GROUNDWATER INVESTIGATION IN THE PIEDMONT ZONE OF HIMALAYAN FOOTHILL REGION, INDIA, USING ELECTRICAL RESISTIVITY TECHNIQUES

Mufid alhadithi
Department of Survey,
Baghdad Institute of Technology
E-mail: mufidalhadithi@yahoo.com

Asmat Ramzi abdulgafor
Department of Physics
College of science
Al-Anbar University

Abstract

Electrical resistivity, observations well and lithological data are used for the groundwater investigation in the piedmont zone Ratmau –Pathri Rao watershed in Haridawre Districted of Uttaranchal India, The analysis of the resistivity data in the light of known lithology indicates that two aquifer (shallow and deep) are generally present in the area

The resistivity of aquifers are generally varies in wide range. This is due to the presence of different size of ranges of grains condition consisting of fine sand and gravel (pebble) in the Tarai zone which further grade to coarser material (Boulder in the Bhabhar zone)

الخلاصة:

تم استحدام المقاوميه الكهربائيه والابار المشاهده والمعلومات اليثولوجيه للتنقيب عن المياه الجوفيه في منطقة البيدمونت في الحد الفاصل ليرتماو باثري راو(Ratmau-Pathri Rao) في مقاطعة هيردوار في الهند. ان تحليل المقاطع الكهربائيه يدل على ان هناك طبقتين حاملة للمياه(ضحله وعميقه) وهذه الطبقات تظهر تنوع في المقاوميه الكهربائيه والسبب يعود الى وجود احجام مختلفه من الحبيبات والتي تتالف من رمل ناعم الى حصى صغير في نطاق تراي(Tarai) وتتدرج الى حبيبات خشنه (بولدر) في نطاق البهابر(Bhabhar).

Introduction

Groundwater forms one of the most important sources of potable water. It is believed to be safe, free from pathogenic bacteria and from suspended matter. The exploration of groundwater in piedmont and alluvial regions require use of suitable techniques to give optimum results. The aim of the present study is to delineate the aquifer system in the piedmont zone situated in Himalaya foothill region of India, using Electrical Resistivity Techniques

The basic aim of a geophysical investigation is to study the subsurface geological formation by measuring physical field on or beneath the surface, in the borehole or in the air. The available physical fields used for such investigations are seismic wave field, gravity, magnetic, electrical and electromagnetic etc. Some of these fields are generated by an active experiment such as seismic, electrical and electromagnetic whereas other fields are passive which do not require any man made source. Characteristics of these physical fields are governed by the properties of the medium in which they propagate, as well as their source. It is the medium property which is determined by geophysical techniques and this is subsequently interpreted in terms of subsurface geological formation.

The highly varying of all the physical properties of geological formation is the electrical resistivity. Accordingly, electrical resistivity method has extensively been used in solving various problems related to the geohydrological investigations.

Electrical resistivity method is the most effective and economic technique for solving various problems related to groundwater investigation (1),(2),(3),(4)&(5) in estimating the hydrogeological parameters and estimating the groundwater quality (6),(7),(8),(9),(10)&(11) have also been studied the contribution of geophysics to the study of alluvial deposits.

Area of Study

The study area is located between latitudes 29° 50' 00" to 30° 11' 21" North and Longitude 77° 54' 19" to 78° 06' 21" East falling in Ratmau-Pathri Rao watershed covering an area of approximately 430 km^2 (Fig. 1). The area is bound by Siwalik hills towards the northeast from which most of the seasonal rivers are flowing towards southwest.

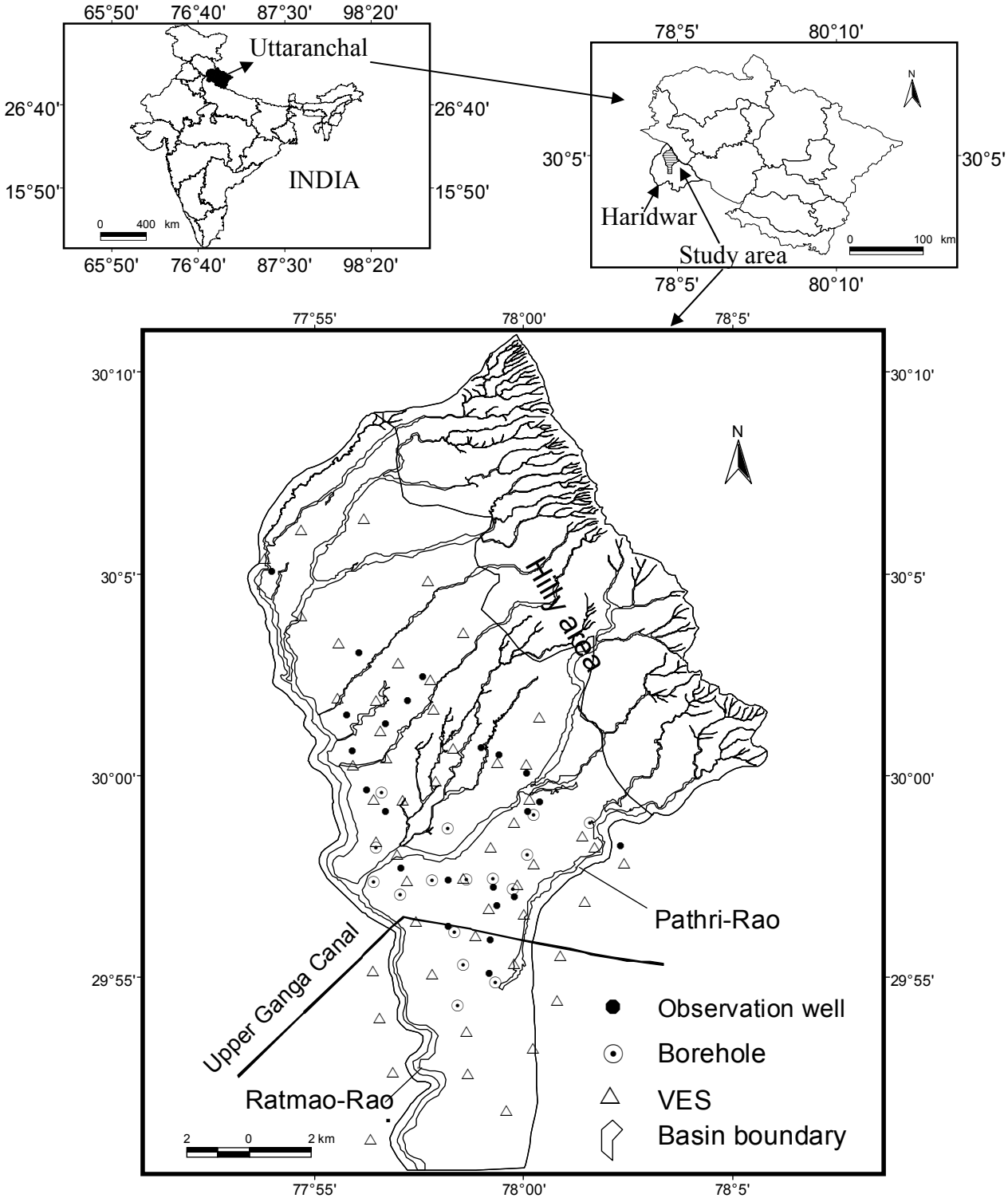

Fig.1: Location map of the study area

As the study area is highly hilly towards northeastern part and is covered by dense forest as well as infested by wild animals. The dominant population in this part

of the study area is tribal commonly referred as "Vangujjars" who do not have any regular sources of income due to their backward living. As there is no regular agriculture in the hilly Terrain, big settlements or villages are not found in this forested area.

The area experiences moderate type of sub-tropical monsoon climate. The rainy season in area extends from June to September under the influence of south- west monsoon. The area also receives some rainfall during January and February from north- east monsoon. July and August are the main rainy-months. Normally, the rainfall ceases by the end of September. There is considerable variation in rainfall from year to year as well as from month to month in a year.

Objectives and scope of present work

The objective of present study is to delineate the aquifer geometry in complex geohydrological setup of the Bhabhar and Tarai tracts of Ratmau- Pathri Rao catchment, in the piedmont zone of Uttaranchal, India, using geoelectrical technique. The main objectives in the present study can be summarized as flows:

- Identification of the surface manifestations which influence the occurrence and movement of groundwater.
- Estimation of seasonal water table fluctuation by field monitoring of groundwater levels.
- Delineation of aquifer geometry using electrical resistivity sounding and other hydrogeological data.

To meet these objectives the following techniques and data products have been used:

- Image processing software ERDAS (ERDAS, 1997) is used to enhance LISS III image for interpretation of the hydrogeological features, which in turn are digitized using a GIS software (Arc View 3.1) from which thematic maps of digital elevation, geology, and hydrogeomorphology maps are prepared.
- Water table monitoring for premonsoon 2002 (i.e. before- rainy season) and the postmonsoon 2002 (i.e. after- rainy season) a period has been carried out.

Geology and Hydrogemorphology of the study area

Geologically the study area comprise of Siwalik rocks and alluvial deposits (12). Towards north, the Siwalik sedimentary rocks are composed of indurate to compacted clastic sediments exposed in Haridwar district and represent an over 6000 m thick sequence, consisting of interbedded mudstones, sandstones, conglomerates

and subordinate marls (13). The formation occurring to south of the Siwaliks is alluvial fan deposits of recent age. The alluvial fan deposits are made up of assorted sands and gravel associated with occasional clays (14)&(15). After necessary ground checking and correlation with the existing literature, the geologic units are mapped using GIS to prepare thematic map for geology of the area (Fig. 2).

Based on hydrogeological characteristics, the area is classified into four geomorphic units. The geomorphic boundaries are digitized on the enhanced image through GIS and generated hydrogeomorphological map is shown in Fig.3. ***The Upper Piedmont*** zone also known as Bhabhar, bordering the ***Siwalik hill*** comprise of unconsolidated coarse material. From groundwater point of view this belt provides an excellent hydrogeological setup for recharge and infiltration. ***The Lower Piedmont*** (also known as Tarai) is separated from the Bhabhar by the spring line along their junction. This zone is composed of coarse-grained sand and clays with gravel. ***Flood plains*** form the youngest geomorphic unit and include various landforms formed by fluvial action i.e. sandbars, channel bars, and meander scars. These are characterized by very gentle slope and consist of sub rounded to rounded fragments of sand, silt and clays.

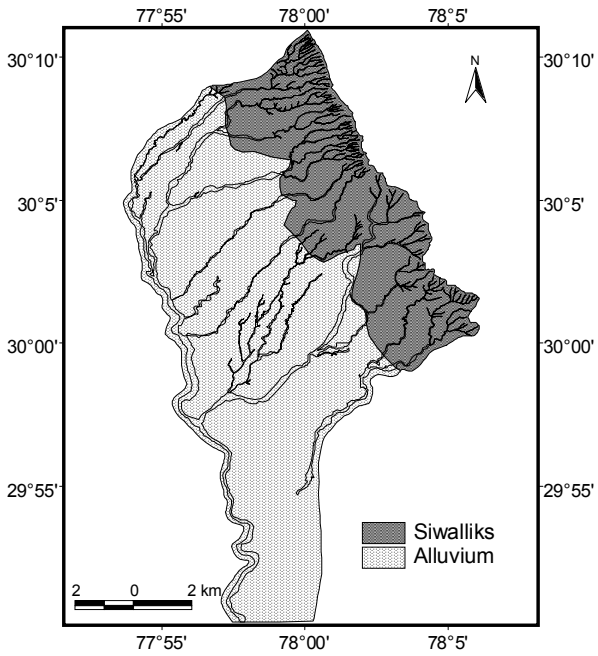

Fig. 2: Geological map of study area

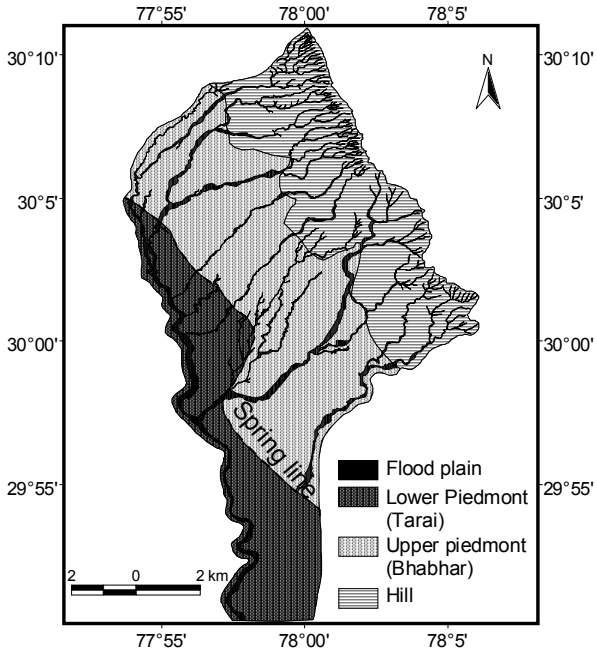

Fig. 3: Hydrogeomorphological map

Subsurface Geology

Data of sixteen tubewells collected from U.P. Tubewell division, Roorkee have been used to prepare fence diagram of the area. Their locations are shown in Fig. 4. Lithologs in the study area show that aquifer in the area is irregular and varies in a wide range. Clay, clayey sand, sands, gravels and occasionally boulder or pebble beds are present in all boreholes, though their proportion varies. The clay beds also occur with varying thickness and with limited areal extent; very thick clay with kankar is available in some parts of the study area. The main aquifers are comprised of sand with pebbles and boulder, generally fining upwards; further, unconfined, confined and semi- confined aquifers are present in the area

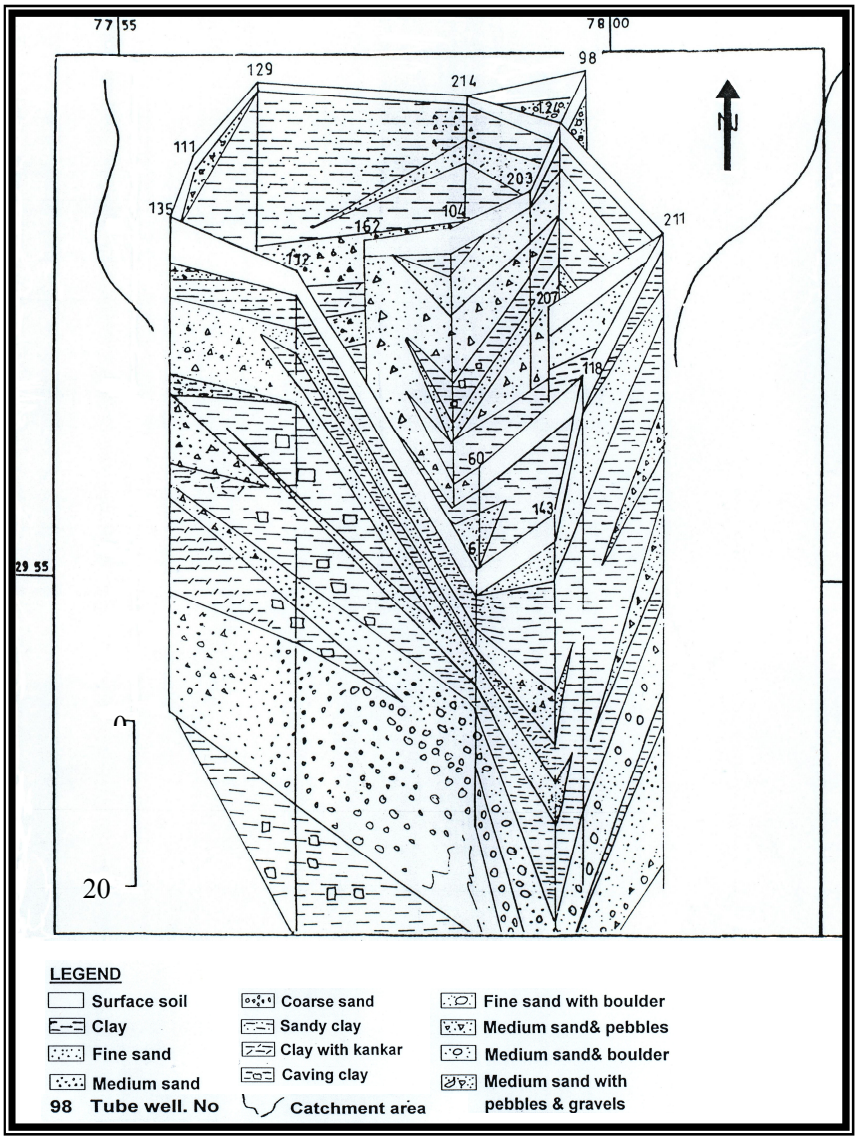

Fig. 4: Fence diagram of the study area

Water table fluctuation

Twenty one observations well have been used to monitor the water table depth to groundwater in the entire study area. The depth to water table maps have been prepared for premonsoon 2002 (pre- rainy season) and the postmonsoon 2002 (post-rainy season) seasons (Fig 5 and Fig. 6). Corresponding thematic maps generated using Arc View, a GIS software (3.1 versions) exhibit variation in the depth of groundwater in different parts of the area. The water table rises considerably and is found to occur at shallow depth (0.5m to 4m below ground level) in the transitional zone between Upper piedmont (Bhabhar zone) and Lower piedmont (Tarai zone). Also water levels are found to occur at deeper levels more than 20 m in the Bhabhar zone. The seasonal groundwater fluctuation (from premonsoon to postmonsoon) is large towards north and northeast in the Tarai zone which gradually decreases southwards and towards the northwest in the Bhabhar zone.

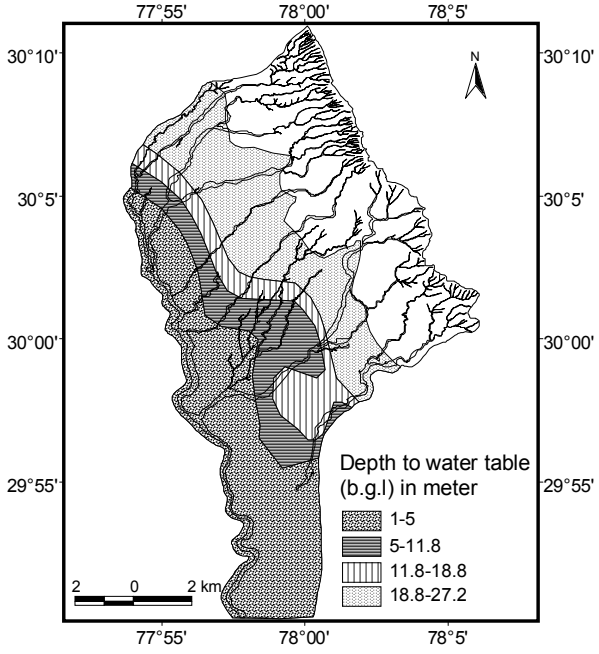

Fig. 5: Thematic map of depth to the water table for premonsoon,

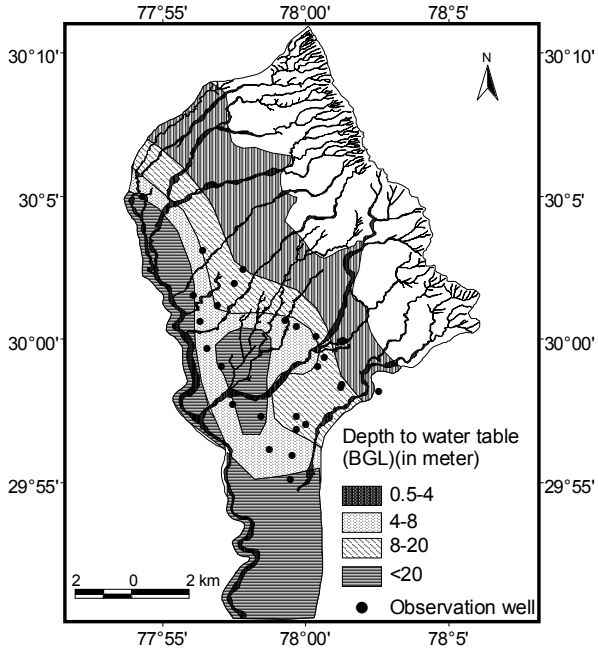

Fig. 6: Thematic map of depth to the water table for postmonsoon

Resistivity data collection and interpretation

Seventy Vertical Electrical Sounding (VES) have been recorded by Schlumberger configuration using ABEM Terrameter SAS 1000 with a maximum electrodes spacing of 900 m. Locations of these VES are shown in Fig.1. Spacing between the consecutive sounding points is normally kept 2 km. However, to examine the detailed features in some localized zones, the spacing is kept as low as 500 m is

also used. The station spacing is also guided by the availability of space and topography around the sounding points. At some stations, VES data have also been collected in perpendicular direction with a common center. An automatic computerized interpretation method (16) has been used to obtain true resistivity and depth from the measured apparent resistivity data at each site. For the geological interpretation of resistivity values, the interpreted resistivity values are correlated with the known available boreholes data in the study area. Table.1 shows the range of electrical resistivity values as revealed by correlation of the electrical section with lithological data.

Table. 1: Resistivity ranges of the various lithological units in the study area

Lithology	***Resistivity range (ohm-m)***
Surficial (Top) soil	20 – 65 (in Tarai) & 200-900 (in Bhabhar)
Clay	10 - 20
Clay with kankar (saturated)	30- 40
Hard clay	40-50
Silty sand (Saturated)	20-30
Sand with gravel (Saturated)	35-100

Delineation of aquifer system

The analysis of the resistivity data in the light of known lithology indicates that the resisitivity of shallow aquifer zone varies from 25 to >130 Ohm-m. Lower resistivity range of 21-50 Ohm-m of aquifer zone was obtained for the aquifer in the Tarai zone; where the aquifer zone is characterized by presence of medium to coarse sand the resistivity of aquifer zone is high (50 to > 130 Ohm-m) in the Bhabhar zone where aquifer may consist of gravel of varying sizes. The thematic map showing the resistivity of shallow upper aquifer is shown in Fig. 7. The thematic map of thickness of shallow aquifer (Fig. 8) shows that aquifer thickness is higher (10- 14 m) in Tarai zone with a minimum in Bhabhar zone (less than 2 m). Fig 9 and Fig. 10 show the resistivity range and thickness respectively of deeper aquifer in the area. It may be clarified here that resistivity range of deeper aquifer is relatively lower (15- 100 Ohm-

m) in comparison to that of the shallow aquifer. This seems to be due to the presence of coarse sand and gravel of relatively smaller grain size, thereby decreasing the bulk resistivity of aquifer zone.

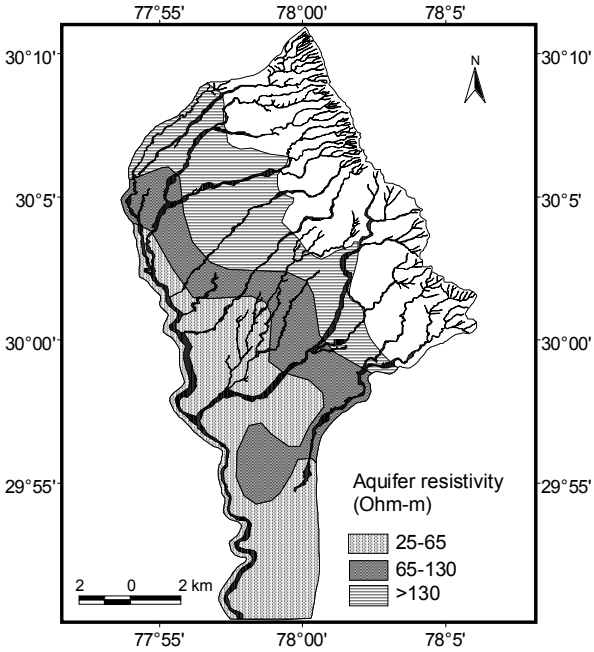

Fig. 7: Thematic map showing the resistivity of upper aquifer

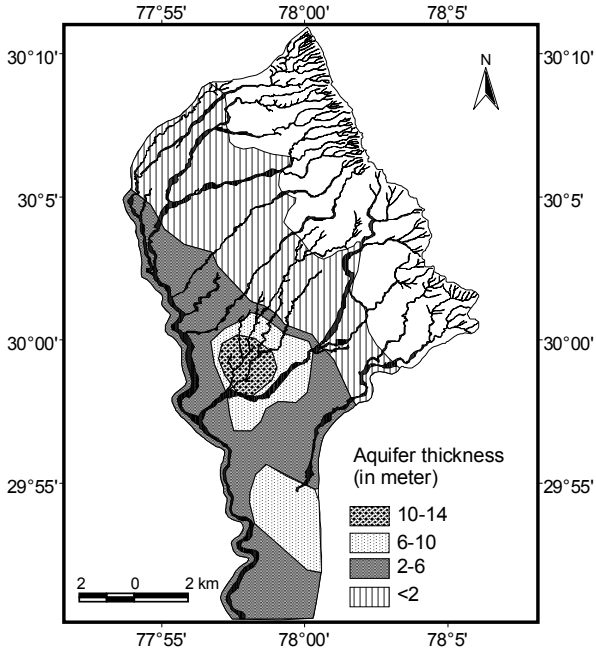

Fig. 8: Thematic map showing the thickness of upper aquifer

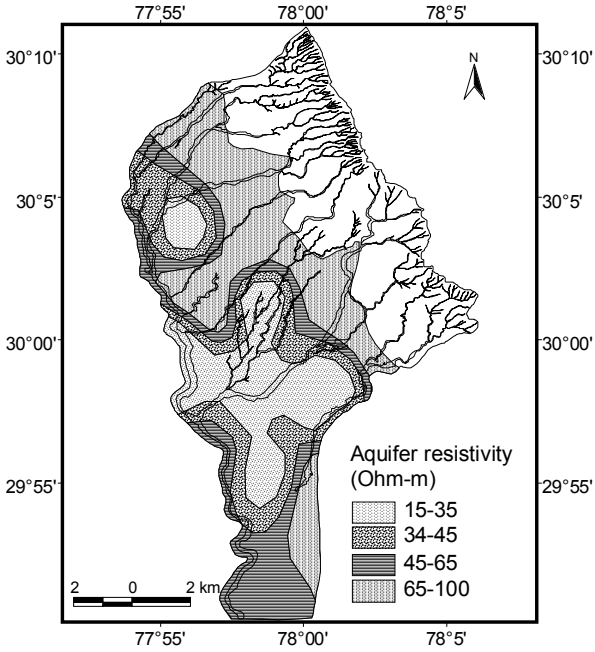

Fig. 9: Thematic map showing the resistivity of deepr aquifer

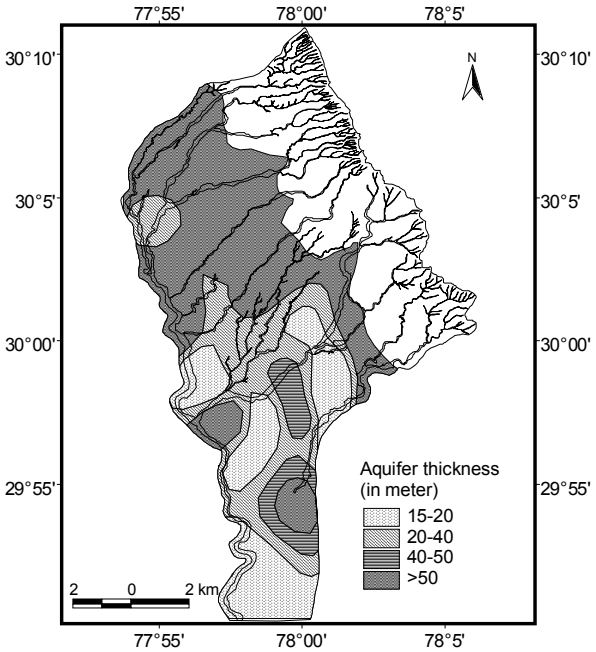

Fig. 10: Thematic map showing the thickness of deeper aquifer

Conclusion

Vertical Electrical sounding data have been used in the present study to delineate the aquifer in the piedmont zone, Haridawre Districted of Uttaranchal India. This study shows that the electrical resistivity technique along with the hydrogeomorphological and lithological data can be effectively used to delineate detailed aquifer geometry in the piedmont zone.

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