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Estimation of Groundwater Recharge by Water Budget Method Under the Depleting Water Table

Sidhant Kumar Saurav^{1*}, P K Singh¹, Manjeet Singh¹, K K Yadav¹

¹Department of Soil and Water Engineering, College of Technology and Engineering, MPUAT, Udaipur, Rajasthan, India

*Corresponding author

ABSTRACT: Estimation of groundwater is an effective tool for proper planned and optimal utilization of water resources in the context of future requirement. Our main purpose for the estimation of groundwater in Dharta watershed is to make a complete assessment of groundwater resources and produce information that can be incorporated for future requirement. The study was undertaken based on the recommendation of groundwater estimation committee, 1997 (GEC-97). Methodology used the estimation of annual groundwater recharge from rainfall and other sources including irrigation, water bodies and artificial recharge, determination of present status of groundwater utilization and categorization of assessment units based on the level of groundwater utilization and long-term water level trend. Water level fluctuation techniques and empirical norms were used for recharge estimation. The data collected for investigation were water table fluctuation, rainfall, cropping pattern, number of groundwater structures, geographical area, groundwater draft, ponds area etc. The study reveals that for Dharta watershed the total annual groundwater recharge is 1871.42 ha-m, the groundwater draft in monsoon season is 87.66 ha-m. The stage of groundwater development is for Bhinder block which fall in critical categories. The energy requirement for abstraction of groundwater available for future agriculture is 1.62×10^6 KWh for Dharta watershed.

KEYWORDS: Water table, Water Table Fluctuation, Evapotranspiration

I. INTRODUCTION

India constitutes about 15 per cent of the world's population, but only about 2 percent and 4 percent of world's are land area and water resources, respectively. India is the world's largest groundwater user with a usage of 230 km^3 per year (CGWB, 2013; Hoekstra, 2013). Globally, India has 39 million ha of agricultural land under groundwater irrigation, followed by China and the USA with 19 and 17 million ha, respectively (World Bank, 2010; Siebert et al., 2010).

Groundwater is an essential resource for farmers in India, especially in arid to semiarid regions where the rainfall is a most non-reliant phenomenon. Following green revolution, India has encouraged irrigation in agriculture as a policy, initially through surface water storage dams, but later also reaching out groundwater sources. There are many reasons behind the worsening groundwater situation that have led to a scarcity of quality water supply for sustaining lives and livelihoods in India, as well as in other parts of the world. The lack of a proper scientific understanding of this situation by the various stakeholders has been identified as one of the important gaps in the sustainable management of groundwater.

Groundwater is the major source of drinking water in both urban and rural India. Besides, it is an important source of water for the agricultural and the industrial sector. Rainwater is the main source of water for agriculture but groundwater, which is 38.5 per cent of the available water sources of the country, plays a vital role in irrigation, rural and urban drinking water supply and industrial development. Throughout the world, groundwater resources are under increasing pressure caused by the intensification of human activities and other factors such as climate changes. The prime cause of overexploitation of groundwater is the rising demand from agriculture.



II. METHODOLOGY

2.1 Study Area

Dharta watershed is located at Bhinder block of Udaipur district. The area is bounded by $74^{\circ} 08'$ to $74^{\circ} 15'$ E longitude and $24^{\circ} 30'$ to $24^{\circ} 36'$ N Latitude. It is situated at a distance of 12 km from the Tehsil headquarters and covers a total geographical area of 54.53 km^2

2.2 Soil characteristics

The soil of the study area falls under sandy loam to clay loam texture and is typically one-meter-deep overlying granitic gneiss that can be weathered up to a depth of 28 m. The area undulates with an average slope of about 2 per cent with well-developed drainage

2.3 Climate

The Dharta watershed is characterized by subtropical and sub-humid to semi-arid climatic conditions. The monsoonal pattern of the basin is modified by the altitude, the orientation of hills and the presence of water bodies in the form of lakes resulting in hot summers (35°C to 40°C), cold winters (10°C to 15°C) and distinctively defined rainy seasons from the middle of June to the end of September. The average annual rainfall of the watershed is about 616.70 mm and about 90 per cent of which is experienced during the rainy season through Arabian Sea monsoon winds.

2.4 Geology

Udaipur district is part of the peninsular region of India and thus possesses peninsular characteristics logically, it consists of rock groups of the Archean system. The main rock formation of the area under study is dolomitic, marble, gneiss, mica, schist and quartzite. Dharta watershed has hardrock aquifers and these aquifers are well known for their low porosity and low connectivity and how the movement of groundwater occurs mostly through faults, fissures and fractures. Similar to other hardrock regions, both confined and unconfined aquifers are present in this region.

2.5 Groundwater Recharge

The methodology used for groundwater recharge is water budget method and water table fluctuation method. The water budget method for recharge of ground water is given by the continuity equation which is expressed as,
Inflow = outflow + change in storage

Schicht and Walton (1961) used this approach to estimate the groundwater recharge, using this equation they derived an expression

$$R + Q_{on} = A_p \times ET + PG \pm Q_{off} + Q_{bf} + \Delta S \quad \dots(1)$$

Where, R = Total ground water recharge.

Q_{on} , = Ground water flows onto the basin.

A_p = Area of different grown crops in the study area

ET = Evapotranspiration.

PG = Ground water draft

Q_{off} = Ground water flows off the basin.

Q_{bf} = Base flow.

ΔS = Change in ground water storage.

$$S = \Delta h \times S_y \times A \quad \dots(2)$$

Combining equation (1) and (2),

We get,

$$R + Q_{on} = A_p \times ET + PG + Q_{off} + Q_{bf} + \Delta h \times S_y \times A$$

Due to unavailability of data on G.W. inflow and outflow into and out of the basin the values of Q_{on} and Q_{off} is taken to be equal as suggested by Patra (2011)

Considering the above assumptions the equation becomes,

$$R = A_p \times ET + PG + Q_{bf} + \Delta h \times S_y \times A \quad \dots(3)$$

Where,

Δh = Water table fluctuation.

S_y = Specific yield

A = It is the area of assessment.

Here, R is the ground water recharge due to the several components.

So, $R = R_{rf} + R_{gw} + R_{wc} + R_t + R_c$

Where, R_d = Recharge due to rainfall.

R_{gw} = Recharge due to irrigation return flow.



R_{wc} = Recharge due to water conservation structures.

R_t = Recharge due to ponds.

R_c = Recharge from canal system.

So, equation (3) can be written as;

$$R_{rf} + R_{gw} + R_{wc} + R_t + R_c = A_p \times ET + PG + Q_{bf} + \Delta h \times Sy \times A \quad \dots(4)$$

The wet season (from June to September) during which the water table rises due to rainfall is followed by the dry season (other than June to September) in which water table drops mainly due to the G.W pumping. Therefore, the hydrological year can be divided into two distinct seasons, each with a distinct water level rise or fall.

Applying equation (4) for wet season (Monsoon season).

$$R_{rf}^{wet} + R_{gw}^{wet} + R_{wc}^{wet} + R_t^{wet} + R_c^{wet} = A_p \times ET^{wet} \pm PG^{wet} + Q_{bf}^{wet} + \Delta h \times Sy \times A$$

$$S_y = R_{rf}^{wet} + R_{gw}^{wet} + R_{wc}^{wet} + R_t^{wet} + R_c^{wet} - A_p \times ET^{wet} - PG^{wet} - Q_{bf}^{wet} \quad \dots(5)$$

$$\Delta h \times A$$

The value of specific yield for monsoon and non-monsoon season is same as recommended by GEC-97. Hence the specific yield calculated for the monsoon season can be used for non-monsoon season also.

The hydrological recharge is given by

$$R = A_p \times (ET^{dry} + ET^{wet}) + PG^{dry} + PG^{wet} + Q_{bf}^{wet} + Q_{bf}^{dry} + \Delta h \cdot S_y \cdot A \quad \dots(6)$$

III. RESULTS AND DISCUSSION

3.1 Water table fluctuation

Water table behaviour was studied for 50 wells of village of Dharta watershed. The average total depth of selected 50 wells in Dharta village is 25 m. The average water table fluctuation from 2013 to 2022 varies from 2.6 m to 17.4 m. The minimum water table fluctuation is found -4.8 m in year 2015 with depth of well is 24.6 m and maximum water table fluctuation is found 27.0 m in year 2016 with depth of well is 30m.

3.2 Rainfall recharge in monsoon season (R_{rf}^{wet})

R_{rf}^{wet} is the ground water recharge in monsoon season from rainfall. It is calculated by rainfall infiltration method or from rainfall infiltration factor which is given as.

$$R_{rf}^{wet} = f \times A \times \text{normal rainfall in monsoon season.} \quad \dots(7)$$

Where, f is rainfall infiltration factor (For Weathered granite, gneiss and schist with clay content it is varied from 0.1 to 0.12 GEC-1997) and A is the area of computation of recharge. The normal monsoon rainfall (July to october) of were calculated from the monthly rainfall data, which is 738 mm.

Thus Rainfall recharge in monsoon season is 558.37 ha-m.

3.3 Computation of ground water draft for monsoon season (PG^{wet})

The ground water draft for monsoon season is the amount of water pumped from the ground to provide proper irrigation to the crops grown in the study area. Depending upon the number of irrigations and the depth of water requirement, the ground water draft is calculated as the product So, the volume of water (PG^{wet}) required by major kharif crops (maize, cotton, sorghum, Groundnut, soyabean) grown in study area .

$$= \Sigma(\text{cropping area} \times \text{depth of irrigation}). \quad \dots(8)$$

Table 1 Ground water draft of field crop

S.N	Crops	Cropping area (ha)	No. of irrigation required	Depth of water Applied(mm)	Ground water draft PG^{wet} (ha m)
1.	Maize	2346 ha	4-5	20	46.92
2.	Cotton	109 ha	4-7	60	6.54
3.	sorghum	609 ha	4-5	40	24.36
4.	Grouddnut	249ha	2-3	40	9.96
5.	soyabean	148ha	3-4	60	8.88

So, Total PG_{draft} for Monsoon Season = 87.66 ha-m



3.4 Computation of annual ground water draft

The total annual ground water draft of Bhinder block is 2855.1 ha-m, which was computed by multiplying the unit draft with different types of ground water extraction structures (Dug wells, Shallow tube wells and Deep tube wells) and groundwater draft of dharta from Kharif crop is 87.66 ha-m.

3.5 Recharge from ponds (R_t)

It is obtained by multiplying the pond area with recharge factor 1.4 mm/day for the period in which the tank has water, based on the average area of water spread. It is observed that groundwater recharge in monsoon season obtained by equation 8 of material and method is 9.275 ha-m more than non monsoon season. Recharge from tank is maximum in monsoon season of 2022 because of highest rainfall of 738 mm and rainwater remains for more time increasing groundwater recharge compared to non monsoon season. and minimum recharge from tank occurs in year 2013 because of lowest monsoonal rainfall of 333.25 mm.

Table 2 Recharge from pond

S.N	Area	Pond area	Recharge from ponds(R _t)	
			Non-monsoon	Monsoon
1.	Dharta	53 ha	8.904 ha-m	18.179 ha-m

3.6 Recharge from ground water irrigation (R_{gw^{wet}})

Recharge from return flow from ground water irrigation (R_{gw}) of Bhinder block is 856.53 ha-m, which is the 30% of the ground water draft during monsoon season as per the norms of GEC-97.
 $R_{gw}^{wet} = 30\% \text{ of } PG_{wet}$

3.7 Evapotranspiration and crop water need.

Evapotranspiration is also known as crop water need. It is defined as the depth (or amount) of water needed to meet the water loss through evapotranspiration. In other words, it is the amount of water needed by the various crops to grow optimally.

ET will be calculated as suggested by Blaney-Criddle Method by using equation

$$ET_0 = p (0.46 T_{mean} + 8) \dots(9)$$

ET₀ = Reference crop evapotranspiration (mm/month) as an average for a period of one month

T_{mean} = Mean daily temperature

And $ET = k \times ET_0$

Where, K=crop coefficient

ET₀=reference ET

ET=crop evapotranspiration

Table 3 Evapotranspiration of field crops

S.N	Crop	Area(ha)	Kc	ET ₀ (Average)	ET
1.	Wheat	802.6	0.65	5.829376	3.7890944
2.	Gram	55	0.70	5.179674	3.625772
3.	Maize	2346	0.55	3.59592	1.977756
4.	Barley	57.87	0.25	5.380962	1.3452405
5.	Groundnut	249	0.60	4.167678	2.500606

Crop water need

The crop water needed by field crops in its period is being calculated by multiplying evapotranspiration (ET) to its sown area. The ET, the sown area and the crop water need is listed in the following tables. Thus crop water need is highest in maize crops and lowest in barley crops

$$\text{Crop water need} = \text{Area of crop} \times \text{Evapotranspiration} \quad \dots(10)$$

Table 4 Total crop water need of various field crop

S.N	Crop	Area(ha)	ET (mm)	Crop water need(ha-m)
1.	Wheat	802.6	3.7890944	2.96
2.	Gram	55	3.625772	0.199
3.	Maize	2346	1.977756	4.45
4.	Barley	57.87	1.3452405	0.07
5.	Groundnut	249	2.500606	0.62

IV. SUMMARY AND CONCLUSIONS**Based on the analysis of data following conclusions can be drawn**

- The average water table fluctuation from 2013 to 2022 varies from 2.6 m to 17.4 m. The minimum water table fluctuation is found -4.8 m in year 2015 with depth of well is 24.6 m and maximum water table fluctuation is found 27.0 m in year 2016 with depth of well is 30m.
- Recharge from rainfall in monsoon season for Dharta watershed in the year 2021 and 2022 is 558.37 ha-m and 410.83 ha-m respectively.
- Ground water draft in monsoon season for Dharta watershed is 87.66 ha-m.
- The total annual ground water draft of Bhinder block is 2855.1 ha-m, which was computed by multiplying the unit draft with different types of ground water extraction structures (Dug wells, Shallow tube wells and Deep tube wells).
- Total recharge from ponds in monsoon and non monsoon season is 18.179 ha-m and 8.904 ha-m
- Recharge from return flow from ground water irrigation of Bhinder block is 856.53 ha-m.
- The calculated value of specific yield for Dharta watershed is 0.03104.
- Total annual ground water recharge 1871.42 ha-m.
- The net annual ground water availability of bhinder block is 3088.4 ha- m
- Of the total study area, about 20 per cent is found with good groundwater potential, 31 per cent with moderate and 40.1 per cent with very poor groundwater potential.
- Ground water development (%) is 92.44% these values are Between 90% and 100%. Hence, Bhinder blocks critical category.
- The energy requirement for exploitation of the ground water has been estimated to be about 1.62×10^6 KWh.



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