

SUBSURFACE WATER SYSTEMS UNDER URBAN STRESS: QUALITY DECLINE AND RISK FRAMEWORK

A CASE STUDY FROM BHUBANESWAR, ODISHA

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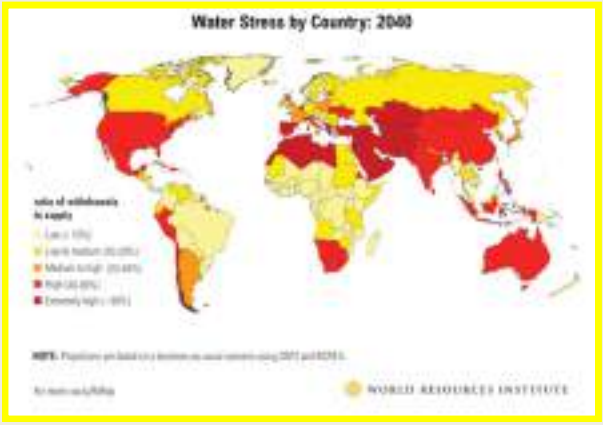


Ground Water



- **Groundwater accounts for**
- 60 % of irrigation needs
- 85% of rural drinking water needs
- 50% of urban water needs
- >80% of net irrigated area during the last 4 Decades.

- **Growing Concerns**
- India is the largest user of groundwater in the world, which accounts for more than 25% of the global total.
- Over-exploitation- leading to dwindling well yield and declining water levels (27% of the assessment units either overexploited, critical or semi critical or Saline)
- Ground Water contamination- Arsenic, Fluoride, Iron, Salinity etc.





CGWB & NAQUIM





- GW Development to **GW Management**
- Launched in 2012: **"Know your Aquifer, Manage your Aquifer"**

- **Mapping vertical and horizontal extents of aquifers**
- **Delineate & characterize aquifers**
- **Identification & Quantification of Issues**
- **Preparation of Management Plans**
- **Supply Side - AR Interventions**
- **Demand side - Micro-irrigation, crop diversification etc.**



1.Exploratory Drilling



2.Geophysical studies



3.Ground Water Monitoring



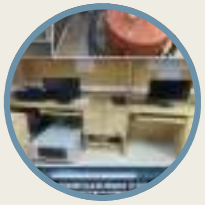
4.Hydro chemical studies



5.Hydrogeological studies





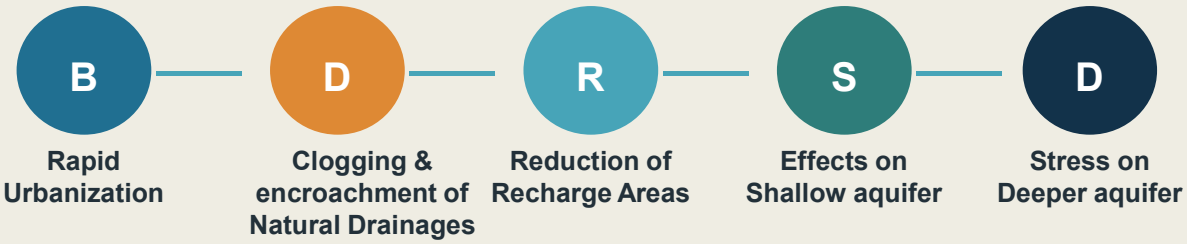




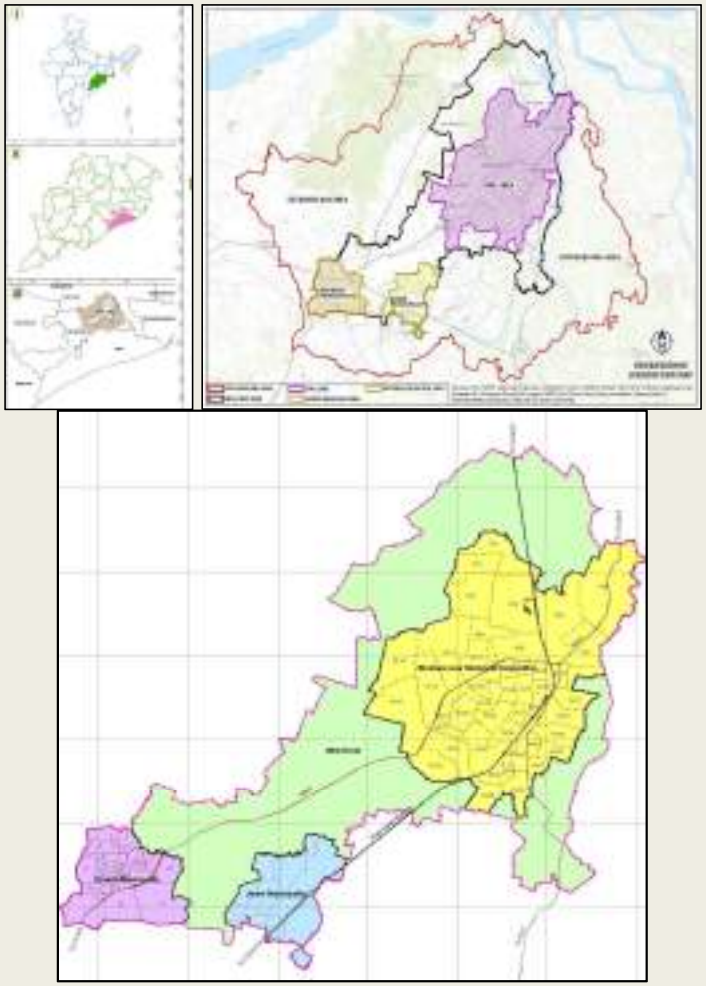


URBAN AQUIFER STRESS, BHUBANESWAR

URBAN SURFACE → DRAINAGE → AQUIFER



Bhubaneswar at a Glance.



AT A GLANCE	
Bhubaneswar Development Area (BDA) Priority Area: Urban Agglomerations	**Total Area: 425 Sq.Km** BMC: 186 Sq.km Jatani: 26 Sq.km Khurda: 30 Sq.km Peri-Urban: 183 Sq.km
	Latitude:20° 79′ 36″ N to 20° 24′ 37″ N Longitudes: 85° 35′ 26″ E to 85° 54′ 25″ E
Population	10.7 Lakh (2011) **19.1 Lakh (2025)** 67.04 Lakh (2047 Projected)
Current Water Supply	**390 MLD** 238 MLD from Surface Water (6 Major WTP) (Mundali, Palasuni, Chandrasekharpur, Naharkanta, Bhuasuni and High Level Tank Systems) 152 MLD from Ground Water (65.5 MLD Municipality connections, 86.5 MLD CGWA) 82 MLD NRW (Non Revenue Water) **Total Water available for end users: 308 MLD**
Water Demand	**360 MLD** Wastewater Generated 190 MLD Wastewater Treated 50 MLD

Issues and Challenges / Objectives

- Increasing Water Demand
- Declining Water Table
- Water Quality Issue
- Reduction in Natural Recharge Area
- Encroachment on Water Bodies
- Unplanned Solid Waste Disposal
- **Drainage and Sewerage Issue**
- **Policy Gap and Poor Infrastructure**

- Assess Urban Growth and Correlation with LULC Map
- Spatio-temporal variations in water levels
- Spatio-temporal variations in water Quality
- Microbiological Study and Microplastic Study
- Aquifers Disposition and Recharge Area
- Reccommend sustainable groundwater management strategies

Demand and Supply Gap

DEMAND	
BMC demand	304 MLD
Jatni municipality	18 MLD
Khurda municipality	13 MLD
Rural peri-urban BDA villages (~2–3 lakh)	25 MLD
Total BDA area demand	**360 MLD**

SUPPLY	
Surface WTP supply	238 MLD
Groundwater Extraction by Pumping wells (WATCO+CGWA)	152 MLD (65+87)
NRW (Non Revenue Water)	82 MLD
Total Available for end Users	**308 MLD**

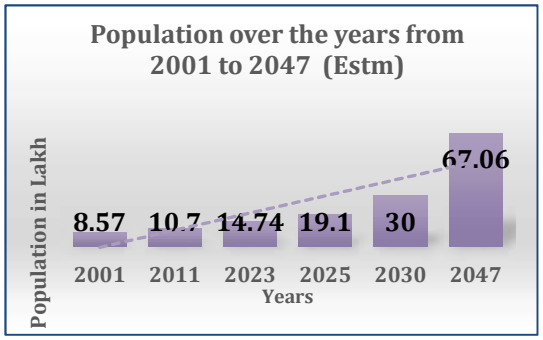
Wastewater generated	190 MLD
Treated (actual, partial STPs)	50 MLD
Treated & recirculated to potable supply	0
DEFICIT	52 MLD

- Surface water not delivered uniformly, leaving areas dependent on borewells
- Treated water from STPs are not utilised for infrastructural uses like construction, gardening, washing.
- Re-used concept is not accepted by people, simply getting drained
- NRW water to be reduced

Why the aquifer is under stress

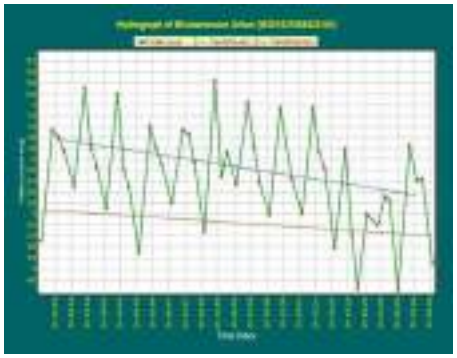
1 URBAN GROWTH

Population concentration
Land-use change
Infrastructure expansion



2 WATER STRESS

Higher abstraction
Declining natural recharge
Allocation pressure



3 POLLUTION LOAD

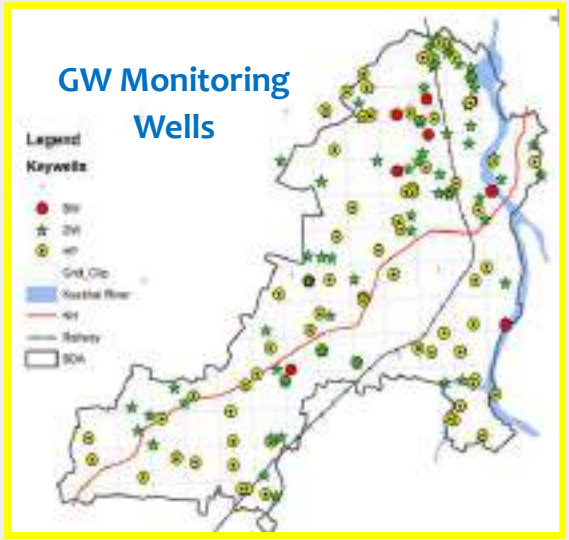
Sewage infiltration
Waste / landfill leachate
Industrial discharge



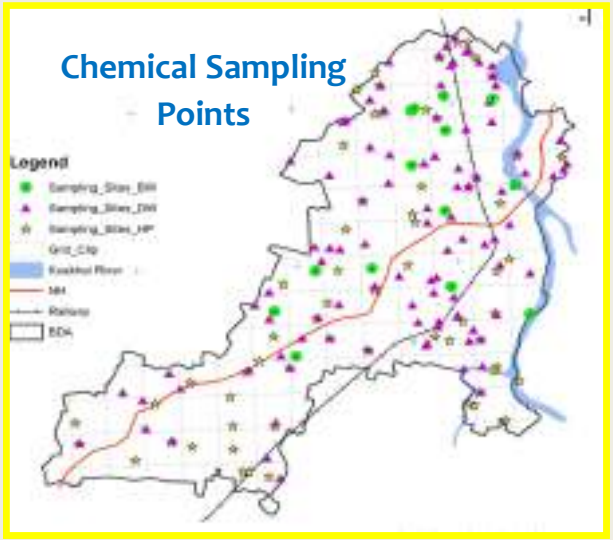
Urbanization + Inadequate Waste Management → Declining aquifer health

Investigations Undertaken

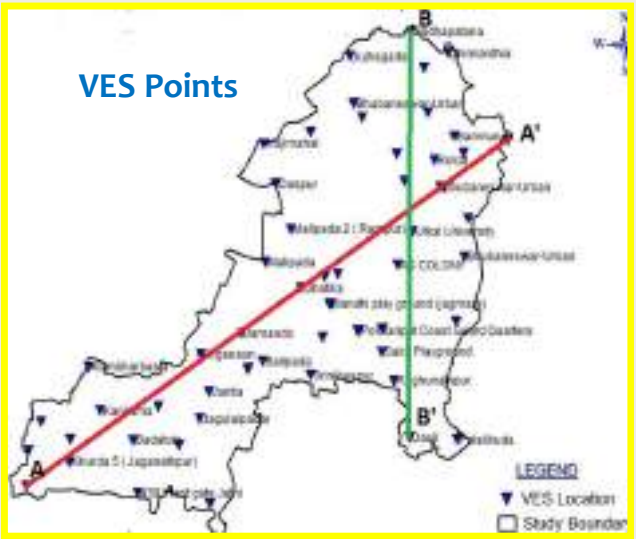
GW Monitoring Wells



Chemical Sampling Points

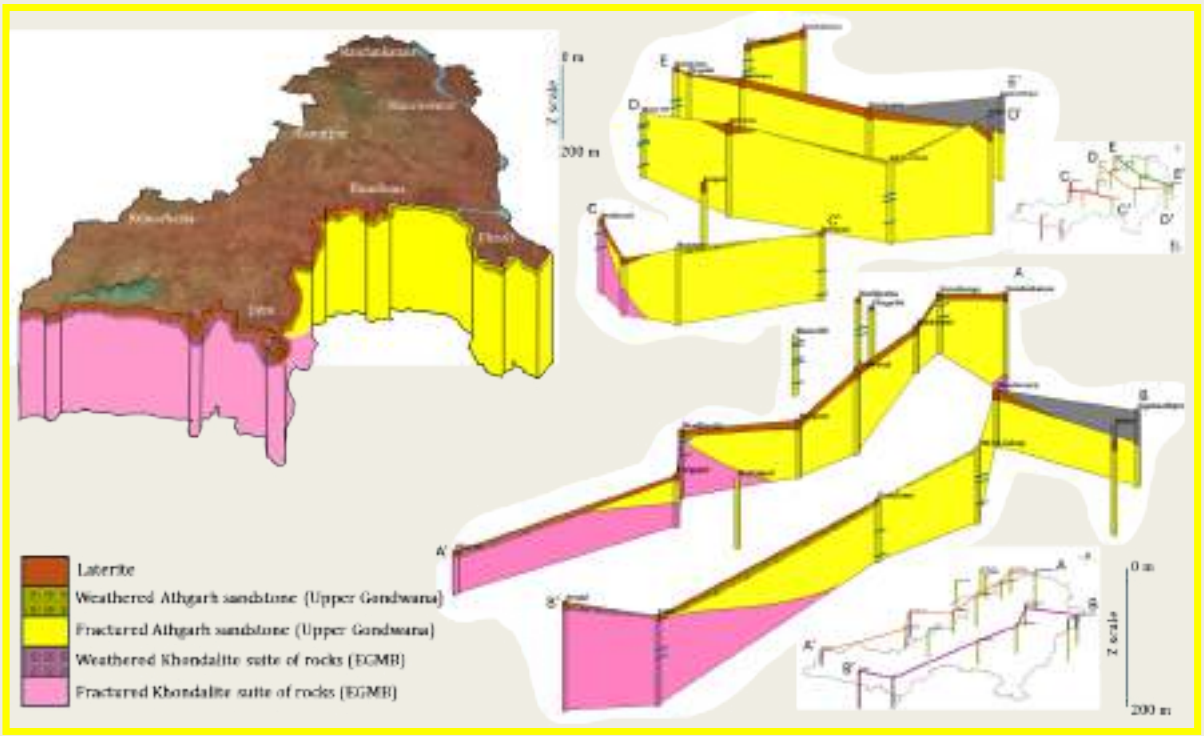


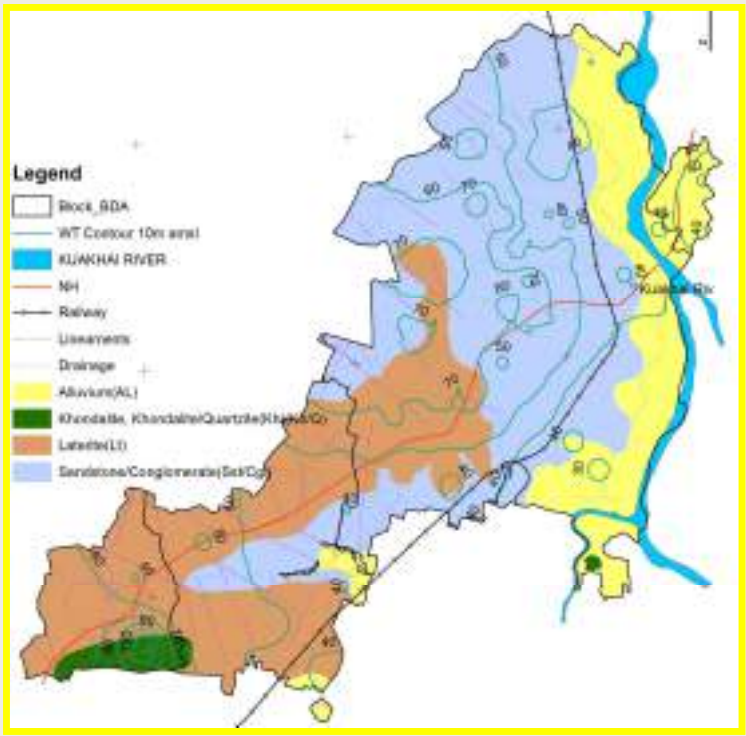
VES Points



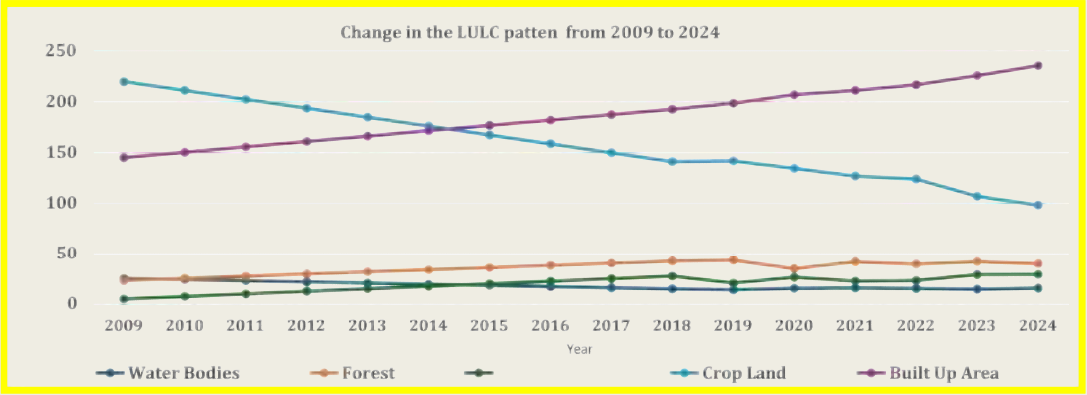
Activities	Existing	Generated
Monitoring Wells	40 (34 DW, 6 PZ)	177 (Pre-Monsoon) (85 DW, 83 HP, 9 BW)
		177 Post-Monsoon(85 DW, 83 HP, 9 BW)
		* (2 wells/5 sq.km)
Chemical Sampling Sites	34	177 (Pre-Monsoon)
		177 (Post-Monsoon)
	Microplastics	30
	Microbiological	25
Drilling Sites	47(26: EW 8:OW 13: PZ)	Ancillary data collected from wells constructed by PHED and Operated by WATCO
Vertical Electrical Sounding	19	62
Stake Holders/Farmers Feedbacks	-	50

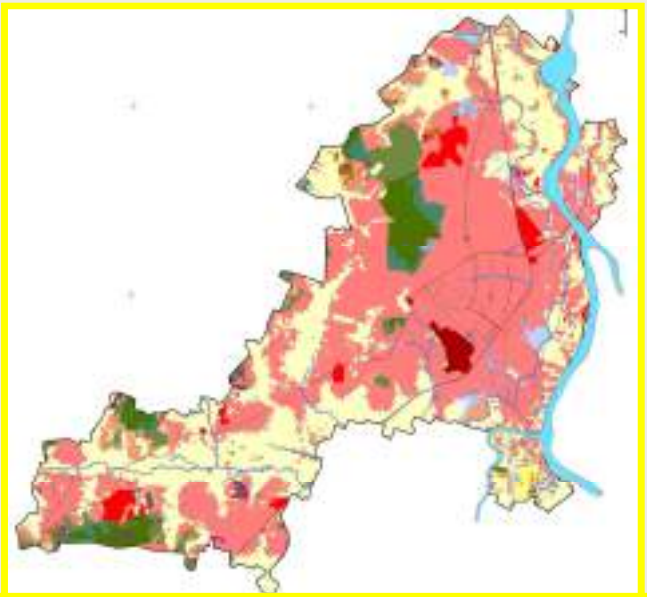
Aquifer Disposition and Geology

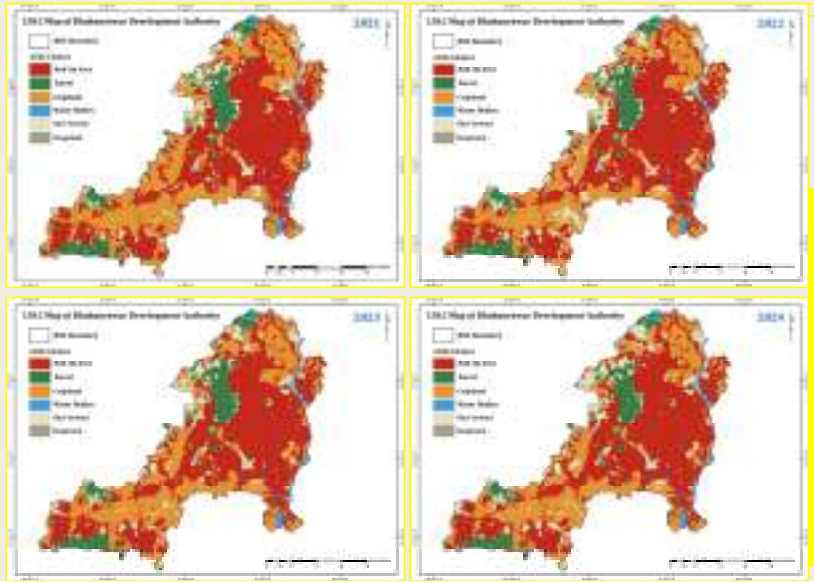




Land Use Land Cover (LULC)





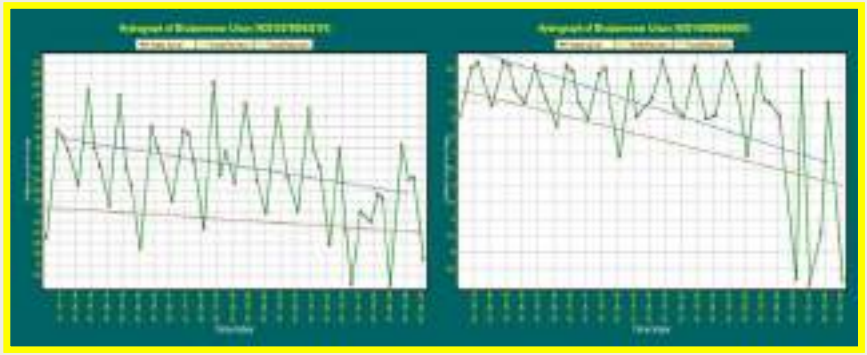


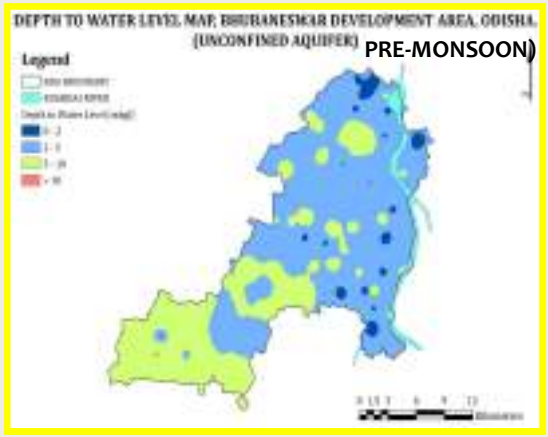
Legend

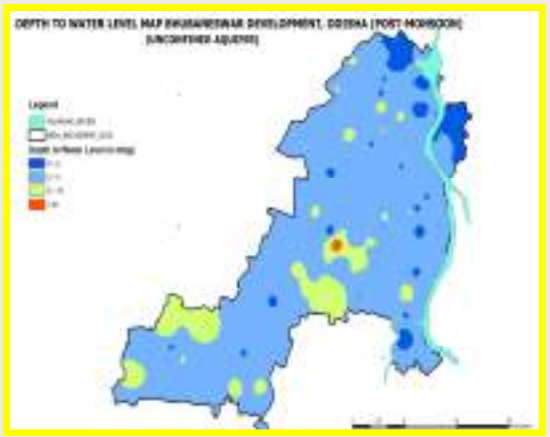
LULC

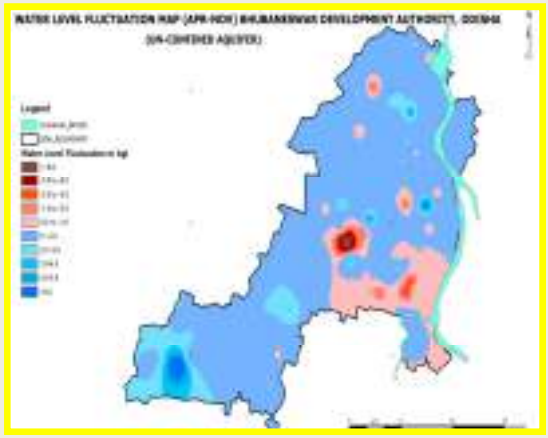
- Agriculture - Aquaculture
- Agriculture - Crop Land
- Agriculture - Plantation
- Built Up - Core Urban
- Built Up - Industrial Area
- Built Up - Peri Urban
- Built Up - Rural Hamlet and Dispersed Household
- Built Up - Rural Mixed Village Settlement
- Built Up - Rural Other Area
- Built Up - Transport Infrastructure
- Built Up - Transport Network
- Built Up - Transport Network (Railway)
- Built Up - Urban - Other Area
- Closed Forest
- Forest Plantation
- Open Forest
- Others - Mining / Quarry / Mining Dump
- Wasteland - Barren Rocky
- Wasteland - Dense Scrub Land
- Wasteland - Sparse Scrub Land
- Wasteland - Waterlogged Area
- Water Body - Canal / Drain
- Water Body - Lake / Pond
- Water Body - Reservoir / Tank
- Water Body - River
- Water Body - Stream

Water Level Decline in Shallow Aquifer











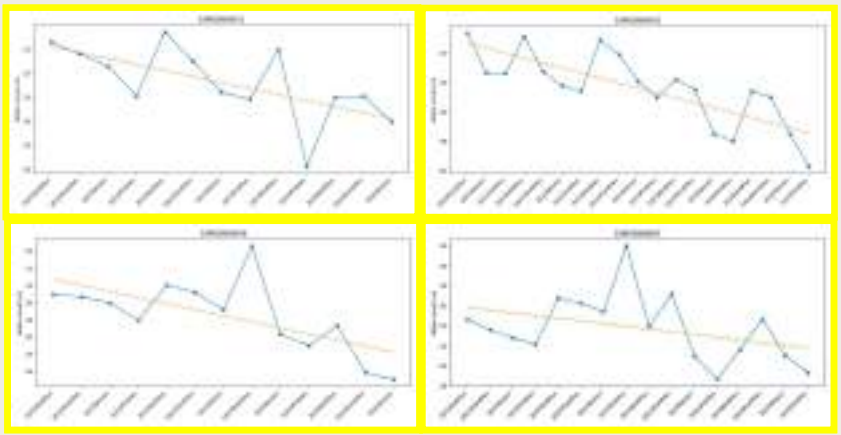
- Water Table in the phreatic aquifer follows the regional gradient of the area.
- Flow direction is towards East and South-East towards the Kuakahi river.

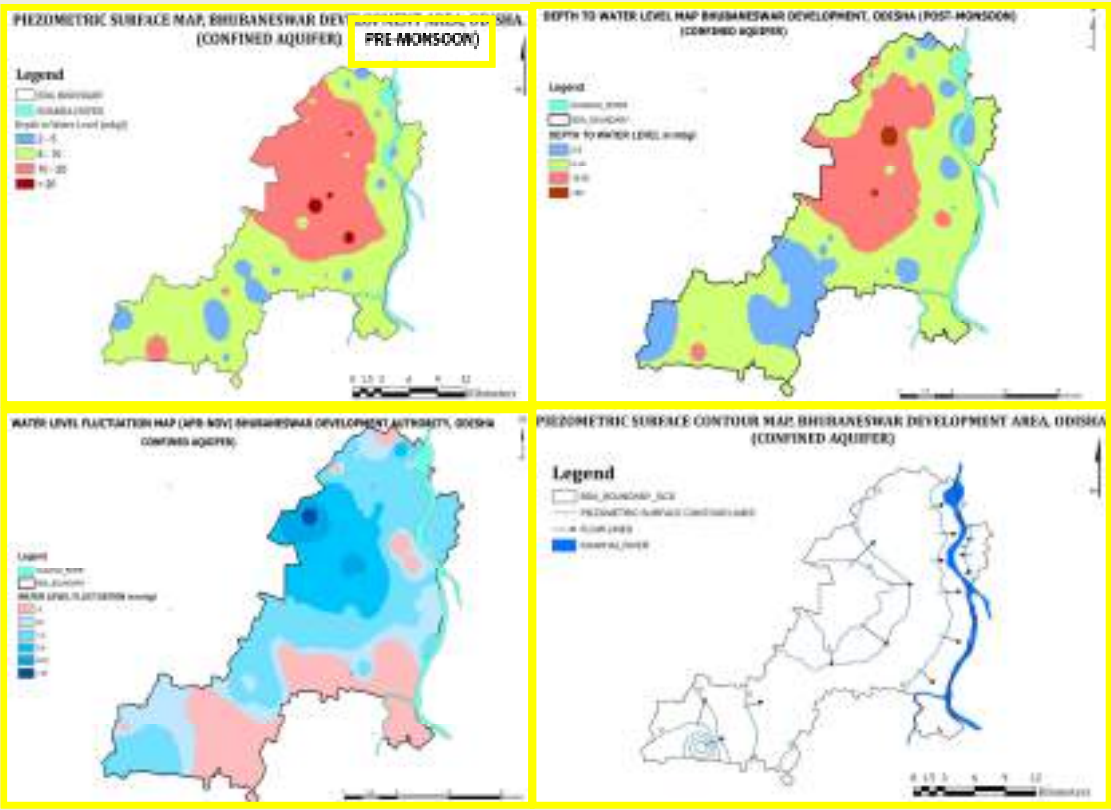
WL FLUCTUATION

Fall		
Interval	Area Sq.km	% Area
0-2	58	5
2-5	3	
5-10	1	

Rise		
Interval	Area Sq.km	% Area
0-2	316	74
2-5	43.3	10
5-10	4	1

Water Level Decline in Deeper Aquifer





Water Table of the in Deeper Semi-Confined aquifer follows the regional gradient of the area.

Flow direction is towards East and South-East towards the Kuakahi river.

Rise		
Interval	Area Sq.km	% Area Sq.km
0-2	320	75.3
2-5	68	16.0
5-10	15	3.5
>10	1.6	0.4

WL FLUCTUATION

Fall		
Interval	Area Sq.km	% Area Sq.km
0-2	20	4.7

WATER QUALITY SCENARIO

Standards / Methods

APHA / AWWA / WEF Standard Methods, 24th Ed. (2023), as stated in the study.

Biological indicators

Dissolved oxygen, biochemical oxygen demand, chemical oxygen demand, total & faecal coliform.

Interpretation

Compare with hydrochemistry, aquifer type, drainage, waste-disposal setting and season.

01 GIS / field screening

02 Pre / post-monsoon sampling

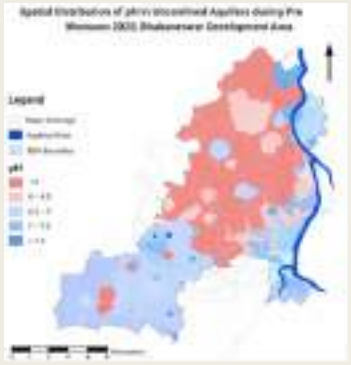
03 DO • BOD • COD

04 TC • FC analysis

05 Quality interpretation

pH & Nitrate

Ca–Mg–HCO_3 remains the dominant signatu

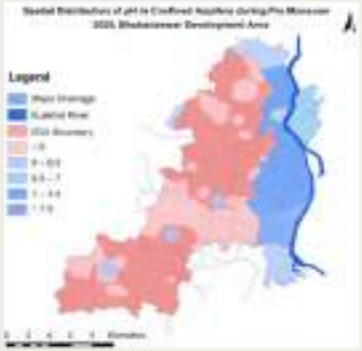


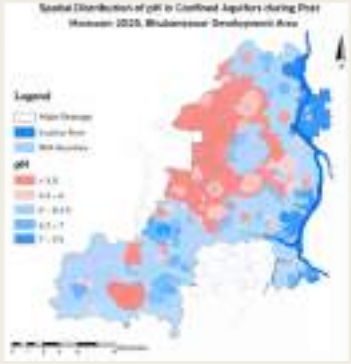




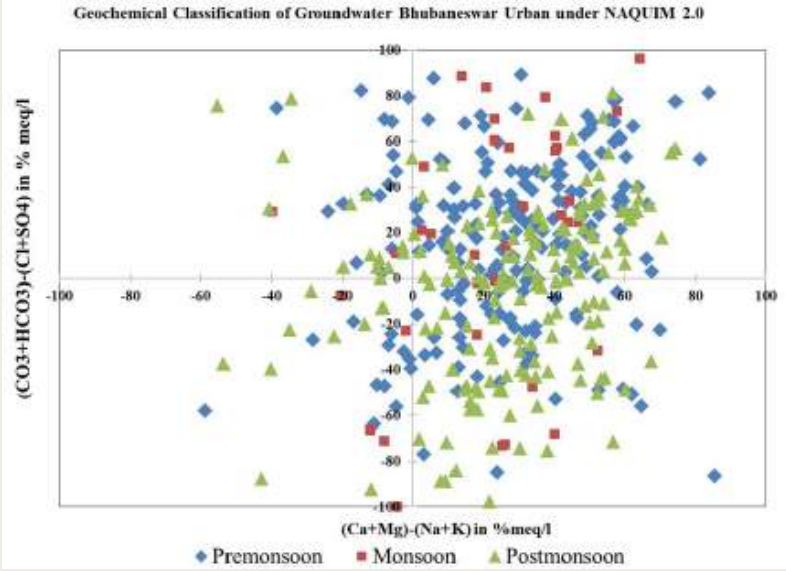


groundwater chemistry in Bhubaneswar urban area is not controlled by a single process



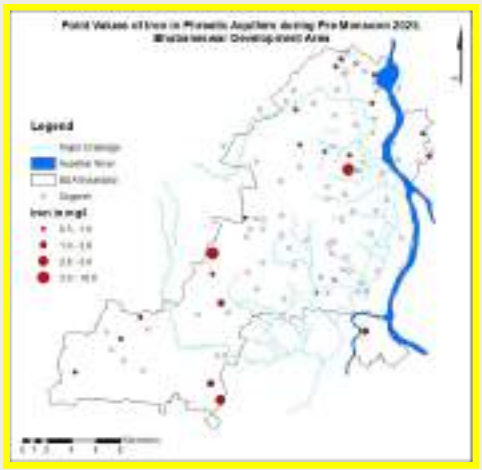


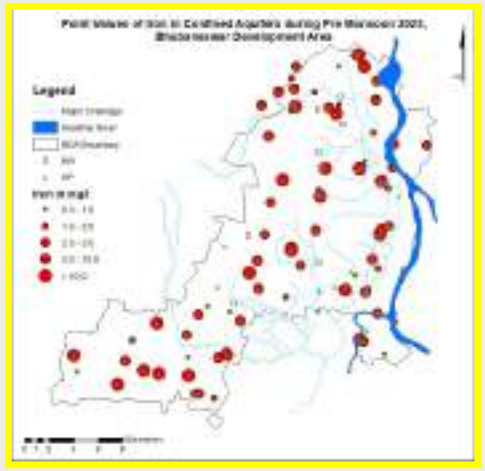
Parameters	Concentration		Range	No. of Samples	% of Samples	Indian Standard (BIS)	
	Min	Max				Desirable	Permissible
pH	4.36	7.63	<6.5	94	47	6.5-8.5	No Relaxation
			6.5-8.5	104	53		
			>8.5	0	0		



Major and Micro elemental Analysis

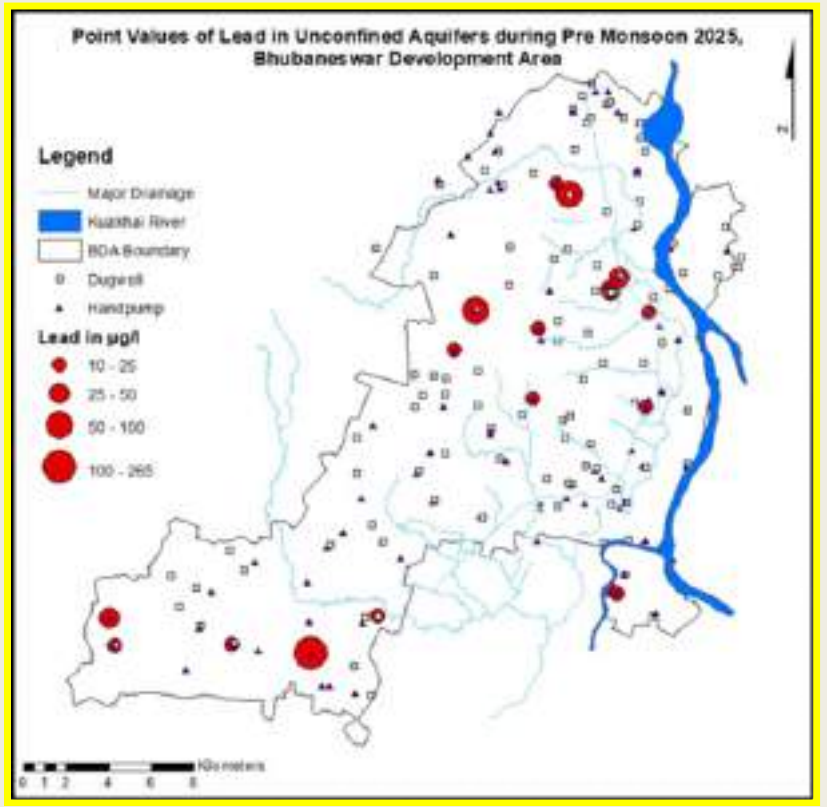
Iron





Parameters	Range	Unconfined		Confined	
		No. of Samples	Percentage of Samples	No. of Samples	Percentage of Samples
Fe mg/L	<1.0	96	94.12	32	33.33
	>1.0	6	5.88	64	66.67
Pb µg/L	<10	101	99.02	79	82.29
	>10	1	0.98	17	17.71

Lead



Iron (Fe) is the clearest chemical hotspot

64 / 84

hand-pump samples
above 1.0 mg/L

Permissible limit: 1.0 mg/L

6 / 102

dug-well samples
above 1.0 mg/L

Maximum: 8 mg/L

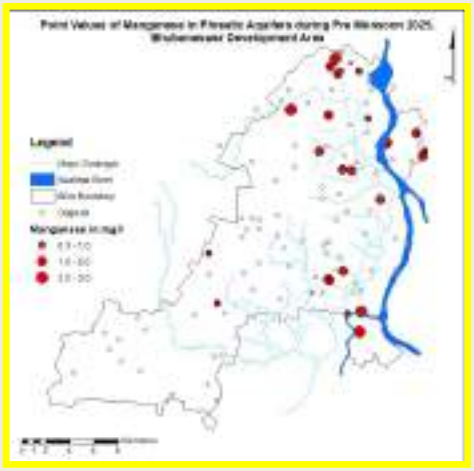
55 mg/L

maximum iron
reported in confined-zone hand-pump samples

Possible contributors noted: mineral dissolution, pump corrosion, and leaching from soil / waste.

Major and Micro elemental Analysis

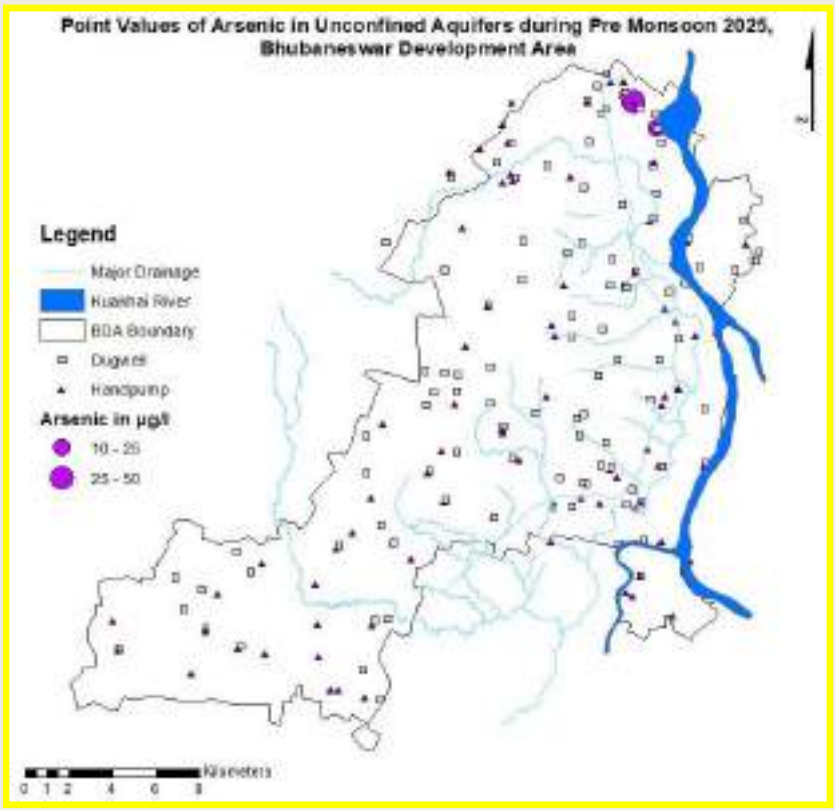
Manganese





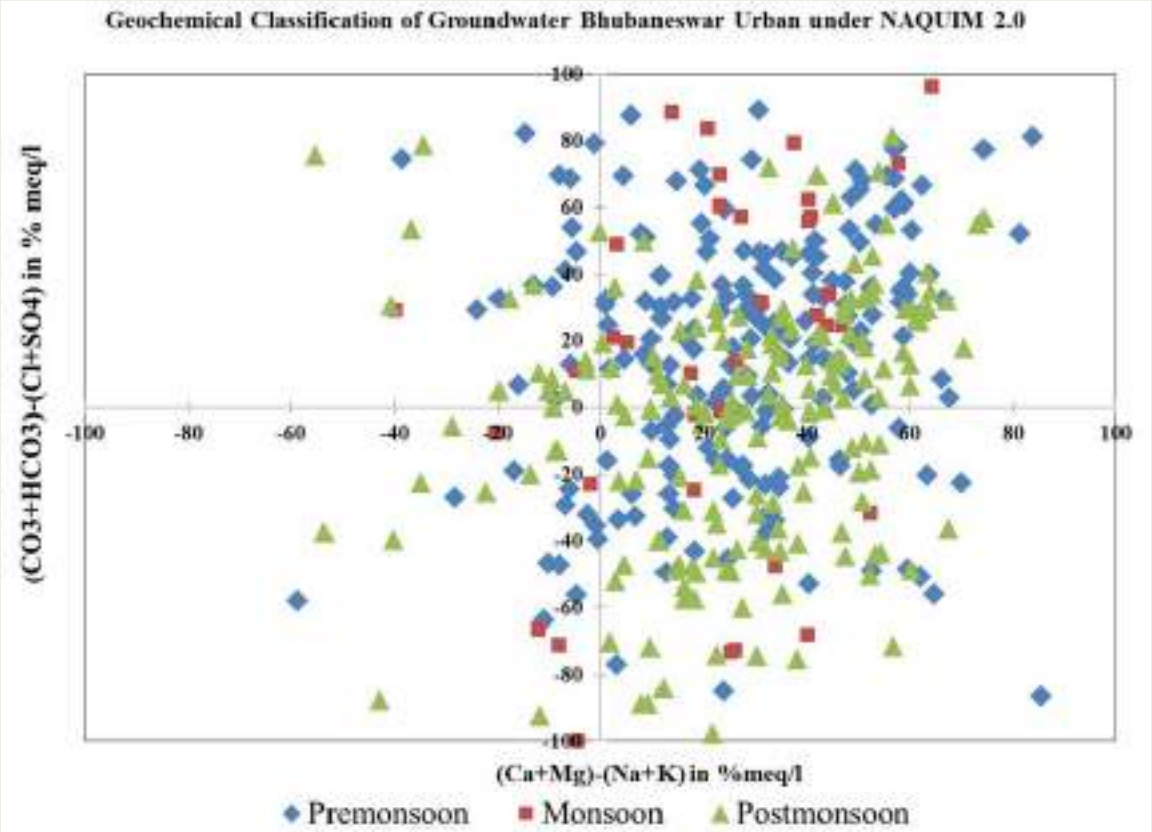
Parameters	Range	Unconfined		Confined	
		No. of Samples	Percentage of Samples	No. of Samples	Percentage of Samples
Mn mg/L	<0.1	50	49.02	45	46.88
	0.1-0.3	27	26.47	27	28.12
	>0.3	25	24.51	24	25
As µg/L	<10	102	100	94	97.92
	>10	0	0	2	2.08

Arsenic



The Signature

$Ca–Mg–HCO_3$ remains the dominant signature



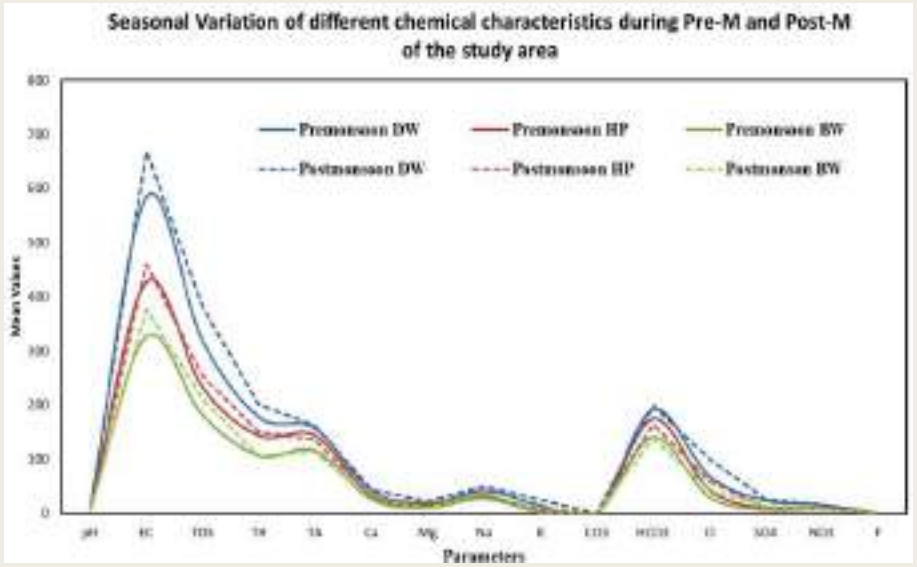
groundwater chemistry in Bhubaneswar urban area is not controlled by a single process

- **Natural water–rock interaction** in crystalline hard-rock aquifers
- **Recharge through lateritic/weathered soil zones**
- **Bicarbonate generation from soil CO_2 and silicate weathering**
- **Urban influence from sewage, drains, waste disposal and surface runoff**
- **Seasonal variation between premonsoon, monsoon and postmonsoon periods**
- **Low buffering condition in several samples, supporting acidic groundwater behaviour**

Anthropogenic signal

$Na–Cl–SO_4$ enrichment at some sites

Variation in Pre-Post Monsoon Samples



Most samples remain within key chemical limits

TDS >500

14% pre-monsoon

17% post-monsoon

TH >600

1% pre-monsoon

1% post-monsoon

pH <6.5

47% pre-monsoon

52% post-monsoon

NO_3 >45

4% pre-monsoon

3% post-monsoon

F >1.5

0.5% pre-monsoon

0% post-monsoon

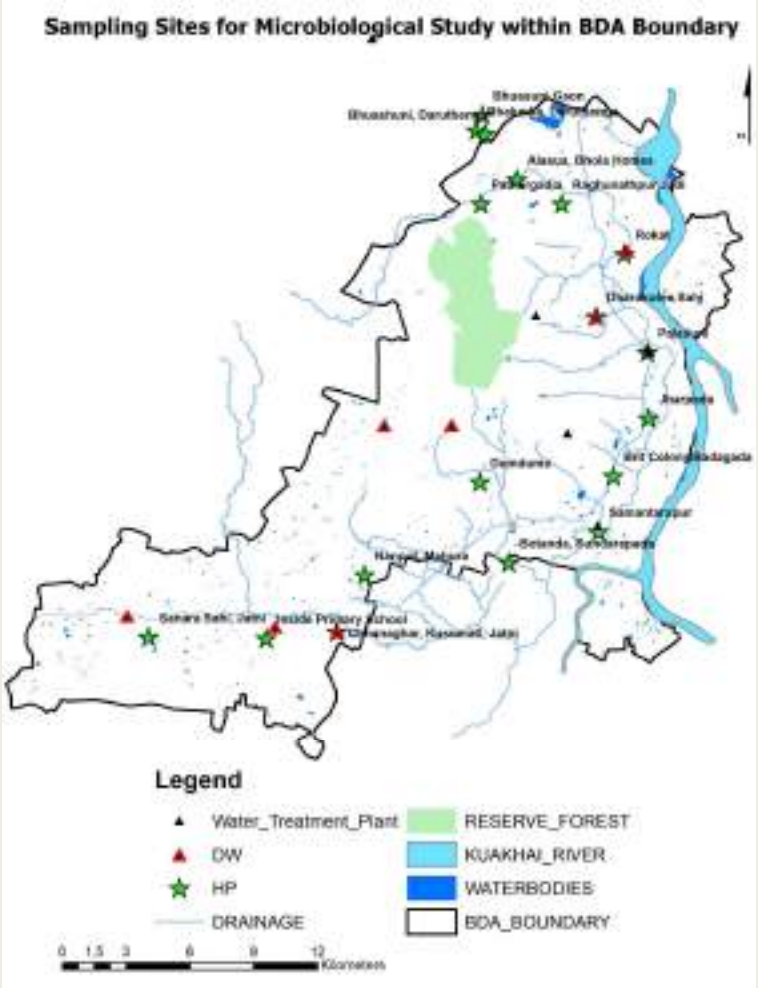
+45.5%
K increase
Mean: 11 → 16 mg/L

+37.9%
Cl increase
Mean: 58 → 80 mg/L

+13.0%
TDS increase
Mean: 278 → 314 mg/L

Fluoride: 99–99.5% < 1.0 mg/L

Microbiological Study with SPCB



- 15 HPs
- 8 DW
- 1 BW
- 1 Surface Water



Microbiological Study with SPCB..

Dissolved Oxygen (DO)

- **Higher DO:** Open dug wells
- **Lower DO:** Hand pumps & bore wells
- Lower DO linked to **limited atmospheric exposure**
- Higher DO generally indicates **better water quality**
- **No significant seasonal variation** in DO

BOD

- BOD indicates **oxygen consumed by bacteria**
- Most samples: **< 1.0 mg/L**
- Indicates **low biodegradable organic matter**
- One exception: **Dharkutee Sahi dug well – 2.6 mg/L**

COD

- Most samples: **> 10 mg/L**
- Indicates **contaminated water.**
- Dharkutee Sahi well:
  - **Pre-monsoon:** 27 mg/L
  - **Post-monsoon:** 15 mg/L

Dharkutee Sahi Well

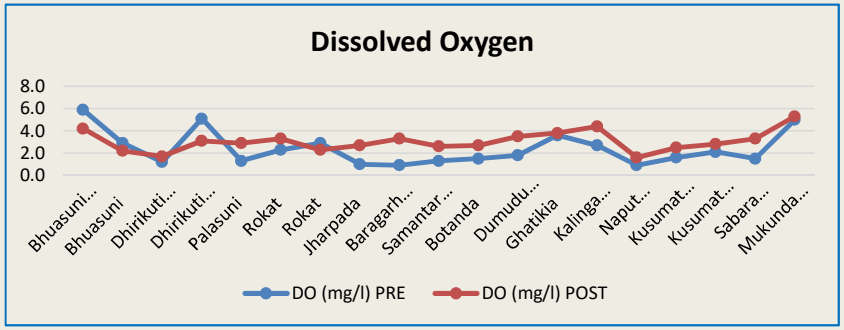
- Located in a **slum area**
- Situated **near a public toilet**
- Higher BOD & COD likely indicate **localized contamination influence**

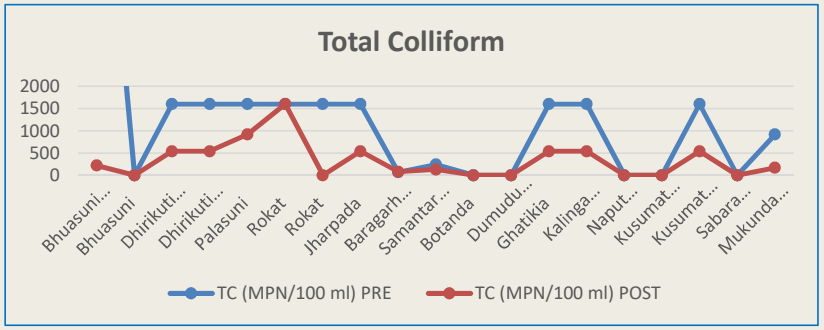


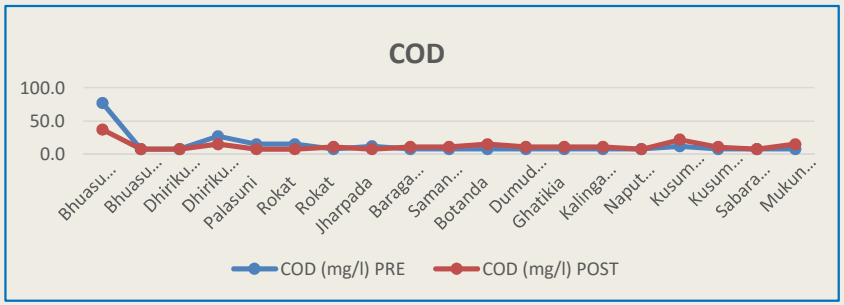


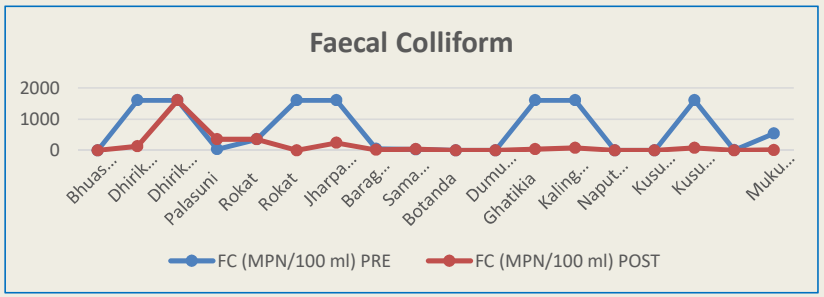

Parameters	Pre-monsoon-2025				Post-monsoon-2025			
	Unconfined		Confined		Unconfined		Confined	
	Min	Max	Min	Max	Min	Max	Min	Max
DO mg/L	0.9	5.1	1.2	2.3	1.6	5.3	2.1	2.5
BOD mg/L	<1.0	2.6	<1.0	<1.0	1.2	2.6	<1.0	<1.0
COD mg/L	7.7	27	7.7	7.7	7.5	22	7.5	7.5
TC MPN/100 ml	<1.8	1600	<1.8	920	79	1600	<1.8	<1.8
FC MPN/100 ml	<1.8	1600	<1.8	540	11	1600	<1.8	<1.8
TKN mg/L	1.68	8.4	3.36	5.04	1.68	14.56	3.92	4.48
Total PAH µg/L	0.342	5.168	2.832	3.516	0.068	0.119	0.096	0.114

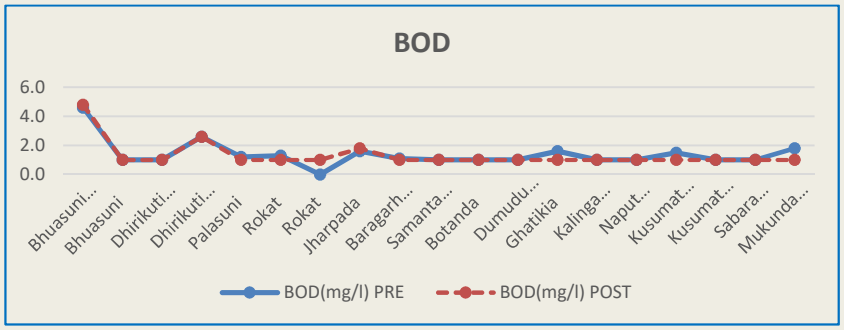
Microbiological Study with SPCB..





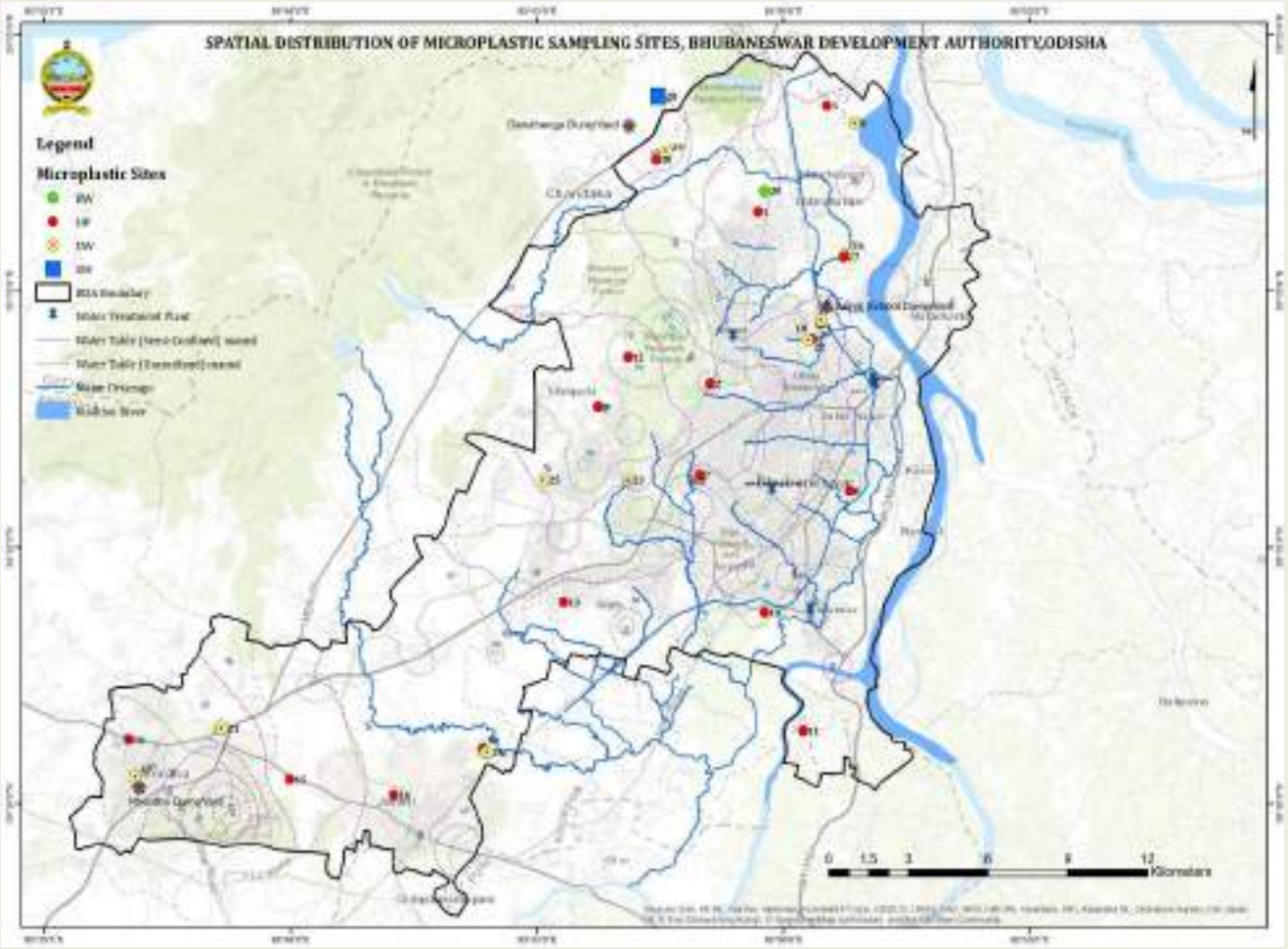






- All samples shows high Total Coliform, Faecal Coliform in both pre-monsoon and post Monsson
- Surface Water samples near Daruthenga dump-yard has elevated FC, TC, COD,

Microplastics in Ground Water

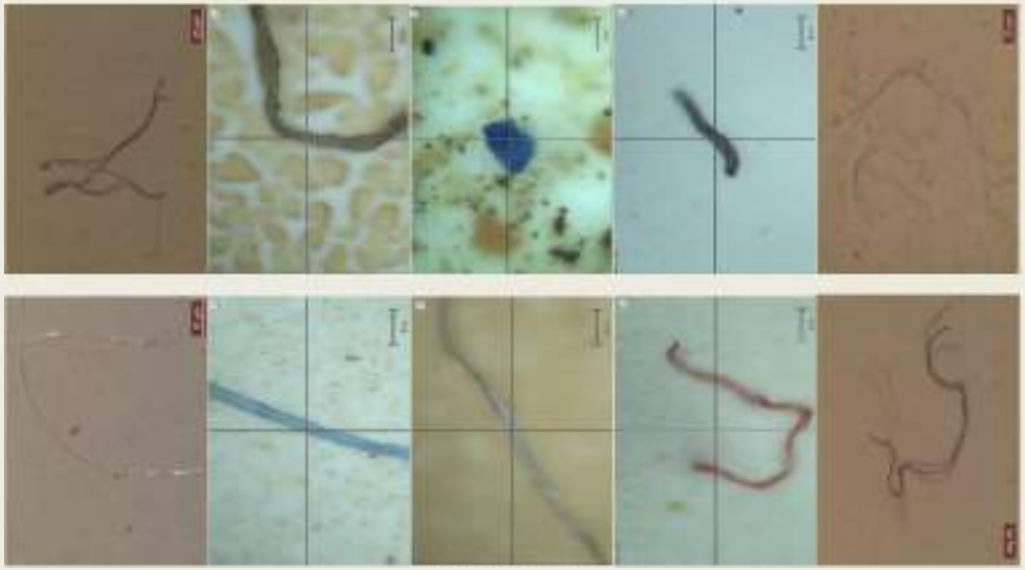


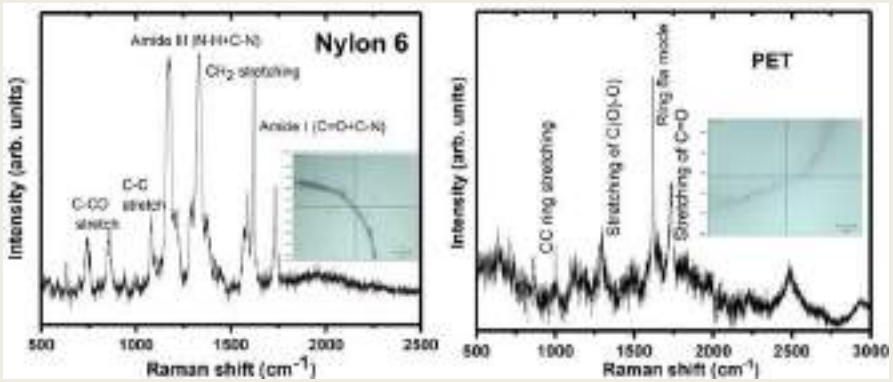
- <10 particles/L → background / low risk
- 10–100 particles/L → anthropogenic influence
- 100 particles/L → localized contamination source present





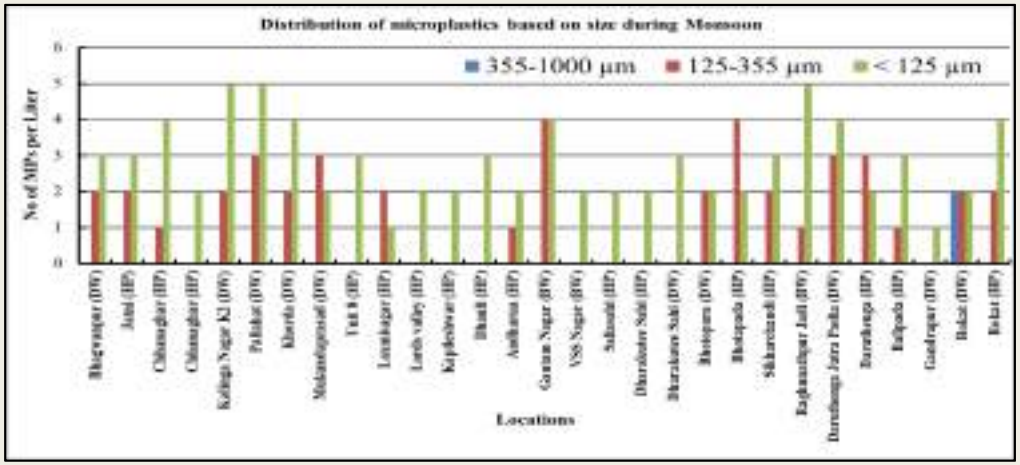
Microplastic Analysis

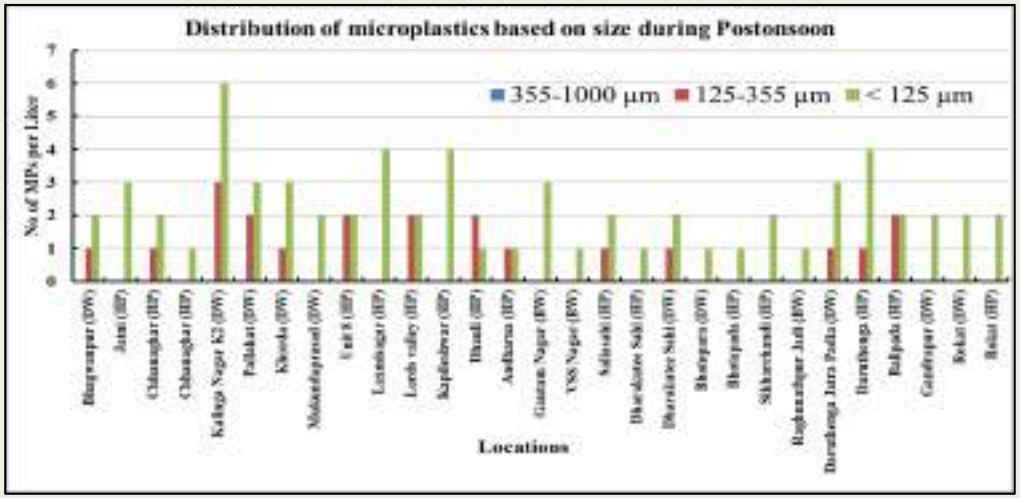




Polymer detected	Common full name	Probable source in urban/environmental samples
Nylon-66	Polyamide-66 / PA-66	In urban samples, it is commonly linked to laundry fibres, textile dust, carpets, road dust and industrial wear.
PET	Polyethylene terephthalate / Polyester	In cities, PET is usually from plastic bottles, packaging waste and synthetic textile fibres released during washing and abrasion.
Polyethylene	PE; includes HDPE, LDPE, LLDPE	In urban runoff, PE usually comes from single-use plastic bags, wrappers, packaging films, degraded bottles and plastic litter.
Polyurethane	PU / PUR	In cities, PU particles may come from furniture foam, construction insulation, coatings, footwear wear and industrial materials.
Polystyrene	PS / EPS	Commonly linked to thermocol packaging waste, disposable food-service items and building insulation fragments.
Polypropylene	PP	In urban samples, PP is commonly from food packaging, plastic caps, woven bags, disposable masks, sanitary waste and household plastic litter.

Microplastic Analysis





Monsoon is both Recharge and transport window

Rainfall can dilute surface waters yet simultaneously mobilise contaminants into vulnerable aquifer zo

1 SUMMER

Evaporation
↑ ions

2 MONSOON

Rainfall
↓ surface concentration

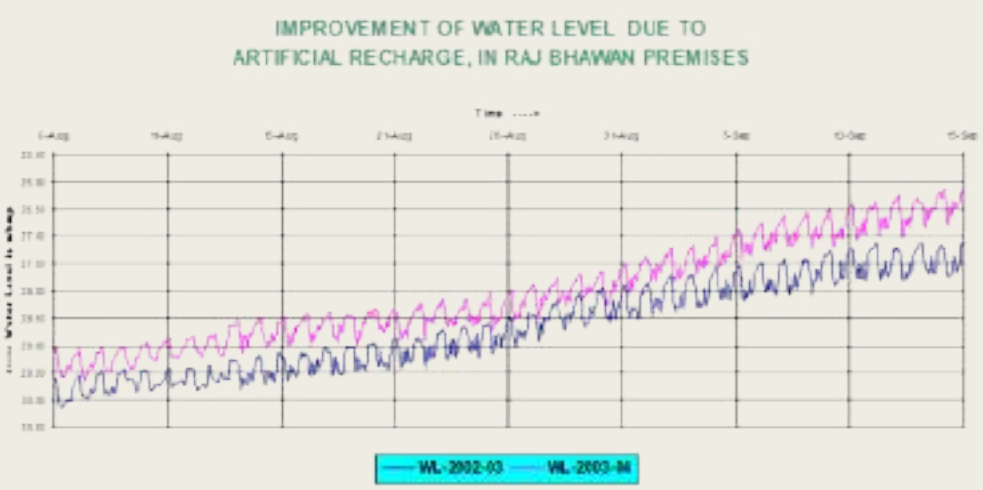
3 POST-MONSOON

Recharge / runoff
mobilises contaminants

Risk mechanism

Surface runoff + Enhanced recharge → Contaminant mobilisation → Groundwater Quality deteriorati

THE WAY FORWARD



A Framework for Urban Aquifer Protection

The study points to a combined infrastructure, monitoring, recharge and governance respon

01

Waste

Scientific landfill Management

Leachate control

02

Sewerage

Reduce infiltration

Upgrade sanitation

03

Aquifer

Controlled abstraction

Continuous monitoring

04

Recharge

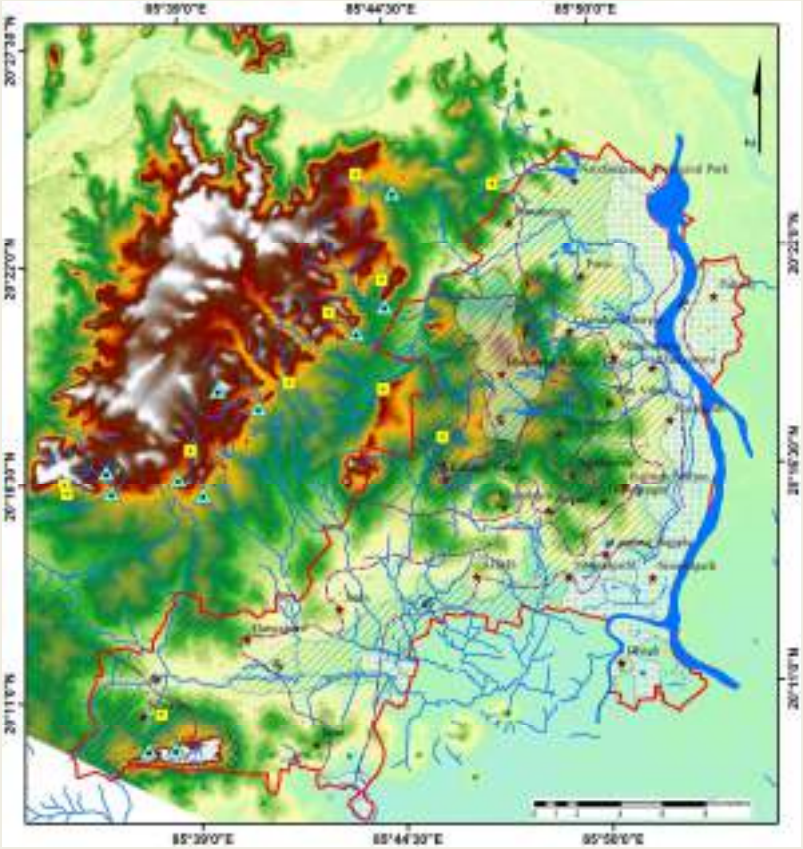
Revive water bodies

Protect permeable space

Keep pollution out • keep recharge pathways open • keep the aquifer observable

Proposal for AR Structures

(Augmentation + Dilution)



Legend

- Check Dam
- Nala Bund
- Major Locations
- Drainage
- WT Contour
- Water Bodies
- Kuakhai River
- BDA BOUNDARY

Rock Type

- Alluvium(AL)
- Khondalite(Kh)
- Laterite(Lt)
- Sandstone/Conglomerate(Sst/Cgl)
- Bharatpur Reserve Forest

SRTM DEM in m

Value

- High : 296
- Low : -21



Tentative Location of Nala Bunds		
Sl. No.	Longitude	Latitude
1	85.728	20.402
2	85.738	20.357
3	85.714	20.344
4	85.695	20.315
5	85.763	20.29
6	85.593	20.275
7	85.789	20.396
8	85.737	20.311
9	85.633	20.177
10	85.65	20.288
11	85.594	20.271



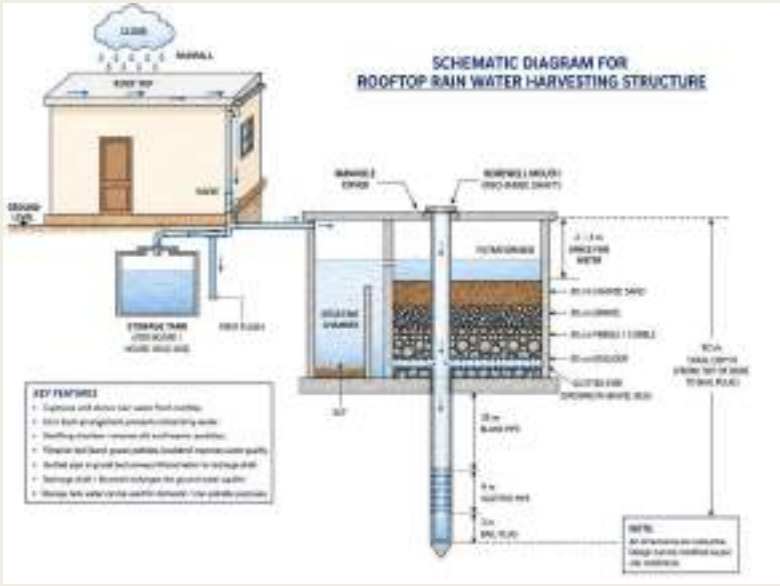
Tentative Location of Check Dams		
Sl. No.	Longitude	Latitude
1	85.744	20.394
2	85.739	20.346
3	85.726	20.335
4	85.681	20.305
5	85.627	20.162
6	85.614	20.271
7	85.639	20.162
8	85.663	20.313
9	85.655	20.269
10	85.612	20.28
11	85.644	20.276

Proposal for AR Structures

Suggested artificial recharge structure in urban area

Area	Total Household	No of Household for recharge calculation (10%)	Total RWHS*	Annual Recharge in Ham
Bhubaneswar Municipal Corporation (BMC)	197661	19766	19766	280
Khurda ULB	9328	933	933	53.3
Jatni ULB	11891	1189	1189	14.3

AR structures are to be constructed in the Chandaka Reserve Forested area spread across 193 Sq.km situated in the N-W part of the area(acts as recharge zone outside the study area



Increase in GW Resource after Interventions in ULBs

Area	Present Annual Extractable Ground water Resource (ham)	Annual Recharge in Ham	Expected Annual Extractable Ground water Resource (ham)	Total Draft	Predicted Stage of Ground Water Extraction (%)	Present Stage of Ground Water Extraction (%)
Bhubaneswar Municipal Corporation (BMC)	3911.8	280	4191	3928.5	93.6	100.0
Khurda ULB	524.5	53.9	578.4	284.4	49.2	54.0
Jatni ULB	313.1	14.3	327.4	200.7	61.3	64.0

The Way Forward/Management Strategy

Deficit in Supply

- The gap to Demand and Supply is 52 MLD which should be mitigated by enhancing the surface water supply both in the ULBs and Peripheral rural BDA.

Recharge Protection

- Bharatpur, Chandaka-Dampara Wildlife Sanctuary, green belts, and open government lands should be declared as **"Groundwater Recharge Sanctuary"**

Artificial Recharge (Forested Areas)

- Construction of **nala bunds, staggered trenches, gully plugs** in Chandaka catchment area should be executed in coordination with Odisha Forest Department. 22 percolation tanks, 11 nala bunds and 11 check dams are to be constructed in the recharge areas as proposed.

Drainage Channel Management

- A **minimum of 50 m buffer zone** should be maintained along major drains and **Gangua Nala–Kuakhai River system** for **linear recharge corridors** and clogging of channels should be periodically removed.

Roof Top Rainwater Harvesting (RWH)

- 21,888 No of house hold of 150m^2 roof area to adopt RTRWH systems to harvest 3.4 MCM water annually.

Reduction of Non-Revenue Water (NRW)

- 82 MLD of NRW should be properly managed.

Universal Piped Water Supply

- Ensure **100% household tap connections** to reduce stress on Ground Water.

Microplastic occurrence

- Scientific municipal waste disposal (lined landfills) should be adopted. To introduce monitoring of microplastics in groundwater

Sewerage Network Expansion

- To check the biological contamination, all households to be connected to proper sewer systems.

Sl No.	Proposal	Capacity in MLD
1	130 MLD WTP at Mundali (in 6 Months)	130
2	20 MLD WTP at Naharkanta by 2028	20
3	WATCO proposing to lift 1000MLD Mahanadi Water at Mundali in 2 Phases for BBSR Water for next 50 Years	1000
4	400 MLD WTP under Viksit Bharat, 2047	400
	Total	1550

Thank You

