CHAPTER 2

LITERATURE REVIEW

Several works have been reported in the literature for assessment of groundwater level, delineation of groundwater potential zone, analysis of groundwater quality and land use / land cover changes. The following are only a brief review of the work reported in the context:

2.1 Studies on assessment of groundwater level

Lanyon et al., (1982) have attempted the observation of two-dimensional variations in groundwater level on beach profiles at South Beach, Wollongong, support and extend observations previously reported. Time-series curves showing water-level change at individual wells along the profiles are markedly asymmetrical and their ranges of oscillation are dependent on tidal range and distance landward of the beach face. The asymmetry is attributed to filtering processes at the beach face and in the beach that separate the various tidal constituents. Tidally induced groundwater changes are superimposed on a three-dimensional water-table surface that is tied to the beach morphology and groundwater recharge from the backshore zone. The groundwater rise begins earliest in shoreline embayment and spreads landwards and outwards to higher water-table surfaces near shoreline salient and in the backshore zone. Groundwater responses, therefore. Differ on the salient and in the embayments: a landward water-table slope prevails in the embayments and a seaward slope characterizes the salient.

Nevulis et al., (1989), studied the analysis of groundwater level time series for the purpose of obtaining details for a conceptual hydrogeologic model at a time when conventional hydraulic stress testing was not feasible due to regulatory considerations. The study area is located in south-central Washington in the Pasco Basin which was a candidate site for underground disposal of high-level radioactive nuclear wastes. Through this approach, natural and incidental man-made groundwater level variations, most of which are quite small, are examined by statistical and analytical methods in conjunction with hydrogeologic models to draw inferences on the hydrogeology. Vertical connectivity of the hydrostratigraphic units is also examined by analyzing the groundwater level time series of five units at three piezometer nests. It is concluded that a combination of statistical/analytical approaches used in a complementary fashion can provide useful information about the hydrogeology of a given area.

Van der Kamp and Maathuis, (1991) worked on the long-term hydrographs for deep confined aquifers in southern Saskatchewan, Canada, show annual fluctuations characterized by a gradual rise in the head from October to May/June and a rapid drop from May/June to October. These fluctuations are distinctly different from the seasonal fluctuations observed in surficial and shallow semi-confined aquifers, which reflect the response of these aquifers to recharge derived from snowmelt and early spring rains. On the basis of field data and theoretical considerations, it is demonstrated that seasonal fluctuations of the water table are not transmitted down to the deep aquifers, provided the confining layers are thick and have sufficiently low hydraulic diffusivity. The annual fluctuations in the deep aquifers thus do not reflect seasonal recharge to these aquifers. It is postulated that the annual head fluctuations in the deep confined aquifers reflect changes of the mechanical load on the formations, caused by seasonal changes of the soil moisture, snow, and storage at the water table. The deep confined aquifers thus act as large-scale, inexact, weighing lysimeters.

Li and Jiao, (2002) presented an analytical solution to describe tidal groundwater level fluctuations in a coastal leaky aquifer system bounded by water–land boundaries that form a right angle (referred to as L-shaped coastlines). The system consists of an unconfined aquifer, a confined aquifer and a leaky layer between them. Previously published analytical solutions that discuss only single aquifer constitute a special case of the new solution when the permeability of the leaky layer approaches zero. A simple approximate solution without integral is presented. Error analysis and hypothetical example show that the approximate solution has adequate accuracy for both groundwater level prediction and parameter estimation for an L-shaped leaky aquifer system.

Jan et al., (2007) investigated the relationship, we first employed the BAYTAP-G program to filter out the response of the groundwater level to non-rainfall effects, such as barometric pressure and earth tide. Because both the present and antecedent rainfall events give an impact on the groundwater level increment, an effective accumulated rainfall amount was defined to account for their influences using the exponential-decay weighting method. The resulting groundwater level, conventionally termed the residual groundwater level, was found to linearly depend on the effective accumulated rainfall amount. Lastly, we demonstrated that rainfall occurring beyond the surface watershed within which the Donher well station locates indeed affects the residual groundwater level.

Shamsudduha et al., (2009) resolved trend and seasonal components in weekly groundwater levels in the Ganges-Brahmaputra-Meghna (GBM) Delta, we apply a nonparametric seasonal-trend decomposition procedure (STL) to observations compiled from 1985–2005 in Bangladesh. Seasonality dominates observed variance in groundwater levels but declining groundwater levels (>1 m/yr) are detected in urban and peri-urban areas around Dhaka as well as in north-central, north-western, and south-western parts of the country (0.1–0.5 m/yr) where intensive abstraction of groundwater is conducted for dry-season rice cultivation. Rising groundwater levels (0.5–2.5 cm/yr) are observed in the estuarine and southern coastal regions. This novel application of the STL procedure reveals, for the first time, the unsustainability of irrigation supplied by shallow aquifers in some areas (e.g., High Barind Tract) of the GBM Delta and the hydrological impact of potential seawater intrusion of coastal aquifers associated with sea-level rise.

Bhuiyan, (2010) carried out a study to the assessment of relations between water-level fluctuations (WLF) with various hydrogeological factors that is not straightforward. In the present study, various hydrogeological factors that could influence aquifer recharge in the deformed crystalline Aravalli terrain of India have been analyzed. Frequency plots have been used to assess the variations in WLF under different geological parameter classes. Seasonal WLF associated with these factors have been compared using various statistical parameters. Parametric and non-parametric statistical tests have been used to determine the statistical significance of fluctuation difference. The study infers that saturated thickness, lineament, lineament-intersection, and drainage beside surface elevation and well depth are the main geological factors influencing aquifer recharge in the Aravalli terrain. Median values under these factors are integrated and compared with the interpolated values of mean WLF at hypothetical well locations. They are found to closely resemble each other. This infers the capability and applicability of the technique in identifying key factors governing WLF, and in predicting WLF at unexplored locations.

Tiwari et al., (2015) evaluated the parameters which have significant impact on groundwater level fluctuation in West Bokaro coalfield by using remote sensing, GIS, and field-based water level data for two seasons. The objective is achieved by preparation of thematic maps of parameters which have significant impact on groundwater level fluctuation viz. geology, drainage map, soil map, slope map, and elevation map using digital elevation model and Survey of India Toposheet in GIS and analyzed with respect to field-collected groundwater level data to determine the overall water level situation of the study area. Based on results and discussion, it has been found that the northwest, southwest, and central region of the study area show higher water level fluctuation (WLF) whereas the northeast and southeast regions have shown lower WLF. Thus, the study have shown that there is definite relationship of WLF with the above-mentioned parameters which are physically related to slope and elevation, lithologically related to geology, texturally related to soil, and hydro-geologically related to drainage pattern.

Tiwari et al., (2017) studied the groundwater-level monitoring has been carried out on 26 observation dug wells in the Aosta Valley region, Italy, during the dry season (June 2013) and wet season (November 2013) in order to assess the water-level fluctuation (WLF). The depth to water level varied from 3.04 to 28.70 meters below ground level (mbgl) in the dry season and from 2.92 to 25.62 mbgl in the wet season. The WLF of the study area varied from 0.01 to 6.80 mbgl, and the western and north-western regions of the study area showed higher WFL. The WLF map was validated with a statistical analysis and elevation value of the area in a geographic information system environment, and this indicated that validation can be accepted for the WLF in the Aosta Valley. The results of the study demonstrated that the eastern region could be considered as a safe and good recharge zone for the groundwater in the Aosta Valley region.

Prasad and Rao, (2018) monitored for groundwater levels at 41 observation wells during 2013–2015. Along with groundwater levels, the daily rainfall data is also collected for these years. A continuous decrease in groundwater levels was observed during the study period more particularly in the year 2015 which also had minimum rainfall. Groundwater depletion is observed mostly in the Eastern and South Western part of the basin where pumping wells are more. Groundwater balance studies have indicated that 11.3 MCM of groundwater can be utilized in the basin annually. However, the net annual groundwater draft has been found to be 16.6 MCM. Hence, over-abstraction of 5.66 MCM is the main cause for depletion of groundwater levels.

Anand et al., (2020) worked on the long-term trend detection and spatiotemporal variation of groundwater levels were analyzed using Geographical Information System (GIS) and performing statistical tests for the Lower Bhavani River basin, Tamil Nadu, India. For this purpose, 32 years of long-term groundwater-level data (1984–2015) of 57 observation wells spread over the study area were collected from the government departments. Seasonal variation of groundwater levels was plotted spatially for pre-monsoon (March to May), post-monsoon (January and February), southwest (SW) monsoon (June to September) and northeast (NE) monsoon (October to December) seasons using GIS. The trend variation of groundwater levels was predicted by performing statistical tests such as Mann–Kendall test and Sen's slope estimator. The present study indicates that the average annual groundwater level has lowered beyond 15 m (below ground level) during all the monsoon seasons in the years 2003 and 2004, which highlights less rainfall infiltration and overexploitation of groundwater. This leads the hard rock aquifer into stress. The study also shows that the groundwater fluctuation is very high in the southeastern and north-eastern parts of the basin, and it is moderate in the northern and north-western parts of the basin. However, the fluctuation is comparatively less in the central part of the basin because of the replenishment of groundwater by the Bhavani River. The trend analysis highlights that the declining water table is mostly found during the SW monsoon season (summer season), which is observed more than 50% area of the basin. The places such as Emmampoondi, Kumbapanai, Kandisalai, Alukuli, Perikoduveri, P.Mettupalayam, Pudupalayam, Sathyamangalam, Nallagoundanpudur, Kullampalayam and Baguthampalayam are mostly affected by the declining trend in the groundwater level. Therefore, this study recommends for the implementation of large-scale rainwater harvesting system in the Lower Bhavani River basin to augment groundwater resources.

2.2 Studies on delineation of groundwater potential zone

Sondhi et al., (1989) have determined the available additional groundwater potential and its distribution in the Mahi Right Bank Canal Project in Gujarat is presented. The procedure is based on the use of specific empirical constants for estimating groundwater recharge from the water conveyance and distribution system and the annual water balance of the project. The spatial distribution of groundwater potential is determined by "recharge distribution coefficients" derived from a digital simulation model of the groundwater basin of the project area. The annual groundwater potential are obtained in the Mahi Right Bank Canal project in India is about $265 \times 106\ m^3$. This is about 1.6 times the existing level of groundwater abstraction. The spatial distribution of this potential over the project area is not uniform. It is relatively high in the central and southern portions of the project area and is low at the northern and western boundaries.

Panigrahi et al., (1995) used the information collected from a survey of India Toposheet and by visual interpretation of satellite imagery of bands 2, 3 and 4, different thematic maps such as geomorphology and lineaments, drainage and land use, and land cover were prepared. These thematic maps have been superimposed and finally a groundwater potential zone map delineated on a survey of India Toposheet. The whole block has been demarcated into 5 zones. Zones 1 and 2 are considered ideal groundwater potential areas, zone 3 is moderately ideal, and zones 4 and 5 are unfavorable for groundwater exploration. The validity of the demarcation of the study area into different zones, as decided by remote sensing technology, has been justified by analyzing the geo-resistivity-sounding data of a number of places in this area. The net potential of the study area is estimated by the GEC norm. It is observed that only 11.8% of annual utilizable groundwater is now used and there is vast scope for further exploitation of this resource.

Shahid et al., (2000) used the Geographical Information System (GIS) integration tool is proposed to demarcate the groundwater potential zone in a soft rock area using seven hydrogeologic themes such as lithology, geomorphology, soil, net recharge, drainage density, slope and surface water bodies. Except for net recharge and slope, the other five themes are derived from remote sensing data. IRS-1B LISS-II data was used for a 631 km^2 area in Midnapur District, West Bengal, India. While the slope was calculated using topographic sheets, net recharge was obtained from annual water table fluctuation data. Each feature of all the thematic maps was evaluated according to its relative importance in the prediction of groundwater potential. The evolved GIS-based model of the study area was found to be in strong agreement with available borehole and pumping test data.

Murthy et al., (2003) used remote sensing data combined with the Geographical Information System (GIS) technique to the identification of groundwater potential of any area. In this study, IRS IA, LISS II data has been used to identify the groundwater potential zones by integrating various thematic maps generated on 1"50,000 scales. These maps are integrated after assigning weight factors to the identified features in each thematic map depending upon their infiltration capacities and the groundwater potential zones in the Bhamini Mandal (developmental block) of Srikakulam district, Andhra Pradesh are demarcated. The area of investigation has been classified into seven groundwater potential zones. The present results show that integration of all attributes provides more accurate results in groundwater potential zones identification.

Vittala et al., (2005) evaluated to delineate groundwater potential zones based on the characteristics of geomorphic units together with slope, geology, lineaments, bore well data using Remote Sensing and Geographic Information System (GIS) techniques. The slope varies from nearly level (0-1%) to very steep (>35%). The different geomorphic units in each sub-watershed consist of denudational hills, residual hills, inselbergs, pediment inselberg complex, pediments, shallow weathered pediplains, moderately weathered pediplains and valley fills. The lineament map for each sub-watershed has been prepared and the trends were analyzed with rose diagrams. The analysis of bore-well locations and their yield data in association with lineaments at sub-watershed level reveals that the lineaments are acting as a pathway for groundwater movement. The integrated map comprising groundwater potential zones prepared by "Union" function using GIS indicate that valley fills and moderately weathered pediplains are very good to good, shallow weathered pediplains are good to moderate, pediment inselberg complex and pediments are moderate to poor and denudational hills, residual hills and inselbergs are poor to very poor groundwater prospect zones.

Prasad et al., (2008) carried out a study to delineate groundwater potential zones in hard rock terrain using the integrated approach of Remote Sensing and geographical information systems (GIS).The remotely sensed data at the scale of 1:50,000 and topographical information from available maps have been used for the preparation of groundwater prospective map by integrating geology, geomorphology, slope, drainage-density and lineaments map of the study area. Further, the data on yield of the aquifer, as observed from existing bore wells in the area, has been used to validate the groundwater potential map. The final result depicts the favorable prospective zones in the study area and can be helpful in better planning and management of groundwater resources especially in hard rock terrains.

Magesh et al., (2012) studied the various groundwater potential zones for the assessment of groundwater availability in the Theni district have been delineated using remote sensing and GIS techniques. Survey of India Toposheet and IRS-1C satellite imageries are used to prepare various thematic layers viz. lithology, slope, land-use, lineament, drainage, soil, and rainfall were transformed to raster data using the feature to raster converter tool in ArcGIS. The raster maps of these factors are allocated a fixed score and weight computed from multi influencing factor (MIF) technique. Moreover, each weighted thematic layer is statistically computed to get the groundwater potential zones. The groundwater potential zones thus obtained were divided into four categories, viz., very poor, poor, good, and very good zones. The result depicts the groundwater potential zones in the study area and found to be helpful in better planning and management of groundwater resources.

Kaliraj et al., (2014) utilized the application of the Analytical Hierarchical Process (AHP) on geospatial analysis for the exploration of potential zones for artificial groundwater recharge along the Vaigai upper basin in the Theni district, Tamil Nadu, India. The morphology of earth surface features such as geology, geomorphology, soil types, land use and land cover, drainage, lineament, and aquifers influence the groundwater recharge in either direct or indirect way. These thematic layers are extracted from Landsat ETM+ image, topographical map, and other collateral data sources. In this study, the multilayers were weighed accordingly to the magnitude of groundwater recharge potential. The AHP technique is a pair-wise matrix analytical method was used to calculate the geometric mean and normalized weight of individual parameters. Further, the normalized weighted layers are mathematically overlaid for preparation of groundwater recharge potential zone map. The results revealed that 21.8 km^2 of the total area is identified as high potential for groundwater recharge. The gentle slope areas in middle-east and central part have been moderately potential for groundwater recharge. Hilly terrains in the south are considered as an unsuitable zone for groundwater recharge processes.

Sar et al., (2015) studied the various groundwater potential zones for the assessment of groundwater availability in the Keleghai river basin have been delineated using remote sensing (RS) and geographic information system (GIS) techniques. Survey of India (SOI) Toposheet, field observations and satellite imageries are used to prepare various thematic layers viz. (a) drainage density, (b) geomorphology, (c) lineament density, (d) land use/land cover, (e) soil type, (f) water bodies density, (g) normalized difference vegetation index (NDVI), (h) slope and (i) mean annual rainfall were transformed to raster data using the feature to raster converter tool in ArcGIS platform. The thematic maps have been ranked in a scale of 1–9 depending upon their suitability to hold groundwater. The rank of each map has been converted to a probability weight using Bayesian Decision Theory. Integration analysis was carried out using the overlay-intersect method and a composite groundwater potential map was generated. The composite potential index was obtained by multiplying weightages with rank numbers of each category and summing up the values of all categories. The resultant final map indicates the potentiality of groundwater occurrence in the study area. This map was then classified into five categories based on the groundwater potential index value.

Senanayake et al., (2016) carried out a study to delineated potential artificial recharge sites in the Ambalantota area within Hambantota using a GIS approach. Influential thematic layers such as rainfall, lineament, slope, drainage, land use/land cover, lithology, geomorphology and soil characteristics were integrated by using a weighted linear combination method. The results of the study reveal high to moderate groundwater recharge potential in approximately 49% of the Ambalantota area.

Das et al., (2017) carried out a study to delineate groundwater potential zones in Hingoli district, Maharashtra, India. Remote sensing and traditional data were collected from different sources and analyzed in GIS software to prepare thematic maps of different geo-environmental factors such as lithology, drainage, lineaments, slope etc. as these factors having an impact on groundwater availability of an area, directly or indirectly. All these factors have been integrated into GIS software and multi influence factor method was applied to delineate groundwater potential zones. The result has shown about 50% area is having a good potentiality of groundwater, whereas about 6% of the region falls under the very low potential area. The Central part of the study area is having very low groundwater potential, mainly due to the steep slope and rocky outcrop. The southern part of the Hingoli district has shown good groundwater potential, because of the gentle slope which influences water to infiltrate. All the major towns and villages are located in good groundwater prospect areas. Therefore, these locations do not experience extreme drought conditions.

Kumar and Krishna, (2018) carried out a study to delineate groundwater potential zones using geospatial technology and analytical hierarchy process (AHP) techniques in mining-impacted hard rock terrain of Ramgarh and part of Hazaribagh districts, Jharkhand, India. Relevant thematic layers were prepared and assigned weight based on Saaty’s 9-point scale and normalized by the eigenvector technique of AHP to identify groundwater prospects in the study area. The weighted linear combination method was applied to prepare the groundwater potential index in the geographic information system. Final groundwater prospects were classified as excellent, very good, good, moderate, poor and very poor groundwater potential zones. The study thus revealed that the excellent, very good and good groundwater potential zones, respectively, cover 148.3, 373.66 and 438.86 km^2 of the study area, whereas the poor groundwater potential zone covers 180.05 km^2.

Anbarasu et al., (2019) carried out a study to delineate the groundwater potential zones in the Chinnar River basin of Perambalur district, southern India, using remote sensing and GIS methods. Toposheet and satellite imageries were used to prepare various thematic maps such as geology, soil, drainage density, slope, lineament density, geomorphology, and land use. These data were combined with the weighted overlay method to demarcate the groundwater potential zones. The multi-influencing factor (MIF) method was used to derive the weights for the seven layers, and ranks were assigned to the features within the layers based on local knowledge and from literature. The study suggests that the geology, slope, land use, and geomorphology features play a major role in determining the availability of groundwater in the study area. The groundwater potential was high in 54%, medium in 21%, and low in 25%of the study area. The groundwater level fluctuation that varies based on the rainfall and different rock types was used to validate the groundwater potential map. Areas with high groundwater potential had the lowest groundwater fluctuation compared with the medium and low groundwater potential areas.

2.3 Studies on water quality assessment

Sgambat et al., (1980) was studied the past effects and the possible future effects of underground coal mining activities on groundwater resources in the region east of the 100th meridian. Such effects are highly dependent on the location of the mine with respect to natural flow system. In these cases, secondary fractures extend up through overlying strata and may increase rock permeabilities by several order of magnitude. Lowered groundwater levels around active mines commonly do not recover to pre-mining conditions after closure. Studies indicate that contamination of groundwater exists in many places in the immediate vicinity of coal mines. The nature and extent of the contamination is governed by the geochemistry of the individual seam being mined, the nature of the flow around the mines, the presence or absence of calcareous material in associated strata and the time contact with various minerals.

Schubert and Prodan, (1981) carried out systematic studied to assess Hydrologic and water quality monitoring at an abandoned refuse disposal site in south-western Illinois was conducted six months prior to and four years following grading, liming, covering, and revegetating the site. Although the coal refuse lay unreclaimed at the site for over 50 years, contamination of groundwater from acid leachates was not detected more than 150 m from the gob pile. The hydraulic conductivity was low enough and the neutralizing capacity of the underlying calcareous, silty - clay till was great enough to prevent further subsurface migration of the acid leachates. The effects of the 1977 site reconstruction on groundwater was monitored using 47 piezometers and 16 residential wells. Rapid acidification of parts of the basal portion of the graded refuse and underlying till were observed. However, some improvements have occurred in this area since 1979. Water quality in the slurry disposal area has improved significantly since reclamation and is now approaching ambient groundwater quality.

Lines, G. C. (1985) was studied the ground-water system in the Trail Mountain area in order to provide hydrologic information needed to assess the hydrologic effects of underground coal mining. Well testing and spring data indicate that water occurs in several aquifers. The coal-bearing Blackhawk-Star Point aquifer is regional in nature and is the source of most water in underground mines in the region. The specific yield of the aquifer was estimated at 0.05, and the storage coefficient is about 1× 10-6 per foot of aquifer where confined. Water in all aquifers is suitable for most uses. Dissolved solids concentrations range from about 250 to 700 milligrams per liter, and the predominant dissolved constituents generally are calcium, magnesium, and bicarbonate. Subsidence will occur above future underground mines, but the effects on the ground-water system cannot be quantified. Subsidence fractures possibly could extend from the roof of a mine into a perched aquifer several hundred feet above. Such fractures would increase down ward percolation of water through the perching bed, and spring discharge from the perched aquifer could decrease. Flow through subsidence fractures also could increase recharge to the Blackhawk-Star Point aquifer and increase inflows to underground mines.

Viswanathan, (1990) studied the impact of mineral sand mining activities on groundwater in New South Wales, Australia. Tomago sand beds is a coastal unconfined aquifer, where mining of mineral sands, like Rutile, Zircon, Ilmenite, etc., was in progress since 1972. Groundwater is also extracted from Tomago aquifer for urban water use. Groundwater iron levels vary from 0.1 mg/litre to about 10 mg/litre. Iron in excess of 0.3 mg/litre is removed by chemical treatment. The mining of mineral sands resulted in the substantial increase of iron levels. The level of increase itself being very site-specific. Several processes were identified as being responsible for such increases. If water were to be extracted from the mined area, additional treatment would be required to remove excess iron.

National Research Council. (1990), the several parameters relavant to groundwater recharge can, in principal, be measured for a given point. However, spatial and temporal varibilities would require intensive instrumentation at high costs and these varibilities and the uncertainity in measurement techniques would generally preclude accurate extrapolation to mine scale areas.Nonpoints method for estimating ground water recharge, made by hdrograph separation, tracer techniques and regional water budgets are also not exact. The errors in resulting estimates of groundwater recharge may exceed the change in recharge due to mining.Although accurate determination of difference between pre and post-mining recharge rates is not pratical.

Jamal et al., (1991) studied the feasibility of this technique as a means of controlling the acid mine drainage problem in one of the opencast coal mining project at Singrauli Coalfield, of the Northern Coalfields Limited, where pH of the water was found to a extremely low (Dhar et al, 1986). Physico-chemical analysis of water samples revealed that, the effluent of Gorbi mine is highly acidic and is fully loaded with the total suspended solids (TSS) and total dissolved solids (TDS). Among the dissolved solids, iron and sulfate concentrations are high. The concentrations of hazardous metals such as chromium, lead, copper and zinc are also found to be above the tolerance limit. In the Jhingurdah mining project, the Chatka nalla, a tributary of Bijul receives the mine effluent. The water of this nalla on the upstream side is suitable for bathing and drinking purposes but because of the presence of various undesirable constituents above permissible limit, the downstream of Chatka nalla has deteriorated to a significant level. The clear water changes into blackish due to high concentration of oil, grease, suspended particulate matter and high acidity. In the field investigation it was observed, that when the sump water of Jhingurdah mine flows flown to a distance of approximately 1km in the Jhingurdah nalla through coal-overburden, water gets almost neutralized i.e. its pH has raised from 5.5 to 7.44. The water of Jhingurdah nalla then mixes with the water of Mehrauli nalla, the pH of which is about 8.7. This thus causes a complete neutralization of Jhingurdah mine water before it gets finally discharged into

Bijul stream. Similar observation was also noted with the sump water of Gorbi mine. The pH of this water increases from 2.5 to 3.14 when it flows for a distance of 1.5km in the nalla which is in the Barakar rock formation, pH in this case shows only a slight increase from 3.14 to 3.21 even after flowing for a distance of over 3km in the nalla through Archean rock formation.

Rösner, (1998) determined the impact of abandoned mines on surface water and groundwater in the historical mining districts of the Cerbat Mountains, Arizona. The surface water in the mining areas was found to be contaminated by various combinations and concentrations of heavy metals. Elevated arsenic, cadmium, and iron concentrations were detected in most surface-water samples, while lead, copper, and zinc contamination differed from region to region, depending on the ore mined. The groundwater was seriously polluted by arsenic, cadmium, lead, zinc, iron, and manganese in the immediate vicinity of mines that processed ore on the site, such as the Tennessee Mine near Chloride. Chloride’s groundwater, however, showed no evidence of contamination.

Stamatis et al., (2001) worked on the impacts of past mining activities and inefficient water resources management on groundwater quality in the Lavrio area. Thirty-three water samples were collected during March 1998 and were analyzed for major ions (Ca, Mg, Na, K, HCO_3, Cl, NO_3, SO_4, and PO_4), trace elements (Fe, Pb, Ni, Zn, Mn, Cu, Cr, Cd) and physical parameters. High concentrations of heavy metals (lead, cadmium, zinc, nickel) are recorded in groundwater samples in the Lavrio area. The highest concentrations are recorded in the unconfined aquifer (alluvial deposits and schists), due to mining activities. Quality deterioration of groundwater is also documented and attributed to seawater intrusion and nitrate pollution of agricultural origin.

Zhang et al., (2002) worked on the distribution and origin of arsenic in groundwater. The results demonstrate that the affected district boundaries encompass an area with high contents of As in well water, which the local inhabitants drink and use in daily life. This district is labeled as a population pathological change area. The average content of As in the drinking water is as high as four times more than the environmental standard of As in drinking water. The study suggests that the origin of the As in groundwater of the population pathological change area in Hetao Area is transported from higher elevations where mineral deposits exist. Mining of some of the deposits has occurred for a long time. Mining practices can result in the release of toxic elements, which can then be transported from the mining district down gradient.

Haritash et al., (2008) carried out a study to assess the suitability of groundwater for drinking, irrigation, and industrial use. A total of 34 groundwater samples were collected from Rewari town and its perimeter from the land chiefly used for agriculture. Physico-chemical characterization of the samples revealed that groundwater from most of the sources was not fit for drinking owing to a high concentration of calcium, magnesium, hardness and fluoride. Suitability for irrigation, too, was low since most of the sources had high value of sodium adsorption ratio (SAR), residual sodium carbonate (RSC), soluble sodium percentage (SSP) and magnesium hazard which can render salinity and alkali hazard to soils on long term use in irrigation. No source of water was found to be suitable for industrial applications. It was observed that sodium, sulfate, and chloride were the chief ions present in water. The high concentration of the chemical constituents is attributed to the lithological composition of the area.

Khan et al., (2012) carried out a study in the Singrauli area of north India to know the water quality at selected sites. Physico-chemical parameters such as pH, total dissolved solids (TDS), bicarbonate, hardness, calcium, magnesium, sodium, potassium, chloride, sulfate, copper, iron, cobalt, manganese, zinc, and chromium were examined in 27 water samples. Locations selected for sampling were based on the preliminary field survey carried out to understand the overall impact of mining and industrialization on the surface and groundwater resources of Singrauli. Land use were categorized into 15 categories out of which major area occupied by open forest covers 20.33 %, uncultivated land 20.25 %, cultivated land 12.60 %, dense forest 11.00 %, and other categories cover 35.82 %. The results obtained are compared with World Health Organisation standards for drinking water quality. The physicochemical analysis shows the alkaline nature of water, soft to moderately soft, TDS and total alkalinity exceeds the desirable limit. The major ions in water like calcium, and magnesium are within desirable limits, and sulfate and potassium exceed in limit at some locations, whereas sodium and chloride show higher values. The minor ions like copper and zinc show values within desirable limits whereas iron, cobalt, and chromium show higher values than the desirable limits which deteriorate the quality of water.

Abdalla et al., (2013) conducted an analysis to investigate the impacts of phosphate mining activities on the groundwater quality in the area, three groundwater samples that represent all water wells in the area were collected and analyzed for major ions and some heavy metals. In addition, three bulk samples representing the phosphatic sediments collected from upstream and downstream of the drainage basin were collected and analyzed to understand the source of groundwater contamination. The total concentrations of dissolved solids suggest that the groundwater in the area grades from fresh to brackish water (961–1,580 mg/l), and is characterized by sodium-calcium–sulfate–chloride and sodium– magnesium–sulfate–chloride chemical types. The results showed high concentrations of the heavy metals in well nos. 1 and 2 in downstream parts compared to well no. 3 in the upstream part reflecting their influence by the mining activities.

Elango et al., (2014) carried out a study to assess the suitability of groundwater and to understand the impact of water stored in a check dam on groundwater quality near Chennai, Tamil Nadu, India. Water samples were collected from a check dam across Arani River and 13 nearby wells during October 2010, January 2011, and April 2011. These samples were analyzed for pH, electrical conductivity (EC), and calcium, magnesium, sodium, potassium, carbonate, bicarbonate, chloride, and sulfate concentrations. The World Health Organization and the Bureau of Indian Standards guidelines were used to assess the suitability of groundwater for the purpose of drinking. Suitability of water for irrigation was determined based on the EC, SAR, US Salinity Laboratory diagram, percentage sodium, Wilcox's diagram, Kelly's index, and Doneen's permeability index. About 38 % of the groundwater samples were suitable for drinking and 70 % were suitable for irrigational use. Water stored in the check dam and groundwater in the wells closer to the structure were suitable for both drinking and irrigation purposes. The study confirms that the check dam in this area improves the groundwater quality in its surroundings.

Arkoc et al., (2016) investigated in order to determine the possible environmental impacts of coal mining on water pollution. The water samples were analyzed for chemical, trace metal and microbiological quality, and compared with international directives (EPA and WHO) in order to determine the impact of the mining activities as a source of pollution on bodies of water. Tozaklı coal was lignitic rank, and sulfur content varied between 9 and 4 %. The pH values of the water were between 8.04 and 6.92 for the mine ponds, and 8.7 and 6.6 for the groundwater and surface water. All the major cation and anion and trace element concentrations were below admissible limits of both

EPA and WHO, except for SO_4^- andNO_3^-.The geoaccumulation index values of the clay samples from the mining area revealed that the soils were moderately contaminated by Ni, whereas As and Ni concentrations had high anthropogenic shares due to coal mining. The surface and groundwater of the study area were not polluted by the coal mining operations.

Tiwari et al., (2016) investigated the hydro-geochemical processes and groundwater quality for drinking and irrigation uses. For this purpose, 33 groundwater samples from different mining areas of the West Bokaro coalfield were collected and analyzed for pH, electrical conductivity (EC), total dissolved solid (TDS), dissolved silica (SiO2), major cations (Ca2+, Mg2+, Na+, K+), anions (F−, Cl−, HCO3 −, SO4 2− and NO3 −) and trace metals (Mn, Cu, Pb, Zn, Ni, Co, As, Se, Al, Cd, Cr, Ba and Fe). The analytical results show the slightly acidic to alkaline nature of groundwater and dominance of HCO3 − and SO4 2− in anionic and Ca2+ and Na+ in cationic abundance. High SO4 2− concentrations are attributed to the oxidative weathering of pyrite and gypsum dissolution. The data plot on the Gibbs and Piper diagrams revealed that the groundwater chemistry is mainly controlled by rock weathering with secondary contribution from anthropogenic sources. In a majority of the groundwater samples, alkaline earth metals exceed alkalies and strong acids dominate over weak acid. Ca-Mg-HCO3, Ca-Mg-SO4-Cl and Ca-Mg-SO4 were the dominant hydro-geochemical facies. Quality assessment for irrigation uses reveals that the groundwater is of good to suitable category. Higher salinity and magnesium hazard values at some sites restrict the suitability of groundwater for irrigation purposes.

Zhao et al., (2017) was studied the impact assessment of groundwater has to be conducted for a coal project to predict and mitigate the impacts in consideration of the government requirements. In this paper, the groundwater assessment modelling of mine pits was discussed in predicting of groundwater inflows and reviewing analytical and numerical approaches. A methodology of groundwater impact assessment for an open cut mine in NSW with a three-dimensional groundwater flow model Modflow Surfact demonstrated its functions in simulating the project's impacts on the groundwater regime. The key findings with mitigations are discussed and recommended in the paper to reduce impacts on groundwater and fulfil regulation requirements in NSW.

Singh et al., (2017) carried out a study to assess the impact of coal mining on surface and groundwater resources of Korba Coalfield, Central India. Accordingly, water samples collected from various sources are analyzed for major ions, trace elements, and other mine effluent parameters. Results show that the groundwater samples are slightly acidic, whereas river water and mine water samples are mildly alkaline. Elevated concentrations of Ca^{2+}, Na^{+}, HCO_3^{-}, and SO_4^{2-} alongside the molar ratios $(Ca^{2+}+Mg^{2+})/(SO_4^{2-}+HCO_3^{-}) <1$ and $Na^{+}/Cl^{-} >1$ suggest that silicate weathering (water-rock interaction) coupled with ion exchange are dominant solute acquisition processes controlling the chemistry of groundwater in the study area. The overall Hydrogeochemistry of the area is dominated by two major hydrogeochemical facies (i.e., Ca–Cl–SO4 and Ca–HCO3). Analysis of groundwater and river water quality index (GRWQI) elucidates that the majority (82%) of samples are of “excellent” to “good” category, and the remaining 12% are of “poor” quality. The concentration of trace element constituents such as As, Zn, Cu, Cr, and Cd is found to be well within the stipulated limits for potable use, except for Fe, Mn, and Pb. Suitability of water samples for irrigation purposes, established using standard tools like Wilcox and USSL diagrams, reveal “excellent to permissible” category for majority of the samples.

Luo et al., (2018) was conducts statistical analysis on coal yield and drainage volume from several large-scale mines in the mining area. Meanwhile, research determines average water volume per ton coal, and calculates four typical years' drainage volume in different mining intensity. Then during mining drainage, with the combination of precipitation observation data in recent two decades and water level data from observation well, the calculation of groundwater table, precipitation infiltration recharge, and evaporation capacity are performed. Moreover, the research analyzes the transforming relationship between surface water, mine water, and groundwater. The result shows that the main reason for reduction of water resources quantity and transforming relationship between surface water, groundwater, and mine water is massive mine drainage, which is caused by large-scale coal mining in the research area.

Singh et al., (2018) carried out a study in the Bokaro district of the Jharkhand state to identify the hydro-geochemical characteristic of the groundwater and assess its quality with reference to drinking, domestic, and agriculture purposes. In the study area, 102 groundwater samples were collected during the pre-monsoon season and post-monsoon season (51 samples per season) and analyzed for pH, electrical conductivity (EC), total dissolved solids (TDS), total hardness, F^-, Cl^-, HCO_3^-, SO_4^{2-}, NO_3^-, Ca^{2+}, Mg^{2+}, Na^+, and K^+. The analytical results show the slightly acidic to slightly alkaline nature of the groundwater in the study area. Ca^{2+} and Na^+ are the dominant cations, while anion chemistry is dominated by HCO_3^- and Cl^- during both seasons, respectively. The data plotted on the Piper and Gibbs diagram, as well as statistical analysis, reveals that the chemistry of the groundwater in the study area is mainly controlled by rock weathering phenomenon with secondary contributions from anthropogenic sources. The water quality assessment indicated that TDS, hardness, Ca^{2+}, Na^+, HCO_3^-, and Cl^- are the major concern parameters in the study area during both seasons. Sodium adsorption ratio, sodium percent, residual sodium carbonate, magnesium hazard, Kelly's ratio, and permeability index are calculated to identify the suitability of water for irrigation purposes and revealed that most of the groundwater is suitable for irrigation purposes, except few sites.

Prathap and Chakraborty, (2019) carried out a study to characterize the groundwater of Charhi and Kuju coal mines in Jharkhand, India and assess its suitability for irrigation and domestic use. Groundwater samples were collected from thirty-one locations covering active operational sites, abandoned sites and areas yet to be mined (control), and analyzed for physical and chemical parameters including the ions and metals. Overall results suggested the groundwater in the study area, though fit for irrigation, grossly unsuitable to be used as drinking water, mainly due to its elevated concentration of arsenic and selenium. The concentration of total arsenic was 0.09 mg/L in summer, 0.08 and 0.06 mg/L in monsoon and winter respectively. Total selenium concentration was as high as 0.29 mg/L in summer, 0.22 mg/L in monsoon and 0.18 mg/L in winter season. The calculated carcinogenic risk was also prominent with 7.28 due to arsenic and 2.26 due to selenium in summer.

Qiao et al., (2019) provide a potential model outlining the hydrogeochemical evolution of groundwater as influenced by coal mining, a multi-layer groundwater system in a coal mining area was investigated. A total of 76 groundwater samples were collected between 1964 and 2018 for hydrogeochemical analysis from boreholes, underground tunnels, and surface pits at Xinglongzhuang Coal Mine in China. The concentrations of Na+ and Ca2+ in the groundwater from the lower Quaternary aquifer changed over the studied period (~54 years). The gradual increase of Na^+ and decrease of Ca^{2+} concentration verified the action of cation exchange. Analysis of 26 heavy metals in the mine drainage water showed that there is only minor pollution after the water has been simply treated. These data analysis methods and results could be useful in areas with long-term mining to interpret the evolution of groundwater and to promote groundwater quality management.

2.4 Studies on analysis of land use /land cover changes

Fung and Ellsworth, (1987) have presented Principal Components Analysis (PCA) has been applied for land-cover change detection with multi-temporal Landsat Multispectral Scanner (MSS) data. In the computation of principal components, the eigenvectors used for transformation can be derived from a covariance matrix (with non-standardized data) or a correlation matrix (with standardized data); and from the total area or a subset area of specific land-cover types. In this paper, we examine the effect of using different types of matrices for principal components transformation with special emphasis on its application in land cover change detection in the Kitchener-Waterloo-Guelph area, Ontario, Canada. It is found that standardized principal components are more accurate than the non-standardized components because of their better alignment along with land cover changes in the multi-temporal data structure. Statistics extracted from the total study area are also better and more reliable than those extracted from the subset area. It is concluded that principal components analysis is scene dependent, and the use of this technique requires a careful appraisal of the Eigen structures and images of the principal components.

Tin-Seong, (1995) have discussed a relatively simple but accurate automated land-cover and land-use classification technique using microcomputer-based image analysis and geographic information system. This problem could be overcome by satellite remote sensing technologies, such as the Landsat Thematic Mapper (TM) and the SPOT High-Resolution Visible (HRV), which are very useful for gathering land use and land cover information. This study presented two major findings. First, the overall classification accuracy can be increased substantially by incorporating median filtered image data prior to classification. In the tests discussed, the overall accuracy increased by 9 percent when median filtered XS3 data was used together with the two PCA bands. Second, the classification accuracy can be improved significantly by dividing the image into built-up and non-built-up segments on the basis of existing map data and applying prior probability. It has been shown that the overall accuracy increased to 94.6 percent compared to the 78.9 percent recorded from the untransformed SPOT-HVR imagery.

Jaiswal et al., (1999) carried out a study to analyze the land use/ land cover changes over a period 30 years using remote sensing in the Gohparu block, Shadol district of Madhya Pradesh. land use/ land cover maps were prepared by visual interpretation of two-period remotely sensed data. Post-classification techniques was adopted for this purpose. The loss of vegetation cover was estimated to be 22% and 14% of the land was found to have been transformed into wasteland between 1967 and 1996. The overall rate of change was found to be 1.8% per year during this period.

Dewan and Yamaguchi, (2009) carried out a study to evaluate the land use/cover changes and urban expansion in Greater Dhaka, Bangladesh, between 1975 and 2003 using satellite images and socio-economic data. Spatial and temporal dynamics of land use/cover changes were quantified using three Landsat images, a supervised classification algorithm and the post-classification change detection technique in GIS. Accuracy of the Landsat-derived land use/cover maps ranged from 85 to 90%. The analysis revealed that substantial growth of built-up areas in Greater Dhaka over the study period resulted significant decrease in the area of water bodies, cultivated land, vegetation and wetlands. The urban land expansion has been largely driven by elevation, population growth and economic development. Rapid urban expansion through infilling of low-lying areas and clearing of vegetation resulted in a wide range of environmental impacts, including habitat quality.

Charou et al., (2010) presented the work by using of multi-temporal Landsat-5 and Landsat-7 images, SPOT Panchromatic, and ASTER data to map the natural environment on a local scale, and to assess the impact of mining activities by indicating the changes on land and water resources. Three case studies are presented: Lake Vegoritis and the Amynteon mine (both located in northern Greece) and the Lavrio mine area, in central Greece. We found that using high-resolution satellite remote sensing data and state of the art GIS techniques with the parallel development of a fully integrated geospatial database system provided monitoring and feedback at appropriate spatial scales; therefore, such data can be used for long-term environmental management and monitoring of reclamation and rehabilitation of mining areas.

Areendran et al., (2013) carried out a study to analyze the spatial and temporal changes in the land use/land cover using Landscape metrics. In addition, Markov transition matrix and change rate were also calculated for each of the LULC classes. The transitions from one class to the other were depicted with the help of change matrices. The analysis suggests that the vegetation cover is undergoing continuous negative change in terms of composition and extent. The rate of deforestation and forest fragmentation has also increased while built up and mining areas have registered a positive change.

Meshesha et al., (2016) carried out a study to analyze the trend of land use/land cover change and its cause and consequence on human livelihoods as well as on the environment is a matter of concern for sustainable development and management of the natural resource. Retrospective analysis of land use/land cover dynamics and its driving force has been undertaken using satellite images of Landsat5 TM 1984, Landsat5 TM

1999, and Landsat8 TM 2015 with 30 m spatial resolution for Beressa watershed of Ethiopia. ArcGIS10.2.2 and ERDAS Imagine14 have been used for image processing to produce 6 land use/land cover classes in the study area. The result of the classified image indicated that in the last 3 decades, farmland and settlement area increased @ 71.6 ha/year and 16.8 ha/year respectively. Between 1984 and 1999, forest cover and water body decreased @ 5 ha/year and 0.03 ha/ year respectively but increased @15.6 ha/year and 7.1 ha/year between 1999 and 2015 respectively. This increase could be possible due to the involvement of local communities to plant trees around their homestead and farmlands. In this program, plantation of indigenous tree species other than eucalyptus (which affect the ecology) was encouraged. The % share of grazing land and barren land has been decreased to 10 and 10.1 % respectively during 1999 that further reduced to 6.1 and 5.2 % during 2015 as against the 12.4 and 13.1 % during 1984 respectively in the Beressa watershed. Rapid population growth demanded more land for cultivation, more trees for domestic fuelwood consumption and more area for settlement had been responsible for a drastic change in the land use/land cover change in the last 3 decades in the Beressa watershed.

Ojaghi et al., (2017) analyzed the land cover change of one of the wetlands in the southern part of Lake Urmia, known as Ghara-Gheshlagh wetland, in the period 1989–2015 using post-classification change detection and machine learning image classification. For this analysis, three Landsat images, acquired in 1989 (TM), 2001 (TM), and 2015 (Landsat-8), were used for the classification and change detection. Support vector machine learning algorithm, a supervised learning method, is employed, and images are classified into four main land cover classes namely “water,” ”barren,” “salty land,” and “agriculture and grassland.” Change detection was carried out for pairs of years 1989 to 2001 and 2001 until 2015. The results of this classification show that there is a sharp increase in the area of salt-saturated land as well as a decrease in the area of water resources. Overall classification accuracy obtained were high for the individual years: 1989 (91.48%), 2001 (90.63%), and 2015 (88.6%). Also, the Kappa coefficients for individual maps were high in 1989 (0.89), 2001 (0.8742), and 2015 (0.84). After that, the land cover change map of the study area is obtained between 1989 to 2001 and then 2001 to 2015.

Garai and Narayana, (2018) carried out a study to analysis the land use/land cover changes in the Godavari coalfield area were analyzed for a period of 24 years i.e., from the year 1990 to 2014. The changes were detected on a 5-year time interval using Landsat-5 TM, Landsat-8 OLI and TIRS satellite images and the human impact on the landscape are discussed. In addition, change analysis and quantification of spatial-temporal dynamics of land use/land cover patterns were also discussed. The study reveals that the water body slightly increases from 2.77% in 1990 to 3.29% in 2014. The mining area increased from 0.04% in 1990 to 0.23% in 2014. On the other hand, forest cover has decreased from 36.38% in 1990 to 31.67% in 2014. Built-up area and barren land increased from 0.34% to 0.89% and 1% to 1.69% in 1990 and 2014 respectively. Agricultural land steadily increased from 59.46% in 1990 to 62.22% in 2014.

Kayet et al., (2019) proposed a technique to LULC effects on the groundwater table. LULC extract based on time-series Landsat imagery (1988, 1993, 1998, 2003, 2007, 2013 and 2017) and its effect on the groundwater table. SVM algorithm is used for the classification of LULC features and its higher accuracy. In the study area, groundwater data (2001–2012) used for groundwater table change analysis. The result showed that 1.03 mbgl (Metres Below Ground Level) groundwater decreased in the study area.

Analysis of the time-series climate data (1988–2014) based on the study area shows apex's for maximum temperature increased between 0.2 and 0.8 °C and 0.3 to 1.5 °C for minimum apexes. At the same time, analysis of historical rainfall data indicated that rainfall decreased by 10 mm, respectively during the years 1988–2014. The classification results showed that the SVM algorithm overall accuracy of 86.67% and the kappa coefficient of 0.82. The relationships among LULC and, climate, groundwater change values showed both positive and negative correlations. This paper highlighted the LULC change effect on the groundwater table change in arid areas.

Coal mining activities in India started decade back, since then the groundwater is getting affected. Opencast coal mining disturbs the underground water table in terms of its level, quality and quantity. Along with coal mining, leachates generated from large number of industrial waste and overburden dumps that are in abundance around the mining areas, may reach the groundwater and may adversely affect its quality (Khan et al., 2005; Mohammad et al., 2010). Many areas of the country are faced with the problem of over exploitation of groundwater resources resulting in alarming lowering water table. Therefore a lot of care has to be taken in estimating the water need and the mines of future are likely to be subjected to a lot of constraint on water use and discharge. The study is important to provide a perennial water supply of pollution free water to local population.