www.cafetinnova.org

ISSN 0974-5904, Volume 10, No. 02

DOI:10.21276/ijee.2017.10.0232

International Journal of Earth Sciences and Engineering

April 2017, P.P. 361-366

Hard Rock Aquifers of Trivandrum, Kerala, India: A Critical Analysis of Its Status and Prospects

PRATHIBHA RAVEENDRAN AND E SHAJI

Department of Geology, University of Kerala, Kariavattom Campus, Trivandrum-695581, India

Email: *shajigeology@gmail.com*

Abstract: *Groundwater in the hard rock aquifers of Trivandrum district has been studied to characterize the groundwater potential and prospects. The study area is occupied by four watersheds (Ayirur, Vamanapuram, Karamana and Neyyar) and groundwater is one of the main sources of water for drinking and agricultural purpose. The groundwater scenario has been assessed by using the water table contour maps and groundwater level fluctuation maps based on the data obtained from 93 observation wells. The average water level in the region is 9 to 13 and 8 to 10 mbgl during pre and post monsoon seasons respectively. The deepest water level (20.21 mbgl to 26.67 mbgl) is recorded from places such as Chovvarapotta, Pazhayaucchakkada and Ozhukupara and shallowest water level (0.85 mbgl to 1.61 mbgl) is in places like Irumba, Punnamkarikkakam, Kathipara and Erattachira. Most of the deep dug wells go dry during summer months, though these wells show good water level fluctuation during rainy season. A detailed investigation has revealed that substantial quantity of groundwater is being lost as base flow. This base flow of groundwater makes the rivers and river lets, perennial in the area. The long term trend analysis shows that (ten years data), majority of the wells are showing declining trend (1.99 m/year) and this decline is attributed to the change in land use pattern in the area and less recharge from the rainfall. The rainfall analysis shows that there is not much variation in the rainfall pattern over the last few years. On the basis of mathematical projection the water level trends for the next ten years has been predicted. The analysis shows that the groundwater potential in the hard rock aquifer is depleting hence an immediate recharge measures have to be implemented in this region to arrest the decline trend and the base flow.*

Keywords: *Hard rock aquifer, Kerala, Groundwater resources, Hydrochemistry, Long term trend.*

1. Introduction

Groundwater has become immensely important and dependable source of water supplies in all climatic regions including both urban and rural areas of developed and developing countries (Todd and Mays, 2005). Groundwater is one of the important natural resources which support human health, economic development and ecological diversity (Chandra, et al., 2010).

In general groundwater occurs beneath the surface under semi confined, confined or unconfined state. The groundwater availability varies from place to place and its distribution is not uniform. This is due to the variation of rainfall in different regions at different time and differences in geology and geomorphology of the terrain. The irregular distribution of groundwater and its over exploitation in certain areas are the main reason which leads to the scarcity of drinking water in many parts of the country (Jaganathan, et al., 2000). The groundwater potential of hard rock aquifers of India has been studied by various workers (Dewandel, et al., 2011; Perrin, et al., 2011; Preeja, et al., 2011; Dewandel, et al., 2010; Prasad, et al., 2008; Chandra, et al., 2008; Marechal, et al., 2006). However, the groundwater potential in the hard rock aquifers of Kerala has not been systematically studied so far. This study focuses on the status and groundwater potential of the hard rock aquifers of Trivandrum district, southern India. This study covers various aspects of the groundwater scenario of the area with special attention on the groundwater status during past, present and future.

2. Hydrogeology of the area

The study area lies between North latitudes 80 16′ 59″ to 80 46′ 59″ and East longitude 760 40′ 59″ to 770 15′ 59″ (Fig 1). The area falls in survey of India Toposheets 58 D & H and the area covered by hard rock is 1970 sq.km. As shown in the figure 1 the study area consists of four watersheds namely Ayirur (part), Vamanapuram, Karamana and Neyyar (part) river basins. In which Vamanapuram and Karamana river basins falls completely within the study area and the other two river basins are partly within it. The study area falls in the tropical climatic zone with a mean temperature ranges from 22°C to 34°C. The average annual rainfall is about 1643 to 3449 mm (CGWB, 2013). The South-West monsoon (June-September) and the North-East monsoon (October-December) are the major contributors of rainfall in the area.

The occurrence and movement of groundwater is controlled by various factors like physiography, climate, geology and fracture patterns (Yousef, et al.,

Received: November 12, 2016; Accepted: January 27, 2017; Published: April 26, 2017

International Journal of Earth Sciences and Engineering, 10(02), 361-366, 2017, DOI:10.21276/ijee.2017.10.0232

2015). The major aquifers in the study area are the weathered, fissured and fractured crystalline rocks. The formations of the area are grouped into (1) the Precambrian crystalline rocks (2) the Tertiaries (3) laterite and (4) the Quaternaries. Khondalites and charnockites are the major hard rock's of the area (Fig. 1). The charnockites are found in limited extend in the area. These are found in the central and northeastern part of Trivandrum district. These are dark coloured, medium grained rocks found in massive form. Khondalites are the major rock type of the study area. Khondalites are medium to coarse grained rocks with gneissosity and garnet, cordierite, sillimanite and feldspars are the major minerals. The khondalite, charnockite and granitoids are intruded by younger dykes. Pegmatite veins and quartz veins are also common (GSI, 2005; Soman, 2002).

The groundwater in these crystalline formations is found in unconfined and semi to confined conditions. The occurrence and movement of groundwater in this region is controlled by the secondary porosity in the crystalline rocks. Due to the variation in lithology and fracture patterns these aquifers are highly heterogeneous in nature (Alain et al., 2014). Groundwater occurs in phreatic as well as deeper zones in the weathered crystalline rocks and the fractured crystalline rocks respectively. The shallow aquifers generally occur within a depth of 25m. The yield of wells in these formations ranges from 6 to $12m^3$/day. The deeper fractures (between 50 and 80 m depth) in hard rock form major potential aquifers at places. The yield of wells tapped in deeper fractures ranged from 30 to 1200 lpm (CGWB, 2013).

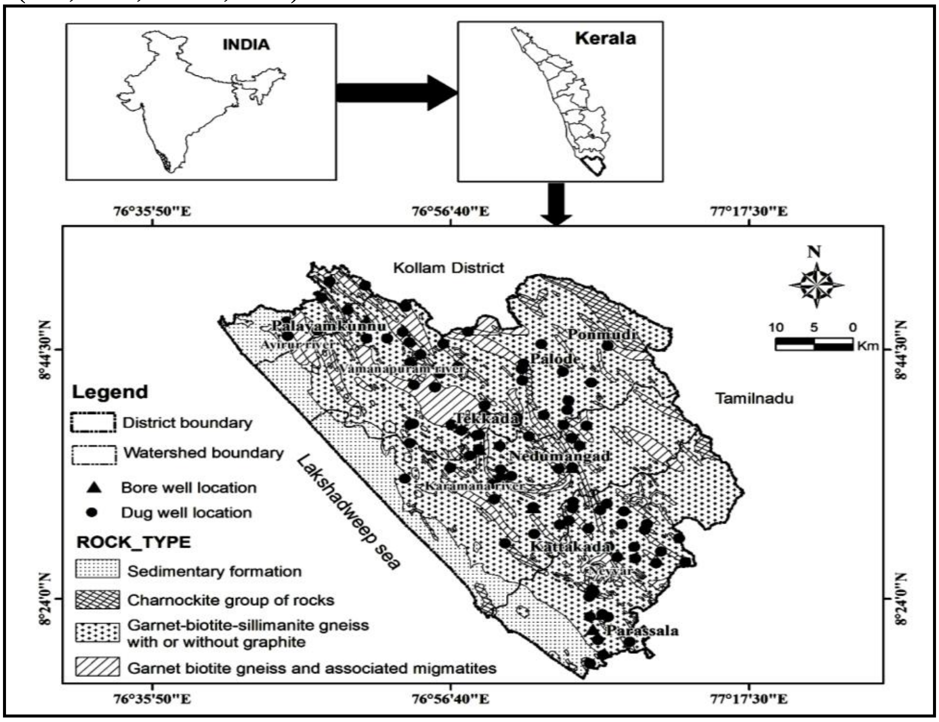

Figure. 1: *Location map of the study area*

3. Groundwater levels – present scenario

The groundwater occurs in unconfined condition in shallow aquifers, weathered crystallines and semi to confined condition in the deeper hard rock aquifers. The water level is monitored (pre and post-monsoon) during the months of April and November 2014. For monitoring the water level, 93 observation wells (Figure 1) were established. The deepest water level (20.21 mbgl to 26.67 mbgl) is recorded from places such as Chovvarapotta, Pazhayaucchakkada and Ozhukupara and shallowest water level (0.85 mbgl to 1.61 mbgl) is in places like Irumba, Punnamkarikkakam, Kathipara and Erattachira. Deepest water level between 17 and 26.67 mbgl is recorded in the Vamanapuram and Neyyar (part) river basins. The midland portion of the basins record deepest water level compared to the highland regions. During post-monsoon the total scenario changes (Figure 2a & b).

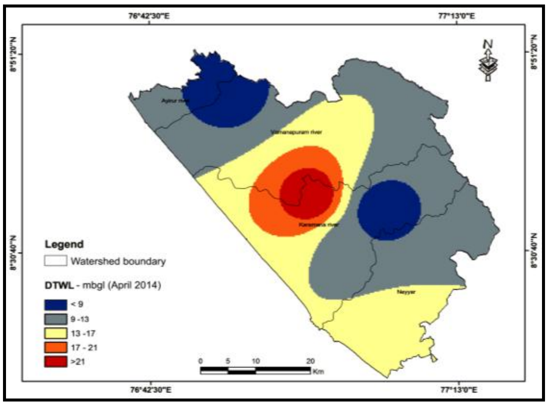

Figure 2a: *Depth to water level during pre-monsoon season (April 2014)*

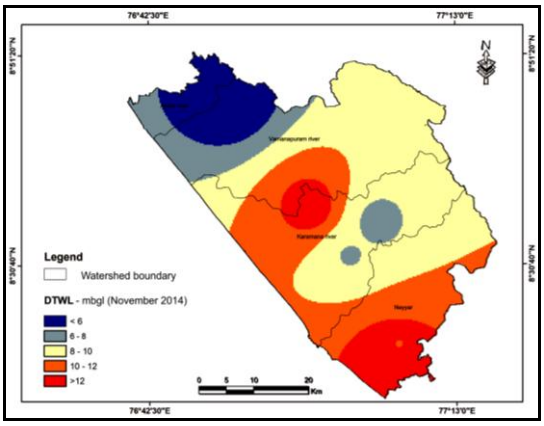

Figure 2b: *Depth to water level during post-monsoon season (November 2014)*

Fluctuation is maximum in Vamanapuram and Karamana river basins (4.31 and 16.31 mbgl). Whereas the minimum fluctuation is recorded in the Neyyar river basin (-2.04 mbgl). The midland portions of Vamanapuram and Karamana river basins have maximum fluctuation. So recharge occurs maximum at these areas. Minimum fluctuation is observed from Kottakkal and maximum fluctuation is from Alanthara. The Figure 3 shows that the rate of fluctuation minimal in the southern part of the area (1098 sq km).

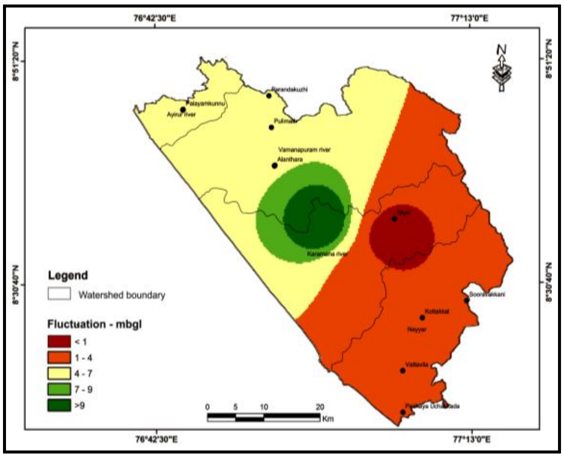

Figure 3: *Fluctuation map (2014)*

These areas are occupied by the Neyyar and Karamana river (part) watersheds. The northern part covering the watersheds of Karamana (part), Vamanapuram and Ayirur rivers shows better water level fluctuation, which indicates good recharge from rainfall than the southern part of the area. This may be due to the change in land use pattern in different watersheds of the area. The land use analyses show that the area is covered under rubber plantation, built-up areas, mixed plantations, double crops like kharif and rabi etc. Water table contour map (Figure 4) shows that the groundwater varies with the topography of the basins and is trans-boundary. The groundwater flow occurs across the watershed divides. The groundwater is flowing towards the major stream and there is a subsurface flow towards the ocean. The groundwater is lost as a base flow during summer season. Hence there is a decline in water level every part of the study area.

The water levels monitored from the bore wells indicate that deeper aquifer water level ranges from 5.28 to 26 mbgl during pre-monsoon and 3.25 to 13.82 mbgl during post-monsoon. The fluctuation of water level ranges from -1.44 to 12.7 mbgl.

From the seasonal groundwater level, deepest water level recorded from Pazhayauchakkada and shallow water levels from Kathipara. About 7% of the locations show negative seasonal fluctuation, ie. the post-monsoon seasonal water level is lower than that of the pre-monsoon water level. This indicates the groundwater is not sufficiently recharged from the precipitation.

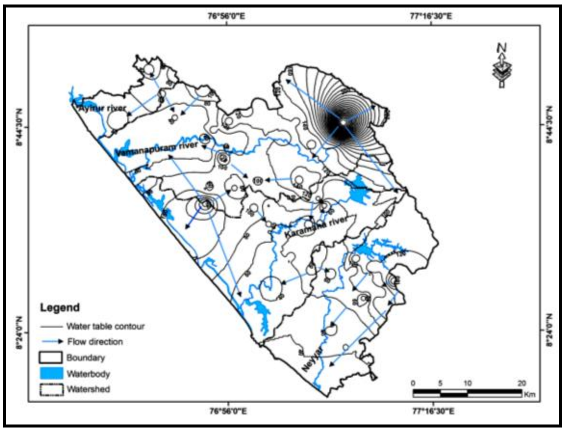

Figure 4: *Water table contour map*

4. Groundwater level- long-term trends (past)

Long-term trend of the groundwater levels in the hard rock aquifers of the study area is studied using historical (ten years) data collected from Central Groundwater Board, Regional Office, Trivandrum. For analysing the long-term trend, water level data of 15 dug wells were used. Hydrographs for pre-monsoon and post-monsoon water level are prepared using GNU plot 4.6 and the location wise hydrographs are shown in the Figure 5. GNU plot is a command-line program that can generate two and three dimensional plots of functions, data and data files. It is frequently used for publication-quality graphics as well as education. GNU plot can produce output directly on screen, or in many formats of graphic files like PNG, EPS, SVG, JPEG etc (www.gnuplot.info). The hydrographs with red arrows (Figure 5) show the locations with declining water level and green arrow indicates locations with rising trend, over the last ten years.

Combined hydrographs of all locations for different periods were also prepared. Figure 6a. shows the premosoon water levels during 2004, 2009, 2013 and future water level for the year 2020 and Figure 6b. represents the post monsoon water levels. The figure shows that there is continuous decline of water levels in both pre and post monsoon seasons.

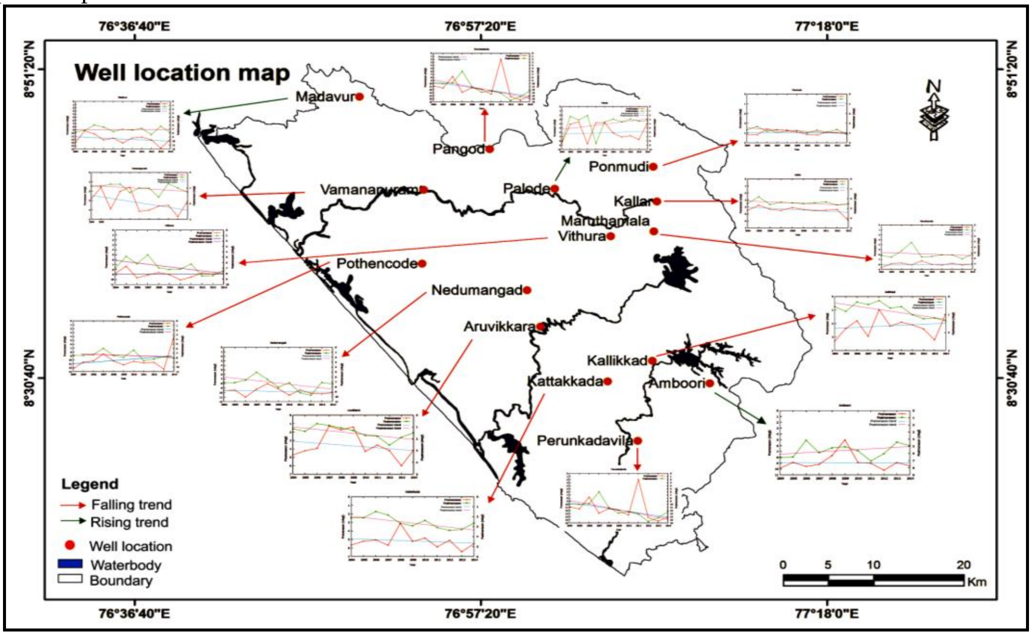

Figure 5: *Hydrographs of water level for 15 well locations*

Long-term trend of the water level depicts that the locations such as Vamanapuram, Perunkadavila, Pangod, Nedumangad, Kattakkada, Kallar and Aruvikkara show a rate of decline of pre-monsoon water level ranges from 0.5 to 6 mbgl and the rate of decline of post-monsoon season ranges from 0.4 to 4.9 mbgl. This shows that groundwater level has a decline trend in all river basins during pre-monsoon season. Water level in Palode shows rising trend with a rate of 0.6 and 2.3 mbgl during pre-monsoon and post-monsoon respectively. The water level trend in areas such as Pothencode, Vithura, Maruthamala and Kallikkad shows a falling trend during post-monsoon season only. That is during post-monsoon season groundwater level shows a decline trend in Vamanapuram and Neyyar river basins. In Amboori, water level is constant during pre-monsoon and shows a rising trend during post-monsoon season.

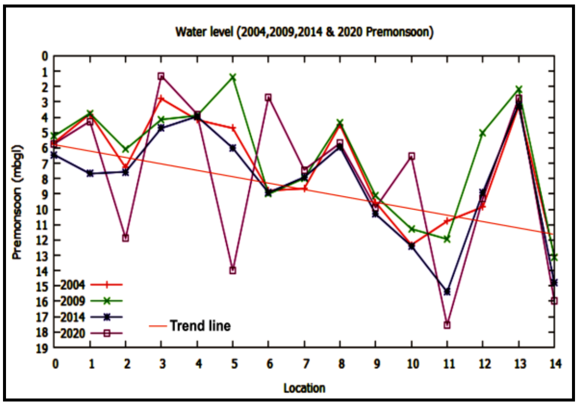

Figure 6a: *Hydrographs showing pre-monsoon water levels for the years 2004, 2009, 2014 and 2020*

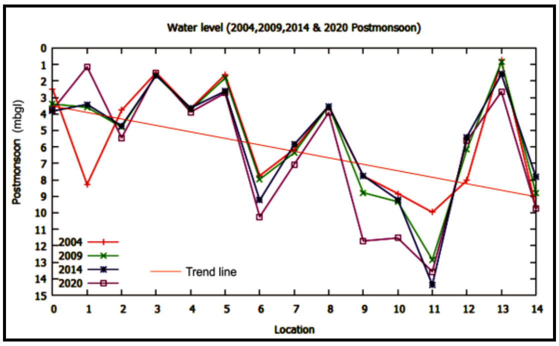

Figure 6b: *Hydrographs showing post-monsoon water levels for the years 2004, 2009, 2014 and 2020*

The long term trend analysis shows that (ten years data), majority of the wells are showing declining trend (1.99 m/year) and this decline is attributed to the change in land use pattern in the area and less recharge from the rainfall. The long-term trend of the water level shows a declining trend during post-monsoon season in most of the area indicates that there is no sufficient recharge occurs from the rainfall. This may be due to insufficient fracture patterns to enter the rainwater into the aquifer. Palode and Amboori are the locations with sufficient recharge occur where the post-monsoon water level shows a rising trend.

5. Groundwater future trends

This study has made an attempt to predict the future water levels and trend based on mathematical simulations. The future water level is determined using the software Eureqa. Eureqa is a mathematical software tool uses symbolic regression to determine mathematical equations that describe sets of data in their simplest form. Using symbolic regression this program can create accurate predictions (www.formulize.nutonian.com).

The future prediction made by this software shows that the post-monsoon water level in the Vamanapuram and Karamana river basins (places Vithura, Nedumangad, Pothencode) will continue to decline further by the year 2020. The pre-monsoon water levels in all watersheds (areas include Pangod, Aruvikkara, Perunkadavila and Madavur) show a declining trend by the year 2020 (Figure 6a & b). The future water level and the water level of 2004, 2014 and 2020 are tabulated in Table 1. The maximum pre monsoon water level decline is expected in the areas around Aruvikkara (Karamana basin) and Perunkadavila (Neyyar basin) and post monsoon it is in Nedumangadu and Perunkadavila. The prediction shows that the water levels in the hard rock aquifers will continue to decline irrespective of the good rainfall received in the area. This may be due to the change in land use pattern, construction activities, paddy field reclamation and reduction in groundwater recharge due to clay filling in the fracture zones.

Table 1: *The water level for the years 2004, 2014 and 2020*

Sl.No.	Locations	Premonsoon 2004	Postmonsoon 2004	Premonsoon 2010	Postmonsoon 2010	Premonsoon 2020	Postmonsoon 2020
1	Kattakkada	5.66	2.48	4.84	2.77	5.73	3.76
2	Palode	3.8	8.28	6.19	2.96	4.27	1.14
3	Pangod	7.28	3.78	7.14	2.17	11.88	5.45
4	Vamanapuram	2.80	1.50	4.03	1.68	1.31	1.52
5	Ponmudi	4.17	3.67	4.14	4.00	3.8	3.89
6	Aruvikkara	4.72	1.62	4.30	2.40	14	2.73
7	Vithura	8.78	7.75	10.10	7.92	2.69	10.24
8	Maruthamala	8.65	6.15	8.12	6.02	7.43	7.06
9	Kallar	4.50	3.53	4.49	3.40	5.7	3.92
10	Nedumangad	9.56	7.77	10.57	7.83	9.89	11.71
11	Pothencode	12.32	8.83	10.34	7.48	6.56	11.53
12	Perunkadavila	10.78	9.97	13.51	12.45	17.54	13.57
13	Amboori	9.85	8.04	8.86	6.89	9.31	5.64
14	Kallikkad	3.30	0.75	1.90	0.75	2.76	2.65
15	Madavur	13.01	9.68	11.55	9.04	15.96	9.72

6. Conclusions

- Hydrogeology of the hard rock aquifers of Ayirur (part), Vamanapuram, Karamana and Neyyar (part) river basins has been investigated.
- The groundwater potentials and recharge characteristics are not uniform in all the basins. Groundwater is the primary source of water for domestic and agricultural use in all the basins. The present water level trends show that the midlands of Vamanapuram and Neyyar river basins record the deepest water level (up to 26.67 mbgl). The groundwater level fluctuation is more in the northern part of the area than that of the southern part. However the areas with deepest water levels in parts of Vamanapuram and Karamana river basins record highest fluctuation.
- The water table contour map shows that the groundwater varies with the topography of the basins and is trans-boundary. The groundwater flow occurs across the watershed divides. The groundwater is flowing towards the major streams and there is substantial subsurface flow (base flow) towards the major rivers. The groundwater is lost as a base flow during summer season. Hence there is a decline in water level in most part of the study area.
- The long-term trend shows that groundwater levels decline during post-monsoon season in Vamanapuram and Neyyar river basins. Whereas during pre-monsoon season groundwater level in the entire river basins show falling trend.
- The future trend of the groundwater level is predicted using mathematical prediction software Eurequa. The future prediction shows that the post-monsoon water level in the Vamanapuram and Karamana basins (places Vithura, Nedumangad, Pothencode) will continue to decline further by the year 2020. The pre-monsoon water levels in all watersheds watersheds (areas include Pangod, Aruvikkara, Perunkadavila and Madavur) show a declining trend by the year 2020. The prediction shows that the water levels in the hard rock aquifers will continue to decline irrespective of the good rainfall received in the area.
- The present study shows that the groundwater resources of the hard rock aquifers are depleting and lack proper recharge from the rainfall. This may be due to the change in land use pattern, construction activities, paddy field reclamation and reduction in groundwater recharge due to the blockage of fractures with clay minerals.
- Intense artificial recharge schemes are necessary in the area. Subsurface dykes, recharge shaft and bore well recharge are recommended in the area.

Acknowledgements

We extend our sincere thanks to University of Kerala for the financial support for this work. We are thankful to Dr. Nandakumaran, Director, and Dr N

Vinayachandran, Scientist 'D' CGWB, Kerala Region for providing data and guidance. We also thank Dr. Satheesh Kumar, Department of Futures studies for his help in this work.

References

[1] Alain, P. F, Maciek, W. L, Jean, R, Fernando, A.M.S., and Mohammad, R. M.A. (2014). in hard rocks-Sardon catchment (Spain).Jour.of Applied Geophysics. 110: 63-81.

[2] CGWB. (2013). Groundwater resources and development Potential of Thiruvananthapuram District, Kerala.

[3] Chandra, S, Ahmed, S, Ram, A, & Dewandel, B. (2008). Estimation of hard rock aquifers hydraulic conductivity from geoelectrical measurements: a theoretical development with field application. Journal of Hydrology, 357(3): 218-227.

[4] Chandra, S, Dewandel, B, Dutta, S, & Ahmed, S. (2010). Geophysical model of geological discontinuities in a granitic aquifer: Analyzing small scale variability of electrical resistivity for groundwater occurrences. Journal of Applied Geophysics, 71(4): 137-148.

[5] Dewandel, B, Lachassagne, P, Zaidi, F. K, & Chandra, S. (2011). A conceptual hydrodynamic model of a geological discontinuity in hard rock aquifers: Example of a quartz reef in granitic terrain in South India. Journal of Hydrology, 405(3): 474-487.

[6] Dewandel, B, Perrin, J, Ahmed, S, Aulong, S, Hrkal, Z, Lachassagne, P, Samad, M, & Massuel, S. (2010). Development of a tool for managing groundwater resources in semi arid hard rock regions: application to a rural watershed in South India. Hydrological Processes, 24(19): 2784-2797.

[7] Edward, K. P. B, Tetteh, T. A, Shiloh, O, Samuel, Y. G, Dickson, A, Abass, A.G, Elikem, A, and Godfred, A. (2011). Major ions and trace elements partitioning in unsaturated zone profile of the Densu river basin, Ghana and the implications for groundwater. African Journal of Environmental Science and Technology 5(6): 427-436.

[8] Geological Survey of India. (2005). Geology and mineral resources of the states of India, Miscellaneous publication No.30, Part IX, Kerala.

[9] http://formulize.nutonian.com/documentation/eureqa/general-reference/building-blocks/

[10] http://www.gnuplot.info/docs_4.4/gnuplot.pdf resources development in hard rock terrain - an approach using remote sensing and GIS techniques. JAG, v.2, Issue ¾.

[11] Jagannadhan, K., Arul, M., Venkitakrishnan, J. and Manivel, M. (2000). Groundwater

[12] Maréchal, J. C, Dewandel, B, Ahmed, S, Galeazzi, L, & Zaidi, F. K. (2006). Combined estimation of specific yield and natural recharge in a semi-arid groundwater basin with irrigated agriculture. Journal of Hydrology, 329(1): 281-293.

[13] Owen, R, Maziti, A, and Dahlin, T. (2007). The relationship between regional stress field, fracture orientations and depth of weathering and implications for groundwater prospecting in crystalline rocks. Hydrogeology Journal, 15: 1231-1238.

[14] Perrin, J, Ahmed, S, & Hunkeler, D. (2011). The effects of geological heterogeneities and piezometric fluctuations on groundwater flow and chemistry in a hard-rock aquifer, southern India. Hydrogeology Journal, 19(6): 1189-1201.

[15] Prasad, R. K, Mondal, N. C, Banerjee, P, Nandakumar, M. V, & Singh, V. S. (2008). Deciphering potential groundwater zone in hard rock through the application of GIS. Environmental geology, 55(3): 467-475.

[16] Preeja, K. R, Joseph, S, Thomas, J, & Vijith, H. (2011). Identification of groundwater potential zones of a tropical river basin (Kerala, India) using remote sensing and GIS techniques. Journal of the Indian Society of Remote Sensing, 39(1): 83-94.

[17] Soman, K. (2002). Geology of Kerala, Geol.Soc.India, Bangalore.

[18] Todd, D.K, and Mays, L.W. (2005). Groundwater Hydrology (Third Edition), John Wiley and Sons, New York, 636.

[19] Yousef A.H, Prijub, C.P, and Narasimha P.N.B. (2015). Delineation of Groundwater Potential Zones in Deep Midland Aquifers along Bharathapuzha River Basin, Kerala using Geophysical Methods. Aquatic Precedia, 4: 1039-1046.