Open access e-Journal
Earth Science India, eISSN: 0974 – 8350
Vol. 4(I), January, 2011, pp.21-28
http://www.earthscienceindia.info/

Application of Three Dimensional Electrical Resistivity Tomography to Identify Seawater Intrusion

S. Sathish[1], L. Elango[1*], R. Rajesh[2] and V.S. Sarma[2]
[1] Department of Geology, Anna University, Chennai, Tamil Nadu, India – 600 025.
[2] National Geophysical Research Institute (Council of Scientific & Industrial Research) Uppal Road, Hyderabad, Andhra Pradesh, India – 500 007.
Email: s.sathish.au@gmail.com,*elango@annauniv.edu, rekapalli@gmail.com, vssarma.ngri@gmail.com
*Corresponding author

Abstract

This study was carried out with the objective of assessing the zone of mixing between seawater and groundwater in south of Chennai, Tamil Nadu, India using High Resolution Electrical Resistivity Tomography technique. The study area is bounded by water on all the four sides with Bay of Bengal in the east, Buckingham canal in the west, the Adyar river in the north and Muttukadu backwater in the south. The Wenner and Schlumberger config uration was used to create three dimensional and two dimensional apparent resistivity model. The maximum length of profile is 170m and the maximum depth of penetration is 28.7m. The apparent resistivity ranges from 0.3 ohm m to 30,000 ohm m. The subsurface lithology was derived and it is compared with borehole logs of nearby wells. The low apparent resistivity zone in the 2D and 3D images indicated the seawater intrusion. The maximum distance of seawater intrusion from the coast was 120m. The distance up to which the seawater has intruded is comparatively more in northern part of the area. This is due the over pumping of groundwater which lead to seawater intrusion in the northern part of the area. The study demonstrated the application of three dimensional high resolution electrical resistivity tomography to identify of seawater intrusion in the costal aquifer.

Keywords: Electrical Resistivity Tomography, Seawater intrusion, Coastal aquifer, Chennai

Introduction

Seawater intrusion is a major problem in coastal areas due to over extraction of groundwater. The identification of seawater intrusion begins as early as 1845 on Long island, New York. In recent days, seawater intrusion is most common in developing countries. This is due to urbanization, industrial development, coastal vegetation, agriculture etc., which lead to over pumping of groundwater resulting in encroachment of seawater into freshwater aquifer. The identification of seawater intrusion was done by various methods including isotope studies, geochemical and geophysical studies (FAO, 1997). Geophysical resistivity methods are advantageous as they are indirect methods, rapid and relatively inexpensive (Ebraheem *et al.*, 1990; Ebraheem *et al.,* 1997; El Mahmoudi, 1999). The present study was carried out with the objective of assessing the zone of mixing between seawater and groundwater in south of Chennai, Tamil Nadu, India using High Resolution Electrical

Resistivity Tomography(HERT). The groundwater characteristics of this area were reported earlier by Gnanasundar and Elango, 1998; 1999. The previous studies were based on groundwater sampling, groundwater level monitoring and by using 1D resistivity survey. The present research is carried out with the optimization of resistivity model including three dimensional and two dimensional methods, which is very useful to delineate the low apparent resistivity zones. It is easy to identify the distance of intrusion of seawater in to the aquifer.

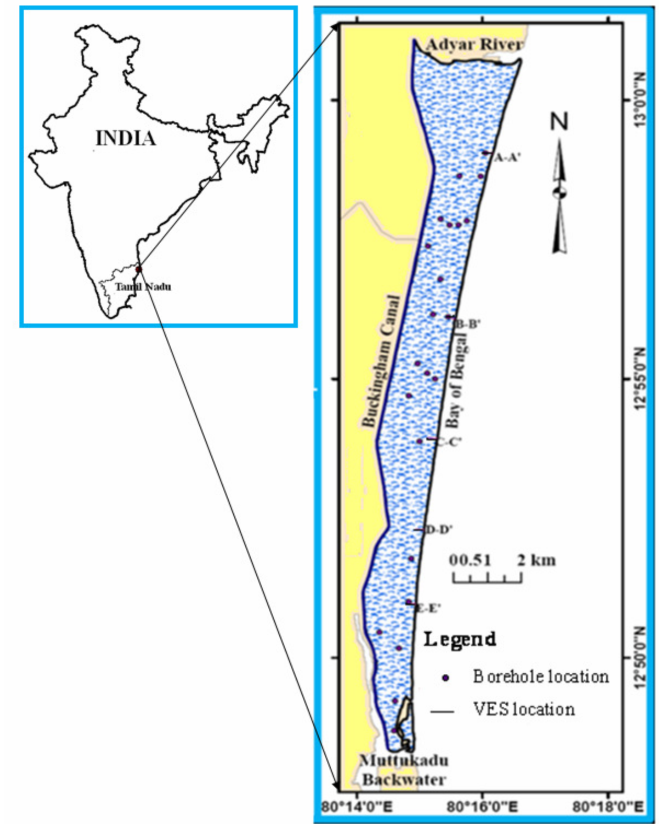

Fig. 1: Map showing area of study.

Study Area

The area of study is around 35. km^2 in the southern part of Chennai which is the fourth largest city in India. The atmospheric temperature varies seasonally with summer values ranging from 35° C to 42° C and in winter it ranges from 25° C to 34° C. The southwest monsoon prevails from July to September and the northeast monsoon is active from October to December. The average annual rainfall is about 1200 mm. Rainfall recharge is the main source of the aquifer replenishment. This area is bounded by water on all the four sides with Bay of Bengal in the east, Buckingham canal in the west, the Adyar river in the north and Muttukadu backwater in the south (Fig.1). The Adyar river and the Muttukadu backwater consist of saline water most of the time except during times of severe monsoonal rains. The Buckingham canal that run parallel to the Bay of Bengal carry contaminated water due to the discharge of domestic sewerage from the settlements around the canal.

Earth Science India, eISSN: 0974 – 8350
Vol. 4(I), January, 2011, pp.21-28
http://www.earthscienceindia.info/

Topographically the central part of the region is elevated along north-south with gentle slope towards east and west. The highest topographic elevation is about 12 m above msl towards the northern boundary (Fig. 2). The landuse and landcover map (IRS-LISS III 24/02/2004) show that the settlement is comparatively high towards north than south (Fig. 3). The area comprise of beaches, sand dunes, build-up lands including settlements, theme parks and hotels, and with small agricultural lands and industries. The central part of the area comprise of unconsolidated sand which function as an unconfined aquifer.

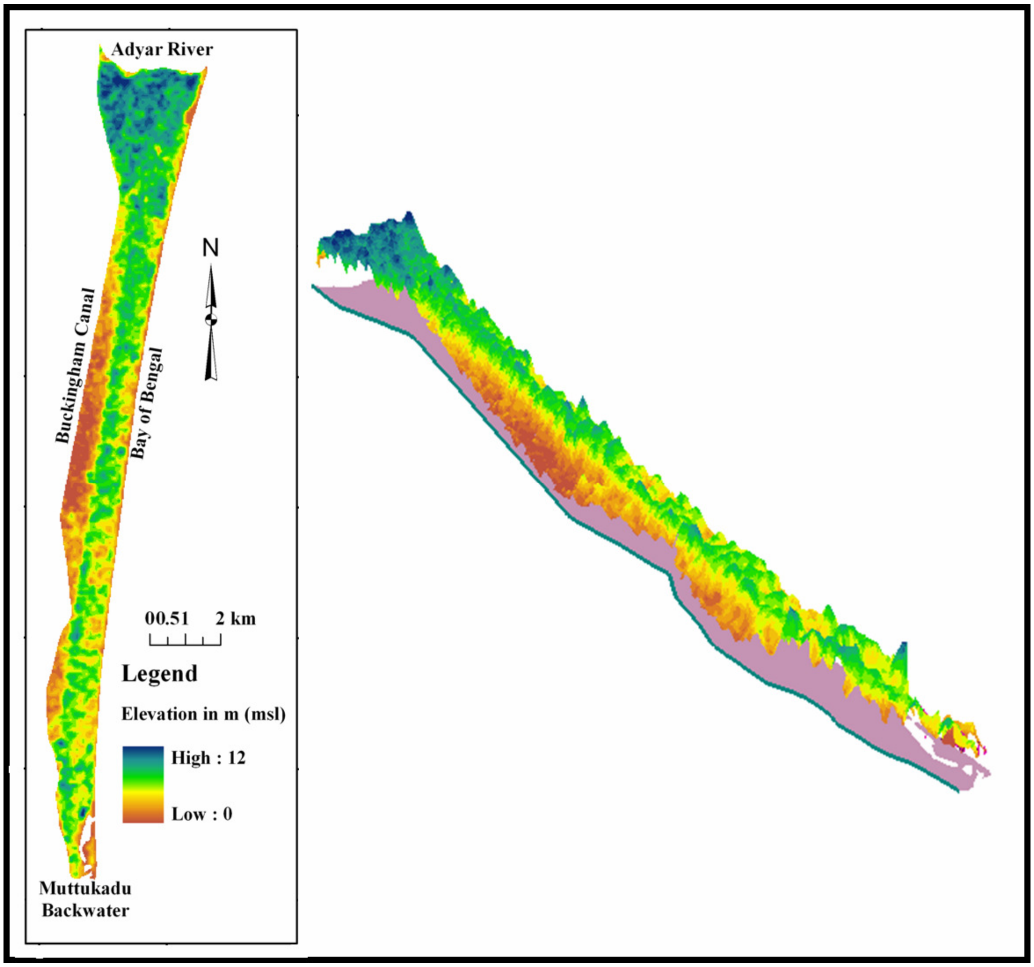

Fig. 2: Topographic elevation in the study area.

Methodology

To achieve an objective of the study, HERT resistivity 3-D survey and profiling was carried out during May 2008. The survey was carried out in five profiles perpendicular to the sea using IRIS make SYSCAL Pro-96 system. The Wenner-Schlumberger configuration was used to carry out the study. The advantageous of this configuration is that it is comparatively less sensitive in both horizontal and vertical variationthen all the other remaining configurations (Loke and Barker, 1996). The location of profiles were selected in such a way that there are no undulation in the topography and absence of electrical cable both beneath and above the ground surface. The inter electrode spacing was kept at 2.5m or 5m. The maximum length of profile is 170m. RES2DINV software was used to create inverted resistivity model. Borehole logs of 33 wells were collected and ROCKWORKS software was used to obtain the 3D lithological model. This was used to check the lithological interpretation made from resistivity section.

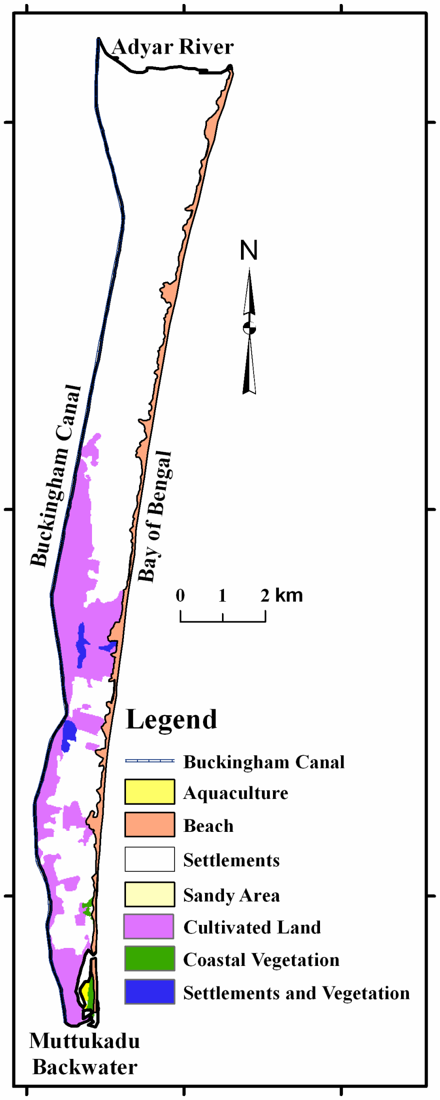

Fig. 3: Landuse and landcover map derived from IRS-LISS III (24-02-2004).

Result and Discussion

Subsurface geology:

The geology of the study area is shown as block diagram in the Fig. 4. The precambrian gneiss of charnockitic composition is the basement which is covered by quaternary formation. The basement charnockitic rock is weathered in the top and the thickness of weathered zone varies from 1.5m to 10.7m. The quaternary formation predominantly consists of sand, however in western boundary along Buckingham canal clay is dominant. The thickness of quaternary formations varies from 7m to 23.2 m. The thickness of quaternary formation is comparatively high towards north direction. Sand dune and beach sands occur along the coastal boundary a few hundred meters wide.

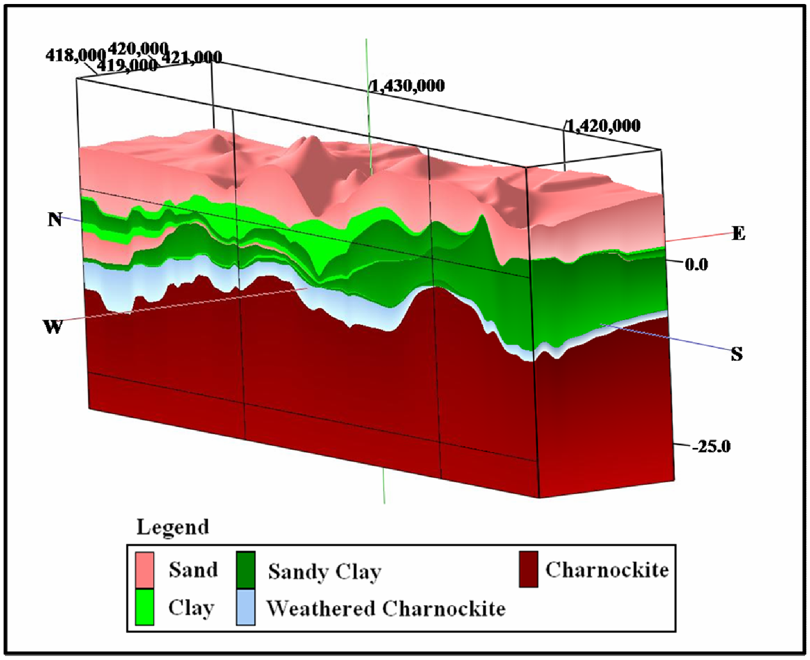

Fig. 4: Three dimensional block diagram of the subsurface lithology.

Three Dimensional apparent resistivity model:

Three dimensional apparent resistivity model developed from a 3D tomography carried out at the distance from 20 to 70m from the coastal boundary is shown in Fig. 5. The size of model is 50m x 20m. The depth penetration is 6m and the apparent resistivity value goes up to 1000 ohm m. The low resistivity value was measured towards the coast indicating the seawater intrusion which is indicated in Fig. 5.

Two dimensional apparent resistivity model:

Two dimensional resistivity tomography was carried out perpendicular to the coast from a distance of about 5m to 80m from coastal boundary. The length of the profile varies from 100m to 170m (Figure 6). The maximum depth of investigation was 28.7m below the surface.

The depth of water table varies from 1m to 4m below ground surface. The unsaturated zone comprising of sand had apparent resistivity ranging from 20.4 ohm m to 9371 ohm m. Relatively high apparent resistivity was measured in northern part of the area (Profile A-A'). The saturated zone is visible includes unconsolidated quaternary formation and weathered charnockite. The saturated zone thickness varies from 11m to 15.6m. The apparent resistivity value in the saturated zone varies from 0.3 ohm m shown in the unconsolidated quaternary formation (Profile D-D') to 9371 ohm m shown in the weathered charnockite (Profile A-A'). The hard rock occurs at the depth from 13m to 19m measured at the middle of the each profile in order to reduce the noise error. The maximum apparent resistivity value is 30,000 ohm m.

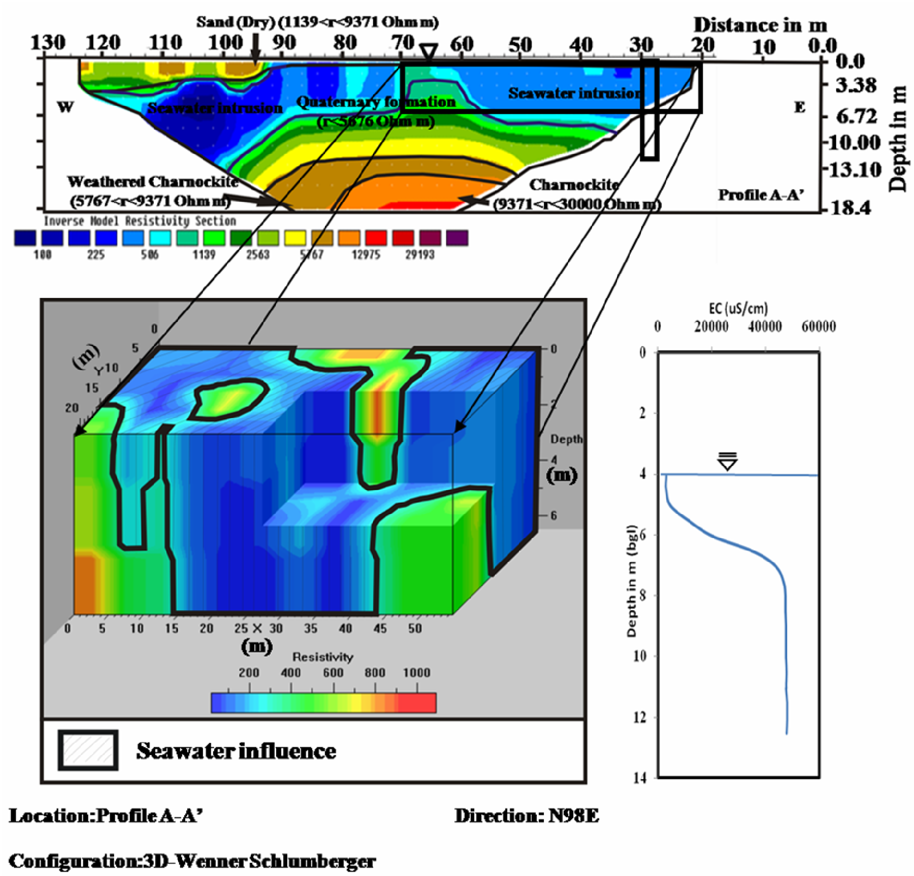

Fig.5: Three dimensional apparent resistivity model.

The low apparent resistivity zone indicates the mixing of seawater with freshwater. The zone of mixing of seawater is clearly visible in all the profiles. The distance of encroachment is measured by using the apparent resistivity profile. The accessible maximum distance of encroachment is 120m (Profile A-A'). The zone of low apparent resistivity is completely occupying the saturated zone in profile A-A'. Hence, the extent of encroachment is still more then above mentioned distance.

Conclusion

The apparent resistivity model helps to determine the zone of seawater intrusion. The maximum distance of seawater encroachment is relatively more in the northern part of the study area. This is comparable with the landuse and landcover pattern where the settlement is comparatively high that lead to over pumping of groundwater in the northern part of the area. Hence, the apparent resistivity model helps to identification of seawater mixing with freshwater. This method is rapid and low cost, producing high resolution apparent resistivity model to identify seawater encroachment. Rapid identification for seawater mixing zone will help in proper and efficient management of coastal groundwater resources. The study

Earth Science India, eISSN: 0974 – 8350
Vol. 4(I), January, 2011, pp.21-28
http://www.earthscienceindia.info/

demonstrated the application of three dimensional high resolution electrical resistivity tomography to identify of seawater intrusion in the costal aquifer.

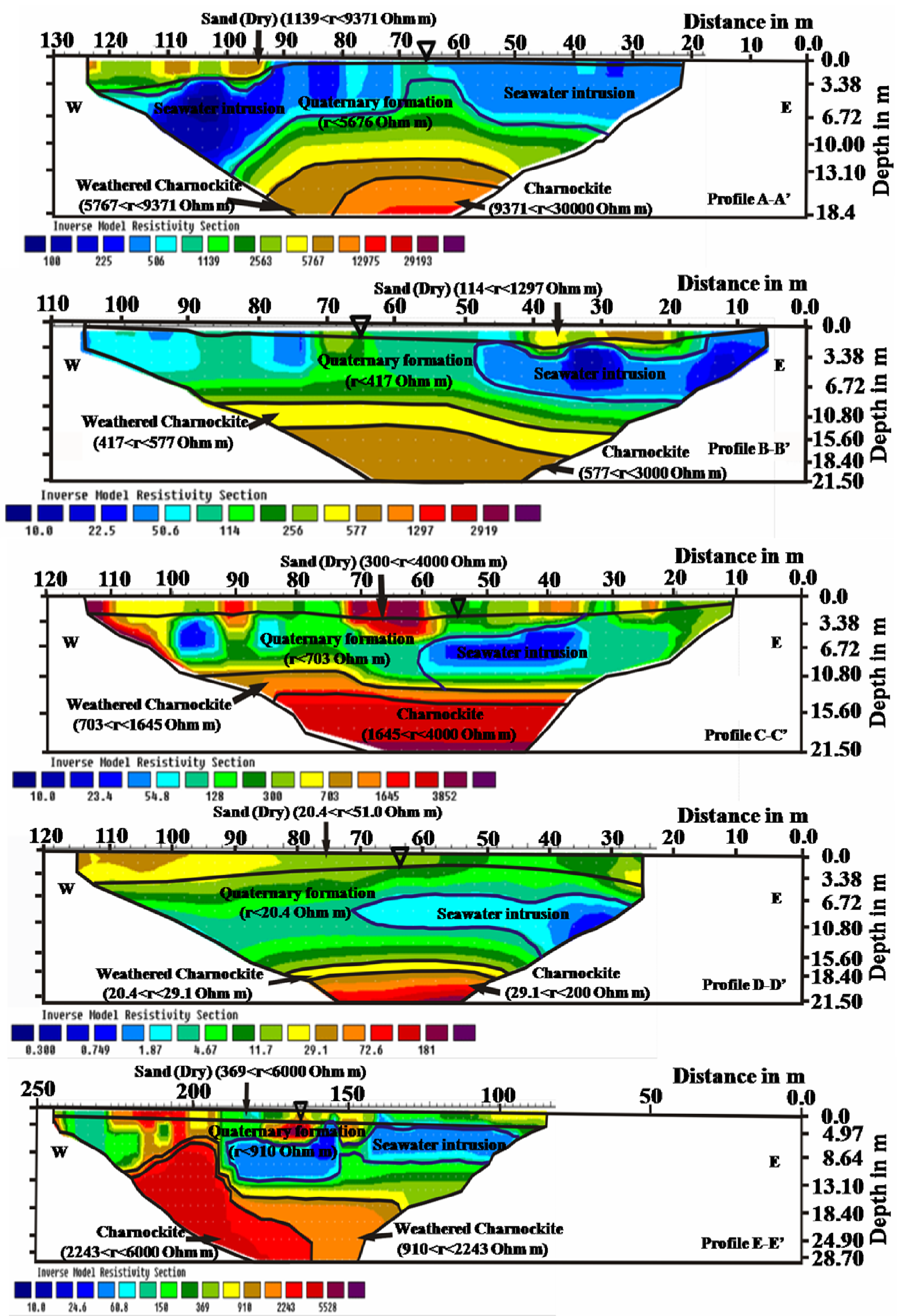

Fig. 6: High resolution apparent resistivity pseudo sections

Acknowledgement: The authors wish to acknowledge FIST, Department of Science and Technology and DRS, University Grants Commission, New Delhi, for providing research grant to carry out this research.

Reference

Ebraheem, A.M. Hamburge, M.W. Bayless, E.R. and Krothe, N.C (1990) A study of acid mine drainage using earth resistivity measurements. Groundwater. v. 28 (3), pp. 361-368.

Ebraheem, A. M. Senosy, M.M. and Dahab, K.A. (1997) Geoelectrical and hydrogeo- chemical studies for delineating groundwater contamination due to salt- water intrusion in the northern part of the Nile Delta*,* Egypt. Groundwater. v. 35(2), pp. 216–222.

EL-Mahmoudi, A.S. (1999) Geoelectric Resistivity Investigations of Kafr Saqr Sheet, Sharrqiya Governorate, East Nile Delta. J. Petrol. Min. Eng., v. 2(1), pp, 84– 108.

Food and Agriculture Organization (FAO)(1997) Seawater intrusion in coastal aquifers, guidelines for study, monitoring and control. Water Report No 11.

Gnanasundar, D. and Elango, L. (1998) Groundwater Quality of a Coastal Urban Aquifer. Indian J. Environmental Protection, v. 18 (10), pp. 752-757.

Gnanasundar, D. and Elango, L. (1999) Groundwater Quality Assessment of a Coastal Aquifer Using Geoelectrical Techniques. J. Environmental Hydrology, v. 7(2), pp. 21-33.

Loke, M H. and Barker, R D. (1996) Practical techniques for 3D resistivity surveys and data inversion; Geophys. Prospect, v. 44, pp. 499–523.