

Hydrogeological Characterization By Specific Yield Determination In Parts of Araniyar - Kortalaiyar (A.K) Basin, Thiruvallur District, Tamilnadu, India

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ABSTRACT

The study area, part of Araniyar- Kortalaiyar (A.K) river basin ,Tamil Nadu is covered by alluvium of both rivers and has good groundwater potential. Hence, Chennai metropolitan water supply and sewerage Board supplied groundwater to cater habitants of sub-urban areas of Chennai for more than 3 decades in this region. Due to heavy pumping, groundwater levels have declined and sea water has been intruded around in the study region particularly in Minjur area. The hydrological characterization of specific yield parameter was determined for the unconfined alluvial aquifer in the four well fields constructed in the study area. Conducted Step Drawdown Test (SDT) for 4 steps of 60 minutes duration and on the basis of the results, Long duration Aquifer Performance Test(APT)(pumping test) was conducted for 5800 to 10000 minutes well fields and Specific yield was computed by three methods: Volume Dewatering Method, Ramsohoye – Lang Method and Curve Matching Method (Neuman). Specific yield (Sy) of sand aquifer is found to ranging 7% at ponneri and upto 20% Minjur.

Keywords: Araniyar -Kortalaiyar river basin, Specific yield , Step Drawdown Test (SDT) ,Aquifer performance test (APT) , Ramsohoye –Lang method, Curve matching method (Neuman)

I. INTRODUCTION

Groundwater meets the increasing need for domestic water demand arising due to increase in population and agricultural requirements in our country. Groundwater is developed through large number of dugwells, borewells and tubewells which are spread in the agricultural fields, residential and industrial area. The heavy withdrawal of groundwater has resulted in lowering of groundwater levels which in turn has caused deterioration of groundwater quality. The continuing groundwater exploitation has resulted in lowering of groundwater levels and wide variation in the zone of fluctuation in comparison to the groundwater scenario three decades back. The rainfall recharge is estimated by two methodologies, viz., Groundwater level fluctuation method (using the

parameter of specific yield) and Rainfall infiltration method (using rainfall infiltration factor). Specific yield is the fundamental and basic parameter to understand recharge and discharge mechanisms and to estimate groundwater resources of an aquifer system. Hence estimation of specific yield parameter is carried out in this research study so as to decipher recharge areas in parts of Araniyar and Kortalaiyar Basin, South India. The data of specific yield and infiltration factor available in the state is very limited, apart from a few laboratory estimation carried out by Central Ground Water Board (CGWB) under UNDP project during the period 1978 to 1982. It may also be mentioned that the categorization of blocks or firkas in terms of groundwater development may likely to change drastically if the specific yield value does not represent field situations. Specific yield of the

formation is the capacity of saturated formation to drain water under the force of gravity. It is the water draining capacity of the geological formation. This is an important property which defines the ability of geological formation to drain water or take water and expressed as percentage to the volume of water yielded by draining a saturated geological formation to its total volume. As this property is effective in furnishing water supply to wells, it is also known as Effective Porosity (Johnson, 1967). The determination of specific yield of the water table aquifer is an important aspect in groundwater evaluation studies. Specific yield is an important factor used in the groundwater assessment. Groundwater resource estimation requires realistic specific yield values for different hydrogeological units to define the field situation. An attempt has been made to determine the specific yield and infiltration factor in the part of Araniyar – Kortalaiyar basin of Northern Tamil Nadu State in Southern India

II. STUDY AREA

The Study area, part of Araniyar – Kortalaiyar river basin (A-K basin) forms a part of Tiruvallur district, covering an area of 600 square.kms and is located between North latitude $12^{\circ} 54' 00''$ & $13^{\circ} 24' 00''$ and East Longitude $80^{\circ} 10' 00''$ & $80^{\circ} 20' 00''$ (Fig.1). This basin consists of alluvial formations of both rivers and forms prolific aquifers. The groundwater in this basin has been heavily pumped and forms drinking water supply source to sub-urban areas of Chennai (CGWB, 2005). As per the CGWB report, due to heavy pumping, groundwater levels have declined and sea water intrusion has taken place at Minjur (CGWB 2005). As part of the study, four well fields have been constructed at Velliyur, Kannigaipair, Ponneri & Minjur, with construction of one pumping well and 6 observation wells at a distance of 10m to 60m from pumping well. The study area receives rainfall under the influence of both southwest and northeast monsoons. Rainfall data

analysis shows that the normal annual rainfall varies from 950mm to 1150mm. The rainfall gradually increases towards east. The study area enjoys a tropical climate. The period from April to June is generally hot and dry. The weather is pleasant during the period from November to January. Usually mornings are more humid than afternoons. The relative humidity varies between 65 and 85% in the mornings while in the afternoon it varies between 40 and 70%. The annual mean minimum and maximum temperature are 24.3° and 32.9°C respectively. The day time heat is oppressive and the temperature is as high as 41.2°C . The lowest temperature recorded is of the order of 18.1°C . The area is drained by mainly by Araniyar and Korattaliyar River which are ephemeral in nature. The Araniyar originating in Chittur district of Andhra Pradesh flows through the northern part of the study area and finally discharges into Bay of Bengal near Pulicat lake, while Korattliyar river originates from vellore district. A check weir (ANICUT) is constructed across the Korattliyar river at Tamaraipakkam and the river water is directed to Sholavaram and Red hills reservoirs. The river joins with Bay of Bengal sea near Ennore back waters. Geomorphologically the study area has topographic elevation in the range from 45 m amsl in the west to sea level in the east.

GEOLOGY

The study area is underlain by alluvium formation which was deposited on the worn down and eroded surface of tertiary and Gondwana rocks. The alluvium consist of fine to coarse sand, sandy clay, clayey sand and clay partings of various shades of grey and brown. The alluvium deposited by Araniyar river comprises pure sands where as the Korattalaiyar alluvium consist of reddish loamy sands intermixed with clay. The basement was not encountered upto the depth of 764.20 m bgl at Puduvoyal village, which is located between Minjur and Kannigaipair village. (CGWB, 2005) The important aquifer systems

in the area are the unconsolidated formations of sand. The porous formations in the study area include sandstones and clays of Jurassic age (Upper Gondwana), marine sediments of Cretaceous age, Sandstones of Tertiary age and Recent alluvial formations

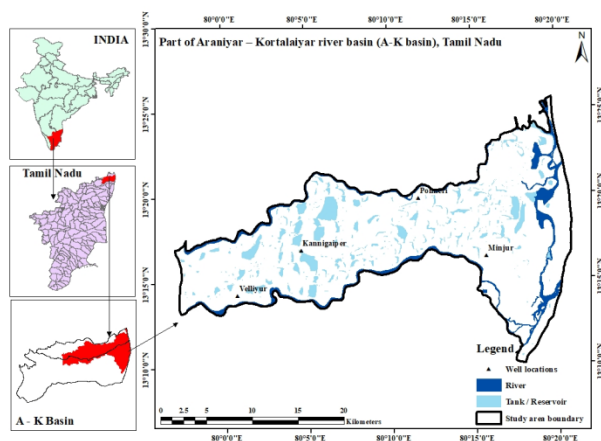


Figure 1

HYDROGEOLOGY

The groundwater in the study area occur in the unconsolidated & semi-consolidated formations forming important aquifer systems .. Groundwater occurs under phreatic to semi-confined conditions in the inter-granular pore spaces in sands, sandstones, the bedding planes and thin fractures in shales. In the area underlain by Cretaceous sediments, groundwater development is rather poor due to the limited yield and the poor quality of the formation water.

Quaternary formations comprising mainly sands, clays and gravels are confined to major drainage courses in the study area. The maximum thickness of alluvium is 40m whereas the average thickness is about 15m. Ground water occurs under phreatic to semi-confined conditions in these formations and is being developed by means of dug wells and filter points. Alluvium, which forms a good aquifer system along the Araniyar and Korattalaiyar river bed is one of the major sources of water supply to urban areas of Chennai city and also to the industrial units. The thickness of weathered zone in the district is in the range of 2 to 12m. The depth of the wells ranged from 8 to 15m bgl.

The depth to water level in the study area ranges between 1.6 – 13.36 m bgl during pre-monsoon (May-2010) and 0.79 – 5.30 m bgl during post monsoon (Jan-2011). The seasonal fluctuation shows a rise between 0.28 and 4.80 m bgl. The piezometric head varied between 2.20 to 10.30 m bgl (May 2010) during premonsoon and 2.72 to 8.55 m bgl during post monsoon (Jan-2011). In the porous formation the specific capacity values vary from 23.5 to 509.9 lpm/m.drawdown and the transmissivity values ranged from 40 to 625 m²/day. The specific yield varied from 7 % to 20%. High specific yields are noticed in the river alluvium.

OBJECTIVES OF THE STUDY

The study has been carried out with the following objectives

- ✓ To determine specific yield and aquifer characteristics for different hydrogeological setting in the study area and conduct field experiments of pumping tests
- ✓ To evolve methods for optimal design of rainwater harvesting structures based on the hydrogeological, geological setup and rainfall incidences.
- ✓ To demarcate area as per structures designed and validate for effective recharge of aquifers.

III. METHODOLOGY

Four well fields have been constructed at Velliur, Kannigaipair, Ponneri and Minjur with one pumping well and 6 observation wells at a distance of 10m to 60m from pumping well. The depth of the well varied from 25 to 40m bgl, depending on the thickness of the phreatic aquifer available at the site. The electrical logging method was used for giving well assembly to facilitate the accuracy in placing the well screen. Grain-size analysis was carried out for samples of all the well sites. 24 Infiltration tests were also

carried out in and around all the well fields. The wells were completely developed and Step Drawdown Test (SDT) with 4 steps of 60 minutes duration was carried out. On the basis of the results, pumping test was conducted for 5800 to 10000 minutes. The discharge was monitored using current meter and manometer and discharge was regularly measured using volumetric method and corroborated with current meter. The drawdown was measured in all the wells including pumping well at regular intervals to study the behavioral pattern of the groundwater system to the induced stress. The data of the long duration pumping tests were analyzed by three methods: Volume Dewatering method, Ramsaye- Lang Method and Neuman method. The entire volume of water computed using radius of influence is not dewatered and portion above the cone of depression is only dewatered. Hence, the drawdown configuration in the well field is plotted on a graph paper and the volume of desaturated portion is determined.

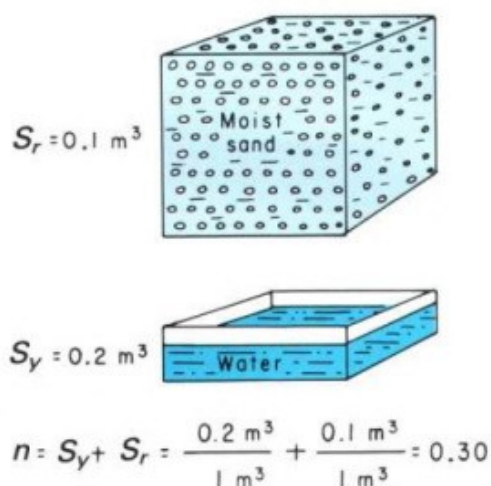


Figure 2

DETERMINATION OF SPECIFIC YIELD

Specific yield tells how much water is available for man's use, and specific retention tells how much water remains in the rock after it is drained by gravity. $n = S_y + S_r$

$$S_y = V_d / V_t, S_r = V_r / V_t$$

where n is porosity, S_y is specific yield, S_r is specific retention, V_d is the volume of water than drains from a total volume of V_t , V_r is the volume of water retained in a total volume of V_t , and V_t is total volume of a soil or rock sample. The following table gives some values of total porosity and specific yield for various aquifers:

Table 1. Hydraulic characters of different materials

Material	Porosity	Specific yield	Specific retention
Soil	55	40	15
Clay	50	2	48
Sand	25	22	3
Gravel	20	19	1
Limestone	20	18	2
Sandstone (semiconsolidated)	11	6	5
Granite	.3	.09	.01
Basalt (young)	11	8	3

In unconfined aquifers, the storativity is almost exactly equal to the specific yield. The most reliable method of calculating the storage coefficient (S) and/or the specific yield (S_y) is to carry out test pumping. A schematic representation of the well field and the behavioral pattern due to induced stress is given below.

If the actual volume of aquifer material dewatered is V_1 and the volume of water pumped out as measured is V_2 , Specific yield is given by the expression

$$\text{Specific Yield} =$$

In the Ramsaye –Lang Method, the volume of dewatered material with the total volume of water discharged using Darcy's Law with the assumption of general equilibrium formula. The expression used for the computation is given below.

$$S = Q_t / V$$

Where,

S = Specific Yield,

Q = Average Discharge in Cu.m/Day,

t = time in days,

V = Volume of dewatered material in Cu.m

Volume of dewatered material determined following equation, r = distance of observation well from pumping well,
 s = drawdown at time t ,
 T = Transmissivity in m^2/day

$$\log V = \left(\frac{\log Q r^2}{4 T} \right) + \frac{5.45 T s}{Q}$$

Where,

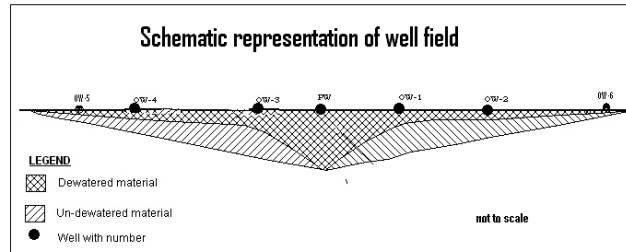


Figure 3, Schematic representation of well field

Table 2. Summarized results of Well fields specific yield results

Location	Lithology	Depth drilled (m)	Well constructed (m)	Zone Tapped (m)	Aquifer thickness (m)	Development Q (lps)	SWL (mbgl)	Duration of pumping test (min)	Q (lps)	DD (m)	SY (Determination) (%)		
											Volume Dewatering method	Ramsohoye – Lang Method	Curve matching metod (Neuman method)
Velliyur	Sand, with intercalation of thin clay underlined of Gravelly sand stone	25.2	25.2	13-16 17-20 21-24	9	3.28	17.55	10000	4.5	1.52	15	18	16.5
Minjur	Sand, with intercalation of clay	39.5	39.5	21-27 28-34 35-38	15	5.41	12.54	7260	4.03	0.28	20	-	19.5
Ponneri	Sand & Clay	33	33	16-19 23-32	12	0.5	23.38	8000	1.5	2.70	7	-	7.35
Kannigaipair	Sand, with clay and boulders at various	26.5	26.5	13-19 22-25	9	1.2	16.88	5800	2.47	3.74	14.4	-	12.35

	depths													
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IV. RESULTS AND DISCUSSIONS

The long duration pumping tests were analyzed by three methods: Volume Dewatering method, Ramsaye- Lang Method and Neuman method. The values of specific yield vary from 7% to 20% (Table.1). The Transmissivity values ranged upto 1328 m²/day. There is considerable heterogeneity of aquifer material and there is erratic behaviour of the water levels observed in the A-K basin even within short distances. The sub-surface lithological variations pose and challenge in construction of a well field for determination of Specific yield in terms of the depth of the observation wells and aquifer zones to be tapped. The specific yield of aquifer material works out to vary between 7% and 20%. The specific yield determined by volumetric method more or less corresponds with the results obtained from analysis of data using analytical method of Ramasahoye and Lang. The specific yield determined can be used in many groundwater management projects including groundwater resources estimation.

The study area has recent alluvium underlain by Gondwana conglomerates and Sandstones. The thickness of the alluvium ranges from 5 to 40m bgl in the study area. The highest specific yield values were obtained during the study was 20 % in Minjur site to the lowest Specific yield values of 7% in Ponneri site. The sites located in the Minjur, Velliyur and Kannigaipair area comprised of alluvium and there were variations in the grain size of the sands in these locations which resulted in variation of Specific Yield from 14 to 20 %. In the case of Ponneri site the formations encountered were sandy clay and mixed

sand with clay which resulted in low specific yield i.e., 7%.

The usefulness of these methods in the determination of field specific yield values has been proved and the same can be used as input for the decision support tool for planning artificial recharge schemes.

V. CONCLUSIONS

Four well fields have been constructed at Velliyur, Kannigaipair, Ponneri&Minjur with one pumping well & 6 observation wells at a distance of 10m to 60m from pumping well. The depth of the well varied from 25 to 40m bgl, depending on the thickness of the phreatic aquifer available at the site. Grain-size analysis was carried out for samples of all the well sites. 24 Infiltration tests were also carried out in and around all the well fields. The wells were completely developed and Step Drawdown Test (SDT) with 4 steps of 60 minutes duration was carried out. On the basis of the results, pumping test was conducted for 5800 to 10000 minutes. The values of specific yield vary from 7% to 20%. The highest specific yield values were obtained during the study was 20 % in Minjur site to the lowest Specific yield values of 7% in Ponneri site. The Transmissivity values ranged upto 1328 m²/day.

RECOMMENDATIONS

- High specific yield values are observed in the region between the Araniyar-Korattalaiyar

River were the flood plains thickness is maximum.

- The structures suitable for the A-K basin are the Percolation pond with injection well – suitable artificial recharge structure.
- Observation of the results indicates that the specific yield is high in the well fields which were supplying drinking water to Chennai city. These are only potential aquifer available near the Chennai city. Groundwater level has lowered to 12 to 18 m bgl and the thickness of the aquifers is only 40 m bgl. The saturated thickness is only 10 to 15 m only. Large scale artificial recharge i.e., percolation pond with injection well has to be taken up to revive and protect these aquifers.

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