The Kulhan nala (the longest tributary of the Kharun river) basin, in Raipur district of Madhya Pradesh, lies between north latitudes 21°02' and 21°34' and east longitudes 81°38' and 81°54' and spreads in an area of 992.09 Sq.Km. The study area falls in the Survey of India toposheet numbers 64G/10, 11,12,14, 15 and 16 (Scale 1: 50,000) and includes parts of Arang, Abhanpur, Dharsiwa and Tilda blocks of Raipur district. The entire western margin of the basin is bounded by Mandhar Branch Canal while the southeastern and northeastern portions are delimited by Mahanadi Main Canal and Jamunia Nadi basin respectively.

The study area experiences a tropical climate. It exhibits low relief and a gently undulating topography with general slope due northwest. The maximum and minimum elevations are 320m and 255m above the mean sea level respectively. The terrain supports scanty vegetation.

Geologically, the study area forms a part of the Chhattisgarh basin, consisting of lower Gunderdehi shale Formation and younger Chandi limestone Formation (Raipur Group) belonging to the Chhattisgarh Supergroup of Upper to Middle Proterozoic age. The southern part of the study area is occupied by Gunderdehi shale. It is purple in colour, finely laminated, compact, medium to fine grained, calcareous, impermeable in nature and weathers easily into
thin splinters. Towards the southeastern margin of the basin, intercalations of arenaceous bands in shale, appear as an arcuate outcrop. The sandstone is purple to maroon coloured, coarse grained and ferruginous in nature.

Chandi limestone Formation, comprises two members viz., Pendri and Nipania having gradational contact. This formation exhibits prolific growth of stromatolites. The central part of the basin consists of fine grained grey limestone designated as Pendri member, showing effects of dolomitisation. Pendri member grades into overlying Nipania member which comprises of coarse to medium grained stromatolitic purple limestone. Both members exhibit stylolites and secondary chemogenic structures which include grikes, clints, swallow holes and calcite veins etc.

Laterite occurs as small cappings over the sandstone, shale and limestones while the alluvium is restricted to the stream courses only. The cultivated areas consist of grey loamy soil of about a meter thickness.

Drainage characteristics of the Kulhan nala basin reveals that the basin trends N-S, tapering due south while wider in the northern side and possess a zig-zag periphery. The basin has been divided into two sub basins, mainly on the basis of lithology, viz. Sub-basin 'A': comprising Gunderdehi shale and Sub-basin 'B': consisting of Chandi
limestone. The presence of dendritic to sub dendritic drainage pattern in sub basin 'A' indicates a nearly horizontal strata with uniform lithology, while the parallel type of drainage pattern in sub basin 'B' manifests that it is structurally controlled. The flow directions of the stream are sympathetic with the principal joint trends.

The Kulhan nala and its tributaries follow Horton's first and second laws of stream number and stream length respectively. The basin shape parameters viz. form factor, circularity ratio, elongation ratio and lemniscate ratio combinely confirm that the basin is elongated. The drainage basin possesses coarse drainage density with three distinct slope categories viz. 0-2°, 2°-5° and over 5° for sedimentary pediplain (761.93 Sq.Km.), lateritic upland (223.32 Sq.Km.) and dissected lateritic upland (7.74 Sq.Km.) respectively.

Three major geomorphic units viz. valley fills, sedimentary pedipain and lateritic uplands have been identified with the help of remote sensing techniques. Valley fill sediments comprise pebble, gravel, sand and silt deposits. Pediplain, marked by low relief and dark tone in the images, is confined to southern and northern parts of the basin while isolated patches of grey, green colour in images are restricted to the southern, central and northern parts of the study area. Field checks confirm them as laterite, occurring as flat, elevated ground over the shale and limestones.
The hydrometeorological parameters reveal that usually May and June are the hottest months, July and August being the wettest, while December and January are the coldest months of the year. The monthly average maximum temperature in the investigated basin varies from 27.17°C in December to 42.08°C in May, whereas the average minimum temperature ranges from 10.35°C in December to 25.46°C in May. The average annual rainfall, analysed for 35 years at Raipur station (IGKVV) is 1200mm, which indicates that the rainfall is very effective in contributing to the groundwater bodies. The average relative humidity percent ranges from 46.5 (May) to 93.0 (August). The wind velocity is the lowest (1.9Km/hr) during December and the highest (12.5 Km/hr) during June. The maximum evaporation losses ranging from 2.8mm (December) to 12.63mm (May) contribute significant groundwater losses during discharge.

The important hydrolithounits of the study area are laterites, limestones, shales and sandstones. The limestone, represents as a good aquifer in general, whereas the calcareous shale at places acts as a good aquifer. The groundwater occurs under both confined and unconfined conditions. On the basis of pre and post-monsoon well inventory data of 153 dug wells, covering the entire basin, the corresponding groundwater level maps reveal that the movement of groundwater is towards the Kulhan nala. The presence of groundwater mounds and troughs in the area denotes recharge and discharge zones. The water table
contour pattern also shows that the Kulhan nala has influent as well as effluent pockets. The high degree of fluctuation in the water table during pre and post-monsoon periods indicates the presence of less pervious water bearing formations in the area. The study of watertable and topography relationship reveals that the watertable is a subdued replica of the topography.

The groundwater exploration in the study area has been carried out by using three methods viz. i) geological ii) geophysical (electrical resistivity sounding), and iii) remote sensing. The geological study revealed that the weathered and fractured zones of limestone and calcareous shale are good aquifers whereas the compact shale is very poor water bearing formation. A total number of 29 electrical resistivity soundings, spread over the entire basin, indicate that three layers are present in the area, namely top soil/laterite, weathered zone in the middle, and limestone and shale at the bottom. The thickness of top soil/laterite layer ranges from 1.1 to 2.5m and 0.8 to 6.0m, for weathered zone from 2.2 to 12.0m and 0.72 to 35m and for the third layer (bed rock) beyond 13.2m and 36.4m in shale and limestone terrains respectively.

The satellite image interpretation has revealed that from the groundwater potential and prospect point of view, shallow buried pediplain are poor to moderate, whereas the valley fills and moderately buried pediplains are excellent and good respectively. The lateritic uplands are suitable for providing water for domestic needs only.
The pump test data for 8 borewells in limestone terrain indicate that the transmissivity values \((T)\) determined by Cooper-Jacob time-drawdown method for Pendri member is comparatively low (53 to 115 lpm/m) to that of the Nipania member (73 to 137 lpm/m) which might be attributed to widespread karstification in the latter. The storativity values \((S)\) obtained for both Pendri and Nipania members range from \(10^{-3}\) to \(10^{-5}\) exhibiting that the wells are under confined condition.

The low specific capacity values of dug wells in Gunderdehi shale, suggest that the shales are poor water bearing formation. The specific capacity for Nipania member is comparatively higher to that of the Pendri member which might be ascribed to high permeability, numerous joints and higher intensity of karstification in the former. It is also observed that the relation between specific capacities and respective cross-sectional area of dug wells has a direct relation revealing that an increase in cross-sectional area increases the specific capacities of wells. The yield of borewells shows no significant correlation either with lithology nor depth below ground level, however, the Gunderdehi shale has poor yields while the Chandi limestones have better yields at relatively shallow depths.

The chemical analysis of 50 groundwater and 02 surface water samples reveal that these do not exhibit any significant variation in water quality of both the regimes
of the investigated basin are most suitable for domestic and irrigation purposes and to a certain limit for industrial purposes as well. The concentration of major cation, anion and trace elements in groundwater and surface water are within the permissible range. The water, on the basis of hardness and total dissolved solids, has been classified as soft to average harshess and fresh water respectively. The Piper trilinear and modified Hill-Piper diagrams show that the water is of bicarbonate type and salinity lies below 7.5 epm indicating no sodium hazards for irrigation purpose. Following the drinking water standards recommended by WHO and ISI, it is found that the analytical results of both surface and subsurface waters of the study area are well within the permissible limits leading to their suitability for drinking and domestic purposes. Similarly Collin's ratio also shows that both surface and subsurface water are free from any contamination and thus perfectly suitable for drinking purposes. Eaton's Index and Kelly's ratio have also found to be within safe limits, confirming their suitability for irrigation purposes. The classifications based on SAR, Na% and EC have indicated that the water of the Kulhan basin belongs to excellent, excellent to good and good to permissible categories respectively for irrigation purposes. The water classification proposed by Wilcox, Doneen and U.S.D.A. also confirms that the groundwater is perfectly suitable for irrigation without any hazard to crops.
The blockwise groundwater potential of the study area has been estimated using the methodology recommended by G.E.C. The annual recharge and draft in the basin have been worked out to 213.79 MCM and 56.2 MCM respectively which offers 157.59 MCM for future utilisation. The stage of development, with reference to the year 1995, were determined for 2000 AD and 2025 AD. The study reveals that 125.08 MCM and 113.47 MCM are available as groundwater balance for 2000 AD and 2025 AD respectively. This signifies that the Kulhan nala is capable of supplying sufficient amount of groundwater for various purposes for another 30 years.

For the proper management of available water resources, possibilities of groundwater augmentation have been suggested by different methods of artificial groundwater recharging viz: construction of nala bunds, underground bandharas, contour bunds, contour trenches, percolation tanks, recharge basins, hook levees, village tanks, riverside trenches, afforestation and horticulture with reference to topographic and geological aspects of the site. It is concluded that artificial recharge will help in conservation and augmentation of groundwater resource to meet the growing agricultural, forestry, domestic and industrial requirements of the region.

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