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SEA WATER INTRUSION INTO SHALLOW COASTAL AQUIFERS OF KELWA-MAHIM, PALGHAR DISTRICT, MAHARASHTRA USING ELECTRICAL METHODS

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ABSTRACT Water is most important for sustenance of life on planet Earth. The utilization of water has increased due population explosion. It has become essential to increase the productivity of groundwater for human needs. As more areas are being exploited for groundwater several problems arise due to complex geology of the area and seepage into the subsurface. Seawater intrusion is a major factor that affects groundwater quality. It occurs when withdrawal of fresh groundwater from coastal aquifers results in declining groundwater levels, facilitating lateral and/or vertical migration of saline water causing deterioration of groundwater quality. Electrical resistivity sounding techniques and are widely used to determine the intrusion zones between groundwater and saline water in coastal aquifers. In the present paper we have made an attempt to delineate fresh water horizons in the Kelwa-Mine Beach coastal region of western Maharashtra. In order to delineate the fresh water zones using geophysical techniques 53 Vertical Electrical Soundings were carried out at the site. The present investigation presents the importance of VES in delineating saline water-fresh water zones.

KEYWORDS : Saline-Water intrusion, Kelwa-Mine Beach, Electrical method

Introduction

About half of the world's population resides in coastal areas due to the ease of transporting resources and availability of vegetation. The population along the coastal areas would further rise due to population explosion in future (Finkl, 1994). The salinization of the environment in coastal plains limits the supply of fresh water and damages areas of valuable land use (Vandenbohede et al., 2009). Understanding the distribution and origin of saline waters in an aquifer is a key factor to recognize boundary conditions influencing their movement and response to abstraction (Post, 2005). Geophysical methods, especially electrical resistivity sounding techniques were employed to mapand delineate fresh-saline water interface (Lee et al., 2002; Wilson et al., 2006).

The Maharashtra State has a coastline of 720 Kilometers. The proximity of coastal aquifers to seawater creates unique issues with respect to the sustainability of fresh groundwater in coastal regions. Groundwater is a subject of rising social concern, especially in coastal zones where it is increasingly mobilized to satisfy water demands for agriculture and domestic uses. Ground water withdrawal for drinking water supply, agriculture, industry and other uses in coastal area has increased many folds during the last decade. Ground-water development obviously depletes the ground water storage in the aquifer thereby reducing the hydraulic head of fresh water inland aquifer. Due to decrease in hydraulic head in fresh water aquifer the sea water migrates towards the inland side causing the deterioration in groundwaterquality.

Over exploitation of groundwater in Kelwa-Mahim coastal area was observed since 1984. Government of Maharashtra imposed a ban on construction and energization of new wells to stop the infiltration of saline water to fresh water zones. Due to heavy groundwater exploitation resulted in the depletion of groundwater level and deterioration of groundwater quality. In addition to the problem of overexploitation panning of salt and increase in industrial waste in the adjoining areas deteriorated the groundwater quality. The primary concern relating to increasing salinity in groundwater is associated with potential limitations on groundwater usage. This poses serious threat to the availability of the safe and sustainable groundwater for drinking and irrigation purpose.

Variations in the geophysical properties of rocks have been put to effective use for a multitude of purposes (Barker, 1980). Vertical Electrical Soundings (VES) using Schlumberger configuration are popular among geoscientists to demarcate groundwater zones, especially fresh-saline water interface (Zohdy, 1989). Geoelectrical soundings are useful in predicting aquifer properties (Kossinski and Kelly, 1981) general characterization of groundwater potential areas, flow patterns, etc., can easily be identify from resistivity contours (Balasubramanian et al., 1985).

Study Area

The study area lies between the north Latitudes 19^{0}35'00" and 19^{0}41'00"East longitude 72^{0}42'00” and 72^{0}47'30” (Fig.1). The area falls in quadrant C-2 of Survey of India Topo sheet no.47A/14 and 47A/10.

Kelwa and Mahim villages located in the western coastal part of Palghar taluka have an approximate area of 74.00 Sq. Kms. The area receives an average annual rainfall of 2500 mm. A major part of village is occupied by coastal alluvium and basalt rock formations that form part of the aquifers in the area. There are more than 500 irrigation wells in these villages.Major crops like Coconut, Chikku, Banana, Betel nutand Betel leaves are the main cash crops. These villages are located close to the Mumbai Mega City and thus have good market for the agriculture produce. The utilization of groundwater for agriculture purpose is carried out on a large scale since past few decades. Due to the excessivegroundwater exploitation in the area, seawater has encroached in freshwater aquifer zones. Thusgroundwater quality is deteriorating. The irrigation of saline water has reached to a distance of 3.5 to 4.5 kms. inland causing a severe threat to the groundwater regime and environment of the area.

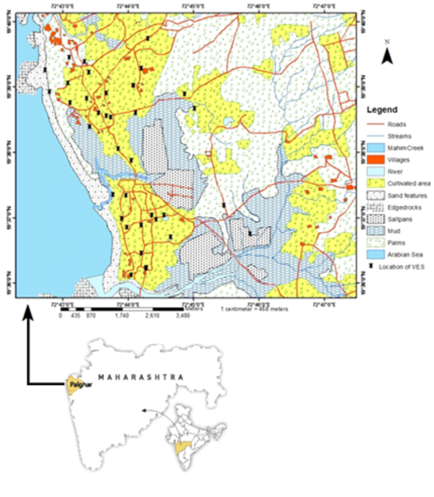

Fig 1.Physiography of Palghar, Maharashtra

Geology and Geomorphology of the area

The Palghar district forms a part of the traditional 'Konkan Plain', lies between 18°42' and 20°20' North latitudes and between 72°37'and 73°45' East longitudes, forms a distinct unit covering 9,558 sq. km area and a population of 8,131,849 persons (2001). The district occupies the northern-most position of Konkan, lies adjoining the Arabian Sea in the north-west part of Maharashtra state.

The geology of the Phalghar, Maharashtra is shown in (Fig.2) The Konkan region on the western coast of Maharashtra is an important geological terrain of western India. The Sahyadri mountain range forms the eastern boundary of the Konkan, and the Arabian Sea marks the western boundary (Kumaran et al., 2004). The area extends 720 km in the north-south and about 50 km in east-west direction. The main stratigraphic units represented in the Konkan region are Achaean complex, Kaladgi Supergroup, Deccan trap, laterite and alluvium (Radhakrishna, 1982; Deshpande, 1998). Deccan basaltic lava flows formed between 60 and 68 million years occupy a large part of Konkan region. The entire pile of horizontal and multilayered lava flow show variation in their physical characteristics (Subbarao, 1988). Besides basalt, other rock types found in the study area are trachytes and rhyolites. The Dharwars are the oldest formations in the area and are represented by phyllites the quartzites at Malvan and Nivti have hitherto been regarded as a fancies of the Kaladgi Series, but later studies show that they belong to the Dharwar Series (Deshpande, 1998).

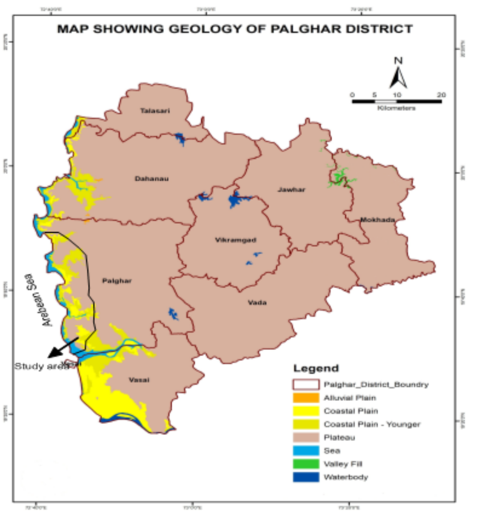

Fig 2.Geology of Palghar, Maharashtra (Ref. GSDA)

The Deccan traps are divided into three major groups, i.e. upper, middle and lower. The Bombay basalt flows have been grouped into upper traps on the basis of the inter-trappean and ash beds present in them (Krishnan, 1968).

Along the coast the sedimentary (detrital) deposits are compact and consist of shell fragments, sand, and gravel cemented together. Beach rock or calcareous grit is also found. The thickness of the beach rock varies from 2 - 8 m with low angle seaward dip. These rocks are locally known as 'Kakra' and overlie basaltic flows.

The Varieties of depositional and erosional landforms are commonly found in the area. Mud flats, tidal marshes, and mangrove swamps are developed along the creek at someplaces.

Geophysical Surveys

Fifty three Vertical Electrical Soundings (VES) is shown in Fig.1. using Schlumberger electrode configuration were conducted uniformly in the Kelwa-Mahim coastal area, with a maximum current electrode spacing (AB) of 100 meters. The depth of penetration for VES is generally found to be approximately one-third of the distance between the electrode separations (Dahlin, 2000). To delineate saline water intrusion into freshwater VES have been successfully used in the Deccan trap region (G.Gupta et al., 2014).

The data obtained from the field was processed and modeled using IPI2WIN software (Bobachev, 2003) for interactive semi-automated interpretation. One-dimensional inversion results of some of the representative VES curves along with the lithological sections are shown in Fig.3. Most of the VES were conducted near the observation wells, a correlation can be obtained between observed well litho log and interpreted data in terms of thickness, depth, and water bearing and transmitting capacity of the aquifers. A sounding curve with a continuously decreasing resistivity is called 'Q' type and such curves are usually obtained in coastal areas where saline waters predominate.

Parameters obtained after the interpretation of VES is presented to compare with the hydrogeological findings and the lithological and structural control on the groundwater accumulation and movement can be deciphered.

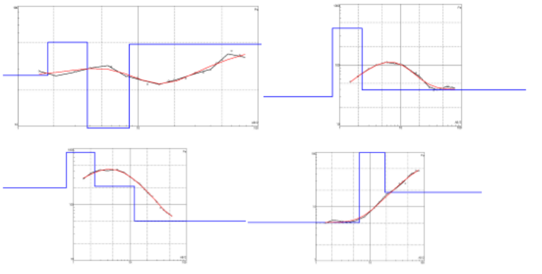

Figure 3.Representative Sample Vertical Electrical Sounding conducted in the area.

Analysis of VES data

The VES curves were interpreted in terms of layer parameters i.e., thickness and resistivity of individual layers. The layer parameters were initially obtained using curve matching technique with the help of standard master curves. These parameters were used as initial model for computer interpretation using IPI2WIN (Bobachev, 2003). The VES data is interpreted up to five layers. Modeling of the resistivity data for the study area displayed the following nine types of geoelectrical curves.

ISO Resistivity Maps:

The resistivity data is used for constructing the Iso-resistivity maps at different half-current electrode separations (AB/2), which gives the variation in resistivity values within the area as high and low resistivity zones. The interpreted results show the true resistivity values and thickness. The results are utilized for preparing geo-electric section with which the various subsurface formations can be delineated.

The low resistivity zones in the Iso-resistivity maps indicate water saturated areas and the high resistivity areas partially saturated or unsaturated zones. The maps indicate zones of different levels of compactness and saturation.

On the basis of various plots generated at various sounding depths, a delineation of groundwater potential zones has been carried out (Fig. 4). The map generated depicts the zones of low, moderate and high potential zones. As seen from the figure most of eastern part lies in the low groundwater potential zone. Whereas, western part of the project area shows high groundwater potential zone.

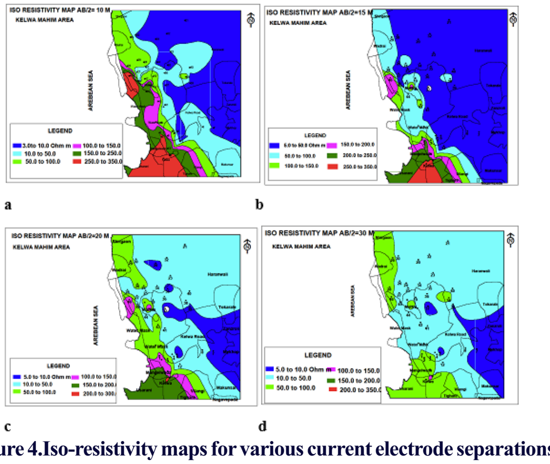

Figure 4.Iso-resistivity maps for various current electrode separations (a) AB/2=10 m (b) AB/2=15 m (c) AB/2=20 m (d) AB/2=30 m

Geoelectrical Modeling

The 2-D geoelectrical section has been generated over four selected profiles (A, B, C and D) in order to understand the geometry of the aquifer developed and the extent of saline water intrusion in and around the study area. The 2-D geoelectrical models are discussed in the following sections.

Profile A

The profile A covers the sounding points 23, 24, 31, 32 and 37 from west to east. VES 23 is 50 m away fromthe coast. The resistivity cross-section (Fig.5)shows low resistivity zone of 11 Ω-m with a thickness of 18 m at VES 23and followed by high resistivity layer. At VES 24 and 32 the resistivity is about 40 Ωm and a thickness of about 45 m. At VES 31a moderate to high resistivity of about 20 ohm m is observed but at VES 31 a low resistivity of less than 5 ohm m is observed to a depth of 1.2m which could be attributed to contamination activity. At VES 37 it is evident that an extreme low less than 6 Ωmto a depth of 50m is due to creek flowing in this area.

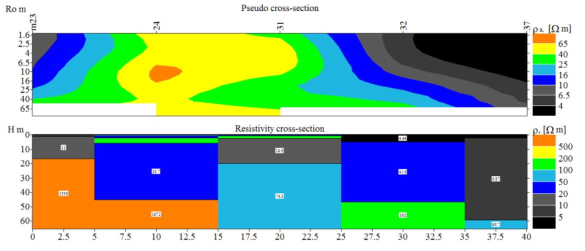

Fig.5 Interpretation of VES along Profile A (a) Depth section (b) Interpreted layers

Profile B

The VES points 44, 19, 33 and 35 were carried out along profileB (Fig. 6).A low resistivity of about 11Ω-m isdelineated to a depth of 2.5m at VES 44 and these extend towards east from 6m to 16m depth, but the top layers is to a depth of 1 to 1.3m with a resistivity 30 Ωm followed by 4 m thick layer of 133 Ωm resistivity which is interpreted as a fractured zone. VES 33 and 35 lie near to industries and hence theresistivity of the layer is around 2.69 to 10.1 Ωm due to industrial contamination with a thickness of about 6m. At VES 33 the top layer has a resistivity of less than 11 ohm m to a depth of 16m and the bottom layer has a resistivity of 37.4 Ωm this is interpreted as a potential groundwater zone but with some contamination. At VES 44 and 35 the resistivity of the subsurface is interpreted about50-68Ωmto a depth of 17m which forms part of an aquifer.

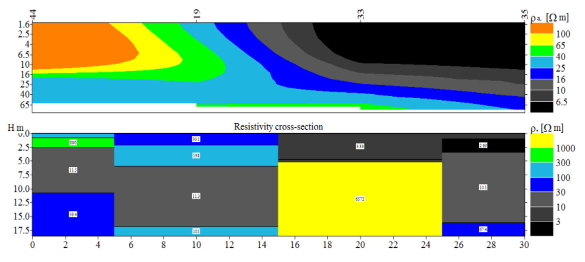

Fig. 6 Interpretation of VES along Profile B (a) Depth section (b) Interpreted layers

Profile C

The profile C is the central profile of the study area from west to east. This profile covers the VES 16, 18, 17, 34 and 36(Fig. 7).The range of resistivity is about 40 to 60 ohm m which is interpreted as a highly saturated groundwater horizon. At VES 16 is interpreted with a resistivity of 60 ohm m and a thickness of 10 m is attributed to lateritic soil cover below which is a low resistivity zone of about 20 ohm m. At VES 18 the top layer has a resistivity of about 60 Ω-mwith a depth of 11m followed by a low resistivity zone of 11 Ω-m below which lies a high resistivity layer basement of Deccan Basalts. At VES 17, 34 and 36 bottom layers show a resistivity range of 44-58 Ω-m. These VES locations are potential ground water zones and the ground water recharge is towards the west, the top layer show a low resistivity of less than 16.5 Ω m may be due to industrial contamination.

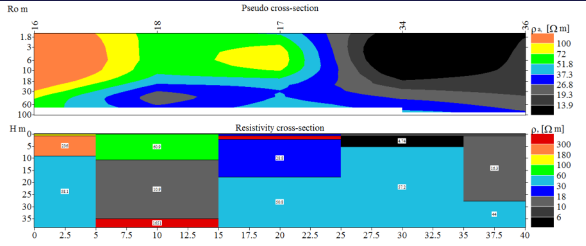

Fig. 7 Interpretation of VES along Profile C (a) Depth section (b) Interpreted layers

Profile D: The sounding points 1, 2, 3, 5, 4, 6, 8 and 7 contain profile B (Fig.8).This profile is heterogeneous nature. Low resistivity zones are observed towards the east of the profile while high resistivity zones are to the west of the profile. This could be because of the salt water intruding in the eastern part of the area.

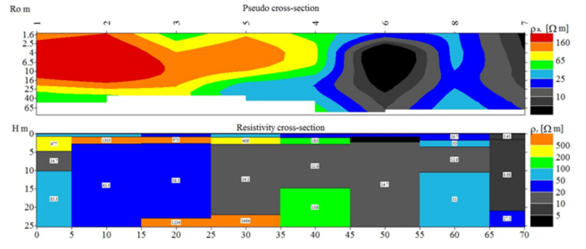

Fig. 8 Interpretation of VES along Profile D (a) Depth section (b) Interpreted layers

CONCLUSION

The Iso-resistivity and VES interpreted sections indicate zones of different levels of compactness and saturation. The apparent resistivity values are categorized as low, moderate and high groundwater potential zones (Table.1).

Table.1 Range of resistivity interpreted from geophysical surveys

S. No.	Interpreted layer resistivity	Range of resistivity
1	Low resistivity	2 to 10 ohm m
2	Moderated resistivity	10 to 100 ohm m
3	High resistivity	100 to 500 ohm m

Based on the geophysical interpretation the following are the conclusions:

1) On the basis of the Iso-resistivity maps at different current electrode separation (AB/2) the groundwater potential zones have been delineated. The mapsdepict the zones of low, moderate and high groundwater potential zones.
2) It is inferred that most of the eastern part of Kelwa-Mahim area lies in the low groundwater potential zone and saline water. The west part of this area shows high groundwater potential indicating a fresh water aquifer for exploitation.
3) These inferences have been confirmed with two core drilling sites suggested in the area, one is low resistivity zone and another in the high resistivity zone.

References:

1. Balasubramanian, A., Sharma, K.K. and Sastri, J.C.V. (1985). Geoelectrical and hydro geochemical evaluation of coastal aquifers of Tambraparni basin, Tamil Nadu, Geo phys. Res. Bull. 23(4): pp. 203-209.
2. Barker, R.D. (1980). Application of geophysics in groundwater investigations. Water Surv, 84: pp. 489-492.
3. Bobachev, A., 2003. IPI2Win 1D automatic and manual interpretation software for VES data, Available online: geophys.geol.msu.ru/ipi2win.htm.
4. Choudhury, K., Saha, D.K., and Chakraborty, P. (2001). Geophysical study for saline water intrusion in a coastal alluvial terrain. Journal of Applied Geophysics 46: 189-200
5. Deshpande G. G., Geology of Maharashtra, Geological society of India, Bangalore. (1) 129-160 (1998).
6. Dahlin, T.(2000), Electrode charge-up effects in DC resistivity data acquisition using multi electrode arrays. Geophys. Prospecting, v.48, no.1, pp: 181-187.
7. El-Waheidi, M.M., Merlanti, F. and Pavan, M. (1992).Geoelectrical resistivity survey of the central part of Azraq basin (Jordan) for identifying saltwater/freshwater interface. J. Applied Geophysics v. 29, pp. 125-133.
8. Finkl, C.W., Jr., (1994). Coastal hazards, perception, susceptibility and mitigation. Journal of Coastal Research, Special Issue 12, 372.
9. Frohlich, R.K. and Urish, D. (2002). The use of geoelectrics and test wells for the assessment of groundwater quality of a coastal industrial site, J. Appl. Geophys., v. 50,

pp. 261-278.
10. Gupta G, Maitis and Erram V C (2014). Analysis of electrical resistivity data in resolving the saline and fresh water aquifers in west coast Maharashtra, India; J. Geol. Soc. India 84 555–568.
11. Kaya, G.K. (2001). Investigation of groundwater contamination using electric and electromagnetic methods at an open waste—disposal site: acase study from lsparta, Turkey, Environmental Geology, v. 40, pp. 725731.
12. Kelly, E.W. (1976). Geoelectric sounding for delineating ground water contamination. Ground Water v. 14, pp.6-11.
13. Kossinski, W.K. and Kelly, W.E. (1981). Geoelectric sounding for predicting Aquifer Properties, Groundwater, v.19, pp. 163-171.
14. Krishnana M.S. Geology of India and Burma, Published by Higginbothams(1968).
15. Kumaran KPN, Shindikar M, Limaye R (2004) Mangrove associated lignite beds of Malvan, Konkan: evidence for higher sea-level during the Late Tertiary (Neocene) along the west coast of India. Curr Sci 86:335–340.
16. Lee, S., Kim, K., KO, I., Lee, S., Hwang, H., 2002. Geochemical and geophysical monitoring of saline water intrusion in Korean paddy fields. Environ. Geochemistry and Health 24, 277-291.
17. Matias, M.J.S. (2002). Squary array anisotropy measurements and resistivity sounding interpretation, Journal of Applied Geophysics v. 49, pp. 185-194.
18. Post, V.E.A., 2005. Fresh and saline groundwater interaction in coastal aquifers: Is our technology ready for the problems ahead? Hydrogeology Journal 13, 120-123.
19. Radhakrishna, B.P., 1982, Achaean granite-greenstone terrain of the south Indian shield: Precambrian of south India, Ed. Naqvi, S.M and Rogers, J.J.W., Geol. Soc. India, memoir, v.4, pp:1-46.
20. Subbarao, K.V., 1988, Deccan Flood Basalts, Geol. Soc. India Mem.No.10, 393 p.
21. Song, S.H., Lee, J.Y. and Park, N., 2007, Use of vertical electrical soundings to delineate seawater intrusion in a coastal area of Byunsan, Korea. Environmental Geology, 52, 1207–1219.
22. Vandenbohede, A., Van Houtte, E., Lebbe, L., 2009. Sustainable groundwater extraction in coastal areas: a Belgian example. Environ. Geol. 57.
23. Wilson, S.R., Ingham, M., McConchie, J.A., 2006. The applicability of earth resistivity methods for saline interface definition. Journal Hydrology, 316 (1-4), 301-312.
24. Zohdy, A. A. R., (1989). A New Method for the Automatic Interpretation of Schlumberger and Wenner Sounding Curves, Geophysics, v. 54 (2), 245p.