Groundwater Management in India

A multi-state field study of availability, utilisation and locally appropriate solutions for sustainable, equitable and efficient use of groundwater

West Bengal State Report

September 2022

RAJIV GANDHI
INSTITUTE FOR CONTEMPORARY STUDIES

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1 Executive summary

1.1 Groundwater scenario in India

Over the last few decades our dependence on ground water has increased tremendously. It has become a major source of water for domestic and agricultural use in India. According to an estimate the ground water resource meets 80% of our water demand. Agriculture is a major consumer of the ground water; it supplies nearly 60% of water demand of the agriculture sector. Worryingly, since the 1990s the area under canal and tank irrigation has observed absolute decrease in India, whereas, ground water fed agricultural area has increased in these years. The convenience and efficient last mile connectivity of ground water resources encouraged many farmers in this country to switch from canal/tank irrigation to the tube well/bore well.

A committee constituted by the government of India to review water governance in the country led by Dr. Mihir Shah in his report in 2016 observed that the public finance on water resources after independence largely focused on surface water.[1] Huge amount was invested on creating surface water infrastructure. The ground water resource remains neglected despite it is replacing surface water from agriculture to domestic use in the last some decades. Individuals invested hugely in ground water infrastructure especially after the green revolution as it was easier and efficient in terms of available for the end use. The technological advancement and availability & affordability of power also helped individual investors (largely farmers) to create groundwater structures. Currently there are around 30 million groundwater structures in this country.

For the purpose of ground water extraction, enough knowledge and data is available. The problem is with lack of data on aquifer management. Being a large country, the geological and hydrological characteristics of the landmass varies from region to region. It further creates complexity to understand sub-surface characteristics pertinent to water seepage, storage and water movement. The CGWB has categorized 14 different aquifer settings in India. Major aquifers include Alluvial, Laterite, Sand stone, shale aquifer, Lime stone aquifer, Basalt aquifers and Crystalline aquifers. According to a classification of geohydrologist Dr. Kulkarni, Crystalline and Alluvial aquifers comprise 59% of the total aquifer area in the country. The mountain and volcanic system of aquifers accounts for 16% of the total area each. These complex aquifer systems require detailed mapping and study for better management of ground water.

[1] https://www.indiawaterportal.org/sites/default/files/iwp2/report_on_restructuring_cwc_cgwb.pdf

1.2 Groundwater policy gaps

The increasing unsustainable extraction of groundwater is a serious issue that has now turned into a water crisis in many parts of the country. In the states like Punjab, Rajasthan, Haryana, Delhi, Madhya Pradesh, parts of Uttar Pradesh and Tamil Nadu have started withdrawing more water from sub surface than available for usage. This gap in demand and supply is continuously increasing as there is no aquifer management system in the place. The numbers of critical and over exploited units are on rise. This invited crisis due to mismanagement of natural wealth has serious social, economic and ecological consequences. There are many reasons behind this problem and these problems have been discussed a number of times.

Ground water extraction is largely unregulated. The only law that loosely governs this precious resource in India is the Indian Easement Act, 1882. This law gives all rights to land owners to extract the ground water. In other words it excludes land less people from access and use of groundwater. This law does not control or regulate water extraction and its usage by the land owner. To strengthen the regulatory mechanisms, the central government has so far issued four versions of model law to be adopted by state governments. The first model bill was released in 1992 and the latest bill was released in 2017. Yet not all states have converted the model Bill into state legislation. Andhra Pradesh, Assam, Goa, Bihar, Delhi, Himachal Pradesh, Jammu and Kashmir, Karnataka, Kerala, Lakshadweep, Puducherry and West Bengal have adopted the older version of model bill, but in most cases the attempt is half hearted.[2] Moreover experts believe that the model Bill must also move from command and control mode to participatory mode to ensure full participation of people.

The unavailability of data and knowledge on aquifer systems is another big problem in developing better management plans for the ground water. The CGWB collects data from selected wells four times a year to monitor ground water development. The sample size for this yearly exercise is so low that nothing can be argued conclusively based on collected information. There is a long pending demand of mapping aquifers in this country for better management plan. The CGWB has been attempting to map aquifers for all districts in the country. This data and mapping of aquifers would definitely improve our ability to manage groundwater better.

The absence of an integrated approach of ground water recharge and extraction is completely missing in India. There have been some attempts through government and non-government agencies to integrate both of these aspects, but this idea is still not part of national or state level management plans. The absence of regulations and public finance for the management of ground water further discourages any national or state level plans for ground water resource management.

In the past the CGWB attempted to design a national level master plan for artificial recharge of aquifers in 2002 and 2013. The board has now revised this master plan in 2021. According to this master plan, nearly 1.41 crore artificial recharge structures are needed across the country. The type of structures recommended for states and districts varies depending on their geological and hydrological features. The plan is expected to be financed by ongoing projects such as MGNREGA and Watershed Management. The implementation of the master plans requires investment of Rs. 1.33 lakh crore.[3]

Involvement of people in planning and execution of activities related to artificial recharge and ground water extraction has not been seriously promoted at the policy level. However, we have numerous small examples across the country to show that if people are involved aquifers can be managed sustainably and benefits can be shared equitably.

1.3 The multi-state study

There have been some attempts in various states commissioned by nongovernmental organizations to empower farmers with knowledge and capacity to help them to make the right agricultural decisions and choices. Many of these serious attempts helped in yielding good results as well. On the other hand there are numerous examples where projects related to artificial recharge were carried out successfully both by the government and non-government agencies. Some states also tried to regulate groundwater resources. All these actions by different organizations generated huge knowledge and experiences to vet success and failure of each type of programs. These small scale and localized solutions for ground water management are effective in terms of striking a balance between water supply and demand.
Learning from these models can help improving ground water regulations in different states. Therefore this study was commissioned by Rajiv Gandhi Institute for Contemporary Studies (RGICS) in 2021 in ten different states namely Punjab, Rajasthan, Gujarat, Uttar Pradesh, West Bengal, Assam, Madhya Pradesh, Maharashtra, Telangana and Tamil Nadu. Main objectives of the study were as follows:

- To develop an overview of the hydro-geological characterises of different states/regions and the extent of ground water extraction.
- To document and assess the regulatory framework in different states for the management of ground water resources
- To assess the ability of localized solutions for management of ground water resources to strike a balance between demand and supply of groundwater.
- To draw policy lessons from successful localized solutions for ground water resource management

Groundwater experts and NGOs specialized in groundwater management in different states helped us to implement this project. This is a qualitative research project which involved methods like field work, stakeholder consultation and secondary data analysis. This state report gives an overview of the context and main natural features- geographical, geological, hydrological and hydrogeological- which impacts that status of groundwater in the state. Then it deals with the human interventions – in terms of demand and utilisation, the major policies, laws and regulations, programs, schemes and institutions pertinent to groundwater in the study state.

The main incremental contribution is in the section on lessons from locally appropriate solutions for sustainable groundwater management.We have given summaries of case studies from different location in the study state documenting such locally appropriate solutions.

Finally we summarise the main lessons from the study in a section titled the eightfold path.

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[2] https://scroll.in/article/929433/as-the-water-crisis-deepens-can-india-afford-to-leave-groundwater-unregulated

[3] http://cgwb.gov.in/Whatisnew/2021-06-30-Final-Approved%20Master%20Plan%202020-00002.pdf

2 West Bengal state report

2.1 Context and key features

West Bengal is situated towards the north-eastern part of Indian Peninsula, which lies tentatively between Latitudes 25°-20°30′ and Longitude 87°30′ – 90° 30′. The entire state can be divided into two main hydrogeological units namely fissured hard rocks and porous alluvial rock formations. The Fissured formations in the state include crystalline, volcanic and metasedimentary rocks. Nearly two third of the State is underlain by alluvial sediments mainly deposited by Ganga and Brahmaputra river systems.

Aquifers in the alluvial region of the West Bengal can be further divided into three zones based on yield of wells. Wells in Japlaiguri to Kochbihar in north to Medinapur and 24 Pargana in South yield 150 cubic meter water per hour. Yielding around 50 to 150 cubic meter per hour occurs in parts of Malda, Dinajpur and western Murshidabad. In Marginal alluvial tracto in parts of Birbhum, Bankura, Burdawan and Mushibad well yielding is less than 50 cubic meter per hour.[4]

The ground water situation in West Bengal is more complicated than it seems. For instance, if we look at the base map, we can see that one agroclimatic area is located below mean sea level, whereas the other five are located above. This section describes geo-hydrological setting of three different agro climatic zones namely Hills, Coastal Saline and Red-lateric.

2.1.1 Undulating Red Lateritic Zone

The Red Lateritic agro- climatic zone is situated at the western part of the State and the districts bordering to Jharkhand and Orissa. This is considered to be an extension of Chhotanagpur plateau, characterized with undulating terrain prone to low soil depth and erosion. The annual average rainfall varies from 1200mm to 1400 mm, but due to the high runoff and low water harvesting provisions the area usually remains mono-cropped. Poor availability of water (both the surface and the ground) creates drinking and irrigation scarcity of the area. Groundwater here less explored and less defined, said to have the seepage lines pass through the permeable layers in between the hard rocks. The lithological analysis, on the other hand indicates the availability of the aquifer materials/shallow aquifers underneath, when the intensive exploration and participatory groundwater monitoring is done.

2.1.2 Himalayan foothills

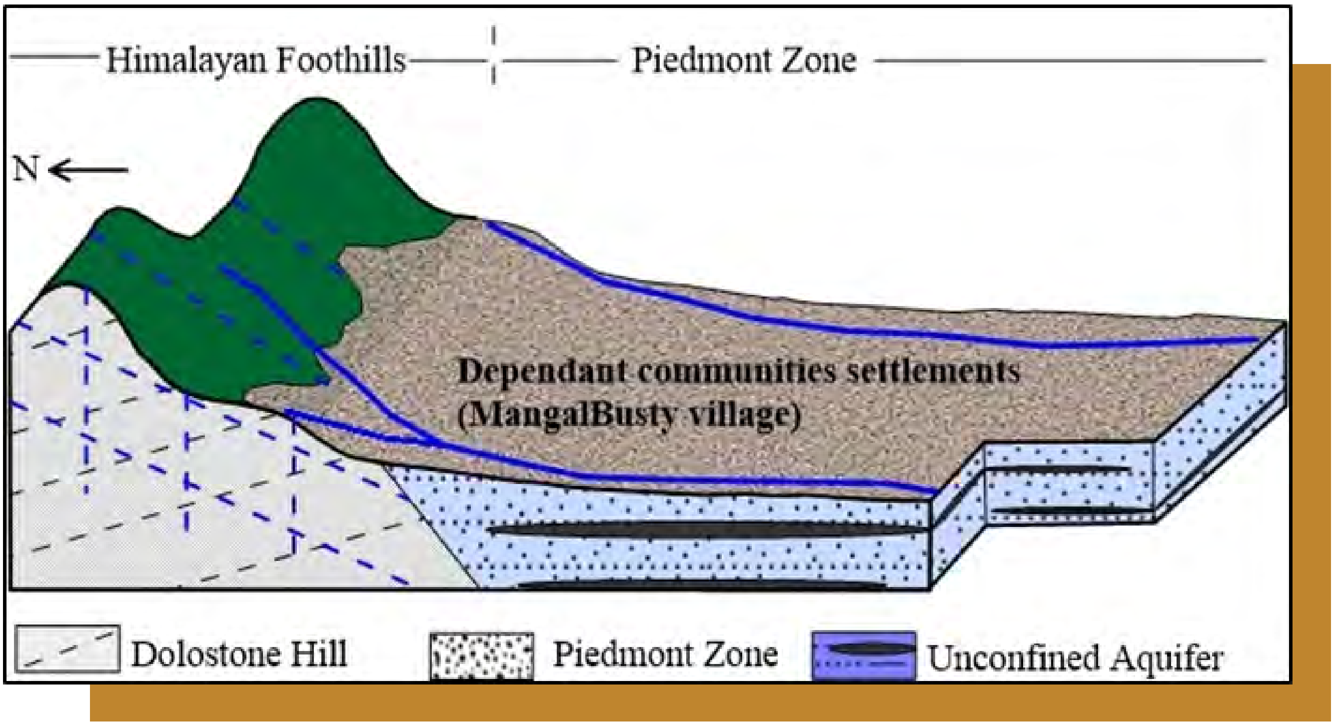
Dooars region of Northern Bengal, in the foothills of Himalayas, is one of the wettest places of the state with an average annual rainfall of 3600mm. The area is famous for three 'T's, i.e. Tea, Timber and Tourism and bordered by the Himalayan foothills which form the part of the mainland Bhutan in the north. In this picturesque landscape the Himalaya meets the plains. The sudden changes in the elevation and its unique geo-morphology play a vital role in the availability of the groundwater.

[4] http://cgwb.gov.in/gw_profiles/st_westbengal.htm

The Himalayan foothill region in West Bengal has many vital issues such as, Human Wildlife Interface (prominently with elephants), limited socio-economic opportunities, high illiteracy rate, weak tourism management, overdependence on natural resources, and poor health facilities. The scarcity of water for drinking is one of them making life difficult for the inhabitants. Geologically, it falls into the bhabher zone, known for high transmission rate of groundwater rather than storage. In view of changing climatic events, reduction in the groundwater level is experienced by the locals, these effects, coupled with increasing population and settlements demanding more water have pronounced the scarcity, making the area deficit in water resources. Further, lack of knowledge on the current ground water table and its behavior with environmental factors had also contributed to its improper management.

The most of the region of Himalayan foothills in the state is located in the piedmont alluvial Plains formed by the deposition of sediments carried by the Himalayan rivers/ streams flowing downhill in front of Himalayan foothill zone (Shiwaliks) towards south. Shiwaliks, a geological unit composed dominantly of sandstones, is juxtaposed to the Great Plains throughout the Himalayas, but in this particular zone the Shiwaliks rocks are not observed. The northern boundary of *bhabhar* zone has an abrupt structural contact with the lesser Himalayan rocks, Dolostone in this case. The dolostone rocks are trending east to west with beds dipping roughly towards the north direction (GSI, 1968).

The piedmont zone is further classified as 'bhabhar' and 'figure'. Bhabhar zone, consists mainly of sorted unconsolidated sediments like, gravel, pebbles, sand and silt with intervening clay layers. Clay lenses are expected to be of limited extent in this zone. The belt exhibits east to west elongation all along the Himalayan foothills.



2.1.3 Sundarbans

Sunderbans is formed by the lower Ganga- Brahmaputra delta spread in India and Bangladesh. It is located at the northern apex of the Bay of Bengal and forms the world's largest delta both in terms of area and sediment discharge. Apart from these two major rivers, it is also land of many small and medium sized peripheral streams that emanate from surrounding uplands.[5]

The accumulation and movement of groundwater is a function of two basic 'hydrogeological' properties of rocks – the porosity and the hydraulic conductivity (commonly referred to as permeability). In simple terms, the porosity and hydraulic conductivity are properties of rocks, properties that broadly indicate the porous and permeable aspects of the rock. On the other hand, when aquifers are identified and described, it becomes necessary to gauge the storage capacity and the transmission capability of an aquifer. The coefficient of storage (storativity) and transmissivity define the storage and transmission functions (capacities) of an aquifer. Pumping tests constitute the most straightforward methodology for estimating the storativity and transmissivity of aquifers.

2.2 Ground water availability and utilization in West Bengal

The Ganges-Padma River divides West Bengal in two parts, namely North West Bengal and South West Bengal. The entire landmass of the state is part of Ganga-Brahmaputra-Meghana Basin. Rivers flowing in the state namely Teesta, Torsa, Jaldhaka, Raidak and several other small rivers and streams belong to the Brahmaputra basin and flowing in northern districts of the State namely Darjeeling, Jalpaiguri and Coochbehar. These rivers originate in the eastern Himalayas of Sikkim and Bhutan. Other rivers of the state namely Mahananda, Dauk, Tangon, Nagar, Atreyeee, Punarbhaba and a number of their tributaries drained through districts such as Uttar and Dakshin Dinajpur and Malda. These rivers are part of Ganga basin. Except Mahananda, all these rivers originate in the plains of West Bengal and Bangladesh and join the Ganga and Padma at downstream.[6]

West Bengal cumulatively receives about 1851.4 mm rainfall every year. However its high uneven distribution leads to extreme weather conditions in the state. According to data published by India Meteorological Department, 30% of the rainfall it receives is from the south west monsoon in July month. The August month gets 26% of the south west monsoon rainfall. June and September month receives 22% of south west monsoon rainfall. In total around 77% of annual rainfall it receives is during the southwest monsoon i-e June to September.

The sub-Himalayan region of the West Bengal especially Darjeeling and Kalingpong region receive on an average 69-76 rainy days out of 122 days of south west monsoon. On the other hand the most of Gangetic West Bengal region gets 42-49 rainy days. Instances of heavy rainfall are normally observed 10-12 days every year in sub Himalayan region and 2-4 days in Gangetic west Bengal.[7]

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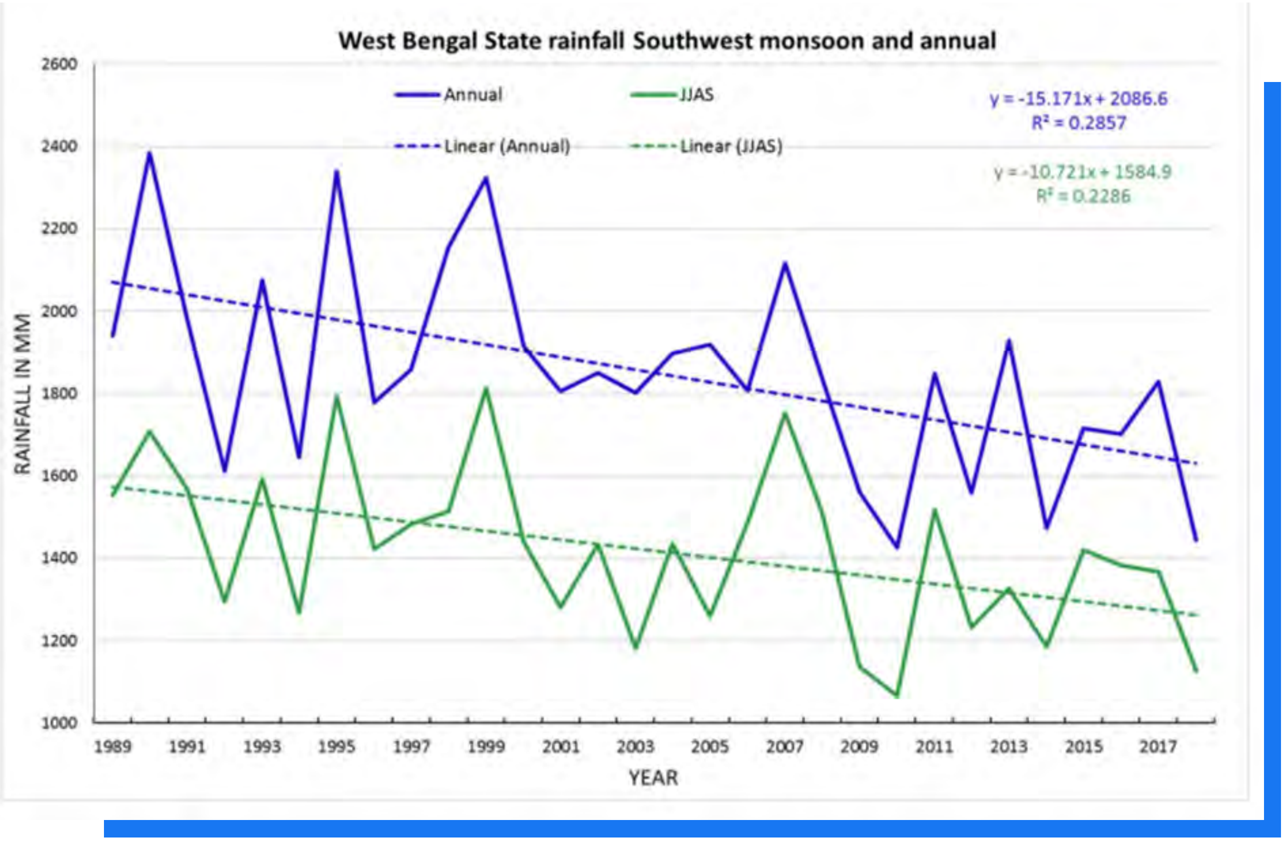
[5] https://documents1.worldbank.org/curated/en/119121562735959426/pdf/Sundarban-A-Review-of-Evolution-and-Geomorphology.pdf

[6] http://wbdmd.gov.in/pages/flood2.aspx

[7] https://imdpune.gov.in/hydrology/rainfall%20variability%20page/wbengal_final.pdf



Dynamic Ground Water Resources	
Annual Replenishable Ground water Resource	30.36 BCM
Net Annual Ground Water Availability	27.46 BCM
Annual Ground Water Draft	11.65 BCM
Stage of Ground Water Development	42 %

Ground Water Development & Management	
Over Exploited	NIL
Critical	1 Block
Semi- critical	37 Blocks
Ground Water User Maps	18 districts
Artificial Recharge to Ground Water (AR)	• Area identified for AR: 7500 sq km • Quantity of Surface Water to be Recharged: 2664 MCM • Feasible AR structures: 11200 percolation tanks with shafts, 3606 gabion structures, 1054 nala bund/ cement plug, 1680 re excavation of tanks, 500 desiltation of village pond, 1000 spring development, 70 sub surface dykes, 1500 RTRWH for Kolkata & Darjeeling.
	AR schemes completed during VIII Plan: 2 AR schemes completed during IX Plan: 5

Ground Water Quality Problems	
Contaminants	**Districts affected (in part)**
Salinity (EC > 3000 μS/cm at 25 ° C)	Haora, Medinipur, S- 24 Parganas,
Fluoride (>1.5 mg/l)	Bankura, Bardhaman, Birbhum, Dakhindinajpur, Malda, Nadia, Purulia, Uttardinajpur
Chloride (> 1000 mg/l)	S-24 Parganas, Haora
Iron (>1.0 mg/l)	Bankura, Bardhaman, Birbhum, Dakhindinajpur, E. Midnapur, Howrah, Hugli, Jalpaiguri, Kolkatta, Murshidabad, N-24praganna, Nadia, S-24pragannas, Uttardinajpur, West Midnapur
Nitrate (>45 mg/l)	Bankura, Bardhaman
Arsenic (>0.05 mg/l)	Bardhaman, Hooghly, Howrah, Malda, Murshidabad, Nadia, North 24 Praganas, South 24 Pragannas

http://cgwb.gov.in/gw_profiles/st_westbengal.htm

The high amount of rainfall in the state provides for a good amount of surface and ground water resources for various uses. The dynamic ground water report published by the Central Ground Water Board reveals that cumulatively the state has net 27.46 billion cubic meter ground water for various uses. The state withdraws nearly 11.65 BCM every year, which is roughly 42% of the net ground water availability. In terms of ground water development out of 341 blocks in the state, 37 blocks are semi-critical and 1 block falls in the critical category as per the CGWB norms. However, the quality of ground water is a serious concern in the state. The salinity in the delta region and fluoride, iron, nitrate and arsenic contamination in other districts is a serious cause of concern.

2.3 Groundwater policies and governance in the state

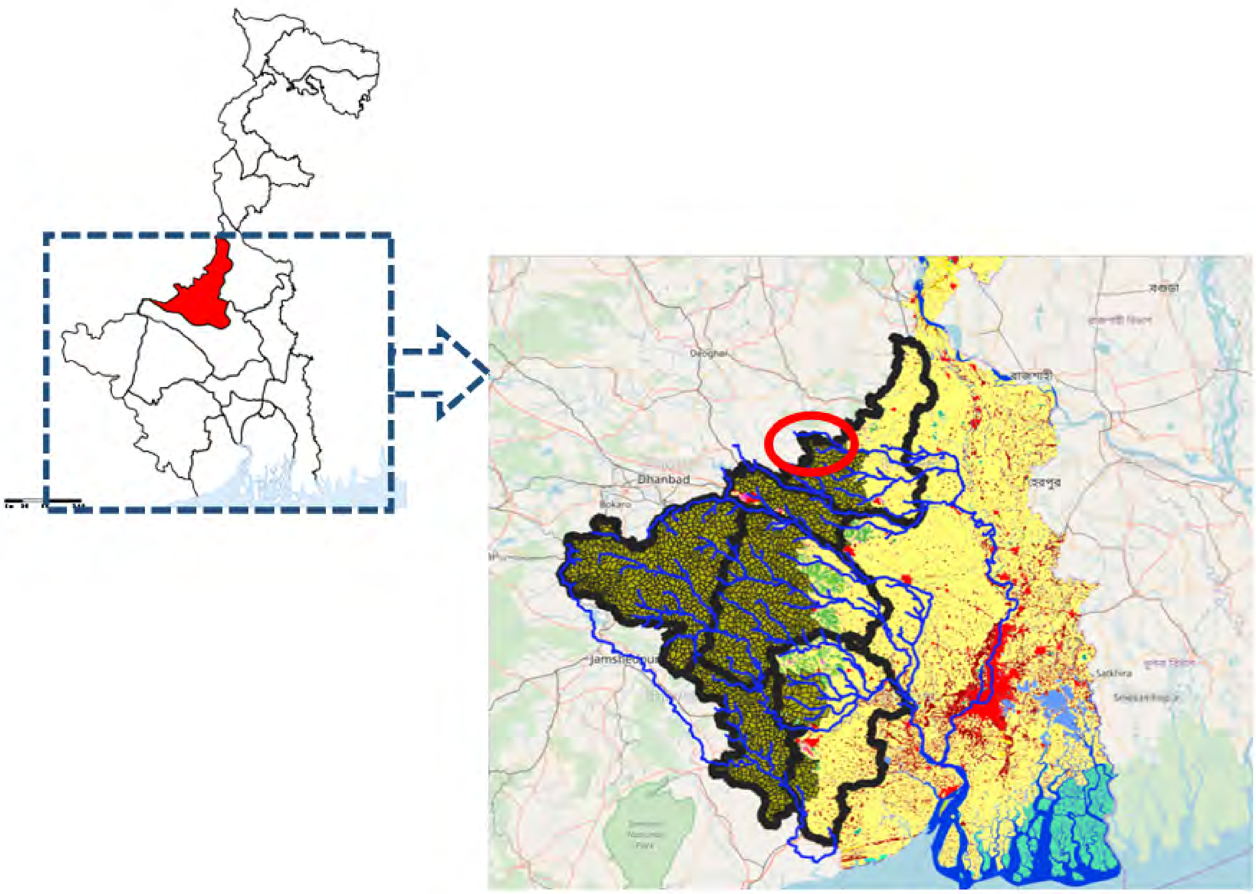
Major Policies and Legislations Governing Ground Water Resources in West Bengal	
West Bengal Ground Water Resources (Management, Control, and Regulation) Act, 2005	• Establishment of State Ground Water Resources Development Authority to regulate ground water with the help of district and corporation level authorities. • No ground water user shall sink wells without the permission of state level authority
East Kolkata Wetlands (Conservation and Management) Act, 2006	• This act is for the conservation and management of the East Kolkata Wetlands (EKW), spreading over 12,500 hectares in Kolkata and in the North and South 24 Parganas districts of West Bengal. The EKW Management Authority was created under this act to conserve the wetlands, make rules, enforce land use controls, and regulate all activities. Prior permission from the authority is required for any project activities in the notified area
The Bengal Irrigation Act, 1876	• This Act provides for construction, maintenance and regulation of canals for the supply of water from thereof and levy rate for water supplied through canals.
The Bengal Embankment Act, 1882	• The Act provides for construction, management and maintenance of embankments and water courses.

2.4 Locally appropriate solutions for groundwater management

2.4.1 The undulating Red Lateritic Zone of West Bengal - An overview

Western districts of West Bengal bordering to Jharkhand and Orissa are extension of Chota Nagpur Plateau. This region is characterized with undulating terrain prone to low soil depth and erosion. The annual average rainfall varies from 1200mm to 1400 mm, but due to the high runoff and low water harvesting provisions the area usually remains mono-cropped. Poor availability of water (both the surface and the ground) creates drinking and irrigation scarcity of the area. Groundwater here less explored and less defined, said to have the seepage lines pass through the permeable layers in between the hard rocks. The lithological analysis, on the other hand indicates the availability of the aquifer materials/shallow aquifers underneath, when the intensive exploration and participatory groundwater monitoring is done.

PRASARI in partnership with the state government of West Bengal under the MGNREGA scheme assessed static ground water level to plan the watershed activities more efficiently in the region. The team of PRASARI had set up a monitoring network of an area in Birbhum and Bankura district, where all the open wells are measured with their static water level (SWL) once in a month for a period of at least a year. For this study Gurujandihi Micro watershed was taken as sample. They took help of the local community representatives to measure and record the SWL of the selected area. The SWL-data are fed to a software which generates the ground water contours and the recharge and discharge zones for an area. Based on the ground water movement is indicated, in a scaled ground water contour map. Once the groundwater flow map is prepared, the same is superimposed on the Google map to exactly figuring out the plots to undertake the aquifer recharge activities, for an area.

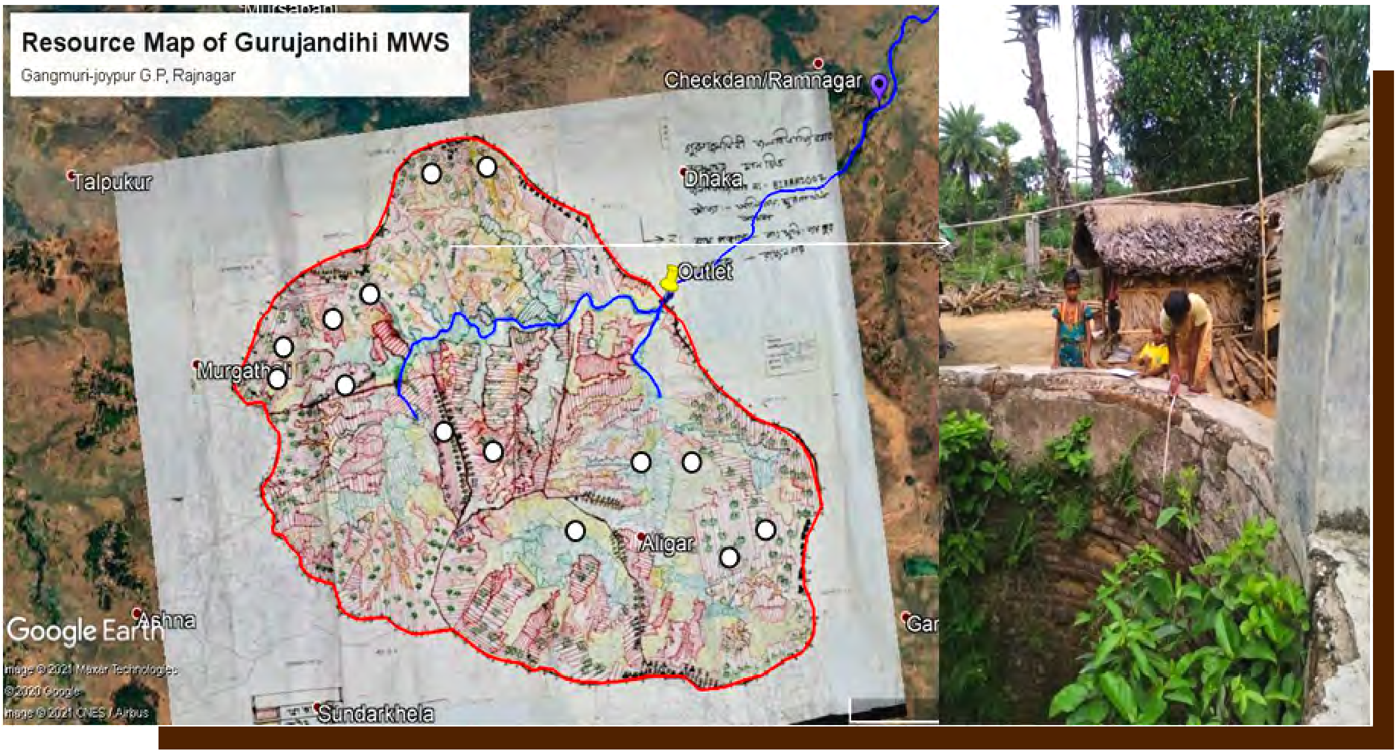


Watershed, traditionally undertake the soil and water conservation activities and categorically manages the surface runoff, within a given hydrological boundary. Measurement of the static water tables in the wells from a watershed area, is a very common and significant measuring indicator. This tracks the changes in the static water levels due to the recharge activities executed in the upstream. The experiment here has used the SWL, otherwise, not to measure the impact but to decide and strengthen pinpointing the recharge areas for the activities to effectively recharge the shallow aquifers and corresponding ground water sources, towards permanency.

<u>The intervention - Participatory Ground Water Management (PGWM)</u>

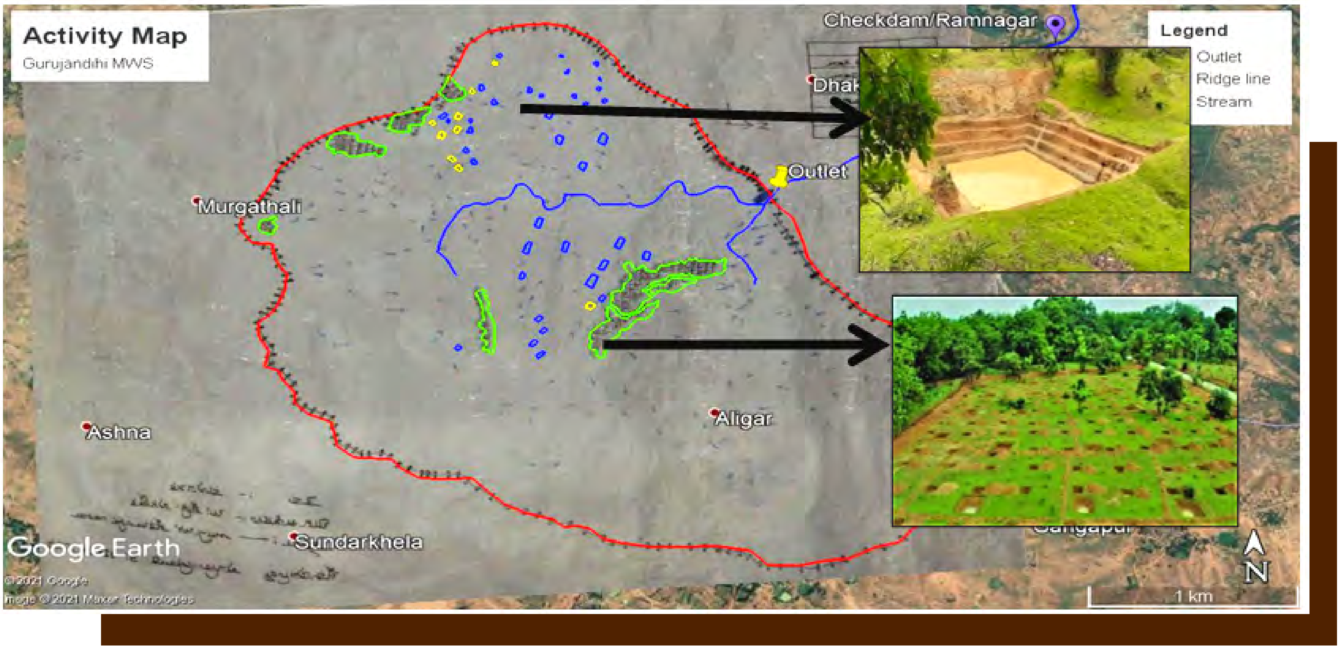
There are six tribal dominated villages in the selected micro watershed where women from the households have formed there institution called Women Livelihoods Committee (WLC) in the respective villages and have been trained and were involved from the very delineating of the watershed to plan the activities, executing them to create and monitor the assets. The WLC members here, along with all other villagers from the respective hamlets came up with the traditional watershed activity planning through the PRA exercises.

These planning exercises followed by the plot visits, resource maps for the watersheds are prepared on the pasted revenue sheets to form the scaled map for the watershed. The activities there after, are drawn on the respective plots/patches using a tracing sheet adhering to the resource map scale. The WLC members thereafter introduced with the concepts of participatory groundwater management (PGWM), aquifer and groundwater flow, recharge and discharge of and from the groundwater sources. Gradually they are introduced with the typologies of storage- confined and unconfined aquifers and the static water levels in the open wells. The participatory planning exercise set up the groundwater monitoring network of open wells for regular collection of the static well data at an interval of 15 days.



The SWL thus collected fed to a software to generate the groundwater flow diagram. The contours for groundwater have been generated and based on the flow directions, indicated the recharge and the discharge zones are identified. The groundwater contour map showing the zone, flow is converging into (here near the outlet region in the picture) is considered to be the discharge zone. The groundwater flow, always do not follow the same direction of the surface, as this has slightly differed in the present case. The groundwater contour maps, thus generated, are superimposed on the delineated watershed on Google map. A data set of at least three years prominently indicates the recharge and discharge zones with prominent ground water contours. The data above is based on last year's (2020-21) analysis and have been used for intensifying the recharge activities in the indicated zones of recharge within the micro watershed. Following two figures would typically explain the use of the mapped groundwater flow to plan the recharge activities.

As shown in the picture below, is a typical activity map of the Gurujandihi watershed adapting the principles of planning of the activities in the respective upland (water/moisture harvesting activities backed with the plantation work) depending on the willingness of the landholders in the up/medium or low land of the watershed. The activities are planned to arrest maximum water and to reduce the surface runoff.



Groundwater flow map in a sense in this experiment has worked as a decision-making tool to plan the spots for essential recharge activities. When the activity map of the Gurujandihi watershed has been reviewed with this tool, the WLC members too could identify, the significant areas in the recharge zones have been left out without any recharge measures planned. In the modified activity map, the watershed has been planned with more water harvesting structures in the private lands. This has been found a good chunk of forest land, too falls in the recharge zone, led to dialoguing with the Department of Forest and being granted with recharge activities in the forest lands of the micro watershed. The PGWM outputs were used to convince the forest land as well.

Another key finding, which could never be possible unless this exercise would have been done!! The recharge zone identified has shown some significant coverage of the homes and homesteads within the watershed area, where in-situ activities cannot be planned. The criticality, thus have been planned to addressed through point recharge techniques by adapting roof water harvesting system in the households located in the recharge zone. This has further strengthened the entire recharge plan.

The recharge activities planned hereafter are getting implemented using the MGNREGA fund. The convergences are also facilitated with the Department of Water resources and Tribal welfare Department for the drainage line structures and roof top rain water harvesting activities. A new intensification effort has been in place through other private funding to experiment and replicate the idea with more micro watersheds.

2.4.2 Springshed management in Himalayan West Bengal

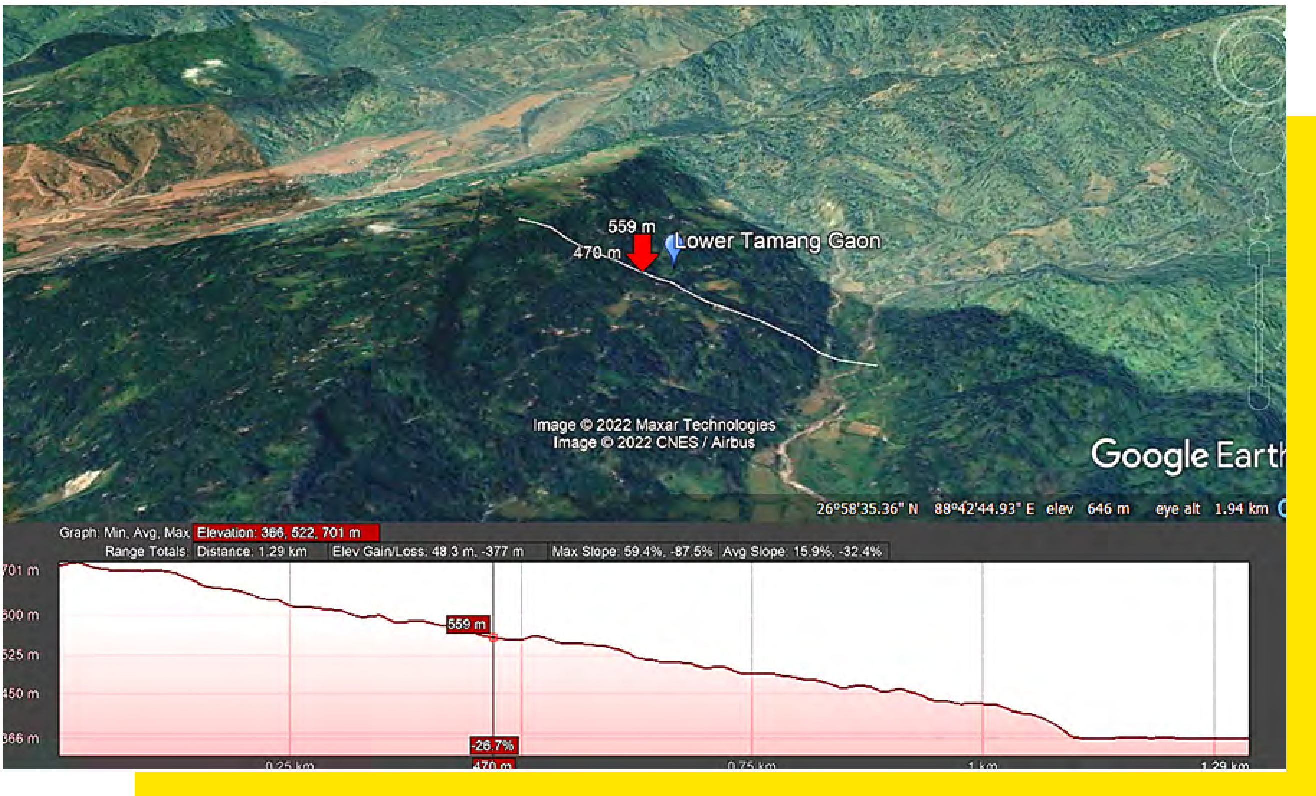
Springs are the sole sources of water in the Himalayas fed by the aquifers, underneath. The entire Darjeeling and Kalimpong districts and the portions of Jalpaiguri and Alipurduar districts of West Bengal survive solely on spring water. Compared to other parts of the state this Himalayan region of West Bengal receives more rain, yet water crisis is deep in this area especially from December to May every year.

The springs in the Himalayan West Bengal are having varied discharge pattern 1 lpm to 200 lpm; (lpm=litre per minute) and are major contributors to the lakes and rivers. These springs further provides water for domestic and agricultural use in the region. According to 2011 census over two million people in the West Bengal Himalayas are dependent on springs. The water crisis for these people is continuously increasing as many springs are drying across the region at a very rapid pace due to a combination of climatic and anthropogenic reasons.

Darjeeling and Kalimpong towns are available with only one fourth of its peak water demands for the months from December to May, when the 'water mafias' take the full control of 'water market' and the price goes up to the extent of Rs. 5 per litre, depending on the distance from the source and the delivery point. Situations are even worse in the villages. Agri-horticulture in the hills, is extremely dependent on the springs and coverage areas under the cropping is showing a reducing trend due to uncertainty in irrigation, and inability in attaining the peak market prices.

Aquifers, the water sources for the springs are recharged with the water infiltrates to the ground after precipitation. The last 100 years analysis of the rainfall data for the region has revealed that there is no quantum change in the total annual rainfall but the duration is reduced and has become more erratic. The denudation of the forest now has been coupled with the higher intensity of rainfall has increased the runoff and reduced the scopes for recharging the aquifers. Since, aquifers are not recharged to their full capacities, the discharge and duration of spring flows is reducing. This now desperately, needs the arrangement to facilitate water entry in the aquifers to save the springs and the entire water system of the Himalayan hills.

PRASARI has been working on spring rejuvenation in four Himalayan Districts (Darjeeling, Kalimpong, Alipurduar and Jalpaiguri) Of West Bengal. The Water Resource and Development Department of the GoWB is the formal partner in this initiative to pilot with 12-15% of the total springs in the West Bengal Himalayas. The state government invest in the spring rejuvenation through MGNREGA fund and PRASARI provides technical and social mobilization input in this entire process.



PRASARI has executed the spring rejuvenation successfully in Lower Tmang Gaon village of Kalimpong district. Lower Tamang Gaon village is small village nested in the slopes of Kalimpong Himalayas. All 21 households of the hamlet are engaged in agriculture and allied activities for their livelihoods. This village depends upon two springs for all of their water needs. Among these two, Simsar Dhara or SImsar Spring is the only perennial spring which provides water to the community for drinking and all other domestic needs. Over last few decades the villagers have observed significant reduction in the discharge of the spring, especially during the dry season.

In the words of Bimal Tamang, a resident of Lower Tamang Gaon- **"हम लोग इस सिमसर धारा का ही पानी पीते हैं , जब हम छोटे थे तब ऊपर पहाड़ में जंगल था , अब जंगल काम हो गया है और धारा में पानी भी बहुत काम हो गया है। अब यह पानी खेती किसानी के लिए पूरा नहीं होता है इसलिए हम खेती के लिए बारिश के पानी पर ही निर्भर रहते हैं। पानी की कमी की वजह से बहुत लोग खेती छोड़ रहे हैं , खास तौर से युवा लोग।युवा लोग काम की तलाश में सिलीगुड़ी या कोलकाता चले जाते हैं।"** This is evident that the reducing discharge was impacting the life and livelihoods of the 21 dependent households of the village in many ways. The situation was further worsened by the earthquake in Nepal in 2015 which impacted the local hydrogeological system and as a result spring discharge was reduced.

The initiative - Springshed Water Users Association (WUA)

PRASARI started working in this village in March, 2020. A village level institution, named Simsar Dhara Water Users Association (WUA) was formed comprising members from 17 willing households. An orientation about Springshed management and spring hydrogeology was conducted in a very lucid manner to ensure the community participation at every stage of the intervention. PRASARI follows a 'nine step methodologies' for any springshed management initiative which is as follows-

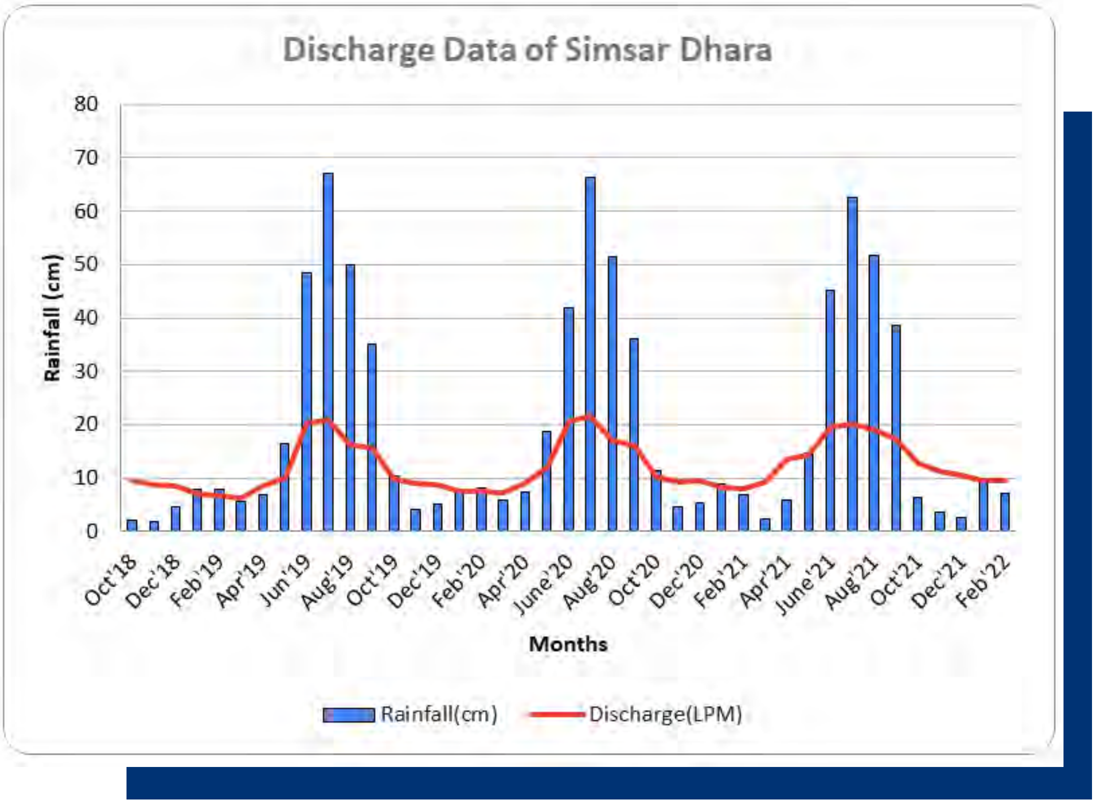
i. Formation and visioning of village level institution
ii. Selection of volunteer or Dhara sevak (para-hydrogeologist) by the community and Gram Panchayat
iii. Technical training of the Dhara sevak and community members
iv. Transact and traverse walk throughout the springshed area
v. Hydrogeological survey by Dhara sevak, supported by professional
vi. Coming up with conceptual hydro-geological map of the springshed
vii. Identifying the recharge zone (Gross recharge area) and workable area (net recharge zone= gross recharge zone - non workable area) and plotting on Google Earth
viii. Planning and designing possible recharge activities (combination of civil engineering measures and vegetative measures) and forming Detail Project Report including budget estimation
ix. Execution

*All these steps are followed by monthly discharge data collection which is a recurring process and carried out by the Dharasevak.

All these steps were conducted for this particular spring as well which helped to identify the recharge zone and plan different recharge measures. This also helped to identify the recharge zone which is the hydrological boundary above the spring line. Based on the land use, land cover and slop of the terrain appropriate recharge measures were designed.

The land use pattern in the recharge zone of 2 hectares played an important part while designing the structures. As most of the recharge zone was areca nut plantation so, not much of trenches were planned. Out of these 2 hectares nearly 50% of the area was workable and thus, strengthening the field bunds at the edges of terraces was planned. Along with the filed bunds in 2.5 acres 68 recharge pits were also planned.

The WUA with the help of Dharasevak and professionals from the organization executed the work of field bunds and recharge pits which cost a total of INR 3.18 lakhs. This amount was leveraged from the WBADMIP programme under the Jhora Rejuvenation-JR component. Apart from that, members from 18 households of the village contributed their labour work for treating the spring recharge area. This total execution phase took little more than 3 weeks to compete and the spring was ready to receive the monsoon of 2021. The Dharasevak from the village has been collecting the discharge data of the spring in every month.



The recharge intervention was done in the month of November, 2020 since then only one monsoon has been received by Simsar dhara. Previously, the spring used to rapid growth in discharge at the beginning of monsoon and it used to reduce significantly after the monsoon. Thus, the spring hydrograph of pre implementation phase shows quite steep slope before and after the monsoon. As it can be seen in the above hydrograph that in the last year, (2021) despite of similar rainfall like previous years the spring has got a stable discharge even to till date. The stable and steady discharge in the present dry spell has motivated the community to carry out more recharge activities in the rest of the recharge zone this year and they are hopeful to complete it before the upcoming monsoon which may result in positive change in the spring discharge on a sustainable basis.

2.4.3 Aquifer Storage and Recovery System (ASR) in the Sundarbans

In Indian Sundarbans based at the eastern coast line of West Bengal are a World Heritage site with over 2226 species in total coexisting with4.5 million inhabitants in 102 of its islands (Bhadra et al., 2018). Both wild and lives co-existing with human being were suffering moderate to severe at places for the dearth crisis of drinking water mainly due to overexploitation of the water resources in the region (Saha and Saha, 2020).In this area community use shallow and deep tube wells to draw water from ground, most of which, become inoperable due to drop in the ground water table from winter months to summer months. Along with this water scarcity, sodic salinity levels reach up to 16dS/m during the summer months from end of April to beginning of monsoon in early June (Burman et al., 2019).

The current practices, use of submersible water pumps, of the farmers degraded the static ground water table by 15-45ft at places. This further limiting the scope for any horticultural or agricultural crop cultivation during summer in the most of the parts of the region and creating critical drinking water crisis starting from the month of February each year. Additionally, Sundarbans is sinking as a result of alluvial soil settlement and rising sea levels, at a rate of 12mm per year since 2006 (Hazra et al., 2019). Moreover, rainfall was very heavy, increasing the region's vulnerability to tropical storms and tropical cyclones.

While the majority of people depend on agriculture, fishing, cattle rearing, and non-timber forest product gathering, they have lately faced severe fresh water shortages and have resorted to groundwater extraction, exacerbated the water crisis throughout the summer and winter months. This region gets moderate rainfall, between 1600 and 2000mm per year, and has 84 to 90 rainy days per year, resulting in year-round fresh water shortages for residential and agricultural usage. Moreover, in dry summer months with falling ground water tables, sea water intrusion occurs and at that time situation become even worse with the tropical cyclones which further worsen the access to drinking water.

This area was a jungle even 150 years ago and most of the people came as migrant labourer either for the British rulers or for the local Zamindars majority of them are now dependent on agriculture or allied livelihood vocations. Now in recent times that pressure on land has further augmented with growing population. Further, this had increased the crop demand and as a result it impacted the ground water demand in a negative way. In Indian Sundarbans fresh water supply was limited due to moderate monsoonal rainfall i.e., 1600-2000mm per annum continuously failing meet year-round fresh water demand for crops in the region. As a result, ground water abstraction became a regular practice by the farmers leading to severe water crisis during summer time.

Indian Sundarbans

Key points on water situation in Indian Sundarbans

- Around 80% of total annual rainfall in Sundarbans falls during the south–west monsoon season, providing sufficient water for Kharif rice cultivation;
- For many years, community residents have perceived a delay in the onset of the south–west monsoon, as well as a decrease in monsoon rainfall and warmer temperatures, all of which have a detrimental effect on agriculture and community life.
- Farmers in the area have been draining groundwater to irrigate land for the production of a second season of rice known as Boro rice, which they plant in the winter and harvest in the hot summer months, lowering the water table and limiting household users' access to water;
- When combined with declining trends in freshwater availability and a rise in water and soil salinity, this man-made strain on the groundwater supply results in what people refer to as a water crisis.

Aquifer characteristics of Sundarbans

The accumulation and movement of groundwater is a function of two basic 'hydrogeological' properties of rocks – the porosity and the hydraulic conductivity (commonly referred to as permeability). In simple terms, the porosity and hydraulic conductivity are properties of rocks, properties that broadly indicate the porous and permeable aspects of the rock. On the other hand, when aquifers are identified and described, it becomes necessary to gauge the storage capacity and the transmission capability of an aquifer. The coefficient of storage (storativity) and transmissivity define the storage and transmission functions (capacities) of an aquifer. Pumping tests constitute the most straightforward methodology for estimating the storativity and transmissivity of aquifers.

In order to understand that pumping tests were performed on pre-selected tube wells to obtain estimates of T and S values to gauge aquifer properties, understand their variability across and within aquifers While conducting systematic long-duration pumping tests is extremely challenging in areas where there is perpetual groundwater pumping, farmers in the villages co-operated enough to make this possible. However, much as one would have liked, not all pumping tests could be conducted for equal durations. PRASARI used its own automated water-level loggers (pressure sensors) to record water levels during each test; discharge rates were measured according to PRASARI's standard pumping test protocol.

The data obtained from pumping tests was used to calculate the aquifer parameters and the specific capacity of individual wells. Various methods of analysing pumping test data are available. The purpose of conducting pumping tests, in this case, was not to arrive at very precise estimates of T and S, but to make a good comparison of these values across the study area. Three methods were used to estimate aquifer and well characteristics. The *Cooper-Jacob method (1964)* was used to estimate T and S.

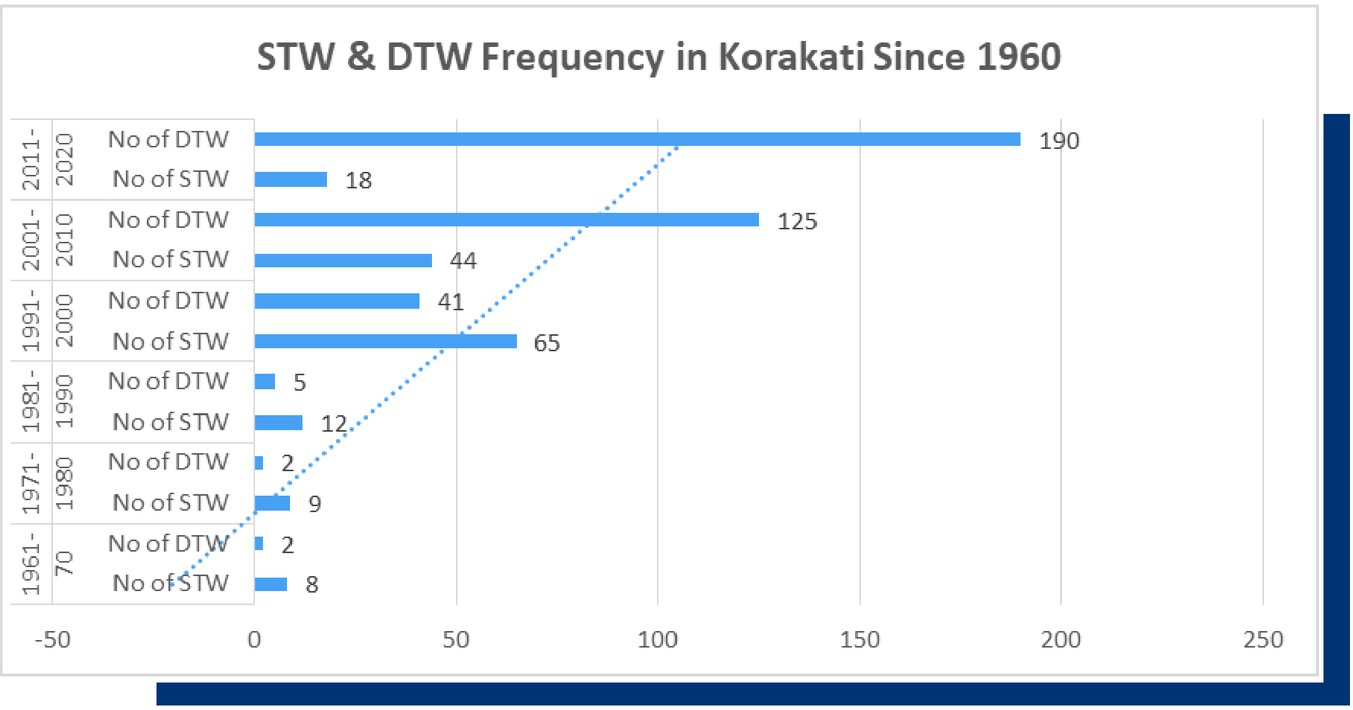
PRASARI has conducted many pumping tests in the area to ascertain aquifer parameters like transmissivity and storativity. Table below summarises these estimates by providing ranges of values (where they tend to vary) or specific values. Aquifer is showing good transmissivity (273 – 308 m2/day); which means, the aquifer can release water to wells at this rate across a unit cross sectional area per unit time and storativity indicates that the aquifer can store 10.5% water out of its total volume.

Transmissivity *(m2/day)*	Stortivity
273 – 308	0.105

Socio-hydrogeology of the Sundarbans

Korakati GP area consisting of three revenue villages of Korakati, Tushkhali and Duchnikhali is part of the Sandeshkhali II block of 24 North Parganas district of West Bengal. The hamlet has been chosen for convergence of different government programmes for beneficiaries consisting of tribal people from the area. This community has also been chosen for the Participatory Groundwater Management activities in the region to understand problems related to groundwater and water in general, research local hydrogeology, monitor rainfall and chosen tube-wells from the area to understand groundwater movement and map aquifers and perform water quality testing. The goal underlying all these efforts is to arrive at an educated knowledge of groundwater dependence and issues in the community and come up with a management plan targeted at fair distribution of this common pool resource and guaranteeing sustainability of the same.

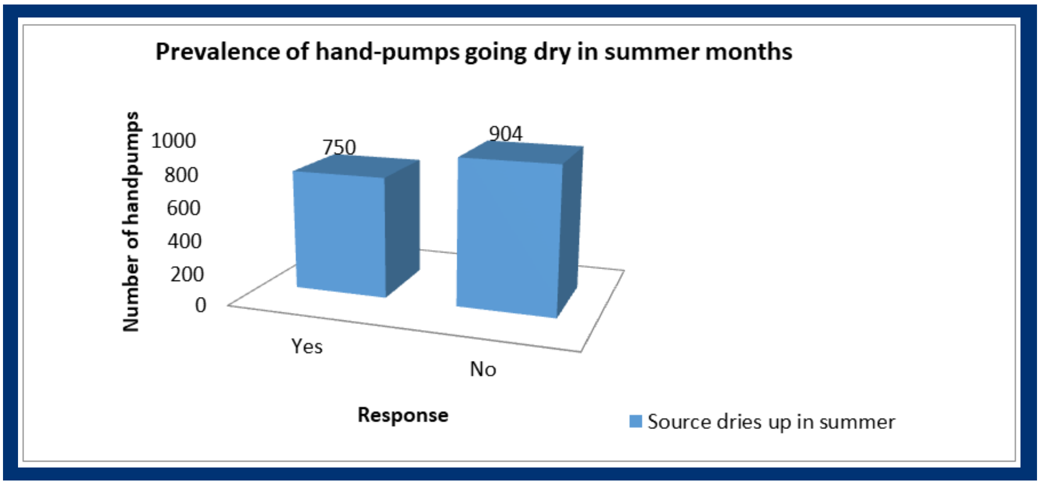
The comprehensive survey was performed by the team members of PRASARI and the local community resource people and the main data was gathered. From the FGDs that PRASARI organized in the community identified how the frequency of deep tube-wells (DTWs) has increased since the beginning of the new millennium and how the frequency of Shallow Tube-wells (STWs) declined in that period.



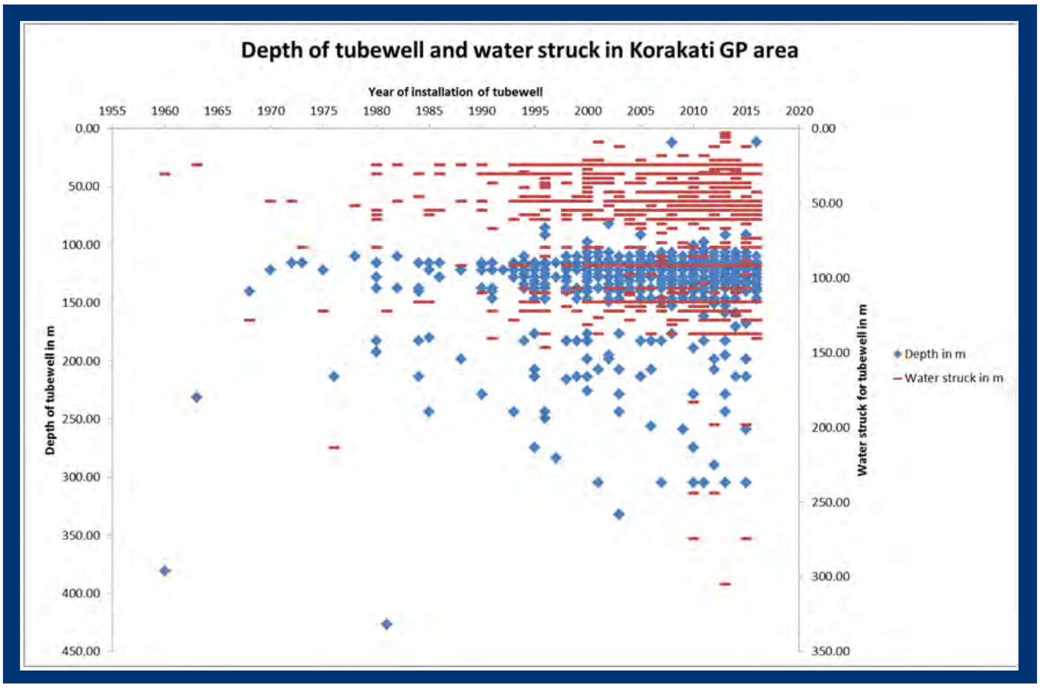
Participatory mapping of Irrigation Tube-wells

The graph depicts the increasing trend of shallow and deep tube-wells in the Gram Panchayat area for crop cultivation as well as for drinking water purposes. It can be observed that about 190 tube-wells were constructed for this purpose from 2011-2020 while the percentage of DTWs are on the rise. This rate of development is alarming and poses a threat to the local water security since both the uses predominantly source water from a single aquifer system i.e., the 340-420 feet aquifer. The members of the community reported hand-pumps from this depth going dry during summer as shown in the above-mentioned figure.

Detailed interview with some farmers was conducted during our interaction through a semi structured interview schedule. It was informed that the irrigation tube-wells are being pumped for a period of 3 months from January to April mostly for cultivation of rice which is the dominant crop grown in the area. The tube-wells are pumped for 10-12 hours daily, which amounts to about 1000-1200 hours of pumping from a single such tube-well. Nowadays good quality submersible pumps are set at the depth of 350-420ft depth in order to harvest water from the second or third aquifer. These are electric pump-sets and waters were often shared between farmers at an agreed price (1200/- per bigha of Boro paddy cultivation).



Participatory mapping of hand pumps gone dry in the summer months



Depth of tube-well in the study area

Groundwater development in Korakati GP area

Above figure depicts the development of groundwater in Korakati Gram panchayat. It is evident from the graph that there has been tremendous development of groundwater sources in the last decade and a half. This development has mostly been privately sourced. Many of these sources are being increasingly used for irrigation purposes.

Drinking water situation

Groundwater is used extensively in the region for drinking and household purposes. During one conversation, it was estimated that the Gram Panchayat had between 1500 and 1800 private tube wells and about 200 government tube wells. There are no dug-wells in the immediate vicinity. One of the explanations given by the residents was that the water at shallow depths is salty and therefore unfit for human consumption. Nonetheless, ponds may be found throughout the Gram Panchayat territory. Because the water in these ponds is salty, it is not suitable for drinking but is utilised for other household purposes. People do not treat tube-well water prior to consuming it, and therefore consider it to be of high quality. Gram Panchayats are in poor health when it comes to sanitation. Only 35-40% of homes in the Gram Panchayat have access to toilets, and many of them are seldom or completely inoperative. However, the Gram Panchayat was declared as Nirmal Panchayat years back.

In one of the Mouza (revenue village) Korakati, a 'Jal Swapna' under Public Health Engineering Department's water supply system was built in 2018 at 1300-1400ft depth by boring which supplies domestic water to the Mouza's individual homes and clusters through pipe water supply. Most of the homes are now fetching water from the taps but also maintaining irrigation and drinking water tube-wells as alternative sources for natural calamity.

Agriculture water situation

Tube-well reliance for drinking water is being questioned as more tube-wells are being sourced for agricultural reasons. Paddy is the area's only crop. It is consumed twice a year, during the monsoon and throughout the winter. Winter paddy, on the other hand, needs considerable irrigation, which is provided by these tube-wells. These tube-wells are equipped with three- to five-horsepower pumps. Centrifugal pumps are utilised, not submersible pumps. There are about 500 tube-wells being utilised for irrigation reasons at the moment, according to information gleaned from local conversations. In the hamlet, feeder separation has been accomplished, and an irrigation power schedule is being followed. While the area under winter rice cultivation is restricted at the moment, an increasing number of individuals are installing shallow tube wells in order to grow an irrigated winter crop. According to reports, the Tushkhali Mouza has the most irrigation infrastructure among the three revenue villages.

The region's perceived groundwater issue is the depletion of water in these tube wells from February to March each year during the last several years. The rise in area under winter agriculture, the growth in the number of tube wells, and the reduction in rainfall are cited as causes for the region's groundwater depletion. The area's in-situ water quality is poor; salinity and total dissolved solids levels are slightly over the permitted range. Additionally, the iron content exceeds acceptable limits in a variety of hand pumps and tube-wells.

The study in the Sundarbans

This research was conducted in collaboration with water users and other relevant stakeholders to get a better understanding of the water situation in the Indian Sundarbans, both quantitatively and qualitatively (over a period of time per se). The methodology used was following the exploratory design and participatory in nature, which the research team capacitated community to use.

Barefoot hydrologist didis were used selected handheld data collection devices such as salinometers, GPS devices, and field kits to test for bacterial contamination in order to establish the relationship between surface and ground water disconnections, as well as the relationship between water abstraction and water quality (both surface and ground water) parameters collected in the field by barefoot hydrogeologists as part of our exploratory research design utilising a participatory ground water management approach.

Ensuring participation is very crucial for successful understanding of the groundwater dynamics and planning activities for the same. In this connection a participatory data repository along with community data sharing platform was created with water users to regulate and maximize optimal use of fresh water. Simulated model on artificial recharge in this regard shows monsoonal rainfall in Indian Sundarbans was sufficient to generate alternative water source option for the region during summer and winter season.

We argue that our empirical findings demonstrate that BFGs have been implemented with adequate consideration of (1) the static ground water table and its relationship to surface water uses, and (2) the 'overexploitation' effect on ground water, such as a reduced static ground water table and an increase in salinity over time, as evidence of how ground water quality can be impacted over time as a result of water table degeneration.

Revenue village	GW Dependence	GW occurrence Depth levels	GW related issues
Duchnikhali	Irrigation + Drinking water	1200 ft, 600 ft, 400 ft	Drying up of tube wells during summer months
Tushkhali	Irrigation + drinking water	1150 ft, 600 ft	River embankment, GW competition
Korakati	Drinking water	450 ft	No issues reported

Ground Water Balance

Order	Particular	Year
A	Year of calculation	2021-22
B	Potential aquifer storage	3465 mm
C	Actual aquifer storage	2100 mm
D	Total groundwater abstraction through pumping	408,25,920 Cum

To get a quantitative knowledge of aquifers, both the inputs (recharge) and outputs (discharge) from the aquifer must be quantified (Harvey et al., 1995). Due to the fact that assessing the groundwater balance of a restricted aquifer using the water level fluctuation technique is not feasible, additional variables such as aquifer storage and total groundwater abstraction have been calculated. Aquifer storage has been estimated using the aquifer's thickness and storativity. The aquifer's storativity value was determined via pumping tests. There is a significant gap between potential and likely aquifer storage, which may be closed by expanding groundwater augmentation initiatives.

Projected outcome from Aquifer Storage and Recovery System (ASR)

Aquifer storage and recovery (ASR) is a way of managing water resources to meet existing and future freshwater demands. It is the direct injection of surface water supplies such as potable water, reclaimed water (i.e. rainwater), or creek water into an aquifer for later recovery and use. In this case we are supposed to use the reclaimed water method and want to store it in the saline aquifers using the injection method and extraction through well. This rainwater ASR is supposed to help to keep the rainwater within an area. ASR water can be used for any purposes but in this project we are considering agricultural purposes only.

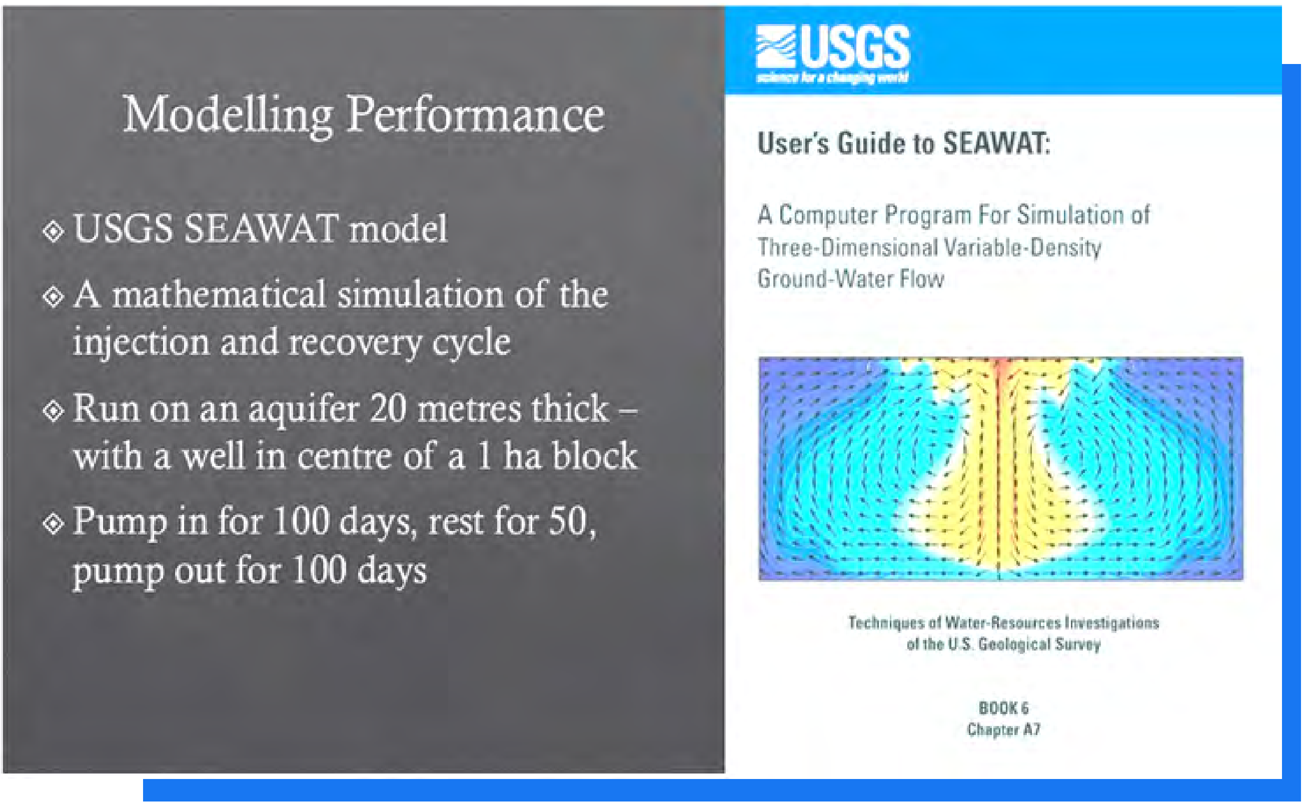
Cooper Jacob expression used to calculate groundwater mounding over a 100 day injection period in Indian Sundarbans and the following graph was generated for different Q value and injection rate.

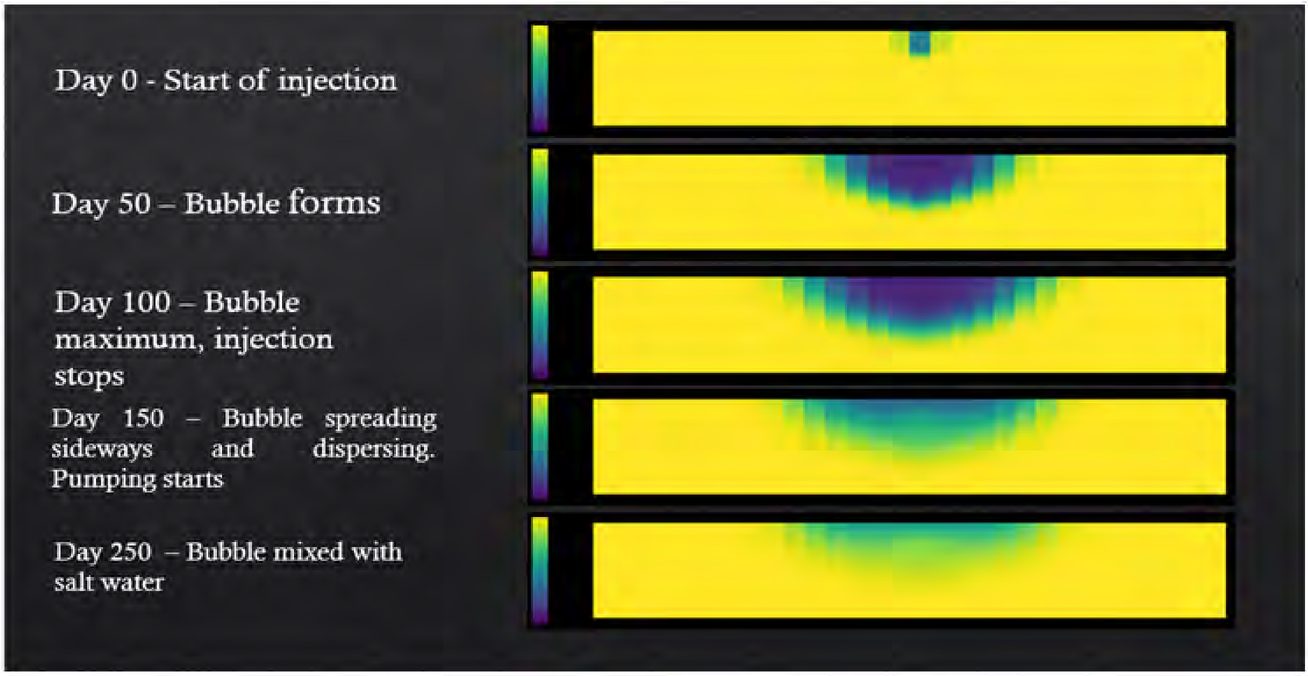
$$h_w - h_o = \frac{2.3Q_D}{4\pi T} \log \frac{2.25Tt}{r^2S}$$

Range was taken between:0.1 to 2.3 l/sec
Preferred values of T (Transmissivity) & S (Storativity): T = 200 m2/day; S = 0.0001
Max Pumping Rate (Q): 2 l/sec; 10 m3/day

Simulated model of ASR for Indian Sundarbans

Injection rate at different depth in the ground of Indian Sundarbans





Is it feasible to implement ASR on Sundarbans?

Performance of an ASR system is complex and depends on aquifer properties, water qualities and fluid-rock interactions all of which can greatly affect ASR system performance. We have gone through following four stages:

i. Conceptual modelling of aquifer system (developed through PGWM), quantifying depths and aquifer properties,

ii. Project specific field data collection gathering data on the lithology and chemical isotopic analysis with purposive sampling considering salinity and depth into account. Analytical assessment for system operation using the data gathered in stage 'i' to confirm the feasibility the system as designed and test its sensitivity to range of aquifer properties with economic feasibility check. In the stage

iii. Numerical modelling- SEAWAT Model was used to simulate system performance over repetitive injection and abstraction cycles.

iv. As a result, in this study we have gathered as much lithology data possible to generate through first hand data collection method and validate the same through participatory aquifer storage and recovery management to run solute-transport groundwater modelling; required to predict how stored water will migrate over time, given different conditions and how saline aquifer properties will affect the quality of stored water.

It has been well-demonstrated, by model generated using Jupyter Notebook (in Python), that ASR systems can provide very large volumes of storage at a lesser cost than other options in Indian Sundarbans. The challenges moving forward are to field test the success of ASR systems, optimize system performance, and set expectations appropriately.

3 Lessons from the fieldwork in West Bengal – The eightfold path

This is a multi-state study of locally appropriate solutions of groundwater management to draw policy lessons from them. In each state, we found exceptional work at micro level ensuring sustainable, efficient and equitable management of groundwater resources. Based on our findings from ten different states, we have developed eight principles which can guide our policy formulation and actions on ground. This section attempts to describe this eightfold path in the context of West Bengal.

3.1 Need for a new approach to achieve sustainable, equitable, efficient use

West Bengal cumulatively receives about 1851.4 mm rainfall every year. However its high uneven distribution leads to extreme weather conditions in the state. According to data published by India Meteorological Department, 30% of the rainfall it receives is from the south west monsoon in July month. The August month gets 26% of the south west monsoon rainfall. June and September month receives 22% of south west monsoon rainfall. In total around 77% of annual rainfall it receives is during the southwest monsoon i-e June to September.

The high amount of rainfall in the state provides for a good amount of surface and ground water resources for various uses. The dynamic ground water report published by the Central Ground Water Board reveals that cumulatively the state has net 27.46 billion cubic meter ground water for various uses. The state withdraws nearly 11.65 BCM every year, which is roughly 42% of the net ground water availability. In terms of ground water development out of 341 blocks in the state, 37 blocks and semi-critical and 1 block falls in the critical category as per the CGWB norms. However, the quality of groundwater is a serious concern in the state. The salinity in the delta region and fluoride, iron, nitrate and arsenic contamination in other districts is a serious cause of concern. The uneven distribution of precipitation along with highly diverse hydro-geological formation of the state provides for differentiated regional potential of groundwater recharge and withdrawal. In such conditions, locally appropriate approaches for groundwater recharge and withdrawal is important.

3.2 The efficacy of participatory data collection

Ground water development is a 'People's programme'. Therefore, education and involvement of people in its management projects including development, conservation, protection and augmentation will be the prime requisite to protect resources against quality degradation and guarantee quality assurance. The study of locally appropriate solutions for groundwater management in West Bengal reveals that capacity development of barefoot engineers especially in western and northern parts of the state helped people to manage their water resources more efficiently. The example of participatory exploration of availability and quality of groundwater resources helped people to understand their challenges and motivated them to take action.

The watershed management activities in Chotanagpur region carried out by PRASARI is a great example of participatory management of groundwater management. The organization has developed a cadre of women to collect field data and interpret that in order to develop plans with the community for demand-supply balance.

3.3 Understanding the prevailing policy framework and using it beneficially

Policies have a crucial role in regulating and managing natural resources to ensure sustainable usage and equitable distribution of benefits. West Bengal has enacted the Groundwater Resources (Management, Control and Regulation) Act, 2005. This legislation provides for the establishment of the State Groundwater Resources Development Authority to regulate groundwater with the help of district and corporation level authorities. Apart from this crucial law, the state has laws such as the Kolkata Wetlands (Conservation and Management) Act, 2006 to conserve wetlands in Kolkata, North 24 Pargana and South 24 Pargana districts of the state. Moreover the state has a long history of legislative regulation of water resources such as the Bengal Irrigation Act, 1876 and the Bengal Embankment Act, 1882. It is important to understand these policy frameworks and use them for the benefit of common people.

3.4 Whistleblowing in the face of non-Implementation of laws and regulations

Once the community is involved with collecting the data and understands the prevailing policy, laws and regulations, it can become a watchdog against any violations. Moreover, demands can be raised for more appropriate laws and policies. Like in many other parts of the country, concerned individuals and institutions have been raising voices against non-implementation of existing laws. India has updated its national water policy in 2012 that has set new priorities. West Bengal has yet to update its state policy in accordance with prioritises highlighted by the national policy. Such concerted effort and voices from people would strengthen policy discourse leading to better management of groundwater resources in the state.

3.5 Planning for balancing demand with supply

The cumulative net annual groundwater availability of West Bengal is 27.46 BCM out of which the state draws 11.65 BCM every year. This leads to cumulative groundwater development in West Bengal about 42%. Yet 37 blocks in the state are in semi-critical and 1 block is in critical stage in terms of groundwater draft. To ensure sustainable use of groundwater resources in every part, more localized solutions are required.

Moving from conservation oriented development to managing the use, the community demonstrated the capacity to work on both the supply side management options and demand side management strategies. By studying the provisions under the law, and using it for developing water resources in the aquifer, communities can move towards sustainable water governance. Various examples of locally appropriate solutions documented in this study shows that people have developed solutions based on local hydrological and geo-hydrological situations. For example, micro watershed activities in the Chhotanagpur region of West Bengal by PRASARI have enhanced water availability by creating more water harvesting structures. The region receives around 1200mm to 1400mm precipitation every year, but due to high runoff, farmers in the region are only able to harvest one crop.

Enhancing water conservation capacity in six villages by a joint program of PRASARI and the state government has significantly improved the availability of water in the region.

3.6 Enhancing supply by groundwater conservation and recharge

To reduce disparity in terms of availability of groundwater, effective management of water resources is important. The intervention of PRASARI in association with Government of West Bengal related to spring rejuvenation in Darjeeling and micro watershed management in the region of Chhotanagpur region are good examples of enhancing availability of water for longer duration. The intervention in Darjeeling involves civil engineering and vegetative measure to rejuvenate springs. In the very short period after the treatment, it has been observed that despite normal rainfall in 2021, treated springs produced stable discharge throughout the year.

3.7 Rationalising demand for water by rationalising prices for crops and energy

India has 18% of world population, having 4% of world's fresh water, out of which 80% is used in agriculture. India receives an average of 4,000 billion cubic meters of precipitation every year. However, only 48% of it is used in India's surface and groundwater bodies. A dearth of storage procedure, lack of adequate infrastructure, inappropriate water management has created a situation where only 18-20% of the water is actually used. India's annual rainfall is around 1183 mm, out of which 75% is received in a short span of four months during monsoon (July to September). This results in run offs during monsoon and calls for irrigation investments for the rest of the year.

Examples documented in this report shows that wherever the supply of the water has increased due to locally appropriate solutions, the agricultural productivity has also increased. In many cases farmers have started harvesting two crops in a year. Such developments are really good, but it is necessary to rationalize demand to ensure sustainability of demand and supply of water. Moreover, pricing of energy and water is an important factor to ensure sustainability.

3.8 Building capacity of the community for the above functions is a must

It is very clear that the 'one size fits all' approach is not going to solve the problem of groundwater. Every step from groundwater recharge to the utilization of water has deep social, economic, geological, hydro geological and geo morphological underpinning. Therefore, it is necessary to understand physical and social sciences in each region to experiment locally appropriate solutions for groundwater management. Moreover, this exercise cannot be done without building capacities of the community. It is worth mentioning here that all successful interventions documented in this study have attempted to develop the capacity of people. PRASARI developed the capacities of community leaders such as Dhara Sevak in North West Bengal and Barefoot hydrologists (Didis) in the region of Chotanagpur and Sundarbans. Moreover, they attempted to mobilize and organize communities in all regions to ensure true participation of people.

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