Groundwater Management in India

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

Rajasthan State Report

August 2022

RAJIV GANDHI
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Contents

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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. 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.

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[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 Project

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 studied state documenting such locally appropriate solutions.

1.4 Lessons from the Fieldwork in Rajasthan – 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 Rajasthan.

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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

1.4.1 Need for a New Approach to Achieve Sustainable, Equitable and Efficient Use

Rajasthan receives much lower rainfall compared to the other parts of the country. In 2019 the average annual rainfall of the state was 665mm, which was 29.5% more than the normal annual rainfall.[4] The state receives 90 % rainfall from the southwest monsoon from June to September. The winter rainfall is meagre. The state has a fairly mature topography developed during the long period of denudation and erosion. The present physiography and landforms are greatly determined by geological formations and structures and is the product of the past fluvial cycle of erosion and the recent & continuing desert cycle of erosion.

Out of the total rainfall, a sizable portion is in the beginning of the rainy season which is mainly used for building the soil moisture and is also lost to evaporation because of the arid conditions. The amount infiltrating through the soil mass to contribute to ground water storage is of the order of 5% to 7% in areas underlain by hard rocks and 10% to 15% in alluvial areas. Management of groundwater in such a highly water scarce part of the country requires extra effort to sustainably manage the groundwater resources.

1.4.2 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 Rajasthan reveals that most of successful grass root initiatives have deep rooted social and cultural underpinning. Initiatives like 'Par' 'Pal-Pokhar' and 'Johad' are traditional systems of rain water harvesting and groundwater recharge. These initiatives have a strong element of people's participation. Other studied initiatives in the state include watershed management, water-bank, rooftop rain harvesting and Bhujal Jankar are also deeply influenced by the idea of people's participation to collect data, participatory analysis of data and common decisions.

1.4.3 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. Rajasthan has enacted a number of legislation in recent time to regulate water resources and incentivize rainwater harvesting. Major legislations enacted by the states include the Rajasthan Water Resource Regulatory Act, 2012 and the Rajasthan River Basin and Water Resources Planning Act, 2015. Moreover, the state had adopted a state water policy in 2010. To regulate the groundwater resources, the state had drafted The Rajasthan Ground Water Management Bill in 2006. However, it is still in draft form. It is important to understand these policy frameworks and use them for the benefit of common people.

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[4] https://www.moes.gov.in/sites/default/files/RS-English-165-03082021.pdf

1.4.4 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. Rajasthan has yet to update its state policy in accordance with prioritises highlighted by the national policy. People have to also voice for enactment of the Groundwater Management Bill which was drafted in 2006. This law can pave the way for effective management of groundwater resources.

1.4.5 Planning for Balancing Demand with Supply

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, 'Par' initiatives are developed in western part of the state where storing water in deep aquifers is not a viable solution. Similarly Pal-Pokhars are adopted in eastern part of the state where run-off is high due to steep hills. Such planning is highly important to ensure balancing demand of water with supply.

1.4.6 Enhancing Supply by Groundwater Conservation and Recharge

A well designed and effectively implemented watershed project in Udaipur district documented in this report shows that in the Jhabla watershed concerted effort of donor agencies and local NGOs helped to increase groundwater level tremendously. Compared to 2011, in 2017 all six wells monitored in the watershed observed significant rise in the water level. Similarly the roof rainwater harvesting in Alwar district shows that the intervention has ensured conservation of 5200 cubic meter water in the sub surface by just 20 roof rainwater diversions. Other examples listed in this document from other parts of the state are also effective ways to enhance the supply. Such enhancement of supply is highly important in states like Rajasthan where the annual precipitation is abysmally low compared to many other parts of the country.

1.4.7 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. Rajasthan has Rajasthan Water Resource Regulatory Act, 2012 that provides for fixing of water charges. Effective implementation of this legislation is crucial to ensure effective planning.

1.4.8 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. Organizations promoting traditional systems of rain water harvesting in Rajasthan have also attempted to revive traditional and cultural knowledge related to rain water harvesting to enhance capacities of villagers. The program intervention of Bhujal Jankar is aimed to further improve the capacity of selected villagers to understand hydrology and geo-hydrology of the region to plan effectively with the help of fellow villagers.

2 Rajasthan State Report

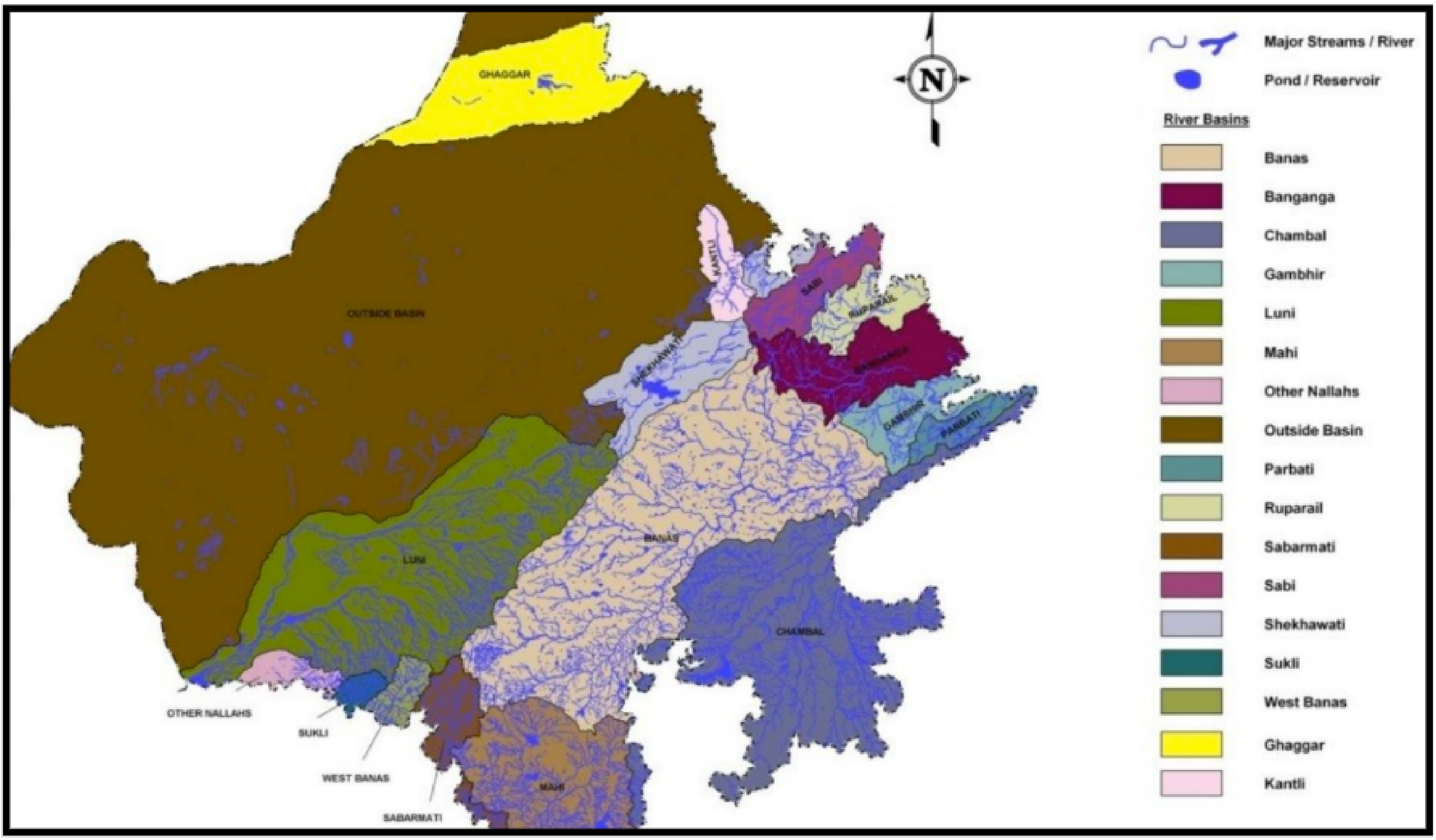
2.1 Context and Key Features

The State of Rajasthan comprising of 33 districts (236 blocks) has a geographical area of 3,42,239 square kilometre. It is situated between north latitudes 23°03′ and 30°12′ and east longitudes 69°30′ and 78°17′.

The state has a fairly mature topography developed during the long period of denudation and erosion. The present physiography and landforms are greatly determined by geological formations and structures and is the product of the past fluvial cycle of erosion and the recent & continuing desert cycle of erosion.

Different regions of the state and their characteristics

The Aravalli Hill Ranges from the main water divide in Rajasthan. Luni is the only river west of Aravallis. In the remaining area of western Rajasthan comprising about 60% of the geographical area of the state, the drainage is internal, and the streams are lost in the desert sands after flowing for a short distance from the point of origin. In the east of Aravalli ranges, the main rivers are Chambal, Banganga, Banas, Sahibi, Kantli and Mahi.



Drainage map of the Rajasthan state

- Luni itself essentially is an ephemeral stream with flood cycle of 16 years. Drainage in western Rajasthan is towards west and south - west.
- In the east of Aravalli ranges the main drainage is towards north - east. The other important catchments include Yamuna-Ganga in the north east, Mahi and Sabarmati in the south west with flow towards south. The former three catchments support perennial rivers.
- In the northern and north-eastern parts of eastern Rajasthan, the Banganga, Barah, Sota, Sahib and Kantli rivers are of inland nature.
- The drainage in the whole of Rajasthan is generally dendritic.
- In the desert area a few salt lakes and depressions exist, prominent among them being theSambhar Lake, Didwana Lake, Bap, Pachpadra and Rann of Jaisalmer and Pokhran.

The average annual rainfall of the State during the period 2019 works out to be 829.4 mm.

Climatically, the year in Rajasthan can be divided into three major conventional seasons with two sub seasons in cold-weather Season:

- The Hot- Weather Season (March to end of June)
- Monsoon Season (End of June to September)
- The Cold- Weather Season (October to February)
    - o The season of retreating monsoon (October to December)
    - o The cold season (January to February)

Rajasthan receives much lower rainfall compared to the other parts of the country. Out of the total rainfall, a sizable portion is in the beginning of the rainy season which is mainly used for building the soil moisture and is also lost to evaporation because of the arid conditions. The amount infiltrating through the soil mass to contribute to ground water storage is of the order of 5% to 7% in areas underlain by hard rocks and 10% to 15% in alluvial areas.

The normal annual rainfall of Rajasthan is 549 mm. However, during the period from 2010 - 2018, highest average annual rainfall of the State occurred in the year 2011 and lowest in the year 2017. The average annual rainfall (2019) is 29.5% more than the normal annual rainfall. Rainfall is the major source of ground water recharge in the state. The state receives 90% rainfall from southwest monsoon from June to September. The winter rainfall is meagre.

The hot weather season commences in the month of March and continues through April to June. In the month of May the diurnal range of temperature increases more and the day become hotter. During June the mean maximum temperature reaches as high as 48^{0}C. January is the coldest month. The normal minimum temperature (in January) range from 2^{0}C to 7.8^{0}C in the southern part of the state. At Mount Abu (1195^{0}m AMSL), temperature dips to freezing point during the month of December/January. In eastern Rajasthan the range of normal minimum temperature (January) in and around the Aravalli hill ranges is 7^{0}C to 8^{0}C which increases towards the east and attains a high of more than 10^{0}C in the districts of Kota and Bundi.

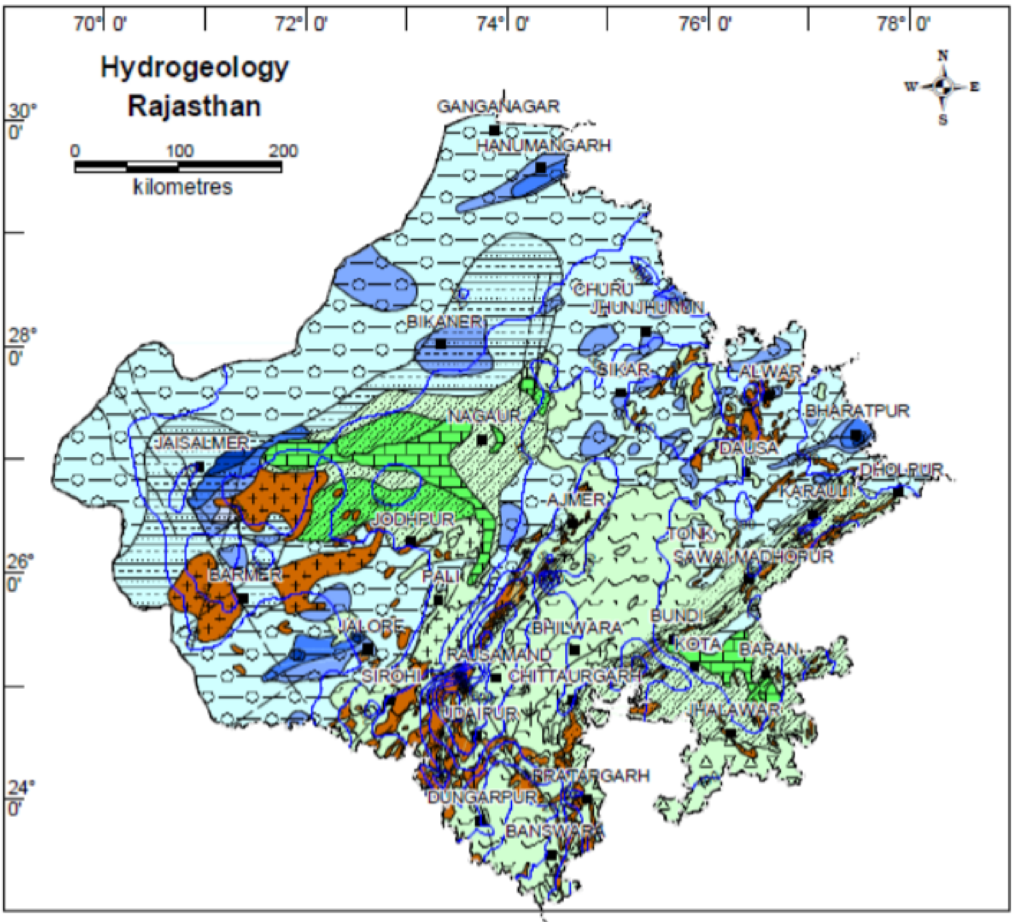
Geological Conditions

Diverse rock types ranging from the oldest Archaean Metamorphics to Sub-Recent to Recent alluvium and wind-blown sand are exposed in Rajasthan. However, in a major portion of the area, particularly in Western Rajasthan, the older rocks lie concealed below a cover of alluvium and blown sand. The State in underlain by hard rock (nearly 40%) consisting of the Archaean crystalline (Bhilwara Super Group), Proterozoic rocks comprising Aravalli and Delhi Super Groups, Erinpura Granite, Malani volcanics and plutonic suite of rocks and their equivalents, Marwars, Vindhyans and Deccan Traps. The soft rocks include the alluvium and the blown sand, which occupy the major portion in the remaining part of the State. Diverse rock types ranging from the oldest Archaean rocks to sub- Recent alluvium and wind-blown sand are exposed in Rajasthan. In a major portion of the area, particularly in western Rajasthan, the oldest rocks are concealed below a thick cover of alluvium and windblown sands.

Hydrogeology

The principal source of recharge to ground water in Rajasthan is rainfall. In canal irrigated areas, a part of canal water through seepage from conveyance system and part of water i.e. utilised for irrigation also returns to ground water and contributes to storage. The State can be divided into three hydro-geological units namely, **unconsolidated sediments, semi-consolidated sediments and consolidated rocks.**

The unconsolidated sediments are of two types- alluvial sediments and aeoline deposits. The Alluvial deposits are confined to Barmer, Jalore and Jodhpur district, consisting of sand, clay, gravel and cobbles. Valley fills have been reported from Jhunjhunu, Ajmer, Bhilwara and Udaipur district. The Aeoline sediments constitute one of the major aquifers east of major fault, east of Bikaner. It occupies an area of 1400 sq.km. The aquifer thickness is 40 to 80 m. The yield of wells ranges from 100 to 150 m^3/hr.



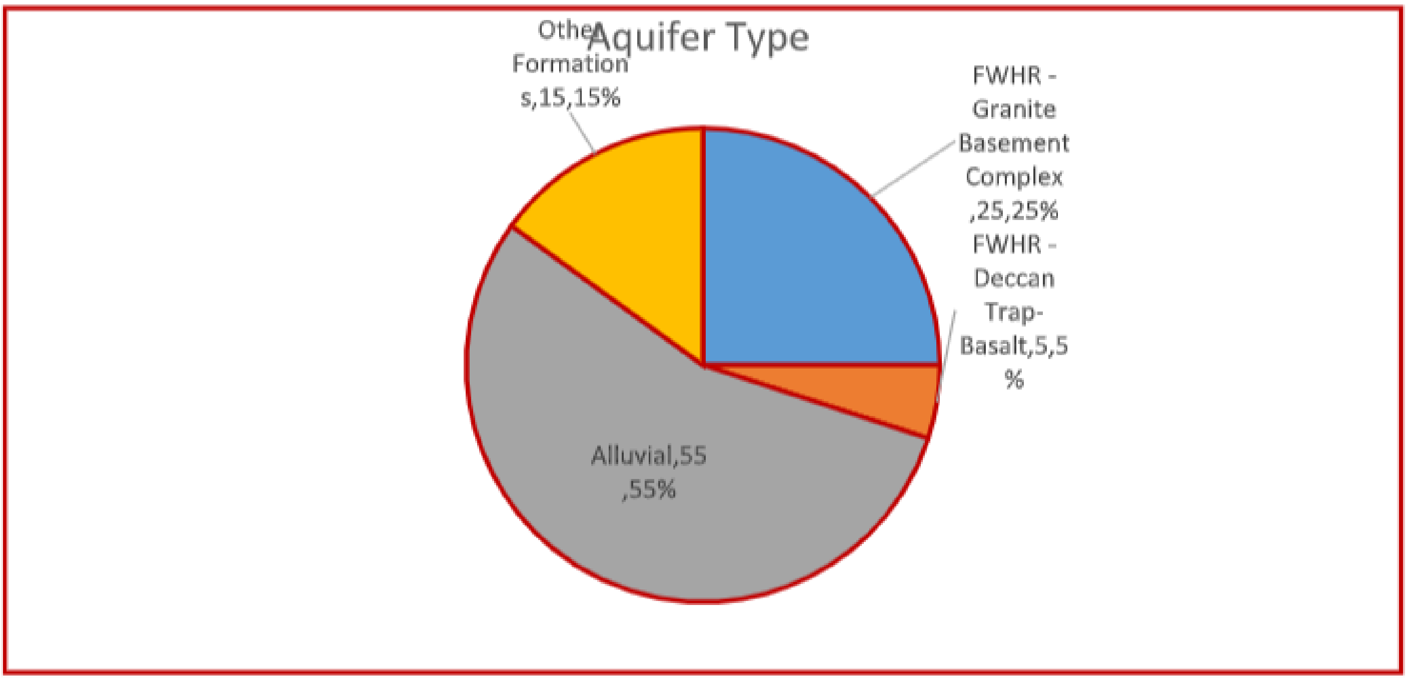
Semi-consolidated formations include sandstones, limestones and Aur beds, covering Jaisalmer and Barmer districts. The dug wells in Jaisalmer limestones yield 13 to 68 m^3/day. The yield of wells in Lathi sandstone varies from 50-150 m^3/hr.

The consolidated rocks includes gneiss, granites, schist, phyllites, marble and Vindhyan sandstones, limestone, quartzite and basaltic flows, mostly restricted to eastern part of the State. The yield prospect is limited unless the well is located near major lineaments or any other weak planes. The ground water quality is in general poor (brackish to saline) at deeper levels.

Porous Formations

The Quaternary sediments comprising younger as well as older alluvium are most important unconsolidated formations due to their wide-spread occurrence. The sediments are composed of clay, silt, sand, gravel and mixture of concretions etc. Sand, gravel and mixture of these form the potential aquifers in northern, eastern, north-eastern, western and south-western parts of the state. The maximum-drilled thickness of alluvium is 543.51metres below ground level (m bgl) at Anupgarh in Ganganagar district.

The semi-consolidated formations belonging to Palaeozoic, Mesozoic and Cainozoic Groups are composed of siltstone, clay stone, sandstone, shale, conglomerate and limestone. Sandstones and lime stones form the main aquifers in Jaisalmer, Jodhpur, Barmer and Bikaner districts. Sandstones of Lathi formation are the most potential aquifers in the districts of Jaisalmer, Jodhpur and Barmer.



Aquifer Type based on CGWB estimates 2006

Fissured Formations

Fissured formations, as hydro-geological unit, occupy 32% area of the state and can be broadly classified into four units.

Consolidated sedimentary rocks, excluding carbonate rocks, include sandstones and shales. In eastern and south-eastern part of the state these belong to Vindhyan Super group whereas in western Rajasthan these belong to the Marwar Super group.

Igneous and metamorphic rocks of lower Proterozoic age comprise slate, quartzite, phyllite, schist, gneiss and various crystallines of Bhilwara Super group. These are mostly found in the districts of Banswara, Dungarpur, Udaipur, Chittorgarh, Bhilwara, Tonk, Jaipur, Alwar and Jhunjhunu in eastern Rajasthan and Nagaur, Churu, Barmer, Jaisalmer, Pali, Jalore, Sirohiand Jodhpur districts in western Rajasthan.

Volcanic rocks include Deccan Trap Lava Flows and occur in parts of Barmer, Jhalawar, Chittorgarh and Banswara districts. These are basaltic to doleritic in composition. Occurrence and movement of ground water in these formations is controlled by the presence of vesicles, extent of weathering, jointing and fracture pattern.

Carbonate rocks include limestone, marble and dolomite of Proterozoic and Upper Palaeozoic to Mesozoic age and occupy parts of Kota, Bundi, Jaipur, Sawai Madhopur and Alwar districts on the eastern side of Aravallis and parts of Nagaur, Bikaner, Jaisalmer and Jodhpur districts in western Rajasthan.

2.2 Ground Water Availability and Utilization

The ground water monitoring is being carried out through a network of observation wells- the National Hydrograph Network Stations (NHS). The National Hydrograph Network Stations set-up is a system of spatially distributed observation points at which periodic monitoring of ground water and regime behaviour viz.

The ground water resource estimation in the state of Rajasthan is being carried out regularly as per GEC guide lines. The projected position of the groundwater resource by the year 2025 has been given as follows:

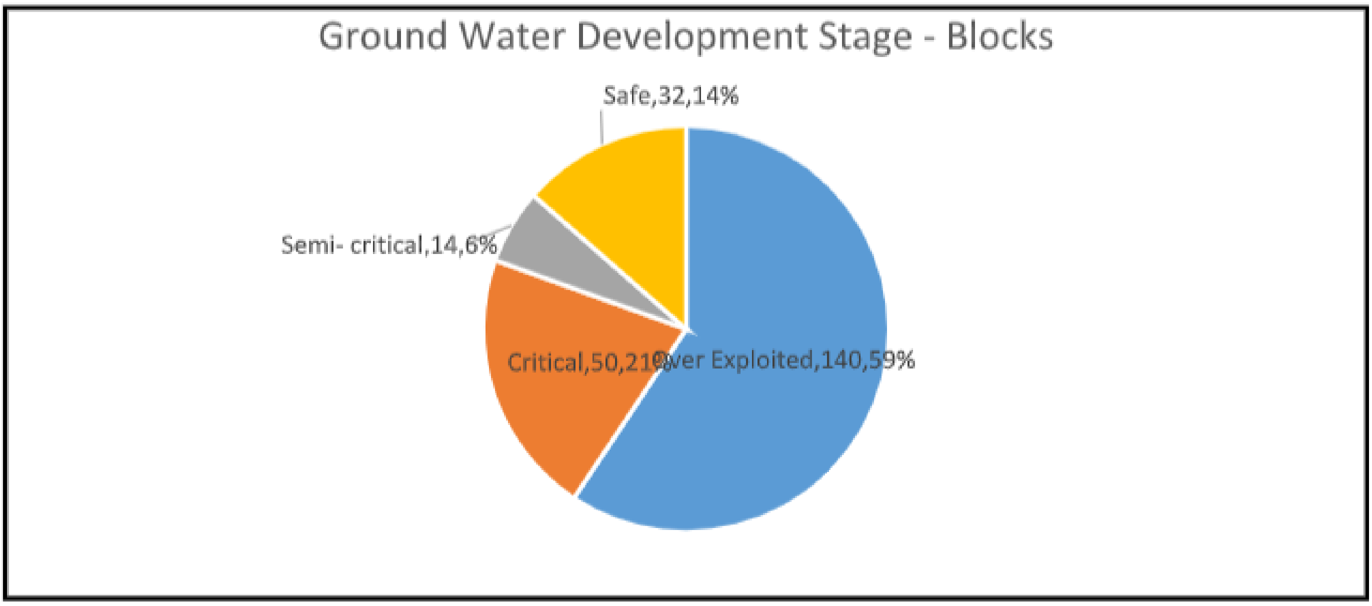
(i) Annual Ground Water Replenishment = 11156 mcm
(ii) Ground Water Draft = 21410 mcm
(iii) Ground Water Balance = (-) 10254 mcm
(iv) Stage of Ground Water Development = 191.90%

Ground water replenishment in the State mainly takes place through monsoon rainfall. Annual ground water availability thus varies with rainfall condition during a particular year. The projected ground water draft and stage of ground water development will thus further be modified corresponding to rainfall condition and management activities taken up in the near future.

The status of groundwater development stage in the state of Rajasthan is quite unique and very critical as compared to other states. Almost all parts of the state face exploitation beyond annual replenishable quantity. Substantial ground water level declines are being witnessed both in hard rock and alluvial areas.

There are areas like that of Alwar[5], Bharatpur, Dausa, Tonk, with unconsolidated aquifers, where the situations of over-draft are manifested in declining water levels, action to reduce the draft by at least 20% must be taken as an immediate measure. In such areas re-use and recycling of urban wastewater should receive added attention of municipal bodies. The liquid urban wastes can be recycled through aquifers to improve their quality and pumped out for reuse particularly for irrigation. It shall however, be essential to ensure that urban & industrial wastes are not inter-mixed. Where such a situation exists, the industrial wastes must be treated before disposal to remove the toxic elements.

An adequate storage capacity is available in the aquifer system where water level during pre-monsoon period is less than 10m bgl like those of Southern regions of the state.[6] Therefore, the underground storage of additional water in those areas will not only ensure the availability of water during dry season but also reduce the evaporation losses. There are hard-rock regions where area specific works of impounding and recharging the storm water run-off from other sources may be adopted. Suitable locations in nalas & gullies should be utilised for the construction of check-dams, sub-surface dams, ponds etc. for ensuring stagnation of water & thus its infiltration underground for augmenting groundwater storage. Such structures must be located and designed keeping in full view Geology, Geomorphology and Hydrogeological set-up prevailing in the area.

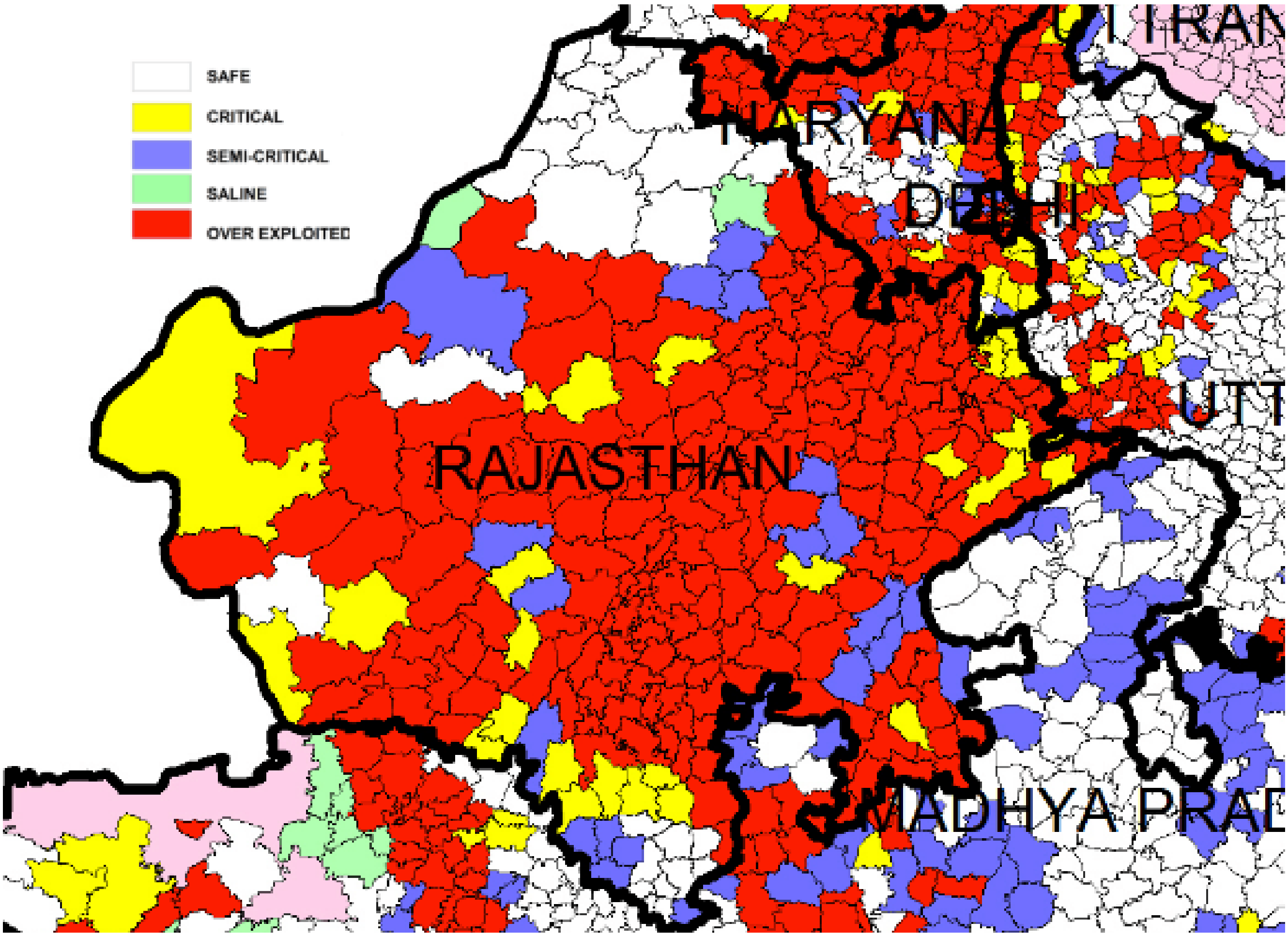


Groundwater Development Stage Graph

[5] Shown within circle in decadal change figures

[6] Shown within rectangle shape in the decadal change figures

According to the data published by the Central Ground Water Board (CGWB) the total annual groundwater gecharge of the State has been assessed as 13.21 BCM and Annual Extractable Ground Water Resource as 11.99 BCM. The Annual Ground Water extraction is 16.77 BCM and the Stage of ground water extraction in the state is 140%. Out of the 295 assessed blocks, 185 blocks have been categorized as 'Over Exploited', 33 as 'Critical', 29 as 'Semi-Critical', 45 blocks as 'Safe' and 3 as 'Saline'. As compared to 2013 estimate, the Annual Ground Water Recharge and Annual Extractable Ground Water Resource have increased from 12.51 to 13.21 BCM and 11.26 to 11.99 BCM respectively. Annual ground water extraction and stage of ground water extraction has increased marginally from 15.71 to 16.77 BCM and 139.52 to 139.88% respectively. The marginal change in recharge is due to changes in norms of GEC-2015 methodology and increased draft is due to revision of well census data.



Groundwater development stage-blockwise

There is progressive increase in ground water draft due to increasing population, urbanization and industrialisation. Out of 295 blocks, as many as 185 blocks the draft has exceeded the estimated replenishable resource. In 33 blocks, the stage of development has reached critical levels and semi critical levels in 29 blocks (Ground water resource estimation 2017) leaving only 45 blocks in safe category. Any further increase in the draft will aggravate the already worsened situation of declining water levels and/or degrading water quality in some areas.

The fact that overall status of groundwater is associated with the factors like low rainfall, limited ground water storage availability, ground water salinity in many areas, deep water levels in most of western parts of state and desertic conditions in nearly 50% of the state's area. Thus, these aspects should be taken as a core consideration for planning and implementing ground water development and management programmes. A holistic approach taking all aspects into consideration shall therefore, need to be adopted. There are different regions with different combinations of agro-climatic situations and aquifer types, thus specific regional planning required to address such variations.

2.3 Groundwater Policies and Governance in the State

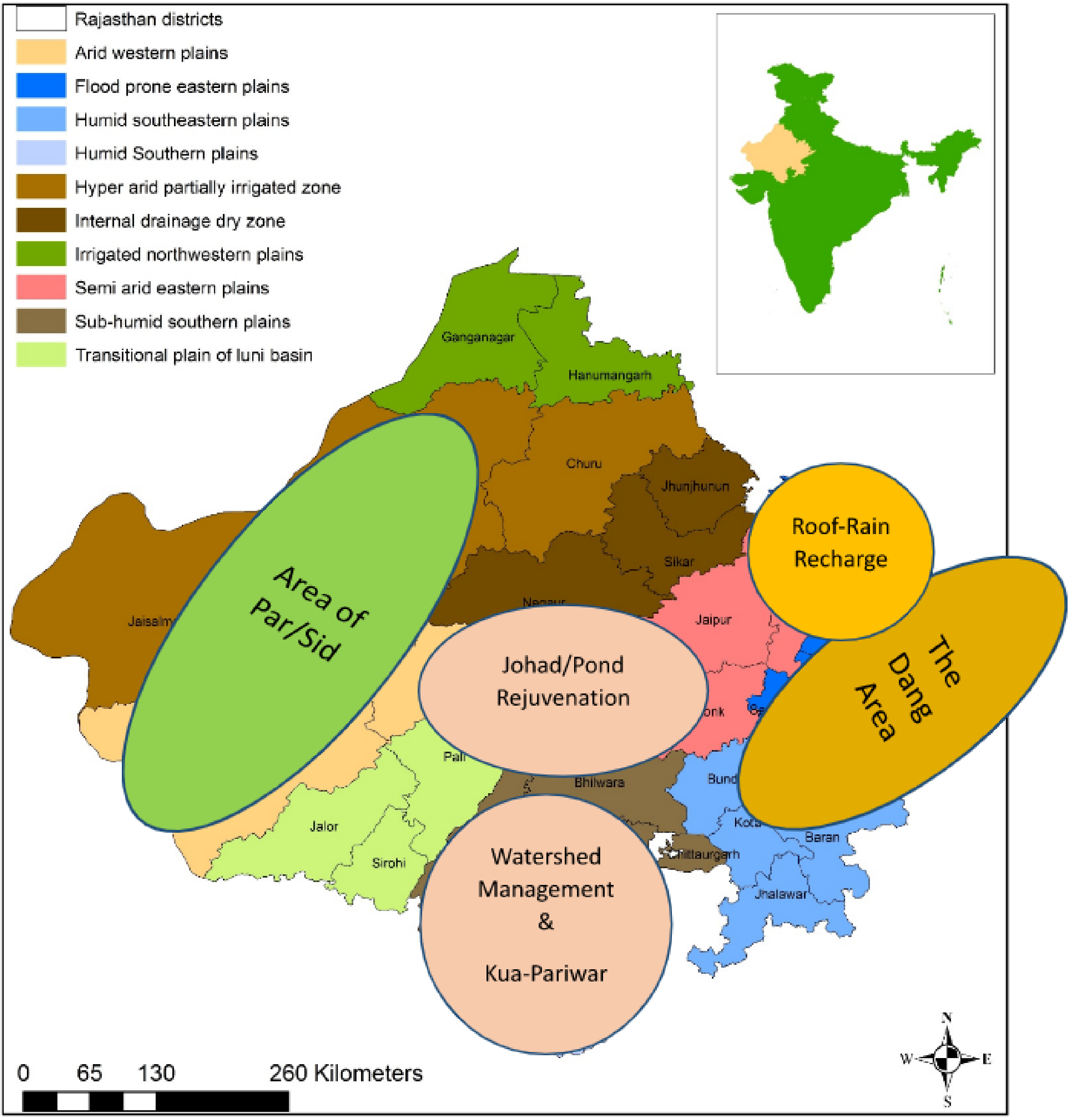
Rajasthan has enacted number of legislation in the recent time to regulate water resources and incentivize rainwater harvesting. Major legislations enacted by the states include the Rajasthan Water Resource Regulatory Act, 2012 and the Rajasthan River Basin and Water Resources Planning Act, 2015. Moreover, the state had adopted state water policy in 2010. To regulate the groundwater resources, the state had drafted The Rajasthan Ground Water Management Bill in 2006. However, it is still in the draft form. Brief description of major legislations and policies enacted by the state are highlighted in the following matrix.

Major Policies and Legislations Governing Ground Water Resources in Rajasthan	
Rajasthan Water Resources Regulatory Act, 2012 (Rajasthan Act No. 38 of 2013)	An Act to provide for the establishment of the Rajasthan Water Resources Regulatory Authority to regulate water resources within the State of Rajasthan, facilitate and ensure judicious, equitable and sustainable management, allocation and utilization of water resources, fix the rates for use of water for drinking, agriculture, industrial, and other purposes, and matters connected therewith or incidental thereto.
Rajasthan River Basin and Water Resources Planning Act, 2015	An Act for the establishment of State Water Resources Advisory Council and Rajasthan River Basin and Water Resources Planning Authority to adopt an Integrated Water Resources Management approach for management and development of river basins and sub-basins on sustainable basis by planning of all watershed, irrigation and drinking water projects covering the basins, sub-basins, aquifers and watersheds to develop state level water resources plans to ensure optimal and efficient utilization of ground and surface water including inter basin water transfer, interlinking of rivers from surplus to deficit basins, sub- basins and to amend the Rajasthan Water Resources Regulatory Act, 2012 .

Rajasthan State Water Policy, 2010	"Exploitation of groundwater for agriculture and purposes other than drinking will be so managed by public participation so as not to exceed the average long-term recharge potential." "The current ethos of uncontrolled groundwater extraction as an "individual right", will be discouraged. It will be replaced by an ethos of community responsibility for the long-term sustainability of the aquifer as a community resource." "A programme of water metering for water management purposes will apply to all significant water users irrespective of source and water ownership." "Differing stepped water rates may be charged for agricultural, industrial, commercial, and municipal purposes. In all cases, the highest rate will be a strong disincentive for profligate water usage."
The Rajasthan Ground Water Management Bill, 2006	Draft
Roof Top Rain Water Harvesting (RTRWH) in building by law, 2005	The Govt. has made provision of compulsory installation of rainwater harvesting system in all newly and existing construction building and Govt. offices vide order dated 31.05.2000 and 12.12.2005 disconnection of water supply, has also been made.

2.4 Locally Appropriate Solutions for Groundwater Management

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 resource against quality degradation and guarantee quality assurance. Mass awareness programmes aimed at educating the users regarding the adverse effects of over-exploitation of groundwater on its quality & quantity, economic and efficient use of water, voluntary regulation of abstraction, etc. will ensure utilisation of the resource at optimal levels. This section highlights few major locally appropriate solutions adopted by communities in the different part of the state.



2.4.1 Par Management

In the western parts of state particularly in the districts of Bikaner, Barmer, Jaisalmer, where most of the deeper zones of groundwater are saline and brackish, there are regions with shallow perched groundwater, where fresh groundwater lies hanging above the regional saline groundwater level due to clay barrier. Such shallow zones are locally called Par (in Barmer area) and Sid (in Bikaner area). In such shallow regions presence of large trees and bushes (fog, bui) which has a huge network of roots evaporates this perched groundwater. Thus, local communities in some parts of Barmer district used to follow practices of removing vegetation within the immediate reach of Par regions. But in the present day this practice is slowly-slowly disappearing.

2.4.2 Johad Rejuvenation

Majority of villages in the areas which are located near to Aravalli mountain range on both western and eastern side are traditionally known to have surface water harvesting structures, which were also helping in managing the groundwater level higher. Thus traditional system was more a conjunctive approach in water management. Some of the traditions of annual rejuvenation of Johad from this region used to maintain harvesting capacity of structure on one hand and also improve recharge potential by removing clogging of surface encrustation. But approaches of separate verticals for surface and groundwater have created a rift within the integrated management system resulting in overall harm to whole system. There are many civil society organisations who are working on rejuvenating Johad, nadi, nada, pond to improve upon creating harvesting capacity and also improve recharge to groundwater.

Work carried out under CSR support of IndusInd Bank, at Deoriya village, Jaitaran Tehsil of Pali district is an example of community collaboration and project support, where the whole story started with the revival of Pond. Presently it has nearly 800 live plants of (80% success in 2nd year out of 1000 plants.

It all started when villagers of Deoriya approached ACF for the revival of the Samadra Nada or Deoriya Pond. The Pond was dis-formed due to irregular sand mining, creating a high risk for animals and children. The revival work was initiated under the project 'SARAL'; In June 2020, deepening and de-silting work was done, resulting in an increased water storage capacity of 14,815 cubic meters. It proved to inspire the villagers to take this further and develop it as an asset of the area. A committee of 21 members (now 25) was formed, constituting Panchayat representatives & good samaritans from the community. The committee members contributed to developing the nearby pasture land to protect local & migratory bird species. They came with the idea of establishing it as a local bird reserve, named 'Radha Krishna Pakshi Vihar. Around 1000 indigenous saplings were planted, and fencing was done around the Pond. To ensure the sustenance of plants drip irrigation system was also installed with ACF support. Around 30 lac Rupees were invested, in which 72% was community share. The transformation of the area turned out as a model for surrounding villages. Moreover, the Government of Rajasthan has also given sanctions for further developments as Model Pond.

Thus, the impact of the revival of traditional ponds, which mainly focuses on the de-silting, can be seen with the two separate lenses. First can be increased harvesting and storage capacity to provide drinking water to village cattle for longer durations. The second impact can be in terms of increased groundwater recharge. Groundwater at most villages is brackish and alkaline, not fit for irrigation; thus, the community mostly prefers to have 1st impact, i.e., increased storage, so that they can have increased availability of drinking water for cattle drinking for an extended period. In most of the ponds revived through the project, this aspect is achieved, except for the chhatri talab (Patwa), where groundwater recharge is fast.[7] Such a situation poses a real dilemma which impact is to be considered and where to fix the line. Both the impacts are significant, one for immediate community needs and another for more comprehensive environmental benefits and ecosystem services. Thus, the project may include a revival of ponds with both purposes depending on locations and it offers good potential for convergence of actions from different stakeholders, as undertaken at the development of traditional Pond at Deoriya. Further exploring the approach can be helpful to evolve a package of practice for broader replication of similar approaches within MGNREGA, Community, and CSR projects, and adoption by Jal-shakti Ministry.

2.4.3 Watershed & Groundwater

Limited groundwater movements characterize the Indian peninsula's hard-rock regions except for localized secondary openings. In such a region's groundwater occurrence is mainly within the shallow aquifer zone with a depth of fewer than 50 to 150 m below ground level. In Rajasthan, the Udaipur district is covered by what is called "hard rocks" that are mostly of metamorphic origin. Many parts of Udaipur obtain water supplies from groundwater stored in these rocks. It is especially true for large rural tracts that obtain water for agriculture and domestic supplies entirely from the groundwater stored in these rocks. There are ephemeral rivers in the Udaipur district, and hence groundwater plays an essential role in the district's farmers' economy.

Watershed development is one of the flagship programs of the Indian government. National Bank for Agriculture and Rural Development (NABARD) is one of India's prime institutions working towards the sustainable development of the rural environment and economy through different programs and schemes. With the German Development Bank (KfW) support, NABARD initiated a project called Indo-German Watershed Development Project (IGWDP) from 2010 to 2017. It has supported nearly 32 watershed projects under this collaboration in the Southern Rajasthan. Seva Mandir, a local NGO in Udaipur, was involved in implemented a watershed development project at Jhabla, Girwa, and Udaipur under this project.

In 2017, Seva Mandir and IGWDP planned to work on climate-proofing the watershed development work carried out in this area. The interventions during this phase are part of climate change adaptation supported by the Adaptation Fund. Under this project, a study was perceived to assess the watershed geo-hydrological study and assess the overall water-balance situation. This study presents the findings made during the year 2 nd semester of the year 2020, the year of turmoil in both the health and agriculture policy sector.

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[7] Indicated by increased water level in nearby well owners.

The following is the summary of key observations made on the overall water situation in the Jhabla watershed.

The geomorphological, geological, and hydro-geological situations in the Jhabla watershed provide limited groundwater recharge opportunities, but watershed development interventions within the IGWDP project facilitated by Seva Mandir and implemented Jal-Grahan Vikas Samiti. The weathering zones (15-20 meters) and fracture mostly up to 60-80 meters restrict water's vertical movement. Therefore, groundwater in the Jhabla watershed mostly occurs in water-table conditions where the water level rises during the rainy season and slowly-slowly lower down post-monsoon.

Regarding hydrogeological conditions, the Jhabla-watershed can be subdivided into two zones depending on elevation, slope. The upper zones in the West, North-west, North-east, and Eastern regions above the contour-line of 380 MSL acts as recharging zone for the watershed. The lower zones of valley portions which act as recharging and discharging zone depending on seasons.

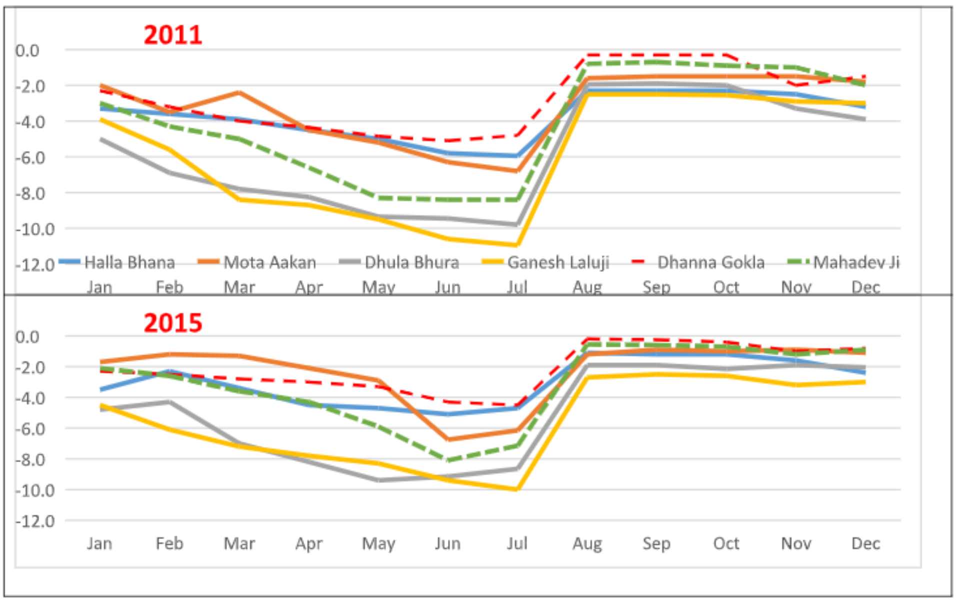
The Jhabla watershed outlet is located in the South-Central region; in this region and other lower parts along the streams, most wells have water levels at shallow depth and provide water all the year.

The project has implemented a variety of soil and water conservation measures. These measures have helped support the enhanced inflow of water in shallow wells ranging in depth to 12-15 meters. This depth zone is mainly a weathering zone; thus, the interplay of fractures and weathering helps groundwater base-flow movement. But as the depth increases, fractured openings become narrow with lesser fractures. The yield from borewells in the watershed is not large enough to support discharge even to household level domestic supply, particularly during extreme summer.

The project interventions of decentralized water harvesting in the form of small masonry check-dams, earthen-nala bund, dry-stone pond, and recharge-pits have provided scope for enhancing the poor's resilience and marginal community in the area by increasing the water holding capacity of the watershed.

Most wells are shallow (depth range 5-10 meters) located along/near the secondary and primary stream. It indicates that there is scope for extending the depth of such shallow pits to 10-12 meters depth to tap additional fractures and create scope for socially just utilization of groundwater to benefit the wider community.

Monthly Water level Fluctuation : Jhabla Observation Wells



It is estimated that the Jhabla watershed receives 846.5 ha-m at the annual average precipitation of 627 mm. Out of this, 106.7 Ha-m (12.61%) water is utilized through Maize, Paddy, Black-gram, Cow-pea, Okra (Desi-Bhindi), and seasonal-vegetables during Kharif, cultivated in around 180.6 ha sloping and leveled agriculture fields.31.8 ha-m water (3.76% of precipitation), from 212.3 ha wasteland (private and public), evaporates without much bio-mass production from revenue owned wasteland. It offers scope for further expanding the component of private and common pastureland and protected pasture so that the community can harness the potential of utilizing this land and water to strengthen the livestock component of livelihood.

Project activities created increased recharge of 124.5 ha-m water to the weathered upper zone and base flow, which resulted in an increase in Rabi cropping from 19.56 ha (pre- project) to 46.2125 ha (post-project), mainly cultivating wheat, barley, mustard. The cropping intensity has increased by 7.91%, i.e., from 117.69% in the base year to 125.61% in the study year 2020.

The various interventions in the watershed have effectively enhanced the community resilience to climate change-induced weather variations in precipitations to the level of 20% deficit in rains in-case 40% deficit, drinking-water availability might get affected beyond May.

The hydro geological study of these watershed development project indicates still a good potential to improve land-utilization further, adding to cropping intensity further and increased water utilization percentage in production activities. Thus, it indicates need for adopting programme approach in watershed rather then short term project approach focusing on conjunctive use of available water with approach of water-audit and water-balance.

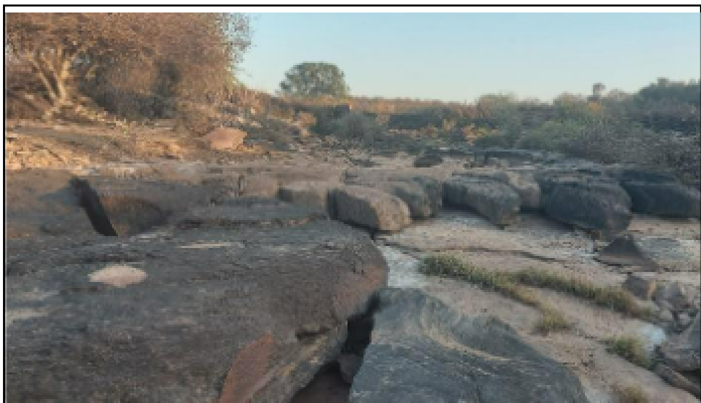
2.4.4 Pal-Pokhar

Eastern and South-eastern part of Rajasthan, which is marked by the presence of low-height table mountains of Vindhyan are known as Daang region. There are around 500 villages located in this upland spread over in four districts namely Karauli, Dholpur, Sawai Madhopur, and Bundi. The main region of Kaila Devi wildlife sanctuary and its peripheral region have a specific approach of conjunctive use of water for sustaining livelihoods of its small and marginal community. One small stream area, its catchment and command jointly called as **Chhid** area, as shown in the Photo- and ; Through **Pal**, soil is conserved, which is supported with harvest of water in **Pokher**.

Chhid Management in the Dang region of Rajasthan

Rabi Cropping through Chhid management

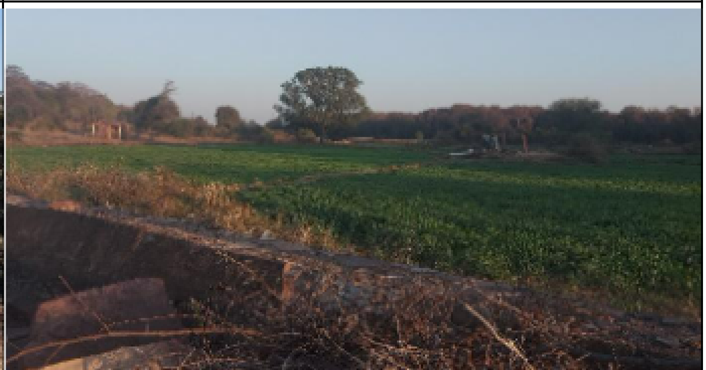
The groundwater recharge to shallow weathered and fractured zone is tapped through shallow wells. This whole approach not only supports community in plateau region only rather it also helps in recharge of deeper zones which are tapped by community in plain areas below.



Fractured Rock in Chhid

Well to tap shallow groundwater

Pokher



Pal

2.4.5 Water-Bank

In the southern Rajasthan and central belt of Aravalli Mountain, slopes are steep and valleys are narrow with think fractured and weathered zone (up to 100 feet). In such region a few civil societies are involved in an approach of Kua-pariwar and Water-bank. The approach is somewhat similar to that of Chhid management in Dang region. Upper reaches are treated using soil and water conservation measures of trenching, bunding, gully-plug, loose stone check dam, etc. They are further supported with masonry check dam and earthen ponds. Such structure created in stream to harvest water which mainly starts recharging zones adjoining to stream. The water which is deposited in weathered and fractured zone as bank-deposit (dynamic water) is utilised in Rabi and summer season, thus an annual flow of water is managed as cash-flow, thus terms as water-bank. There are locations where large areas are irrigated using this approach.

Earthen Nadi applied for recharging groundwater

Well in the central part of the whole area is treated as withdrawal structure, with number of pumps for different zones

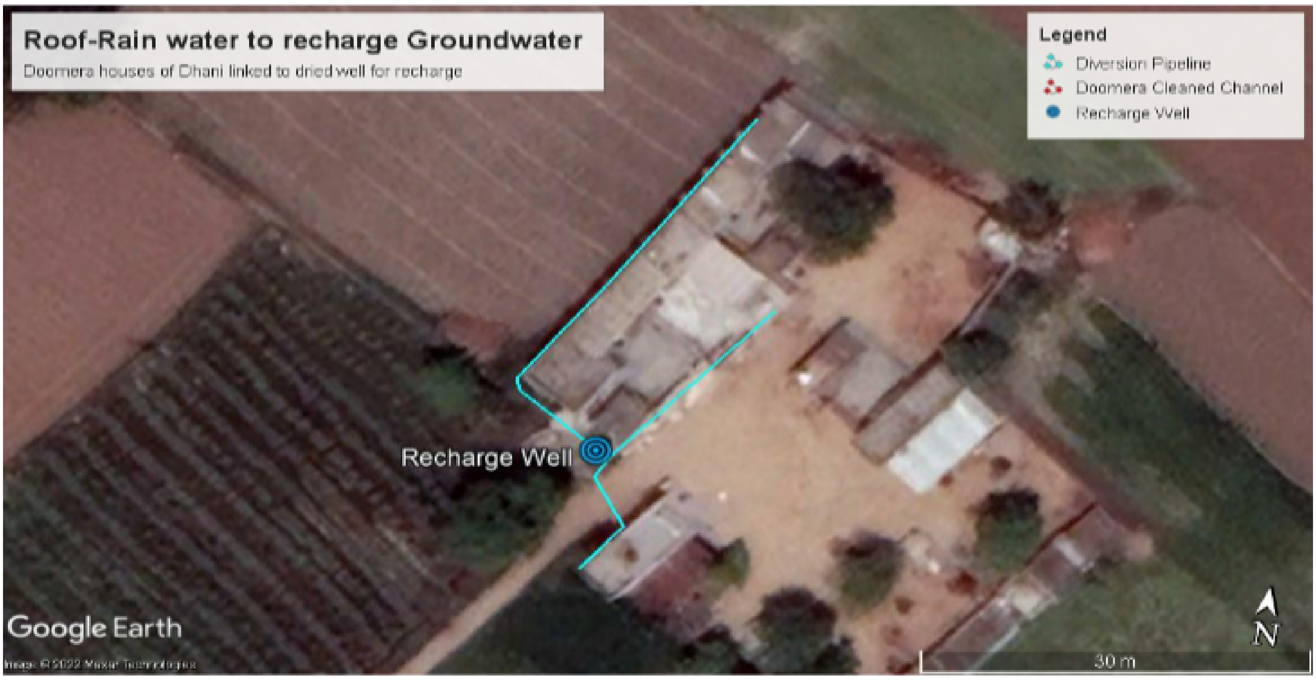
2.4.6 Groundwater Recharge from Roof Rain Water

The solution is applied at Kerwa cluster, located near Matasya Industrial Area (MIA), Malakheda Tehsil of Alwar district, Rajasthan, The area represent eastern alluvial belt spread over in Alwar, Bharatpur, Dausa, Tonk, parts of Sawai-Madhopur, Gangapur City and Karauli. In this area groundwater level is declining very fast, thus leading towards drinking water scarcity particularly for those who do not have their own sources particularly borewells. Villagers mainly women and girls spend large time in fetching water for their families and face lot of drudgery. It is a semi-arid area with an average annual rainfall of 400-500 mm with high variability. The area is part of catchment of Ruparel river originating from the west of Alwar and flowing towards the east. The depth of groundwater access sources, mainly borewells varies between 200-400 meters. Nearly all the open-wells in the area are dry. The solution is adopted by **Ambuja Cement Foundation** at Kerwa cluster at the close vicinity of Alwar, within a CSR funded project of Ashok Leyland. The solution has three major constituents;

a) Catchment, the safe source (roof),
b) Conveyance system (pipeline), and
c) Recharge structure (open wells/dug-cum bore wells)

The case presents a very comprehensive approach of artificial recharge using defunct groundwater utilisation structures to adapt as groundwater recharge shaft. The project diverted roof-rainwater to dry dug-cum-borewells. So far, 20 Roof-rainwater diversion for groundwater recharge involving 135 families, 10300 Square meter roof area providing opportunity to recharge 5200 cubic meter (500 mm rain) water annually at the structures created through the project support. These unique measures are creating a good impression, but there is need to further strengthen understanding among the community members on regular maintenance in future.

Collecting water from different roofs for diverting to dry-well (shown in red circle)



Google Earth Map showing layout of Dhani and recharge measures

This approach of Roof-rainwater diversion for groundwater recharge is an innovative and safe practice adopted in this project. It gives innovative intervention to improve groundwater management in alluvium areas, which are facing threat of fast depletion of groundwater. In the case of increasing pollution of surface water, where artificial recharge demands for intensive monitoring on regular basis, this solution could be answer in community managed projects. In Rajasthan, majority people live in remote Hamlets (Dhanis) where a group of five to ten houses live together around a traditional open-well, thus adaptation of such recharge measures could offer best solution to ground water enhancement particularly in state like Rajasthan where evaporation losses among the surface water are more.

2.4.7 Bhujal Jankar

The approach of nurturing a trained cadre of 'Bhujal Jankar' is quite popular in southern part of Rajasthan. Various organizations have used this idea to develop community level human resource to understand and monitor local hydrology and hydrogeology to support effective management of the ground water. These trained youth are not technically trained but also use their social capital to motivate and mobilize their own community for better changes. This unique approach of village level engagement was developed in the MARVI project. With appropriate training and capacity building, BJs monitor groundwater levels, rainfall, check dam water levels and water quality, making sense from a village perspective of what is happening to village groundwater recharge and availability. BJs convey this information to farmers and others in their own language and help in the planning and the use of groundwater at the local level. BJs are an effective, trusted and valuable interface between village communities and government agencies, NGOs and researchers.

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