ISSN (Online) 2456 -1304

International Journal of Science, Engineering and Management (IJSEM)

Volume 13, Issue 08, August 2026

Assessment of Groundwater Potential Zone of Khuldabad Subdivision using RS – GIS, AHP

[1] Snehal Korke, [2] Dr. Shubhada Koranne

[1] P.G. Student of Water Resources Engineering Department, Government and Engineering College, Chhatrapati Sambhajinagar, Maharashtra, India

[2] Assistant Professor & HOD of Civil Engineering Department, Government and Engineering College, Chhatrapati Sambhajinagar, Maharashtra, India

*Corresponding Author Email: [1] mt24f08f006@geca.ac.in, [2] headcivil@geca.ac.in

Abstract*— In semiarid areas with limited access to surface water, groundwater is an essential resource. Khuldabad region of Chhatrapati Sambhajinagar is situated on the Deccan Plateau and has surface water shortage due to basaltic geology, over extraction and unpredictable rainfall. This study applies RS-GIS together with AHP. This research identifies areas with the potential to contain groundwater. Various influencing parameters including topography (elevation), land gradient (slope), drainage characteristics, soil properties, geomorphological features, LULC and vegetation conditions (NDVI) were created to categorized different weights. Subsequently, weightage overlay based spatial evaluation method was perform for finding groundwater suitability zone, which were categorized as very high, high, moderate, poor and very poor. The most influencing elements according to the results are elevation (27%) and geomorphology (23%). Based on the results RS, GIS and AHP integration is a cost effective and efficient method for assessing groundwater and managing sustainably.

Index Terms: Khuldabad, Groundwater Potential, Thematic Layers, Remote Sensing, Weighted Overlay Analysis, GIS, AHP.

I. INTRODUCTION

A. General

Groundwater serves as vital source of water significantly contributes to improving living conditions and supporting societal and economic growth. It is important in meeting the demand of domestic water supply, supporting irrigation, enabling industrial activities, and maintaining ecological balance. In many regions across the globe, mainly in water scare and semi dry areas where access to surface water is limited and groundwater becomes primary and most dependable source of freshwater. Therefore, sustainable management of groundwater is essential for long term water security.

India supports nearly 17% of the global population, while having access to just about 4% of the freshwater available worldwide (Dhawan, 2017). This disparity between water supply and rising demand has created substantial pressure on current water resources. UN's WWD report 2022 states that India records highest extractor and consumer of groundwater worldwide, with an estimated annual withdrawal of approximately 230-251km3, accounting for nearly 25-26% of total global groundwater extraction. Over the past few decades, increasing anthropogenic pressure such as rapid urbanization, population growth, intensive agricultural practices, and climate variability results in continues reduction in groundwater availability along with degradation of water quality.

According to the 2019 report issued by the national groundwater authority under the ministry of water recourses, Khuldabad has experienced a declining groundwater level more than 0.2m/year.

To promote long-term groundwater management, regular assessment and monitoring of groundwater conditions are necessary, evaluate the influencing factors and implement appropriate management strategies to control excessive extraction and depletion.

Groundwater potential mapping is important for distinguish recharge zone, controlling over extraction and ensuring long term utilization. Traditional methods are often insufficient for handling multiple spatial variables, whereas GIS-based multi-criteria approaches provide a more accurate and comprehensive assessment.

B. Importance of RS- GIS and AHP

Geographic Information System (GIS) serves as an effective technique in hydrological studies by facilitating the for evaluation and integration of spatial dataset related to terrain characteristics, land utilization patterns, soil properties, and drainage patterns. It supports applications including watershed delineation, runoff estimation, flood risk assessment, and groundwater potential mapping. Groundwater Potential Zone (GWPZ) mapping identifies areas with varying groundwater availability by combining multiple thematic layers and is particularly important in hard rock regions where groundwater occurs in weathered and fractured zones.

Thomas L. Saaty introduced AHP in 1977. This is a MCDM technique applied for assigning weights to different influencing factors. Combining remote sensing and geospatial techniques with AHP enables systematic and data driven identification and management of groundwater potential zone.

ISSN (Online) 2456 -1304

International Journal of Science, Engineering and Management (IJSEM)

Volume 13, Issue 08, August 2026

C. Objectives

i. To generate different layers representing elevation, soil texture, geomorphology, slope, NDVI, LULC, and drainage density through GIS analysis methods.
ii. To delineate and analyse groundwater suitability areas or GWPZ within the Khuldabad Subdivision through the application of satellite driven data (RS) and GIS techniques.
iii. To determine the significance of various GWP influencing factors using AHP.
iv. To suggest suitable locations for groundwater extraction.
v. To provide scientific basis and planning for sustainable groundwater management.

D. Selection of Study Area

Khuldabad subdivision which is in the Chhatrapati Sambhajinagar (Aurangabad) district of Maharashtra is situated in semi-arid Deccan Plateau region, which is characterized by intermittent rainfall and common water shortage. Due to this, groundwater is the main source of domestic, agricultural, and industrial requirements, which requires a thorough evaluation of the potential of groundwater.

Geologically speaking, the region consists of basaltic rocks of the Deccan Traps, which are heterogeneous in their nature in terms of joints, fractures and weathered areas which considerably determine the occurrence and movement of the groundwater. The topography (undulating), different slopes, and drainage networks like the Shivana and Girija rivers further regulate the processes of runoff, infiltration and recharge. The climate in the region is semi-arid with an average rainfall of around 778.5 mm annually although long term records have also shown that the region is not stable and tends to undergo a downward trend of around 4.47 mm/year which also adds to water scarcity in the region.

There is also a likelihood of droughts in the region, of average droughts of 16% and extreme droughts of 6%. The groundwater levels normally lie 10-20m below ground level, although the tendency has been on a decreasing regime of more than 0.20 m/year which reflects overexploitation. There is also the low rate of soil infiltration (Approximately 0.60 cm/hr) which restricts recharge through the natural process. Even though projects like the Girija irrigation project, Nirgudi, Sobalgaon, and Gandheshwar schemes, KT weirs and lift irrigation schemes support irrigation, water availability is not adequate in general.

Based on factors of falling rainfall, frequent droughts, limited surface water, rising groundwater extraction and agricultural pressure Khuldabad is a perfect location to draw Groundwater Potential Zones (GWPZ). Such research will be critical in determining appropriate recharge areas and be useful towards sustainable groundwater management.

a. Location

The Khuldabad subdivision is between 20°00′ - 20°30′ North latitude and 75°00′ - 75°30′ East longitude in the Chhatrapati Sambhajinagar district of Maharashtra. The study area is bounded by kannad taluka to the north, Soegaon taluka to the northeast, Chhatrapati Sambhajinagar to southeast and Vaijapur taluka to the south.

b. Topography

The study area is also typified with the topography, which is undulating, and the terrain is characterized by elevations between the mean sea level (MSL) of about 500 m to 700 m high. Such difference in height affects the surface runoff, ground water infiltration and ground water recharge in the region.

c. Climate

The area Experiences hot summers, moderate monsoon and mild winters. The mean yearly precipitation varies between 600mm to 750 mm, with most of the rainfall occurring in the southwest rainy period from June through September.

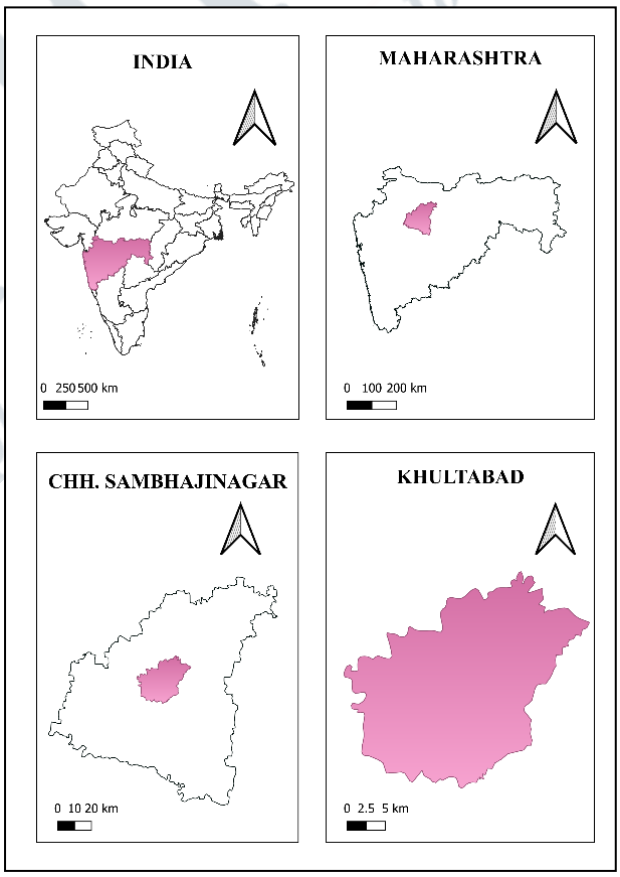


Fig. 1. Location Map

ISSN (Online) 2456 -1304

International Journal of Science, Engineering and Management (IJSEM)

Volume 13, Issue 08, August 2026

II. METHODS AND MATERIALS

A. Data use

- 30 m SRTM DEM data was downloaded USGS portal, then this data is applied for deriving elevation, drainage density (DD), slope and related parameters.
- The soil thematic layer was generated using global digital soil dataset obtained through Digital soil map of world (DSMW) developed by FAO (food and agricultural organization) to support soil categorization, and mapping purposes.
- Geomorphological data was acquired through Bhukosh portal of GIS, used for landform interpretation and mapping.
- LANDSAT OLI satellite imagery was employed for generating the LULC classification layer.
- NDVI analysis was carried out using satellite datasets acquired through USGS Earth Explorer.

B. Data Processing and Cleaning

a. Importance

Reliable and properly prepared datasets are necessary for delineating groundwater potential zones. Data preparation and analysis are important steps in GWPZ assessment because they strongly affect the accuracy and reliability of the outcomes. Careful processing of information collected from different sources reduces errors, removes inconsistencies, and fills data gaps. As a result, the groundwater potential distribution can be represented more accurately, supporting better resource planning and long-term water resource management.

b. Processes

SRTM DEM and Landsat imagery were pre-processed to eliminate errors and standardize the datasets for analysis. The DEM Was first corrected for depressions using the fill tool in the QGIS [Processing Toolbox → SAGA → Terrain Analysis → Preprocessing → fill sinks (Wang &Liu)]. Subsequently, flow direction and flow accumulation raster were created to determine water movement and identify stream networks, with threshold value of 500 pixels applied to delineate drainage lines.

These streams were classified using Strahler's stream ordering method. The extracted stream raster was converted into vector features, and drainage basin were delineated using basin analysis tools along with pour points to define outlet location. The basin raster was further converted into polygon format for detailed spatial analysis. Overall, flow direction and accumulation datasets were integrated to establish a comprehensive drainage network across the study area.

C. Methodology

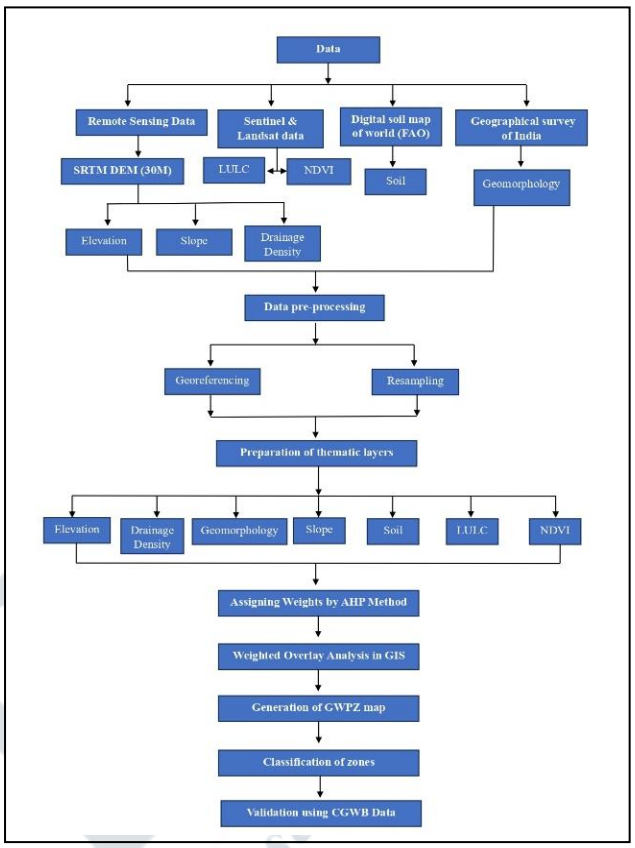


Fig. 2. Methodological Flow Chart of GWPZ using GIS

a. Thematic Layer Preparation using RS-GIS

Preparation of thematic layers plays an important role in environmental and spatial analysis. It involves the development of individual spatial datasets that represent specific physical, environmental, and human-induced characteristics of region. These layers serve as essential inputs for analysis and decision-making on Geographic information system (GIS) - based studies.

Thematic layers are widely used in applications such as groundwater potential mapping, natural resource management, land degradation assessment and environmental impact analysis. Each layer focuses on a particular parameter that influences the overall behavior of system being studied. Commonly prepared thematic layers include slope, elevation, drainage density, geomorphology, soil texture, NDVI, LULC. Combined interpretation of these datasets helps in better evaluation of the study region and supports effective planning and resources management.

1. Elevation

The topographic elevation map indicates the vertical variation of landforms with reference to mean sea level and can be prepared from digital elevation model (DEM) dataset using GIS platforms like QGIS. In the present study, elevation information for Khuldabad was extracted from 30 m SRTM DEM datasets obtained through the USGS portal.

ISSN (Online) 2456 -1304

International Journal of Science, Engineering and Management (IJSEM)

Volume 13, Issue 08, August 2026

The elevation values within the study region were observed to vary mainly between 551 m and 936 m. location lying within the lower elevation ranges of 551-630 m exhibit favorable groundwater condition because of gentle terrain and better infiltration capacity. In contrast, higher elevation zones between 806m and 936m possess relatively poor groundwater potential owing to steeper slopes and increased surface runoff.

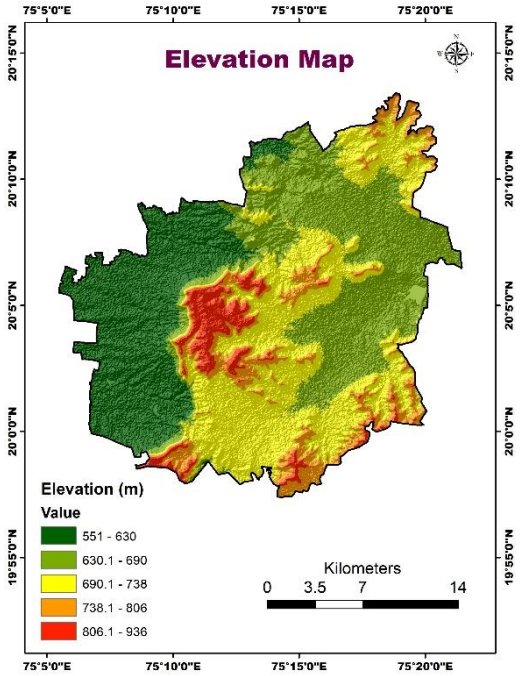


Fig. 3. Elevation Map

Table I: Elevation Categories

Class	Elevation	Groundwater potential
1	551 – 630	Very good
2	630.1 – 690	Good
3	690.1 – 738	Moderate
4	738.1 – 806	Poor
5	806.1 – 936	Very poor

2. Geomorphology

Geomorphology deals with landforms and their effect on water movement and infiltration. The geomorphology map for the Khuldabad region was generated using Bhukosh portal of GSI. The study area consists of the eight different geomorphic units, including pediment-pedipalin complex, plateus, flood plains, and water bodies Among these, the pediment–pediplain complex is the dominant feature. This is highly viable in recharging groundwater with basically the gentle slope and worn out surface that facilitates a high degree of infiltration. Since there are few surface water resources, the area relies primarily on ground water.

Low-moderate density drainage areas have widely spaced streams which result in increased infiltration and enhanced groundwater recharge. By contrast, dense drainage results in quick surface run-off because of spacing-near channels, decreasing infiltration. Therefore, such regions exhibit comparatively low groundwater recharge capability.

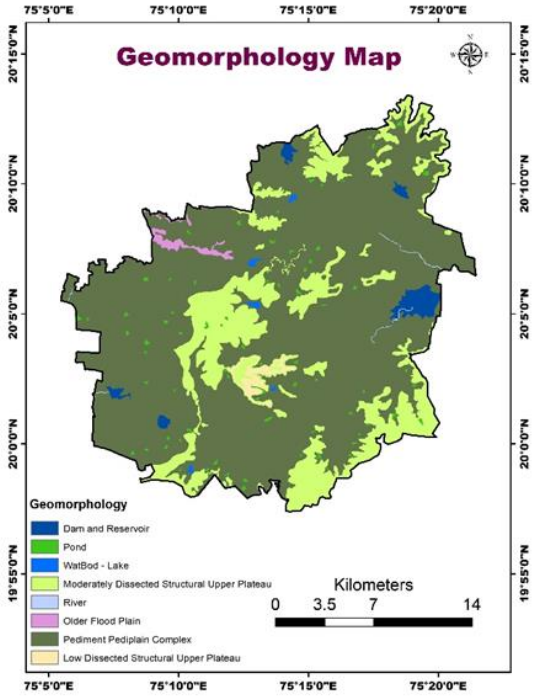


Fig. 4 Geomorphology Map

Table II: Geomorphology Categories:

Class	Class Categories	Groundwater potential
1	Dam and Reservoir	Moderate
2	Pond	Good
3	Water body – lake	Good
4	Moderately discrete structural upper plateau	Very Good
5	River	Poor
6	Older flood plains	Poor
7	Pediment pedi-plain complex	Very Good
8	Low discrete structural upper plateau	Good

3. Normalized Difference Vegetation Index (NDVI)

NDVI represents vegetation assessment index obtained using satellite imagery. This is calculated using reflectance information from red to near infrared (NIR) spectral regions. This index varies between -1 and +1, where greater values generally reflect healthier and more abundant vegetation, while smaller or negative values indicate limited vegetation cover, bare land or built-up area.

ISSN (Online) 2456 -1304

International Journal of Science, Engineering and Management (IJSEM)

Volume 13, Issue 08, August 2026

In this study NDVI ranges from -0.148 to 0.799 and is classified into five categories. Low NDVI values indicate poor groundwater recharge, while moderate values show average potential. High to very high NDVI values represent dense vegetation, which enhances infiltration and supports good groundwater recharge.

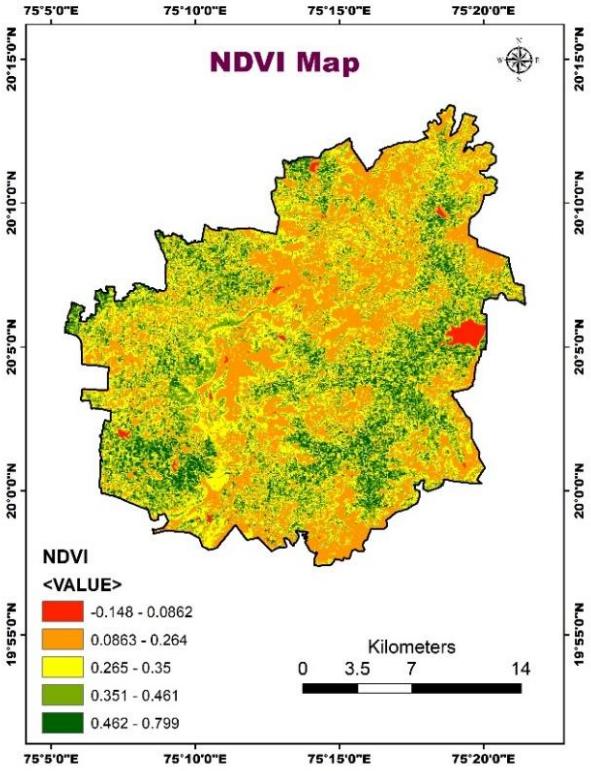


Fig. 5. NDVI Map

Table III: NDVI Categories

Class	NDVI	Groundwater potential
1	0.462 – 0.799	Very good
2	0.351 – 0.264	Good
3	0.265 - 0.35	Moderate
4	0.0863 – 0.264	Poor
5	-0.148 - 0.0862	Very poor

4. Drainage Density

Areas having relatively low to intermediate drainage density have widely spaced streams, which enhance percolation and improve recharge conditions. On the other hand, areas with high drainage density, characterized by closely spaced channels promote rapid surfaces runoff and reduce infiltration, resulting in poor recharge potential. The Region was categorized into five drainage density categories ranging from lowest to highest values.

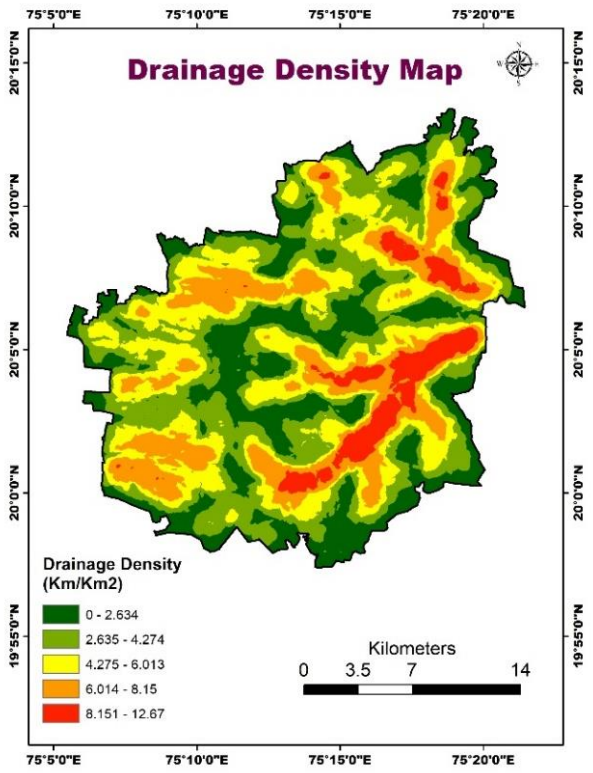


Fig. 6. Drainage Density Map

Table IV: Drainage Density Categories

Class	Drainage Density (km/km2)	Groundwater potential
1	0 - 2.634	Very Good
2	2.635 - 4.274	Good
3	4.275 - 6.013	Moderate
4	6.014 - 8.15	Poor
5	8.151 - 12.67	Very Poor

5. Slope

Slope is an important terrain factor that controls water infiltration, percolation and runoff behaviour. Steeper slopes promote rapid runoff and reduce infiltration, whereas gentle slopes allow and reduce infiltration and enhance groundwater recharge.

For the present analysis, slope information was derived from SRTM DEM data through GIS-based processing and represented in degrees. the generated slope layer was grouped into five classes varying from nearly flat (0-3.07) to steep terrain (24.21-56.09).

Nearly flat and gentle slopes identified as favourable for groundwater occurrence because they permit higher percolation of water, while steep slopes show limited recharge capability due to increased runoff. Spatially, most of the study areas fall under gentle slope categories, indicating favorable condition for groundwater recharge.

ISSN (Online) 2456 -1304

International Journal of Science, Engineering and Management (IJSEM)

Volume 13, Issue 08, August 2026

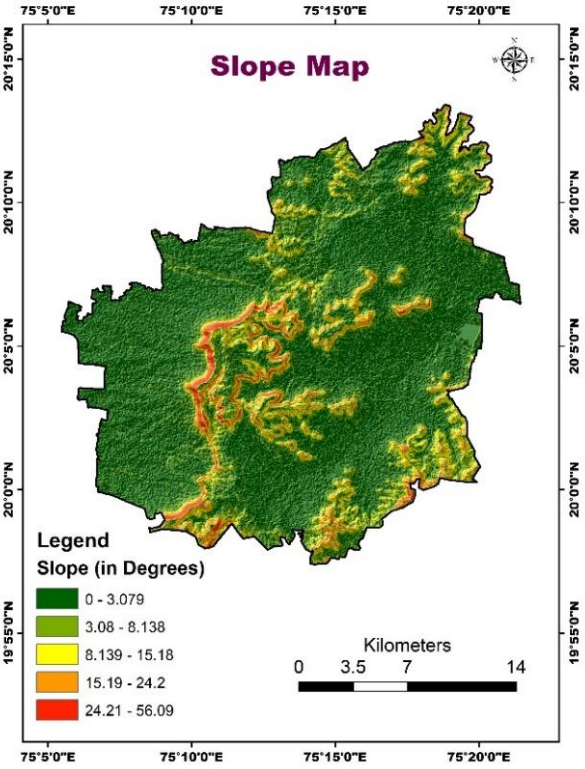


Fig. 7. Slope Map

Table V: Slope Gradient

Class	Slope (degrees)	Slope category	Ground water potential
1	0 - 3.079	Nearly flat	Very good
2	3.08 - 8.138	Very gentle	Good
3	8.139 - 15.18	Gentle	Moderate
4	15.19 - 24.2	Moderate	Poor
5	24.21 - 56.09	Steep	Very Poor

6. Soil

Soil is an important factor controlling groundwater recharge because it affects the movement, storage, water holding capacity, infiltration and percolation of water through the ground.

Different soil types vary in their ability to allow water percolation, making soil an important parameter in ground water studies.

The soil layer was prepared using DSMW data provided by the FAO, from which soil is classified into two types, clay soil and clay loam. Clay soil, dominant in the western part, has low permeability and restricts infiltration, resulting in poor groundwater recharge.

In contrast, majority of areas covered by clay loam soil, it has moderate permeability and better moisture retention, making it more favorable for groundwater recharge.

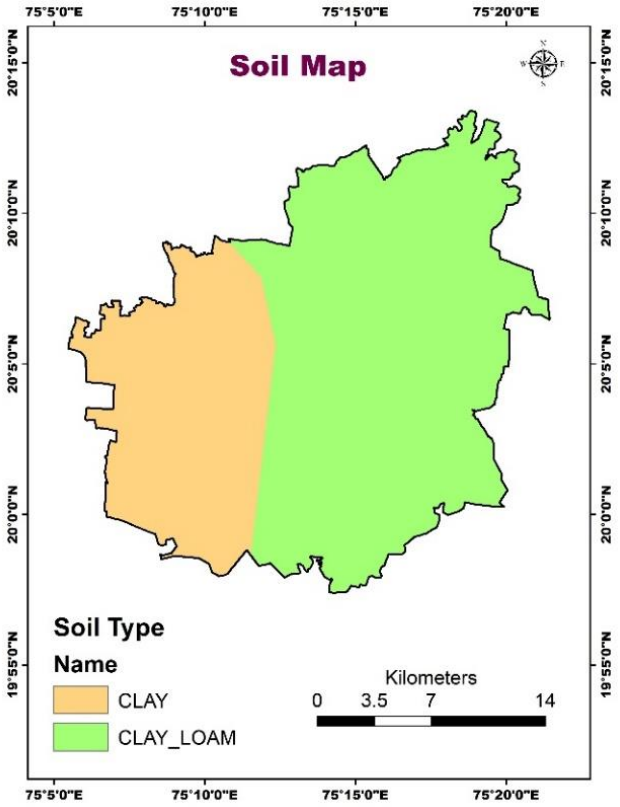


Fig. 8. Soil Map

Table VI: Soil Type

Class	Soil type	Groundwater potential
1	Clay loam	High
2	Clay	Very Poor

7. Land Use Land Cover

LULC strongly influences groundwater recharge by controlling infiltration and surface runoff. Vegetated and agricultural areas promote infiltration, while built-up regions with impervious surfaces restrict percolation and reduce recharge.

Sentinel – 2 imagery is used to derive LULC and categorized into six classes such as, water bodies, trees, rangeland, cropland, built-up areas and bare ground.

Cropland dominates major areas, supporting moderate to good recharge while rangeland shows variable infiltration. built-up areas reduce recharge, whereas water bodies act as direct recharge zones. Overall, the study area exhibits moderate groundwater recharge potential.

ISSN (Online) 2456 -1304

International Journal of Science, Engineering and Management (IJSEM)

Volume 13, Issue 08, August 2026

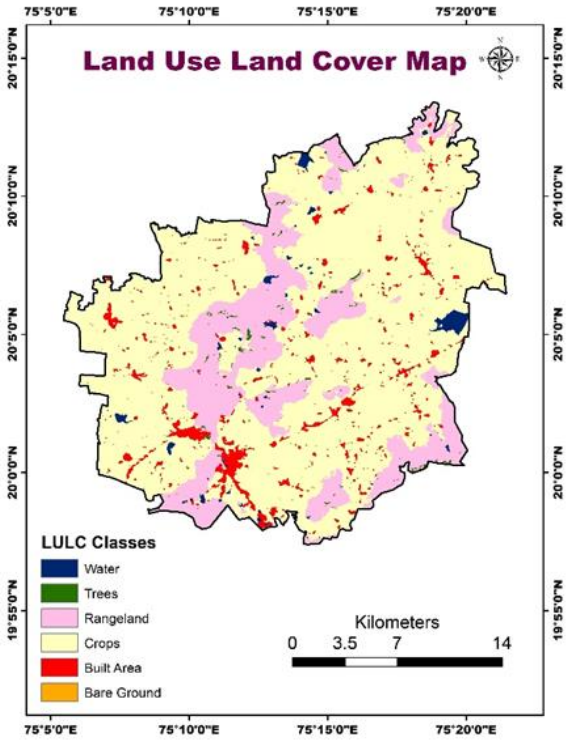


Fig. 9. Land Use Land Cover Map

Table VII: LULC Categories

Class	LULC	Groundwater potential
1	Water	Very good
2	Trees	Good
3	Crops	Moderate
4	Built up area	Poor
5	Bare Ground	Very Poor
6	Rangeland	Very Poor

D. Assigning Weight to Parameters using AHP

AHP is a multi-criteria decision-making (MCDM) approach commonly adopted for assigning suitable weights in groundwater potential zone (GWPZ) studies. This method is useful for determining the significance of different factors like soil, geomorphology, slope, and LULC according to their effect on groundwater occurrence and recharge conditions.

i. A pairwise comparison matrix (PCM) was prepared to compare thematic parameters with one another and determine their significance in groundwater assessment
ii. The comparison matrix was normalized to obtain priority values representing the influence of individual thematic parameters on groundwater recharge.
iii. Reliability of comparison matrix was checked through the consistency ratio (CR). A consistency value below 0.1 was considered satisfactory for the analysis.
iv. The obtained parameter weights were incorporated into weighted overlay analysis (WOA) within the QGIS environment to prepare the final groundwater potential zonation map.

III. RESULTS AND DISCUSSION:

A. Showing Ranking and Weightage used for Groundwater Potential Zone

Table VIII: Showing Ranking and weightage used for groundwater potential zone

Parameter	Class	Ground water Prospect	Weight (%)	Rank
Elevation (m)	551 – 630	Very good	27	5
	630.1 – 690	Good		4
	690.1 – 738	Moderate		3
	738.1 – 806	Poor		2
	806.1 – 936	Very poor		1
Geomorphology	Dam and Reservoir	Moderate	23	3
	Pond	Good		4
	Water Bodies – Lake	Good		5
	Moderately Dissected Structural Upper Plateau	Very Good		2
	River	poor		
	Older Flood Plain	Very Good		5
	Pediment Pediplain Complex	Very Good		5
	Low Dissected Structural Upper Plateau	Good		4
		Very Poor		1
NDVI	-0.148 - 0.0862	Very Poor	18	1
	0.0863 - 0.264	Poor		2

ISSN (Online) 2456 -1304

International Journal of Science, Engineering and Management (IJSEM)

Volume 13, Issue 08, August 2026

Parameter	Class	Ground water Prospect	Weight (%)	Rank
	0.265 - 0.35	Moderate		3
	0.351 - 0.461	Good		4
	0.462 - 0.799	Very good		5
Drainage Density Km/km2	0 - 2.634	Very good	12	5
	2.635 - 4.274	Good		4
	4.275 - 6.013	Moderate		3
	6.014 - 8.15	Poor		2
	8.151 - 12.67	Very Poor		1
Slope (Degrees)	0 - 3.079	Very good	11	5
	3.08 - 8.138	Good		4
	8.139 - 15.18	Moderate		3
	15.19 - 24.2	Poor		2
	24.21 - 56.09	Very Poor		1
LULC	Water	Very good	5	5
	Trees	Good		4
	Crops	Moderate		3
	Built up area	Poor		2
	Bare Ground	Very Poor		1
	Rangeland	Very Poor		1
Soil Map	Clay Loam	High	4	2
	Clay	Very Poor		1

B. Groundwater Potential Zone for Khuldabad Subdivision

Groundwater potential areas within the Khuldabad subdivision were delineated through the integration of several thematic parameters including elevation, geomorphology, drainage characteristics, soil, terrain slope, vegetation index, and land utilization patterns. All these factors were assigned relevant weight and rank based on the strength of their effects on groundwater recharge. The map created by the weighted overlay analysis approach was created as the final map.

This shows that the factor most likely to influence groundwater potential in the study area is elevation (topography) and its contribution is approximately 27. Geomorphology (contribution 23) indicates that fluvial landscapes and water bodies would have potential groundwater quality and that the denudational features and artificial landscapes, have relatively lower recharge potential. The NDVI was also useful in measuring the ground water potential-those with high vegetation cover were more conducive to infiltration, and barren lands played the worst role as far as ground water recharge was concerned. Regions that were of low drainage density, and of low steepness were identified to be favourable in providing ground water recharge, although, high drainage density, and steepness limited infiltration because of too much runoff. The Land Use/Land Cover analysis revealed that groundwater in the subdivision of what was known as the very poor groundwater potential map was divided into five categories; Very Poor, Poor; Moderate; High; and Very High on the analysis of all the influencing factors. The findings reveal that very little area, approximately 6.55% (32.13 sq. km), is under the very poor category and 13.04% (64.01 sq. km) is under the poor category which implies that there is limited supply of groundwater in these regions. An approximate of 18.13 percentage (88.94 sq. km) of the region has a Moderate groundwater potential.

A large portion of the subdivision is favourable as 38.99% (191.33 sq. km) High and 23.29% (114.29 sq. km) Very High groundwater potential dominant regions. This is a clear indication that most of the area covered in the study has moderate to high potential of groundwater hence it can be used to develop groundwater as well as to plan how the ground water can continue being used without being depleted.

Lastly, the map is a clear indication that potential of groundwater is not evenly distributed throughout the area. The north and western are very much in favour, whilst the belt of central-southern is the least favourable in the occurrence of groundwater. This zonation is crucial for sustainable groundwater management and planning.

The spatial distribution pattern further indicates that the western and northern sectors are comparatively more suitable for groundwater occurrence, whereas the central and southern regions exhibit lower groundwater prospect. Such zonation can provide valuable support for groundwater planning and resource management activities.

ISSN (Online) 2456 -1304

International Journal of Science, Engineering and Management (IJSEM)

Volume 13, Issue 08, August 2026

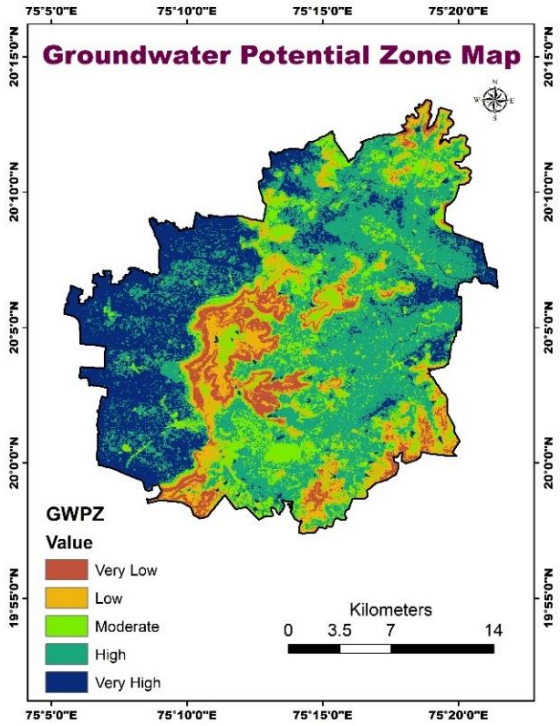


Fig. 10. Groundwater Potential Zone Map

Table IX: Ground water potential zone Area

Class	Area (sq.km)	Area (%)	Groundwater potential zone
1	32.1282	6.548	Very Poor
2	64.0062	13.044	Poor
3	88.9407	18.126	Moderate
4	191.327	38.991	High
5	114.289	23.291	Very High

IV. CONCLUSION

This research successfully identified groundwater suitability area within the Khuldabad subdivision of Chhatrapati Sambhajinagar district through the remote sensing data, Geospatial analysis, and the analytic hierarchy process (AHP). Finding obtained from the weighted overlay-based evaluation shows that a considerable share of the region concentrated within the high (38.99%) and very high (23.29%) groundwater suitability categories, highlighting favourable conditions for groundwater recharge and sustainable development.

The analysis further demonstrate that elevation and geomorphology are the dominant factors governing groundwater occurrence, whereas soil contributes comparatively less than the remaining influencing parameters. The combined use of geospatial dataset with multi-criteria decision-making techniques provides a systematic, objective, and reliable framework for groundwater assessment.

The generated groundwater potential map can support planning and resource management by assisting engineers and decision makers in selecting appropriate location for groundwater development and recharge interventions, thereby contributing to efficient and long-term water resource planning across the study area.

REFERENCES

[1] Central Groundwater Board. (2011). *Groundwater information report of Ahmednagar, Aurangabad, Jalna, Beed, Parbhani, Nanded and Nashik districts, Maharashtra*.

[2] Central Groundwater Board. (2013). *Groundwater information report of Adilabad and Nizamabad districts, Telangana*.

[3] Dutta, D., Sharma, J. R., & Adiga, S. (2002). *Watershed characterization, prioritization, development planning and monitoring using remote sensing approach* (ISRO–NNRMS Technical Report No. ISRO–NNRMS–TR–103–2002). Bangalore: Indian Space Research Organisation (ISRO).

[4] Gottschalk, L. C. (1964). Reservoir sedimentation. In V. T. Chow (Ed.), *Handbook of applied hydrology*. New York: McGraw-Hill.

[5] Horton, R. E. (1945). Erosional development of streams and their drainage basins: Hydro physical approach to quantitative geomorphology. *Geological Society of America Bulletin, 56*, 275–370.

[6] Hare, P. H., & Gardner, T. W. (1985). Geomorphic indicators of neo tectonism. In M. Morisawa & J. T. Hack (Eds.), *Tectonic geomorphology*. Boston: Allen & Unwin.

[7] Horton, R. E. (1932). Drainage basin characteristics. *Transactions of the American Geophysical Union, 13*, 350–361.

[8] Melton, M. A. (1957). *Analysis of climate, surface properties and geomorphology*. Columbia University Technical Report.

[9] Horton, R. E. (1945). Hydrophysical approach to quantitative geomorphology. *Geological Society of America Bulletin, 56*, 275–370.

[10] Miller, V. C. (1953). *Quantitative geomorphic study of drainage basin characteristics*. Columbia University Technical Report.

[11] Twarakavi, N. C., & Kaluarachchi, J. J. (2006). Aquifer vulnerability assessment using ordinal logistic regression.

[12] Schumm, S. A. (1956). Evolution of drainage systems and slopes in badlands at Perth Amboy, New Jersey. *Geological Society of America Bulletin, 67*, 597–646.

[13] Sharma, S. K., Singh, V., & Chandel, C. P. S. (2001). Groundwater pollution and physico-chemical analysis. *Journal of Environmental Ecology, 22*, 319–324.

[14] Strahler, A. N. (1957). Quantitative analysis of watershed geomorphology. *Transactions of the American Geophysical Union, 38*, 913–920.

[15] Strahler, A. N. (1964). Quantitative geomorphology of drainage basins. In V. T. Chow (Ed.), *Handbook of applied hydrology*. New York: McGraw-Hill.

[16] Tribhuvan, P. R., & Sonar, M. A. (2016). Morphometric analysis of Phulambri River basin using GIS. *International Journal of Advanced Remote Sensing and GIS, 5*(6), 1813–1828.