Demarcation of Groundwater Potential Zones Using Remote Sensing And GIS

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Abstract- *Bijatala block of Mayurbhanj district of Odisha is covered by hard crystalline rock of Pre-Cambrian age. Granite is the most dominate litho unit. The present work deals with identification of groundwater potential areas using RS and GIS techniques for sustainable development and utilization of groundwater resources in consolidated formation.GIS based model to demarcate groundwater potential area is derived by combining different thematic layers prepared from IRS-1C LISS-III data and data created by conventional surveys. The different GIS layers used are Geomorphology, Lithology, Lineaments, Soil, Drainage density, Slope and LU/LC. Arc GIS software version 10.2.2 was used to prepare groundwater potential zones map of Bijatala Block. Thus four different potential zones were demarcated, namely Very Good, Good, Moderate and poor. The area having Very Good to good ground water potential is about 54%of study area,situated mostly in the South Western part of the study area The villages falling under these zones are Kankadabeda hill, Bhimkhanda, Khejurijharan , Dumurikudar, Belpahadi, Khejuri, Saranda, Dalki, Ambadiha, Mundhathakura, Paunsia, Damudibeda, Baghiatangar, Mundakati, Ektali, Joapokhari, Bhalukichua, Bankati,Tulsibani , Dumadlhi, Palasbani, Nusadihi, Jamda, Khandadeuli, Barajiani, Jaunti, Bankati, Karkachia, Asansikhar.verification of this model with the borewell data found in agreement with various potential zones. Finally it is concluded that RS and GIS techniques are very effective and helpful for identification of groundwater potential area in a diverse hydrogeological set-up. The groundwater potential map can form a guide map to water planner for groundwater development activity in Bijatala block of Mayurbhanj District, Odisha*

Keywords- Potential, Geomorphology,Lineament, Remote sensing

I. INTRODUCTION

Groundwater is a form of water occupying all the voids within a geological stratum. Groundwater is one of the most basic and imperative resource, and economic provision of potable water supply in support for human life, economic development .Groundwater can shield against deficiencies of surface water during periods of drought. The occurrence and movement of groundwater mainly controlled by porosity and permeability of lithology. The study of hydrological feature like topography, lineament, drainage density, rock type, land form, soil, land use and slope are important to understand groundwater condition. The drainage pattern is key for the recognition of precipitation infiltrates into the ground. Lineament may be used to infer groundwater movement and storage. An area of high drainage density indicates high surface runoff and unfavorable site for groundwater potential as compared to low drainage density area. In India, 65 per cent of the total geographical area is covered by hard rock formations. Therefore, efficient management planning of groundwater in these areas is importance. Because in consolidated hard rock terrains the accessibility of groundwater is of partial extent. Occurrence of groundwater in hard rock is essentially confined to fractured and weathered horizons. Conventional surveys like field-based hydro-geological and geophysical investigations reviews, are tedious, time consuming apart from being impractical in the inaccessible and inhospitable terrain,do not generally represent the different variables that control the event and development of groundwater (Sharma and Biswas 2013; Sharma et al. 2014; Gautam and Biswas 2016) During the last three decades, remote sensing technology in groundwater resources evaluation has been practised (Chatterji et al.1978;Nandi et.al 2014; Seelan and Thiruvengadachari, 1980; Behera, 1989; Baker and Panciera, 1990: Das et al. 1997; Harinarayana et al. 2000; Selvam et al. 2013d). GIS techniques facilitate integrated and conjunctive analysis of large volumes of multi-disciplinary data, both spatial and non-spatial, within the same georeferencing scheme. There are different perspectives of groundwater studies have been done by several researchers based on their ideas, Nandi, et al. (2017), Nandi, et al. (2015), Saraf and Choudhury 1998; Jaiswal et al., 2003; Acharya et al ., 2017; Sener et al., 2005; Chowdhury et al., 2009; Jha et al., 2010;Sahu 2017. The objectives of this study are to set up various thematic maps of Bijatala block such as Geology, Geomorphology, Soil, Slope, Drainage & its density, Landuse/landcover, soil from toposheet, satellite imagery and ground truth data. To identify the groundwater potential zone by assigning weightage for each theme based on MIF technique, and contribute a systematic groundwater delineation study.

II. STUDY AREA

Bijatala area in Mayurbhanj District of Odisha is underlain by hard crystalline rock of Pre-Cambrian age. The study area lies between 22° 08´ 00" to and 22° 22´ 30"latitude and 86° 12´ 00" to and 86° 27´ 00" longitude . 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 315 sq.km. According to the 2011 Indian census, total population is 64,193. The average rainfall of this area is 518.9 mm.The block is Characterised by the presence of Granite and Granophyre and Mica shist of pre-Cambrians age. The maximum temperature of the block is 45°C and minimum temperature is 30°C. Out of gross area 7518 ha is under rain-fed. During the summer, the groundwater level in this block lowers beyond the economic lift, which constituting the main source of agriculture proposed for this region. The study area is severely suffering from water scarcity, has a direct impact on the livelihood, health and sanitation of the local people

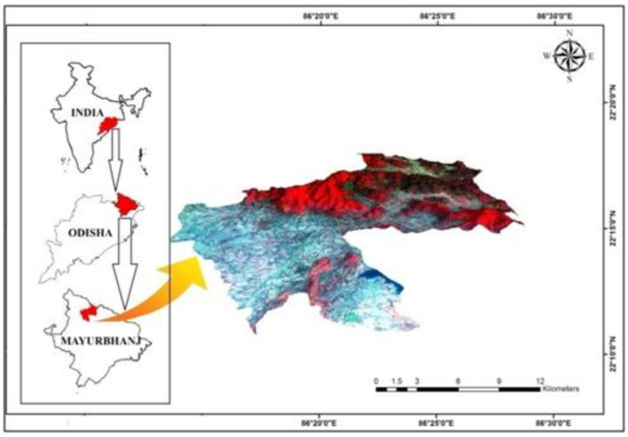

Figure:1 Location of the study area

III. MATERIALS AND METHODOLOGY

For this Present study of Bijatala block to delineate groundwater potential we used three types of data. Survey of India (SOI) Topo sheets i.e 1:50,000 scale. Satellite imageries (LISS-III) ,SRTM DEM and some other secondary data are employed .The Survey of India (SOI) topographic map (Nos. 73 J/3,73J/4, 73J/7 and 73J/8 of scale 1: 50,000) along with Resourcessat 1 LISS-III , Path 106, Row 56, March 2013) was used for preparation of different themes like , Geomorphology , geology, liniament, soil, Drainage density, LU/LC.The slope map was prepared by using SRTM data downlord form Earth explore of Glovis data using 3D analysis of Arc GIS software. With the help of ERDAS and Arc GIS soft ware and technical guidelines of (NRSC Technical guidelines, 1995).) we prepared of various thematic maps and final groundwater potential map. The knowledge base weighted overlay analysis was applied to determine the groundwater potential zones. The methodology flow chart are given in figure: 2 and figure 3 respectively.

IV. FACTORS CONTROLLING GROUNDWATER REGIME

The occurrence and movement of ground water are influenced by lithology, structure, geomorphology and drainage while replenishment is further affected by land use, precipitation and infiltration rate. In this study, seven thematic layers viz.Geomorphology lithology, slope, land-use, lineament, drainage, soil have been generated for analysis and integration into a prospects map.

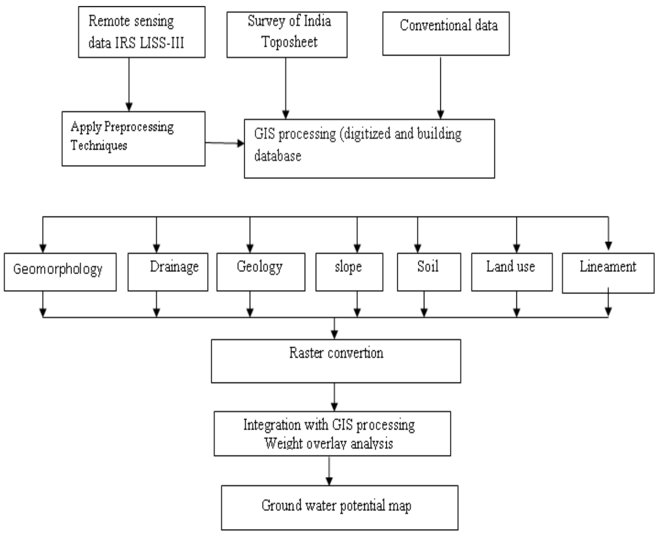

Figure :2 Flow chart showing the methodology adopted for groundwater potential map.

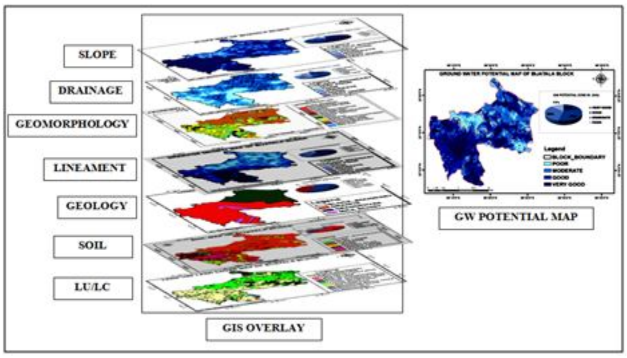

Figure :3 Flow chart showing the Groundwater Potential map

V. LITHOLOGY

The study area is characterised by presence of Mica schist, Granophyre and Granite of Precambrian age. The main rock types are granite and Granophyre. Percentage of Granite and Granophyre is 63%and 33% respectively. These rocks lack Primary porosity. Ground water occurrence is restricted to a weathered and fractured zone. Ground water occurs in unconfined and semi confined aquifer condition. The Lithology map is given in the figure 4

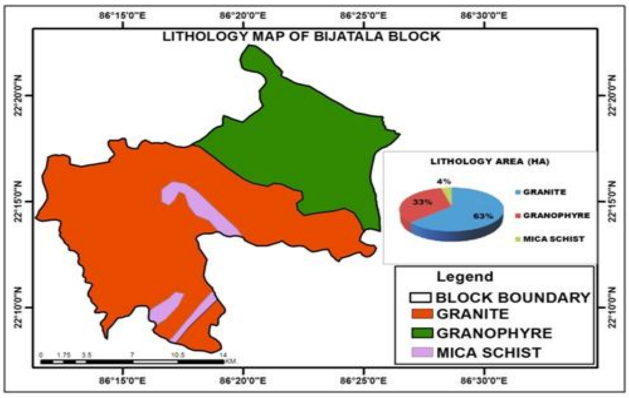

Figure: 4 Lithology/Geology map of the study area

VI. GEOMORPHOLOGY

Geomorphology shows the relationship between the hydrogeomorphic units and groundwater resources (Subba Rao and John Devada 2003). Geomorphological units are very helpful for demarcate groundwater potential zones.Thelarge area of synoptic view of satellite imagery facilitates better mapping of different landforms. The geomorphic unit of Bijatala Block are identified as per the guidelines of National Remote Sensing Centre, Hyderabad (NRSC Technical guidelines, 1995).By taking image interpretation key such as tone, texture, shape, colour and association over the satellite image, the geomorphologic units are interpreted. The geomorphologycal feature of the Bijatala block are Denutational Hill (1%), Intermontane Valley (2%), Plateau (2%), Shallow weathered/ shallow buried Pediplain (24%), Structural Hills (39%), Valley Fill/ filled-in valley (1%), Water Body (1%). The structural hill is present in Northern part of the study area. The residual hill can be seen in the small part of Northern and Central part of the study area. The Physical Character of the different landform are present in Table 1.The detail of geomorphology of Bijatala block is given in the figure 5 and figure 6 respectively.

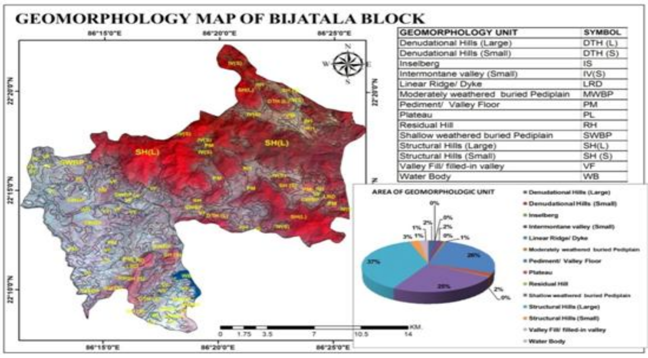

Figure :5 Geomorphology feature of the study area

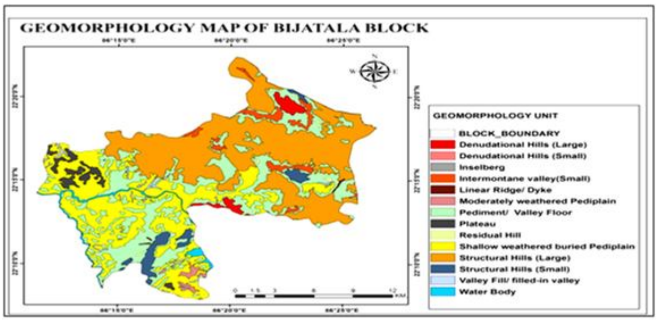

Figure :6 Geomorphology feature of the study area

Table No: 1 Image and physical characteristics of different land form in the study area

Map Symbol	Geomorphic unit	Image elements	Landform Characteristics (Ground observation)	Ground water Potential
SH(L,S)	Structural hills	Dark red tone coarse texture irregular shape	Linear to arcuate hills, dissected, granitic rocks, mostly dendritic drainage, jointed ridges, average height 300 m. very steep slopes	VERY POOR
DTH	Denudational hills	Dull red tone, coarse texture irregular shape	Granite, dendritic drainage, moderate to steep slopes, sparse vegetation	VERY POOR
RH	Residual hills	Dark gray tone, coarse texture, shape and size-irregular and rounded	Erosional surfaces, isolated mounds which have undergone the process of denudation, Steep slopes, radial drainage act as runoff zones	VERY POOR
PM	Pediments	Light red to red tone, moderate to fine texture	Gentle to moderate slopes, devoid of vegetation with various depths of weathering material, shallow sediment covers rocky and gravel surfaces, dendritic to sub-dendritic drainage, mostly vegetated or cultivated lying at the foot hills	POOR
SWBP	Moderately Shallow Weathered pediplains	Green-bluish mixed tone, moderate to fine texture	These units are characterized by the presence of relatively thicker weathered material. The thickness of the weathered material is (up to 5 m. These hydrogeomorphic units are developed mostly upon Mayurbhanj Granite	MODERATE
IV	Intermountain Valley	Green-bluish mixed tone, moderate to fine texture	A linear or curvilinear depression, valley within the hills, filled with alluvial deposits of IOG sediments	GOOD
PL	Plateau	Dark red tone coarse texture irregular shape	Table land shaped hill with a flat surface at the top with sloping sides	VERY POOR
VF	Valley fill	Green-bluish mixed tone, moderate to fine texture	A linear or curvilinear depression, valley within the hills, filled with alluvial deposits of IOG sediments	EXCELLENT

VII. LINEAMENT DENSITY

The study area of Bijatala block is underlying under the consolidated hard rock, the movement and occurrences of groundwater of this area depends mainly on the secondary porosity and permeability. so the lineament study in this area is important from the groundwater potential point of view. The lineament detail of Bijatala block is given in the figure 7.The lineaments are linear character pattern and play a important clue for infiltration of surface run off into sub-surface and movement, storage of groundwater. Major lineaments presents in NE to SW and NSW part are shown in Figure In the study area 22% of area has very low density, 26% has low density, 22% has moderate density and 21% has high and 9% is very high density lineament. Lineament-length density (Ld); the total length of all recorded lineaments divided by the area under study (Greenbaum 1985):

$$\text{lineament density} = \sum_{i=1}^{n} Li/A(m^{-1})$$

Where $\sum_{i=1}^{n} Li$ denotes the total length of lineaments (L) and A denotes the unit area (L2).

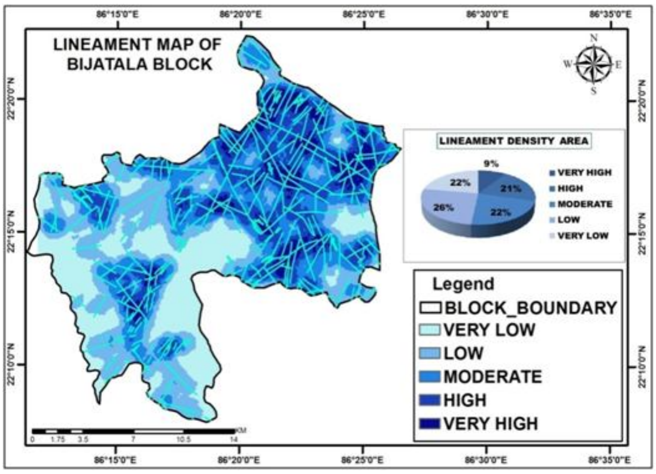

Figure :7 Lineament map of the Bijatala Block

VIII. DRAINAGE PATTERN AND DRAINAGE DENSITY

The drainage map of Bijatala block is practice with the help of survey of India (SOI) topographic map with scale 1:50,000 .Dendritic drainage pattern is seen in most of the the area of Bijatala block. Drainage density is designed as the closeness of spacing of stream channels. Drainage density is a measure of the total length of the stream segment of all the orders per unit area. The drainage density is inversely proportional to permeability. According to the drainage density the study area is divided into 5 categary according to the groundwater prospects i.e Very high, High, Moderate, low and very low. The drainage densities were calculated in each of the grid square (Murthy 2000).The drainage along with density map of Bijatala block is shown in figure 8.

$$DD = \sum \frac{LWS}{AWS}$$

Where,

DD = Drainage Density

LWS = Total Length of streams in Watershed

AWS = Area of the Watershed

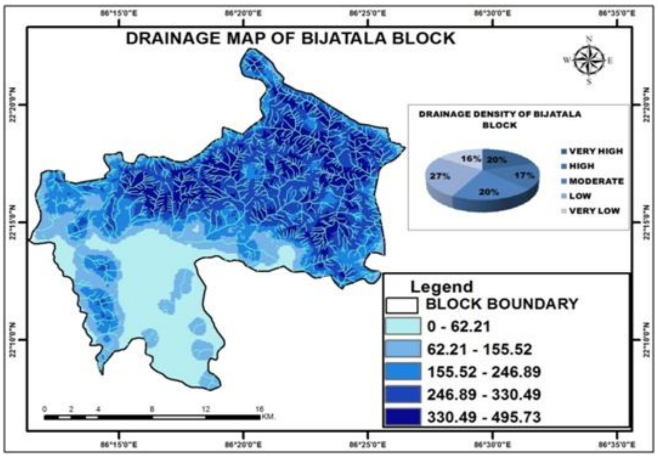

Figure :8 Drainage map of the Bijatala Block

IX. LAND USE/ LAND COVER

Remote sensing technique is very handy tool for providing reliable basic information for land use/land cover mapping ,which play very important role in demarketing land use pattern by visual interpretation. Land use/ Land cover is a major factor affecting the recharge process. The study area has five major land use class i.e forest (28%), agriculture land (61%) Waste land (3%), Built up land (7%) and water bodies (1%).The weights were assigned according to influence on groundwater occurrence. Water bodies are coming under good categories and Lands which are not used for any purpose classified as wasteland and Built up land is categorized as Poor for groundwater prediction. Agriculture is categorized as moderate categories groundwater occurrence, holding and recharge.The detail land use/ Land cover map and its area is shown in the figure 9 and figure 10 respectively.

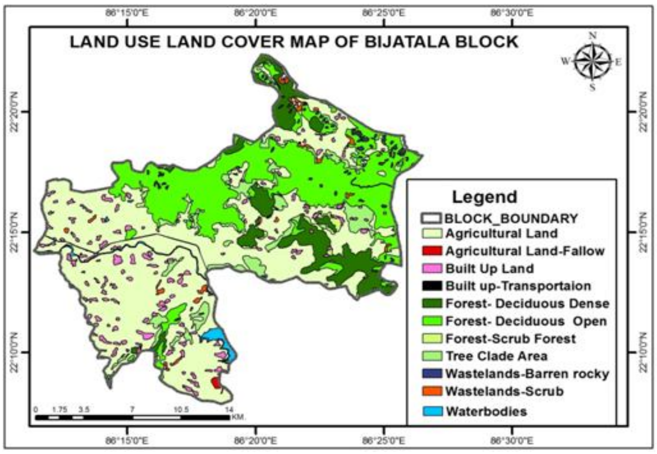

Figure :9 Land use land cover of the Bijatala Block

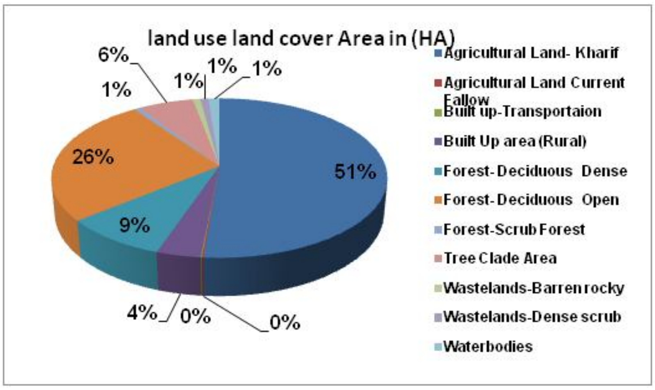

Figure :10 Pie Chat Lane use land cover map of the Bijatala Block

X. SLOPE

Slope has a important role for the identification of groundwater potential zones. Steep slope area facilitates high runoff with feeble recharge potential. Base on slope the study area is divided into four classes. The area under 0 degree to 3 degree is very low, 3 degree to 7 degree is low, 7 degree to 13 degree is moderate,13 degree > 18 degree considered as high and 18 degree to 34 degree is considered as very high slope. The slope map is shown in the figure no 11.

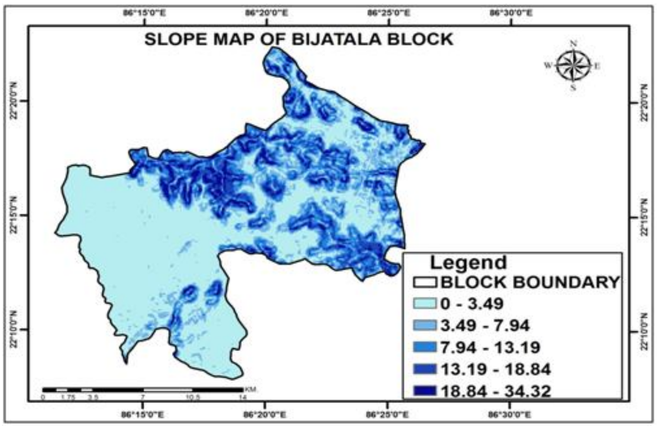

Figure :11 Slope map of the Bijatala Block

XI. SOIL

Soil is a one of the important factor for delineating ground water potential zone. The soil act as a natural filter and penetration of surface water into an aquifer system and directly related to rates of infiltration, percolation and permeability. The movement and penetration of surface water into ground is based on the porosity and absorbency of soil. The result of soil classification found that, the study area has six types of soils such as, Laterite Soil, Sandy Loam, Sandy Clay, Clay,Clay Loam and Sticky Clay. In the study area soils, such as Clay and Sandy Clay Loam, have poor water-holding capacity and have been given a low weightage. The soil map of Bijatala block is given in figure 12.

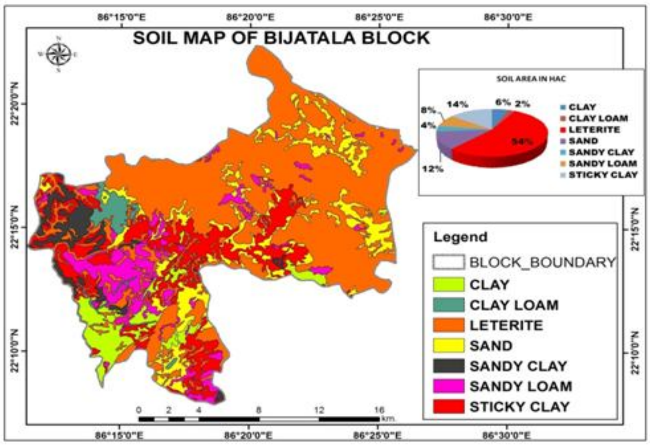

Figure :12 Soil map of the Bijatala Block

XII. RESULTS AND DISCUSSION

FACTORS AFFECTING RECHARGE POTENTIAL:

The groundwater potential of an area is controlled by its lithology, structure, geomorphology and drainage and also affected by land use, precipitation and infiltration rate. In this study, we take seven influence factors which controlled the groundwater potential viz. litho type, linear structure,drainage characterictics, Land use pattern, slope and pedology for analysis of groundwater prospect map. The groundwater potential zone has been worked out by ma research workers (Krishnamurthy et al.1996; Shahid et al. 2000; Shaban et al. 2006; Yeh et al. 2009, 2014, 2016; Selvam et al. 2014, 2015a, b,)

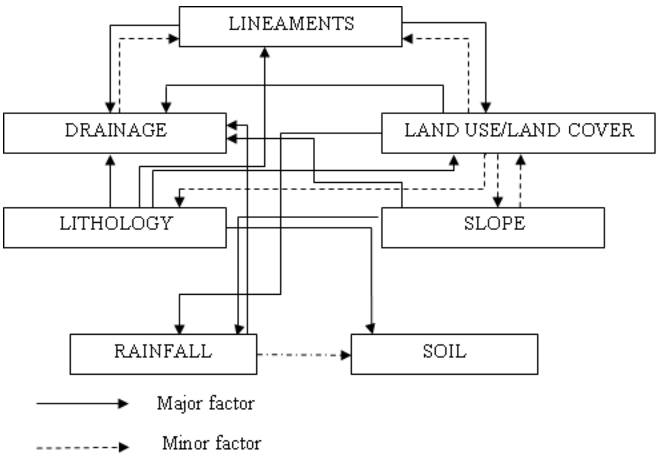

Figure :13 Interactive influence of factors concerning recharge properly (modified from Shaban et al. 2006)

Table :2 Effect of influencing factor, relative rates and score for each potential factor.

Factor	Major effect(A)	Minor Effect(B)	Proposed relative Rate (A+B)
Lineaments	1+1	0	2
Land use	1+1	0.5+0.5+0.5	3.5
Lithology	1+1+1	0	4
Drainage	1	0.5	1.5
Slope	1+1	0.5	2.5
Rainfall	1	0.5	1.5
Soil	1	0	1

XIII. WEIGHT ASSIGNMENT AND GEOSPATIAL MODELING

Suitable weights set apart to the seven themes according to their hydrogeological importance in groundwater occurrence. The weightages of the individual thematic layers were assigned according to the multi Influence Factor controlling, storage and distribution of groundwater,. weightages of 25, 15, 12,15,18,10 and 5 were assigned for geomorphology, Slope, Drainage density, lineament density, geology, soil and land use land cover respectively. obtained through the Saaty's analytical hierarchy process (AHP)The weights assigned to different themes are presented in Table 2.The integrated final map was divided into five classes, i.e. 'very good', 'good' 'moderate', 'poor' and 'very poor' in order to delineate groundwater potential zones.

Table 3: Ranks assigned to different parameters used for overlay

Sl No	Parameters	Classes	Feature score	Map Weight
1	Geomorphology	Denudational Hills (Large) Denudational Hills (Small) Habitation Intermontane valley/ Structural Valley (Small) Pediment/ Valley Floor Pediplain Plateau Shallow weathered/ shallow buried Pediplain Structural Hills (Large) Valley Fill/ filled-in valley Water Body	1 1 1 8 8 2 7 2 6 6 2 8 10	25
2	Slope classes (Degree)	0 to 3 3 to 7 7 to 13 13 to 18 18 to 34	8 6 3 2 1	15
3	Drainage density (Km/Km^2)	0-62 62-155 155-246 246-330 330-495	9 7 6 4 3	12
4	Lineament density (Km/Km^2)	0 - 0.9 0.9 - 1.9 1.9-2.9 2.9-3.9	9 8 6 3	15
5	Land use /land cover	Agriculture Land Built up land Forest land Water body Waste land	8 2 6 9 3	05
6	Geology	Granite Granophyre Mica Schist	2 3	18
7	Soil	Clay Clay loam Laterite Sand Sandy clay Sandy loam Sticky clay	1 2 4 8 3 2 1	10

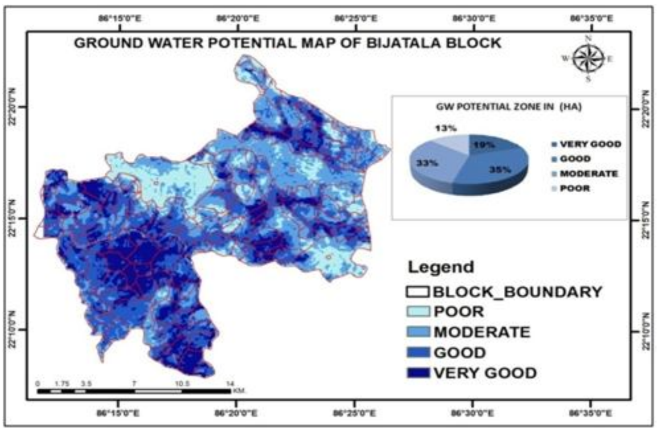

Figure :14 Groundwater potential map of Bijatala Block

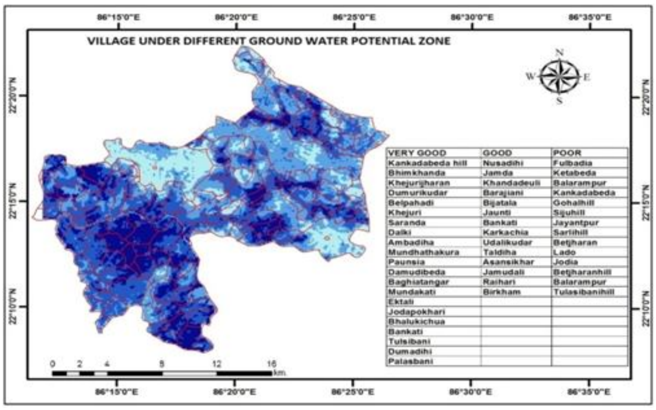

Figure :14 Groundwater potential of Village in Bijatala Block

Table: 4 The village list of different groundwater potential zone of Bijatala block

Very Good	Good	Poor
Kankadabeda hill	Nusadihi	Fulbadia
Bhimkhanda	Jamda	Ketabeda
Khejurijharan	Khandadeuli	Balarampur
Dumurikudar	Barajiani	Kankadabeda
Belpahadi	Jaunti	Gohalhill
Khejuri	Bankati	Sijuhill
Saranda	Karkachia	Jayantpur
Dalki	Bijatala	Sarlihill
Ambadiha	Udalikudar	Betjharan
Mundhathakura	Taldiha	Lado
Paunsia	Asansikhar	Jodia
Damudibeda	Jamudali	Betjharanhill
Baghiatangar	Raihari	Balarampur
Mundakati	Birkham	Tulasibanihill
Ektali		
Joapokhari		
Bhalukichua		
Bankati		
Tulsibani		
Dumadlhi		
Palasbani		

XIV. CONCLUSION

It is concluded that the area under is covered by hard crystalline rock of Pre-Cambrian age. Granite is the most dominant litho unit. Identification of groundwater potential areas using RS and GIS techniques for sustainable development and utilization of groundwater resources in consolidated formation is found to be very effective.GIS based model to demarcate groundwater potential area is derived by combining different thematic layers prepared from IRS-1C LISS-III data and data created by conventional surveys. The different GIS layers used are Geomorphology, Lithology, Lineaments, Soil, Drainage density, Slope and LU/LC. Arc GIS software version 10.2.2 was used to prepare groundwater potential zones map of Bijatala Block. Thus four different potential zones were demarcated, namely Very Good, Good, Moderate and poor. The area having Very Good to good ground water potential is about 54%of study area,situated mostly in the South Western part of the study area The villages falling under these zones are Kankadabeda hill, Bhimkhanda, Khejurijharan , Dumurikudar, Belpahadi, Khejuri, Saranda, Dalki, Ambadiha, Mundhathakura, Paunsia, Damudibeda, Baghiatangar, Mundakati, Ektali, Joapokhari, Bhalukichua, Bankati,Tulsibani , Dumadlhi, Palasbani, Nusadihi, Jamda, Khandadeuli, Barajiani, Jaunti, Bankati, Karkachia, Asansikhar.verification of this model with the borewell data found in agreement with various potential zones. Finally it is concluded that RS and GIS techniques are very effective and helpful for identification of groundwater potential area in a diverse hydrogeological set-up. The groundwater potential map can form a guide map to water planner for groundwater development activity in Bijatala block of Mayurbhanj District, Odisha

XV. ACKNOWLEDGEMENT

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