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GEOELECTRIC SOUNDING FOR THE DETERMINATION OF GROUNDWATER CONDITIONS AROUND IWAYA AREA OF LAGOS, NIGERIA

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ABSTRACT

High apparent resistivity contrasts between the saturated freshwater zones and apparent low resistivity of the saturated seawater intrusion were measured on eleven vertical electrical soundings field curves using the Schlumberger electrode array in Iwaya area of Lagos. The field measurements were inverted to subsurface layers.

The results of the interpretation revealed four to five geoelectric layers. Resistivity maps were constructed at depths of 6m, 10m, 15m and 40m. Resistivities of between 4 and 20Ωm indicated areas of seawater intrusion with average depth range of 6m. Trough like pattern of the resistivity map at 6m depth indicate the shape of the seawater plume. Resistivities higher than 100Ωm indicate areas of freshwater zone at an average depth of 10m.

KEY WORDS: Resistivity, Seawater, Schlumberger, Resistivity map, Fresh water.

INTRODUCTION

The study area lies within the coastal plain of southwest Nigeria (Figs 1a and 1b). In this part of the world, government is unable to provide enough potable water for the people and as such, water needed for daily activities is obtained from groundwater sources. In the coastal areas, withdrawal of a large volume of groundwater may lead to saltwater intrusion into the freshwater aquifers (Ali et al., 1999). This potential saltwater pollutant poses a threat to the sustainable development and economic well-being of the Iwaya area of Lagos. Measurements from water quality survey studies carried out earlier by Oyedele (2000) in other coastal parts of Lagos suggested that the salt / freshwater interface is relatively shallow and water withdrawals are from depths close to the salt / freshwater interface. An excessive level of water withdrawal from coastal regions may cause intrusion of saltwater into freshwater aquifers (Fennema and Newton, 1982).

The large apparent resistivity contrasts between saltwater saturated zones and the freshwater saturated zones have been used by a number of researchers for determination of saltwater intrusion in many coastal areas of the world. Van Dam and Meulenkamp (1967) determined salinity of groundwater in the western part of the Netherlands using the resistivity method. Their interpreted resistivities were closely related to the salinity of groundwater. Sabet (1975) estimated a range of 20Ωm to several hundred Ωm for the resistivity of clean sand and gravel (not containing silt or shale) which is saturated with freshwater in southern region of Virginia and the northern part of North Carolina. Ali et al. (1999) summarized that resistivity of less than 30Ωm are indicative of seawater zones in the eastern shore of Virginia.

The frequent problems of seawater intrusion into the shallow coastal plain sand aquifers of Iwaya has necessitated this study. Here electrical resistivity method was employed and measurements were carried out at some selected areas of Iwaya with a view to delineating saltwater saturated zones from freshwater zones based on their resistivity differences so as to provide some background information for future groundwater development in the area.

Regional Geology and Hydrogeology

The Abeokuta group, Ewekoro formation, coastal plain sands and recent sediments constitute aquifers in the Dahomey Basin. Iwaya lies within the coastal plain sands of the Dahomey basin. Sands and gravels constitute the lithologies in aquifers of the coastal plain sands (Jones and Hockey, 1964).

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Table 1: Interpretation of sounding data from Iwaya, near Lagos.

Station	Layers	Resistivity Ωm	Thickness (m)	Inferred Sediments	Interpretation
VES 1	1	190	2.6	Coarse sand, gravel clay, no sand	Topsoil
	2	47	6.24	Sand, gravel, minor clay	Intermediate freshwater
	3	55	7.2	Sand gravel minor clay	Intermediate freshwater
	4	11.6		Sandy clay, sandy gravel	Brackish water
VES 2	1	95	0.4	Sand, gravel, no clay	Topsoil
	2	51	3.8	Sand, gravel, minor clay	Intermediate freshwater
	3	20	11	Sand, gravel, some clay	Poor quality water
	4	2.2	17	Porous sand or saturated clay	Seawater, very saline
	5	16		Sand, gravel, some clay	Poor quality freshwater
VES 3	1	23	0.9	Sand, gravel, some clay	Topsoil
	2	69	0.3	Sand, gravel, minor clay	Intermediate freshwater
	3	208	24	Coarse sand, gravel, no clay	Very good quality freshwater
	4	24	9	Sand, gravel, some clay	Poor quality freshwater
	5	7		Sandy saturated or sandy clay	Saline water
VES 4	1	42	1	Sand, gravel, minor clay	Topsoil
	2	126	6	Coarse sand, gravel, no clay	Good quality freshwater
	3	11	10	Sandy clay, sandy gravel	Brackish water
	4	52	25	Sand, gravel, minor clay	Intermediate freshwater
	5	8		Sandy saturated or sandy clay	Salty brackish water
VES 5	1	140	0.9	Coarse sand, gravel, no clay	Topsoil
	2	35	0.6	Sand, gravel, minor clay	Intermediate good freshwater
	3	76	42	Sand, gravel, no clay	Good quality freshwater
	4	47	6.5	Sandy saturated or sandy clay	Salty brackish water
	5	3.4		Porous sand or saturated clay	Saline water
VES 6	1	46	1.0	Sand, gravel, minor clay	Topsoil
	2	31	0.5	Sand, gravel, minor clay	Intermediate quality freshwater
	3	102	29	Coarse sand, gravel, no clay	Very good quality freshwater
	4	20	6.5	Sand, gravel, some clay	Poor quality freshwater
	5	0.6		Very porous sand or saturated clay	Seawater, very saline water
VES 7	1	12	0.8	Sandy clay, sandy gravel	Topsoil
	2	24	0.6	Sandy gravel, some clay	Poor quality freshwater
	3	14	26	Porous sand or saturated clay	Brackish water
	4	148	8	Coarse sand, gravel, no clay	Very good quality freshwater
	5	28		Sand, gravel, some clay	Poor quality freshwater
VES 8	1	36	0.8	Sand, gravel, minor clay	Topsoil
	2	29	2	Sand, gravel, minor clay	Poor quality freshwater
	3	68	28	Sand, gravel, minor clay	Intermediate quality freshwater
	4	4	7	Porous sand or saturated clay	Saline water
	5	160		Sand, gravel, no clay	Good quality freshwater
VES 9	1	95	1.2	Sand, gravel, no clay	Topsoil
	2	100	5.4	Sand, gravel, no clay	Good quality freshwater
	3	41	22	Sand, gravel, minor clay	Intermediate quality freshwater
	4	56	8	Sand, gravel, minor clay	Intermediate quality freshwater
	5	28		Sand, gravel, some clay	Poor quality freshwater
VES 10	1	15	0.8	Sandy clay, sandy gravel	Topsoil
	2	18	9	Sand, gravel, some clay	Brackish water
	3	64	17	Sand, gravel, minor clay	Intermediate quality freshwater
	4	6.5	5	Sandy saturated or sandy clay	Salty brackish water
	5	53		Sand, gravel, minor clay	Intermediate quality freshwater
VES 11	1	27	0.8	Sand, gravel, some clay	Topsoil
	2	50	2	Sand, gravel, minor clay	Intermediate quality freshwater
	3	17	29	Sand, gravel, some clay	Poor quality freshwater
	4	170	5	Coarse sand, gravel, no clay	Very good quality freshwater
	5	2		Very porous sand or saturated clay	Seawater, very saline water

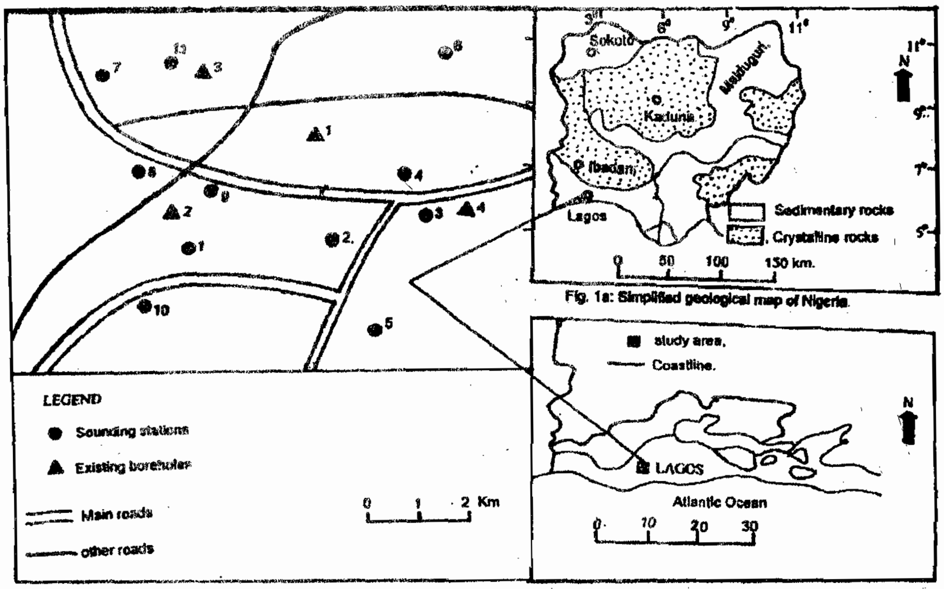

Fig 1a: Map of the study area showing sounding stations and access roads

Fig 1b: Map of Lagos showing the study area

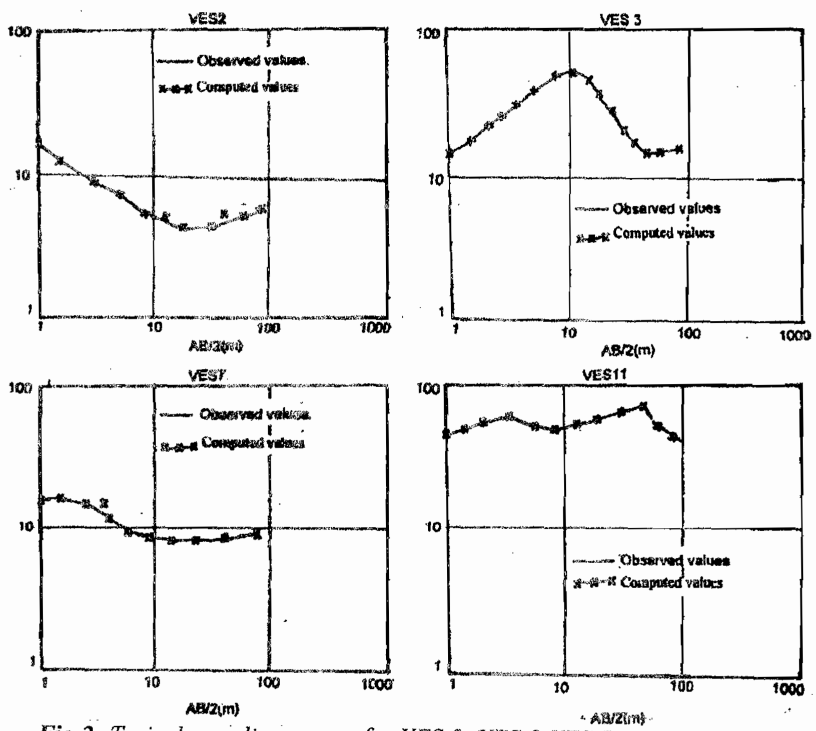

Fig 2: Typical sounding curves for VES 2, VES 3 VES 7 and VES 11

Coode Blizard (1997) reported that over 95% of all boreholes in Lagos obtain their water from the coastal plain sands. There is a lot of lateral variation in lithology and water quality in this aquifer. The aquifer thickens from its outcrop area in the north to the coast in the south and the sand percentage in the formation also increases to the south.

Kampsax-Kruger and Shwed (1977) subdivided the aquifers in Lagos State into four, with the first aquifer representing the recent sediments and the second and third aquifers being within the coastal plains sands. The fourth aquifer represents the Abeokuta formation. The terms second and third aquifer as used by Kampsax-Kruger are henceforth referred to as upper and lower coastal plain sands respectively.

The groundwater salinity in the aquifer changes from north to south. Saltwater intrudes into the first aquifers with the second aquifer being freshwater-bearing in the northern and central parts of the state, with Iwaya showing saltwater intrusion in the northern and north-west pattern. As the saltwater in the upper coastal plains sands aquifer overlies freshwater in the lower coastal plains sands aquifer, there is always a clay layer that separates the saltwater above from the freshwater below as shown on the resistivity of the inferred geoelectric layers (Table 1).

Field metnod ana Data Analysis

We used the Schlumberger array and ABEM Terrameter SAS 300B for this survey. The maximum electrode spacing (AB) was 200m. All the data were calculated in the field to check the quality of data and to avoid mistakes. The apparent resistivity obtained from the field was plotted against half of the current electrode separation (AB/2) on a log-log graph paper to obtain the initial model parameters, which were used in a computer program to obtain final parameters. Most of the sounding curves (Fig. 2) reflect the presence of four to five geoelectric layers. Table 1 shows the summary of the results for all the sounding stations while Figure 2 shows typical sounding curves.

In addition to the availability of existing borehole data, one of the soundings were made at near an existing well for correlation purposes. The location of the existing well is indicated in Fig. 1c.

Resistivity maps at various depths (Figures 3-6) were constructed to give the horizontal extent of the saltwater intrusion. These maps were made at depths of 6m, 10m, 15m and 40m. Layer resisitivity obtained by the inversion are controlled by the resistivity of the pore water and the resistivity of the host rock (Telford et al., 1990; Burger, 1992). Resistivity of water may vary from 0.2 to over 1000Ωm depending on its ionic concentration and the amount of dissolved solids (Ali et al., 1999). Resistivity of natural water and sediments without clay may vary from 1 to 100Ωm while the resistivity of wet clays alone may vary from 1 to 120Ωm (Parasnis, 1986). The resistivity of a layer saturated by saline water and some dissolved solids is in the range of 8 to 50Ωm (De Breuk and De Moor, 1969; Zohdy, et al., 1993).

In this study a modified form of Zohdy et al. (1993) work on resistivity variation as a function of salinity and water quality for the Oxnard Plain, California, was used as a guide for the interpretation of resistivity data in terms of probable lithology and water quality and the result was presented on Table 1. The available borehole logs within the study area were used to correlate with some of the inferred geoelectric sections beneath VES 2, VES 3, VES 7 and VES 11.

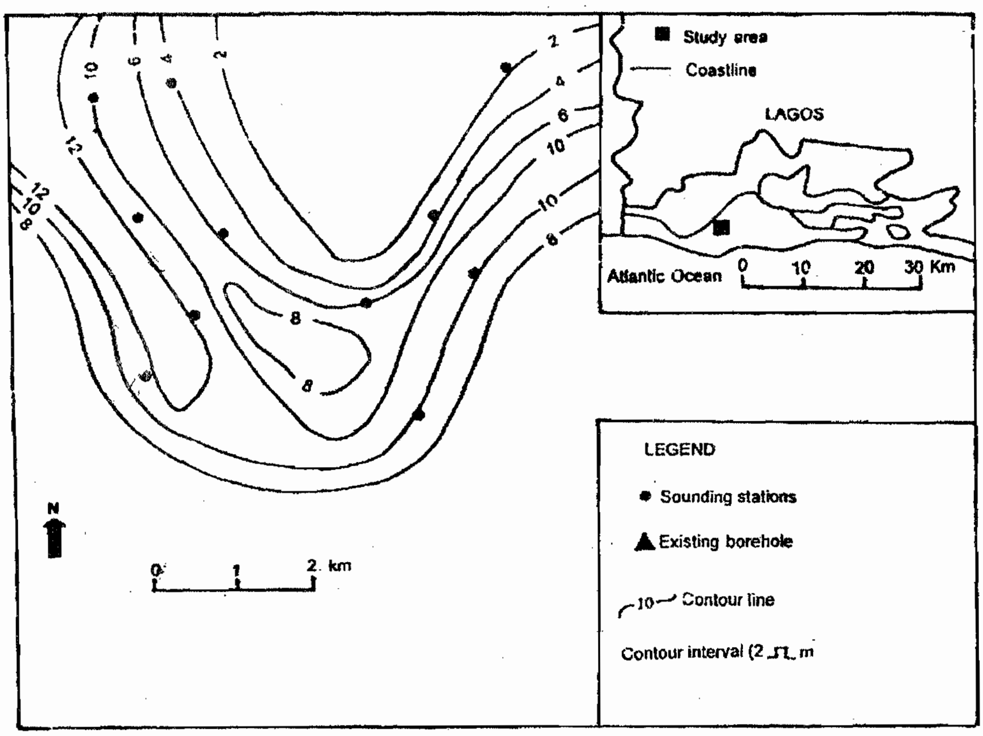

Fig 3: Resistivity map showing the saltwater shape. Parts of this may have resistivity lower than 2Ω m. The average depth range was 6m

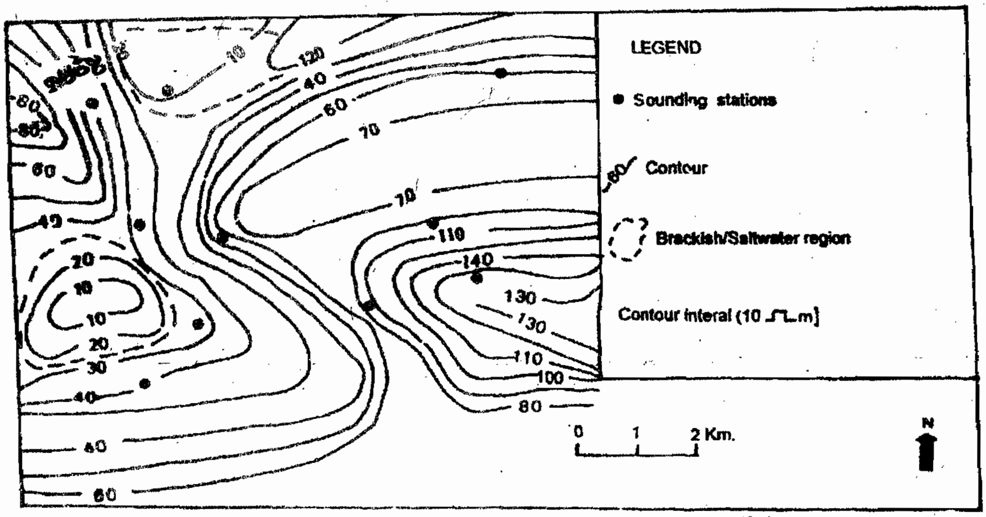

Fig 4: Resistivity map at 10m depth: The dash line indicates areas likely polluted by brackish/saline water

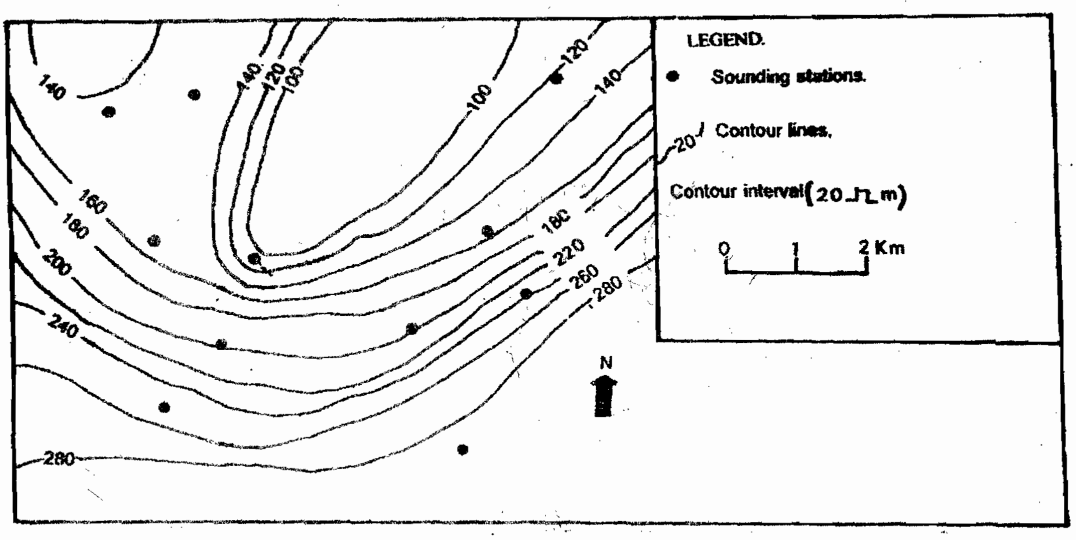

Fig 5: Resistivity map at 15m depth showing the fresh water flowing pattern.

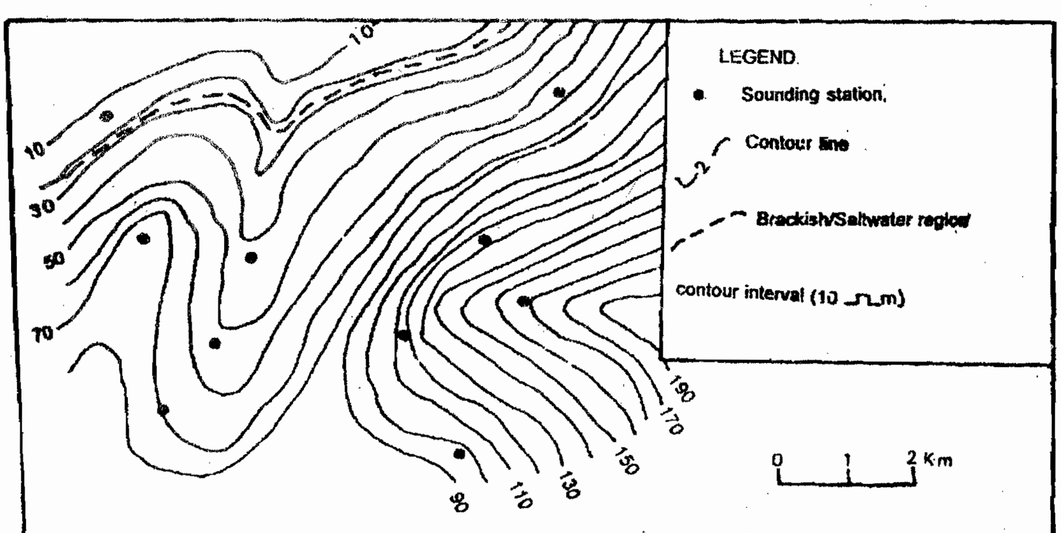

Fig 6: Resistivity map at an average depth of 40m. The dash line indicates brackish region with resistivity ranging from (10-20Ω.m).

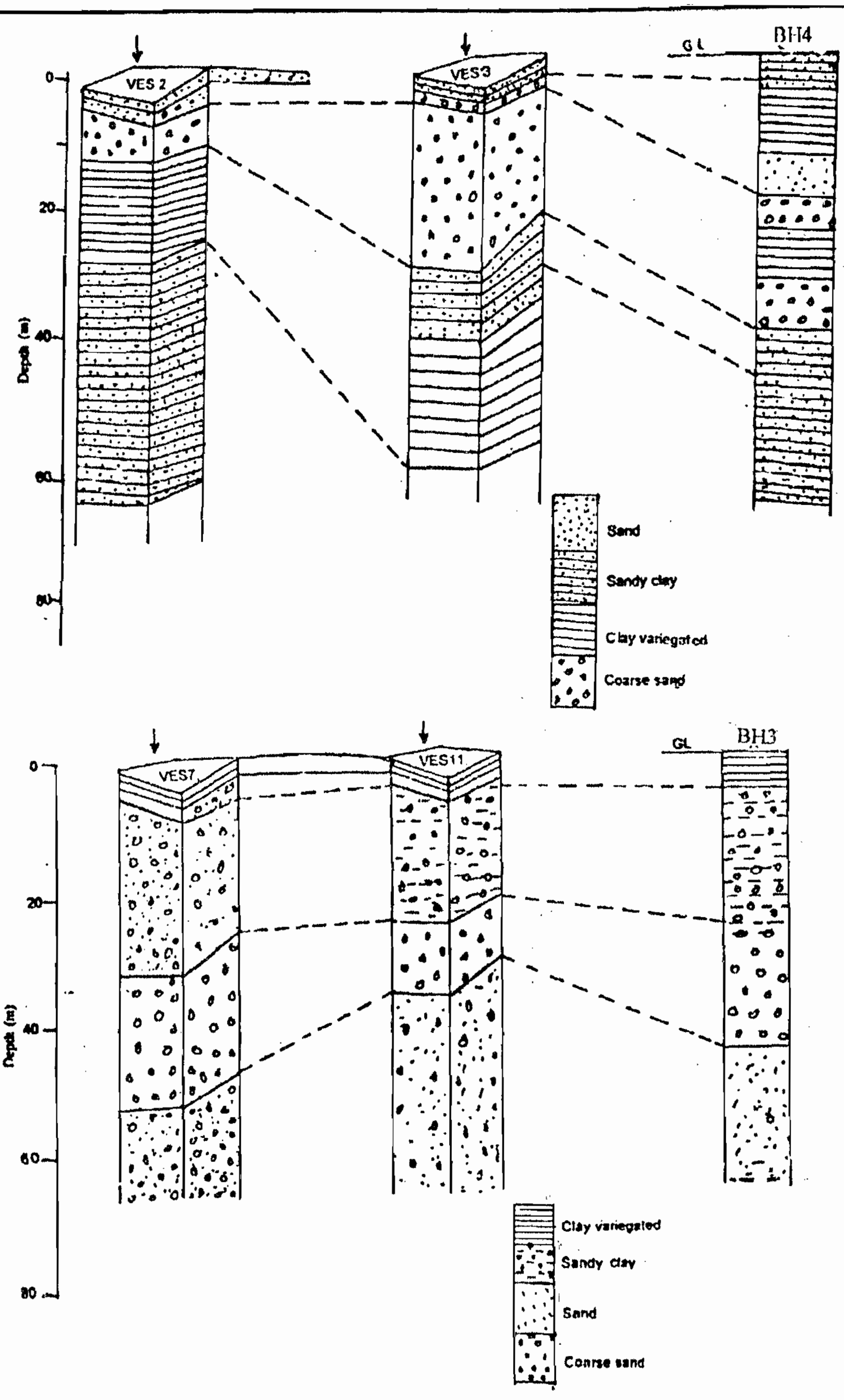

Fig. 7: Geoelectric section beneath VES 2, 3, 7 and 11 correlated with available borehole logs from Iwaya BH3 and BH4

DISCUSSION OF RESULTS

Four resistivity maps at depths of 6, 10, 15 and 40m were constructed. These maps show the freshwater zones and the horizontal extent of saltwater intrusion at those depths.

Figure 3 shows resistivity at 6m depth. The contour interval was 2Ωm. Here parts of the area may have resistivity lower than 2Ωm. The saltwater plume form ridge and depression in some parts of the area. Here the saltwater trends east-west pattern.

Fig. 4 represents resistivity contour map at 10m depth. The contour interval was 100Ωm. The northern and western parts of this map show resistivity values in the range of 10-20Ωm. These areas are probably indicative of saltwater zones. They are demarcated by broken lines.

Figure 5 shows resistivity map at 15m depth. The contour interval was 20Ωm. There were no indicative of saltwater intrusion at this depth as the average resistivity being above 100Ωm. This depth shows the purest groundwater at shallow depth with no traces of intrusion.

Fig. 6 represents the resistivity map at 40m depth. This map indicates the presence of seawater intrusion from the lagoon into the freshwater aquifer at the northern and western parts of the study area. The dash-line indicates the saltwater zone.

Figure 7 presents the correlated geoelectric sections beneath VES 2, VES 3, VES 7 and VES 11 with available borehole logs BH_1 and BH_2. Here the top of the formation corresponds with the sandy clay variegated of the available borehole logs. The second geoelectric section consists of medium - coarse sand with some minor amount of clay in some cases. The third layer consists of coarse sand, gravel no clay and this constitutes the freshwater bearing zone. This layer represents the prolific shallow aquifer tapped by many productive boreholes drilled in this area. The fourth layer consists of very porous and intercalated with sandy clay and this constitutes most of the polluted aquifer. The presence of thin bands of clay representing suppression were not resolved. This might not be unconnected to our short depth range and limitation in the resolution of electrical resistivity method.

CONCLUSIONS

This study has enabled delineation of zones of freshwater occurrence from saltwater zones using the resistivity contrast. The resistivity of the saltwater was found to be in the range of 0.6 to 28Ωm. Between 6 and 10m depth, low resistivity are indicated around the northern and western part of Iwaya. This is probably due to seawater saturated sediments or to high clay content in the sediments near the coastline. At 15m depth the high resistivity observed within the saturated layers indicate the presence of freshwater. The interpreted resistivity map at 40m depth also signifies the movement of saltwater in north-western direction of Iwaya along the coastline. Most part of the area at this depth show an appreciable presence of higher quality freshwater under the seawater region.

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