ISSN NO. 2320-5407

Journal homepage: http://www.journalijar.com

INTERNATIONAL JOURNAL OF ADVANCED RESEARCH

RESEARCH ARTICLE

Geo-hydrology of South Mahanadi Delta and Chilika Lake, Odisha

Siba Prasad Mishra[1], Soumyak Dwibedy[2]

(1) Assistant professor, Centurion University of Technology & Management, Ramachandrapur, Khordha, 752050,Mob:91 9438668332, E-mail 2sibamishra

(2) Final year student, Civil Engineering Department, Centurion University of Technology and management, Ramachandrapur, Jatni, Khordha, 750250ENT

Manuscript Info

Manuscript History:

Received: 22 September 2015
Final Accepted: 25 October 2015
Published Online: November 2015

Key words:

Mahanadi, Delta, Groundwater, Delta, Recharge, draft

Corresponding Author

Siba Prasad Mishra

Abstract

Ground water is a perennial water bank which is credited by recharging and debited through drafts or well capture. About 80% of people live in villages. They depend upon wells for domestic uses and agriculture. Climatic anomalies, uplift/down drift and excess draft have depleted or contaminated the ground water. Irrigation, the largest user of ground water is in jeopardy or underdevelopment today. About 200 to 300sqkm area from 1532sqkm of Chilika area is deprived of surface irrigation. Irrigation cannot be provided to remote hilly and lacustrine patches of the south corner of the Mahanadi basin. Chilika Lagoon and six blocks around could not use surface flow for water logging, salinity intrusion and back water. Alternate can be the ground water. Recharging and discharging rates to aquifers are difficult to access. Surface Water available is sometimes inadequate and inappropriate to meet the demand. Location of aquifers, their depth, extension and rate of recharge in south Mahanadi delta and the lagoon area is discussed in the paper. Ground water recharge in two major towns Bhubaneswar and Puri is focused and correlated with rainfall. Though ground water depletion is not vulnerable at present but its scarcity in future is anticipated. Optimum use of Ground water and their recharging at the field level are the topic of research.

1.0 Introduction

The hydrologic cycle consists of three reservoirs, clouds, ice, water and glaciers on the earth crust and water in aquifers. Both surface water and movement of clouds are visible. The underground water movement is invisible. Rapid urbanization, industrialization, infrastructural growth and modernization have increased ground water draft in last five decades. Groundwater (GW) is easy to extract, a cheap source, self-rechargeable and well protected from contaminants. Chance of pollution and contamination of underground water is less. Hence it is the best choice for drinking water out of the three. So water is the popular resource for usage in many under-developed and developing countries. However, over exploitation of GW sources in urban areas are common nowadays. Lack of technical knowhow and knowledge of conservation and harvesting and optimal use of this vast resource, water is under wild research. Thus, there is a growing emphasis on proper groundwater management.

2.0 Study area

The delta of river Mahanadi of area 9000sqkm is divided into three demarked geo-morphologic zones South, North and Central. South Mahanadi delta (SMD) comprises parts of Khordha, Cuttack and Puri districts of

Odisha. SMD consist of 12blocks having area 1777sqkm and Chilika lagoon near the corner is 1532sqkm (including islands and spits) **[Mishra et al 2015][1]** (Fig 2). The apex of the delta is at Naraj where the river Mahanadi throws its southern limb Kathajodi. The rivers, Daya and Bhargovi are two southern branches of Kathajodi system are major source of inland flow of Chilika. Major lacustrine areas associated with SMD are Chilika lagoon, Samang Lake, Deras and Phulajhari swamps, vast water logged coastal areas of Delang, Kanas, Sakhigopal and Puri Sadar. These areas lie in the flood plains and drainage system of rivers Kuakhai, Daya, Bhargovi, Nuna and Ratnachira. The soil is alluvium except some parts of Jatni and Bhubaneswar which contain of Laterites. Southern part of the landform comprise of flood plains, alluvial fans, intermountain valley, river terraces, pediplain, old mender channels which can be favourable for formation of aquifers. SMD and Chilika encompases rocks of Eastern Ghats belt. The vast land is thickly populated and population density 651no/sqkm (2011census) and primarily agriculture based. The Land form of SMD comprises of the Aeolian, Alluvial Deltaic and Upper fluvial zone. [Fig 1)

2.1 The upper deltaic reaches (Cuttack district)

The upper deltaic reaches spread from Naraj (20 -29' N lat and 86-47' E) to Pipili (20 -24' N lat and 86-57' E) consisting of igneous sedimentary and metamorphic rocks. The average depth of water table is available at 3 to 10m below ground level(bgl). The fresh water yield of the wells and tube wells in shallow stratum is less 1-5lps whereas for bore wells the capacity is 15-20lps.The yield of deep bore wells have range 3-75lps, drawdown 3-17m and hydraulic conductivity 50-150m/day. The soil is unconsolidated alluvium over Athgarh formation with alternated layers of sand, silt and clay. Ground water table (GWT) is 4-6m below ground level. Two confined aquifers has been identified one at 15-20m and other at 30m and 40m. **(Mahallik 1996)[2]**.

2.2 The deltaic reaches (Khordha District)

Khorda district (Lat 20^0 18' Latitudes 85^0 68') has a total geographical area of about 2887.5 sq. km. and a total population of 22,46,000 with about 48.11% in villages(District portal) and urban populationof 1080000, highest in the state .The district generally forms a lateritic upland with inselbergs. The area covers Bhubaneswar city, Jatani and a part of Balipatna block in thedeltaic plains of SMD (Fig 3). The district is partially delimited by the Chilka Lake in the south. The district enjoys a humid subtropical climate with an average annual rainfall of about 1305mm. Jatani is a small town 12km from Khurdha.Irrigation sources in the district are surface irrigation 92840Ha by 21Canals, open wells 2950numbers irrigating 1350Ha, bore wells 1489numbers irrigating 2900Ha and 7167 lift irrigation points provide water to 2900Ha of land. Khurdha district have net annual ground water resources 73877HaM out of which irrigation supply is 62795HaM, draft 3730HaM and Groundwater resources left out for future use is 67155HaM. (CGWB -2002)[3]. Production wells in 189in number contribute 42.19MLD and spring tanks provides 2.27Mld of ground water. Present water demand Bhubaneswar city is 116.37MLD and present level of water supply 246.53MLD.

2.3 Aeolian and deltaic landform (Puri District)

Puri district (19^0 28' and 20^0 35' N lat and $84^0$29' and $86^0$25' E long) covers an area of 10,182sq.km with average annual rainfall of 1488mm. Floods and water logging in the coastal landform are regular features. Depletion of GWT is a remote problem in Puri but its proximity with the brackish water lagoon and coastal interface induces salinity intrusion in the GW and back water propagation. One Lakh hectare of land in Puri is provided by surface irrigation. About 0.5 lakh Ha was irrigated by GW sources by 451 lift irrigation projects (2012 data). The GWT ranges from 2-12m below ground. The estimated annual ground water recharge potential in Puri district is 224180 Ham. The net annual GW recharge by irrigation water was 190550 Ham. The present draft is 10,080 Ham and balance ground water available for future use is 18047Ham. The stage of development at present is 5.2%.

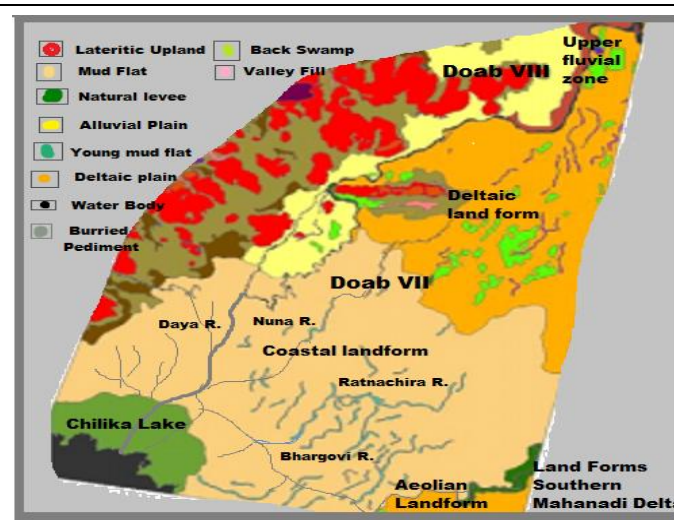

Fig 1: Landform in south Mahanadi delta & Chilika

1.7lakh ha can be irrigated by lift from the available source. (State water plan 2004 ,W. R. Deptt, Odisha)[4].

2.4 Lagoon landform (Chilika Lagoon)

The Chilika, the largest brackish water lagoon is 1165sqkmx 906sqkm in monsoon and summer days. The north-western bank touches the SMD. The soil in the area is non-uniform in structure comprises of lateritic, alluvial, clayey or gravel. There are 301villages in and around Chilika comprising of 1372sqkm. The aquifers are available at 6m depth in the area. The m^3/hour, low during recharge rate is 5-10 summer and high during monsoon. The average salinity of ground water during post monsoon in open wells, ponds and tube well 2.21, 2.75 and 2.93 mmho/cm (1mmho/cm= 1DeciSemens/m) respectively. The corresponding salinity of ground water during pre-monsoon averages is 2.72, 4.12 and 2.0mmho/cm. This shows the salinity of soil during post monsoon is higher than the pre-monsoon. The post monsoon pH values of open wells, rivers and tube wells are 7.29, 7.2 and 7.53 Mmho/cm and during pre-monsoon are 7.87, 8.5 and 7.82 respectively. The average alkalinity is 00 to152m. (Das M. 2006)

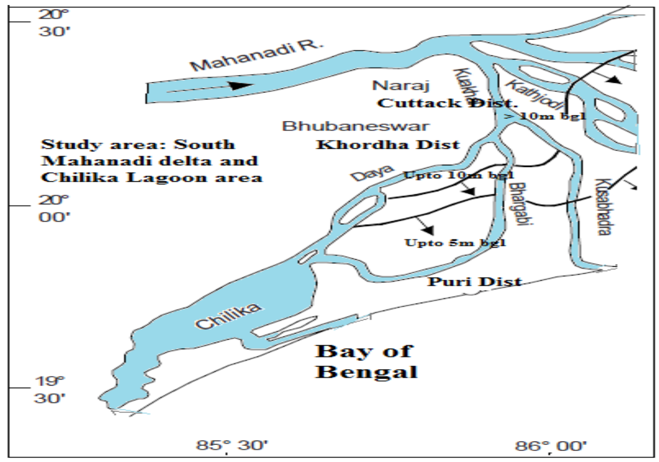

Fig 2: Hydrologic system of SMD and Chilika

3.0 Problem statement

The lowering of GWT leads to scarcity in water availability, increased cost of pumping, deficient runoff and hence surface water non-availability, flood plain subsidence, water quality distresses and cause finally moisture stress or permanent wilting point to vegetation. Areas in India have depletion of ground water table by 70cm and agriculture suffers by 25% for want of ground water. CGWB reported that GWT is depleting rapidly in 24 out of the 30 districts in Odisha. The aquifers in many areas of Odisha are under tension and gradually drying up. The national average water loss in class – I cities in India was 21.62% whereas Bhubaneswar stood the apex having loss of 40%.

Since the study area is mostly of rural base, the major source for domestic use is either a well or a tube well where draft of ground water considered as the highest. Erratic monsoon and arresting recharge through concrete jungles have reduced recharge rate. The demand of GW source may over rule the supply. The water in coastal belt is not fit for use for its increasing salinity. The GW of Chilika area is more saline and deprived of both irrigation and portable water. Recharging of GW occur four to five months annually whereas draft is round the year. The depletion in ground water table (GWT), particularly in urban areas resulted in reduction of water body, deterioration have instilled land subsidence and increased cost of pumping. Contamination in quality and salinity intrusion has created regular health concern. The present scenario demands study of geohydrology and their curative measures.

4.0 Literature review:

Hydro-geological surveys, water quality study and draft of GW were conducted in the Mahanadi delta since the year 1950, initially by the Ground Water Division of Geological Survey of India (Bhatnagar et al. 1970)[5] and later by the Central Ground Water Board (Radhakrishna et al., 1976[6], Chakladar,1981[7]) Afterwards during study of the impact of Mahanadi delta stage II, the well data collected by Water Resources Department from 1980 to 1984 in south Mahanadi delta only (Delta dev. Plan, GOO, 1986) [8].Srivastab et. al. 2013[9],2014[10] have reported factors responsible for the GWT fluctuation in a specific morphologic environment and prediction of future water depth by artificial neural network model. The results were that Meso-scale impacts of depletion in GWT shall affect MSL. It is assessed that globally the groundwater drawl has increased from 312 to 734km^3 and recharged from 126 to 283 km^3 between 1960 to 2000 (Wada Y. et al 2010)[11].Their report specifies one third of world's ground water has been drawn without recharge. **Sara Maatta, 2011[12]** predicted groundwater levels in an unconfined shallow aquifer in the winter using ANN when water levels are high. A method developed by **Chandni Kapoor et al 2012**[13]about a technique to find depth of ground water at any place without help of usual method of well data or bore hole data but by knowing its geological history. However Ground Water Table in the south Mahanadi delta in an average 2-5m observed in 2013 and trend is rising as per **Central Ground Water Board MOWR, GOI[14]**. The yield of sediment in the catchment of river Mahanadi is of order 200-400tons/km^{2}highin India**(Meijerink, 1982-83)[15].** In peninsular

India, there is deep circulation of ground water having cavities or deeper water bearing fractures and yield varies from 2-10lps. In coastal areas there is no change in GWT due to salinity intrusion (**Jha et al 2008**)[16].

Samples from solid waste dump yards if Bhubaneswar city during 2009-11 and their biological, physical and chemical parameters had shown high iron and turbidity**.** The leachates and heavy metals absorbed by GW got contaminated. Drinking water norms were not fulfilled in the dump areas of Bhubaneswar and Puri, **Mishra et. al, 2013[17]**. Average seasonal water level fluctuation in the area 2.2m, average discharge 35.37lps, and drawdown is 10.44m. The ground water development in coastal Odisha have increased from 23% in 199 to 43% in 2009.**Srivastava S. K. 2013**[18]The type of soil for possibilities of having aquifers should be sandy loam, clayey loam, gravel, sand of all types and fractured rocks. Groundwater is vanishing fast from the world and India is among the worst hit, shows data from NASA's Gravity Recovery and Climate Experiment (GRACE) satellites **(NASA 2015)**[19]. **Dash et al 2015[20]** have made the hydro-geological studies of Chandanpur, a coastal area of Puri district in Odisha. They have reported GW quality is brackish which is fairly poor for domestic and moderately hard for agricultural use.

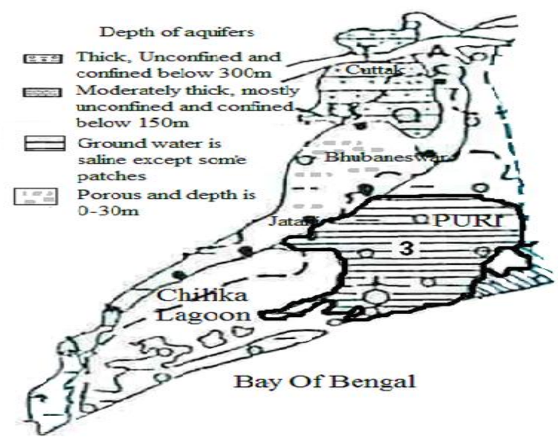

Fig 3: Depth of aquifers in SMD & Chilika

5.0 Methods and methodology

Extent of recharging of groundwater or estimation of GWT can be done by various ways. The methods adopted are water balance study, Chloride balance method, rate of movement of trace element in shallow subsurface layer or by field test methods. Hydrogeologic interventions on natural drainage system, Water supply, Surface irrigation and precipitation contribute to discharge, recharge and GW flow. Water bodies, and flood irrigation in the area contributes on a large scale to increase water in the Vadose zone, saturated zones, and in GWT. Exploitation of GW in the last 30years through lift irrigation has impact on the GWT.

The GW responsive areas are the urban areas. They are part of Khordha including Bhubaneswar and Puri town. Observations were considered only from thirty two wells in Khordha district (Fig 8) and fifteen wells in Puri district (Fig) and water levels are taken in pre, mid and post-monsoon. The depths of recharging were found considering the lowest and highest water level. The satellite towns are Barang, Pipili, Sakhigopal, and Chandanpur where quantum of GW has fewer problems but its quality matters. The reasons are the drainage system in the delta is anastomosed. GW is available just near the ground level and extends to even 300mtrs below these places. However salinity intrusion, biological organisms and pollutant contamination make the GW unfit for use.

Classification of quality of ground water according to use as per world bank norms are a. **Class** A: water used as drinking water source after disinfection but having no conventional treatment, b. Class B: water can be considered for organized open-air bathing, c, Class C: water can be used for drinking source with conventional treatment and disinfection. d. Class D: water to maintain aquatic life (i.e. propagation of wildlife and fisheries), e. Class E: waters for use for irrigation, industrial cooling and controlled waste disposal.

Ghyben-Herzberg developed a relationship between the relative densities of fresh water and salinity of the ground water and h_f fresh water head above sea level and h_s depth

Fig 4: A well in Jatni in post monsoon 17.75m deep

of interface below sea level.hs $= \left[\frac{\Upsilon f}{\Upsilon s - \Upsilon f}\right]$ h$_{f.}$ ideal Ghyben-Herzberg model with Ys = 1.025gm/m^3 and Yf =1.0 gm/m^3 gives $\mathbf{h_s = 40\ h_f}$ (Arnold V. 1968)[21]

6.0 Geohydrlogy Setup

All the rock forms i.e. igneous, sedimentary, alluvium, and metamorphic can have possibilities of aquifer underlain the bgl. Isolated aquifers found in the coastal belts of Puri and Chilika areas mostly. They are generally extending from 5 to 50m deep. But in other places, the extention is upto 300m.The regional extended aquifers in SMD are multilayered or inter connected being separated by clayey layers.There are freshwater aquifers under paleo fluvial sediment deposits or under sand dunes (Fig7). These aquifers are found in entire coastal areas extending from Malud (a village in Chilika area) to Konark. All other aquifers are deep upto 25-30km. They are either saline or brackish. All aquifers (below 30-300m) in coast are saline. SMD covers unconsolidated alluvium. It isa good source for brackish water aquifers. The aquifer in the study area are unconfined, deep, inter connective, multi layered and of varying depths.

Aquifers in the deltaic landform (below Naraj) are the Sedimentary rock aquifers. They have regional connections and cover more than one village. The ground water quality in the area has less health hazards with less contamination except iron. In Alluvial and Tertiary sedimentary formations of GW under phreatic zone are shallow aquifers. The saline sweet water interface is about 20-25km from the coast but narrow. They are semi confined to confined condition in deep-aquifers. The GW travel in sand and gravel layer form potentially shallow and deep aquifers having gradient towards coast. The inter face between fresh and saline ground water is sharp and lies between 20-25km from coast line. The depth of dug wells in these formations is about 10m.

The yield of the tube wells may range up to 1-5 lps or more depending on the thickness of aquifer (fig 5).The southern boundary of the SMD are of unconsolidated formations include laterites and recent alluvium. The yield of tube wells tapping granite gneisses ranges between 10-35 m3/hr. whereas other consolidated formations, it ranges between 5-18 m3/hr. The yield of tube wells in semi-consolidated formations range lies between 20-115 m3/hr (Lohani et al 2012) [22].

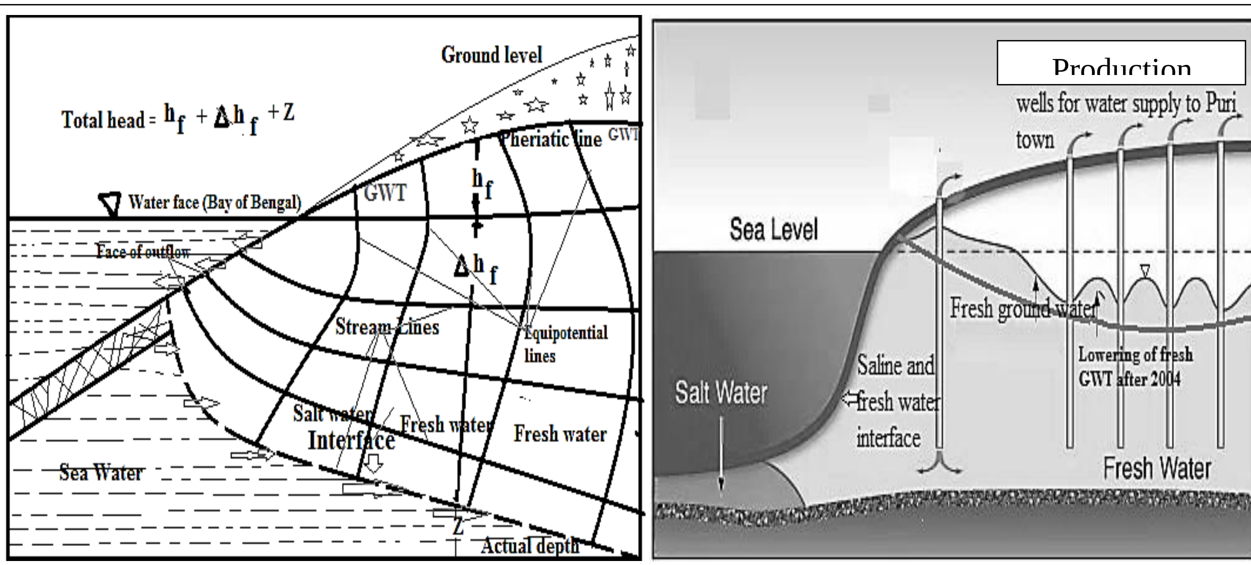

Fig 5: The mechanism salinity intrusion , GW drawl in production wells of Puri & Chilika coast

6.1 Demand and nature's contribution

Harnessing irrigation water from GW source is a million dollar question today. Well irrigation in past superseded by lift irrigation today. Major sources of ground water are through infiltration, precipitation and inefficient irrigation surpluses. Surface water source of 1.71Mcum (@47MLD/day) of water is supplied to Cuttack town and Bhubaneswar city from source Mahanadi. Water supply projected @75 MLD of water from Bhargovi as source in this year and rest are harnessed from ground water. Bhubaneswar is a city of 50 years and population of 1.0million (2013). Projected for 2030 shall be 1.7million.The national average water loss in class – I cities in India was 21.62% whereas Bhubaneswar stood the apex having loss of 40%. Present water supply Bhubaneswar city was 239.13MLD (96MLD wasted) in 2012. Projected demand by 2030 shall be 253MLD (CDPA Report 2012) [23]

6.2 Soil stratification in SMD and Chilika

South Mahanadi delta (SMD) covers unconsolidated alluvial sediments of age from post Mio-Pliocene to present being the good source for fresh water aquifer. The soil type in the lower delta is SPSM type, sandy loam, clayey loam and gravel mixed with sand. It is a good source for both fresh and brackish water aquifers. The bore hole data depict that the aquifer in the study area are unconfined, deep, inter connective, multi layered and of varying depth. The periphery of Chilika and southern part of the delta has a large number of Pedi plains and Pediments which are also a moderate source for ground water potential. The bald hills and inselbergs are the runoff zone. The land use is cultivation, aqua culture, water body, waste land, swamps, grass and shrubs.

6.3 LU/LC in Upper deltaic reaches

Aquifers are possible to form under agricultural land, water body, forests, mudflats, swamps, grass etc (Dixit P. K. 2014) [24]. Regarding LU/LC changes (1999-2012), it was observed that agricultural land and water body were decreased by 10.92sqkm and 1.32sqkm, whereas forests, swamps, urban area and human settlement were increased by 6.82sqkm, 3.16sqkm, 1.39sqkm and 1,69sqkm, respectively in SMD. The swamps, agricultural lands and water spread area of Chilika had decreased by 7.8sqkm, 7.4sqkm and 1.2sqkm, whereas prawn culture area and human settlement increased by 8.5sqkm and 2.3sqkm, respectively(Samal et al 2013)[25] The decrease in swamps, agricultural lands and lacustrine area indicate the ground water area and depth of aquifers is decreasing (fig 6)

6.4 Lithology

GW source in its hinterland of SMD is perinneal as people use both the surface water and shallow aquifers of maximum 50-60m deep. Prevalence of ground water is solely depends upon lithology of the area. The frustum consists of Archean to post Holocene. The fluvial zone, at the apex of the delta, is of Athgarh formations of Gondwana type. The middle deltaic land form comprise of sand, gravel and clay overlain by old or new alluvium within a depth of 80-100m. Vast stretches of both unconfined and confined aquifers are available in the area. The aquifers may be fresh, brackish or saline depending upon the extent of salinity intrusion. Most of the areas of Pipili, Delang, Jatni and Bhubaneswar comprises of old alluvium of Pleistocene to recent Holocene. Either they are laterites or old alluvium

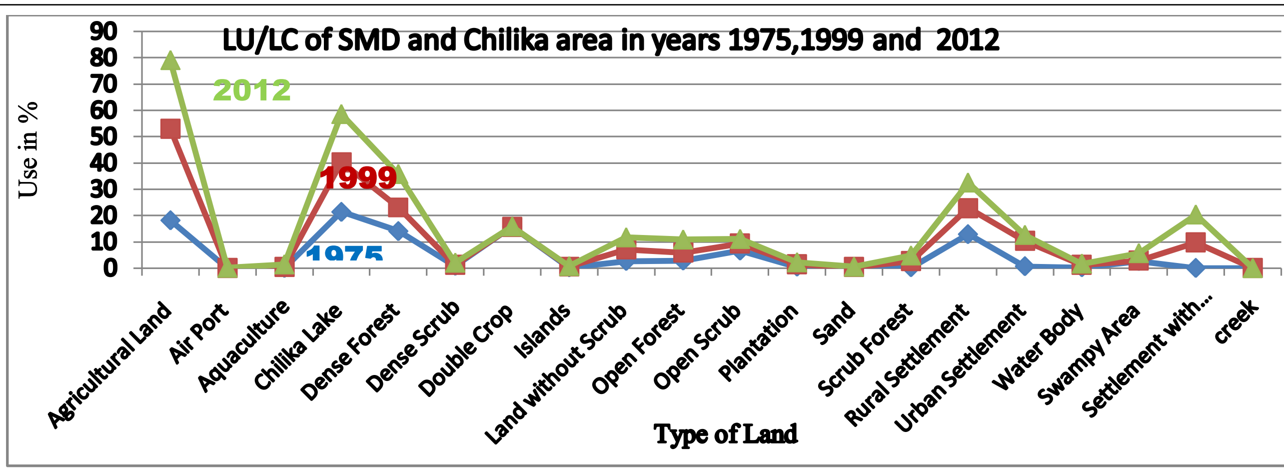

Fig 6: Changes in LU/LC of SMD &Chilika contributing Ground water (Source: CDA and Google)

In granite and khondalites beds fresh water is available from 7m to 14m with a low yield of 1-5lps. In charnokites and anthracites depth of aquifers range from 5-12m and yield is low and even insignificant. The unconsolidated formations of tertiary to recent a large interconnected aquifers exists and the major source GW supply in south Mahanadi delta. Most of the dug wells and wells in SMD explore these areas for the domestic and agricultural use.

Sedimentary thickness of 2000-2500 m is found while construction of foundation of Bridges over Kathajodi and Kuakhai. Two to three depressions are crossing in the alluvium of the area directing the distributaries to flow through the gorges where GWT is found near bgl. The interfaces of the above geological formations are the buffer zone and the loci of the aquifers (Mishra et al 2015) [26]

Aeolian landform is the formation of pre-Holocene to present. The barrier spits are even 500-1000years old. The deposits are sand, clay, gravels and pebbles. Except some confined freshwater aquifers most of them are saline. The salinity intrusion has increased after Tsunami-2004. In the catchment of Chilika synformal and antiformal folds with a 20-22km of mylonyte zone of foliation is available.

7.0 Status of GWT Odisha

In alluvium/ hard rocks and total unconsolidated rocks, the ground water coverage is 162 KM^3 in Odisha within a coastal stretch of 450km. As per India - Ground water potential exploited till date is about 26.14%. These ground water potential is available within 600m depth. The hazard that is bumped into utilization of groundwater is the salinity intrusion which extends up to 30 to 40km inland. The depth of ground water availability during monsoon is 0-7m where as in non-monsoon period it is available at a depth of 4-20mt or even more. Perched aquifers are also available at a very low depth of 0-3m. About 4.36BCM of ground water is being drafted with irrigation sector extracting the highest (79.6 per cent) in coastal areas of south Mahanadi delta. Odisha is taking the benefit of ground water through lift irrigation by 5447nos of lift irrigation projects.

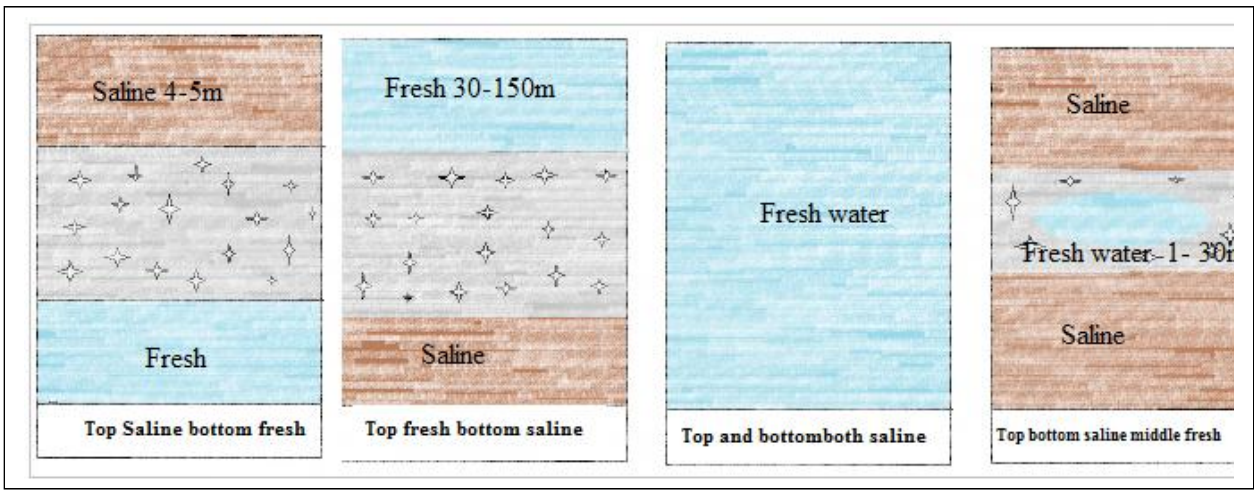

Fig 7: Position of saline and fresh GW aquifers in coastal areas of south Mahanadi delta and

Geographically the south Mahanadi delta has ample coverage of alluvial stratum of flood plains, river terraces, sedimentary and metamorphic origin which is good sources for ground water potential. They are SPSM type consisting of sandy loam and clayey loam in alluvial fans. In South Mahanadi delta the utilization of ground water for Irrigation Processes is the less i.e. 30.44% though irrigation potential created is the highest except Krushna Prasad Block in Chilika area. The deep tube wells used for irrigation purposes are only harnessing 11% and dug wells 29%. (Srivastav S.K, et al. 2013)[9]

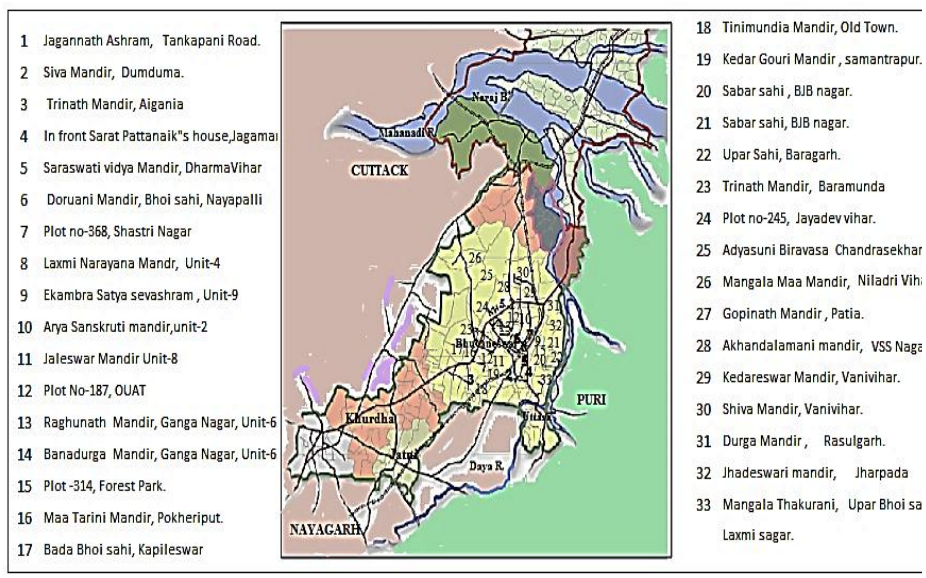

Fig 8: The observation wells in Khordha district (Year: 2006-2015)

7.1 Cuttack District

The area covered by SMD in Barang block of Cuttack district have Ground water variance of 4-6m bgl during summer and 0-2m bgl in monsoon days. (CGWB Report 1995). These aqufers lie in Athgarh formation and possess good portable water except patches obtain water with iron and calcium. The soil in the upperlayer of Barang block are covered with unconsolidated alluvium having alternate layers of sand, silt, clay and gravels. Recharging ofGW is done through Kanjia Lake existing in Nandan Kanan, a zoo in Odisha.

7.2 Khordha district

These areas are Bhubaneswar, Jatni and Khordha and the lithology are part of Athgarh sandstone or laterite formation. The ground water is fresh and portable. The ground water is extended up to 100m. Scarcity of ground water is faced during summer as ground water draft is very high (Fig 4). Upward propagation is not a problem in Khordha and Cuttack district for the geological formation. The rainfall of Bhubaneswar city is taken for the year 2006-2014. A linear regression is developed with the recharging. It is also observed that the rate of recharging is high in the west and north- west of the town. The ground water level is higher towards east and north east as Kuakhai is running in the outskirt. Considering the amount of draft of the area for the period a prospective linear regression model is given in Fig 9 and Table 2.

The depth of water table in Bhubaneswar range from 5-12m in the Laterites and the weathered sandstones to 40-150m in the fractured and friable sandstones forming the deeper aquifers that is under semi-confined to confined conditions. The rock types in and around the western parts of Bhubaneswar store water recharged by rainfall. The recharge data is analysed in Table 2.

Table 2: Recharge data of different wells observed in Bhubaneswar (2006-2015)

#	Latitude [DMS]	Longitude [DMS]	Dia well in m.	Recharge Ht 2006 (m)	Recharge Ht 2007 (m)	Recharge Ht 2008 (m)	Rech Ht 2009 (m)	Recharge Ht 2010 (m)	Rich Ht 2011 (m)	Rech Ht 2012 (m)	Recharge Ht 2013 (m)	Recharge Ht 2014 (m)	Recharge Ht 2015 (m)
1	$20^0$14'36"N	$85^0$51'17"E	1.2	1.19	1.08	1.35	1.80	1.35	2.59	2.60	1.45	1.12	1.56
2	$20^0$14'36"N	$85^0$47'48"E	1.75	3.40	3.25	1.70	2.55	2.80	1.40	3.20	3.20	1.93	2.37
3	$20^0$14'59"N	$85^0$46'59"E	1.13	4.22	4.02	3.35	3.35	4.00	2.45	2.60	2.35	2.09	2.29
4	$20^0$15'20"N	$85^0$47'31"E	1	3.69	3.55	3.25	3.95	4.50	2.65	3.80	3.70	3.71	3.49
5	$20^0$15'47"N	$85^0$47'32"E	1.27	1.55	1.44	1.75	1.58	2.10	0.88	1.35	2.10	2.75	2.80

6	20^{0}17'21"N	85^{0}48'59"E	2.1	3.88	3.85	3.75	2.55	4.35	3.35	0.30	1.30	2.56	4.30
7	20^{0}17'01"N	85^{0}48'21"E	1.25	2.65	2.50	2.20	2.40	1.00	0.35	0.25	0.35	1.84	1.87
8	20^{0}16'53"N	85^{0}49'42"E	1.2	1.93	1.80	2.25	2.40	1.90	1.35	2.05	2.05	2.45	3.14
9	20^{0}16'47"N	85^{0}50'12"E	2	2.65	2.50	2.75	2.30	2.45	1.75	1.60	2.00	2.80	3.02
11	20^{0}16'38"N	85^{0}48'21"E	3.15	3.27	3.20	3.50	3.10	2.20	2.00	1.90	5.10	2.46	2.97
12	20^{0}16'06"N	85^{0}48'29"E	1.6	1.30	1.39	1.45	2.25	1.70	0.85	1.25	1.60	2.64	2.70
14	20^{0}15'51.6"N	85^{0}49'04"E	1.7	-2.25	-2.25	-2.25	4.95	2.55	1.45	1.10	1.35	3.31	3.53
15	20^{0}15'23"N	85^{0}49'45"E	1.25	2.95	3.10	2.30	2.45	3.05	2.20	2.15	3.25	2.25	3.23
16	20^{0}14'13"N	85^{0}48'09"E	1.6	4.40	4.27	4.40	4.45	4.65	2.05	2.35	2.45	5.68	5.68
17	$20^{0}13^{I}54$"N	85^{0}49'42"E	1.55	1.83	1.74	2.65	1.40	0.75	0.65	0.20	0.90	2.25	1.45
18	20^{0}14'16"N	85^{0}50'06"E	1.5	1.70	1.61	0.95	1.32	1.55	0.90	2.70	1.35	1.70	1.56
19	20^{0}14'32"N	85^{0}50'25"E	2.7	0.12	-0.01	-0.03	0.02	0.13	0.33	0.06	0.15	0.11	0.33
22	20^{0}15'03"N	85^{0}51'33"E	1.75	1.08	0.89	1.65	1.38	1.10	-0.1	1.35	2.85	2.75	2.95
23	20^{0}16'21.1"N	85^{0}47'50"E	1.6	2.00	1.84	1.70	2.10	1.25	0.40	0.25	0.55	1.01	1.09
24	20^{0}17'55.4"N	85^{0}49'19"E	1.15	5.18	5.00	4.05	3.35	1.80	1.71	1.50	1.10	1.66	1.90
25	20^{0}18'45.5"N	85^{0}48'31"E	1.15	11.10	11.10	10.75	11.1	xx	2.20	9.45	9.65	3.81	7.18
26	20^{0}19'47"N	85^{0}48'35"E	1	0.90	0.76	0.73	0.72	1.10	1.20	0.90	1.60	1.75	2.39
27	20^{0}20'43"N	85^{0}49'46.3"E	2.55	5.00	4.82	4.50	4.10	4.60	3.20	3.10	3.05	4.73	5.24
28	20^{0}18'05"N	85^{0}50'02"E	1.25	3.05	3.00	2.75	1.85	0.65	1.40	1.10	0.40	0.76	0.83
30	20^{0}18'27"N	85^{0}50'38"E	1.38	0.00	0.00	0.00	0.00	0.00	-4.1	4.1	1.50	4.06	4.33
31	20^{0}17'49.3"N	85^{0}51'32"E	1.55	1.47	1.41	1.40	1.05	2.30	1.60	0.75	0.95	2.31	2.31
32	20^{0}16"31"N	85^{0}51'32.5"E	1.5	0.86	0.70	1.20	0.90	1.30	1.20	0.65	1.00	1.91	1.16
	Av (m}			2.56	2.47	2.37	2.28	2.18	2.09	1.99	1.90	1.80	1.71

The soils in Khordha district comprise of lateritic low land and mixed upland. Murom, sand stone and laterite beds cover in Jatni, Chilika, Tangi and Bhubaneswar blocks around SW corner of the SMD Fig. 5. The water table is charged by deep zone. Patches of low land, alluvial situation found in central SMD i.e.

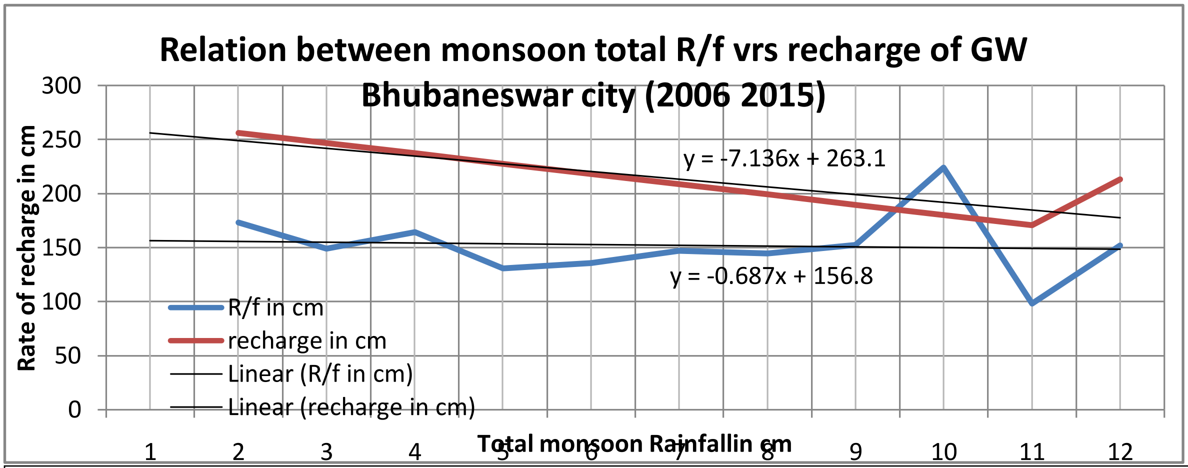

Fig 9: The linear relationship between the total r/f and GW recharge in Bhubaneswar town

Bhubaneswar, Balianta and Balipatana blocks. Recharging rate is in a down ward trend in Khordha district when it is compared to rainfall rate. Increase in number of bore wells are putting extra stress in the GW stratum and are depleting the GWT. Derash, Phuljhari are the large water bodies around Bhubaneswar that helps in charging the GWT (Fig10).

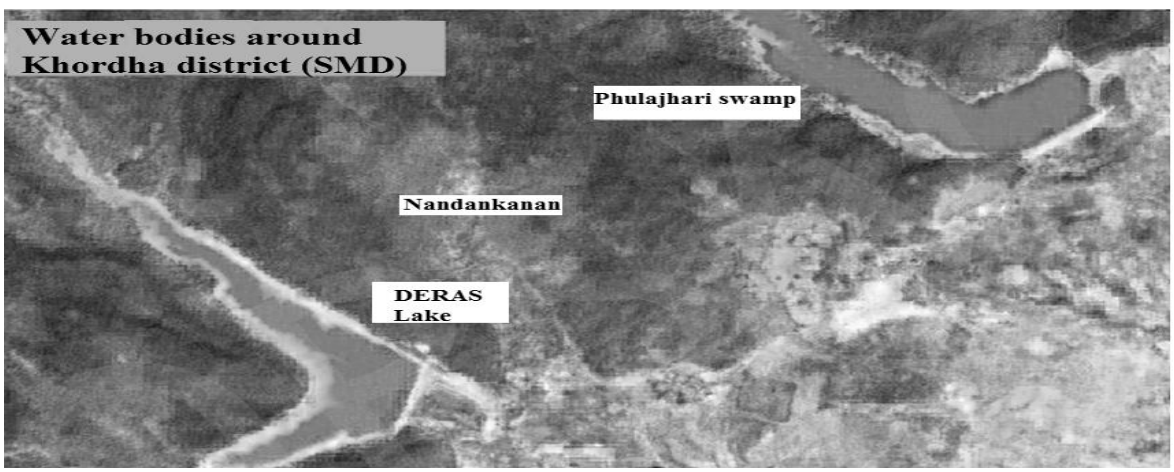

Fig 10 : Lacustrine areas in and around Khordha Dist. can recharge the GW if protected

7.3 Puri district

Pipili block is adjacent to Bhubaneswar. The block possesses abundant surface water and drawl of GW is less. The rock formation is granites capped by laterites. The hydro geological formations are available within the fractures and fissures of the granites. There is no salinity intrusion and the aquifer water is fresh and available up to 100m. It is an ideal place for aquifers. The ground water status in Delang block is partly brackish and eastern part is fresh. The southern and eastern part up to Periphery of Chilika the ground water is brackish. But local patches of fresh water are available

Fig 11: The observation wells in Puri district (Year: 2011-2014)

The parts of Puri Sadar, Brhamagiri and Sakhigopal block are brackish and rich with iron. However local patches and sand dune areas near coast possesses fresh water aquifers where water is of good quality. The GW of all the blocks of coastal Puri is suffering from increased salinity intrusion.

The salinity rates of wells have increased after Tsunami on 26th Dec 2004 far inland exhibiting salinity intrusion. Salinity issues are acute in Kanas, west Sakhigopal and north Delang area. They are due to upwelling of deep circulating GW as the underlain stratum is black clay, sand and silt. Lift irrigation is adding to the process as pumping, bore wells drafts are bringing deep ground water upward. Gradually there is an upward propagation of underground water to top. Water supply of Puri Town is made from the shallow aquifer existing near the ground level or bellow sand dunes near coast. The small water bodies created for the wild life (Balukhanda) near the water drawl zone gradually drying up. It is observed from 2004 onwards. The data of wells are taken in table 3 and analyzed. The regression equation is arrived. The mechanism of recharge is given in fig 5.The trend of recharging of well indicate the rate of recharge is decreasing indicating there is chance of salinity ingress to the fresh water aquifer where water is supplied to Puri town. The recharge data of wells are taken (fig 11) and analysed in Fig. 12.

Table 3 : Recharge data of different wells observed in Puri town (2011-2015)

#	Location Latitude	Location longitude	Total depth [well]	Dia [m]	Ht above bgl [m]	Rech 2011 (m)	Rech 2012 (m)	Rech 2013 (m)	Rech 2014 (m)	Av rech (2011-14) (m)
1	19^0 49'14"N	85^{0}50'31"E	6.5	1.3	0.4	2.0	0.8	**1.4**	**0.9**	**1.2**
2	19^0 49' 13"N	85^{0}50'33E	6.4	1.5	0.3	1.9	0.7	**1.4**	**0.8**	**1.2**
3	19^0 49' 09"N	85^{0}50'50"E	4.3	1.1	0.4	1.4	0.8	**1.8**	**0.5**	**1.1**
4	19^0 47'37"N	85^{0}49'3"E	8.4	1.1	0.4	1.0	1.0	**1.3**	**1.2**	**1.1**
5	19^0 48'12"N	85^{0}48'63"E	4.6	1.4	0.5	1.7	0.8	**1.3**	**2.4**	**1.5**
6	19^0 48'14"N	85^{0}48'51"E	10.3	2.0	0.5	1.4	0.5	**1.0**	**2.3**	**1.3**
7	19^0 49' 00"N	85^{0}50' 23"E	6.7	2.6	0.6	1.8	0.9	**1.4**	**1.4**	**1.4**
8	19^0 49' 03"N	85^{0}50' 24"E	7.9	1.9	0.6	2.9	2.5	**2.3**	**2.3**	**2.5**
9	19^0 49'25"N	85^{0}50'45"E	4.5	0.7	0.2	2.1	1.2	**1.2**	**1.2**	**1.4**
10	19^0 49' 28"N	85^0 50' 50"E	2.9	0.6	0.4	1.3	1.3	**1.3**	**1.3**	**1.3**
11	19^0 48'14"N	85^{0}48'49"E	12.2	1.5	1.1	1.1	0.6	**1.0**	**1.1**	**0.9**
12	19^0 47'39"N	85^{0}49'06"E	13.1	2.5	1.4	1.8	1.7	**1.8**	**1.6**	**1.7**

13	19^0 48'15"N	85049'21"E	8.7	2.8	0.6	1.4	0.6	**0.6**	**0.6**	**0.8**
14	19^0 48' 16"N	85^0 49' 22"E	9.4	0.8	1.0	1.7	1.7	**1.7**	**1.7**	**1.7**
15	19^0 48'32"N	85^{0}50'12"E	5.3	1.0	0.5	2.3	1.3	**2.1**	**2.1**	**1.9**
	Average					1.7	1.1	**1.4**	1.4	**1.4**

This over drawl may cause a). Lateral flow from the sea for over- exploitation, tidal fluctuations and increase in mean sea level. b.) The rising and propagation of water from deeper saline zone to the up-cones near coastal discharge of pumping wells may be other causes. From the average area of recharge in Puri, the wells in saline aquifers are fluctuating with the recharge rate. It is seen that the average rate of recharge of the wells have an increasing trend. The reasons may be due to excess recharge of water from the sea to the production wells in the northern corner of Puri town. The sweet water zones available in Puri are to be conserved either constructing water conservation structures o recharge pools. The encroached Settlements need to be legally banned in the pumping zone area to avoid contamination. The process of salinity ingress to GWT of Puri is shown in Fig.14.

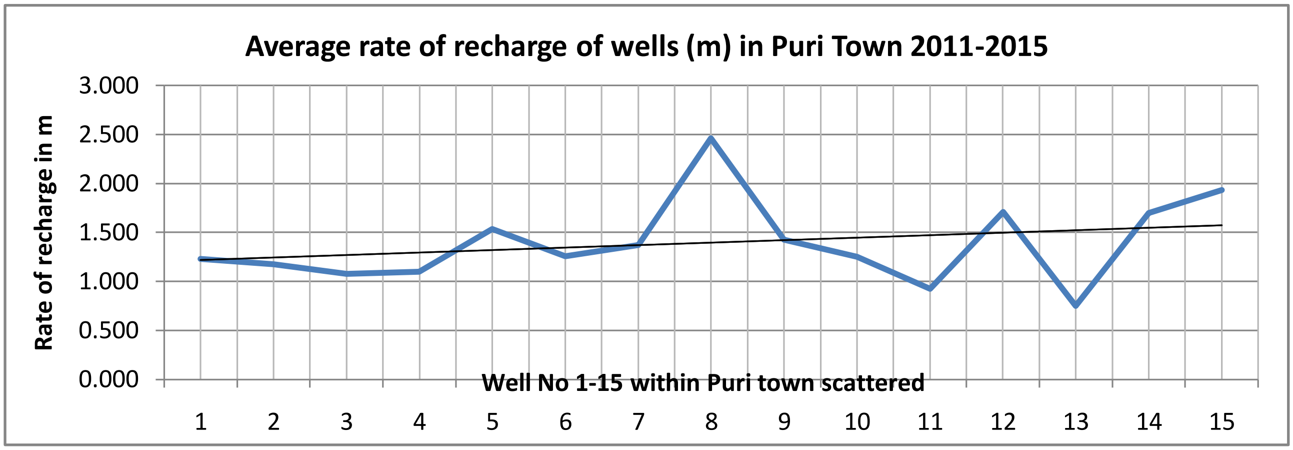

Fig 12: Av. rate of recharge at saline water in Puri town and the trend line from year 2011-2015

8.0 Observations

A paradigm shift in thinking is essential while planning, designing and implementation of Water Resource projects. Public participation in ground water management is an easy task for improvement in ground water structures than surface water. Loss less free ground water conveyance is more efficient than surface water management through ample losses of evapotranspiration, conveyance and anthropogenic activities. But ground water withdrawal without thinking of equivalent recharge can have a heavy pecuniary loss. So legal restrictions are imposed for withdrawal of groundwater above 65% without replenishment is a ban today. The methods of replenishing GW is shown in Fig 13.

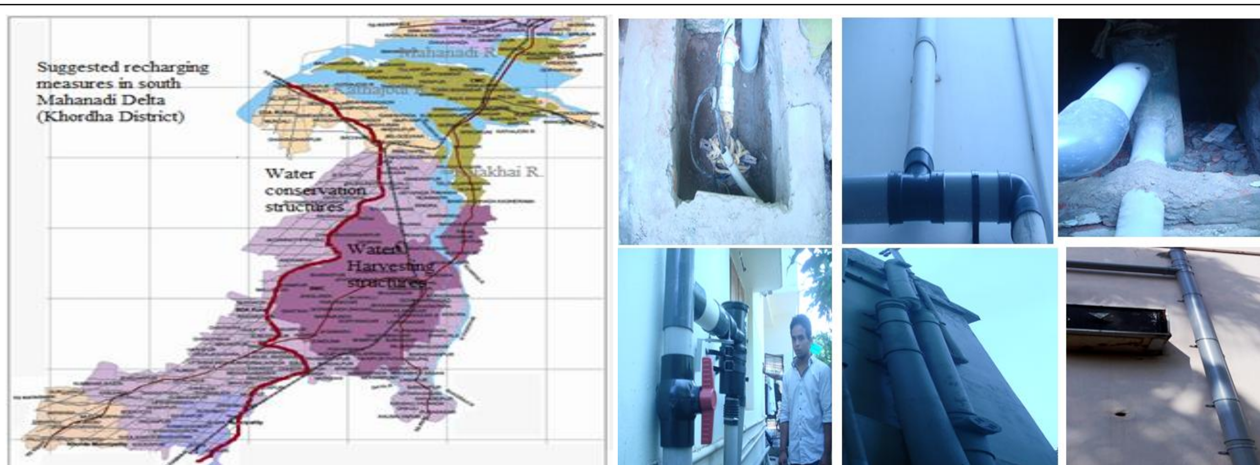

Fig13:GW recharge strategies of Bhubaneswar city partly conservation and partly harvesting

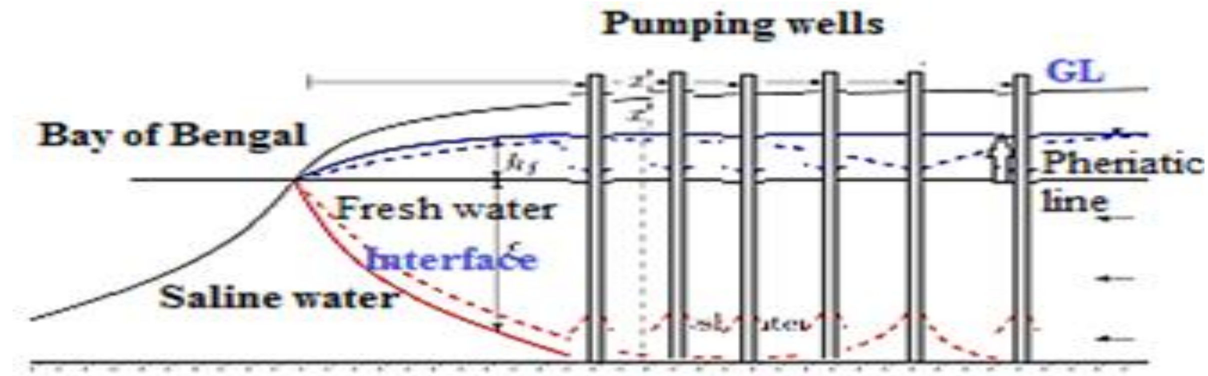

Fig 14: The saline –fresh water inter face at water supply scheme in Helipad area in Puri

Aquifer management and its sustainability are of prime concern present days. The efficient management is possible by estimation of the losses, conservation of surface water potential and an improved recharge process. Accomplishing a suitable method for not allowing ground water of the area to be free from contamination and pollution is the global problem today. South Mahanadi delta is under subsidence and excess soil erosion. Increased intensity in SW monsoon rainfall, flash floods and balding the forest cover increases run off volume and reduces quantum of recharge. Water exchange can occur between confined and unconfined aquifers and vice versa. The transfer occurs through fractures between two alternate layers and the leak is governed by the hydraulic gradient.

9.0 Chilika lake area

Some areas in Brhamagiri, Kanas and NE bank of Chilika in SMD, have auto yield brackish water from surface of artesian type. Scattered shallow and deep observation tube wells were dug by Danish International Development Assistance (DANIDA) of depth 10-15m and 150-230m the penultimate or the deepest aquifers are in unconfined form. In and around Chilika the status of GW aquifers are in SW corner there lies a fresh water aquifer at 20mbgl, but other two deep aquifers are saline at depths 40-60m and 100-118m. In the extreme south of the lake the tube wells bored up to 100-200m are rich in Cl^{-1} ion and the water is brackish. But in central lake area a shallow fresh water aquifer is at 100mbgl. **(Naik et al, 2007)[28]** The entire barrier spit area has brackish water deep tube wells. But it is found there are some shallow aquifers from where villagers draw their drinking water but they become brackish during summer. However the periphery of Chilika suffers a lot in agriculture, drinking water and industrial use for its salinity. The climatic anomalies, global warming, meteorological and geologic extremes shall increase the msl. The subsidence of the south Mahanadi delta shall allow more marine ingress and encroachment. The 480sqkm mudflats in and around Chilika may be marooned and under brackish water.

10.0 Options for Ground water recharging and decontamination

1. Enactment of Odisha GW Regulation and control of development and management bill 2006.
2. Regulating exploitation of GW from the coastal zone by CRZ regulation act of GOI.
3. Swamps and water bodies in rural front need to be maintained clean and encouraged for surface irrigation and water supply without disturbing ground water source
4. Attempts are to be stressed upon in urban areas on-water harvesting structures and water conservation (Fig 11)
5. Since 35-40% water in Bhubaneswar goes waste to drains, the spilled water from exhaust pipes in overhead tanks by suitable arrangement may be recirculated (Fig. 11).
6. Federal initiation to be taken for more number of check dams, creeks, minor dams and water harvesting structures to replenish the ground water and also provide irrigation.

11. Conclusion

Apprehension of depletion of GW in the SMD it is pertinent to develop technology and disseminate to recharge the GW. Stress is to be given upon implementation of Governmental policies and monitor the activities after initiation. Construction of ground water harvesting and maintenance of the conservation structures and a sustainable development is needed for protecting the GW source from pollution and contamination. In maintaining the above economic development of the stake holders and the ecology of the area should not be disturbed.

11.1 Recommendations

In Krushaprasad, Brahmagiri and Puri Sadar blocks geophysical surveys are necessary to identify the pockets of fresh ground water as most of the wells are either iron or salinity contaminated. In the canal command areas of Mahanadi delta conjunctive use of surface and ground water is to be optimized to avoid water logging. More check dams and minor irrigation projects to be developed to increase water bodies and lacustrine area. Care should be taken not to disturb the hydrological balance between freshwater/saline water zones, leading to saline water ingress.

In the upper fluvial zone and west of Bhubaneswar large water bodies to be created to enhance recharge and maintain GWT. Creeks to be developed in coastal drainage network to reduce surface saline water ingress to inland.

Exploratory drilling aided by photo geological studies and geological surveys may be continued for delineation of deeper water saturated fracture zones in hard rock areas and for precise delineation of fresh water – saline water interface. Care should be taken not to puncture the over lain ground water.

Acknowledgement: We acknowledge our thanks to GW & I Department, Odisha, Water Resources Dept,, Odisha and Chilika Development Authority, Odisha for supplying the well data used in this paper. We acknowledge the students Subhranshu Sahu, Siddhant Joshi, Satish Kumar Nayak, Sambit Swain, Sonu Kumar and Prgyan P. Mohanty of final year Civil Engineering Dept., CUTM, Jatni who helped in data observation and collection of data.

REFERENCE

1. Mishra S. P. and Jena J. G., (2015), "Morphological Reconstruction of Southern Mahanadi Delta and Chilika Lagoon, India – a critical study ",Int. Journal of Advanced Research (2015), Volume 3, Issue 5, 691-702
2. Mahalik N.K.,Das C. and Wataru Maejima,(1996), Geomorphology and evolution of the Mahanadi delta, India, Journal of Geosciences, Osaka City University, Vol-39(6) pp- 111-122, 1996.
3. Government of Odisha, 2004, State water plan (2004), water Resources Department, Govt. of Odisha.
4. Das Madhumita, Sethi R. R., Sahoo N., Aswani Kumar, (2006), Strategies of managing water resources in coastal water logged areas at Chilika, Report No 36, Water technology center for eastern region, ICAR, Chandrasekhar Pur, BBSR, Odisha
5. Bhattnagar, N.C, Sundarajan, K.V. et. Al. (1970) Geology and Ground water Resources of Balasore and Cuttack districts, Orissa. Bull. Geol. Surv. India, pp.220.
6. Radhakrishna, I. and Dutta, D.K. (1976), Groundwater resource evaluation in selected tracts of coastal Orissa. Unpubl. Tech. Rept. CGWB, E.R, Govt. of India.
7. Chakladar, S. (1981) Report on the exploration by deep drilling in parts of coastal Orissa. CGWB Tech. Report, Ser A, No.12.
8. Government of Odisha, Water Resources Department, (1986), Delta Development plan, Mahanadi delta stage II, Posthumous Drainage Division, Puri, W R Department , Odisha, (Unpublished)
9. Srivastava S. K., Sethi R. R., Ashwani Ku., Srivastava R. C., and Nayak A. K. (2013),Groundwater Development and Energy Use Dynamics for Irrigation in Odisha, ICAR, Research Bulletin 56, Directorate of Water Management (Indian Council of Agricultural Research), Chandrasekharpur, Bhubaneswar-751023, Odisha,India.p-45
10. Srivastava S. K., Bhargav J.S., Kumar Y.S., (2014), Contamination of shallow groundwater of Bhubaneswar city due to urbanization, EM International, Vol.33, Issue 01, 2014; Page No.(139-145)
11. Wada, Y., L. P.H. van Beek, C. M. van Kempen, J. W.T.M. Reckman, S. Vasak, and M.F.P. Bierkens (2010),Global depletion of groundwater resources, Geophysical Research Letters, Letters-37, I 20402, doi: 1029/2010 GL 044571

12. Sara Maatta, (2011) "Predicting groundwater levels using linear regression and neural networks", CS229 final project, December 15, 2011.
13. Kapoor C., Bajaj H.,. Kaur N, (2012), Integration of Bacteria Foraging Optimization and Case Base Reasoning for Ground Water Possibility Detection", International Journal of Applied Information Systems (IJAIS) – ISSN : 2249-0868 Foundation of Computer Science FCS, New York, USA Volume 2– No.4, pp-30-35May 2012 – www.ijais.org
14. CGWB, Groundwater Scenario of India, (2010), Ministry of Water Resources, Government of India, 2010.
15. Meijerink A.M.J.,(1982):Dynamic geomorphology of the Mahanadi Delta. ITC Journal, Special Versta
16. Jha B.M., & Sinha S.K.,(2008), "Towards Better Management of Ground Water Resources in India", Central Ground Water Board Bhujal Bhawan, CGO Complex, NH IV, Faridabad- 121 001, Haryana, India. e-mail: chmn-cgwb@nic.in,
17. Mishra S., Mohanty S. Ku. and Rout S. P.,(2013), Physicochemical analysis of ground water near municipal solid waste dumping site in Bhubaneswar municipal corporation, Odisha, International Journal of Plant, Animal and Environmental Sciences Page: 5-16, www.ijpaes.com
18. Srivastava S.K.,. Sethi R. R, Ashwani Kumar, Srivastava R.C. ,Nayak A.K. , (2013)2010), Groundwater Development and Energy Use Dynamics for Irrigation in Odisha. Research Bulletin No. 56. Directorate of Water Management (Indian Council of Agricultural Research), Chandra sekharpur, Bhubaneswar-751023,
19. NASA's Gravity Recovery and Climate Experiment (GRACE) satellites, 2015, "Groundwater depletion in India worst in world: NASA", Decan Herald, 7 Sept, 2015
20. Das Avijit, Bandopadhyay, Dilip Kumar, Jee Pravas Kumar, Indrarup Roy Chowdhury, (2015), Hydrogeochemistry of groundwater in Chandanpur area of Odisha, India, International journal of Geomatics and Geosciences, volume 5, no 3, pp 448-458, 2015
21. Arnold Verruijt, (1968), A note on the Ghyben-Herzberg formula, Bulletin the International Association of Scientific Hydrology, XIII, 4 - 12/1968
22. Lohani Tarun Kumar, (2012), "Salient Features of Lithological Distribution and Feasibility Study of Water Resources in Coastal Aquifers of Puri, India" , International Journal of Environmental Engineering Research, Volume 1, Issue 2, 2012, pp- 60-69
23. IIT Khadagpur, 2012, Final Proposal: Comprehensive Development Plan for Cuttack Development Plan Area (CDPA)Final Proposal: Comprehensive Development Plan for Cuttack Development Plan Area (CDPA) , Indian institute of science Khadagpur.
24. Dixit Prasanna Kumar, 2014, Ground Water Prediction Using Bacterial Foraging Optimization Technique, American Journal of Computing Research Repository, 2014, Vol. 2, No. 3, 44-48
25. Samal R.N., Rout J., Ojha A., Pradhan S., et al., Geomorphologic change analysis of Chilika Lagoon Inlets- A case study, Chilika Development Authority, C-11 BJB Nagar, Bhubaneswar, 2013.
26. Mishra S. P. and Jena J. G., (2015), "Morphological Reconstruction of Southern Mahanadi Delta and Chilika Lagoon, India – a critical study" Int. Journal of Advanced Research, Volume 3, Issue 5, 691-702
27. Van Genuchten, M. Th. 1980. A closed-form equation for predicting the hydraulic conductivity of unsaturated soils. Soil Sci. Soc. Am. J. 44: 892–898.
28. Naik P. K. , Pati G.C. Choudhery A., Naik K.C. 2008, Conservation of Chilika lake, Odisha India. Proceedings of TAAL 2007, 12th World lake Conference 1988-1992