Status of Aquifer In Hard Rock Terrain: A Hydrogeological Approach

Pramod Chandra Sahu
Dept of Geology
MPC Autonomous Colleges, Baripada, Odisha,India

Abstract*- The present study illuminates the status of Aquifer in hard rock terrain in a part of Easternghats belt of Odisha using Hydrogeological approach. Ground water occurs under phreatic conditions in weathered zones (shallow aquifer) and under semi confined to confined condition in the deeper fracture zone (deep aquifer). The weathered residuum ranging in thickness from 5 m to 15m and the fractured zones constitute the principal repository of ground water in the area Well inventory reveals that the seasonal fluctuation of water table varies from 2.1 m to 7.5 m. Most of the area show fluctuation between 3 to 6 m. In general, topographic highs have higher water table fluctuation (seasonal) than the topographic lows. The delineated geomorphic units of the study area are pediplain, flood plain, pediment, structural valley, denudational hill, structural hill and inselberg. Ground water potential is moderate to good in hydrogeomorphic units such as flood plain and weathered pediplains.The net annual utilizable ground water resource of the block is 4118.36 HM. The net ground water draft is 852.95 HM (Unit draft method, based on 100% well census). The ground water balance of the block as on December 2007 is 3265.41 HM, out of which 326.50HM can be utilized for domestic and drinking purposes and 2938.91HM for additional irrigation purpose. At present, the stage of ground water development is 20.71% and falls under safe category. Hence, there is a vast scope for ground water development through suitable abstraction structures for development of agrarian economy. The ground water in the investigated area shows limited seasonal variation in quality. Comparison of the Hydrochemical parameters results of the study area with that of ISI (1983) standards ensures the potability and other domestic utility of the ground water of the block except very few locations. Optimal and judicious utilization of ground water through properly designed abstraction structure constructed at suitable locale with accompanying protection, augmentation and conservation measures can being about laurels to the agrarian economy of the area and can mitigate the problems of drinking water scarcity faced during summer*

Keywords*-* Hydro geomorphology, Draft, Aquifer, Sustainable, Hydrogeochemistry

I. INTRODUCTION

Digapahandi block of Ganjam district is a chronically drought prone and economically backward area of Orissa. About eighty percent of the population are rural folks. Agriculture is their mainstay. Surface water irrigation is very limited and also not dependable due to vagaries of monsoon rainfall. Drinking water problem is very acute during summer as most of the wells go dry or yield less water.The economy of the area is basically agrarian. The development of agrarian economy demands stabilized agriculture and crops insurance against drought. The expansion of agriculture is inevitable. The area requires development of ground water through suitable structures to combat drought and to increase crop yield by covering more areas under irrigation. The study indicates that the stage of ground water development is only 20% and there is a vast scope for ground water development through suitable structures. Optimum utilization and efficient management of ground water resources in the block will boost agricultural production and improve socio-economic condition of the people.

The literature available on ground water evaluation, development and management was reviewed in detail. Sikdar et al. (2007), Sankar and Venkatram (2002), Chauhan (2000) Rokade et al. (2007), Mahapatra et al. (2000), Patnaik(2003), Reddy et al.(2003), Sahu and Sahoo (2006) and Sahu (2008) in their study relating to ground water exploration and targeting potential ground water zone, have emphasized that integrated geological, geophysical, remote sensing and GIS techniques should be adopted for targeting potential ground water zones in hard rock areas. Reddy (1999) has emphasized the need to adopt modern know-how i.e. Remote sensing and GIS to evaluate the ground water potential in hard rock provinces.Josrotia and Singh (2007), Singh et al. (2007), Prasad (2007) and Pandian (2007) and Sahu (2003) studied on the hydrochemistry and ground water quality in different parts of the country and emphasized the need of qualitative evaluation for sustainable development of ground water resources. Chadha (2000), Patnaik (2003), Jha (2000), Viswanathan (2002), Umrikar (2002), Nayak et al. (2003), Pradhan (2003), Sahu (2003) and Das (2006) in their studies on ground water development and management has remarked that artificial recharge structures / rain water harvesting structures play a key role in sustainable development of ground water resources. Implementation of water harvesting structures have improved the status of water table in the area.

Located on the east coast of India, Digapahandi block of Ganjam district, Orissa is bounded by 19^{0}11’30” to 19^{0}24’0” N Latitude and $84^{0}19^{'}50^{"}$ to 84^{0}41’24” E longitude (fig.1) falling in the Survey of India Topo sheet Nos. $74\frac{A}{7}, 74\frac{A}{8}$ and $74\frac{A}{11}$. It has a geographical area of 422.18 sq. km. Digapahandi block is situated at a distance of 60 km from district headquarters Chatrapur. It is well connected by all weather roads, State Highways. Berhampur, the principal town of the Ganjam district, located at a distance of 30 km from the block headquarter, is well connected by roads. Howrah- Madras broad gauge line of East Coast Railways passes through the Berhampur City. As per 2001 census, the total population of the block is 136618. Literacy rate is 49.72%. Male and female literacy rate are 66.82% and 32.83% respectively. Total no. of villages is 232. No. of households is 28855.

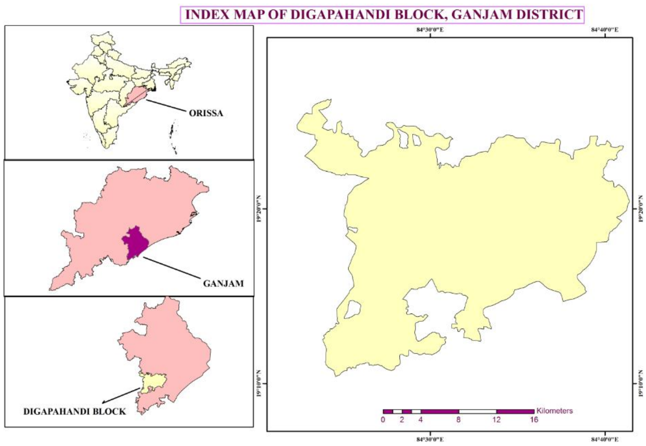

Figure 1: Location map of Digapahandi Block Ganjam District

II. OBJECTIVES

1. To delineate potential aquifer zones for taping ground water.
2. Quantitative assessment of ground water resources and ground water budgeting.
3. To estimate the additional areas that can be brought under irrigation.
4. Qualitative assessment of ground water resources in terms of irrigational and domestic uses.
5. To demarcate areas suitable for different ground water abstraction structures.
6. To demarcate suitable sites for specific water harvesting/ artificial recharge structures for augmentation of ground water resources which will act as buffer in the event of drought.
7. 7.To prepare a plan for ground water development and management

III. METHODOLOGY

1. Collection of secondary data like population, rainfall, ground water abstraction structures and irrigation potential. Collection of Toposheets, references etc.
2. Reconnaissance survey with special reference to lithology, structure, topography and weathering characteristics.
3. Systematic collection of hydro geological data for both pre and post monsoon period during well inventory studies and interpretation of data. Preparation of water table contour map and water table fluctuation map.
4. Estimation of ground water resources using “water table fluctuation method” recommended by the Ground water Estimation Committee (GEC-1997) constituted by Govt. of India.
5. Remote sensing technique has been adopted. Hydro-geomorphological map, lineament and structure maps have been used.
6. Vertical Electrical Sounding (VES) survey has been carried out in 21 selected locations and interpretation has been done to understand the gross aquifer condition.
7. Systematic collection of ground water samples from shallow and deeper aquifers during pre and post monsoon period and chemical analysis for ions like Ca, Mg, Na, K, CO_3, HCO_3, Cl, SO_4, NO_3 and other parameters like Ph, Temp., TDS, EC etc. are measured in the field.
8. Hydro-geochemical evaluation based on studies established by Doneen (1964), Richards (1954) etc. have been carried out.
9. Based on the hydro-geological set up, a map showing suitable site-specific artificial recharge structures has been prepared.

IV. RESULTS AND DISCUSSION

Ground water occurs under phreatic conditions in weathered zones (shallow aquifer) and under semi confined to confined condition in the deeper fracture zone (deep aquifer). The weathered residuum ranging in thickness from 5 m to 15m and the fractured zones constitute the principal repository of ground water in the area. The water yielding fracture zones are generally restricted within a depth of 100m bgl. Two to three water bearing fracture zones have been encountered within 100m depth. Well inventory reveals that the seasonal fluctuation of water table varies from 2.1 m to 7.5 m. Most of the area show fluctuation between 3 to 6 m. In general, topographic highs have higher water table fluctuation (seasonal) than the topographic lows. The ground water flow direction is generally towards SE. Depletion of phreatic aquifer is a common phenomenon during October to mid-June period due to recession of ground water table, rendering dug wells dry. The rapid decline of water table is mainly attributed to the base flow and sub-surface flow in the perennial and ephemeral streams. The phreatic zone gets replenished through rainfall recharge and accounts for the dynamic ground water resources. The monsoon recharge to the phreatic aquifer is sufficient and accounts for 3 to 6 m rise in water level over the pre monsoon level in major part of the investigated area.

Based on satellite data, four sets of lineaments have been identified. The trends of dominant lineaments are NE-SW and NNE-SSW. The lineament density is high in NW part of the block. The probability of encountering aquifers with high potentialities is maximum in the vicinity of lineaments and intersection of lineaments in the NW part of the block. The delineated geomorphic units of the study area are pediplain, flood plain, pediment, structural valley, denudational hill, structural hill and inselberg. Ground water potential is moderate to good in hydrogeomorphic units such as flood plain and weathered pediplains. The residual hills, denudational hills and pediment- Inselbergs complexes have been identified as run-off zone. The area characterized by deeply weathered buried pediplain along with high lineament density have been identified as "**High**" groundwater potential zone (Dekhali, Bomkei, Padmanavpur, Digapahandi, Denkari, Gokarnapur, Bhismagir villages). The potentiality of aquifer system for ground water development is moderate to good in 60% area of the block. The classified ground water potential zones map based on satellite data and field observations can form the base map for the concerned authorities to take necessary action in future ground water development activities in the study area.

Table 1. Groundwater Potential Zones of the study area

Groundwater Potential Zone	**Characteristic features of the zone**	**Areal distribution (Approx.)**	**Important Locations**
HIGH	Deeply weathered buried pediplain, flood plain, high lineament density, Intersection points of lineaments, flat to gentle slope, depth to water table 1m to 5m bgl	30%	Ganeswarpur, Denkari, Gokarnapur, Digapahandi, Khamarigam, Pentha, Santarapur, Bhismagiri, Jakamari, Sahadeb, Gajapatipatna, Padmanavpur, Bajragumma, Jakarapali,Sanakelajhori, Jakar, Dekali and Bomkei
MODERATE	Shallow weathered buried pediplain, moderate lineament density, moderate slope, depth to water table 5m to 8m bgl, extension of lineament to pediment.	32%	Talapada, Talasingi, Bhusanda, Ankorada, Kusapada, Jharipadar, Turubudi, Komarada, Karapada, Dharmapada, Nandagaon,Sidheswar, Kotinada and Shyamasundarpur
LOW	Pediment without lineaments, depth to water table greater than 8m bgl, high to moderate slope	38%	Gumma, Engarsing Padmapur, Rajghada, Badapur Bidyadharpur, Tada, Dhepaguda, Kusaput, Kinchirida, Allalingi, Dhamanapadar, Mahulpaa, Rangaputa, Arakhapada, Keshapur, Kuruma, Damapur and Mahulapada

The net annual utilizable ground water resource of the block is 4118.36 HM. The net ground water draft is 852.95 HM (Unit draft method, based on 100% well census). The ground water balance of the block as on December 2007 is 3265.41 HM, out of which 326.50HM can be utilized for domestic and drinking purposes and 2938.91HM for additional irrigation purpose. At present, the stage of ground water development is 20.71% and falls under safe category. Hence, there is a vast scope for ground water development through suitable abstraction structures for development of agrarian economy. A total additional area of 3672 hect. and 2203 hect. can be irrigated during kharif and Rabi season respectively by utilizing the balance ground water.

Table 2. Groundwater Resource Estimation and Budgeting of Digapahandi Block

Ground water resources estimation (water table fluctuation method)					
Lithology	**Land form**	**Area in Hect.**	**Specific yield**	**Water table fluctuation (m)**	**Unitwise resource estimation in HM (3x4x5)**
1	2	3	4	5	6
Alluvium	Flood plain	1930	0.065	4.0	501.93
Granite gneiss	Deeply Weathered Buried Pediplain	13822	0.050	4.8	3117.28
	Shallow Weathered Burried Pediplain	10759	0.025	6.0	1613.90
	Pediment	3088	0.015	8.5	393.72
	Inselberg	514	-	No water table	-
	Structural Valley	257	0.040	5.5	56.54
	Structural Hill	7207	-	No. water table	-
Charnockite and Khandalite	Denudational Hill	4633	-	No water table	-
Gross Ground water Resources –				**5883.37 HM**	
Net Utilisable Resources (70% of gross) –				**4118.36 HM**	

Ground Water Budgeting

Resources	
1. Gross Ground water Resources	5883.37 HM
2. Net Utilisable Resources (70% of gross)	4118.36 HM
Draft (Unit draft method, 100% well census)	
1. Gross Ground Water Draft (Annual)	1218.50 HM
2. Net Ground water Draft (70% of Gross)	852.95 HM
Ground Water Balance	3265.41 HM
Stages of Development	20.71%
Category	**Safe/White**
Allocation	
1. Domestic and Drinking (10% of Balance)	326.50 HM
2. Available for irrigation	2938.91 HM

The ground water in the investigated area shows limited seasonal variation in quality. Comparison of the Hydrochemical parameters results of the study area with that of ISI (1983) standards ensures the potability and other domestic utility of the ground water of the block except very few locations. With respect to sodium Adsorption Ratio (SAR), Residual Sodium Carbonate (RSC), Total Dissolved Solid (TDS), Percent Sodium (%Na), Magnesium Hazard and Permeability Index (P.I), the ground water of both dug wells and bore wells falls within the good to excellent category for irrigation except very few cases.

Depending upon the thickness of the saturated weathered zone, intensity of fracture zones, and depth to massive bed rock, suitable ground water abstraction structures have been suggested to harness ground water for sustainable growth of rain fed agriculture and mitigating drinking water problem in the area. The ground water can be developed by sinking open wells, dug-cum-bore wells, shallow tube wells and bore wells at hydro geologically favourable locations. Based on the hydrogeological set-up, natural recharge conditions, soils, slope of the area, land use pattern, future optimal use of ground water; suitable sites for specific artificial recharge structures such as percolation tank, percolation-cum-irrigation tank, check dam, contour bund, gully plug and vegetative measures have been suggested to maintain the balance between the recharge and draft.

V. CONCLUSION

Scientific well siting on the basis of the results of the present hydrogeological studies is recommended. Suitable steps for revitalization of old and defective wells and rain-water harvesting structures may be under taken. The existing dug wells, which go dry during summer, may either be deepened or bore well can be drilled to meet the water requirement. Horizontal bores may be drilled for increasing the well yields. Rain water Harvesting (RWH) and Artificial Recharge Structures such as percolation pond, check dam, gully plug, contour bund and vegetative measures may be taken up by government agencies for serving dual purposes of improving the health of ground water sanctuary and solving geo-environmental problems like land degradation by soil erosion. This activity may generate additional employment opportunity for rural youth. Steps are to be taken up for speedy energisation of the wells already constructed to ensure optimal utilization of the ground water potential for rural development. As there is an ample scope for development of ground water in the investigated area, financial institution should come forward for financing ground water development schemes. Optimal and judicious utilization of ground water through properly designed abstraction structure constructed at suitable locale with accompanying protection, augmentation and conservation measures can being about laurels to the agrarian economy of the area and can mitigate the problems of drinking water scarcity faced during summer. Water Resource Management (WRM) being an interdisciplinary area; hydrogeologists, environmentalists, agriculturalists, engineers in the area of hydrology, hydraulies, water supply, irrigation, economists, sociologists, politicians and end-users should be involved in decision making of the ground water development projects.

REFERENCES

[1] Ahnfors, M.(1981)"Methods to sustain Groundwater for Longer Duration by means of subterranean Dams", UNESCO Rept. on Inter-Regional Seminar on Groundwater in Hard Rocks, Coimbatore, India. pp. 101-104.

[2] Ballukraya, P.N. (2001) Over- exploitation of Groundwater: Consequences and Remedial measures, Jour. Appl. Hydrol, Vol. XIV, No.4, pp.27-36.

[3] Chadha, D.K. (2000) Groundwater Resource Potential and Scope for Development in Orissa. In" Proc. of Seminar on "Prospect of Groundwater Development and Management in Orissa" Central Ground Water Board, Bhubaneswar, Orissa. pp.1-9.

[4] Chauhan, S.S. (2000) Achievements, constraints and Remedies- Groundwater Exploration in Orissa. In: Proc. of Seminar on "Groundwater Resources of Orissa for 2020", Central Ground Water Board, Bhubaneswar, Orissa, pp. 1-11

[5] Das, S. (2006) Ground water in "Geology and Mineral Resources of Orissa. SGAT Publ. (3rd Edn., Bhubaneswar, pp 415-433.

[6] GEC (1997) Groundwater Estimation Committee, Report, Ministry of the Water Resources, Govt. of India, New Delhi.

[7] ISI (1983) Indian standards specifications for drinking water, IS: 10500.

[8] Jasrotia, A.S. and Singh, R. (2007) Hydro chemistry and Ground water quality, Around Devak and Rui watersheds of Jammu Region, J.K. Jour. Geol. Soc. India. Vol.69. pp. 1042-1954.

[9] Jha, B.M. (2000) Sustainability of water resources in Orissa. In: Proc. of Seminar on "Groundwater Resources of Orissa for 2020", Central Ground Water Board, Bhubaneswar, Orissa. pp.13-22.

[10] Karanth, K.R. (1987) Groundwater Assessment, Development and Management. Tata McGraw- Hill Publ. Co. Ltl, New Delhi, India 720p.

[11] Mahalik, N.K and Nanda, J.K. (2006). In "Geology & Mineral Resources of Orissa. SGAT Publ. (3rd Edn.), Bhubaneswar, pp. 45-90.

[12] Mohapatra, S.S., Tripathy, P.K. and Behera, G.(2000) Application of Remote sensing for identification of Groundwater potential zones and measures for groundwater recharge. In : Proc. Seminar on "Groundwater resources of Orissa for 2020" CGWB, Bhubaneswar. pp.120-127.

[13] Nayak, N.C., Behera, S.C. and Naik, K.C (2003) – Augmentation of Ground water Resources through construction of Artificial Recharge structures in part of Ghodahada basin in Sanakhemundi block of Ganjam dist., Orissa. In proc. Net. Sem. "Ground water management in Orissa- The prospects and challenges. CGWB, Bhubaneswar. pp. 64-76.

[14] Pandian, K. and Sankar, K. (2007). Hydrogeochemistry and Ground water quality in the Vaippar River Basin, Tamil Nadu. Jour. Geol. Soc. India. Vol. 69. pp. 970-982.

[15] Patnaik, J. (2003) Groundwater situation in Orissa. Proc. Nat. Sem. "Assessment and Management of water Resources", SGAT, Bhubaneswar, pp.101-120.

[16] Pradhan, K. (2003) Artificial Recharge to Ground water. The need and scope in Hill region of Orissa. In Proc. Nat. Sem. "Ground water management in Orissa its prospects and challenges " CGWB, Bhubaneswar pp. 50-54.

[17] Prasad, NBN; Shivraj, P.V. and Jegatheesan, M.S. (2007). Evaluation of ground water development prospect in Kadalundi River Basin. Jour. Geol. Soc. India. Vol.69. pp.1103-1110.

[18] Raghunath, H.M. (1987) Groundwater, Willey Eastern Ltd., (2nd Ed.) New Delhi, India, 563p.

[19] Reddy Obi, G.P. and Maji, A.K. (2003) Delineation and Characterisation of Geomorphological Features in a part of Lower Maharastra Metamorphic Plateau using IRS-ID LISS-III Data. Jour. Ind. Soc. Remote sen., v.31. No. 4. pp.241-250

[20] Reddy, P.R (1999) Remote sensing in Ground water studies : In: Remote sensing for Earth Resources (Ed. D.P.Rao), Publ. Of Asso. Expl. Geophysists, Hyderabad, India (2nd Edn.) pp. 183-203.

[21] Rokade, V.M., Kundal, p and Joshi, A.K. (2007). Groundwater Potential modeling through Remote sensing and GIS : A case study from Rajula Taluka, Chandrapur District, Maharastra , Jour. Geol. Soc. India, V. 69, pp. 943-948.

[22] Sahu, P.C. (2003), Hydrogeological studies in the Bonai Sub-division of Sundargarh dist, Orissa, India, Ph.D Thesis (Unpublished), Sambalpur University, Burla.

[23] Sahu, P.C. (2008) Geomorphological and Lineament Studies for targeting Ground water in Digapahandi block, Ganjam disrict, Orissa. Vistas in Geol. Research U.U. Spl. Publication Geology (7), pp. 193-200.

[24] Sahu, P.C. and Sahoo, H.K (2006). Targetting Ground water in tribal dominated Bonai Area of drought prone sundergarh disrict, Orissa India- A combined Geophysical and Remote sensing Approach. J.Hum. Ecol, 20(2), pp. 109-115.

[25] Sankar, K. and Venkatraman, S.(2002). Geological and Geomorphological maping in and around Bharathidarsan University. A Remote sensing Approach. Jour. App. Hydrology, V. XV, No. 1, pp. 15-22.

[26] Shukla, N. K. (2000) Iron in Groundwater- Experiences from Rural Water Supply Sector in Orissa. In: Proc. of seminar on "Prospect of Groundwater Development and

Management in Orissa” CGWB, Bhubaneswar, pp. 121-123.

[27] Sikdar, P.K, Adhikari, S.K. and Bhattacharya, B.B. (2007) Lineament Density Modelling to Identify High Potential aquifers in Hard rock areas. Jour. Geol. Soc. India, v.69. pp.1118-1131.

[28] Singh, A. ; Mandal, G.C. ; Singh, S.; Singh, P.K.; Singh, T.B.; Tewary, B.K. and Sinha, A. (2007). Aquatic Geochemistry of Dhanbad, Jharkhand ; source evaluation and quality Assessment Jour. Geol. Soc. India. Vol 69. pp 1088-1102.

[29] Umrikar, B. N. (2002) Artificial Recharge and Water Conservation Techniques in Deccan Trap Aquifers of Maharastra. Jour. Appl. Hydrol., Vol. XV, No.1, pp. 23-30.

[30] Viswanathan, K.S. (2002) Water Resources Development- Management of Critical areas in Eritrea, Asmara. Jour Appl. Hydrol., Vol.XV, No.-4 pp. 21-25.