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Delineation of Shallow Groundwater Aquifer in the Piedmont Area (Uttaranchal –India) Using Surface Resistivity and Hydrogeological Data

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ABSTRACT

Seventy Vertical Electrical Soundings (VES) have been conducted in the study area using Schlumberger configuration with maximum electrode spacing (AB/2) of about 900 m and at the station interval of about 2 km and less. An automatic computerized interpretation method has been used to obtain true resistivity and layer depth from the measured apparent resistivity data at each site. For the geological interpretation, the resistivity values are correlated with the known lithology from available borehole data in the study area. This correlation helps in defining the resistivity ranges for various layers in the area which ranging 22 -165 Ohm-m. The lattest indicate water bearing sand with gravel and form the shallow aquifer in the Bhabhar and Tarai zones. The thickness of this aquifer varies between 2 to 8m in the Bhabhar and 5 to15 m in the Tarai. The depth to the shallow aquifer zone varies from 17 to 32 m in the foothills (Bhabhar zone) and 1 m to 7 m in the Tarai. Due to occurrence of the finer materials in the Tarai belt, the groundwater occurs under confined, semi- confined and unconfined condition.

Introduction

The earlier work in the piedmont zone and associated alluvial plain of Himalayan foothills has largely dealt with mapping of water table [1] groundwater resource evaluation [2] groundwater quality and recharge sources [3] and [4] estimation of aquifer characteristics using pumping test data and grain size analysis [5] and [6]. These studies, however, did not focus on the subsurface study and delineation of shallow groundwater aquifer in the piedmont zone. Several geophysical techniques are common in field investigation related to delineation of aquifers. Some of these techniques, in public domain, are in routine use by various Governments and Private Agencies for solving problems related to groundwater investigations. The highly variable of all the physical properties of a geological formation is the electrical resistivity. Accordingly, electrical resistivity method has been extensively used in solving various problems related to the geohydrological investigations. In the present paper surface resistivety has been use to delineate of aquifer geometry in complex geohydrological setting of the Bhabhar and Tarai tracts of Ratmau- Pathri Rao catchment, a typical watershed in the piedmont zone of Uttaranchal, India.

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The main approach of the study is summarized as under:

- 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 for past three years.
- Delineation of aquifer geometry using electrical resistivity sounding and other hydrogeological data.

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 of District Haridwar of Uttaranchal state, covering an area of approximately 430 km2 (Fig.1.). The area is bounded by Siwalik hills towards the northeast from which most of the seasonal rivers and nallas are flowing towards southwest. As the study area is highly hilly towards northeastern part, it is covered by dense forest as well as infested by wild animals.

Contrary to the above, in the southern part of the area villages, and settlements are found at smaller distances and the population density is higher as compared to that in the hilly terrain towards northeast. The main occupation of the population in the sloping piedmont area is agriculture, the notable crops being paddy, wheat, and sugar cane.

METHODOLOGY

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

- Image processing software ERDAS [7] 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, hydrogeomorphology, drainage density and landuse and slope maps are prepared.
- Water table monitoring for past three years (viz., from 2001 to 2003), for premonsoon (i.e. before-rainy season) and the postmonsoon (i.e. after- rainy season) periods has been carried out.
- Subsurface lithological maps have been prepared using Vertical Electrical Sounding (VES) data in association with available lithological data.

HYDROGEOLOGICAL RESULTS

Water table fluctuation profile for the premonsoon and postmonsoon periods during the year 2002 has been prepared with villages as shown in Fig. 2. The seasonal groundwater fluctuation is small towards northeast and central part in the Bhabhar zone (at Puranpur, Aneki Kala, Aneki khurd and Hetampur villages whereas the fluctuate gradually increases southwards in the Tarai zone at Rathaura, Lalwala, and Asafnagar villages. The greater magnitude of water table fluctuation in the Tarai zone as compared to that in the Bhabhar is indicative of lower specific yield of shallow aquifer in the former compared to that in the Bhabhar zone.

A Fence diagram has been also prepared based on lithological variation from the study area (Fig. 3) shows ground water table and depth of aquifer in the area which is heterogeneous 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 from one to another well. The clay beds are available in variable thickness with limited aerial extent; very thick clay with kankar is available in some parts. The main aquifers constituents in all wells are composed of sand with pebbles and boulder generally fining upwards. The aquifer sediments in most wells occur as relatively thin sandy clay towards top, with coarser fraction to them under lain by clay kankar below the aquifer. Further, both unconfined and semi- confined aquifers are present in the area.

The geological formations occurring in the study area comprise of Siwalik rocks and alluvial deposits. The formations occurring to south of the Siwaliks are alluvial fan deposits of recent age. The alluvial fan deposits (referred as Piedmont zone) are made up of assorted sands and gravel associated with occasional clays. The belt extends in an elongated manner along the foothill region, roughly along NW-SE direction. To the south of this belt the Ganga plain is occurring. 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. 4).

Based on physiographic characteristics, the area is classified into four geomorphic units. The geomorphic boundaries are digitized on the enhanced image through GIS and a hydrogeomorphological map is prepared which is shown in Fig. 5. The Upper Piedmont zone (covering 170.65 km^2) of the area also known as Bhabhar, bordering the Siwalik Hills with gentle slope comprising of unconsolidated coarse material is distinctly interpretable. This belt provides excellent hydrogeological setup for recharge and infiltration. The Lower Piedmont, also known as Tarai is separated from the Upper Piedmont (Bhabhar) by the spring line along their junction line and is covering about 109.82 km^2 of the area. This zone is composed of coarse-grained sand and clays with gravel (boulders and pebbles). Due to occurrence of interbeded nature of sand and clays; therefore the groundwater occurs in confined to semiconfined condition in the Tarai belt.

The groundwater prospects in this landform are good to very good. Flood plains form the youngest geomorphic unit and include various landforms formed by fluvial action i.e. sandbars, channel bars, paleochannels and meander scars. These are characterized by very gentle slope and consist of subrounded to rounded fragments of sand, silt and clays. It is a highly permeable zone helping in partial bank recharge and subsurface flow. Groundwater prospects in this landform are good to very good.

SURFACE RESISTIVITY DATA COLLECTION AND INTERPRETATION

The physics of the electrical current flow suggests that a good contrast in electrical resistivity exists between the different lithological units (e.g. clay, sand and gravels) and between the water-saturated and unsaturated formations [8]. Thus, the electrical resistivity method can be used successfully to differentiate lithological units in the study area. A detailed discussion on the depth of investigation and the resolution for the various electrode configurations is given by [9] and [10]. Considering the depth used, and the resolution and ease in field operation, the Schlumberger configuration has been used for the field resistivity measurements in the present work.

Seventy vertical electrical soundings were recorded in the study area using the Schlumberger configuration with maximum electrode spacing of about 900 m; the minimum electrode spacing was 1 m and recordings were made at station intervals of about 2 km. The electrode spacing is sufficient to provide information about the resistivity variation at near surface and deeper than 100 m, which provides information about the shallow and deeper aquifer system. The [11] method was used to invert measured apparent resistivity data to true resistivity as a function of depth at each site. The method works in apparent resistivity domain and can be used for the automatic iterative interpretation of Schlumberger and Wenner sounding data. The method is primarily designed on a certain rule of thumb based on the study of a large number of theoretical curves for layered media. The field curve is digitized at a logarithmic interval equal to (or a multiple of) sample interval of the filter to be used in calculating the theoretical sounding curve. A digitized field curve is interpreted by the iterative method, as also explained by [12]. The interpreted resistivity values were correlated with the known available borehole data in the study area and calibrated with the known lithology. The lithological correlation of resistivity values obtained from the interpretation of measured apparent resistivity on one site in the Bhabhar zone is shown in Fig. 6a.

DELINEATION OF AQUIFER SYSTEM

The analysis of the resistivity data in the light of known lithology shows the resisitivity of shallow aquifer zone varies from 20 Ohm-m to 182 Ohm-m. Lower resistivity range of 20-50 Ohm-m of aquifer zone was obtained in the Tarai zone which gradually increases towards the Bhabhar zone up to 182 Ohm-m. The large variation in resistivity of aquifer is due to the presence of different size of grains consisting of fine sand and gravel (pebble) in the Tarai zone which further grade to a coarser material (Boulder) in the Bhabhar zone. The thematic map showing the resistivity of shallow aquifer is shown in Fig. 6b.

The thematic map of shallow aquifer thickness shows that the maximum thickness is 10 m- 14 m in the Tarai zone whereas, the minimum thickness (up to 5m) of the shallow aquifer is observed in the Bhabhar zone as shown in Fig. 7.

The depth to shallow aquifer is shown in Fig.8. It has been observed that aquifer depth is minimal (1 m- 8 m) in the Tarai zone and in area close to spring line in the Bhabhar zone. Maximum depth more than 16 m was observed in the south central part of the area in the Bhabhar zone due to southward shifting of the spring line. The greater depth to shallow aquifer in the Bhabhar zone can be explained due to high permeability of assorted and unconsolidated deposits in the Bhabhar zone in the absence of confining clay layers at shallow depths.

CONCLUSIONS

An integrated approach of geomorphological, geohydrological, geoelectrical data has been used to delineate the shallow aquifer in the piedmont zone of Himalayan foothill region of District Haridwar, Uttaranchal, India The resistivity ranging from 20 -165 Ohm-m indicates water bearing sand with gravel and forms the shallow aquifer in the Bhabhar and Tarai zones. The thickness of this aquifer varies between 2 to 8m in the Bhabhar and 5 to15 m in the Tarai. The depth to the shallow aquifer zone varies from 17 to 32 m in the foothills (Bhabhar zone) and 1 m to 7 m in the Tarai. Due to occurrence of the finer materials in the Tarai belt, the groundwater occurs under confined, semi- confined and unconfined condition.

REFERENCE

1- Dwivedi, N. K. and Gupta, P. N. (1961): Behavior of groundwater table in Ganga Yamuna Doab, Uttar Pradesh Irrigation Research Institute, Roorkee. T. M. No. 31, RR (G-42).

2- Pandey, M. P., Raghava Rao, K. V. and Raju, T. S. (1963): Groundwater resources of Tarai-Bhabhar belts and intermountain Doon Valley of Western UTTAR PRADESH. Report Prepared For MFAA. 253p.

3- Anonymous, (1999): Water quality of District Haridwar (U. P.), Tech. Rep. CS (AR) - 10/98-99, National Institute of Hydrology (NIH), Roorkee.

4- Rao, M. S., Kumar, B., Nachiappan R. m. P, Jagmohan. (2000): Identification of aquifer recharges sources and zones in parts of Ganga-Yamuna Doab using environmental Isotopes. ICIWRM-2000 Proceedings of International Conference on Integrated Water Resources Management for Sustainable Development, 2000, New Delhi India, pp. 271-281.

5- Agrawal, C. S. (1994): Quantitative analysis of aquifer parameters in part of western Utter Pradesh, for groundwater Estimation, Hydrology Journal of IAH.

6- Shakeel, M. (1997): An integrated approach for evaluation of hydraulic properties of alluvial aquifers Ph. D. thesis, Unpublished, Department of Hydrology, Indian Institute of Technology Roorkee, Roorkee.

7- ERADS, (1997): ERADS Imagine, Tour Guides, ERADS, Inc., Atlanta, USA, 454 pp.

8- Zhdanov MS, Keller GV (1994): The geoelectrical methods in geophysical exploration. Elsevier, Amsterdam

9 - Apparao A, Gangadhara Rao T (1974): Depth of investigation in resistivity methods using linear electrodes. Geophys Prospect, Vol. 22 pp.211–223.

10- Schultz R (1985): Interpretation and depth of investigation of gradient measurements in direct current geoelectrics. Geophys Prospect, Vol. 33, pp.1240–1253.

11- Zohdy, A. A. R. (1989): New method for automatic interpretation of Schlumberger sounding curve. Geophysics, Vol. 2, pp. 245-253.

12-Israil M, Pachauri (2003): Geophysical characterization of a landslide site in the Himalayan foothill region. Journal of Asian Earth Science, Vol. 22, pp.253–263.

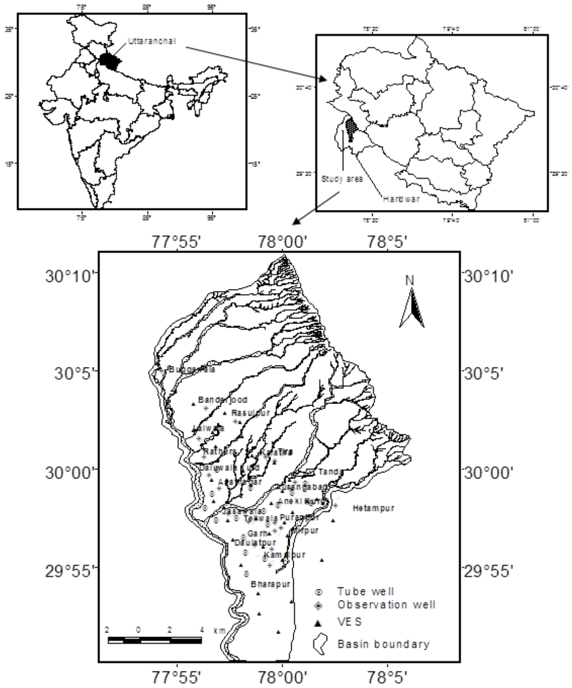

Fig. 1: Location map of the study area showing VES and tubewells

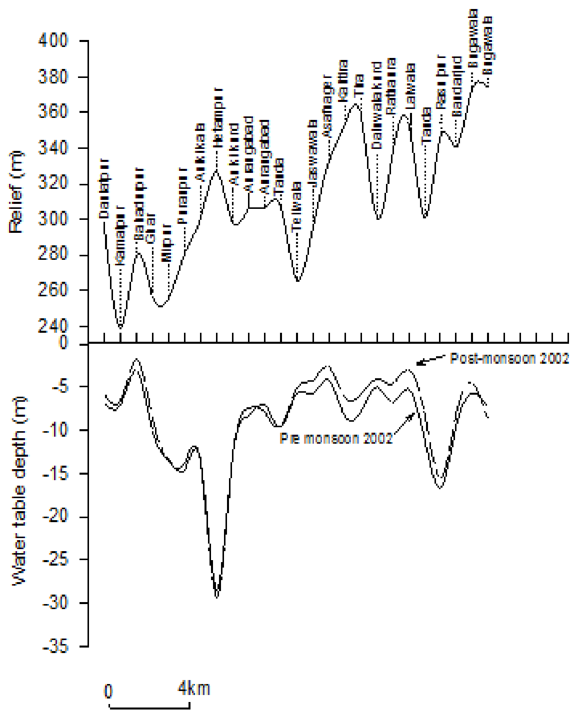

Fig. 2: Surface elevation and water-table fluctuation measured in the villages shown in top plot in the study area

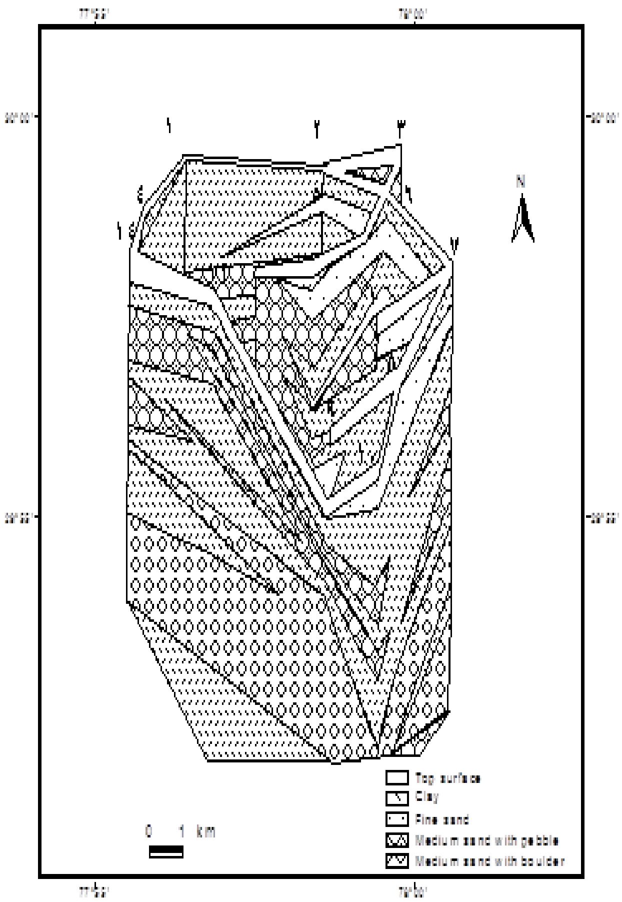

Fig. 3: Fence diagram of the study area

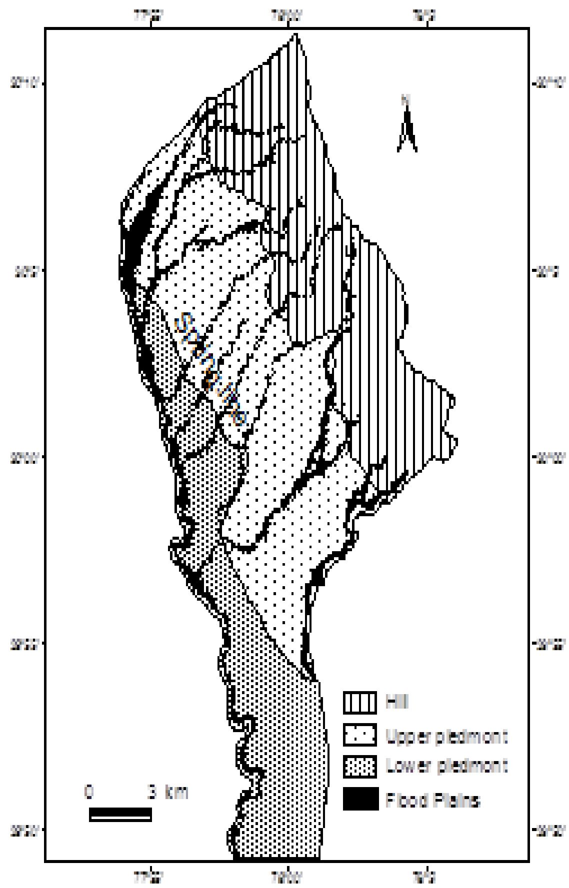

Fig. 5: Hydrogeomorphological map Of the study area

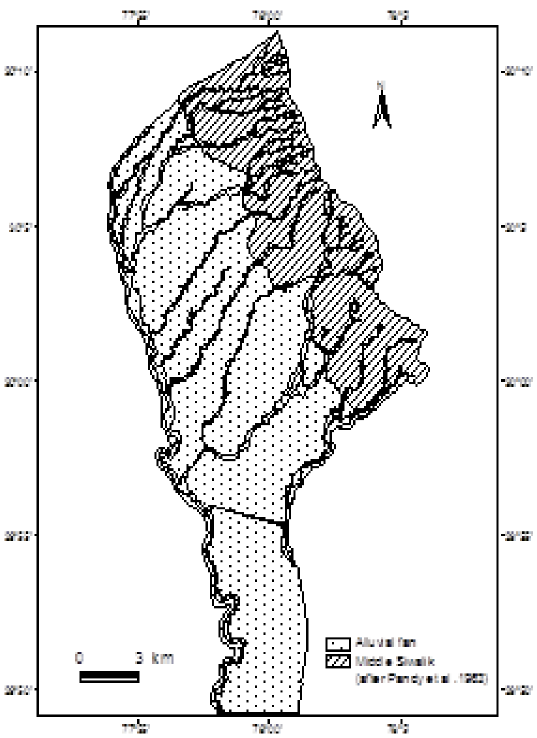

Fig. 4: Geological map of the study area

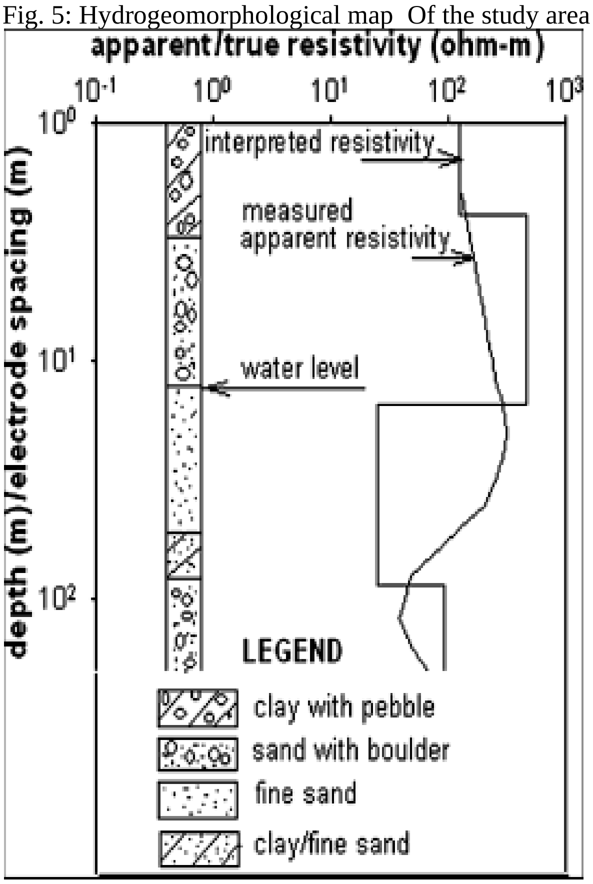

Fig. 6a: Lithological correlation of resistivity data at a site in the Bhabhar zone

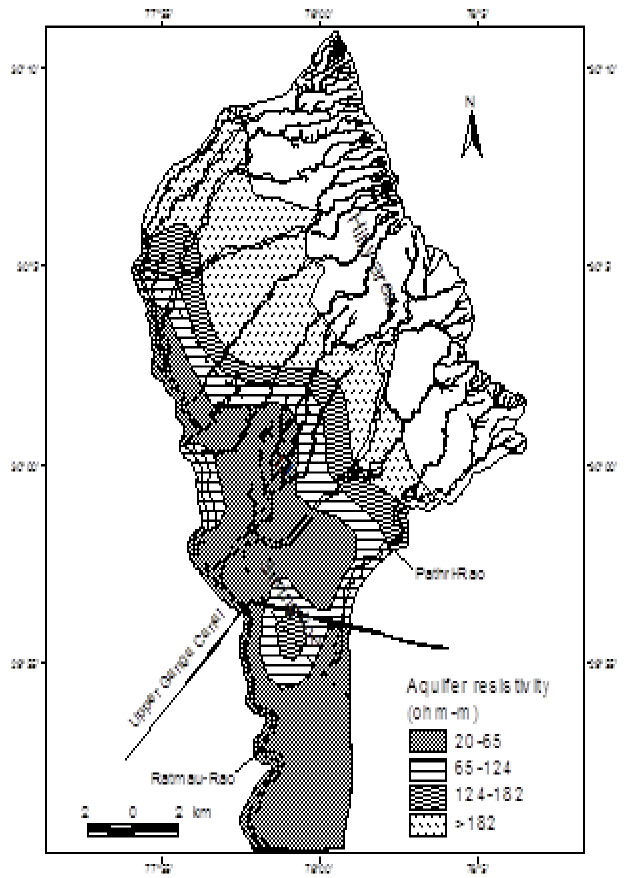

Fig. 6b: Resistivity map of shallow aquifer

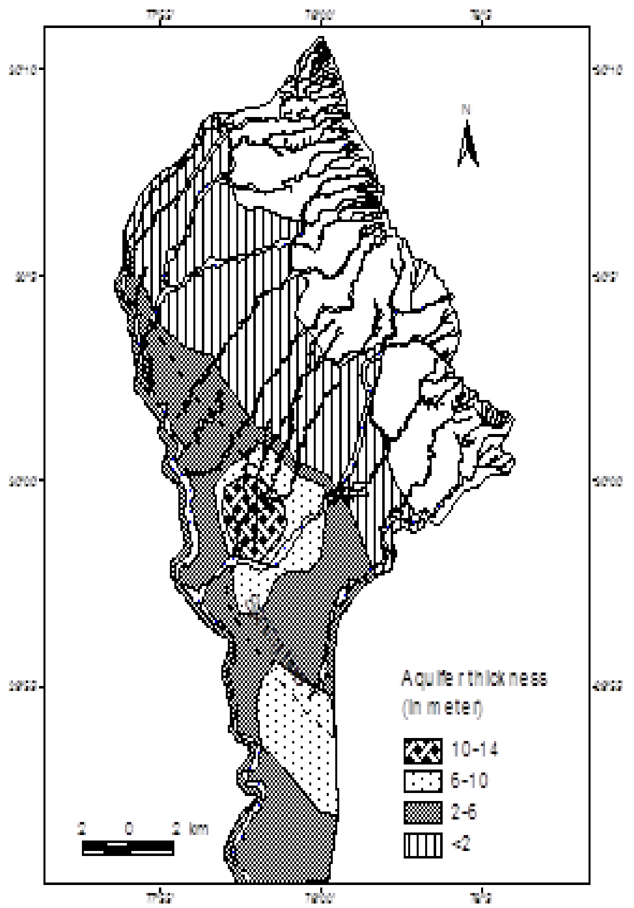

Fig.7: Thickness map of shallow

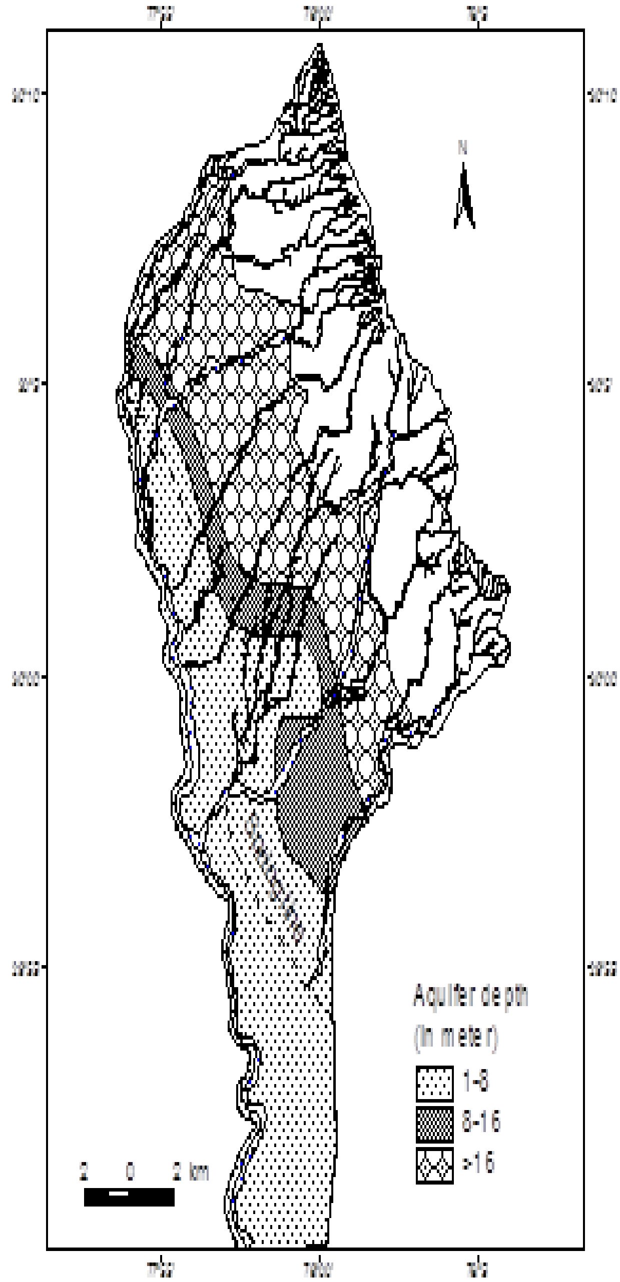

Fig. 8: Depth of shallow aquifer

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تحديد طبقة المياه الجوفية الضحلة في منطقة البديمونت في مقاطعة اتراشال – الهند باستخدام بيانات الطرق الجيوفيزيائية والهيدروجيولوجية

مفيد سعدي الحديثي ابراهيم جاسم عبدالله

الخلاصة

تم اجراء سبعون جس كهربائي عمودي باستخدام ترتيب شلمبيركر وبتباعد 900 م بين قطبي التيار لكل المواقع وبمسافه 2كم او اقل بين موقع واخر. تم استخدام برنامج جاهز باستخدام الحاسب الالي للحصول على المقاومه الحقيقيه وعمق الطبقات من خلال المقاومه الظاهريه المقاسه في الحقل. قورنت النتائج مع المقاطع الليثولوجيه المتوفره لمنطقة الدراسه حيث حددت المقاومه النوعيه للطبقات او التكوينات الموجوده في منطقة الدراسه حيث تبين انها تتراوح من 22–165 اوم. م للطبقات الحامله للمياه والمكونه من رمل مع حصى ناعم والتي تشكل الطبقه الضحله لحزام او نطاق بهابر (Bahber belt) وكذلك لحزام تاراي (Tarai belt). كما تبين ايضا ان سمك الطبقه الحامله للمياه تتراوح من 2– 8 متر في نطاق بهابر و5– 15 متر في نطاق تاراي وكذلك يتضح ان عمق الطبقه الحامله للمياه تتراوح من 17– 19متر في نطاق البهابر ومن 1– 7 متر في نطاق تاراي كما تظهر الطبقه الحامله للمياه محصوره وشبه محصوره وغير محصوره بسبب الترسبات الناعمه في نطاق تاراي.