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Saline Water Contamination of the Aquifer Zones of Eastern Kolkata

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ABSTRACT
A number of saline/brackish water zones are present in the subsurface around the Kolkata metropolis. Mixing of fresh and brackish ground water has created environmental problems in certain areas. Vertical Electrical Soundings (VES) employing Schlumberger configuration have been deployed in the eastern and south eastern Kolkata metropolis for delineating the subsurface saline water zones. Interpretation of VES data has indicated disposition of saline / brackish and fresh water zones at different depth level which would be useful in the ground water management with minimum risk of saline contamination. Resistivity surveys have also delineated clay formations, which act as barriers for saline water percolation or transmission. Aquifer zone at some depths south of Bhangar canal is vulnerable for saline water contamination as large part of this area is occupied by brackish/ saline water in the subsurface. It has been found that the area north of the canal does not contain any appreciable saline water in the subsurface. It is further inferred that the sea water was trapped inland in the Holocene times during marine transgression causing salinity of ground water at several places.

INTRODUCTION

Large number of saline and brackish water zones are present in the subsurface in the southern and eastern part of Kolkata metropolis. A number of brackish water zones in the subsurface has been produced due to mixing of saline water zones with fresh water ones (Choudhury, Saha & Ghosh 2000). This inference is also corroborated by the earlier general findings of Kalimas & Gregorauskas(2002) who opined that excessive ground water abstraction intensifies migration of contaminants to the subsurface from above and activates salt water encroachment into pumped aquifers from neighbouring ones. Rapid urbanisation in the area has necessitated overdraft of groundwater at many places which, in turn, has aggravated the problem. Geophysical survey involving 205 VES with Schlumberger configuration have been taken up in the eastern and south eastern part of the metropolis for delineating the saline/brackish water zones in the subsurface and to ascertain the efficacy of the resistivity surveys in delineating such zones that are potential hazards for contaminating the adjacent fresh water aquifers.

The area of study falls in the Deltaic area of the lower part of Bengal basin. In the shallow subsurface, fine sand, silt and silty clay occur in the levees while clayey silt and clay occur in the inter distributory marshes (Banerjee & Khan 1982 ; Chakraborty, Ghosh & Hore 1985). The major group of aquifers consists of coarse and medium grain sands occasionally mixed with gravel and occur within the depth range of 40m to 250m in Kolkata with lower limit increasing to 300m in the surrounding areas (Choudhury, Saha & Ghosh 2000). It was believed that groundwater occurs in confined condition in Kolkata and in the southern and eastern parts of Kolkata metropolis. Choudhury et. al. (1997) reported the occurrence of ground water in unconfined condition at many places in the eastern Kolkata metropolis from their study of resistivity sounding data. Ground water level in the study area is found to vary from 3m to 6m below ground level even though this water is saline/brackish in the southern part (Fig.1).

Subsurface lithology at each sounding point has been inferred from the interpretation of sounding data after their correlation with available borehole lithologs. Conductivity of groundwater samples collected from different boreholes near the sounding points have also been measured with the help of a ‘Conductivity Meter’ which gives an estimation of Total Dissolved Solids (TDS) in the water samples. Besides delineating the subsurface saline/brackish water zones, the present VES investigations have also delineated the various

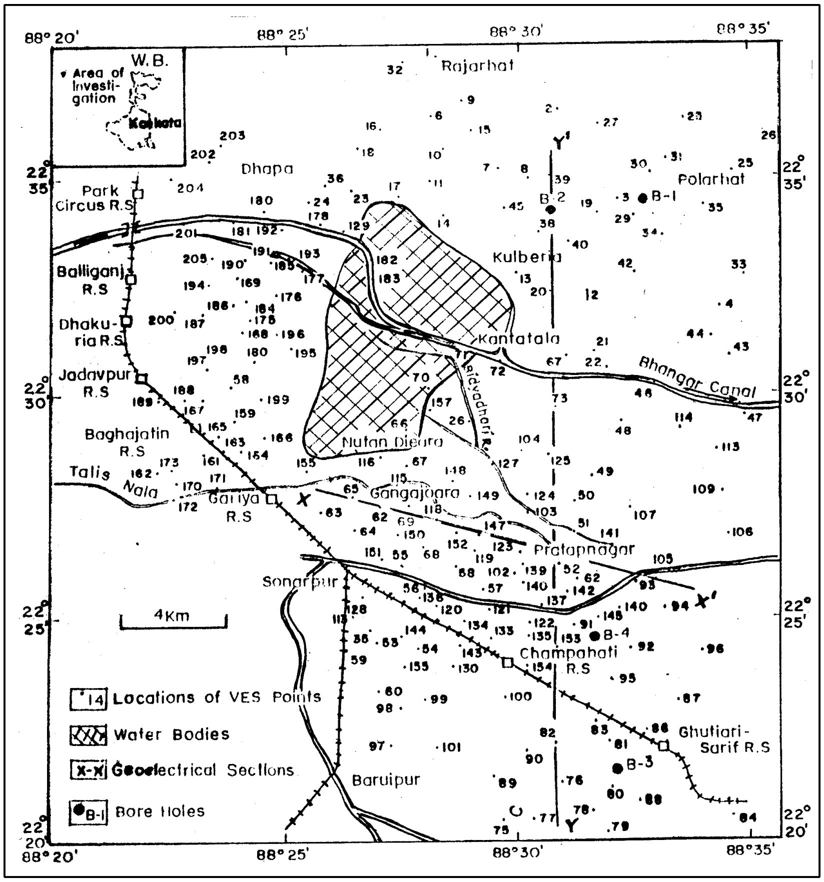

Figure 1. Layout Map of eastern part of Kolkata, West Bengal.

subsurface formations including thickness of the top clay layer which often act as barriers against percolation of saline water.

DATA ACQUISITION AND INTERPRETATION

VES technique employing Schlumberger configuration with current electrode separation (AB) of the order of 1000m - 2000m was employed in the area. A TSQ-3 transmitter and RDC-10 receiver unit, both manufactured by Scintrex, Canada were used for resistivity measurements. The transmitter had a 3KW power with a maximum current of 15 ampere and normal operating range between 2 ampere and 3 ampere. The receiver had a range from microvolt to volts.

Current was sent into the ground through a pair of steel electrodes connected to a generator and a transmitter. The resulting potential drop was measured with the help of the RDC-10 receiver and two porous pots filled with saturated copper sulphate solution.

The VES curves were initially interpreted using the master curves of Orellana & Mooney (1966). A standard resistivity inversion programme RESIST (Vander Velpen 1988) was then used for inverting the data. Only those estimated models were accepted whose RMS variation was less than 2.0. Resistivity of these geophysical models was finally interpreted in terms of lithology.

Electrical Conductivity (EC) of water samples collected from the aquifer near the sounding points has been measured with the help of a portable conductivity meter (TIM, Model 621E) for providing additional parameters for interpretation of resistivity data as well as for estimation of salinity of groundwater. EC of groundwater of the deep aquifer in the area varies from 1050 to 2620 mS/cm.

ANALYSIS OF GEOPHYSICAL RESULTS

Some typical representative sounding curves of the area along with their interpretations is shown in Fig.2. On the basis of some parametric soundings conducted

Table-1. Litho-resistivity relationship

Lithology	Resistivity range
Saline/brackish water zone	1 ohm.m to 4 ohm.m
Saturated clay/silt	About 4 ohm.m to 8 ohm.m
Saturated silty sand/clayey sand/fine sand	About 8 ohm.m to 18 ohm.m
Saturated medium/coarse sand	Above 18 ohm.m

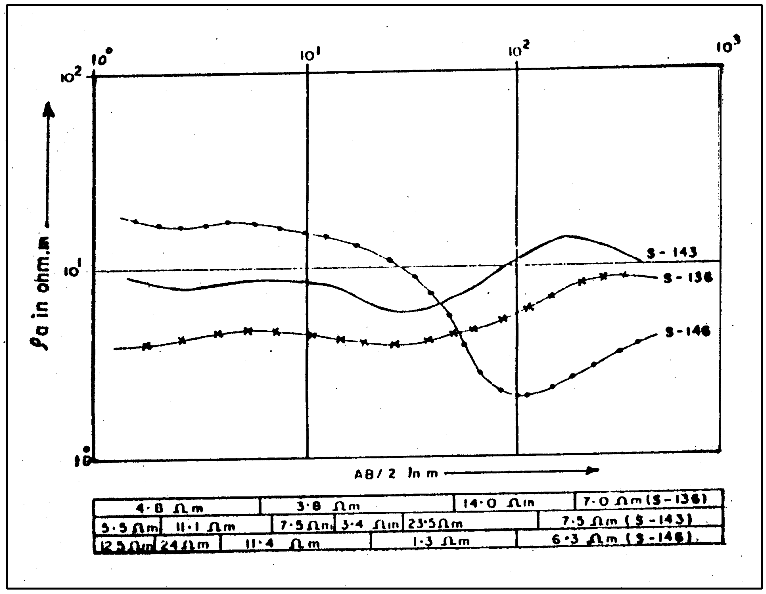

Figure 2. Representative resistivity sounding curves in the study area.

in the area close to the borewells where lithologs are known a litho-resistivity relationship has been established (Table-1). The range of resistivities obtained against each geological formation is compatible to the one obtained earlier in the eastern and south eastern part of Kolkata metropolis (Choudhury, et al 1997 ; Saha, Choudhury & Murthy 2002).

The interpreted resistivity values in the study area show that sand and clay are the main formations in the subsurface. Saline/brackish zones are also inferred at several locations. It is further seen from resistivity distributions that large areas north of Bhangar canal have higher resistivities (>6 Ohm.m) and devoid of saline/brackish water where as the vast areas south of the canal are having brackish water zones in the subsurface as characterized by resistivity less than 4 Ohm.m. This can be explained to some extent by the downward percolation of saline water from the tidal rivers of Bidyadhari which used to flow in the southeastern part and was connected to the sea through the Matla river. Another probable cause could be that in the Holocene times the sea had transgressed & the depressions were filled by sea water where the sediments were deposited giving rise to salinity in the vast areas of deposition. Presence of large stretches of brackish groundwater could be explained by the deposition of sediments under marine conditions trapping the saline water in the process. It is known that resistivity of a formation is the combined effect of formation resistivity and the pore fluid resistivity. Resistivity of groundwater measured from borewells at different depth levels in the area shows similarity of values north of Bhangar canal. This shows that resistivity variation in the area is due to change in formation resistivity i.e. change in lithology.

Interpretation of sounding data near boreholes B/3 and B/4 to the south of Bhangar canal indicates that even though formations are similar to the northern part, resistivity drops down in the southern part due to higher conductivity of ground water (Table-2). Thus it is concluded that resistivity variation of subsurface formations south of the canal is mainly due to the higher values of fluid conductivity. Further, it is seen in the southern part that groundwater conductivity at a deeper level of more than 130m is similar implying that resistivity variations can be attributed to changes in formation resistivity/lithology (Table-2).

Table - 2. Correlation of interpreted resistivity values with the existing geological formations in borewells along with EC of groundwater samples.

Boreholes and associated VES No.	Observed lithology and depth range (m).	Interpreted resistivity in Ohm.m and depth range (m) of different layers from sounding data.	E.C. of water samples from aquifer zone of boreholes (µS/cm)
B/1 (VES - 3)	Fine sand (0-1.0) Course sand (1.0-25.8) Clay (25.8-45.5) Fine sand (45.5-47.6)* Clay (47.6-56.0) Medium to coarse sand (56.0-95.0)	17.2 (0-1.0) 38.5(1.0-28.7) 4.4(28.7-58.3) 33.6 (58.3 - ∞)	1130
B/2 (VES - 38)	Medium to coarse sand (0-1.0) Clay (1.0-8.5) Clayee sand (8.5-10.8)* Fine sand (10.8-19.5) Clay (19.5-30.0) Medium to coarse sand (30.0-110)	23.8 (0.0-0.6) 7.2 (0.6-9.2) 13.8 (9.2-20.6) 6.6 (20.6-31.5) 20.8 (31.5 - ∞)	1060
B/3 (VES - 80)	Clay (0-0.8) Clay (0.8-10.5) (saturated with brackish groundwater) Fine sand (10.5-12.4)* Clay (12.4-62.0) Sandy clay (62.0-69.5)* Midium to coarse sand (69.5-85.0).	4.9 (0-0.7) 1.8 (0.7-12.0) 5.7 (12.0-73.5) 13.0 (73.5 - ∞)	2550
B/4 (VES-91)	Clayee sand (0-1.0) Clay (1.0-12.2) (saturated with brackish ground water) Fine sand (12.2-58.8) Sandy clay (58.8-64.0)* Medium to coarse sand (64.0-122)	8.7 (0.0-1.1) 2.5 (1.1-14.6) 7.1 (14.6-66.3) 13.0 (66.3-178.3) 9.3 (178.3 - ∞)	2600

* These formations have not been detected by the present investigation.

Geoelectrical section along XX′ :

The geoelectrical section along XX′ in NW-SE direction (Fig.1) is shown in Fig.3. Eleven VES fall along this line. Vertical variation of interpreted resistivity values at each station is shown. The interpreted resistivity section has brought out the disposition of saline/brackish water zones, sand formations as well as clay clay beds. The saline/ brackish water zones characterised by very low order resistivity (less than 4 Ohm.m) are found at shallow subsurface throughout the section. In case of excessive pumping the saline/brackish water is likely to percolate downward and pollute the immediate deeper aquifer. The SE part of the section constitutes comparatively better aquifer comprising medium/coarse sand as brought out by resistivity values of 18 Ohm.m to 45 Ohm.m.

Geoelectrical Section along YY′ :

The geoelectrical section along YY′, in N-S direction (Fig.1) across the Bidydhari river and Bhangar canal, is shown in Fig.4. Fifteen VES fall along this line. The interpreted section indicates the presence of saline/brackish water zones in the near surface varying in thickness from 10m to 60m except in the northern part (VES-38 and VES-39). clay, clayey sand and fine

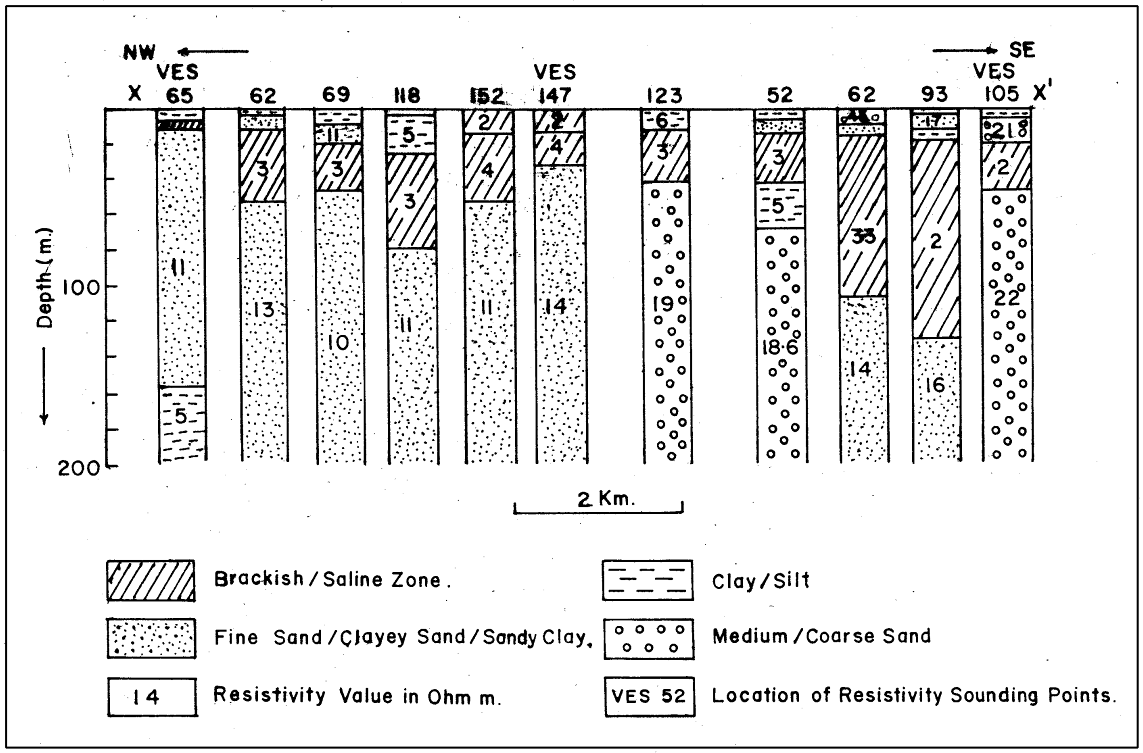

Figure 3. Geoelectrical section along XX′ in the study area.

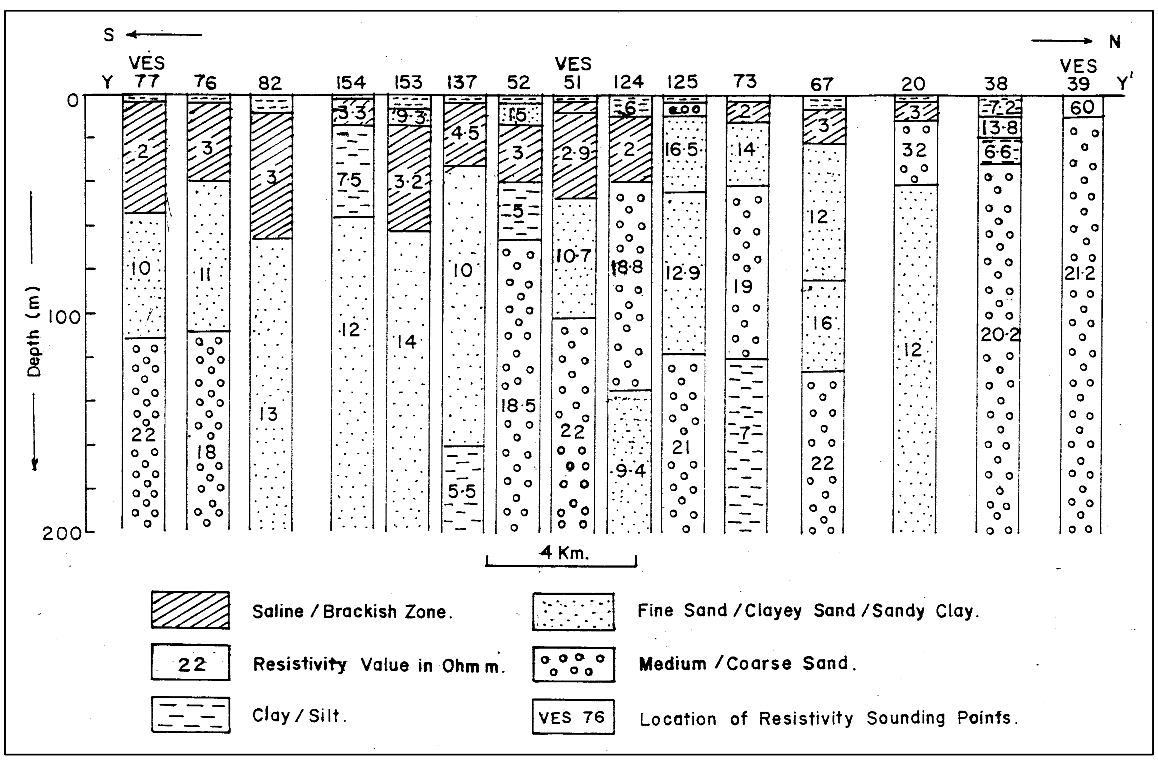

Figure 4. Geoelectrical section along YY′ in the study area.

sand are also interpreted along the section. Medium/ Coarse sand saturated with fresh water is interpreted at varying depths in the area and constitutes the aquifer zone which has a resistivity between 18 Ohm.m and 60 Ohm.m (Fig.4). The aquifer in the northern part is, in general, free from any saline water contamination.

Resistivity Distribution at Different Depth Level :

Interpretation of resistivity sounding data at various VES locations has been utilized to prepare resistivity contour maps at the depth level of 10m, 50m, 100m and 150m (Fig.5) which indicate the horizontal extent of the saline water zones and the disposition of fresh water aquifer zones at various depths.

Fig.5(a) shows the resistivity contour map at 10m depth. Keeping in mind the characteristic resistivity signatures of different geological formations in the area, it is interpreted that at 10m depth the major part of the area is occupied by saline water zone except some areas in the northern, northeastern and eastern part. The interpreted resistivity of many places are moderately high (14-40 Ohm.m) characteristic of sand formation saturated with fresh water.

Fig.5(b) shows the resistivity contour map at 50m depth. The areas north of Bhangar canal, northeast of Pratapnagar and north of Baruipur show higher order resistivity (14-39.4 Ohm.m) due to the presence of sand formations. The zones characterised by resistivity of 4.0 Ohm.m or less represent formations saturated with saline/brackish water.

The interpreted resistivity contour map at 100m depth level [Fig.5(c)] shows that barring a few small patches, the entire area is occupied by sand formations of different grain sizes having resistivity 12.0 Ohm.m

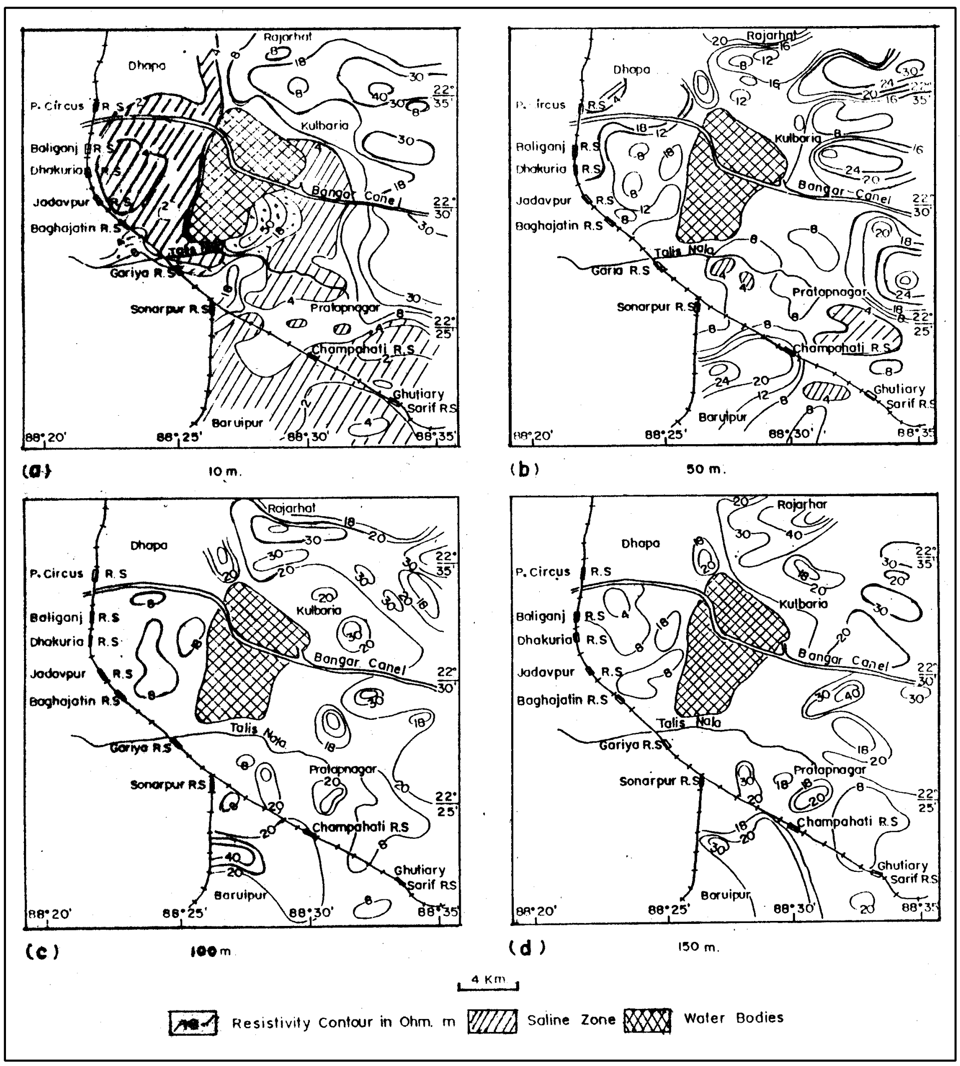

Figure 5. Resistivity contour maps at different depth levels in eastern part of Kolkata.

to 40.0 Ohm.m. Saline/brackish water zones are not present at 100m depth level in the area.

The interpreted resistivity contour map at 150m depth level [Fig.5(d)] indicates that large area is occupied by saturated medium to coarse grain sand showing resistivity more than 18 Ohm.m and constitutes the best aquifer of the area. Saline/ brackish zones do not occur at this depth.

CONCLUSIONS

The electrical resistivity soundings in the eastern and southeastern suburbs of Kolkata have indicated the distribution of different, subsurface saline/ brackish water zones as well as clay, sand layers and aquifers.

Salinity as inferred from low resistivity values is generally high in the southern part of Bhangar canal. Excessive withdrawal of fresh water in these areas may lead to deterioration in the water quality of the pumped aquifer due to a likely increase in salinity caused by the downward percolation of saline water from above. Groundwater at shallow subsurface at many places upto a depth of 50m appears to be saline/ brackish. The zones of saline contamination of aquifer have been clearly indicated by electrical resistivity soundings.

The area north of Bhangar canal does not have clay cover at many places and the whole area is generally devoid of any saline/brackish water zones except a few locations.

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