Geomorphological And Geoelectrical Studies For Targeting Groundwater In Hard Rock Terrain of Rairangpur Block, Odisha

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Abstract- *Rairangpur block of Mayurbhanj district is underlain by hard crystalline rocks of Pre-Cambrian age. Granite and Epidiorite are the most prevalent litho units in the study area. The present work aims at targeting groundwater in hard rock area using Remote Sensing and Geo electrical techniques. The geomorphological features of the Rairangpur block are Denudational Hill (8%), Habitation(1%), Intermontane Valley(1%), Padiplain (1%),Plateau (10%),Shallow weathered/ shallow buried Pediplain (36%),Structural Hills (Large) (20%),Valley Fill/ filled-in valley(0.74%),Water Body (1%). The areas characterized by weathered pediplain , high lineament density,low drainage density and low slope are identified as Moderate to High Groundwater Potential Zone. On the basis of resistivity survey 4 or 5 geoelectrical subsurface layes set-up is found in the area. These layers are top soil, highly weathered zone, semi-weathered zone, fracture zone and the bed rock. In a 4 layered cases, the 2nd and 3rd layers are interpreted as the potential zones from which ground water can be extracted. The thickness of the aquifer varies from 12.0m to19.0m. Groundwater potential is poor in this case. In 5 layered cases, the 2nd, 3rd and 4th layer constitute the aquifer zone whose thickness varies from23.0m to 64.0m and groundwater condition is moderate to good. Groundwater can be taped from 2nd layer through dug wells, from third layer through dug-cum-bore wells and from 4th layer through ¬only deep bore wells*

Keywords- Remote Sensing, Lineament, Aquifers, Geomorphology, Geo-electrical

I. INTRODUCTION

Water is the most precious and commonly used resource in nature. The demand on ground water has increased manifold in recent years. The occurrence and yield potential of ground water in aquifers are basically controlled by geology, geomorphology and structural set-up of an area. It is important to target ground water potential zone prior to any planning for ground water development. Geomorphology exercises a significant control over ground water regime. The landform - cum- lineament mapping is very useful in targeting ground water. During last decades, remote sensing data have been increasingly used in ground water targeting exercises. The geophysical investigation forms a relatively quick and inexpensive way to gain subsurface information. The application of this method for selection of site for wells in areas underlain by hard crystalline rocks is very popular. This method helps to delineate top soil, weathered, fractured and bedrock zone for construction of suitable ground water structures because in hard rock terrain, there is a good contrast in resistivity value among the bedrock, the fractured zone, the weathered zone and the top soils. The weathered and fractured zone constitute the potential loci for ground water occurrence. The present study aims at getting information on ground water prospects in hard rock terrain of Rairangpur area in drought-prone Mayurbhanjdistrict, Orissa, India using geoelectrical and remote sensing techniques.

The literature available on groundwater resources related studies was reviewed in detail. Choudhury et. al. 2010[1], Deepika et. al.2013[2], Dinesh et al.2007[3], Jaiswal et. al.2003[4], Jesiya et. al.2015[5], Magesh et. al.2012[6], Reddy et. al.2003[7], Saud2010[8], Shaban et al.2006[9], Sharma & Ray2015[10], Suja Rose &Krishna(2009[11] and Tweed et al.2007[12] have emphasized on utilization of remotely sensed data in conjunction with co-lateral data in GIS platform in delineation of groundwater potential zones. Ballukraya 2001[13], Janardhana Raju et. al.1996[14], Kumar & Srinivasan 2016[15], Mahala et. al.2013[16] and Selvarani et. al.2016[17] have described in their study, the application of geophysics in targeting groundwater in hard rock areas. Sahu 2017[18] and Sahu 2017[19] in his study highlighted on the integration of geological, geophysical and remote sensing data for sustainable development and management of groundwater in hard rock terrain. Their research method can be applied for sustainable development and management of groundwater resources in the drought prone, and poverty-stricken Rairangpur block of Odisha.

Study Area

Rairangpur block ofMayurbhanj District lies between 22° 11´ 30" and 22° 26´ 30"latitude and 86° 06´ 30" and 86° 21´ 15" longitude(Fig.1). The block falls in the Survey of India (SOI) topographic sheet no 73J/3, 73J/4, 73J/7, 73J/08 .The block is covering an area of 258 sq.km. Total population is 69374. The average rainfall of this area is 445.47 mm. The block is underlain by Granite and Epidiorite of pre-cambrian age. The maximum temperature is 45°C and minimum temperature is 30°C. During the summer, the groundwater level in this block goes beyond the economic lift, which constitutes the main source of drinking water for this region. The study area is severely suffering from water scarcity and the sustainability of water supply is threatened. The water scarcity has a direct impact on the livelihood, health and sanitation of the local people.

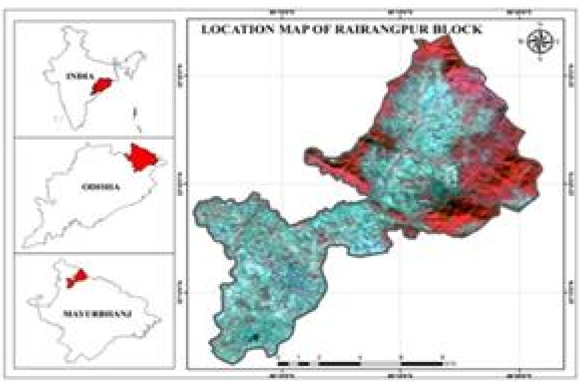

Figure 1: Location map of the Study Area

II. METHODOLOGY

The hydro-geomorphological and lineament maps were prepared by digital image processing using IRS-IA (LISS-II) data The drainage system for the study area was digitized in ArcGIS 10.2.2 from the Survey of India (SOI) toposheets. The drainage density and lineament density maps were prepared using the line density analysis tool in ArcGIS. The electrical resistivity method has been employed in ground water investigation in which electrical resistivity of formations are measured. Vertical Electrical Sounding (VES) have been conducted at 12 locations in different hydro-geomorphic units to assess the types and thickness of different geo-electrical layers to understand the aquifer system in each unit. The recorded field data were plotted on a standard log-log paper and interpreted my matching with those of the standard curves published by the European Association of Exploration Geophysicists.

III. RESULTS AND DISCUSSION

Geology: The study area is characterized by the presence of Epidiorite and Granite of Precambrian age. The main rock types are granite and Epidiorite. Percentage of Granite and Epi-diorite is 83%and 17% respectively(Fig.2). These rocks lack Primary porosity. Ground water occurrence is restricted to weathered and fractured zone. Ground water occurs in unconfined and semi-confined aquifer conditions.

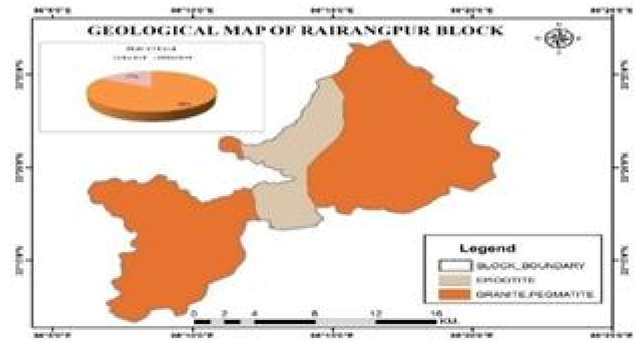

Figure 2: Lithology of the Study Area

Hydrogeomorphology: Hydrogeomorphological study shows that there is a close relationship between the hydrogeomorphic units and groundwater resources. Geomorphological units are extremely helpful for delineating groundwater potential zones and artificial recharge sites. By taking image interpretation characteristics such as tone, texture, shape, colour and association over the geocoded FCC image, the geomorphologic units are interpreted. The geomorphological features of the Rairangpur block are Denudational Hill(8%), Habitation(1%), Intermontane Valley(1%), Padiplain (1%),Plateau (10%),Shallow weathered/ shallow buried Pediplain (36%),Structural Hills (Large) (20%),Valley Fill/ filled-in valley(0.74%),Water Body (1%)(Fig.3)..

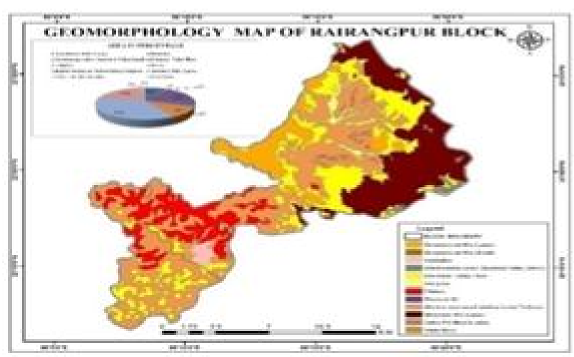

Figure 3: Hydrogeomorphology Map of the area

Lineament density: Lineaments are structurally controlled linear or curvilinear surface expression of zones of weakness or structural displacement in the crust of the earth , which are identified from the satellite imagery by their relatively linear alignments. Lineament density of an area has a major role for the groundwater potential. High lineament density is good for groundwater potential zones. In hard rock terrain lineaments and fractures act as principal conduits in movement and storage of groundwater. In the Rairangpur block 33% of area has very low density, 45% has low density, 18% has moderate density and 2% has high density lineament(Fig.4).Drainage density is moderate(Fig 5).

Slope: Slope has a important role for the identification of groundwater potential zones. Steep slope area facilitates high runoff allowing increased erosion rate with feeble recharge potential whereas, less residence time for rainwater to percolate and hence comparatively less infiltration. The slope map of the study area was prepared based on SRTM data using the 3D analysis tool in ArcGis10.2.2. Base on slope, the study area is divided into four classes. The area under 0 degree to 4 degree is very low, 4 degree to 11 degree is low,11 degree to 21 degree moderate, more than 21 degree considered as high slope and more runoff area(Fig.6).

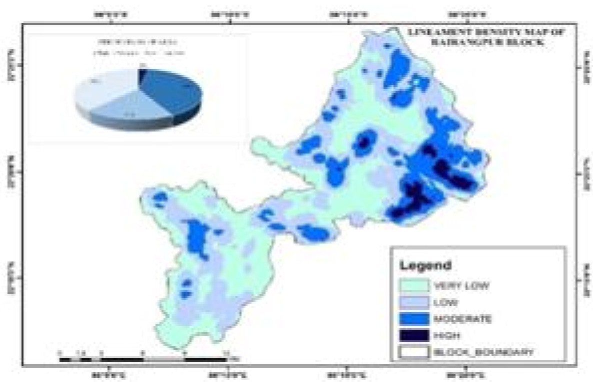

Figure 4: Lineament Density Map of the area

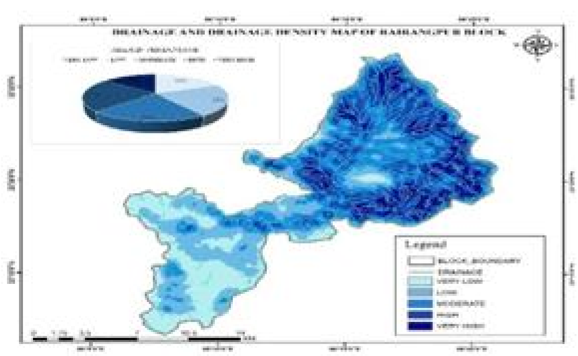

Figure 5: Drainage density map of the study area

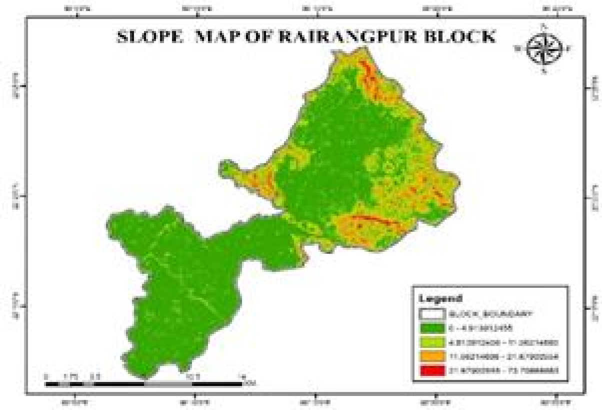

Figure 6: Slope map of the study area

Electrical Resistivity Survey

Geoelectrical technique is the most popular geophysical method for groundwater survey because it gives a strong response to sub-surface conditions. The electrical resistivity method was employed to delineate weathered and fractured rocks in hard rock terrain for construction of suitable groundwater abstraction structures. In hard rock terrain, there is a good contrast in resistivity value among the bed rocks, the fractured zone, weathered zone and top soils. Because of such variation vertical electrical sounding have been conducted to access the type and thickness of different layers. Vertical electrical sounding (VES) with Schlumberger electrode configuration using (AB/2) separation up to 100m were carried out at 12 locations. The details is given in table 1. The selection of VES stations was done keeping in view of geological complexity, accessibility and field layout feasibility.

Table 1: Interpreted Resistivity data of the study area

Sl. No.	Location	ϱ=Layer Resistivity (Ohm-m)	h= Layer thickness (m)	Probable lithology	Layers forming aquifers and thickness of aquifer (m)	Groundwater Potential
1	Ruanal	ϱ1 = 192.0 ϱ2 = 45.0 ϱ3 = 102.0 ϱ4 = 282.0 ϱ 5 > 590.0	h1 = 2.6 h2 = 6.0 h3 = 5.2 h4 = 12.8 h5 = Thick	Top lateritic soil Highly weathered zone Semi-weathered zone Fractured zone Hard rock	h2, h3 and h4 (240)	Moderate
2	Dhadikidiha	ϱ1 = 24.5 ϱ2 = 38.0 ϱ3 = 96.2 ϱ4 = 199.0 ϱ 5> 482.0	h1 = 2.5 h2 = 10.5 h3 = 18.8 h4 = 31.5 h5 = Thick	Sandy loam Highly weathered zone Semi-weathered zone Fractured zone Hard rock	h2, h3 and h4 (60.8)	Very good
3	Naupada	ϱ1 = 18.0 ϱ2 = 42.0 ϱ3 = 94.8 ϱ4 = 220.0 ϱ 5= 684.0	h1 = 2.0 h2 = 12.2 h3 = 18.8 h4 = 33.0 h5 = Thick	Top soil Highly weathered zone Semi-weathered zone Fractured zone Hard rock	h2, h3 and h4 (64)	Very good
4	Tolak	ϱ1 = 22.0 ϱ2 = 38.0 ϱ3 = 112.0 ϱ4 = 218.5 ϱ 5= 550.0	h1 = 3.2 h2 = 5.0 h3 = 6.6 h4 = 20.4 h5 = Thick	Top soil Highly weathered zone Semi-weathered zone Fractured zone Hard rock	h2, h3 and h4 (32)	Moderate to good
5	Sundhal	ϱ1 =24.0 ϱ2 =46.5 ϱ3 =102.6 ϱ4 =254.0 ϱ 5 =598.0	h1 = 1.9 h2 = 4.2 h3 = 6.8 h4 = 12.0 h5 = Thick	Top soil Highly weathered zone Weathered zone Fractured zone Hard rock	h2, h3 and h4 (23)	Moderate
6	Gandida	ϱ1 = 11.5 ϱ2 = 76.0 ϱ3 = 192.0 ϱ4 = 480.5	h1 = 2.4 h2 = 8.8 h3 = 10.2 h4 = Thick	Top soil Weathered zone Fractured zone Hard rock	h2 and h3 (19)	Moderate
7	Badada	ϱ1 = 10.4 ϱ2 = 36.6 ϱ3 = 101.5 ϱ4 = 496.0	h1 = 1.6 h2 = 9.5 h3 = 10.5 h4 = Thick	Top soil Weathered zone Fractured zone Hard rock	h2 and h3 (20)	Moderate
8	Rairangpur NAC	ϱ1 = 192.0 ϱ2 =54.0 ϱ3 =112.4 ϱ4 =204.0 ϱ 5=488.0	h1 = 2.2 h2 = 10.8 h3 = 12.2 h4 = 16.0 h5 = Thick	Top lateritic soil Highly weathered zone Semi-weathered zone Fractured zone Hard rock	h2, h3 and h4 (39)	Moderate to good
9	Bhalubasa	ϱ1 = 17.0 ϱ2 = 39.0 ϱ3 = 96.5 ϱ4 = 180.0 ϱ 5 = 490.0	h1 = 2.0 h2 = 9.5 h3 = 13.4 h4 = 20.6 h5 = Thick	Top soil Highly weathered zone Semi-weathered zone Fractured zone Hard rock	h2, h3 and h4 (45.5)	Moderate to good

10	Naujoda	ϱ1 = 8.0	h1 = 1.8	Top soil	(30.2)	Moderate
		ϱ2 = 48.5	h2 = 7.0	Highly weathered zone		
		ϱ3 = 101.0	h3 = 10.5	Weathered zone		
		ϱ4 = 196.5	h4 = 12.7	Fractured zone		
		ϱ 5 = 675.0	h5 = Thick	Hard rock		
11	Anandpur	ϱ1 = 10.0	h1 = 3.0	Top soil	h2 and h3	Poor
		ϱ2 = 66.0	h2 = 4.0	Weathered zone	(12)	
		ϱ3 = 120.5	h3 = 8.0	Fractured zone		
		ϱ4 = 496.0	h4 = Thick	Hard rock		
12		ϱ1 =12.0	h1 = 3.0	Top soil	h2 and h3	Poor
		ϱ2 =44.8	h2 = 5.0	Weathered zone	(14.5)	
		ϱ3 =248.0	h3 = 9.5	Fractured zone		
		ϱ4 =684.0	h4 = Thick	Hard rock		

Interpretation of resistivity data: On the basis of resistivity survey 4 or 5 geoelectrical subsurface layers set-up is found in the study area. These layers are top soil, highly weathered zone, semi-weathered zone, fracture zone and the bed rock. The top layer of variable nature has resistivity value between 8 to 192, whose thickness is less than 3.2m. the top soil is followed by highly weathered, semi-weathered, fractured and/or massive bed rock sequentially. The highly weathered layer is identified with resistivity value ranging from 36.6 to76.0 having maximum thickness of 12.2m. The semi-weathered zone indicated by the resistivity value 94.2 to192.0 having a maximum thickness of 18.8 m. The fractured zone is indicated by resistivity value 112.0 to 292.0. However, the prominent fracture zones are restricted within a depth of 35 to 50 m below the ground surface. The VES conducted at different points in the study revealed 4 layered and 5 layered situations. In a 4 layered case, the 2^{nd} and 3^{rd} layers are interpreted as the potential zones from which ground water can be extracted. The thickness of the aquifer varies from 12.0m to19.0m. Groundwater potential is poor in this case. In 5 layered case, the 2^{nd}, 3^{rd} and 4^{th} layer constitute the aquifer zone whose thickness varies from 23.0m to 64.0m and groundwater condition is moderate to good.

From the resistivity data, it is apparent that 5 layered cases are confined to the areas underlain by granitic rocks with pediplain landforms, high lineament density, low drainage density and less slope, whereas 4 layered cases are observed in Epidiorite and granite terrain with shallow buried pediment landform. It is also clear that groundwater can be taped from 2^{nd} layer through dug wells, from third layer through dug-cum-bore wells and from 4^{th} layer through only deep bore wells. Thickness of the aquifer in the area is found to vary between 12.0m to 64.0m.VES studies in the area reveal that the area has high potentiality for exploitation of ground water through different kinds of ground water structures. Depending upon the depth to massive bedrock, suitable ground water structures may be developed. The depth to bedrock ranges from 30 to 70 m in most parts of the geomorphic units like Alluvial Plains, Intermontane Valleys and Buried Pedi plain. However, the depth to massive bedrock is 15 to 30 m in pediment. The dug-cum-bore wells along with dug wells may be constructed in areas where depth to bedrock lies between 15 to 30m and bore wells along with dug wells and dug-cum-bore wells are suitable in areas where depth to bedrock is more than 30 m.

IV. CONCLUSION

Application of remote sensing techniques for ground water targeting has taken a definite role to understand the hydro potentialities of different terrain in terms of hydro-geomorphic units and fracture trace analysis. The hydro-geomorphologic map and lineament map generated from remote sensing data and geophysical survey made during the present study will help the planners and decision makers for devising sound and feasible ground water development plans for drought management. Finally, it is concluded that the integrated approach of “Geological- Hydrological-Geophysical-Drilling-Satellite Image and Aerial Photo-interpretation” should be applied for sustainable development and management of ground water resources in tribal dominated Rairangpur area of drought - prone Mayurbhanj district, Orissa, India.

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