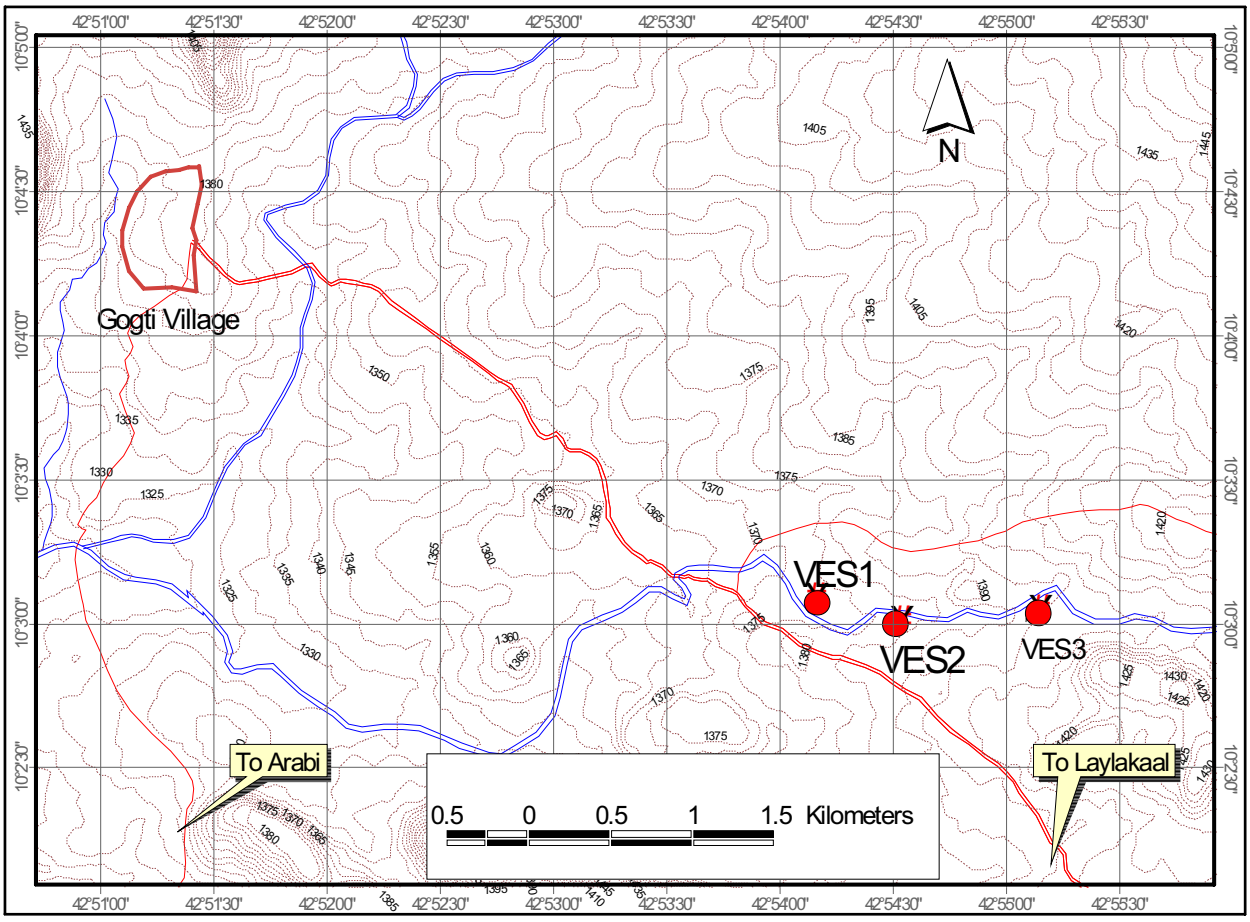
Gogti Area Hydrogeological Investigation
Final Report



Prepared by: SHAAC Engineering Consulting PLC
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July, 2011

SITE WATER INVESTIGATIN AREA

1. Location and accessibility

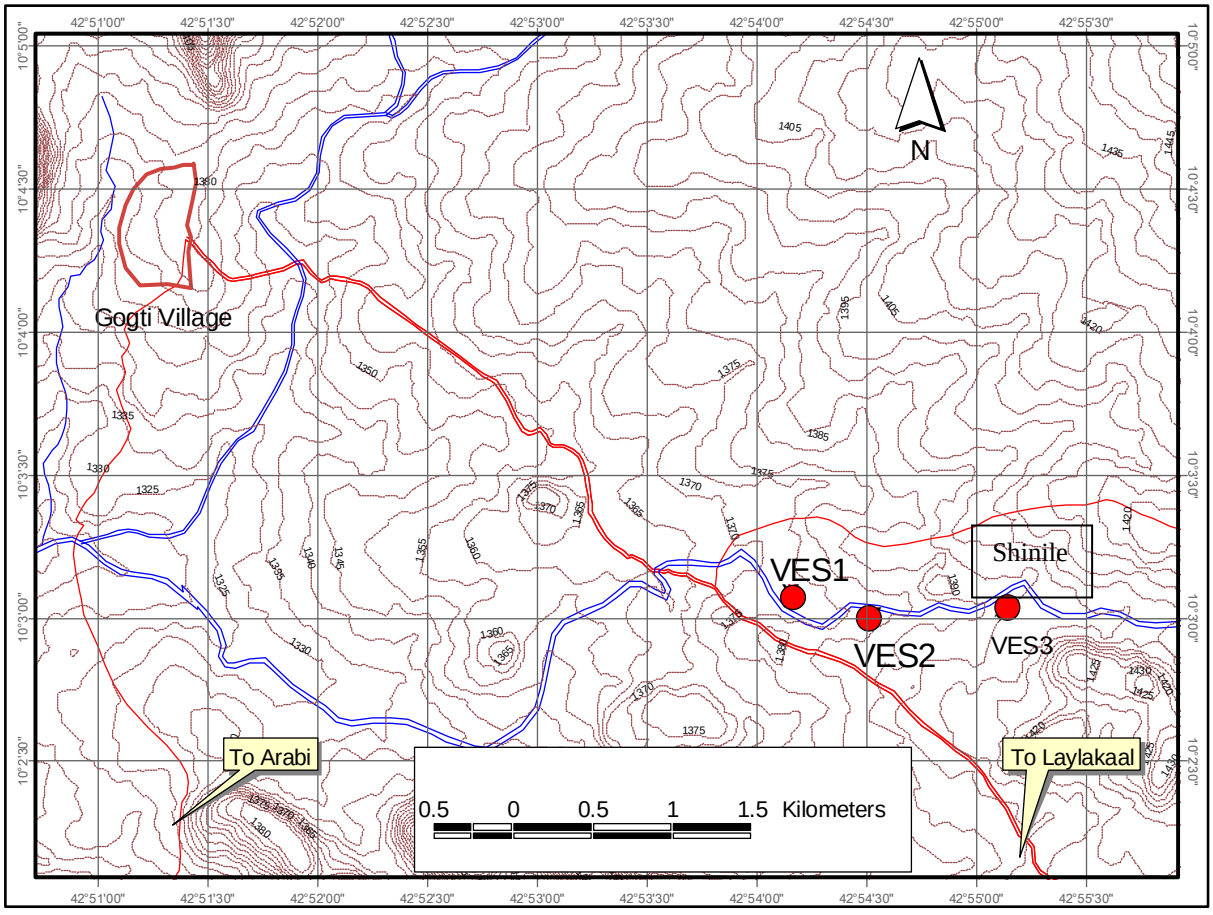
Investigated sites are Gogti village, Awbube and Farjano (Las Anod) areas of Awbare district of Somali Regional State. In Gogti town, previously two shallow wells were drilled by ESRDF on behalf Regional Water Bureau and both wells were abandoned due to being low yield, because of lack of proper survey, the areas that were selected fresh Basement rocks were encountered at shallow depth.

Therefore, current water investigations were concentrated at Awbube area which is located at about six kilometer southeast of the village.

The second site investigated is Farjano (Las Anod) which is locate at about eight kilometer southeast of the Gogti village or about two kilometer east of Awbube area and is intended for water supply source for small village located at about 2 km south of this sites which lies on the road to Dharwanaje village (Figure 1).

The area can be accessed from a dry weather road from Dharwanaje village and could be accessible only during dry seasons (look Figure 1).

Figure 1. Location Map



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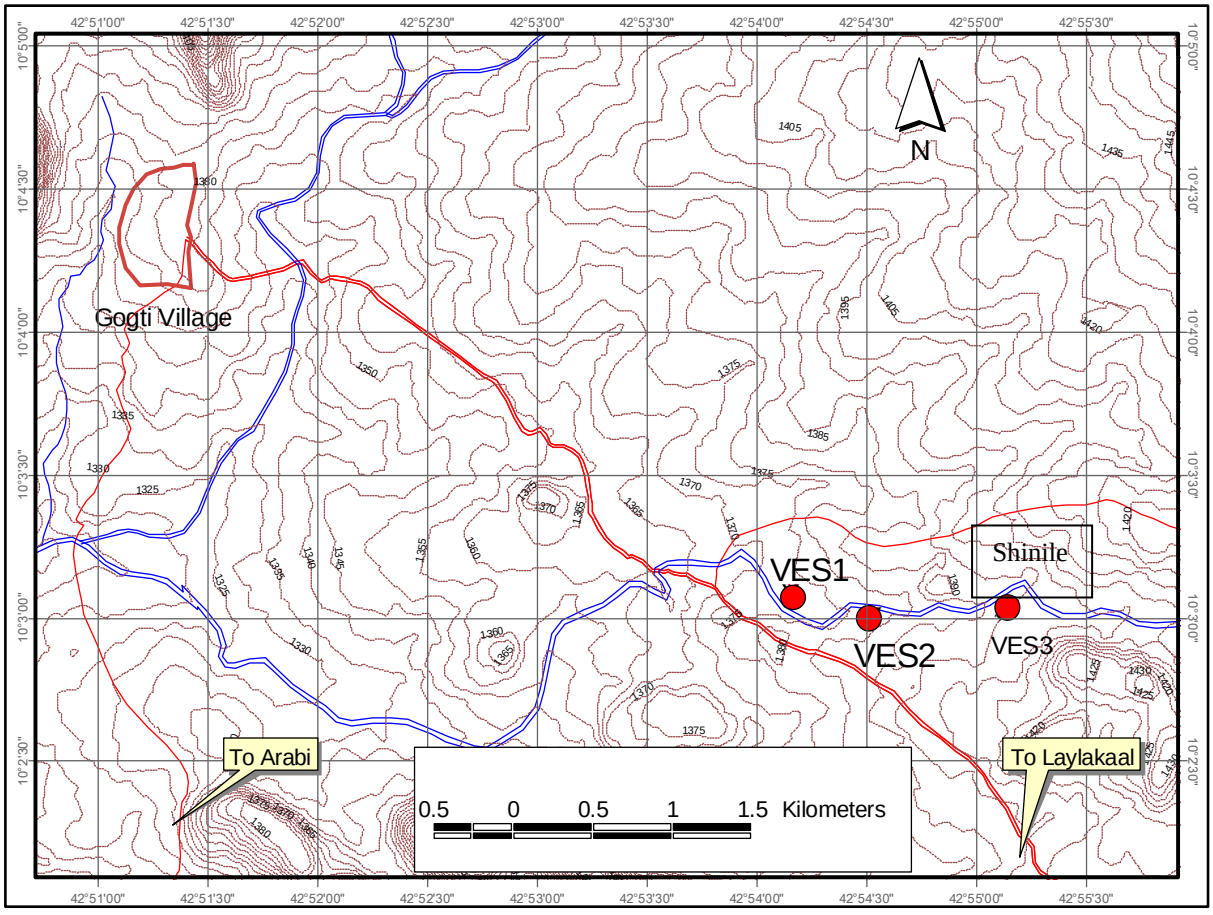

2. Geological History

2.1. General History

Different geologists and different oil companies have studied the geology of Somali Region of Ethiopia. Several geological maps were published including the one published by V.Kazmin in 1975 at a scale of 1:2,000,000. Others include geological map of Ogaden at a scale of 1:1,000,000 published by Ministry of Mines and Energy. There is also unpublished geological map of Ethiopia compiled by the Regional Geology Department, Ethiopian Institute of Geological Survey in 1990. The hydrogeology of Ogaden basin has also been reported in a generalized form by P. Hadwin & Girma Mengesha (1969); Girum lissanu & Mezmure Hailemeskale (1979). In addition, D. Baudin and P.Durrenib (1973) have described the water bearing capacities of the various rock types in Wabi Shebelle river basin. Several water investigations in different part of Somali region was undertaken by SHAAC Consulting Company for Water Bureau.

The classification of different geological formations that do exist in the study area will follow the above mention reports. The main lithological units that outcrop in the study sites from the bottom to top in the stratigraphic column are Basement Complex, Kabridahar Formation, Main Gypsum Formation and Quaternary deposits.

The geological history of the region can be followed from the Precambrian Era which is represented metamorphic and igneous rocks of the basement system. The regional metamorphism was followed by various cycles of regression and transgression, and localized volcanism.

During the Precambrian era, vast sediments accumulated and at the end of the era, a period of regional folding and metamorphism has occurred. As a consequence of this large scale tectonic activity, the original sediments were subjected to high temperature and pressure, which caused partial melting and subsequent re-crystallization and growth of new minerals. Depending on the parent material and the prevailing temperature and pressure, different types of gneisses, schists and granites were formed.

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The Precambrian era was followed of uplift and erosion and the peneplained basement rocks were covered by conglomerate and sandstone during the Lower Jurassic which marks the sea transgression depositing the Adigat sandstone. Marine sediments were deposited during the Middle Jurassic over the regions. These sediments are predominantly fossiliferous limestone, marl and shale.

Towards the end of the Jurassic, gradual uplift of the shield resulted in sea regression and subsequent erosion of part of the Jurassic sediments. With the formation of tectonic scarps and grabens caused by faulting, the Jurassic sediments were preserved from erosion in some areas. This retreat of the sea was followed by the deposition of sandstone, sand and sandy clay of the Jessoma Sandstone formation. From west to east the Cretaceous sediments range from continental through lagoonal to marine.

As a consequence of this early faulting the Cretaceous sediments are thicker and in stratigraphic continuity with the Jurassic in the east whereas to the west they tend to be thinner and lie directly over the basement. The continental deposits dated as Upper Cretaceous to Lower Paleocene are known as the Nubian or Jessoma Sandstone.

The exposed land covered by the Nubian Sandstone was flooded by a deep sea incursion during the Lower Eocene when the Auradu limestone was deposited. The sea gradually retreated during the Middle Eocene and an evaporitic environment prevailed with anhydrite, gypsum and marls of the Taleex Formation being deposited. Further marine ingression during the Upper Eocene resulted in the Karkar Formation of shales topped by calcarenites, marine cherty limestone with intercalations of marls.

2.2. Local Geological Formations and General Hydrogeology

Based on the existing geological maps as well as the findings from the field survey, two geological formation outcrop in both areas and are as follows:

1. Basement Complex
2. Recent Alluvium

Basement Complex:

Almost entirely, the area is covered by Basement Rocks consisting on gneiss and schist. Due to less well developed fractures, basement rocks in the area are not considered as good aquifer.

Pleistocene to Recent Alluvium:

Pleistocene to Recent sediments is found in the valleys and along the stream beds. The sediments are of mixed texture and consist of alluvial clays, silt sand, and gravel.

3. Geo-Electrical Survey Results

3.1. General

A great variety of geophysical methods are available in the assessment of geological subsurface conditions. In groundwater exploration, the most widely applied techniques geo-electrical resistivety, electro-magnetic (EM) profiling, seismic refraction and geophysical borehole logging. Other, less common investigation tools

are induced polarization (IP) surveys, magnetometer surveys, gravity method and airborne geophysics. The most widely used geophysical survey for ground water investigation is the geo-electrical survey and was used for this investigation.

Two VES measurement were made at Awbube area and one VES was conducted at Farjano area and all the measurements were made for the Schlumberger configuration. Table 1 below is summarized VES locations of Balol area.

Table 1. Geographical Coordinates of VES Sites of Gogti and Las Anod areas

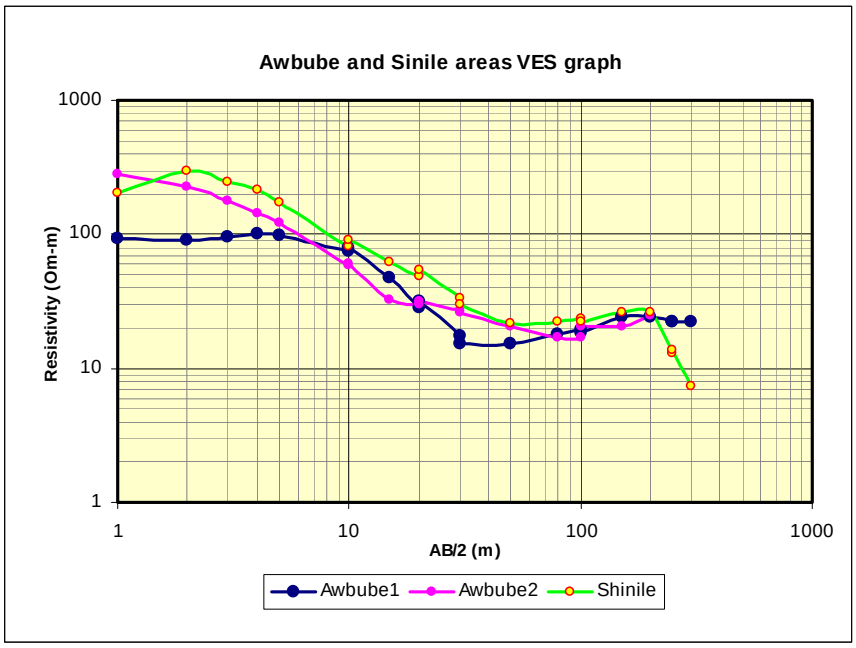
VES ID	Longitude	Latitude	UTM-East	UTM-North
VES1	42.89457^0	10.05762^0	269,246	1,112,524
VES2	42.89825^0	10.05542^0	269,648	1,112,278
VES3	42.90580^0	10.5588^0	270,840	1,167,964

The Vertical Electrical soundings (VES) were executed in the area and the Schlumberger measuring array was applied with the current electrode spacing expanded to 600-900m at each VES point (AB/2 = 300-450m). The VES data has been interpreted both qualitatively and subsequently by means of recognised modelling softwares (Resist and IPI-Win) ID programs to provide quantitative 1-D depth-Resistivity model interpretation of the probed locations of measurement and analysis of equivalent solutions.

3.2.Results and interpretation

The sounding curves of Investigated site generally have similar characteristics which are classified according to the shape, number of ascending and descending limbs. In other words, all the soundings are within similar environment encountering similar rock types. Significant differences only arise in the lithological variations especially in texture of the rocks encountered at different places as well as thicknesses of geo-electric layers encountered

Figure 2. Combined VES Graph



The interpreted results of VES soundings have been summarised and presented in the following tables. Layer-specific resistivity ranges (presented in the tables) are determined lithological and geological background of the area. The descriptions may therefore not necessarily represent the actual formations that will be encountered during drilling.

Awbube VES-1 Interpretations.

Table 2 - Hydrogeological Interpretation of Awbube VES-1

Depth (mbgl)	Thickness (m)	Resistivity (Ohmm)	Interpretation	Auriferous
0.00-2.1	2.1	87.1	Sandy top soil	No
2.1-5.29	3.19	144	Gravel	No
5.29-44.6	39.3	10.9	Clay	No
44.6-122	77.6	68.8	Wet sandy aquifer	Yes
>122	∞	350	Basement Rocks	No

Based on VES-1 interpretation as depicted in Table 2 above, 5 geo-electrical layers were identified and maximum penetration of 122 m depth was reached. The upper 122 m depth alluvial sediment consisting of sandy, gravel and clay were encountered. The aquifer zone in found within the alluvial sediment starting from 44.6 m depth and extends up to the Basement rocks. Below 122 m depth, Basement rocks were encountered.

This site, shallow well can be drilled and the maximum recommended drilling depth is 130 to 150 m depth. Based on the resistivity value of the inferred aquifer zone which is 68.8 Ωm is found that the quality is fresh.

Awbube VES-2 Interpretations.

Table 3 - Hydrogeological Interpretation of Awbube VES-2

Depth (mbgl)	Thickness (m)	Resistivity (Ohmm)	Interpretation	Auriferous
0.00-0.96	0.96	308	Dry top soil	No
0.96-3.87	2.9	145	Gravel	No
3.87-28.2	24.3	28.7	Sandy clay	No
28.2-57.2	29.1	7.02	Clay	No
57.2-117.2	60.0	152	Wet gravel sand	Yes
>117.2	∞	370.8	Basement	No

Based on VES-2 interpretation as depicted in Table 3 above, 6 geo-electrical layers were identified and maximum penetration of 117.2 m depth was reached. The upper 117.2 m depth alluvial sediment consisting of sandy, gravel and clay were encountered. The aquifer zone in found within the alluvial sediment starting from 57.2 m depth and extends up to the Basement rocks. Below 117.2 m depth, Basement rocks were encountered.

This site, shallow well can be drilled and the maximum recommended drilling depth is 130 to 150 m depth. Based on the resistivity value of the inferred aquifer zone which is 152 Ωm, the aquifer zone is interpreted as gravel sand which contains fresh water.

Shinile (Las Anod) VES-3 Interpretations.

Table 4 - Hydrogeological Interpretation of Shinile (Las Anod) VES-3

Depth (mbgl)	Thickness (m)	Resistivity (Ohmm)	Interpretation	Auriferous
0.00-0.44	0.44	146.5	Dray top soil	No
0.44-1.08	0.63	991	Dry gravel	No
1.08-12.59	11.51	77.77	Sand	No
12.59-23.0	10.41	8.24	Clay	No
23.0-115	104.59	32.32	Wet sand	Yes
>115	∞	450.5	Basement	No

Based on VES-3 interpretation as depicted in Table 4 above, 6 geo-electrical layers were identified and maximum penetration of 115 m depth was reached. The upper 115 m depth alluvial sediment consisting of sandy, gravel and clay were encountered. The aquifer zone in found within the alluvial sediment starting from 10.41m depth and extends up to the Basement rocks. Below 115 m depth, Basement rocks were encountered.

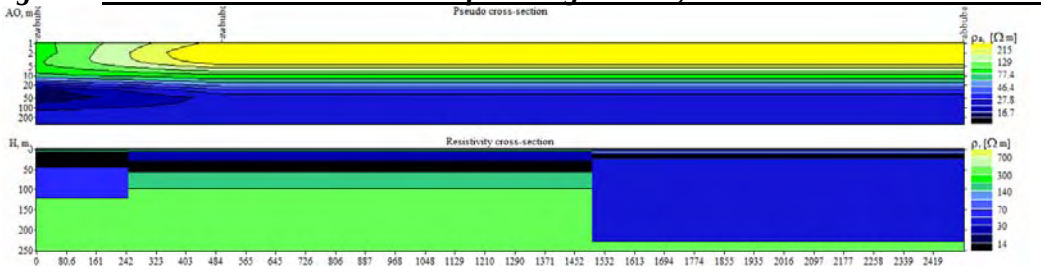
This site, shallow well can be drilled and the maximum recommended drilling depth is 120 to 150 m depth. Based on the resistivity value of the inferred aquifer zone which is 32.32 Ωm, the aquifer zone is interpreted as sandy aquifer which contains fresh

3.3. VES evaluation and site selection

In this regard, the selection criteria were based on identifying at which site the aquifer zone has most likely to yield enough water. For the selection evaluation purpose, interpreted geo-electrical cross section was prepared from the resistivety and Pseudo Resistivety cross sections of the Investigated site (Figure 3).

The interpreted VES data for both Awbube area and Shinile area were used for correlation. Both areas, the aquifer zone was found within the alluvial sediment, and below the aquifer zone is underlain by the Basement rocks. The main auriferous zone targeted to provide adequate discharge and thus the water supply for both area is the alluvial sediment.

Figure 3.Geo-electrical cross sections of Investigated site, Awbube and Las Anod areas



Distance in meters

Based on the interpreted VES readings of both Awbube and Las Anod areas, the area is quite homogenous and there is no great difference in subsurface lithology, both areas, the subsurface geology is composed of alluvial sediment underlain by Basement rocks. The water bearing unit at both areas are within the lower part of the

alluvial sediment. The maximum expected aquifer depth at both sites is 130 – 150 m.

Both sites could be drilled for shallow wells and the maximum recommended drilling depth is 130 to 150 m depth.

4. Conclusions and Recommendation

For Gogti area:

- The area surrounding the villages is found to be covered by Basement rocks and since Basement has less fracture, it is found to have no good aquifer.
- Therefore, the current survey has concentrated Awbube area located at about 6 km southeast of the town along the Gogti stream.
- Two VES stations were established at Awbube area, and both VES sites have shown very promising in regard to groundwater development.
- Awbube area was found to be covered by moderately thick alluvial sediment underlain by the Basement rocks.
- The alluvial sediment at both VES site in Awbube area is found to have 115 to 120 m thickness.
- The aquifer zone is found to be at the lower part of the alluvial sediment.
- Therefore, shallow borehole is recommended at Awbube area for Gogti village.
- Any VES site can be drilled, since the subsurface geology is found to be homogenous.
- The maximum recommended drilling depth is 130 to 150 m depth.

For Las Anod area

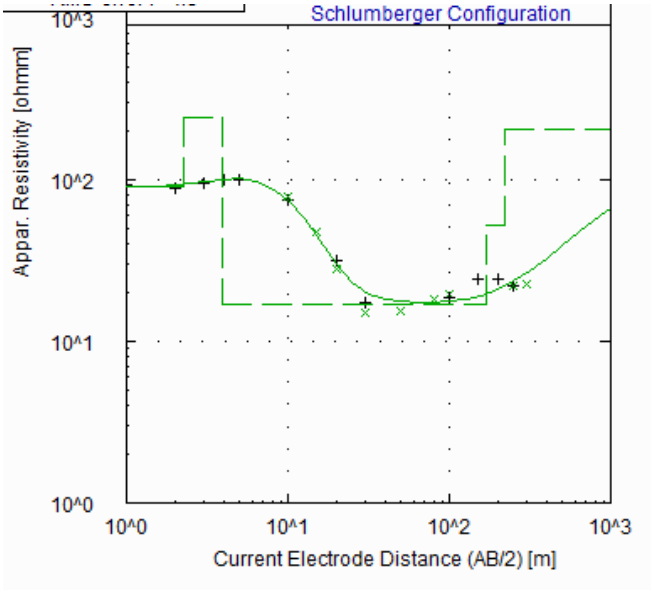
- For Las Anod area, a farm (Gardhle) located along the stream was investigated.
- The subsurface geology is found to be composed of alluvial sediment underlain by the Basement rocks.
- aquifer.
- One VES station was established at Las Anod area and the VES data have shown very promising in regard to groundwater development.
- The area was found to be covered by moderately thick alluvial sediment underlain by the Basement rocks.
- The alluvial sediment area is found to have 115 m thickness.
- The aquifer zone is found to be at the lower part of the alluvial sediment.
- Therefore, shallow borehole is recommended at to be drilled in the farm.
- The investigated VES site should be drilled.
- The geographical coordinates for the recommended site are 42.90580^0 East and 10.05588^0 North.
- The maximum recommended drilling depth is 130 to 150 m depth.

APPENDIX-1
RESISTIVITY DATA

VES-1

Data & Interpretation

AB/2	Awbube1
1	94.12
2	89.63
3	96.32
4	99.89
5	98.91
10	75.39
10	78.89
15	47.69
20	28.26
20	31.89
30	17.46
30	15.17
50	15.32
80	18.17
100	19.61
100	18.44
150	24.46
200	24.37
250	22.24
250	22.05
300	22.53



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44.6-122	77.6	68.8	Wet sandy aquifer	Yes
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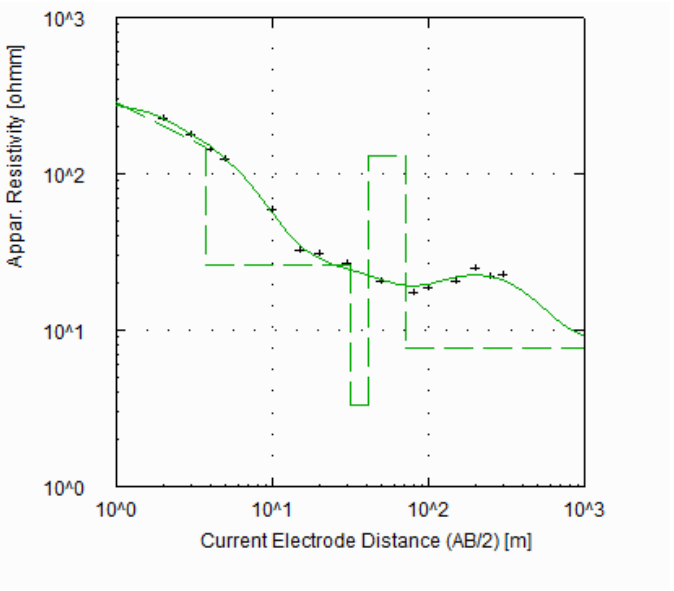
VES-2

Data & Interpretation

AB/2	Awbube2
1	281.76
2	223.91
3	179.33
4	143.28
5	123.44
10	58.71
10	59.82
15	32.27
20	30.260
20	31.580
30	26.910
30	26.000
50	20.43
80	17.23
100	16.930
100	20.270
150	20.62
200	24.95
250	22.24
250	30.88
300	33.1



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57.2-117.2	60.0	152	Wet gravel sand	Yes
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Las Anod ***VES-3***

Data & Interpretation

AB/2	Shinile
1	202.87
2	298.47
3	246.83
4	213.83
5	172.8
10	80.86
10	89.47
15	62.91
20	49.18
20	54.78
30	33.28
30	30.28
50	21.84
80	22.01
100	23.23
100	22.188
150	26.28
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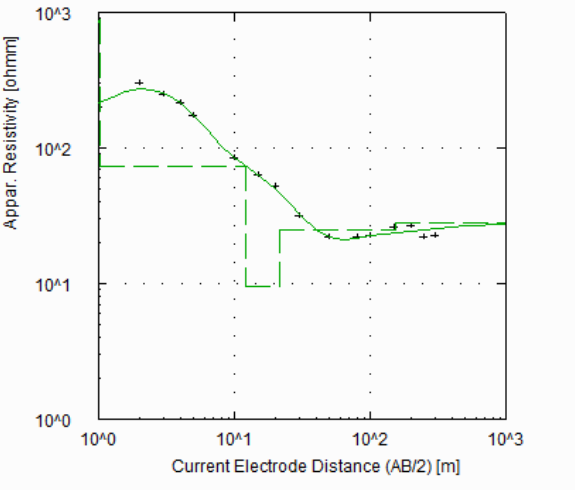
300	28.9



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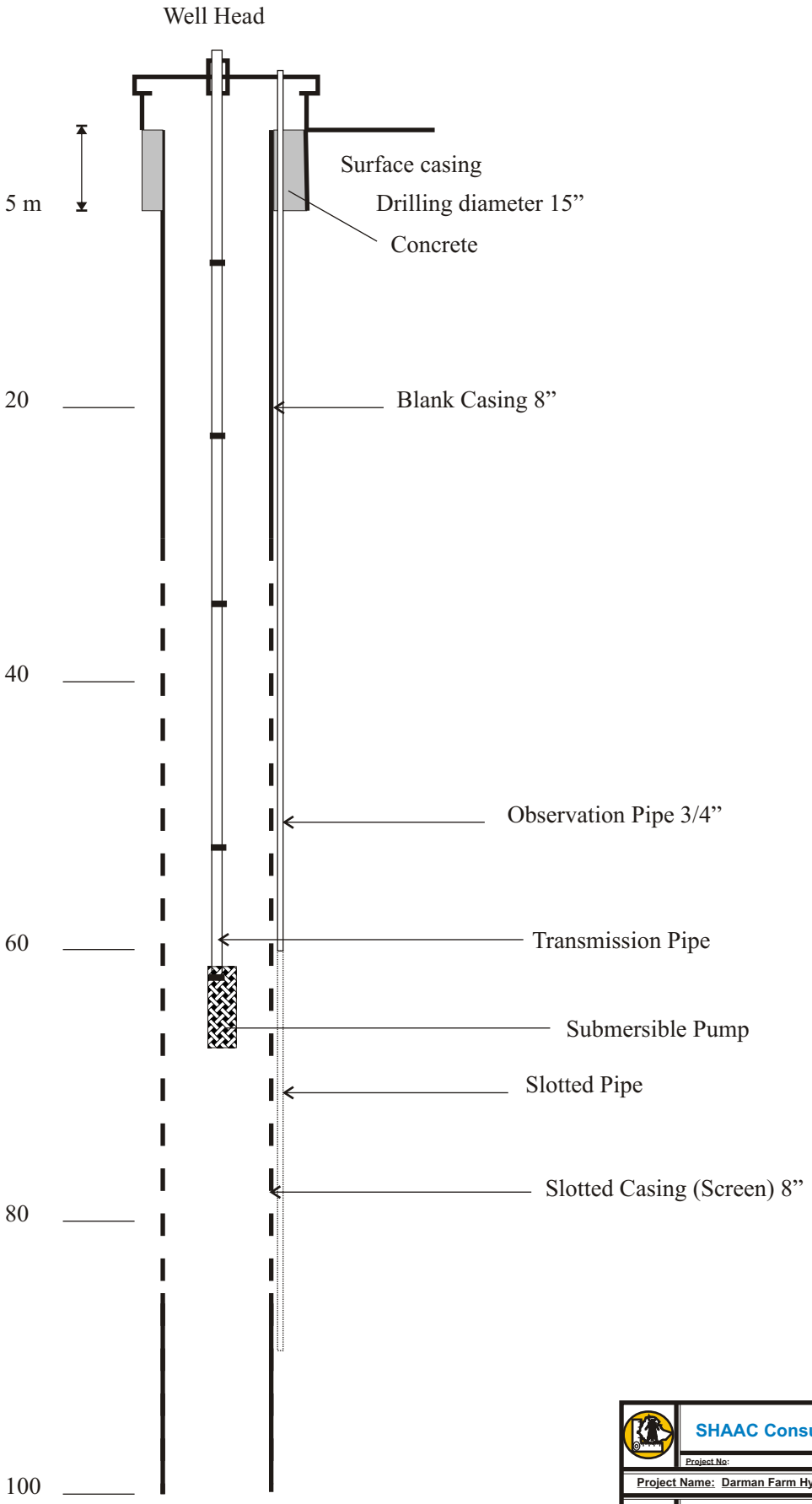
Typical Borehole Design



	SHAAC Consulting Company
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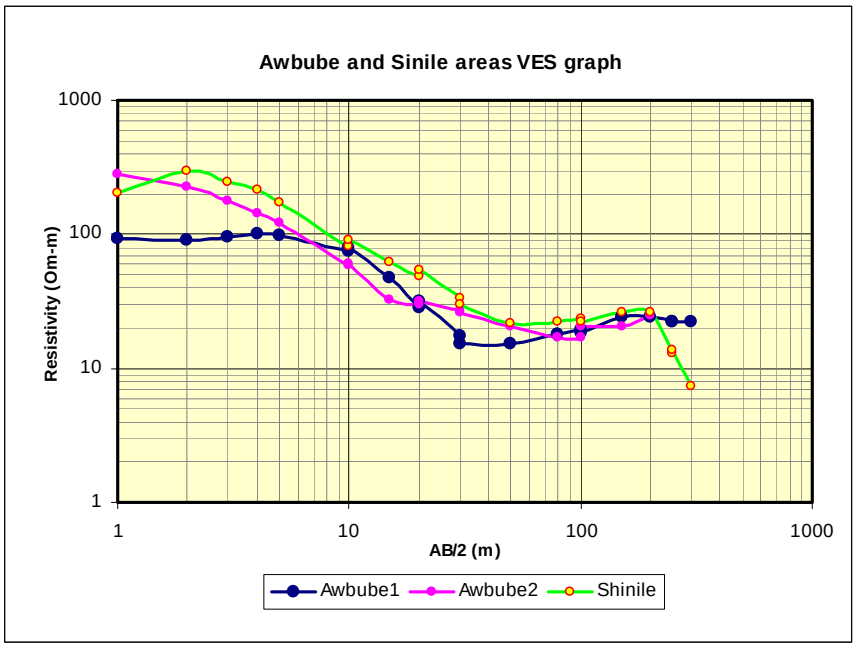

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2.1-5.29	3.19	144	Gravel	No
5.29-44.6	39.3	10.9	Clay	No
44.6-122	77.6	68.8	Wet sandy aquifer	Yes
>122	∞	350	Basement Rocks	No

Based on VES-1 interpretation as depicted in Table 2 above, 5 geo-electrical layers were identified and maximum penetration of 122 m depth was reached. The upper 122 m depth alluvial sediment consisting of sandy, gravel and clay were encountered. The aquifer zone in found within the alluvial sediment starting from 44.6 m depth and extends up to the Basement rocks. Below 122 m depth, Basement rocks were encountered.

This site, shallow well can be drilled and the maximum recommended drilling depth is 130 to 150 m depth. Based on the resistivity value of the inferred aquifer zone which is 68.8 Ωm is found that the quality is fresh.

Awbube VES-2 Interpretations.

Table 3 - Hydrogeological Interpretation of Awbube VES-2

Depth (mbgl)	Thickness (m)	Resistivity (Ohmm)	Interpretation	Auriferous
0.00-0.96	0.96	308	Dry top soil	No
0.96-3.87	2.9	145	Gravel	No
3.87-28.2	24.3	28.7	Sandy clay	No
28.2-57.2	29.1	7.02	Clay	No
57.2-117.2	60.0	152	Wet gravel sand	Yes
>117.2	∞	370.8	Basement	No

Based on VES-2 interpretation as depicted in Table 3 above, 6 geo-electrical layers were identified and maximum penetration of 117.2 m depth was reached. The upper 117.2 m depth alluvial sediment consisting of sandy, gravel and clay were encountered. The aquifer zone in found within the alluvial sediment starting from 57.2 m depth and extends up to the Basement rocks. Below 117.2 m depth, Basement rocks were encountered.

This site, shallow well can be drilled and the maximum recommended drilling depth is 130 to 150 m depth. Based on the resistivity value of the inferred aquifer zone which is 152 Ωm, the aquifer zone is interpreted as gravel sand which contains fresh water.

Shinile (Las Anod) VES-3 Interpretations.

Table 4 - Hydrogeological Interpretation of Shinile (Las Anod) VES-3

Depth (mbgl)	Thickness (m)	Resistivity (Ohmm)	Interpretation	Auriferous
0.00-0.44	0.44	146.5	Dray top soil	No
0.44-1.08	0.63	991	Dry gravel	No
1.08-12.59	11.51	77.77	Sand	No
12.59-23.0	10.41	8.24	Clay	No
23.0-115	104.59	32.32	Wet sand	Yes
>115	∞	450.5	Basement	No

Based on VES-3 interpretation as depicted in Table 4 above, 6 geo-electrical layers were identified and maximum penetration of 115 m depth was reached. The upper 115 m depth alluvial sediment consisting of sandy, gravel and clay were encountered. The aquifer zone in found within the alluvial sediment starting from 10.41m depth and extends up to the Basement rocks. Below 115 m depth, Basement rocks were encountered.

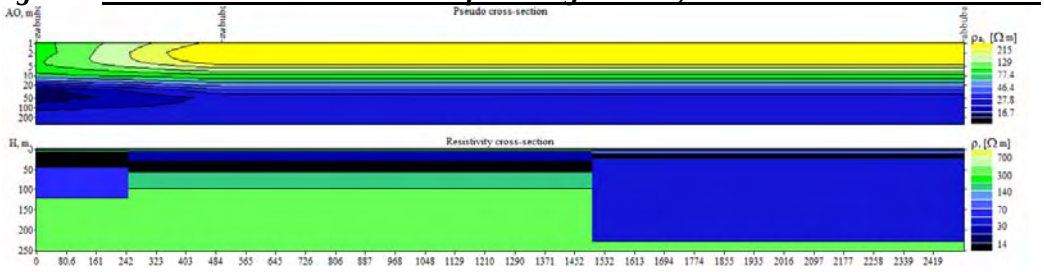
This site, shallow well can be drilled and the maximum recommended drilling depth is 120 to 150 m depth. Based on the resistivity value of the inferred aquifer zone which is 32.32 Ωm, the aquifer zone is interpreted as sandy aquifer which contains fresh

3.3. VES evaluation and site selection

In this regard, the selection criteria were based on identifying at which site the aquifer zone has most likely to yield enough water. For the selection evaluation purpose, interpreted geo-electrical cross section was prepared from the resistivety and Pseudo Resistivety cross sections of the Investigated site (Figure 3).

The interpreted VES data for both Awbube area and Shinile area were used for correlation. Both areas, the aquifer zone was found within the alluvial sediment, and below the aquifer zone is underlain by the Basement rocks. The main auriferous zone targeted to provide adequate discharge and thus the water supply for both area is the alluvial sediment.

Figure 3.Geo-electrical cross sections of Investigated site, Awbube and Las Anod areas



Distance in meters

Based on the interpreted VES readings of both Awbube and Las Anod areas, the area is quite homogenous and there is no great difference in subsurface lithology, both areas, the subsurface geology is composed of alluvial sediment underlain by Basement rocks. The water bearing unit at both areas are within the lower part of the

alluvial sediment. The maximum expected aquifer depth at both sites is 130 – 150 m.

Both sites could be drilled for shallow wells and the maximum recommended drilling depth is 130 to 150 m depth.

4. Conclusions and Recommendation

For Gogti area:

- The area surrounding the villages is found to be covered by Basement rocks and since Basement has less fracture, it is found to have no good aquifer.
- Therefore, the current survey has concentrated Awbube area located at about 6 km southeast of the town along the Gogti stream.
- Two VES stations were established at Awbube area, and both VES sites have shown very promising in regard to groundwater development.
- Awbube area was found to be covered by moderately thick alluvial sediment underlain by the Basement rocks.
- The alluvial sediment at both VES site in Awbube area is found to have 115 to 120 m thickness.
- The aquifer zone is found to be at the lower part of the alluvial sediment.
- Therefore, shallow borehole is recommended at Awbube area for Gogti village.
- Any VES site can be drilled, since the subsurface geology is found to be homogenous.
- The maximum recommended drilling depth is 130 to 150 m depth.

For Las Anod area

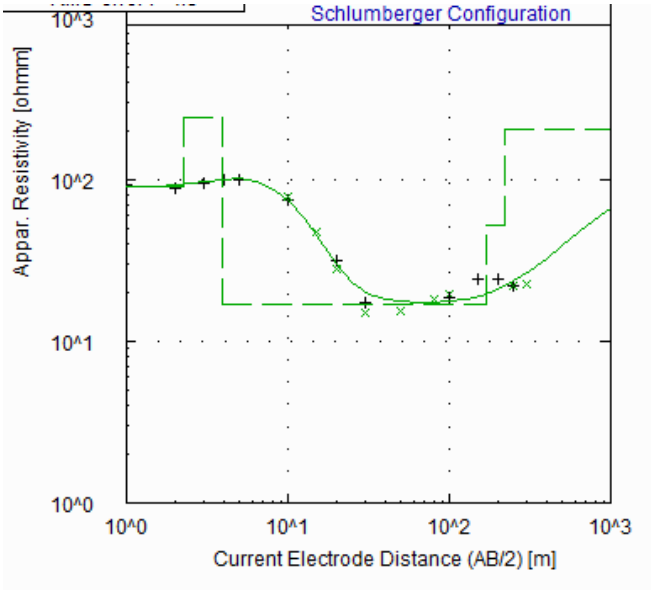
- For Las Anod area, a farm (Gardhle) located along the stream was investigated.
- The subsurface geology is found to be composed of alluvial sediment underlain by the Basement rocks.
- aquifer.
- One VES station was established at Las Anod area and the VES data have shown very promising in regard to groundwater development.
- The area was found to be covered by moderately thick alluvial sediment underlain by the Basement rocks.
- The alluvial sediment area is found to have 115 m thickness.
- The aquifer zone is found to be at the lower part of the alluvial sediment.
- Therefore, shallow borehole is recommended at to be drilled in the farm.
- The investigated VES site should be drilled.
- The geographical coordinates for the recommended site are 42.90580^0 East and 10.05588^0 North.
- The maximum recommended drilling depth is 130 to 150 m depth.

APPENDIX-1
RESISTIVITY DATA

VES-1

Data & Interpretation

AB/2	Awbube1
1	94.12
2	89.63
3	96.32
4	99.89
5	98.91
10	75.39
10	78.89
15	47.69
20	28.26
20	31.89
30	17.46
30	15.17
50	15.32
80	18.17
100	19.61
100	18.44
150	24.46
200	24.37
250	22.24
250	22.05
300	22.53

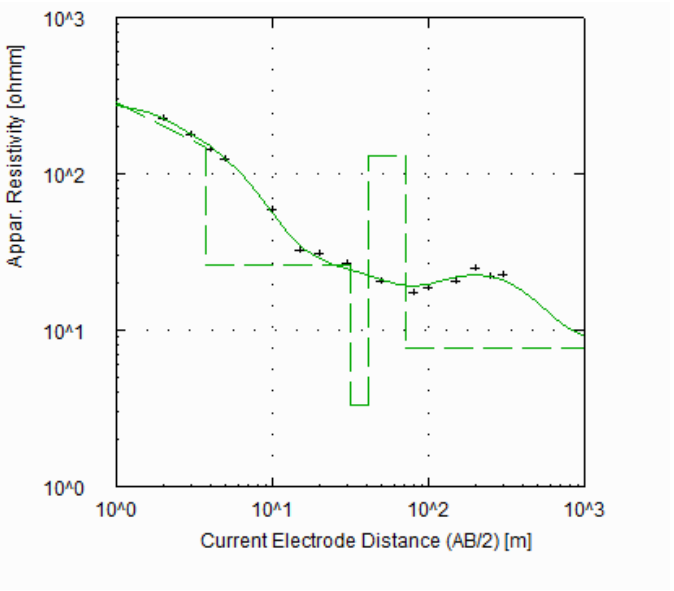


Depth (mbgl)	Thickness (m)	Resistivity (Ohmm)	Interpretation	Auriferous
0.00-2.1	2.1	87.1	Sandy top soil	No
2.1-5.29	3.19	144	Gravel	No
5.29-44.6	39.3	10.9	Clay	No
44.6-122	77.6	68.8	Wet sandy aquifer	Yes
>122	∞	350	Basement Rocks	No

VES-2

Data & Interpretation

AB/2	Awbube2
1	281.76
2	223.91
3	179.33
4	143.28
5	123.44
10	58.71
10	59.82
15	32.27
20	30.260
20	31.580
30	26.910
30	26.000
50	20.43
80	17.23
100	16.930
100	20.270
150	20.62
200	24.95
250	22.24
250	30.88
300	33.1

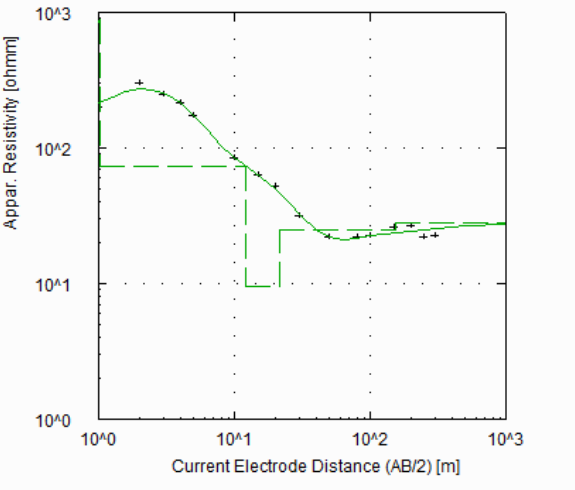


Depth (mbgl)	Thickness (m)	Resistivity (Ohmm)	Interpretation	Auriferous
0.00-0.96	0.96	308	Dry top soil	No
0.96-3.87	2.9	145	Gravel	No
3.87-28.2	24.3	28.7	Sandy clay	No
28.2-57.2	29.1	7.02	Clay	No
57.2-117.2	60.0	152	Wet gravel sand	Yes
>117.2	∞	370.8	Basement	No

Las Anod ***VES-3***

Data & Interpretation

AB/2	Shinile
1	202.87
2	298.47
3	246.83
4	213.83
5	172.8
10	80.86
10	89.47
15	62.91
20	49.18
20	54.78
30	33.28
30	30.28
50	21.84
80	22.01
100	23.23
100	22.188
150	26.28
200	26.43
250	25.1
250	26.7
300	28.9



Depth (mbgl)	Thickness (m)	Resistivity (Ohmm)	Interpretation	Auriferous
0.00-0.44	0.44	146.5	Dray top soil	No
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1.08-12.59	11.51	77.77	Sand	No
12.59-23.0	10.41	8.24	Clay	No
23.0-115	104.59	32.32	Wet sand	Yes
>115	∞	450.5	Basement	No