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ASSESSMENT OF ANOMALOUS SEEPAGE CONDITIONS IN THE OPA DAM EMBANKMENT, ILE - IFE, SOUTHWESTERN NIGERIA.

M. O. OLORUNFEMI, A. I. IDORNIGIE, H. O. FAGUNLOYE and O. A. OGUN

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ABSTRACT

An integrated geophysical survey, involving the vertical electrical sounding (VES), dipole-dipole electrical horizontal profiling, spontaneous potential (SP) profiling and magnetic profiling, was carried out along the embankment of the Opa dam located within the campus of the Obafemi Awolowo University, Ile-Ife, Nigeria. The aim of the investigation was to map possible anomalous seepage zones along the embankment of the dam.
The geoelectric section revealed three distinct layers, namely the clayey sand/lateritic (cap rock) topsoil, the clay/sandy clay weathered layer (core) and the basement (bedrock). The dipole-dipole delineated anomalously low resistivity zones suspected to be seepage zones within stations 8 and 15 (40-75 m), 19-25 (95-135 m), 26-32 (130-160 m) and 38-42 (190-210 m) from the northwestern end of the embankment. SP total field and gradient profiles identified two major interfaces within the anomalously low resistivity zones at around stations 14 (70 m) and 20 (100 m). These are the major seepage zones.
Verdant vegetation on the downstream side of the embankment and location of water ponds at the toe of the embankment around the identified seepage zones are field confirmation of the anomalous seepage.

KEYWORDS: Anomalous seepage, Assessment, Opa Dam Embankment.

INTRODUCTION

Dams are large civil engineering structures usually erected at great costs to impound surface water. In their designs, provisions are usually made for controlled seepage and spillage. However, anomalous seepages may some times occur through permeable soils, rock aquifers controlled by their structure/bedrock topography, and faults/master joints (McLean and Gribble, 1979). Apart from the loss of impounded water through leakage under a dam or through the embankment, the uplift pressure by the percolating water may also affect the foundation. Progressive erosion of weak rocks and soils along leakage paths produces piping, which can occasion dam failure. Other possible causes of uncontrolled leakage/failure include age of dam, poor construction materials, defects in the design, etc. (Olorunfemi et al., 2000). This underscores the importance of routine post-construction investigation for possible spurious seepage to make for proper maintenance and putting in place remedial measures where necessary.

Against this background, the Opa Earth Dam located within the campus of the Obafemi Awolowo University (O.A.U.), Ile-Ife was investigated using geophysical methods to detect possible anomalous seepages. This dam, which is about 320 m long and about 8 m high, impounds a volume of about 633 million gallons of raw water in the adjoining lake that is about 15 m in depth and about 1.5 km long. Thus it was designed to be capable of supplying between 1 and 1.2 million gallons of treated water daily all year round. The investigation was carried out with the aim of;

(a) delineating the various subsurface lithological units beneath the dam axis,
(b) determining the geoelectric parameters of the subsurface layers, and
(c) mapping possible seepage zone(s) under or in the embankment.

GEOMORPHOLOGY AND GEOLOGY OF THE DAM SITE

The Opa Earth Dam is erected across the Opa River that drains the NW part of Ile-Ife town. The site lies within the O.A.U., Campus (Fig. 1). The topography in the site is gently undulating with elevation of between 240 m (along the river channel) and over 260 m in the surrounding slopes that roll gently towards the river. The area surrounding the dam site is covered with thick vegetation typical of the tropical rain forest vegetation belt of Nigeria.

The dam axis is located on granite gneiss and mica schist, which are exposed along the river channel. These rocks are foliated with trends varying between N-S and NE-SW. The dam reservoir rests on mica schist, which is concealed in the immediate vicinity of the dam. These rocks are of the Precambrian Basement Complex of southwestern Nigeria (Boesse, 1989; Rahaman, 1989).

METHOD OF STUDY

For the investigation, an integrated geophysical survey involving electrical resistivity, self-potential (SP) and magnetic methods was adopted. All measurements

M. O. OLORUNFEMI, Department of Geology, Obademi Awolowo University, Ile - Ife, Nigeria
A. I. IDORNIGIE, Department of Geology and Mining, University of Jos, Jos, Nigeria
H. O. FAGUNLOYE, Department of Geology, Obademi Awolowo University, Ile - Ife, Nigeria
O A OGUN, Department of Geology, Obademi Awolowo University, Ile - Ife, Nigeria

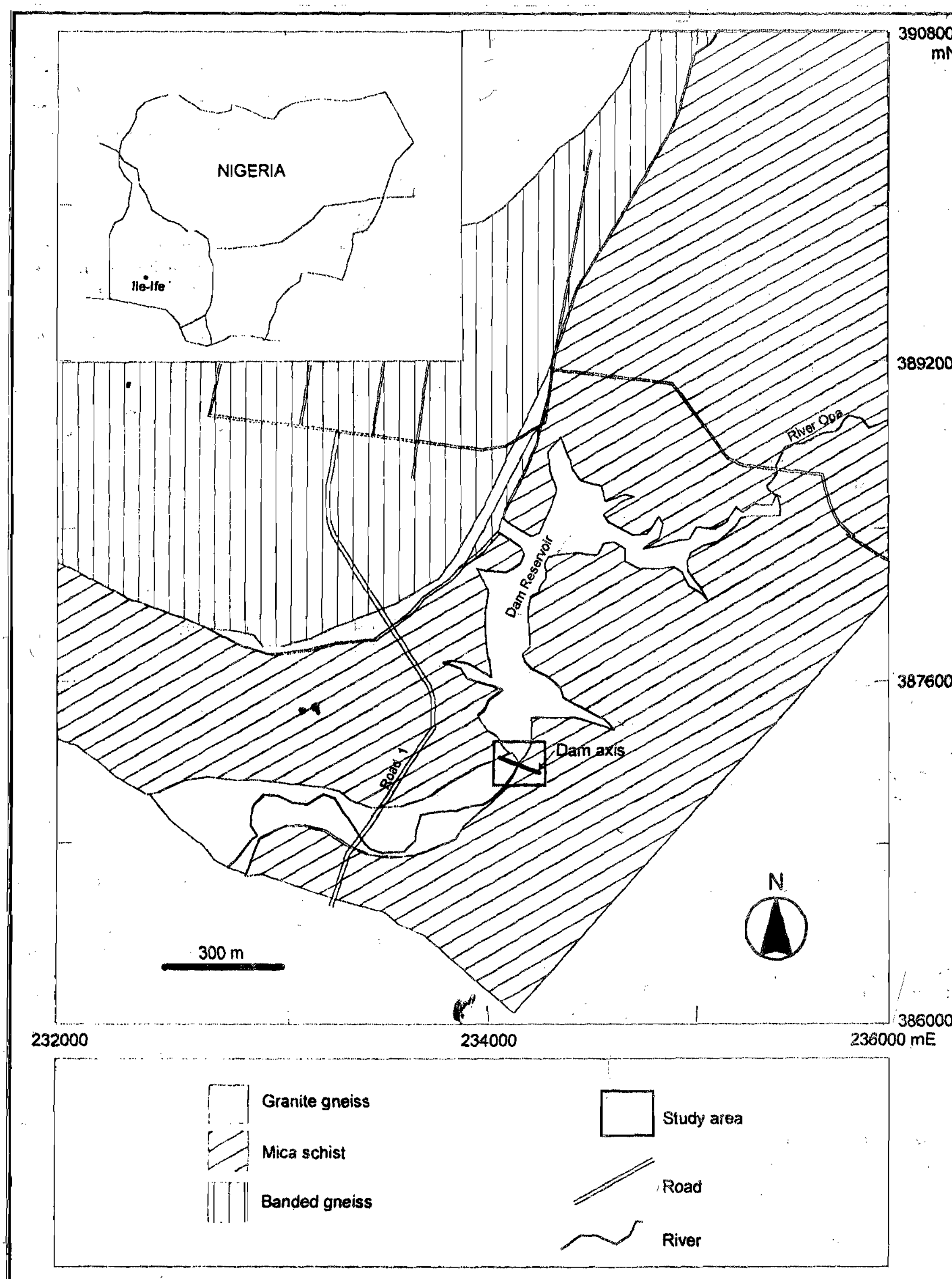

FIG. 1 SKETCH GEOLOGICAL MAP OF THE OBAFEMI AWOLOWO UNIVERSITY CAMPUS (MODIFIED AFTER BOESSE, 1989) SHOWING LOCATION OF THE STUDY AREA.

were taken along the 320 m dam axis oriented approximately N130^{0}E (Fig.2). ABEM SAS 300C Terrameter was used for the electrical resistivity and SP measurements, while the Scintrex Fluxgate Magnetometer was used for the magnetic measurements. The resistivity survey employed the Wenner Vertical Electrical Sounding (VES) and the dipole-dipole horizontal profiling techniques.

Eleven (11) VES stations were occupied along the dam axis. The electrode spacing was varied from 1 to 48 m, while a VES station interval of 20 m was adopted. An electrode spacing of 5 m with an expansion factor, n, varying from 1 to 5 and depth range of 2.9-6.8 m (Roy and Apparao, 1971) was used for the dipole-dipole profiling, thus occupying 46 stations. The SP survey employed the total field (fixed based) and the gradient (dipole) arrays. The station separation for the SP gradient survey was 5 m. During the magnetic survey, the vertical component, Z, of the Earth's magnetic field was measured. Measurements were taken at every 5 m interval along the dam axis. Both time (diurnal) and offset corrections were carried out on the magnetic data.

DATA PRESENTATION

Characteristic depth sounding curves realized during the survey are shown in Figure 3. The curves are the H and KH types, with the H-type curve predominant. The curves were interpreted quantitatively using the partial curve matching and computer iteration techniques. The W-Geosoft/Winsev 5.1 computer software was used for the iteration. The interpretation results were used to construct a 2-D geoelectric section (Fig. 4).

The 2-D pseudosection obtained from the dipole-dipole apparent resistivity data is illustrated in Figure 5. The contours were automatically generated with the aid of ArcView GIS 3.2 software. A 2-D inversion (Fig. 6) was carried out on the dipole-dipole field data using the RES2DINV software developed by Loke (1998). The inversion utilized the least squares method.

The profiles resulting from the plots of SP and magnetic measurements against horizontal distance are shown in Figures 7 and 8, respectively. The magnetic data were filtered using the three point running mean filter.

DISCUSSION OF RESULTS

Geoelectric Section:

The geoelectric section (Fig. 4) displays three distinct geologic layers. The topmost layer is characterized by resistivity values varying between 149 and 723 ohm-m, with thickness range of between 1.5 and 3.0 m. The composition is essentially clayey sand and laterite. This layer constitutes the caprock of the embankment. The second layer has thickness values ranging from 3.4 to 22.1 m. This comprises clay/sandy clay of resistivity values in the 72-197 ohm-m range. The upper segment constitutes the embankment core, while the lower segment, the weathered basement. The water level in the dam lake falls within this horizon, which

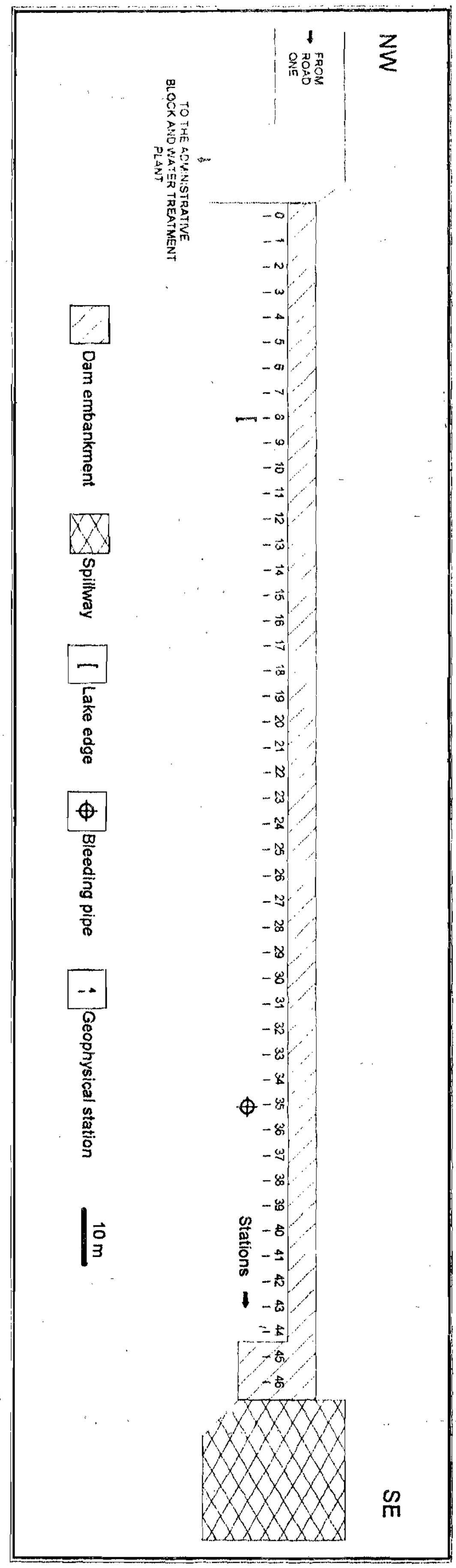

FIG. 2 SITE PLAN OF THE OPA DAM EMBANKMENT GEOPHYSICAL STATIONS.

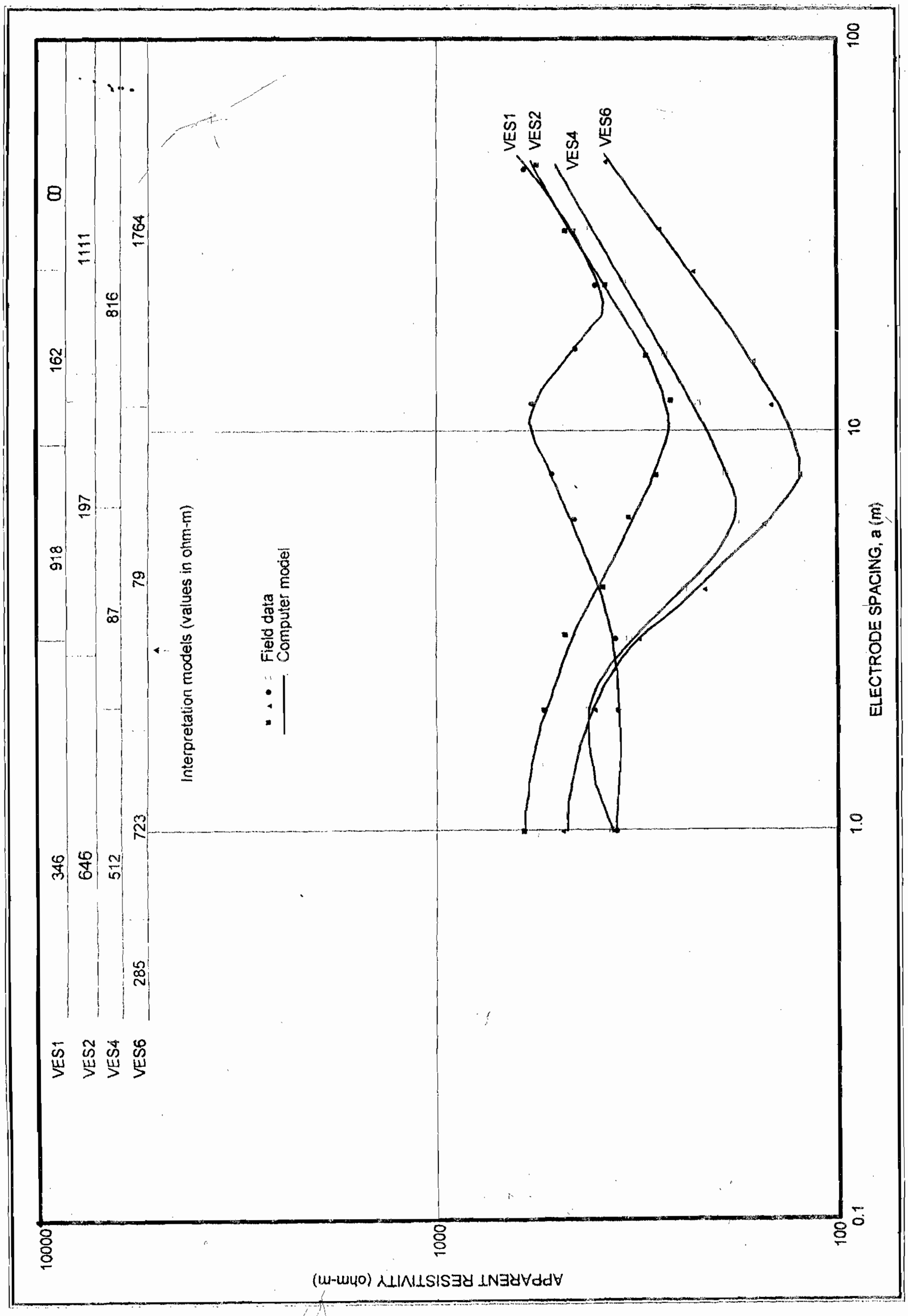

FIG. 3 TYPICAL DEPTH SOUNDING CURVES FROM THE OPA DAM EMBANKMENT.

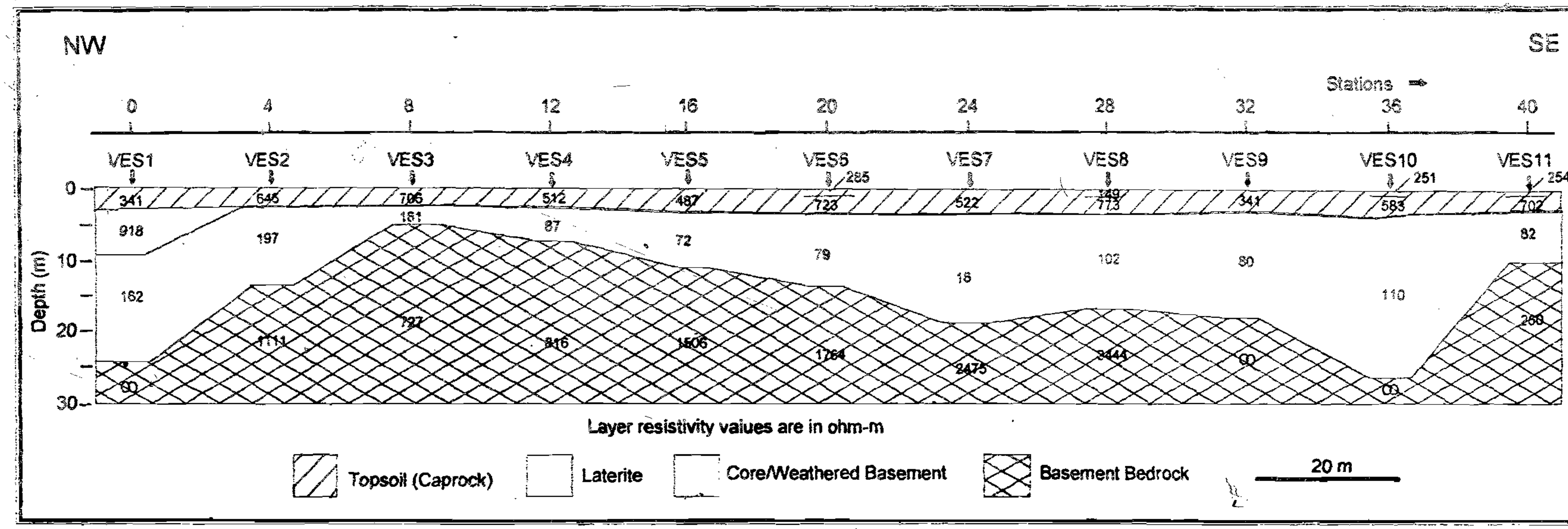

FIG. 4 GEOELECTRIC SECTION ALONG THE OPA DAM EMBANKMENT.

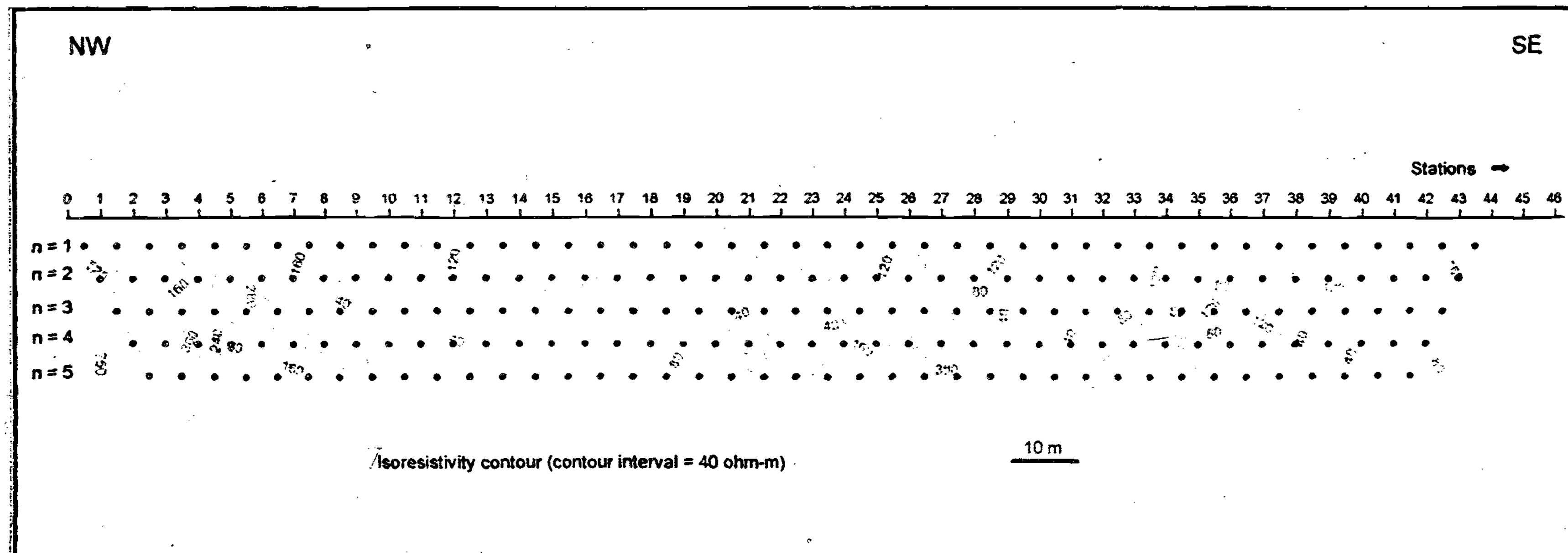

FIG. 5 DIPOLE-DIPOLE PSEUDOSECTION ALONG THE OPA DAM EMBANKMENT.

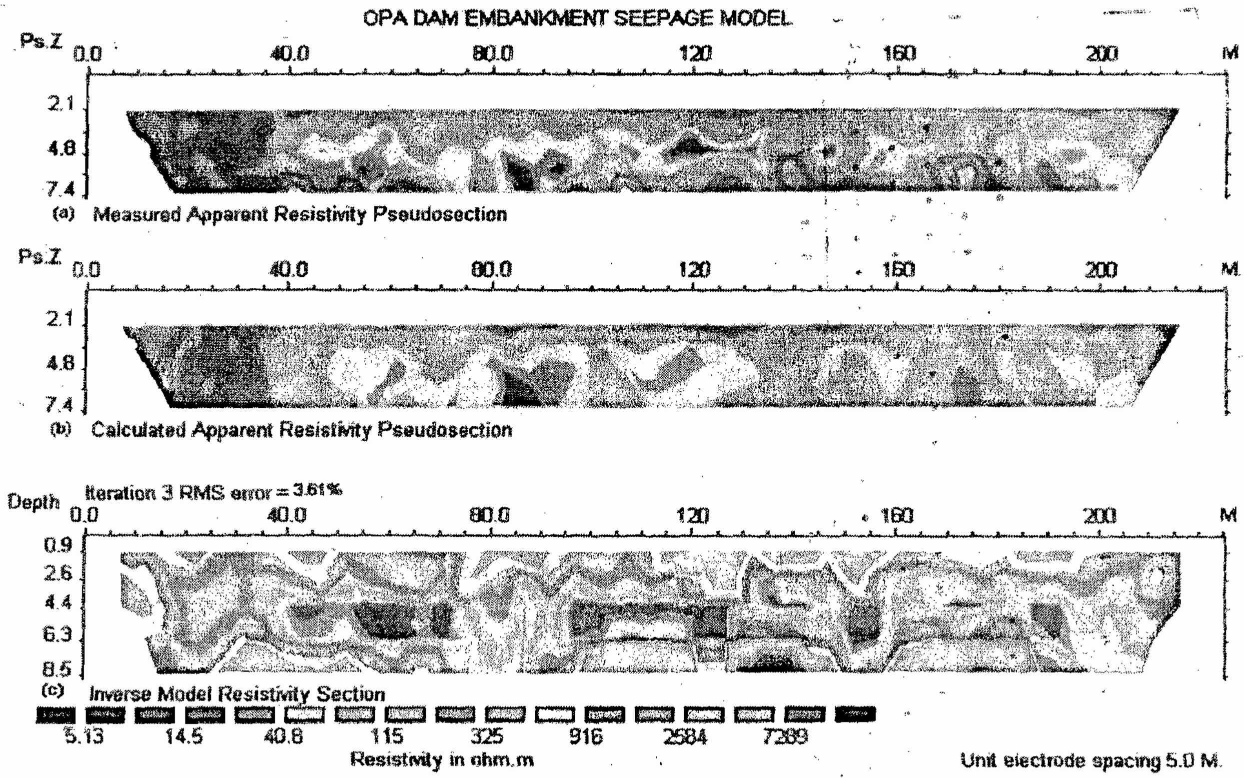

FIG. 6(a) OBSERVED DIPOLE-DIPOLE PSEUDOSECTION (b) CALCULATED PSEUDOSECTION AND (c) INVERSE MODEL ALONG OPA DAM EMBANKMENT.

makes it a marker bed for seepage zones with characteristically low layer resistivity values due to high moisture content. The third layer is the basement bedrock characterized by resistivity values of 722-8 ohm-m. The depth to rockhead varies between 4.9 and 25.0 m. This depth range agrees with the estimates of Ako (1976), taking into cognizance the about 8 m height of the dam embankment.

Pseudosection:

The dipole-dipole pseudosection shows apparent resistivity values that vary between 2.0 and 700 ohm-m. Low resistivity values of less than 120 ohm-m that are symptomatic of clays and sandy clays underlie most of the dam axis (Figs 5 and 6). Low resistivity closures characteristic of wet clays/sandy clays and typical of possible seepage zones are prominent at depth between stations 9 and 15 (45-75 m), 16 and 27 (80-135 m), 29 and 33 (145-165 m), and 38 and 42 (190-210 m) from the northwestern end of the embankment.

The inverse resistivity model displays the anomalously low resistivity zones at depths generally below 3.0 m as observed in the geoelectric section (see Fig. 4). The low resistivity closures are however limited within stations 8 and 15 (40-75 m), 19 and 25 (95-125 m), 26 and 32 (130-160 m), and 38 and 42 (190-210 m). The localized low resistivity closure at about 4.4 m beneath station 35 (175 m) is representative of a metal bleeding pipe (see Fig. 2).

Self Potential Profiles:

Conductive paths, including seepage zones, are located beneath troughs on total field SP profiles or inflection points on an S-shaped gradient SP profiles. Coincidence of such troughs with inflection points is therefore a strong indication of a conductive pipe.

The total field SP profile shows values ranging from about 40 mV to 162 mV (Fig. 7). The significant troughs along the profile seem to indicate zones within the embankment with high streaming potentials and/or diagnostic highly conductive bodies. Prominent troughs located at station 8 (40 m), 12 (60 m), 14 (70 m), 20 (100 m), 27 (135 m), 35 (175), 37 (185 m) and 43 (21 m). The gradient array Sp profile is generally of lower amplitude, ranging from –162.0 mV to 20.0 mV. Over areas of high streaming potentials and highly conductive bodies, gradient SP profiles display S-shaped signatures with the inflection point coinciding with the top of target. Inflection points of identified S-shaped anomaly coincide with troughs of total field profile at around stations 14 (70 m), 20 (100 m), and 35 (175 m) where the bleeding pipe is located. The inflection point at station 7 (35 m) is shifted northwards by a station away from the total field trough.

Magnetic Profiles:

The magnetic profiles (Fig. 8) display amplitude ranges of between –270 nT and 280 nT and –245 nT and 230 nT for the raw and filtered data, respectively. The profiles are flat for most part of the traverse, except

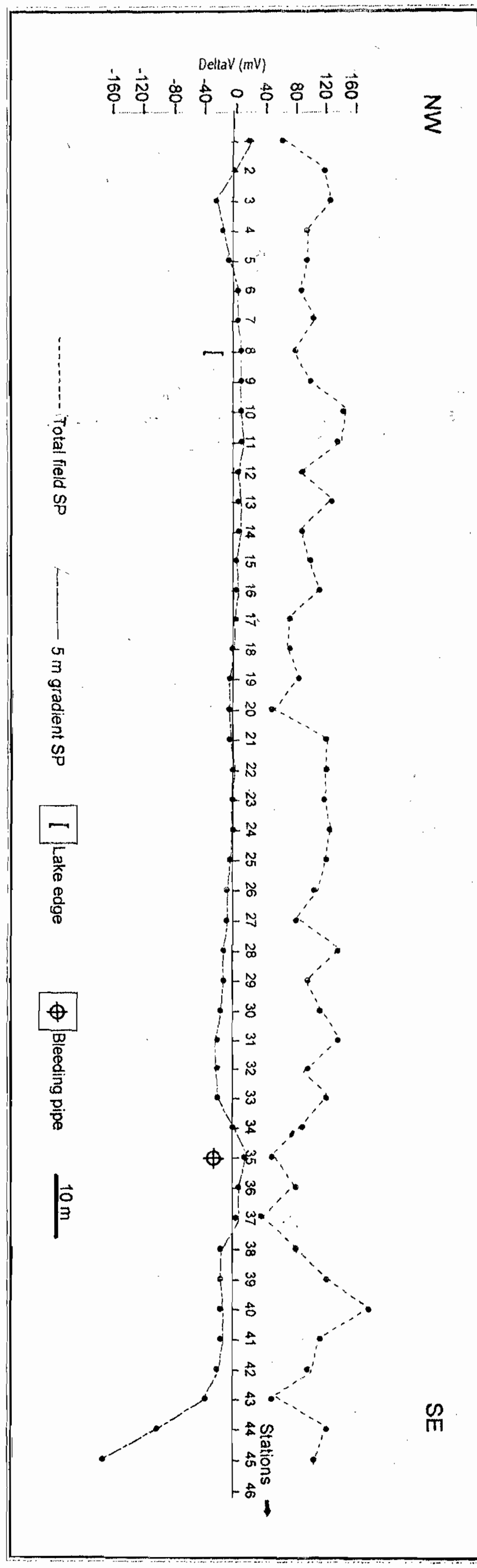

FIG. 7 SELF POTENTIAL PROFILES ALONG THE OPA DAM EMBANKMENT.

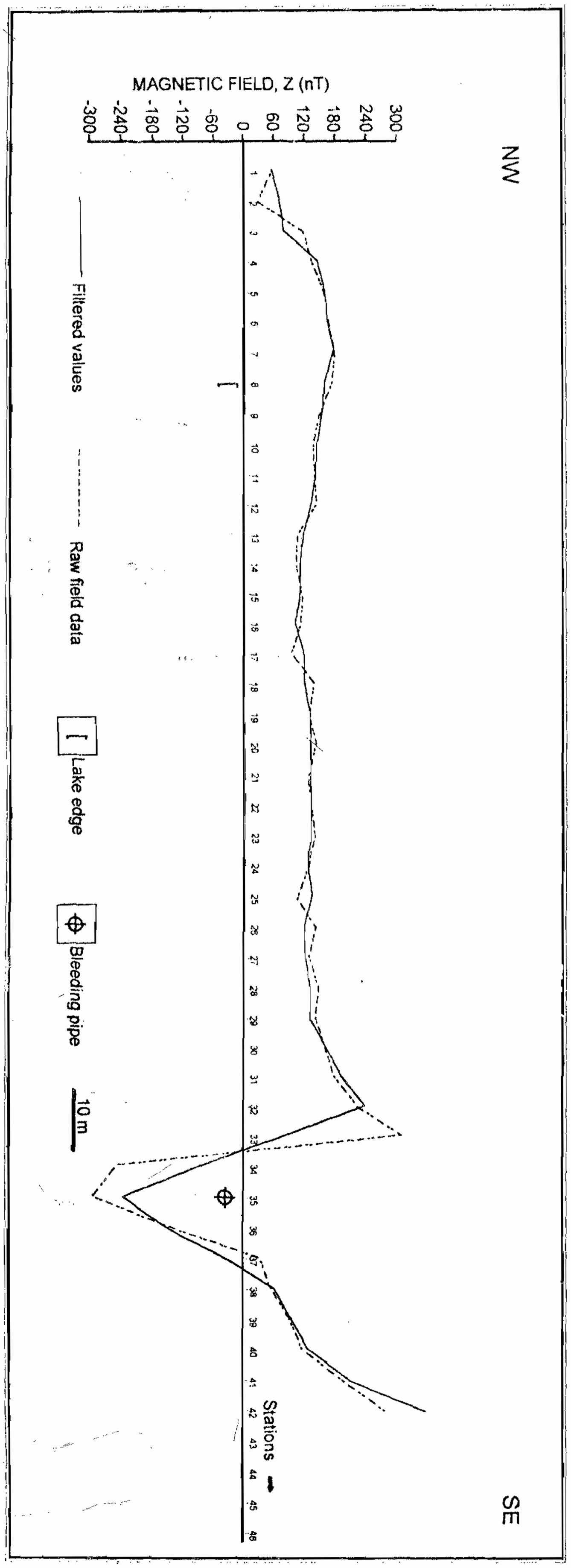

FIG. 8 MAGNETIC (Z-COMPONENT) PROFILES ALONG OPA DAM EMBANKMENT.

between stations 32 (160 m) and 38 (190 m) where a magnetic trough delineates the hollow metallic bleeding pipe located beneath station 35 (175 m).

CONCLUSIONS

Vertical electrical sounding and dipole-dipole, self-potential and magnetic profiling were carried out along the embankment of the Opa dam with the aim of detecting possible zones of anomalous seepage. The geoelectric section delineated three distinct layers, which include the topsoil (caprock) made up of clayey sand and laterite, the weathered layer (core) of clay/sandy clay in composition and the basement bedrock.

The dipole-dipole pseudosection and the inverse dipole-dipole resistivity section corroborate the three-layer section comprising a high resistivity topsoil underlain by a low resistivity core/weathered layer resting on a resistive basement bedrock. The embankment core displays low resistivity zones typical of saturated seepage zones within stations 8-15 (40–75 m), 19-25 (95–125 m), 26-32 (130–160 m) and 38-42 (190–210 m).

The total field and gradient SP profiles identify two major interfaces within two of the identified anomalously low resistivity zones at around stations 14 (70 m) and 20 (100 m). These are the possible seepage zones along the dam embankment.

Field observation on the downstream side of the embankment showed more luscious and verdant vegetation cover around the identified seepage zones. Water ponds were also located at the toe of the embankment around the said stations.

The SP profiles also delineated the metal bleeding pipe. The magnetic profile displayed a single anomaly over the bleeding pipe. It is not diagnostic of the seepage zones.

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