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Geomorphic Characteristics of WRC-1 Watershed, Chargarh River Basin, Central India: Possible Implications on Hydrogeological Status

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Abstract

Every geomorphic feature has its own distinct impact on the static groundwater level (SWL), seasonal water table fluctuation (WTF) and yield of the wells. The aim of this study was to analyze the role of geomorphic features over the groundwater regime and its possible implications on hydrogeological status within WRC-1 watershed. The watershed is covered by the Deccan basalt lavaflows and Quaternary alluvium. The geomorphic units of study area are HDP, MDP, residual hill, valley fills, scarp, pediment, pediplain, butte, alluvial plain and gullied land to identify the relationship between geomorphic units and corresponding hydrogeological status. The pre-monsoon SWL, WTF and yield of the open-dug wells are analyzed. The high groundwater level fluctuation is indicated by residual hill, plateau remnant, HDP, MDP, pediment as compared to pond, river, younger alluvial plain and pediplain. Pre-monsoon yield of dugwells in river older alluvium are comparatively high; butte, residual hill, pond, river, dam/reservoir and valley fill which are comparatively moderate to low. The overall findings indicate that seasonal WLF in the hard rock terrain(basalt) is high compared to soft rock formation(alluvium). The best suitable area identified is Pediplain which is categorized as very good groundwater prospectus zone with pre-monsoon SWL (5.8 mbgl), WTF (3.1 m) and yield of the well (108000 L/day) respectively.

Keywords: Chargarh river basin; Geomorphology; Hydrogeology; Remote sensing; GIS.

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1. Introduction

Groundwater is one of the most precious natural resources of our planet and plays a vital role in every facet of human life [1]. It is a dynamic system influenced by combinations and interactions of various factors such as geological characters which includes depth of weathering, the extent of fractures and secondary porosity in the rock and also surface topography [2]. Groundwater is a precious natural resource, stored in the strata below the earth's surface in the critical zone of the asthenosphere [3,4]. It plays a crucial role in the hydrological cycle, biodiversity and ecosystem [4]. The landforms are distinctive land

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surface configurations created by natural processes such as erosion, denudation and deposition [5]. Hydrogeomorphology is an interdisciplinary discipline that studies the relationship between hydrologic processes and earth materials as well as the interaction of geomorphic processes that influence the flow regime of surface water and groundwater [6-12]. Groundwater potential zones can be determined by combining geological, hydrological and geomorphological data. Geomorphology has revealed a close relationship between surface and underground water. With the use of remote sensing and GIS technologies, geospatial parameters such as land use/land cover, hydro-geomorphology, slope morphometry, digital elevation model and groundwater level maps played a vital role in demarcating groundwater potential zones map and artificial recharge structures [13,14]. The hydro-geomorphological properties of the watershed are a combination of hydrological, geomorphological and geological attributes [15-19].

Remote sensing (RS) and Geographical Information System techniques (GIS) systems are effective tools to elucidate, apprising and imparting the hydro-geomorphological analysis of the basins [20-24]. The hydrogeomorphology is the study of landforms caused by action of water. Different geomorphological units of the research area have been retrieved from the satellite data because hydrogeomorphological units have a direct impact on the groundwater condition of any region [25,26]. Remote sensing and GIS technology may be effectively used in a basaltic hard rock terrain and undulating topography for groundwater research [27]. Badhe *et al*. [28] proposed an easy and systematic procedure, in which areas with potential for groundwater can be successfully identified. Therefore, this method can be applied wherever in the world where there are hard rock aquifers. The lithological control over the pre-monsoon and post-monsoon SWLs and seasonal water table fluctuates within the watershed [29]. This study was conducted to analyze the variation of the hydro-geomorphological environment along Baekgok wetland, which is experiencing periodic inundation, in that water-level fluctuation of reservoir caused by irrigation [30]. Conclusions investigating the spatial and temporal dynamic behavior of the groundwater level fluctuations in mountainous areas can assist in obtaining effective strategies for development and management of groundwater resources [31]. This study used long-term groundwater level monitoring data in the mountainous area of Taiwan to analyze GWLF potentials during the wet and dry seasons and developed a technique for mapping the spatial distribution of GWLF potential [31].

The aim of this study was to analyze the role of geomorphic features over the groundwater regime and its possible implications on hydrogeological status within WRC-1 watershed, that is, to investigate the hydrological aspects with respect to different geomorphic landforms in the Chargarh river basin.

2. Study Area

The WRC-1 watershed of the Chargarh river basin is covered by the Survey of India toposheets 55G/15, 55G/16, 55K/3, and 55K/4 and bounded by 77°45' to 78°05' E longitude and 21°0' to 21° 25' N latitudes, covering approximately 412.51 Sq.km area of

Amravati district, Maharashtra State, India (Fig.1). The Chargarh river originates in Satpura mountain and flows in the North-West to South-East direction. The river flows through Ghatladki, Khed and Udkhed areas, with general South to East trend, which is parallel to the water divide and joins the Wardha river near Bhambora village of Morshi tahsil, Amravati district, Maharashtra.

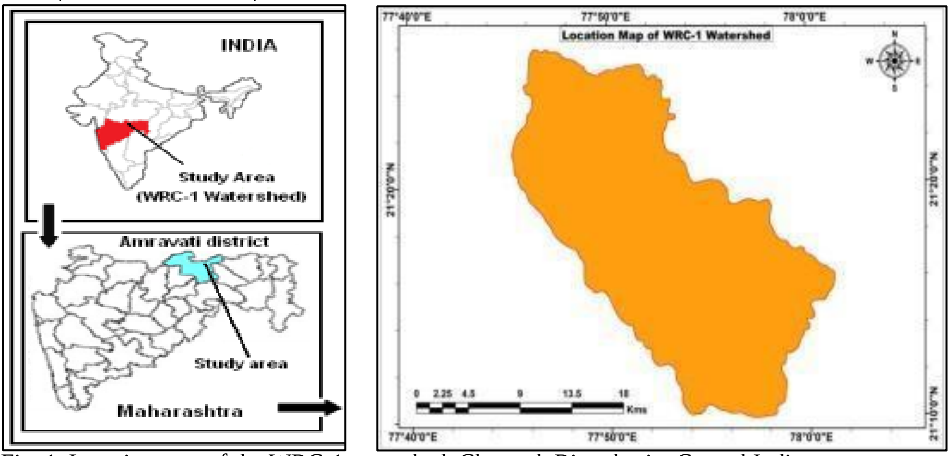

Fig. 1. Location map of the WRC-1 watershed, Chargarh River basin, Central India.

2. Methodology

The entire study area is delineated and mosaiced on Survey of India topographic maps 55G/15, 55G/16, 55K/3, and 55K/4 of 1:50,000 scale, with the help of Arc-GIS software and by utilizing UTM, WGS 1984, 43˚N projection system. The IRS-1D-LISS-III data analysis reveals distinct geomorphological landforms in the area, which are observed on the basis of remotely sensed data through Digital Elevation Model (DEM) in Arc-Map 10.2 software. To recognize major changes in the drainage pattern, IRS-Resourcesat-2, LISS III (Tile No. F43R15, F43R16, F43M03 and F44M04) 24 m, resolution which was captured on 3 Nov. 2017 false color composite (FCC) Satellite imageries were utilized. The data was gathered using satellite imagery. The visual interpretation keys established by Lillesand and Kiefer [32] are used to retrieve information from satellite images. Other important aspects like size, shape, tone, pattern, texture, shadow, association and photo-interpretation keys are used to prepare geomorphic, structural and lineament maps from combined satellite data. The Digital Elevation Model (DEM) was created using data from the Shuttle Radar Topographic Mission (SRTM), Global Elevation Model Version-2 (GDEM-V2), with a resolution of 30 meters.

2.1. *Geology*

The basaltic lava flows exposed in the basin area belong to the Sahyadri Group of the deccan trap formation, which is stratigraphically categorized as Chikhli, Karanja and Ritpur formations [33]. The six non-porphyritic to moderately porphyritic lava flows are exposed in the area designated as Chikhli formation. The lava flows range in thickness from 45 to 130 meters. The Karanja Formation has 8 to 14 non-porphyritic to strongly porphyritic 'Aa' flows. The Rithpur Formation consists of 7 'Aa' lava flows of non-porphyritic nature with thickness ranges from 55 to 117 meters [33]. The Deccan basalt exposed in the central and northern parts of the watershed belongs to the Upper Cretaceous to Lower Eocene age, whereas Quaternary alluvium belongs to the Cainozoic age [33]. The vesicular, amygdaloidal, compact, massive nature of basalt as well as distinct structural elements, distinguish the individual lava flow. The WRC-1 watershed is covered by the deccan basalt lava flows and Quaternary alluvium.

3. Result and Discussion

3.1. *Geomorphology*

The geomorphological aspects include delineating distinct units from satellite data and classifying them according to their origin, extent and processes [34]. The satellite remote sensing techniques are useful for groundwater exploration, especially for delineating hydro-geomorphic units [35-37]. Most of the features are well represented on the high-resolution satellite data, which provides reliable information to generate geomorphological maps in conjunction with slope and drainage parameters. The analysis of IRS-1D-LISS-III data of the WRC-1 watershed reveals distinct geomorphological units, which can be divided into denudational and depositional landforms based on their origin and genesis (Fig. 2). The denudational landforms are identified in conjunction with relief and drainage parameters. Abrupt vertical cliffs and low-lying plains made up of horizontal basalts run northward, with numerous scraps observed on the southern edge of the area. The geomorphic study reveals that erosional landforms predominate over depositional landforms.

The remote sensing data interpretation of the WRC-1 watershed indicates different geomorphic units, which are highly dissected plateau, moderately dissected plateau, residual hill, valley fill, scarp, pediment, pediplain, butte, alluvial plain, gullied land, valley fills and water bodies (Fig. 3). The drainage pattern of the area is dendritic over the Deccan basalt and parallel to sub-parallel over the alluvium. Alluvial plains are formed due to the deposition of fine sediments consisting of sand, silts, mud, clays, etc., in the flood zone of the river. These valley-fill deposits are sand, silts, clay and rock fragments. This unit represents very good groundwater potential, which is reflected in high yield and low water table fluctuation at 54000 liter/day and 6.5 meters respectively (Fig. 4e and 5).

2.2. *Dynamics of the unconfined aquifer*

The geomorphologic units directly control groundwater occurrence in any area [25,26]. The hydrogeological conditions in the Deccan traps mainly depend on the permeability and porosity of the groundwater reservoirs, which further depend on the joints, fractures, flow contacts and depth of weathering. Although the vesicles of the flows are porous but generally not permeable due to a lack of interconnectivity [36,38]. Secondary, amygdaloidal, glassy stuff, and other substances are commonly seen in the vesicles [38].

The red bole layer, flow breccia with secondary mineral growth and huge portions of the flow with non-interconnected joints are all resistant to water [39]. The secondary porosity (joints and cracks) decreases with depth in the unconfined aquifer system [21,40]. In fresh condition, the upper portion of this flow is primarily vesicular, un-jointed and water tight [38,41]. The joints run through many basalt flows and serve as recharge channels for deeper Deccan basaltic aquifers [41,42]. The original gas cavities are filled with secondary minerals in the Pahoehoe-type flow, obliterating the original vesicular character [39].

The older alluvium is mostly clayey with only one or two thin beds of gravel at the base near the Trap basement [42]. Younger alluvium is lacustrine and older alluvium is marine [43]. The basement of the alluvium is basalt at different depths, which may be due to pre-trappean topography or due to faults with upthrown and downthrown blocks [43]. Predominant slope of the Trap basement is towards the North [43]. The alluvial aquifer in the basin is an unconfined aquifer, which indicates a partly filled aquifer, where the upper water surface is at atmospheric pressure and the groundwater is free to rise and decline [44,45]. The water levels in unconfined aquifers are commonly controlled by topography [43]. In the alluvial zone, static water levels are comparatively deeper, which is 12.19 to 17.5 meters (bgl) (Fig. 6a). Similarly, water table fluctuation ranges between 1.8 to 3.1 meter and yield ranges between 72000 to 108000 L/day (Table 1, Fig. 6b). It shows that the seasonal water level fluctuations in the hard rock terrain (basalt) are high compared to soft rock formation (Alluvium). The high weightage is assigned to valley fill, water bodies and the younger and older plain of fluvial origin, which is reflected in the high average yield of the dug wells, especially in the good and very good groundwater potential zones as 103500 L/day and 81900 L/day respectively (Table 2, Fig. 4d and 4e). The low weightage is assigned to butte, residual hill, plateau remnant, HDP, and MDP, which is reflected in the low average yield of the dug wells, especially in the poor groundwater potential zones as 36,000 L/day (Table 2, Fig. 4a).

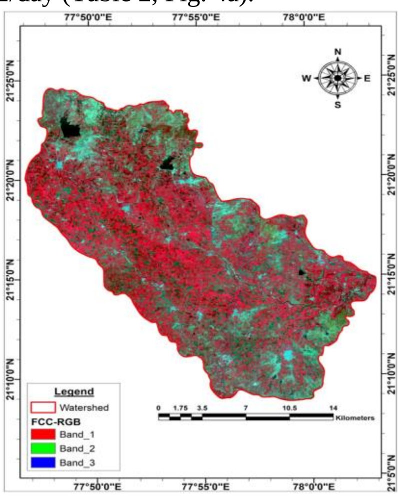

Fig. 2. IRS LISS- III false color composite satellite imagery of WRC-1 watershed.

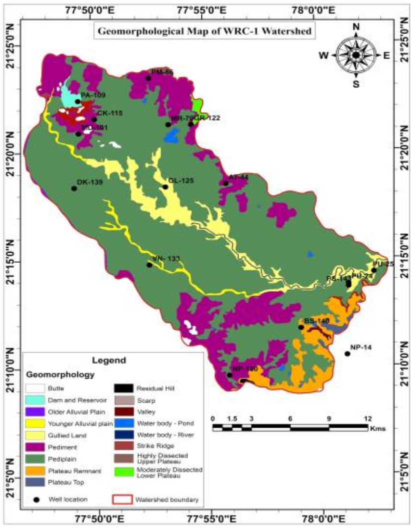

Fig. 3. Geomorphological map of WRC- 1 watershed with dug wells in the different geomorphic units.

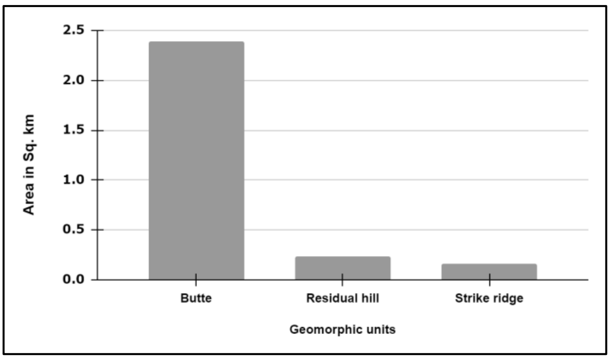

Fig. 4(a). Area of poor groundwater prospectus in WRC-1 watershed.

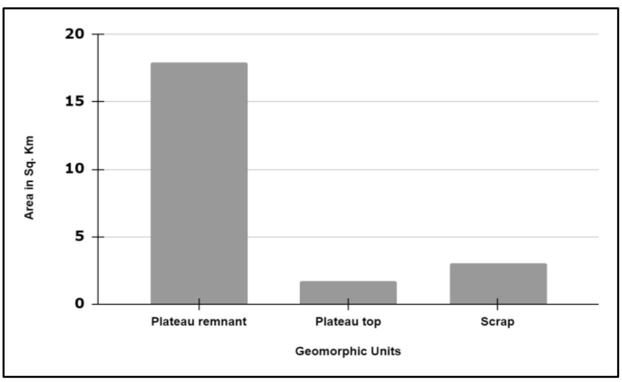

Fig. 4(b). Area of poor to moderate groundwater prospectus in WRC-1 watershed.

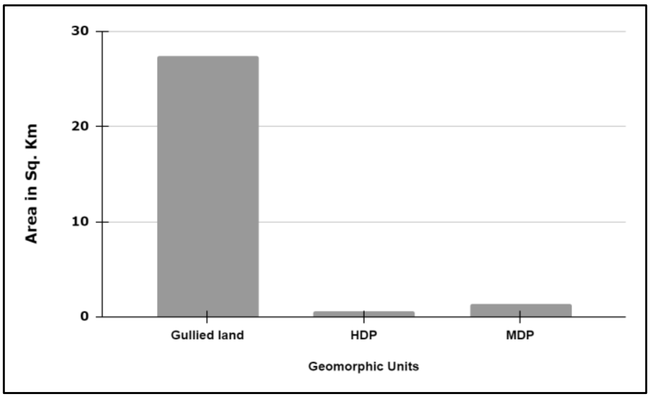

Fig. 4(c). Area of moderate to good groundwater prospectus in WRC-1 watershed.

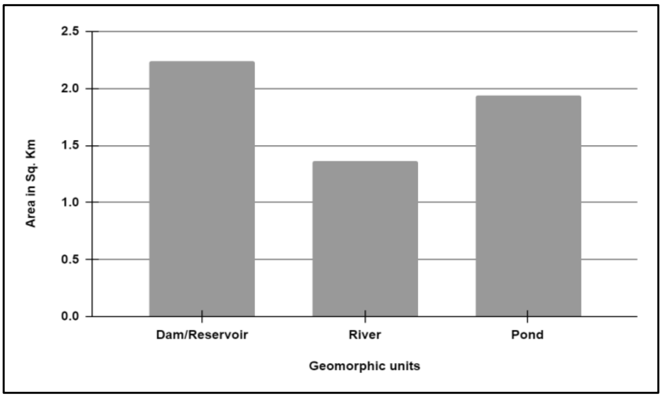

Fig. 4(d). Area of good groundwater prospectus in WRC-1 watershed.

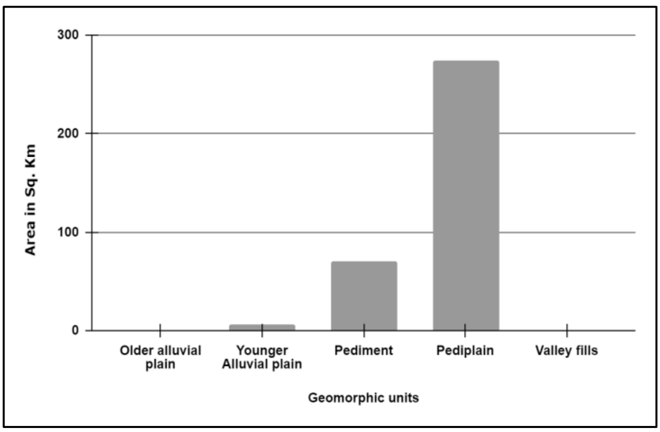

Fig. 4(e). Area of very good groundwater prospects in WRC-1 watershed.

The static water level in the pre-monsoon season (2021) ranges between 4.12 mbgl to 22.56 mbgl (Table 1). The seasonal water level fluctuations in the Chargarh river basin range is between 1.8 to 10.66 mbgl. The pre-monsoon yield of the dug wells ranges between 36000 L/day to 225000 L/day (Table 1). The Groundwater potential zone of the WRC-1 watershed is divided into five zones: poor, poor to moderate, moderate to good, good and very good. The area of moderate to good groundwater potential covers an area of 29.42 sq.km (Fig. 4c), and very good groundwater potential covers 351.96 sq.km area of the basin (Fig. 4e). The pre-monsoon static water level, water table fluctuation, and yield of the open dug wells are analyzed with respect to different geomorphic units and five groundwater potential zones (GWPZ). The low groundwater level fluctuation is represented by pond, river, younger alluvial plain and peneplain as zero (equilibrium stage), 2.13 meters, 1.8 meters and 3.1 respectively (Fig. 6b). Similarly, high groundwater level fluctuation is indicated by residual hill, plateau remnant, highly dissected plateau, moderately dissected plateau as 9.95 meter, 6.1 meter, 5.8 meter and 4 meter respectively (Fig. 6b). On the other hand the static water levels of dam/reservoir, pond and the river are lower viz. 4.12, 4.4 and 7.32 meter (bgl) respectively as compare to SWL of valley fills, pediment, younger alluvial plain, HDP and Gullied land which are 14, 22.56, 17.5, 8.84 and 15.1 meter (bgl) (Fig. 6a). Pre-monsoon yield of the dug wells in river and older alluvium are comparatively high as 225000 liter/day and 108000 liter/day respectively (Fig. 5 and 6c). On the other hand, butte, residual hill, pond, river, dam/reservoir and valley fill has 36000 liter/day, 36000 liter/day, 67500 liter/day yield respectively, which is comparatively low (Table 2). The best suitable area for groundwater occurrence identified from the watershed is in Pediplain, which is approximately 274.42 sq.km (66.53%) area (Tables 1 and 2). This area is categorised as a very good groundwater prospectus zone with pre-monsoon SWL (5.8 mbgl), WTF (3.1 m) and yield of the well (108000 L/day), respectively (Table 1).

Fig. 5. Variation of average yield of the wells (Litre/day) with respect to Geomorphic units.

Table 1. Pre-monsoon static water level, water table fluctuation and yield of the open wells with respect to different geomorphic units and groundwater potential zones in the WRC-1 watershed.

Sr. No.	GWPZ	Area in Sq. Km	Total	Category/ Class	Well ID	Pre monsoon water level (mbgl)	Water level fluctuations (meter)	Yield of the well L/day)	Lithology
1.	Poor	2.39	2.62	Butte	SW-81	8.85	4.8	36000	LS+WB+SW+MB
2.		0.23		Residual hill	NP-150	12.08	9.95	36000	WMB+SW+AVB+CMB
3.	Poor to moderate	17.89	20.92	Plateau remnant	PU-24	14.49	6.1	112500	LS+VB+CMB
4.		3.03		Scrap	-	-	-	-	-
5.	Moderate to Good	27.42	29.42	Gullied land	GL-125	15.1	3.8	36450	LS+WB+MB
6.		0.65		HDP	PM-86	8.84	5.8	67500	WB+AB+MB
7.		1.35		MDP	GR-122	16.4	4	37125	LS+WB+CB+MB
8.	Good	1.94	5.54	Pond	MR-79	4.4	0	67500	WB+FJMB+MB
9.		1.36		River	PU-25	7.32	2.13	225000	LS+AVB+MB
10.		2.24		Dam/ Reservoir	PA-109	4.12	8.07	18000	LS+RB+SW+CB+MB
11.	Very Good	0.61	351.96	Older alluvial plain	MD-101	12.19	10.66	108000	LS+VB+MB
12.		5.99		Younger Alluvial plain	VN- 133	17.5	1.8	72000	S+LT+LS
13.		70.48		Pediment	LH-19	22.56	7.92	67500	WR+VB+CB
14.		274.42		Pediplain	DK-139	5.8	3.1	108000	LS
15.		0 54		Valley fills	NP-14	14	6.5	54000	FMB+JMB

WB: Weathered basalt
MB: Massive basalt
VB: Vesicular basalt
AVB:Amygdaloidal /Vesicular basalt
RB: Red bole
FMB: Fractured massive basalt
CMB: Compact massive basalt
JMB: Jointed massive basalt
LS: Loose Soil- Unconsolidated sediments WMB:Weathered massive basalt
SW: Spheroidal weathering
FJMB: Fractured and Jointed massive basalt
S: Soil
LT: Laterite
AB: Amygdaloidal basalt etc.

Table 2. Pre-monsoon static water level, water table fluctuation and yield of the open wells with respect to groundwater potential zones in the WRC-1 watershed.

Sl. No.	Groundwater Potential Zone (GWPZ)	Poor	Poor to Moderate	Moderate to Good	Good	Very Good
1	Area in Sq.Km.	2.78	22.65	29.42	5.54	351.96
2	Avg. SWL (mbgl)	10.46	14.49	13.44	5.28	14.41
3	Avg. WTF (meters)	7.37	6.1	4.53	5.1	5.9
4	Avg. Yield (L/day)	36000	112500	47025	103500	81900

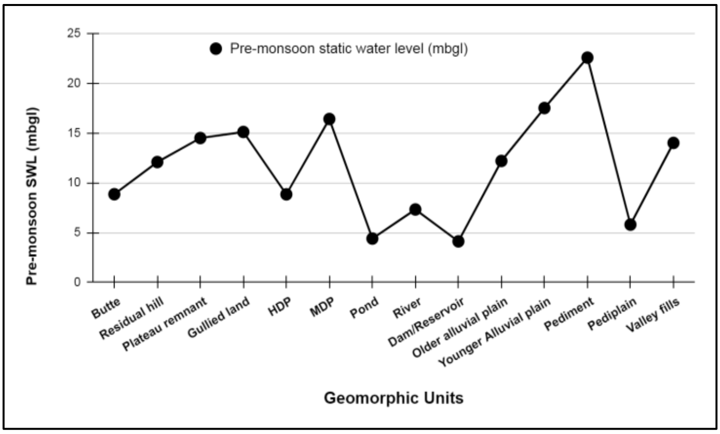

Fig. 6(a). Variations in the SWL with respect to geomorphic units.

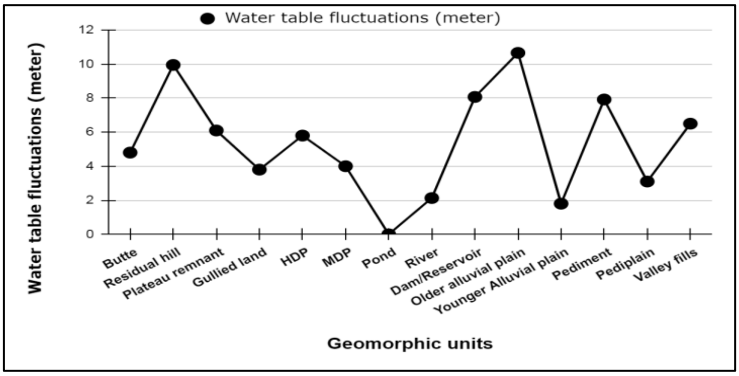

Fig. 6(b). Variations in the WTF with respect to geomorphic units.

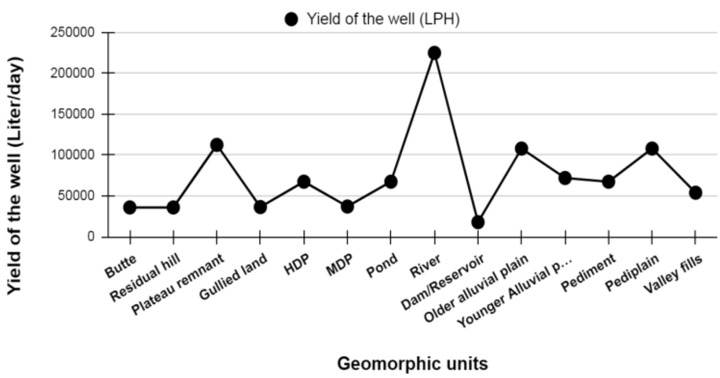

Fig. 6(c) Variations in the yield with respect to geomorphic units.

3. Conclusion

The hydrogeological response of any area is highly influenced by the geomorphic landforms. The findings demonstrate that the area has denudational, structural and alluvial landforms which have distinct hydrogeological characteristics with respect to geomorphology. Detailed hydrogeomorphic study can lead to better understanding of the long-term recharge and development of water resources, especially within overexploited areas. The pre-monsoon static water level, water table fluctuation and yield of the open-dug wells are analyzed with respect to different geomorphic units and five groundwater potential zones (GWPZ). The area of moderate to good groundwater potential covers an area of 29.42 sq.km. and very good groundwater potential covers 351.96 sq.km of the basin. The low groundwater level fluctuation is represented by pond, river, younger alluvial plain and peneplain as zero (equilibrium stage), 2.13 meter, 1.8 meter and 3.1 meter respectively. Similarly, high groundwater level fluctuation is indicated by residual hill, plateau remnant, highly dissected plateau and moderately dissected plateau as 9.95 meter, 6.1 meter, 5.8 meter and 4 meter respectively. On the other hand, the static water levels of dam/reservoir, pond and river are lower as compared to SWL of valley fills, pediment, younger alluvial plain, HDP and Gullied land respectively. Pre-monsoon yield of the dug wells in river and older alluvium are comparatively high as butte, residual hill, pond, river, dam/reservoir and valley fill, which is comparatively low. The overall findings indicate that seasonal water level fluctuations in the hard rock terrain (basalt) are high compared to soft rock formation (alluvium). The best suitable areas for groundwater occurrence identified from the watershed are Pediplain which is approximately 274.42 sq.km (66.53 %) area which is categorised as a good groundwater prospectus zone with pre-monsoon SWL (5.8 m bgl), WTF (3.1 m) and yield of the well (108000 L/day) respectively.

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