DEVELOPMENT OF 1-D INVERSION ALGORITHM FOR GEOELECTRICAL DATA AND APPLICATION OF GEOELECTRICAL AND GIS FOR GROUNDWATER STUDY IN SINGRAULI COALFIELD REGION, M.P, INDIA

Thesis submitted in partial fulfillment for the

Award of Degree

Doctor of Philosophy

By

Dharmendra Kumar Singh

DEPARTMENT OF MINING ENGINEERING
INDIAN INSTITUTE OF TECHNOLOGY
(BANARAS HINDU UNIVERSITY)
VARANASI – 221005

Roll no- 15151502

2023

CHAPTER-7

SUMMARY AND CONCLUSIONS

7.1 Summary

The application of geophysical methods mainly depends upon the contrasts in physical properties of sub-surface formations, viz. density, resistivity, or velocity contrasts of different formations. Among other geophysical methods, resistivity methods are very popular and widely used for groundwater exploration. Therefore, in the present work, vertical electrical sounding (VES) using Schlumberger electrode configuration in collaboration with satellite remote sensing data are used for evaluation of groundwater potential zones and delineation of drilling locations for productive tube well/dug well for ensuring sustainable water supply in the area.

The geology of the district reveals the presence of different rock formations, from granites of the Archean era to alluvium of the recent age. Other significant formations exposed in the district are the Cretaceous-Eocene Deccan Traps, Gondwanas from Paleozoic to Mesozoic, limestone, sandstone, shale, of Vindhayans and quartzites, phyllites, granites, and gneisses of the Archean age.

The presence and movement of water in the sub-surface are mainly influenced by geological factors, such as the nature of rock formations, including their primary and secondary porosity as well as permeability. The district is underlain by varied geological formations, which give rise to different types of aquifers within the area. The primary geological units in the region are the Gondwana formations and the Archean. The main aquifers in the district consist of weathered and fractured granitic gneiss, schist, phyllites, sandstone, and alluvial deposits. The occurrence and flow of

groundwater in the areas depend primarily on the degree of interconnection among secondary pores or voids formed by fracturing, along with the extent of weathering.

The hydrogeomorphologic and morphometric data analysis were carried out using geospatial techniques (Remote Sensing and GIS techniques) to evaluate different valuable parameters that could give the appropriate locations which were selected for electrical resistivity survey and also for further detailed study. There are four features, namely, geomorphologic unit, slope, drainage, and lineament (surface lineament) maps extracted from satellite imagery on 1:50,000 scales of the study area, which were used to study their influence on groundwater occurrence.

The groundwater level data for the pre-monsoon, monsoon, and post-monsoon periods for the year 2021 are collected at 100 monitoring stations. Spatial variation in the depth of water level for pre-monsoon, monsoon, and post-monsoon is analyzed. An assessment of WLF and its comparative analysis with different hydrogeological parameters using GIS is analyzed.

The electrical resistivity methods are used to delineate the potential zones of groundwater in the study area along with the applications of the remote sensing and GIS. Remote sensing technique is used to obtain the prior information of the study area. Different thematic maps such as elevation maps, geomorphology maps, slope maps, lineaments maps, etc. are generated for the demarcation of potential zones of groundwater.

The developed MATLAB-based code for inverting 1-D Geoelectrical data using a Genetic Algorithm (GA), efficiently inverts synthetic data. Its validity was also tested using published VES data from Mandal et al. (2021) study; it was observed

that the inverted model matched well with the model of the research article. Then developed code is used for the inversion of acquired 55 VES data in the Singrauli coalfield region to get layer parameters (true resistivity, thickness).

A total of fifty-five VES data is acquired in the Singrauli coalfield region with a Schlumberger electrode configuration with a maximum current electrode separation (AB) of 400 m. The acquired VES data were interpreted using the developed code to obtain layer parameters. To know the range of resistivity variation of the lithological units present in the study area, the interpreted results of VES data have been correlated with the available borehole lithologies. This correlation corroborates the lithological unit present in the borehole and the lithology obtained from the VES data. Based on these results, six Geoelectrical cross-sections were prepared. The Geoelectrical cross-section gives information about lithological changes and subsurface geology. The visual inspection of the five Geoelectrical cross sections shows that three to five distinct lithological units are present in the area, and a brief description of the five Geoelectrical cross sections has been presented and summarized. From this study, it is inferred that the highly weathered sandstone to less compact sandstone and fractured zone are the potential zones of groundwater in the study area. The secondary parameters, known as Dar-Zarrouk parameters, were evaluated, and spatial maps of longitudinal conductance, transverse resistance, and coefficient of anisotropy were generated for the characterization of the aquifer. Finally, based on this study the drilling of productive boreholes is recommended in the study area.

7.2 Conclusions

Based on the work presented in this thesis, the following conclusions have been drawn.

- The developed MATLAB-based program for the inversion of 1-D Geoelectrical data using Genetic Algorithms performs effectively for the inversion of 1-D Geoelectrical data. It is observed that response misfit (RRMSE) ranges from 0.018 to 0.097, which is within the acceptable range.
- The different geomorphologic units have been delineated in the study area such as dissected Hills and Valleys; low dissected Plateau, pediment Pediplain complex, quarry and mine dump, and Water bodies. It is observed that these geomorphologic units have a significant impact on the groundwater.
- The slope has been classified into five categories: very gentle (0°–3.5°), gentle (3.6°–8.0°), moderate (8.01°–14.31°), steep (14.32°–27.1°), and very steep (27.2°–57.03°). The very gentle and gentle slope is identified in the significant part of the study area except in the mining area. In the mining area, a steep slope occurred in the shape of a W in the central portion of the study area. The slope is always an essential factor in determining groundwater potential. A steep slope will cause more runoff and less infiltration, resulting in a poor groundwater prospect compared to a gentle slope region.
- In the study area general elevation above mean sea level (amsl) ranges from 235 meters in the plains to more than 550 meters on the plateau. The geography of the mining block region is undulating and hilly, sloping in three different directions: east, west, and south. The coalfields stand as a high plateau above the surrounding

plains covered with Barakar, Talchir, and Raniganj deposits, and the plateau's base spreads over roughly 325 m above mean sea level.

- The lineament and lineament density maps may or may not identify the fractured zones. However, it gives the appropriate locations which are selected for the electrical resistivity survey and also for a further detailed exploration.
- The Land use/Land cover classification reveals surface water bodies occupies a small part, about 1.09% of the study area. The agricultural land, i.e., the cropland and trees, occupies approximately 33.56% of the study area. The combined mining area and bare ground occupy the largest area of about 47.64% of the study area.
- The depth of groundwater level is highly variable in the study area; it varies from 0.85 to 22.97mbgl in pre-monsoon, 0.25 to 21.87 mbgl during monsoon, and 0.65 to 23.50 mbgl in the post-monsoon season.
- By comparing the pre-monsoon and monsoon maps, it is found that there is good infiltration of surface water to the sub-surface aquifer in a major portion of the region except for some parts in the central axis.
- In the study area Water Level Fluctuation (WLF) map has been categorized into two groups: rise (0.01 to 9m) and fall (-3.8 to 0m). The rise and fall correspond to positive and negative WLF, respectively. Most portions of the study area show positive (rise) WLF, and only some parts of the central region, north-western and north-eastern, show negative WLF. This may be due to higher elevation, steep slopes, and activities such as coal mining.
- From the analysis of WLF, it is concluded that the regions showing positive WLF are acting as recharge, and areas showing negative WLF are acting as discharge.

- Hydrogeological parameters, namely geology, elevation, drainage, and slope, have been carefully examined within the study area and found to have a substantial impact on groundwater level fluctuation.
- It has been observed that the presence of mining activities and associated industries has a noticeable influence on groundwater level fluctuations within the study area.
- The hydrogeomorphic and morphometric analyses evaluated the different valuable parameters that could help in the planning of further detailed exploration for groundwater.
- VES interpreted depth of VES-9, VES-10, and VES-40 correlated with the boreholes depth of BH-4, BH-8, and BH-11, the correlation coefficient was found to be 0.97,0.91, and 0.95 respectively. The correlation between the litho-logs of existing boreholes in the area and the Geoelectrical parameters is found to be in good agreement with each other and proves the efficacy of the electrical resistivity method.
- The different geological formations are identified using the electrical resistivity method which shows that the resistivity of surface layers in the area varies due to moist and dry surface conditions. The very high resistivity value of the basement indicates compact sandstone and hard rock (In the northern part of the study area).
- The vertical Geoelectrical cross-section gives information about lithological changes and subsurface geology and is also very useful in the assessment of hydrogeological and hydrological knowledge of the study area.
- The semi-weathered to highly weathered sandstone occurs as the second, third, and fourth geo-electric layers in the study area. So the presence of semi-weathered

to highly weathered sandstone formations indicates the good potential of groundwater resources.

- An isopach map of the total thickness of soil cover including clay, sands, and weathered/fractured sandstone filled up to the bedrock indicates the presence of a good aquifer (groundwater potential zone) wherever thick alluvium/soil cover is present.

- Dar-Zarrouk parameter calculated for aquifer characterization around Gorbi mines(northern portion of the study area) show that the northern, eastern, north-western, south-eastern, and some central portion around Gorbi mines exhibit a total transverse resistance(T) exceeding 20,000 ohm-m^2 and a total longitudinal conductance(S) below 0.8 mhos. Thus these areas are observed to have good groundwater potential due to their low S and high T values.
- A major portion of the study area around Gorbi mines has an S value greater than 0.4 mhos, except for some regions on the northern and eastern sides. So a substantial part of the study area has moderate to very good protective capacity. Hence, most of the study area aquifer is well protected from contaminants.
- The value of the coefficient of anisotropy around a significant portion of Gorbi mines has a value between 1 to 1.5, so these regions have good groundwater potential zones. The remaining part has a value greater than 2, so these regions are associated with low porosity and permeability.
- It can be finally concluded that the combined approach of remote sensing, GIS, and electrical resistivity method is very fruitful in identifying hydrogeological and hydrological knowledge of the study area.

7.3 Suggestions for future studies/ works

There are following suggestions for future studies/ works:

- It is suggested to conduct more geophysical surveys using Electrical Resistivity Tomography (ERT) and Very low-frequency electromagnetic (VLF-EM) to explain the pattern of fractures in the study area.
- The joint inversion of ERT and VLF-EM should be encouraged to reduce the time and cost of the survey.
- A pumping test should be carried out to determine the aquifer parameters.
- In the Gorbi region, there is the case of Acid Mine Drainage (AMD). So, hydrogeochemical characterization and suitability analysis of groundwater for domestic and irrigation purposes should be carried out in these regions.