9th India International Water Week 2026 : Climate Resilient Water Management (22-26 September 2026)

Theme 7: Water for People and Planet

TF20: Water and Human Health

"Assessment of Groundwater Quality Degradation and Pollution Vulnerability in the Urban & Peri-Urban stretch of Ayad River Watershed, Udaipur: Implications for Sustainable Groundwater Management"

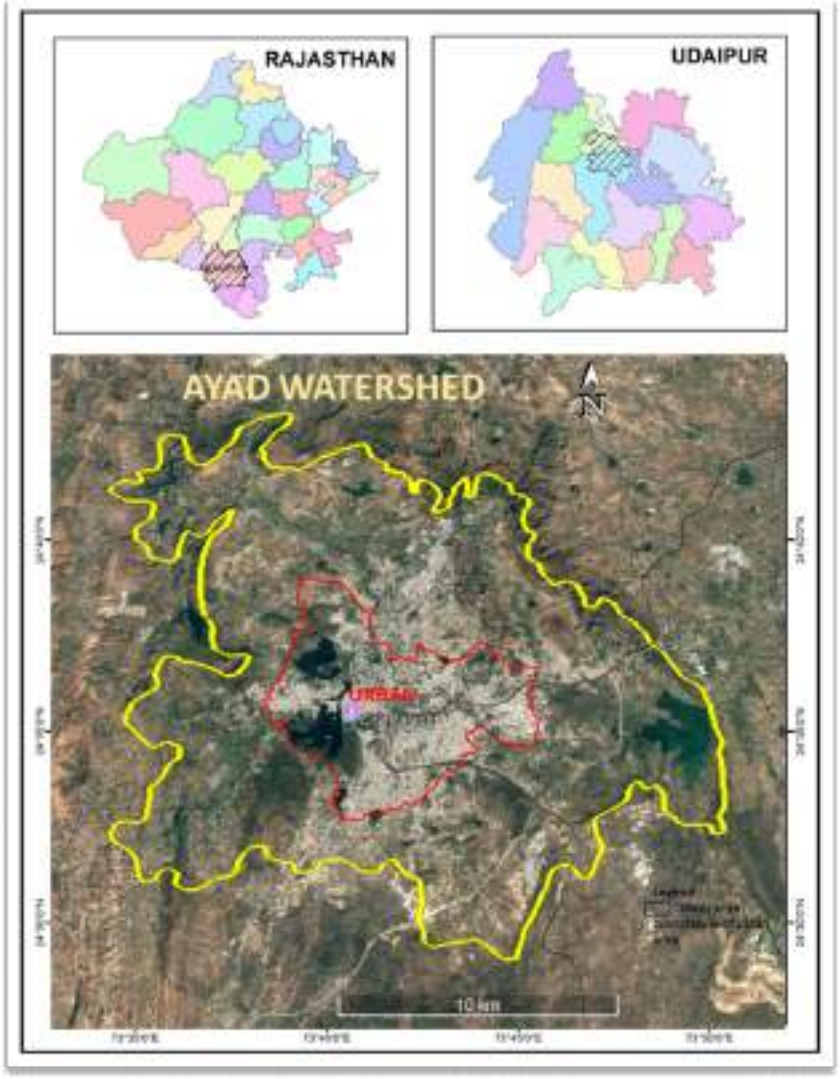
Maria Dominic, Aruna Saini, Priya Kanwar, Prashant Shrivas, Gyan Prakash Tiwari, Sunita Devi



Presented By ,
Maria Dominic, Scientist-C(HG)

CENTRAL GROUND WATER BOARD
Ministry of Jal Shakti
Department of Water Resources, River Development and Ganga Rejuvenation
Government of India

STUDY AREA DETAILS



Priority area: Urban Agglomerate

Total Study Area (Watershed)	382 Sq. Km
Urban & Peri urban area	262 Sq. Km
Hilly area	120 Sq. Km
District	Udaipur
Blocks	Girwa,Badgaon,Udaipur Urban,Kurawar
Lattitude	24°30′00″ to 24°40′00″ N
Longitude	73°35′00″ to 73°50′00″ E
Population (2011)	4.5 lakh (Census 2011)
Geomorphology	Burried pediment, Pediment, Valley fills, Denudational Hills
Major River & Lakes	Ayad River, Lake Pichola, Fatesagar, Udai Sagar
Prinicipal Aquifers	Phyllite, Granite, Gneiss ,Dolomite and Quartzite
Average Annual Rainfall	~ 690 mm
Elevation Ranges	525 to 955 m amsl
GWR Categorization 2025	Udaipur urban-Over exploited Badgaon block- Over exploited Girwa Block- Critical Kurawar-Over exploited

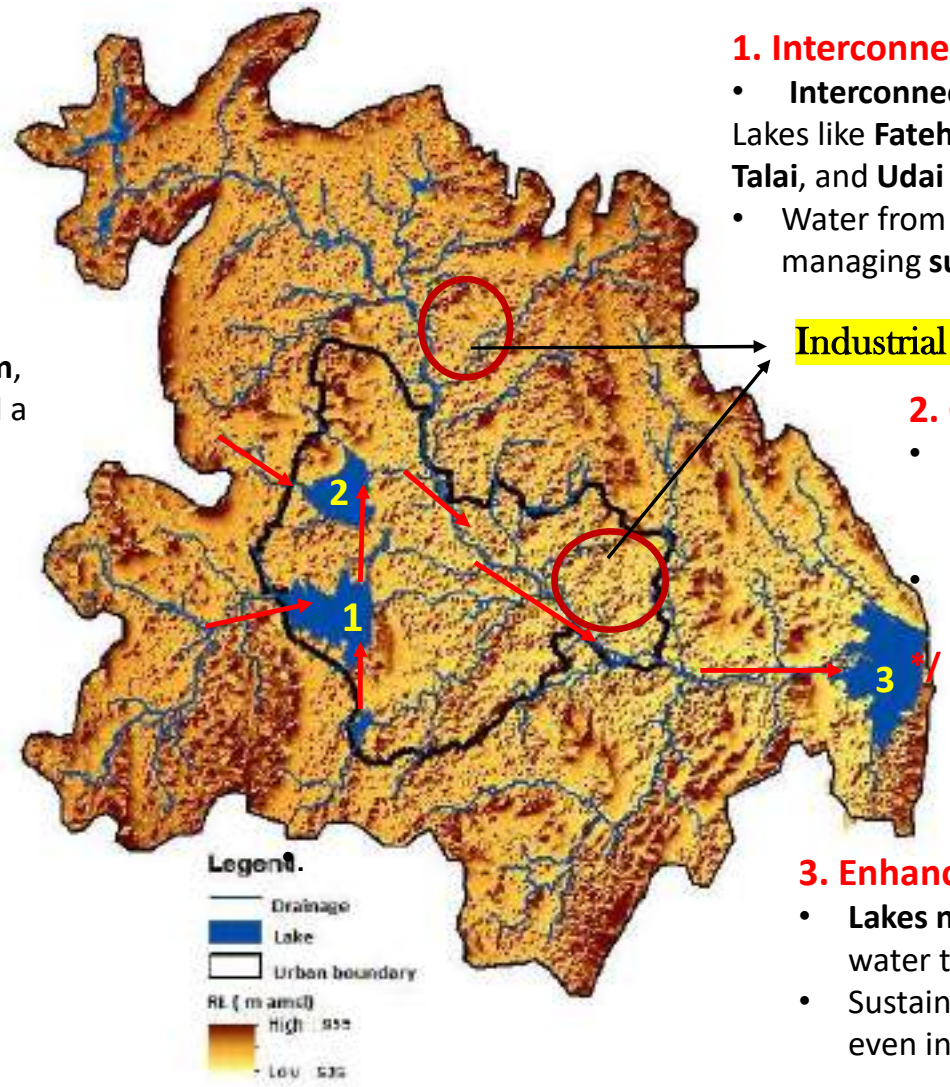
UDAIPUR LAKE SYSTEM: A TRADITIONAL MASTERPIECE OF WATER WISDOM

1. Interconnected Lake Network

- **Interconnected Chain of Lakes**

Lakes like **Fateh Sagar**, **Pichola**, **Swaroop Sagar**, **Dudh Talai**, and **Udai Sagar** were built in a cascading manner.

- Water from one lake naturally flows to the next, managing **surplus runoff** and preventing flooding.



2. Catchment-Based Watershed Design

- The lakes were positioned strategically along the **Ayad River basin**, capturing monsoon rainfall from the Aravalli hills.
- Enabled **maximum surface water storage** and **minimum runoff loss**.

3. Enhance Natural Groundwater Recharge

- **Lakes naturally** connected to streams allowed water to slowly percolate into the ground.
- Sustained **shallow wells** and **stepwells (baoris)** even in dry months.

4. Urban Flood Moderation

Lakes acted as **stormwater buffers**, absorbing peak rainfall flows and thus controls urban flooding

5. Eco-cultural Integration

Supported **biodiversity**, **tourism**, **religious activities**, and created a unique **lake-city identity**.

PRESENT CONDITION



Polluted Baoris



Unused and Polluted Dugwell





Polluted Ayad River sites

FIELD PHOTOGRAPHS OF POLLUTED AYAD RIVER, STEPWELLS AND LAKES

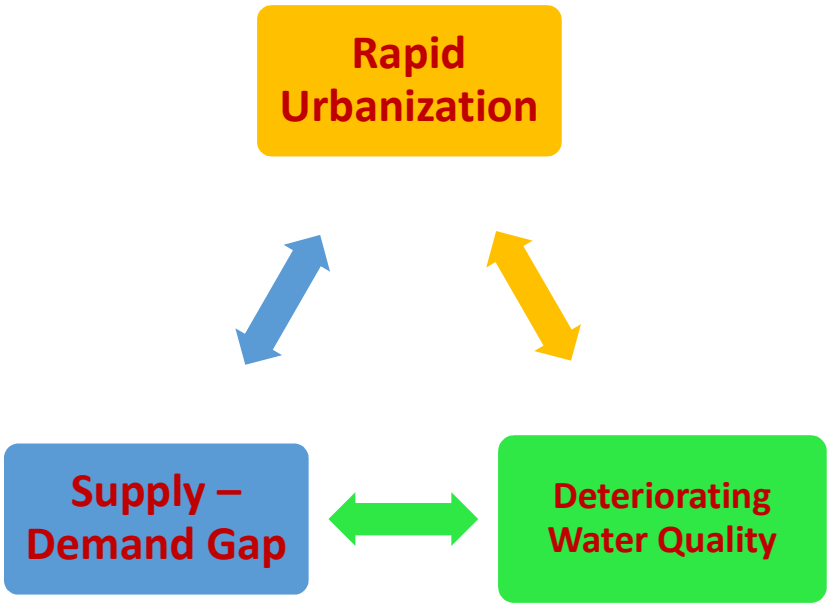


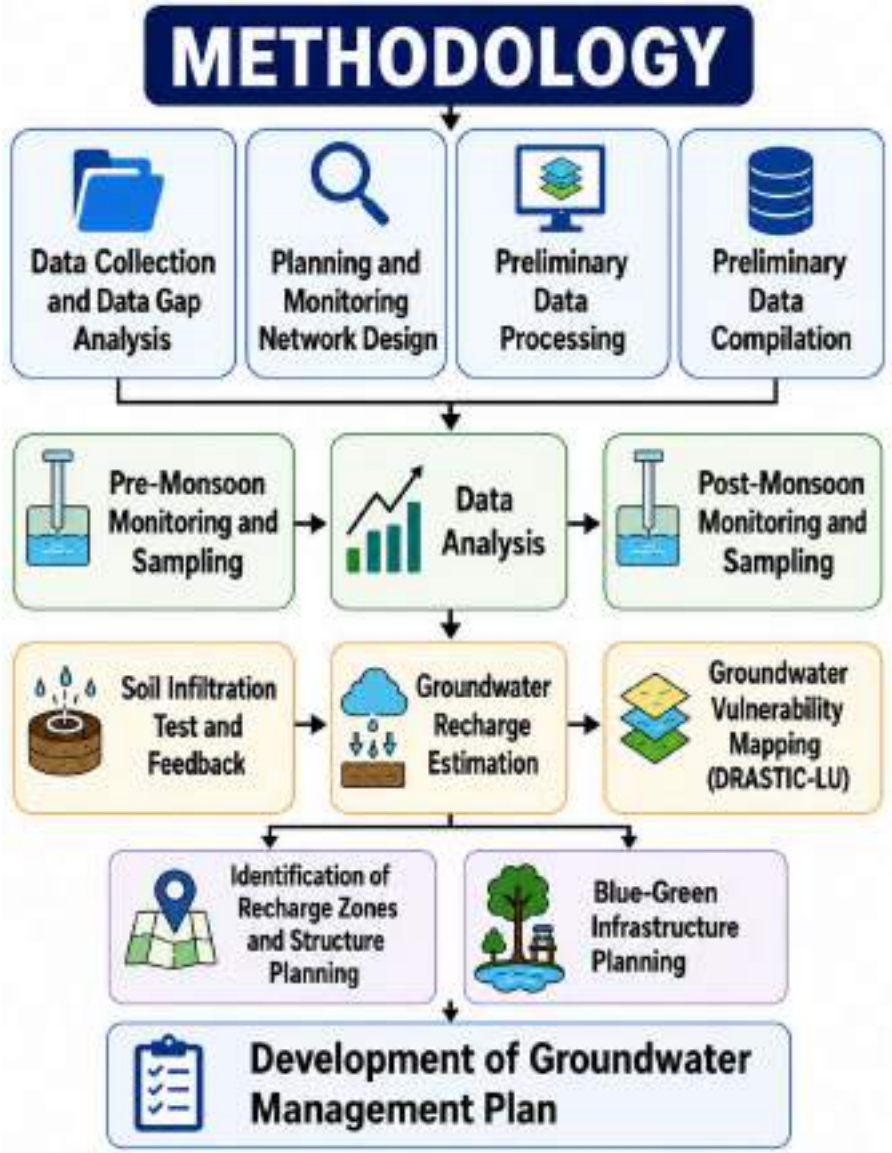
Polluted Udai Sagar Dam Site

OBJECTIVE OF THE STUDY

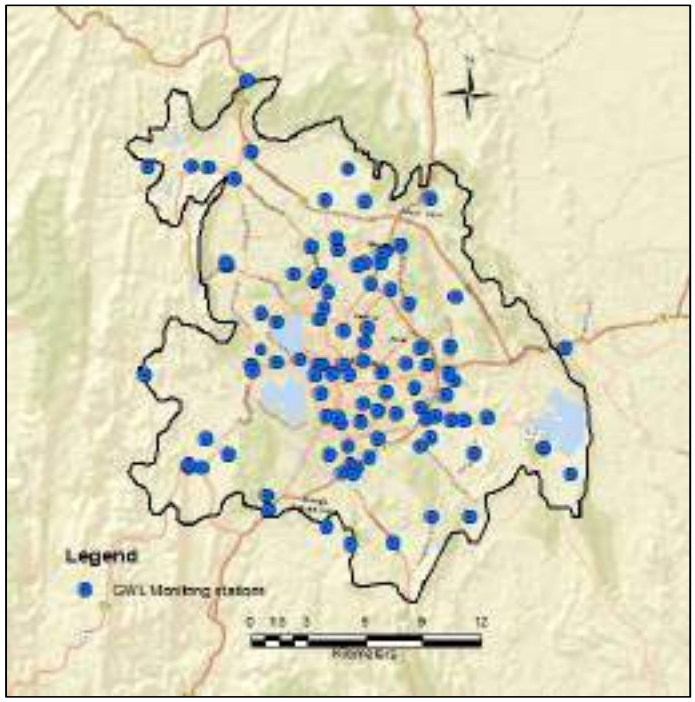
- ✓ To evaluate the effects of urbanization and surface water pollution on groundwater quality.
- ✓ To assess land use change and its impact on groundwater dynamics.
- ✓ To delineate groundwater vulnerability zones and identify suitable recharge areas.
- ✓ To develop a sustainable groundwater management strategy.

PROBLEM STATEMENT

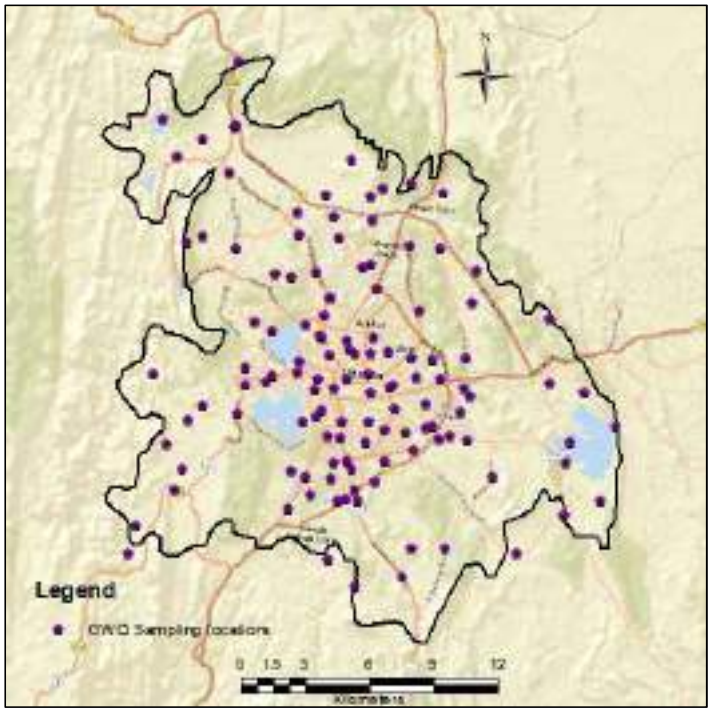




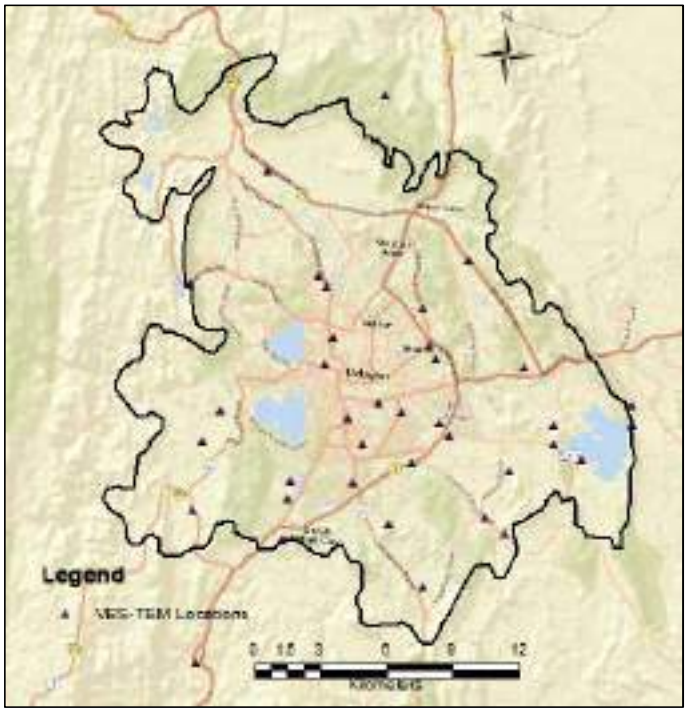
LOCATIONS OF NEW DATA GENERATED FOR AYAD WATERSHED UNDER NAQUIM 2.0



GWL monitoring stations -65

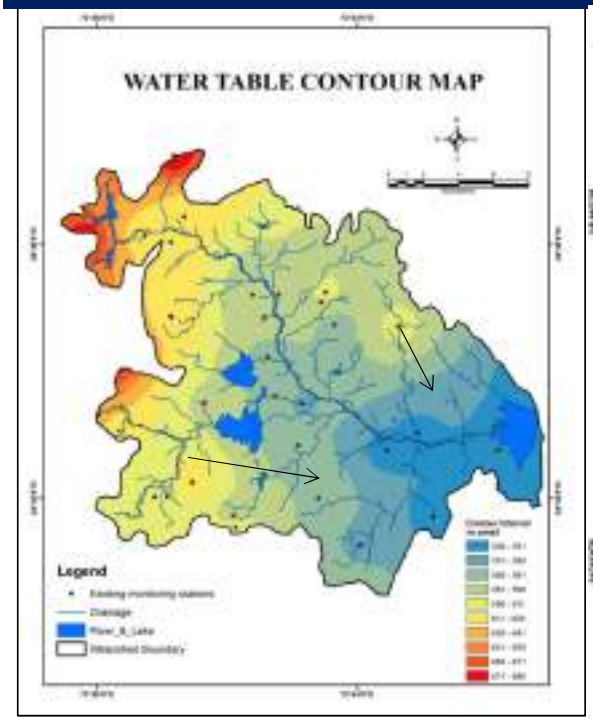


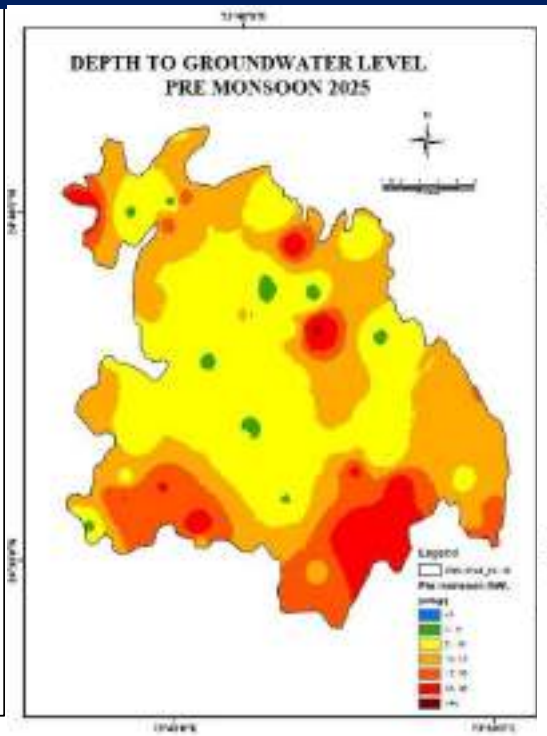
GWQ monitoring stations -99

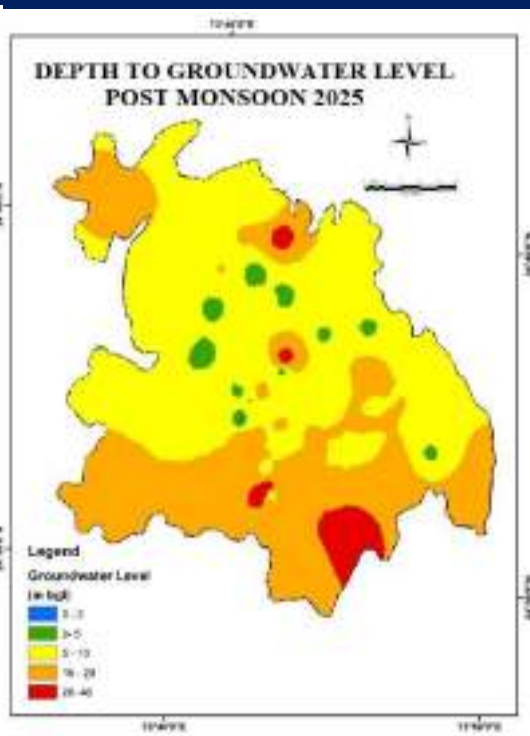


VES-TEM Locations-37(28 VES,64 TEM)

GROUNDWATER LEVEL SCENERIO







Legend

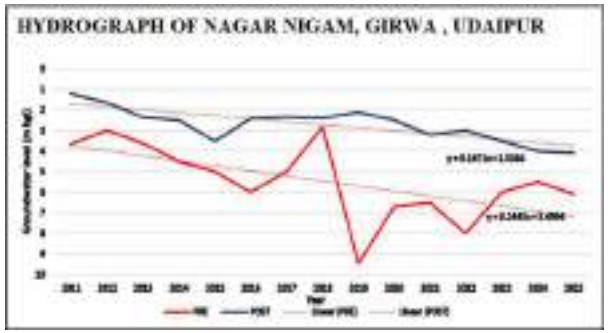
Groundwater Level (m bgl)

- 0 - 2
- 2- 5
- 5 - 10
- 10 - 20
- 20- 40

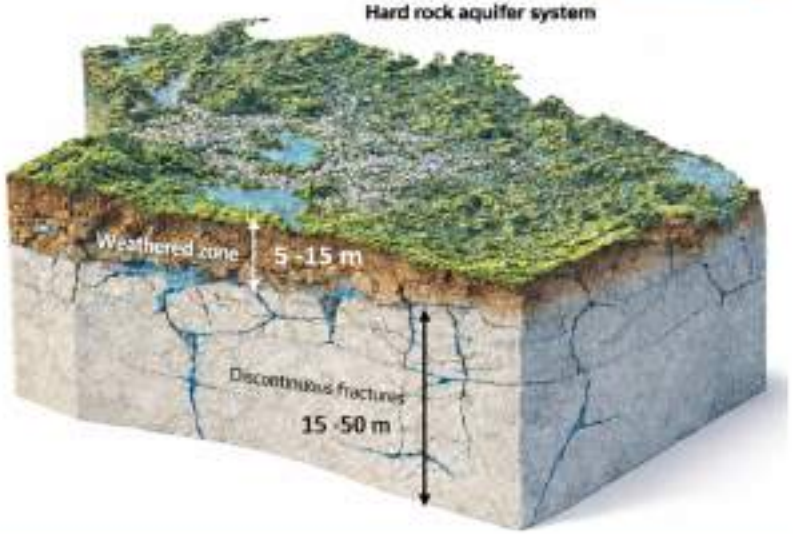
Groundwater Elevation Range :536 m to 686 m a msl
Flow Direction: W-NW to E-SE

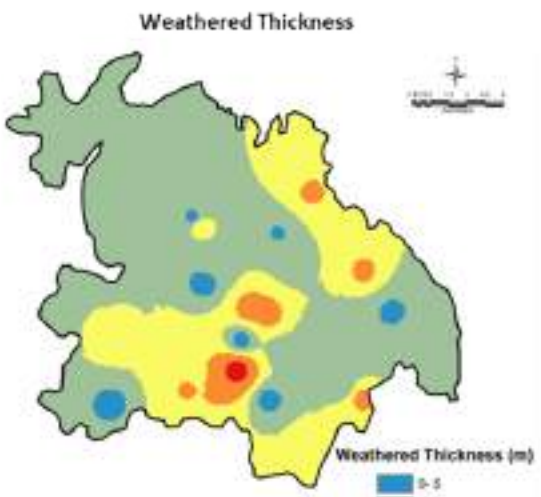
- **Pre-monsoon GWL range :2.5 to 34.65 m bgl**
- **Post monsoon GWL range :2.2 to 32.56 m bgl**

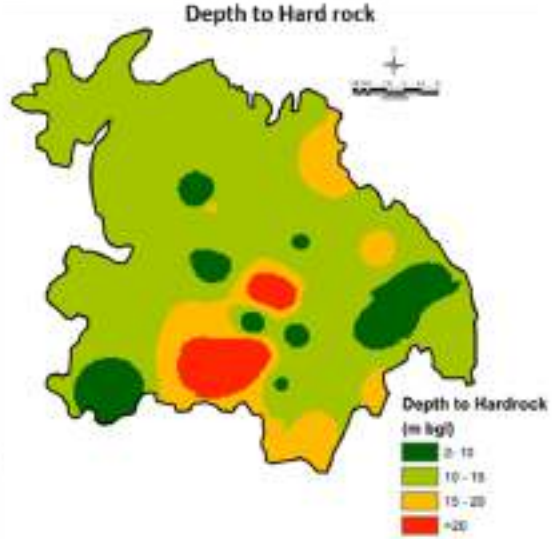
Hydrograph showing Pre & Post declining trends



CONCEPTUAL MODEL OF HARDROCK AQUIFER SYSTEM URBAN AND PERI-URBAN AREA OF AYAD WATERSHED

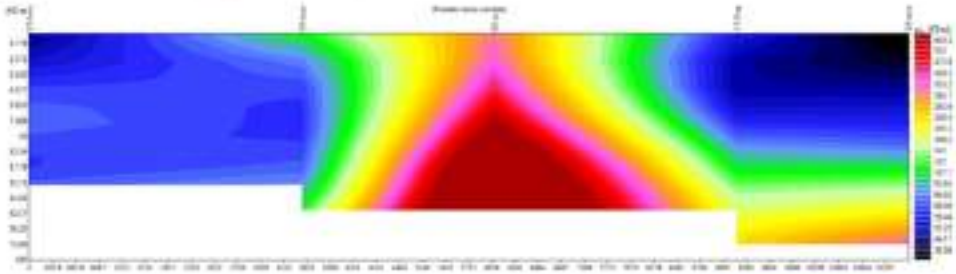






Type of Aquifer	Formation	Average thickness of zone (m bgl)	Range of Yield (lps)	Sustainability (hrs)	Aquifer parameter (Transmissivity – m2/day)
Aquifer Unit I	Weathered zone (Phyllites)	5-15	0.3-1.6	2-3 hrs	3.8 - 117
Aquifer Unit II	Compact with discontinues fracture zone	15-50	0.7 - 0.75	1-3 hrs	

Based on VES,TEM and exploration data Weathered thickness and Depth to Hard rock was delineated.

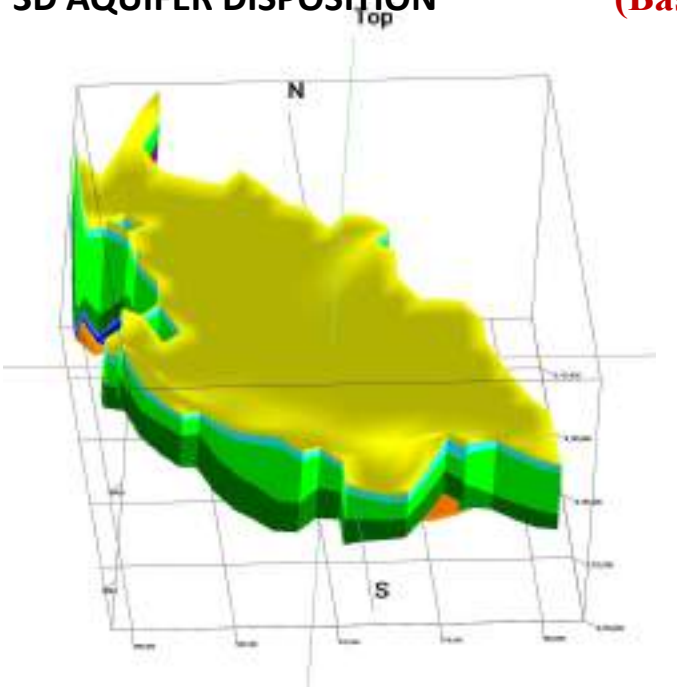


Pseudo sections of Apparent resistivity was prepared with VES data using IPI2win software for understanding the depth to hardrock variation.

AQUIFER DISPOSITION

3D AQUIFER DISPOSITION

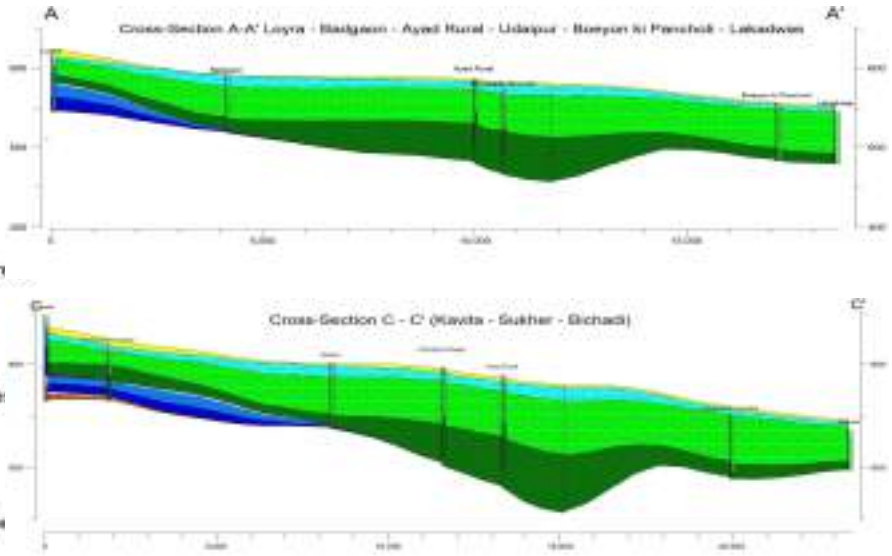
(Based on VES, TEM & Exploration data)



Lithology



2D- CROSS SECTIONS

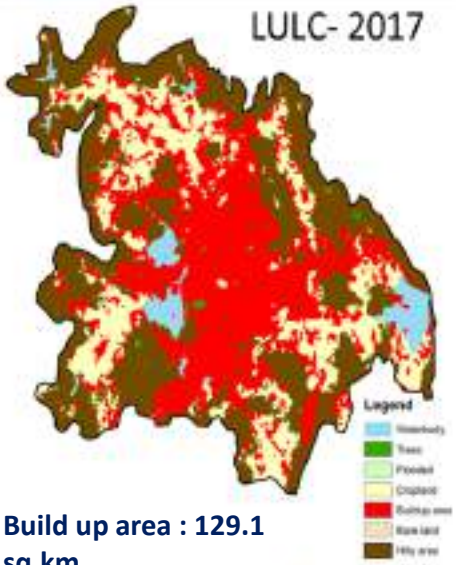


Major Aquifers of the Watershed :

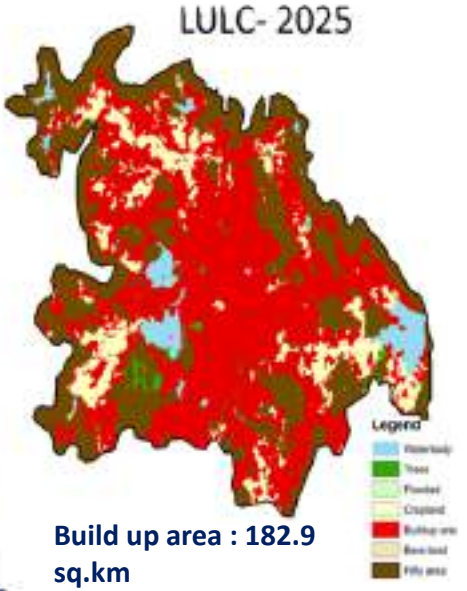
- Aquifer zone –I : Weathered Formations (Phyllites /Schists) average thickness varying 5 to 15 m
- Aquifer zone –II : Phyllites / Schists with isolated fractures average thickness 15 to 50 m bgl
- Hard and Compact formations: > 50 m bgl

Potential Zones		**5 – 29 m**
Specific yield (Aq-I)		**0.01- 0.02**
Discharge (lps)	**Weathered zone**	**0.3 – 1.6**
	Compact with fractures	**0.7 – 0.75**
GWL (mbgl)	**Weathered zone (DW)**	**2- 15 m bgl**
	Compact with fracture (PZ)	**10 – 38 m bgl**

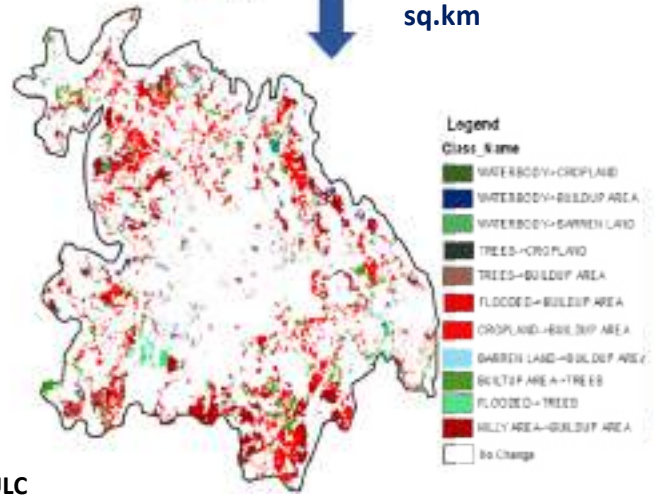
URBANISATION

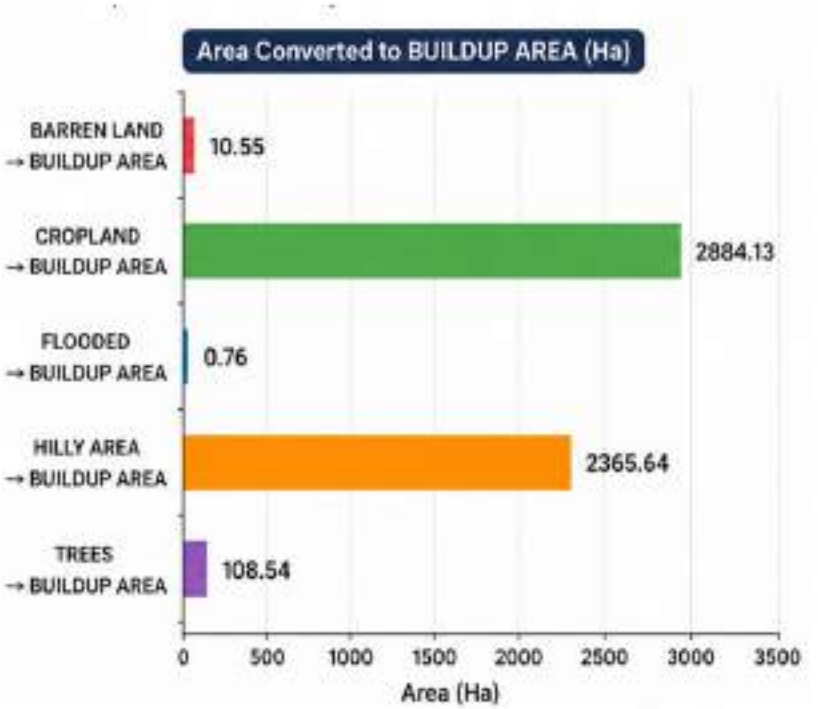


Build up area : 129.1 sq.km



Build up area : 182.9 sq.km



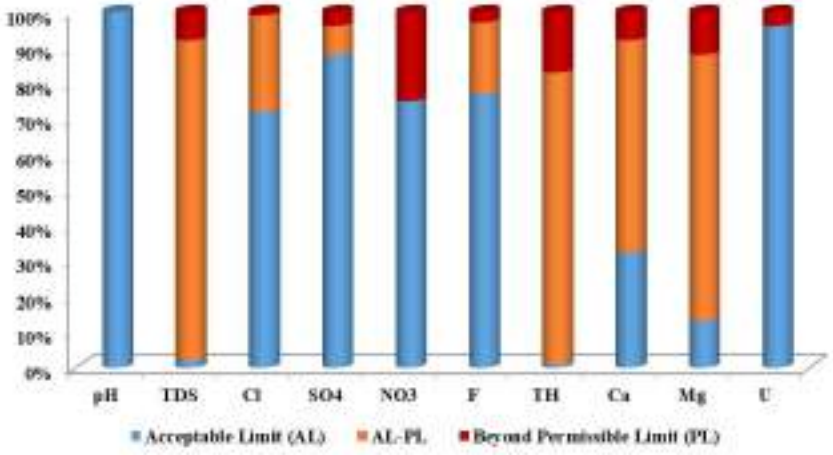


BARREN LAND → BUILDUP AREA	CROPLAND → BUILDUP AREA	FLOODED → BUILDUP AREA	HILLY AREA → BUILDUP AREA	TREES → BUILDUP AREA	TOTAL AREA CONVERTED TO BUILDUP AREA
10.55 Ha (0.20%)	2884.13 Ha (53.73%)	0.76 Ha (0.01%)	2365.64 Ha (44.06%)	108.54 Ha (2.02%)	5369.62 Ha

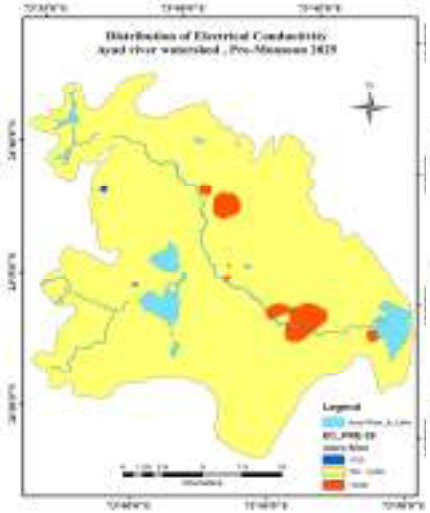
Additional 15% of Total Area Converted To Buildup Area from 2017 To 2025

Source:Sentinel LULC

MAJOR GROUNDWATER QUALITY FINDINGS



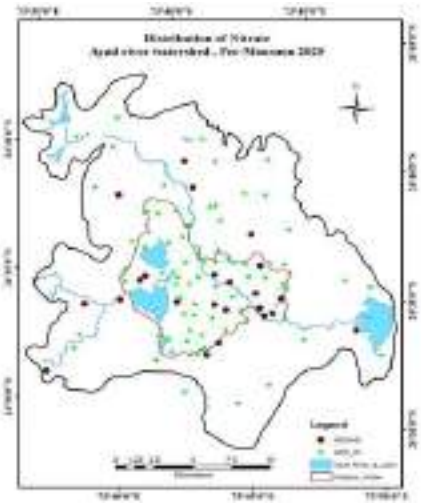
Percentage Distribution of Ground Water Samples as per BIS (2012) Drinking Water Standards.



Distribution of EC



Distribution of CL



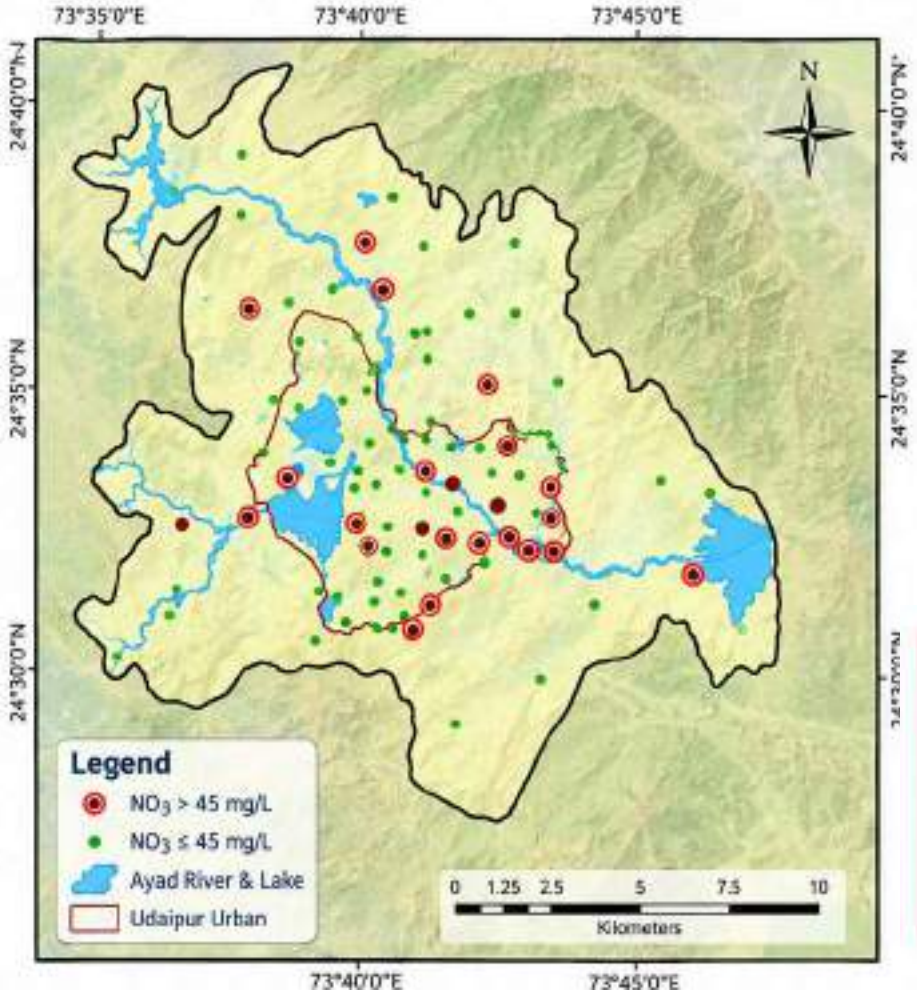
Distribution of Nitrate

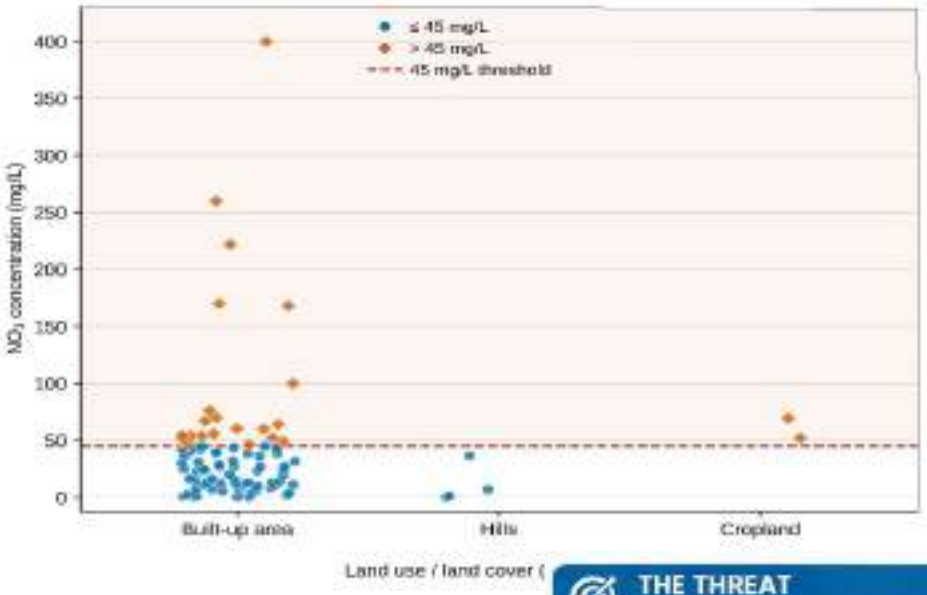
- ✓ **TDS: 90% samples exceeded the acceptable limit but remained within the permissible limit of 2000 mg/L, while 8% samples were found to exceed the permissible limit. (Range:445 -3757 mg/l)**
- ✓ **NO_3^-:25% samples exceed the acceptable limit (45 mg/l) indicating localized contamination in and around the watershed. (Range:0.1 - 400 mg/l)**
- ✓ **TH: 82% fall between acceptable and permissible limits, and 17% exceed permissible limit, showing predominantly hard water. (Range:150 - 1640 mg/l)**
- ✓ **Heavy metal contamination: generally low, with only localized exceedances in Mn, Fe, Cd, and Ni, indicating minor geogenic and anthropogenic influence**

NO_3 Contamination in Shallow Aquifer

Ayad River Watershed, Pre-Monsoon 2025

Higher nitrate levels indicate increasing risk to groundwater quality





THE HEALTH RISK

Nitrate (NO_3) above 45 mg/L in shallow groundwater can cause methemoglobinemia (blue-baby syndrome) in infants under 6 months, restricting oxygen transport in the blood.

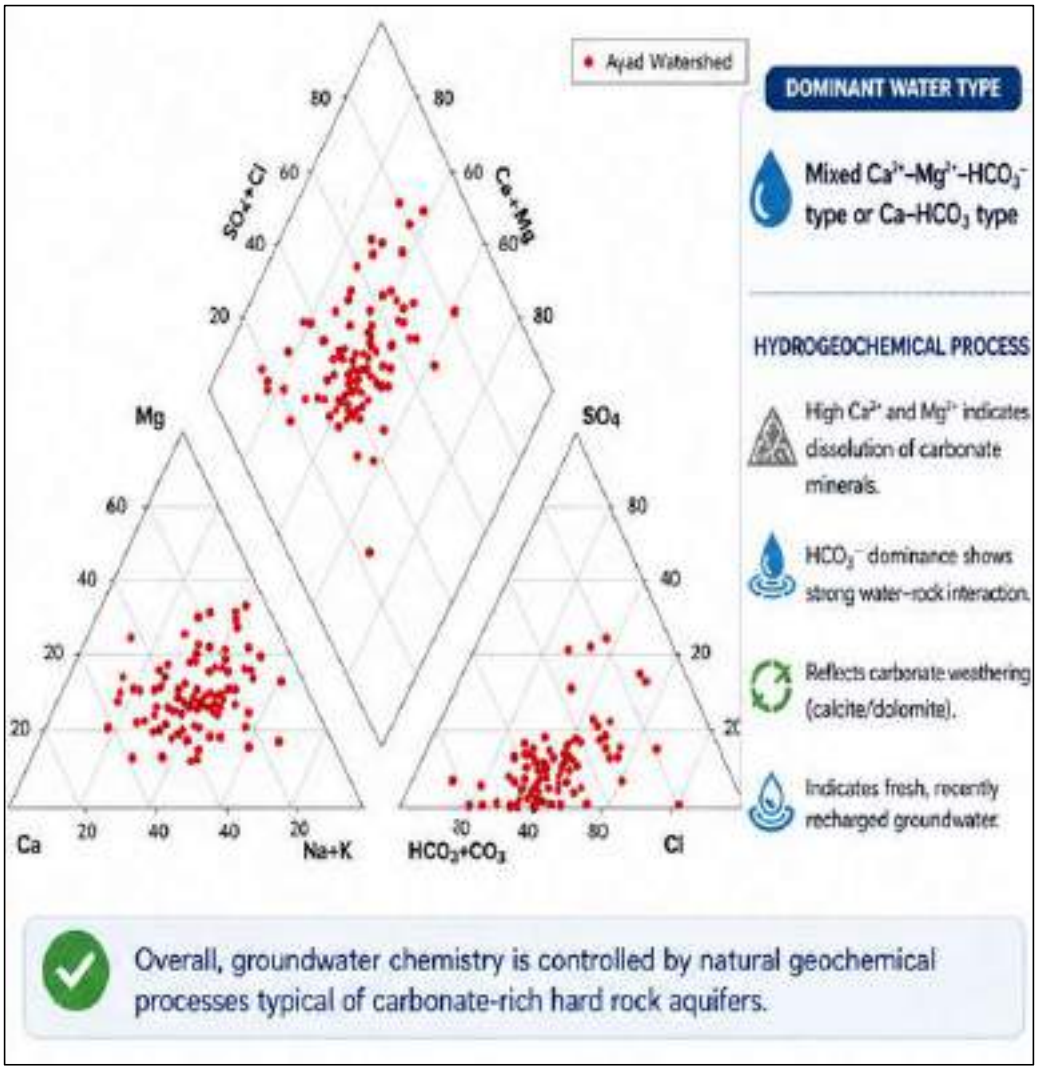
THE THREAT

Nitrates range from 0 to 400 mg/L across the pre-monsoon dataset. ~25% of the entire aquifer system is beyond permissible limits.

PEAK DANGER ZONES

Mehta Farm House	400 mg/L
Tempessa Instrument	268 mg/L
Scientist Hostel LW	222 mg/L
Near Rajasthan Gramin Bank	170 mg/L

Groundwater Chemistry



Carbonate Weathering Dominance

Groundwater chemistry is mainly controlled by dissolution of carbonate minerals (calcite/dolomite).

Natural Geochemical Signature

Dominance of Ca–Mg–HCO_3 type indicates fresh, recharge-driven groundwater.

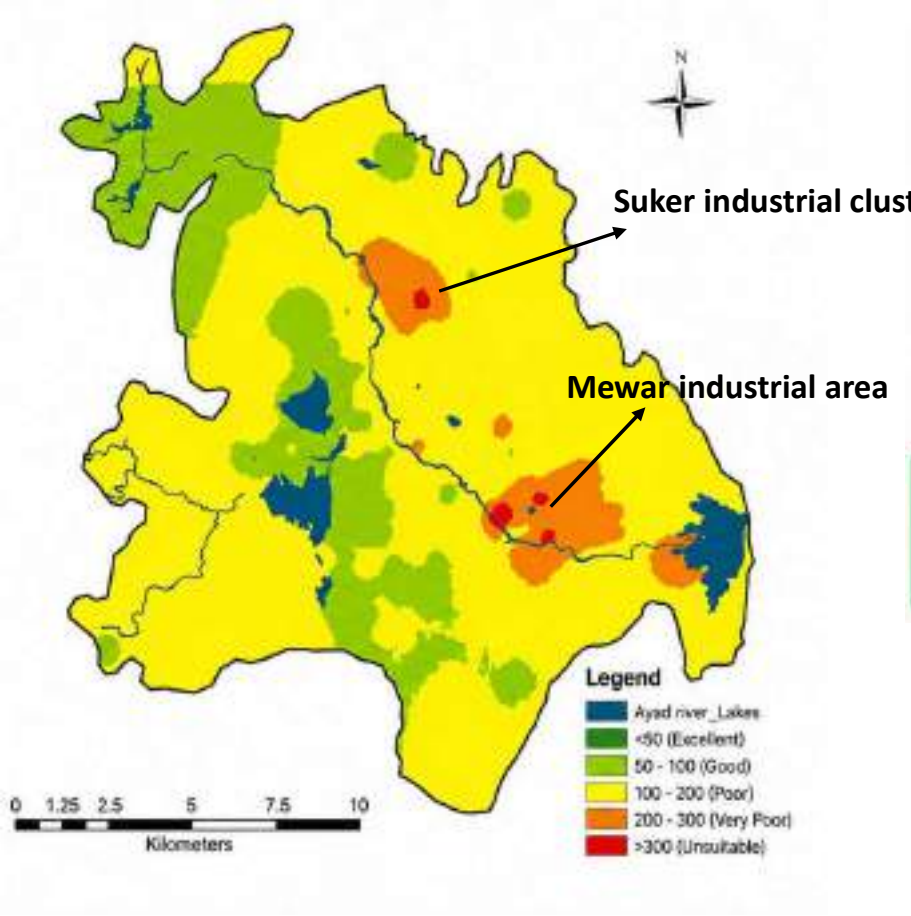
Localized Anthropogenic Influence

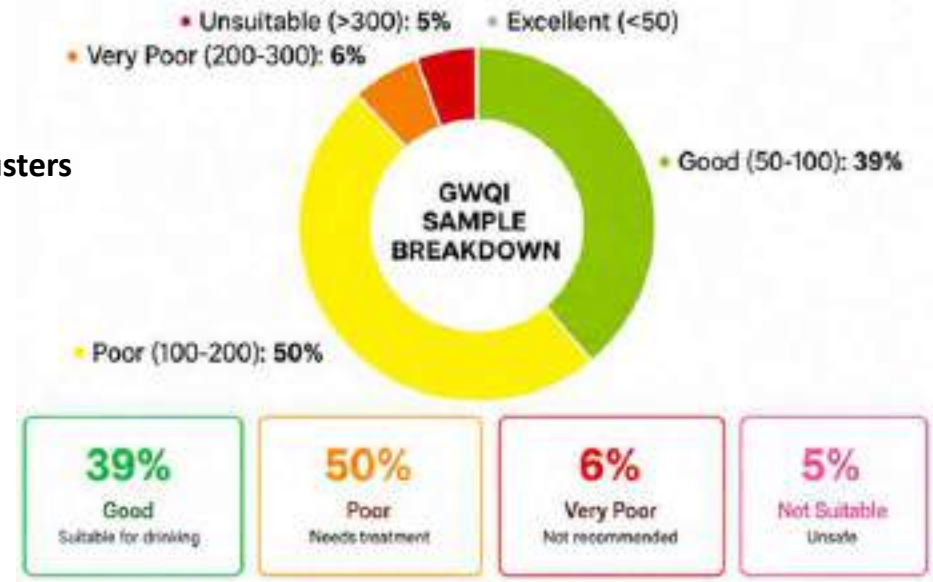
Some samples show higher EC and sodium enrichment suggesting impact from urban activities (sewage leakage, waste disposal, evaporation).

Water Quality Implication

Overall quality is good to moderate, but requires monitoring in high EC zones and sodium-affected areas.

DRINKING PROGNOSIS:GROUNDWATER QUALITY INDEX



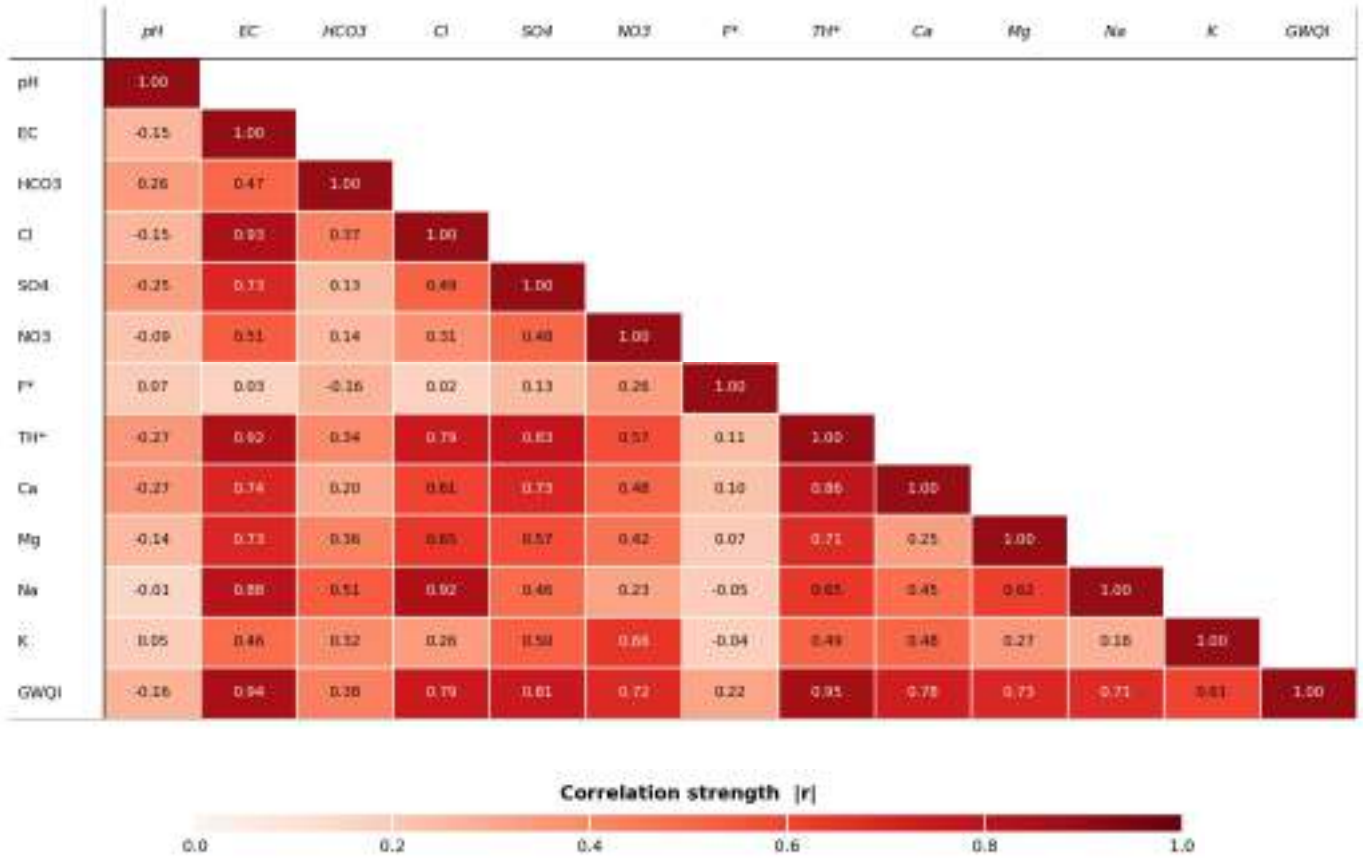




- ✓ The water quality index (WQI) using the weighted arithmetic average method (proposed by Horton (1965) and developed by Brown et al.) is an important tool to determine the **suitability of groundwater for human consumption.**
- ✓ Ranks water quality from Excellent (<50) to **Unfit for Drinking (>300)**
- ✓ Helps authorities identify contaminated zones, manage pollution risks, and prioritize water quality improvement

GROUNDWATER QUALITY: CORRELATION MATRIX

Pearson correlations among 13 physico-chemical parameters (pH, EC, major ions, F, TH, GWQI)

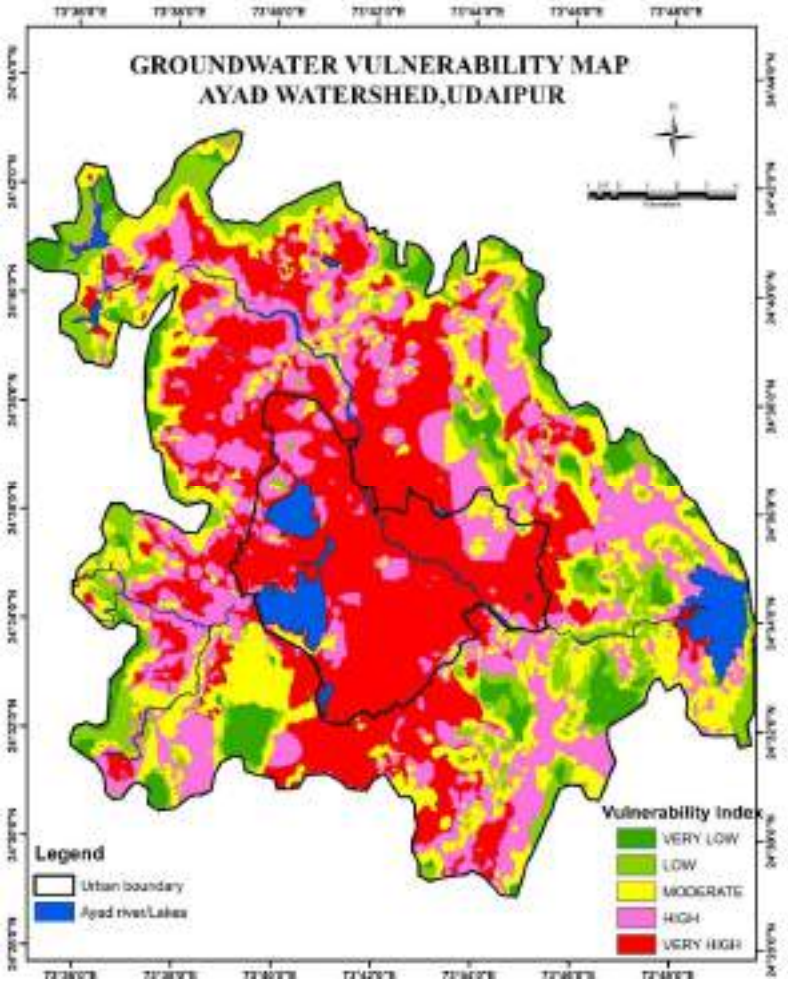


KEY INSIGHTS

1. **TH, EC, Cl & SO4 show the strongest positive associations with GWQI (r = 0.79–0.95) — indicating their major contribution to overall water-quality variation.**
2. **Nitrate correlates with K (0.66) & GWQI (0.72) — signals agricultural / sewage contamination.**
3. **pH is weakly, often negatively, correlated with all ions (–0.27 to 0.07) — not a major control here.**
4. **Fluoride behaves independently of major ions — points to a separate mineral source.**
5. **Two distinct pathways: geogenic salinity (EC/Cl/TH/Na) vs. anthropogenic input (NO3/K).**

GROUNDWATER VULNERABILITY INDEX MAP : DRASTIC-LU MODEL

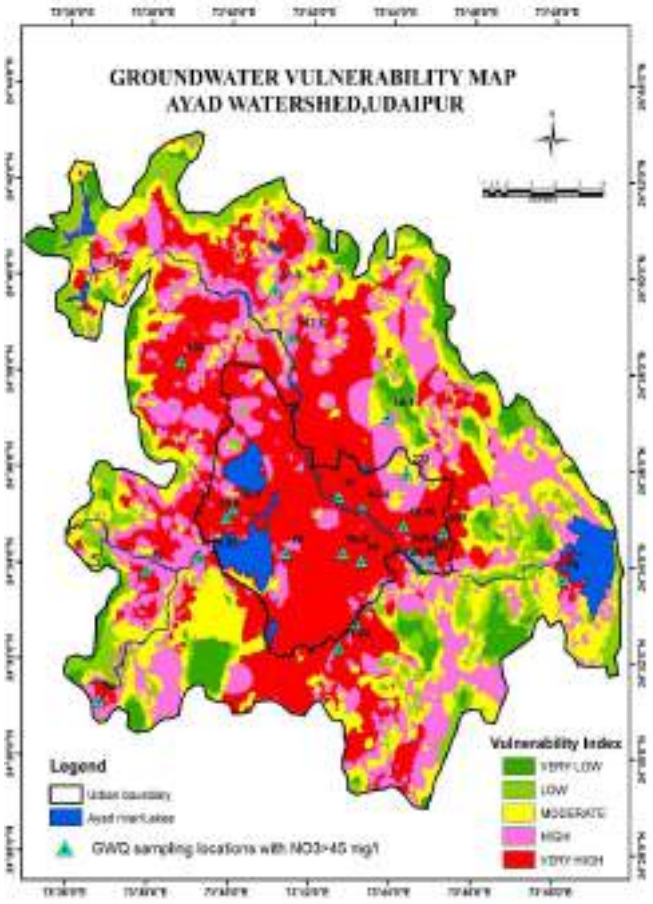
"Groundwater vulnerability mapping aims to delineate areas susceptible to contamination, thereby supporting sustainable groundwater management and informed land-use planning".



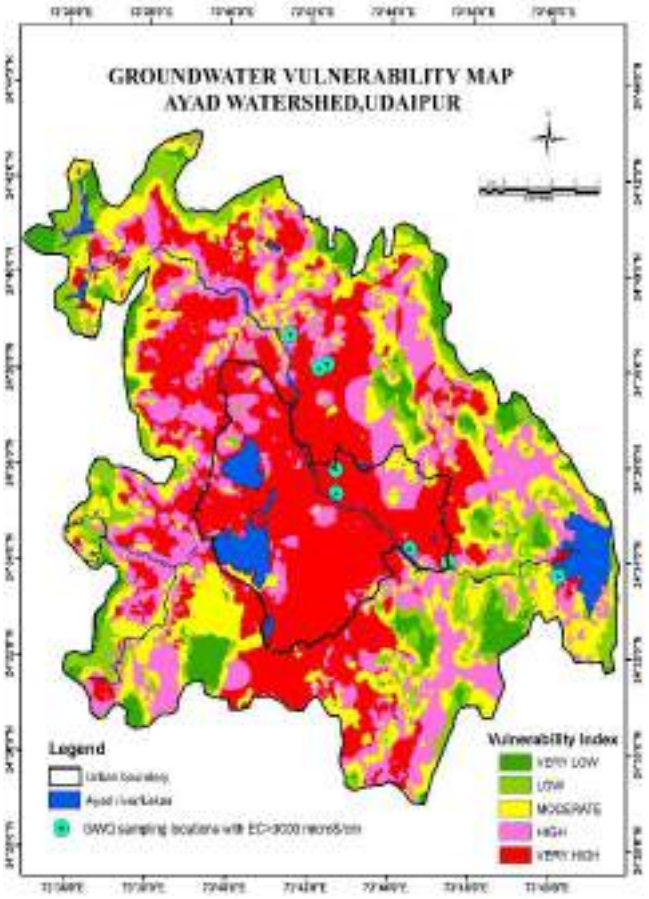
DRASTIC–LU PARAMETERS		Weight
D	Depth to Water (D)	5
R	Recharge (R)	4
A	Aquifer Media (A)	3
S	Soil Media (S)	2
T	Topography (Slope) (T)	1
I	Impact of Vadose Zone (I)	5
C	Hydraulic Conductivity (C)	3
LU	Land Use / Land Cover (LU)	5

DRASTIC-LU = Sum of (Rating × Weight) for all parameters + Land Use factor

GROUNDWATER VULNERABILITY MODEL VALIDATION



Validation with observed NO3 values

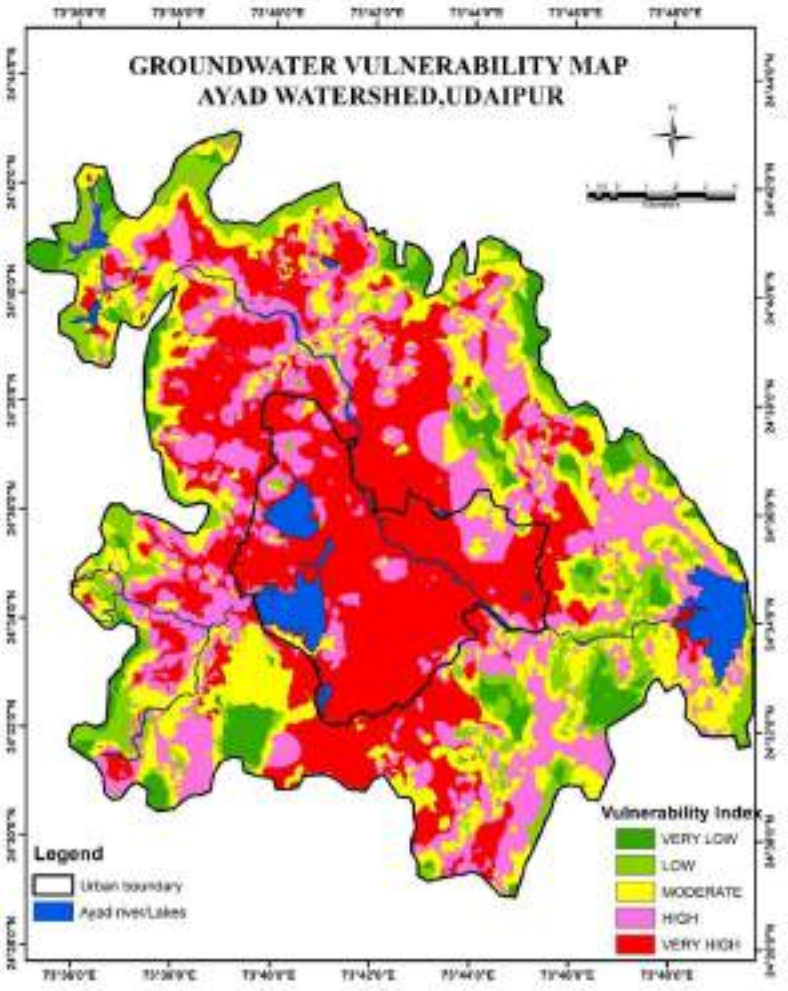


Validation with observed EC values

Highlights:

- ✓ **Strong correlation with high vulnerability zones:** Areas classified as **high to very high vulnerability** show **elevated nitrate and EC values**, confirming the model's reliability in identifying contamination-prone zones.
- ✓ **Urban and peri-urban impact clearly captured:** Higher NO_3^- and EC concentrations are mostly aligned with **urbanized and anthropogenically influenced areas**, indicating that the **Land Use factor improved model accuracy**.
- ✓ **Effective tool for groundwater management:** The validated model helps in **targeting pollution hotspots and planning recharge interventions**.

RECHARGE MANAGEMENT STRATERGY BASED ON DRASTIC VULNERABILITY INDEX



MANAGEMENT STRATEGY BASED ON VULNERABILITY INDEX

VULNERABILITY INDEX	ZONE (Color)	RISK / CONDITION	MANAGEMENT STRATEGY	SUITABLE RECHARGE STRUCTURES	KEY CONSIDERATIONS
VERY HIGH (Red)		• Very high contamination risk • High permeability • High pollutant load (urban core)	CONTROLLED RECHARGE ONLY Use engineered systems with treated water only	• Recharge shafts (with filtration) • Injection wells (treated water) • Stormwater pre-treatment units	Avoid direct infiltration. Ensure water quality is treated and monitored.
HIGH (Magenta/Pink)		• Moderate to high contamination possibility • Peri-urban transition areas	SEMI-CONTROLLED RECHARGE Combine treatment with natural filtration	• Recharge trenches (with filter media) • Percolation tanks (with sediment traps) • Bio-swales	Provide pre-treatment and sediment removal to reduce pollutant load.
MODERATE (Yellow)		• Moderate vulnerability • Mixed land use • Balanced infiltration and protection capacity	ENHANCED RECHARGE STRUCTURES Use nature-based solutions for storage enhancement	• Rain gardens • Soak pits • Recharge trenches • Check dams (small scale)	Promote infiltration while maintaining groundwater protection.
LOW (Light Green)		• Low contamination risk • Good infiltration potential	MAXIMUM RECHARGE ZONES Encourage decentralized natural recharge systems	• Percolation ponds • Farm ponds • Recharge wells • Infiltration basins	Prioritize open recharge structures to enhance groundwater storage.
VERY LOW (Dark Green)		• Safest zone for groundwater recharge • Good natural filtration capacity (hilly/forest areas)	NATURAL RECHARGE CONSERVATION Conserve and protect natural recharge reserves	• Wetlands restoration • Check dams • Contour trenches • Afforestation-based recharge	Protect as groundwater recharge reserves. Avoid land use changes.

BLUE - GREEN RECHARGE SOLUTIONS FOR UDAIPUR

(Integrated Approach for Water Security in Urban and Peri Urban Areas)







BLUE - GREEN RECHARGE SOLUTIONS IN PARKS AND OPEN SPACE



Location: Sheetla Matha Park,Sector5,Hiran Magri,Udaipur





References:

1. Central Ground Water Board (CGWB). (2023). NAQUIM 2.0 Toolkit: Department of Water Resources, River Development & Ganga Rejuvenation, Government of India.

2. Pareta, K., Karan, S., Enemark, T., Reddy, T., Dashora, Y., Issar, T., & Jensen, K. H. (2024). Groundwater quality assessment for drinking and irrigation purposes in the Ayad River Basin, Udaipur (India).

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THANK YOU

Current Scenario: Udaipur City Water Supply–Demand–Gap

WATER SUPPLY SOURCES

A. SURFACE WATER SOURCES


Lake Pichola


Fateh Sagar Lake


Jaisamand Lake


Badi Lake


Mansi Wakal Dam

Total from surface water sources
78.5 MLD (≈ 94%)

B. GROUNDWATER SOURCES


50
Tube Wells


32
Step Wells


180
Panghats


2,650
Hand Pumps

Total from groundwater
5 MLD (≈ 6%)

TOTAL WATER PRODUCTION
83.5 MLD

WATER TREATMENT INFRASTRUCTURE


10
Water Treatment Plants (WTPs)

84.24 MLD
Total Treatment Capacity

Major WTPs
- Dooth Talai WTP
- Neemuch Mata WTP
- Fatehsagar WTP
- Nandeshwar WTP
- Tentardi WTP

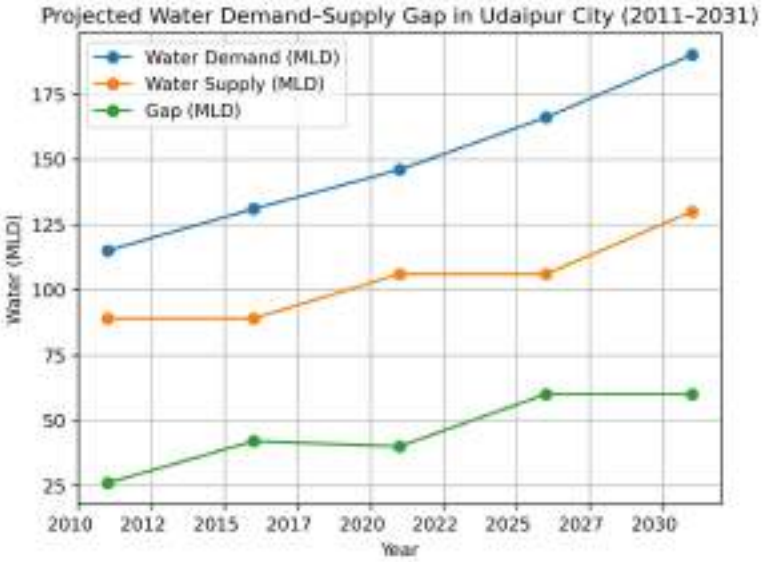
SUPPLY-DEMAND-GAP

CURRENT SCENARIO

TOTAL DEMAND	TOTAL SUPPLY	SUPPLY–DEMAND GAP
115 MLD	83.5 MLD	31.5 MLD (≈27%)

Population (2011)	Floating Population	Average Supply	Baseline Water Stress (BWS)
4.51 lakh	30,000	155 LPCD	>80% (Severe Stress)

Year / Scenario	Population (Lakh)	Demand (MLD)	Supply (MLD)	Gap (MLD)
2011 (Base Year)	~4.5	115	83.5	31.5
2021 (Projected)	~6.8	146	106.5	39.5
2026 (Projected)	~8.5	166	106.5	59.5
2031 (High Demand)	~10.0	~213	~106	~106



Source: Udaipur Master Plan -2011-2031,PHED report, Smart city Project,Research papers

DYNAMIC GROUNDWATER RESOURCES

AYAD WATERSHED

RECHARGE POTENTIAL AREA OF WATERSHED	ANNUAL RECHARGE	ANNUAL EXTRACTABLE RESOURCE	GROSS DRAFT	STAGE OF EXTRACTION
36,500 ha	2,065.24 ham	1,854.52 ham	2,028.17 ham	109.36% Over-Exploited

RECHARGE FROM OTHER SOURCES

WATERSHED

Rainfall Recharge (ham)	Canals (ham)	Surface Water Irrigation (ham)	Ground Water Irrigation (ham)	Tanks and Ponds (ham)	Water Conservation Structure (ham)	Pipelines (ham)	Sewages and Flash Flood Channels (ham)
1163.5 ham	26.7 ham	25.5 ham	177.2 ham	201.4 ham	32.1 ham	25.7 ham	413.0 ham

GROUNDWATER EXTRACTION

WATERSHED

Domestic	Industrial	Irrigation
676.21 ha.m	645.99 ha.m	706.74 ha.m

UDAIPUR URBAN

RECHARGE POTENTIAL AREA OF WATERSHED	ANNUAL RECHARGE	ANNUAL EXTRACTABLE RESOURCE	GROSS DRAFT	STAGE OF EXTRACTION
6,400 ha	689.44 ham	620.49 ham	628.65 ham	101.32% Over-Exploited

RECHARGE FROM OTHER SOURCES

UDAIPUR_URBAN

Rainfall Recharge (ham)	Canals (ham)	Surface Water Irrigation (ham)	Ground Water Irrigation (ham)	Tanks and Ponds (ham)	Water Conservation Structure (ham)	Pipelines (ham)	Sewages and Flash Flood Channels (ham)
163.74 ham	0.00 ham	0.00 ham	0.00 ham	86.97 ham	0.00 ham	25.7325 ham	413.0 ham

GROUNDWATER EXTRACTION

UDAIPUR_URBAN

Domestic	Industrial	Irrigation
533.32 ha.m	95.33 ha.m	0.00 ha.m

Groundwater Quality Assessment

Statistical summary and BIS compliance of 99 groundwater samples

Parameter	BIS Range (AL / PL)	Total Samples	Min	Max	Mean	Sample < AL No. / %	Sample between AL & PL No. / %	Sample > PL No. / %
pH	6.5–8.5 / NR	99	6.91	7.37	7.78	99 / 100%	—	—
EC (µS/cm)	– / –	99	685	5780	1690	—	—	—
TDS (mg/L)	500 / 2000	99	445	3757	1102	2 / 2%	89 / 90%	8 / 8%
Cl^- (mg/L)	250 / 1000	99	28	1631	252	71 / 72%	27 / 27%	1 / 1%
SO_4^{2-} (mg/L)	200 / 400	99	0.0	920	103	87 / 88%	8 / 8%	4 / 4%
NO_3^- (mg/L)	45 / NR	99	0.10	400	42.6	74 / 75%	—	25 / 25%
F^- (mg/L)	1.0 / 1.5	99	0.01	5.95	0.84	76 / 77%	20 / 20%	3 / 3%
TH (mg/L)	200 / 600	99	150	1640	507	1 / 1%	81 / 82%	17 / 17%
Ca^{2+} (mg/L)	75 / 200	99	24	472	105	32 / 32%	59 / 60%	8 / 8%
Mg^{2+} (mg/L)	30 / 100	99	19	168	59	13 / 13%	74 / 75%	12 / 12%
U (µg/L)	30 / NR	99	0.0	4.4	60	95 / 96%	—	4 / 4%

AL = Acceptable Limit | PL = Permissible Limit | NR = No permissible limit specified

Red highlight: percentage of samples exceeding the Permissible Limit (PL)