



The use of geoelectrical imaging surveys for the delineation of different subsurface geological and man-made features

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Abstract: Geoelectrical imaging surveys are becoming increasingly important exploration tools in various shallow geotechnical and environmental investigations. The wide range of resistivity variations between the anomaly and the host has made it an attractive physical parameter for subsurface exploration.

New field concepts and techniques have been developed for situations where an understanding of subsurface conditions in detail is required. The Multi-scale survey technique has greatly enhanced the horizontal coverage and the resolution of the array used. Moreover it has partially suppressed the effect of electrical noise on the field measurements as well as strengthened the voltage signal to noise ratio of the Wenner-Schlumberger array by using multiple dipole lengths. Interpretation of the resulting resistivity cross-section has enabled the clear identification of the subsurface features.

INTRODUCTION

Geophysical methods are routine procedures to delineate geological structures and other subsurface phenomena (Dahlin, 1996; Zeng and McMechan, 1997). Proper usage of these methods leads to an increase in the resolution of the resulting subsurface section. Electrical tomography (Griffiths and Barker, 1993), also known as the electrical imaging method, has the ability to image subsurface features by examining its resistivity distribution.

In this study, the use of the geoelectrical imaging technique for the delineation of different subsurface geological and man-made features is explored. The new field survey concepts and techniques that emerged to improve the data acquisition are given in some detail. The results obtained during field surveys employing the Wenner and Wenner-Schlumberger electrode arrays on resistivity traverses in several sites to detect and map a variety of subsurface features are described.

DESIGN OF THE FIELD SURVEY

Electrical tomography surveys are normally carried out by deploying electrodes in a line perpendicular to the strike of the subsurface target which needs to be imaged. The data acquisition is accomplished by a computer-controlled system

(Griffiths *et al.*, 1990) whereby a series of resistivity measurements are made in constant-separation profiles with the electrode spacing being increased in each successive traverse (Fig. 1). The data collected from these surveys are then processed (Loke and Barker, 1996) to be interpreted accurately.

It has been found (Abdul Nassir, 1997) that the conventional electrical tomography survey techniques would be impractical and uneconomic particularly for long resistivity traverses that are usually carried out for environmental and geotechnical studies. The Multi-scale survey technique has been developed to handle such surveys, since in this technique a series of measurements are carried out using different electrode spacings over the same survey line.

The sparse data points produced by these surveys are then compiled to build up the final pseudo-section (Fig. 2). As the Multi-scale survey technique provides more opportunities to extract valuable information from the subsurface than ever before, a broader picture with detailed information on shallow and deeper layers of the surveyed area is obtained from these surveys.

In the Wenner-Schlumberger array, the potential dipole spacing is increased after multiple numbers of depth levels (Edwards, 1977) depending on the geology of the area, the electrode spacing and the amount of current injected to the ground (Abdul Nassir, 1997). An increase in the current

electrode spacing while keeping potential dipole length constant leads to an increase in the measuring cross section area beneath the electrode setup. This will result in a decrease of the measurable voltage signal, since the later is inversely proportional to the cross sectional area between the outermost electrodes (Mooney, 1980).

When the resistivity surveys are conducted in noisy areas, the current signal introduced into the ground via current electrodes has to be as high as

possible in order to secure a good signal to noise ratio. Meanwhile the duty time of the DC-current pulsation as well as the digital stacking of measurements collected at each electrode setup also have to be increased so as to filter the field measurements from electrical noise disturbances (Hoogervorst, 1975). Therefore, the effect of electrical noise on the resistivity measurements would be suppressed, and thus conserves the measurable voltage signal as a smooth square waveform.

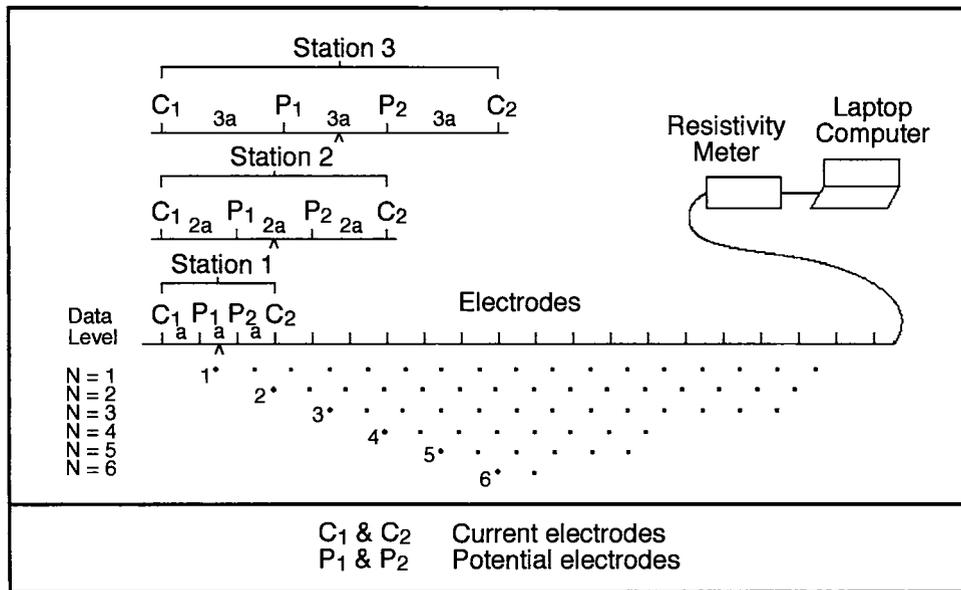


Figure 1. Schematic diagram of the sequence of measurements used to build up a 2D resistivity pseudosection made by a computer-controlled multi-electrode Wenner system.

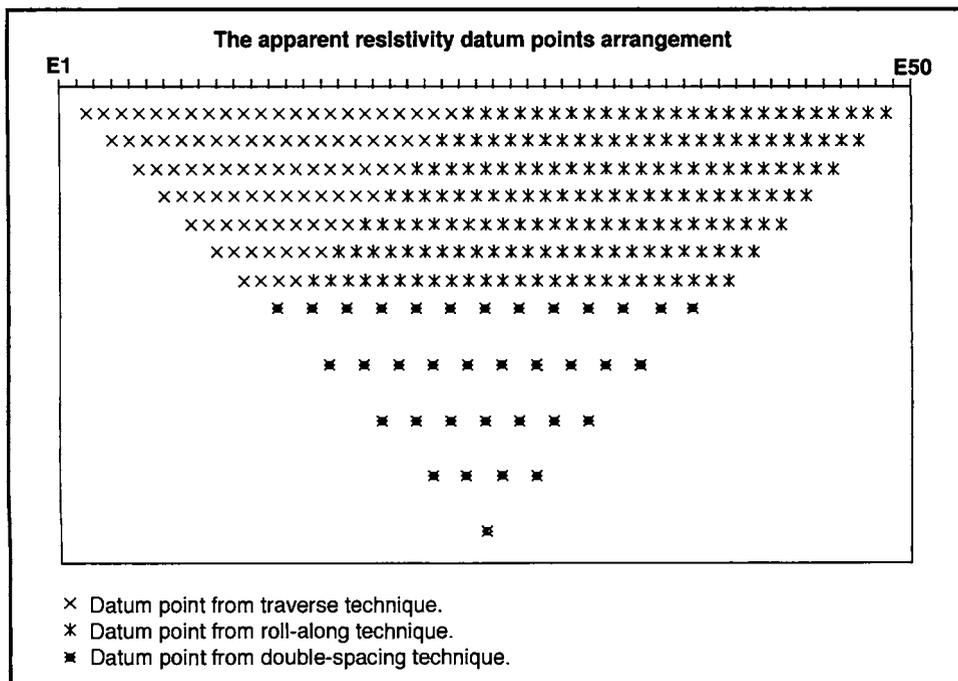


Figure 2. The measurement sequences for building up a 2D-resistivity pseudo-section of the Wenner array by using the Multi-scale survey technique.

FIELD EXAMPLES

In this section, the application of electrical tomography using the Wenner and Wenner-Schlumberger arrays for the mapping of several subsurface features is given. The proposed field techniques were incorporated into these surveys to lower the cost of survey, enhance the measurable voltage signals and increase the horizontal coverage and resolution of the resistivity sections.

Granite bedrock survey

A 2D-electrical imaging survey using the Wenner-Schlumberger array was conducted on a slope to the east of the Student Affairs Office in the Universiti Sains Malaysia campus (Fig. 3). According to an outcrop exposed near the survey site, the geology of the surveyed area consists of two main layers. The top layer consists of a light to dark brown silty clay with a little fine to coarse sand and gravel while the second layer or bedrock is made up of weathered granite.

The resistivity model section (Fig. 4) clearly resolves the topography of granite bedrock, since it shows up as an undulating high resistivity zone in the resistivity section. The low resistivity plume on the top left side of the resistivity section is due to the embankment material that had been used to pave the road crossing the area while the low resistivity zone at the other end of the inverse section represents the original surface layer. This layer varies in thickness but in general it gradually becomes thicker as it progresses slope down from the middle of the section.

Salt water intrusion survey

The survey site is located east of Yan, Kedah State in Malaysia (Fig. 5). The salt water intrusion boundary was earlier located by the 1D resistivity sounding and borehole surveys conducted by the Geological Survey of Malaysia. Due to the inherent capability of the electrical imaging method for detecting lateral changes in pore-water salinity, a 2D survey using the Wenner array was conducted to map the salt-fresh water intrusion boundary.

The survey line has an almost north-west south-east orientation, which is perpendicular to the postulated intrusion boundary. The fresh water and saline water boundary in the Wenner inverse model (Fig. 6) is clearly shown as a steeply dipping curved boundary between the fresh and saline zone.

The high resistivity zone corresponds to the fresh water. The source of fresh water is believed to be rainwater descending from the Gunung Jerai catchment area (Bradford, 1972) towards the lower areas covered by paddy fields. The low resistivity

zone corresponds to the sea water intrusion from the Straits of Malacca.

Underground pipe survey

The survey was conducted over an underground metal pipe located at the Convocation field in the USM campus (Fig. 7). The area in the vicinity of the surveyed site has a number of electrical noise sources that affect the resistivity measurements and have the ability to redistribute electrical current.

The Wenner-Schlumberger model resistivity section (Fig. 8) shows the correct shape and location of the metal pipe, which is indicated by a low resistivity area in the inverse section. The highly resistive regions above the anomaly are due to a layer of dry silty clayey sand with gravel. The highly resistive region on the right side of the inverse model is due to the effect of an underground sewerage pipe crossing that area at the end of the survey line.

CONCLUSION

The electrical tomography method reveals significant details of the subsurface structures, and produces a more accurate 2D geological picture. The proposed techniques have proved to be a rapid, economic and valuable tool for delineating localized features including man-made voids and for precise mapping of the salt-water intrusion boundary and bedrock profile. It appears to be an effective approach to producing a broader picture of subsurface structures with information from various depths.

ACKNOWLEDGEMENT

The authors wish to thank the Geophysics Laboratory assistants of School of Physics, Universiti Sains Malaysia, for aiding in the fieldwork. Abdul Nassir would like to thank the Public Services Department, Malaysia (JPA) for the scholarship provided.

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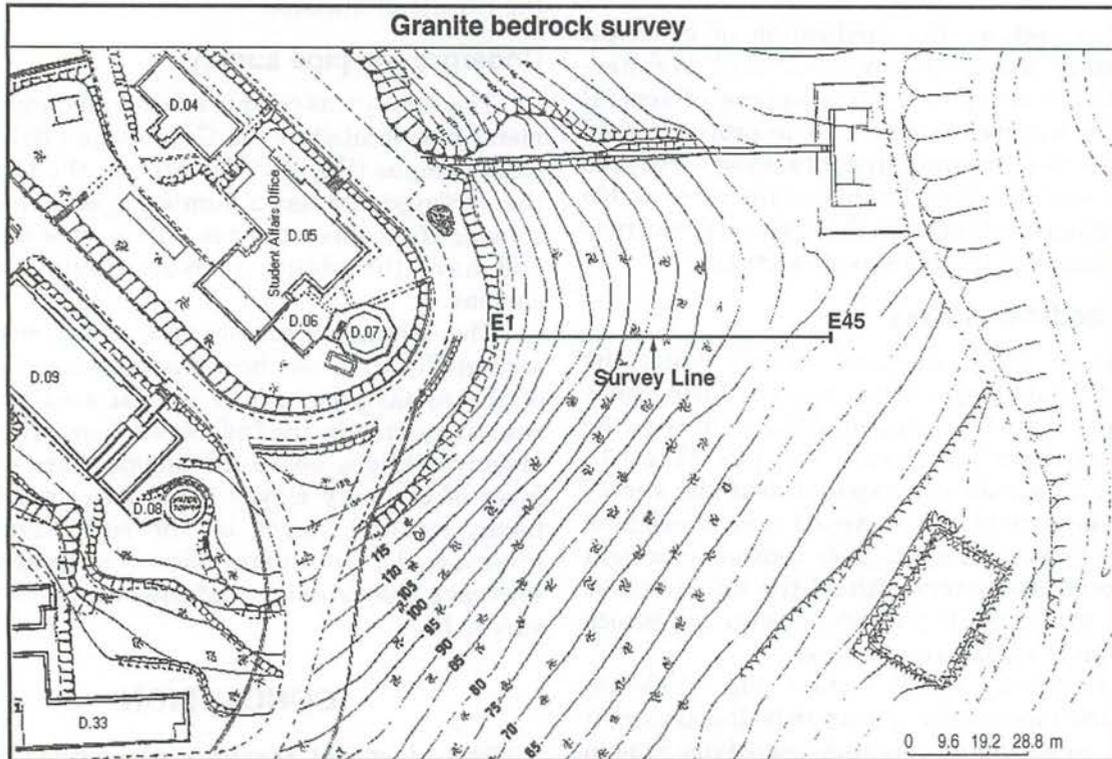


Figure 3. Granite bedrock survey. Map showing the location of the survey line at the USM-Campus.

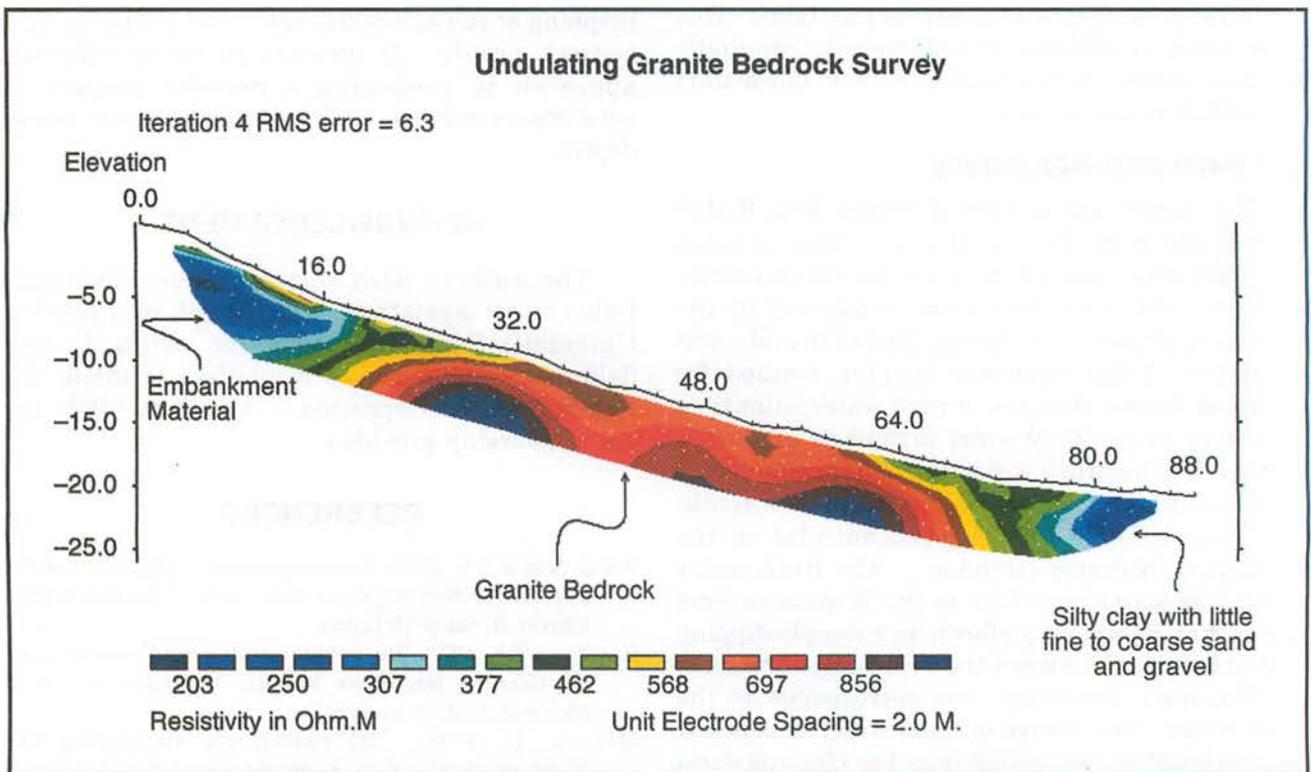


Figure 4. Granite bedrock survey. The Wenner-Schlumberger inverse section with topography.

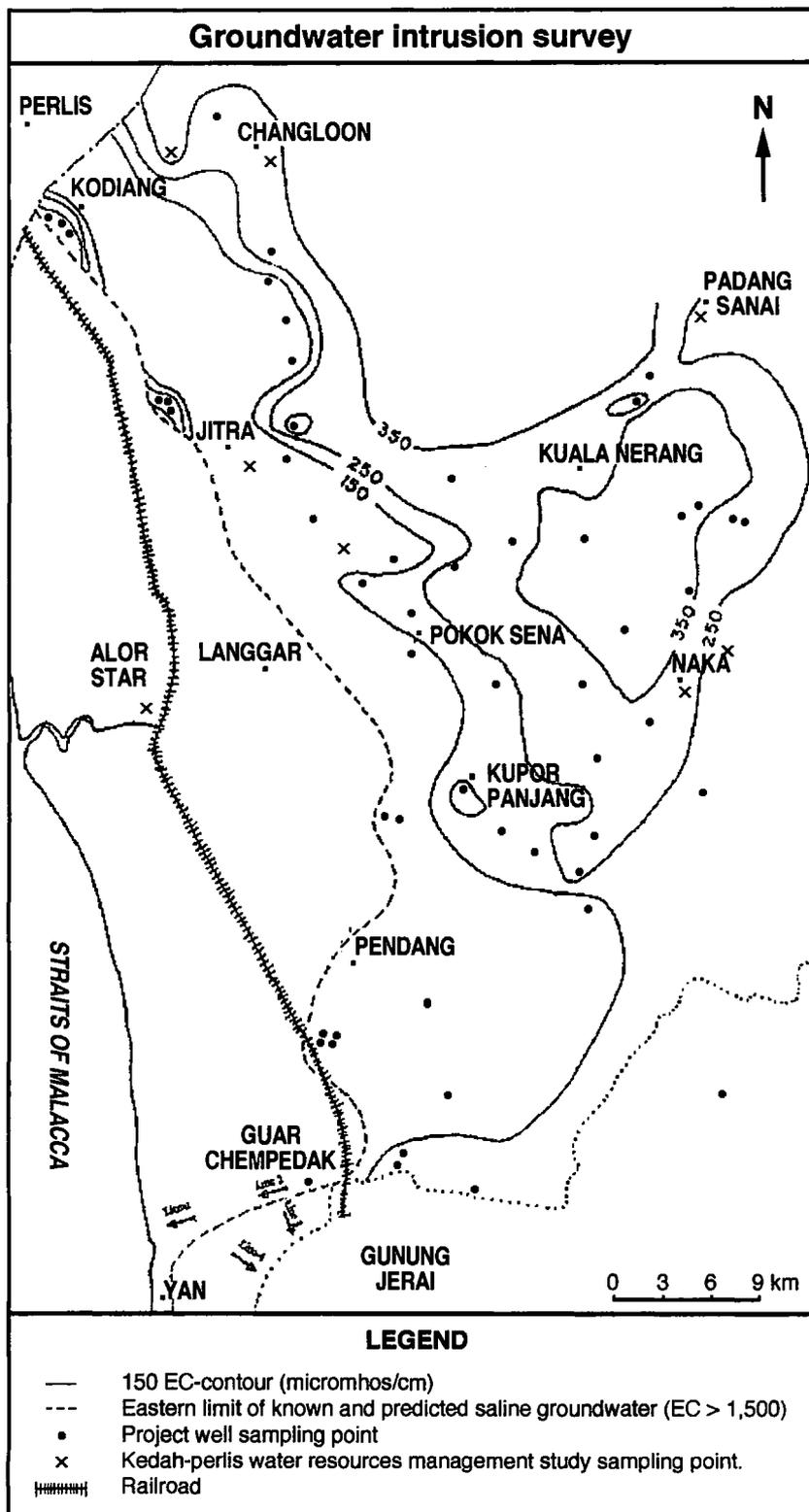


Figure 5. Salt water intrusion survey. Map showing the location of the resistivity survey lines near Yan, Kedah State (after the ministry of works and public utilities report, 1983).

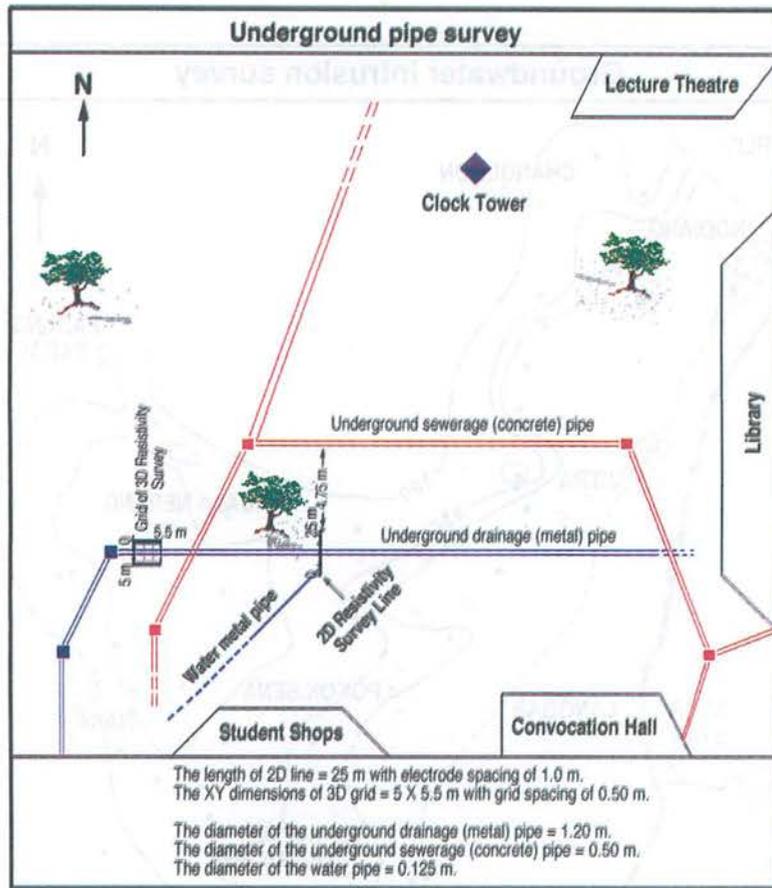


Figure 7. Underground pipe survey. Sketch (not to scale) of the survey site in the Convocation field, USM-campus showing the location of the resistivity survey line.

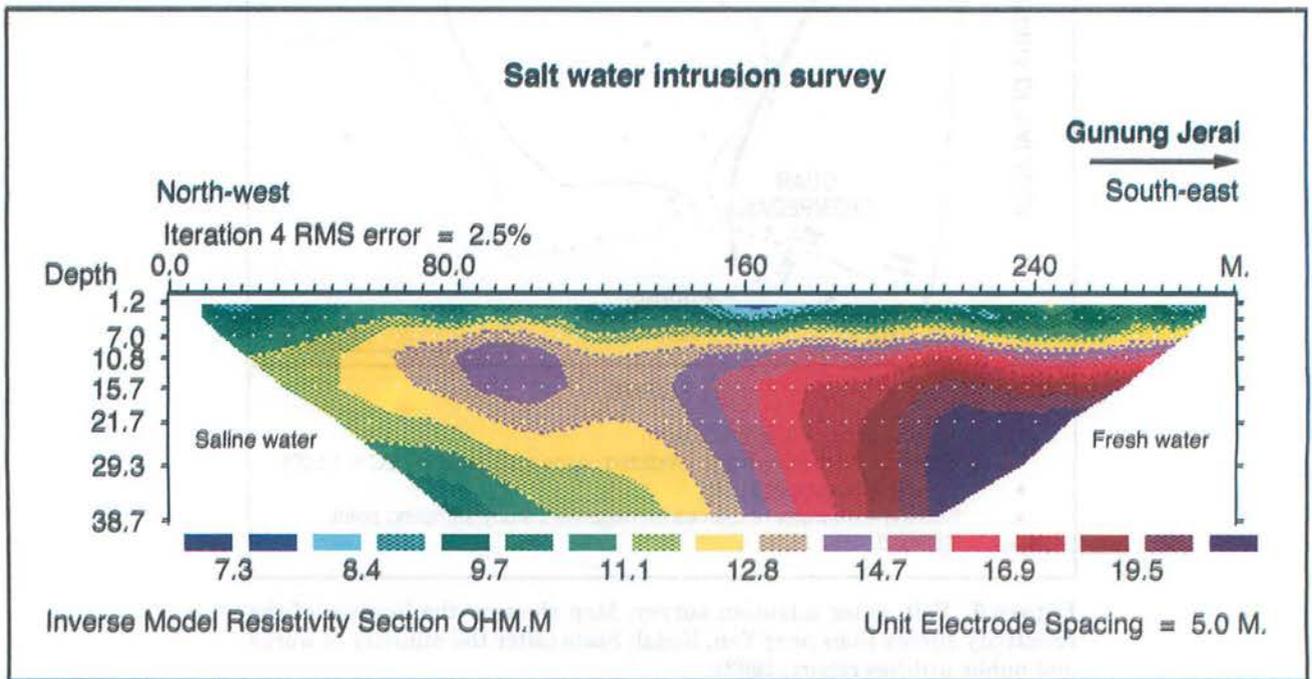


Figure 6. Salt water intrusion survey. The Wenner inverse model section.

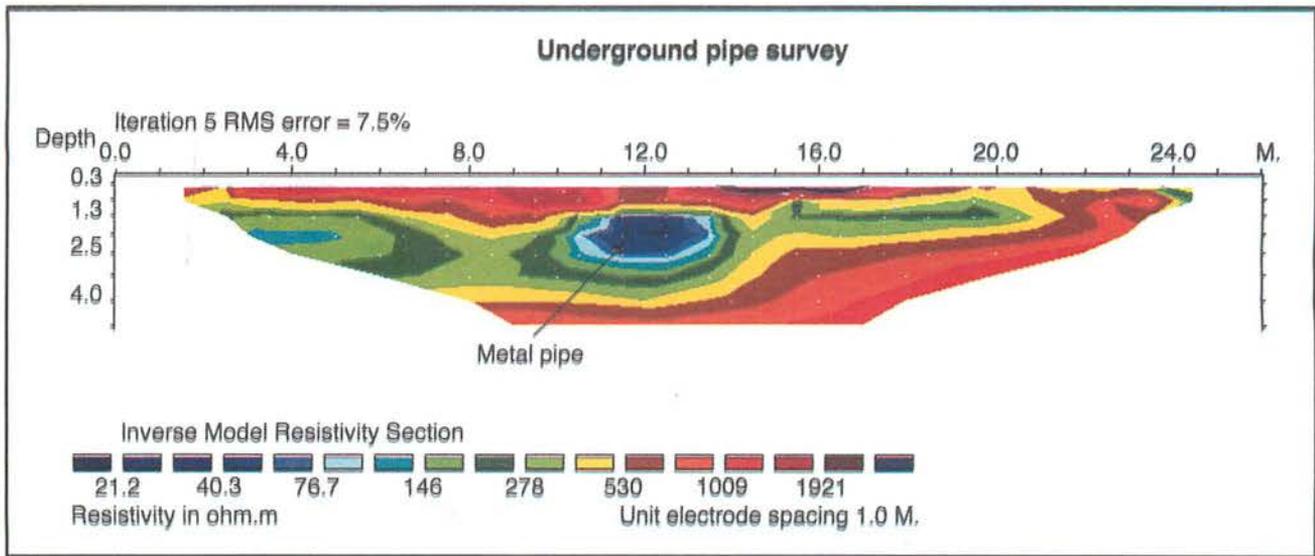


Figure 8. Underground pipe survey. The Wenner-Schlumberger resistivity inverse section.

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Manuscript received 18 August 1998