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Hydrogeology of Hard Rock Aquifer System - A Case Study from Turinjahalli Watershed, Dharmapuri District, Tamilnadu, India

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ABSTRACT

Hydrogeology hard rock aquifer system is very complex and the occurrence and movement of groundwater mainly controlled by secondary porosity developed from the weathering and structural deformity undergone by the rocks. The study area forms part of the poly-metamorphic and multistructural Archaean complex is underlain by crystalline formations consists of charnockite and hornblende biotite gneiss. There are major aquifer units delineated in the watershed based on the aquifer parameters and water level behaviour. The aquifer units are weathered aquifers and fractured aquifers, depth of weathered and fractured aquifers in the study area ranged between 2 to 29 m and 29 to 185 m respectively. The weathered aquifer contains water during monsoon season and becomes dry whereas the fractured aquifers yield water and four to five sets of fractures encountered in the aquifer system. 103 monitoring stations were established for groundwater level monitoring and carried out pre- and post-monsoon water level measurements. The depth to water levels in observation wells tapping aquifer during pre monsoon ranged between 10.90 m.bgl and 25.30 m.bgl and during post monsoon ranged between 12 and 31.20 m.bgl. The water table elevation map was prepared using the reduced levels for the monitoring stations to know the groundwater flow direction in the watershed. The map reveals that groundwater flow direction is from south-west to east/north-east direction. Based on Darcy's equation, the rate of flow of groundwater in the aquifer system depends on the hydraulic gradient and hydraulic conductivity. The total amount of groundwater flowing through aquifer system in the watershed is 4.36 cubic meters per second.

Keywords : Hard Rock Aquifers, Water Levels, Groundwater Movement, Turinjahalli Watershed, Dharmapuri

I. INTRODUCTION

Thus the water is essential for sustenance of all forms of life and is one of the principal elements which influence economic, industrial and agricultural growth of the mankind. The increasing demand and quest for groundwater due to ever increasing population has compelled mankind to efficiently manage this precious resource. As groundwater continues to play an important role in the development of the human civilization, there arises a strong need for protecting groundwater from increasing threat of over extraction and contamination. Hence, it is important to understand the aquifer system and its hydrodynamics so as to properly manage the groundwater resources. About three-fourths of Tamil Nadu state is underlain by hard crystalline rocks of Archaean age (Ramesh et al., 1983 and Subramanian et al., 2001), which are devoid of any primary porosity on account of its massive and consolidated nature. The occurrence and movement of groundwater in these rocks are restricted to the weathered zone or fractures at depth and the groundwater potential of these rocks, in general, are poor (Sivaramakrishnan et al., 2016). The over exploitation of groundwater resources, frequent drought and erratic rainfall have leading to decline in groundwater level and drying of aquifers has put a stress on the available groundwater resources of Turinjahalli watershed, Dharmapuri district, Tamiladu, India. Hence, this watershed or aquifer system has been taken up in this research study with an objective to delineate the aquifer units, occurrence and movement of groundwater in hard rock aquifers.

Study area

In order to understand the groundwater occurrence and its movement in the hard rock aquifer system, the Turinjahalli watershed is part of Vaniar River basin were considered. The Turinjahalli watershed covers areas, comprises of Morappur, Harur and Pappireddipatti blocks, Dharmapuri district, Tamilnadu. The percentage of area of watershed falls in the blocks of Morappur, Harur and Pappireddipatti are 70, 23 and 7 percent respectively. Harur and Kadathur are the major town falls in the watershed. The total geographical area of the watershed is 304.6 sq.km The study area is located between North latitude 11°59'00" to 12°07' 15" and East longitude 78°12' 45" to 78°32' 00" and is covered in parts of Survey of India toposheet Nos. 57L/4, 57L/8, 57L/12 and 57I/5. The topographic elevation ranges from 314 to 1103 m above mean sea level (a.msl). The population of the study area works out as 102510. About 95 percent of the population resides in rural areas. The administrative map of Turinjahalli watershed are shown in figure 1.

Tuinjahalli River is ephemeral river and it is tributary of Vaniar river (Nanadakumaran 2007). The river carries substantial flow only during monsoon period. The drainage patterns observed in the watershed are dentritic to sub-parallel. Agriculture is main activities and about 60 percent of the area under agriculture activities. Flowers, vegetables, paddy, maize and raggi are the main crops, source of irrigation through groundwater only. The geomorphic unit present in the watershed includes buried pediments, valley fill, dissected hills, pediment inselberg and inslberg complex. The soils occur in this watershed are hill bottom soils and red sandy soil hill soil, reserve forest soil, black cotton soil and laterritic soil.

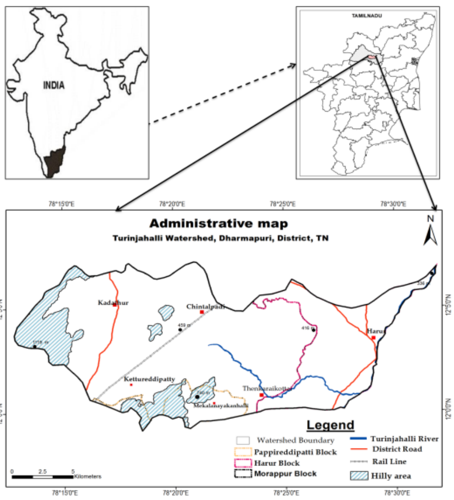

Figure 1. Administrative setup of Turinjahalli watershed

II. METHODS AND MATERIAL

Field studies included geological investigations, drilling of bore wells, geophysical investigations and groundwater level monitoring. In order to understand the geology of the region, the available geological maps and existing reports were studied. The thickness and intensity of weathering were studied from borehole lithological data, geophysical data and information from river cuttings and well sections. To carry out the present study, it was necessary to have more number of representative wells. Hence, initially a well inventory study was carried out in most of the wells present in this area. The area under study has been studied on a regular basis by monitoring of groundwater levels. 103 monitoring stations were established and basic data on the monitoring stations such as depth, topographic elevation, weathered thickness and fracture depth were recorded. Water levels were monitored during pre and post monsoon period, i.e. June and January months for the period of two years from 2013 to 2015. Groundwater level was measured in open wells and bore wells using water measuring tape and water level recorders.

III. RESULTS AND DISCUSSION

Geology

The study area forms part of the poly-metamorphic and multi-structural Archaean Complex of Peninsular India and is underlain by crystalline formations with localised very small patches of recent alluvial deposits along the river. Charnockite and hornblende biotite gneisses occur extensively in the watershed. Amphibolites, ultramafic rocks and veins of pegmatite/quartz are seen in the rocks all over the watershed. The hornblende biotite gneiss is comparatively friable than the charnockite. The hornblende biotite gneiss is more susceptible for weathering and charnockite are less susceptible. The geological map of the Turinjahalli watershed is shown in figure 2. The two dimensional disposition of different aquifers in the Turinjahalli watershed in different section lines (figure 2) prepared and two dimensional aquifer disposition with respect to depth is presented in figures 2a, and 2b respectively.

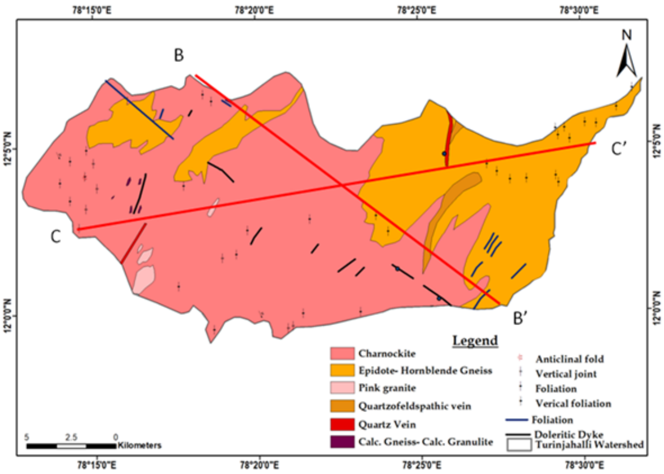

Figure 2. Geological map and section lines drawn for two dimensional aquifers disposition

Aquifer system

Based on the results of groundwater exploration, geophysical data (CGWB 2003, 2013) and field studies undertaken in watershed, the rock formations grouped as two aquifers system (Panneer et al., 2013, 2016) and the aquifers exists in watershed are classified in to; ***Phreatic aquifers***, depth range from 2 to 29 m and contain water during monsoon season, discharge ranged from negligible to 180 litres per minute. The yield of large diameter wells tapping the weathered mantle of crystalline rocks ranges from 100 to 150 m^3/day for a drawdown of 3–6 m/day and is able to sustain pumping for 1–2 hours. The specific capacity and transmissivity values of weathered aquifer ranges from 6 to 28 lpm/m/dd and 12 to 20 m^2/day respectively. Groundwater in these aquifers occurs in un-confined conditions. ***Fractured aquifers*** occur at depth ranges from 29 to 185 m and contain water, yield of the aquifers maximum of 150 lpm. Four to five sets of fractures are encountered up to the depth of 200 m bgl in a bore wells. The specific capacity and transmissivity value in the fractured/fissured formations ranges from 3 to 150 lpm/m/dd and 0. 5 to 117.32 m^2/day while the storativity ranged from 4.37 x 10^{-4} to 7.89 x 10^{-3}. The groundwater in this fractured/fissured formation occurs under semi-confined to confined condition.

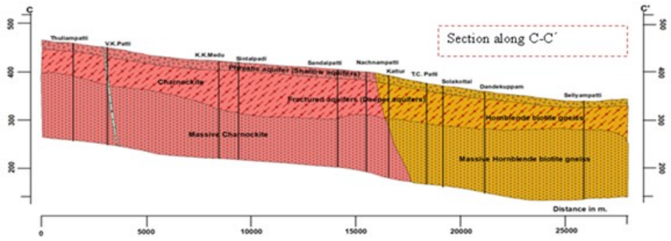

Figure 2a. Two dimensional aquifer dispositions along line B-B´

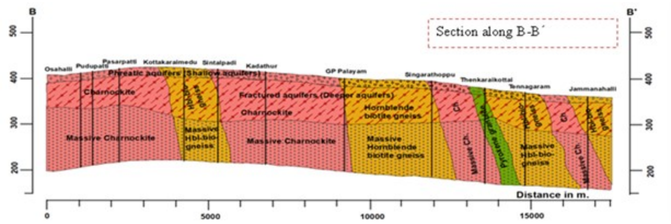

Figure 2b. Two dimensional aquifer dispositions along line C-C′.

Depth to water levels

The relationship between water level and rainfall was studied from the seasonal and spatial variations in the groundwater table. The groundwater level of the study area is a composite representation of heads of the single aquifer of two sub layers varying lithologically and hydrogeologically. The wells monitored were tapping both the aquifers and are hydrogeologically connected. The map showing locations of groundwater level monitoring stations are shown in figure 3.

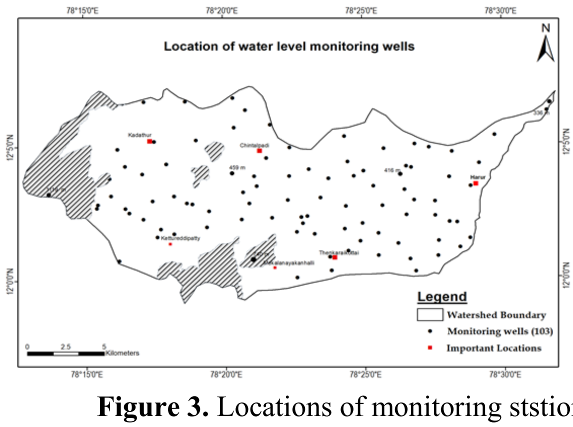

Figure 3. Locations of monitoring ststion

During pre-monsoon in May 2014, the depth to water levels in observation wells tapping the phreatic aquifer in the basin ranged from 10.90 m.bgl (Location: Ettiapatti) to 25.30 m.bgl (Location: Andipatti Pudur). The depth to water level in the watershed is in the range of 15 to 20 m.bgl in 80 percent of the wells analysed, 12 percent of wells analysed have recorded the water levels between 20 to 25 mbgl, the water levels between 12 and 15 m.bgl in 6 percent of wells and one percents of wells recorded water level less than 12 m and 25 to 30 respectively. The depth to water levels in the watershed during pre-monsoon prepared using water level data of monitoring stations in Turinjahalli watershed are shown in figure 4.

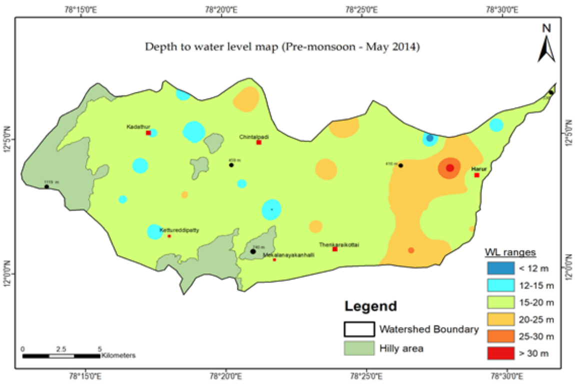

Figure 4. Depth to water level map during pre-monsoon

During post monsoon in January 2015, the water levels in the study area shown similar pattern water level of pre-monsoon due to failure of monsoon. Continuous withdrawal groundwater for agricultural and domestic need the post-monsoon water is deeper than pre-monsoon. The shallowest water levels less than 15 m were observed predominantly in Kadathur and adjoining area, where groundwater extraction is less as the surface water tanks cater the agricultural needs. Majority of observation wells showed water levels in the range of 15 to 20 m.bgl. Water levels in the range 20 to 25 m.bgl were observed near the Harur town and adjoining area. Deepest water levels greater than 30 m were observed in north eastern part of the watershed, where the ground water is withdrawn for Morapaur town cater the town water supply. The map showing the depth to water level map observed during post monsoon period is presented in figure 5.

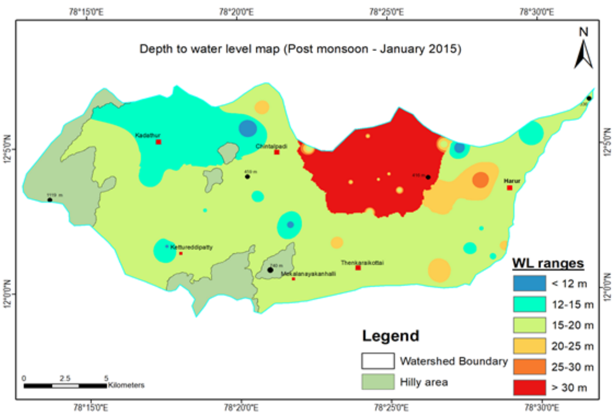

Figure 5. Depth to water level map during post monsoon.

The seasonal fluctuations of ground water levels in the aquifer system in the watershed have been analysed and presented. The seasonal water level fluctuation in the area has been analysed using the water level data of May 2014 and January 2015. The fluctuation of water levels (figure 6) indicates the very little extent of replenishment of shallow aquifers due to the monsoon rainfall. The water level fluctuation in the study area ranged from a decline of 1.72 m. (Location: Sunkarahalli) to a rise of 7.30 m (Location: Punganur) during the period. Rise in water levels during the period has been observed in more than 68 percent of the wells considered. The rise in water levels is in the range of 0 to 2 m. in about 70 percent of these wells, between >2 and 4 m in about 29 percent and more than 4 m in about 1 percent of well. Fall in water levels is observed in about 32 percent observation wells in the study area with a magnitude of less than 2 m during the period, indicating recharge insufficient to compensate the withdrawal of ground water from phreatic zone.

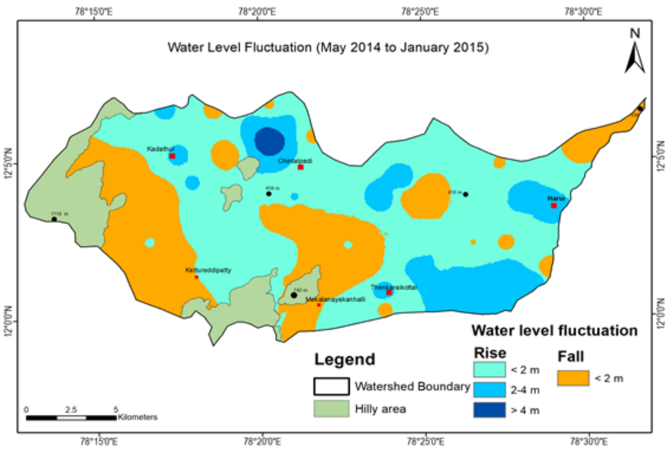

Figure 6. Seasonal water level fluctuation map.

A water-level contour map is a common tool used to understand groundwater flow directions in a watershed. Todd (1959) asserts that under steady state conditions, flow lines lie perpendicular to water table contours. From field measurements of static water levels in wells, a water table elevation contour map can be constructed for a watershed. Water level elevation contours were generated using water levels and elevation data of monitoring wells. The water level elevation map defines the potentiometiric surface and distribution of potential energy in the hard rock aquifer system. Each contour or equipotential lines represents the line of equal hydraulic gradients. Groundwater flows from high to low hydraulic gradient as the case of surface water.

Elevation of ground water table during May 2014 ranged from 300.8 m. above msl (Location: Kilanur) to 994.30 m. above msl (Location: Sungarahalli). A map showing the elevation of ground water table in aquifer in the study area during premonsoon along with flow lines showing the direction of ground water movement is shown in figure 7. The gradient is toward east and northeast and the ground water flow in the aquifer system is east to north east and the same marked by an arrow on the map.

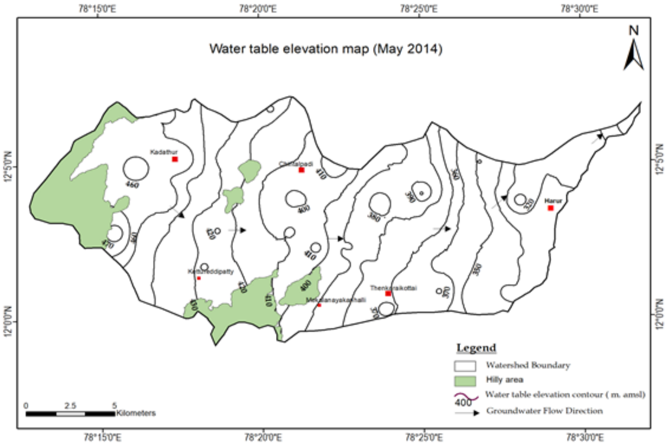

Figure 7. Water table elevation map of Turinjahalli watershed.

As we know, the groundwater flow depends on the hydraulic gradient and hydraulic conductivity (Darcy's law). The hydraulic gradient is nothing but the head differences (h1-h2) two water level elevation contours. In two dimensions, the hydraulic gradient is defined by the slope of water level elevation contours, just as the slope of the topographic maps. Darcy's law describes the relationships between the instantaneous rate of flow through porous medium (aquifers system) and head differences at a particular distance.

Darcy's law is expressed as:

$$Q = -K*A*dh/dl$$

Wherein

Q is the rate of groundwater flow, K is the hydraulic conductivity of aquifer system, A is the cross sectional area between two water level elevation contours and dh/dl indicates the hydraulic gradient, i.e, the difference between two water level elevation contours and the length of the contours.

The amount of ground water flowing out through the aquifer system in Turinjahalli watershed calculated as by assuming the hydraulic conductivity value for the aquifers 0.004 meter per second, dh/dl calculated from the water level elevation map, the value of dh (h_1-h_2) is 10 m and dl is 1558.4 m. The cross sectional area of the two elevation contours is 16992 square meters. The total amount of groundwater flowing through aquifer system in the watershed is 4.36 cubic meters per second.

IV. CONCLUSION

Turinjahalli watershed comprises rocks of Archean age and mainly charnockite, epidote hornblende gneiss and ultramafic rocks like pyroxene granulites, characterised by hard rock aquifer system consists of two distinct aquifers, the groundwater availability in the aquifers are very limited due to frequent failure of monsoon and over extraction of groundwater than the annual replenishable recharge through monsoon. The studies revealed that the depth of occurrence of fracture limited to 185 m below ground level, the user community drilling the bore wells for groundwater abstraction beyond the depth and hence wasting their all resources. The water levels in the aquifer system are deep, thus amble scope exists for recharge of aquifers. The amount of groundwater flowing through aquifer system from the watershed calculated and it approximately is 4.36 cubic meters per second. It is necessary to characterise the subsurface for better understanding of geological formations and for better management of the subsurface resources in a more scientific manner.

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