Delineation of underground aquifer with natural EM in Jaisalmer district of Rajasthan

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Abstract

Natural source EM method (MT) has got wide application in studying the crust and its properties. The MT data of frequency band ranging from 40 Khz -64 Hz was acquired in Thar desert of Rajasthan to investigate if it can be used for detecting presence of fresh water at shallow depth. Data collected at few stations show the possibility of identifying both fresh water & saline water bearing areas. However recording of good quality MT data in the high frequency band was not always possible due to inherent weakness of signal & noises.

Introduction

Thar Desert of Rajasthan which gets very scanty annual rainfall and does not have any rivers are mainly depends on ground water. In most of the areas the ground water is not potable because of higher salt content. Major source of irrigation and house hold uses is the ground water. The fresh water in the western part of the desert i.e. area adjacent to Pakistan is believed to be along the Paleo track of Saraswati river which is believed to have flowed in that area around 7000 years ago.

Earlier ONGC carried out Vertical Electrical sounding on 42 stations in this area through Water and Power Consultancy Services (India) Ltd. Maximum electrode spacing (AB/2) was 2.0 KM. Based on this data one well Saraswati-1 was drilled near the town Jaisalmer which produced water of salinity about 3.05 gms/lt, which though not suitable for drinking but may be used for other purpose.

Comparison of data of drilled wells and Vertical Electrical Sounding, conducted by Ground Water Board of Government of Rajashthan, has shown that the formation with resistivity value of about 40 ohm m & above hold sweet & potable water. Formations of resistivity values 5 ohm m & below holds highly saline water and formations of intermediate resistivity values holds moderately saline water.

Since the depth of the water bearing formations lies within 300 m and also the contrast of resistivity values between saline & sweet water bearing formation is large hence it was felt that MT data of high frequency band should be able to distinguish between saline & sweet water bearing formations. This MT data can be acquired in less than 60 min time per station compared to several hours per station in typical Vertical Electrical Sounding (VES).

Under Corporate Social Responsibility (CSR) program of ONGC the Knowledge Management (KM) Group and Geophysics Group, KDMIPE jointly conducted a feasibility study for detecting fresh & saline water aquifer with Magneto Telluric equipment in the Thar Desert, Rajasthan. MT Survey was conducted in the working area shown in Fig-1 where data was recorded at 15 MT stations.

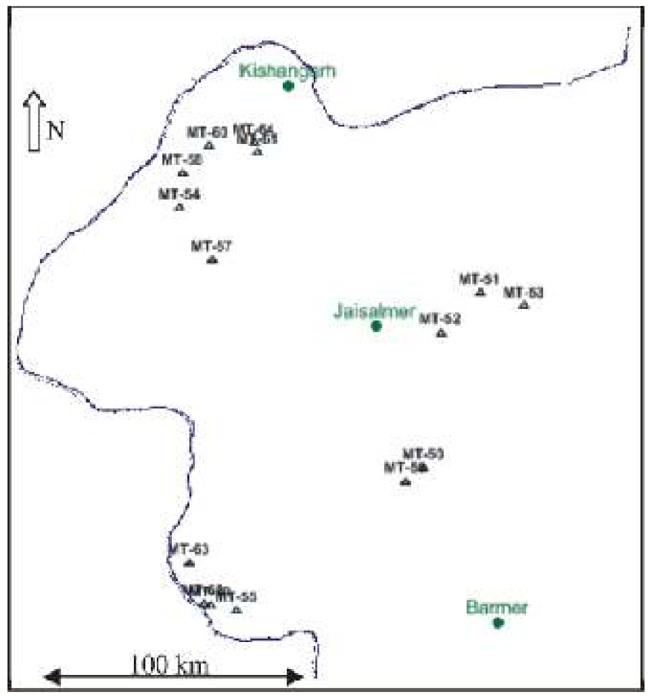

Fig. 1: Location map showing working area.

Main strategy of the study is to calibrate the MT data with existing tube wells data and to compare with the earlier acquired vertical electrical sounding (VES) data and use it for applying to other area. Unfortunately all the VES stations and many tube well locations were near high tension power lines hence these were not at suitable place for conducting MT survey. Therefore, it was tried to occupy the VES stations and existing tube wells at an offset of 1 km in order to avoid electrical noise. As a result calibration may not be perfect in almost all the locations except at one well i.e. location of MT64, which was acquired by the side of a sweet water tube well.

Methodology

Acquisition of data is carried out similar to the normal MT survey. Difference here is that though orthogonality of electric field and magnetic fields measurements are maintained but the convention of direction is not followed.

Equipments used were (i) ADU06 unit of Metronix, Germany for recording EM signal (ii) MFS-06 coils of Metronix for recording magnetic field (iii) Carbon tetrachloride electrodes, manufactured by Geo Sensors, Hyderabad for recording electrical field (iv) MAPROS software package of Metronics for processing and (v) WINGLINK and in house developed software package for interpretation.

For measuring electrical field four holes were dug ranging between 30 -50 cm and it was filled with an emulsion of water and black soil. This helps in maintaining good coupling of electrode with the loose sands as black soil has the capability of holding water for long time. Contrary to normal belief the loose sands below the surface were found to be damp in most of the working area as a result the resistivity of the soil remains between 700-2500 ohm meters throughout the survey. The distance between pair of electrodes is maintained within 84 m to 95 m depending on the availability of flat ground area.

Magnetic fields along the orthogonal directions of electric field are measured with single coil magnetometers.

Data was recorded in most of stations with the following time periods:

HF – 7 seconds at 40960 samples per sec
LF1 – 10 minutes at 4096 samples per sec
Free – 30 minutes at 512 samples per sec
LF2 – 60 minutes at 64 samples per sec

Long hour recording was carried out only at two stations (i) at MT-51 for 7 hrs of LF2 and (ii) MT-59 for 8 hrs of LF2 & 23 hrs of LF3 bands.

Shallow aquifer up to 200 -300m depth can be detected in high frequency bands. Data acquisition is quite tricky as natural source such as lightning is the primary source for high frequencies (>1Hz). It depends on luck rather than expertise to get good quality high frequency data. So after recording of each high frequency data it was processed immediately on the spot and checked whether the data is good or bad if it is found to be bad it was repeated again. Therefore, high frequency band data acquired for a number of times till an interpretable good quality data is recorded. In most of the station the high frequency data is affected in the period 0.0001-0.001 seconds. Sometimes even repeated attempt is not fruitful one such data is shown in figure no.2.

Processing of MT data was carried out with proprietary software MAPROS. Different frequencies ranging from 12000 Hz to 0.1 Hz, dividing it into 70 equal intervals, were used for estimating the apparent resistivity and phase. Time

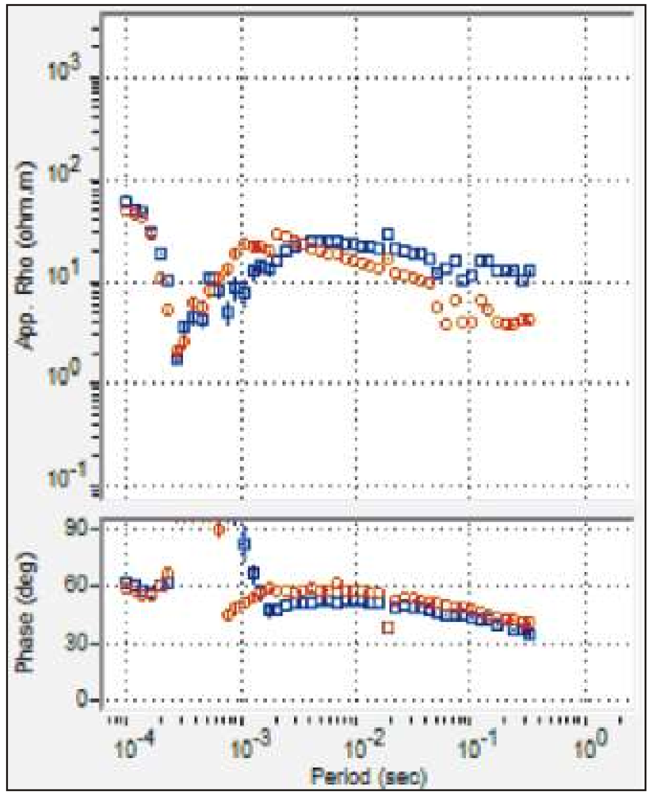

Fig. 2: Resistivity-phase curve of MT50.

series of MT-53 is subjected to notch filter of 50 Hz and its odd multiples to remove noise arising out of power line transmission.

Calibration

For calibration purpose four MT stations were chosen where the data recording was made nearest to sweet and salty water tube wells.

The station data of MT52 & MT64 were acquired closed to nearby sweet water tube wells while the data of MT58 & MT63 were acquired near salty water tube well. Interesting observation in the resistivity curve is that it starts to fall from a maximum depending on its surface resistivity as the time period increases. It is evident from MT63 and MT64 where the starting resistivity values of both are same but the fall in the curve in the case of salty water and at a period of 0.01 sec the resistivity value of fresh water is above 10 ohm-m while the salty water sites are having resistivity (0.01) value of less than 10 ohm-m. Though the curves shown are beyond 0.01sec our study will mainly be confined within this period as static water level is <100 m (A.K. Gupta et.al., 2003), According to the thumb rule (skin depth ˜500v(.T)) at this period the penetration is more than 150 m if . is taken as 10 ohm-m. 1D inversion shows a 40 ohm-m layer at a depth of 40 m for MT52 and at the same depth a 15 ohm-m layer for MT64. Similarly MT58 has 7 ohm-m at a depth of 50m and MT63 has 4 ohm-m at a depth of 40m. Therefore, from the above observation we can make a general inference to segregate sweet and salty water is that in case of Magneto telluric the resistivity of fresh water is above 10 ohm-m and for salty water it will be less than this value.

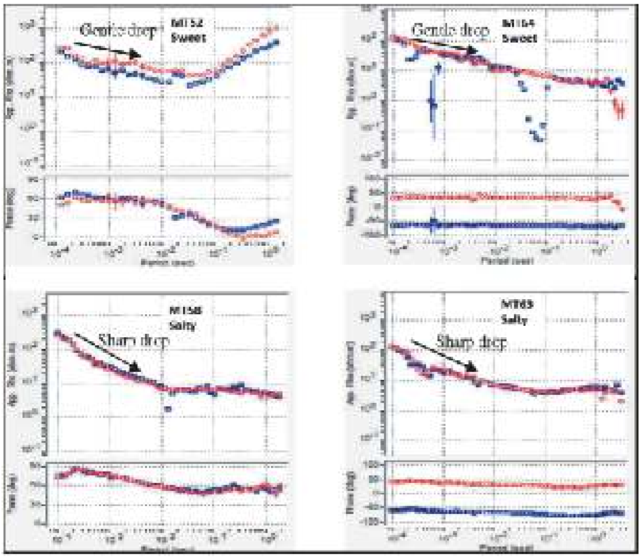

Fig.3. Resistivity Phase curves of MT52 (top left) data recorded at an offset of 200m from a sweet water tube well. MT64 (top right) data collected side by side of a sweet water tube well. MT58 (bottom left) data collected at an offset of 500m from a salty water tube well and MT63 (bottom right) data recorded at an offset of 100m from a saty water tube well.

Following the above findings the interpretation of other MT stations shown in Fig. 4 was carried out.

The entire stations exhibit a decrease in resistivity as mentioned earlier with increase in time period (i.e. decreasing frequency) as expected and this may be caused due to the damp sands. Inversion result shows a high resistivity layer 100-2000 ohm-m at the top with thickness varying from 18-60 m. All the interpretations are based on the layer below this highly resistive layer. Base on 1D inversion result the stations of MT50, MT53 and MT56 were found to have fresh water at a depth of 20, 40 and 43 meters respectively. Fresh water may be expected at a depth of 38m at the location of MT54 but the chances are gloomy as the layer is sandwich between two layers of having resistivity less than 10 ohm-m. But for deeper prospect this site is bright as it shows another 60 ohm-m layer at a depth of 103m having thickness at least 100m. Another important parameter from the inversion result is the thickness of the layer. Based on this the site of MT52 is best as the thickness of sweet water layer is more than 200m while others are having less than and equal to 120m. But looking at deeper prospects is not encouraging as the rise in resistivity may be caused due to change in geology also.

Such uncertainty can be observed in stations MT55, MT57 and MT59 where a raise in resistivity is observed at 0.1 second.

However, exceptions were observed in the case of MT61, at though the resistivity at 0.01 sec is more than 10 ohm-m inversion result does not support finding of sweet water in this area. And the same in case of MT54 which has resistivity less than 10 ohm-m at same period but 1D inversion shows a 15 ohm-m layer at a depth of 38m.

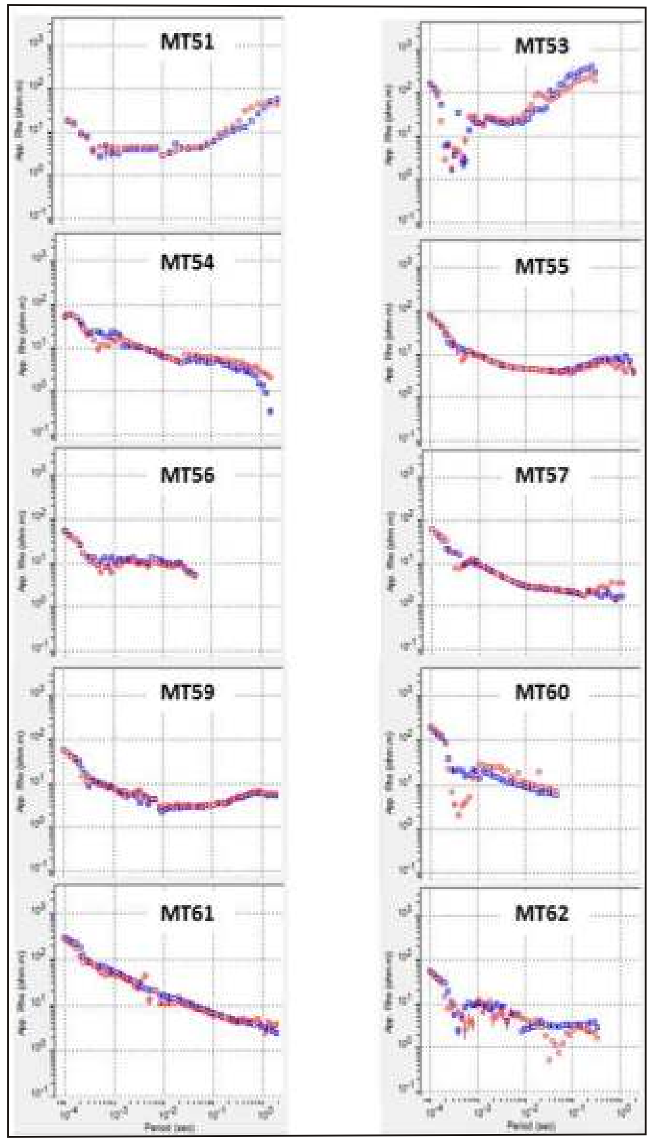

Fig.4. Resistivity curves of MT stations collected at different part of Thar desert, Rajasthan details of which are given in Table-1

In general chance of finding salty water is more than striking sweet water in tube wells and supply of salty water will be more than sweet water as thickness of salty water layer thickness is ~200m. Results of 1D inversion is summarized in Table-1 along with the details of locations. These findings may not tally with the existing tube wells because of MT station offsets.

Conclusions

Sweet water aquifer is expected at MT50, MT53 and MT56 at depths ranging from 20m to 45m.

Sweet water may also be encountered at a depth of 38m in the location of MT54, it has brighter deeper prospects.

Based on calibration of MT data and tube well it can be inferred without ambiguity that this method can be used as effective tool for finding sweet/salty water aquifers.

Sl. No.	Station name	Area	Latitude	Longitude	Any	Remarks nearby wells	Interpreted	
							Depth (m)	Sweet/Salty water
1.	MT-50	Near Fatehgarh	26°21'39.76"N	71° 6'9.10"E	No		20	Sweet
2.	MT-51	Chandan Firing Range	27° 3'19.73"N	71°19'31.85"E	No		18	Salty
3.	MT-52	Bhagu Dhani	26°53'52.53"N	71°10'6.90"E	Yes	Sweet	40	Sweet
4.	MT-53	South Lathi	27° 0'11.19"N	71°30'8.47"E	No		40	Sweet
5.	MT-54	Near Ghotaru	27°23'24.39"N	70° 8'0.60"E	No		38	Sweet
6.	MT-55	Aldad Ki Dhani	25°47'50.38"N	70°21'30.88"E	No		38	Salty
7.	MT-56	Nearby Drilling Rig	26°18'34.59"N	71° 1'51.84"E	Yes	Slightly salty	43	Sweet
8.	MT-57	Kunda Ki Dhani	27°11'5.73"N	70°15'43.98"E	No		30	Salty
9.	MT-58	Longewala	27°31'34.75"N	70° 8'41.49"E	Yes	Salty	57	Salty
10.	MT-59	Rikhiani	25°48'58.87"N	70°15'19.22"E	Yes	Salty	30	Salty
11.	MT-60	Sadewala	27°38'10.68"N	70°14'41.50"E	Yes	Slight salty	42	Salty
12.	MT-61	South East of Ranau	27°36'37.17"N	70°26'36.97"E	No		60	Salty
13.	MT-62	Panchala Padma Road	25°49'30.14"N	70°13'34.73"E	No		22	Salty
14	MT-63	Panchla Village	25°59'6.17"N	70°10'11.00"E	yes	Salty	38	Salty
15.	MT-64	Girduwala West of Ranau	27°38'52.25"N	70°25'42.79"E	yes	Sweet	40	Sweet

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