Over-Exploitation of Aquifers: Need for Proper Planning, Management Tactics, Awareness and Legislation (Examples from West Bengal and Orissa)

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Abstract: West Bengal and Orissa are two such states in India having vast alluvial aquifers deposited in the deltas along the coastal plains and in the doabs of the inland river valleys. In comparison to West Bengal, extensive areas in Orissa are underlain by hard crystalline rock formations with limited groundwater potential. Non-availability of potential shallow aquifers in hard rock areas causes low utilization of ground water for irrigation in Orissa. However, shallow aquifers are ubiquitous in the coastal Orissa as also in deltaic West Bengal. Although the quantitative utilization is in the low key, the irrigation pattern and its trend in the coastal Orissa has keen resemblance with that of West Bengal. Redundant and unscientific draw from the shallow aquifers has caused problem in the shallow tube well irrigation in the states along with the possibilities of environmental menace. Ignorance, lack of awareness on groundwater overuse and management, non-availability of specific data on crop water requirement and cropping pattern, poor agricultural extension, absence of groundwater legislation are responsible for aggravating the problems. Government of West Bengal has already taken some action on tube well energisation to check unscientific withdrawal. In Orissa such steps are yet to be taken by the state government. In this paper the groundwater irrigation, various causes of misuse and overuse of ground water in the states, their possible effects on environment, needful remedial measures and scientific planning are critically discussed.

INTRODUCTION

Comparative abundance and sustainability of ground water over surface water has accelerated rapid development of groundwater irrigation in the country. Easy access and economic viability has motivated the farmers for utilization of shallow aquifers. Potential shallow aquifers are available in the vast deltas in the states of West Bengal and Orissa, having coastal tracts and the inland river valleys which have been extensively developed. To accelerate the food grain production as also to develop the rural economy through development of agriculture, when there is need for large scale groundwater resources development, with the unplanned approach, haphazard development without any scientific know-how and negligent attitude from the public sector for enacting the prohibitory legislation, over-exploitation of the aquifers is taking place all over the country which may be of great concern. These will not only cause the curtailment of agricultural production, several environmental menaces also may crop up. Two case studies from Orissa and West Bengal (Fig. 1) are cited in the paper.

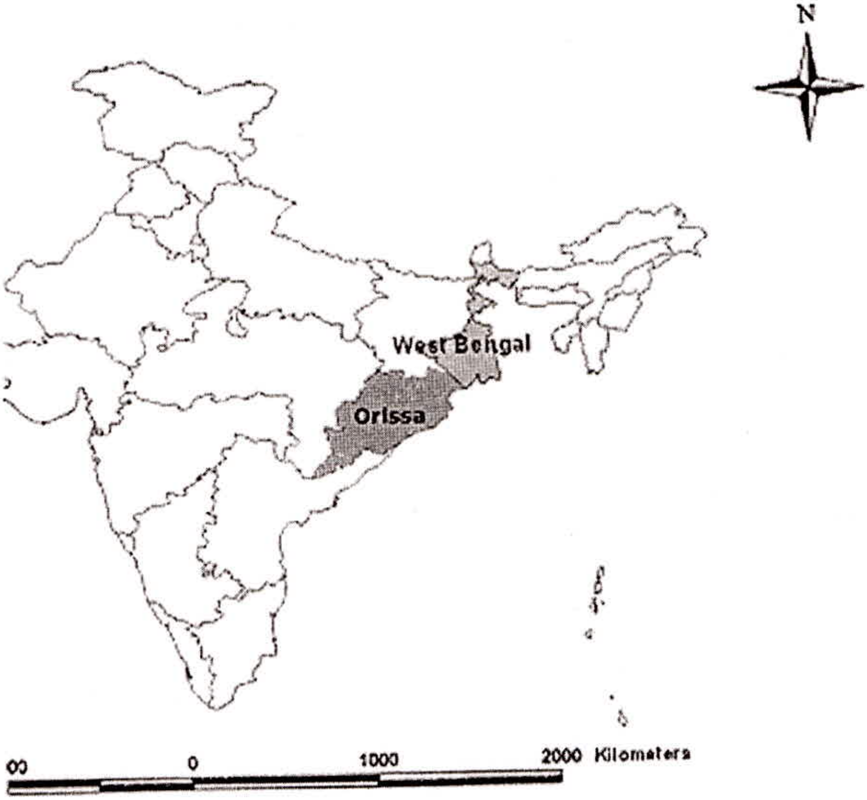


Fig. 1. Location map.

HYDROGEOLOGICAL SET UP AND GROUNDWATER AVAILABILITY

WEST BENGAL

The entire West Bengal covering a geographical area of 88,752 km^2 is administratively divided into 19 districts and 341 blocks. The districts are: Bankura, Barddhaman, Birbhum, Puruliya, Paschim Medinipur, Purba Medinipur, Haora, Hugli, North 24 Parganas, South 24 Parganas, Nadia, Murshidabad, Uttar Dinajpur, Dakshin Dinajpur, Malda, Jalpaiguri, Darjeeling, Kooch Behar, and Kolkata. The state can be broadly subdivided into two hydrogeological units (Fig. 2), e.g., Fissured formation and Porous formation.

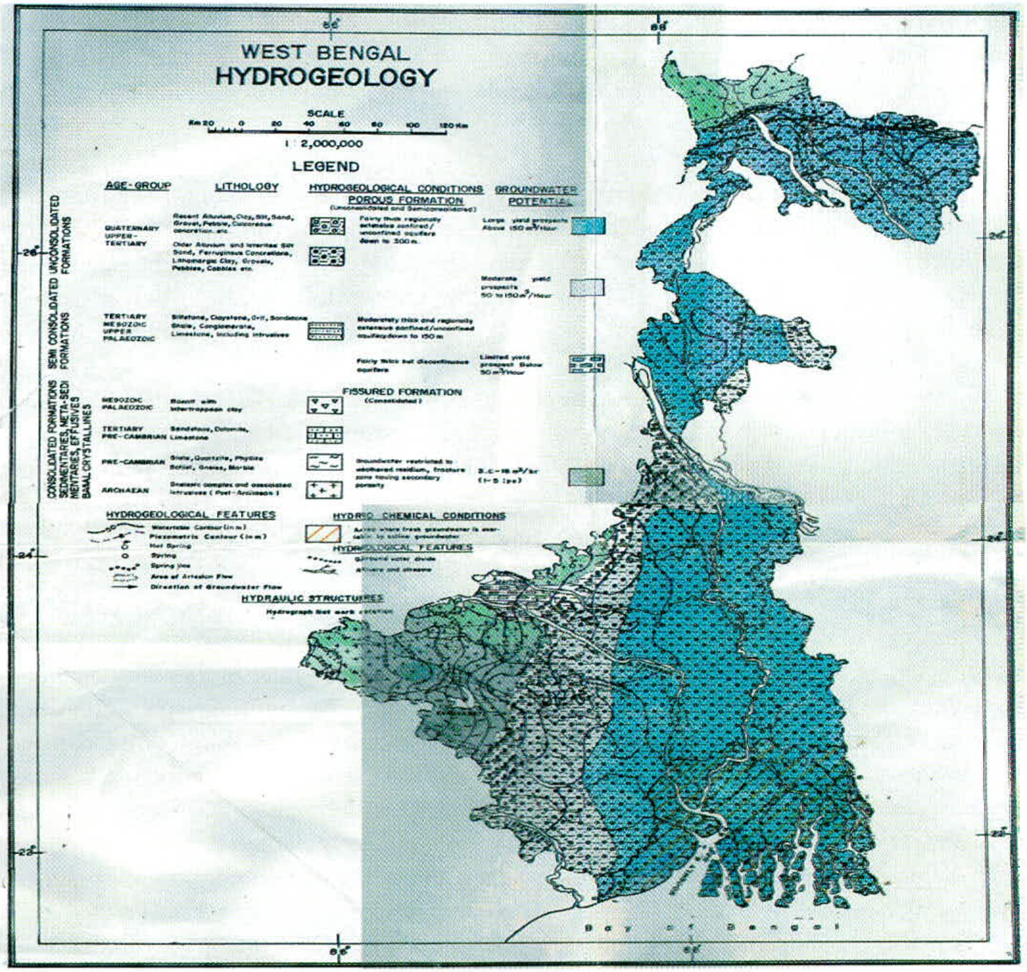


Fig. 2. Hydrogeological map of West Bengal.

Fissured Formation

Proterozoic gneisses and schists, younger Gondwana super group and Siwalik rocks of Extra-Peninsular region in Darjeeling and Jalpaiguri districts in the north and Archaean to Proterozoic gneisses and schists in Peninsular region occurring in western part of Barddhaman, Bankura, Birbhum and northen part of Medinipur and whole of Purulia districts and younger Gondwana and Purana sediments (Susunia quartzite of Bankura) deposited in the intracratonic basins in the shield area and Rajmahal basaltic traps in the eastern fringe area of the shield fall under fissured formation. Ground water in this formation occurs under two zones.

Weathered Mantle

Ground water occurs under unconfined condition in the top-most weathered residuum of the consolidated to semi-consolidated rocks. The thickness of the weathered part with top-soil varies from place to place depending on rock type. The thickness of the weathered mantle of the consolidated and semi-consolidated rocks in general varies from less than 1 to 5 m in extra-peninsular region and from 5 to 10 m in peninsular region. This zone is generally tapped by dug wells yielding 5 m^3/hour.

Saprolitic Zone

Saprolitic zone is the sandwiched zone lying between the weathered mantle and fresh rock mass. This zone is partly weathered but still retains the original characters of the fresh rock and in fact, represents the transitional character between the fresh rock mass and the weathered mantle. In general, the depth of occurrence of this zone varies from 10-50 m below ground level with an average thickness of 4 m. The thickness of this zone mainly depends on the mineralogical composition as well as geomorphological setup.

Groundwater in this part occurs under semi-confined condition. The yield of this aquifer sometimes goes up to 2.5 lps. Drawdown in the bore wells tapping this zone is much less and recovery is quite fast as compared to other productive zones. Shallow bore wells fitted with hand pump are generally restricted to this zone.

Zone of Secondary Porosity

The secondary porosity plays an important role in the deeper part of the consolidated and semi-consolidated rocks below the weathered mantle and saprolitic zone in extra-peninsular region and in peninsular region in the state. The movement and storage of groundwater in this part is controlled by joints, fractures, fissures and faults etc. developed in the later phase during tectonic movements to which the rock formations were subjected. Groundwater occurs under semi-confined to confined condition in this zone of secondary porosities. The depth of occurrence of these weak zones varies from place to place depending upon the rock type and its structural pattern. Gently dipping fractures, joints etc. form promising repositories for yielding groundwater whereas steeply dipping fractures, joints etc. helps in fast movement of ground water from a higher altitude to lower altitude and, therefore, are not generally favourable areas for groundwater development. Constructed bore wells may yield 10 to 20 m^3/hour in hydro-geologically favourable locales tapping both the saprolites and the fractured horizons.

Porous Formations

Nearly two-third of the state is occupied by a thick pile of unconsolidated sediments laid down by the Ganga-Brahmaputra river system, which increases from marginal platform area in the west towards the east and southeast in the central and southern part of the basin following the configuration of Bengal Basin. These unconsolidated sediments are made up of repetitive succession of clay, silt, sand and gravel of Quaternary age overlying Mio-Pliocene sediments. The Quaternary sediments are made up of recent and older alluvium. Occurrence and movement of ground water in this hydrogeological unit is controlled by the primary porosities of the sediments. Depending upon the yield characteristics, the Quaternary formations can be subdivided into the following groups.

1. Older alluvium of Plio-Pleistocene age occur in two units:
   a. The sub-montane zone of Himalayan, mainly in the foothills in Darjeeling and Jalpaiguri Districts, i.e. Bhabar stretching for a width of 10-15 km to the south, with deep water table

with seasonal variation of 10-15 m. The aquifers are not highly productive. At places auto flowing (5-10 lps free flowing) condition available.

   b. In the marginal platform area. In the western margin of the state bordering the Peninsular area and Gondwanas, falling in the districts of Birbhum, Bankura, Bardhaman and Medinipur (w). At places in the presence of tertiary gravels the formation yield 80 to 100 m^3/hour.

2. The unconsolidated sediments can be grouped as under:
   a. Areas with very high yield prospects. These areas fall in Jalpaiguri-Kooch Bihar to the 24-Parganas and Medinipur (E&W) in South Bengal. Fairly thick aquifer system interconnected down below 400 m. Yield more than 150 m^3/hour.
   b. Areas with moderate potential (50 to 150 m^3/hour) fall in parts of Malda, W&S Dinajpur, W. Murshidabad, marginal areas of Birbhum, Bardhaman, Bankura and Medinipur (W) districts.
   c. Areas with poor developmental prospects (yield less than 50 m^3/hour). This includes western-most part of Birbum, Bardhaman, Bankura and Murshidabad districts.

In the coastal tract of Medinipur (E), S.24-Parganas, parts of N-24 Parganas, in some parts of Howrah district a group of fresh aquifers are sandwitched by saline aquifers occur at a depth range below 120-300 m. Here ground water occurs under confined condition with piezometric head varying from 1 to 4 m with a hydraulic gradient towards sea. Along Kasai River in Bankura and Medinipur districts autoflowing conditions are seen at places.

Aquifer Characteristics

Aquifer characteristics vary considerably from north to south and west to east in the state. In most of the areas, aquifers show both water table as well as confined conditions. Shallow aquifers generally occur under water table condition while deeper aquifers exhibit semi confined to confined conditions. Aquifers in the entire coastal area, encompassed by 59 blocks occur under confined condition of which 29 blocks are in S.24 Parganas, five blocks in N.24 Parganas, nine blocks in Haora and 16 blocks in Purba Medinipur. The aquifer system supplying water for the metropolis also shows confined condition.

Orissa

Orissa possesses a geographical area of 1,55,700 km^2 with a vast tract of coastal plains. Thirty administrative districts and 314 C.D Blocks constitute the state. It receives on an average annual precipitation of 1503 mm. The state is endowed with a good network of rivers and rivulets. The hydrogeological parameters are well conducive for steady replenishment of ground water.

The diverse rock types, ranging in age from Archaean to recent origin underlie the state. The Archaeans occupy about 70% of the total geographical area of the state. The Quaternary formations are restricted mainly to the coastal tracts.

The prevailing topography, climate and soil condition exert lot of influence on the infiltration-run off characteristics of the hydrological cycle. The hilly and undulating topographic features are more prevalent in the western and southwestern parts of the state. Based on the modes of occurrence of ground water and water yielding properties the various hydrogeological units (Fig. 5) of the state have been clubbed into three major groups such as, the consolidated formations, the semi-consolidated formations and the unconsolidated formations.

Consolidated Formations

The consolidated formations (covers a lion's share i.e. 70% of the total geographical area) include the hard crystalline and compact metamorphic rock formations belonging to the Archaeans and Pre-Cambrian age. These formations lack in primary porosity. These only render secondary porosity when weathered and fractured. Ground water occurs under water table condition in the weathered residuum and circulates through underlying fractures and fissures. The weathered residuum generally ranges in thickness from 5 to 15 m (30 m maximum), and the water saturated fractured zones constitute the repository of ground water in the hard rocks. The development of ground water in this tract is feasible through open wells and bore wells.

The weathered and fractured granites and granite gneisses form productive aquifers. The general yield characteristics of granites and granite gneiss vary between 3 and 10 lps while that of Schist, Quartzite, Khondalite, Charnockite formations within 1-5 lps. The exploratory drilling in Koraput, Kalahandi, Bolangir, Bargarh, Keonjhar and Mayurbhanj districts down to a depth of 200 m reveals the occurrence of 3 to 4 water bearing fracture zones and support cumulative discharge to the tune of 90 m^3/hour.

Semi-consolidated Formations

The semi-consolidated formations (cover 10% of the state area) include weathered and friable Gondwana sedimentary and loosely cemented Baripada beds of Mio-Pliocene age. The coarse grained, weathered, fractured and friable sandstone of the Gondwana, and the semi-consolidated sand stones of Baripada group form the aquifers with moderate potential. Ground water occurs under water table condition in the near surface aquifers and under confined to semi-confined conditions in the deeper horizons. The Lower Gondwana sandstone, and Athgarh sandstone, when weathered and friable are moderately good water yielder. The tube wells drilled in lower Gondwana sandstone of Dhenkanal district sustained a discharge upto 21.3 m^3/hr, and the tube wells in Athgarh and sandstone of Bhubaneswar city can have yield up to 115 m^3/hour.

Unconsolidated Formations

The unconsolidated formations (cover 20% of the state) include Laterites of Pleistocene age and Recent to sub-Recent alluvium. The alluvium comprises some of the most prolific aquifers in the state. Laterites occur extensively in Orissa and form good shallow aquifers. Ground water occurs under water table condition in the shallow zones and is developed through open wells. The maximum development of alluvial formations is in the coastal tract. The thickness of alluvium increases towards the coast exceeding 600 m in Mahanadi delta. The alluvial formations constitute the most productive aquifers. Sand and gravel horizons in the alluvium form the main repository of ground water. Alluvium also occurs in discontinuous patches, adjoining the major drainage courses. The thickness of alluvial deposits in the inland river basins varies from 11 to 43 m averaging 15 m. Ground water occurs both under water table conditions in the shallow zone and under confined conditions in the deeper horizons. Exploratory drilling in the coastal tract has revealed occurrence of thick fresh water aquifers within a depth of 300 m. The tube wells tapping about 15 to 60 m of saturated granular zones sustain yield of 174 to 276 m^3/hr for draw down of 3 to 24 m. The Transmissivity (T) values range from 199.5 to 4721 m^2/day.

The eastern part of the coastal tract, close to the coast, is beset with salinity problems. In a narrow tract extending from Chandeneswar in Balasore district in the northeast to Brahmagiri in Puri district in the southwest, saline aquifers occur at different depths. The maximum width (55 km) of this tract is in the Mahanadi delta. The salinity hazards are not uniform throughout the coastal tract. In Brahmani-Mahanadi delta region over a large area the top aquifers down to a depth of 60 to 320 m are saline to brackish in nature and freshwater aquifers occur below this depth. In the eastern part of Puri, around Nimapara, Kakatpur and Gop, freshwater aquifers occur down to depth of 70 to 110 m below which the formation of water is brackish to saline in nature. In Puri-Balighai–Ramchandi tract a second group of freshwater aquifers occurs in the depth range of 135 to 290 m. In the area, west of Puri town, aquifers are generally brackish to saline, except in local pockets. The various modes of groundwater occurrence in the state may be broadly summarized as porous formations, comprising unconsolidated and semi-consolidated sediments. Aquifers are generally inter-connected and often extensive, both continuous and discontinuous, having moderate to very high yield potentials. Fissured formations consisting of consolidated hard rocks are rendered porous by weathering and fracturing. Aquifers are discontinuous in nature and having limited yield potentials.

GROUNDWATER RESOURCES AND ITS ESTIMATION

In the year 1982, Government of India constituted "Groundwater Estimation Committee (GEC)" with the members drawn from various organizations engaged in hydrogeological studies and groundwater development. In 1984 this committee, after reviewing the data collected by Central and State agencies, research organisations, universities etc., recommended the methods for groundwater resource assessment. These norms were further refined in 1997. The latest revised methodology is known as GEC norms 1997. The assessment of groundwater resources of West Bengal and Orissa has been done based on the Groundwater Estimation Committee (GEC) norms 1997, taking the blocks as the assessment units. However, the details of the estimation procedure is not coming into the purview of this paper and the same is described in detail in the GEC methodologies (CGWB, 1998). In the following paragraph one of the important parameters of groundwater estimation i.e. stage of groundwater development which is used as the index of groundwater development is briefly discussed.

Stage of Groundwater Development

The stage of groundwater development in an area is to be taken as the ratio of gross annual draft for all uses to the total utilisable groundwater resource (GEC, 97). It is normally expressed in percentages.

Stage of groundwater development in percentage (%)

$$= \frac{\text{Gross annual draft for all uses (Hectare metre)} \times 100}{\text{Utilizable resource (Hectare metre)}}$$

For the purpose of clearance of schemes by financial institutions, categorization of areas (Table 1) based on stage of groundwater developments has been recommended as follows subject to the various conditions of pre-monsoon and post-monsoon watertable trends.

In over-exploited areas, micro-level surveys are required to evaluate the groundwater resource more precisely for taking up further groundwater development. As per National Water Policy, ground water development is limited to annual replenishable groundwater resource; hence groundwater exploitation is not permitted in over-exploited areas. The pre-monsoon and post-monsoon watertable trends and their levels are the ultimate indicators of the extent of groundwater development taking place in an area (Table 2).

According to the latest assessment (Table 3), Orissa and West Bengal has an annually replenishable ground resource of 2100928 and 2745813 Hectare-Metre (ham) respectively, out of which 115290 and 124005 ham is committed for the domestic and industrial requirements for coming 25 years. The balance 1692754 and 1532016 ham is available for irrigation use. The present demand for irrigation use is estimated to be 300901 and 1084172 ham in the States under discussion.The stage of groundwater development in the states is estimated to be 18% and 42 % as per the latest assessment.

Table 1. Criteria for categorization of groundwater development

Category of area	*Stage of groundwater development (%)*
Safe	<=70
Semi-critical	>70 to < 90
Critical	90 to <100
Over-exploited	>100%

Table 2. Water level trend in West Bengal

State	*Number of observations*	*No. of observation wells/percent wells show decline*			*Percentage of observation wells show decline*
		Decline 0-2 m	*Decline 2-4 m*	*Decline > 4 m*	
West Bengal	377	120/32%	25/6%	25/6.33%	45%

Source: CGWB

Table 3. Groundwater resources of Orissa and West Bengal as per G.E.C-97

Sl. No.	*State*	*Total .G.W. Resources (ham)*	*Net G.W. availability (ham)*	*Existing gross G.W. for irrigation (ham)*	*Existing gross G.W. draft for domestic and industrial use (ham)*	*Existing gross draft for all uses (ham)*	*Allocation for domestic and industrial uses for next 25 years (ham)*	*Net G.W. availability for future irrigation (ham)*	*Stage of G.W. development (%)*
1	Orissa	2308615	2100928	300901	83866	384767	115290	1692754	18%
2	West Bengal	3035857	2745813	1084172	80566	1164736	124005	1532016	42%

G.W. - Ground water, ham - Hectare metre, dom - Domestic.
Source: CGWB, ER-2004 and CGWB, SER-2004

Comment on State-level Development Figures

From the above stage of development figure (Table 3) it may be conjectured that even in the state of West Bengal where ground water is extensively utilized for irrigation, the term high utilization or over-use of ground water may not be true. While there is a global slogan for saving water for future especially in the water scarce or over-developed areas, the overall developmental stage of 42% may not give that signal for West Bengal, while it is termed as a water abundant state (Mukherjee, 2006) of India. Consequently from the paltry figure of Orissa one can opine that the state have abundant groundwater resources to exploit and there is nothing to be worried regarding the measures on groundwater over-use and legislation. The figures are representing the average of utilization figures of all C.D. Blocks falling in the entire states of West Bengal and Orissa, where there are vast differences in geology and groundwater availability in various parts of the states. Consequently the groundwater development in different parts of the states are not uniform. Actually various factors like hydro-geological set up, agro-climate, socio-economic status, easy availability of Govt. and bank loan and subsidies, availability and price of electricity or diesel, communication facilities, good market with after-sales service of machineries play vital role on faster groundwater development. Various data and figures as also the field studies indicate that barring few water scarce (GOWB, 1994) and hard rock areas, groundwater irrigation in West Bengal is vast and extensive and steadily it increased from 1980 onwards. while in Orissa the groundwater irrigation intensity is highy variable and it is maximum in the Balasore district (stage of development 42%). In Balasore district itself the stage of development in the CD blocks is variable and the three coastal blocks of Baliapal, Bhograi and Jaleswar attain maximum 70%, 57% and 55% groundwater development as on 31.3.04 (CGWB, SER, 2004).

Low Stage Groundwater Development in Hard Rock Areas

The low scale development in the hard rock areas for the states of Orissa and W.B. is mainly dependent on: (1) lack of exploration and research data on productivity of hard rocks especially at shallow depth (within 30 to 60 metres, maximum 100 m) and (2) socio-economic status of people. In both the states poor S.C. and S.T. population are dominating in the areas underlain by hard rocks. Spectacularly it is observed that even in the other water scarce areas the tribals dominate. As in the water scarce Barind tract in Malda and S. Dinajpur Districts of W.B., the tribals pre-dominate over the non-tribals. Consequently the poor tribals in the hard rock areas can't afford costly DTH drilling for construction of a bore well in his land or resistivity surveys to pinpoint the proper drilling site to get more yield. Hence extensive research and development studies in micro level basis should be carried out by the govt. departments and research institutions and the common data bank is to be generated which can be utilized in a coordinated manner to unravel the true picture of the shallow horizon in such hard rock terrains. Similarly artificial recharge, water shed development and various practices of rain water harvesting and conjunctive use should be practiced in these areas. New projects of tribal development and drought prone area development should be taken up by the government of India through concerned state for integrated development of such areas and of course there should be good coordination among all the central and state govt. departments, NGOs and who else are working. Actually it is observed that lack of coordination and earnest motivation of the working organizations are chiefly ailing such developments in India. The backward population should be taught for successful activities through cooperative movement. Role of institutional finance and NGO would be vital for socio-economic upgradation of the tracts and thus gradually the groundwater development may occur which will automatically augment the agrarian activities.

Groundwater Development in the Alluvial Areas and Role of State Governments

Barring few districts of Darjeeling and Jalpaiguri in the North and Bankura, Purulia and parts of Burdwan, Medinipur (W) and Birbhum in the west, the entire state of West Bengal (Fig. 2) is underlain by fairly thick alluvial formations. Number of aquifers are disposed sequentially up to greater depth. Amongst these aquifers, the unconfined to semi-confined aquifers available within the depth range of 10 to 60 metres are extensively developed by the private shallow tube wells for irrigation. The medium deep and deeper aquifers within the depth zone of 60 to 200 metres are developed by the tube wells constructed by the public sector. The boom in agricultural development in West Bengal from 1980 onwards was made possible with the land reforms (Ghatak et al., 2002; Banerjee et al., 2002; Bardhan et al., 2006) and accelerating progress of shallow tube wells construction through private entrepreneurship, institutional and govt. funding. Easy access, availability of good quantity of ground water and cost effective construction of shallow tube wells even with indigenous technology (bamboo tube wells) made the shallow tube well irrigation in the entire tract of West Bengal and Orissa wide spread. The bamboo boring is available and popularized in Bihar state and in the contiguous district of Malda as also in few other parts in West Bengal. The bamboo boring can be observed in the areas where water table occur at shallow depth and it is highly potential. In Orissa (Fig. 5) ground water is also developed in the coastal tracts of Balasore, Bhadrak, Jagatsinghpur, Kendrapara, Puri, Khurda and Ganjam districts. Tube well irrigation also could be seen in the inland river valleys of Keonjhar, Mayurbhanj, Nayagarh, Ganjam, Raygada districts and in the narrow inland alluvial tracts of all other districts. Because of occurrence of fresh ground water in the shallow aquifers, shallow tube well irrigation has been highly practiced in the district of Balasore. In Orissa the major coastal tracts of Puri, Cuttack, Jagatsingpur, Kendrapara, Khurda, Bhadrak Districts possess fresh water bearing aquifers at greater depth overlain by the saline water bearing aquifers. Consequenty shallow tubewells are not feasible in such areas. Similarly in some parts of North and South 24-Parganas and Howrah districts of West Bengal shallow aquifers are not existing. The tube well density, irrigation coverage from shallow tube wells in West Bengal is much higher than in Orissa. The figures (Figs 3, 4) and data (Tables 4, 6) indicate that the tube well irrigation, which is possible only in the alluvial areas, have a steady increase in both the states. However, the huge number of dugwells and its increase in Orissa is indeed indicative of the larger occupancy of hard rock areas (70%) over the alluvial terrain (20%). On the contrary the cumulative number of dug wells in W.B. is showing declining trend (Table 4, Fig. 4). In the alluvial areas in W.B. the running dug wells are getting defunct in large numbers every year which is the cause of the waning trend. Although new dug wells are being constructed in the hard rock areas of W.B., still the comparative ratio of geographical areas of alluvial formation versus hard rock is much higher in W.B. So the new construction is not reflected in the state figure. Besides the data and figures on increase of pump set (Table 7; Fig. 5) in the states also indicate an increase in groundwater irrigation. However, in West Bengal the energisation is mostly related to shallow tube wells whereas in Orissa it is indicating both energisation in dug well (hard rock areas) and tubewell (alluvial areas). In the state of W.B., the development in rural areas (Banerjee et al., 2002; Ghatak et al., 2002; Hanstad, 2002; Bardhan et al., 2006) was mainly possible through land reforms and development of agriculture through groundwater irrigation. In this regard, the motivated effort of various concerned state departments has played a vital role in the development in West Bengal (at least during 1978-1990). whereas in Orissa, in the rural areas the activities of the state govt. counterparts were not at par with that of W.B., at least during the specified period (Personal comm. with the farmers during field observations in Orissa and W.B.). In this regard the progress in rural electrification in the past decades in West Bengal has been praise worthy. Tube wells ownership through co-operative venture has not been wide spread in both the states.

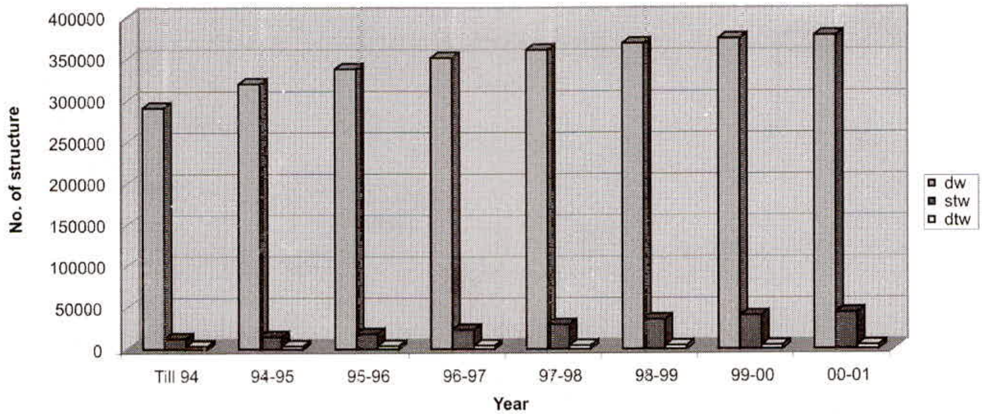


Fig. 3. Groundwater irrigation in Orissa.

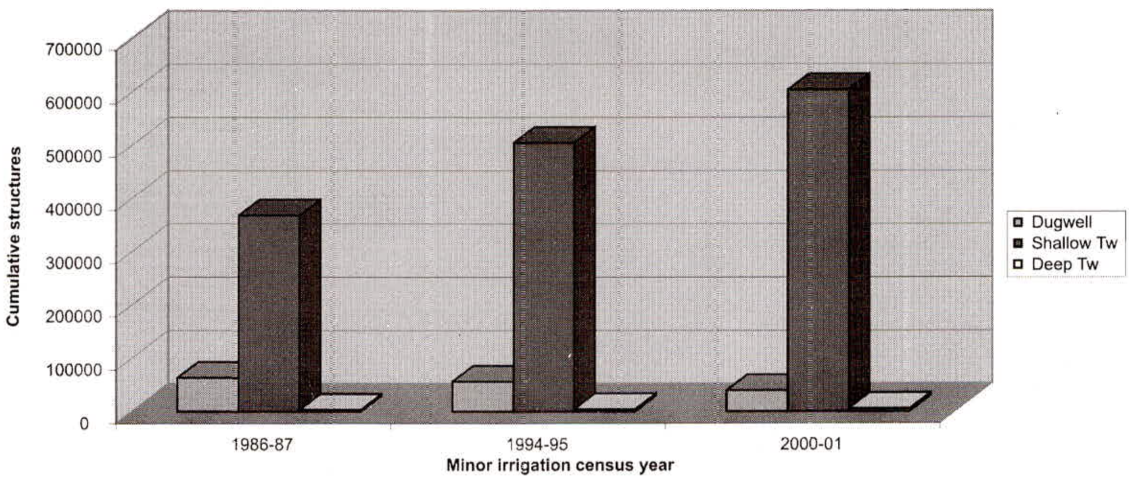


Fig. 4. Pace of groundwater irrigation in West Bengal.

Table 4. Progress of groundwater irrigation in West Bengal

Sl. No.	*Type of structure*	*No. of schemes existing during 1st M.I. census (1986-87)*	*No. of schemes existing during 2nd M.I. census (1994-95)*	*No. of schemes existing during 3rd M.I. census (2000-01)*	*CCA in ha during 1st M.I. census (1986-87)*	*CCA in ha during 2nd M.I. census (1994-95)*	*CCA in ha during 3rd M.I. census (2000-01)*	*GCA in ha during 1st M.I. census (1986-87)*	*GCA in ha during 2nd M.I. census (1994-95)*	*GCA in ha during 3rd M.I. census (2000-01)*
1	Dugwell	63387	55983	39377	31984	24386	27961	44054	39879	45411
2	Shallow tubewell	368316	504638	603667	624507	1015476	1169906	994475	1543586	2002210
3	Deep tubewell	3122	4039	5139	121689	154065	183162	197650	258192	308731

CCA - Culturable Command area, GCA - Gross Command area, Ha - Hectare, M.I. - Minor Irrigation.

Source: 3rd. Minor Irrigation census (GOWB-2003)

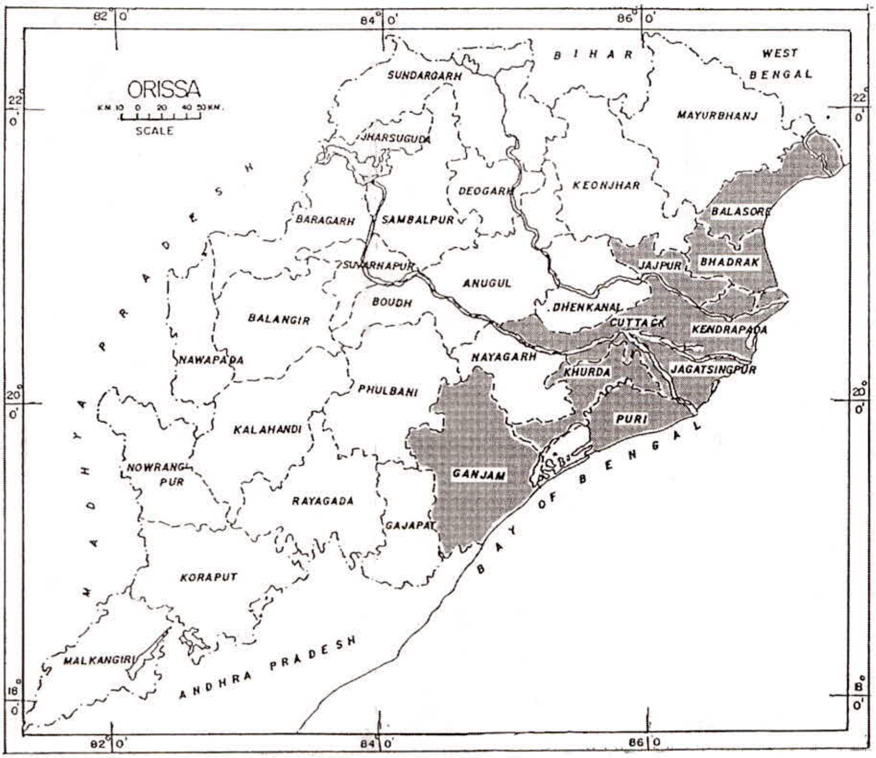


Fig. 5. Map showing broad hydrogeological set up of Orissa.

Scope of Groundwater Marketing

With the popularity of groundwater irrigation through shallow tube wells, the scope of marketing of ground water in entire West Bengal as also in Orissa has been widened. Through land reforms huge number of marginal farmers were generated in West Bengal whose pecuniary status naturally created a good pool of groundwater buyers. (Detailed analysis is beyond the scope of this paper.) In Orissa as well the marginal farmers are the groundwater buyers. In these states even the small farmers are gradually becoming groundwater buyers with the rapid development of ground water (Figs 8, 9, 10a, b&c). Initially in the entire alluvial tract of W.B. and Orissa where shallow aquifers with close water level was existing, the shallow tube well irrigation started with centrifugal pumps (both electric and diesel). Consequently with the high use of ground water the aquifers have been stressed. The decline in water level started especially during the Summer paddy cultivation. Initially the farmers started cutting ditch to negotiate the decline (Figs 9, 10). After some period they leave tube well irrigation and ultimately buy ground water from the rich and small/medium farmers. A case study (Kar, 1996) was carried out in Bhograi and Jaleswar Block in Balasore District, Orissa and in various parts in Malda district of W.B. (Kar, 1999). The study revealed that the farmers were owning shallow tube wells fitted with both centrifugal and submersible pumps. In case of the latter the farmer used to get sustainable production whereas in case of the former the crops often damaged or the irrigable area

Table 5. Status of Groundwater development in W.B. and Orissa

State	*No. of white* category block (as per GEC-84) with year of study*	*No. of grey* category block (as per GEC-84) with year of study*	*No. of dark* category block (as per GEC-84) with year of study*	*No. of over-exploited* category block (as per GEC-84)*	*No. of safe category block (as per GEC-97) with year of study*	*No. of semi-critical category block (as per GEC-97) with year of study*	*No. of critical category block (as per GEC-97) with year of study*	*No. of over-exploited category block (as per GEC-97) with year of study*
West Bengal	a. 253/271 Year-1991 b. 238/271 Year-1996	a. 19/271 Year-1991 b. 34/271 Year-1996	a. 01/271 Year-1991 b. 01/271 Year-1996	a. Nil Year-1991 b. Nil Year-1996	231/269 Year-2004	37/269 Year-2004	1/269 Year-2004	Nil Year-2004
Orissa	314/314 year-1991	Nil	Nil	Nil	314/314 Year-2004	Nil	Nil	Nil

271 blocks were assessed in 1991 and 1996 in W.B, While 269 blocks were assessed in 2004

1. White* means level of groundwater development ≤ 65%, 2. Grey* means Level of groundwater development > 65% but < 85, 3. Dark* means level of groundwater development > 85% but ≤ 100, 4. Over-exploited* means level of groundwater development > 100 as per G.E.C.-84 norm.

Source: Groundwater Resources of W.B. and Orissa (CGWB, 1995; CGWB, SER-1996; GOWB, 1994; CGWB, ER-2004; CGWB, SER-2004)

Table 6. Progress of groundwater irrigation structure in Orissa

Sl. No.	*Year of observation*	*No. of dug well*	*No. of shallow tubewell*	*No. of deep tubewell*	*Irrigation potential created by dug well in kharif (as in 2001)*	*Irrigation potential created by dug well in rabi (as in 2001)*	*Irrigation potential created by shallow tubewell in kharif (as in 2001)*	*Irrigation potential created by shallow tubewell in rabi (as in 2001)*	*Irrigation potential created by deep tubewell in kharif (as in 2001)*	*Irrigation potential created by deep tubewell in rabi (as in 2001)*
1	Till 1994	2901430	12439	3535	123049	62762	63152	85463	-	-
2	1994-95	320206	15108	3724	-	-	-	-	-	-
3	1995-96	338056	18511	3912	-	-	-	-	-	-
4	1996-97	351422	23310	4084	-	-	-	-	-	-
5	1997-98	361090	29650	4252	-	-	-	-	-	-
6	1998-99	368869	35799	4422	-	-	-	-	-	-
7	1999-00	374677	40282	4521	-	-	-	-	-	-
8	2000-01	378379	43881	4592	-	-	-	-	-	

Source: MOWR NIC, M.I. Census, 2001.

Table 7. Total number of pumpsets in W.B. and Orissa

State	*Number of elec. pump*	*Number of diesel pump*	*Total no. of pumps*
West Bengal@	9000	77000	86000
Orissa#	15322 (1)/13833 (2)	25411 (1)/29821 (2)	40733 (1)/43654 (2)

@ pumps are fitted in tubewells, # Pumps are fitted both in dug well (1) and Shallow tube wells (2)

Source: M.I census, MOWR, NIC, 2001

became reduced and finally the tube well used to become defunct with the malfunctioning of the centrifugal pump. However, the factors like frequent hike in diesel rate as also the occasional rise in electricity tariff by the State Governments (it is highly variable and the policies of rate fixation as also subsidies for agro-irrigation varies from Govt. of West Bengal to that of Govt. of Orissa) influence the price as also the market of ground water. Generally in India the irrigation policies in various states are highly political and generally guided by the political lobbies who control the farmers (Mukherjee, 2006).

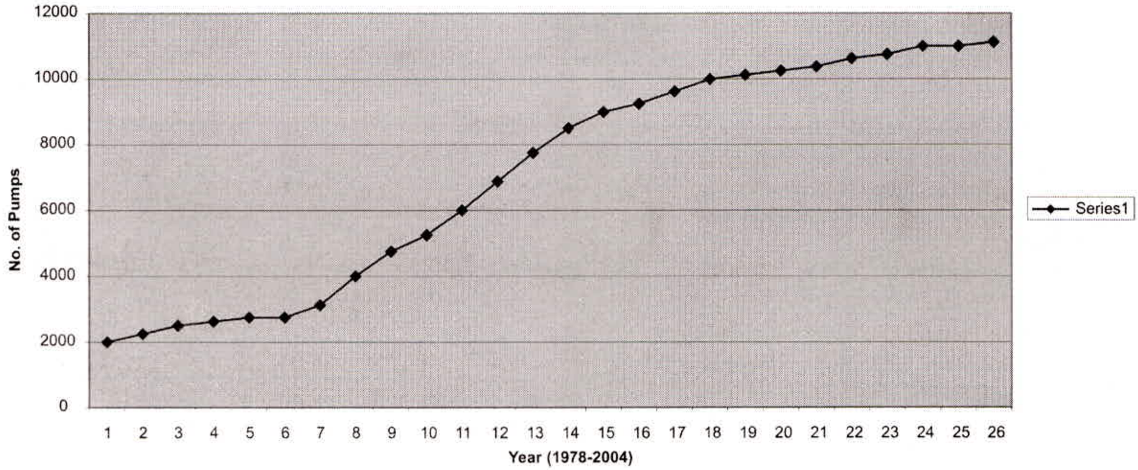


Fig. 6. Electrification of pumps in West Bengal.

EFFECT OF FASTER PACE OF GROUNDWATER IRRIGATION IN W.B. AND ORISSA, ORIGIN OF SWID CERTIFICATE

Various facts and figures (Tables 4, 5, 6 and 7; Figs 3, 4 and 6) as mentioned above indicate that there has been a very fast growth of groundwater irrigation in the state of W.B. Till mid eighties very few were knowing about the menace of geogenic arsenic in the ground water of Gangetic W.B. Gradually with the rapid spread of arsenic pollution in West Bengal and Bangladesh, extensive research activities were started. The studies revealed that rapid lowering of groundwater level facilitates the release of toxic arsenic from the sediments to ground water.

With the recommendation of Groundwater Estimation Committee, Ministry of Water Resources requested all the state governments to assess the groundwater resources in coordination with the Regional Offices of CGWB following the norms (GEC, 1984). First minor irrigation census (MOWR, 1986) was also taken up by the State Govt. with the assistance of Ministry of Water Resources, Govt. of India. Accordingly with the facility of the M.I. census data, the ground water resources of West Bengal was assessed. The essence of the assessment as on 1991 as also in 1996 is presented in Table 5. Subsequent assessment as per GEC-97 and categorization of blocks are also presented in Table 5. With the motivation of the farmers during the agrarian development (Banerjee et al., 2002) in W.B., three times cultivation became highly popularized. Especially the high yielding Boro (summer paddy) cultivation and its high water requirement for a hurried harvest started extracting huge quantity of ground water and obvious result was the decline in ground water (Tables 2, 5). Basically for high withdrawal of ground water, submersible pumps were being commissioned unscientifically (Fig. 7) by the farmers which caused the rapid decline in water level (Table 2). Similarly the result of assessment done by the state level committee (as per GEC-84) revealed 19 grey blocks in 1991 and 34 grey blocks in 1996, while as per 1997 methodology, 37 semi-critical blocks are observed in W.B. These are presented in Table 5. In view of the observation of the state level groundwater estimation committee, Govt. of West Bengal decided to take some prohibitory regulation to stop the massive withdrawal especially during summer, in 1993. This is the background of genesis of the SWID certificate. However, for introducing the prohibitory measure, the impact of large hue and cry since early nineties, by the health, environmental and social activists, in the national and international forum, on the topic of wide spread ongoing arsenic pollution and its real and severe affects on human health and mortality in West Bengal and its relation with groundwater overuse and decline, cannot be ruled out.

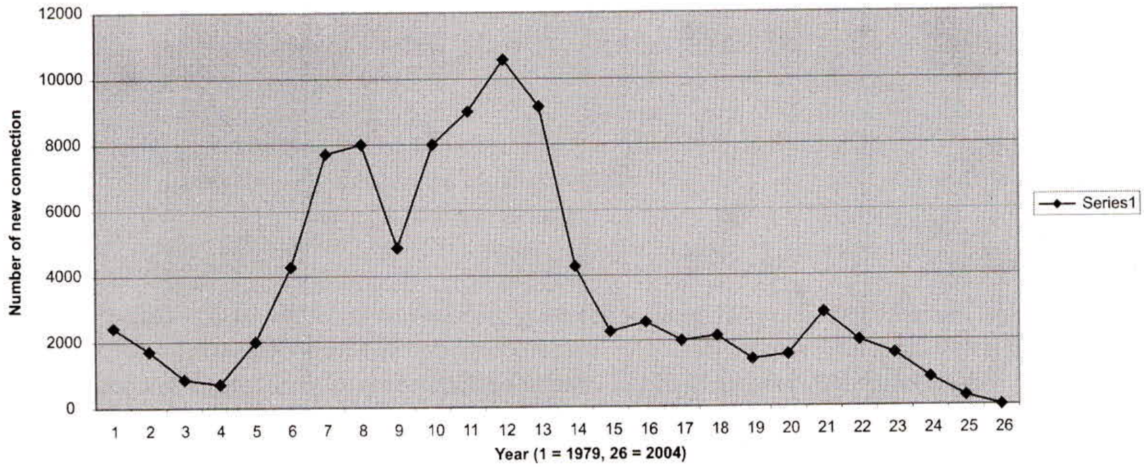


Fig. 7. Number of new electric pump connections by WBSEB in W.B during 1979-2004.

Accordingly a decision was taken by the Govt. of W.B. that West Bengal State Electricity Board (WBSEB) would only give electric connection to the submersible pumps after getting clearance (i.e. the SWID certificate) from SWID (State Water Investigation Directorate). This restriction was imposed in seven districts of West Bengal where considerable withdrawal of ground water was observed by the state level committee (GOWB, 1994). These districts were: 1. Barddhaman, 2. Hooghly, 3. Malda, 4. Medinipur, 5. Murshidabad, 6. Nadia and 7. North 24 Parganas. It was also decided that no connection would be given in the dark (only one in W.B.) and over-exploited blocks (nil in W.B.). However, new electric connections to the submersible pumps can be given in the white and grey blocks (GEC-84). Currently as per the GEC-97 norm, equivalent blocks of white and grey are termed as safe and semi-critical (Table 5). In such cases one has to apply for a new electrical connection for submersible pump in the SWID prescribed format. The format has to be forwarded by the Pradhan of the Gram Panchayat (GP), where he will certify (i) the residential status of the applicant under the jurisdiction of his GP, (ii) possession of a land by the farmer as per deed and (iii) occurrence of no submersible pump within a distance of 600 m from the proposed site. In case of white blocks the permission can be given by the district authority of SWID. In case of grey blocks the applications are required to be forwarded to the SWID headquarters at Kolkata. The decision of approval or denial is taken through a state committee meeting and the same is conveyed to the farmer. In each case the view of CGWB is always taken who also participate in the meeting. After getting the permission the farmer can apply to the WBSEB for electricity connection to the submersible pump. This process of granting approval for new electrical connection for submersible pump has been termed as delaying and intensely political (Mukherjee, 2006).

In the detailed paper published by Mukherjee, 2006, it is narrated that the process of getting SWID certificate is a delaying process, which is highly political and the ban prohibits the farmers for easy access to ground water in the Water abundant West Bengal. However, in the other water scarce states, even with aggravated situation, such measures are not being taken by the concerned state government. This move is indirectly curtailing the productivity of Boro rice in the state of W.B. and monetary profit of the farmers through compelling them to go for irrigation with diesel pumps. However, the reality of the comments as mentioned above can further be verified with very large size sample and extensive surveys in all the seven districts. In the critical review the author did not throw any light on the menace of arsenic poisoning as happening in W.B. with the rapid decline in water level or the probability of occurrence of other environmental effects (i.e. salinity ingress) in the deltaic coastal tract of W.B. as it happened elsewhere in the globe. Simultaneously comments on necessity for environmental restoration and methods of future sustainable agrarian development in an eco-friendly manner have not been put forward. Rather the comparative productivity of Boro paddy with submersible pumps (drawing more water) and diesel (Fig. 9) pumps (drawing less ground water) have been highlighted.

In Orissa on the contrary, state govt. is not taking any such step even in the Balasore district where groundwater irrigation is highly practiced. The field studies carried out in Balasore district (Kar, 93, 96, 98) was the initial endeavour to reveal the level of groundwater irrigation in the district and its effect on environment. In Balasore district the shallow tube well was popularized in the late eighties and early nineties after the beginning of agricultural development in W.B. Similar situation as observed in W.B. was also noticed in Orissa during 1992-96 while the marginal farmers were abandoning shallow tube wells fitted with centrifugal pumps (Figs 10a, b and c) and high level groundwater marketing started with the introduction of submersible pumps. The studies also reveal few endangered patches in Bhograi-Jaleswar tract where the water table contour was seen below the M.S.L. This observation was subsequently published (Das, 2000) and the matter was brought to the concern of state authority during a National Seminar in 2000 at Bhubaneswar. During the study it was also observed that awareness of people on groundwater development and management was unsatisfactory. Sometimes the farmers go for tube well construction to satisfy their ego or jealousy with their neighbour (Fig. 8), rather than to reduce the cost of construction and better management of groundwater through sharing of water from a single tube well, constructed through joint venture. The concept of groundwater development through farmers cooperative is almost absent in Orissa as also in West Bengal. In many places (a) inherent age old hostility and (b) strong difference in political thinking under political banner (especially in W.B.) exist among the fellow farmers which give rise to unhealthy rural politics and disharmony. It hinders the cooperative movement of groundwater irrigation in the states. NGOs, working on socio-economic upliftment in rural areas, may take appropriate projects on such matters of cooperative groundwater irrigation in the states of West Bengal and Orissa. This may help to upgrade the socio-economic status of the marginal and small farmers. It is observed during the field studies in Orissa (AK, 1993, 1996) that the M.I. data kept even at the block level was not fully informative, sometimes incomplete to go for detailed and authentic micro level analysis on groundwater irrigation. Hence the groundwater resources assessment based upon such data, especially for the coastal blocks with high utilization of ground water, may further be reviewed with further micro level census of M.I. structures. The state level committee of Orissa, however, has decided not to allow any further development in the blocks which already have reached more than 60% development and accordingly the financial institutions are advised not to extend agricultural loan on groundwater development in such blocks. In this category only one block i.e. Baliapal falls (70%) while in two other blocks Bhograi (57%)and Jaleswar (55%) the development is close to the prescribed threshold value. However, besides the cited blocks of Balasore including Baśta and few others, the overall groundwater development situation in the state of Orissa is not much alarming (CGWB, SER, 2004).

Few Other Examples of Water Level Decline in W.B. and Steps taken by the State Govt.

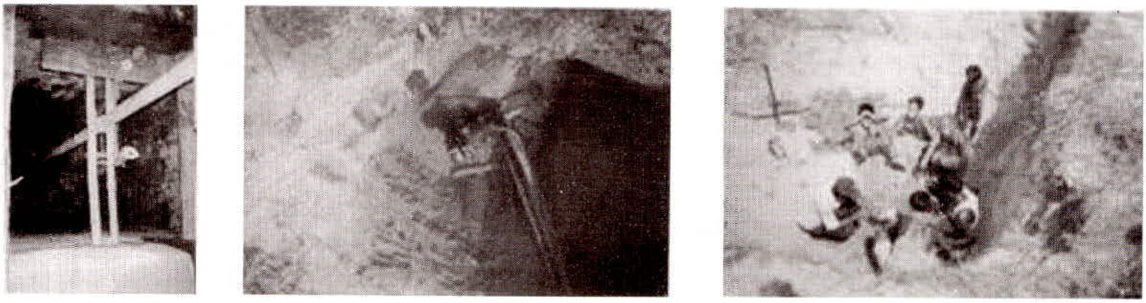
Studies of CGWB in Kolkata Metropolitan City area revealed the lowering of piezometric surface of the deeper confined aquifers and it is also opined that this lowering may invite saline water ingress into the depressurized aquifers. Simultaneously the request of Ministry of Water Resources to enact the ground water model bill to stop over-use of ground water had created the background of implementation of prohibitory regulation on groundwater withdrawal even in urban areas. In this way Kolkata Corporation prohibited further construction of energized tubewells inside Kolkata Corporation area. Subsequently following the study of CGWB the Haldia Municipal area was declared notified in view of groundwater over-development.

ECO-FRIENDLY DEVELOPMENT VIS-A-VIS UNSCIENTIFIC RAPID GROWTH: WHAT'S ACTUALLY NEEDED?

From the foregoing discussion it is observed that with the rapid pace of groundwater irrigation in the major parts of the state of W.B. and in small parts of Orissa already rapid decline in water level has been resulted. This has either invited various environmental problem or the background for future menace is prepared with the unscientific withdrawal. In this context one question generally comes into the mind that what is actually needed? Rapid progress of irrigation and agricultural sustainability with whimsical unscientific method of withdrawal (Fig. 8) and groundwater tapping? or eco-friendly sustainable growth of agriculture. There is no doubt that the backbone of agrarian India and its economy lies with the development of rural areas especially with the development of agriculture. The envisaged green revolution can only be achieved with fuller growth of irrigation potential. Because of vagaries of monsoon, while surface water sources and rainfall become undependable, the development of agriculture totally depends on the groundwater irrigation. But over-pumping of ground water ushers several environmental problem as discussed. So it is really enigmatic, what's actually wise in the present context? In this regard undoubtedly it may be opined that the agricultural development cannot be stopped but middle way is to be adopted. Hence conjunctive use options of surface and ground water and optimum utilization of the rain water, proper cropping pattern and artificial recharge of groundwater combined may stop the groundwater over-use and control the ongoing decline of water level for a better environment in the future.

Fig. 8. Peril to the environment! Two close energized shallow tube wells, Basta, Balasore dt.

Fig. 9. Over pumping for Boro (summer paddy) cultivation is causing decline in water level. Old Malda, W.B.



(a) (b) (c)

Fig. 10. More examples of water level decline in Orissa and W.B. A process of conversion of marginal farmers with irrigable tubewell to groundwater buyers. a. Defunct and abandoned shallow tube well at Jaleswar Balasore dt., Orissa; b. Shallow tubewell in a ditch four metres below ground level, Malda, W.B.; c. Partially defunct shallow well tubewell in a ditch. Habibpur, Malda, W.B.

CONCLUSION AND RECOMMENDATIONS

It may be concluded that the shallow aquifers over a major part of deltaic West Bengal and coastal Orissa are under rapid withdrawal for irrigation for a couple of decades which has caused environmental menace. In Orissa a huge area (>70%) is occupied by hard rocks where ground water is not properly developed in want of scientific data on availability of shallow productive zones and low economic status of the people. Profitable groundwater market is developed in W.B. and for generation of high number of marginal farmers after the land reforms and agricultural development since 1980. In parts of Orissa also where tubewell irrigation is going on, groundwater marketing is practiced. The groundwater resources for both the states are assessed as per GEC-84 and GEC-97 norms. Widespread arsenic pollution took place in major parts of the Gangetic delta of W.B. and Bangladesh, where groundwater level decline has been postulated as the main reason of arsenic release to ground water.

As per the result of the assessment of groundwater resources by the state level committee, some prohibitory regulations on ground water irrigation in seven groundwater developed districts of W.B., has been introduced in the form of SWID certificate. New tube well construction for groundwater pumping inside Kolkata Corporation area has been stopped. Haldia Municipal area has been notified in view of over-development. Govt. of Orissa has yet to take any legislative steps in the needful areas of Balasore district. The following recommendations are made for the two states.

1. In order to decipher the shallow productive zones for development of ground water in the extensive hard rock areas of Orissa and limited areas under crystalline formations in W.B., extensive integrated hydro-geological and geophysical surveys coupled with groundwater drilling and exploration are to be taken up by the central and state govt. departments and research organizations.
2. For proper development a central data bank is to be created where all the user organizations may have access. There should be good coordination among the research and development organizations.
3. To monitor the periodic development of ground water in the alluvial areas, regular measurement of water level and quality assessment should be done.
4. Detailed micro level surveys are to be carried out to unravel the proper hydrogeological set up of the area.
5. Detailed geophysical surveys are to be carried out to find out the thickness of the clay blanket in the underdeveloped areas in the coastal tract to construct ponds for rain water harvesting.
6. In the areas with shallow aquifers recharging tanks are to be constructed.
7. All old tanks and ponds are to be desilted both in alluvial and hard rock areas to conserve rain water.
8. Conjunctive use of surface and ground water as also optimum utilization of harvested rain water would be highly beneficial for the alluvial areas under high groundwater irrigation.
9. Artificial recharge through roof top and all other possible means is to be popularised as per the availability of source water and aquifer disposition and condition.
10. Aquifer parameters of all aquifers along with data on zone of interference is to be deduced in micro level basis for proper implementation of procedural actions by the State Governments as per the recommendations of the state level committee findings as also for future imposition of notification on irrigation water in case of critical and over-exploited blocks.
11. For calculation of proper draft, the minor irrigation structure census are to be taken up expeditiously on micro level basis especially in Orissa.
12. Agricultural extension is to be upgraded. Rigorous studies to adopt proper cropping plan and studies on crop water requirement are to be taken up in the entire states of West Bengal and Orissa by ICAR, state governments and the agricultural universities.
13. If it does not hamper the national/state sustainability of annual rice production then the water intensive summer paddy may be replaced with any other cash crop of identical agro climate with less water requirement. For this, urgent researches should be undertaken by the agricultural research organizations and the universities.
14. Regular mass awareness campaign through camps in rural areas as also through print and electronic media is to be conducted to educate the people on groundwater development and management.
15. Aspects of groundwater development, its good and bad effects are to be introduced in environment chapter, which is required to be introduced in schools right from primary level.

ACKNOWLEDGEMENTS

The authors express their sincerest gratitude to Dr. Saleem Romani, Chairman, CGWB for his kind permission to publish the paper. Authors are indebted to S/Shri B.M. Jha, Member (SAM), A.K. Sinha, Member (SML) and Shri C.S. Ramasesha, Commissiner (GW) for their kind encouragement for the publication. The first author is thankful to Shri S. Datta, Scientist-D and Ms. Sipra Bandyopadhyay, Scientist-B, CGWB, E.Region for helping him.

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