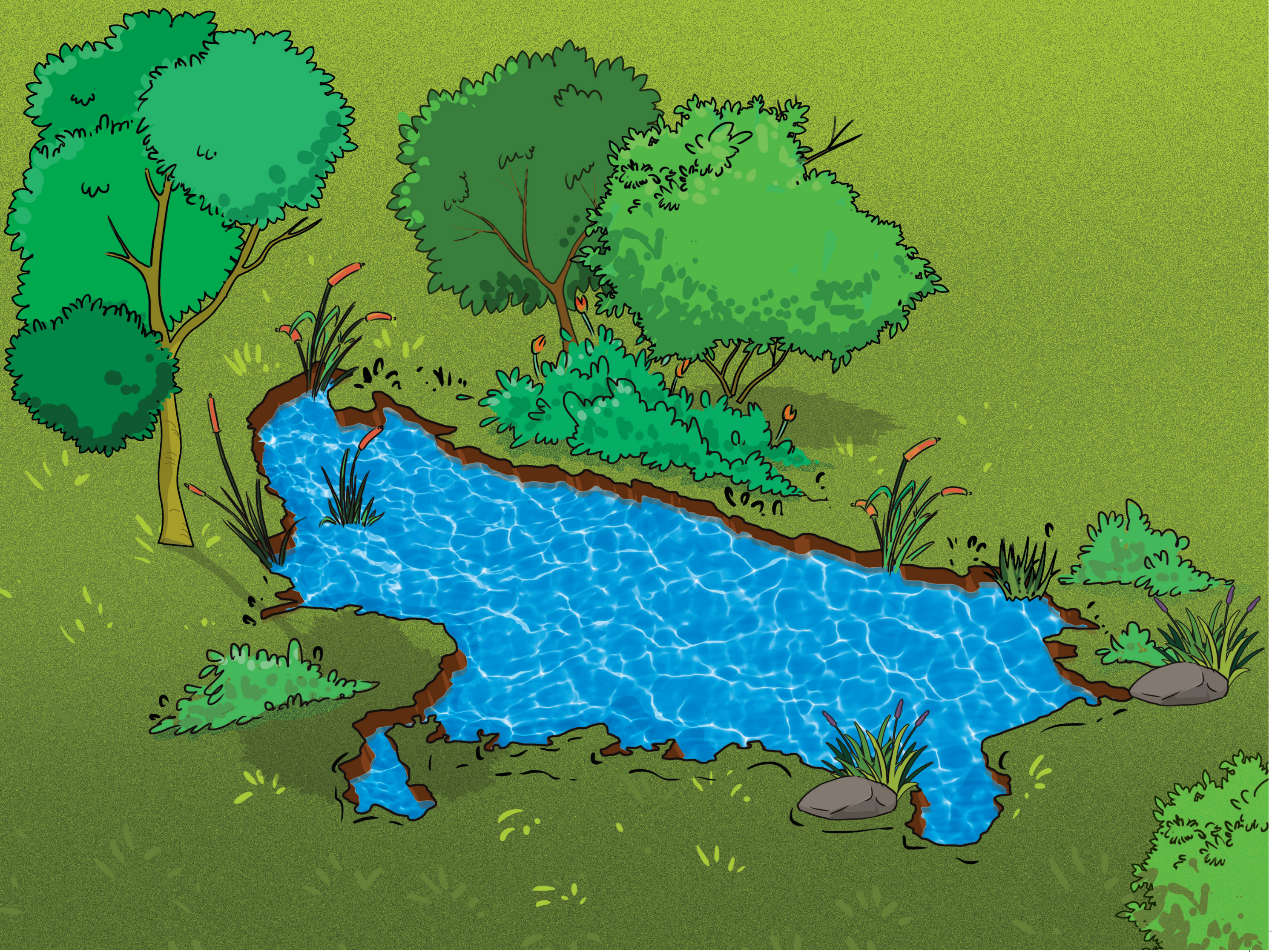
INFUSING NEW LIFE

Gaps and challenges in managing lakes and ponds and groundwater in four selected AMRUT cities of Uttar Pradesh



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Gaps and challenges in managing lakes and ponds and groundwater in four selected AMRUT cities of Uttar Pradesh

Author: Sushmita Sengupta, Pradeep Kumar Mishra, Swati Bhatia, Vivek Kumar Sah and Mehak Puri

Research inputs: Dhiraj Kumar and Mohit Patel

Editor: Archana Shankar

Cover and design: Ajit Bajaj

Maps and illustrations: Pradeep Kumar Mishra and Vivek Kumar Sah

Production: Rakesh Shrivastava and Gundhar Das

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Maps in this report are indicative and not to scale.

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41, Tughlakabad Institutional Area
New Delhi 110 062
Phones: 91-11-40616000
E-mail: sales@cseindia.org
Website: www.cseindia.org

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Chapter 1: Background and introduction

Background

Cities and towns are using groundwater injudiciously down to the last drop. They are simultaneously killing their waterbodies, which could recharge underground water. Loss of the waterbodies—which work as sponges by absorbing extreme rainfall events—lead to waterlogging in urban areas during heavy rain. Cities suffer when it rains excessively and pray for rain when the floodwaters recede. During floods, sewage mixed floodwater flows through the storm-water drains and reach waterbodies, polluting them. This is also the situation in the largest tract of alluvial plain of the country, the Indo-Gangetic Plains.

New Delhi-based think tank Centre for Science and Environment (CSE) has been working with the Department of Urban Development (DoUD), Uttar Pradesh, since 2018. The partnership entails safe management of faecal sludge in 56 towns of Uttar Pradesh. Taking this partnership further, DoUD is collaborating with CSE to work on managing groundwater and rejuvenating lakes.

Four cities, where there have been developments under the Atal Mission for Rejuvenation and Urban Transformation (AMRUT) 2.0, have been selected strategically. The AMRUT Scheme is under the Ministry of Housing and Urban Affairs (MoHUA). AMRUT 2.0, launched in October 2021, aims to promote the circular economy of water through development of a city water-balance plan for each city while focusing on recycle and/or reuse of treated sewage, rejuvenation of waterbodies and water conservation.

To understand the challenges of managing groundwater, lakes and waterbodies, CSE identified four cities where groundwater showed no prominent rise in levels or where groundwater levels were plunging due to increased urbanization. Increased rate of urbanization has led to concretization and reduction in natural recharge of groundwater. Over and above degradation or loss of lakes and ponds in these four cities, groundwater recharge has also fallen to negligible levels.

This study identifies the issues and challenges of managing groundwater, lakes and ponds in the selected cities and brings out possible solutions.

Groundwater, soil, geology, rainfall, drainage and waterbodies in Uttar Pradesh

The major part of Gangetic Plain falls in the state of Uttar Pradesh. The plain stretches from east to west. Other geomorphic features include (i) the Shivalik foothills (ii) Terai and (iii) Vindhya Hills and the plateau. The economy of the state is dependent on the Gangetic Plain.

The population of the state has increased by almost 20 per cent in just ten years, from 16.62 crore in 2001 to 19.98 crore in 2011.[1] Along with the urbanization, the demand for water increased. While parts of the state reel under water crisess, other parts face regular floods.

According to Uttar Pradesh State Water Policy 2020, the state receives an average of 228.28 billion cubic metre (BCM) of precipitation each year. Out of this, only 118.47 BCM (50 per cent) can be used due to the absence of advanced technologies. Currently, large parts of Uttar Pradesh are water stressed. Groundwater exploitation is expected to rise from 45.58 BCM in 2020 to 72.06 BCM by 2025.[2] This increased demand is for domestic, industrial and irrigation needs of the growing population (see Table 1).

Table 1: Groundwater resources: A comparison

Groundwater scenario	India (in BCM)	Uttar Pradesh (in BCM)
Extractable groundwater (annual)	392.70	65.32
Extraction of groundwater (annual)	248.69	45.84
Irrigation/agriculture use	221.45	40.89
Domestic use	24.86	4.95
Industrial use	2.38	Not reported
Net availability for future use	144.01	19.48

Source: State of Groundwater in Uttar Pradesh, WaterAid, 2021

Soil

Uttar Pradesh is a large state, with geographies varying from hills to plains. The state enjoys a range of weather conditions. The soils in the state can be classified into six groups, including bhabar soil, tarai soil, Vindhyan soil, Bundelkhand soil, Aravali soil and alluvial soil. The northern-most part of the state along the foothills of Shivalik Mountains contains bhabar soil, i.e. newly formed alluvial soil. To the south of region with bhabar soil lies the region with tarai soil, including fine clay and silt. Alluvium forms the largest part of the soil in the state, spreading from west to east in the plains. This plain belt of the state has both old as well as younger forms of alluvium (bangar and khadar). The Vindhyan region of the state has red and yellow loamy soil. In the Bundelkhand part of the state, the major soil found is clay and sandy loam.

Geology

The state of Uttar Pradesh has varied geography from the Gangetic Plains to the Bundelkhand and Vindhyan Plateau. The Gangetic Plains form 85 per cent of the state land resources.[3] The remaining 15 per cent is covered by the Bundelkhand and Vindhya Plateau.

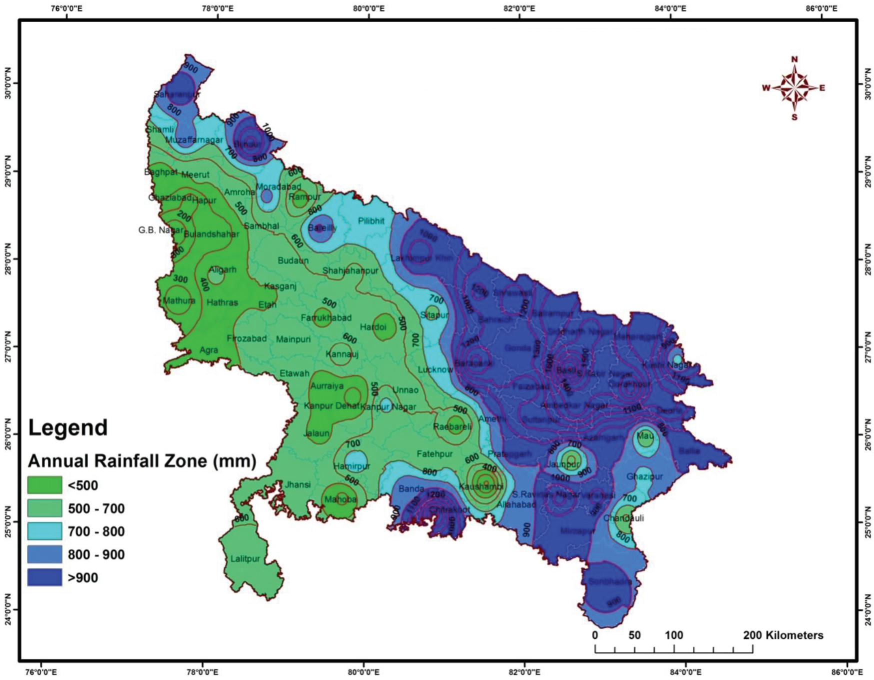
The geology of the state has both porous and fractured formations. The porous formations form the larger part that includes the soft rocks of fluvial sediments, also known as the unconsolidated formations. In the Gangetic Plain, such unconsolidated formation includes the sediments which are a mixture of pebbles, gravel, sand, silt, clay and kankar. The sediments are coarse in the north and become fine in the southeast of the state.

The consolidated formation includes the hard rock area which is predominant in Bundelkhand region and Vindhyan region of the state. In this area, massive hard rock is found at the depth of 15–60 metre below ground level.

Rainfall

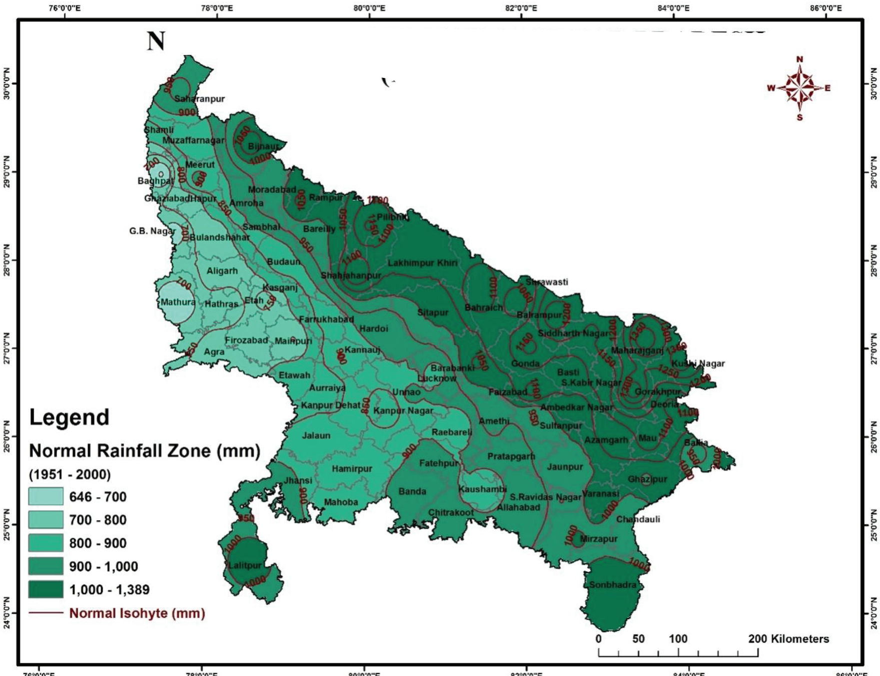
The state of Uttar Pradesh received normal rainfall of 980.8 mm, with average rainfall of 827.64 mm for the last 25 years (1998–2023).[4] The districts in the state receive an extreme range of rainfall, varying from a minimum of 98.9 mm in Gautam Buddh Nagar district to 1,910.5 mm in Basti district.[5] The isohyetal map of the state for 2020–21 and normal rainfall map (1957–2000) is shown in *Figure 1* and *Figure 2 respectively*. The quantity of rainfall ranges from the highest in the eastern part to the lowest in the western part. Some districts in the northern part of the state at the foothills of the Shivalik range receive a good amount of rainfall (>900 mm).

Figure 1: Isohyetal map of Uttar Pradesh for 2020



Source: Groundwater Year Book 2020–21, Central Groundwater Board

Figure 2: Normal rainfall map of Uttar Pradesh for 1957–2000



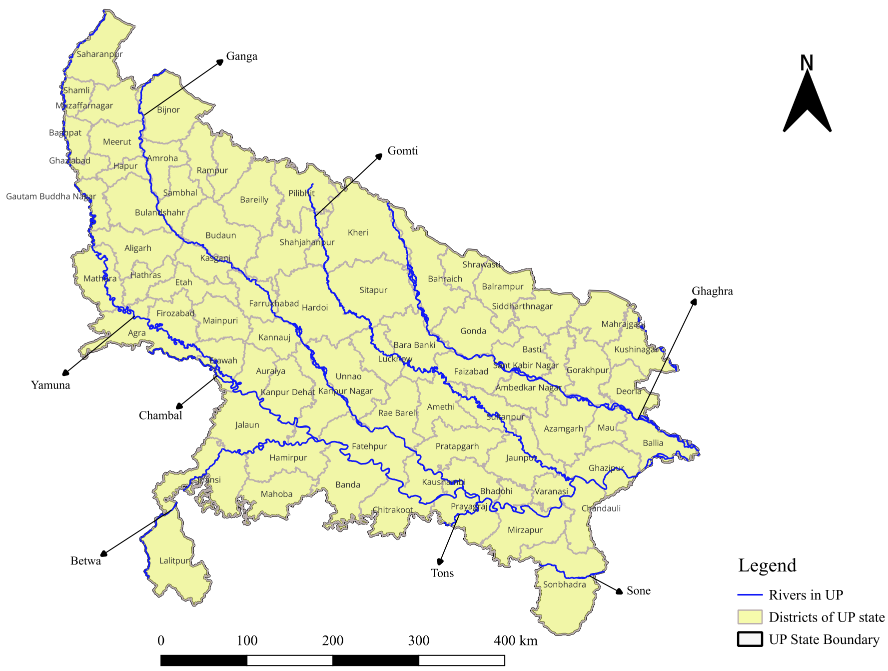
Source: Groundwater Year Book 2020–21, Central Groundwater Board

Drainage and waterbodies

The state of Uttar Pradesh forms a large part of the Indo-Gangetic Plain. The river Ganga flows through the length of the state with several major and minor tributaries contributing to the main flow. The major tributaries of the Ganga River, including the Gomti, Ghaghara, Kosi, Gandak and Yamuna, form the largest alluvial tract in India (see *Figure 3*).

According to the 2023 Waterbodies First Census report, 10.1 per cent of the total waterbodies in India are in Uttar Pradesh.

Figure 3: Drainage system of Uttar Pradesh



Source: www.data.gov.in (accessed on May 24, 2024)

Uttar Pradesh accounts for 63 per cent of all the waterbodies in the country. According to data from first census on waterbodies, Uttar Pradesh has 245,087 waterbodies, of which 98 per cent (240,139) are in rural areas while the remaining 2 per cent (4,948) are in urban areas (see *Table 2*).

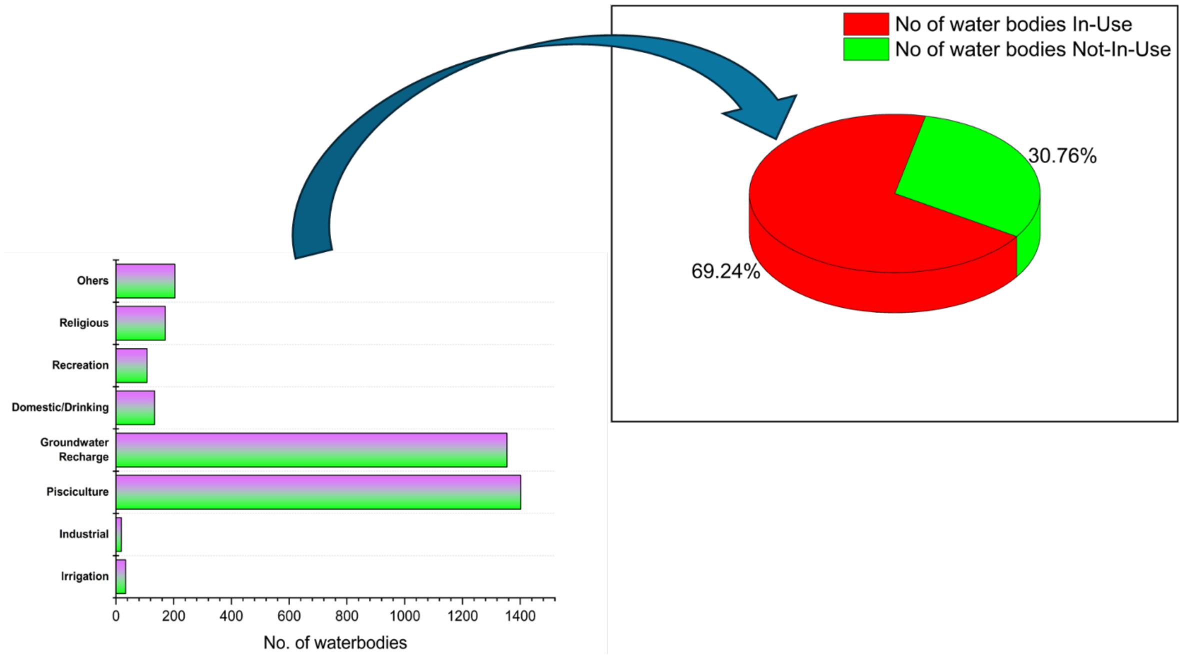
Table 2: Category of waterbodies and their percentages

Category of waterbodies	Percentage
Ponds	97.89
Water-conservation schemes (percolation tanks, check dams)	1.70
Tanks	0.23
Reservoirs	0.09
Lakes	0.07
Others	0.01

Source: Waterbodies first census report 2023, Ministry of Jal Shakti

Of the total waterbodies in the state, 91 per cent (223,150) are natural waterbodies and 9 per cent (21,937) are manmade. Of the manmade waterbodies, 98 per cent (21,500) are found in rural regions, and 2 per cent (437) in urban areas. Most manmade waterbodies were initially constructed at a cost of up to Rs 5 lakh. There are in total 4,948 waterbodies in urban areas of Uttar Pradesh, of which 69.24 per cent (3,426) are in use and 30.76 per cent (1,522) are in disuse (see *Figure 4*).[6]

Figure 4: Different uses of waterbodies in the state of Uttar Pradesh



Source: Waterbodies First Census Report 2023, Ministry of Jal Shakti and complied by CSE.

Several reasons were reported for disuse of waterbodies (1,522), including drying up (462), encroachment for construction (15), siltation (68), destruction beyond repair (142), salinity (25), industrial effluents (6), and other (804). Encroachment was one of the biggest reasons for losing waterbodies. A total of 378 urban waterbodies were reportedly encroached upon making the situation even more concerning (see *Table 3*).

Table 3: Number of waterbodies and their percentage of encroachment

S. no.	Number of waterbodies	Percentage of encroachment
1	128	Less than 25
2	108	25–50
3	24	50–75
4	19	More than 75

Source: Waterbodies First census report 2023, Ministry of Jal Shakti

As a result, it is now necessary to map the aquifers to understand the quantity and quality of groundwater resources in the state. It is also equally important to monitor waterbodies for their sustainability and water security.

Chapter 2: Setting out the objective and data collection

Four cities—Jhansi, Banda, Rampur and Rae Bareli—where issues of groundwater quality and quantity are observed were chosen for this study. In the last decade, groundwater in these cities has either shown a continuous decline or remained almost static. Lakes and ponds in these cities have either been encroached on or polluted to the brim.

This paper will identify the state of groundwater and waterbodies in the four selected cities and the reasons for deterioration of groundwater and the sponges (lakes and ponds) and make suggestions for their sustainability. Templates for the management plans can be used in other fast-growing towns and cities in the Indo-Gangetic Plain.

The study was done by the CSE team in August–November 2023. This enabled data collected to be compared during the monsoon, post-monsoon and dry periods. Data on population, gender ratio, rainfall, area of the cities, water supply, topography, drainage, geology, soil, borehole logs (for details of local strata) and satellite imageries were collected from different government departments and web portals.

Readings on groundwater levels from piezometers and open wells from different locations of the four cities were collected from the state groundwater department for the last one decade to understand the trend of decline (or rise) in groundwater in the cities. The lakes and ponds along with the catchments and feeder channels were surveyed on the three periods.

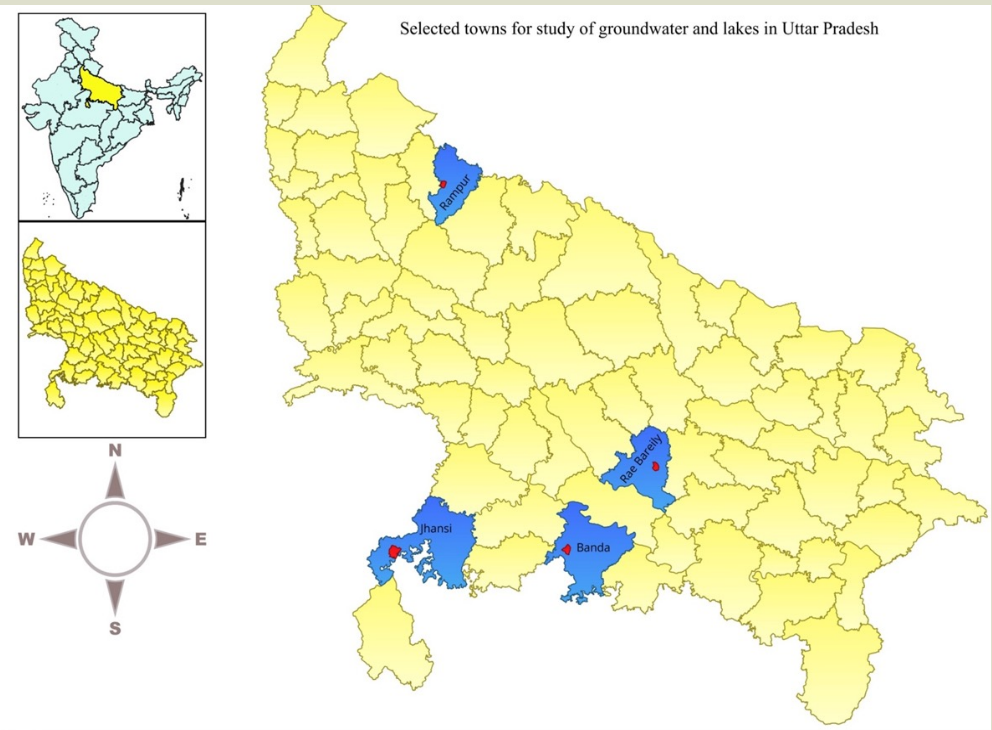
Apart from this, the interaction with different stakeholders was carried out to understand the state of water supply, sanitation practices, and rise and fall of groundwater in different wells across years.

DATA SURVEYED IN ONE GLANCE

- ✓ Cities studied: 4
- ✓ Wards surveyed: 165
- ✓ Number of piezometers/wells studied: 212
- ✓ Number of borehole logs studied: 112
- ✓ Number of lakes and ponds surveyed: 47
- ✓ Focused group discussions: 20 FGDs and 200-plus interviews

Source of data: UP Jal Nigam, UP Groundwater Department, Municipality, Municipal Corporation, Minor Irrigation Department, Nalkoop Department

Figure 5: Selected AMRUT cities in Uttar Pradesh to study the state of groundwater and waterbodies



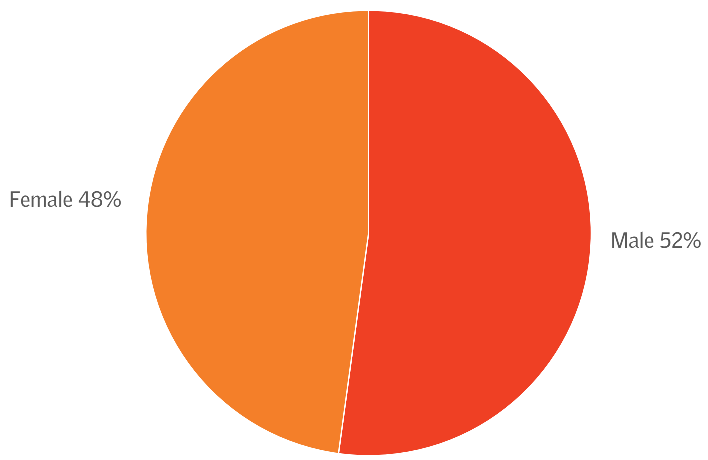
Source: Compiled by CSE

Chapter 3: Basic information and observations from the ground on water and waste of surveyed cities

Jhansi

The city of Jhansi, the municipal headquarter of Jhansi district, is located 416 km (in the southwest direction) from the state capital Lucknow. It has an area of 160 sq. km and is divided into 60 wards. The total population of this city is around 5 lakh, with an average density of 3,100 persons per sq. km. The residents are engaged with local business, government and private jobs. The poor community generally work as labourers in construction work. The gender ratio of the city is 905 females per 1,000 males (see *Figure 6*). The city has a literacy rate of 83.02 per cent.[7]

Figure 6: Gender-wise population percentage of Jhansi city



Source: Census 2011

The city receives an average annual rainfall of 724 mm (25-year average [1998–2023]). Groundwater if the source of water supply to the city. Uttar Pradesh Jal Nigam (Urban) is the agency responsible for supplying the city water.

Jhansi city is dotted with borewells, open wells, tubewells and handpumps. Almost 85 per cent of these groundwater extraction structures belong to the water utility board.

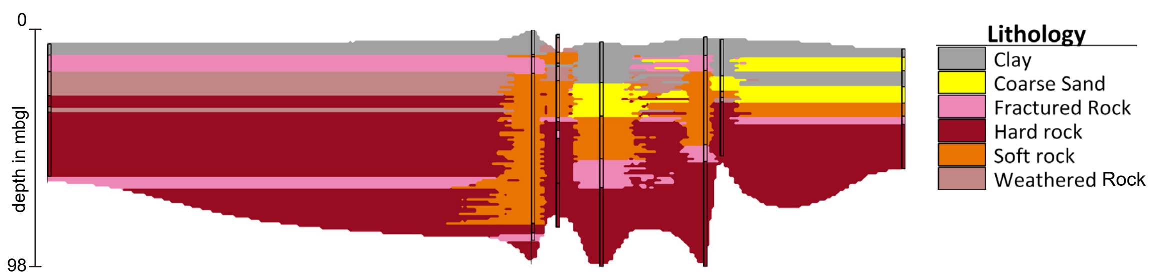
Most of the households are connected to the city supply and they have water supply for two hours per day. The water supply is interrupted regularly by power cuts. During summer months, as the groundwater levels plunge, water supply to the city is reduced.

Water supplied to households is stored in tanks constructed on the premises of the households. During summer months, the city reels under huge water stress as there is scarcity of water. Tankers enter into the city limits, and long queues are observed near the tankers. The tankers are mainly provided by the municipality, but in some places residents buy tankers in a group for Rs 400–700. Every summer, around 20–25 wards of the city face water scarcity. Due to rapid urbanization, there is a huge increased demand of water in the city every year, creating more and more scarcity and dependency upon tankers during summers.

The city is mostly dependant on septic tanks. The septic tanks are basically holding tanks—black water flows out of these tanks and into the storm-water drains and eventually into waterbodies. Most of these drains are uncovered and badly designed, and are not wide and/or deep enough to hold the water flowing through them. Waterlogging becomes a regular event due to clogged storm-water drains. During heavy showers, a cocktail of black water and greywater along with the rainwater flows into lakes.

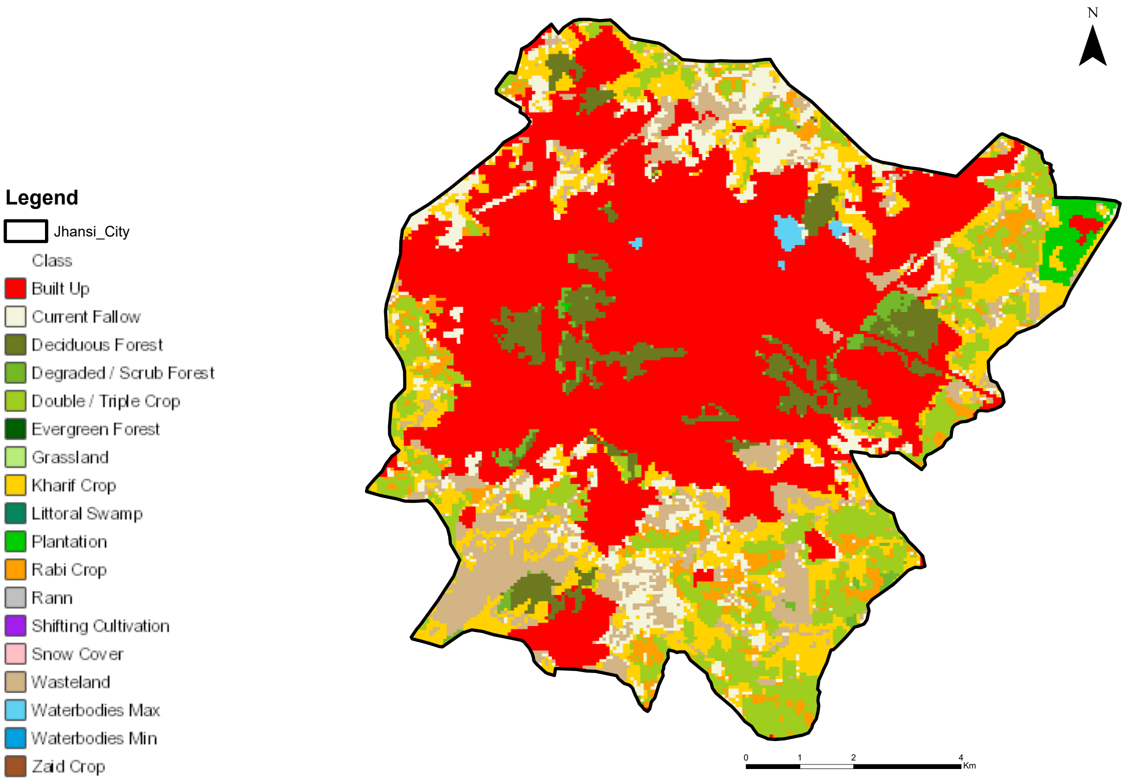
The city has two rivers, the Betwa, which flows 8 km to the east of Jhansi city, and the Dhasan, which flows approximately 50 km to the east of the city. Both the rivers are tributaries of the Yamuna. The soil of the city is mainly clayey. A litholog plotted shows a sequence of clay, coarse sand, fractured rocks, hard rock, soft rock and weathered rock from top to bottom (see *Figure 7*). The litholog has been created from borehole data at the depth of 0–98 metre. The city has four waterbodies.

Figure 7: Lithology of Jhansi city



Source: Borehole logs provided by UP Jal Nigam, compiled by CSE

Figure 8: Land use land cover of Jhansi city



Source: www.indiawris.gov.in, compiled by CSE

Around 40 per cent of the city has been built over (see *Figure 8*). The green and the open areas cover the remaining 60 per cent of the city. The residential and the institutional areas are clustered towards the western and central parts of the city.

Due to urbanization in the last one decade, groundwater levels in the city are plummeting. Data of the last 10 years shows that the groundwater levels have plunged from 10.60 metre below ground level (mbgl) to 12.45 mbgl. This can be attributed to both low rainfall and low natural recharge (due to increased concretization of the area). According to locals, concretization of the area has increased from 10 to 25 per cent.

The major challenges faced by the waterbodies are encroachment and pollution. The area around the waterbodies is encroached on, with buildings constructed all around. Another challenge for the city is the dumping of solid waste in and around waterbodies, which is polluting the lakes and the ponds, despite the city's cleanliness drives to make the surroundings clean and healthy. The storm-water

LOCAL INTERACTION

'Ten years ago, the groundwater level in borewells was around 10–12 mbgl. But the situation has now deteriorated. The water level in borewells has fallen so low that water can be pumped for only one to two hours a day. Sometimes the water from the borewell is saline. We are also facing the issue of fluoride in our borewells. The condition of water in our area is very bad and we are worried about the future.'

—Ankit Mishra, 31, resident, Jhansi

drains are poorly designed and largely clogged with household garbage, plastics and other solid waste. The catchments of the lakes have been encroached by the residential and commercial buildings. Wastewater from these buildings flows freely into the open drains and mixes with storm water during the rainy season. During heavy downpours the storm-water drains overflow causing waterlogging. Waterlogged streets become breeding grounds for mosquitoes, and waterborne diseases are common during this time. Around 20–50 per cent of the income generally goes into this as per the local sources.

MOHIT PATEL/CSE

After every shower, the storm-water drains of ward number 3 in Jhansi overflow. The drains carry a cocktail of water and wastewater. The drains are also clogged at places due to rampant dumping of solid waste. This clogging of drains is a common feature in all the wards of the city.

MOHIT PATEL/CSE

The storm-water drains in most of the wards of Jhansi are poorly built and broken, and spill over even after light showers

MOHIT PATEL/CSE

There is no management of the solid waste in the city. Solid waste is dumped everywhere, including in storm-water drains. The drain in ward number 11 is a good example of drains choked with solid waste, especially plastics.

MOHIT PATEL/CSE

Solid waste is dumped along the periphery of Atiya lake, in the northern part of the city. The government has focused on beautification of the lake, and a peripheral boundary as well as a fountain have been created inside the lake. But low community awareness has affected the water quality of the lake. The people residing near the lakes regularly dump their waste there.

MOHIT PATEL/CSE

Ward number 2 of Jhansi city depends on one handpump. The city supply—one hour in the early hours of the day—is insufficient. Borewells dry up during peak summer and the locals are forced to purchase tanker water, spending up to Rs 1,200 per 5,000-litre tanker.

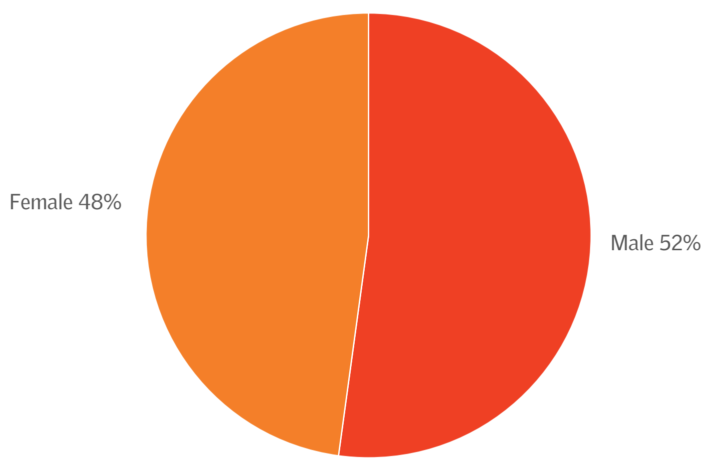
Rampur

The city of Rampur, the municipality headquarter of Rampur district, is located 322 km northwest of the capital city of Lucknow. It has an area of 84 sq. km and is divided into 43 wards. The population of the city is 3.45 lakhs, and it has an average density of 4,107 person/sq. km. The main occupation of the residents is small business and enterprises along with government and private jobs. The male to female gender ratio of Rampur is 1000:917 (see Figure 9) and the literacy rate is 50.98 per cent.[8]

The 25-year average of rainfall of the city of Rampur is 1,109.672 mm. The city depends on groundwater sources for water, extracted through handpumps and borewells. The supply of water is under the Department of Uttar Pradesh Jal Nigam (Urban). Water is supplied for two to four hours daily. Residents store water in tanks in their house premises. Water supplied is not sufficient for the residents, especially in summers.

Rampur is a highly dense city, and population influx is continuously increasing. Due to the population growth, there is a huge demand of water, creating a shortage of supply. The toilets used by more than 70 per cent of the residents are septic tank based. The remaining 30 per cent of the toilets are linked with sewer lines. The septic tanks are basically holding tanks, most of which are poorly constructed. Black water flows out of these tanks and into storm-water drains and eventually into waterbodies. The storm-water drains of the city are in a severely degraded condition as they are encroached, clogged and filled with black water. Many drains can be seen filled with solid waste, including plastics. Garbage and solid waste

Figure 9: Gender-wise population percentage of Rampur city



Source: Census 2011

choke the drains and wastewater spills onto the roads during the rainy season. Waterlogging is a regular event due to clogged storm-water drains. During heavy showers, a cocktail of black and greywater along with the rainwater flows into the lakes. The entire city depends on septic tanks and black water and greywater flow into open drains. Wastewater freely flows into the ponds of the city, polluting them severely.

DHIRAJ KUMAR/CSE

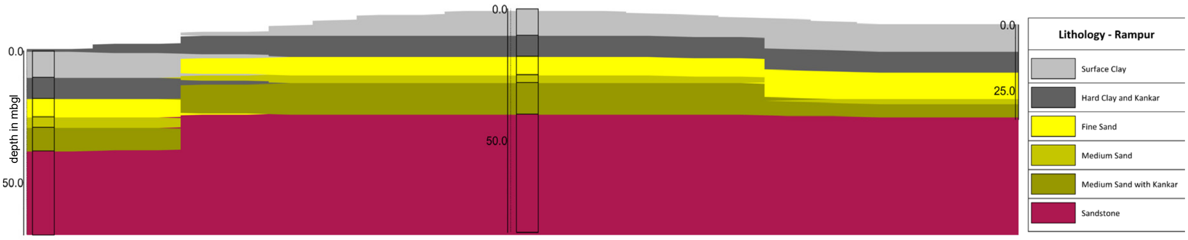
Plastic waste and wastewater are dumped in large and small drains in Rampur. Ward number 5 of the locality Bamanpuri is an example of how the drains look in the dry period—November—when water flow in the drain is low. During the monsoon, similar drains in almost all the wards overflow and flood neighbouring areas.

DHIRAJ KUMAR/CSE

The narrow undersized drains in the Nalapaar area (ward number 28) of Rampur are choked with plastic, and greywater from households flows unabated into the drains. Spilling of wastewater is a common issue in the area after the rains.

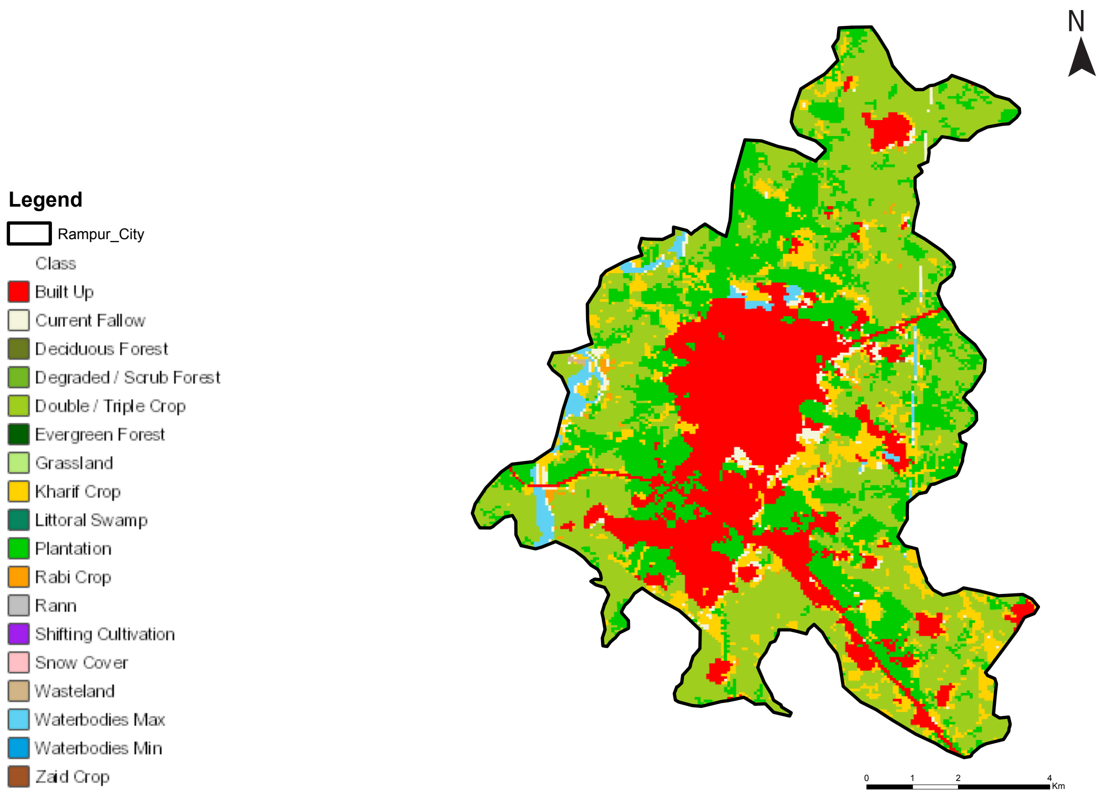
The Kosi River flows 3.5 km east of the city. The soil of the city is mainly clayey. The litholog plotted from the borewell logs between the depths of 0 and 60 metre below ground level shows the soil sequence as surface clay, hard clay and kankar, and fine and medium sand from top to bottom (see *Figure 10*). The city has two waterbodies. Around 40 per cent of the city has been built over (see *Figure 11*). Green and the open areas occupy around 50 per cent of the city. Residential and the institutional areas are clustered towards central part of the city.

FIGURE 10: LITHOLOGY OF RAMPUR CITY



SOURCE: BOREHOLE LOGS PROVIDED BY UP JAL NIGAM, COMPILED BY CSE

FIGURE 11: LAND USE LAND COVER MAP OF RAMPUR CITY



SOURCE: WWW.INDIAWRIS.GOV.IN, COMPILED BY CSE

LOCAL INTERACTION

'There has been a sudden increase in urbanization in last 10–15 years in Rampur city, which has increased the stress on groundwater. Our city is dependent on groundwater for all needs. Industries like sugar mills and breweries in our city too extract groundwater for production. Though the government is trying to meet the water demands through city water supplies, it needs to work more on providing sufficient water.'

—Sohail Khan, 44, resident, Rampur

Due to rapid urbanization in the last one decade, groundwater levels in the city are plummeting. Data of the last five years shows that the groundwater level has plunged from 6.04 metre below ground level (mbgl) to 7.28 mbgl. This can be attributed to both low rainfall and low natural recharge (due to increased concretization of the area). According to locals, concretization of the area has increased from 20 per cent to 30 per cent.

The waterbodies have become receptacles of sewage and solid waste. The major challenges they face include encroachment, an unmaintained lake with no fencing, a collection centre of wastewater, and a dumpsite of solid waste around and in the lake. The Police Line talab has been encroached on and there is presence of wastewater in the lake. In the Nalapaar pond, encroachment, greywater, and dumping of solid waste has deteriorated the condition of the pond.

DHIRAJ KUMAR/CSE

Greywater from households flows through a storm-water drain into the Police Line talab in ward number 15 of Rampur. People living in the vicinity dump solid waste in and around the talab.


DHIRAJ KUMAR/CSE

Nalapaar talab in Rampur is encroached on by illegal setllements. Wastewater from these settlements flows freely into the talab. The water stinks and is visibly black.

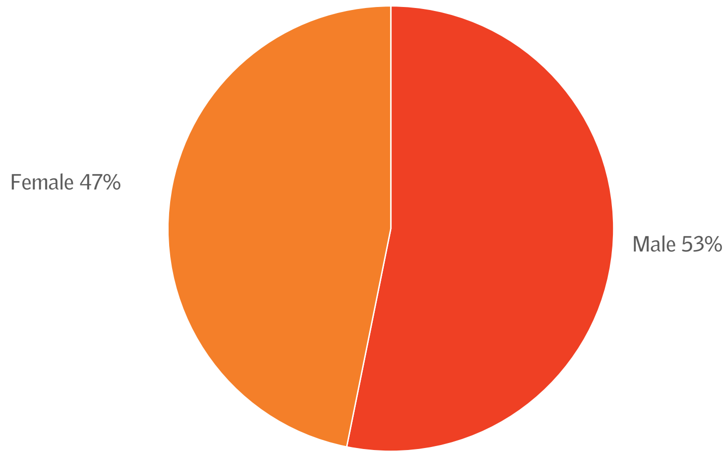
The city supply is not interrupted during summers, but during the rainy seasons when, due to heavy rains, clogged storm-water drains overflow and the streets get waterlogged; the maintenance of water-carrying pipelines becomes difficult. In such cases, tankers are brought to deliver water to people. Waterlogged streets lead to breeding of mosquitoes, and waterborne diseases are common during this time.

Banda

The city of Banda, the municipal headquarter of Banda district, is located at distance of 198 km to the south from the capital city of Lucknow. The city has an area of 48.6 sq. km and is divided into 31 wards. Its population is 1.5 lakh, with an average density of 3,125 persons per sq. km. The main occupation of the residents is based on local business, construction, labour and private and government services. The gender ratio of male and female in Banda city is 1000: 860 (see *Figure 12*) while the literacy rate is 68.11 per cent.[9]

The city receives normal annual rainfall of 962.5 mm. The 25-year average of rainfall is 837 mm.[10] Uttar Pradesh Jal Nigam (Urban) supplies water to one-third of the population. Water is supplied for one to two hours twice a day. Residents store water in storage tanks in their houses. Residents also have private borewells which bridges the demand–supply gap. Water supplied is sometimes insufficient, especially in summer. The groundwater level plunges, sometimes more than 100 metre in summers, interrupting the city supply. Toilets used by more than 60 per cent of the residents are septic tank-based, and the remaining 40 per cent are

Figure 12: Gender-wise population percentage of Banda city



Source: Census 2011

connected to sewer lines. Most of the septic tanks are poorly made; they do not follow specifications and at places are poorly maintained. Untreated black water flows out from these septic tanks into city drains.

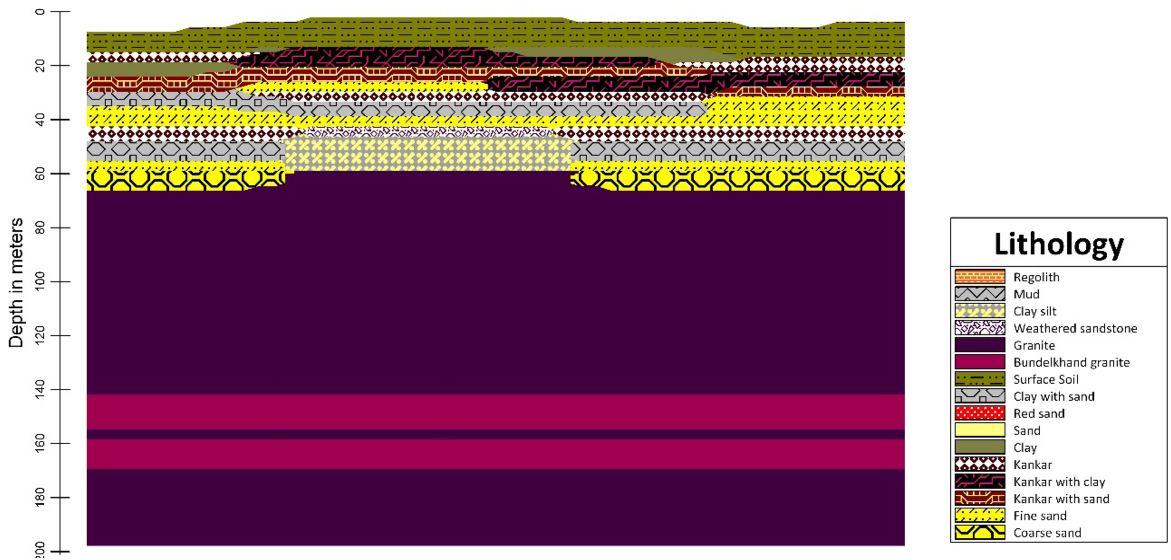
The river Ken flows through the city. The soil of the city is mainly black cotton soil. The litholog created from the borehole logs at the depth of 0–200 metre shows a sequence as regolith, mud, clay silt and weathered sandstone from top to bottom (see *Figure 13*). The city is dotted with more than 30 ponds.

Around 30 per cent of the city has been built over (see *Figure 14*). Green and the open areas occupy 25–35 per cent of the city. Residential and the institutional areas are clustered towards northeastern part of the city.

Due to rapid urbanization in the last decade, the groundwater level in the city is plummeting. The last 10 years data (2013–23) received from state Groundwater Department show that the groundwater level has plunged from 14.15 metres below ground level (mbgl) to 18.90 mbgl. This can be attributed to both low rainfall and low natural recharge (due to increased concretization of the area). According to locals, concretization of the area has increased from 20 to 30 per cent during the same years.

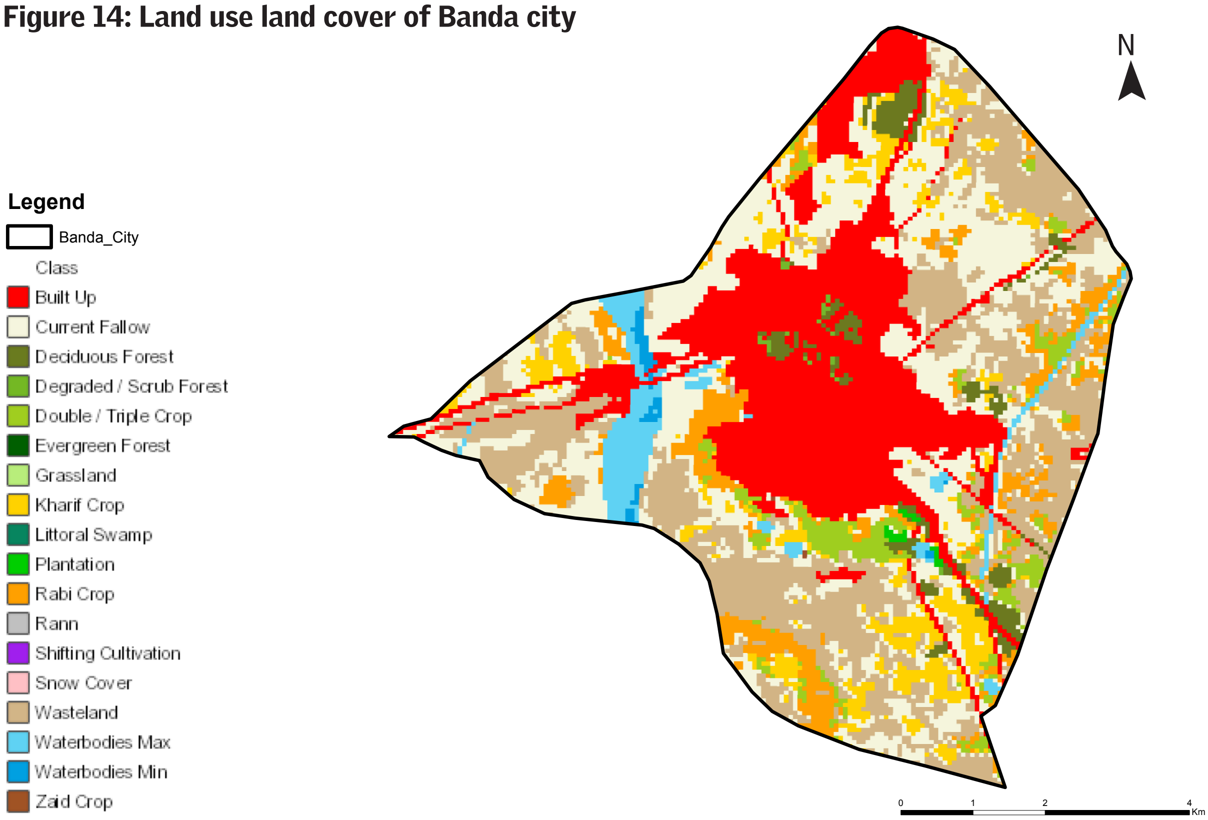
Most of the drains in the city are poorly constructed and not maintained properly. Solid waste clogs the drains in many wards of the city. Due to unavailability of proper drainage systems, wastewater can be seen to be flooding open spaces in ward number 15 of the city.

Figure 13: Lithology of Banda city



Source: Borehole logs provided by UP Jal Nigam, compiled by CSE

Figure 14: Land use land cover of Banda city



Source: www.indiawris.gov.in,complied by CSE

LOCAL INTERACTION

In Banda city, a significant portion of the population, around 70–75 per cent, relies on private borewells. Around 80 per cent of the urban water supply is sourced from the Ken River by two intake wells which are located on western side of the city, while the remaining 20 per cent is extracted from 25 tubewells that have been constructed by Jal Nigam.

—Yogendra Singh, Junior Engineer, Uttar Pradesh Jal Nigam Urban

The major challenges faced by waterbodies in Banda are encroachment and pollution. Most of the waterbodies have their catchments and feeder channels encroached on by illegal construction. The ponds are polluted with dumping of

MOHIT PATEL/CSE

The narrow drains on both sides of the bricked road in ward number 10 of Banda are clogged with plastics. Greywater from households also flows into the same drains.

MOHIT PATEL/CSE

Wastewater, overflows from the neighbouring poorly designed storm-water drains floods the roads in August in Banda's ward number 15.

The talab in ward number 12 in Banda receives wastewater from surrounding households through storm-water drains. Solid waste is also dumped in and around the waterbody.

solid waste, mainly plastics. Wastewater from households flows through drains, discharging into the waterbodies. Kandhardas pond in ward number 12 of the city receives household wastewater along with the solid waste dumping.

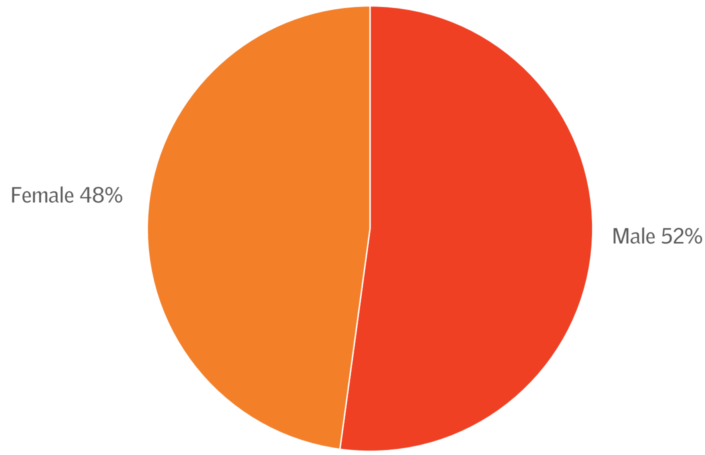
During summers, the water demand increases and the city water supplies become insufficient and water tankers are called. Long queues can be seen near the tankers. Residents buy tanker water at the cost of Rs 300–600 during peak summers. During the rainy season, waterlogging can be seen all around the city, making it a breeding ground for mosquitoes. Water-borne diseases are common during rainy seasons. The residents face many issues because of poor facilities of sanitation and drainage. According to the local sources, around 20–50 per cent of the income is generally spent as medical expenses.

Rae Bareli

The city of Rae Bareli, the municipal headquarter of Rae Bareli district, is located 105 km to the south of capital city of Lucknow. The area of the city is 43 sq. km and it is divided into 31 wards. The total population of the city is around 1.9 lakh, with an average density of 4,418 persons per sq. km.The main occupation of the residents is local business, government and private jobs; and poor people are engaged as construction. The gender ratio (male to female) in the city is 1000:915 (see *Figure 15*) and the literacy rate is 81 per cent. [11]

The city receives a normal rainfall of 949.1 mm every year. The 25-year average (1998–2023) rainfall of the city is 637 mm.[12] The supply of water is under Uttar

Figure 15: Gender-wise population percentage in Rae Bareli city.



Source: Census 2011

DHIRAJ KUMAR/CSE

The main drain of the city flows through ward number 6 of Jhansi. A cocktail of water and wastewater flows through this drain and empies into the waterbody nearby.

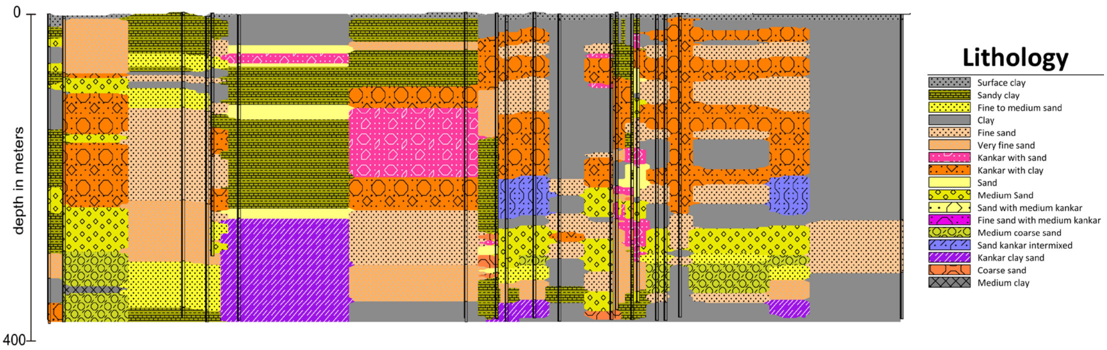
Pradesh Jal Nigam. Water is supplied for one to two hours a day, twice a day. The residents store water in storage tanks in their house premises. Water supplied is not sufficient for the residents, especially in summers. Due to delay in supply or no supply during summers, the residents source the water from private borewells.

The toilets used by more than 80 per cent is septic tank based, while the rest are connected to sewer lines. The septic tanks are basically holding tanks, most of which are poorly constructed. Black water from these tanks flows out to storm-water drains and eventually into waterbodies. The storm-water drains are poorly constructed and most of them are encroached on by households. In the dense unplanned settlements, the situation is even worse, where unplanned drains are all clogged due to household garbage and solid waste dumps.

The Sai and Gomti Rivers flow in the west and east part of the city in north–south direction, joining the Ganga River in south at around 40 km from the city. The soil lithology of the city between the depths of 0 and 370 metre shows the occurrence of alluvium mainly, with clay as the top layer (see *Figure 16*). The city is dotted with around 30 waterbodies.

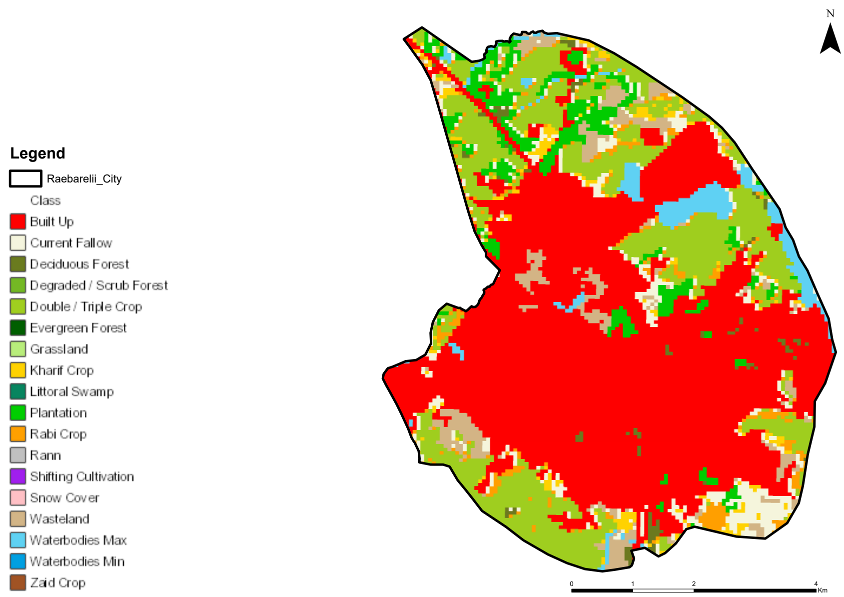
Around 60 per cent of the city has been built over (see *Figure 17*). Green and open

Figure 16: Lithology of Rae Bareli city



Source: Borehole logs provided by UP Jal Nigam, compiled by CSE

Figure 17: Land use land cover of Rae Bareli city



Source: www.indiawris.gov.in, compiled by CSE

INTERACTION WITH NAGAR PALIKA PARSHAD

'We are developing drains and nallahs in parts. We have around 99 nallahs, 9 big drains, 48 small drains and 42 medium drains. The drains are faulty and not designed as per specifications. We just plan drains and get it done to connect it to main sewer lines. Even the communities build over or encroach the drains due to which the water logging happens. As of now we have planned two ponds for revival under AMRUT where we are pumping out the water using a mud pump to the nearby main drain. Post that it will be de-weeded and desilted with a sanctioned amount of Rs 193.72 lakh. We have approximately 175 waterbodies which we eventually plan to take up.'

—Neha Parveen, Assistant Engineer—Construction, Nagar Palika Parishad, Rae Bareli

DHIRAJ KUMAR/CSE

Solid waste is dumped on the waterbody of ward number 17 of Rae Bareli and it is almost completely encroached on. Only 10 per cent of the waterboby is filled with water; most of it is filled with sewage.

areas occupy 30 per cent of the city. Residential and the institutional areas are clustered towards the southern part of the city.

Due to urbanization in the last one decade, the groundwater level in the city has been plummeting. Data from the last nine years (2015–23) from the state Groundwater Department shows that the groundwater level has plunged from 6 metre below ground level (mbgl) in 2015 to 8 mbgl in 2023. This can be attributed to both low rainfall and low natural recharge (due to increased concretization of the area). According to locals, concretization of the area has increased from 30 per cent in 2015 to 60 per cent in 2023.

The major challenges faced by the waterbodies are encroachment and pollution. The catchment and pondage area of most of the waterbodies are encroached on.

Solid waste is dumped in these waterbodies. Household wastewater and garbage enter the waterbodies freely.

During summers there is scarcity of water and tankers are needed to supply water to households. There are long queues near the tankers during peak summers. The tankers are provided by the municipality. Sometimes, when the tankers provided by the municipality are not sufficient, the residents have to buy water at the cost of Rs 400–800.

During the rainy season, the streets of the city are flooded with a mix of wastewater and storm water. Drainage systems are poor, with waterlogged streets breeding mosquitoes and water-borne diseases are common during this time. According to the residents, around 30–40 per cent of the income generally goes into their medical expenditure.

WASTEWATER FLOODING WOES

Arjun, 35-year-old labour, hails from Bihar, where his family lives. Arjun stays in Rae Bareli and works as construction labour. In his ward, roads are often waterlogged. He works at a construction site where waterlogging is frequent as the drains are usually clogged and are not cleaned. The situation is worse during rains. In many places drains either do not exist or are encroached on by houses. Due to his work, he is often exposed to dirty, stinking water and suffers from skin diseases. He does not have a filter at home and drinks groundwater directly.

DHIRAJ KUMAR/CSE

Skin disease caused by long exposure to wastewater

Chapter 4: Challenges in managing groundwater and waterbodies

This chapter talks about gaps in the management of groundwater in the four surveyed cities of Uttar Pradesh.

The amount of rainfall during the past ten years has decreased in all the four cities except for Rae Bareli, which does not exhibit a trend. The number of rainy days has also decreased during the past three to four years in all the four cities. The cities continuously extract water from underground sources without a plan for groundwater recharge. Unconfined aquifers in most cases have been exploited completely and the cities have moved to the deeper confined layers that have no provision for natural recharge. During the field survey it was observed that the open wells were mostly dry, indicating exploitation of unconfined aquifers. In all the four cities, groundwater mostly show a declining rate, except for some areas of Rampur which showed a stable level of groundwater. In Jhansi and Rae Bareli,

Table 4: State of groundwater and waterbodies in the last five years 2018–22) in the four selected cities

City	Population (in lakhs)	Area (sq. km)	Total wards	Wards surveyed	Rainfall trend in the last decade	Number of rainy days in the last decade	State of groundwater in the last one decade	State of lakes/ waterbodies	Annual RWH potential (MCM)
Jhansi	5	160	60	60	Decline	Decline	Decline	Polluted	58.08
Rampur	3.45	84	33	33	Negligible increase	Decline*	Nominal increase	Polluted	46.58
Banda	1.5	48.6	31	31	Decline	Decline	Decline	Encroached and polluted	20.34
Rae Bareli	1.9	43	31	17	The last three years show a constant decline	The last three years show a constant decline	Decline	Encroached and polluted	13.69

*Data available for the last five years only (2018–22)
Source: Data collected from different government departments/portals. Compiled by CSE.

excessive groundwater extraction has increased the salinity and fluoride content in the groundwater (see *Table 4*). The rainwater harvesting potential of the cities clearly shows that the groundwater and the waterbodies can be recharged by rainwater through proper planning. The need for this planning is urgent as rainfall and rainy days are decreasing. Sustainability of the sources in this climate-risked world will be possible only when the groundwater is recharged either through harvesting of covered and uncovered areas or through restoration of lakes and waterbodies.

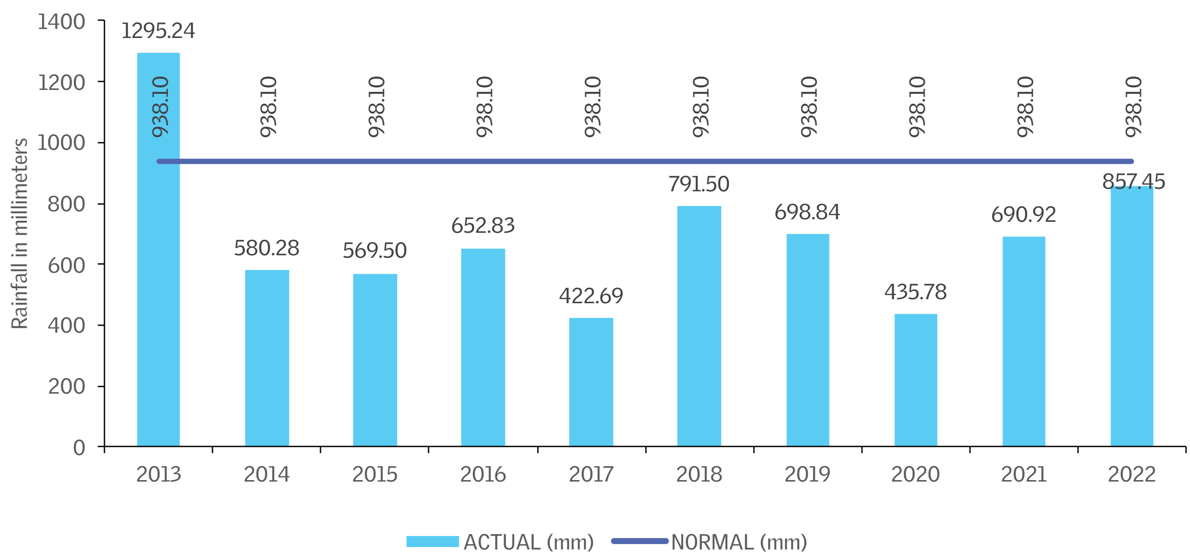
Jhansi

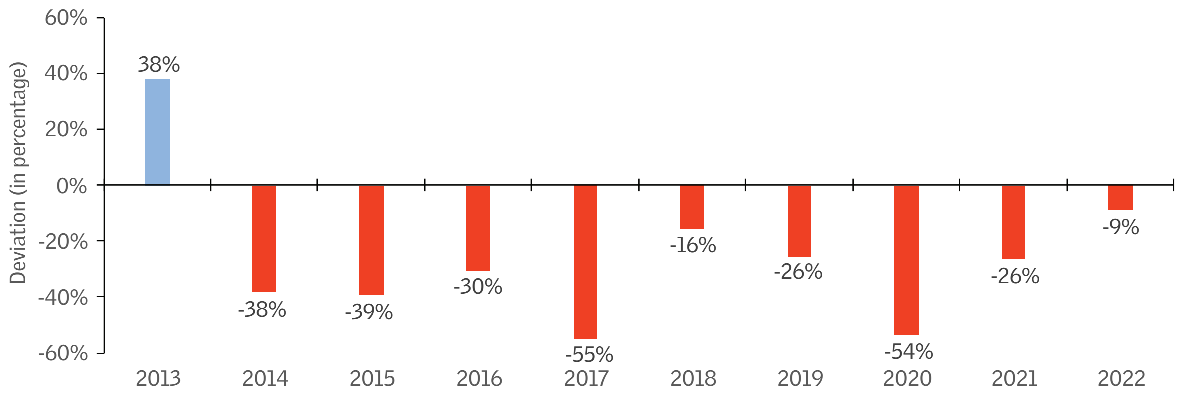
The city was already dependent on unconfined aquifers, but extraction from confined aquifers has now increased. In 2014–22, the amount of rainfall showed a declining trend. The number of rainy days during the period decreased from 71 in 2013 to 56 in 2023, and the lowest being 41 in 2020 (see Figure 18).

Due to unplanned extraction from aquifers, groundwater sources will soon hit rocks. Communities in the outskirts of the city also depend heavily on groundwater for domestic and agricultural uses.

There are four waterbodies in the city, namely Lakshmi Taal, Atiya Taal, Pani ki Dharmshala and Lakshmi Kund. No flow of water is seen to enter Pani ki

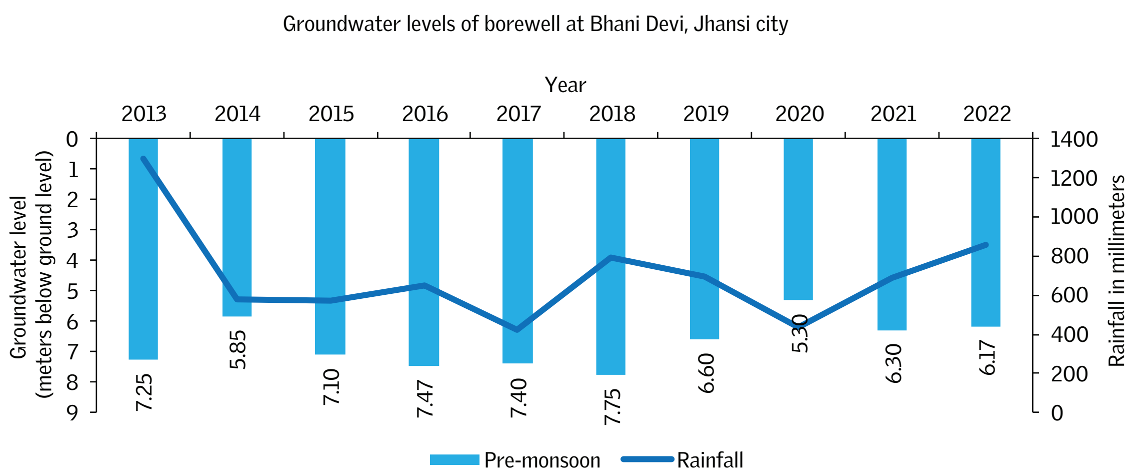
Figure 18: Annual average rainfall and percentage deviation in rainfall of Jhansi (2013–22).

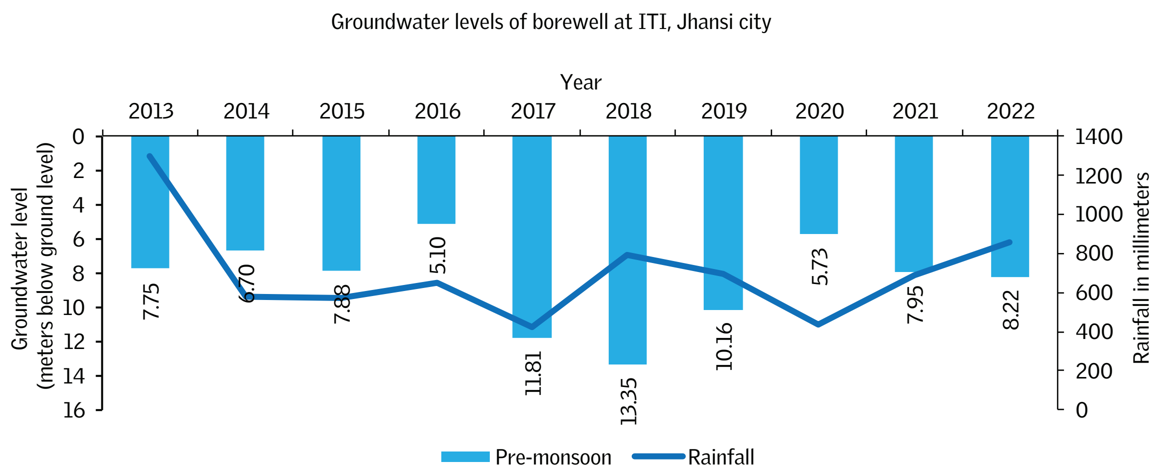




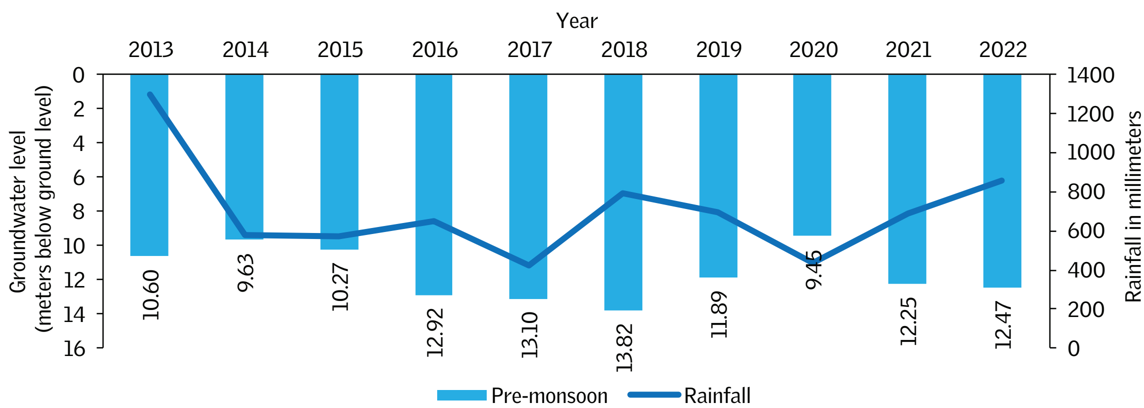
Source: www.indiawris.gov.in, accessed on February 5, 2024, complied by CSE.

Figure 19: Data showing rainfall and trend of groundwater in Jhansi

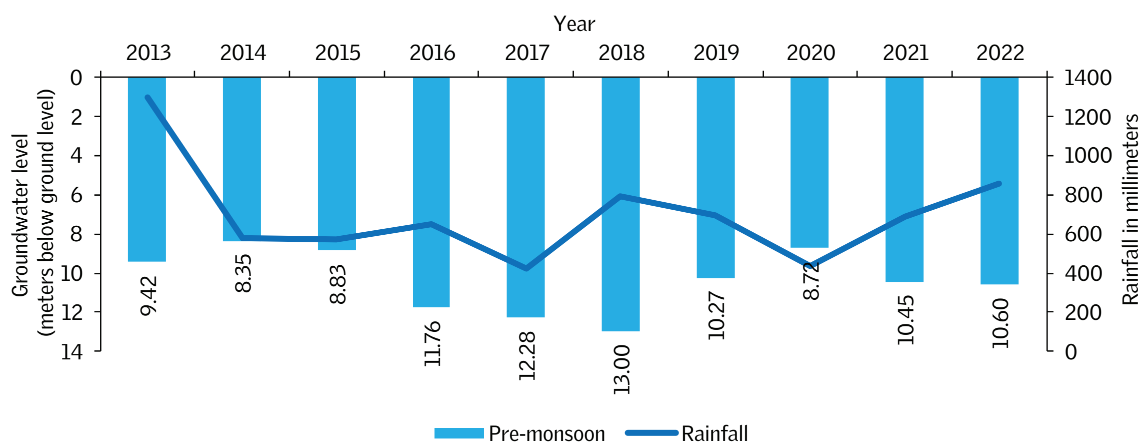




Groundwater levels of borewell at Betwa canal station, Jhansi city

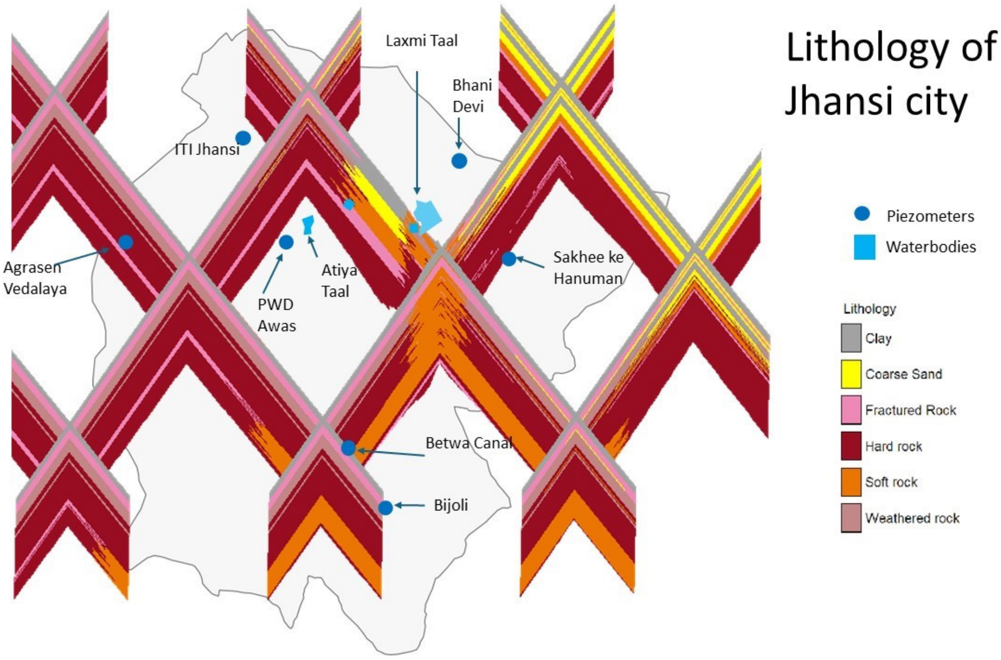


Groundwater levels of borewell at PWD awas station, Jhansi city



Source: Groundwater data provided by Uttar Pradesh Groundwater Department and rainfall data accessed from www.indiawris.gov.in, accessed on February 10, 2024

Figure 20: Fence diagram showing lithology of Jhansi city



Source: Lithology data provided by Uttar Pradesh Jal Nigam, analysed by CSE

Figure 21: Satellite imagery of Lakshmi Tal in Jhansi city in 2011

Water spread area is 36.6 hectare

Source: Google Earth Pro, accessed on February 5, 2024

Figure 22: Satellite imagery of Lakshmi Tal in Jhansi city in 2023

Water spread area reduced by 60 per cent as compared to 2011

Source: Google Earth Pro, accessed on February 5, 2024

Dharmshala, a pond located in the central part of the city. The lake Lakshmi Taal, also popularly known as Rani Lakshmi Bai Talab, located in the northeast of the city, shows a reduction of 60 per cent in its area between 2012 and 2023. its area reduced from 36.6 hectare to 22.6 hectare (see *Figures 21 and 22*) due to encroachment by new buildings around the lake in the last one decade—the process began around 2012–13—over and above wastewater from surrounding areas also entering the lake freely. Weeds grew around the sides of the lake, covering 20–30 per cent of the water spread. A budget of roughly Rs 6 crore was approved before 2021 for the renovation of Lakshmi Taal by 2026. Till November 2023, some concrete structures were erected. This includes a boundary wall around the lake and strengthening of the existing embankment. Another step taken by the city authority to keep septage entering into the lake and degrading the water quality is the construction of faecal sludge treatment plants.

Rampur

The city of Rampur has recently seen a boom in the number of private borewells. These borewells have even reached the confined aquifer below to more than 25 metre below ground level to extract the groundwater injudiciously. The city has been receiving more or less around 1,100 mm per year in 2018–23. A negligible rise in rainfall (6.5 per cent) is seen in the last five to six years (2018–23) (see *Figure 23*). The number of rainy days increased by 5 per cent in the same period.

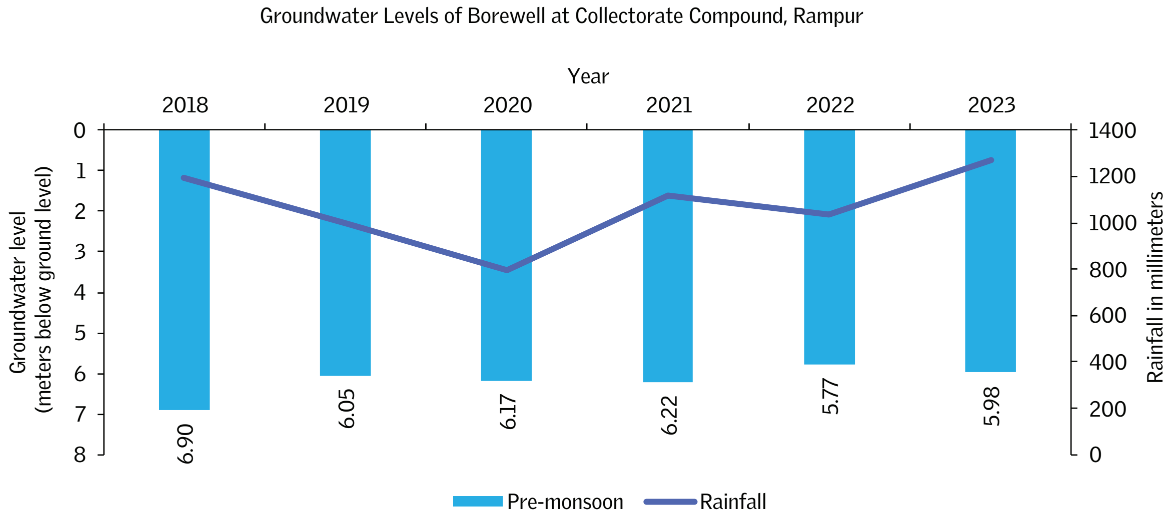
But this has not improved the groundwater level significantly (see *Figure 24*). The villages surrounding the city have shifted to water-guzzling crops, cultivated three times a year in the last five to six years. A huge amount of water is extracted from the lower confined aquifer without any plan of recharge.

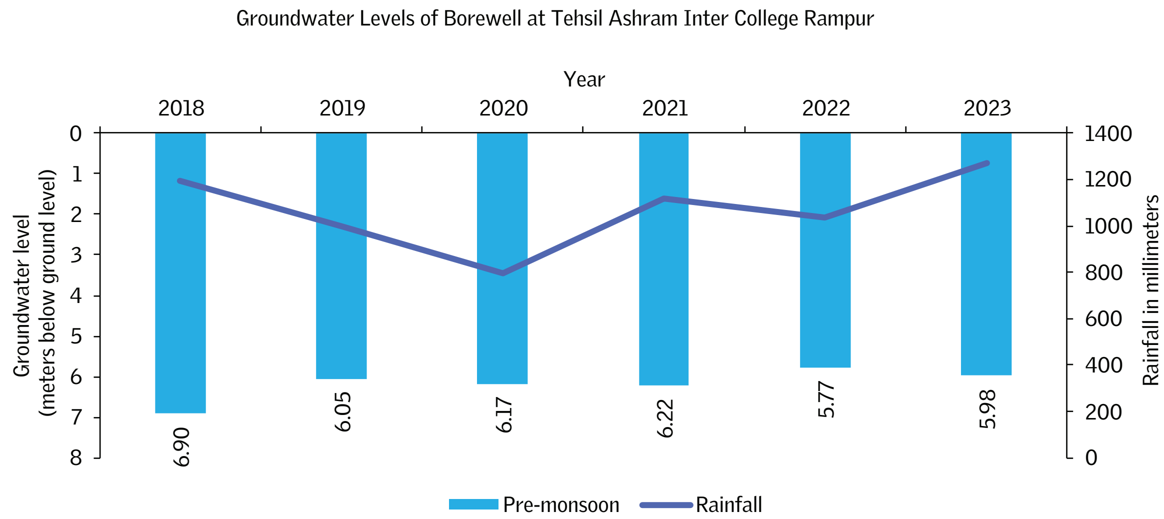
Two major waterbodies in Rampur are Police Line talab and Nalapaar pond. Wastewater from the nearby residential area enters freely into these waterbodies. Solid waste is also dumped in and around these waterbodies. The newly constructed buildings around the Police Line talab, located in the north of the city, encroaches

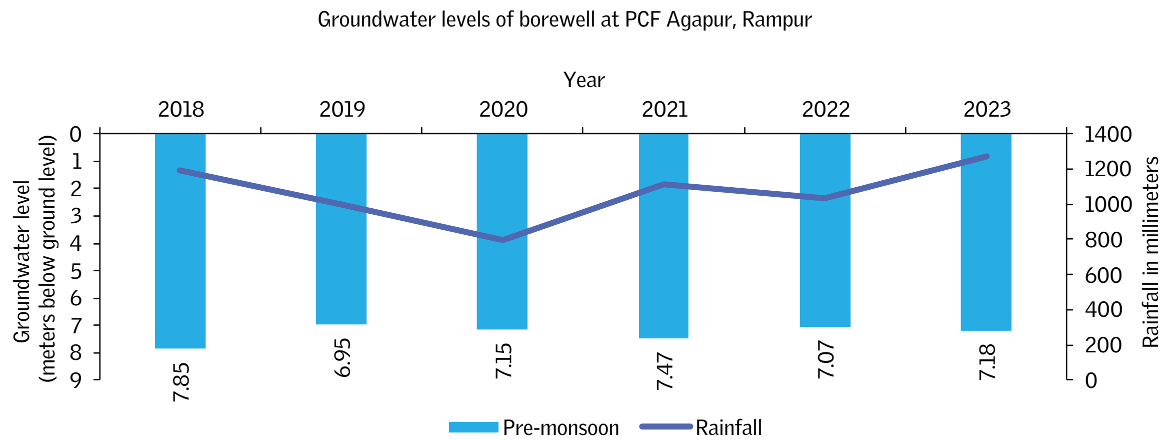
Figure 23: Annual average rainfall and percentage deviation from normal rainfall of Rampur (2018–23)

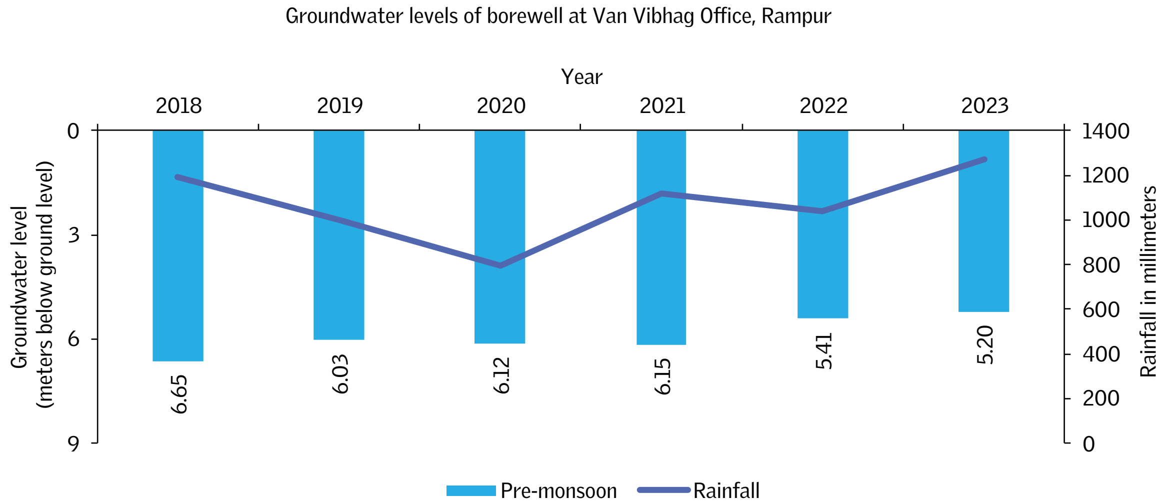
Source: www.indiawris.gov.in, accessed on February 5, 2024, and complied by CSE.

Figure 24: Graphs showing rainfall and trend of groundwater in Rampur



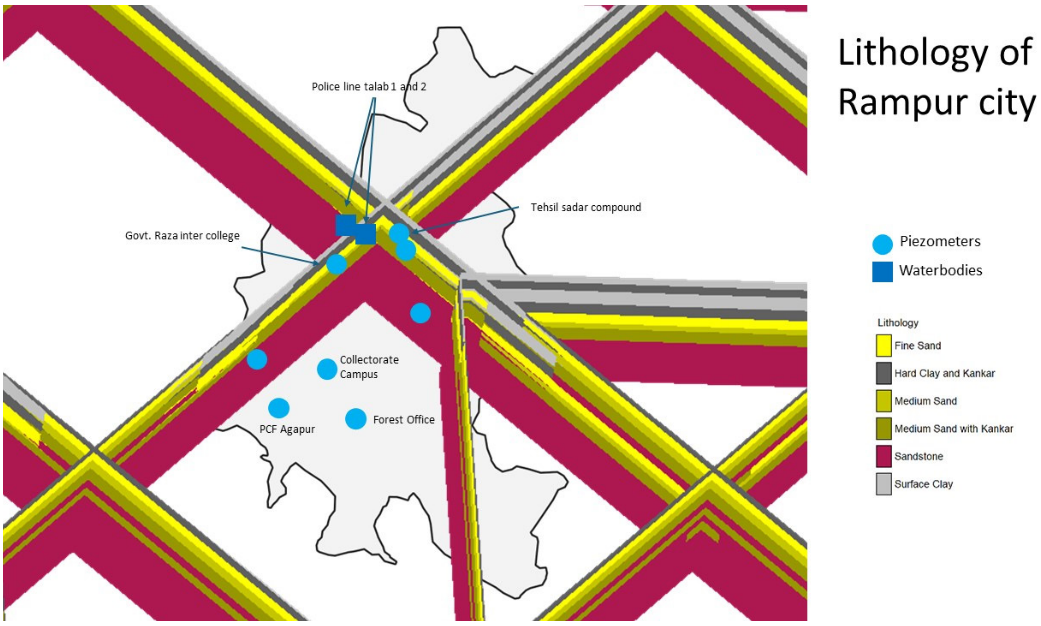






Source: Groundwater data provided by Uttar Pradesh Groundwater Department and rainfall data accessed from www.indiawris.gov.in, accessed on February 10, 2024

Figure 25: Fence diagram showing lithology of Rampur city



Source: Lithology data provided by Uttar Pradesh Jal Nigam, analysed by CSE

on the lake. In 2011–24, the area of the pond reduced from 0.72 hectare to 0.40 hectare (see *Figure 26*). The water quality of the Nalapaar pond has been severely affected due to the wastewater flowing from the surrounding areas (see Chapter 3). Solid waste, including plastics, can be seen floating on the surface of the pond.

Figure 26: Satellite imageries of Police Line talab in Rampur city

Water spread area has reduced by 44 per cent between 2011 and 2023

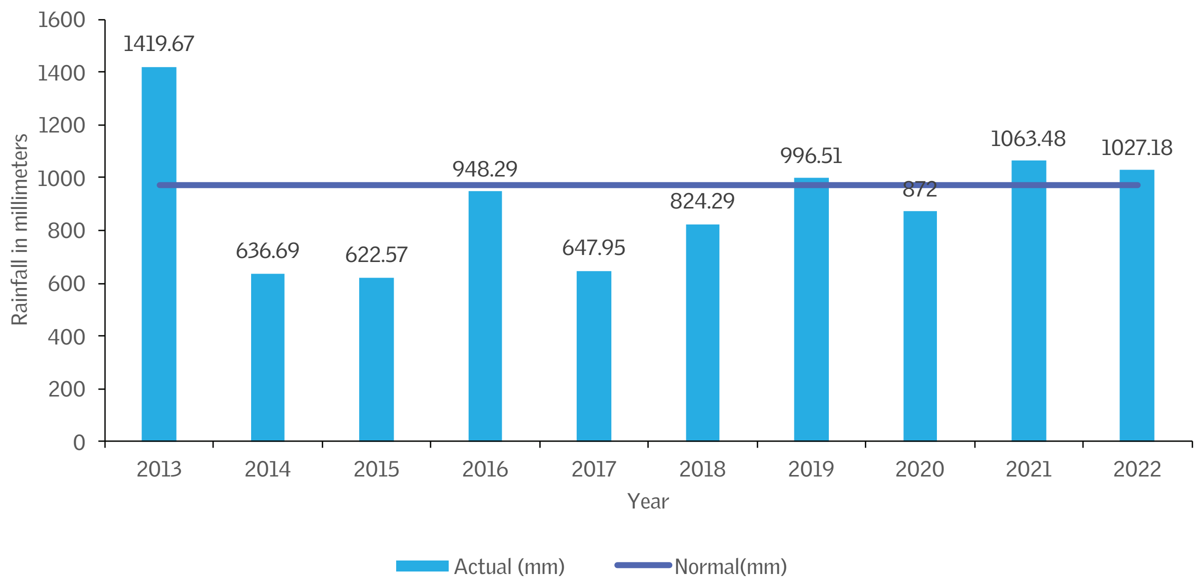
Source: Google Earth Pro, accessed on February 5, 2024

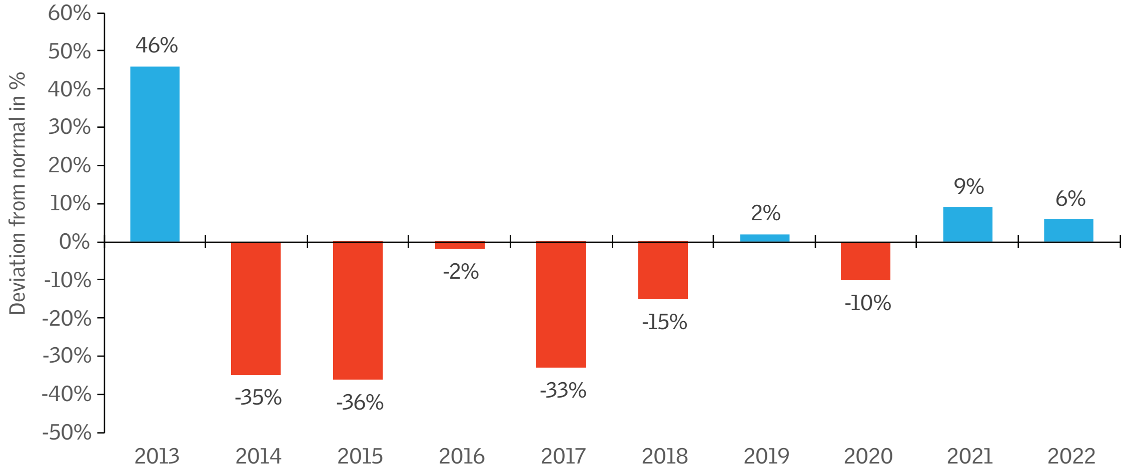
Banda

Seventy-five per cent of the population of Banda city relies on private borewells for its domestic water needs. This has already created stress on the aquifer. The city is part of the Bundelkhand region, which is prone to frequent droughts. Most of the years during the period 2013–22 witnessed annual rainfall below normal rainfall of 976 mm (see *Figure 27*). Even the percentage of rainy days decreased by 33 per cent during 2013–17. This has reduced the natural recharge of groundwater.

Urbanization, to accommodate the growing population, has led reduction in the open spaces. In 2000, the city was noted to have had around sixty open wells that were utilized for drinking. The groundwater in these open wells was found at 7–10 mbgl (see *Figure 28*). Only 50 per cent of the wells in the city have some water, while the rest have gone dry. In most of the dry wells, sewage and solid waste is being dumped.

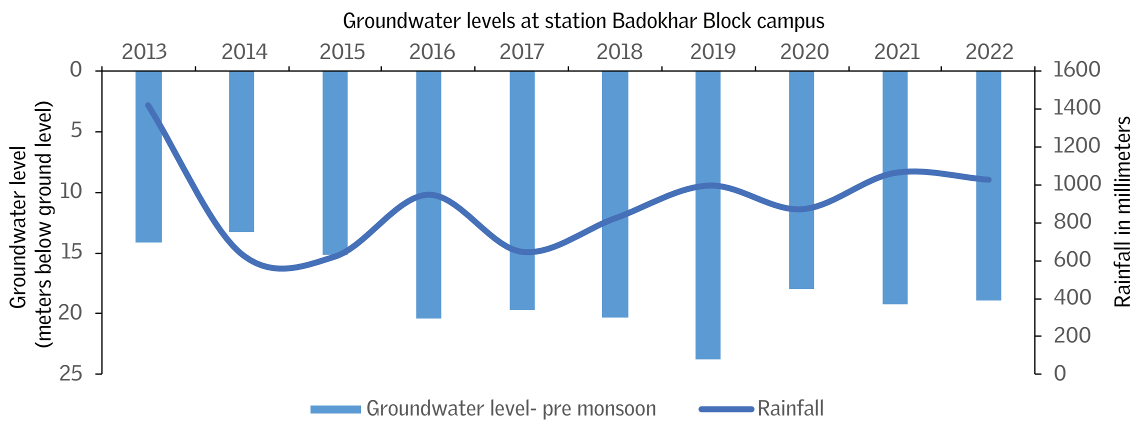
Figure 27: Annual average rainfall and percentage deviation from normal rainfall of Banda (2013–22)

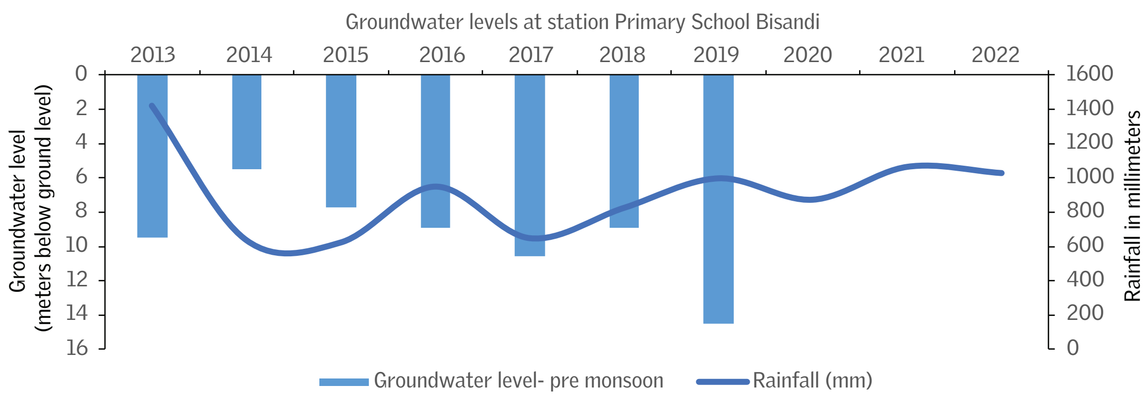




Source: www.indiawris.gov.in, accessed on February 14, 2024, and complied by CSE

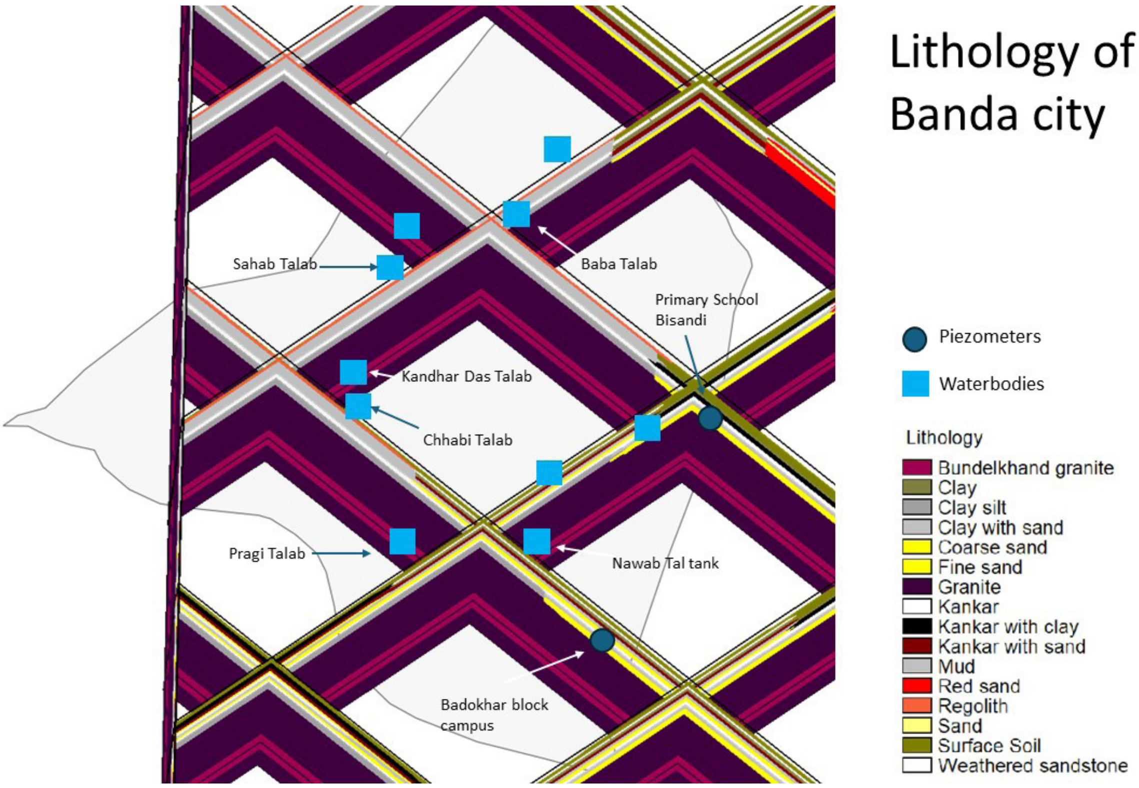
Figure 28: Graphs showing rainfall and trend of groundwater in Banda





Source: Groundwater data provided by Uttar Pradesh Groundwater Department and rainfall data accessed from www.indiawris.gov.in, accessed on February 10, 2024

Figure 29: Fence diagram showing lithology of Banda city

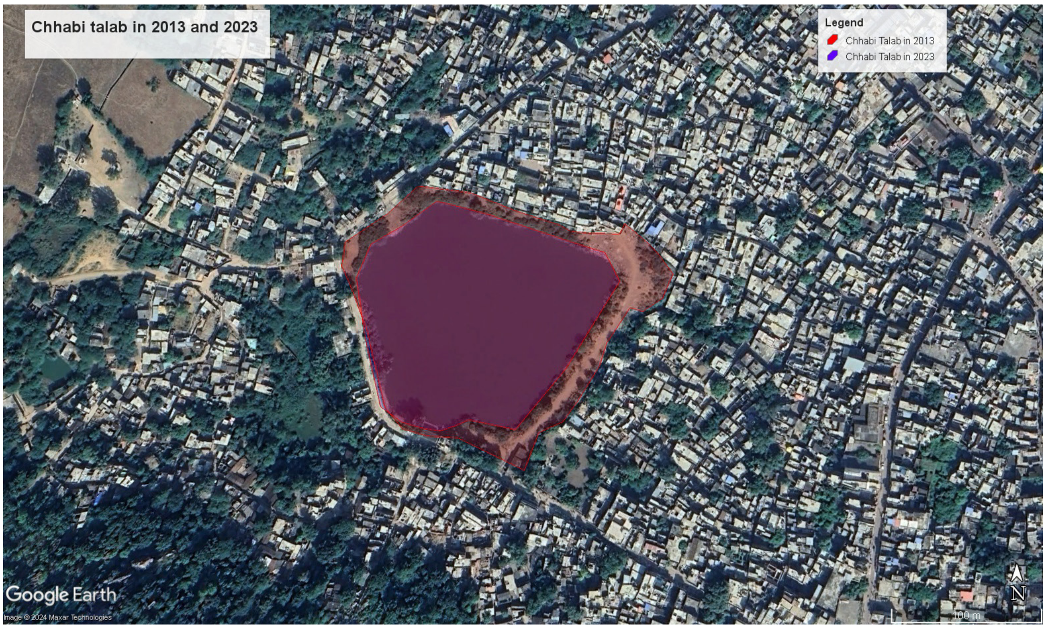


Source: Lithology data provided by Uttar Pradesh Jal Nigam, analysed by CSE

There are around 30 waterbodies spread over 31 wards of the city. These waterbodies are encroached on and highly polluted. In the name of rejuvenation of the ponds, the city authority focuses on beautification only. Chhabi talab, a 100-year-old waterbody situated in the central part of the city, was turned into a dumpsite. During 2013–23, the area of the lake reduced from 2.87 to 2.24 hectare (see *Figure 30*). In contrast, the Nabab Taal tank in the southeast part of the city, is a great example of waterbody management and operation. The waterbody is under the Irrigation Department, and is filled with canal water. Regular monitoring is carried out for this waterbody by the Irrigation Department. Nagar Nigam has developed a park near this lake.

Figure 30: Satellite imageries of Chhabi talab

Water spread area has reduced by 22 per cent between 2013 and 2023



Source: Google Earth Pro, accessed on February 14, 2024

VIVEK KUMAR SAH/CSE

The unabated flow of wastewater from households into the Chabbi talab of Banda city degrades the water quality of the talab. The water stinks throughout the year.

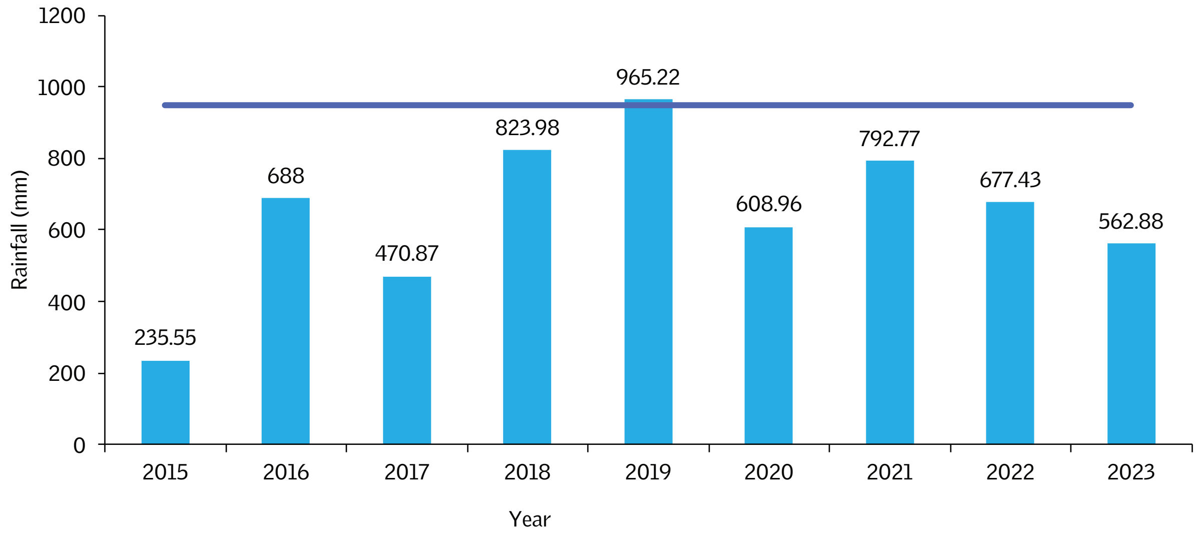
Rae Bareli

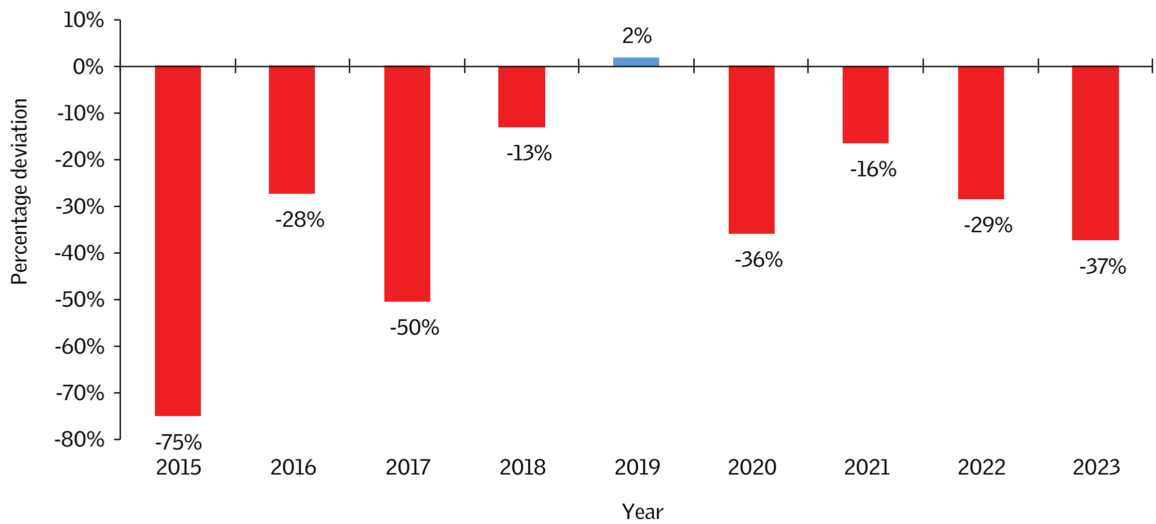
During 2013–23, rainfall in the city is always below the normal rainfall of 949.1 mm, ranging from 235.55 mm in 2015 to 823.98 mm in 2018 (see *Figure 31*). The last three years (2021–23) witnessed a consistent decline in rainfall, from 792.77 mm in 2021 to 562.88 mm in 2023.

Since the city depends heavily on groundwater sources, the data available shows the decline of groundwater in the last seven years. Over-extraction of groundwater has also resulted in increase in the salinity of groundwater. Groundwater below 40 metre below ground level is saline. The communities have reported salinity in their groundwater, especially in summers when the level of the groundwater falls below 40 mbgl.

According to the Municipal Corporation of Rae Bareli, there are more than 171 waterbodies in the city. Most of these waterbodies are encroached on, dumped

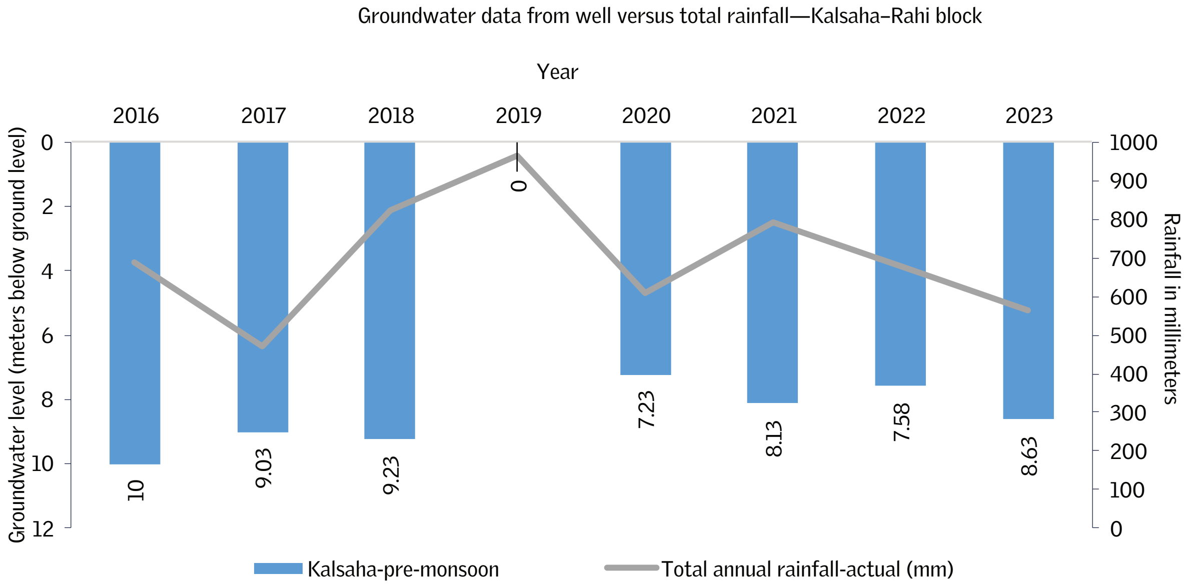
Figure 31: Annual average rainfall and percentage deviation from normal rainfall of Rae Bareli (2015–23)

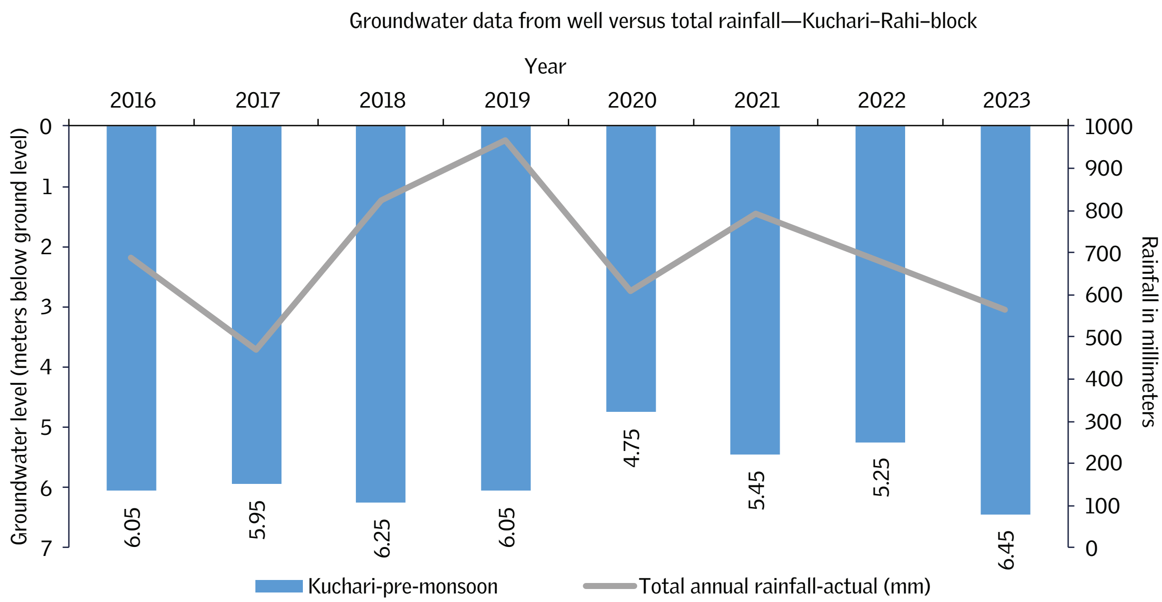




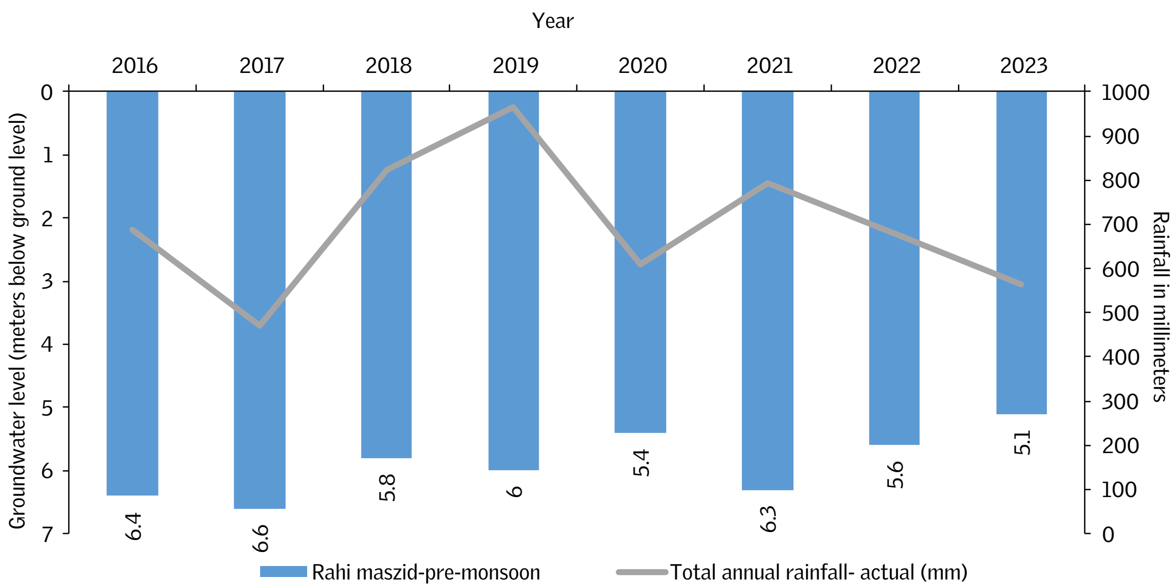
Source: www.indiawris.gov.in, accessed on February 10, 2024, and complied by CSE

Figure 32: Rainfall data and groundwater levels in Rae Bareli

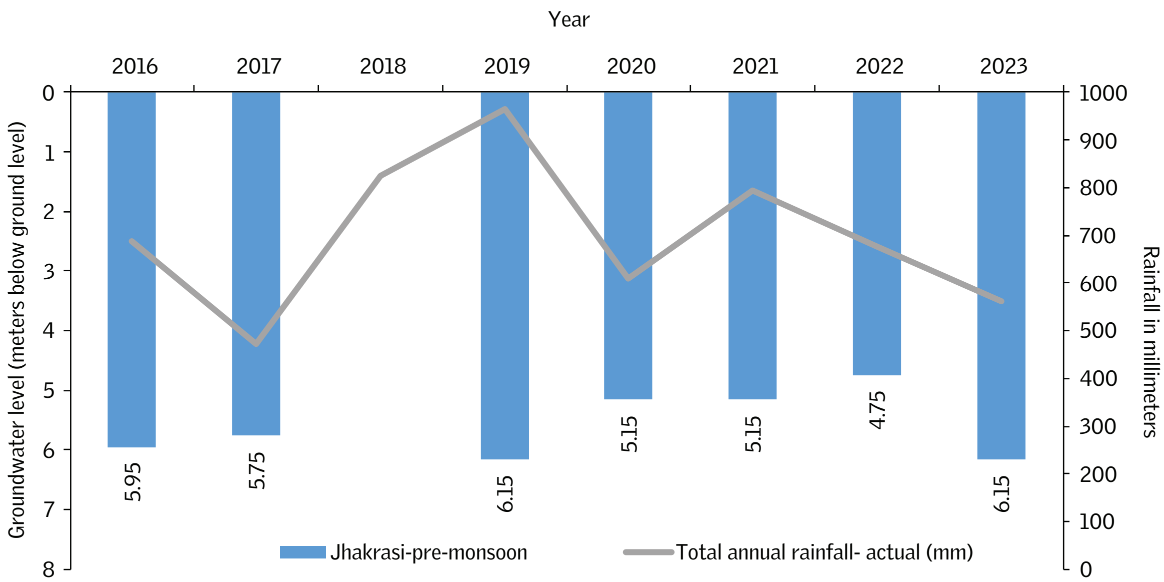




Groundwater data from well versus total rainfall–Rahi Maszid–Rahi block

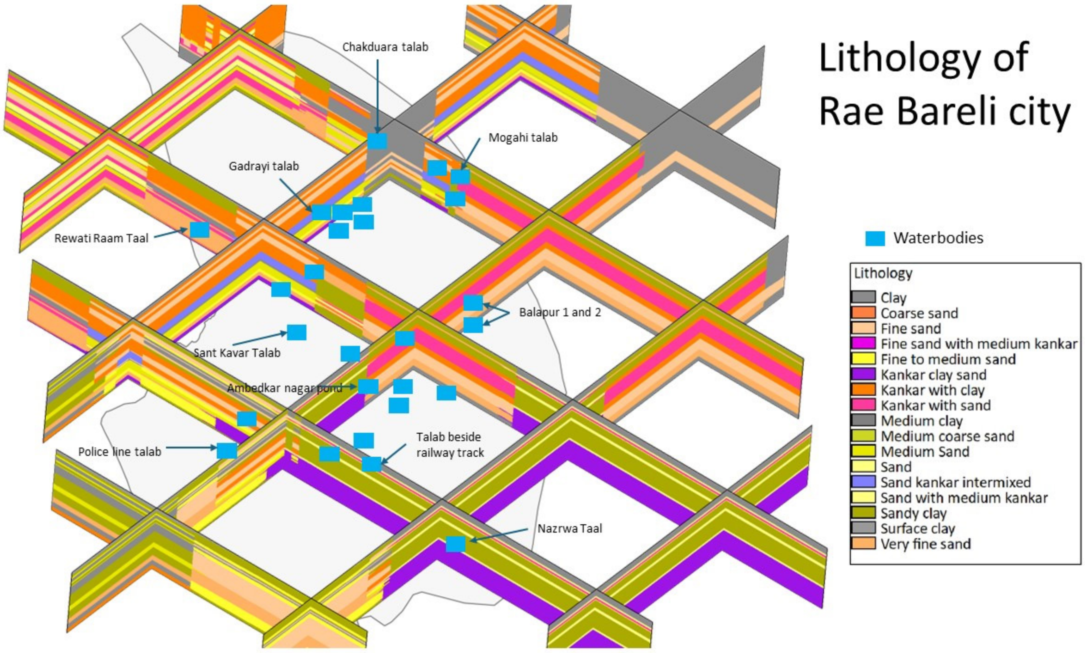


Groundwater data from wells versus total rainfall–Jhakrasi–Rahi block



Source: Groundwater data provided by Rae Bareilly groundwater department. Rainfall data accessed from IndiaWRIS (www.indiawris.gov.in), accessed on February 10, 2024

Figure 33: Fence diagram showing lithology of Rae Bareli city



Source: Lithology data provided by Uttar Pradesh Jal Nigam, analysed by CSE

with solid waste or converted to cesspools. In 2021, two waterbodies were taken up for rejuvenation under AMRUT 2.0. But in the name of waterbody restoration, the city limited itself to just the beautification of these waterbodies. The rejuvenation work did not account for catchment restoration or improvement of water quality. Nazarwa taal, located in ward 14 in the south of the city, was taken under AMRUT 2.0 for rejuvenation work. As per data shared by the Municipal Corporation, a total of Rs 1.1143 crore was sanctioned in 2021 to restore the waterbody. An additional amount of Rs 9.91 lakh was sanctioned for operation and maintenance work. But the actual restoration work included beautification of the waterbody only. In 2022, the bunds around the pond were strengthened to improve its aesthetics.

Figure 34: Satellite imageries of Nazarwa tal in Rae Bareli district (2012–23)

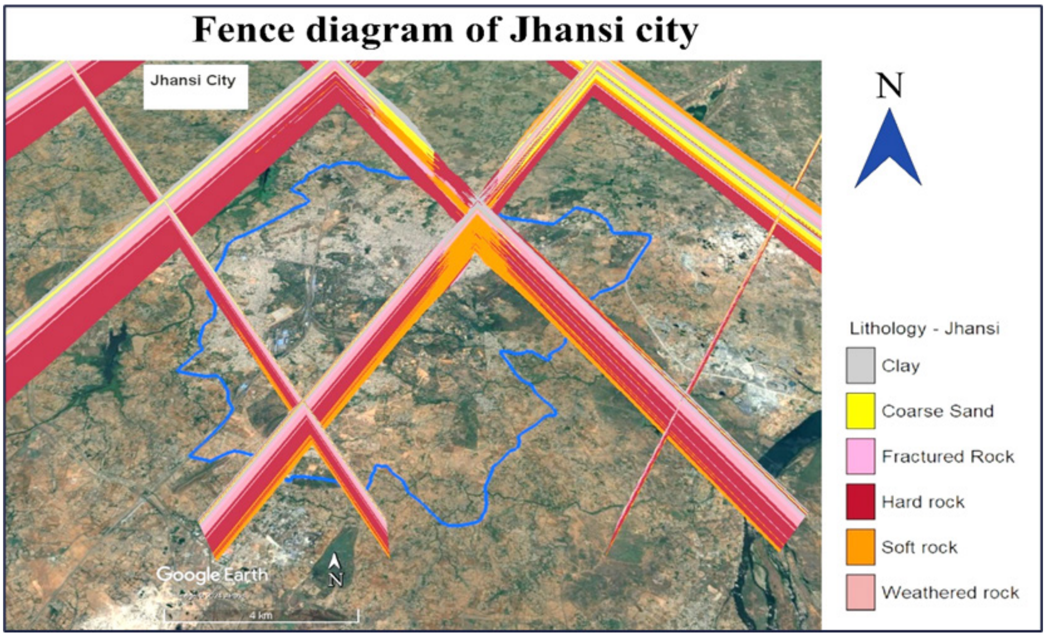
Pollution level in the waterbodies increased between 2012 and 2023. The increased number of settlements between these years near the waterbody caused increase in sewage inflow into the tal

Source: Google Earth Pro, accessed on February 10, 2024

Chapter 5: Locating groundwater recharge areas through mapping of local aquifers

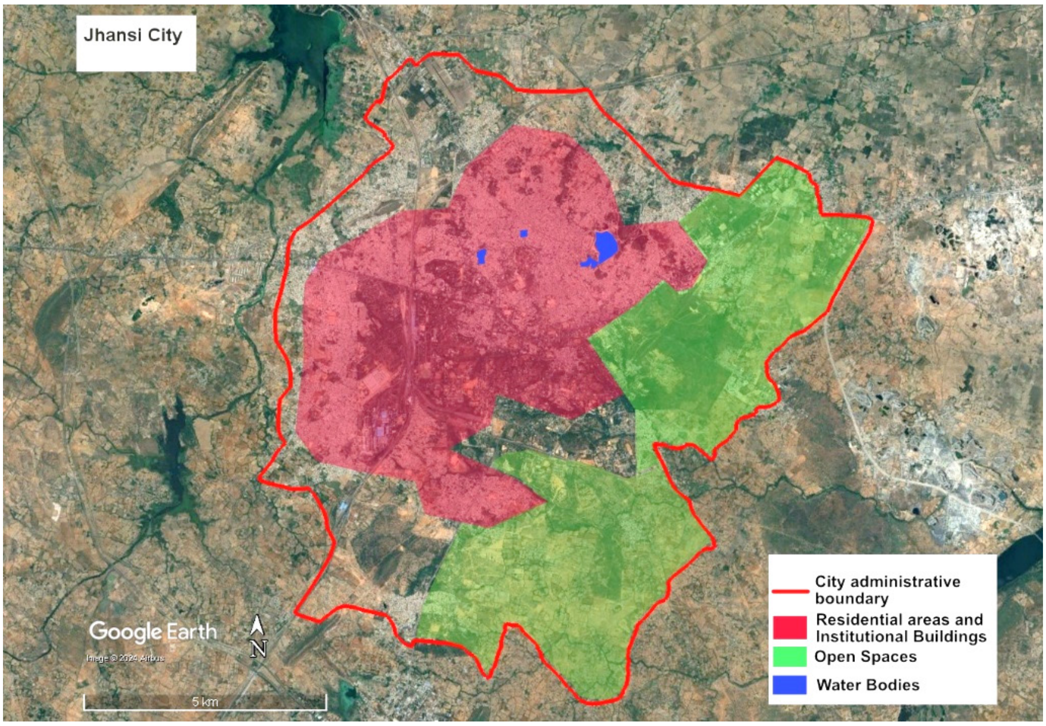
Jhansi

Figure 35: Superimposition of soil log on satellite imagery of city of Jhansi



Source: Google Earth Pro, accessed on February 20, 2024

Figure 36: Satellite imagery of Jhansi city indicating built-up areas, areas under green cover and water spread



Source: Compiled by CSE on Google Earth Pro

Observations from the satellite imagery (see *Figure 35*)**:**

1. The west central part of the city has most of the residential and institutional buildings.
2. Open areas are available in east and south of the city.
3. Waterbodies are located mainly to the north part of the city.

The overlay of the fence diagram on this imagery indicates the following (see *Figure 36*)**:**

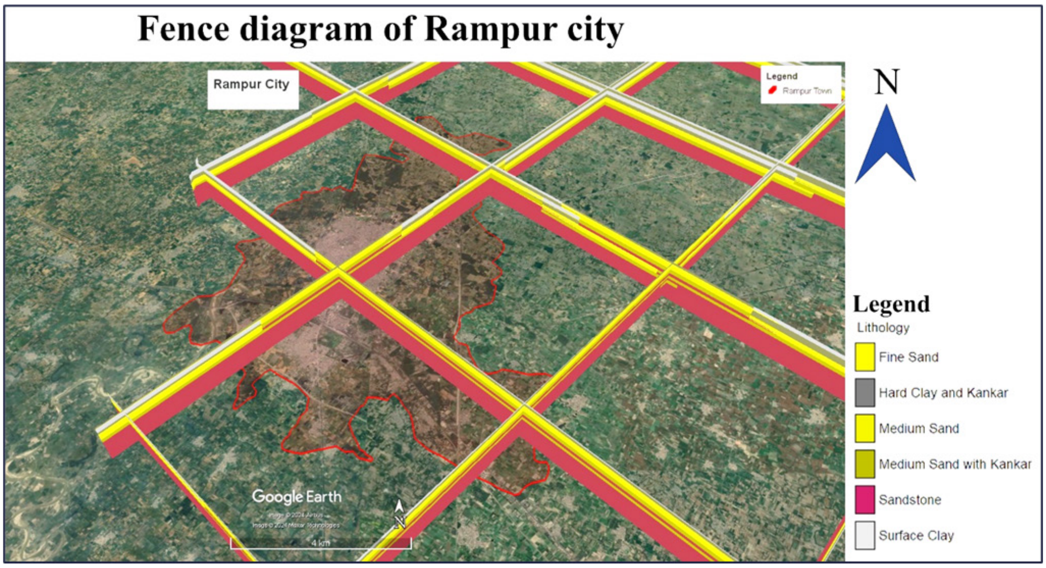
1. Clay is the dominant topsoil.
2. In the east of the city, clay is followed below by a porous and permeable sand layer (also observed in the centre of the city).
3. In rest of the city, the clay layer is followed below by fractured rock, which also—like sand—has good potential of groundwater recharge

To improve the groundwater recharge, the city needs to harvest rainwater and recharge. The lakes and waterbodies need to be rejuvenated. The options for this are as follows:

- Rainwater harvesting at building and institutional levels may be the most suitable solutions for the central part of the city. Recharging into the sand and the fractured rock below the clay layer (where the buildings, residential and institutional, are located) is suggested.
- The lakes and waterbodies in the northern of the city need immediate restoration to improve the groundwater levels.
- ✓ The green areas in the east (with clayey top soil) may be used for creation of new waterbodies or innovative rainwater harvesting solutions like rain gardens.

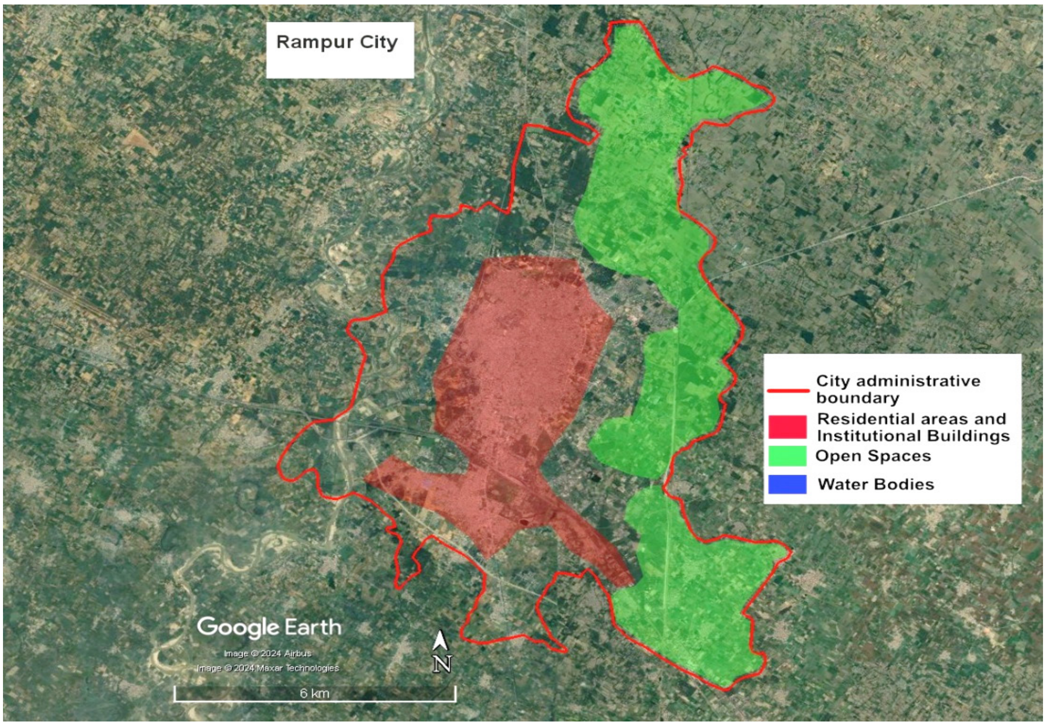
Rampur

Figure 37: Superimposition of soil log on satellite imagery of city of Rampur



Source: Google Earth Pro, accessed on February 20, 2024

Figure 38: Satellite imagery of Rampur city indicating built-up areas, areas under green cover and water spread



Source: Compiled by CSE on Google Earth Pro

Observations from the satellite imagery (see Figure 37):

1. The central part of the city has most of the residential and institutional buildings.
2. Open areas are available majorly in northern, eastern and southeastern part of the city.
3. Waterbodies are located mainly to the north and south of the city.

The overlay of the fence diagram on this imagery indicates the following (see Figure 38):

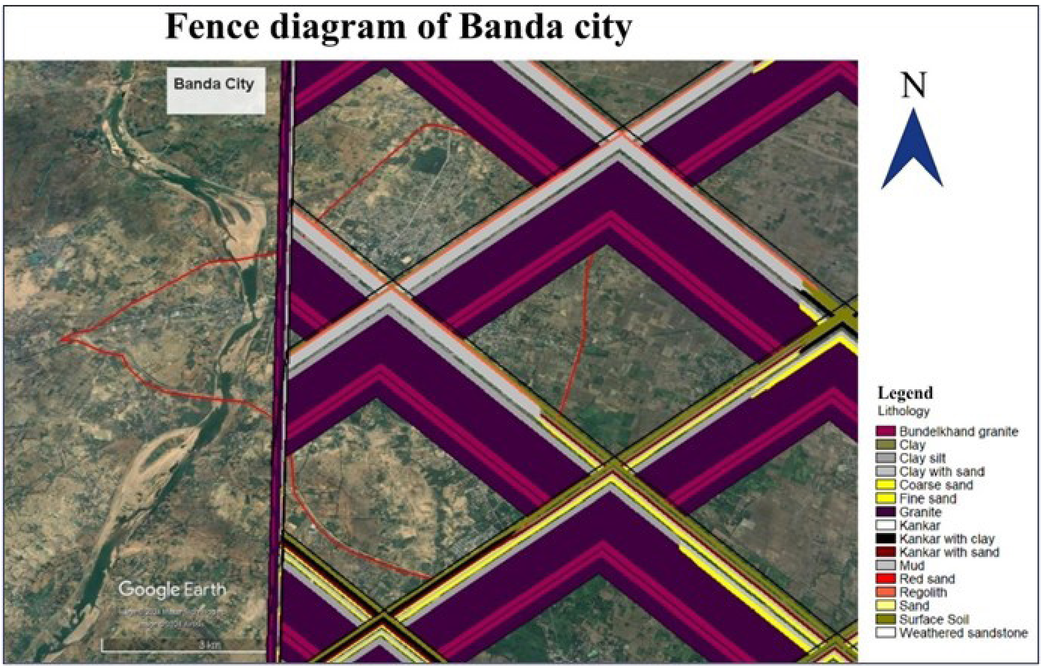
a. Clay is the dominant topsoil.
b. On the east of the city, layers of surface clay alternate with hard clay and kankar.
c. In rest of the city, the clay layer is followed below by fine and medium sand, which have good potential of groundwater recharge

To improve the groundwater recharge, the city needs to harvest rainwater and recharge. The lakes and waterbodies need to be rejuvenated. The options for this are as follows:

- Rainwater harvesting at building and institutional levels may be the most suitable solutions for the central part of the city. Recharging into the fine and medium sand below the clay layer (where the buildings, residential and institutional, are located) is suggested.
- The lakes and waterbodies in the northern and southern part of the city need immediate restoration to improve the groundwater levels.
- The green areas in the eastern, northern and southeastern part (with clayey top soil) may be used for creation of new waterbodies or innovative rainwater harvesting solutions like rain gardens.

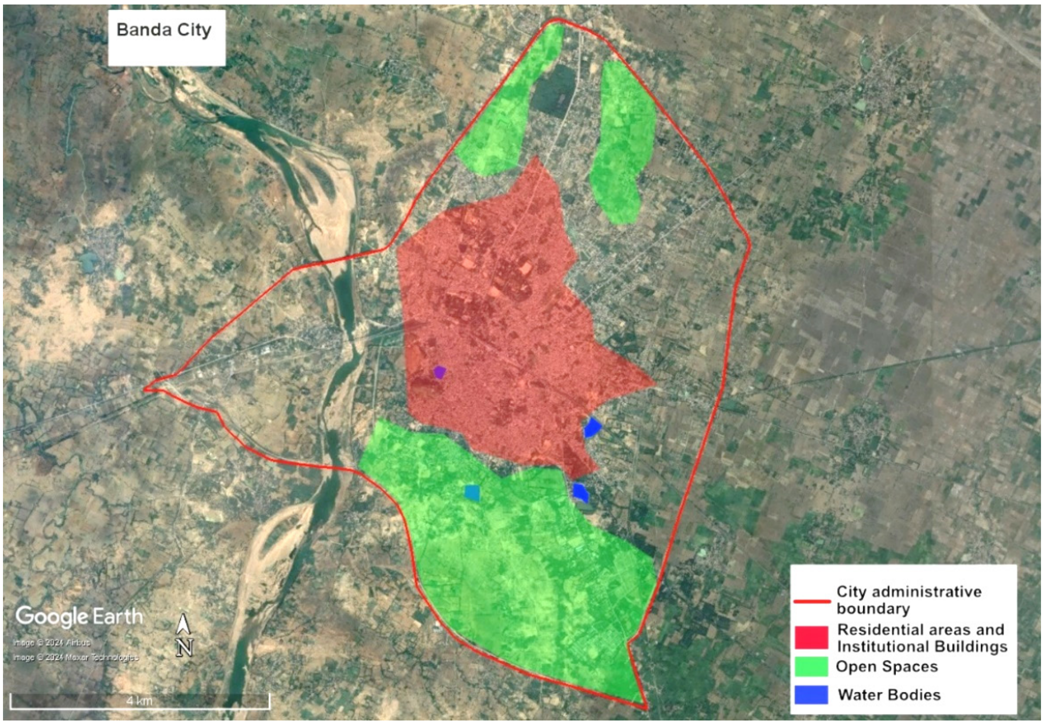
Banda

Figure 39: Superimposition of soil log on satellite imagery of city of Banda



Source: Google Earth Pro, accessed on February 20, 2024

Figure 40: Satellite imagery of Banda city indicating built-up areas, areas under green cover and water spread



Source: Compiled by CSE on Google Earth Pro

Observations from the satellite imagery (see Figure 39):

1. The central, northern and eastern part of the city has most of the residential and institutional buildings;
2. Open areas are available majorly in the western, southern and northern part of the city;
3. Waterbodies are located in almost all parts of the city.

The overlay of the fence diagram on this imagery indicates the following (see Figure 40):

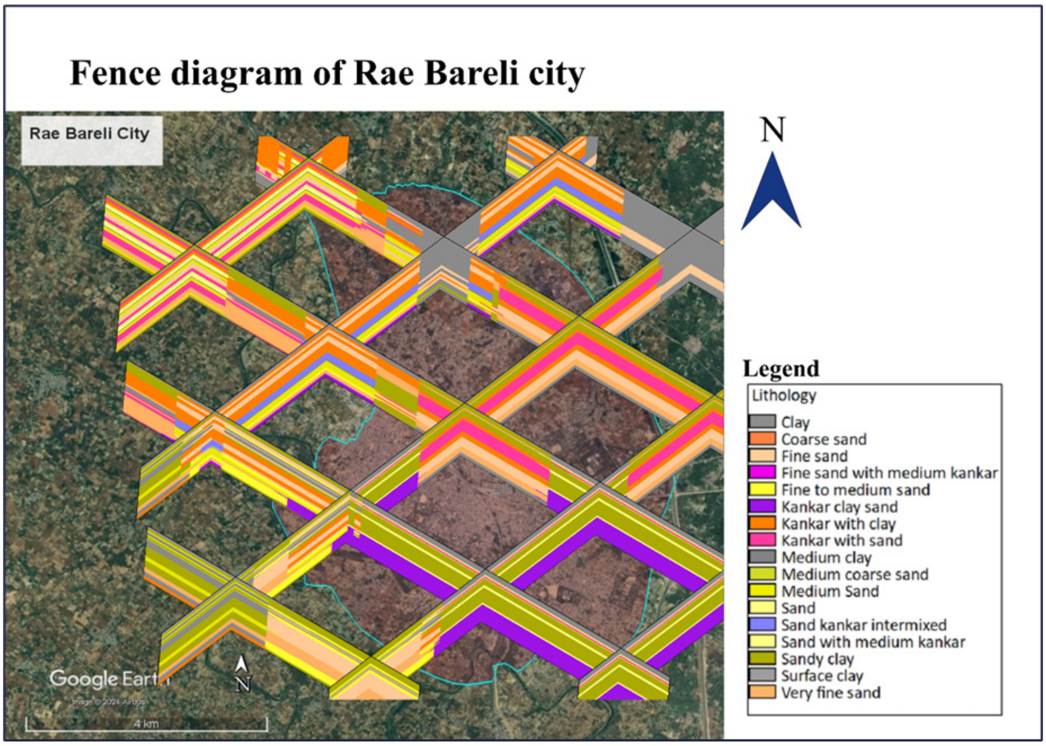
a. Clay is the dominant topsoil, with regolith present in the north-eastern part of the city;
b. On the southern part of the city, alternative layers of coarse and fine sand are present, which has good potential of groundwater recharge;
c. In the rest of the city, the clay layer is followed below by kankar and silty clay.

To improve groundwater recharge, the city needs to harvest rainwater and rejuvenate the lakes and waterbodies. The following are options are suggested:

- Rainwater harvesting at building and institutional levels may be the most suitable solutions for the central, eastern and northern part of the city. Recharging into the fine and medium sand below the clay layer (where the buildings, residential and institutional, are located) is suggested.
- The lakes and waterbodies in every part of the city need immediate restoration to improve the groundwater levels.
- The green areas in the western part (with clayey top soil) may be used for creation of new waterbodies or innovative rainwater harvesting solutions like rain gardens.

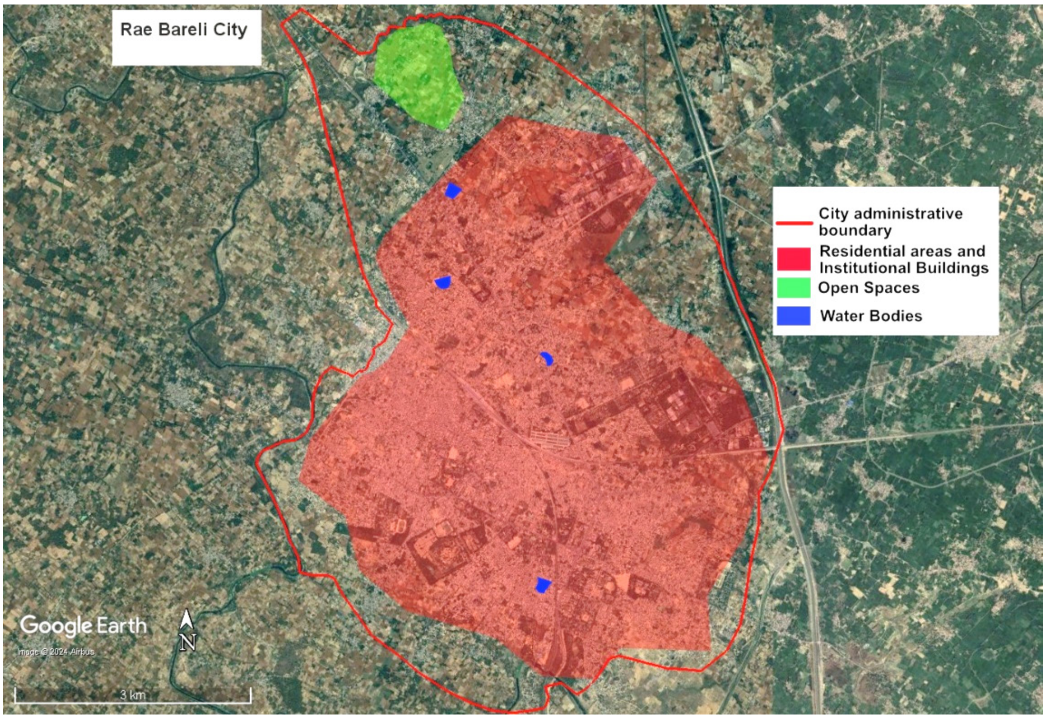
Rae Bareli

Figure 41: Superimposition of soil log on satellite imagery of city of Rae Bareli



Source: Google Earth Pro, accessed on February 20, 2024

Figure 42: Satellite imagery of Rae Bareli city indicating built-up areas, areas under green cover and water spread



Source: Compiled by CSE on Google Earth Pro.

Observations from the satellite imagery:

1. The central, northern and southern parts of the city have most of the residential and institutional buildings;
2. The city is densely populated, with very little open spaces; and
3. Waterbodies are located in almost all parts of the city.

The overlay of the fence diagram on this imagery indicates the following:

a. Clay is the dominant topsoil;
b. The other prominent layers include coarse sand, fine sand and kankar mix sand distributed in the central and western parts of the city, with great potential for groundwater recharge.
c. Sand is present in almost every part of the city as the layer following clay, with different mixes of clay, kankar and silt.

To improve the groundwater recharge, the city needs to harvest rainwater and rejuvenate the lakes and waterbodies. The options suggested for this are as follows:

- Rainwater harvesting at building and institutional levels may be the most suitable solutions for the central, southern and northern parts of the city. Recharging into the fine and medium sand below the clay layer (where the buildings, residential and institutional, are located) is suggested.
- The lakes and waterbodies in every part of the city need immediate restoration to improve groundwater levels.
- The green areas in the western part (with clayey top soil) may be used for creation of new waterbodies or innovative rainwater harvesting solutions such as rain gardens.

Chapter 5: Conclusion and recommendations

The Centre for Science and Environment (CSE) has been working with the Department of Urban Development (DoUD), Uttar Pradesh, since 2018. The partnership entails safe management of faecal sludge in 56 towns of Uttar Pradesh. Taking this partnership further, DoUD collaborated with CSE to work on challenges of managing the groundwater and waterbodies in four selected cities—Jhansi, Banda, Rampur and Rae Bareli—in the Gangetic Plains of Uttar Pradesh.

The cities were strategically selected as they were centres of development under the Atal Mission for Rejuvenation and Urban Transformation (AMRUT) 2.0. CSE had identified the four cities where groundwater showed no prominent rise or was plunging due to unplanned extraction. Increased rate of urbanization in these cities has also led to concretization and reduction in natural recharge of groundwater. Over and above degradation and/or loss of lakes and ponds in these four cities, groundwater recharge has been minimal. This study identifies challenges of managing groundwater, lakes and ponds in the four cities and offers possible solutions.

CSE researchers studied the lakes, ponds and groundwater in 165 wards in the four cities during the period August–November 2023. The study was conducted in the monsoon and post-monsoon periods to get an idea of the groundwater levels and waterbodies across different periods. Groundwater data from more than 200 locations was collected and studied in these cities. A total 47 lakes and ponds were surveyed. To understand the soil lithology, more than 120 boreholes were collected from different government departments.

Analysis of the rainfall in the last one decade (2013–22) for Banda, Rampur and Jhansi shows a more or less declining trend of 23 per cent (Rampur) to 34 per cent (Jhansi). Rae Bareli did not show a decadal decline, but it was clearly observed that the rainfall had been in a continuously declining trend for the last three years (with a drop of 29 per cent). The number of rainy days is also decreasing in all the four cities in the last four years (2013–22) to 15 per cent (Rae Bareli) to 24 per cent (Banda). An increase in private borewells in the four cities has led to plummeting groundwater levels of 1.5–2 m below ground level in 2013–23. There are two levels of aquifers, unconfined and confined, in all the four cities. The unconfined layer extends 15–30 m below ground level in all the four cities; the cities have already exploited the unconfined aquifers. There is a tendency for private diggers to reach the deeper confined aquifers, which cannot be naturally recharged. The city-level recharge sponges in the cities are polluted and encroached on. The focus of rejuvenation plans is largely on the beautification of lakes and ponds only. The exception is the Nawab Tal in Banda.

The storm-water drains in all the four cities are mostly clogged with solid waste, and plastic flows freely through the drains. The wastewater flows into these storm-water drains and ultimately enters the lakes and ponds. During heavy rains, the drains overflow, causing waterlogging and leading to waterborne diseases. As climate change raises the spectre of more rain in fewer days, all the four cities will need to drain their flood. If cities do this in a way that helps recharge their aquifers, they can survive prolonged periods of water scarcity and drought.

Taking clues from the four cities, CSE's recommendations for making the four cities in Gangetic Plain water prudent are as follows:

Task 1—Harvest rainwater: The presence of porous, permeable soil and fractured and weathered rocks in the soil profile are ideal layers for recharge of the groundwater. Rainwater harvesting was made compulsory in the state in 2019 for new residential and commercial buildings. Ensuring the implementation of this act is the need of the hour. The government has made compulsory implementation of rainwater harvesting in government and semi-government buildings. The city authority should ensure that rainwater harvesting systems are constructed in these buildings. Jhansi's model of implementing rainwater harvesting in 100 government buildings can be propagated to spearhead the implementation movement in other cities. Jhansi may continue to harvest rainwater at the building level in residential and commercial buildings. The urban local bodies should work with the State Groundwater Board and the University Departments for working out detailed technical designs for the structures.

Task 2—Monitoring the impact of the groundwater recharge projects: Implementation of the rainwater harvesting system does not mean the end of the job. The impact of these projects, both in terms of quantity and quality, has to be monitored periodically; a database of the monitoring data should be developed and made public for promoting rainwater harvesting. Additionally an assessment of the recharge and extraction volume of groundwater will ensure that the source is not being exploited.

Task 3—Protect, rejuvenate and create waterbodies: Lakes and other waterbodies are sponges of a city—they hold excess rainwater and recharge the groundwater for times of scarcity. An analysis of the lithology in the four cities clearly shows that the top soil in all the four cities is predominantly clayey, which is suitable for creation of waterbodies. The existing waterbodies are already sited on clayey layers, but as they are mostly polluted and encroached on they should be restored to their original state. The rejuvenation plan should not aim at cosmetic makeover of the waterbodies. The plan should focus on restoring the waterbodies, its catchment and the feeder channels.

Task 4—Clean storm-water drains and use them as part rainwater harvesting and lake rejuvenation projects: Storm-water drains were found clogged in all the four cities, with a cocktail of black and greywater flowing through these drains. So, the four cities should focus on managing its solid waste—mainly plastics—as part of their cleanliness drive.

Care should be taken to ensure that black water does not flow into storm-water drains by keeping a check of the faulty septic tanks in the cities (as the cities depend mostly on septic tanks). These drains connect with the waterbodies in the cities. Sewage needs to be managed so that these sponges of the city—which replenish groundwater—do not become the receptacles of its waste.

The three cities as per Central Public Health and Environmental Engineering Organisation (CPHEEO) norm are supplied with 135 litre per capita per day (excluding Banda, which has no sewage treatment plant and hence as per the norm is supplied with 70 lpcd). Communities extract groundwater through private borewells to supplement the city water supply. This results in huge generation of greywater from washing areas, bathrooms and kitchens. Provisions should be made for managing greywater at the household and community levels so that it cannot enter storm-water drains.

Provisions should also be made so that the runoff from the built-up and green areas can enter storm-water drains and be recharged through rainwater-harvesting structures near the storm-water drains. The drains may carry runoff to nearby lakes to fill them up. The challenge is to ensure that not only water structures, but also the connecting channels are protected.

Task 5—Use treated wastewater to fill lakes and ponds: Treated wastewater from the faecal sludge treatment plant (FSTP) and sewage treatment plants

(STPs) may be used to fill dry lakes nearby. While Jhansi and Rae Bareli have one STP each, of capacity 26 and 18 MLD respectively, Rampur has three STPs, with a cumulative capacity of 34 MLD. Additionally, there is one FSTP in each of the three cities (except Rampur) while Jhansi has three FSTPs with cumulative capacity of 50 KLD; Banda and Rae Bareli have one FSTP each with a capacity of 32 KLD. Treated water is available from both STPs and FSTPs. Regular monitoring of the quality of treated wastewater entering the waterbodies from the treatment plants will be compulsory—we cannot afford to fill up the lakes and the ponds with polluted water. Recycling wastewater and using treated wastewater to replenish lakes for groundwater recharge is crucial in a climate-risked world, where rainfall is becoming highly variable.

Annexures

Annexure 1: Locations of borehole logs

1. Jhansi

S. no.	District	Block	Location	Lat.	Long.	Easting	Northing
1	Jhansi	Badagaon	Marai Mata Mandir	25.47307	78.63531	262258.4	2819443
2		Badagaon	Gram Samaj Abadi	25.54669	78.69293	268195.7	2827497
3		Babina	Khaira village	25.36052	78.34187	232495.6	2807528
4		Badagaon	Badagaon gate bahar	25.463	78.5855	257229.1	2818417
5		Badagaon	Badagaon gate bahar 2	25.46243	78.58482	257159.2	2818355
6		Jhansi	Galla Mandi	25.4503	78.58834	257489.5	2817005
7		Nagar Nigam	Paramedical boundary	25.46962	78.6266	261376.5	2819077
8		Nagar Nigam	Nagar Nigam Park	25.47832	78.57124	255825.8	2820140

2. Rampur

S. no.	District	Block	Station	Lat.	Long.	Easting	Northing
1	Rampur	Saidnagar	Ladaura	28.717386	79.027762	307363.38	3178268.56
2		Saidnagar	Thakurdwara	28.724946	78.974443	302168.56	3179193.76
3		Saidnagar	Kajipura	28.670936	79.270312	330983.75	3172753.28
4		Saidnagar	Hardaspur	28.683992	79.221334	326218.60	3174270.42
5		Chamrua	Bajawala	28.913681	79.033429	308277.01	3200013.49
6		Chamrua	Bainjani	28.894107	79.004603	305429.60	3197891.19
7		Chamrua	Jagatpur	28.683087	79.229779	327042.36	3174157.86
8		Chamrua	Parsupura	28.873135	78.974648	302468.34	3195616.48

3. Banda

S. no.	District	Block	Location	Lat	Long	Easting	Northing
1	Banda	Badokhar khurd	Agriculture University Campus	25.529406	80.333581	433041.91	2823738.0
2		Tindwari	On Govt Land	25.565278	80.462667	446028.09	2827651.8
3		Badokhar Khurd	Chhaneharlalpur Madrasa Gusiya Ke Pass	25.458471	80.490518	448780.31	2815813.1
4		Badokhar Khurd	Mohd. Najeed ke Farm house ke pass	25.477636	80.479783	447709.36	2817939.5
5		Badokhar Khurd	Mahamai ke sthan shukal chowk	25.41105	80.365732	436209.95	2810615.5
6		Badokhar Khurd	Near beta mishra ke pass me	25.420244	80.361993	435838.77	2811635.4
7		Badokhar Khurd	Hamir talab ke hanuman mandir ke pass	25.415591	80.394529	439108.49	2811104.9
8		Badokhar Khurd	Near Ramsharan Aarkah	25.582201	80.439009	443659.66	2829535.7
9		Badokhar Khurd	Bundelkhand inter college	25.424923	80.388617	438518.65	2812141.0

4. Rae Bareli

S. no.	District	Block	Location	Lat	Long	Easting	Northing
1	Rae Bareli	Rahi	Bela- Bhela	26.13461	81.22701	522692.21	2890610.99
2		Rae Bareli	Khatrana Tubewell	26.237901	81.226202	522592.01	2902050.02
3		Rae Bareli	Ali Miyan Colony Rebore	26.240760	81.231875	523158.04	2902367.65
4		Rae Bareli	Firoz Gandhi Degree College	26.216606	81.244090	524383.03	2899694.89
5		Rae Bareli	Gulab Road Rebore	26.231711	81.231940	523166.33	2901365.50
6		Rae Bareli	Vikas Bhawan	26.214766	81.246824	524656.53	2899491.63
7		Rahi-RB	Bela Khara TW1	26.123734	81.179621	517957.20	2889399.11
8		Rahi-RB	Bela Khara TW 2	26.120296	81.183044	518299.94	2889018.84
9		Rahi-RB	Bela Bhela TW 1-Zone 1	26.135919	81.228076	522799.02	2890756.14
10		Rahi-RB	Bela Bhela TW 1- Zone 2	26.139809	81.236192	523609.54	2891188.39
11		Rahi-RB	Bela Bhela TW 2-Zone 1	26.127915	81.223346	522327.72	2889868.91
12		Rae Bareli	Ahiyapur	26.247116	81.228150	522784.77	2903070.90
13		Rae Bareli	Ali Miyan Colony Rebore 2	26.242931	81.230047	522975.05	2902607.76
14		Rae Bareli	Firoz Gandhi Colony Park TW	26.219178	81.253261	525298.60	2899981.49
15		Rae Bareli	Government Colony	26.208459	81.254851	525459.76	2898794.70
16		Rae Bareli	Nirala Nagar Forest Campus	26.220280	81.244654	524438.60	2900101.88
17		Rahi	Rahi Store TW	26.237701	81.304078	530370.00	2902043.78
18		Rahi	Kila Bazar/ Slaughter House	26.236464	81.227405	522712.44	2901891.09
19		Rae Bareli	Town Hall TW	26.232386	81.230309	523003.29	2901439.97

Annexure 2: Details of groundwater levels (pre-monsoon) from four cities

Jhansi—2013–22

S. no.	City	Hydrograph station	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
1	Jhansi	Bhani Devi	7.25	5.85	7.10	7.47	7.40	7.75	6.60	5.30	6.30	6.17
2	Jhansi	ITI	7.75	6.70	7.88	5.10	11.81	13.35	10.16	5.73	7.95	8.22
3	Jhansi	Betwa Canal	10.60	9.63	10.27	12.92	13.10	13.82	11.89	9.45	12.25	12.47
4	Jhansi	PWD Awas	9.42	8.35	8.83	11.76	12.28	13.00	10.27	8.72	10.45	10.60

Rampur—2018–22

S. no.	City	Hydrograph station	2018	2019	2020	2021	2022
1	Rampur	Tehsil Sadar Compound	5.02	3.97	3.50	3.70	3.33
2	Rampur	Collectorate Compound	6.90	6.05	6.17	6.22	5.77
3	Rampur	PCF Agapur	7.85	6.95	7.15	7.47	7.07
4	Rampur	Van Vibhag Office	6.65	6.03	6.12	6.15	5.41

Banda—2013–22

S. no.	City	Hydrograph station	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
1	Banda	Badokhar Block	14.15	13.25	15.17	20.38	19.68	20.30	23.75	18.00	19.25	18.90
2	Banda	Primary School Bisandi	9.50	5.50	7.74	8.90	10.55	8.90	14.50	-	-	-

Rae Bareli—2015–23

S. no.	City	Hydrograph station	2015	2016	2017	2018	2019	2020	2021	2022	2023
1	Rae Bareli	Jhakrasi	-	5.95	5.75	-	6.15	5.15	5.15	4.75	6.15
2	Rae Bareli	Kalsaha	-	10	9.03	9.23	-	7.23	8.13	7.58	8.63
3	Rae Bareli	Kuchari	-	6.05	5.95	6.25	6.05	4.75	5.45	5.25	6.45
4	Rae Bareli	Rahi Maszid	-	6.4	6.6	5.8	6	5.4	6.3	5.6	5.1

Annexure 3: Location of urban waterbodies surveyed in four cities

1. Jhansi

Lake/pond	Ward Name/Village	Latitude	Longitude	Rural or urban
Lakshmi taalab	Ward no. 33 Orcha Gate Bahar 2	25.458967	78.590336	Urban
Atiya taalab	Ward no. 53 Khandreva Gate	25.458967	78.590336	Urban
Pani ki dharmshala		25.46246	78.576246	Urban
Lakshmi kund	Ward no.33 orcha gate bahar 2	25.458053	78.590092	Urban

2. Rampur

Lake/pond	Ward /village	Latitude	Longitude	Rural or urban
Police line talaab	ward no.15 Police Line	28.82106	79.0226437	Urban
Drainage pond	ward no.28 Nalapaar	28.823054	79.023159	Urban

3. Banda

Lake/pond	Ward/village	Latitude	Longitude	Rural or urban
Chaavi talaab	Ward no. 4	25.473696	80.326034	Urban
Nawaab taal	Nairaini Road Banda	24.458809	80.348595	Urban
Babu talaab	Ward no. 20 Aliganj	25.466059	80.348701	Urban
Kandhardaas taalab	Ward no. 12 Katra	25.478767	80.326973	Urban
Basant talaaab	Kanchanpurwa	25.498055	80.346321	Urban
Sahab talaab	Ward no. 14 Swaraaj Nagar	25.490866	80.331261	Urban

4. Rae Bareli

Lake/pond	Ward /village	Latitude	Longitude	Rural or urban
Nazrwa taal	Ward no. 14	26.208241	81.262691	Urban
Sarvodya taal	Ward no. 12 Barwari Pur	26.228676	81.255455	urban
Shakti Nagar taal	Ward no. 14 ITI Road	26.229087	81.250584	Urban
Shivaji Nagar talaab	Ward no. 10 ITI Road	26.234902	81.256012	Urban
Behind Lakhpati Market pond	Ward no. 17 Rattapur	26.243244	81.243001	urban

Lake/pond	Ward /village	Latitude	Longitude	Rural or urban
Ambedkar Nagar pond	Ward no. 4 Kallu ka Purwa	26.233071	81.24802	urban
Shatkti ka talaab	Ward no. 4 Kallu ka Purwa	26.228795	81.249522	urban
Balapur talaab	Ward no. 1 Chaturbuj	26.236792	81.265218	urban
Balapur 2 talaab	ward no. 1 Chaturbuj	26.239453	81.265243	urban
Azaad Nagar bairana taalab	ward no.15 Azaad Nagar	26.235605	81.240181	Urban
Rewati Raam talaab	Ward no. 2 Kishanpur Rai	26.248993	81.226558	Urban
Sant Kavar taalab	Ward no. 7 FGTI	26.241414	81.2382034	Urban
Kothare Lala talaab	Ward no. 2 Devanandpur	26.249332	81.245972	urban
Karsen talaab	Ward no. 3 Devanandpur	26.252439	81.249802	Urban
Mogahi taalaab	Ward no. 5 Khaspari	26.256123	81.262779	Urban
Darzi talaab	Ward no. 5 Khaspari	26.256824	81.260979	Urban
Gadrayi talaab	Ward no. 2 Devanandpur	26.250645	81.24427	Urban
Front of CMS school pond	Ward no.2 Devanandpur	26.250587	81.245323	urban
Chamariya talaab	Ward no. 2 Devanadpur	26.250828	81.246597	urban
Bibiya ka talaab	Ward no. 2 Devanandpur	26.250851	81.247864	urban
Chakduara talaab	Ward no. 5 Khaspari	26.260464	81.25148	urban
Chinauta ka talaab	Ward no. 5 Khaspari	26.253019	81.262131	urban
Soniya Nagar talaab	Ward no. 16 Ghosiyana	26.221724	81.249992	urban
Biharin Toal talaab	Ward no. 16 Ghosiyana	26.221258	81.164635	urban
Talaab beside railway track	Ward no. 16 Ghosiyana	26.218809	81.250519	Urban
Police Line talaab	Ward no. 20 Amreshpuri Colony	26.220284	81.229782	urban
Sarvodaya Nagar talaab	Ward no. 12 Bharwaripur	26.226755	81.254211	Urban
Sarvodya Nagar taalab 2	Ward no. 12 Bharwaripur	26.228674	81.256081	Urban
Sarvodya Nagar taalab 3	Ward no. 12 Bharwaripur	26.22806	81.261017	Urban
Amar Nagar talaab	Ward no. 31 Amar Nagar Colony	26.224716	81.232819	Urban

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The Centre for Science and Environment selected four cities—Jhansi, Banda, Rampur and Rae Bareli—of Uttar Pradesh to study the challenges of lake management in urban areas of the state. The waterbodies in these towns face the problems of encroachment and pollution. Untreated sewage enters the waterbodies in these cities, which depend on septic tanks, and solid waste is dumped in them. The waterbodies, which are the recharge areas in the cities, have thus lost the capacity to effectively recharge the groundwater below, and these cities have had plunging groundwater levels in the last decade. The storm-water drains, which drain rainwater from different parts of the city to the waterbodies, are in most instances encroached on and clogged with solid waste, mainly plastics. After heavy showers, the storm-water drains cannot hold the rainwater and the streets flood.

In our climate-risked world, great amounts of rain fall in a short span of time. Lakes act as urban sponges in absorbing extreme storm events. The solution to holding rain lies in rejuvenating these waterbodies and the storm-water drains carrying the rainwater to the drains.

This study shows that to restore lakes into its former state, faecal sludge needs to be managed and the catchment, feeder channels and waterbodies need to be treated so that clean runoff enters the waterbodies. The report recommends filling the lakes with treated wastewater from nearby sewage treatment plants. The learnings can be replicated in other big and small towns that face similar issues.

Centre for Science and Environment
41, Tughlakabad Institutional Area, New Delhi 110 062
Phones: 91-11-40616000 Fax: 91-11-29955879
E-mail: cse@cseindia.org Website: www.cseindia.org