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A review on Water Resource Planning and Management with Special Reference to Groundwater using Remote Sensing and GIS Techniques

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Abstract

Water is one of the most important natural resources and a physiological necessity to humankind. Freshwater is one of the necessities for the sustenance of life. The use and development of water resources in a sustainable manner is essential in the modern age due to the regular increase in water crises. Remote sensing and GIS techniques are powerful tools for analyzing and manipulating water resource development and management data. GIS technology provides suitable alternatives for the efficient management of large and complex databases. The most significant advantage of using Remote Sensing data for hydrological modeling and monitoring is its ability to generate information in the spatial and temporal domain. Remote sensing and GIS techniques are found efficient to minimize the time, labor, and money and make quick decisions for Sustainable water resources management. Remotely sensed data are most valuable when combined with numerical modeling, geographic information systems, and ground-based information. In short, both these techniques play a significant role in hydrology for water resources development and management. The remote sensing data helps in fairly accurate hydro geomorphological analysis and identification and delineation of land features. The review paper highlights Remote Sensing and GIS techniques and presents a brief review on the application of these two emerging techniques for groundwater resource management and development. Thus, surface investigation of groundwater has proved to be more accessible, time consistent, and cheaper using geomatics technologies.

Keywords: Ground water, water resources planning, RS and GIS

1. Introduction

Groundwater is the primary source of domestic, agricultural, and industrial use in many regions of the world (Burke and Moench, 2000; Hosseinifard and Mirzaei Aminiyan, 2015). Groundwater has been found to be a more preferred resource due to its less susceptible contamination than surface water (Naghibi et al., 2017). It can be considered as the largest single fresh water source in many parts of the world, especially during prolonged dry periods (Assaf and Saadeh, 2008). The utility of water is continuously growing and causes groundwater resource stress predictably (Vaux, 2011). In developing countries like Ethiopia, the unregulated growth of population and improper management resources affected directly and/or indirectly both the quality and quantity of groundwater. Hence, unscientific exploitation and improper use of water policy are also possible factors. Therefore, the assessment of groundwater resources is critical for sustainable management.

Most groundwater potential investigation techniques (i.e., geophysical methods, ground-based survey, and exploratory drilling) are uneconomical and time-consuming and require large data sets (Nampak et al., 2014; Singh and Prakash, 2002). However, an integrated GIS and remote sensing study can provide the appropriate platform for the convergent analysis of large volumes of data and quite decision-making techniques for groundwater exploration. Remote sensing data that are a wide-range scale of the space-time distribution provide good opportunities to current science in improving the understanding of the hydrological system (Hoffmann and Sander, 2007). Besides of its scale, remote sensing provides information on inaccessible areas (Sener et al., 2005) and saves time and money as well (Murthy, 2010; Solomon and Quiel, 2006; Tweed et al., 2007). Thus, remote sensing and GIS are being increasingly used for the identification of groundwater potential zones (Andualem and Demeke, 2019) as well as ground water recharge and discharge zones (Chenini et al., 2010; Russo et al., 2015). GIS has also been used for processing and interpretation of groundwater quality data (Srinivasan and Jugran, 2003). Moreover, researchers have been used an integrated approach using remote sensing, GIS, and geophysical techniques to assess groundwater resources (Srivastava and Bhattacharya, 2006).

Recently, several studies have been applied using weighted overlay analysis for assessing groundwater potential zones (Andualem and Demeke, 2019; Das et al., 2019; Hussein et al., 2016; Ibrahim-Bathis and Ahmed, 2016; Kumar et al., 2016; Magesh et al., 2012; Rahmati et al., 2014). Among many determinant factors of the occurrence and movement of groundwater, topography, geomorphology, lithology, geological structures, lineaments, porosity, slope, drainage patterns, rainfall, LULC, water quality, depth to water, net groundwater recharge, and climate can be listed as examples (Andualem and Demeke, 2019; Elewa and Qaddah, 2011; Jaiswal et al., 2003; Jha et al., 2007; Murthy and Mamo, 2009). Hence, the factors used are different per researches, and consequently, the results vary (Magesh et al., 2012).

The practical development of the groundwater resources will have a significant effect on the improvement of the community livelihood. In fact, generating groundwater potential map has a significant effect to enhance sustainable management of groundwater resources in the study area as well as in the country. Thus, a detailed study has been performed to identify the potential areas of groundwater resources for better utility. Accordingly, this paper contributes by providing delineated groundwater potential zones through implementing remote sensing techniques and GIS tools to have proper administration, management, and sustainable use of groundwater resources in the sub-basin. Seven determinant factors, namely, lithology, slope, LULC, rainfall, lineaments, and drainage density, were accounted for in the study.

2. Historical Background

In the semi-arid region of Tamilnadu's Dharmapuri district, Shrinivasan (1978) conducted a thorough study on the application of remote sensing techniques for groundwater studies. The visual interpretation was first used to delineate primary geomorphological zonation and structural features of interest, which are manifested as lineaments in Landsat imageries were picked up. The land sat black and white imageries of 1:50000 scale, and a false-color composite of 1:1000000 scale was used.

According to Lerner et al. (1990), the choice of methods to investigate groundwater recharge is dependent on the objectives and the study area characteristics (including the flow mechanisms within the study area leading to the recharge), which determine the adequacy of the methods and the investigation time step.

For permanent yearly recharge predictions and comparison of estimates for aquifers with comparable physical and climatic parameters, Lerner et al. (1990) offered further strategies to reduce uncertainty in estimating methodologies. Indeed, groundwater recharge estimation according to the temporal variability of the components should never be done only once but in a continuing iterative process to update estimates and adjust management.

In 1994, Rango evaluated the application of remote sensing to hydrology. Still, it did not list groundwater among its operational applications, possibly because "most approaches use surface indicators of the underlying groundwater reservoir and require considerable skill and knowledge on the part of the interpreter". This is true, but it does not prevent operational use by many hydrogeologists in certain types of shallow groundwater systems.

Using remote sensing and GIS techniques, Chaudhary et al. (1996) created an HGM (Hydro geomorphological) map that illustrates the groundwater potential zones of the Sohna block in Gurgaon, Haryana. Various thematic maps were prepared by visual interpretation of satellite data, stereoscopic interpretation of panchromatic B/W aerial photographs, and information extracted from digital image processing of satellite data. The maps were further supplemented with selected group checks. Maps were digitized and integrated into IDRISI Geographic Environment to prepare final map showing prospective groundwater areas.

In the Raisen District of M.P. and surrounding regions, Shukla (1997) explored structural and geomorphological controls on groundwater occurrence. His study was focused on the management of water resources using integrated Remote Sensing techniques. He suggested stopping dams, checking dams, and recharge structures for water resource management.

A mathematical model created by Gert A. Schultz in 1997 establishes a link between data derived from satellite (Meteosat) photography and the actual situation on the ground. The parameters of the nonlinear mathematical model are calibrated based on short-term simultaneous satellite and ground truth data. Runoff time series it is possible to estimate the expected future performance of the intended water project. The model was applied to the Tano River basin (16 000 km^2) in Ghana, West Africa.

In a region of The Netherlands with unconsolidated rocks for which a systematic inventory of flow systems was performed, Peters and Stuurman (1989) used thematic Mapper (TM) imagery for a precise cover-type classification.

The significance of the spatial and temporal scales of the recharge estimation in directing the selection of groundwater recharge methods and techniques was emphasized by Bridget Scanlon et al., 2002. In addition, subsidiary factors like the methods, costs of remote sensing techniques, and the required duration for deriving the parameters in the recharge estimation are also restrictive when selecting a process.

Schmugge et al. (2002) worked on remote sensing in hydrology. In that study, they use satellite data for various purposes like land surface temperature from thermal infrared data, surface soil moisture from passive microwave data, snow cover using both visible and microwave data, water quality using visible and near-infrared data, and estimating landscape surface roughness using lidar. Using these state variables, methods for estimating the hydrometeorological fluxes, evapotranspiration, and snowmelt runoff are also described.

In the Dhanbad district of Jharkhand state's Jharia and Raniganj coalfields, Basudeo Rai et al. (2005) identified groundwater potential zones. In the study, they used MSS sensor data of Land- sat. Using visual Image interpretation elements like shape, size, tone, texture, and pattern, the study area various hydro-geomorphological units like linear ridge (dyke), residual hills, peneplain, buried pediment, dissected buried pediment, and lineament identified. Subsequently, the prospective groundwater zones were tested by using geoelectrical methods.

Techniques for aquifer characterisation were reported by Puri et al., 2006. They quoted the use of digital satellite images, including multi-spectral data from Landsat thematic mapper and Radar images from the Spaceborne Imaging Radar to map the eastern Sahara groundwater basins. Besides the variety of methods aforementioned in the recharge estimation, none alone has enough accuracy to provide reliable recharge estimates. It is partly due to the hidden nature of groundwater resources, which implies that calculations be at best approximate based on consistent assumptions on the components governing the resource occurrence as aquifer and known to be temporally and spatially variable and therefore likely to induce inaccuracies in the evaluation.

Rokde et al. (2007) used GIS and remote sensing approaches to model groundwater potential. They did their study in Rajura Taluka, Chandrapur District of Maharashtra. Using satellite data, they created geology, geomorphology, structural, etc., maps, found suitable recharge conditions, and delineated Groundwater potential maps.

A thorough analysis of the RS and GIS technologies' applications to groundwater hydrology is provided by Jha et al. (2007). A detailed survey of literature revealed significant areas of RS and GIS applications in groundwater hydrology: exploration and assessment of groundwater resources; selection of artificial recharge sites; GIS-based sub-surface flow and pollution modeling; groundwater- pollution hazard assessment and protection planning; estimation of natural recharge distribution and hydrogeological data analysis and process monitoring.

Mukherjee (2008) worked on the role of satellite sensors in groundwater exploration. The study found that IRS 1D-LISS data with a 23.5-meter resolution has produced excellent results in delineating interconnected lineaments over buried pediment plains as vegetation anomalies when merged with the panchromatic data. Further, the impact of urbanization on groundwater recharge in the terrain was studied by generating a Normalized difference Vegetation Index (NDVI) map, which was possible to develop by using the LISS-III sensor of IRS-1D satellite.

With the aid of RS and GIS, Chowdary et al. (2008) implemented their integrated water resource development plan for the sustainable management of India's Mayurakshi Watershed. This approach involves the preparation of different thematic maps (resource maps) by using remote sensing data and by conventional sources. The critical analysis of thematic maps derived from satellite data interpretation and other collateral data leads to the identification of problems and potentials of each of the thematic information in terms of its availability, sensitivity, severity, and criticality of the resources for the optimum utilization of the resources. Combining these thematic layers under a GIS environment using a set of logical conditions, an integrated water resource development map for each watershed was generated and identified suitable areas for the development of groundwater and the location of recharge sites depending on the terrain. Boolean logic is used for the selection of artificial recharge sites.

Using Terra-1 MODIC data, Shreenivas et al. (2010) investigated the detection of sub-surface waterlogging. The study was taken up to evaluate the potential of near-IR, short-wave IR (SWIR), and thermal-IR data from Moderate Resolution Imaging Spectrometer (MODIC) aboard terra-1 acquired during day and night time post-monsoon data for detection of subsurface waterlogging.

Using GIS modelling, Kumar (2010) investigated the evaluation of groundwater quality in shallow and deep aquifers in the U.P. state of Dhampur. The main aim of this study is to evaluate the groundwater quality for drinking and irrigation regarding recommended standards prescribed by WHO. This study had two main objectives to assess the concentration of some of the significant constituents of groundwater such as pH, EC, TDS, Fluoride, Chloride, and Total Iron in shallow and deep aquifers.

Using a geographic information system (GIS), Balakrishnan et al. (2011) mapped the groundwater quality in Gulbarga City, Karnataka, India. In his study, they analyzed for Physico-chemical parameters like TDS, TH, Cl, and NO_3, using standard techniques in the laboratory and compared with the standards. The groundwater quality information maps of the entire study area have been prepared using GIS spatial interpolation technique for all the above parameters. The final map shows potable and non-potable zones in terms of water quality.

In the Dhanbad district of Jharkhand, India, Srivastava et al. (2012) investigated the mapping of groundwater prospects utilizing remote sensing, GIS, and geoelectrical resistivity techniques. The groundwater resources have been reviewed by analyzing IRS LISS -II multi-band remote sensing data along with geological as well as geophysical resistivity sounding data carried out at places in the GIS environment. Finally, the groundwater resource prospect map of the area has been prepared based on the integrated thematic maps, weighted analysis in Arc-GIS environment.

In the Palleru sub-basin, which includes the Andhra Pradesh districts of Warangal, Nalgonda, and Khammam, Sarala (2012) discovered groundwater potential zones using remote sensing and GIS techniques. Her work involves creating a database, both spatial and non-spatial, with the help of Survey of India toposheets and Remote Sensing Imagery. Various thematic maps like drainage, contour, slope, soil, hydro-geomorphology, and lineament maps were prepared using Survey of India topo sheets. After integrating all thematic maps using the weighted overlay analysis tool, groundwater prospects maps were generated.

Using remote sensing, GIS, and MIF approaches, Magesh et al. (2012) identified probable groundwater zones in the Theni district of Tamil Nadu. MIF includes seven influencing factors: lithology, slope, land use, lineament, drainage, soil, and rainfall, identified to delineate potential groundwater zones. The interrelationship between these factors and their effects is weighted according to their strength. The representative weight of a characteristic of the potential zone is the sum of all weights from each element. A factor with a higher weight value shows a more significant impact, and a factor with a lower weight value shows a more negligible effect on potential groundwater zones. Integration of these factors with their potential weights is computed through weighted overlay analysis in ArcGIS.

The Groundwater Quality Assessment of Gangavalli Taluk, Salem District, Tamil Nadu, India was a 2013 project for Florence and Paul Raj. They used multivariate statistical techniques for this purpose. Groundwater samples collected from open wells, bore wells, and hand pumps for the Pre-Monsoon and Post-Monsoon periods were analyzed for their physicochemical characteristics. Each parameter was compared with the standard permissible limit of the parameter as prescribed by World Health Organization (WHO). The multivariate statistical tools such as Correlation Coefficient Analysis (CCA), Factor Analysis (FA), and Cluster Analysis (CA) were also used for the interpretation of water quality data and its spatial variations.

In order to analyse groundwater vulnerability in Coimbatore South Taluk, Tamilnadu, India, Murali et al. (2013) took a severe method. The study developed an empirical model DRASTIC to identify the vulnerability index owing to groundwater contamination with increasing population, industrialization, and agricultural activities. The most important factors for mapping that control the groundwater potential are depth of water, net recharge, aquifer media, soil media, topography, the impact of the vadose zone, and the hydraulic conductivity of the aquifer. Estimating the DRASTIC Index involves multiplying each parameter weight by its rating corresponding to its study area and summing the total. Based on DRASTIC index values, they observed that the vulnerability class in the study area falls between low vulnerability to high vulnerability. The results provided important information for the local authorities and decision-making personals to effectively manage groundwater resources.

In the Parbhani district of Maharashtra, Waikar et al. (2014) used remote sensing and GIS techniques to identify the groundwater potential zone. The information obtained from the parameters considered for identifying the potential groundwater zone such as geology, slope, drainage density, geomorphic units, and lineament density was generated using the satellite data and survey of India (SOI) toposheets scale 1:50000. It is then integrated with weighted overlay in ArcGIS. Suitable ranks are assigned for each category of these parameters.

In the Lekkur sub-basin of the Mangalur Block, Cuddalore district, Tamil Nadu, South India, Senthil Kumar et al. (2014) used GIS to analyse groundwater potential zones. All the thematic maps were such as geology, geomorphology, soil hydrological group, land use/land cover, and drainage map were prepared and converted into the grid (raster format) and superimposed by weighted overlay method (rank and weightage wise thematic maps). From the analysis, the groundwater potential zones with excellent, very good, good, moderate, and poor prospects.

Verma et al. (2013) assess the quality of the Lucknow, U.P., ground water using IRS-P6 and LISS-III to produce a map of land use and urban settlement. The ground water samples were collected from the selected locations and were analyzed for different physico-chemical analysis and a water quality index was prepared. Water quality index (WQI) was then calculated on the basis of WHO standards to classify suitability for drinking water. The WQI map was interpolated using inverse distance weight (IDW) method on GIS for spatial variation and suitability of quality assessment.

Murry (2013) used LISS-III data to create thematic maps and prepare groundwater prospect maps. In addition, Groundwater recharge was estimated using lumped Water Balance approach (GEC, 1997) and a distributed physical, hydrological model (VIC). Interpolation techniques such as IDW (Inverse Distance Weighting) and kriging were tested to obtain groundwater quality parameters.

A location for artificial recharge was found by Balachandar et al. Using Landsat data, drainage, lineament density, geomorphology, land use, and land cover were constructed for this purpose. Using digital image processing, the supervised, unsupervised Classification, band rationing, filtering, and NDVI Techniques for updating the all-thematic maps.

The IRS-P6 Image was utilized by Nag and Lahiri, 2011. to identify various hydro geomorphological units and a map of lineaments. Created DEM and by GIS overlay find suitable zones for groundwater potential.

LISS-III and PAN of IRS-1D were utilised by Prajit et al. (2013)

to determine ground water recharge by water harvesting structures.

Using remote sensing, GIS, and geoelectrical resistivity techniques, Srivastava et al. (2012) identified groundwater potential in the Dhanbad area of Jharkhand. Analyzing IRS LISS-II multi-band remote sensing data along with geological and geophysical resistivity sounding data carried out at places in the GIS environment.

Using RS and GIS methods, Sharma et al. (2012) discovered groundwater prospect zones in and around Gola block, Ramgarh district, Jharkhand, India.

IRS-IC, LISS-II, Landsat TM digital, and SRTM data were used by Biswas et al. (2012) for the delineation of groundwater potential zones in the Ganjam district of Orissa, India. Landsat ETM+ image was utilised by Jawad et al. to investigate groundwater.

The likelihood of groundwater was shown on a map by Oikonomidis et al. (2015) using five classifications that range from extremely high to very low in terms of groundwater potentiality. The extraction of this map is based on the study of input data such as rainfall, potential recharge, lithology, lineament density, slope, drainage density, and depth to groundwater. Weights were assigned to all these factors according to their relevance to groundwater potential, and eventually, a map based on a weighted spatial modeling system was created. Furthermore, a groundwater quality suitability map was illustrated by overlaying the groundwater potentiality map, showing the potential zones for drinking groundwater in the study area. The results provide essential information, and local authorities could use the maps for groundwater exploitation and management.

In their 2019 study, Nigam and Tripathi concentrated on finding prospective groundwater potential zones and a groundwater quality score that considered both quantity and quality. The Analytic Hierarchy Approach is utilized to identify the potential groundwater zones. Conclusively, 27.1% area falls under the low– medium groundwater potential zone, and 9.3% area falls under the permissible water quality limit. In total, 240 suitable water harvesting structures, namely storage tank (120 nos.), percolation tank (70 nos.), stop dam (34 nos.), and check dam (16 nos.) with their sites, were identified and suggested for water harvesting to enhance the groundwater conditions to meet the scarcity of water resources in agriculture and domestic use.

3. Remote Sensing and GIS Application for Water Resource Management

“Remote sensing (RS) is the science and art of obtaining information about an object, area, or phenomenon through the analysis of data acquired by a device that is not in contact with the object area, or phenomenon under investigation” (Lillesand et al., 2004) . Remote sensing is the science of acquiring information about the Earth’s surface without actually contacting it. It is done by sensing and recording reflected or emitted energy and processing, analyzing, and applying that information” (Canada Centre for Remote Sensing Tutorial).

The radiation emitted or reflected from various objects are of a different amount. Same the emitted or reflected radiations are recorded by multiple sensors. Multiple sensors have other type of bands which records specific ranges of electromagnetic radiation (EMR). Every radiation or light is made of Electromagnetic energy and reflected according to the surface or object interacted with. Generally, a smooth surface reflects more radiations; that’s why the tones recorded by the sensors are light. In the case of surface water, most of the radiations are transmitted through water, so they provide a generally dark tone. For the management and development of water resources, re- mote sensing data provides a platform for doing an initial and fast survey. Although very few remotely sensed data can be directly applied in hydrology, such information is of great value since many hydrological relevant data can be derived from remote sensing information. However, RS technology involves a large amount of spatial data management and requires an efficient system to handle such data. From the groundwater point of view, the occurrence and movement of groundwater are mainly controlled by many factors such as rock type, landform, geological structures, soil, land use, rainfall, etc. Remote sensing-based groundwater prospect zone map is a base for further exploration using hydrogeological and geophysical methods to locate well sites.

Remote Sensing data and GIS play a rapidly increasing role in hydrology and water resources development (Seth et al., 1999). Remotely sensed data are most useful when combined with numerical modeling, geographic information systems, and ground-based information (Becker, 2006). The selection of suitable sensors has a cutting edge on natural resource exploration and management, including groundwater (Mukherjee, 2008). Parameters relevant for hydrogeology are spatially distributed and may show significant temporal variability. Earth Observation (EO) data, when used jointly with in situ data, can provide an essential contribution for the creation of inventories of surface water resources, the extraction of thematic maps relevant for hydrogeological studies and models (land cover, surface geology, lineaments, geomorphology) or the retrieval of geophysical parameters; water quality, temperature, soil moisture, etc. (Gert et al., 2000). The concentration of drainage density and lineament density also help the infiltration ability of the groundwater system. Remote sensing, GIS, and MIF techniques are found efficient to minimize the time, labor, and money and thereby enable quick decision-making for Sustainable water resources management (Magesh et al., 2012). In the physical applications of imaging sensors, long-wave radar can sometimes detect groundwater levels at depths of a few meters and other subsurface features, such as buried channels (McCauley et al., 1982), but only if all conditions are suitable, i.e., coarse-grained deposits, a dry vadose zone without vegetation and some a priori knowledge of geology. Radar imagery has its general use in hydrogeology for the interpretation of geological structures (Koopmans, 1983; Drury, 1993).

4. Geographic Information System (GIS)

"A GIS is an organized collection of computer hardware, software, geographic data, and personnel designed to efficiently capture, store, update, manipulate, analyze, and display all forms of geographically referenced information." (Redlands, CA: Environmental System Research Institute, 1990). Geographic Information System is Computer hardware and software-based technology that collects, stores, analyzes, and displays spatial and non-spatial data and generalizes data for users.

GIS is a relatively new branch of technology. Land Information System (LIS) is a similar system. In 1960 Canadian Geographic information System (CGIS) was developed. In 1973 the United States geological society started the development of the geographical information retrieval and analysis system (GI-RAS) to handle and analyze land use and land cover data. With the growth in the application of topology for analyzing spatial data, GIS became a more useful tool. In 1982, the Environmental System Research Institute (ESRI) released the popular GIS software Arc Info. The advancement in the operating system, computer graphics, DBMS, computer-human interaction, and graphical user interface design. GIS has now become versatile, sophisticated, and user-friendly software.

GIS hydrological modeling was analyzed by Jenson S. K. and J. O. Domingue 1988, while Eli Robert N, 2000, gives a detailed analysis of the current state of the art and proposes a new algorithm based on relaxation processes. The interesting of all such work is that the basic information needed to begin with is the terrain surface represented by a digital elevation model (DEM).

Various GIS components are people, data, hardware, software, and methods. People are an essential component in a GIS; they must develop the procedures and define the task of the GIS. They can often overcome shortcomings in other components of the GIS, but the best software and computers in the world cannot compensate for the people's incompetency. The availability and accuracy of data can affect the results of any query or analysis. Hardware capabilities affect processing speed, ease of use, and the type of output available. The software includes existing GIS software and various databases, drawing, statistical, imaging, or other software. Analysis requires well-defined, consistent methods to produce accurate, reproducible results. Capturing of data (Digital format, Hard- copy, GPS, Vector and Raster formats), Querying data (Identifying specific features based on conditions), Analyzing data (Proximity, Overlay, Network), Displaying data (Maps, Graphs, and Reports), Output (Paper Maps, Images, Documents) are the function of GIS. Terrain modeling, hydrological modeling for quantity and quality, hydrodynamic modeling for flow simulation, the study of spatiotemporal variation, and providing management strategy in map form are techniques for acquiring topographic information of inaccessible areas.

The hydrologic modeling functions in ArcGIS Spatial Analyst provide methods for describing the physical components of a surface. The hydrologic tools allow identifying sinks, determining flow direction, calculating flow accumulation, delineating watersheds, and creating stream networks. Using an elevation raster or digital elevation model (DEM) as input, it is possible to delineate a drainage system and quantify its characteristics automatically.

Using the DEM as input into the flow direction tool, the direction in which water would flow out of each cell could be determined. With the Sink function, any sinks in the original DEM are identified. To ensure proper drainage mapping, these depressions can be filled using the Fill tool. Using the Watershed tool, the watersheds are delineated for specified locations. To create a stream network, use the flow accumulation tool to calculate the number of upslope cells flowing to a location. The output of the flow direction tool from above is used as input. A threshold can be specified on the raster derived from the flow accumulation tool; the initial stage defines the stream network system. This task can be accomplished with the con tool or using map algebra. Apply the stream order tool to represent the order of each of the segments in a network. The available methods for ordering are the Shreve and Strahler techniques. Using the flow length tool, the length of the flow path, either upslope or downslope, from each cell within a given watershed can be determined. It helps calculate the travel time of water through a watershed (ESRI).

5. Conclusion

Groundwater occurrence being subsurface phenomenon, its identification and location are based on indirect analysis of directly observed terrain features like geological and geomorphic features and their hydrologic characters of lithology, hydrogeomorphology, lineament have been taken up. Remote sensing provides an opportunity for better observation and systematic analysis of geomorphic units, lineament features, the integration with the help of GIS to demarcate potential groundwater zones. Furthermore, monitoring water quality can be achieved with remote sensing techniques, at least to certain extent.

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