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Inventory of bore wells and correlation of geo-electric resistivity with subsurface lithology - A case study from Ramanagara taluk, Karnataka, India.

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Abstract

Exploration for bore wells is a challenging task which includes systematic studies on topography, geomorphology, hydrogeology, well inventory, recharge area and more importantly geophysical survey to pin point the exact location. Over 200 existing and failed borewells in Ramanagaram taluk of Karnataka were surveyed to understand sub-surface lithology, water table level, water yield and aquifer status. Several Vertical Electrical Sounding (VES) data was collected near to active and failed borewells to correlate resistivity values with the subsurface lithology. The geo-electric sections revealed four important layers viz., top soil, weathered rock, fractured bedrock and fresh bedrock. It can be inferred from borewell inventory and VES recording that highly weathered rock (second layer) has the resistivity which ranges from 40-70 Ωm and in fractured rock zone (third layer) it ranges from 150-250Ωm. Further, around 75% of the existing borewells belongs to deep to very deep horizon and only 10% falls in shallow aquifer zones. Thus, detailed geomorphological, hydrological and geophysical studies along with reports on status of individual borewells in a particular zone would be helpful for successful exploration of new site for the wells.

Keywords: Groundwater bore well inventory, vertical electrical sounding (VES), electrical resistivity.

1. Introduction:

Groundwater is a valued natural resource, which constitutes about two-third of the fresh water reserves of the world (Chilton, 1992). A major portion of India's irrigation wells is located in the hard rock areas where both recharge and discharge potential presently face severe stress (Nagaraj and Chandrakanth, 1995). The hard rock areas have hard nonporous, igneous and metamorphic rocks, expected to store not more than 10% of the annual rainfall (Radhakrishna, 1971). The occurrence and movement of groundwater in hard rock terrains, especially in fractured bedrock aquifers is governed by factors such as topography, lithology, geological structures and its extension, geomorphology, slope, depth of weathering, drainage pattern and climatic conditions.

Generally, well inventory survey is carried out to know groundwater chemistry, seasonal variation in water table levels, water yield, utilization and balance for future use. Majority of the research articles focuses on physico-chemical and biological parameters of groundwater of an area highlighting water quality and its suitability for drinking and irrigation purposes (Somashekar et al., 2000; Nirmala et al., 2012; Madhusudhan and Inayathulla, 2015; Manjunatha and Basavarajappa, 2015; Ganesha et al., 2016; Nagareju et al., 2016; Vidal et al., 2016; Ganesha et al., 2017; Thompson et al., 2018).

As far as inventory of borewell is concerned, some studies have been carried out on the seasonal variation in groundwater yield of bore wells particularly in pre and post monsoon seasons. Pisal and Yadav (2015) studied 40 bore wells in Bhogvati river basin and found that 35% of the bore wells having good yield, 37.5% of bore wells having moderate yield and 27.5% having low yield in pre-monsoon season whereas, in post-monsoon season 60% of bore wells having good yield, 17.5% having moderate yield and 22.5% having low yield. Similarly, Nagaraj et al, (2015) have done bore well inventory in Byramanagala watershed, Bangalore, for groundwater yield in pre and post monsoon seasons. The bore well inventory analysis reveal that 68% of bore wells having good yield and 44% having low yield in pre-monsoon season whereas, in post-monsoon season 98% of bore wells having good yield and 8% having low yield.

Geophysical method is helpful to find out the hidden subsurface hydrogeological setting. Electrical Resistivity Method has been widely applied for groundwater exploration, because of its easy field operation, greater depth of penetration, and it is accessible to modern computer systems (Roy and Apparao, 1971; Todd, 1980; Singh et al., 2002; Ariyo, 2007; Selvam et al., 2010; Kumar et al., 2015; Ganesha and Suresh, 2020). The interpreted VES results are also correlated with the drilled bore well litho-logs, showing good agreement with them. The NGRI (National Geophysical Research Institute, which is a research institution in geosciences under the aegis of the Council of Scientific and Industrial Research, Ministry of Science and Technology, Govt. of India) team have been working for the past 55 years in various geophysical studies and the review article published by Sarma (2014) brings about their contribution.

Ramanagara taluk of Ramanagar district of Karnataka has a serious water scarcity due to more consumption of water for drinking and agricultural purpose and no sincere attempt has been made either at the micro or macro levels to recharge the aquifer. Agriculture is the main occupation for the majority of the population of the study area and hence water consumption is more compared to domestic purpose. Hence, groundwater pumping from deeper aquifer is inevitable in the taluk and as such most of the shallow borewells have dried. In general, the water level is declining in almost all wells in the basin. Acute shortage of potable water in many villages of Ramanagara taluk has been a perennial problem mainly because of mismanagement of these precious resources for domestic, agricultural and industrial purpose. Further, scientific way of drilling of borewells shows that, water-bearing joints / fractures occur beyond a depth of 150 mts. The crux of the groundwater challenge in the study area is that there is extreme overexploitation of this natural resource and the status has reached an unstable level in most parts of the taluk.

This paper focuses on the inventory of existing borewells for their depth of drilling, nature of soil or weathered mantle and yield, covering entire taluk and geophysical survey correlating resistivity curves with respect to sub-surface lithology.

2. Study area:

The study area belongs to Ramanagara taluk of Ramanagara district. The investigated area forms part of the western Dharwar Craton and lies between the longitude 77°08'23"-77°29'03"E and latitude 12°35'08"- 12°52'44", ~780m above MSL covering an area of 633 Sq. km (Figure 1) . Ramanagara taluk is characterized by red and brown sandy / gravelly /clayey sand with a profile thickness of about 3-5 mts having low permeability.

3. Geology of the study area:

The study area is predominantly made up of peninsular gneiss with tonalite and trondhjemite to granodiorite composition. However, the principal rock types encountered are peninsular gneisses which form the country rock, intrusive rocks are granites, quartzo-feldspathic veins and dyke rocks along with minor patches of high grade rocks like charnockite. The Closepet granite has a strong geomorphic expression and occurs as a chain of prominent hills within the plateau with largely flat topography. Structurally, these rocks are fractured, jointed and sheared. The occurrence of deep borewells suggests that these fractures control the water bearing aquifers in the dominant litho-types of the studied area.

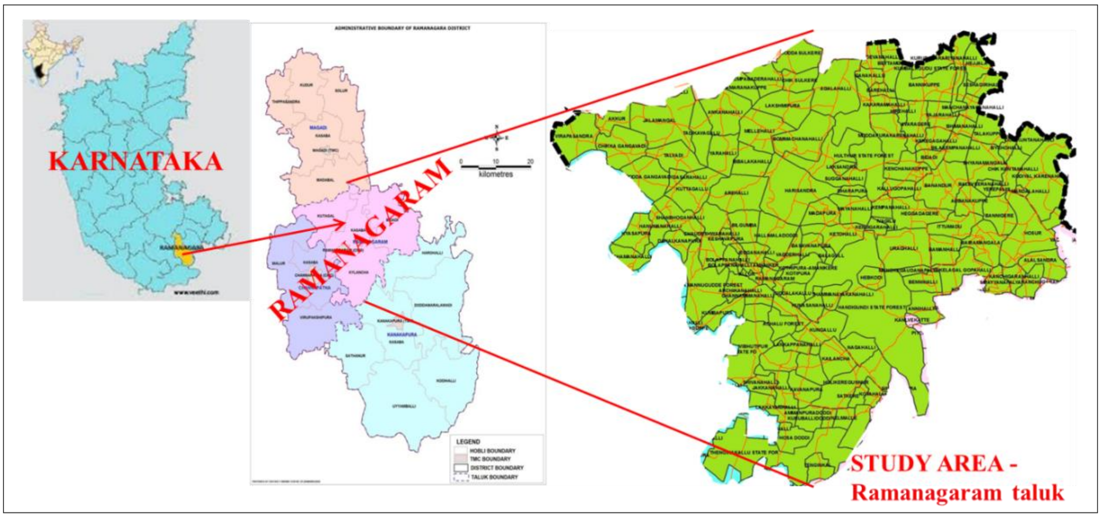

Figure 1 Location map of the study area

4. Methodology:

The present investigation has two components. The first component is on the inventory of existing borewells. Entire taluk covering almost all the villages have been surveyed to record authentic information on borewells particularly on parameters like depth of drilling, casing pipe inserted, groundwater yield and year of drilling. This exercise gave real information on occurrence of groundwater in shallow or confined aquifers, nature of fracture zone and to some extent water table level. The field work was carried out using SOI toposheet no. 57H/5, 57H/1, 57H/5, 57H/6, 57H/7 and 57H/3 and quadrangle map of the GSI. The coordinates of the active/failed borewells locations in terms of latitudes and longitudes were taken with GARMIN GPS-60 CSX.

The second component is on the VES data collection in the proximity of the active or failed borewells. Aqua meter CRM-20 (Computerized Resistivity Meter) has been used to conduct the geophysical survey in this study. The current electrode separation (AB) is varying from 1.5 mts up to 160 mts in successive steps. Vertical electrical sounding (VES) were performed at selected locations to determine soil thickness or weathered mantle thickness, depth to the fractured bedrock, where borewells have already been drilled. Vertical Electrical Sounding data collected were interpreted qualitatively and quantitatively to obtain layered resistivity parameters. The sounding data were initially interpreted using partial curve-matching technique and later quantitatively analysed using IPI2Win software and best fit theoretical curve along with the acceptable RMS error.

5. Results and discussions:

Following are the results of detailed borewell inventory and geophysical survey carried out at specific locations.

5.1 Bore well Inventory:

Over 200 bore wells have been surveyed and recorded complete information on borewells regarding depth of drilling, casing pipe inserted, groundwater yield and year of drilling. Fig.2 shows GPS coordinates of the surveyed locations in the taluk and Table 1 gives details of data collected during the fieldwork. As the data for entire 200 wells are too exhaustive, only typical and selected borewells details are given in Table 1. This exercise gave real information on occurrence of groundwater in shallow or confined aquifers, nature of fracture zone and to some extent water table level.

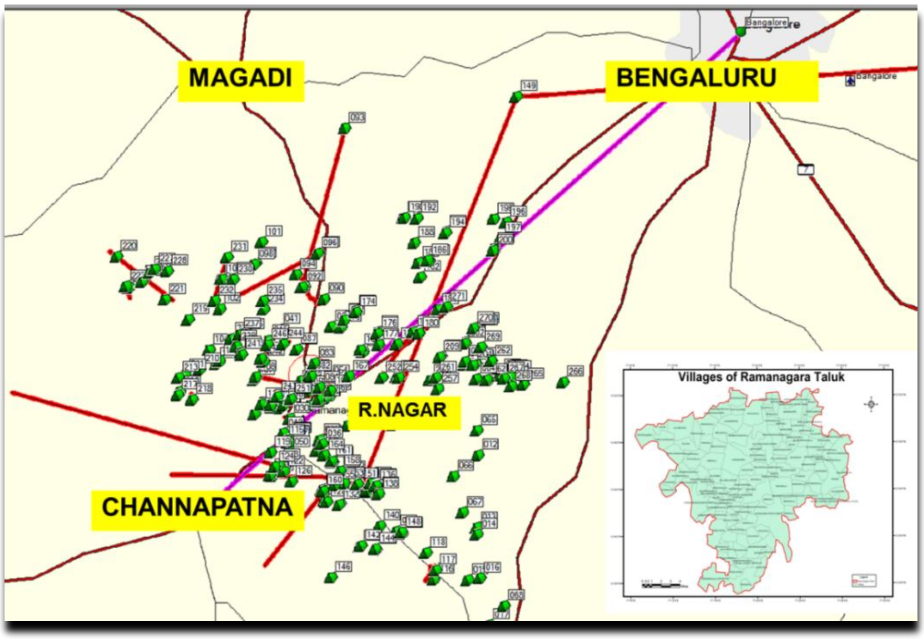

Figure 2 GPS locations of borewell inventory

Table 1
Details of bore well inventory in Ramanagara taluk
(PS: Out of 200 bore wells surveyed only 18 no. of representative wells are selected)

Sl. No.	Village	Bore Well Location	Bore Well Owner	Drilling Year	Drilling Depth (ft)	Water Struck at (ft)	Casing Pipe (ft)	Yield (inch)	Purpose*	GPS Reading
1	Hosuru	Near Cow farm	Ashok	1989	180	120	40	2.5	IR & DO	N12 40.352 E77 17.770
2	Kemapashe tty Doddi	Near Vasdevi Vilas PU College	Prakash H.C.	2002	180	120	40	3.0	DO	N12 41.775 E77 17.858
3	Thirumale Gowdana Doddi	Jalamangal a to RMG main road	Moodala Giriaiah	1988	200	80	20	2.5	DO	N12 50.412 E77 15.210
4	Acchalu Doddi	Kanakpura Highway	Puttaiah	1980	300	230	30	3.0	IR & DO	N12 41.088 E77 18.528
5	Chikka Gangavaadi	Near Shanimahat ama temple	Uday Kumar	2014	350	100	20	2.0	IR & DO	N12 47.279 E77 12.068
6	Hirehalli	Near Lokesh land	Lokesh	2003	400	250	30	1.5	DO	N12 46.052 E77 16.687
7	Kallugoppa na Halli	Near NH 275 Petrol Pump	Mayamma	2016	450	250	20	2.5	IR	N12 44.026 E77 17.634
8	Bettanager	Near Banyan tree	Giriyappa	2007	550	350	40	2.0	IR	N12 48.581 E77 16.923
9	Virupa Sandra	Near Water tank	Chandra	2013	600	450	60	2.5	IR & DO	N12 48.551 E77 09.565
10	Bettanagere	Near Banyan tree	Venkata Ramappa	2009	670	550	40	2.0	IR	N12 48.578 E77 17.034
11	Hirehalli	Near Lokesh land	Siddaraju	2012	700	625	43	2.5	DO	N12 46.027 E77 16.689
12	Lakshmipu ra	Near Shivraj land	Shivafraju	2012	800	400	40	2.5	IR	N12 49.989 E77 17.622
13	Kenchana Kuppe	Near NH 275	Lingappa	2012	850	750	20	3.0	DO	N12 44.969 E77 17.217
14	Manchanay akana Halli	Near Milk diary circle	Byatappa	2015	850	725	80	1.5	DO	N12 48.916 E77 13.469
15	Vaddara Doddi	Near Jalamangal a road	Krishna	2012	900	895	22	1.5	IR	N12 46.033 E77 12.954
16	Arehalli	Temple cross road	Shivaraju	2009	1000	400	80	2.0	IR	N12 45.839 E77 14.328
17	Kootgal	Opposite Road	Simhaiah	2011	1100	735	50	2.0	DO	N12 47.663 E77 15.271
18	Akkur	Near Panchayat	Byallaiah	2005	1200	600	60	2.5	DO	N12 48.803 E77 10.102

*Purpose: IR-Irrigation, DO- Domestic

The summary of the data pertaining to borewell inventory is tabulated in Table 2 and Figure 3 shows well inventory pertaining to number of active wells drilled at different depths. It can be inferred that 41% of the surveyed borewells are between the depth of 600-800 ft. Around 22% of the wells are considered as deep bore wells (800-1000 ft.). Similarly, 22% falls in between 400 and 600 ft. As far as thickness of weathered mantle is concerned, 37% of the borewells show medium to highly weathered rock up to a depth of 60 ft. Further, the weathered zone in most of the study area is favorable for infiltration of rainwater as the thickness varies from 0-80 ft.

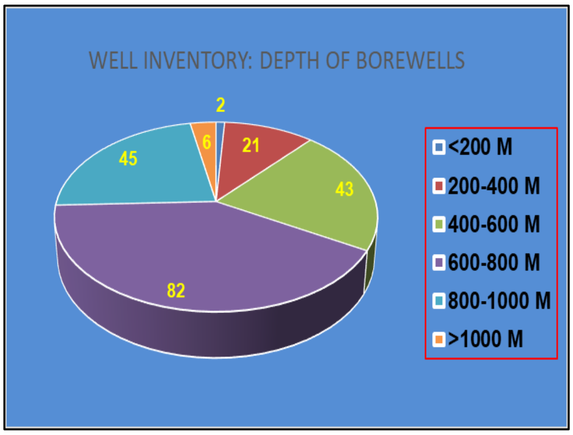

Figure 3 Pie chart showing number of active bore wells drilled at different depths

Table 2

Summary of bore wells survey in Ramanagaram taluk

Bore well		**Casing Pipes**		**Ground Water Yield**	
Depth of Bore well (Feet)	Nos.	Pipe Length (Feet)	Nos.	Yield (inches)	
<200	2	<20	3	Max^{m}	5.0
200-400	21	0-40	48	Min^{m}	1.5
400-600	43	0-60	74	Average	2.4
600-800	82	0-80	44		
800-1000	45	0-100	23		
>1000	6	>100	7		
Total	200	Total	200		

5.2 Electrical resistivity survey:

VES were conducted near to existing borewells (active/failed) to decipher different sub-surface layers. This survey was done to correlate resistivity of Earth's material at different depths (top soil zone, water saturated weathered zone, fractured potential aquifer zone and solid bed rock) with bore well data collected from field survey.

The failed or very low yield borewells (<0.5 inch of water) are correlated with A-type curve ($\rho1<\rho2<\rho3$), where the resistivity in those locations increased continuously without any shift/change even up to 400 ft. (Fig.4 A & a). These types of curves are correlated with some of the borewells drilled even beyond 600 ft. and evidenced by no water or very less yield of water.

The occurrence of potential aquifers (>500 ft.) is confirmed by H, HA and HK type of curves. The H-type curve is a three layer geoelectrical sequence with curve morphology ρ1 > ρ2 < ρ3 (Fig.4 B & b). The first layer is the top soil with clay-silt bearing layer or saturated sand layer of medium resistivity (~80 Ωm) and the second layer is a fracture zone with medium resistivity (150-200 Ωm). The resistivity values of layers which show continuous decrease in resistivity with respect to depth indicates probable site for groundwater in shallow aquifer zone. The third and infinite layer is the bedrock that can either be fresh, hard and massive, weathered or fractured depending on the resistivity (> 2000 Ωm).

The HA and HK type curves are the most predominant curve and the geo-electric sequence is ρ1 > ρ2 < ρ3 < ρ4 and ρ1>ρ2<ρ3<ρ4 respectively (Fig.4 C, D & c, d). The resistivity of the first layer consist of top soil consists of clayey soil or sandy clay, well saturated with relatively low resistivity (40-100 Ωm). This top soil is directly underlain by saturated clayey sand or highly weathered formation with low resistivity (40-70 Ωm). The third layer has medium resistivity and this layer acts as the shallow aquifer which is a fracture or weathered zone which constitutes an favorably good aquifer (150-250 Ωm). This fracture zone is succeeded by the fresh basement hard rock layer without any fractures indicated by high resistivity (>1000 Ωm).

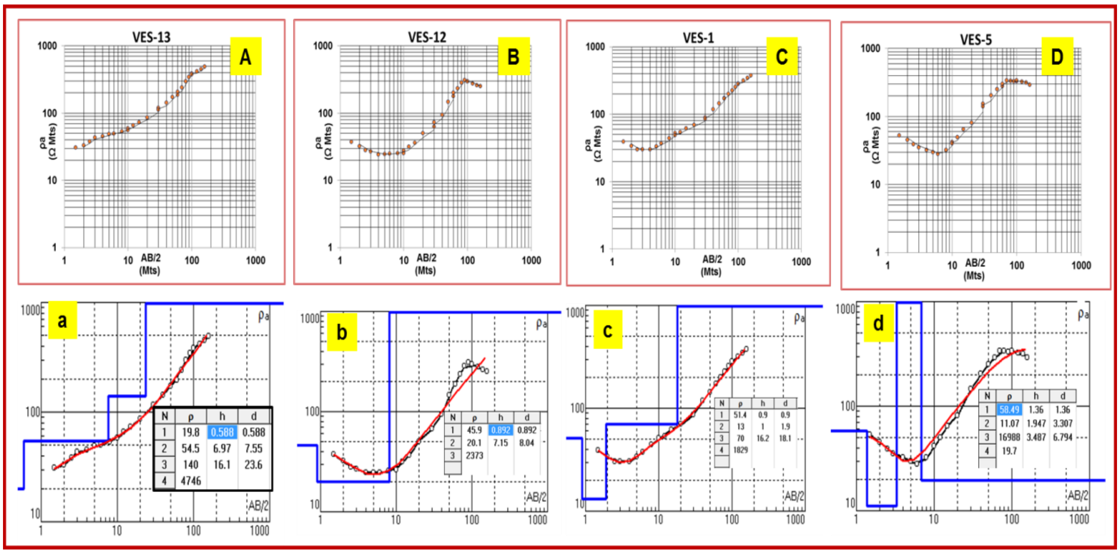

Figure 4 (A-D and a-d): Typical VES curves (A-D) and interpreted curves (a-d) using IPI2WIN software.

Though some of the VES data and interpreted curves do not match exactly with the field data for individual borewells with respect to subsurface lithology or layering, the occurrence of groundwater at different depth can be correlated to H, HA and HK type of curves. In the present study, the spread of electrodes is restricted to 160 mts (~520 ft.) only, but more than 75% of borewells have been drilled beyond this depth and are successful.

The bore well inventory reveals that though the thin veneer of soil cover (sandy / gravelly /clayey sand) followed by weathered mantle favors which rainwater percolation, the aquifers are not recharged every year due to non-existence of any recharge structure near to well and fast runoff.

6. Conclusion:

The groundwater in the taluk is facing a critical situation since a decade due to over exploitation, reduction in recharge potential by change in land use and land cover and improper planning and management. Thus, it is very crucial not only to find out groundwater potential zones essential to conserve, protect and utilize the groundwater to the optimum extent.

The study area has a very large number of borewells as entire taluk is depending on rainwater or groundwater. The depth of borewells varies from 180 to 1230 ft. The reason for drilling deeper tube wells is due to the fact that the shallow wells invariably become dry. Further, the yield of water varies from place to place and not related to depth. The maximum and minimum yield found between 5" and 1.5" with an average of 2.4', thus, the availability of groundwater is just sufficient for irrigation purpose and that too for few type of crops. It is also inferred from this study that none of the wells in the surveyed locations has any type of recharge structures and the replenishment of groundwater is by natural means only.

It can be inferred from the inventory of borewells that over 30% of the wells are below 600 ft with relatively good yield. Around 60% of the bore wells with low yield (<2 "on V-notch) of groundwater is found between 600 to 1000 ft. The geo-electrical layers such as A, H, HA and HK type are the predominant layers and the resistivity of earth material at different depth are correlated with subsurface lithology of the existing borewells. VES data confirms the failure of borewells with A-type curve and saturated weathered mantle and favorably good yield aquifers are correlated with H, HA and HK type of curves. The combination of data on existing borewells along with VES interpretation would be very helpful to delineate groundwater potential zone in the taluk and further would facilitate to locate new borewells.

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