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The effect of watertable fluctuations on water quality : A case history

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ABSTRACT. The effect of watertable fluctuations on groundwater salinity is observed for three well-waters near Visakhapatnam, India. The electrical resistivity of water sample in the well is taken to represent the salinity of water. A correlation between the electrical resistivities of groundwater samples and the corresponding watertable positions over a period of fifteen months is brought out. A peculiar in-phase relation between the water level hydrograph and the salinity curve is recorded, the explanation for which is given in terms of the hydrogeology of the layers constituting the 'host' rock.

1. Introduction

It is an observed fact that the chemical quality of groundwater, to a large extent, depends on the host rocks constituting the aquifer. The chemical constituents of the groundwater in a selected well tapping a single aquifer are only dissolved substances of the material surrounding the well water. As such, the rise and fall of the watertable in the aquifer in the corresponding cycles of recharge and discharge lead to changes in concentration of salt content (Eriksson and Khunakssen 1966).

Many authors in the past have observed that the quality of groundwater at a point changes but slowly with time (Gatewood *et al.* 1950). It is pointed out that the aquifers may be considered as reservoirs, since the movement of groundwater is very slow to be of any significance to the time variation of groundwater quality (Hem 1959). The quality of a water sample at a particular time can be reasonably ascribed to the vertical position of the watertable. As the watertable is fluctuating, the hydrogeological nature of the aquifer affects the 'aqueous solution' present in the well.

Though the phenomenon is understood generally, very few evidences exist about the change of quality with respect to the minor fluctuations of watertable. One such interesting case history is reported in the present work.

2. Present work

During a hydrogeological study near Visakhapatnam (17°48′N, 83°22′E), a few wells located in a flat terrain, which are marked for watertable fluctuations and water quality variations, exhibited a good correspondence between the position of the watertable in the well and its salinity content, represented by 'specific electrical resistance' (electrical resistivity). The explanation is sought in the geological nature of the shallow ground layers in which the watertable is found to fluctuate.

Among the wells that exhibited the 'correspondence', three wells (open) with Nos. 45, 46 and 50, which have recorded the character unequivocally are taken up for study. Monthly observations of watertable positions and simultaneous collections of water samples for determining the electrical resistivity are made for fifteen months during the period 1969-70. Care is taken to avoid observations during heavy rainfalls and domestic and agricultural pumping periods.

3. Hydrogeology

The hydrogeology of the region around Visakhapatnam is represented by a top red loamy soil of 1·5-3·0 m thickness underlain by a weathered kaolinised khondalitic clay layer of 9-12 m thickness. The khondalites, forming the country rock, are garnet-sillimanite gneisses of Archaean age. An intense weathering of khondalites gives rise to a electrically conductive clay zone, lying beneath the loam which has comparatively lesser clay content.

A geoelectrical survey with a resistivity meter has given a high electrical resistivity value of 2000 ohm cm for the upper loamy soil as against a

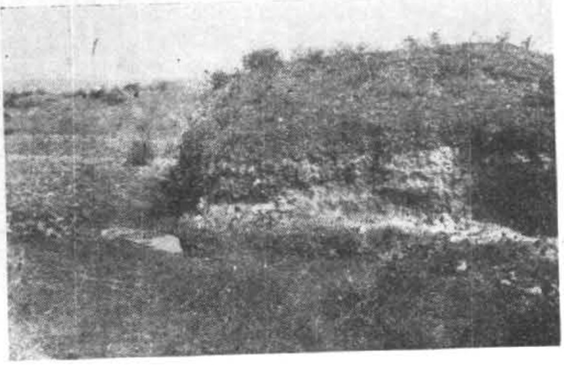

Fig. 1. The photograph of the soil-clay interface taken at a stream-cut in the area

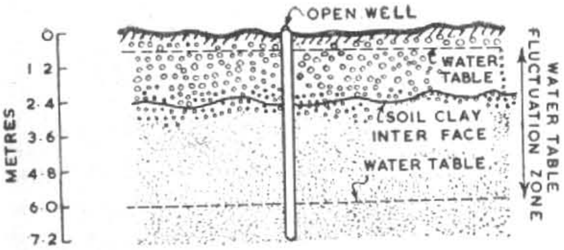

Fig. 2. General geological cross-section upto 6 metres

TABLE 1

Sand, silt and clay percentages of the layers in the three wells

W. No.	Layer	Sand (%)	Silt (%)	Clay (%)	Textural classification
45	Red loamy soil	81·0	9·0	9·8	Loamy sand
	Weathered clay	50·0	5·0	45·0	Clay
46	Red loamy soil	76·0	18·0	6·0	Sandy loam
	Weathered clay	57·6	2·0	40·8	Sandy clay
50	Red loamy soil	79·4	15·6	5·0	Loamy sand
	Weathered clay	48·2	4·2	47·5	Clay

700 ohm cm value for the clay layer below. A direct observation in the three wells shows that the soil layer is 2·4 m thick and soil-clay interface (SCI) is clearly visible. A photograph taken at a nearby stream-cut (Fig. 1) distinctly shows the two layers. Soil samples are taken in a well from both the layers and are analysed for sand, silt and clay percentages. The values are as shown in Table 1.

Though the values clearly show a 40 per cent increase in clay content in the weathered clay zone, it can be understood that the increase of clay content begins much above the SCI and so also the sand content decreases slowly below SCI.

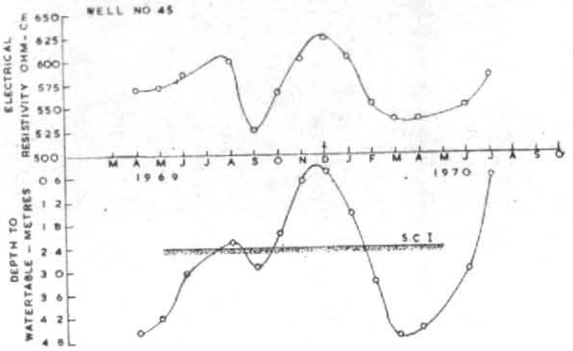

Fig. 3. Watertable and electrical resistivity variations with time (W. No. 45)

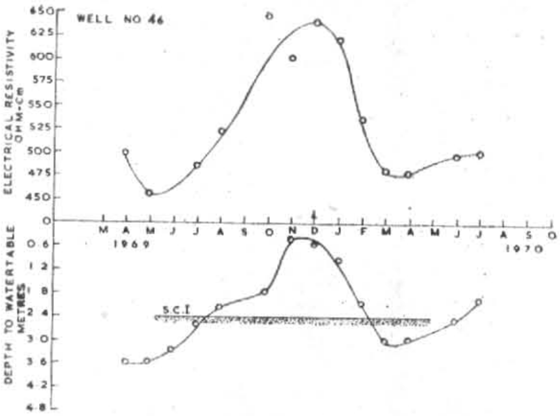

Fig. 4. Watertable and electrical resistivity variations with time (W. No. 46)

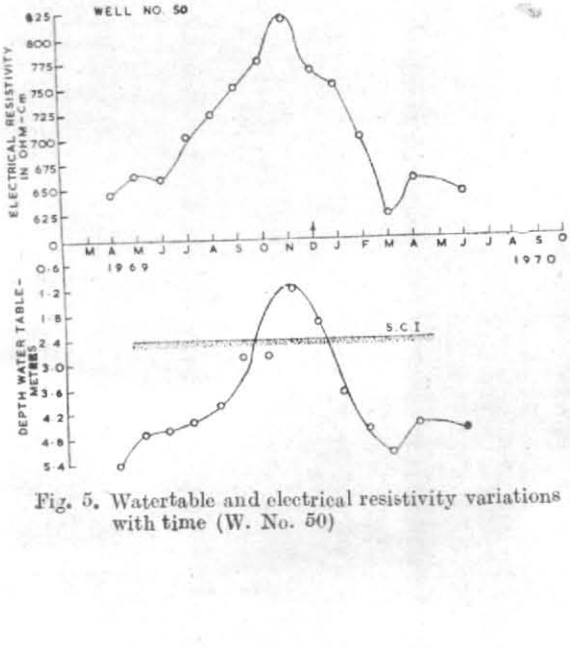

Fig. 5. Watertable and electrical resistivity variations with time (W. No. 50)

A general cross-section of the layers is drawn in Fig. 2.

4. Results

The values of depths to watertable during the fifteen months and the corresponding values of electrical resistivity are given in Table 2. Also at the end of the columns for each well are given the maximum variations in water levels and resistivity values.

Figs. 3, 4 and 5 show the variations of water levels in wells and electrical resistivity values. The line of SCI is also marked in each figure to indicate the 'crucial transition zone' when the watertable fluctuates.

It can be observed from Table 2 that the maximum variations in watertable depths are 4·3 m, 3·2 m and 4·3 m respectively in wells 45, 46 and 50. The corresponding maximum variations in electrical resistivity values are 80 ohm cm, 193 ohm cm, and 200 ohm cm.

As the recharge water raises the water levels in wells, a steady rise of electrical resistivity value can be observed in Figs. 3, 4 and 5. Watertable is at its maximum during the months November-December (immediately after the rainy season) and falls thereafter to a 'minimum' during summer months of February, March and April. The electrical resistivity curve also consistently shows an 'in-phase' behaviour with the watertable curve. This fact indicates that the salinity variations of groundwater are thoroughly guided by the positions of watertable. However, the rate of variation of salinity per foot variation of water level is not constant throughout the year. During the period October-February, the water levels stay above the soil-clay interface (SCI), that is in the soil layer itself. The steep rise and fall of levels during this short period result in equally sharp variations in electrical resistivity. However, the amount of variation in the resistivity value seems to be determined by some more factors other than the presence of watertable alone as in Fig. 3 where a slight fall in level of 0·6 m in August-September 1969, has unduly affected the resistivity curve. Similar situation exists in Fig. 4, where the resistivity values of October-November 1969 are scattered and value in May records a fall.

As such, the general rates of variation of salinity per unit changes in water levels are believed to give a better understanding than the study during isolated periods. The electrical resistivity value and watertable depths are plotted against each other in Fig. 6, for the three wells. The gradients, thus determined, come out to be 17, 60 and 40 ohm cm/metre respectively for the wells 45, 46 and 50.

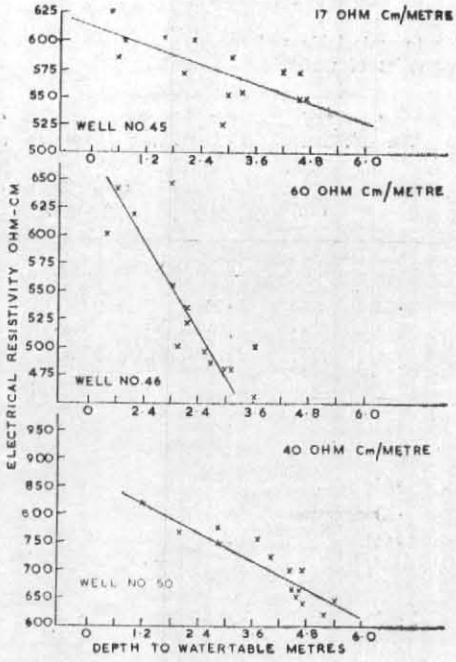

Fig. 6. Variation of electrical resistivity per unit variation of groundwater level

5. Discussion

The explanation for the phenomenon could be sought from the role of clay content in the two layers involved in the 'aquifer' situation. From Table 1, it can be seen that the clay content is nearly 50 per cent in the weathered layer.

Grim Ralph (1953) and Zatentskaya (1962) among others have pointed out that interstitial water in clays exhibits high salinisation due to 'base-exchange' reactions. The surface area of clay materials adsorb ions present in the interstitial water and replace them by adsorbed ions. As such, when the watertable lowers down, it gradually re-enters the pure weathered clay zone, the degree of weathering being normally higher at increasing depths. The presence of water totally in the clay zone enriches the salt content, resulting in a fall of resistivity value. In a similar way as watertable rises it reaches 'cleaner' soil (clean from clay) the resistivity of which naturally rises. This is evident as the soil layer, itself, has a higher resistivity value of 2000 ohm cm.

The average gradient of resistivity-water level graph (Fig. 6) comes to 34 ohm cm/metre. The variations in gradients from well to well may be due to the lateral movements of groundwater and strictly localised aquifer conditions. The maximum variations in water levels and the electrical resistivity values (Table 2) bear testimony to this. It should be pointed out here that the salinity of a water in the well is subjected to both horizontal and vertical movements of groundwater (Anisimov *et al.* 1969) and in the cognizable absence of horizontal seepage only,the salinity variations can be totally attributed to vertical positions. Though the wells are located in a relatively flat terrain, the seepage flow exists especially during high watertable periods which may result in minor variations in water level-salinity gradients.

TABLE 2

Depths to watertable and corresponding electrical resistivities of water samples in the three wells

Period	W. No. 45		W. No. 46		W. No. 50	
	Depth (m)	E.R. (ohm cm)	Depth (m)	E.R. (ohm cm)	Depth (m)	E.R. (ohm cm)
1969						
Apr	4·63	570	3·66	500	5·49	648
May	4·27	573	3·66	455	4 72	666
Jun	3·10	585	3·35	700	4·63	660
Jul	—	—	2·68	485	4·51	700
Aug	2·32	600	2·19	523	4·02	725
Sep	2·92	525	—	—	2·87	750
Oct	2·07	568	1·83	648	2·87	775
Nov	0·73	600	0·43	600	1·22	820
Dec	0·46	625	0·61	640	2·01	766
1970						
Jan	1·56	605	0·98	620	3·72	755
Feb	3·35	555	2·13	535	4·72	700
Mar	4·75	538	3·04	480	5·24	620
Apr	4·57	538	3·04	480	4·57	660
May	—	—	—	—	—	—
Jun	3·04	550	2·56	495	4·73	640
Jul	0·61	585	1·68	500	—	—
Max. variation	4·30	80	3·23	193	4·27	200

6. Conclusion

When the watertable is totally inside the clay zone, the salinity of water is more resulting in a fall of electrical resistivity value in all the three wells. However, a rise of watertable into the soil zone is making the water relatively free of clay particles, thus helping for an increase in the resistivity value of water in the wells.

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