# Delineation of Groundwater Potential Zones Using Remote Sensing and Gis-A Case Study from Pokhran Tehsil, Jaisalmer, Rajasthan

Devendra Singh Tanwar[1], L. N. Sharma[2]
[1]Department of Civil Engineering, PEC University of Technology Sector 12 Chandigarh
[2]Department of Applied Sciences, PEC University of Technology Sector 12 Chandigarh

***Abstract: Water is a natural resource for the basic need for human being. In Jaisalmer district Rajasthan, having negligible annual rainfall and very few perineal source of running water is found, thus groundwater is the major source for all activities. For developing sustainable groundwater resources requires delineation of groundwater potential zones and proper utilization becomes very vital. For more detailed study area limited to the Pokhran tehsil of Jaisalmer district. RS technique provides synoptic view, covering inaccessible areas, repetitive coverage on land use/land cover, geomorphology, soil, slope, etc. that helps in deciphering groundwater potential zone. GIS allow manipulation and analysis of spatial and temporal data crucial for prediction and validation of study. Methodology includes data collection, pre-processing and preparation of thematic maps using raster data model in Arc GIS and ERDAS imagine. Thematic maps were integrated using 'Weighted Overlay analysis' Spatial Analyst Tool in Arc GIS and based on analysis four groundwater potential zones are identified as high, good, moderate, poor in study area. Area covered by Good groundwater potential zone is 4718.40 km$^2$ mostly in the lower central part of Pokhran. Thus, integration of maps prepared from RS and GIS analytical tools proved an efficient method for delineation of groundwater in the Pokhran tehsil.***

***Keywords*: Groundwater potential zones, RS, GIS, Thematic map, Delineation.**

## I. INTRODUCTION

Water is a necessary thing for the survival of human being. Adequate water is needed for better living condition of human like in irrigation, power generation, navigations, industries, domestic requirements. And also important for animals, flora and faunas for their life. It is mostly taken granted by human and used as it has infinite sources, but that is not true. Groundwater represents one of the most important water sources in India and accounts for over 400 km$^2$ of the annual utilizable resource in the country. Due to the highly variable nature of the climate, groundwater has become a popular alternative for irrigation and domestic water use across India. In areas like Rajasthan, especially in Jaisalmer district where very few rivers are found, having negligible annual rainfall due to which it is frequently affected by droughts. Because of scarcity of surface water resources, inhabitants depend mostly on groundwater. Groundwater is a major source of water in this kind of the area, importance of groundwater also increased due to tough living conditions and less resources to know groundwater potential zones. Due to less education and knowledge of technology people in this area, mostly depends on traditional methods for groundwater exploitation which produce not as much of the discharge and these methods are time and money consuming. In addition to considering water quantity, sustainability should also address water quality issues, and development should try to minimize degradation of water resources. Geographical Information System (GIS) is an application-oriented spatial information system with a variety of powerful functions to handle for decision support of problems related to the spatial dimension. All of the data in a GIS are georeferenced that is, linked to a specific location on the surface of the Earth through a system of coordinates. Geographical information attaches a variety of qualities and characteristics of geographical locations. These qualities may be physical parameters such as ground elevation, soil moisture or groundwater levels, or classifications according to the type of vegetation and land cover, ownership of land, zoning, and so on. Such occurrences as accidents, floods, or landslides may also be included. A general term 'attributes' is often used to refer to the qualities or characteristics of places and is considered as one of the two basic elements of geographical information, along with locations.

In this modern era where GIS and RS tools can be used for assessing, monitoring and conserving groundwater resources in the field of hydrogeological science. Integrated approaches in GIS play a swiftly increasing role in the field of hydrology and water resources development. As a subset of hydrology, hydrogeology is concerned with the occurrence, distribution, and movement of groundwater. Moreover, hydrogeology is concerned with the manner in which groundwater is stored and its availability for use. The characteristics of groundwater can readily be input into GIS for further study and management of water resources. Because 98% of the world's available freshwater is groundwater, the need to keep a closer eye on its disposition is readily apparent. It provides suitable options for efficient management of bulky and complex databases developed in different model environments. Remote sensing technology is capable of providing a base for quantitative analysis of an environmental process with some degree of precision. It offers an economical and efficient tool for land cover mapping and has its benefits in planning and management of water resources.

In the absence of any planned groundwater withdrawal approach, many times random drilling of bore wells results into failure. Further, this indiscriminate exploitation has led to decrease in groundwater potential, lowering of water level and deterioration in groundwater quality. It is therefore necessary to develop sustainable groundwater management scheme to properly utilize this vital resources, which in turn requires delineation of groundwater potential zones. There are several methods such as geological, hydrogeological, geophysical and remote sensing techniques, which are employed to delineate groundwater potential zones. Remote sensing technique provides an advantage of having access to large coverage, even in inaccessible areas. It is rapid and cost-effective tool in producing valuable data on geology, geomorphology, lineaments, slope, etc. that helps in deciphering groundwater potential zone. These various data are prepared in the form of thematic map using GIS software tool. These thematic maps are then integrated using ''Spatial Analyst'' tool.

## II. STUDY AREA

The present study has been carried out on the Pokhran tehsil which comes in Jaisalmer district of Rajasthan, which is in the eastern part of Jaisalmer as shown in the Figure. Average Mean sea elevation of the Pokhran tehsil is 230 meter and located within a rectangle lying between is 26°.15' – 28° north parallel and 71°.18'-72°.42' east meridians. Geographical area of Pokhran tehsil is 9830 $km^2$, in northern parts it's boundary touches to the Pakistan. Average annual rainfall in this area is 206 mm for last 15 years. The district experiences arid type of climate. As the district lies in the desert area, extremes of heat in summer and cold in winter are the characteristic of the desert. Pokhran is historical place as it hosted the detonation of India's first nuclear device in May, 1974.

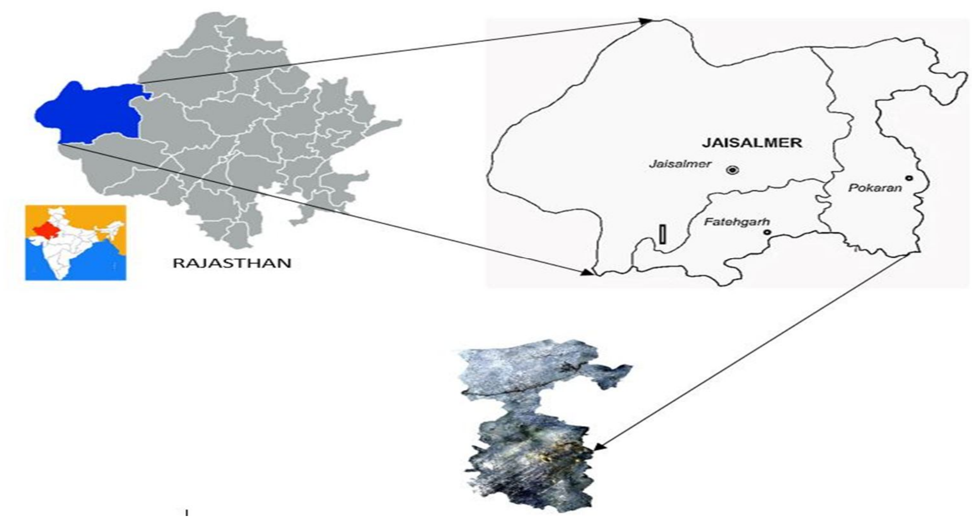


Fig. 1 Location of Pokhran tehsil

## III. METHODOLOGY

Methodology used in present study shown in form of flow chart in fig. 2 Model selected here for analysis is raster data model, method of representing geographic features by pixels is called the raster method or raster data model. A raster pixel represents the generalized characteristics of an area of specific size on or near the surface of the earth. The actual ground size depicted by a pixel is dependent on the resolution of the data, which may range from less than a square meter to several square kilometres. Raster data are organized by themes, which are also referred to as layers for example; a raster geographic database may contain the following themes: bed rock geology, vegetation cover, land use, topography, hydrology, rainfall, temperature The raster data model has advantages of being simple in structure, provision of easy and efficient overlaying and compatibility with RS image data while the vector data model has compact data structure, provision of efficient network analysis and projection transformation, and can generate accurate map output. By integrating these thematic maps into Arc GIS and assigning them the respective weightage groundwater potential map generated.

*A.Data collection*

Data collection is most important step in any study because more the data are true to the ground reality better will be result or less chances of error will be in study. Data should be in bulk quantity and well spread in area. For groundwater potential data must reflected the condition of actual site and it must be true and in bulk so chances of error in the modeling minimized. Different type of data acquired are water level data of wells in the area, the quality of Groundwater, lithology, Toposheets, Soil data, Spatial data viz; Landsat8 images, DEM of the area. Acquired data were then converted in various format so that they can be readily used in software.

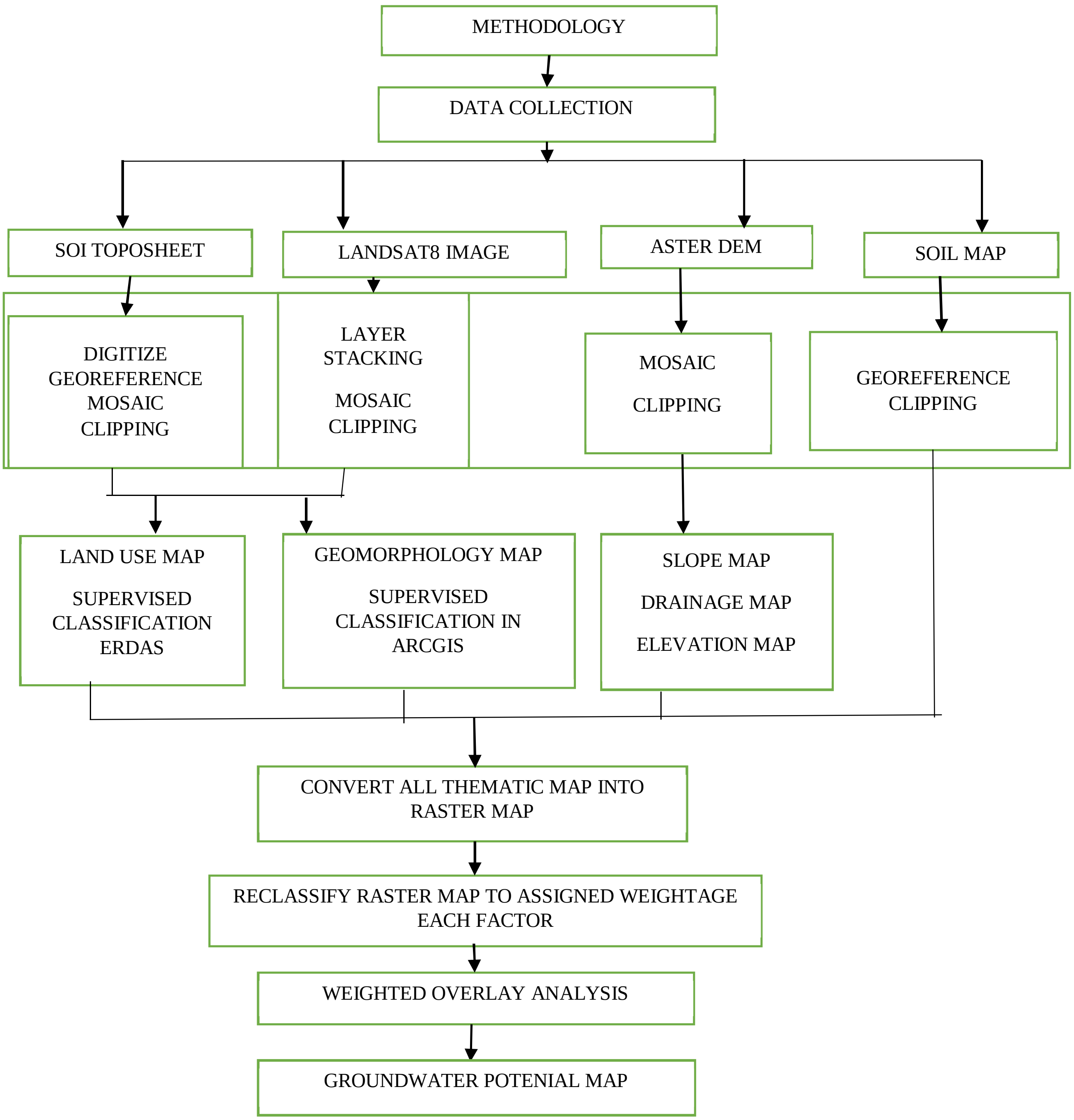


Fig. 3 Methodology Flowchart

*B. Pre-Processing of Data*

To analyse the spatial data for study pre-processing has been done using various tools available in Arc GIS 10.4. Mainly georeferencing of images, mosaicking and clipping of imagery to get the area of interest i.e. Pokhran tehsil. In the present study, the Landsat8, ASTER DEM data have been georeferenced with reference to Survey of India topographic maps.

*C. Preparation of Thematic Map*

In the present study, remote sensing satellite data are utilized to generate six thematic parameters (layers) controlling the groundwater potentiality in the study area. These layers are: geomorphology, soil, elevation, drainage density, slope and land use/land cover.

1) *Land Use/Land Cover:* The term Land cover is often used simultaneously to describe the map that provide information about the types of features found on the earth's surface (land cover) and the human activity that is associated with them (land use). The surface covered by vegetation like forests and agriculture traps and holds the water in root of plants whereas the built-up and rocky land use affects the recharge of groundwater by increasing runoff during the rain, so it is necessary to study what kind of features are covered the study area's land surface. The Landsat 8 satellite image has been used for the study to find out the land use and land cover of study area. The supervised classification method has been used with level – I classification. The result of the study found the study area covered by six different classes.
2) *Geomorphology Map*: Geomorphology is a study of earth structures and also depicts the various landforms relating to the Ground water potential zones and also structural features. Geomorphology of an area depends upon the structural evolution of geological formation. Using false colour composition in landsat8 image supervised classification done by ArcGIS which is checked by available geomorphology map of area. Major geomorphological units are belonging to aeolian and denudational origin.
3) *Drainage Density Map*: Drainage density layer is one of the most important parameters for the hydrogeological studies. Drainage pattern and density give a good indication about the hydrogeological characteristics of the terrain. The drainage networks of the study area are derived from ASTER GDEM (30 m) data. The generated map of the drainage lines shows only the directions and spatial distribution of the drainage networks. To convert this form into density form, a grid with spatial area of about 30 $km^2$ is constructed and the number of drainage lines in each cell is counted.
4) *Slope Map:* Slope determines the rate of infiltration and runoff of surface water, the flat surface areas can hold and drain the water inside of the ground, which can increase the ground water recharge whereas the steep slopes increase the runoff and decrease the infiltration of surface water into ground. The slope map of the trough was generated using the spatial Analyst (slope) of ArcMap based on the DEM model which was based on the ASTER data.
5) *Soil Map:* Soil is the one of the primary factor which determines the amount of groundwater, the study of soil helps to find out the types and as its properties. Soil refers to the thin layer locating over the earth's surface, jointly influenced by climate, relief, gradient of land, nature of parent rocks, vegetation and groundwater also. The soil is an influencing or controlling factor in the process of groundwater recharge because, it may hold the surface water in soil holes and pores. The amount of groundwater recharge, storage, discharge, the extent of groundwater pollution, etc. all are determined by the soil properties like structure, texture, porosity, specific yield, permeability etc. Soils were originally assigned to hydrologic soil groups based on measured rainfall, runoff data. In its simplest form, hydrologic soil group is determined by the water transmitting soil layer with the lowest saturated hydraulic conductivity and depth to any layer that is more or less water impermeable or depth to a water Table (if present). The least transmissive layer can be any soil horizon that transmits water at a slower rate relative to those horizons above or below it. Soils are classified into four classes A, B, C and D based on these characteristics (Chapter 7 Hydrologic Soil Groups, National Engineering Handbook Part 630 Hydrology). The movement and infiltration of water in these types of soil is not same so based on its property the weightages have been assigned.
6) *Elevation Map:* Water tends to store at lower topography rather than the higher topography. Higher the elevation lesser the ground water potential and vice versa, for the present study elevation data having 30-meter spatial resolution has been created based on the ASTER DEM. The study area's elevation ranges between 46 meters to 356 meters from the mean sea level, this values have been classified equally into three classes and weightage for each class have been assigned.

### *D. Reclassify and Weightage Assigned*

After construction of thematic map all maps were converted into raster format so that we can assign each cell some value according to their weightage. Conversion of thematic map into Raster datasets done by Reclassify spatial analyst tool. Weightage and rank was determined for each criteria and their classes by doing thoroughly literature review as well as their capability to affect the groundwater potential of the study area.

### *E. Weightage Overlay Analysis*

After the weightage of each main parameter has been determined, the weightage for the sub class of main parameters have been assigned as mention in Table 1 Then the tool 'Weighted Overlay' in Overlay Toolset which is built inside of Spatial Analyst Tools in ArcGIS has been used to perform an overlay analysis. The weighted overlay tool overlays several raster using a common measurement scale and weights each according to its important which results into present study as groundwater potential map.

Table 1 Assigned weights and rank for overlay analysis

| Sl. No. | Criteria | Classes | Rank | Weights (%) |
|---|---|---|---|---|
| 1 | Geomorphology | Dune Complex | 1 | 20 |
| | | Interdunal Flat | 2 | |
| | | Water Body mask | 3 | |
| | | Pedi Plain | 4 | |
| | | Valley Fill | 5 | |
| 2 | Land Use/Land cover | Desert with Shrubs | 1 | 20 |
| | | Built-up Area | 2 | |
| | | Agriculture Land | 3 | |
| | | Barren Land | 4 | |
| | | Water | 5 | |
| 3 | Hydrological Soil Group | A | 1 | 15 |
| | | B | 2 | |
| 4 | Slope | Low | 1 | 15 |
| | | medium | 2 | |
| | | High | 3 | |
| 5 | Drainage Density ($Km/Km^2$) | High DD | 1 | 15 |
| | | Medium DD | 2 | |
| | | Low DD | 3 | |
| 6 | Elevation | High | 1 | 15 |
| | | medium | 2 | |
| | | Low | 3 | |
| | Total | | | 100 |

## IV. RESULTS

### *A. Land Use/ Land Cover*

In the present study, an attempt has been made to know the land use/land cover in the study area and use it further for groundwater potential. Land use/land cover map was prepared by visual interpretation of digital satellite data of Landsat8 of October 2016. Supervised classification of the clipped satellite image is processed with the help of Toposheets of the study area on scale of 1:50000 under the ERDAS Imagine software. The field knowledge and google earth software also helped to identify and deduce the type of land cover. The five land use/land cover classes i.e. Agriculture land, barren land, Built up area, Desert with shrubs, Water were categorized in the study Area which is shown in Fig. 4.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 5 Issue VII, July 2017- Available at www.ijraset.com

*B. Geomorphology Map*

The identification of geomorphologic units and the occurrence of the groundwater in each unit are found out by the use of geomorphologic map. Geology, Geomorphology and the structural patterns controls the groundwater recharge and its transmission. The geomorphology of the study area is prepared with the help of the satellite imaginaries and the Survey of India (SOI) toposheets of scale 1:50,000 processed in Arc GIS 10.4 for supervised classification. The various geomorphologic unit found are dune complex, Interdunal flat, pediplain, water body mask and valley fill shown in fig. 5

*C. Drainage Density Map*

High drainage density is the resultant of weak or impermeable subsurface material, sparse vegetation and mountainous relief. Low drainage density leads to coarse drainage texture while high drainage density leads to fine drainage texture. The drainage density characterizes the runoff in an area or in other words, the quantum of relative rainwater that could have infiltrated. Hence the lesser the drainage density, the higher is the probability of recharge or potential groundwater zone. Drainage Density is calculated using Focal statistics spatial analyst tool in ArcGIS 10.4. The entire drainage map is divided into three categories low, moderate, good. Major area comes under moderate drainage density shown in fig. 6.

*D. Soil Map*

The product of physical and chemical weathering of rocks is soil as it is altered by interactions between the lithosphere, hydrosphere, atmosphere and biosphere. The characteristics of the soil play a major important role in the recharge of the groundwater. The result of soil classification found that, the study area has four types of major soils such as, Deep Yellowish brown sandy soils, Deep Light yellowish brown loamy sand soils, Medium Light yellowish brown loamy soils and Sandy clay. And further divided into hydrological soil group A and B shown in fig. 7.

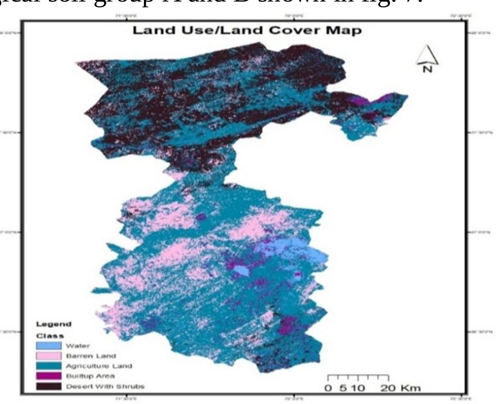


Fig. 4 land use/ land cover map

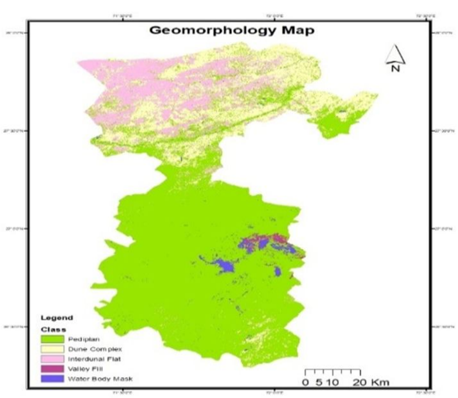


Fig. 5 geomorphology map

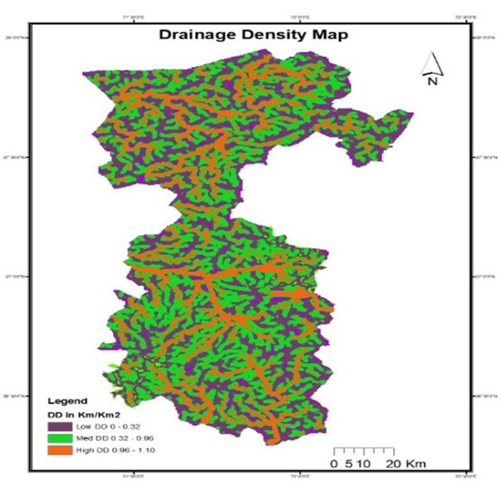


Fig. 6 Drainage Density map

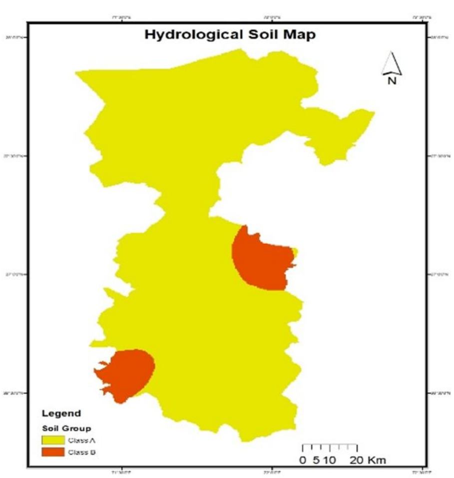


Fig. 7 Soil map

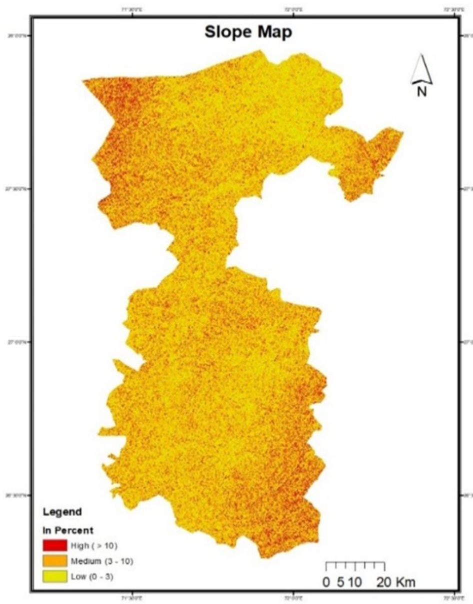


Fig. 8 Slope map

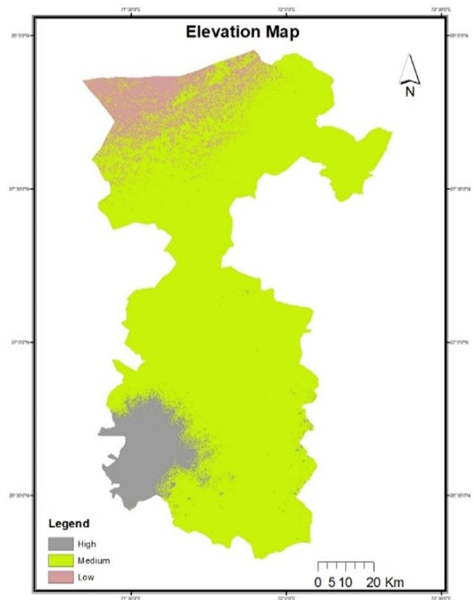


Fig. 9 Elevation map

### *E. Slope Map*

In the gentle slope area, the surface runoff is slow allowing more time for rainwater to percolate, whereas high slope area facilitate high runoff allowing less residence time for rainwater hence comparatively less infiltration. As the most of the area is in plainer region so slope present in this area is gentle and divided into three categories which is shown in the thematic map prepared using spatial analyst tool in ArcGIS. Slope of study area in percent is shown in Fig. 8.

### *F. Elevation Map*

This map is prepared using ASTER Dem and converted into raster format to categories in three class i.e. low, medium, high. Average elevation of area is 230 m. As the slope is gentle so the most of area comes under medium elevation that is shown in Fig. 9.

### *G. Groundwater Potential Map*

Each thematic map such as land use/land cover, geomorphology, drainage density, soil, elevation and slope provides certain clue for the occurrence of groundwater. In order to get all this information unified, it is essential to integrate these data with appropriate factor. Using weighted overlay analysis tool in ArcGIS all the thematic maps were integrated. The weightage for different layers have been assigned considering similar work carried by many workers which studied in literature review. A simple arithmetical model has been adopted to integrate various thematic maps by averaging the weightage. The final map has been categorized into four zones, from groundwater potential point of view High, good, moderate and poor, which is shown in Figure 10. Most of the region comes under Good to moderate groundwater potential area shown in Table 2. Comparison of groundwater potential map to the available groundwater level map shows majority of the wells are presented in good zone that validates the result of the study.

Table 2. Area wise Groundwater Potential in Pokhran

| S. NO. | Potential Zone | Area ($km^2$) | Percentage of area (%) |
|---|---|---|---|
| 1 | High | 13.50 | 0.13 |
| 2 | Good | 4718.40 | 48 |
| 3 | Moderate | 4206 | 42.80 |
| 4 | Poor | 892.10 | 9.07 |
| 5 | Total | 9830 | 100 |

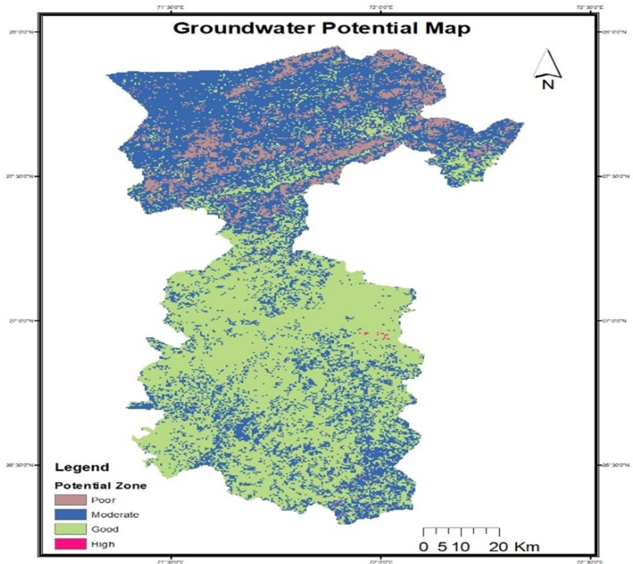


Fig. 10 Groundwater Potential Map of Pokhran

## V. CONCLUSION

From the study it is concluded that agriculture land forms the major land use/land cover in Pokhran area followed by desert with shrubs in the northern part. The dominant geomorphological feature is pediplain in central and southern part followed by dune complex observed in north-west part of area. Most part of the study area is covered with small streams and does not follow any fix drainage pattern. Study area is covered by deep yellowish brown sandy soil except some pockets. General slope of the Pokhran is gentle and towards south-west. Average elevation of area is observed 230 m. Based on Overlaying and analysis of thematic maps in GIS four groundwater potential zones have been delineated i.e. High, Good, Moderate and poor. Area covered by Good groundwater potential zone is 4718.40 $km^2$ mostly in the lower central part of Pokhran. Thus, integration of maps prepared from RS and GIS analytical tools proved an efficient method for delineation of groundwater in the Pokhran tehsil.

## REFERENCES

[1] Agarwal, R. and Garg, P.K. Remote sensing and GIS based groundwater potential & recharge zones mapping using multi-criteria decision making technique. Water resources management, 30(1), pp.243-260, 2016.
[2] Dar, I.A., Sankar, K. and Dar, M.A., Deciphering groundwater potential zones in hard rock terrain using geospatial technology. Environmental monitoring and assessment, 173(1), pp.597-610, 2011.
[3] Fashae, O.A., Tijani, M.N., Talabi, A.O. and Adedeji, O.I., Delineation of groundwater potential zones in the crystalline basement terrain of SW-Nigeria: an integrated GIS and remote sensing approach. Applied Water Science, 4(1), pp.19-38, 2014.
[4] Ghodratabadi, S. and Feizi, F., Identification of Groundwater Potential Zones in Moalleman, Iran by Remote Sensing and Index Overlay Technique in GIS. Iranian Journal of Earth Sciences, 7(2), pp.142-152, 2015.
[5] Hammouri, N., El-Naqa, A. and Barakat, M., An integrated approach to groundwater exploration using remote sensing and geographic information system. Journal of Water Resource and Protection, 4(9), pp.717-729, 2012.
[6] Hutti, B. and Nijagunappa, R., 2011. Identification of groundwater potential zone using geoinformatics in Ghataprabha basin, North Karnataka, India. International Journal of Geomatics and Geosciences, 2(1), pp.91-103.
[7] Machiwal, D., Jha, M.K. and Mal, B.C., 2011. Assessment of groundwater potential in a semi-arid region of India using remote sensing, GIS and MCDM techniques. Water resources management, 25(5), pp.1359-1386.
[8] Mallick, J., 2016. Geospatial-based soil variability and hydrological zones of Abha semi-arid mountainous watershed, Saudi Arabia. Arabian Journal of Geosciences, 9(4), pp.281-296.
[9] Mann, H. S., Sen A. K., 1982. Groundwater Atlas of Rajasthan. Central Arid Zone Research Institute, Jodhpur.
[10] Prasad, R. K., Mondal, N. C., Banerjee, P., Nandakumar, M. V., Singh V. S., (2008). Deciphering potential groundwater zone in hard rock through the application of GIS. Environmental Geology, August 2008, 55(3), pp.467–475
[11] Rao, Y. S., Jugran, D. K., 2003, Delineation of groundwater potential zones and zones of groundwater quality suitable for domestic purposes using remote sensing and GIS. Hydrological Sciences Journal, 48(5), pp. 821-833.
[12] Rathore, M.S., 2005. Groundwater exploration and augmentation efforts in Rajasthan–a review. Institute of Development Studies, Jaipur, India.
[13] Scanlon, B.R., Mukherjee, A., Gates, J., Reedy, R.C. and Sinha, A.K., 2010. Groundwater recharge in natural dune systems and agricultural ecosystems in the Thar Desert region, Rajasthan, India. Hydrogeology journal, 18(4), pp.959-972.

[14] Singh, C. K., Rina, K., Singh, R. P., Shashtri, S., Kamal, V., Mukherjee, S., 2011. Geochemical Modelling of High Fluoride Concentration in Groundwater of Pokhran Area of Rajasthan, India. Bulletin of Environmental Contamination and Toxicology, 86(2) pp. 152-158.

[15] Thilagavathi, N., Subramani, T., Suresh, M. and Karunanidhi, D., 2015. Mapping of groundwater potential zones in Salem Chalk Hills, Tamil Nadu, India, using remote sensing and GIS techniques. Environmental monitoring and assessment, 187(4), pp.164-174.

[16] Thivya, C., Chidambaram, S., Singaraja, C., Thilagavathi, R., Prasanna, M.V., Anandhan, P. and Jainab, I., 2013. A study on the significance of lithology in groundwater quality of Madurai district, Tamil Nadu, India. Environment, development and sustainability, 15(5), pp.1365-1387.

[17] 2007, Chapter 7, Hydrologic Soil Groups, National Engineering Handbook Part 630 Hydrology, United States Department of Agriculture. Available: https://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=22526.wba

[18] 2013, Groundwater scenario Jaisalmer District Rajasthan: A Report, Central Ground Water Board, Jaipur. Available: http://www.cgwb.gov.in/District_Profile/Rajasthan/Jaisalmer.pdf