Geophysical Characterization of the Pecém Port Region (NW Fortaleza City) using Electric (tomography) and Electromagnetic (TDEM) Methods, Ceará State, Brazil

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Abstract

The port region of Pecém has economic importance because there is an industrial complex around it. According to Nogueira et al. (2005) the main source of water supply of local people is groundwater. Nevertheless, a big demand for this resource due to industrial, housing and tourism occupations can cause a possible advance of the saline wedge. This paper aimed to characterize the subsurface of the region of Pecém Port, integrating electrical tomography and electromagnetic transient methods, identifying potential areas to groundwater, saline intrusion and/or contamination plumes. The data acquisition was carried out in an electrical profile of 800 meters and an electromagnetic profile of 3200 meters. The subsurface of port region in Pecém area is characterized by four geoelectric layers, and the second stratum (15 to 20 meters deep) is conductive and can be associated with a saturated aquifer layer. The electrical section shows a possible area more conductive with some lenses shapes. These areas correspond to points of saline intrusion inside the aquifer.

Introduction

The municipality of São Goncalo do Amarante, since 2002, has become an area of great economic interest for the state of Ceará because it was opened the port terminal of Pecém. Shortly after, it was implemented the Indutrial Port Complex of Pecém (CIPP). Moreover, the expectations have increased in relation to building the steel company and the refinery of Petrobras in that same region.

In general, the coast of Ceará consists of sedimentary rocks overlapping the crystalline rocks. Thus, the coastal region is favorable to exploitation of good quality groundwater. Nevertheless, a big demand for this resource due to industrial, housing and tourism occupations can cause the advance of the saline wedge. (Cavalcante, 2006) This happens when the exploitation is superior than recharge of the aquifer and this can cause serious environmental problems (Van Dam, 1983).

Another worrying factor is that many of the activities that are being planned to be developed at CIPP involve environmental risks, such as transport and storage of hydrocarbons. Therefore, it is necessary a constant environmental monitoring of the region as well as a research on the subsurface geology with the acquisition of data by different geophysical methods.

This study aimed to characterize (hydrogeological and geoenvironmental) the subsurface of the region of Pecém Port, integrating electrical and electromagnetic methods, identifying vertical and horizontal resistivity contrasts that indicate lithological changes, potential areas to groundwater, saline intrusion and/or contamination plumes.

The aim was also to evaluate, qualitatively, the geological vulnerability to the future industrial installations of the CIPP. This evaluation intends to provide subsidies for the initial environmental assessment of groundwater, the main source of supply to the local population, and reinforce the necessity for constant geoenvironmental monitoring on possible environmental impacts associated with the deployment and operation of industries in the region.

Methods

The methodology consisted of applying the electrical tomography method and the TDEM eletromagnetic method.

The electrical method is fundamentally based on Ohm's Law that defines an empirical relation between a current flowing through a conductor and the voltage potential required to conduct this current.

The application of resistivity method consists of injecting an electrical current on the ground through two or several electrodes and measuring the potential difference between them through two other electrodes. And then you can calculate the potential difference using the following formula:

$$\rho a = K^*\Delta V/ I$$

ρa: Apparent resistivity of the soil
ΔV: Potential difference
I: Injected current
K: Constant

In the field phase, the electrical survey was carried out in a profile of 840 meters in dunes of the east part of Pecem area using a multichannel/multilectrode system with the dipole-dipole array. Topographic data were obtained with a Differential GPS (Fig. 01).

The transient electromagnetic method (TDEM) measures the electromagnetic response of subsoil due to rapid changes of a primary magnetic field produced by pulses of electric current in a transmitter. The electric field produced generates currents in the Earth's interior that dissipate while the energy is transformed into heat by Joule effect. In turn, these currents produce a secondary magnetic field whose attenuation times are directly related to the underlying resistivity.

Thirty-one soundings were carried out spaced 100 meters using the a TDEM equipment (Tem Fast 48) with the single spiral configuration. Topographic data were obtained with a low-precision GPS.

In the stage of laboratory analysis and interpretation, the data processing and interpretation of resistivity method was done using the software Res2d.inv and the routine inversion (Scales and Smith,1996) of resistivity was based on the smoothness constrained least-squares method.

The data processing of electromagnetic data was done using the software from Interpex, the 1-D Inversion Soundig. Finally, it was done the integration of data for a better interpretation.

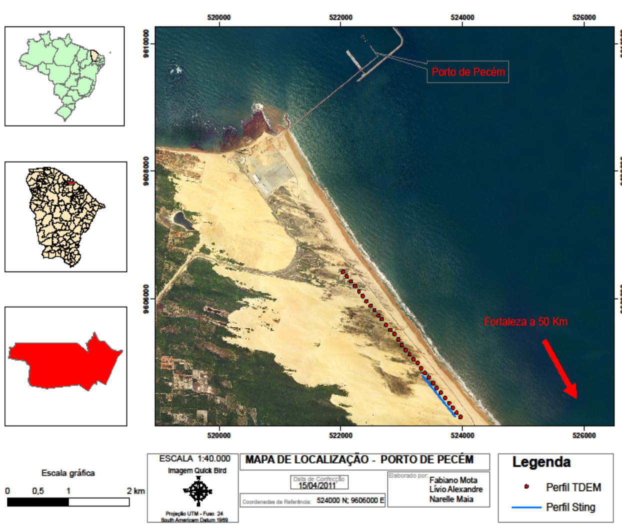

Fig. 01 – *Location map of the study area with electric and electromagnetic profiles, east part of the Pecem Port.*

Results

After processing the data and the construction of 2D geoeletrical imaging, variations of resistivity and thickness, geoelectrical layers were identified and were fundamental to the geological interpretations of the subsurface in the study area.

Electrical method:

The section obtained has a horizontal extension of 840 meters reaching an average depth of investigation of 100 meters.

Throughout the inverted section of resistivity is possible to observe a vertical and horizontal variations. These differences suggest that the section presents four geoelectric layers. (Fig. 02).

Resistivity values nearest the surface present an average resistivity of 500Ω.m indicated by orange, red and violet colors. These colors are distributed horizontally across the section from 0 to 10 meters deep.

In the second geoelectric layer (until 20 meters deep) the resistivity values are presented with a lower average 10Ω.m evidenced by dark green and light green colors. This stratum is continuously placed beneath the first layer (more resistive) throughout the section showing itself more conductive zones. In some areas it presents lenses with very low values zones. This layer has approximately 10 meters thick.

The resistivity values grows again until next 500Ω.m (third geoelectric layer) indicated by yellow, orange and red colors. These higher values of resistivity start to appear from 20 meters depth to indicating the beginning of a more resistive layer extending up to 95 meters deep.

Finally, the more resistive (average 800Ω.m) and deeper layer begins at 95 meters and has indefinitely thick due to the limit of investigation in depth.

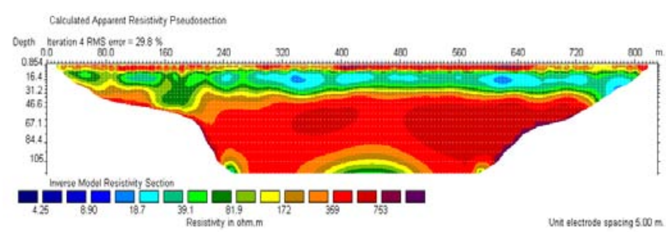

Fig. 02 – *Electrical imaging inverted section showing four geoelectric layers with limit of investigation around 100 meters deep.*

Electromagnetic method:

Three geoelectrical layers were identified using the resistivity section (Fig. 03) obtained from 2-d inverted data.

The first layer is characterized by intermediate values of resistivity (300 to 1000Ω.m) going up to 5 meters deep where the second geoelectric layer starts as a more conductive because it has resistivity values around 10Ω.m. It has 10 meters thick, in other words, 15 meters deep. In the central portion of the section there is a zone with resistivity less than10Ω.m that can be interpreted as indicating a possible saline intrusion.

After 15 meters deep, the resistivity values increase to 800 - 1000Ω.m.

In all soundings, the values began resistive and reaching a depth of 10 to 18 meters; the resistivity decreases sharply. After 19 meters depth, the resistivity increases with increasing in depth.

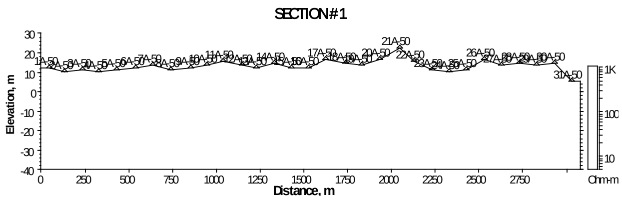

Fig. 03 – *TDEM imaging showing three geoelectric layers with limit of investigation around 20 meters deep.*

Conclusions

After the integration of electric and electromagnetic data and geological observations is possible to conclude.

- The subsurface of port region of Pecém is characterized, until the first 100 meters deep, by four geoelectric layers. The first layer is resistive in the two geoelectrical resistivity sections and can be associated with unconsolidated sediments. The second layer is conductive in the two sections and can be associated with a saturated aquifer layer. The next geoelectrical layer is resistive and can be associated with sandy-clay sediments of the Barreiras Formation. And the last geoelectrical highly resistive layer corresponds to the top of the crystalline basement.

- The aquifer layer can be observed in the both sections of resistivity and with better resolution in electrical imaging where it is possible to identify areas more conductive with lenticular shapes. These conductive areas correspond to points of possible saline intrusion inside the aquifer.

- The acquisition and integration of electric and electromagnetic data is suitable for imaging shallow depths wth na inteest in enviromental purposes.

Acknowledgments

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