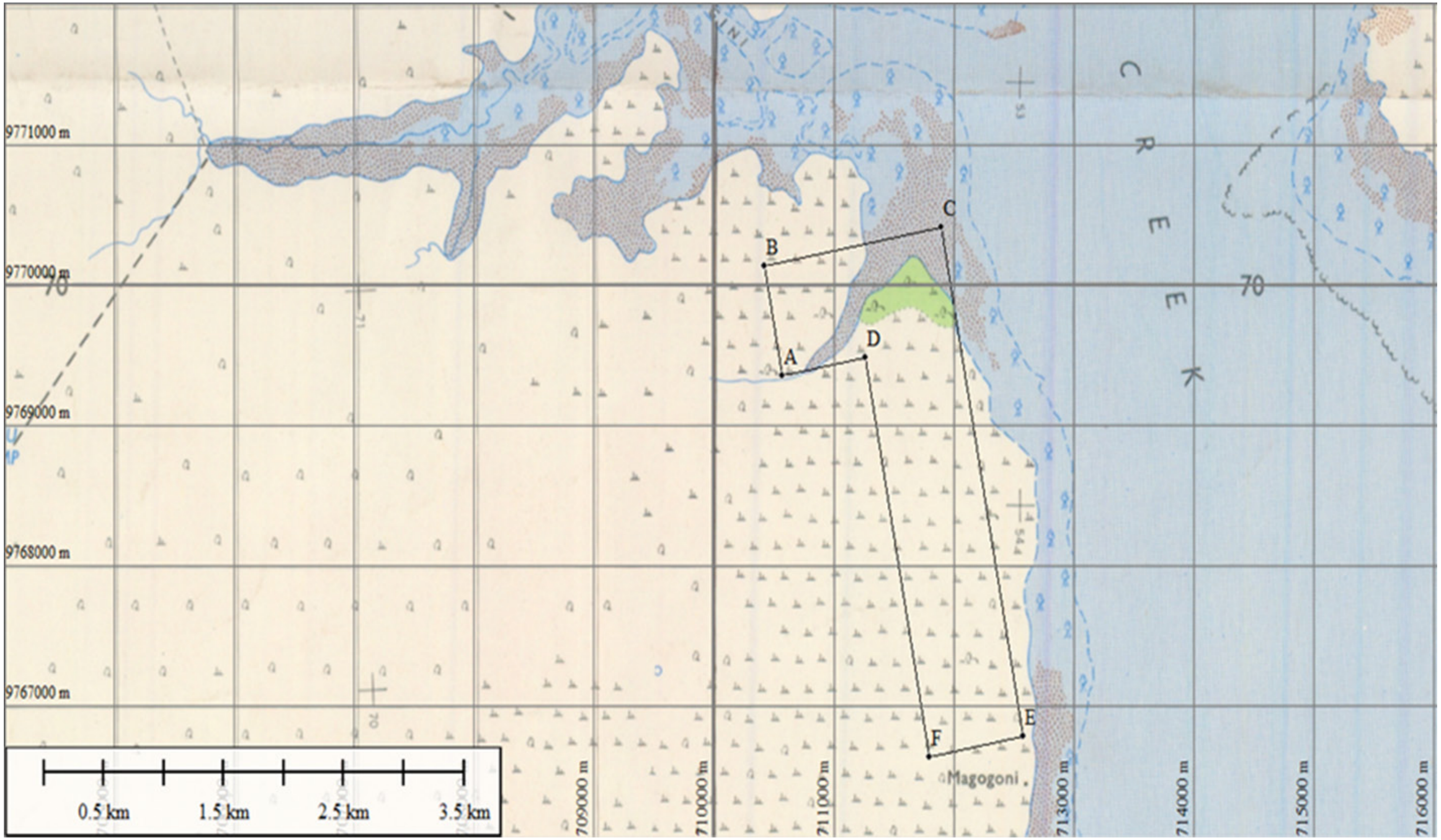
The project site covers 800 hectares of land and is located in Kwasasi sublocation near and about 30 kilometres to the north of the proposed Lamu port. The project site is on land that will be leased by the Lamu County for 25 years. This project will not only benefit the residents and LAPSSET project, but also directly benefit the Lamu County and employ over 1000 youths as well as the sales of electricity to Kenya Power Limited, thus fill the current power generation short fall being experienced in the Country.

Coal is the least expensive, most abundant fossil fuel source for electric generation (IDB, 2009). It is one of the world's fastest growing energy sources and is likely to increase its share in the energy matrix in many countries. Coal-fired power plants produce a series of pollutants and other environmental impacts derived from the combustion of the coal.

Technological developments over the last few decades have led to cleaner coal technologies that are able to increase the efficiency of a coal plant (i.e. increase the amount of energy gained from each tonne of coal) and to significantly decrease its air emissions (specifically sulphur dioxide, particulate matter, and nitrogen oxides) and therefore its environmental impact.

This report therefore gives the sensitivity of the hydrogeological baseline environment in relation to the proposed project and the potential impacts that may emanate due to the proposed development. Mitigation measures are recommended in order to ensure that the potential adverse impacts of the proposed coal power plant development on the hydrogeological environment are mitigated.

Figure 2-3: Topo sheet map 180/2 showing the location of the project area



2.2 Objectives of the Study

The objective of this Environmental Impact Assessment (EIA) Study is:

- To identify the types of hydrogeological environment that exists in the project area;
- To assess the sensitivity of the hydrogeological environment in the subject area with respect to the proposed coal fired power development;
- To identify existence of hydrogeological features such as lineaments, weathered zones, fault lines or fractured zones, groundwater flow direction and water quality which could affect the project location;
- To identify any potential impacts on the hydrogeological environment associated with the proposed development;
- To identify any constraints posed by the existing hydrogeological environment to the proposed development; and
- To propose appropriate mitigation measures in order to ensure that the potential impact of the proposed coal power development is slight and neutral.

2.3 Water demand

During operation phase of the coal fired power facility, substantial water will be required as following:

- Domestic demand by at least 2,000 staff,
- 2No. Plant generators,
- Construction.

Therefore the water demand is estimated as follows:

Domestic demand by at least 2,000 staff	100litres/day/person	200 m^3/day
Plant generators	2 pumps @ 42,160 m^3/hr	2,023,680 m^3/day
Make-up water flow	2 pumps @ 1,000 m^3/hr	48,000 m^3/day
Total water demand		**2,071,880 m^3/day**

From the above calculated water demand, it is observed that there is need to have adequate and sustainable water sources that can meet the over 2 million cubic metres of water required per day.

It is therefore appropriate to use seawater from Manda Bay for generation of steam, cooling of the hot waste water before returning to the sea and also distill part of the steam to meet the domestic water needs.

3 Study methodology

3.1 Desktop study

The study approach involved analysis of various documents available, this included base maps, topographical maps and geological maps of Lamu area. The following data sources were reviewed and used during this assessment.

- "Geological Reconnaissance of the Galole – Lamu area" by Geological Survey of Kenya;
- Topographical Map Sheet 180/2 – Mokowe Sheet by Survey of Kenya;
- Review of existing borehole records within the project area;
- Review of District Development Plans in the Project area;
- Borehole Completion Reports from the Ministry of Water and Irrigation.
- EIA Guidelines – Coal fired power plants – Pakistan 2014.
- Borehole Completion Reports from the Ministry of Water and Irrigation.
- Malindi – Ganda Groundwater investigations.

The geological formations underlying the site were identified from the available geological series map and borehole log data obtained from Borehole Completion Reports. Based on the analysis of the soils, geology and hydrogeology, the potential risk of their contamination with consequent adverse impact on the surface and ground water were assessed.

3.2 Field Survey Methodology

3.2.1 Reconnaissance survey

A site reconnaissance to record observations and features of significance was done on 3rd of February 2015. Pertinent site information was gathered to determine how and where the proposed development can affect the local soils and geological environment. The following information was therefore gathered:

- The general topography and drainage pattern of the project area.
- The Soil types, exposed geology and hydrogeological data available on the study area.
- Potential nearby receptors of contamination, such as rivers, streams, wells, service ducts, and residential areas
- Observation of significant features such as shallow water wells, faults, etc.

3.2.2 Digging of Trial pits

The excavation of trial pits in the project area was carried out simultaneously with the geophysical survey to find out the nature, permeability, vulnerability to pollution and type of the top-soil and determine the depth to the underlying formation. The trial pit sites were sunk at the point of the VES sites. The trial pit sites were done in such a way that they would be used for correlation with geophysical survey (VES) data. There was also a bias on where there were operational shallow water wells or have been abandoned due to declining fresh water levels. Hydrogeological data from hand dug wells such as elevation; water levels, quantity abstracted and quality compared to sea water, were collected. These provided invaluable hydrogeological information as well as hydrological data.

3.2.3 Hydrogeological survey

Major objectives of the Kwasasi project area hydrogeological study were to:

(1) Evaluate the regional hydrogeologic setting,

(2) Delineate and characterize subsurface discontinuities and fractures that control aquifer permeability, and

(3) Monitor the response of the bedrock ground-water system to local ground-water abstraction/pumping.

To accomplish these objectives, the local- and site-specific studies were conducted. The local studies entailed compiling detailed hydrogeologic information on private and publicly owned wells in the vicinity of Kwasasi area and preparing necessary hydrogeological maps. The site specific studies included collection of geophysical VES and shallow well logging data needed to characterize the distribution of lithology and fractures in the subsurface. Local community provided information on reliability, availability, seasonal water level fluctuation and seasonal water quality change (salinity). Detailed subsurface lithology, fracture, and yield data—which are a focus of this report—were compiled to determine what geologic structures, if any, contribute to the development of variable permeability and ground-water yield in the area.

3.2.4 Geophysical survey

Intensive field work was carried out for the next 8 days that included geophysical survey of predetermined 1km by 0.5km grid format spread out in the project area. This involved execution of vertical electrical soundings (VES) using an ABEM SAS300C Terrameter. VES measurements were executed at an expanding Schlumberger array, with electrode spread of between AB/2=50m and AB/2=100m. Depths beyond AB/2=100m were not necessary because that zone was underlain by shales and sea water.

3.2.4.1 Basic Principles

The electrical properties of rocks in the upper part of the earth's crust are dependent upon the lithology, porosity, and the degree of pore space saturation and the salinity of the pore water. Saturated rocks have lower resistivities than unsaturated and dry rocks/formation. The higher the porosity of the saturated rock, the lower its resistivity.

The presence of clays and conductive minerals also reduce the resistivity of the rocks. The resistivity of earth materials can be studied by measuring the electrical potential distribution produced at the earth's surface by an electric current that is passed through the earth. The resistance ***R*** of a certain material is directly proportional to its length ***L*** and cross-sectional area ***A***, expressed as:-

$$R = \rho_s * L/A \qquad \text{(in Ohms)}$$

Where ρs is known as the specific resistivity, characteristic of the material and is independent of its shape or size. With Ohm's Law

$$R = \Delta V/I \qquad \text{(in Ohm)}$$

Where ΔV is the potential difference across the resistor and I is the electric current through the resistor, the specific resistivity may be determined by:-

$$\rho_s = (A/L)*(\Delta V/I), \qquad \text{(in Ohm-m)}$$

$$\rho_s = k*(\Delta V/I), \qquad \text{(in Ohm-m)}$$

For Schlumberger Array, k= π.([(AB/2)^2-(MN/2)^2])/MN)

Thus,

$$\rho_a = \pi.\ ([(AB/2)\text{^}2-(MN/2)\text{^}2])/MN).(\Delta V/I), \qquad \text{(in Ohm-m)}$$

In which, MN/2 and AB/2 are the spacing between potential and current electrodes, respectively.

3.2.4.2 Resistivity Sounding Technique

When carrying out a resistivity sounding, also called vertical electrical sounding (VES), an electrical current (I) is passed into the ground through two metal pins, the current electrodes. Subsurface variations in electrical conductivity determine the pattern of current flow in the ground and thus the distribution of electrical potential. A measure of this is obtained in terms of the voltage drop (ΔV) between a second pair of metal stakes, the potential electrodes placed near the centre of the array. The ratio (ΔV/I) provides a direct measurement of the ground resistance and from this, and the electrode spacing, the apparent resistivity (ρ_a) of the ground is calculated.

The measuring setup consists of a resistivity instrument (usually placed in the middle of the array), connected to two current electrodes (AB), and two potential electrodes (MN) towards the centre. Usually a so-called "Schlumberger" array is used for vertical electrical soundings, while profiles are generally carried out in "Wenner" configuration.

A series of measurements made with an expanding array of current electrodes (Schlumberger Array) allows the flow of current to penetrate progressively greater depths. The apparent resistivity as a function of the electrode separation AB provides information on the vertical variation in resistivity. The depth of penetration varies according to the electrode array, but is also affected by the nature of the material beneath the array. The point at which a change in earth layering is observed depends on the resistivity contrast, but is generally of the order of a quarter of the current electrode spacing AB (Milsom 1989; Roy & Apparao 1971).

The calculated apparent resistivity is plotted against current electrode half separation on a bi-logarithmic graph paper to constitute the so-called sounding curve. The curve depicts a layered earth model composed of individual layers of specific thickness and resistivity.

Interpretation of field data can be done with hand-fitted curves, but this method is time consuming, and practically limited to 3-layer solutions. Modern interpretation is computer-aided, using a curve fitting procedure based on a mathematical convolution method developed by Ghosh (1971).

3.2.4.3 Vertical Electrical Soundings

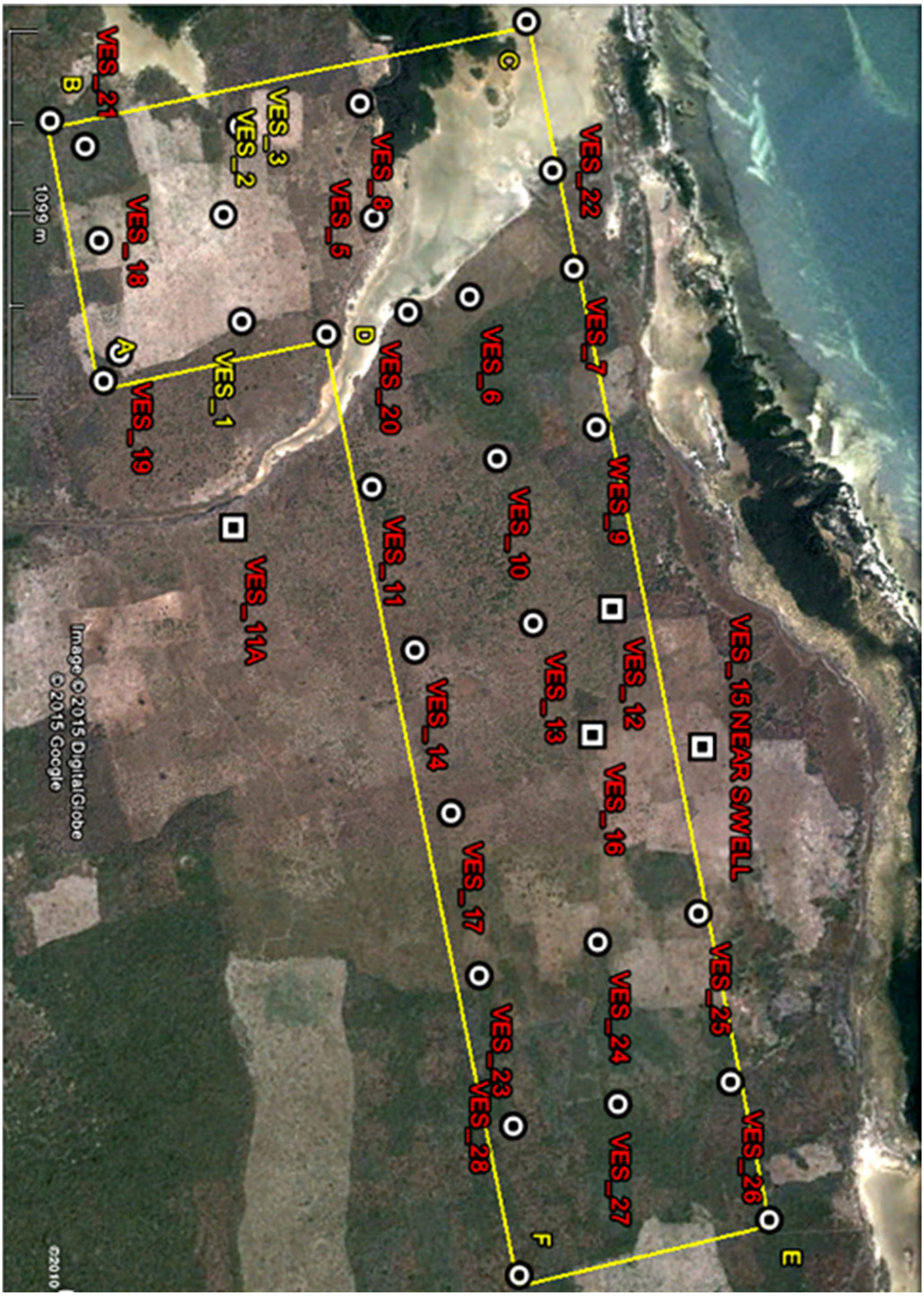
When carrying out a resistivity sounding, current is let into the ground by means of two electrodes. With two other electrodes, situated near the center of the array, the potential field generated by the current is measured. From the observations of the current strength and the potential difference, and taking into account the electrodes separations, the ground resistivity can be determined.

While carrying out a resistivity sounding, the separation between the electrodes is stepwise increased (in what is known as a Schlumberger Array), thus causing the flow of current to penetrate greater depths. By plotting the observed resistivity values against depth on double logarithmic paper, a graph of resistivity versus depth is obtained. This graph can be interpreted in the field by an experienced hydrogeologist. Final interpretation is done with the aid of a computer.

The actual resistivity layering of the subsoil is obtained. The depths by resistivity values provide the hydrogeologist with information on the geological layering, the occurrence of groundwater and water quality. The method is otherwise called Electric drilling.

A total of 28 Nos vertical electric sounding (VES) were carried out at a 500m by 1000m grid to enable adequate coverage of the entire project area within the shortest time line. Below is Satellite Google imagery showing the location of VES_1 to VES_28 survey points within the project.

Figure 3-1: VES location points within the project area



4 Baseline conditions

In order to discuss the baseline hydrogeological conditions within the project site and its environs, a brief description of the soils and geology is first considered. This is due to the fact that hydrogeology is concerned with among other things the recharge of groundwater through the surface and sub-surface soils. Subsequently, given in this section is the baseline soils, geology and hydrogeology around the project site and its environs.

4.1 Soils

4.1.1 Introduction

A baseline study was carried out in the project area to determine the susceptibility of the soils to pollution or contamination as well as erosion, landslides and siltation/ponding.

4.1.2 Type of Soils

The project area is overlain by relatively shallow mainly black cotton soils which in some areas grade into more grayish colored loamy soils. The soils of the Kwasasi sub-location in Lamu area are classified as below. (Speck, 1978, Sombroek et al, 1982).The quaternary soils are usually grey sands clays outcropping in and of the Tertiary marine sediments, which yield off white or buff sandy soils by reworking. Black cotton soils are present along drainage channels and are also found overlaying the tertiary and quaternary sediments along the drainage channels.

4.1.2.1 Ferralsols

Ferralsols occur on gently undulating to undulating topography. They are very old, highly weathered and leached soils, and therefore with a poor fertility, which is restricted to the top soil, as the subsoil has a low cation exchange capacity. Phosphorous (P) and Nitrogen (N) are always deficient. Ferralsols are rich in Aluminium (Al) and Iron (Fe). The nutrient reserves are easily disturbed by agricultural practices. Important management practices include the use of fertilizers (e.g. rock phosphate) and the maintenance of soil organic matter by using green manures, farmyard manures and mulching. Ferralsols have also good physical properties including an excellent capacity to hold moisture. Ferralsols are used to grow several annual and perennial crops, being particularly suited to tree crops such as oil palm and cashewnut.

Figure 4-1: Grey fine sandy Soil

Figure 4-2: Dry well 2m deep brown-grey fine sandy soils.

4.1.2.2 Planosols and Vertisols

Planosols and Vertisols occur on very gently undulating to flat topography, mostly in depressions and water logged areas. They are found in semi-arid and sub-humid environments. Due to the high clay content in the subsoil (higher than in the topsoil), is this layer in the B-horizon impermeable resulting in a very slow vertical and horizontal poor drainage and also in an extremely poor workability of the soils. These soils are dark coloured and strongly cracking.

4.1.3 Results of Digging Trial pits

The surface soil samples were excavated up to a depth of 1.5m and soil texture and colours observed. The results of the soil survey are given below and it gives the baseline soil conditions within the project area.

The reddish-brown to gray fine loose sandy or clayey sandy soils that vary from 5 to over 10m are overlain by fine loose and/or compact sandy soils that are relatively deep and vary in depth between 0.3 and 1.5 metres thickness in most places. The soils are mainly a product of the weathering and deposition of sand dunes, coral limestones, hence giving them the light colour and high quartz content. Loamy and dark clayey soils are also quite widespread in the area.

The soils and geological data from desk study indicate that the area in which the Lamu Coal Fired Power Plant facility is to be built has the following characteristics:

- The first 4m of the ground contain fine loose at the top and compact sandy soil of low fertility but is useful for agricultural practice and farming activities.
- The lithology up to 10m is generally permeable and therefore in the event of construction of coal power facilities, care should be taken to put strong foundations, hard standing and proper underground supporting systems.
- Highly weathered coral limestones are encountered after 3 metres below which saline water is encountered.

- The upper sub-surface geology is vulnerable to the infiltration in the event of the spillage of contaminants and that in the event of leakage and of seepage; the surface and groundwater is likely to be contaminated.

Figure 4-3: Abandoned well sandy clays

Figure 4-4: Fine loose red sands

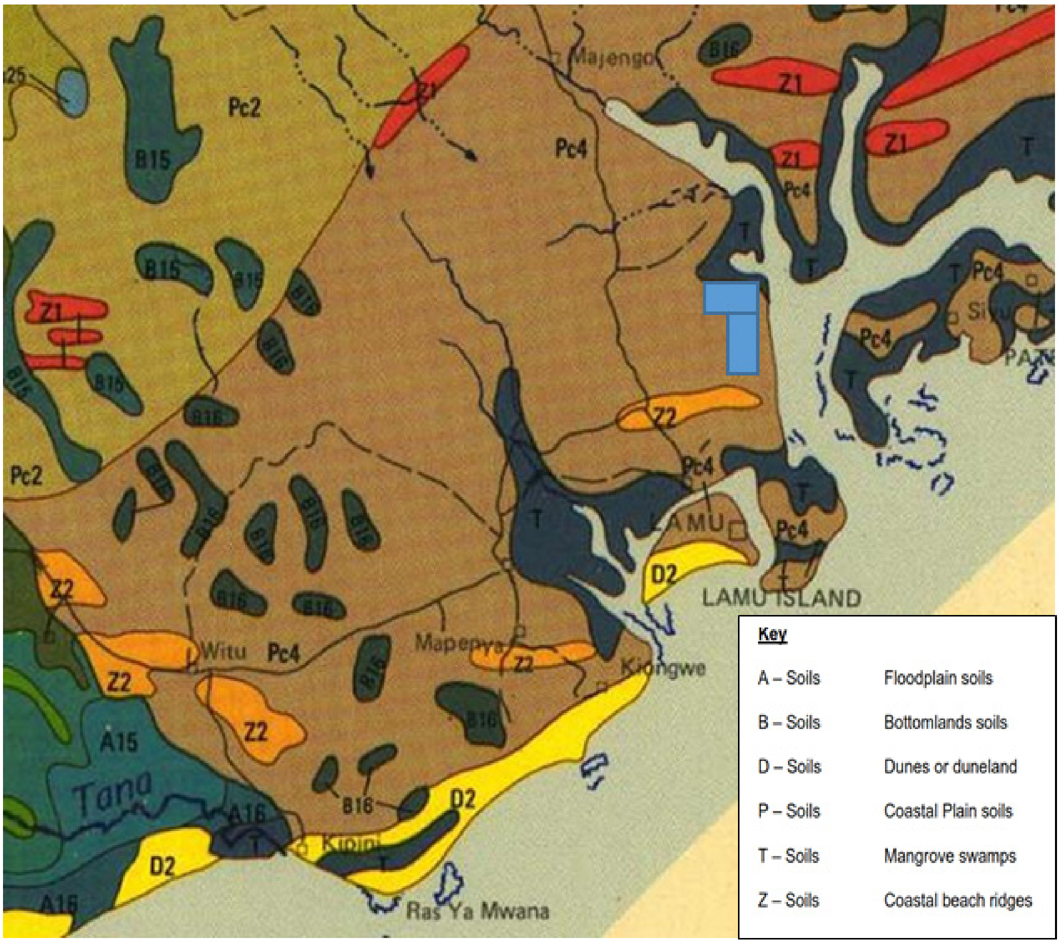
The relatively high sand content of the soil samples obtained at the site (averages about 50 percent) means that the permeability is quite high thus making them vulnerable to pollution in case of any petroleum leak or spill at the proposed site during construction or in its operational stage. The data of each trial pit is summarized in Table 4-1 below.

Table 4-1: Summary of shallow well/Trial Pit Data

VES No. of Pit Site	UTM Location 37m		Altitude (masl)	Thickness (m)		
	Easting	Southing		Top Dry Sandy	Clayey sands	Weathered Coral Limestone
1	711042	9769513	11.1	0-0.1	0.1-2.0	2-2.3
2	711470	9769419	15.2	0-0.2	0.2-0.6	3.0-5.0
3	710527.86	9770060.9	7.0	0-0.4	0.4-1.5	
4	712085.8	9769186	8.0	0-3	3.0-4.0	4.0-5.5
5	712460.8	9767200.9	8.0	0-0.3	0.3-3.0	3.0-6.0

The relatively shallow soil profile implies that any contaminant percolating in the soil will reach the underlying formation rather quickly and start spreading directed by the confining clayey profile. Contamination of the deeper subsurface geological formations and aquifers may also take place through fractures through the coral limestones which would allow vertical penetration of contaminants.

Figure 4-5: Map extract from the Ministry of Agriculture, 1982



4.2 Geology

4.2.1 Introduction

The geology of the Lamu County area reflects a predominantly Quaternary history of marine influence, with numerous sea transgression and regressions, and associated sedimentary features. The area is essentially composed of lagoonal deposits, Aeolian accumulation and fossil coral reefs, occasionally dissected by alluvial sediments. All the rocks are sedimentary in origin and can be divided into three main groups as:- Quaternary soils, Quaternary marine sediments and Tertiary Sediments.

4.2.2 Quaternary soils, Quaternary marine sediments

4.2.2.1 Lagoonal Deposits

Calcareous sands and clays which were deposited on the edge of the Pleistocene seas are present throughout the region. Due to cementation and interbedding with clays, they are generally of low permeability, while their marine origin accounts for highly mineralized porewater. Significant infiltration of rain water is unlikely, while evapotranspiration of near-surface groundwater may be high, suggesting extremely water quality and aquifer properties.

4.2.2.2 Dunes

Several types of dunes are present in the project area. Behind the first raw of recent dunes along the project area, a second raw of fossil dune is found, probably of Upper Pleistocene (the epoch of geologic time, about 1.6 million to 10,000 years ago, characterized by the disappearance of continental ice sheets and the appearance of humans) age. The windblown reddish brown sands of these fossil dunes cover extensive area of the coastal plain and form dune features inland. The fossil sands have been partly ferricreted, giving them a distinct reddish colour and reducing their permeability and porosity. The infiltration rate and the storage capacity necessary for the formation of a suitable fresh-water aquifer is poor. The unconsolidated recent dunes nearest to the ocean are highly porous and have good aquifer characteristics. Where these dunes are underlain by impermeable clays, the actual fresh water storage capacity will be significantly reduced.

4.2.2.3 Fossil coral reefs

Extensive karstification, visible as numerous sinkholes and pans indicates the presence of limestone features in the area. Large sinkholes appear to be related to fossils coral reef, (formed during Pleistocene transgressions) which have been partly dissolved by fresh water. Lesser sinkholes are likely to be related to lagoonal organic and inorganic limestone deposits. The secondary porosity and permeability of such karstified fossil coral reefs imply both the presence of fresh water (as solvent) and excellent aquifer properties.

4.2.2.4 Alluvium

Recent fluvial and lacustrine deposits, consisting of sands, mud and silt have accumulated in and around the ephemeral streams and mangrove swamps at estuaries. Since flooding occurs due to both occasional high tides and heavy rainfall, it is difficult to distinguish between deposits of marine and continental origin in the lowland surrounding the estuary. In estuarine areas with frequent saline inundations (flooding), no fresh water is to be expected, while fresh-water alluvium is unlikely to yield adequate quantities due to the shallow salt water interface.

4.2.3 Tertiary sediments

The oldest Tertiary sediments are the limestones and outcrops at Walu of which their fossil content dates them as Miocene. The limestones-proper are largely covered by secondary limestone. The Walu limestones form a ridge above the end-tertiary peneplain at this point (Baker and Saggerson 1963 map) while the other tertiary sediments rest on the peneplain so are upper Pliocene. The end- tertiary peneplain has been shown to be of mid Pliocene age near Mombasa (Caswell 1953). North-west of the Walu limestones, grey and black sandy clays cover the surface of the area and holes drilled in the area reveal that similar deposits extend to a depth of 300 metres. As the Pliocene sea reached 100 mteres (Caswell1956) the lower part of these fluviatile sediments must have been deposited before the sea reached this height so that the Pliocene marine sands and clays are banked against them. The inland part of the marine sediments was probably laid down under deltaic conditions with interdigitating (*interlock like fingers*) of marine and fluviatile deposits.

4.2.4 Geology of the Kwasasi Project Area

The study area is covered by superficial soils and marine sediments. The oldest rocks are Tertiary limestones and are largely covered by Quaternary limestones. Marine sands and clays occur in a belt varying from 16 to 24 km wide, sub-parallel to the present coast-line. Their surface is covered by sandy soils which are fluviatile in character. The Quaternary marine sediments contain raised coral reefs and wind-blown dunes sands which are often red in colour. These outcrop between the Tertiary sediments and the present coast. The Pleistocene sands and clays, like those of the Tertiary, were probably deposited under deltaic conditions in this region.

The Quaternary soils are usually grey sands and clays outcropping over the Tertiary marine sediments. Black cotton soils are present along drainage channels and are also found overlying the Tertiary and Quaternary sediments along the drainage channels. Red soils in the area may be merely better drained variants of the common grey sandy soils but they may also represent tertiary dunes or valley deposits. The alluvium of the Tana River Valley is of Quaternary age.

Figure 4-6: A generalized geological map of Lamu area

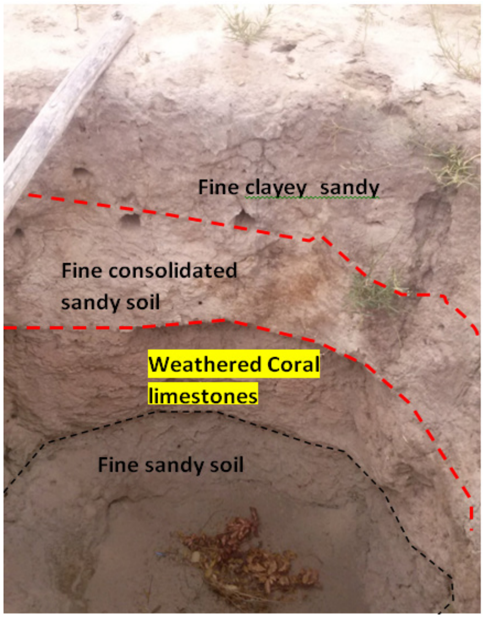
4.2.5 Geophysical survey

In addition to the available data, a geophysical survey was undertaken to unravel the depth to the underlying formation within the project area. The data are presented in the tables below.

Figure 4-7: Preparation of geophysical field data collection

Figure 4-8: Test Pit

Figure 4-9: Seasonal water Well.



4.2.6 Results of Geophysics

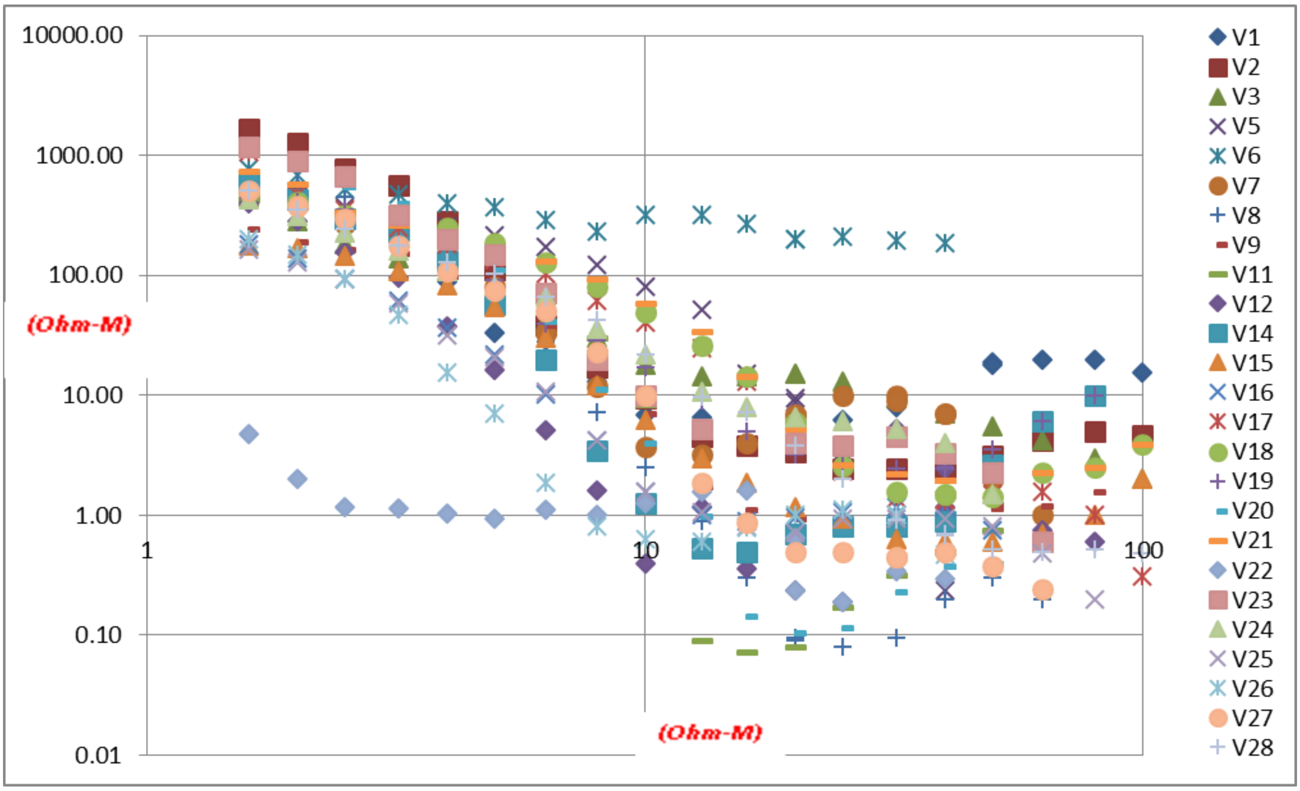
Table 4-2: Raw Field VES 1-16 Data

MN/2	AB/2	V1	V2	V3	V5	V6	V7	V8	V9	V11	V12	V14	V15	V16
(m)	(m)	(Ohm-m)	(Ohm-m)	(Ohm-m)	(Ohm-m)	(Ohm-m)	(Ohm-m)	(Ohm-m)	(Ohm-m)	(Ohm-m)	(Ohm-m)	(Ohm-m)	(Ohm-m)	(Ohm-m)
0.5	1.6	601.61	1661.86	452.11	453.56	772.87	439.78	672.00	243.11	425.99	398.41	586.37	176.35	179.25
0.5	2	521.89	1264.09	285.10	464.17	692.72	393.48	587.87	189.55	397.02	282.74	424.11	170.47	139.96
0.5	2.5	301.97	782.25	180.01	373.97	524.01	268.98	456.16	165.87	317.05	157.77	293.86	145.52	93.30
0.5	3.2	188.62	567.43	139.97	311.02	472.65	239.46	342.09	152.53	263.63	95.72	236.01	107.96	61.54
0.5	4	89.06	279.56	108.36	256.80	400.00	124.69	150.91	98.76	191.98	37.16	132.61	81.64	36.71
0.5	5	33.43	111.97	72.23	216.93	367.78	80.55	75.50	64.22	155.12	16.25	56.45	54.43	22.00
0.5	6.3	20.93	38.41	41.51	173.84	286.22	32.83	27.63	38.16	67.16	5.08	19.80	29.74	10.28
0.5	8	12.96	17.02	30.24	121.77	230.12	11.82	7.21	17.44	30.24	1.60	3.44	12.02	4.21
0.5	10	6.80	9.40	18.00	79.91	317.45	3.76	2.51	6.99	8.46	0.39	1.25	6.27	1.57
0.5	13	6.47	4.52	14.31	51.95	318.08	3.18	0.90	1.75	0.09	1.18	0.53	2.99	1.00
0.5	16	13.66	3.80	14.46	15.27	270.00	4.02	0.30	1.12	0.07	0.36	0.50	1.89	0.90
0.5	20	6.00	3.50	15.07	8.79	200.00	6.80	0.09	0.94	0.08	0.24	0.70	1.18	0.95
5	20	5.50	3.40	15.00	9.47	200.00	6.83	0.09	0.94					
5	25	6.22	2.47	13.01	2.72	210.00	10.00	0.08	0.75	0.17	0.19	0.80	0.94	1.07
5	32	8.00	2.42	9.42		194.27	10.00	0.09	0.70	0.31	5.30	0.80	0.63	1.16
5	32						9.00							
10	40	6.93	2.36	7.07	0.24	185.05	7.00	0.20		0.49	2.45		0.60	1.18
10	40						7.00	0.20	0.94	0.49	1.18	0.90	0.60	
10	50	18.66	3.10	5.50			2.00	0.30	1.13	0.75		2.64		
25	50	18.00					2.00	0.30	1.22				0.60	0.75
25	63	20.00	4.25	4.25			1.00	0.20	1.20		0.75	6.08	0.70	0.61
25	80	19.79	4.95	2.97					1.56		0.61	9.90	1.00	
25	100	15.55	4.67	2.02									2.00	

Table 4 3: Raw Field VES 17-28 Data

MN/2	AB/2	V17	V18	V19	V20	V21	V22	V23	V24	V25	V26	V27	V28
(m)	(m)	(Ohm-m)	(Ohm-m)	(Ohm-m)	(Ohm-m)	(Ohm-m)	(Ohm-m)	(Ohm-m)	(Ohm-m)	(Ohm-m)	(Ohm-m)	(Ohm-m)	(Ohm-m)
0.5	1.6	1062.43	497.832	443.40	1010.18	738.04	4.79	1164.03	428.16	163.28	200.29	515.25	511.62
0.5	2	477.126	409.975	411.15	851.76	580.80	1.99	888.28	313.37	129.00	147.97	380.52	349.89
0.5	2.5	354.369	318.178	350.41	546.63	334.77	1.17	672.92	225.06	92.55	94.44	294.43	246.36
0.5	3.2	246.68	308.507	286.85	402.97	261.12	1.13	316.04	160.00	58.22	46.48	178.21	178.26
0.5	4	181.591	248.883	192.97	200.39	187.03	1.04	200.00	107.37	31.67	15.54	107.91	129.14
0.5	5	135.292	184.277	90.00	109.63	152.86	0.93	147.73	80.86	20.92	7.00	75.12	103.41
0.5	6.3	102.84	128.612	39.77	41.38	131.71	1.12	70.62	65.67	10.78	1.86	50.00	66.91
0.5	8	62.0853	80.9111	28.44	11.22	93.93	1.00	20.03	36.05	4.21	0.80	23.00	42.06
0.5	10	40.6129	49.5127	17.14	4.00	57.97	1.25	10.00	21.94	1.57	0.63	10.00	21.94
0.5	13	25.0226	25.9768	8.91	1.00	33.93	1.59	5.30	10.60	1.06	0.60	1.85	9.80
0.5	16	12.9999	14.4622	5.00	0.15	14.46	1.61		8.03	0.80	0.80	0.87	7.26
0.5	20	5.43099	5.8899		0.11	5.18	0.64	4.00	6.60		1.00		
5	20	5.27784	5.89044	3.20		5.18	0.24	4.00	6.60	0.71		0.50	3.77
5	25	2.33733	2.60122	2.60	0.12	2.64	0.19	3.77	6.14	0.94	1.10	0.50	2.00
5	32	1.40005	1.56921	2.42	0.23	2.20	0.35	4.50	5.20	1.00	1.02	0.45	0.91
5	32							4.50		0.94	1.02	0.45	
10	40	1.33001	1.48439	2.47		1.98	0.30	3.30	4.00	0.94	0.47	0.50	0.70
10	40	1.33996	1.48439	2.50	0.38	1.98	0.47						0.69
10	50												
25	50	1.50795	1.42502	3.58	0.40	1.98		2.26	1.51	0.80		0.38	0.52
25	63	1.58011	2.29724	6.08		2.30		0.61		0.49		0.24	0.50
25	80	1.01928	2.49378	9.90		2.49				0.20			0.52
25	100	0.31102	3.91879			3.92							0.49

Figure 4-8: Lumped Raw Field VES 1-28 curves



The true resistivity of the geological layers derived from the interpreted geophysical data obtained at the various VES sites are tabulated above. These results indicate that the subsurface geological formations are quite permeable and the sedimentary formations are intercalated with weathered coral zones, clays and shales. These zones are likely to be old land surfaces (OLS) which formed in between different episodes of depositional history. The curves have similar shape except VES_6 and VES_22. This implies that the project area is homogenous and comprises of Sand dunes, Raised Coral reef and Marine sands & clays of the Magarini sands in that stratigraphic succession.

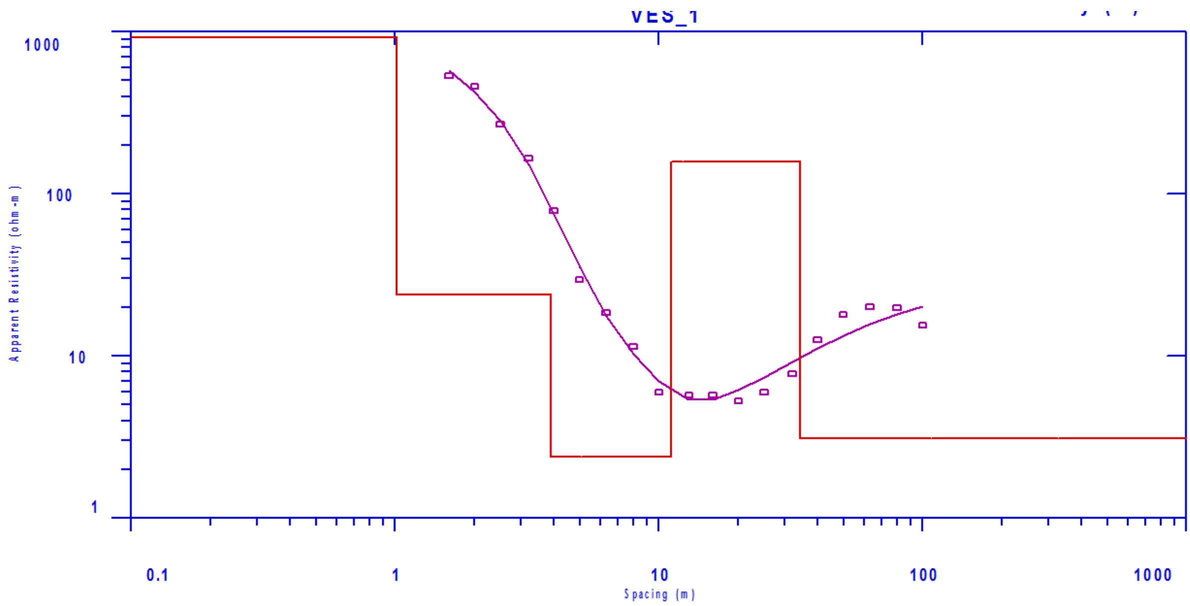
The interpreted geophysical data indicates that the general area in which the coal power project is going to be constructed has the following characteristics:

- The subsurface geological formations are highly weathered and most of the layers have true resistivity of less than 980 Ohm-metre.
- There are shallow aquifers of between 3 and 5 metres below ground level and deeper aquifers of between 10 and 35 metres below ground level.
- The upper sub-surface geology is vulnerable to the infiltration of pollutants from coal ash yard and hydro-carbon pollutants in the event of leakage of petroleum hydrocarbons from heavy vehicles operating in the project area during construction which could lead to the local aquifer systems being contaminated.
- The formation strength is comprised with unconsolidated sands, clays and coral limestone weathering, sands and shales.

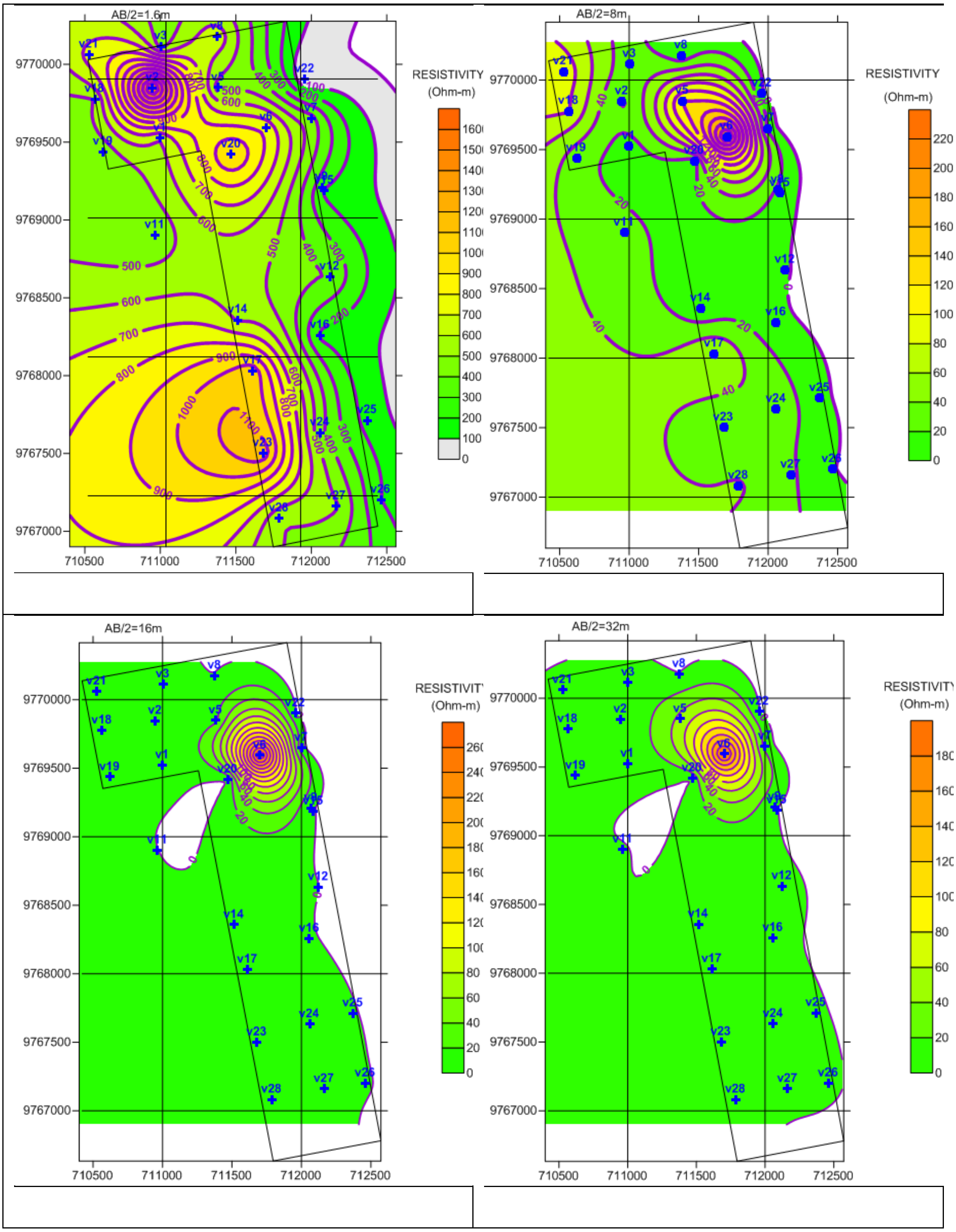
Table 4-3: Results of the interpretation of field data at VES_7

Layer No.	Depth (m)	Thickness (m)	Resistivity (Ohm-m)	Lithology
1	0-1.02	1.01	925.7	Fine Dry Sandy soil
2	1.02-3.88	2.87	23.96	Compact clayey sands
3	3.88-11.11	7.23	2.39	Moist Clayey sands
4	11.11-34.18	23.06	158.33	Weathered Coral limestone
5	>34.18	-	3.12	Moist saline clays/shales

Figure 4-9: Modeled curve and data at VES_7. It represent the rest of the VES surveyed



#	Rho	Thick	Depth
1	925.71	1.0160	1.0160
2	23.960	2.8650	3.8811
3	2.3945	7.2313	11.112
4	158.33	23.064	34.176
5	3.1159		



The geophysical data and map above shows that high resistivity unconsolidated fine sands observed towards the north-west and to the south-west of the project area and are at their thickest at and around VES_6. Below this formation is the compact find sand. For depths of AB/2=8m to over AB/2=32m, the formation comprises of highly weathered coral limestones and/or clays in saline water. VES_6 is highly permeable and a potential fresh water site that requires further investigations, drilling and protection from contamination.

4.3 Hydrogeological assessment

The hydrogeology of the project area is governed by the climate, geology, soils and drainage system. Climatic data is obtained from Lamu Meteorological Station No. 9240001. Lamu area has a wet and humid tropical maritime type of climate. This type of climate is responsible for the dense forests cover as well as the mangrove forest near the ocean.

Average annual rainfall data for the period from 1993 to date is about 1000mm. The lowest rainfall observed was 684mm in 2012 and the highest was 2242mm in 1996. Monthly variation has the typical bi-modal distribution with mean long rains depth of 250mm in May and the short rains depth of about 100mm in November. The months in between have minimal rainfall and are drier.

Figure 4-3: Climatology of Mean Monthly Rainfall

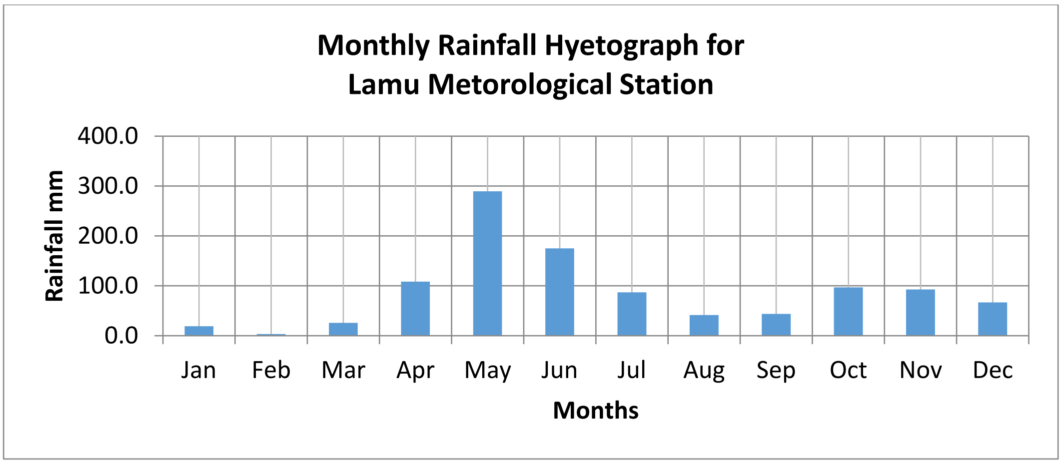
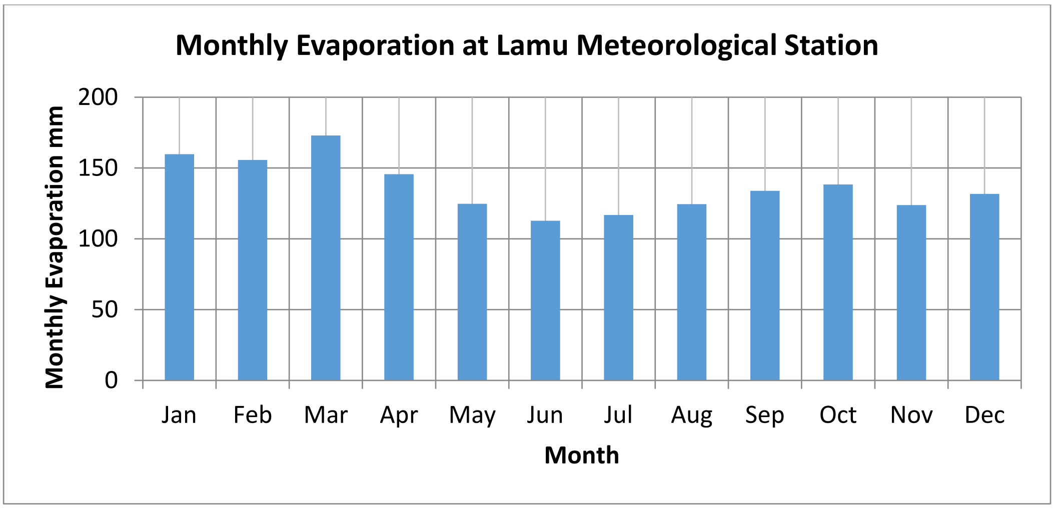


Figure 4-4: Monthly Evaporation



Relative humidity is high ranging from about 65% in the rain seasons to above 80% in the drier months and annual mean evaporation exceeds 1600mm. Mean annual evaporation is therefore higher than mean annual rainfall.

Seasonal storms have high intensity and are often accompanied by thunderstorms. The outcome of such heavy rainfall is localized water logging and flooding of the floodplain. Pools of standing water and ponds are left after rains. These make up for the limited drainage system comprising mainly seasonal streams and shallow but intermittently flowing water into the Indian Ocean. There are no perennial rivers in the area.

4.4 Hydrogeological survey

The objective of the present investigation is summarized as follows:

- To determine the approximate extent of the fresh water aquifer, the recharge and movement of water within the aquifer.
- To determine the approximate reserves of fresh groundwater available for abstraction within the project area and nearby areas.

Figure 4-4: Log samples from core drilling site 2 showing fine sands (By Chinese Geotechnical Team, 2015).

4.4.1 Hydrogeology of the project and its environs

The study area is covered by superficial soils and marine sediments. The oldest rocks are Tertiary limestones and are largely covered by Quaternary limestones. Marine sands and clays occur in a belt varying from 16 to 24 km wide, sub-parallel to the present coast-line. Their surface is covered by sandy soils which are fluviatile in character. The Quaternary marine sediments contain raised coral reefs and wind-blown dunes sands which are often red in colour. These outcrop between the Tertiary sediments and the present coast. The Pleistocene sands and clays, like those of the Tertiary, were probably deposited under deltaic conditions in this region.

The Quaternary soils are usually grey sands and clays outcropping over the Tertiary marine sediments. Black cotton soils are present along drainage channels and are also found overlying the Tertiary and Quaternary sediments along the drainage channels. Red soils in the area may be merely better drained variants of the common grey sandy soils but they may also represent tertiary dunes or valley deposits. The alluvium of the Tana River Valley is of Quaternary age.

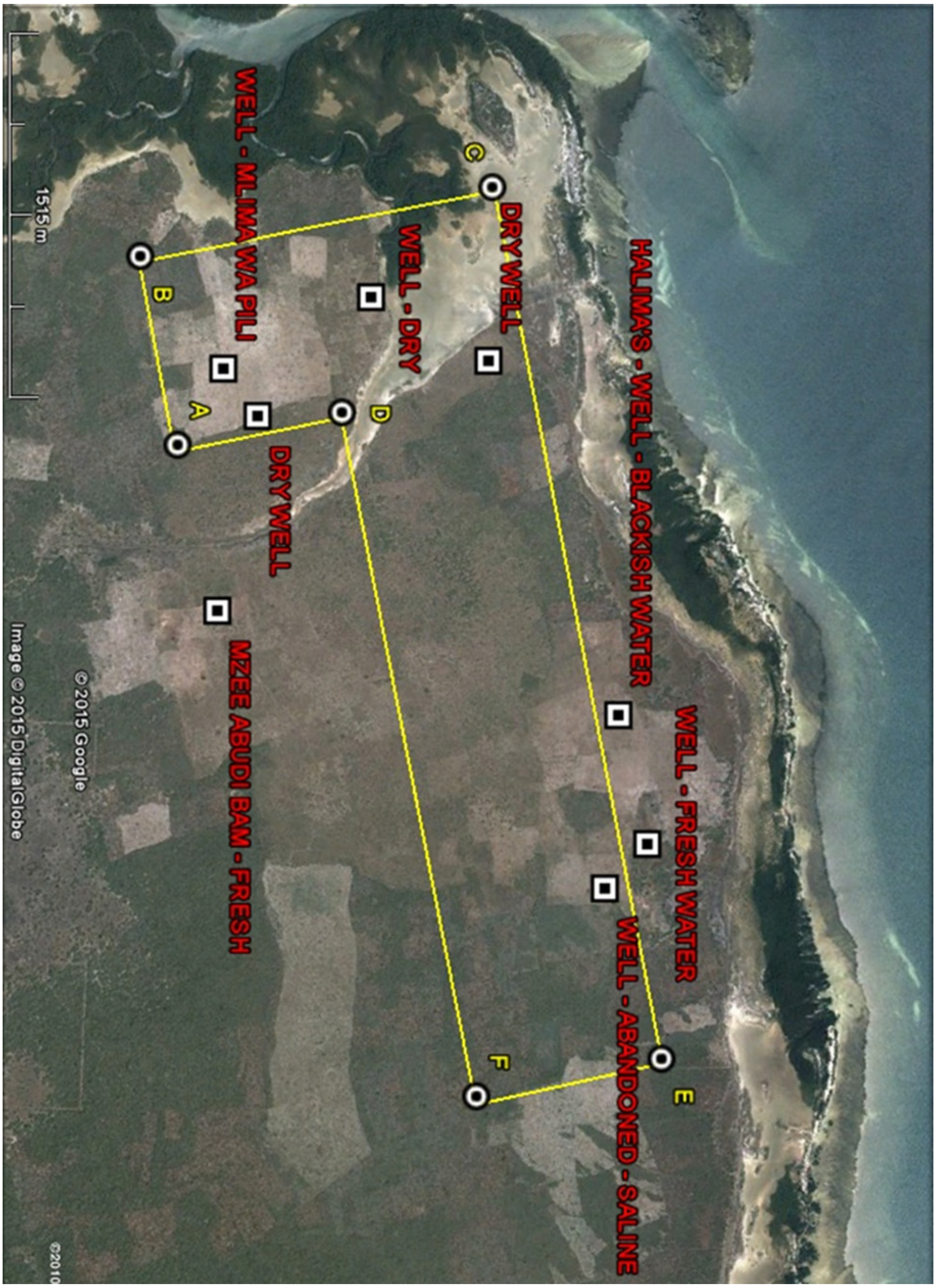
Generally, aquifers are unconfined and found at relatively shallow depth (10-15 m bgl). Aquifer replenishment occurs primarily from direct local rainfall and in rare cases indirectly as groundwater inflow from poorly established surface run-off. The hilly (sand dunes) and flat topography characterized by permeable top sandy soils offers the most appropriate setting for maximum recharge and the only limiting factor is the amount of rainfall, which is moderate in this area.

The water table slopes gently towards the coast (sea), at a gradient of about 0.001 to 0.005 (1-5 metres per kilometre). Whereas water will be encountered anywhere below the sand dunes, saltwater intrusion is a serious problem. In addition, wells should be relatively shallow, in order to keep sufficient distance to the fresh-saline interface. A conservative approach to drilling and pumping seems to conflict with the common desire to obtain as much water as possible. However, it is always in the best interest of the authority in-charge to wisely manage the available groundwater resources, instead of over-exploiting it.

4.4.2 Hydrogeological survey Results

The main topographical features include coastal Island and Dudol plains, sand dunes and the Indian Ocean. The county enjoys two rainy seasons and temperatures ranging between 20^0 and 30^0C throughout the year. The county has four major catchment areas categorized as Dodori coastal zone, Dudol, Lamu bay drainage and Tana River Delta. Water supplies in Kwasasi and the project area is obtained from about 15 hand dug wells which provide water of variable quality depending on season. After the wet seasons, the water tends to become bitter due to seepage from swamps and solutions of salts from clays and seawater intrusion. In drought seasons the well water becomes increasingly brackish and wholly inadequate for even household supplies. The alternative at such dry seasons is from Hindi wells at a cost of KShs 120 per 20 litres container.

Figure 4-10: The status and location of shallow wells within and near the project area.



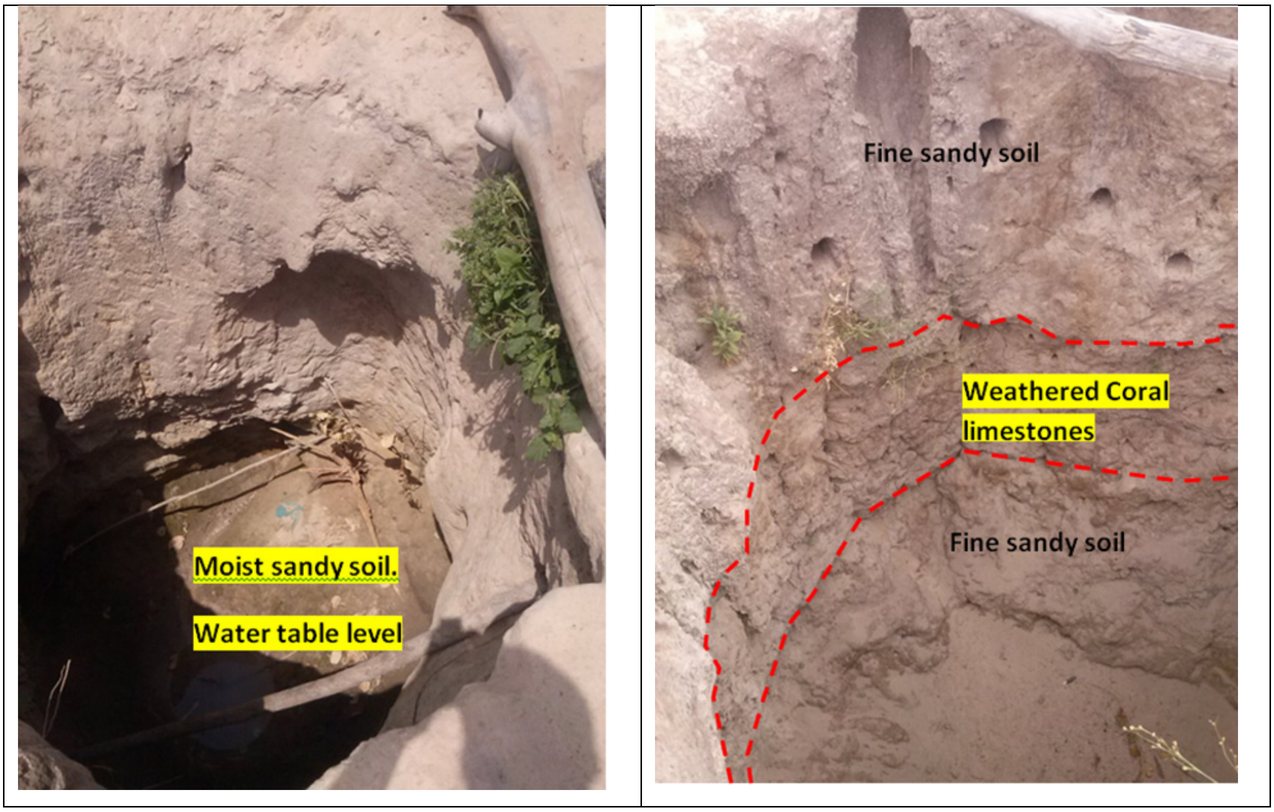


Figure 4-11: A shallow well within 10km that survives the driest time of the year.

4.5 Existing surface and groundwater sources

4.5.1 Hindi-Magogoni Sub Aquifer

Hindi-Magogoni sub aquifer serves as the water source for the residents of Hindi-Magogoni Settlement, an extension of the older Lake Kenyatta Settlement. The water provider in the area is Hindi Magogoni Water Users Association (HIMWA). Five boreholes have been drilled of which four are operational. One borehole is not in use because of the high fluoride level. The five boreholes are located close together, hardly 500m apart. The high fluoride level in one of the boreholes and not in the other four is, therefore, rather intriguing. The groundwater in this area also has hydrogen sulphide. No salinity problem has been reported in the area.

4.5.2 Chomo Sub Aquifer

Chomo sub aquifer is the source of water for Mokowe water supply, run by Lamu Water and Sewerage Company (LAWASCO). The Navy also gets its water from this supply. Three boreholes have been drilled in the area. The three boreholes have turned saline but are still being operated. Chemical analysis of a water sample taken from Chomo swamp showed that the water was fresh but would require conventional treatment to make it potable.

4.5.3 Baragoni Swamp

Baragoni swamp is proposed to be the source of water for the Baragoni water project which is under construction. Chemical analysis of a water sample from the swamp shows the water is fresh (TDS 154 mg/l) but would require conventional treatment to make it potable.

4.5.4 River Tana

River Tana is brown coloured and very turbid as it nears the Indian Ocean. A sample for full chemical analysis was taken at Kipini, near the river mouth. The results showed that the water was severely saline (TDS > 2000 mg/L), with a TDS of 3,125 mg/L. This is an indication that the river had already considerably mixed with the Indian Ocean water at this point. Conventional treatment, therefore, would not be sufficient to make the water potable. It would therefore be advisable to explore a location higher upstream the river for abstraction for the proposed Lamu Coal Fired Power project. Even then, it would be very expensive to remove turbidity by coagulation if the water were to be treated directly from the river. It would therefore be advisable to explore the use of infiltration galleries for water treatment.

4.5.5 Indian Ocean

The Indian Ocean, as a water source, is unlimited in quantity but unfortunately very saline. Desalination would be required to make the water potable. A large scale desalination plant would be ideal to meet the water demands.

4.5.6 Groundwater

The table below shows the groundwater condition within Hindi, Mokowe, Baragoni, Magogoni and Kwasasi project area.

Table 4-4: Data of boreholes near the study area

Borehole No.	Borehole Name	Total Depth (m)	Water struck level (m)	Water rest level (m)	Pumping Water Level (m)	Discharge (m^3/hr)	Ec (µS/Cm)
Bernard	Within Project	5	-	3	-	-	Saline
Abudi Bam	Within Project	5	-	drying	-	-	Fresh
Halima's	Within Project	5	-	4	-	-	Fair
Mlima wa Pili	Within Project	6	-	dry	-	-	Fresh
Mlima wa Pili	Within Project	3	-	-	-	-	Fair
W1	Hindi 1	20.0	3.27	2.05	4.11	22.22	-
W2	Hindi 2	20.0	15,16	5.6	15.39	7.10	-
W3	Hindi 3	17.75	14	3.04	12.13	16.36	-
W4	Hindi 4	17.89	14	2.09	8.95	17.10	-
W5	Hindi 5	18.0	5,16	2.8	5.45	21.05	-
Bellebelle II	Hindi	19	5	4.45	4.80	18.90	-
Bellebelle I	Hindi	15	8	4.94	5.60	18.50	-
C-8871	Mokowe	11	8	7.1	-	-	800
C-8872	Mokowe	21.5	10	9.88	-	-	1450
C-8873	Mokowe	17	11.5	8.34	-	-	1200
C-8874	Mokowe	17	8.5	8	-	-	2100
C-8875	Mokowe	14.6	10	9.25	-	-	3200
C-8876	Mokowe	12.5	6.5	5.4	-	-	9800
C-3223	HINDI	47	-	-	-	DRY	-
C-3594	BARAGONI	26	-	-	18	-	-
Magogoni	Chomo IV	44	42	-	-	-	-
Magogoni	Chomo VI	23	8	8.77	12.0	3.18	-
Magogoni	Chomo III	24	7	8.4	13.10	12.00	-

Generally, the drilled depths range between 5 and 44mtres (amsl), while water rest levels ranges between 3 to 10 m (amsl). The tested yield of boreholes ranges between 3.00 and 22.00m^3/hr, while water quality is fresh for shallower aquifers and shallow well, but turns saline if drilled deeper. Shallow wells depth (3-15 m bgl) within the project area dry up and water quality deteriorates with progression of the dry season. No boreholes within the Kwasasi area and/or a detailed study done for groundwater assessment. From the on-going, groundwater is not the best solution as water source to the coal fired project.

5 Impact Assessment

5.1 Impact in respect to hydrogeological flow regime

Topographic maps and DEM contour mapping has shown that elevation differences between the upper reach and the lower parts of the drainage system in all watersheds delineated in the project area is low. The altitude of the highest point is about 20masl and lowest the ocean at 0m (amsl). Mean elevation is about 15masl. The highest points are generally about 20 kilometers inland. The slope is therefore very low at 0.1% - 0.2% in more than 50% of the landscape. Most of the watersheds are rather flat and have wide floodplains with soils that may not be able to drain all waters generated in the watershed.

Intense and heavy storms of over 200mm in a day are very common in the wet season. This amount of rainfall has potential to generate enormous volumes of flow which are likely to cause water logging, flooding and bank erosion and rise in groundwater level. According to the flood mapping, this will certainly happen in the middle and lower reach with the consequent of enhance transport of particulate matter, river bank erosion and effluents attenuation thereby enhancing pollution. However, due to the porous nature of the top unconsolidated sandy soil, most of this water drains into the sea thus leaving very little water for abstraction through sinking of shallow wells.

5.2 Predicted Impacts and Mitigation Measures

The potential impacts on the hydrogeological environment from the proposed development, in the absence of suitable mitigation measures, are considered to be as follows:

- Direct impacts of the Coal Fired Power Plant construction on the hydrogeological environment due to contamination of surface water from the spillage/leakage of fuels from vehicles and fuel/chemical/waste storage areas.
- Direct impacts from excavated areas where vegetation has been removed and/or compacted by heavy earth moving equipment. This has the effect of releasing silt or sediment laden surface water runoff into local watercourses and enhances soil erosion from loose excavated soil and therefore facilitating fast seepage into the underlying layers.
- Direct impacts of Coal Fired Power Plant operation on the hydrogeological environment since coal Plants operation produces waste water, oils, and leaks from storage areas which may reach surface water and cause pollution to the resource.

In essence, the predicted impacts on the hydrological setting of the project area concern all phases of Power Plant development namely the Construction Phase, Operational Phase and Decommissioning or Post - Operation Phase. The impacts and mitigation measures differ from phase to phase.

5.2.1 Predicted Impacts - Construction Phase

During project development phase work involves site preparation and construction activities. Land is cleared of vegetation and terrain shaping using heavy machinery such as earth movers, lorries and so on. This activity modifies the drainage pattern because the vegetative cover of the soil is removed together with the compacted soils. There is increased surface water runoff due to the introduction of impermeable and permeable surfaces such as excavated site compounds and roads, and the compaction of soils. It also enhances sediment generation and transport. The overall infiltration capacity altered, thereby leading to an increase of the rate and volume of direct surface runoff and groundwater seepage. Consequently, the local drainage systems are modified and sometimes completely changed. In effect modification of the water course may increase channel erosion, sediment loading, flood risk, seepage of leachate from coal ash, temporally parking sites and workers' residential areas.

Plant operators require water to meet their domestic demands. Similarly, construction of working facilities; warehouses, garages and other structures use cement, ballast and sand as well as large volume of water for mixing and dust control. All these activities produce solid wastes and waste water of varying amounts. These demands create pressure on available supply leading to more abstraction to fill the demand supply gap. Further, waste water from the plant may contaminate available surface and/or groundwater.

Other activities that are likely to impact on the flow regime include construction of camp site and on-site housing, access roads, power line etc which have the effect of accelerating water speed velocity at bridge/culvert crossing and occasionally creating backflow and accelerated runoff downstream. The camp site and on-site housing creates conducive conditions for water logging, contamination from waste water and effluent from such sites. In addition, water logging may provide breeding sites for disease transmitting vectors.

Transportation, storage and handling of construction materials, fuels and chemicals and to and from the plant may pre-dispose water resources including ground water to contaminants when there are fuel leaks, spills and poor chemical storage and handling

5.2.2 Proposed Mitigation Measures – Construction Phase

This section outlines proposals for mitigation measures aimed at ensuring that the construction of the proposed development does not result in noticeable or significant negative impact on the hydrological environment. The measures should be implemented before, during and after the construction phase. These measures include but are not limited to the following:-

- Obtaining requisite Permits for Works from WRMA and NEMA.
- Developments along and inside watercourse should be approved by WRMA and a Permit issued for the same.
- Effluent discharge approval and permits should be approved by both NEMA and WRMA before commencement of works.

- Stockpiles must be managed to minimize potential for generation of silt laden runoff, leaks and spillage to safeguard impact on water quantity and water quality.
- Waste water treatment ponds with sufficient retention time be constructed to enable sufficient time for self treatment and settlement of suspended solids to settle from the surface water collected in the silt pond thereby minimizing potential for release of silt laden surface water into surrounding drains.
- Attenuation of release of surface water runoff from construction site to ensure that it does not result in localized flooding further downstream.
- When excavating, the trenches need to be open for the shortest practicable time to minimize potential for the generation of silt laden surface water runoff.
- Construction of Troughs and Acceptable equipment to arrest oils/fuels arising from accidental spills and/leaks to stop leakage towards surrounding groundwater courses.
- Regular inspection of dewatering drains to ensure that they work efficiently.
- Directing surface water runoff away from and around access tracks by implementing a suitably designed drainage system. Watercourse crossings to comprise culverts of suitable design.
- Dumping sites should be approved by NEMA and any other regulating body.
- Coal ash yard should be sealed by use of impermeable HDPE before use.

5.2.3 Predicted Impacts - Operational Phase

The predicted impacts of the proposed Coal Power Plant at its Operational Phase are expected to have significant impacts on the underlying hydrological environment during normal operating conditions. It will require enormous amounts of water for its cooling, cleaning of plants and tools and discharge thermal water among others to the environment.

Most water used in the life cycle of a vast majority of power generation technologies occurs during the operational phase. This phase places high demands for water for purposes of operation of cooling systems and cleaning among other uses. Condensed steam is returned to the boilers and re-cycled. The heated water is normally discharged back to the source water or nearest receiving water bodies (i.e., river, lake, estuary, or the ocean and injected underground).

If the demand is not satisfied, then it necessitates more water withdrawals from water bodies. The withdrawal of large quantities of water has the potential to compete with other important uses such as agricultural irrigation, livestock, recreation or drinking water sources.

This creates competition and conflict with other water uses and users. Plant demands, consumption and thermal discharges determine the level of impact and vulnerabilities to surrounding environment, water courses and water resources.

Heavy earth moving equipment dispose off materials emanating from dredging of ponds, while effluents discharges from cooling towers. This solid waste and waste water disposal may cause water quality degradation to receiving waters and into ground water recharge aquifers through leaching and percolation. Gaseous products, carbon dioxide, sulfur dioxide, water vapour and other combustion products etc emitted by the coal fired plant into the atmosphere may dissolve in rain water and fall back as "acid rain" in future.

In addition, routine inspection and maintenance of vehicles, is also likely to impact on the environment through minor localized contamination to groundwater water bodies in the unusual event of the leakage of oil/fuel from maintenance sites, vehicles and storage facilities. Vehicles plying access roads and tracks will loosen soils and generated dust and enhance erosion and silting of receiving water sources. These are however moderate impacts.

5.2.4 Mitigation Measures - Operational Phase

The mitigation measures proposed are aimed at ensuring that the operation phase does not result in noticeable or significant negative impact on the hydrogeological environment. The measures should be implemented before, during and after the construction phase. These measures include but are not limited to the following:-

- Thermal discharge should be designed to ensure that discharge water temperature does not result in exceeding prescribed ambient water quality temperature for receiving water bodies and avoid being detrimental to the surrounding ecosystem.
- A water recycling plant should be established alongside the development of the Coal Fired Power Plant to guarantee efficiency in steam from boilers, condensed water, waste water and other sources of water is re-cycled and re-used in the operation of the plant.
- Disposal of materials and other contaminants should be directed to dumping sites and treatment facilities to avoid contamination of water resources and wetlands.
- Routine maintenance and inspection of plants and equipment to avoid leaks and spills.
- Vehicles should be maintained to serviceable standards through routine maintenance and inspection.
- Access tracks should be constructed and maintained to best engineering standards to reduce erosion.
- Drainage systems must be designed with sufficient capacity to surface water during floods and any other accidental spills.
- Regular maintenance of bridges, culverts and road crossings to avoid localized flooding and water logging caused by blockages.

Gaseous emissions should meet air quality standards that ensure low concentration of gaseous products, thus avoiding "acid rains" seeping into the groundwater.

Implementation of these mitigation measures during the operational phase will result in long-term, slight and neutral impact on the hydrological environment.

5.2.5 Decommissioning/Post-Operational Impacts

Removal or decommissioning of structures and buildings involves demolishing of facilities, and transportation. Dust, loose soil, damaged structures, spills and solid and liquid waste characterize decommissioning phase. These activities lead to increased run-off, soil compaction and changes in vegetative cover. Sediment and associated contaminants is transported and deposited to river courses and impact negatively surrounding water courses and hydrogeological environment.

5.2.6 Mitigation Measures-Decommissioning/Post-Operational Impacts

Appropriate mitigation measures should be put in place to minimize negative impacts of decommissioning. Such measures should ensure minimum solid waste and erosion generation by implementing appropriate waste and water management practices.

5.3 Cumulative Impacts

Prolonged release of gaseous products may accumulate in the air and lead to acid rain precipitation with adverse effect on human health, flora and fauna thereby impacting negatively the environmental setting. It is important therefore that state-of-art technology is used in the development and operation of the plant. All emissions and effluents from the plant must meet safety standards that preserve hydrogeological environmental integrity.

However, if the proposed development were not to proceed, a status quo would be maintained and hydrogeological environment would remain at the current level.

6 Future Monitoring Requirements

Future monitoring should aim at comparing with (future) and without project (baseline) or prior to disturbance conditions to gauge impact of the project.

In order to be able to carry out this task a baseline scenario of the conditions before commencement of the project must be established.

A detailed evaluation of the current environmental setting in terms of ground water status, availability, distribution, quantities, water quality, sources, uses and users as well as stakeholder as well as an inventory of all stakeholders is therefore necessary.

In this regard, all nearby rivers, streams, wetlands, lakes, aquifers and other water bodies should be identified as well as current uses of the water.

The optimum drilling positions for any boreholes must be selected by a professional hydro geologist. It is important that the topographic setting, possible geological structures, etc., are considered during this phase.

Groundwater levels can be measured on a monthly basis and initial water quality samples can be collected and analysed for reference purposes. Thereafter on-going sampling of groundwater can be conducted on quarterly basis. The chemical analysis of water must include the following determinants: pH; Conductivity; Calcium (Ca); Magnesium (Mg); Sodium (Na); Potassium (K); Bicarbonate (HCO_3^{2-}); Chloride (Cl); Sulphate(SO2-); Nitrate (NO_3); Iron (Fe); Manganese (Mn).

Additionally, existing relevant historic hydrometeorological data in the area of influence should be collected, compiled and analyzed for development of standards and threshold for comparing trends in quantity, quality, timing as well as frequencies and fluctuations in space and time.

The thermal plant consumptive and non-consumptive uses by types and volume and water balance and needs should be assessed and quantified. Its waste water discharges, including thermal discharges data should be augmented by the results of a groundwater water quality monitoring program conducted at specific sites in the project area.

Indicators should be developed for continuous monitoring and evaluation (M&E) of changes in aquifer characteristics, flow characteristics, drainage patterns and run-off characteristics, soils, vegetation, impervious area, recharge areas etc. assist in gauging impact of the development.

To this end the site engineer and the project management should ensure that groundwater monitoring stations and discharge points are mapped and gauged regularly.

7 Mitigation measures and management plan

7.1 Construction phase mitigation measures

It is proposed that the access tracks be constructed of stone and laterite (murram) which should be well compacted in order to carry the weight of the expected heavy vehicles. This should consequently minimize the potential for soil erosion through surface runoff and also minimize the destruction of the soil structure, which could occur by the continuous use of these heavy vehicles on unsealed tracks. The tracks should be constructed in such a way as to allow for easy drainage of surface run-off on either side of the track. This will minimize the potential for water-logging and land slippage around the track. In sloped areas the drainage channels on the sides of the tracks should have concrete barriers at intervals of 30 to 50 metres (depending on the slope) to check erosion and deepening of the drainage channel.

Stockpiles of excavated materials should be stored appropriately in a designated area of the site at a minimum distance of 10m from any nearby watercourses or drains. Measures should also be taken to avoid rainfall on stockpile materials or exposed areas of ground resulting in slippage and washout of sediments into nearby drainage channels. As most of the excavated material is expected to be reused, the generation of significant quantities of surplus spoil is not expected. Excess excavation material should be removed from the site and appropriately deposited in a designated area where it will have minimal chances of being eroded into drainage channels. This would best be in a depressed area that does not have an outlet into the local drainage system.

The control of the generation of silt laden surface water runoff will be by means of the use of mitigation measures such as bunds, settlement ponds, silt fences or by covering the stockpiles with plastic sheeting. Any runoff from stockpiles will be passed through a silt trap or buffer zone prior to any discharge to local watercourses. Stockpiles will be sealed at a suitable gradient and grass planted, if stored long term.

The refueling of vehicles/machinery will be expected to be done offsite. Where necessary, construction machinery will be re-fuelled onsite by means of a mobile fuel bowser (comprising a double skinned tank) accompanied by trained personnel. Refueling operations will only take place at a designated, bunded area of hard-standing that is situated a minimum of 10m from surface water bodies. A spill tray and an emergency response spill kit will be brought onto the site with the mobile fuel bowser during refueling operations. Site personnel operating machinery or vehicles on the site will be trained in the use of emergency spill kits. The spill tray will be placed beneath the fill point of the vehicle and the emergency response spill kit will be used in the event of an accidental spill.

In order to minimize any adverse impact on the underlying subsurface strata from material spillages, all oils, solvents and paints used during construction will be stored within specially constructed bunded areas or suitable bunded lockable storage containers. Filling and draw-off points will be located entirely within the bunded area(s). Drainage from the bunded area(s) shall be diverted for collection and safe disposal.

It is recommended that areas affected during construction phase of the power project that will be outside the perimeter of each proposed facility be rehabilitated by planting grass. This will reduce potential of soil erosion. The overall area that will eventually be covered by the coal power facility and substation will be relatively small compared with the total project area and therefore the effect on the local population's livelihood.

Strict supervision of contractors will be adhered to so as to ensure that all plant and equipment utilized onsite is in good working condition. Any equipment not meeting the required standard will not be permitted for use within the site. This will minimize the risk of soils, subsoil and bedrock becoming contaminated through site activity.

7.2 Operational phase mitigation measures

The volume of traffic is expected to significantly decrease after the construction phase full operation of the coal power facility commences. The only vehicles expected will be those bringing the operators and maintenance crew and therefore there will be a decreased risk of spillage and leakage of oils, fuels and other contaminants from these vehicles.

However, it is recommended that routine checks are carried out around the coal power facility sites to ensure that any leakage of oil/petroleum from the maintenance vehicles and coal ash do not go undetected. A spill kit will be located within the depot to ensure that any minor leaks of oil and from coal ash are cleaned up immediately on detection.

7.3 Environmental management plan (EMP)

The purpose of an EMP is to ensure that social and environmental impacts, risks and liabilities identified during the EIA process are effectively managed during the construction and operation phase of the project. The EMP specifies the mitigation and management measures to which the proposer is committed, and shows how the organizational capacity and resources to implement these measures will be mobilized. The EMP also shows how mitigation and management measures will be scheduled.

The EMP for the hydrogeology environment will therefore be a part of the whole project EMP dealing with all the environmental components of the coal power project facility. The EMP will highlight the sequence of environmental audit by a qualified person to ensure implementation and compliance of all the mitigation measures recommended in the final EIS report.

8 Summary of Impacts and Mitigation Measures

Table 4 summarizes the expected impacts and mitigation measures at each phase of Lamu Coal Fired Power Plant development and Operation.

Table 8-1: Potential hydrogeology impacts and mitigation measures

Phase	Impact	Mitigation Measure
Development/ Construction Phase		
Water quantity	Modification of drainage pattern of streams, rivers and the crossings	Planning & implementing sustainable landscape management
	Enhanced stream flow due to changes in vegetative cover & soil compaction	Ensure minimal land cover disturbance
	Reduced flows due to source destruction; wetlands and swamps	Adhere to WRMA Permit Threshold Abstraction Approval
	Enhanced water consumption - extra demands for construction, domestic and plant cooling	Adhere to WRMA Permit Allocation Approval
	Depletion of nearby water sources due to enhanced demand	Maintain Water Balance & Demand Management Scenarios
	Enhanced source development	Development be guided by thorough Water Assessment Study
Water quality	Enhanced sediment, silt generation and contaminant transport	Planning & implementing sustainable landscape management, Construction of landfill sites and Waste water Treatment facilities
	Potential for spills and leaks due to enhanced activities on transportation	Inventory and construct hazardous material containment facilities & prepare and implement a spill prevention and

Phase	Impact	Mitigation Measure
		response plan including HR capacity building
	Potential for acid rain due to plant emissions	Limit emissions to acceptable standards; update & adopt to new efficient technologies
	Degradation due to plant effluent, waste water and human refuse	Construction of landfill sites, Waste water Treatment facilities and sanitation systems
Cross-cutting	Enhanced conflicts on allocation due to scarcity and competing uses and users	Assess availability, allocation and manage demand thro' Stakeholder consultation
Operational Phase		
Reservoirs for cooling water		
	Enhanced groundwater recharge through leaching and percolation	Continuous Monitoring and Evaluation of quantity, quality and impact to hydrological environment
Water quantity	Enhanced water withdrawals for plant operations, cleaning, effluent material conveyance and ash washout	Water Conservation Management: Water harvesting, recycling, waste water management and re-use, enhance water saving devises,
Water quality	Degrading due to contamination from dredged ponds, effluent from cooling systems, fuel spills and leaching, combustion products; ash, sludge and residue disposal	Construct landfills and Surface impounding reservoirs for high volume wastes, Dry handling, recycling of solid and liquid plant wastes
	Increased water temperature from effluent discharges	Recycling as much as possible and adhere to WRMA &EMCA Permit Thresholds for ecosystem integrity, adjust outfall location
Decommissioning/Post-Operational Phase		

Phase	Impact	Mitigation Measure
Demolition, removal and transport of machinery and equipment	Water quality contamination from disposal of wastes, spills and leaks	Adhere to Spill prevention and Response plan
	Enhanced soil erosion due to transporting activities	Optimize and minimize transport activities
	Enhanced runoff due to soil compaction and changes in vegetative cover	Direct runoff to surface impoundments and treatment works before discharge to receiving waters
	Enhanced sedimentation, silting and associated contaminants into river courses	
Restoration of terrain and vegetation	Reduced erosion	Positive response to be encouraged
	Improved water quality	
	Enhanced runoff and recharge	

ENVIRONMENTAL MANAGEMENT PLAN

IMPACT	**HYDROGEOLOGY/GROUNDWATER** The impact that the construction and operation of the development could have on Hydrogeology.
PHASE	**CONSTRUCTION**
MITIGATION / METHOD STATEMENT	***Sanitation*** 1. Adequate sanitary facilities and ablutions must be provided for construction workers (1 toilet per every 15 workers). 2. The facilities must be regularly serviced to reduce the risk of surface or groundwater pollution. ***Hazardous materials*** 3. Controlled use and or storage of materials, fuels and chemicals which couldpotentially leak into the ground. 4. All storage tanks containing hazardous materials must be placed in bunded containment areas with sealed surfaces. The bund walls must be high enough to contain 110% of the total volume of the stored hazardous material. 5. Any hazardous substances must be stored at least 20m from any water course. 6. The Environmental Liaison Officer should be responsible for ensuring that potentially harmful materials are properly stored in a dry, secure environment, with concrete or sealed flooring and a means of preventing unauthorised entry. 7. Contaminated wastewater must be managed by the Site Manager to ensure existing water resources on the site are not contaminated. All wastewater from general activities in the camp shall be collected and removed from the site for appropriate disposal at a licensed commercial facility. ***Cement mixing*** 8. Cement contaminated water must not enter the water system as this disturbs the natural acidity of the soil and affects plant growth. 9. The site must be managed in order to prevent pollution of drains, downstream watercourses or groundwater, due to suspended solids, silt or chemical pollutants.

	Ruptures 1. Installation of remote controlled and/or automatic shut off valves at regular intervals along the pipeline. It should be activated by pressure loss in the pipeline or activated on instruction when a major leak is noticed/observed. ***Water Flows Across Construction Sites*** 2. Adequate measures will be put into place to control surface water flows across and around all construction sites. 3. The quantity of uncontaminated stormwater entering cleared areas will be minimised by appropriate site design and by installation of control structures and drains which direct such flows away from cleared areas and slopes to stable (vegetated) areas or effective treatment installations. ***Hydro testing (if required)*** 1. In terms of hydro testing, abstraction from identified water sources, agreed with the Owner, will be used for hydro testing. 2. Any water discharge will have to comply with the water quality standards. 3. Both abstraction and discharge permits will have to be obtained. ***Stockpiles*** 1. Stockpiles should not be situated such that they obstruct natural water pathways. 2. Stockpiles should not exceed 2m in height unless otherwise permitted by the owner. 3. If stockpiles are exposed to windy conditions or heavy rain, they should be covered either by vegetation or cloth, depending on the duration of the project. Stockpiles may further be protected by the construction of berms or low brick walls around their bases. 4. The base should be lined with impermeable HDPE membrane to prevent leakage into the underground water.

9 Gaps in knowledge and uncertainties encountered

9.1 Gaps in knowledge

The geological set-up of the project area has not been studied and no previous literature on the same was available since the area was inhabited by wildlife and covered by thick vegetation.

9.2 Uncertainties encountered

It could not clearly be determined either from visual observation or from the geophysics conducted in the area whether the sink-holes and drying-up of the wells as well as increasing salinity with lowering of the water table in the few remaining shallow wells phenomena is also found in the subsurface. This has direct implication on the location of the facility and kind of foundations to be constructed. This however may be resolved by carrying out Geotechnical surveys for each location marked for a facility construction and water level monitoring from drilled boreholes/wells.

10 Conclusions

From the foregoing study of the Kwasasi area it may be concluded:

- That the project and nearby areas do not have adequate and sustainable water sources that can meet the over 2 million cubic metres of water required per day.
- That it is appropriate to use seawater from Manda Bay for generation of steam and distill part of the steam to meet the domestic water needs.
- That the main risk to the hydrogeological environment are during the construction and operation phases when there will be a lot of excavations for road track, coal power facility foundation, cabling as well as the operational phase when raw coal and coal ash stock piling commences and also cleaning of coal and piling up of coal ash and steam during operation phase. However if the proposed mitigation measures are implemented the residual effect on this environment will be slight.
- The Coal Fired Power Plant is expected to have minimal impact to the hydrological environment if the measures spelt above are implemented.

10.1 Recommended Future Monitoring Requirements

Monitoring required during the construction and operational phases will comprise monitoring of nearby surface and ground water quality and levels in order to ensure that the proposed works do not adversely impact on its quality via soil erosion. The site supervisor will conduct routine monitoring by visual means to ensure that the site works (vehicles, equipment and fuel/chemical storage areas) are not adversely impacting on the hydrogeological environment.

- That all mitigation measures at each phase of the project cycle should be implemented to safeguard the hydrological environment;
- That any negative impacts should be addressed immediately after detection;
- That all development must strictly adhere to Constitutional and legal provisions as spelt out by the Constitution of Kenya (CoK, 2010), Water Act 2012, EMCA Act, 1999 and WRMA Regulations including all other relevant Acts that safeguard environmental integrity.
- That all works, emissions, effluent discharges, waste water must meet requisite approved standards, necessary approvals and permits from relevant institutions.

11 References

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12 Appendices

- Map extract of Project Area: Map Sheet 180/2 – MOKOWE
- Contour maps
- Map extract showing location of boreholes, wells and water pans.

Figure 12-1: Location Map of the Project Site in Lamu Area (Map Sheet 180/2 - MOKOWE)

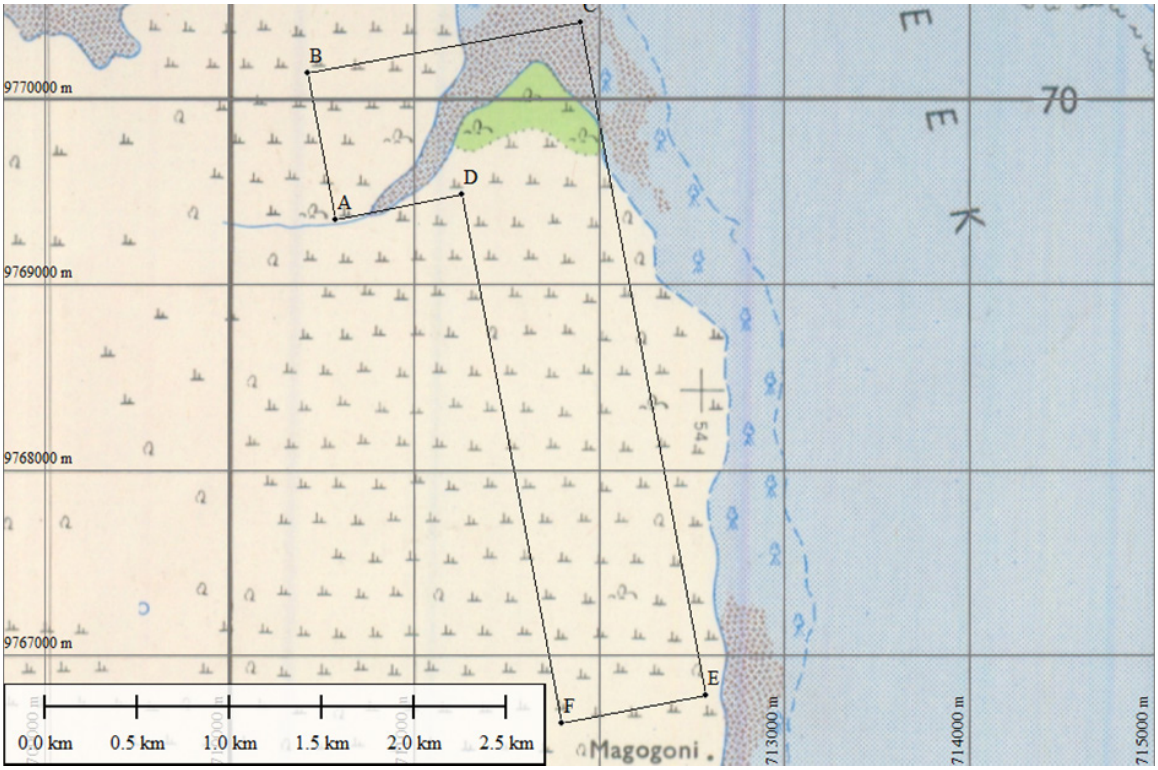


Figure 12-2: Some potential water sources and boreholes near the project area

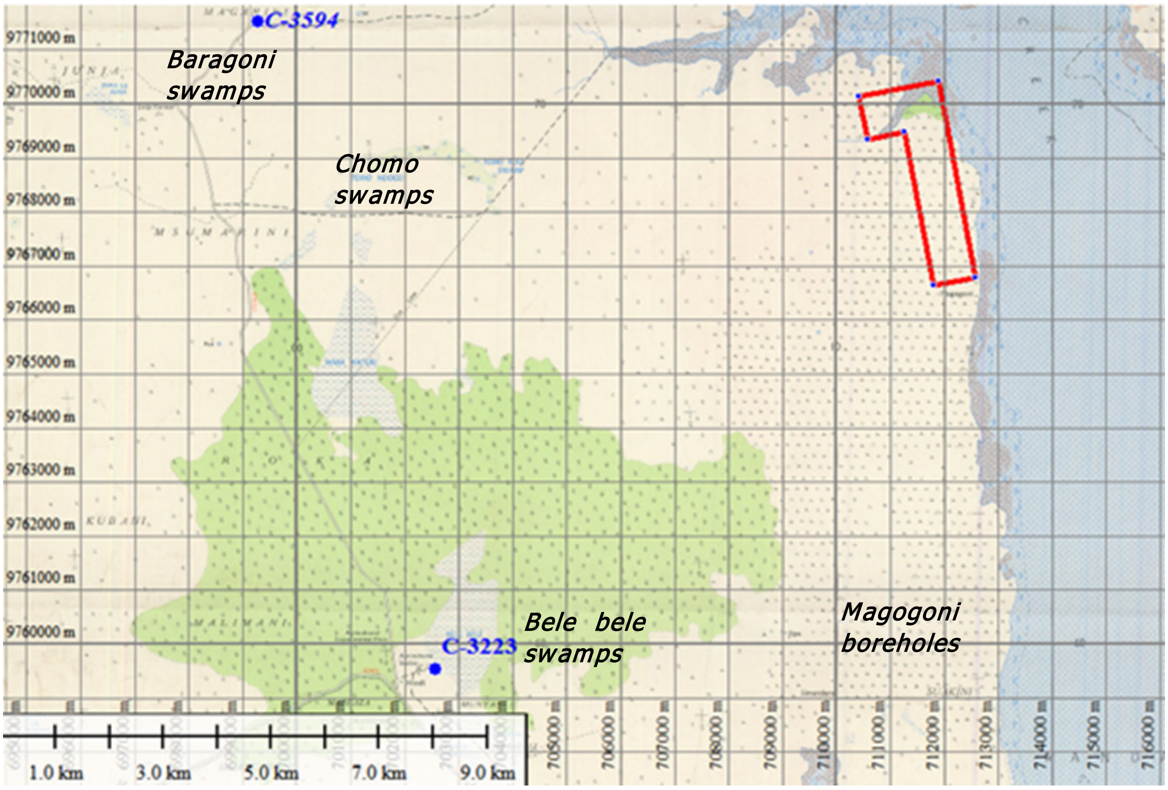


Figure 12-3: Location of seasonal shallow wells within the project area.

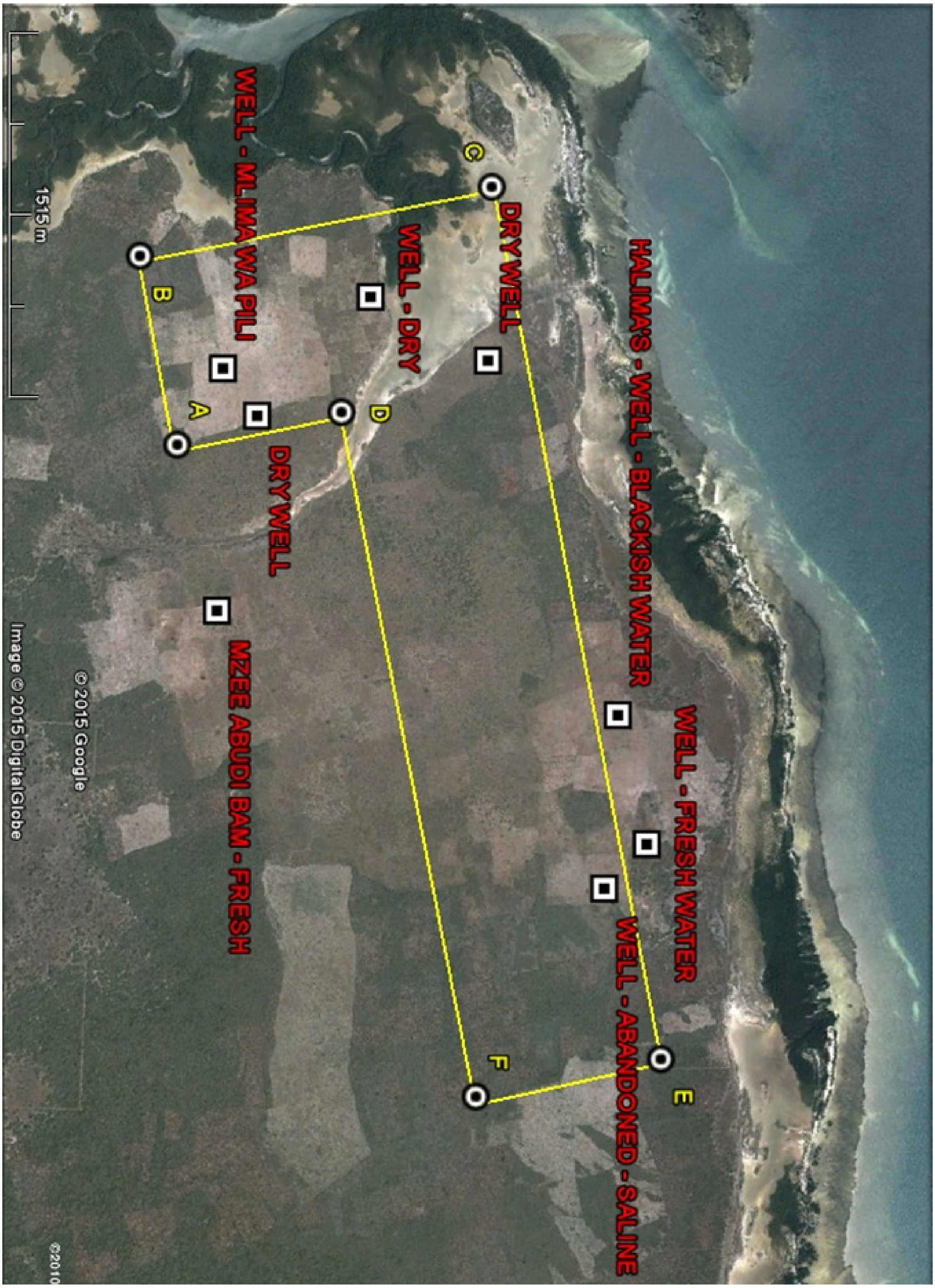


Figure 12-4: Terrain and contour levels of the project and its environs

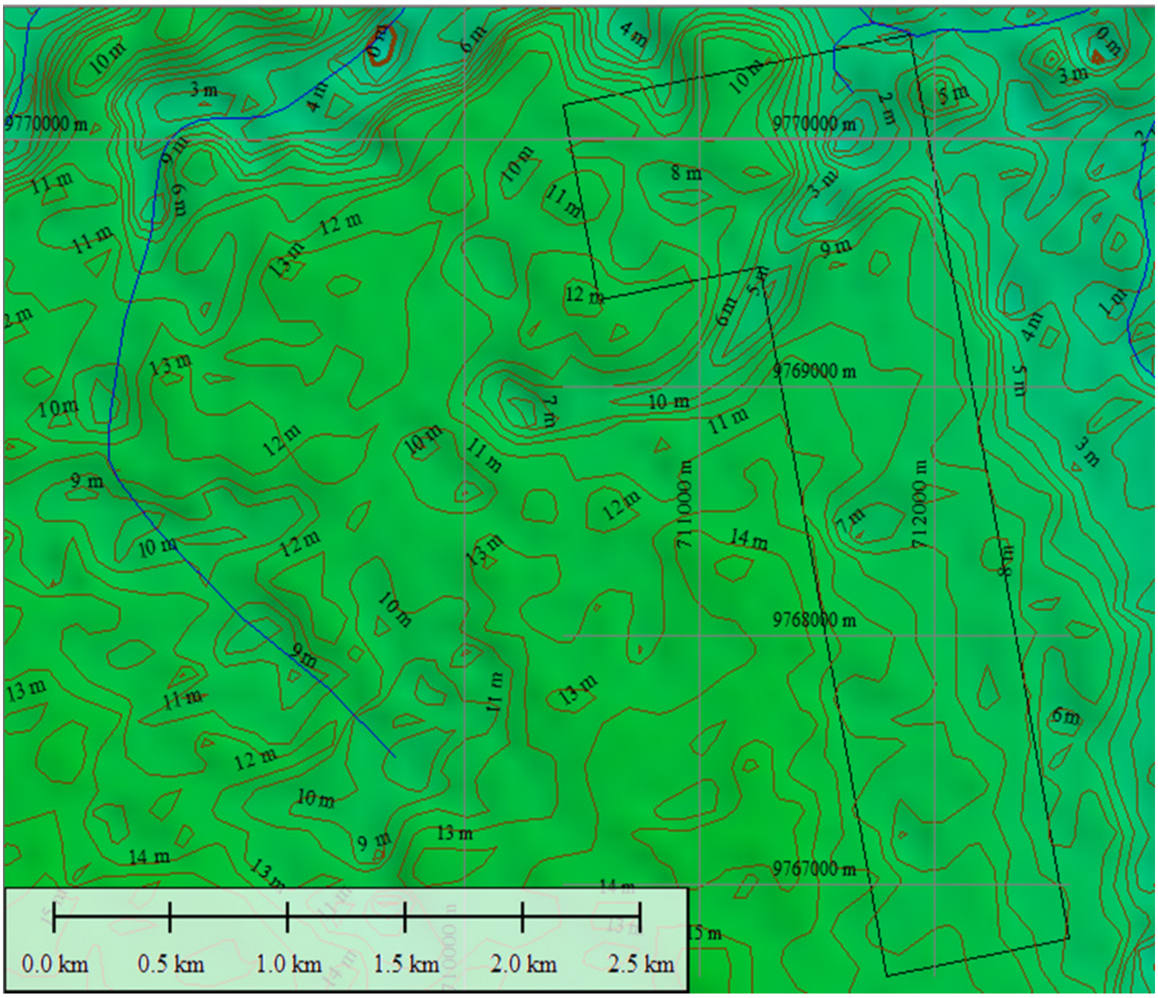
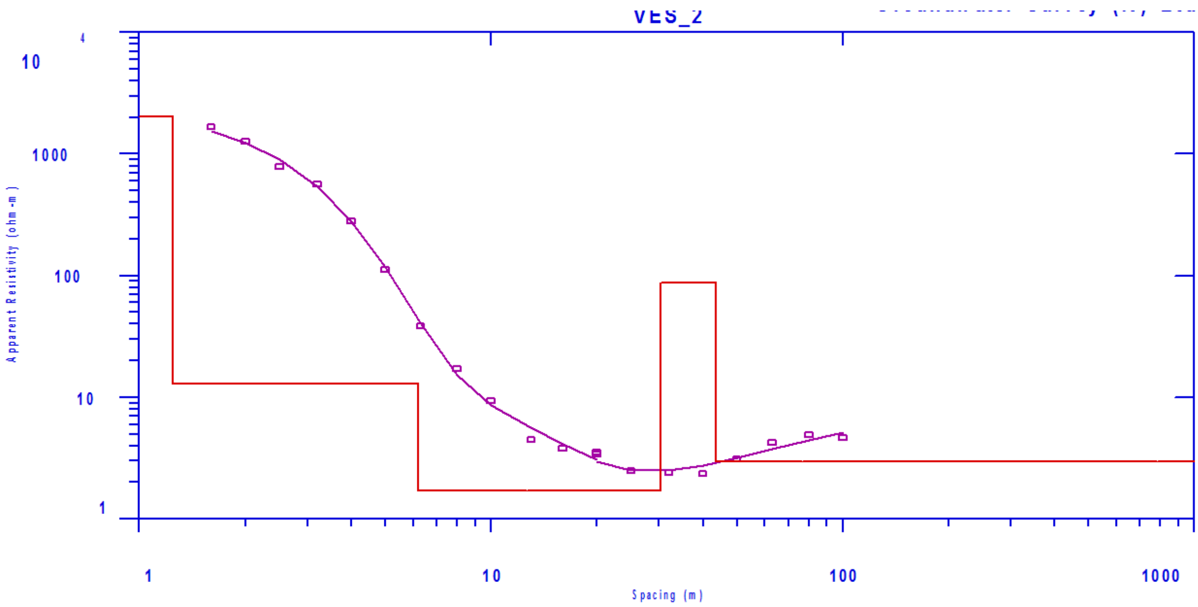
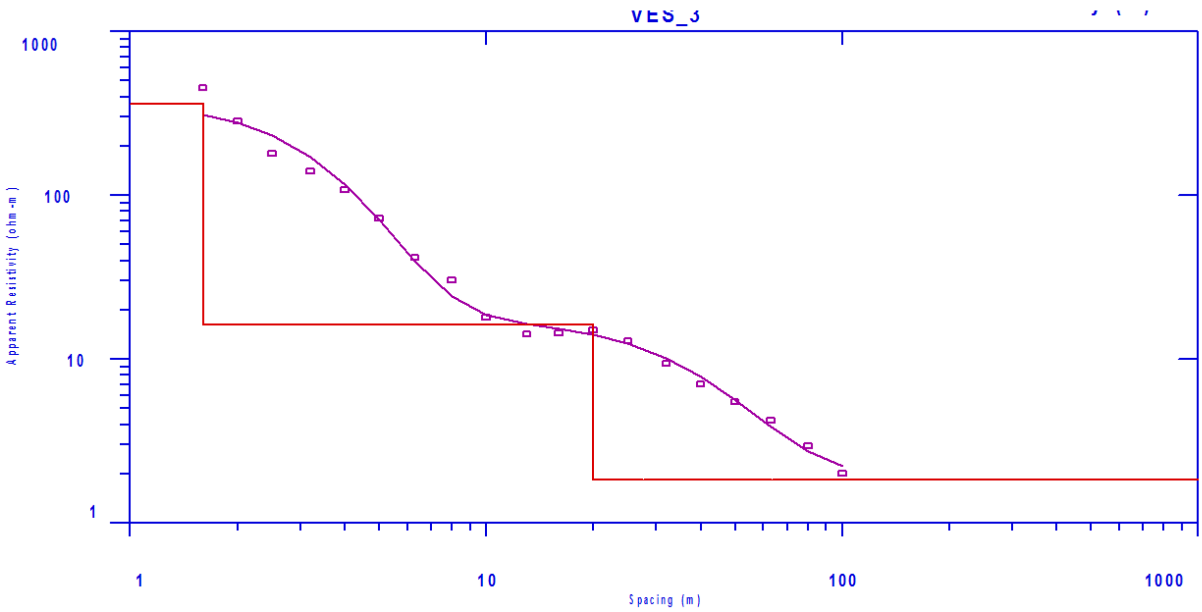


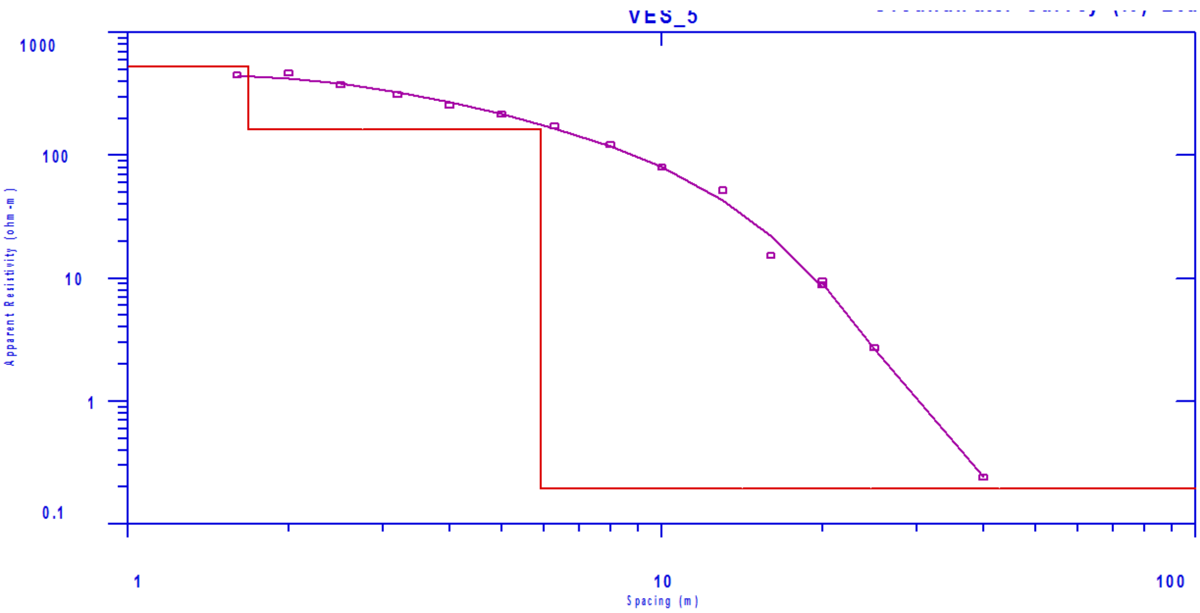
Figure 12-5: Modeled VES_2 to VES_28



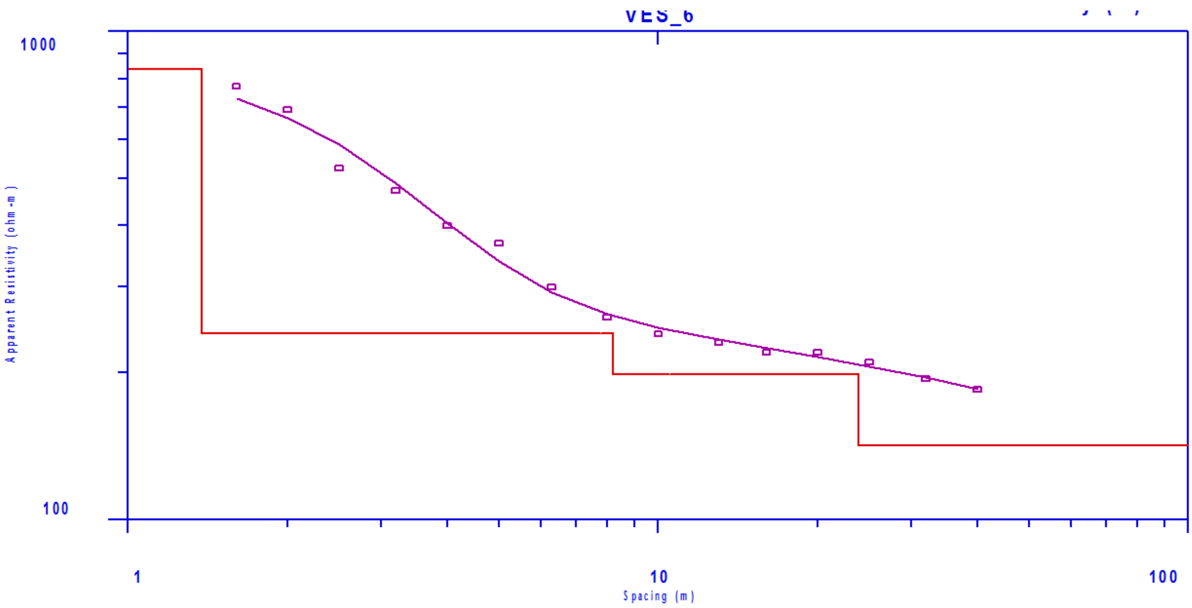
#	Rho	Thick	Depth
1	2028.3	1.2426	1.2426
2	12.808	4.9536	6.1962
3	1.7155	24.091	30.287
4	86.645	13.259	43.546
5	2.9416		



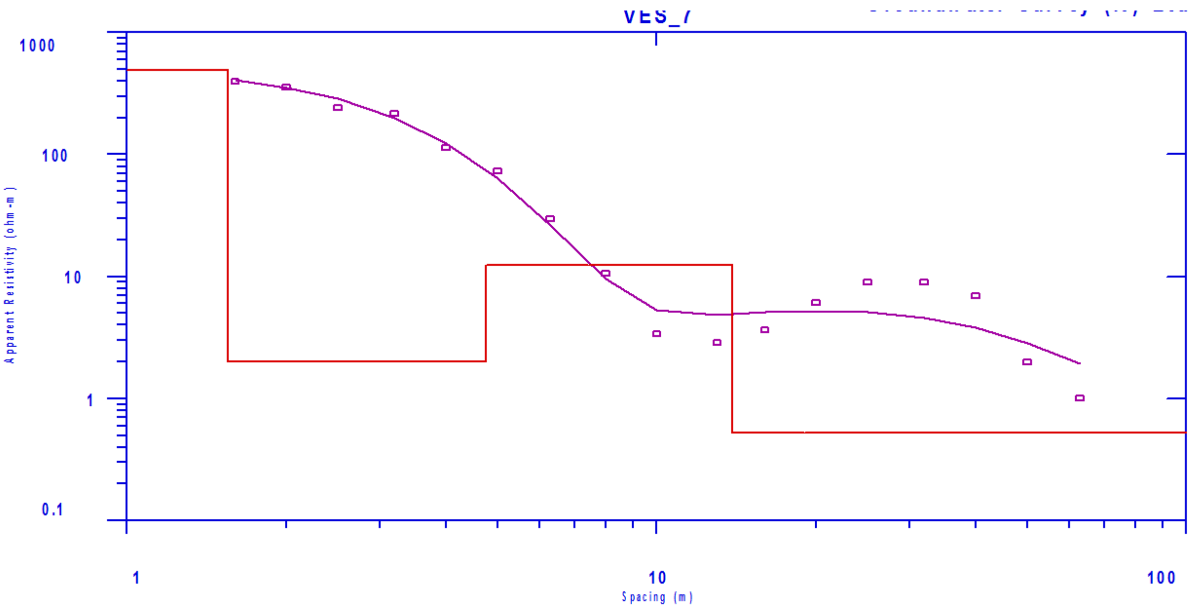
#	Rho	Thick	Depth
1	360.90	1.6051	1.6051
2	16.169	18.406	20.011
3	1.8288		



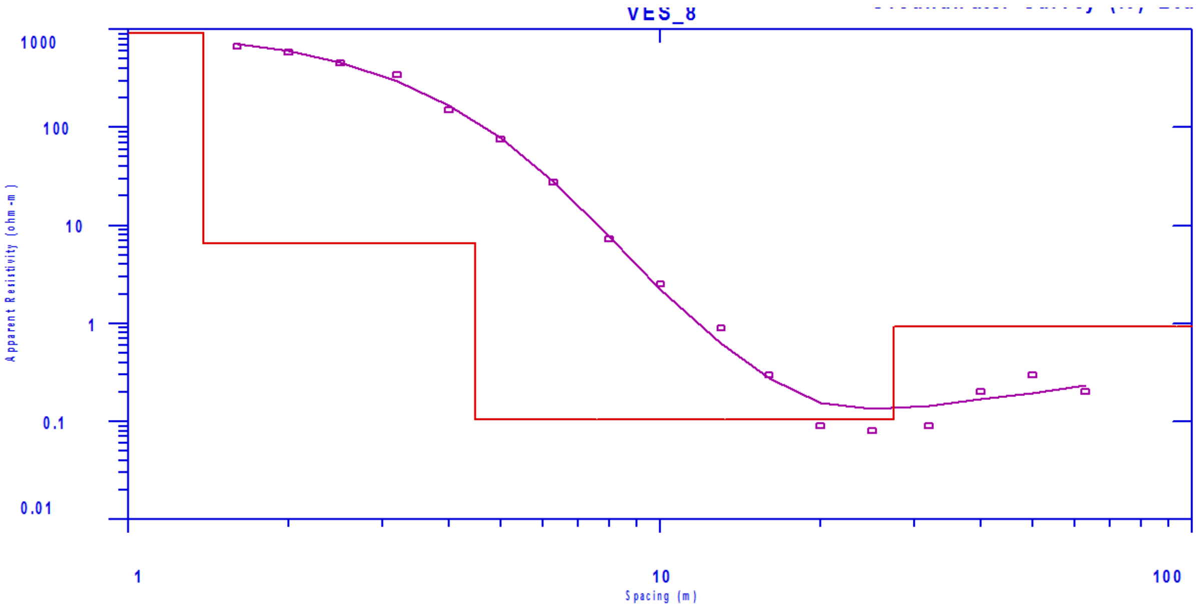
#	Rho	Thick	Depth
1	524.64	1.6790	1.6790
2	160.98	4.2580	5.9370
3	0.19253		



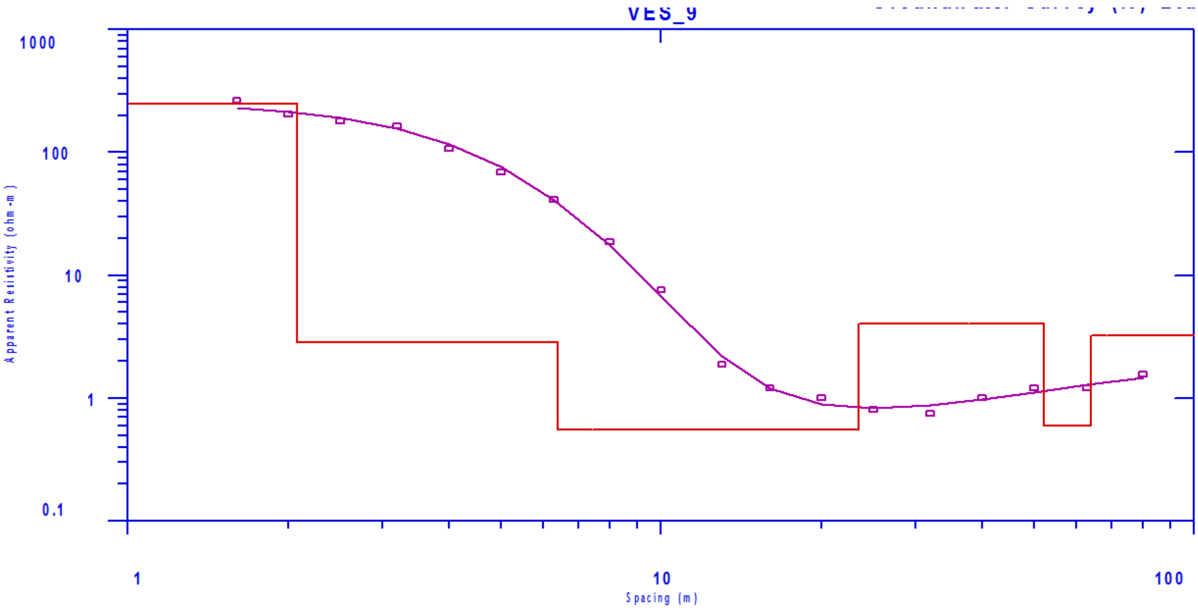
#	Rho	Thick	Depth
1	836.30	1.3772	1.3772
2	240.44	6.8263	8.2035
3	198.25	15.659	23.863
4	141.68		



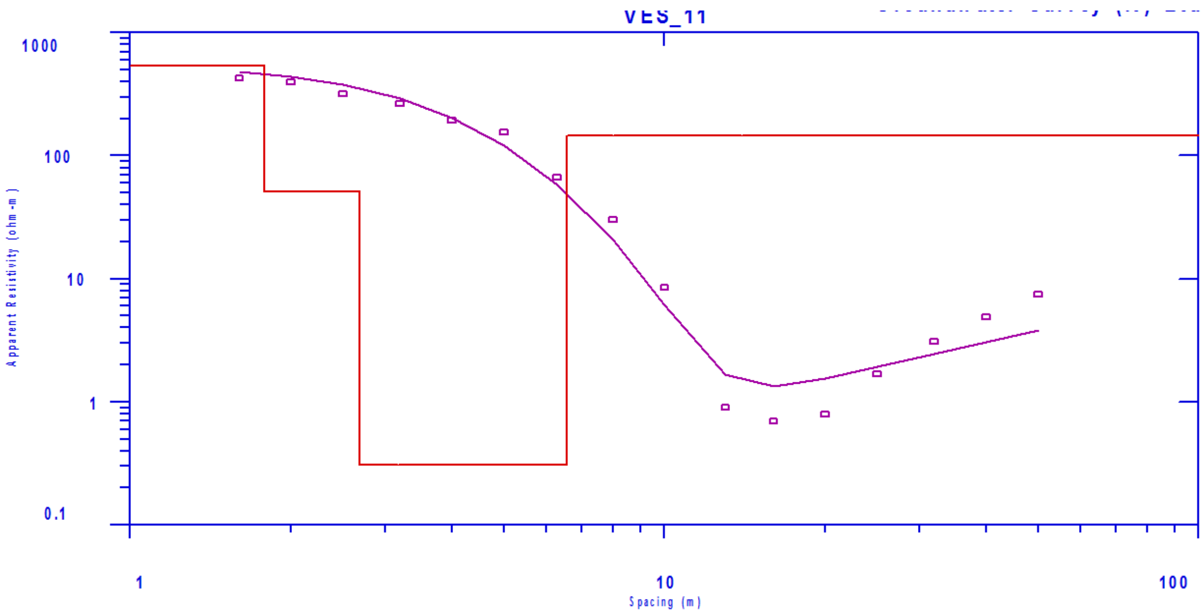
#	Rho	Thick	Depth
1	486.86	1.5496	1.5496
2	2.0035	3.2178	4.7673
3	12.437	9.1331	13.900
4	0.52417		



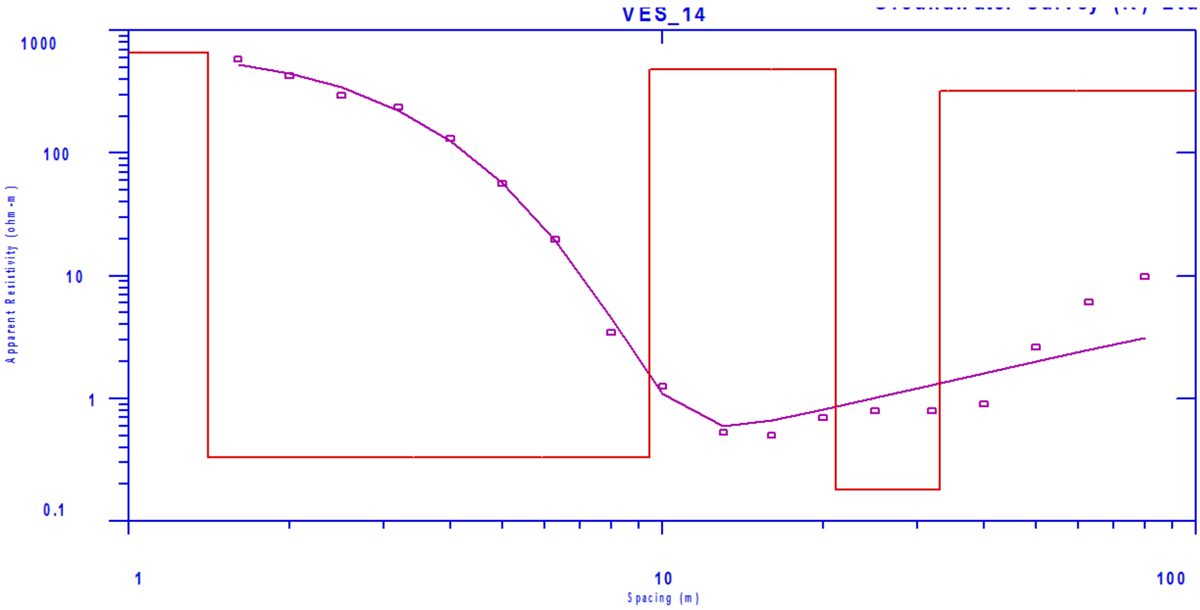
#	Rho	Thick	Depth
1	906.41	1.3819	1.3819
2	6.5668	3.1063	4.4881
3	0.10559	22.903	27.391
4	0.93120		



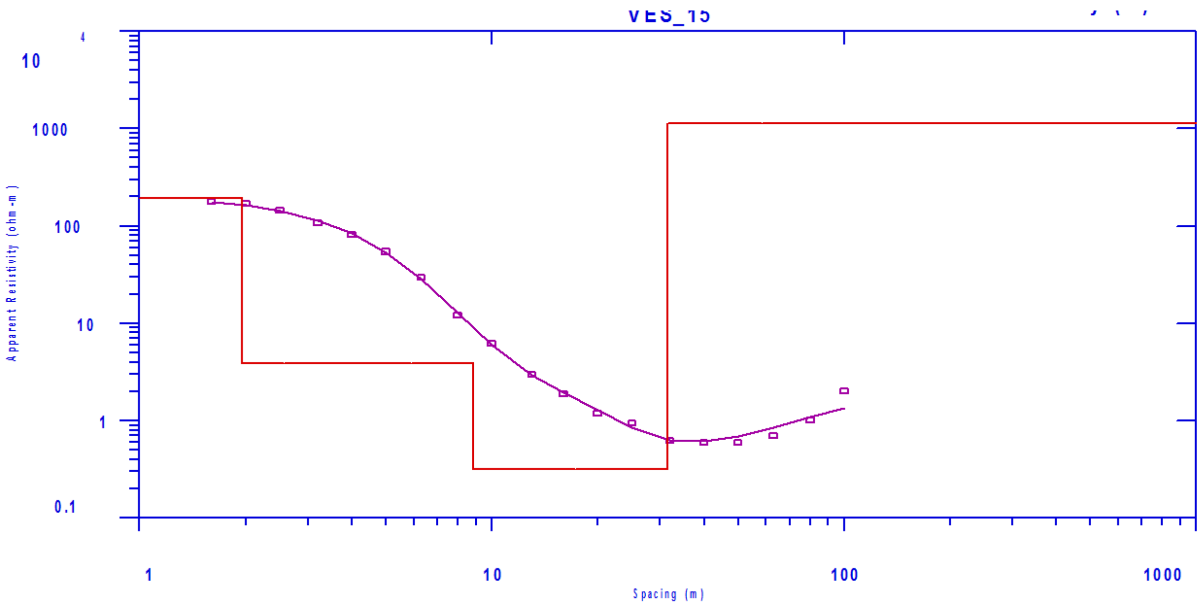
#	Rho	Thick	Depth
1	249.27	2.0754	2.0754
2	2.8452	4.3184	6.3938
3	0.54961	17.048	23.442
4	4.0074	28.687	52.129
5	0.59801	11.881	64.010
6	3.2174		



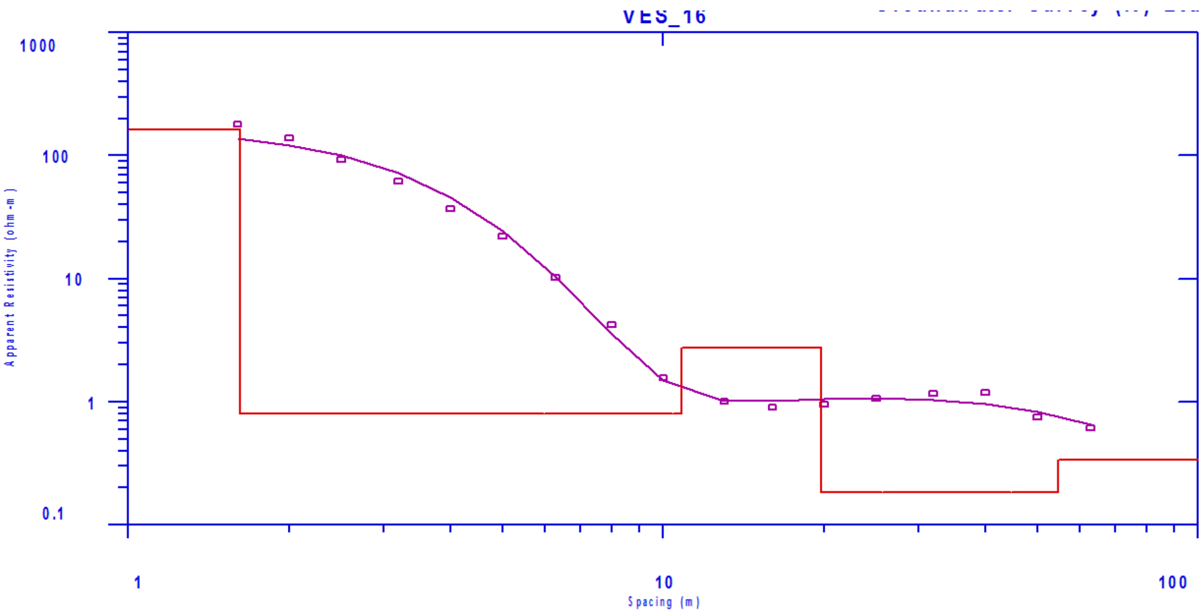
#	Rho	Thick	Depth
1	537.97	1.7849	1.7849
2	51.319	0.90165	2.6865
3	0.30687	3.8841	6.5706
4	144.46		



#	Rho	Thick	Depth
1	660.25	1.4087	1.4087
2	0.33030	8.0446	9.4533
3	477.88	11.623	21.077
4	0.18177	11.957	33.034
5	323.43		



#	Rho	Thick	Depth
1	194.44	1.9556	1.9556
2	3.9109	6.9262	8.8817
3	0.31545	22.679	31.561
4	1120.7		



#	Rho	Thick	Depth
1	162.13	1.6187	1.6187
2	0.80427	9.1781	10.797
3	2.7185	8.9181	19.715
4	0.18503	34.931	54.646
5	0.33616		

Table 12-1: Raw Field VES 1-16 Data

MN/2	AB/2	V1	V2	V3	V5	V6	V7	V8	V9	V11	V12	V14	V15	V16
(m)	(m)	(Ohm-m)	(Ohm-m)	(Ohm-m)	(Ohm-m)	(Ohm-m)	(Ohm-m)	(Ohm-m)	(Ohm-m)	(Ohm-m)	(Ohm-m)	(Ohm-m)	(Ohm-m)	(Ohm-m)
0.5	1.6	601.61	1661.86	452.11	453.56	772.87	439.78	672.00	243.11	425.99	398.41	586.37	176.35	179.25
0.5	2	521.89	1264.09	285.10	464.17	692.72	393.48	587.87	189.55	397.02	282.74	424.11	170.47	139.96
0.5	2.5	301.97	782.25	180.01	373.97	524.01	268.98	456.16	165.87	317.05	157.77	293.86	145.52	93.30
0.5	3.2	188.62	567.43	139.97	311.02	472.65	239.46	342.09	152.53	263.63	95.72	236.01	107.96	61.54
0.5	4	89.06	279.56	108.36	256.80	400.00	124.69	150.91	98.76	191.98	37.16	132.61	81.64	36.71
0.5	5	33.43	111.97	72.23	216.93	367.78	80.55	75.50	64.22	155.12	16.25	56.45	54.43	22.00
0.5	6.3	20.93	38.41	41.51	173.84	286.22	32.83	27.63	38.16	67.16	5.08	19.80	29.74	10.28
0.5	8	12.96	17.02	30.24	121.77	230.12	11.82	7.21	17.44	30.24	1.60	3.44	12.02	4.21
0.5	10	6.80	9.40	18.00	79.91	317.45	3.76	2.51	6.99	8.46	0.39	1.25	6.27	1.57
0.5	13	6.47	4.52	14.31	51.95	318.08	3.18	0.90	1.75	0.09	1.18	0.53	2.99	1.00
0.5	16	13.66	3.80	14.46	15.27	270.00	4.02	0.30	1.12	0.07	0.36	0.50	1.89	0.90
0.5	20	6.00	3.50	15.07	8.79	200.00	6.80	0.09	0.94	0.08	0.24	0.70	1.18	0.95
5	20	5.50	3.40	15.00	9.47	200.00	6.83	0.09	0.94					
5	25	6.22	2.47	13.01	2.72	210.00	10.00	0.08	0.75	0.17	0.19	0.80	0.94	1.07
5	32	8.00	2.42	9.42		194.27	10.00	0.09	0.70	0.31	5.30	0.80	0.63	1.16
5	32						9.00							
10	40	6.93	2.36	7.07	0.24	185.05	7.00	0.20		0.49	2.45		0.60	1.18
10	40						7.00	0.20	0.94	0.49	1.18	0.90	0.60	
10	50	18.66	3.10	5.50			2.00	0.30	1.13	0.75		2.64		
25	50	18.00					2.00	0.30	1.22				0.60	0.75
25	63	20.00	4.25	4.25			1.00	0.20	1.20		0.75	6.08	0.70	0.61
25	80	19.79	4.95	2.97					1.56		0.61	9.90	1.00	
25	100	15.55	4.67	2.02									2.00	

Table 12-2: Raw Field VES 17-28 Data

MN/2	AB/2	V17	V18	V19	V20	V21	V22	V23	V24	V25	V26	V27	V28
(m)	(m)	(Ohm-m)	(Ohm-m)	(Ohm-m)	(Ohm-m)	(Ohm-m)	(Ohm-m)	(Ohm-m)	(Ohm-m)	(Ohm-m)	(Ohm-m)	(Ohm-m)	(Ohm-m)
0.5	1.6	1062.43	497.832	443.40	1010.18	738.04	4.79	1164.03	428.16	163.28	200.29	515.25	511.62
0.5	2	477.126	409.975	411.15	851.76	580.80	1.99	888.28	313.37	129.00	147.97	380.52	349.89
0.5	2.5	354.369	318.178	350.41	546.63	334.77	1.17	672.92	225.06	92.55	94.44	294.43	246.36
0.5	3.2	246.68	308.507	286.85	402.97	261.12	1.13	316.04	160.00	58.22	46.48	178.21	178.26
0.5	4	181.591	248.883	192.97	200.39	187.03	1.04	200.00	107.37	31.67	15.54	107.91	129.14
0.5	5	135.292	184.277	90.00	109.63	152.86	0.93	147.73	80.86	20.92	7.00	75.12	103.41
0.5	6.3	102.84	128.612	39.77	41.38	131.71	1.12	70.62	65.67	10.78	1.86	50.00	66.91
0.5	8	62.0853	80.9111	28.44	11.22	93.93	1.00	20.03	36.05	4.21	0.80	23.00	42.06
0.5	10	40.6129	49.5127	17.14	4.00	57.97	1.25	10.00	21.94	1.57	0.63	10.00	21.94
0.5	13	25.0226	25.9768	8.91	1.00	33.93	1.59	5.30	10.60	1.06	0.60	1.85	9.80
0.5	16	12.9999	14.4622	5.00	0.15	14.46	1.61		8.03	0.80	0.80	0.87	7.26
0.5	20	5.43099	5.8899		0.11	5.18	0.64	4.00	6.60		1.00		
5	20	5.27784	5.89044	3.20		5.18	0.24	4.00	6.60	0.71		0.50	3.77
5	25	2.33733	2.60122	2.60	0.12	2.64	0.19	3.77	6.14	0.94	1.10	0.50	2.00
5	32	1.40005	1.56921	2.42	0.23	2.20	0.35	4.50	5.20	1.00	1.02	0.45	0.91
5	32							4.50		0.94	1.02	0.45	
10	40	1.33001	1.48439	2.47		1.98	0.30	3.30	4.00	0.94	0.47	0.50	0.70
10	40	1.33996	1.48439	2.50	0.38	1.98	0.47						0.69
10	50												
25	50	1.50795	1.42502	3.58	0.40	1.98		2.26	1.51	0.80		0.38	0.52
25	63	1.58011	2.29724	6.08		2.30		0.61		0.49		0.24	0.50
25	80	1.01928	2.49378	9.90		2.49				0.20			0.52
25	100	0.31102	3.91879			3.92							0.49