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Study and Mapping of Ground Water Prospect using Remote Sensing, GIS and Geoelectrical resistivity techniques – a case study of Dhanbad district, Jharkhand, India

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ABSTRACT

Water is an important natural resource, which is available both on surface as well as in recharge zone of weathered layer and in various other suitable water reservoir formations/structures below the surface. As the availability of surface water is erratic and irregular one needs to study and map the underground water reservoirs. Dhanbad district of Jharkhand state is in general part of hard rock terrain, which is mainly covered by Chottanagpur Granite Gneissic Complex and has no perennial river sources for water supply. Therefore, in view of the upcoming industrialization in the region there is need to exploit groundwater resource, which is limited and confined to fractured and weathered zones. Even though the region receives copious rain, the terrain and soil condition allows little storage of water. Hence, the region faces shortage of water in dry seasons. Therefore, it is necessary to explore and study the ground water resources effectively using suitable techniques. Various workers have successfully applied Remote Sensing technique in exploration, evaluation and management of ground water resources in an area as a whole and the results have been published. In this paper also mapping and management strategies for ground water resources have been studied, by analyzing IRS LISS II multi band remote sensing data along with geological as well as geophysical resistivity sounding data carried out at places in GIS environment. Finally, based on the integrated thematic maps, weighted analysis in Arc GIS ground water resource prospect map of the area has been prepared and discussed.

The study has brought out that the high groundwater potential zones are confined along lineaments and in pediment areas. Also alluvial fills, valley fills form potential zones. The other geomorphic units like buried pediplain, peniplains and denundational hills form zones of moderate to good groundwater prospects. Dissected pediments, inselberg complex, undulating upland and buried pediment with intermontane valley are zones of poor prospects. Very poor regions occupy a small part of total study area and are mainly confined to undulating upland and residual hills.

INTRODUCTION

Groundwater is a dynamic and replenish-able natural resource. But, in hard rock terrain availability of groundwater is limited. In such terrains ground water is essentially confined to fractured and weathered zones. Therefore, exploration and exploitation of ground water resources require thorough understanding of geology, hydrogeology and geomorphology of the area. Integration of various data and thematic maps, such as terrain features derived from remote sensing images, hydrogeomorphical details, depth to groundwater table and geophysical resistivity sounding data help in generation of groundwater potential zone maps which when supplemented with geophysical data i.e. VES data in GIS environment, facilitates effective evaluation of groundwater potential zones (Yadav et al., 2007 and Singh et al., 1997). Depth of occurrence of ground water zone and the location of well sites can be determined more effectively by electrical resistivity method. Integrated analysis and study, besides mapping and delineation of potential areas on small and regional scale help in determination of aquifer characteristics, flow pattern, and correlation of lithology (Sabale et al., 2009). Such an approach has been applied successfully in delineation of groundwater potential sites / zones by various workers (Ahmad et al., 2010; Chatterjee et al., 2010; Lokesh et al., 2005; Mondal et al., 2007; Rao et al., 2009; Banerji, 2000; Srivastava, 2000 and Dasgupta, 1994).

The present study area, which is a hard rock terrain, having undulating topography though get sufficient rainfall, suffers from water scarcity for domestic, agricultural, and industrial purposes due to limited nature of aquifers (inadequate weathered and fissured zones). Also, sometimes presence of basic and meta-basic dykes and the quartz reefs in the area have acted as barriers for the flow of water (Singh et al., 1997). Taking into consideration the above scenario an attempt has been made for mapping of ground water potential zones, by integrating various thematic maps, as generated from processed and enhanced remote sensing multi band data, digital elevation model (DEM) created from SRTM data along with vertical electrical survey (VES) data and other geo hydrological data in GIS environment.

LOCATION, GENERAL GEOLOGY AND HYDROLOGICAL SET UP OF THE AREA

Our study area, Dhanbad district is situated in between 23^{0}37'30"N - 24^{0}56'N lat and 86^{0}8'23"E - 86^{0}50'18"E long, in Jharkhand state of Eastern India (Figure 1). The northern boundary of which is marked by Barakar river and the southern boundary by Damodar river, on which two important reservoirs viz Maithon and Panchet are located respectively. The region lies on the eastern part of Chhotanagpur plateau and has an undulating topography with three

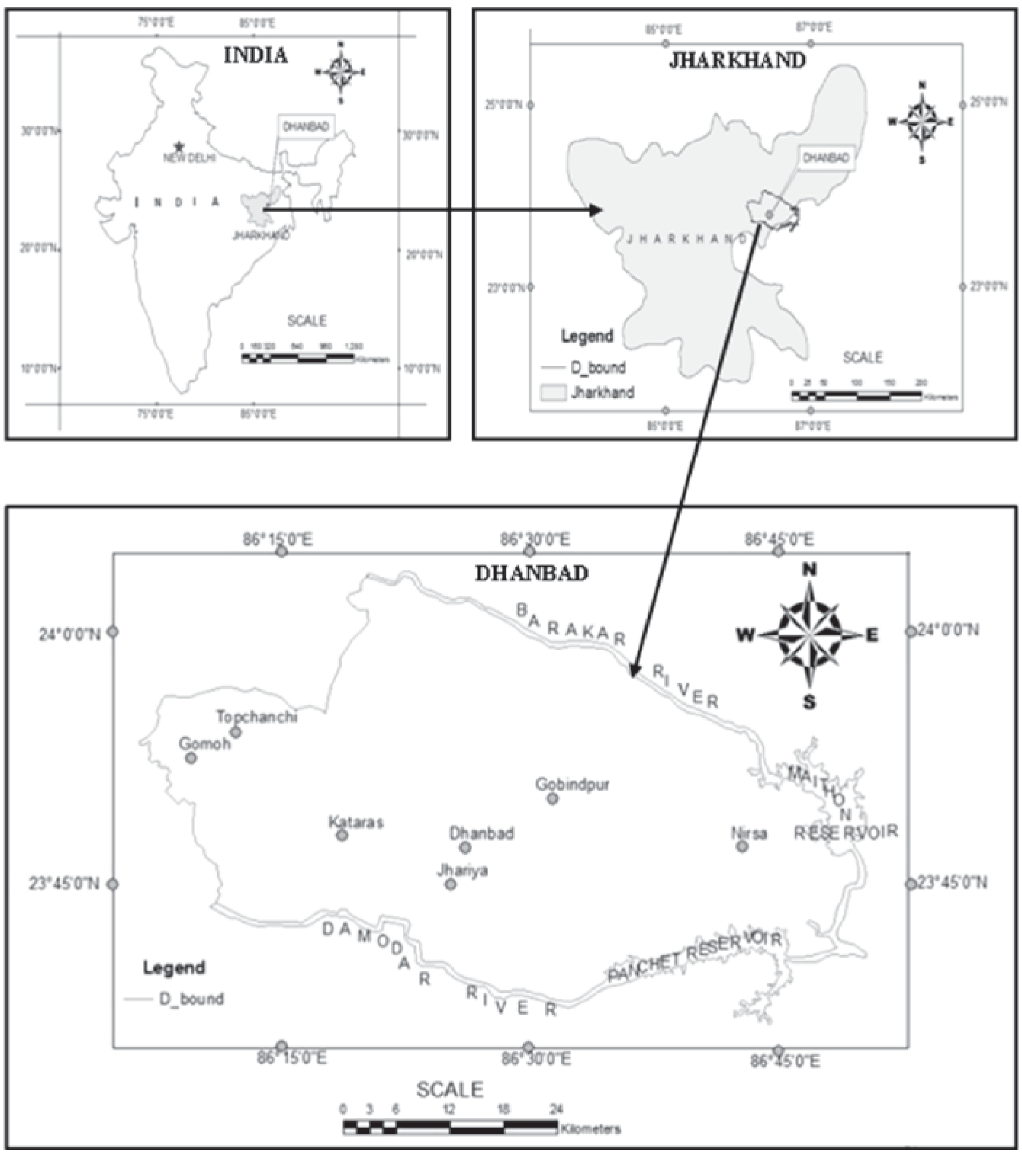

Figure 1. Location map of Dhanbad District, Jharkhand.

distinct geomorphic features from north to south, (a) the hill ranges in north western part, (b) the coal field in southern and eastern part, and (c) the undulating upland and intervening alluvial fill low valleys with isolated bare ridges between them in north. The metamorphic terrain of the region is underlain by a wide range of geological formations ranging in age from Archaean to Recent. The Archeans and Gondwanas constitute the major parts.Thin veneer of Quaternary alluvial deposits occurs in the topographic depressions along the Damodar and Barakar Rivers (Figure 2). Our study is restricted to this Achaean terrain only.

In this terrain ground water occurs under unconfined condition in the weathered zone of consolidated or unconsolidated rocks and in the fractured zone immediately below the weathered zone. It also occurs under semi confined and confined states in deep fracture zones in the metamorphic and sedimentary rocks. Groundwater in such rocks circulates through the secondary openings represented by joints, cracks, fissures and such other planes of discontinuity. The weathered residuum of the hard rocks as well as the fractures, joints, fissures, faults and other zones of discontinuity are the principle repositories of groundwater in the area (Banerji, 2000).

DATA AND METHODOLOGY USED

Details pertaining to the data, processing methodology and analysis followed in the present study (mapping of Ground Water Resources prospect map of Dhanbad district using remote sensing, Digital Elevation Model (DEM) and conventional Electrical Resistivity Sounding (VES) data in GIS environment) are described briefly.

Multi band remote sensing digital data sets of IRS LISS II have been radio metrically processed, enhanced and geo corrected using SOI toposheet no. 73/I. Finally standard false color composite (FCC) was generated in ENVI software for delineating general rock types, landforms, geological structures etc. based on characteristic photo signatures (Figure 3).This was then integrated with published geological map (Figure 2) and Ground Water Table depth map from CGWB report (Figure 4) in Arc GIS environment.

Further the resulting maps were again integrated with Digital Elevation Model (DEM) of the region

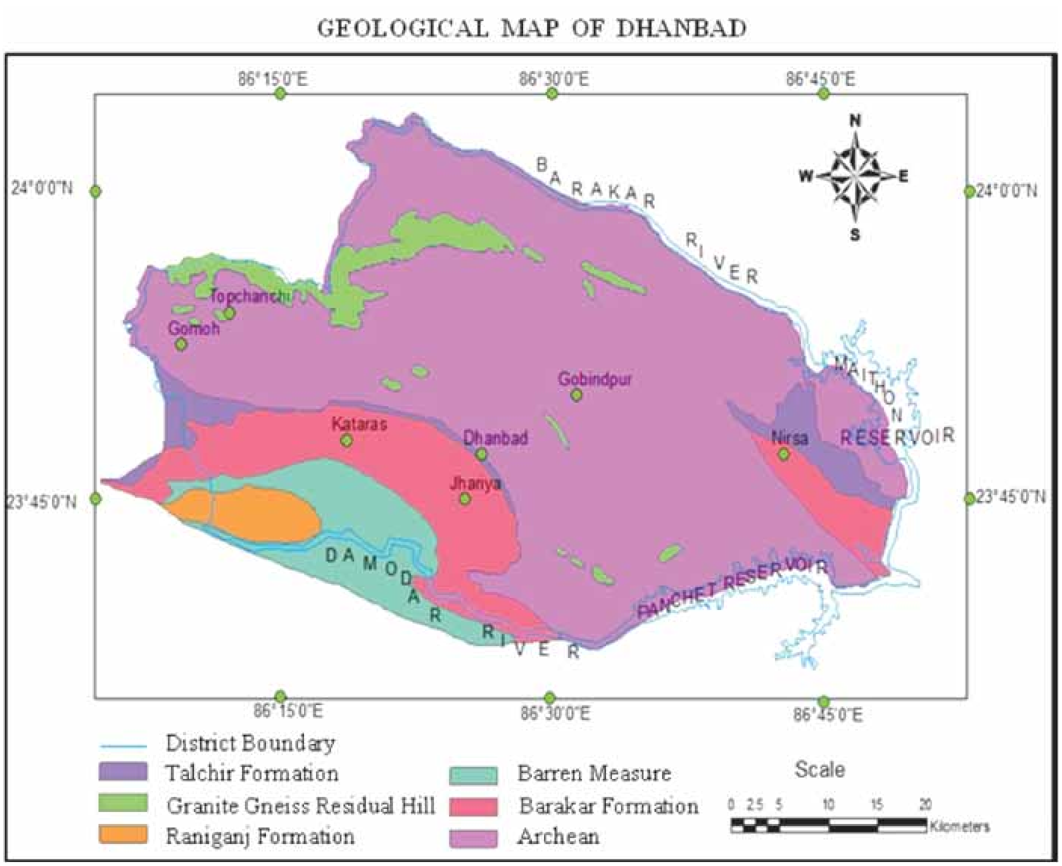

Figure 2. Map showing General Geology of study area (after Krishnan, 1982).

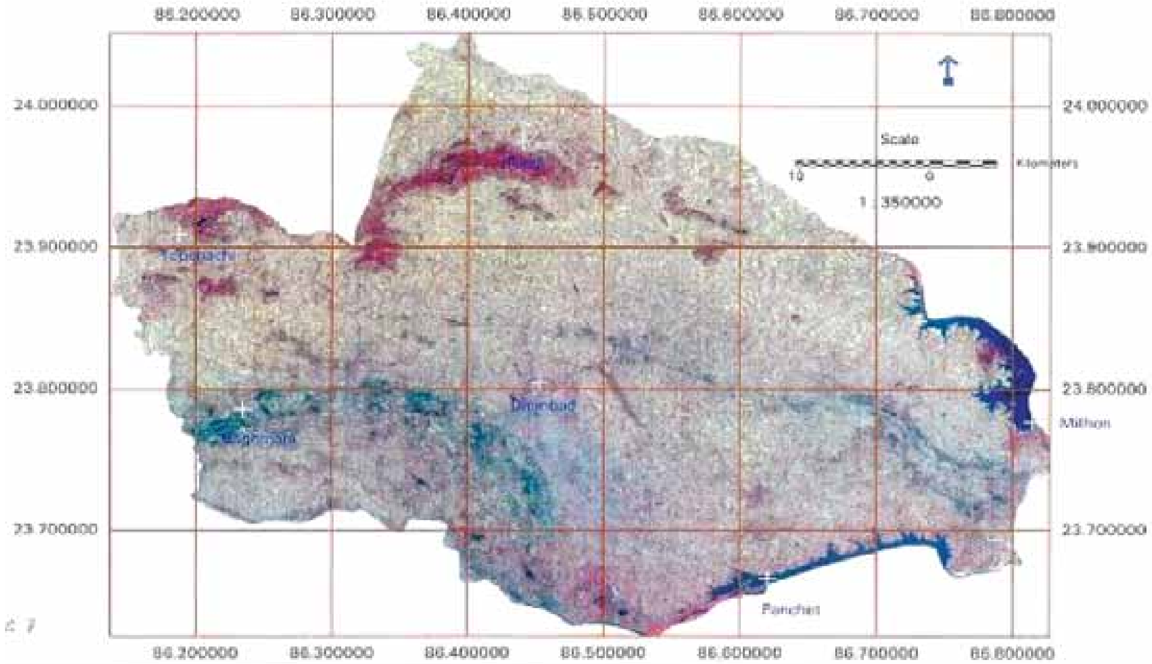

Figure 3. IRS LISS II standard FCC (Geo corrected) image of Dhanbad District.

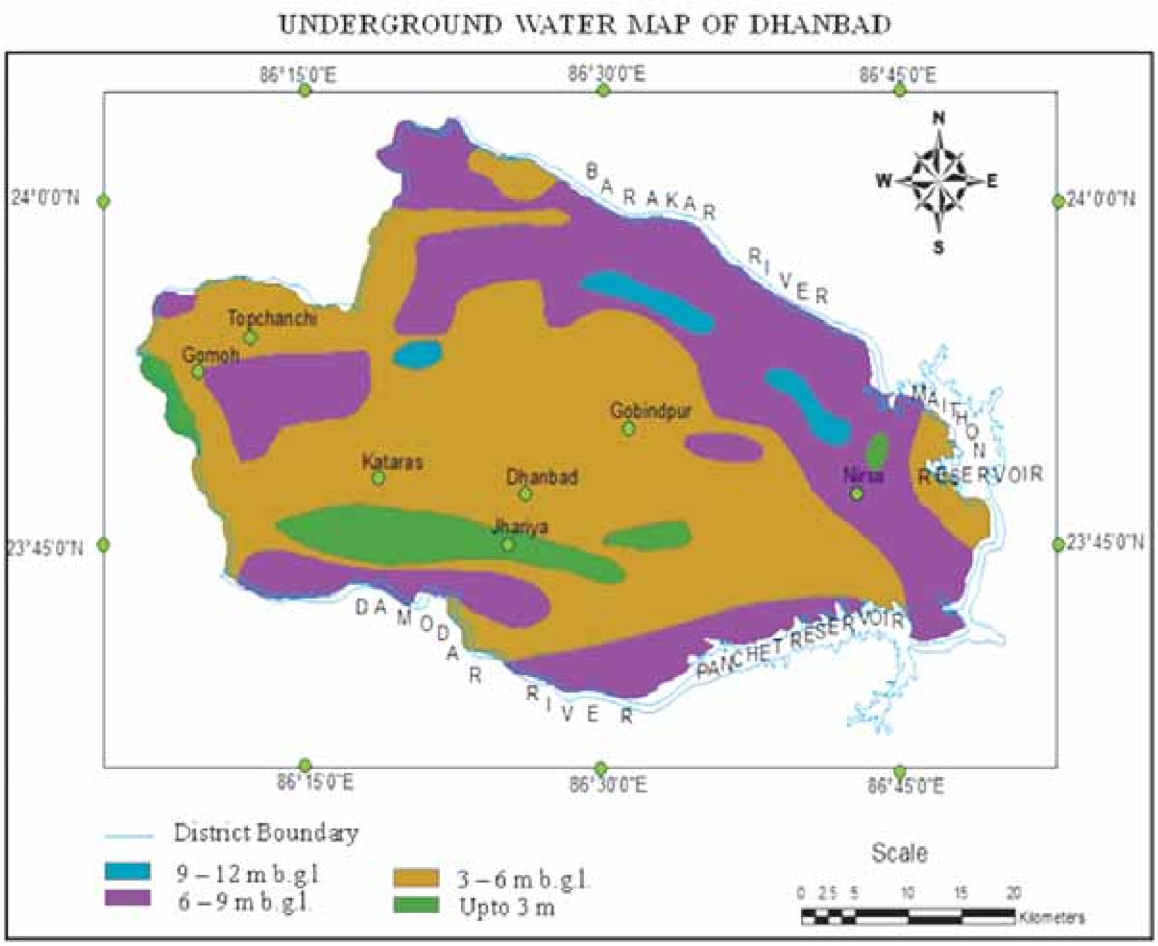

Figure 4. Ground Water Table depth map (after CGWB Report, 2000).

as generated from US- Shuttle Radar Topographic Mission (SRTM) data (Figure 5) with spatial resolution of 90 m down loaded from site www.srtm.csi.cgiar.org and checked with the aquifer depths as interpreted from typical vertical electrical sounding (VES) curve carried out at selected points (Figure 6). In Figure 6 the first layer corresponds to soil cover and weathered zone with depth around 5 m and of 50 ohm meter resistivity value. This shows the possibility of groundwater occurrence, in good quantity, in this layer compared to the underlying layers. The first layer is underlain by semi weathered

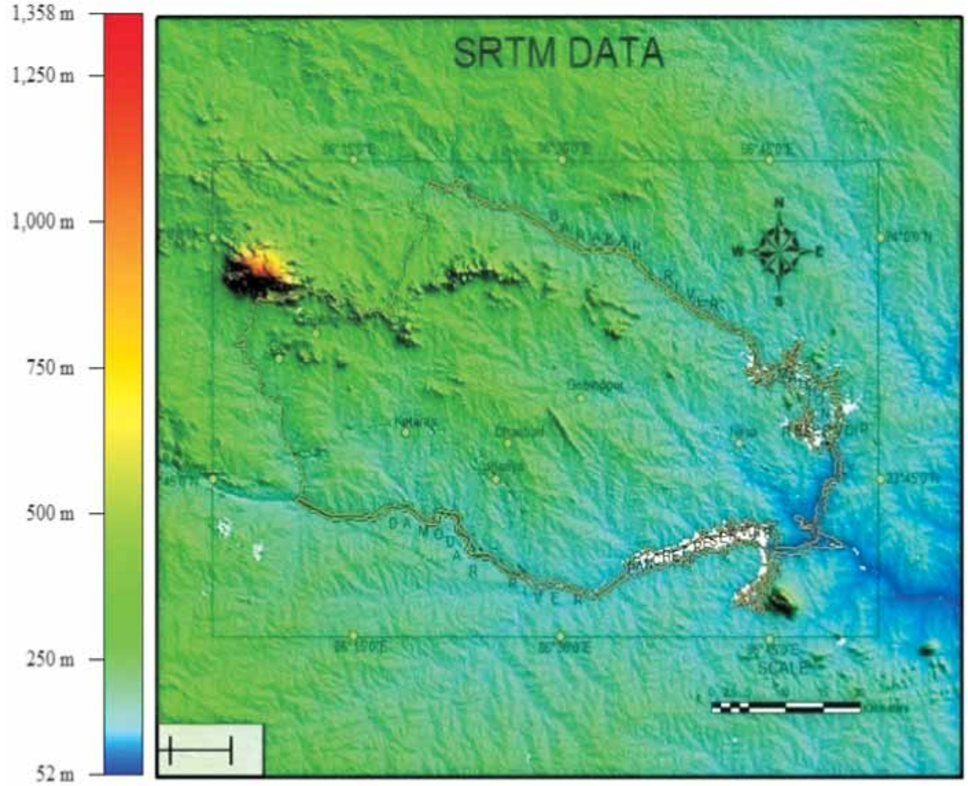

Figure 5. SRTM -Digital Elevation Model (DEM) of Dhanbad District.

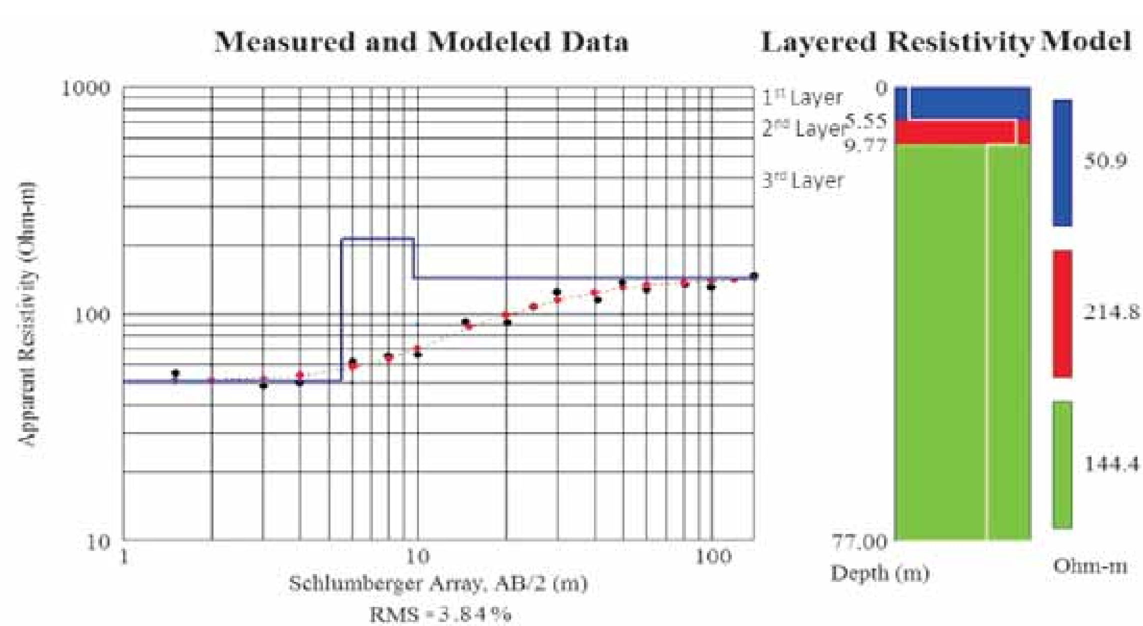

Figure 6. Vertical Electrical Sounding Resistivity curve and modeled section.

2nd layer of thickness 9-10 m with resistivity value of about 214 ohm mt. Underneath, weathered rocks are found. There is a probability that this second layer may have some non-interconnected fractured zones with ground water, with no circulation. Whereas, the third layer with resistivity value of 144 ohm mt may be inferred as the zone that outlines the channels along which groundwater appears to flow. This could be a good potential zone. Finally , all the thematic maps were overlaid and analyzed using weighted overlay technique of spatial analysis tool in Arc GIS 9. This technique provides a method for combining multiple thematic maps by applying a common measurement scale of values to each raster, weighting each according to its importance, and adding them together to create an integrated map. In the present study the weighted overlay analysis has been carried out by giving weight to individual parameters as class weights and thematic maps as weighted theme, according to their degree of prospect (Table 1) for generating Hydro-geomorphological map (Figure 7) and Ground Water Prospect map (Figure 8).

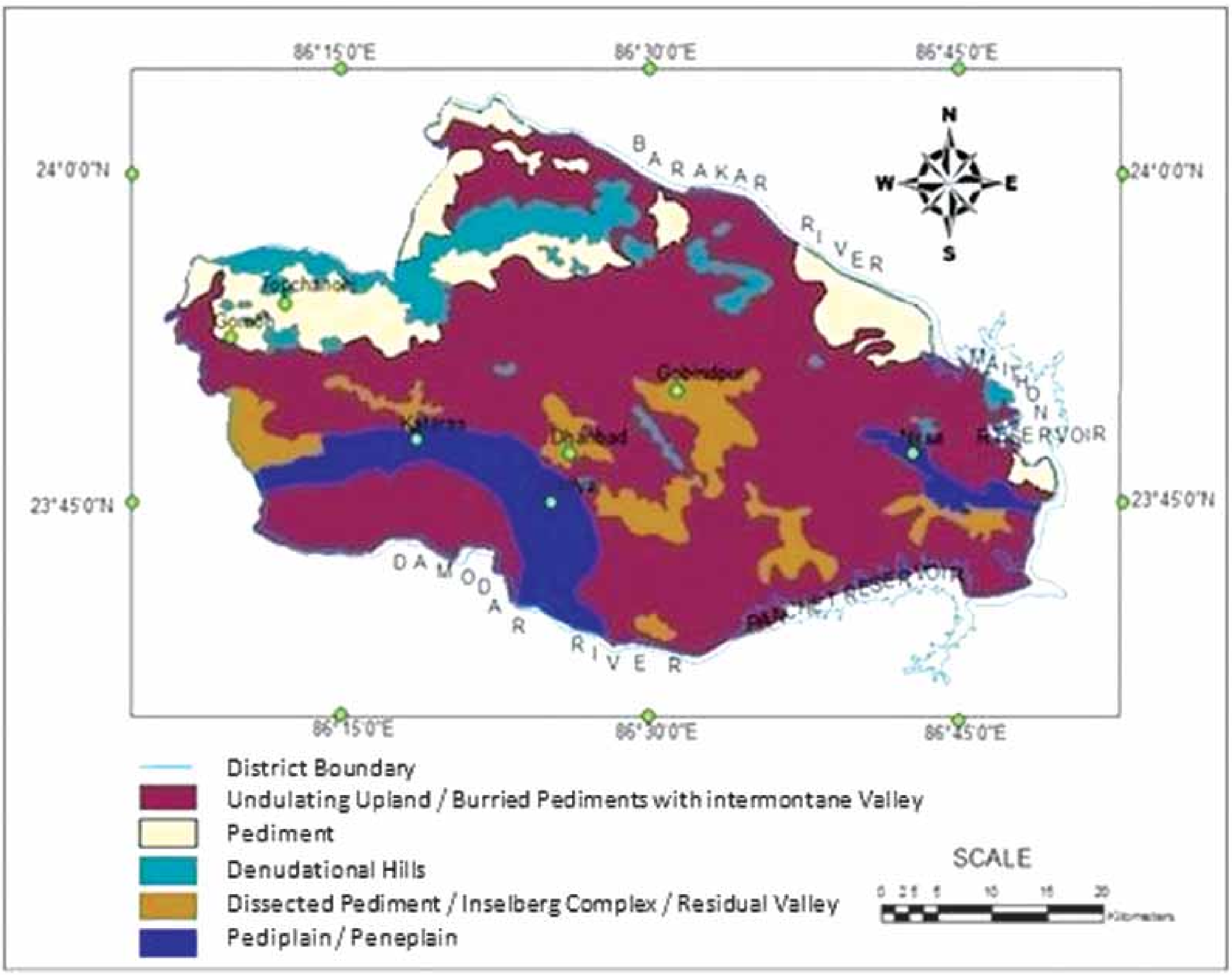

Figure 7. Hydro Geomorphological Map of Dhanbad District (after Banerjee,2000).

Table 1. Different themes and thematic parameters considered for groundwater prospects evaluation and their class weights

Geomorphology (Theme Weight – 40)		**Geology** (Theme Weight – 20)		**Underground Water Table map m b.g.l. (below ground level)** (Theme Weight- 20)		**Digital Elevation Model (Contour) Map** (Theme weight- 20)	
Categories	**Class Weight**	**Categories**	**Class Weight**	**Categories**	**Class Weight**	**Categories**	**Class Weight**
Denundational Hills	6	Granite Gneiss Residual Hill	2	upto 3 m b.g.l.	8	500 - 1200 m	2
Pediment	8	Archean	4	3-6 m b.g.l.	6	301 - 500 m	6
Hillocks and Mounds	2	Talchir	4	6-9 m b.g.l.	6	151 - 300 m	4
Pediment Inselberg Complex	2	Raniganj	6	9-12 m b.g.l.	2	0 - 150 m	6
Peneplaine / pediplain	4	Barren Measure	6				
		Barakar	4				

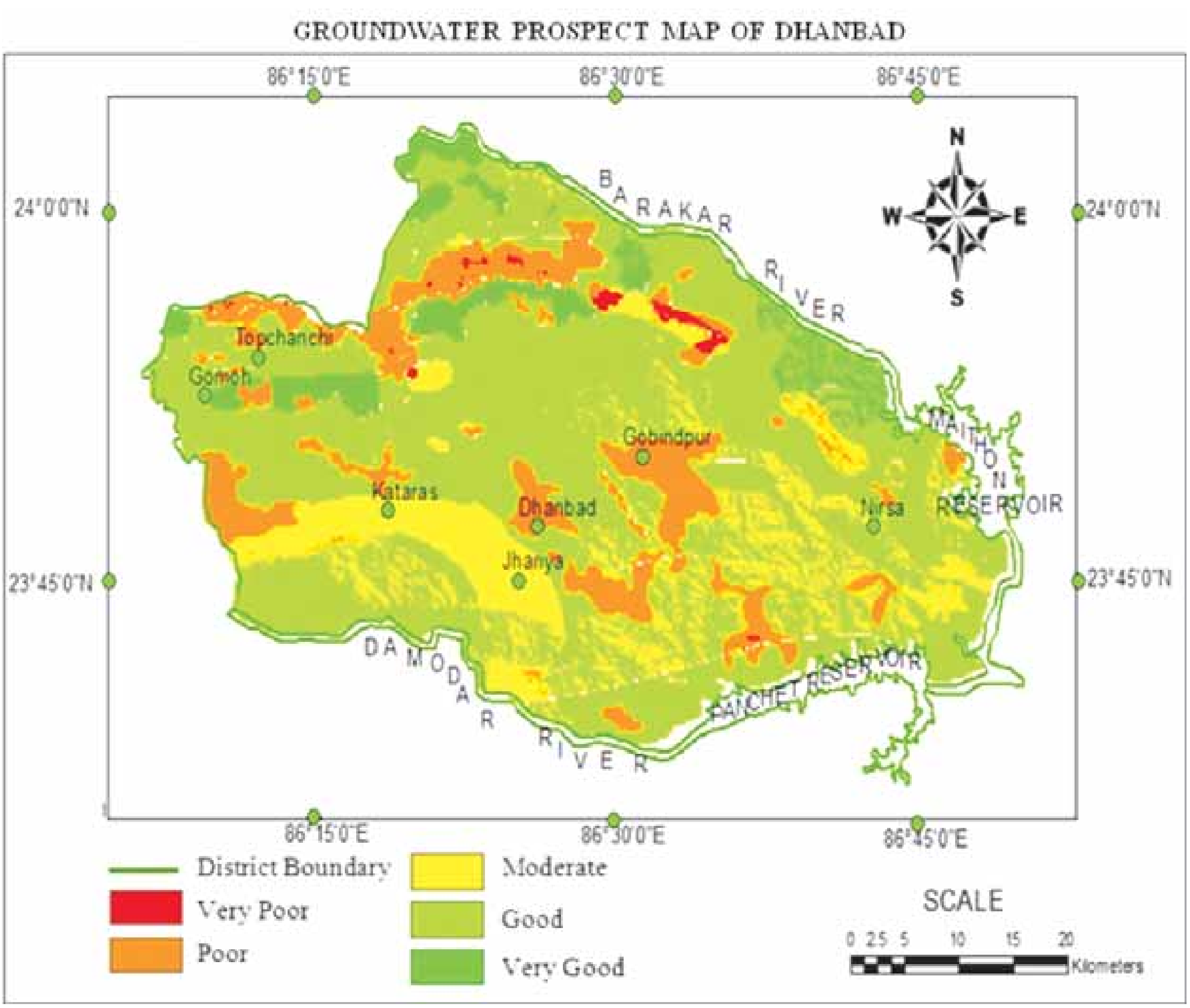

Figure 8. Final Ground water prospect map of Dhanbad District

RESULTS AND DISCUSSION

On the basis of integrated and weighted analysis of various thematic maps such as geological, geo morphological, digital elevation model, vertical electrical resistivity sounding data, ground water table depth map and geo morphological map in Arc GIS, we have generated two very important maps viz.; **A) Hydro-geomorphological map** (Figure 7) showing groundwater potentiality in terms of geomorphology and **B) Ground Water Prospect Map** (Figure 8) of Dhanbad district.

A) Hydro-geomorphological Map

This map shows five distinct hydro geo morphological features from the point of view of water resource prospect as well as for application of water management practices, in order to enhance the status of water resources in the region.

Unit 1) - Denudational Hills: The area is covered with mixed forest and has moderate to low slope resulting in moderate run off. It is shallow and well drained. It is gravelly loamy soil and non-sticking. It is friable when moist. The region is covered with few lineaments/fractures with subradial drainage pattern and hence the groundwater prospect is moderate to good.

Unit 2) - Pediment: The area is covered with bushes with cultivated land in low valley and has moderate to steep slopes (5-10%). The region has dense lineaments. Drainage pattern is dendritic to sub parallel with linear parallel radial drainage pattern. The groundwater prospect is good to very good.

Unit 3) - Undulating Upland: These features represent the buried pediments with intermontane valley. These areas are characterized by moderate to high steep slope resulting in very high run off. Groundwater prospect is poor.

Unit 4) - Pediment Inselberg Complex: These are isolated rock hills, knobs, ridges, or small mountains that rise abruptly from a gently sloping or virtually level surrounding plain. The unit represents barren land with shallow well drained gravelly sandy soil on sloping landscape with severe erosion. Drainage density is poor with sub parallel to sub radial pattern and groundwater prospect is poor.

Unit 5) – Pedeplain / Peneplain: Pedeplains are relatively flat rock surfaces formed by the joining of several pediments and Peneplains. They are gently undulating, almost featureless and plain. The region is covered with moderate number of lineaments with sub parallel to sub dendritic drainage pattern. Groundwater prospect is low to moderate.

B) Ground Water Prospect Map

The final integrated map as generated by applying the weighted overlay analysis in Arc GIS shows five prospect grades in terms of water resources potentiality viz.; very good, good, moderate, poor and very poor (Figure 8). Good Water prospect zone Geomorphologically covering alluvial fills and valley fills covers nearly 45% area (yellowish green color tone) . Very good zones cover only 12% of the study area (green color tone). They are located along lineaments and in pediment areas. Moderate prospect zone covers 15% of the area (yellowish color tone). Features like buried pediplains, peniplains and denundational hills come under this category. Whereas poor regions cover up to 22% (orange color tone). These features are mainly confined to undulating upland and buried pediments with intermontane valley. Lastly, very poor groundwater prospect zones are approximately 10% (red color tone). These features include dissected pediments, inselberg complex and residual hills.

CONCLUSIONS

The present integrated study has brought out the following conclusions.

Geologically it is observed that the groundwater is mainly confined to secondary porosity i.e. fractured zone, fault, joint and weathered column. It is observed from field survey and also from various wells located in the region the hard granite gneisses and meta basic dykes sometimes act as barriers for the groundwater flow in the region.

Based on resistivity variation with depth, it is possible to estimate the depth and distribution of groundwater. The low resistivity value of less than 51ohm-m indicates the presence of weathered zone, which is favorable for groundwater accumulation. The subsequent underlying layers (hard and massive rocks) are more resistive than the first layer.

From the generated ground water resource prospect map, it is observed that high potential zones are mainly located along lineaments and in pediment areas. Alluvial fills, valley fills are good potential zones. The geomorphic units like buried pediplains, peniplains and denundational hills are moderate to good groundwater prospective zones. Undulating upland and buried pediments with intermontane valley, mainly confined in undulating upland, are the regions of poor groundwater prospecting zones. Very poor potential regions cover a small part of total study area (confined to dissected pediments, inselberg complex and residual hills).

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Prof V K Srivastava, a senior Professor of Indian School of Mines, Dhanbad has teaching and research experience in different branches of Geophysics. He has published about 60 research papers in various national and international journals in addition to some in proceedings of various Conferences and Seminars. He has been awarded several Foreign Govt Fellowships to visit abroad as Exchange Scientist/Scholar in particular as Fulbright Fellow in US, DAAD Fellow in Germany, Indo Netherland Scholar in the Netherland and Visiting Scientist in Russia. During his stay in US, he had an opportunity to work at Jet Propulsion Lab of NASA where he did work on Airborne Imaging Spectrometric Data. He has completed several sponsored R& D and consultancy projects. Currently his fields of interest are Remote Sensing and GIS, Environmental Geophysics, Seismology, Paleoseismology and Digital Terrain Modelling.

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