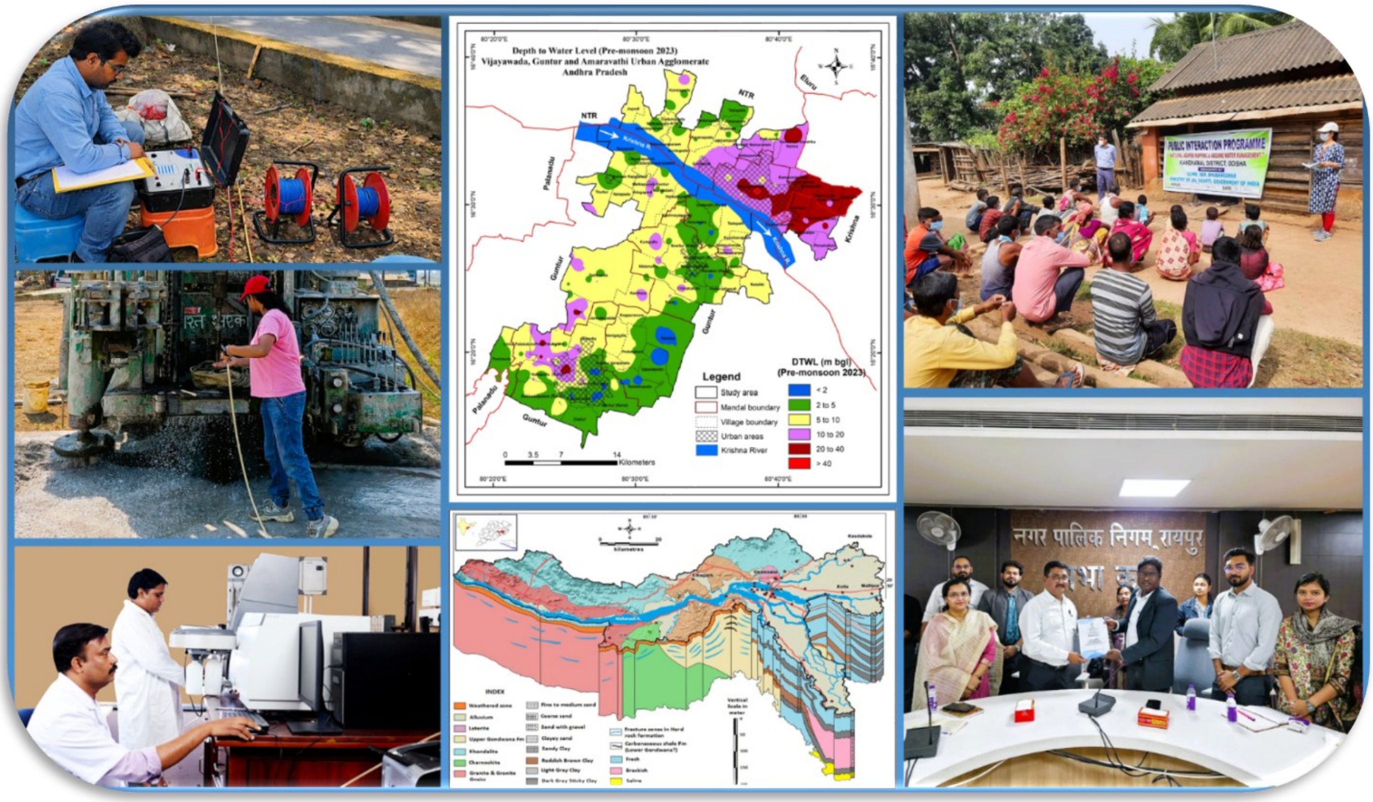
जल शक्ति मंत्रालय
जल संसाधन, नदी विकास और गंगा संरक्षण विभाग
MINISTRY OF JAL SHAKTI
DEPARTMENT OF WATER RESOURCES,
RIVER DEVELOPMENT & GANGA REJUVENATION

NAQUIM GUIDEBOOK

Simplified user guide for stakeholders



NAQUIM

National Aquifer Mapping Programme

For Groundwater Management

CENTRAL GROUND WATER BOARD

Guiding Every Hand- From Farmer to Policy Maker

व्ही. एल. कान्ता राव, भा.प्र.से.
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Secretary

सत्यमेव जयते

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जल शक्ति मंत्रालय
जल संसाधन, नदी विकास
और गंगा संरक्षण विभाग
GOVERNMENT OF INDIA
MINISTRY OF JAL SHAKTI
DEPARTMENT OF WATER RESOURCES,
RIVER DEVELOPMENT & GANGA REJUVENATION

MESSAGE

The National Aquifer Mapping and Management Programme (NAQUIM) is a flagship initiative of the Ministry of Jal Shakti aimed at enabling aquifer-based groundwater management across India. The programme focuses on the systematic scientific mapping of aquifers and the preparation of comprehensive aquifer management plans, thereby providing a strong foundation for sustainable groundwater governance.

Under this programme, the entire mappable area of approximately 25 lakh sq. km has been systematically covered, and aquifer management plans for districts across the country have been prepared and disseminated. These plans are intended to guide implementation by integrating scientific recommendations into development programmes and policies and equipping communities, planners, and administrators with the knowledge, tools, and data necessary for informed decision-making. Through a convergence-based approach, it facilitates the effective implementation of groundwater recharge and management interventions at a national scale.

However, it has been observed that the technical complexity of NAQUIM reports often limits their accessibility and usability for a wider audience. In this context, there is a critical need to demystify these technical outputs and translate them into a more user-friendly and actionable format.

The NAQUIM Guidebook has been developed to address this need. It serves as a comprehensive yet simplified resource that presents groundwater concepts in a structured and accessible manner. The guidebook covers a wide range of topics- from the importance of water and the hydrological cycle to detailed insights on aquifers, groundwater levels, quality, and seasonal variations. It further elaborates on aquifer mapping methodologies, assessment of groundwater potential, key challenges such as over-extraction and contamination, and strategies for sustainable groundwater management.

By combining scientific rigour with practical guidance, the guidebook acts as a bridge between technical knowledge and field-level implementation. It is designed to support citizens, educators, policymakers, and stakeholders in understanding groundwater systems and taking informed actions, enhancing the usability of NAQUIM outputs.

(V. L. Kantha Rao)

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Chairman

सत्यमेव जयते

भारत सरकार
जल शक्ति मंत्रालय
जल संसाधन,
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केन्द्रीय भूमि जल बोर्ड
Government of India
Ministry of Jal Shakti
Department of Water Resources,
River Development & Ganga Rejuvenation
Central Ground Water Board

Message

The National Aquifer Mapping and Management Programme (NAQUIM) has created a strong scientific foundation for understanding the country's Aquifer Systems and groundwater resources. With extensive mapping and preparation of aquifer management plans across the country, a significant knowledge is now available to guide groundwater management efforts.

The next important step is to ensure that this knowledge is easily understood and effectively used by all stakeholders. It has been observed that the technical nature of NAQUIM reports can limit their accessibility, particularly for the field level functionaries. Bridging this gap between scientific information and practical application is therefore essential. The NAQUIM Guidebook has been prepared with this objective. It presents key groundwater concepts in a simple, clear, and structured manner, making them accessible to a wider audience. The guidebook brings together essential information on aquifers, groundwater behavior, quality aspects, and management approaches, along with practical insights that can support planning and action.

By making complex information more accessible, the guidebook seeks to support effective implementation of groundwater management strategies on the ground. It is hoped that this guidebook will serve as a useful reference for all stakeholders and contribute to the sustainable management of groundwater resources in the country.

(Pradeep Kumar Agrawal)

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PART C – GROUNDWATER ISSUES

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NAQUIM IN WATER RESOURCE PLANNING

Why Water is Important?

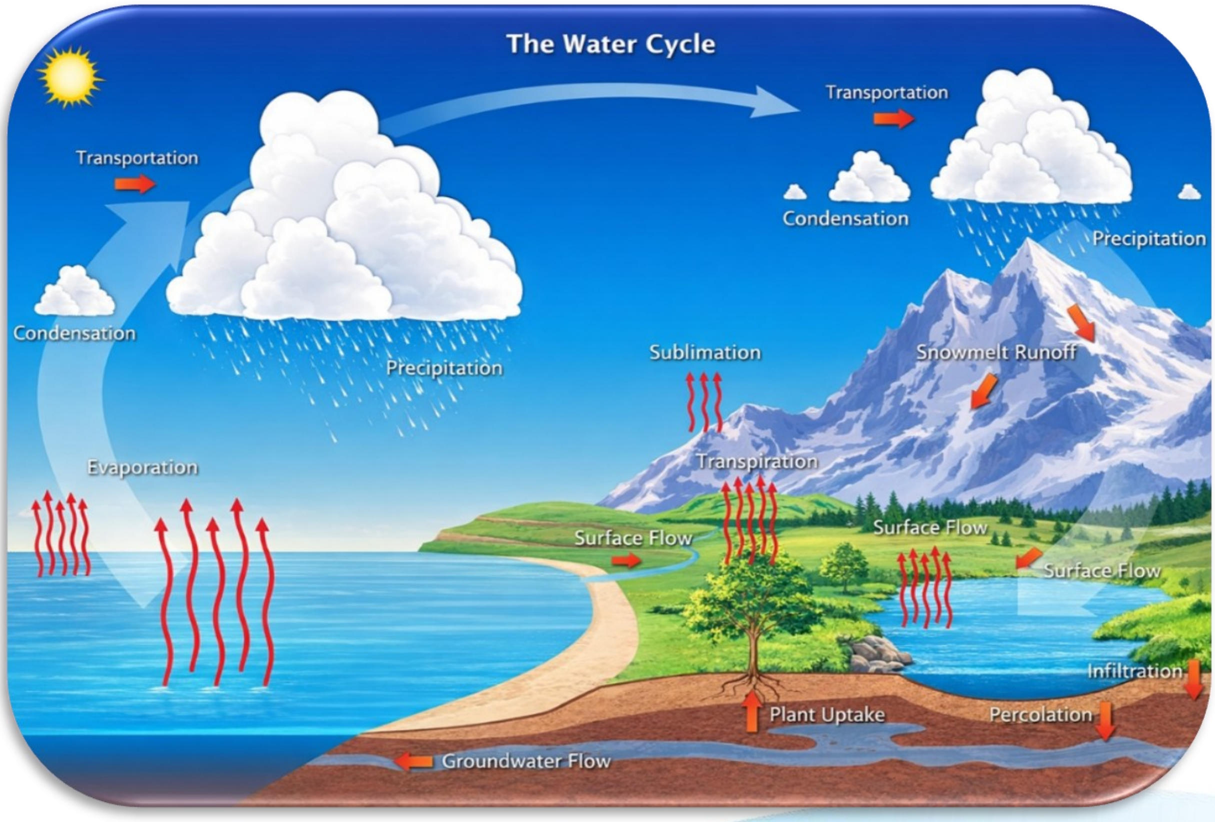
Water is the foundation of life. Every living thing, including plants, animals, and humans, depends on water to survive. People need water for drinking, cooking, and maintaining good health. Plants require water to grow and produce food, while animals need it for their daily survival. Water is also vital for agriculture because crops cannot grow without an adequate supply of it.

The Water Cycle

Now imagine what happens to water after rain falls on the Earth. Water does not stay in one place forever. It moves continuously in nature through a process called the water cycle.

The Sun heats water in rivers, lakes, and oceans. Slowly, the water turns into vapour and rises into the air. High in the sky, this vapour forms clouds. When the clouds become heavy, rain falls back to the Earth.

Some rainwater flows into rivers and lakes. Some of it slowly enters the soil and becomes groundwater. Through this natural cycle, water keeps moving across the planet again and again. This stored underground water is known as groundwater. Groundwater can be obtained through wells, hand pumps, and tube wells. It is an important source of drinking and irrigation in many villages and cities.



Rainwater

Rainwater is the starting point of most freshwater on Earth. When the Sun heats water in seas, rivers, and lakes, evaporation begins. The water vapour rises into the sky and forms clouds.

When the clouds cool and become heavy, rain falls. This rain fills rivers, ponds, and lakes. It also enters the soil and replenishes groundwater. In this way, rainwater supports both surface water and groundwater resources.

Surface Water

When rain falls on land, some water flows across the surface. This flowing water collects in rivers and streams. Sometimes it gathers in low areas to form ponds and lakes.

Because this water is visible on the Earth's surface, it is called surface water. Many towns and villages depend on rivers, lakes, and ponds for drinking water and irrigation.

However, surface water can change quickly. During dry seasons, rivers may shrink and ponds may dry up if rainfall is low.

Groundwater

Not all rainwater stays on the surface. Some of it slowly seeps into the soil. It moves down through small spaces between soil particles and cracks in rocks.

This water collects in underground layers called aquifers. The water stored in these layers is known as groundwater.

Groundwater is invisible, but they can access it using dug wells, hand pumps, and borewells. In many villages and cities, groundwater is the main source of drinking water.

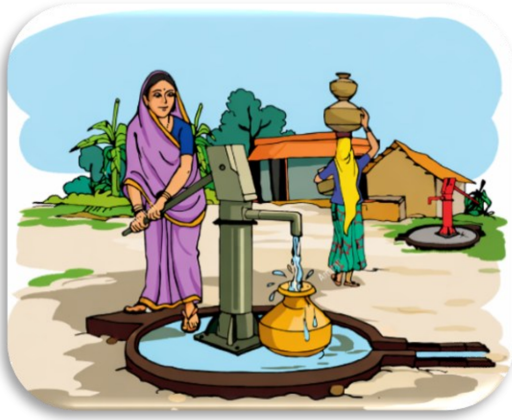
Understanding Groundwater

What is Groundwater?

Imagine digging a hole in the ground. At first, you see dry soil. But if you dig deeper, you may eventually reach water. That water comes from underground storage called groundwater. Groundwater fills the small spaces between soil particles and rock fractures. It stays stored underground until people bring it to the surface through dug wells, handpumps, borewells, tubewells.

1. Dug Wells

Dug wells are one of the oldest methods of obtaining groundwater. They are made by digging into the ground until the underground water level, known as the water table, is reached. Water collects in the well and can be taken out using buckets or pumps. Wells are usually shallow and depend on the level of groundwater in the area.



2. Hand Pumps

In hand pumps, a narrow pipe is drilled into the ground until it reaches the groundwater level. By moving the handle up and down, water is pumped to the surface. Hand pumps are simple to operate and are commonly used in villages and rural areas for drinking water.

3. Borewells / Tube Wells

Borewells or tube wells are deep holes drilled into the ground to reach deeper layers of groundwater stored in aquifers. Water is lifted to the surface using electric or diesel pumps. These wells are useful in places where groundwater is deep and large quantities of water are required for drinking, irrigation, or other purposes.

Importance of Groundwater for Drinking, Irrigation, and Industry

- Major source of water: Groundwater is one of the main sources of water because it is easily available and can be used when surface water from rivers, lakes, and reservoirs is not enough.
- Stored naturally underground: Groundwater is stored below the ground in natural layers. People can access it near their homes through dug wells, hand pumps, and borewells.
- Important for drinking: A large part of the water used in homes comes from groundwater. In many villages and small towns, people depend on dug wells, hand pumps, and borewells for their daily drinking water.

- Major source for agriculture: Farmers use groundwater to irrigate their fields. It helps crops grow properly and plays an important role in producing food.
- Useful for industries: Many industries use groundwater for manufacturing and other industrial processes.

- Available even in dry periods: Groundwater is usually available throughout the year and can still be used during droughts when rivers, ponds, and reservoirs may dry up.
- Supports livelihoods and development: With increasing population and growing cities, the demand for water is rising. Because surface water is limited, groundwater has become very important for daily life, farming, and economic development.

Aquifers – The Storage of Groundwater

Groundwater is stored below the Earth's surface in underground layers called aquifers. Aquifers are made up of soil, sand, gravel, and fractured or porous rocks that can hold and transmit water. Rainwater seeps down through the soil and fills the spaces between particles and cracks in rocks, where it is stored as groundwater.

Water-bearing properties of rocks

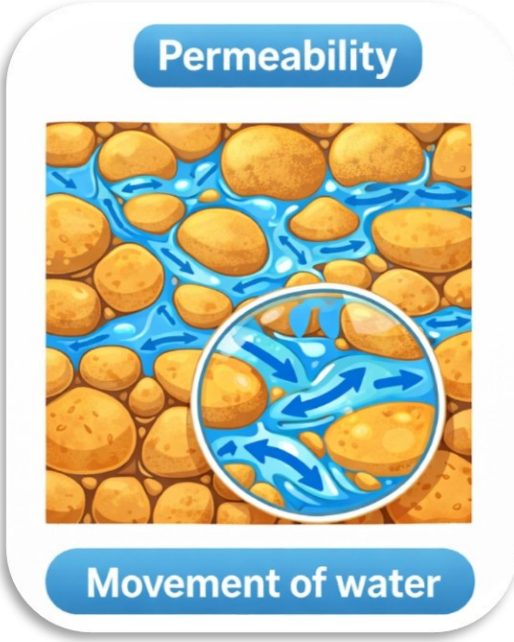
The ability of an aquifer to store and supply groundwater depends on some important water-bearing properties. These properties explain how much water the aquifer can hold and how easily the water can move through it.

1. Porosity

Porosity means the amount of empty space present in soil or rock. These empty spaces may be small pores, cracks, or gaps where water can be stored. If the soil or rock has more empty spaces, it can store more groundwater.

2. Permeability

Permeability is the ability of water to flow through the soil or rock. If the pores or cracks are connected, water can move easily through them. Materials with high permeability allow groundwater to flow quickly within the aquifer.



3. Transmissivity

Transmissivity describes how water an aquifer can transmit or pass through its full thickness. Aquifers with high transmissivity can supply large amounts of water to wells and borewells.

4. Storativity (Storage Coefficient)

Storativity refers to the amount of water an aquifer can store or release when the groundwater level rises or falls. It helps indicate how much groundwater can actually be used from the aquifer.

Types of Aquifers

Aquifers are arranged below the Earth's surface in layers, depending on the type of soil, rock, and geological time scale. These layers form a vertical sequence of water-bearing and non-water-bearing formations.

Soft Rock

Unconfined Aquifer (Shallow Aquifer)

Found just below the ground surface. The top of this aquifer is open to the atmosphere through soil. The level of water in this aquifer is called the water table. It is mainly filled or recharged directly by rainfall. Such aquifers are commonly found in river valleys and alluvial plains.

Aquitard (Separating Layer mostly impermeable)

This layer lies below the unconfined aquifer. It is usually made of clay or very fine soil particles. Water can pass through it only very slowly. It acts like a barrier that separates shallow groundwater from deeper aquifers.

Confined Aquifer (Deep Aquifer)

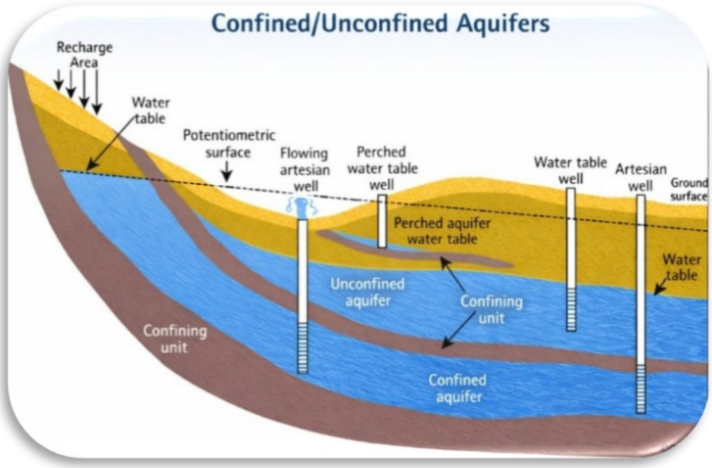
Located below an aquitard layer. It is trapped between two layers that do not allow water to pass easily. The water inside this aquifer is under confined pressure. When a well or borewell reaches this aquifer, the water may rise up in the pipe because of this pressure.

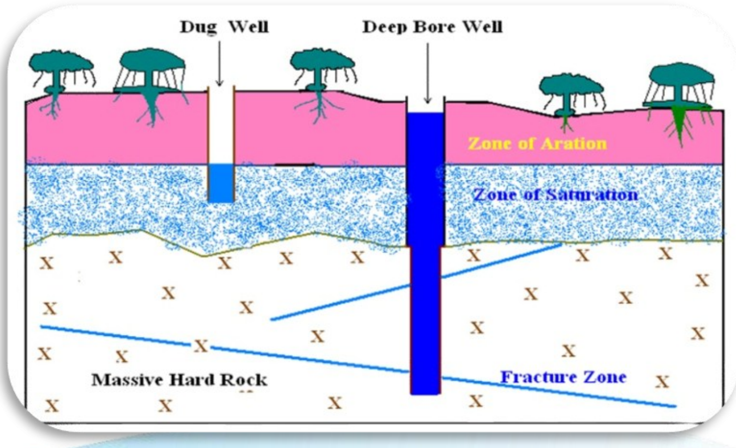
Semi-Confined Aquifer

This aquifer is partly covered by layers that allow some water to pass through. Because of this, a small amount of water can slowly move in or out of the aquifer.

Hard Rock: In hard-rock regions, aquifers are not layered but occur as:

- ✓ Weathered zone (shallow)
- ✓ Fractured zone (deeper)





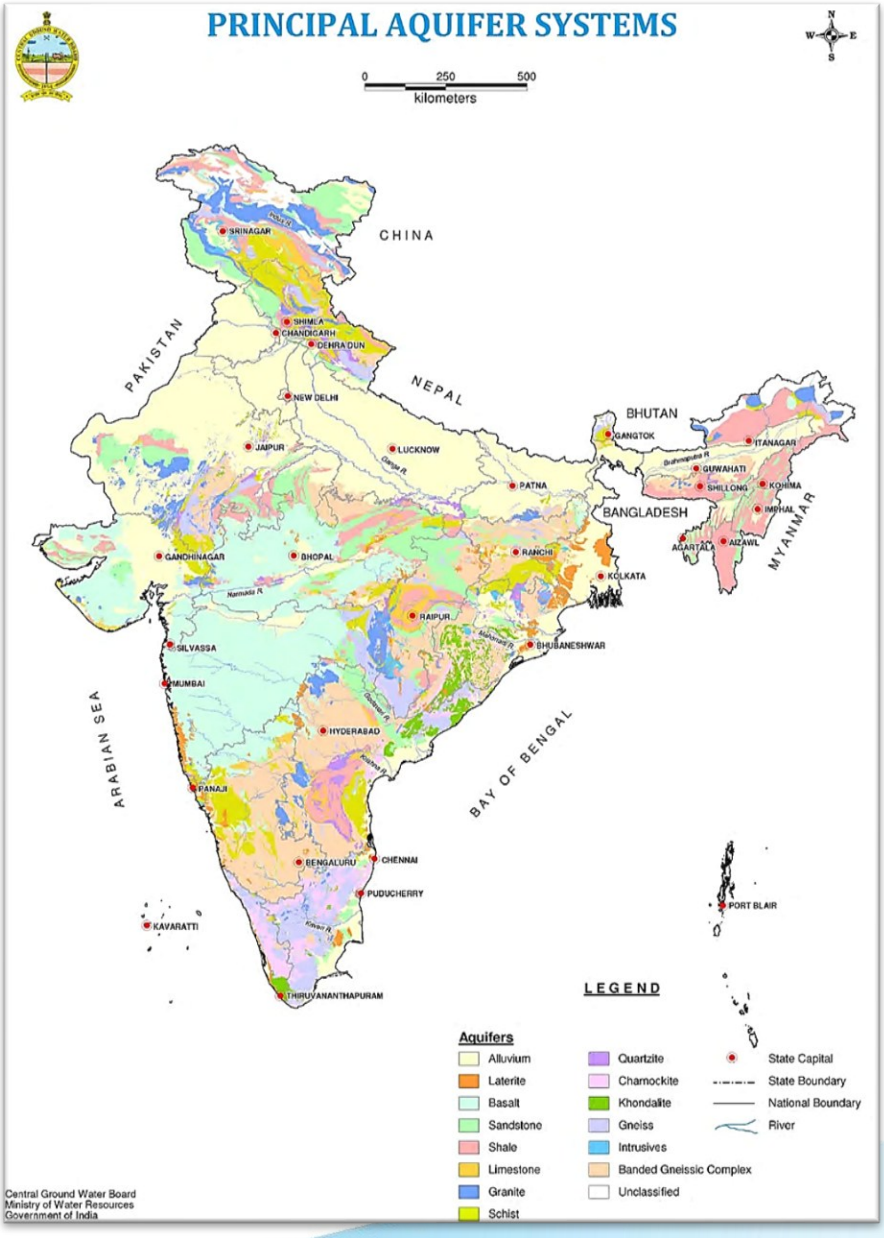
Aquifer System in India

India's groundwater occurs in a wide range of geological formations that have been grouped by the Central Ground Water Board (CGWB) into 14 Principal Aquifer Systems of India for the purpose of National Aquifer Mapping and Management Programme (NAQUIM).

At the broadest level, these principal aquifer systems are divided into:

- Soft-rock (sedimentary / unconsolidated) aquifers
- Hard-rock (crystalline / volcanic) aquifers

This division reflects fundamental differences in rock type, groundwater storage mechanism, aquifer dimension, discharge, and management needs across India.



1. **Soft Rock Aquifers of India**

Soft rock aquifers occur in unconsolidated or semi-consolidated sediments such as sand, gravel, silt, sandstone, limestone, and alluvium. Water is stored in the pore spaces between the sediment particles.

Hydrogeological Characteristics

- High porosity and permeability
- Groundwater stored in pore spaces between particles
- Aquifers are generally layered, extensive, and continuous
- Can occur as unconfined, semi-confined, or confined aquifers
- Wells usually give large and sustained water supply

Geographical Distribution in India

- Indo-Gangetic–Brahmaputra plains (Punjab, Haryana, Uttar Pradesh, Bihar, West Bengal, Assam)
- Major river valleys and delta regions (Ganga, Brahmaputra, Godavari, Krishna, Cauvery, Mahanadi)
- Coastal plains of Gujarat, Odisha, Andhra Pradesh, Tamil Nadu, and Kerala

Groundwater Behaviour and Use

- Easily recharged due to permeable soils and flat terrain
- Suitable for high-capacity tube wells
- Major source of water for irrigation, drinking, and industry

Major Soft Rock Aquifer Systems

- Indo-Gangetic–Brahmaputra Alluvial Aquifer System
- Coastal Alluvial Aquifer System
- Deltaic and River Valley Aquifer Systems
- Sedimentary Basin Aquifers (Vindhyan, Gondwana, Tertiary basins)

2. **Hard Rock Aquifers of India**

Hard rock aquifers occur in crystalline and volcanic rocks such as granite, gneiss, basalt, schist, and quartzite. These rocks have very little natural pore space, so groundwater is mainly stored in weathered zones and fractures.

Hydrogeological Characteristics

- Very low natural porosity
- Groundwater stored in fractures, joints, and weathered layers
- Aquifers are irregular and discontinuous
- Limited storage and water movement
- Well yields are generally low and uncertain

Geographical Distribution in India

- Mainly in Peninsular India, including:
- Deccan Plateau (Maharashtra, Telangana, Karnataka, Andhra Pradesh, Tamil Nadu)
- Central and Eastern India (Madhya Pradesh, Chhattisgarh, Odisha, Jharkhand)

Groundwater Behaviour and Use

- Recharge mainly depends on monsoon rainfall
- Borewell success depends on the presence of fractures
- Wells may fail if fractures are absent
- Groundwater levels show strong seasonal variation

Hard rock aquifers cover large parts of India and pose challenges for sustainable groundwater management.

Major Hard Rock Aquifer Systems

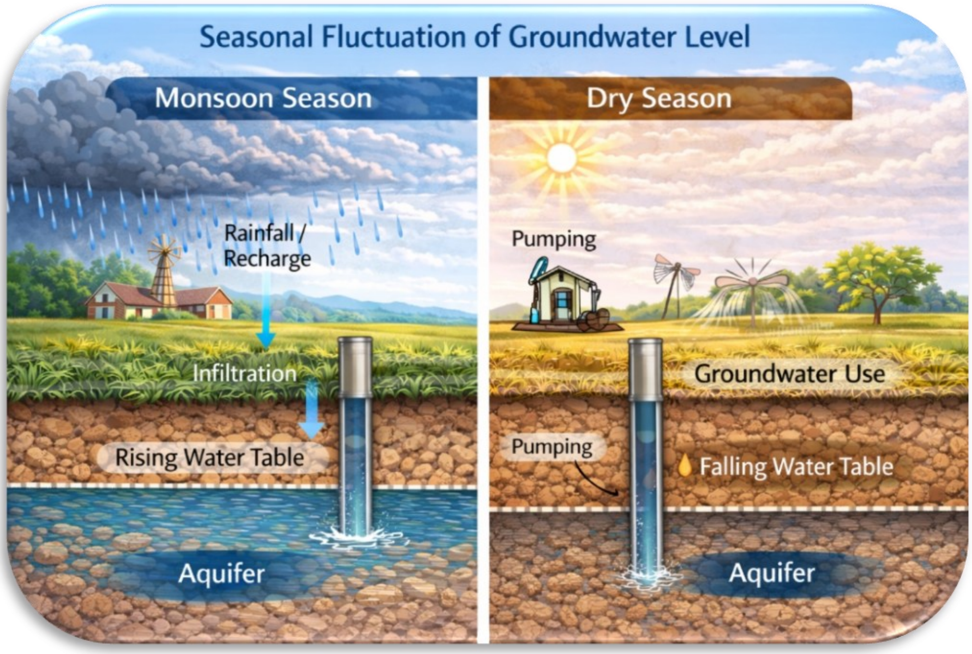
- Crystalline Aquifer System (granite, gneiss, schist)
- Basaltic Aquifer System (Deccan Traps)

Groundwater Levels

What is Groundwater Level?

The groundwater level is the depth at which water is found below the ground surface. It is the level where soil and rock spaces are completely filled with water.

In simple terms, when a well or borewell is dug, the point where water starts appearing indicates the groundwater level. Knowing the groundwater level helps in planning wells for irrigation, and drinking water supply, and is important for managing groundwater wisely.



Seasonal fluctuation of water levels

Seasonal fluctuation is the natural rise and fall of groundwater levels during different seasons. During the monsoon, rainfall infiltrates into the ground and recharges aquifers, causing the water level to rise. In the dry season, recharge decreases while groundwater uses increases, leading to a decline in the water level. The amount of fluctuation depends on rainfall, soil type, groundwater use, and recharge conditions in the area. Understanding seasonal changes in groundwater levels helps in better planning of water use and conservation.

Long term trends

Long-term trends in groundwater refer to the change in groundwater levels over many years. By observing these trends, we can understand whether the groundwater level in an area is rising, stable, or falling. When groundwater is pumped out faster than it is recharged by rain, the water level gradually goes down over time. This is called groundwater depletion. Groundwater depletion usually happens due to excessive use for irrigation, drinking water and industries contributed through increasing population.

Measuring Groundwater Levels

Measuring groundwater levels helps us know how much water is available underground and how it changes over time. This information helps in better management of water resources.

Monitoring Structures

Groundwater levels are usually measured in dug wells, bore wells.

How to Measure Groundwater Levels

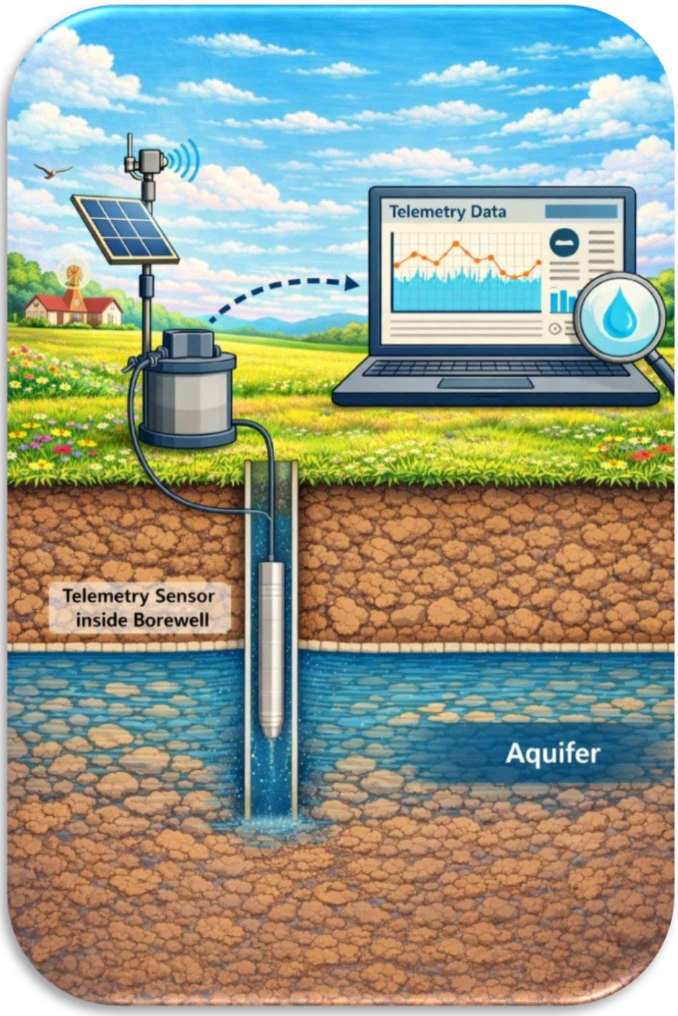
1. Manual Measurement

Groundwater levels are measured manually using simple instruments such as:

- Measuring tape or steel tape lowered into the well until it touches water.
- Electric water level indicator, which gives a signal when it contacts water.

The distance from the ground surface to the water surface is recorded as the groundwater level.

2. Telemetry System/ Digital Water Level Recorder (DWLR)



In this method, a sensor installed inside the borewell automatically records groundwater levels at regular intervals. The data are transmitted through a telemetry system to a central server or computer, allowing continuous monitoring without manual measurement.

Frequency of Measurement: Manual groundwater level measurements are usually taken monthly or seasonally (often four times a year).

Telemetry System measure groundwater levels automatically about four times a day, enabling continuous monitoring of changes.

Groundwater Flow: How Does Groundwater Move?

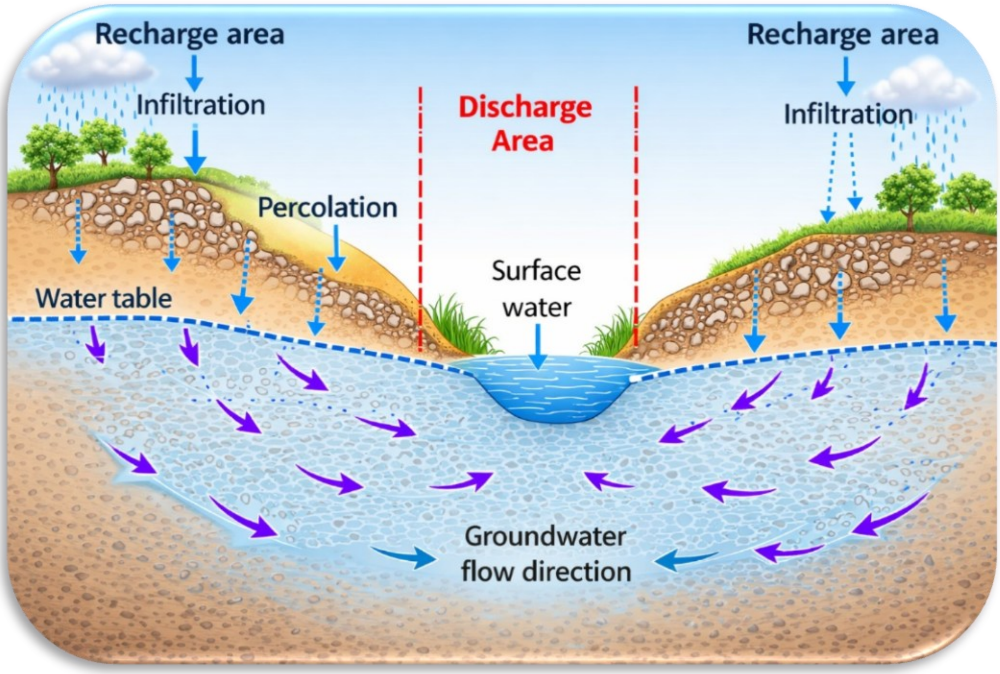
Groundwater is not stationary. It slowly moves through the small spaces and cracks in soil and rocks below the ground. This movement is called groundwater flow.

Direction and Gradient of Groundwater Flow

Groundwater flows from areas where the water level is higher to areas where it is lower, similar to how water flows downhill. The slope or difference in water level that causes this movement is called the groundwater gradient. The steeper the gradient, the faster the groundwater moves.

Recharge and Discharge Areas

- Recharge areas are places where rainwater or surface water seeps into the ground and refills the aquifers.
- Discharge areas are places where groundwater comes out naturally to the surface, such as springs, rivers, lakes, or wetlands.



Interaction Between Surface Water and Groundwater

Surface water and groundwater are closely connected. Rivers and lakes can recharge groundwater by allowing water to seep into the ground. In other cases, groundwater can flow into rivers and streams, helping them maintain water flow even during dry periods.

Understanding groundwater flow helps in managing water resources, and protecting groundwater from overuse.

Groundwater Quality: Is Our Groundwater Clean?

What is Groundwater Quality?

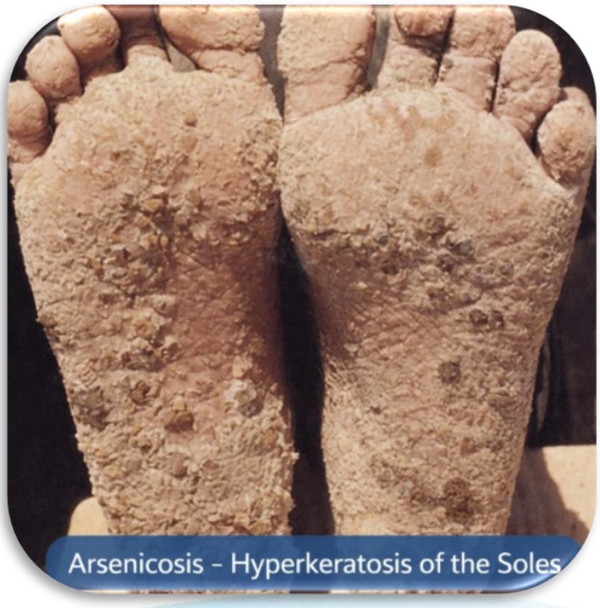
Groundwater quality refers to the chemical and physical condition of groundwater and whether it is safe and suitable for uses such as drinking, irrigation, and industry. Clean groundwater should not contain harmful substances and should meet safe drinking water standards.

Common Groundwater Quality Issues

In some areas, groundwater may contain certain substances in high amounts, which can affect its quality. Common problems include:

- Salinity: High salt content that makes water unsuitable for drinking and irrigation.
- Fluoride: Excess fluoride can cause dental and bone problems.
- Nitrate: Often comes from fertilizers and waste, and may be harmful if present in high levels.
- Iron: Can give water a reddish colour and metallic taste.
- Arsenic: A toxic element that can cause serious health problems if present in drinking water for long periods.


Dental Fluorosis


Arsenicosis – Hyperkeratosis of the Soles

Importance of Water Quality Monitoring

Regular testing and monitoring of groundwater quality help identify problems early. It ensures that the water used for drinking, agriculture, and other purposes is safe, and helps authorities take necessary measures to improve or protect water quality.

Understanding Groundwater Resources

Understanding Groundwater resources means finding out how much groundwater is available, how fast it is being recharged and how much it is extracted.

1. Resource Assessment Concepts

Basic Concept

- ✓ How much groundwater is available in assessment unit
- ✓ How much groundwater can be safely used every year

Key Points:

- ✓ Groundwater is not unlimited.
- ✓ Only the rechargeable portion (refilled by rainfall and other sources) should be used.
- ✓ Over-extraction can lead to long-term groundwater depletion.

2. Recharge vs Extraction

This comparison is the central of groundwater assessment.

❖ **Recharge**

Water enters the aquifer through:

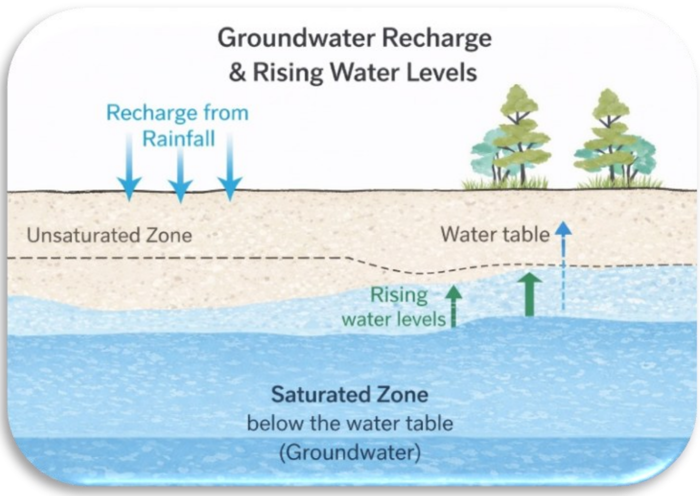
- ✓ Rainfall infiltration
- ✓ Rivers, ponds, canals
- ✓ Irrigation return flow

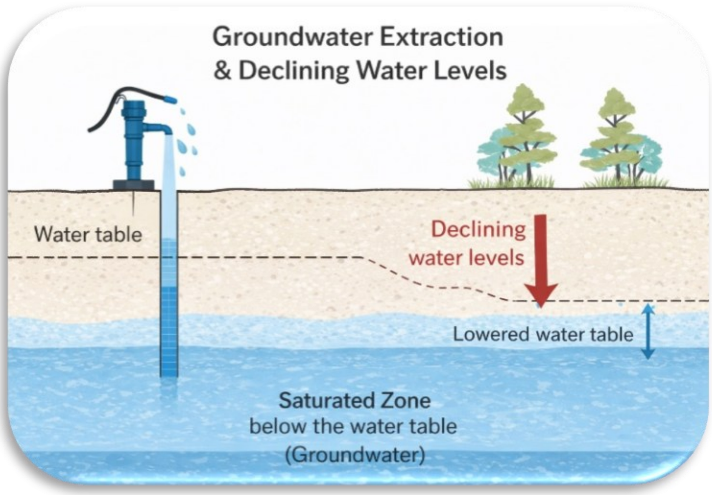
❖ **Extraction (Draft)**

Water taken out through:

- ✓ Dug Wells and Borewells/Tubewells
- ✓ Pumps for irrigation, drinking, and industries

If recharge ≥ extraction → groundwater is sustainable
If extraction > recharge → groundwater levels will fall



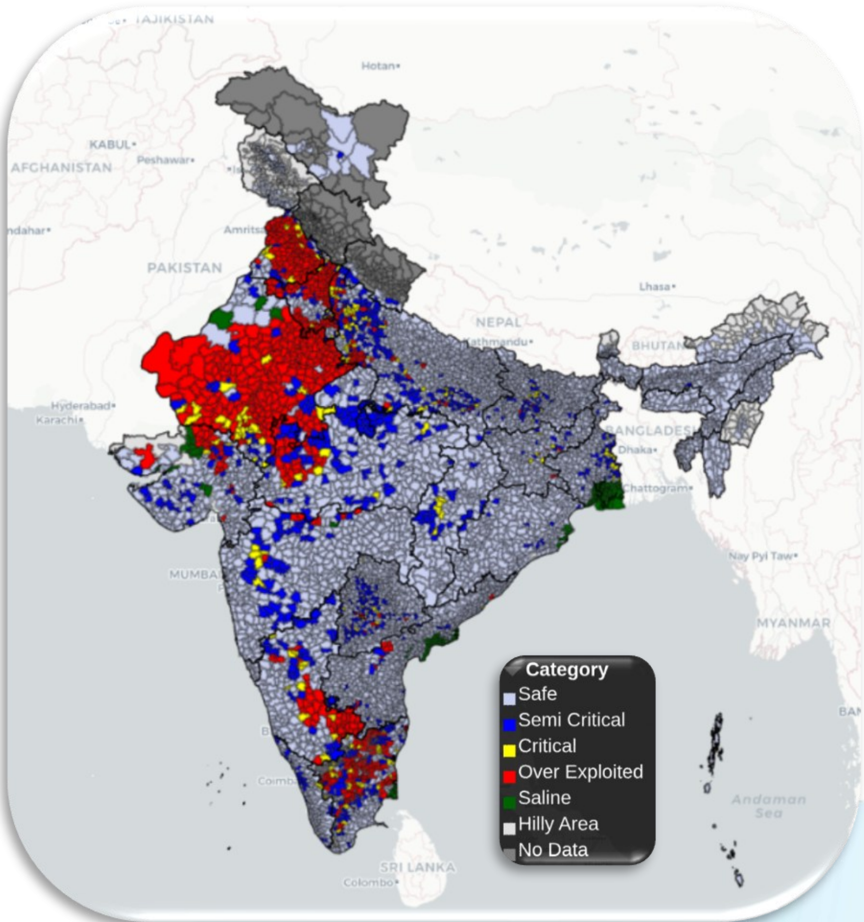


Categorisation of Assessment units based on groundwater assessment

Based on recharge and extraction, areas are classified into four categories:

- ✓ **Safe**
  Groundwater use is within limits; water levels are generally stable. Where less than 70% of the recharged water is extracted.
- ✓ **Semi-Critical**
  Groundwater extraction is close to or exceeding recharge. Where the extraction of the recharged water is between 70% to 90%.
  - Warning stage— careful management needed.
- ✓ **Critical**
  Groundwater extraction is increasing. Where the extraction of the recharged water is between 90% to 100%.
  - Water levels are falling fast.
- ✓ **Over-Exploited**
  Groundwater extracted heavily. Where more than 100% of the recharged water is extracted.

Wells dried up, water quality worsens, urgent action needed. These categories help governments and communities decide where to protect, regulate, or restrict groundwater use.



Aquifer System

Aquifer systems are natural subsurface formations that store and transmit groundwater through interconnected pores and fractures.

What Is an Aquifer?

Underground layers of soil, sand, gravel, or rock that store and transmit groundwater.

How Water Gets There?

Rainfall seeps into the ground, filling tiny spaces and cracks in underground formations.

How We Access?

Extracted through dug wells, hand pumps, or borewells for drinking, farming, and industry.

Single-Layer and Multi-Layer Aquifer Systems

In some areas, groundwater occurs in only one main water-bearing layer, known as a single-layer aquifer system. Wells or borewells in such areas draw water from this single underground layer.

In many regions, however, there are several water-bearing layers at different depths, separated by layers of clay or hard rock. This arrangement is called a multi-layer aquifer system. In these systems, shallow wells tap the upper aquifer, while borewells/tubewells reach deeper aquifers.

Hydraulic Connection Between Layers

Sometimes the aquifer layers are connected through fractures, cracks, or permeable zones in the rocks. This allows groundwater to slowly move from one layer to another. Such movement is called a hydraulic connection. If layers are separated by thick clay or hard rock, the connection is weak or absent, and water in each aquifer remains largely separate.

Understanding Shallow and Deep Aquifers

Aquifers are often described as shallow or deep depending on their depth below the ground. Shallow aquifers occur closer to the surface and are usually recharged quickly by rainfall, but they may be more vulnerable to contamination. Deep aquifers occur at greater depths and are generally accessed through borewells/tubewells. They often contain cleaner water but recharge more slowly. Understanding these differences helps in proper planning and sustainable use of groundwater.

What is Aquifer Mapping?

Aquifer mapping is the science of understanding groundwater—where it is stored, how it moves, and how much is available—so communities can use it safely and sustainably.

Objectives of Aquifer Mapping

01 Storage
Identify where groundwater is stored underground.

02 Availability
Understand how much water is available and how it moves.

03 Quality
Assess water quality for drinking, irrigation & industrial use.

04 Protection
Prevent Overextraction of Groundwater

Why Aquifer Maps Are Needed

Groundwater is hidden below the surface, so using it without knowledge can lead to problems like drying wells, falling water levels, and poor water quality.

Locate good groundwater zones
Identify where productive, safe aquifers exist.

Guide well placement
Choose correct sites and depths; avoid poor or unsafe zones.

Support long-term water security
Enable governments and communities to plan sustainable water use.

Scale of Aquifer Mapping

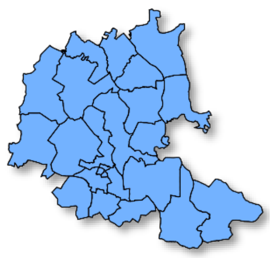
Aquifer mapping is done at different scales depending on the purpose. Each scale gives a different level of detail.

National Level

Broad picture of major aquifer systems. Drives national policy and water security planning.

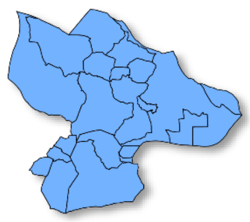
State Level

Shows major aquifers within a state. Supports state-level water management schemes and infrastructure.



District Level

Detailed data on aquifer extent, water levels, and quality. Guides district water supply and agricultural planning.

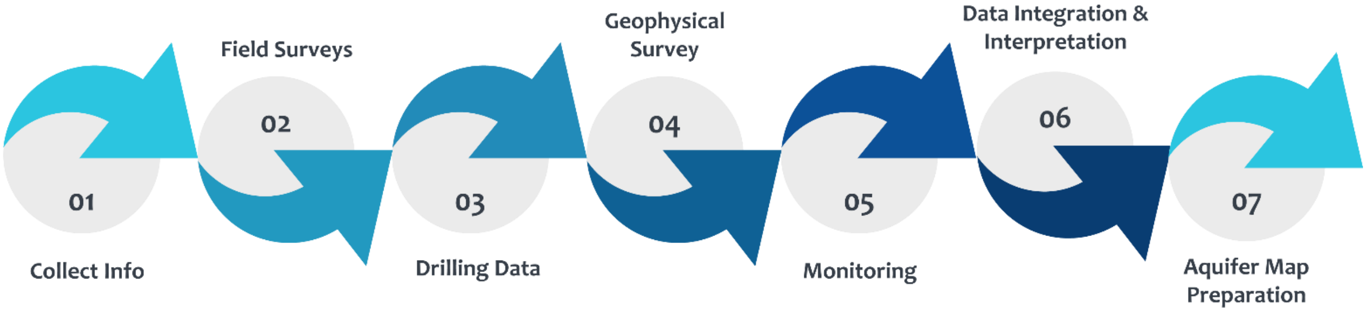


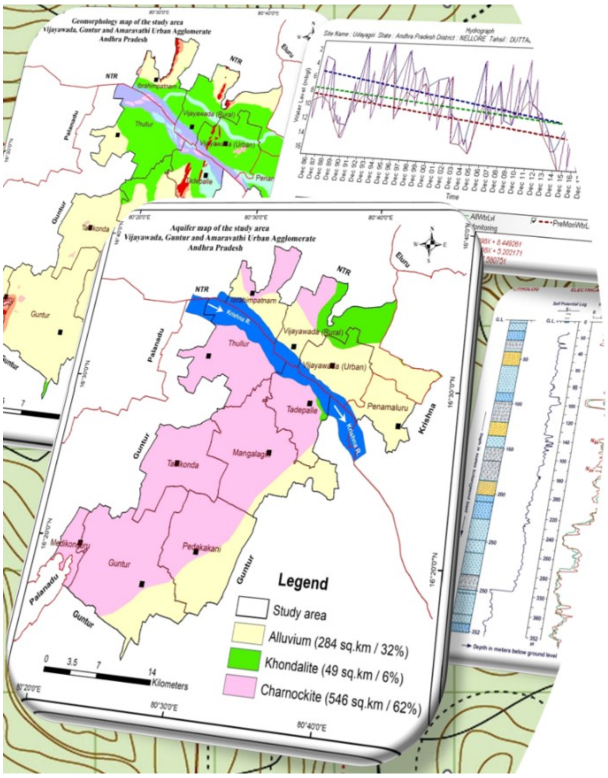
Block /Village Level

Most practical detail. Tells farmers and engineers where to drill, how deep, and how much water can be safely used.

How Aquifers Are Mapped?

Aquifers are mapped by collecting information about what lies underground and turning it into easy-to-understand maps. A combination of field data, existing records, and maps are used to understand groundwater systems. The various steps involved in Aquifer map preparation are provided below:





Step 1: Collect Existing Information

Before any fieldwork begins, scientists gather all available data from state and central government departments.

Thematic Maps
Geological, geomorphological, land use, soil, etc

Well & Borehole Records
Locations, depths, and historical logs

Historical Records
Groundwater levels and water quality data

Rainfall & Surface Water
Hydrology and catchment information

Overall, these maps indicate various scenarios of the study area, which enhance the understanding of the area and require for various interpretations and recommendations.

Step 2: Field Surveys & Observations

Scientists then visit the area to collect fresh information:

Hydrogeology Mapping
Note locations of wells, springs, water bodies, etc

Rock & Soil Study
Exposed formations and surface geology

Community Feedback
Groundwater issues and usage patterns

Understanding local specific groundwater problems, groundwater quality conditions, extraction rates, and both direct and indirect information on subsurface conditions helps in accurately representing ground realities in NAQUIM maps and reports.

Step 3: Drilling & Well Data Analysis

Sub-surface information is collected through ground water exploration studies by drilling wells and collecting information from drilled wells. The following information is collected.

Soil & Rock Layers
Lithology logs from drilling samples

Water-Bearing Zones
Identifying aquifer horizons and their extent

Well Yield
Pumping tests to measure water discharge & aquifer parameters like transmissivity and storage of aquifers

Drilling provides direct information on subsurface aquifer conditions, including yield, depth of occurrence of aquifers, groundwater quality, and aquifer characteristics such as storage and storativity.

Step 4: Geophysical Surveys

Special instruments are used to "see" underground without drilling:

Electrical & Resistivity Survey
Measures the electrical resistance of underground rocks to identify water-bearing layers and aquifer boundaries.

Electromagnetic Survey
An electromagnetic field induces currents in the ground and the measured response helps identify subsurface conductivity and aquifers.

2-types: Transient Electromagnetic Survey, Heliborne-survey

Geophysical surveys are cost-effective scientific methods that cover large areas in a short time. They provide indirect yet reliable information on the subsurface disposition of aquifers. Together, drilling, VES, and field inventory offer valuable information on aquifer disposition.

Step 5: Groundwater Level & Quality Monitoring

Regular monitoring stations including newly established key wells provide information on saturation of aquifer.

Deth to water level
Depth and seasonal rise and fall of the water level and its variation over time and space.

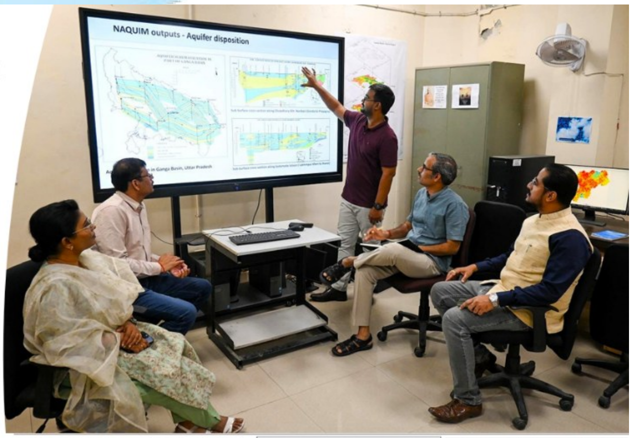
Water Quality
Testing for salinity, fluoride, and other contaminants and its variation over time and space.

Expanded Network
Key wells added at strategic locations to improve spatial coverage.

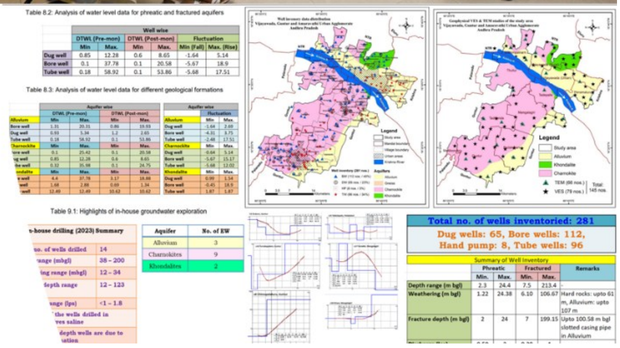
Together the groundwater level and quality provides overall saturation of aquifers, quality of groundwater & its variability

Step 6: Data Integration and Interpretation

All datasets are brought together and analyzed as a unified picture. This synthesis step transforms raw numbers into a scientific understanding of the aquifer system.

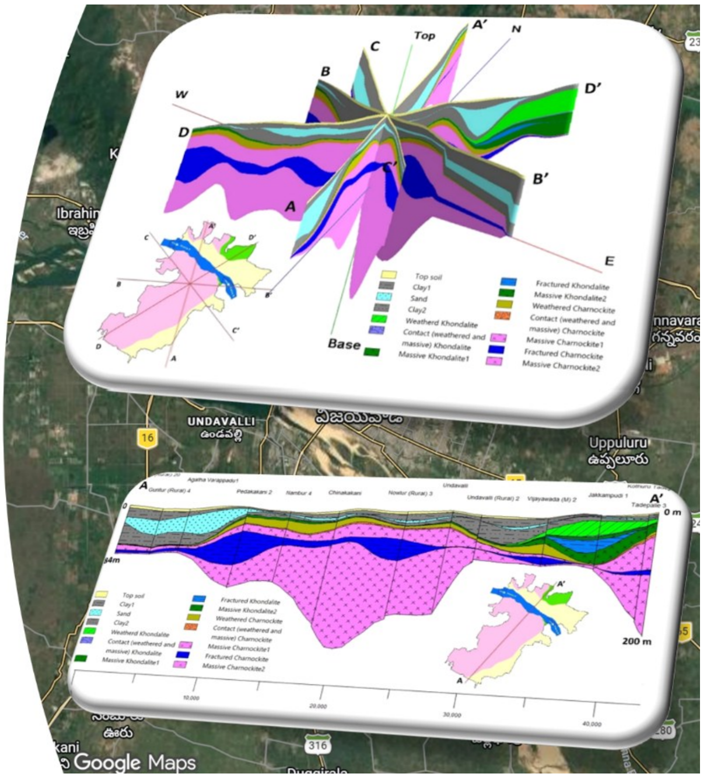


1. **Synthesis of all data**
   Merge well logs, water levels, and quality readings into one dataset
2. **Define Boundaries**
   Identify where the aquifer begins and ends spatially
3. **Groundwater Movement**
   Understand how groundwater flows and at what rate
4. **Identify Issues**
   Groundwater over-extraction, low availability, and quality-related problems.



Step 7: Preparation of Aquifer Maps

All data comes together as a suite of maps — each serving a distinct purpose in groundwater planning and management.



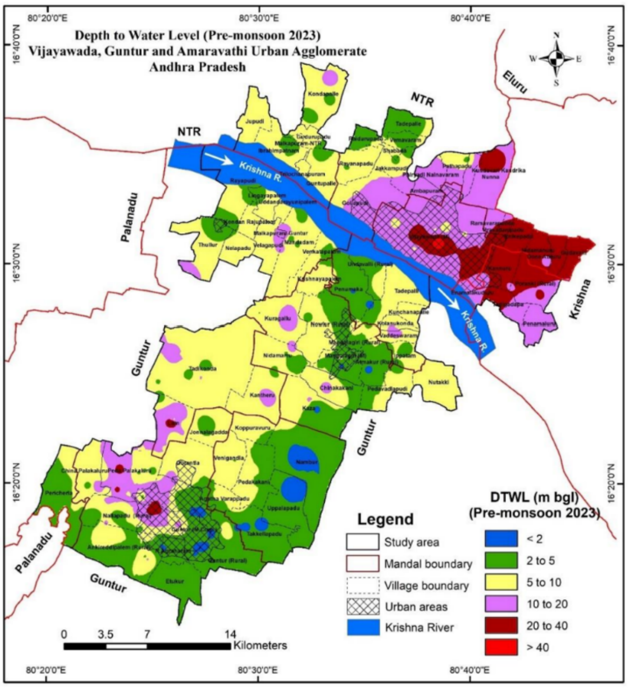
Conceptualisation & Characterisation
3D understanding of aquifer disposition

Water Level & Quality Maps
Spatial distribution of groundwater conditions

Groundwater Potential Maps
Zones of high and low groundwater availability

Management Maps
Guidance for sustainable groundwater use

Interpretation of Maps



1: Depth to Water Level Map

This map shows the spatial variation in groundwater levels across the study area. Generally, the depth to water level is deeper during May (pre-monsoon) and gets recharged during the monsoon, which is reflected as a rise in water levels in the post-monsoon period.

Shallow water level (0–5 m)

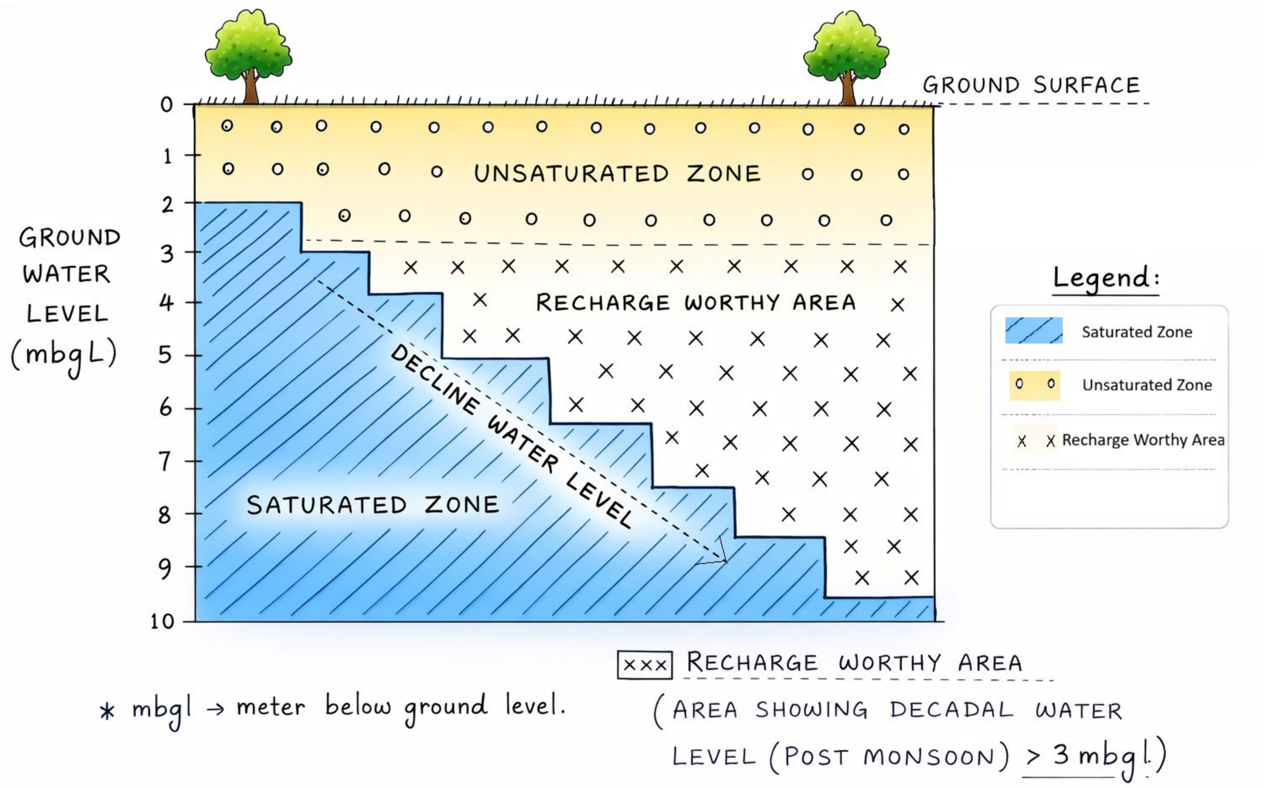
- ✓ Groundwater is close to the surface.
- ✓ Easier and cheaper to access via wells or boreholes.
- ✓ Often found near rivers, floodplains, discharge zones.

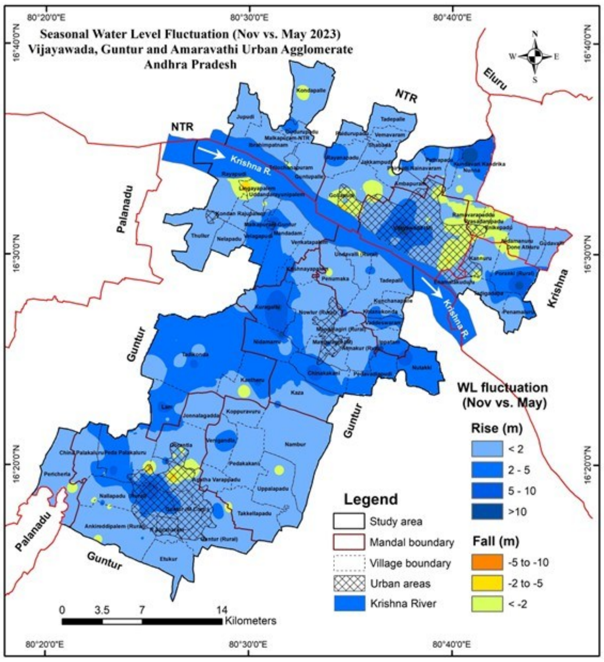
Moderate water level (5-20 m)

- ✓ Common in many agricultural area.
- ✓ Area having high water demand
- ✓ Shows the sign of moderate-high groundwater extraction.

Deeper water level (>20 m)

- ✓ Indicates groundwater depletion due to higher demand.
- ✓ Require prioritized Recharge intervention
- ✓ Higher pumping cost and energy requirement.





2: Water Level Fluctuation Map

This map represents changes- rise/fall in groundwater level. (between pre-monsoon and post-monsoon seasons).

Rise in water level

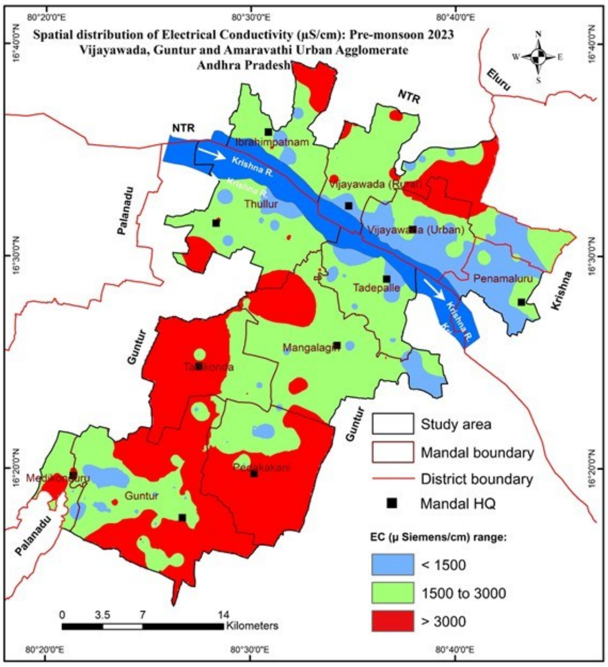
- ✓ Indicates good recharge from rainfall or surface water.
- ✓ Common after monsoon.

Decline in water level

- ✓ Suggests over-extraction or low recharge.
- ✓ Often seen in heavily irrigated areas.

Stable zones

- ✓ Balanced recharge and withdrawal.



3: Groundwater Quality Map

This map shows the chemical quality of groundwater using parameter Electrical Conductivity (µS/cm)

Drinking Purpose

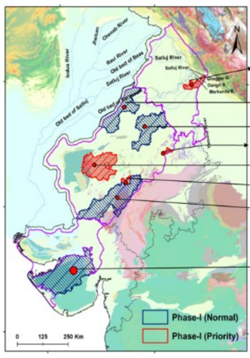
- ✓ <1500 µS/cm (Blue): Suitable for drinking (fresh water).
- ✓ 1500–3000 µS/cm (Green): Marginal; usable with treatment
- ✓ >3000 µS/cm (Red)/: Unsuitable for drinking (saline water)
- ✓ (Safe zones mainly along Krishna River belt
- ✓ Southern & western areas mostly not fit for drinking

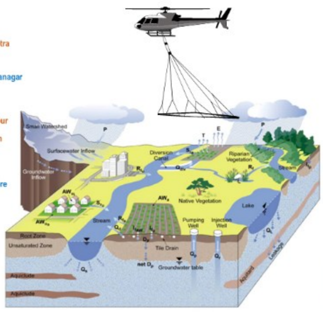
Irrigation Purpose

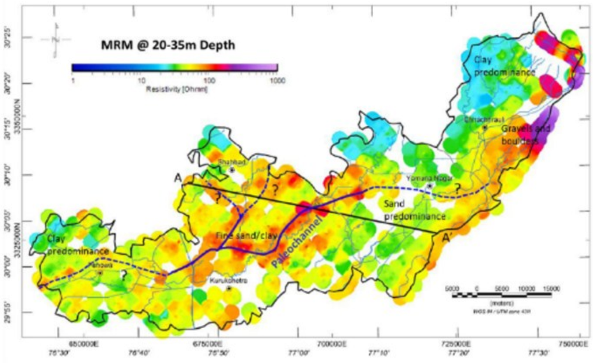
- ✓ 1500 µS/cm: Excellent; suitable for all crops
- ✓ 1500–3000 µS/cm: Moderate; needs drainage & salt-tolerant crops
- ✓ >3000 µS/cm: Poor; risk of soil salinity & low yield
- ✓ River belt → good irrigation quality
- ✓ South & Western zone → high salinity, management required

Geophysical Survey

Geophysical investigations were carried out prior to drilling to identify suitable groundwater-bearing formations and to determine the depth and thickness of aquifers. The results helped in selecting the appropriate drilling locations and guided the design of exploratory wells for groundwater development.







5: Heliborne Electromagnetic (HEM) Survey

In groundwater investigations, CGWB explored helicopter-mounted sensors to survey large areas and assess subsurface hydrogeological conditions without drilling. This enables rapid and reliable mapping of aquifer locations, their depth, and spatial distribution of groundwater bearing aquifer/fracture.

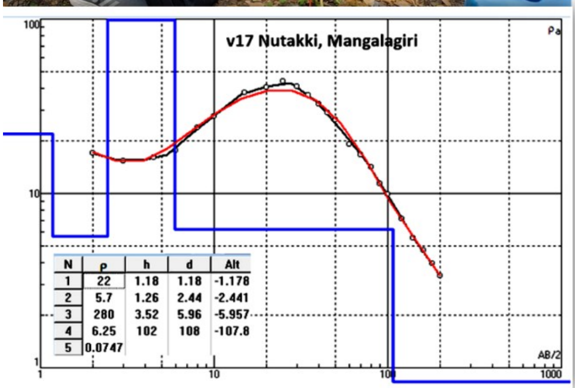
Locate groundwater
- ✓ Identifies likely water-bearing zones

Estimate depth
- ✓ Helps know how deep to drill (Aquifer/Fracture Depth)

Indicate water quality
- ✓ Flags possible fresh vs saline areas

Support planning
- ✓ Guides Exploration wells & Managed Aquifer Recharge sites

Highlight stress zones
- ✓ Identifies overused/vulnerable areas.



6: Resistivity Survey

This vertical electrical sounding (resistivity survey) indicates a 5- layer geoelectrical section. It is non-invasive, cost-effective, and helps accurately locate potential groundwater zones, reducing uncertainty in drilling.

Layer 1
- ✓ Resistivity:: 22 Ω-m, 1.18 m thick → Top soil (surface layer)

Layer 2
- ✓ Resistivity:: ~5.7 Ω-m, ~1.3 m thick → Clay Formation

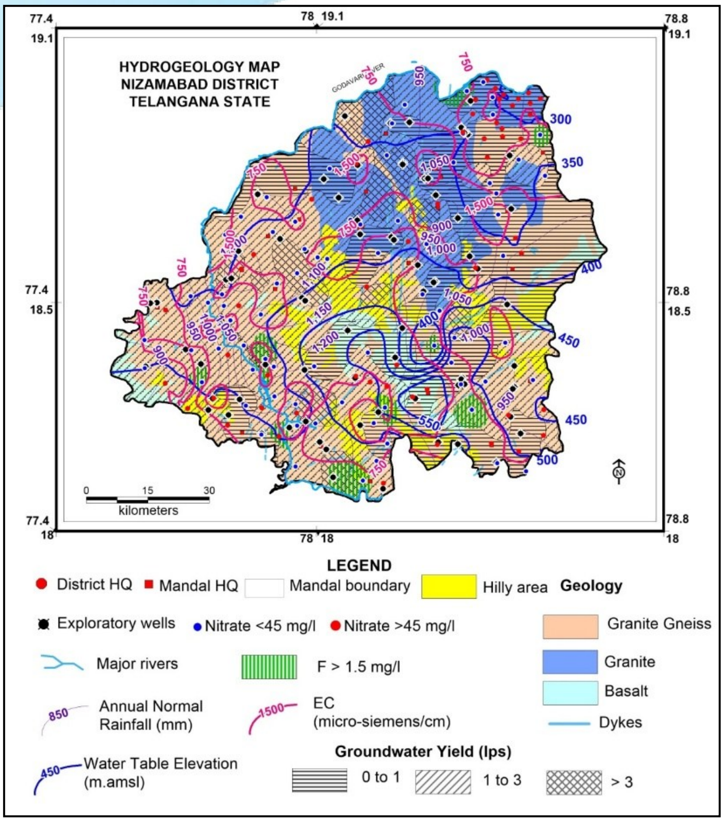
Layer 3
- ✓ ~280 Ω-m, ~3.5 m thick → Sand (limited fresh groundwater)

Layer 4
- ✓ Resistivity:: ~6.25 Ω-m, extends to ~108 m → Clay with saline groundwater

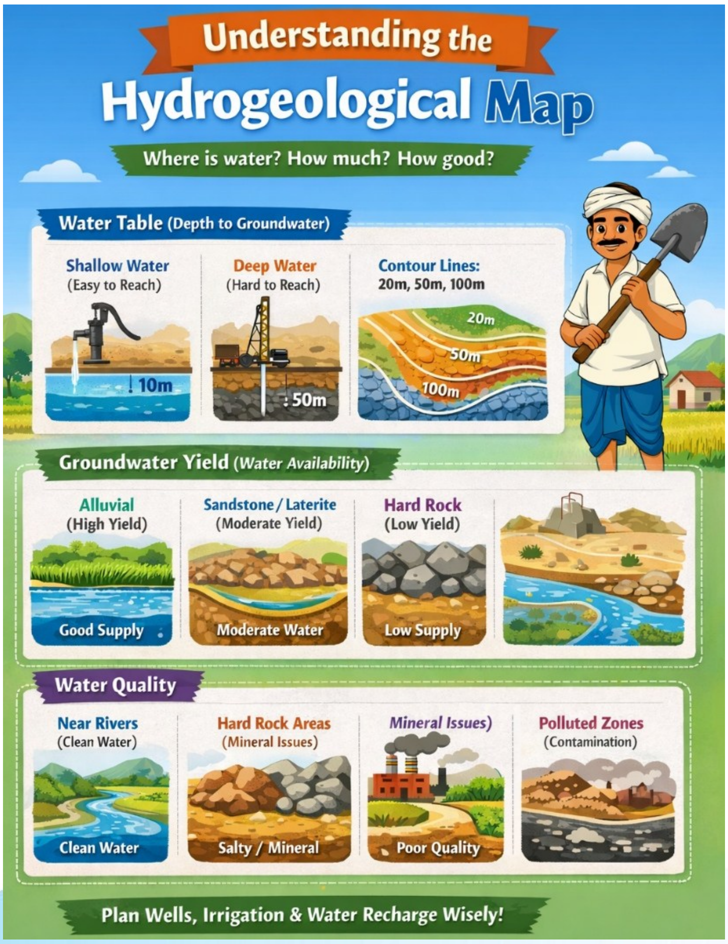
Layer 5
- ✓ ~0.07 Ω-m → Highly saline formation at greater depth (not suitable)

7. Hydrogeological Map

The map shows all features into a single map, providing a holistic understanding of the aquifer system. It integrates output of various thematic maps such as geology, geomorphology, groundwater levels, and aquifer characteristics, providing a complete understanding of groundwater conditions. It helps in identifying where water is available, how deep it occurs, how much can be extracted, and its quality, making it a useful tool for planning and sustainable management of water resources.



1. Shows depth to water table (shallow = easy access, deep = costly extraction)
2. Indicates groundwater availability (yield) based on rock/soil type
3. Highlights high-yield areas (alluvial) and low-yield areas (hard rock)
4. Provides information on water quality (fresh, mineral-rich, or contaminated)
5. Helps identify suitable locations for wells and borewells
6. Guides irrigation planning and crop decisions
7. Supports rainwater harvesting and recharge planning
8. Enables better village-level water management and sustainability
9. It simplifies complex groundwater data into easy insights for practical use.



Aquifer Conceptualisation

Aquifer conceptualisation means understanding how groundwater exists and moves below the ground. Since we cannot see underground directly, we create a clear mental picture of what lies beneath the surface.

01
Where ?
Location of potential aquifers

02
What Depth ?
Depth of aquifer units

03
How it moves
Entry, Flow & Discharge Pathways

Aquifers are like layers of a cake — each layer is different and behaves differently with water.

Subsurface Controls

How underground layers affect groundwater and primarily depends upon:

1 Lithology
Sand & gravel transmit water freely; In fractured rock water movement is limited

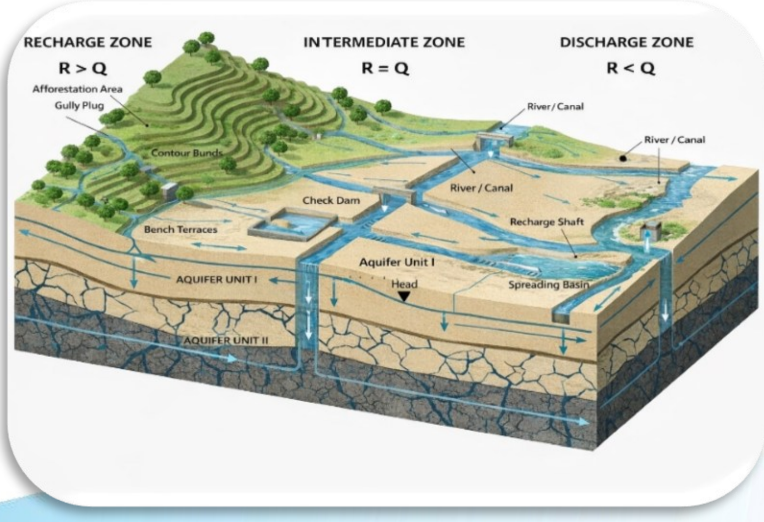
2 Structures
Hard rock: Fractures and joints create secondary porosity.
Soft rock: Sedimentary layered beds

3 Weathering
Near-surface rock breakdown creates a weathered zone with enhanced groundwater storage

Preparing Conceptual Diagrams

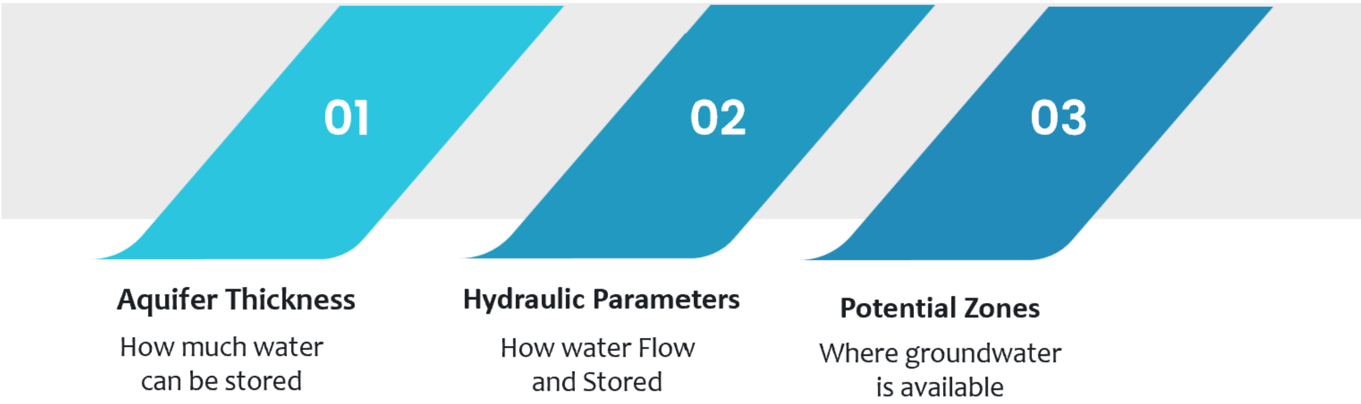
Since we cannot see underground layers, we draw simple diagrams to show:

- ✓ Different soil and rock layers
- ✓ Where groundwater is stored
- ✓ Direction of groundwater flow
- ✓ Recharge areas (where rainwater goes into the ground).
- ✓ Discharge areas (where water comes out through wells, springs, or rivers).



Aquifer Characterisation

Aquifer characterisation means understanding how much water an aquifer can store, how easily water can move through it, and where good groundwater is likely to be found. This helps us decide where to drill wells, how much water can be safely used, and how to protect groundwater.



Aquifer Thickness

Aquifer thickness is the height of the water-bearing layer underground.

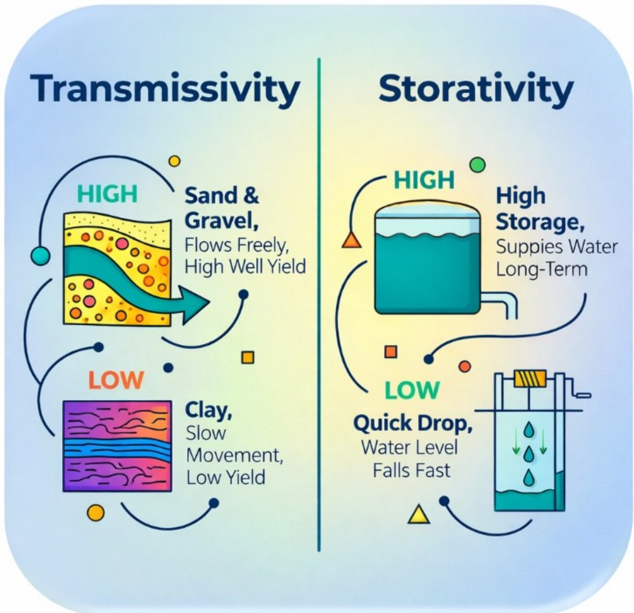
- ✓ A thick aquifer can store more water
- ✓ A thin aquifer holds less water and can dry up faster
- ✓ Knowing aquifer thickness helps estimate how much groundwater is available.

Hydraulic Parameters

Transmissivity

This shows how easily water can flow through the aquifer.

- ✓ High transmissivity → water flows easily → wells give more water
- ✓ Low transmissivity → water moves slowly → wells give less water



Storativity

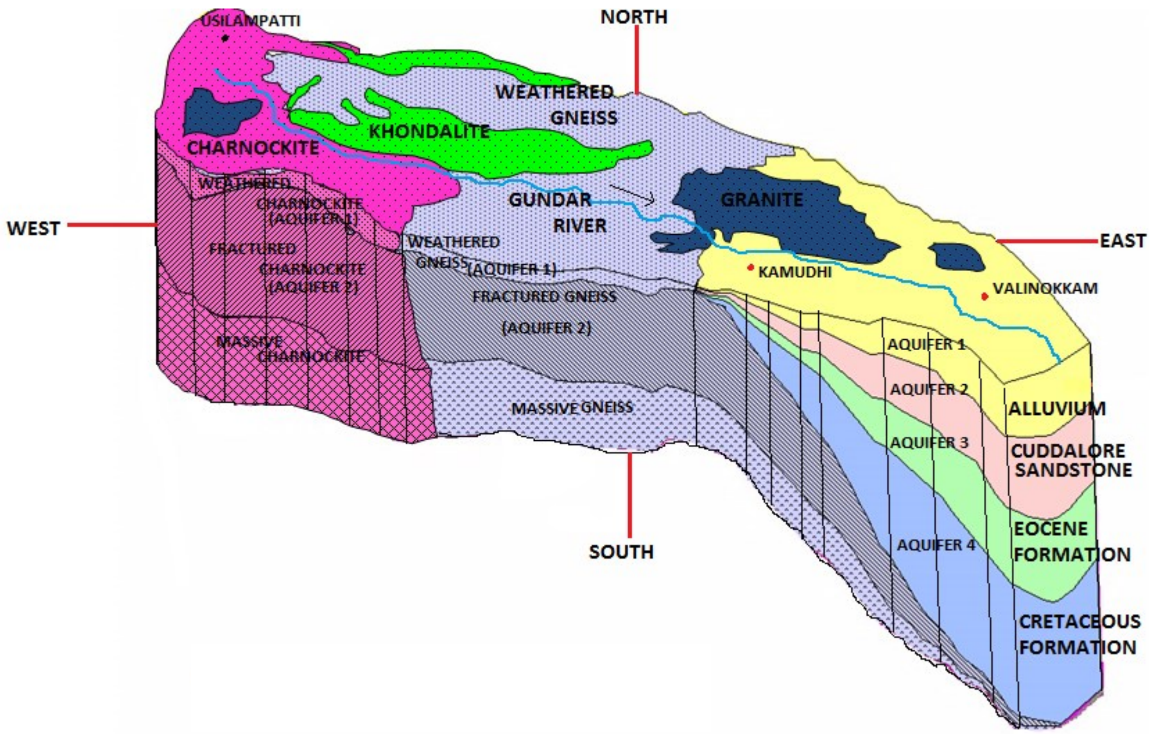
This shows how much water the aquifer can store and release when pumped.

- ✓ High storativity → aquifer can supply water for a long time
- ✓ Low storativity → water level drops quickly when pumping starts

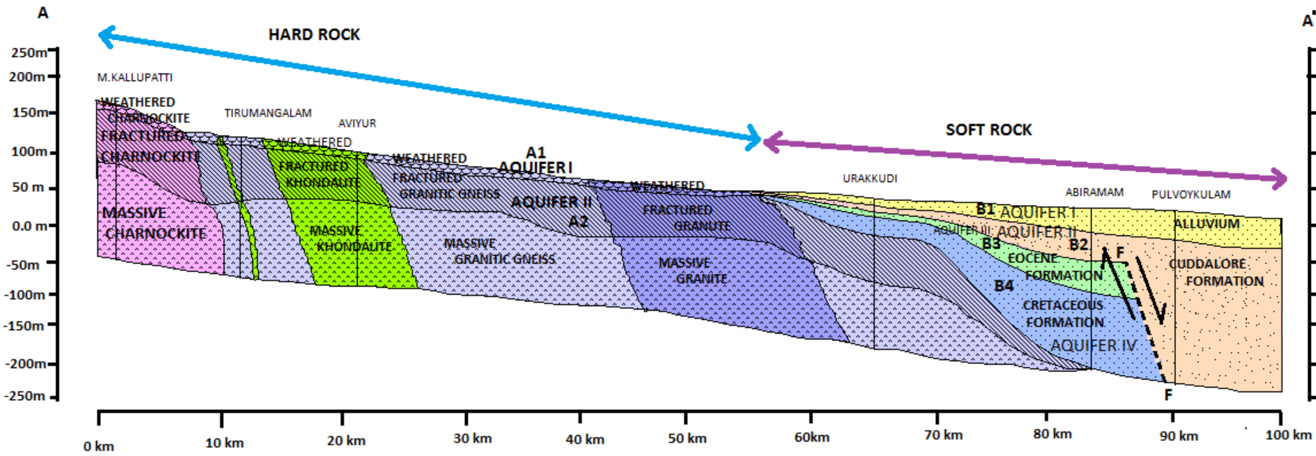
Together, these parameters help to understand well yield and pumping limits.

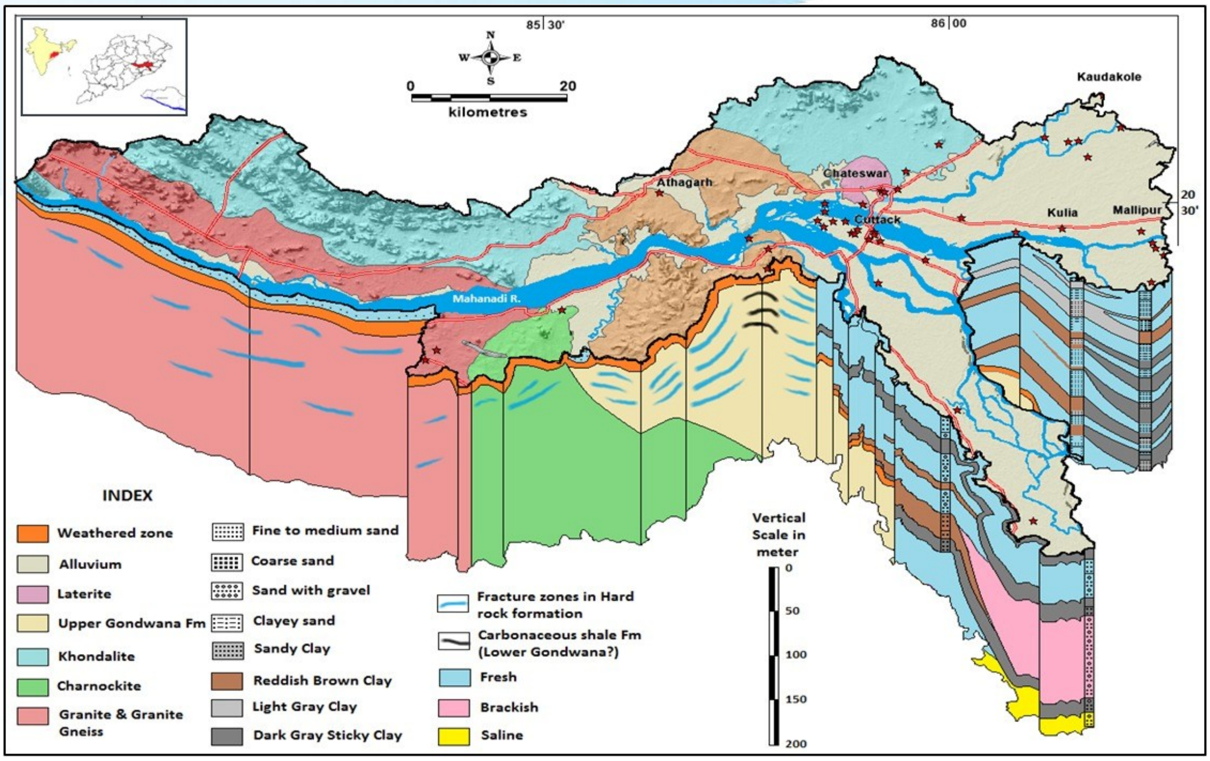
3D & 2D Aquifer Disposition

- ✓ Aquifer mapping helps create 2D and 3D models of aquifers beneath the ground.
- ✓ These models show the depth, thickness, and distribution of aquifer layers.
- ✓ They help understand how different aquifers are arranged and connected underground.
- ✓ The models are prepared using borehole data, geophysical studies, and groundwater information.
- ✓ They help identify productive aquifer zones and support better groundwater planning and management.

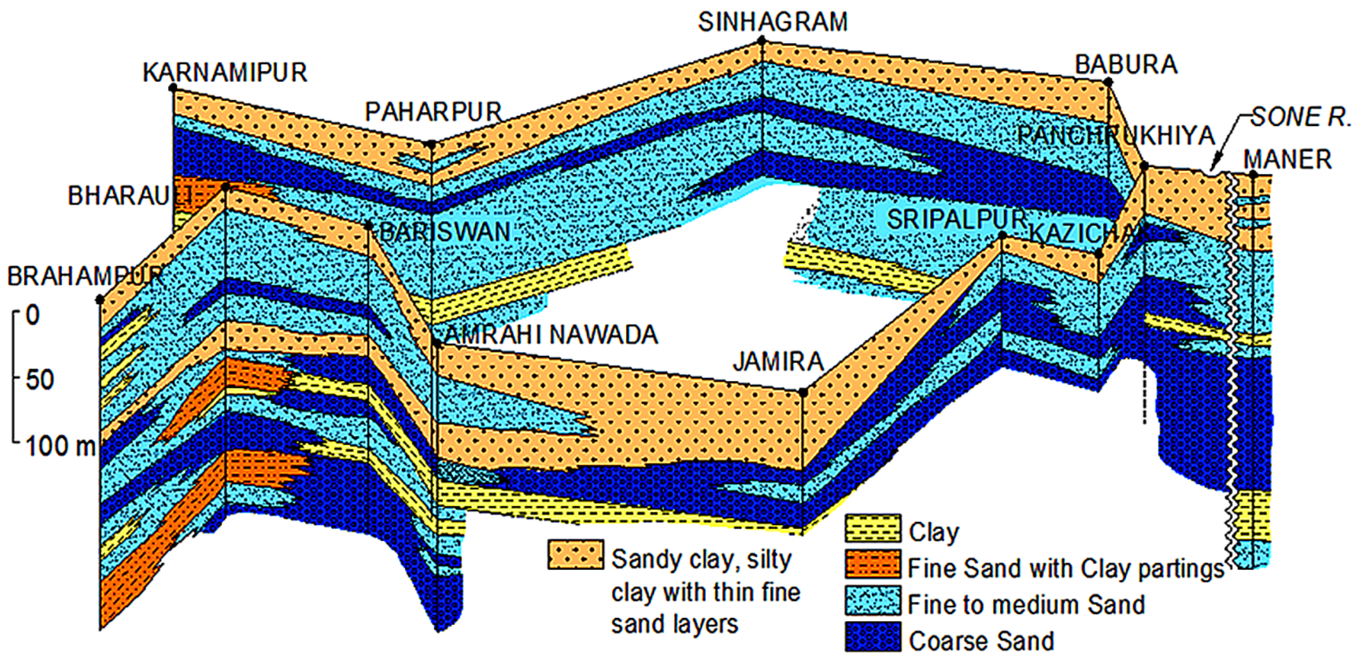


A combination of Hard rock and Soft rock aquifer in Gundar Basin, Tamil Nadu





Hard & Soft rock aquifer in parts of Cuttack District of Odisha



Fence diagram Soft rock aquifer in parts of Bhojpur & Buxar of Bihar

Groundwater Issues identified the aquifer mapping

Groundwater problems arise when water is extracted faster than recharge, or when it becomes polluted. Since groundwater is hidden underground, these problems often go unnoticed until it affects the users.

Based on field studies, integration of maps, and aquifer conceptualization discussed in the previous section, the groundwater issues are as follows:

1. Over-Extraction

Over-extraction means pumping more groundwater than is naturally recharged by rainfall.

This happens due to:

- ✓ Too many borewells in a small area
- ✓ Excessive use of groundwater for irrigation
- ✓ Continuous and indiscriminate pumping

2. Declining Water Levels

Declining water levels mean groundwater getting deeper every year.

Effects of falling water levels:

- ✓ Drying up of Wells and handpumps
- ✓ Deepening of Borewells
- ✓ Pumping becomes more expensive
- ✓ Small farmers and rural households suffer most

3. Water Quality Deterioration

Common problems include:

- ✓ Salinity (salty water)
- ✓ Fluoride (causing health problems)
- ✓ Nitrate (from fertilizers and waste)

4. Climate Change Impacts

Climate change is making groundwater problems more serious. Its effects include:

- ✓ Irregular and reduced rainfall
- ✓ Fewer rainy days but heavier rainfall (more runoff, less recharge)
- ✓ Longer dry periods and droughts

Overall Picture

All these problems are connected:

Over extraction → Falling water levels → Poor water quality → Increased climate stress

Groundwater Management

Based on all the outputs generated from field studies, aquifer mapping, and the issues identified, the next step is to formulate groundwater management plans.

Groundwater management is the planned, scientific and participatory regulation of groundwater development, use, recharge and protection to ensure that groundwater remains sustainable in quantity and quality over the long term.

It focuses on balancing recharge and withdrawal, protecting groundwater from pollution, prioritizing drinking water security, and ensuring equitable and efficient use across agriculture, domestic and industrial sectors.

Why groundwater management is required?

- ✓ Providing a comprehensive plan for administrators for the judicious development and sustainable management of groundwater.
- ✓ Providing safe drinking water: It helps ensure the availability of clean and safe groundwater for human consumption.
- ✓ Sustaining availability during lean periods: Proper management maintains groundwater reserves during dry seasons, droughts, and periods of low rainfall.
- ✓ Building climate resilience: It supports adaptation to climate variability and changing rainfall patterns by improving water storage and availability.
- ✓ Ensuring water security: It helps meet long-term water needs for drinking, irrigation, livelihoods, and economic activities.

What are major groundwater management initiatives?

There are broadly two ways of management for sustainable groundwater management in the country

01

Supply Side

Put more water into the ground.

02

Demand Side

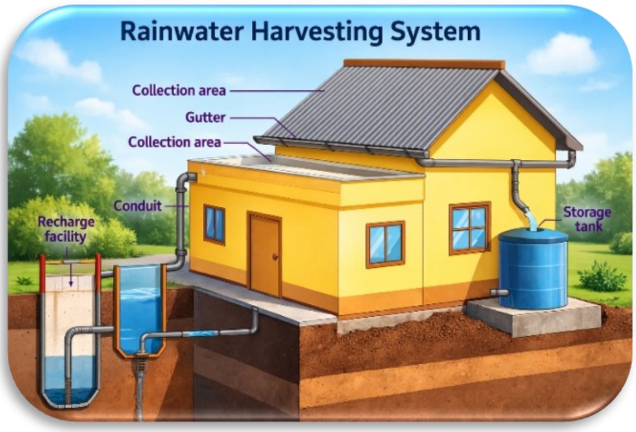
Take less water out of ground

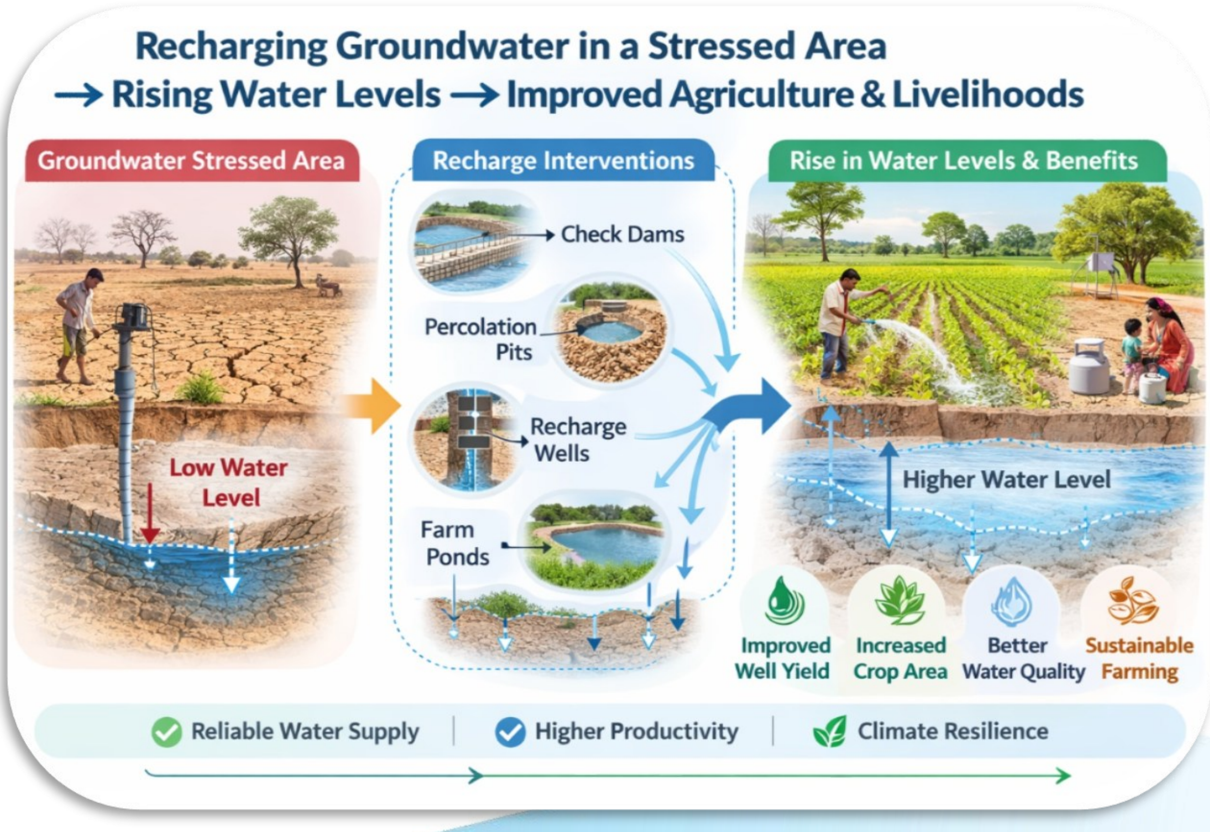
1. Supply-Side Interventions

These initiatives are intended to provide supply (recharge) to groundwater.

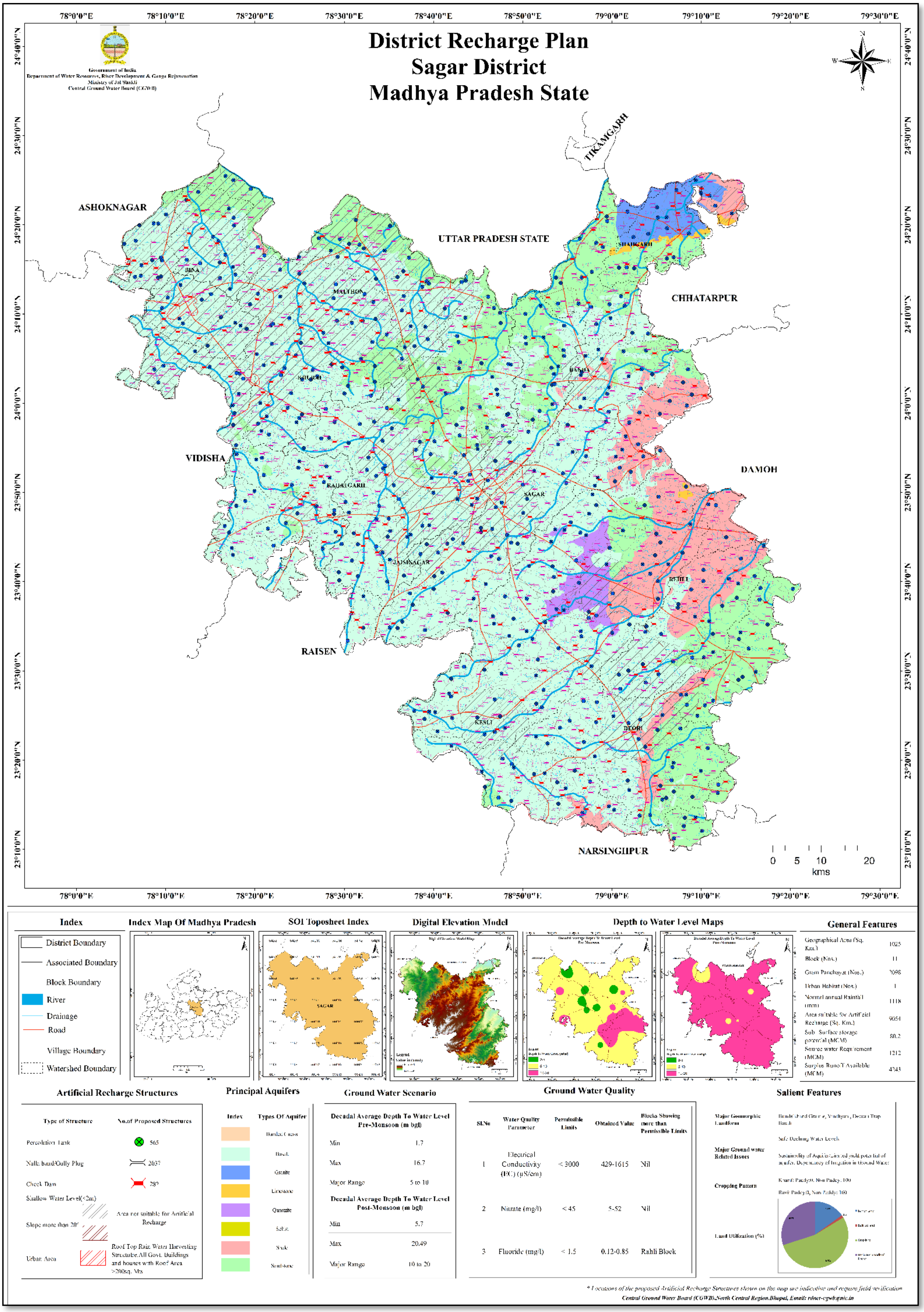
Examples:

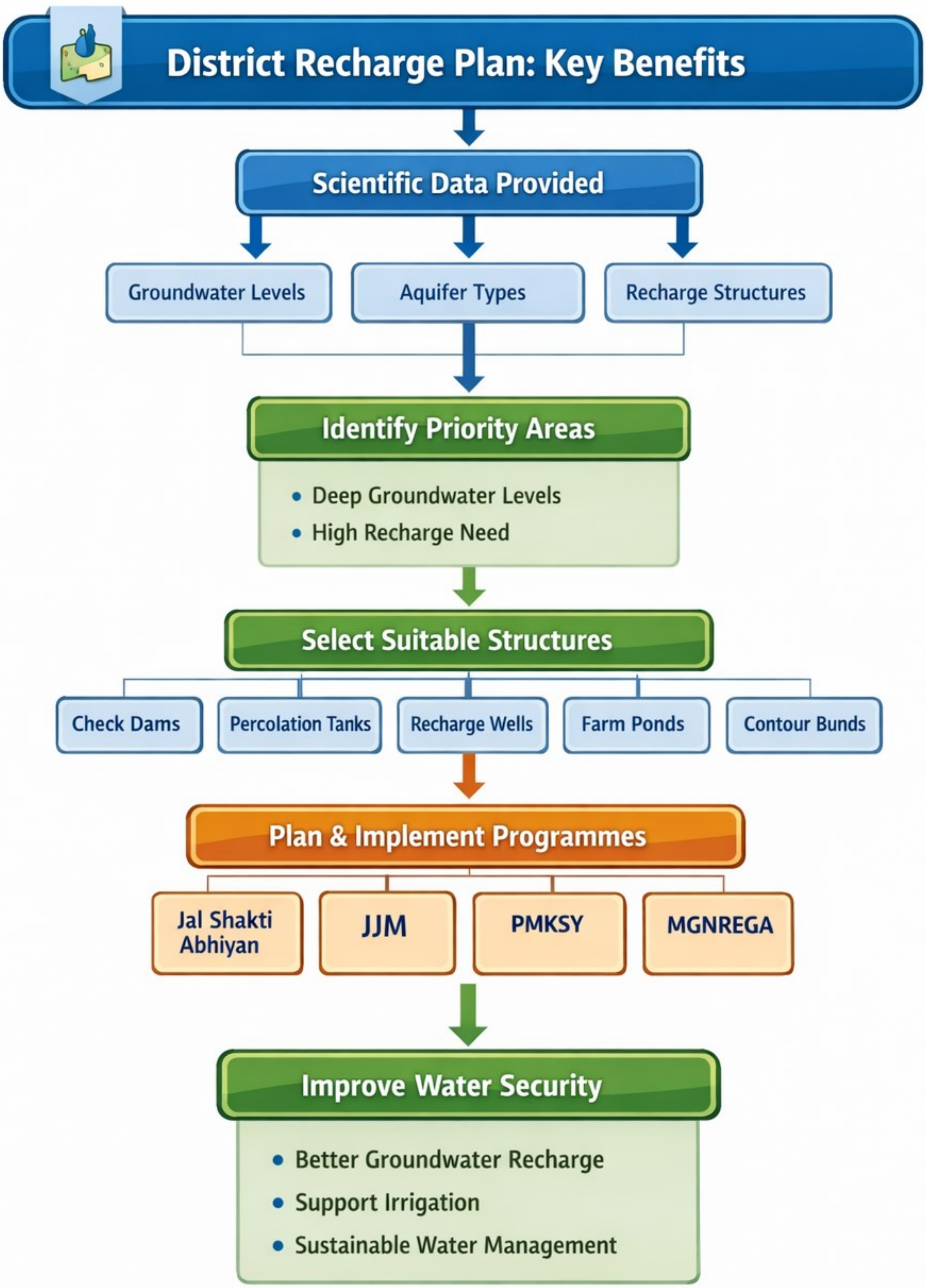
- ✓ Artificial recharge structures (check dams, percolation tanks): Slow down rainwater flow and allow it to seep into the ground, increasing groundwater recharge.
- ✓ Rooftop rainwater harvesting: Collects rainwater from rooftops and directs it to recharge wells or storage systems.
- ✓ Revival of ponds and tanks: Cleaning and deepening old ponds increases their water storage capacity and improves groundwater recharge.
- ✓ Farm ponds and field bunds: Store rainwater in agricultural fields and reduce surface runoff.





District Recharge Plan are site specific and are prepared based the supply side intervention proposed in NAQUIM study.




District Recharge Plan: Key Benefits
Scientific Data Provided
Groundwater Levels
Aquifer Types
Recharge Structures
Identify Priority Areas
• Deep Groundwater Levels
• High Recharge Need
Select Suitable Structures
Check Dams
Percolation Tanks
Recharge Wells
Farm Ponds
Contour Bunds
Plan & Implement Programmes
Jal Shakti Abhiyan
JJM
PMKSY
MGNREGA
Improve Water Security
• Better Groundwater Recharge
• Support Irrigation
• Sustainable Water Management

2.Demand-Side Interventions

These initiatives focus on promoting judicious extraction and conservation of groundwater.

Examples:

- ✓ Drip and sprinkler irrigation: Supply water directly to crops in a controlled manner, reducing water wastage.
- ✓ Growing less water-intensive crops: Cultivating crops like millets instead of paddy in water-scarce areas helps reduce groundwater demand.
- ✓ Avoiding excessive borewells: Limiting the number of borewells helps prevent over-extraction and protects groundwater levels.
- ✓ Efficient water uses at home: Fixing leaks and reusing water wherever possible helps reduce overall water demand.

Outreach Activity

1. Sharing of NAQUIM Reports

Sharing NAQUIM reports and aquifer maps with State and District administrations helps them understand the groundwater situation in their area. The reports provide information on groundwater availability, recharge potential, and water quality. Using this data, authorities can identify stressed areas, plan suitable recharge and conservation measures, and regulate groundwater use. This helps in better policy planning and data-based management of groundwater resources within their jurisdiction.

2. Awareness and Capacity Building

CGWB undertakes awareness generation and stakeholder engagement through Public Interaction Programmes (PIP), training programmes, and workshops for farmers, Panchayati Raj Institutions, State officials, and other stakeholders, encouraging community participation in groundwater management.

Implementation

Central Ground Water Board supports District authorities in implementing NAQUIM groundwater management plans. Based on the NAQUIM study results, CGWB provides technical guidance and helps identify suitable locations for recharge and conservation structures. Officers also assist local agencies in understanding aquifer conditions and the best type of intervention required. This support helps ensure that groundwater management works are carried out at the right places and in an effective way.

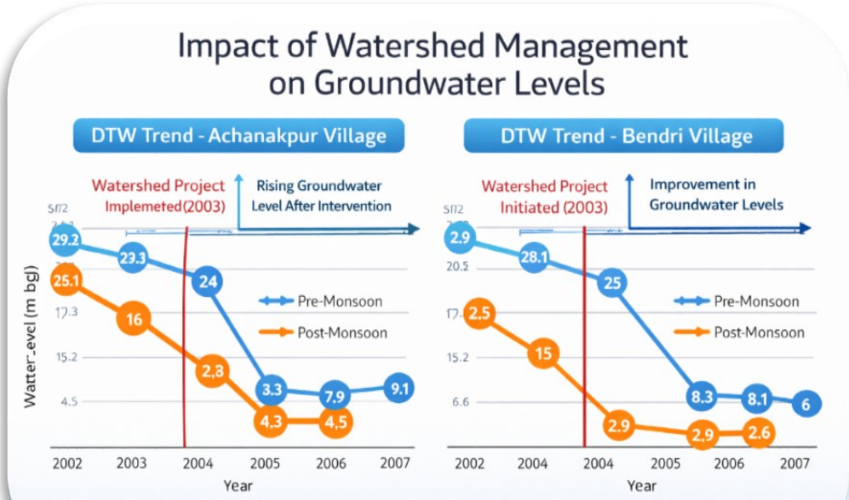

Check Dam at Garja watershed, Chhattisgarh


Arch Check Dam at Chikbalapur District, Karnataka

Impacts of Implementation

The generally observed impacts of implemented artificial recharge structures are on water levels, agriculture, quality, climate resilience.

- ✓ Rise in groundwater levels
- ✓ Improvement in well yield
- ✓ Increase in irrigated area
- ✓ Sustainability of groundwater during dry season.
- ✓ Increase in crop productivity



Implementation of watershed management measures improved groundwater recharge, resulting in a gradual rise in water levels in both villages after 2003.

NAQUIM outputs in planning water conservation activities under Government schemes

Enabling Groundwater Recharge Through Government Schemes

1. Jal Sanchay: Jan Bhagidari (JSJB) through VB-G RAM G (Viksit Bharat Initiative)

- ✓ NAQUIM recommendations guide the planning of groundwater recharge and water conservation works under the Jal Sanchay Jan Bhagidari initiative
- ✓ Amendments in Viksit Bharat – Guarantee for Rozgar and Ajeevika Mission (Gramin) VB-G RAM G enable adoption of NAQUIM-based interventions in rural and water-stressed areas.

2. Atal Bhujal Yojana (Atal Jal)

- ✓ NAQUIM provides aquifer maps and groundwater data, which help identify over-exploited and water-stressed areas targeted under Atal Bhujal Yojana
- ✓ It helps identify suitable locations for groundwater recharge and conservation structures and help in preparation of community-based Water Security Plans (WSPs).
- ✓ NAQUIM data supports sustainable groundwater use and demand-side management practices in agriculture.

3. Pradhan Mantri Krishi Sinchayee Yojana (PMKSY)

- ✓ NAQUIM provides aquifer maps and groundwater data to support irrigation planning under Pradhan Mantri Krishi Sinchayee Yojana.
- ✓ It helps identify suitable areas for groundwater development for agriculture and helps promote efficient use of water in agriculture under "Per Drop More Crop."

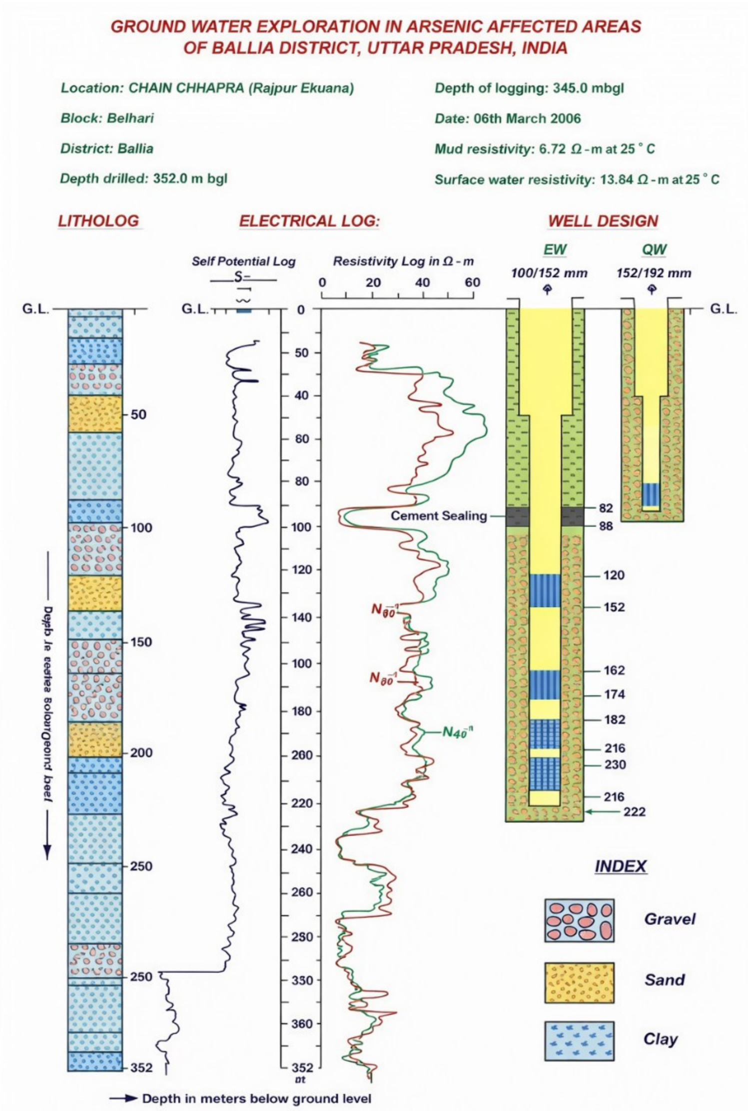
4. Convergence schemes

- ✓ NAQUIM recommendations provide scientific guidance to States for planning groundwater recharge and water conservation works under various State convergence schemes.
- ✓ They help identify suitable locations and types of recharge structures, enabling effective implementation of groundwater management interventions.

5. Societal benefits of NAQUIM outputs

- ✓ NAQUIM studies helped delineate arsenic-contaminated aquifer zones.
- ✓ Based on these findings, CGWB drilled wells and carried out cement sealing in arsenic-affected zones to isolate contaminated layers and prevent mixing with arsenic-free aquifers, ensuring safe drinking water supply.

NAQUIM Outputs in planning Government Schemes



Social Benefits of NAQUIM Outputs

Acknowledgement

The NAQUIM guidebook has been prepared using information compiled from various reports published by the Central Ground Water Board (CGWB). As this document is intended to be a simplified and user-friendly guide, detailed references to these source documents have not been included. The valuable contributions of the authors of these earlier reports are sincerely acknowledged.

Some of the photographs incorporated in this document have been sourced from the public domain. Their contribution in enhancing the quality and effectiveness of this guidebook is gratefully acknowledged.

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