Geological studies for groundwater exploration management and demarcation of groundwater potential
Review paper on groundwater exploration

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Contents

Abstract
The existing industrial and technological development is utilizing various resources at an extremely high rate for the human development. Therefore, the necessity of water is also mounting. However, the fact is always the same, because there are limitations to natural resources, specifically resources of water supply, which are now depleting at a considerable rate, as observed with depletion of the overground and underground water supplies in the terms of quantity as well as quality. The water supply mainly depends on the geographic and geologic locations of the source. The standard groundwater recharge approach has certain limitations. There are simple and wide applicable hydro-geological systems, when the remote sensing and GIS - Geographic Information System applications, and spatial distribution are considered. This study tries to identify and demarcate the prospective groundwater zones for recharge using the locations for artificial recharge, using various influencing parameters like soil, geology, drainage density slope, added minerals and that influence the groundwater recharge procedures. However, the process continues by demarcation of groundwater potential, so as to recharge the locations**,** thus categorizing them for the study area purpose into three zones, like good, moderate and poor, as per their appropriateness for recharge. The study has used to obtain the efficiency status of Remote Sensing and GIS technology to locate groundwater recharge locations.

1) Introduction and background

Groundwater records around 33% earth freshwater, and surface water from rivers and lakes account for nearly 0.4% (Shiklomanov, 1993).

Water is most vital resource, the prerequisite for development, economic and industrial growth, apart from the liquid necessary for the life of all human, animals and plants as food, nutrient, and health. The Groundwater is always available underneath the earth's surface, between rock and saturated soil, that supplies springs and wells. In places where surface water is in shortage, the groundwater constitutes the major part of active fresh water resource around the world. Hence, the entire humanity obviously depends on groundwater resources. The main stress for the groundwater started because of the domestic use, exploding irrigation, and industrial demands. Therefore, all kinds of water resources are explored to quench the thirst and basic water needs of billions of the populace.

The Land-Water resources are unevenly dispersed both temporally and spatially. The monsoon idiosyncrasies and diverse physiographies have given access to unequal water distribution. Due to urbanization, increasing population, agriculture and industrial expansion have heightened the situation. Therefore, the groundwater dependency will increase, while the water requirement of 2050 will be thrice the prevailing level (Gupta and Deshpande, 2004).

Further, the unscientific groundwater exploitation has generated more problems, as the water resource analysis is fragmentary. Hence, an integrated study on watershed groundwater recharge management is a crucial need by accessing remotely sensed field survey data using a GIS platform. The SST - Speck Spatial Tech has taken up a multi-disciplinary methods and developed watershed planning through the artificial recharge attempt using rainwater and ground water harvesting in 2600 square km section in 3 Chhattisgarh districts of India. They delineated 32 watersheds in Mahanadi basin, that allows us to understand the hydrology of aquifers, the underground layers of sediments and permeable rock that yields water, and help evaluate the quantity and quality of ground water.

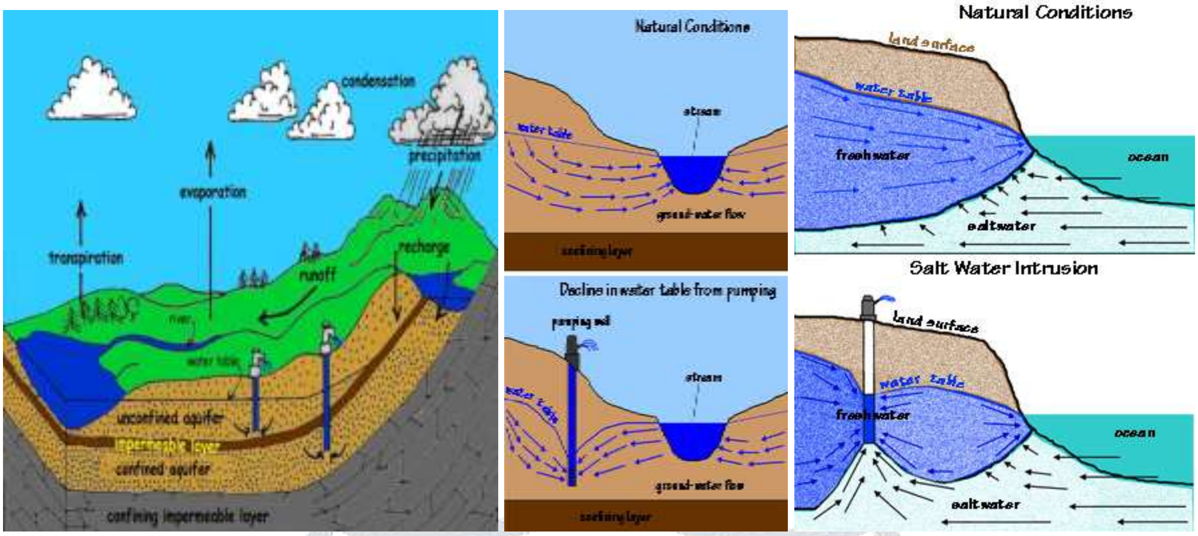


Figure 1, 2 & 3: The groundwater is mostly stored in aquifers (Badrinarayanan, 2014).

1.1 Geographic information systems and their application

Presently, in the absence of a national water policy, there is a lack of comprehensive groundwater assessments, and no specific governance in place to protect it from over-drafting and polluting from high arsenic contamination. Hence, the most challenging task is about enforcing regulations. An estuary, the lower river course where the river current joins the sea tide, gets polluted by construction, industry, garbage, agriculture, and waste disposal. Also, industrial chemicals, sediments, waste, and disease organisms generate the maximum watershed pollutants. The chemicals released into the rivers flow all the way to join the oceans. The pollution remains in the estuary due to the tides affecting it. Tidal currents are likely to hold polluted water in the same zone, shifting it downstream and upstream.

Recharge of Groundwater / deep percolation / deep drainage is the Hydrological process when water shifts from the surface downwards towards groundwater and enters an aquifer. Such process occurs specifically below the plant root vadose zone, expressed as water flux water table surface. The Recharge is a natural process occurring through the water cycle, and anthropogenic process, an artificial recharge of groundwater, when the rainwater together with reclaimed water gets routed towards the subsurface. Depression generated groundwater recharge is essential in arid regions, where plenty of rain water contributes to groundwater supply. It also considerably affected by pollutants and contaminant movements into groundwater. This concern with Karst geological configuration, the topography generated after dissolving soluble rocks like dolomite, limestone and gypsum in groundwater, and they ultimately dissolve into tunnels of aquifers, or enter disconnected streams (LaMoreaux, et al., 2001).

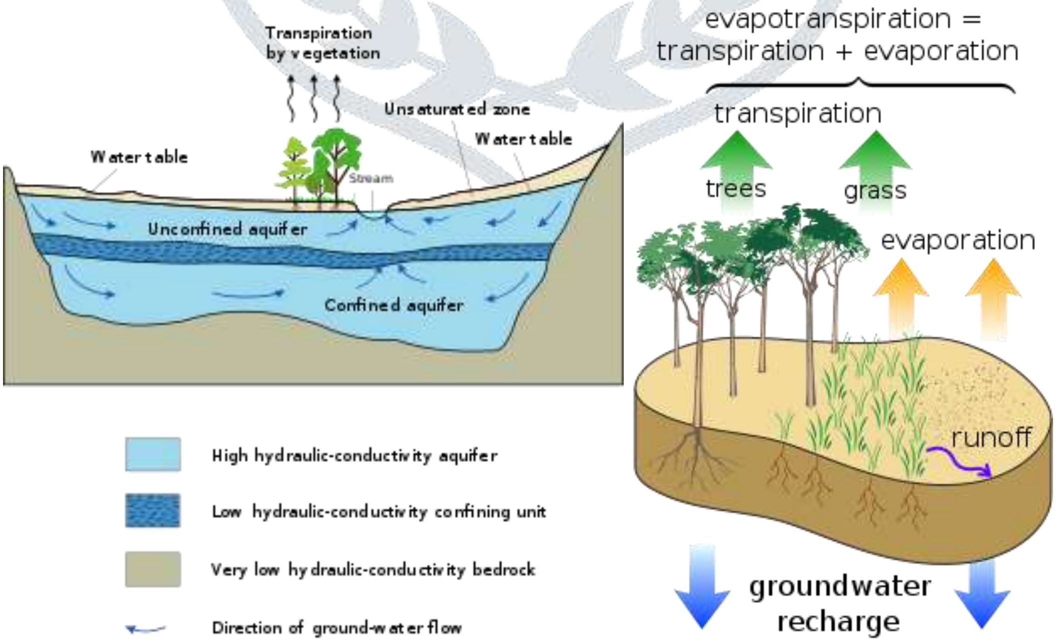


Figure 4 & 5: Groundwater Recharge (Badrinarayanan, 2014)

This extreme kind of form preferred flow, accelerates contaminant movements eroding the tunnels. Hence, the depressions meant to confine runoff water before flowing towards vulnerable resources of water connects groundwater over time. The

Cavitation by forming bubbles and vapor cavities in the water in the tunnel, creates caves and potholes. Further deep pounding develops pressure forcing water in the ground quickly, dislodging contaminants that get absorbed by the soil to carry along. They carry pollutants to elevate the water table into the supply zone of groundwater. Hence, the water quality collected in infiltration basin is important.

Stormwater pollution gets collected in retention basins, and concentrated degradable pollutants accelerate bio-degradation. When water tables are soaring, it affects proper designs of retention ponds, detention ponds, and rain gardens (Glynn & Plummer, 2005).

1.2 Past History

The ground water exploration used in the 6th magnum opus century by the use of Geo-botanical method since ancient Rig, Adharvana Vedas, by Varahamihira, the versatile Astronomer. Bharat Sanhita illustrates the termite mounds linked with Neem and Palm trees act as proper hydrology indicators.

In the developing country similar to India, the minimum daily need of domestic water per person is around 210 liters, while the same quantity is needed for other different purposes. From the estimated water quantity of 1122 billion cubic meters used in India yearly, 440 billion cubic meters are obtained through the surface sources and the remaining obtained from the ground water sources (TWAD Hydrogeologist Hand Book, 2002).

The water resource development initially started first in Egypt and India, when the open wells for drinking water and irrigation system was applied as early as 6,000 years ago during the Mahabharata period. The modern ways of ground water exploitation started extensively after 1935, when the first tube well was done in Uttar Pradesh.

2) Objectives

1. To conduct Geological studies for groundwater exploration management
2. To Investigate, and study the ground water formation, identification and exploration.
3. To survey, study and understand the phases of regional survey;
4. To study and understand various Hydrological cycles, water strata in the regions, to get the overall concept about the water strata region, concerning the nature, type, aquifers, to understand the water quality.
5. To study demarcation of groundwater potential.

3) Demarcation of groundwater potential

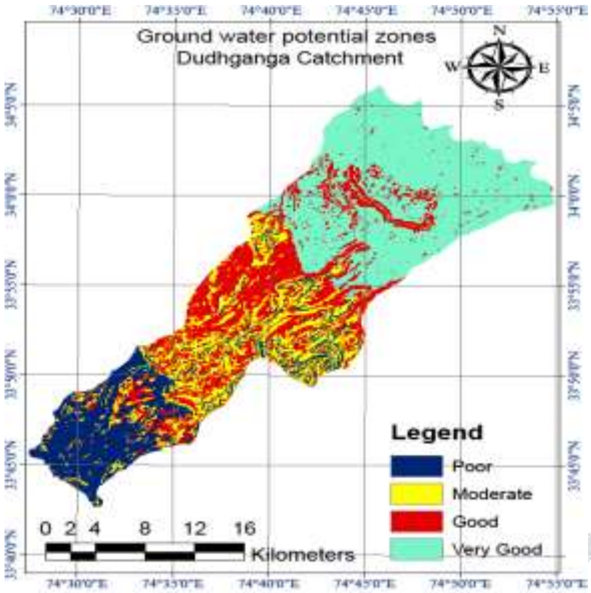
The water scarcity around the world have been aggravated by the contamination and water pollution problems. This situation is leading towards the fresh water crisis, particularly because of improper water resources management added by environmental degradation, resulting in shortage of safe, harmless supply of potable water to billions of people. The crisis of freshwater is very evident in several states of India, as they vary in intensity and scale. The groundwater amount and movement in the specific regions regulated by various factors like Lithology of rock formation, underground Geological Structure, topography, Surface features of groundwater regions, slope, weathering depth, LULC - Land use and Land Cover, and all other interrelated factors (Jasmin & Mallikarjuna, 2011).

In the case of Earth Sciences, the surface of the earth or surrounding atmosphere is constantly observed from outer space by satellites means, and from aircrafts (Gandhi & Sarkar, 2016). The groundwater, to the tune of around 82 billion gallons is withdrawn in the USA, per day. It is equivalent to 25% of daily freshwater withdrawal (Kuwayama et al., 2014).

Integrating Remote Sensing data with GIS - geographical information system to explore groundwater resources is the a breakthrough science in the groundwater research field, which helps to assess, monitor, and conserve different groundwater resources. The GIS method uses the computerized system to capture, store, analyze and display geographical referenced sequences and identifies the data as per the location (Haroon et al., 2014).

Potential Zones in Dudhganga Catchment,

Innumerable groundwater potential regions have been explored to access the groundwater availability in the Theni district of Kashmir Valley, India, were delineated applying remote sensing as well as GIS techniques (Rao & Latha, 2013).



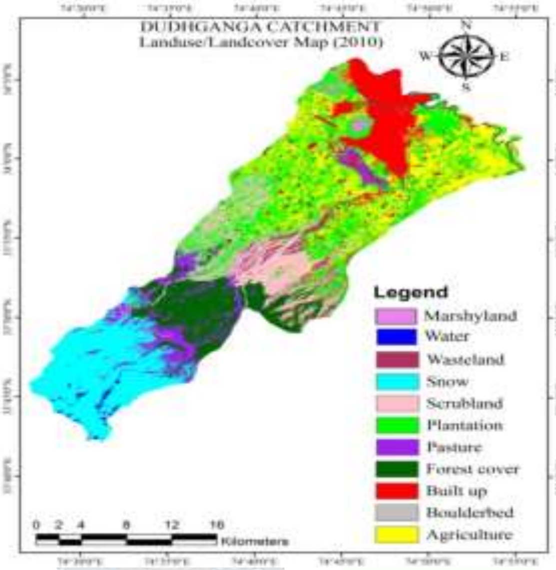


Figure 6: Groundwater Potential Zones, Figure 7: LULC - Land Use and Land cover (Sajjad, et al., 2014)

IRS-1C satellite imaging with Topological sheets of Survey of India are utilized to organize several thematic layers like Slope, Lithology, Land-use, Drainage, Lineament, Soil and Rainfall measures. The information gets converted to features of raster data, applying ArcGIS raster converter tool. The raster maps factors allocate a fixed weight and score worked out through MIF - Multi Influencing Factor technology. Every subjective thematic layer is numerically calculated to obtain the potential groundwater zones, which can be bifurcated into four segments, like, Poor, Moderate, Good, Very Good zones. The findings give a clear picture of potential zones of groundwater in the respected regions, and their help in proper management and planning of groundwater resources.

LULC - Land Use and Land Cover

The LULC area gives a vital link to the amount of groundwater availability, utilization and requirement (Narendra et al. 2013). Considering the synoptic observations through remote sensing techniques can easily provide a multi-spectral facts, which are normally used to classify LULC. The above Figure 7 provides the LULC map of the complete catchment region generated and subsequent statistical data as per the below Table provides the precise details obtained through the image processing software (Preeja et al., 2011).

LULC - Land Use and Land Cover shows the areal extent		
Classes	**Area**	
	Hectares	**Percentage**
Built Up	7475	11.33
Agricultural	9733	14.75
Forestation	6297	9.55
Boulder Bed	553	0.85
Plantations	17544	26.45
Pasture	4465	6.77
Scrub Land	6924	10.35
Wasteland	1954	2.97
Snow	10373	15.58
Water	598	0.92
Marshy Land	384	0.58

The main use of land and land cover classes like 11.4% built up land, 14.8% agricultural land, 26.5% plantation area, 9.6% forest land, 10.3% scrub land, 6.8% pasture, 2.8% wastelands and 0.95% water bodies were known. For the concept of land use, plantation with agriculture becomes a good place to explore groundwater. The water body areas, suffice for better groundwater recharge. Around 67% catchment area with agriculture, plantation, scrub land, forest and water bodies show an excellent groundwater potential. The ranks and weights are based on groundwater prospective zones (Dar et al., 2010).
The direct relief suggests the ruggedness of terrain, featured by the steep topography and hydraulic gradients with the relief increase. The lower parts of relief zones, having 1558 meters to 2388 meters elevation of 71.45%, are known to have a softer grassy crayon, Lithology, which permit additional scope for groundwater recharge, while the higher relief area having an elevation from 3022 meters to 4665 meters comprise 19.35 % area, and contain massive, hard rock formation of runoff zone.

This kind of prior knowledge makes the water availability more possible by influencing different terrain parameters for the water movements, advancement, collection, and to get better groundwater yield. The ranking of several parameters with their subunits gets evolved for modeling of groundwater prospects. To demarcate various prospective groundwater zones, every thematic layer like slope, drainage density, Lithology, topography, LULC and their respective elevations are integrated in Arc GIS by Spatial Analysts (Chowdhury et al., 2009).

There are several methods, but the ground water exploration accomplishment depends mainly on the geological methodology applied and field conditions. The parameters like land formation, geological structure, slope, lineament, soil formation, weathered zone, these all dominate and influence the occurrence of ground water. By geographical information, the water movement can be integrated to locate potential zones of ground water. GIS - Geographic information system, relies on computer for processing and storage of data, and is the best and powerful technique to assess the stability analysis of ground water. GIS provides geographical input, capturing tabular and geographic data storage- Type Victor and Raster, and display results in the formats of Reports, Graphs and Maps.

Methods & Devices of Groundwater Exploration

Aerial	**Surface**	**Below Surface**	**Esoteric**
Photo-Geologic procedure	Geological Procedure	Geological	Water Divining
Landsat and IRS	Geo-Morphological Procedure	Hydro-Geological Method	Astrological Method
Infrared Imagery	Hydro-Geological Procedure	Tracer Technique	Biophysical
EM- Electro Magnetic Techniques	Bio-physical Procedures	Geophysical Logging Techniques	
	Electrical & EM - Electro Magnetic Seismic Magnetic Gravity		
	Geo-Botanical Procedure		
	Geo-Chemical Procedure		

4) Methodology and Techniques

The geophysical techniques applied for groundwater investigation measure variations in rocks and soil and can be bifurcated into a matrix component to understand the pore contents. Different materials indicate specific parameters like acoustic velocity, density, resistivity, conductivity, and magnetic permeability. They are influenced by the type of minerals in water, surrounding grain packing, permeability, porosity, pore contents, like fluid or gas. Hence, the water property is always unique (Gautam et al., 2010).

To investigate groundwater, the most important parameters used to describe an aquifer system is related to permeability and porosity of the aquifer with surrounding Aquitard, the stratum of sediment Electrical conductivity, and resistivity, are the proportional factors and they relate to electrical current to be applied to the water flowing medium, and decided by the electrical charge to pass through a porous material (Allis et al., 1986). A relationship between fluid type and electrical conductivity (Wurmstich & Morgan, 1994), aquifer material properties indicate a clear connection between resistance developed by by and the aquifer hydraulic conductivity (Yang et al., 1994). Seismic velocity relates to material density and elastic moduli, with wave compression velocity correlates with porosity and contents of fluid (Young et al., 1998).

By successfully using geophysical techniques with the careful survey design, the number of key cultural and geological factors and the geophysical data can be gathered. Those factors include: (1) Nature of the target; (2) Depth of burial of target; (3) Target Size; (4) Measurement station interval; (5) Data Calibration.

Magnetic techniques assess residue magnetic field linked with ground water material, indicated by a shift in the Earth's magnetic field connected with the geological structure. Magnetic surveys also can be used to identify strata faults and the crustal weakness location in the water flow paths.

The gravity methods or micro-gravity technical surveys can record the changes in material density of materials, but they are not widely used for groundwater application.

Electromagnetic and Electrical techniques are extensively applied in groundwater applications and geophysical investigation due to correlation exists between geologic formations, electrical properties, and the water content (Yadav & Abolfazli, 1998).

5) Research Views

The groundwater depletion in northern China had reached catastrophic levels. The pumping of groundwater accounted to 30 billion cubic meters per a year, as across the wider region, the water tables had dropped more than two meters each year for almost 10 years, while the water demands were rising. Therefore, the government of China applied GMEP – an improved Groundwater Assessing and managing tools, because it showed better planning and observation tools to assist the decision makers.

The two major technically specific tools were involved in this Groundwater Exploration and Management Packages and they were WEAP and GRACE. The WEAP- Water Evaluation And Planning method is very easy to operate package as it is simple and user-friendly. GRACE is a satellite information and collection method and formed the basics in GMEP for the prevailing and the previous groundwater trends exhibited so far. These packages were applied to evaluate the present and future alternatives for the sustainable and easy to operate groundwater management. The aim of this project was to demonstrate that by effective planning and better observation tools they can help decision makers to locate and assess the grand water parameters very easily (Droogers & Hermans, 2008).

6) Conclusion

Thus, there are many techniques and methods to explore the potential of gauging ground water availability and potential. For the successful ground water exploration, it entirely depends on the methodology applied depending on the field, strata and geology conditions. The exploration process initially starts with drilling stage, followed by development and eventually well completion. If the explored water is exploited properly, correctly and thereafter, managed properly, the sources can be made available for many more decades (Badrinarayanan, 2014).

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