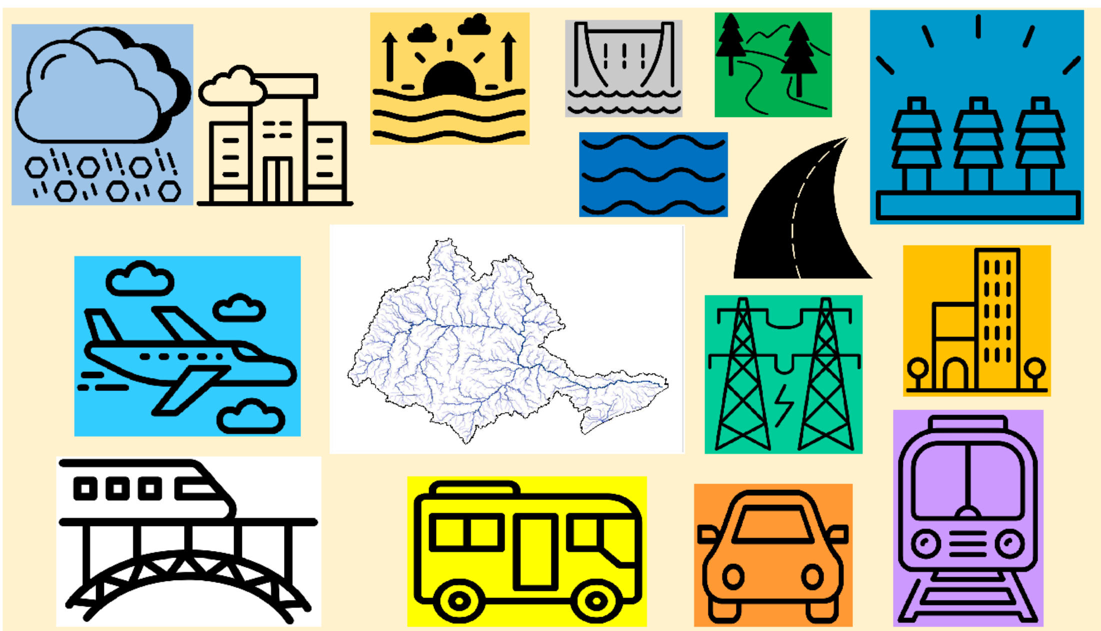
National River Conservation Directorate
Ministry of Jal Shakti,
Department of Water Resources,
River Development & Ganga Rejuvenation
Government of India

Infrastructure and Planning of

Mahanadi River Basin



January 2025

Infrastructure and Planning of Mahanadi River Basin

National River Conservation Directorate (NRCD)

The National River Conservation Directorate, functioning under the Department of Water Resources, River Development & Ganga Rejuvenation, and Ministry of Jal Shakti providing financial assistance to the State Government for conservation of rivers under the Centrally Sponsored Schemes of 'National River Conservation Plan (NRCP)'. National River Conservation Plan to the State Governments/ local bodies to set up infrastructure for pollution abatement of rivers in identified polluted river stretches based on proposals received from the State Governments/ local bodies.

www.nrcd.nic.in

Centres for Mahanadi River Basin Management and Studies (cMahanadi)

The Center for Mahanadi River Basin Management and Studies (cMahanadi) is a Brain Trust dedicated to River Science and River Basin Management. Established in 2024 by NIT Raipur and NIT Rourkela, under the supervision of cGanga at IIT Kanpur, the center serves as a knowledge wing of the National River Conservation Directorate (NRCD). cMahanadi is committed to restoring and conserving the Mahanadi River and its resources through the collation of information and knowledge, research and development, planning, monitoring, education, advocacy, and stakeholder engagement.

www.cmahanadi.org

Centres for Ganga River Basin Management and Studies (cGanga)

cGanga is a think tank formed under the aegis of NMCG, and one of its stated objectives is to make India a world leader in river and water science. The Centre is headquartered at IIT Kanpur and has representation from most leading science and technological institutes of the country. cGanga's mandate is to serve as think-tank in implementation and dynamic evolution of Ganga River Basin Management Plan (GRBMP) prepared by the Consortium of 7 IITs. In addition to this, it is also responsible for introducing new technologies, innovations, and solutions into India.

www.cganga.org

Acknowledgment

This report is a comprehensive outcome of the project jointly executed by NIT Raipur (Lead Institute) and NIT Rourkela (Fellow Institute) under the supervision of cGanga at IIT Kanpur. It was submitted to the National River Conservation Directorate (NRCD) in 2024. We gratefully acknowledge the individuals who provided information and photographs for this report.

Team Members

Samir Bajpai, cMahanadi, NIT Raipur
Mani Kant Verma, cMahanadi, NIT Raipur
Shasikant Verma, cMahanadi, NIT Raipur
Kshitij Upadhyay, cMahanadi, NIT Raipur
Kishanjit Kumar Khatua, cMahanadi, NIT Rourkela
Prof. Santosh Kumar Das, cMahanadi, NIT Rourkela
Arpita Patro, cMahanadi, NIT Rourkela
Bismay Das, cMahanadi, NIT Rourkela
Piyush Paritosh Sarangi, cMahanadi, NIT Rourkela
Jayshree Ojha, cMahanadi, NIT Rourkela
Prachi Pragyan Mahanta, cMahanadi, NIT Rourkela

Preface

In an era of unprecedented environmental change, understanding our rivers and their ecosystems has never been more critical. This report aims to provide a comprehensive overview of our rivers, highlighting their importance, current health, and the challenges they face. As we explore the various facets of river systems, we aim to equip readers with the knowledge necessary to appreciate and protect these vital waterways.

Throughout the following pages, you will find an in-depth analysis of the principles and practices that support healthy river ecosystems. Our team of experts has meticulously compiled data, case studies, and testimonials to illustrate the significant impact of rivers on both natural environments and human communities. By sharing these insights, we hope to inspire and empower our readers to engage in river conservation efforts.

This report is not merely a collection of statistics and theories; it is a call to action. We urge all stakeholders to recognize the value of our rivers and to take proactive steps to ensure their preservation. Whether you are an environmental professional, a policy maker, or simply someone who cares about our planet, this guide is designed to support you in your efforts to protect our rivers.

We extend our heartfelt gratitude to the numerous contributors who have generously shared their stories and expertise. Their invaluable input has enriched this report, making it a beacon of knowledge and a practical resource for all who read it. We hope that this report will catalyze positive environmental action, fostering a culture of stewardship that benefits both current and future generations.

As you delve into this overview of our rivers, we invite you to embrace the opportunities and challenges that lie ahead. Together, we can ensure that our rivers continue to thrive and sustain life for generations to come.

Centre for Mahanadi River Basin
Management and Studies (cMahanadi)
NIT Raipur & NIT Rourkela

Contents

List of Figures

List of Tables

Abbreviations and Acronyms

cMahanadi	Centre for Mahanadi River Basin Management and Studies
MRB	Mahanadi River Basin
MCM	Million Cubic Meter
BCM	Billion Cubic Meter
PWC	Price Waterhouse Coopers
CWC	Central Water Commission
CCA	Cultural Command Area
CGWRD	Chhattisgarh Water Resource Department
AWCs	Approved Anganwadi centers
MSL	Mean Sea Level
LSC	Live Storage Capacity
AAI	Authority of India
NH	National Highway
CSEB	Chhattisgarh State Electricity Board
IIDC	Integrated Infrastructure Development Centres
CSIDC	Chhattisgarh State Industrial Development Corporation
SIPB	State Investment Promotion Board
ICDS	Integrated Child Development Services
CHCs	Community Health Centres
PHCs	Primary Health Centres
CPCB	Central Pollution Control Board
ASP	Activated Sludge Process
OWRCP	Odisha Water Resources Consolidation Project
DoWR	Department of Water Resources
OWPO	Odisha Water Planning Organisation
WRB	Water Resource Board
WAC	Water Allocation Committee
RBOs	River Basin Organisations
WUAs	Water Users' Associations

AMRUT	Atal Mission for Rejuvenation and Urban Transformation
PMAY	Pradhan Mantri Awas Yojana
SEZs	Special Economic Zones
NHM	National Health Mission
ULBs	Urban Local Bodies
SLB	Service Level Benchmarking
NRW	Non-Revenue Water
BPL	Below Poverty Line
JNNURM	Jawaharlal Nehru National Urban Renewal Mission
UIDSSMT	Urban Infrastructure Development Scheme for Small and Medium Towns
IHSDP	Integrated Housing and Slum Development Programme
BRTS	Bus Rapid Transit System
LRTS	Light rail transit system
DMRC	Delhi Metro Rail Corporation
UMTA	Urban Metropolitan Transport Authority
LPD	Litre Per Day
UGS	Underground Sewerage Scheme
ETPs	Effluent Treatment Plants
ESIP	Ecosystem Services Improvement Project
MGNREGA	Mahatma Gandhi National Rural Employment Guarantee Act
CAMPA	Compensatory Afforestation Management and Planning Authority
NAP	National Afforestation Programme
NBM	National Bamboo Mission
NRCP	National River Conservation Plan
NGGB	Narva Garuwa Ghurwa Baari Vikas Yojana
RTWQMS	Real-Time Water Quality Monitoring Systems

Executive Summary

The Mahanadi River Basin (MRB), spanning Chhattisgarh and Odisha, is a vital water resource for agriculture, industry, and domestic use. With a basin area of 141,589 km2, it supports over 38.6 million people, yet it faces challenges in water distribution and utilization. The basin's annual surface water availability is 66.8 billion cubic meters (BCM), but only 50 BCM is effectively used due to uneven distribution and infrastructure deficits.

In Chhattisgarh, agriculture employs 80% of the population but irrigates only 16% of cultivable land, indicating underutilized water resources. Major projects like the Hirakud Dam and Mahanadi Reservoir Complex aid irrigation, hydropower, and industrial water supply, but private sector-driven infrastructure raises concerns about water privatization and sustainability. Odisha, with better irrigation infrastructure, utilizes its resources more effectively but faces challenges in groundwater depletion and stakeholder participation.
Both states have slowed the development of large dams and irrigation projects in recent years due to policy changes and environmental concerns. Riverfront development projects like the Kharun Riverfront in Raipur and the Mahanadi Riverfront in Odisha aim to revitalize urban areas, but disputes over water allocation, particularly for industrial use, have intensified inter-state tensions.

While Odisha boasts a more structured framework, Chhattisgarh's water governance remains fragmented, relying on outdated laws from its time as part of Madhya Pradesh. Both states emphasize public-private partnerships but lack mechanisms for equitable distribution. Odisha's Pani Panchayat Act encourages participatory irrigation management, though implementation gaps remain. Environmental challenges, such as declining river health due to privatization and industrial use, require immediate action. Both states must adopt sustainable practices, transparent governance, and foster inter-state cooperation to address water stress and ensure future water security.

The study on the Mahanadi River Basin emphasizes the importance of this water system for agriculture, industry, and livelihoods. Despite significant annual runoff, water management is inefficient, with Chhattisgarh facing droughts and Odisha struggling with equitable irrigation. Industrial activities, such as thermal power plants and mining, heavily impact water resources, necessitating a balance between growth and conservation. Hydroelectric projects like the Indravati Hydroelectric Project showcase the basin's renewable energy potential but require careful planning to avoid environmental harm. The study also pinpoints infrastructure deficiencies, highlighting the underdeveloped water management framework in Chhattisgarh in contrast to the more comprehensive yet flawed policies in Odisha. Riverfront development initiatives aim to reconcile urban growth and ecological restoration, though privatization and water-sharing conflicts persist. The study provides valuable insights for policymakers on sustainable water resource management, ensuring equitable access and environmental protection for millions reliant on the basin.

1. Introduction

1.1 Mahanadi Basin- A Brief Overview

The Mahanadi River (Maha: mighty and Nadi: river), is one of the major inter-states, east-flowing rivers in peninsular India which originates at 442 m above mean sea level (MSL) near Pharsiya village in the Dhamtari district of Chhattisgarh. The basin lies between the geographical coordinates of 80°30' E to 86°50'E and 19°20'N to 23°35'N (Table 1). It traverses through the plains of Chhattisgarh and Odisha and further narrows down to form a large deltaic region in Puri and Cuttack of Odisha before meeting the Bay of Bengal. The total length of the river is 851 km, of which 357 km falls in Chhattisgarh and 494 km in Odisha. On its way, it is joined by major tributaries like the Seonath, Hasdeo, Mand, Ib, and Jonk above the Hirakud dam, whereas Ong and Tel join the Mahanadi below the Hirakud dam. Rivers Seonath, Ib, and Tel together constitute 46.63 percent of the total catchment of the Mahanadi.

Table 1 Salient features of the basin.

Total area	About 141,589 km2 (73,214 km2 in Chhattisgarh and 65,847 km2 in Odisha, 2,528 km2 across Jharkhand, Maharashtra and Madhya Pradesh) [1]
Length of river	851 km [1], 357 km in Chhattisgarh and 494 km in Odisha
Major tributaries	Seonath, Hasdeo, Mand, (Chhattisgarh) Ib, Ong, Tel and Jonk (Odisha) [1]
Average annual runoff	66.8 BCM [3]
Utilizable surface water	50 BCM
Potentially utilizable groundwater	13.6 BCM (natural recharge process) and 16.58 cm (including augmentation from canal irrigation) [4]
Major water resource Projects	Hirakud reservoir, Minimata Bango project (Minimata Bango reservoir and Hasdeo barrage), Mahanadi reservoir complex (Ravishankar Sagar, Murrum Silli, Dudhawa reservoirs)
Population	38,660,665 [2]
Social composition	16.5% (scheduled castes), 19.2% (scheduled tribes) [2]
Employment	30% cultivators, 27% agricultural labourers, 3% industrial workers
Rainfall	1291 mm [2]
Soil	Red and yellow soils
Major crops	Rice, Gram, Khesari
Irrigation	76 projects (22 major and 54 medium), estimated 1711 Ha of culturable command area under major projects2
Major cities	Raipur, Bilaspur (Chhattisgarh); Bhubaneshwar, Cuttack (Odisha)
Major industries, Industrial zones	Thermal power, iron and steel, mining (coal and bauxite)

Source: [1] Central Water Commission, 2011 [2] Ministry of Water Resources, 2014 [3] Central Water Commission, 2012 and [4] Gupta and Deshpande, 2004

1.2 Significance of Existing Infrastructure and Planning in MRB

The Infrastructure Planning Report for the Mahanadi River Basin (MRB) is a comprehensive document that holds critical significance for addressing water resource management, infrastructure planning, environmental sustainability, and socioeconomic development across Chhattisgarh and Odisha. Spanning an area of 141,589 km², the MRB is a vital water system supporting millions of people, agricultural productivity, industrial growth, and ecological balance. The report highlights pressing issues, identifies infrastructure gaps, and provides strategic insights for sustainable management of the basin.

This report is not merely a technical document; it is a roadmap for stakeholders, policymakers, and implementing agencies to address the challenges facing the Mahanadi River Basin. Its significance extends across multiple domains and stakeholders, providing essential data, analyses, and recommendations that can transform the management of this critical resource.

1. **Holistic Understanding of the Basin's Status**

The report presents a detailed overview of the MRB, including its hydrology, water potential, infrastructure, and governance frameworks. It provides granular data on:

- Surface and groundwater availability
- Irrigation and hydropower projects
- Water resource utilization patterns
- Urban and rural infrastructure development
- Environmental challenges and hotspots

By doing so, the report offers a baseline for understanding the current state of the basin and its utilization, which is indispensable for informed decision-making.

2. **Critical identification of gaps and challenges**

The report identifies significant gaps in infrastructure, governance, and resource management. Chhattisgarh has inadequate irrigation coverage, with only 16% of cultivable land being irrigated, and there are regional disparities in irrigation potential.

- Overexploitation of groundwater resources in Odisha and Chhattisgarh's water governance is fragmented, and stakeholder participation is limited in both states.
- Pollution from industries, urban centers, and agricultural runoff impacts the health of rivers.th.

3. **Data-Driven Insights for Sustainable Development**

The report emphasizes the need for integrated and sustainable planning for the basin, offering data on:

- Live storage capacities

- Waste management infrastructure
- Riverbank protection initiatives

It provides actionable recommendations for short-term and long-term strategies, enabling policymakers to align developmental goals with sustainability principles.

4. **Resolution of Interstate Disputes**

The report addresses the contentious water allocation disputes between Chhattisgarh and the report emphasizes the ecological and downstream effects of barrages and water diversion projects, and it offers a framework for promoting interstate cooperation and conflict resolution.

1.3 Data Source

The Mahanadi River Basin's planning and management involve data collection from various departments. The State Urban Development Agency (SUDA) oversees the planning of urban areas and infrastructure. The State Water Resource Department and India-WRIS guide initiatives such as riverbank protection, recreational spaces, ecological restoration, and walkways. The Chhattisgarh Environment Conservation Board and the Public Health Engineering Department manage public toilets, waste management, and community sanitation programs. The Indian Audit and Accounts Department collaborates with the State Water Resource Department and India-WRIS to identify gaps in plans and initiatives. Additionally, the State Water Resource Department and India-WRIS contribute data on water-related infrastructure, including dams, barrages, weirs, canals, and levees. SUDA and the State Town and Country Planning Department oversee sewerage and drainage systems, while the Chhattisgarh Environment Conservation Board and the Public Health Engineering Department manage storm water drainage and wastewater treatment networks. Collectively, these agencies provide comprehensive data to support sustainable development and resource management within the basin (Table 2).

This report is based on secondary data collected from the Central Water Commission (CWC), the Water Resources Department (WRD), the Chhattisgarh Environment Conservation Board, Indian Audit and Accounts Department Chhattisgarh, State Urban Development Agency (SUDA), the Chhattisgarh Environment Conservation Board, Public Health Engineering Department, and India-WRIS pertinent departmental annual reports, and peer-reviewed journal articles related to the Mahanadi River Basin. Despite our efforts to compile a comprehensive dataset, some data requests remain pending with the relevant departments. We have submitted official requests and are currently awaiting their response. As such, this report is based on the data available at present and provides the most thorough analysis possible currently.

Table 2 Dataset Used.

S. No.	Data	Source (Agency/Department)	Data Type
1	Overview of urban planning and infrastructure development plans	State Urban Development Agency (SUDA)	Excel Sheet, Report
2	Initiatives on riverbank protection, recreational spaces, walkways, ecological restoration	State Water Resource Department, India-WRIS	Excel Sheet, Report
3	Public toilets, waste management, community sanitation programs	Chhattisgarh Environment Conservation Board & Public Health Engineering Department	Excel Sheet, Report
4	Gaps/shortcomings in initiatives and plans	Indian Audit and Accounts Department Chhattisgarh State Water Resource Department, India-WRIS	Excel Sheet, Report
5	Water source management and water-related infrastructure like dams, barrages, weirs, canals, levees, etc.,	State Water Resource Department, India-WRIS	Excel Sheet, Report
6	Sewerage and Drainage Sewerage system	State Urban Development Agency (SUDA), State Town and Country planning	Excel Sheet, Report
7	Stormwater drainage, wastewater treatment Network Plan facilities	Chhattisgarh Environment Conservation Board & Public Health Engineering Department	Excel Sheet, Report

2. Water Supply

Water supply infrastructure is an important part of managing river basins because it makes sure that people, farms, factories, and nature can get water when they need it and keeps river ecosystems alive through natural flows. Environmental flows refer to the minimum water flow required to maintain biodiversity, aquatic habitats, and overall ecosystem health. However, balancing environmental flows with increasing water demands poses challenges as population growth and economic activities intensify competition for resources. Effective management requires understanding both water availability and demand to support human and ecological needs.

Healthy ecosystems depend on natural flow regimes that regulate water quantity, timing, and quality. These dynamics transport nutrients, sediments, and organisms, sustaining ecological balance. Disruptions caused by dams, irrigation, or urban development can degrade habitats, reduce biodiversity, and diminish ecosystem services. Maintaining environmental flows also bolsters resilience against climate variability, mitigating impacts from extreme weather events like droughts or floods. Ensuring adequate flows during critical periods helps ecosystems adapt while supporting dependent communities.

The Mahanadi River Basin's water infrastructure is assessed for its capacity to meet human and ecological needs. Data on household access, source location, water treatment practices, and availability in schools and Anganwadis highlight gaps and opportunities. In Chhattisgarh, 93.1% of households access improved drinking water sources, surpassing the national average of 91.3% (NFHS 2015-16). Rural areas outperform urban areas, with access rates of 93.4% and 91.1%, respectively, uncommon in national trends. Social group disparities are minimal, with Scheduled Castes, Scheduled Tribes, OBCs, and others showing near-equitable access, surpassing national averages.

However, household-level water security remains a concern. Only 30% of households in Chhattisgarh have water within their premises, compared to the national average of 54.5% (Census 2011). Most households (54.5%) rely on sources outside their premises, and 19% on distant sources, disproportionately affecting rural areas (Figure 1). Rural households have lower access (12.9%) to water within premises compared to urban areas (30.6%). Addressing these gaps requires integrated approaches to balance societal and ecological needs, promoting sustainable development in the basin.

The reliance on traditional drinking water sources in Chhattisgarh remains significant, with 58.4% of households depending on hand pumps, 31.4% on wells, and only 9.8% having access to tap water—far below the national trend. Urban areas have better tap water access than rural ones, but piped water infrastructure is generally underdeveloped. Less than 2% of households use alternative sources like tube wells, springs, rivers, and canals.

Rural households face challenges in water collection, spending an average of 18 minutes traveling and 25 minutes waiting, higher than the national averages of 16 and 20 minutes, respectively. Urban households spend less time, which reflects better infrastructure. Water treatment awareness is relatively high, with 451 rural and 697 urban households treating their drinking water per 1,000, exceeding national averages.

Public institutions also face gaps in water access. Only 44.7% of Anganwadis have on-premises drinking water, below the national average of 62.6%, though 62.6% have water within 50 meters. In schools, drinking water access improved from 94.1% to 97% in primary schools and 93.9% to 95.6% in upper primary schools between 2013 and 2016. However, only 77.6% of schools have on-premises water, compared to the national average of 80.3%.

Substantial gaps remain in water security, particularly regarding on-premises access, reliance on piped water, and the time and effort required for water collection. Addressing these issues will require expanding piped water networks, improving household connections, and ensuring consistent water availability in schools and Anganwadis. Strengthening water supply infrastructure in both rural and urban areas is crucial for achieving water security and improving quality of life in Chhattisgarh.

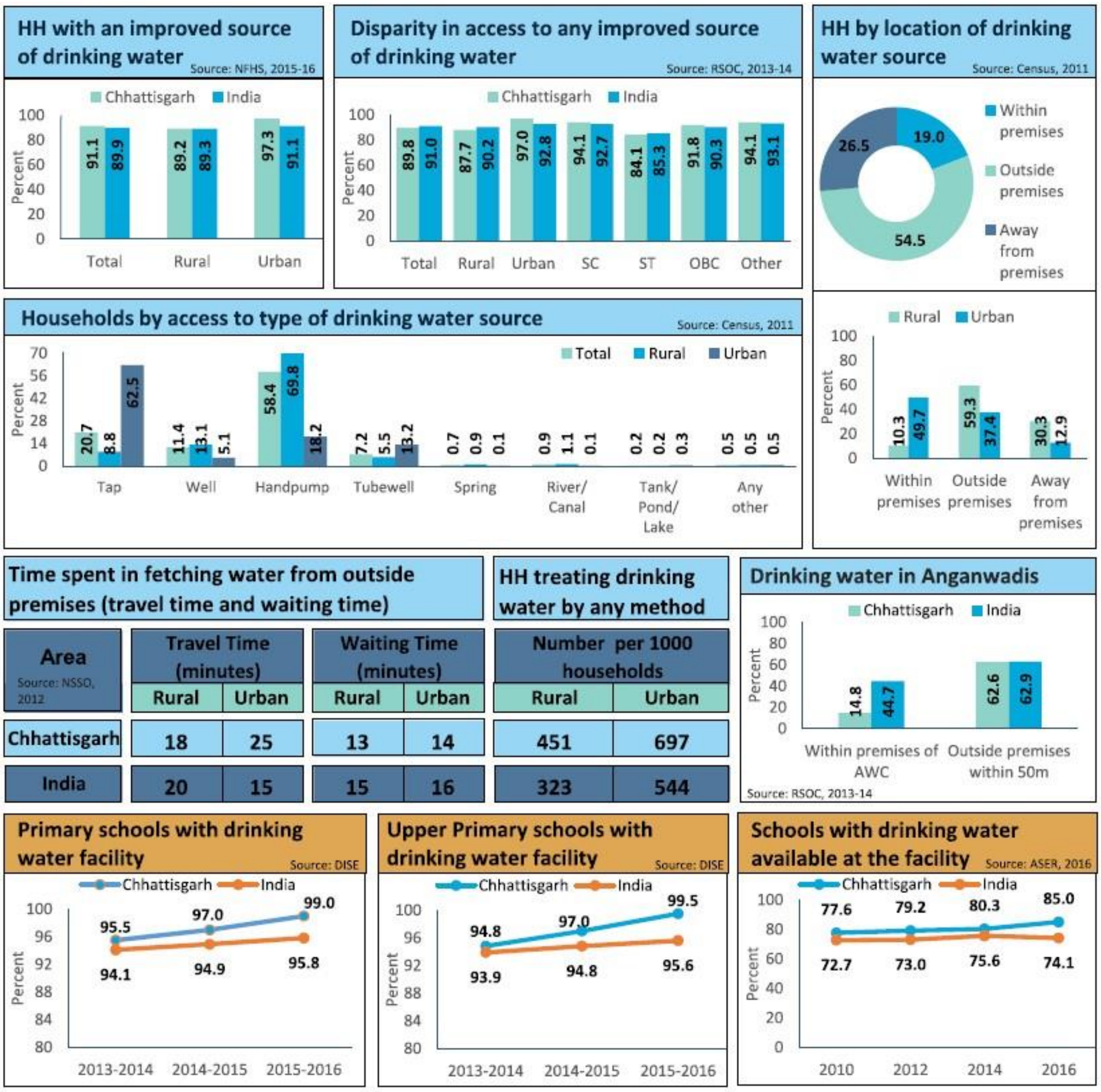


Figure 1 Source of water supply for the Chhattisgarh region.

2.1 Water Source Management

2.1.1 Status of surface and groundwater in Chhattisgarh

Although rich in water resources, Chhattisgarh faces frequent droughts due to neglected conservation practices. It lies within four river systems, including Mahanadi and Godavari, with perennial and seasonal rivers. Despite adequate rainfall, only 16% of cultivable land is irrigated, though the potential exists to increase it to 75%. Agriculture, employing 80% of the population and contributing 38% to the state's economy, relies heavily on water (Table 3). An Action Plan by the Price Waterhouse Coopers (PWC) highlights the need to harness surface water, which could irrigate 4.3 million hectares.

Table 3 Potential & Utilization of Water in Chhattisgarh

Surface Water in Million (Cu. Mtr.)	
Est. Utilizable Potential	41,720 MCM
Potential Irrigable Area	4.30 m ha
Actual Irrigated Area	1.34 m ha
Ground Water	
Net Utilizable Potential	11,960 MCM
Actual Potential Utilized	NA

The apparent abundance of water resources needs to be efficiently and effectively planned to develop and utilize these resources for the overall benefit of the State. In the irrigation sector, utilization of irrigation potential is significantly lower than the national figure. For example, as shown in Table 4, the percentage utilization of created potential for minor schemes and cumulative for the State compares unfavourably with corresponding figures for the country.

Surface water harnessed by irrigation projects is primarily used for irrigation, but other (dinking/industrial) uses are also involved. The use of water from the Mahanadi Project illustrates this point (Table 5).

Table 4 Mahanadi Project Water: Pattern of Use

Use	**Qty. in TMC**	**Use as %**
Irrigation	14.64	75%
Bhilai Steel Plant	3.6	18%
Drinking Water Supply	1.28	60%

(Source: CE, Mahanadi Project, Raipur)

Table 5 Potential & Utilization Pattern in Chhattisgarh & India

Type of Irrigation	**Potential**		**Utilization in %**	
	Potential Created [Lac ha]	**Potential Utilized [Lac ha]**	**Chhattisgarh**	**India**
Major	5.94	4.53	76%	87%
Medium	2.68	2.44	91%	87%
Minor	4.97	2.35	47%	89%
Total	13.59	9.32	69%	89%

The spread of irrigation potential created in various districts is not uniform vis-à-vis the cultivable land available (Figure 2). Dhamtari district is way ahead of others, with the potential facility (131.27%) far exceeding the cultivable area. On the other extreme are the Dantewada, Korba, and Jashpur districts where the potential facility created is just above 6% of the cultivable land available.

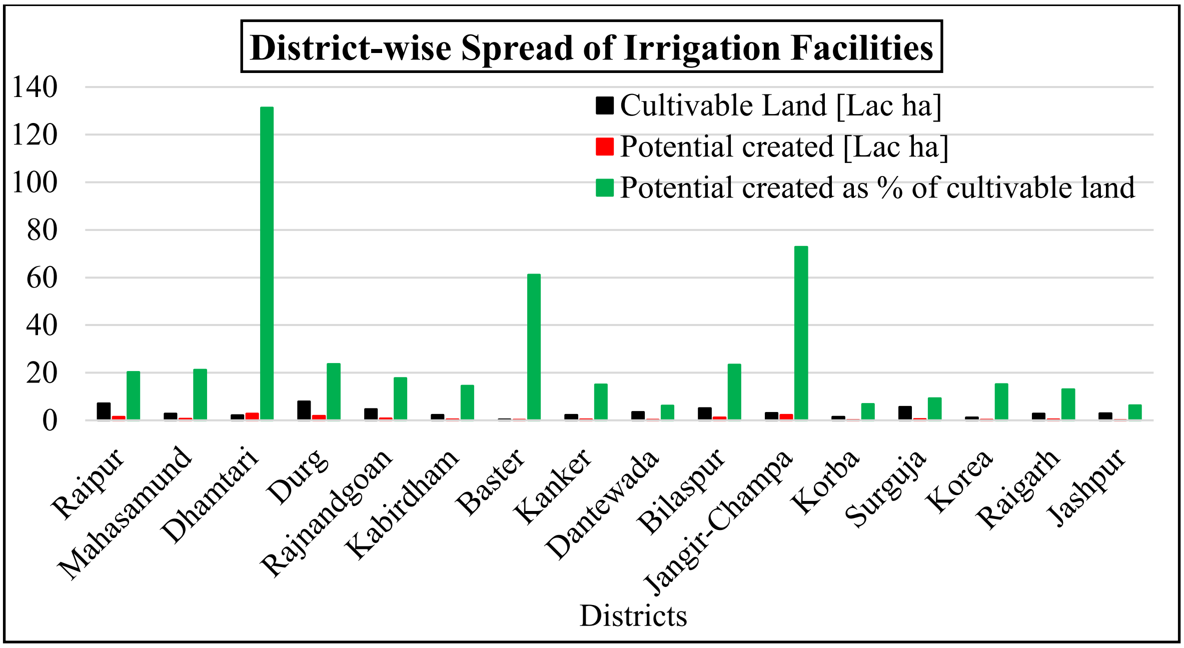


Figure 2 District-wise Spread of Irrigation Facilities.

2.1.2 Status of surface and groundwater in Odisha

Odisha, though rich in water resources, faces frequent droughts due to neglected conservation practices in regions like the Western and Southern parts of the State. It lies within twelve river systems, including Mahanadi and Brahmani, with both perennial and seasonal rivers. Despite adequate rainfall during the monsoons, only 21.484 of cultivable land is irrigated, though the potential exists to increase it to 78%. Agriculture, employing 76% of the population and contributing to the state's economy, relies heavily on water (Figure 3).

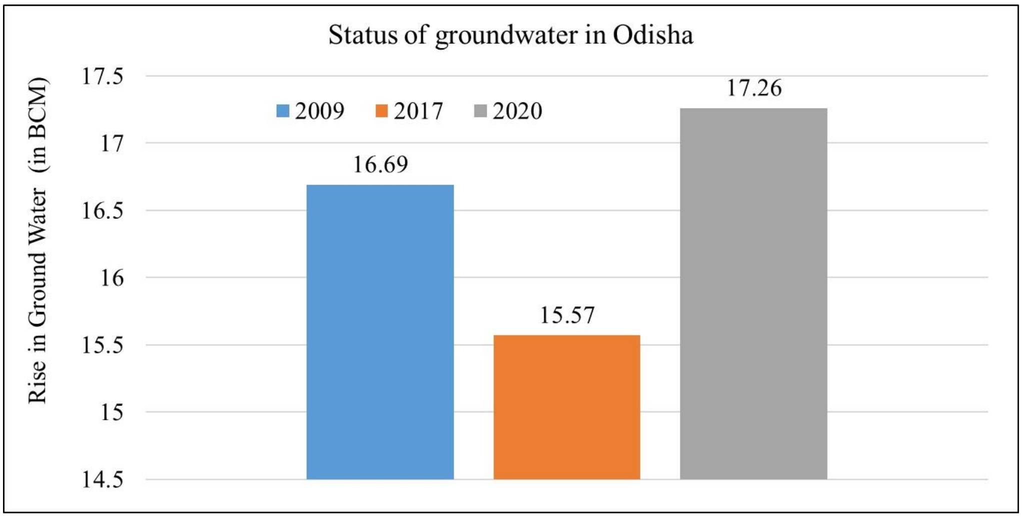


Figure 3 Status of groundwater in Odisha

The state is provided with a vast network of rivers and streams. According to a 2001 study, the average annual surface water availability from the state's drainage border is expected to be 82.841 billion cubic meters. Given the geography and geological limits, it has been determined that 65.679 BCM of water may be used. In addition, interstate rivers provide an annual inflow of 37.556 BCM from neighbouring states.

The utilizable surface water resources are estimated to be 29.861 BCM. Due to the rising demand for water for various purposes, an attempt has been undertaken to estimate the availability of water by 2051. The evaluation finds that the surface water availability from its drainage border stays constant, while the inflow of surface water from neighbouring states will be decreased from 37.556 BCM to 25.272 BCM (Table 6).

Table 6 Irrigation potential in Odisha.

Sector	Irrigation Potential Created (Ha.)
Major and Medium Irrigation	23755
Mega Lift Irrigation	53142
Minor (Flow) Irrigation	935
Minor (Lift) Irrigation	107278
OAIC	3996
Total	189106

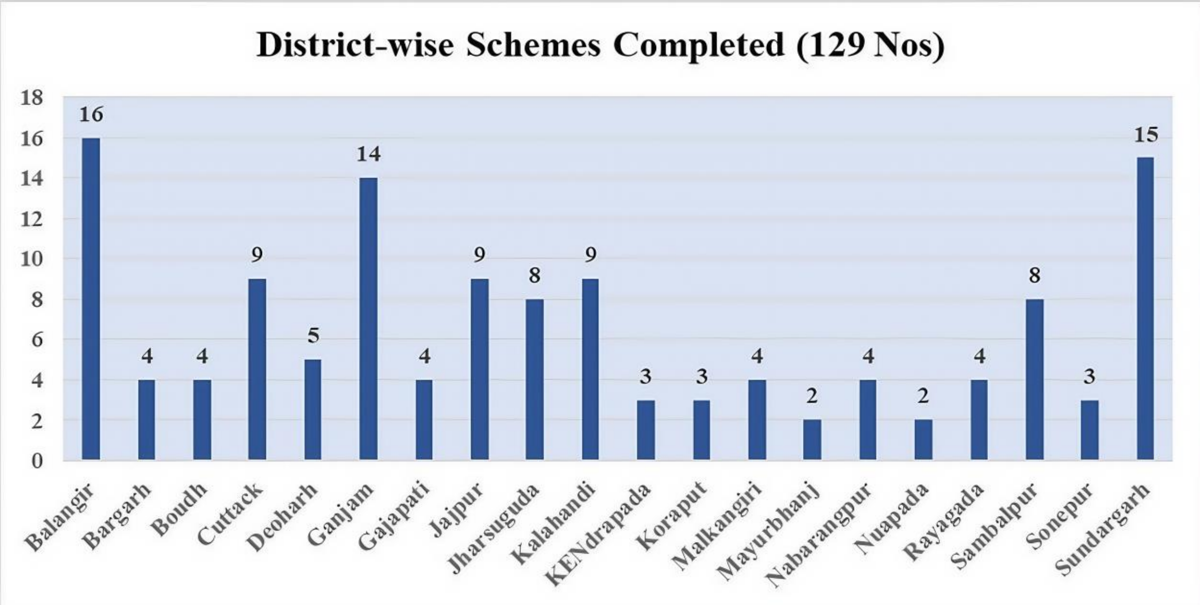


Figure 4 District-wise Spread of Irrigation Facilities.

(Source: WRD-Govt. of Odisha)

Following rain occurrences, groundwater is naturally recharged by percolation from the surrounding terrain. Groundwater potential is often defined as the amount of dynamic groundwater that can be collected each year. The groundwater resources evaluation is carried out at an interval of five years, following the rules and methodology prescribed by The Ground

Water Estimation Committee (GEC) of the Government of India. According to the most recent estimate, the state possesses net dynamic groundwater resources of 16.69 lakh ha.m (BCM) (Figure 4). From there, exploration to the extent of 5.2 lakh ha.m. (BCM) has been created for various purposes.

The spread of irrigation potential created in various districts is overall uniform vis-à-vis the cultivable land available in the district (Figure 9). Balangir, Ganjam, and Sundergarh districts are way ahead of others, with potential facilities ranging between 14 to 16 far exceeding the cultivable area. On the other extreme are the Dantewada, Korba, and Jashpur districts where the potential facility created is just above 6% of the cultivable land available.

2.2 Water Resource Project in Chhattisgarh

The MRB has a total storage capacity of 14467.30 MCM of which the finished project has a capacity of 13006 MCM. The total live storage capacity of projects under construction is 1461.30 MCM. Irrigation projects and hydroelectric projects are the two primary categories for water resource projects (CWC, 2014, CSCCC, 2019).

2.2.1 Irrigation projects in Chhattisgarh State

The river and its tributaries support agriculture by providing water for crops like rice, wheat, pulses, and oilseeds. The Mahanadi River Basin (MRB) hosts 74 irrigation projects (Figure 5), including Ravishankar Sagar Dam, Dudhwaha Dam, Murusilli Dam, New Rudri Barrage, Minimata Hasdeo Bango Project, Tandula Project, Jonk Diversion Project, and Pairy Project. The Minimata Hasdeo Bango Project benefits Bilaspur, Korba, Raigarh, and Janjgir Champa districts, while the Tandula Project serves Durg.

Dam construction in Chhattisgarh peaked between 1981 and 1990, with a sharp rise in total and large dams compared to earlier and later decades. Before 1980, dam construction was modest, and post-1990, it slowed significantly, with fewer projects built from 1991 to 2014 (Figure 6). The cumulative total shows a focus on smaller dams, reflecting an emphasis on small-scale infrastructure.

The Mahanadi RB dominates dam construction in Chhattisgarh, with a significant spike in 1981–1990. In contrast, the Ganga and Godavari basins have far fewer dams. The "Unknown" category indicates minimal data gaps. Overall, dam-building activities have declined in recent decades, likely due to shifting priorities, environmental concerns, or project challenges.

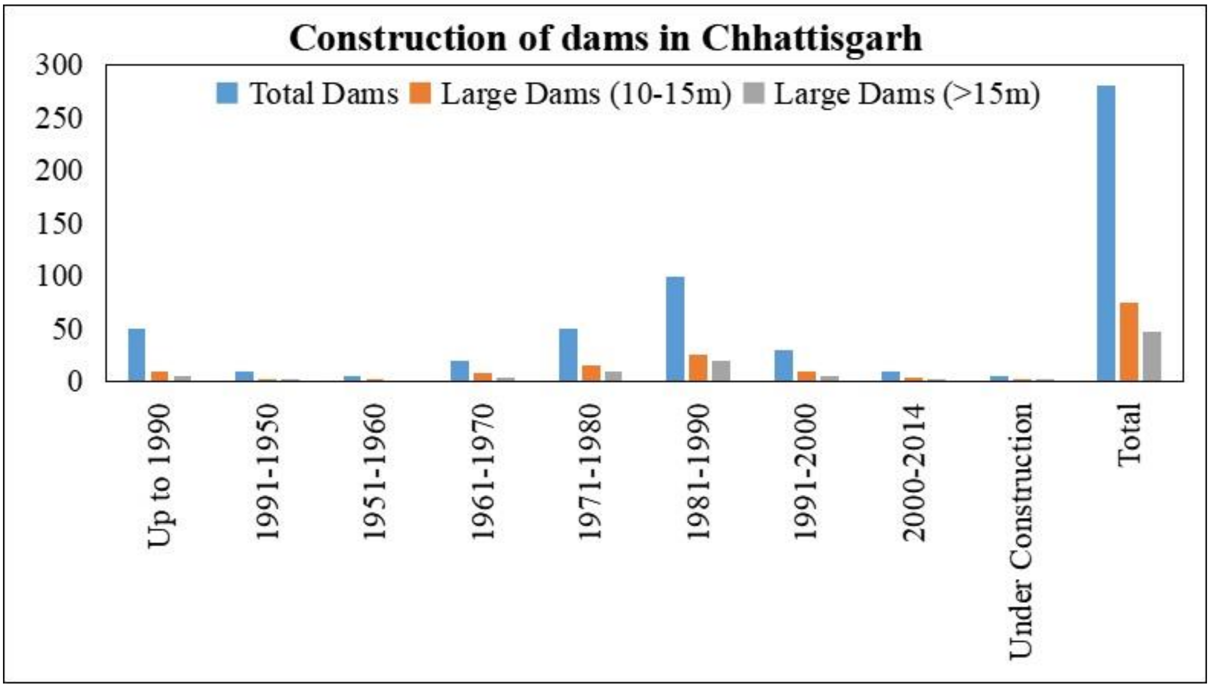


Figure 5 Construction of dams/ surface water management structure in Chhattisgarh.

(Source: CWC, 2017)

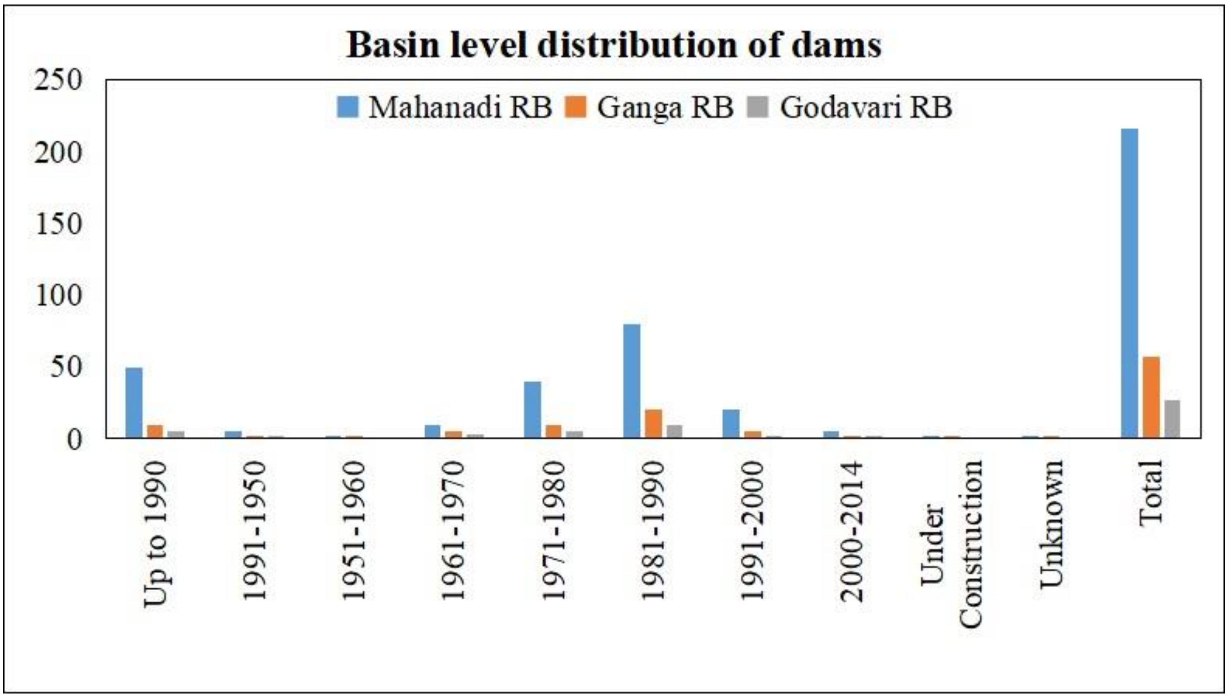


Figure 6 Construction of dams/ surface water management structures in different river basin (RB) in Chhattisgarh

(Source: CWC, 2017)

2.2.2 Hydro Electric Projects

The MRB in Chhattisgarh has significant hydroelectric potential. The major dams in the basin include the Gangrel Dam, Dudhawa Dam, and Hasdeo Bango Dam. The hydropower generation from MRB is 1184.5 MW (Table 7). It comprises five hydroelectric projects and 6 powerhouses. The maximum power (600 MW) is being generated from the Indravati hydroelectric project, the Minimata Hasdeo Bango Project generates 120 MW, the Gangrel hydroelectric project generates 10 MW, and the Sikaser project generates 7 MW (Register of Large Dams, 2017, WC, 2014, India-WRIS).

Table 7 Hydroelectric capacity and major projects within the Mahanadi River Basin (MRB) in Chhattisgarh

Dam/Project	Hydropower Generation (MW)	Remarks
Indravati Hydroelectric Project	600	Largest power-generating project in MRB
Minimata Hasdeo Bango Project	120	Located in the Hasdeo Basin
Gangrel Hydroelectric Project	10	Also known as Ravishankar Sagar Dam
Sikaser Project	7	Smaller-scale power project
Category	**Details**	
Total Hydropower Generation	1184.5 MW	
Number of Projects	5	
Number of Powerhouses	6	

2.2.3 Thermal power plant

Figure 7 depicts the decadal newly installed capacity of thermal power plants in Chhattisgarh across the state and private sectors in megawatts (MW). Key findings indicate that thermal power plant capacity has significantly increased over the decades, with the private sector contributing most of the installed capacity.

Before 2000, the total capacity was minimal, with the state sector contributing 840 MW and no recorded private sector activity. Between 2000 and 2010, the private sector began contributing (1,600 MW), surpassing the state sector's 500 MW. A major surge occurred between 2010 and 2020, where private sector capacity increased dramatically to 11,568 MW compared to the state sector's 1,500 MW. The total installed capacity across all decades is 13,168 MW for the private sector and 2,840 MW for the state sector. This highlights the dominant role of private investment in driving thermal power capacity expansion in Chhattisgarh.

Figure 7 depicts a list of major projects and thermal power plants in the MRB catchment area. These projects obtain water from the river and its tributaries directly or indirectly (CWC, 2014).

Chhattisgarh state, industrial water use is rapidly increasing, particularly for thermal power generation, making it more difficult than ever to allocate usable water among different sectors while also protecting the Mahanadi and its tributaries. In years of drought when river flows are reduced, a quantity of 2,172 MCM of water designated for industrial uses can pose a significant threat to water-based livelihoods such as agriculture, livestock husbandry, and fisheries. (CSCCC, 2019).

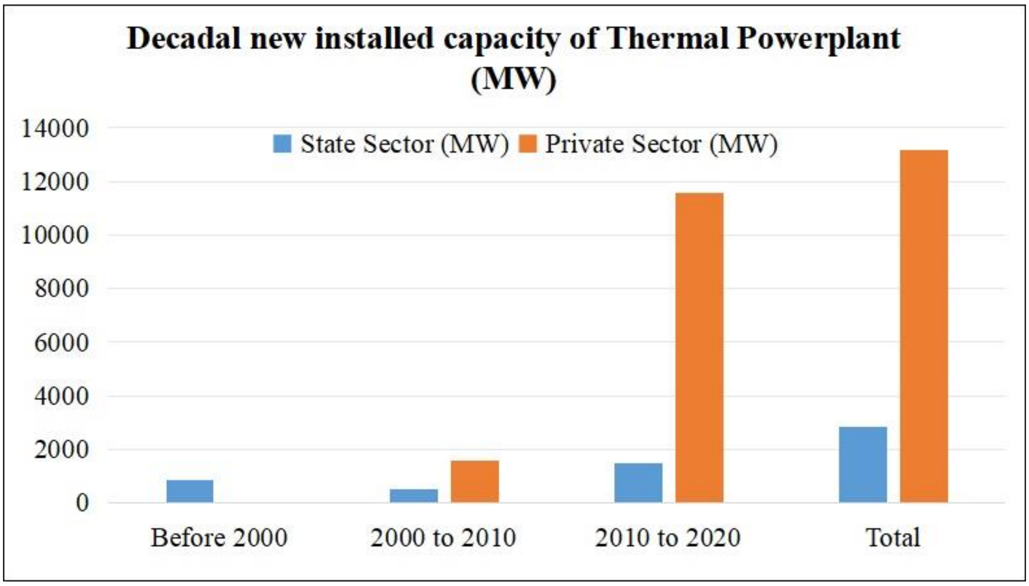


Figure 7 List of industries and power plants in the catchment area with their installed capacity

2.3 Water Resource Projects in Odisha State

The Mahanadi River Basin in Odisha hosts several important irrigation projects, many of which have played a vital role in supporting agricultural activities and water management. These projects include both completed and ongoing initiatives, contributing to the region's infrastructure and irrigation potential.

The Mahanadi River Basin in Odisha is home to several irrigation projects that are vital for agricultural productivity and water resource management. Among the completed initiatives, the Hirakud Dam stands out as a multipurpose project, providing flood control, irrigation, and hydropower. Built between 1946 and 1957, it supports extensive downstream irrigation. Other completed medium-sized and localized projects include Sapua-Badajore and Budhabudhani, which cater to specific regions, enhancing water distribution for Kharif and Rabi crops. The Upper Jonk (Kharkhara Extension) is another critical initiative, significantly boosting the command area's water supply and irrigation potential within the basin.

Several major projects are under development, including the Lower Suktel Project aimed at improving water accessibility in drought-prone areas, and the Gangadhar Meher Lift Canal System, which utilizes Hirakud's reservoir to irrigate upland areas. Proposals for additional projects include 27 barrages and 66 in-stream storages to be constructed in phases across the basin to address water scarcity, manage flow, and improve irrigation (Table 8).

Table 8 Proposed project status in the MRB of Odisha region.

S.No.	Project Name	Dam/ Barrage	Village/ Block/ District	Benefits (Ha.)	Status of DPR/ FR/ TAC			
1	Brutanga Dam	Dam	Manjari/ Daspalla/ Nayagarh	23300	Approved (DPR)			
2	Ong Dam	Dam	Pujharipali/ Jharbandha/Baragarh	30000	Approved (DPR)			
3	Ib Dam	Dam	Katingdhi/ Balisankara/ Sundargarh	106279	Approved (DPR)			
4	Dhauragoth	Dam	Dhauragoth/ Athamalik/ Angul	2230	Approved (DPR)			
5	Upper Lanth	Dam	Chikili/ Belpara / Bolangir	4700	Approved (DPR)			
6	Ranjjore Dam	Dam	Sarandapali/ Barapali/ Bargarh	4125		Accepted		
7	Jeera Dam	Dam	Duanpali/ Bhatli/ Bargarh	4800		Accepted		
8	Surubalijore Dam	Dam	Tentalakhar/ Rairakhol/ Sambalpur	7088			Accepted	
9	Uttei Roul Integrated (Barrage & Dam)	Uttei dam	Gourkela/ M.Rampur/ Kalahandi	60000			Accepted	
		Buda Dam	Sakus/ M.Rampur/ Kalahandi					
			Jurakhaman/ M.Rampur/ Kalahandi					
10	Kutulisinga Dam	Dam	Kutulisingha/ Athamallik/ Angul	2540		Accepted		
11	Brahmanipada Dam	Dam	Bramhanapada/ Chakapada/ Kandhamal	3200			Accepted	
12	Lambadora Dam	Dam	Kadogarh/ Jamankira / Sambalpur	7300		Submitted		
13	Tel Integrated Dam	Tel Dam	Karlaparha/ Chandahandi/ Nawarangpur	9903		Submitted		
			Phatki/ Chandahandi/ Nawarangpur					

14	Laxmipathar Dam	Dam	Kirtangapada/ Harabhanga/ Boudh	3200		Submitted		
15	Katangi dam	Dam	Banjipali/ Khaprakhol/ Bolangir	3681			Submitted	
16	Telijore Dam	Dam	Telijore/ Balisankara/ Sundergarh	82000			Submitted	
17	Sandul Barrage		Dutta/ M.Rampur/ Kalahandi	5000	Approved (DPR)			
18	Aheerajore Barrage		Debdarha/ Lakhanpur/ Jharsuguda	2220		Accepted		
19	Lower Lanth Barrage (Tustapali)		Tustapali/ Saintala / Balangir	1976	Approved (FR)			
20	Khadago Barrage		Landagaon/ Baliguda/ Kandamal	23500			Submitted	
21	Upper Udanti Barrage		Patialapara/ Sinapali/ Nuapada	8000			Submitted	
21	Lower Udanti Barrage		Bordi/ Golamunda/ Lalahandi	9300			Submitted	
23	Lower Lanth barrage (Deng)		Deng/ Saintala/ Bolangir	6799				In Process
24	Ghogar Barrage		Ghogar/ Balisankra/ Sundargarh	9980				In Process
25	Sankhabhanga Barrage		Bhoipali/ Jamankira/ Sambalpur	12433				In Process
26	Sindhikela Barrage		Gandharla/ Bongamunda/ Bolangir	3200				In Process
27	Tel barrage at Kukedmal		Kukedmal/ Tusura/ Bolangir	9834				In Process
28	Tel barrage at Manikpur		Manikpur/ Kantamal/ Boudh	10158				In Process
29	Satighat Barrage		Gurujimunda/ Boudh/ Boudh	5575			Submitted	

Four proposed projects, such as the Tel Integrated Dam and Laxmipathar Dam, are awaiting Central Water Commission approval due to inter-state water sharing disputes. Additionally, efforts include the Suktel Irrigation Project, a delayed but significant undertaking for drought-prone areas in western Odisha. These projects, major and minor, play a crucial role in ensuring the sustainable development of water resources in the Mahanadi basin while addressing challenges posed by seasonal variability and competing demands.

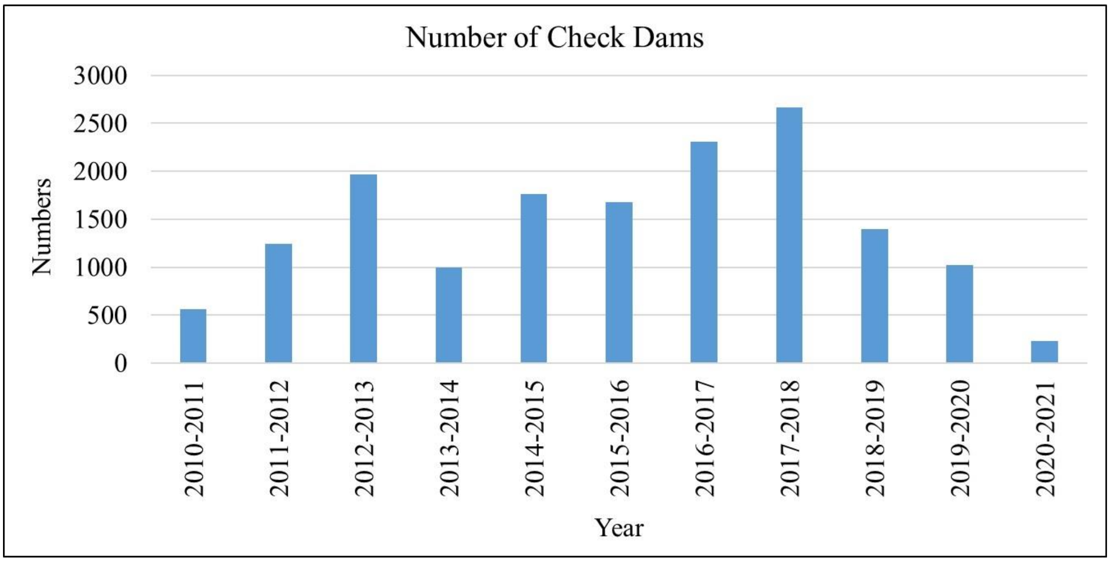


Figure 8 Yearly progress in check dam construction between 2010-11 and 2020-21.

(Source: WRD-Govt. of Odisha)

Figure 8 showcases the yearly progress in check dam construction between 2010-11 and 2020-21. The numbers increased significantly, peaking at 2663 dams in 2017-18. However, there was a declining trend thereafter, with the numbers plummeting to 229 by 2020-21.

Figure 9 reveals that irrigation achievements vary across project categories, with minor irrigation (traditional and OAIC) either meeting or exceeding their targets. However, major-medium, mega-lift, and large minor lift (OLIC) projects fall short of their goals, particularly the Minor Lift (OLIC) category, with a significant gap of 29,061 ha (Table 9).

Table 9 Storage capacity of Reservoirs (Qty. in BCM).

Category	Completed Projects		Projects under construction	
	No	Capacity	No	Capacity
Major	8	15.17	2	0.532
Medium	44	1.82	4	0.145
Minor	2728	0.50	71	-
Total	**2780**	**17.49**	**77**	**0.677**

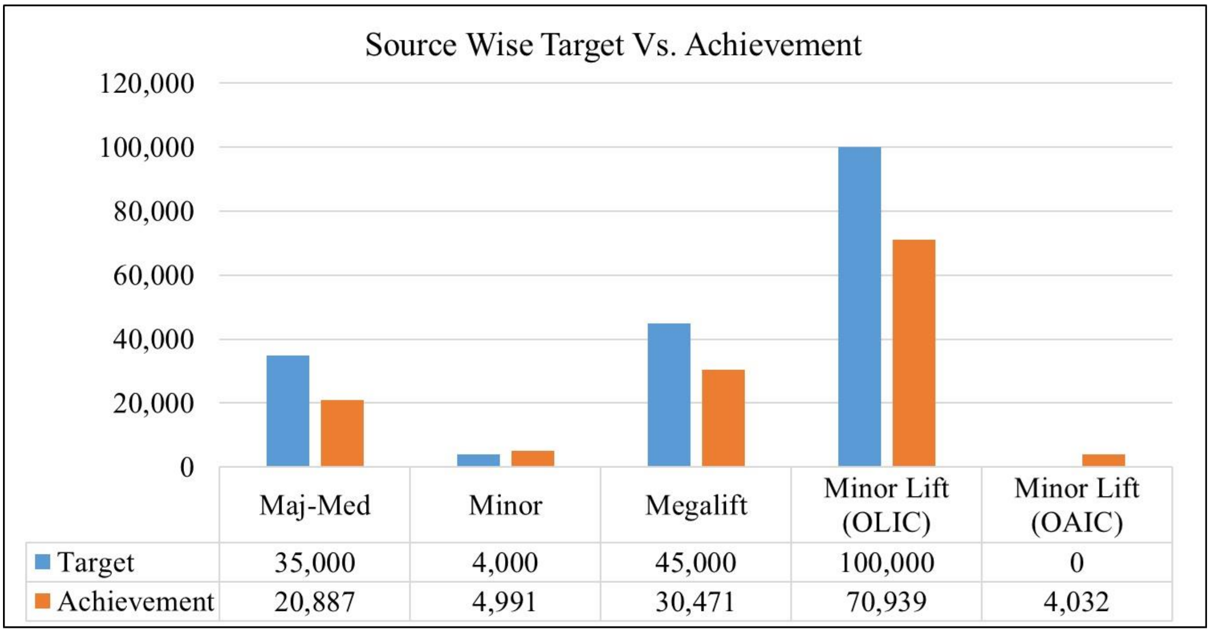


Figure 9 Status of irrigation projects.

(Source: WRD-Govt. of Odisha)

2.3.1 Irrigation Projects in Odisha State

Irrigation contributes significantly to poverty alleviation and economic progress. The state government places a significant premium on irrigation development. The state's total cultivated land area is 61.80 lakh hectares. It is estimated that big, medium, and minor (flow and lift) irrigation projects can span 49.90 lakh hectares (Figure 10).

Before independence, there was little progress in irrigation development in the state. Approximately 1.83 lakh hectares of irrigation infrastructure were created. Following the implementation of the Five-Year Plan by the Government of India in 1951, efforts were made to rapidly harness water resources, with a strong emphasis on accelerating irrigation development.

Many big, medium, and minor irrigation projects have been built in the state during the previous six decades, boosting irrigation capacity from 1.83 lakh hectares in 1951 to 43.07 lakh hectares in 2020. The irrigation facilities developed using various sources are listed below (Table 10).

The irrigation potential created and utilized since 2000-01 is given in the following Table 11. The gap between potential created and utilized is attributed to many factors, but the main reasons are defunct LIPs, MIPs, and deterioration of distribution systems of irrigation projects. Initiatives have been taken to minimize the gap between potential created and utilized. Canal system improvement works in some of the major and medium irrigation projects were completed through different schemes. At present following schemes are being implemented to minimize the gap between potential creation and utilization.

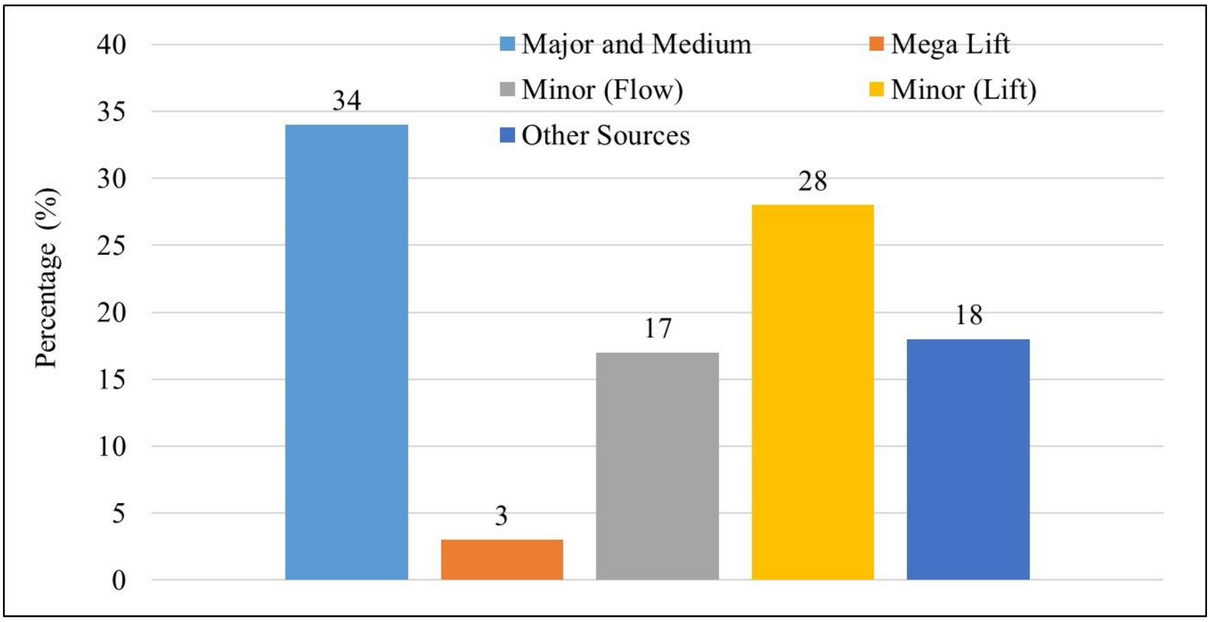


Figure 10 Irrigation facilities created as of March 2020 (Lakh ha.).

Table 10 Status of Irrigation Potential Created & Utilized.

Year	Irrigation Potential Created (Th. Ha.)			Irrigation Potential Utilized (Th. Ha.)			% of Utilization
	Kharif	Rabi	Total	Kharif	Rabi	Total	
2000-01	2533.83	1071.99	3605.82	1589.88	535.84	2125.72	58.95%
2001-02	2554.26	1117.63	3671.89	1752.27	793.64	2545.91	69.34%
2002-03	2608.59	1123.75	3732.34	1246.81	465.21	1712.02	45.87%
2003-04	2674.12	1161.21	3835.33	1737.49	780.87	2518.36	65.66%
2004-05	2707.27	1266.22	3973.49	1845.79	844.87	2690.66	67.72%
2005-06	2731.5	1294.92	4026.42	1922.7	1042.79	2965.49	73.65%
2006-07	2720.46	1318.52	4038.98	2001.98	1147.47	3149.45	77.98%
2007-08	2765.73	1342.06	4107.79	2027	1281.46	3308.46	80.54%
2008-09	2867.01	1407.18	4274.19	2081.13	1096.03	3177.16	74.33%
2009-10	2962.21	1476.81	4439.02	2058.85	979.67	3038.52	68.45%
2010-11	3035.85	1477.97	4513.82	2085.21	1020.7	3105.91	68.81%
2011-12	3089.34	1501.43	4590.77	2078.9	1009.18	3088.08	67.27%
2012-13	3130.51	1573.56	4704.07	2186.86	1178.73	3365.59	71.55%
2013-14	3352.94	1651.79	5004.73	2253.67	1267.35	3521.02	70.35%
2014-15	3457.47	1696.56	5154.03	2327	1134	3461	67.15%
2015-16	3670.91	1803.48	5474.39	2241.41	1052.94	3294.35	60.17%
2016-17	3802.12	1806.52	5608.643	2422.41	1188.843	3611.253	64.39%
2017-18	4047.296	1869.26	5916.556	2262.35	1180.4	3442.75	58.19%
2018-19	4189.25	1911.62	6100.87	2591.66	1307.38	3899.04	63.91%
2019-20	7265.18	1920.49	6185.67	2694.1	1186	3880.1	62.00%

2.4 Live Storage Capacity in the Mahanadi River Basin (Chhattisgarh & Odisha)

In 2013, the Central Water Commission reported that they had created approximately 13 BCM of storage, with an additional 1.46 BCM under construction. Future projects under consideration could raise this to 24 BCM, covering 36% of surface waters. In 2012, the Central Water Commission kept track of Mahanadi's storage and estimated that by 2014, 13.72 BCM had been filled, with 6.61 BCM in Chhattisgarh and 7.11 BCM in Odisha, not counting delta barrages (National Register of Large Dams, 2014).

The Mahanadi Basin, including the Chhattisgarh region (formerly Madhya Pradesh), developed its water resources earlier than Odisha. Pre-independence saw the construction of smaller dams such as Tandula Tank (312 MCM, completed 1920), Murrum Silli (162 MCM, 1923), Maniyari (148 MCM, 1930), and Kharang (1931). The Dudhawa (284 MCM) and Ravi Shankar Sagar (767 MCM) dams, completed in 1963 and 1979, form the 'Mahanadi Reservoir Complex,' irrigating Durg, Dhamtari, Raipur, and Bilaspur districts. In 1990, Chhattisgarh completed the largest irrigation project, the Minimata Bango Project (3046 MCM), primarily serving Janjgir-Champa.

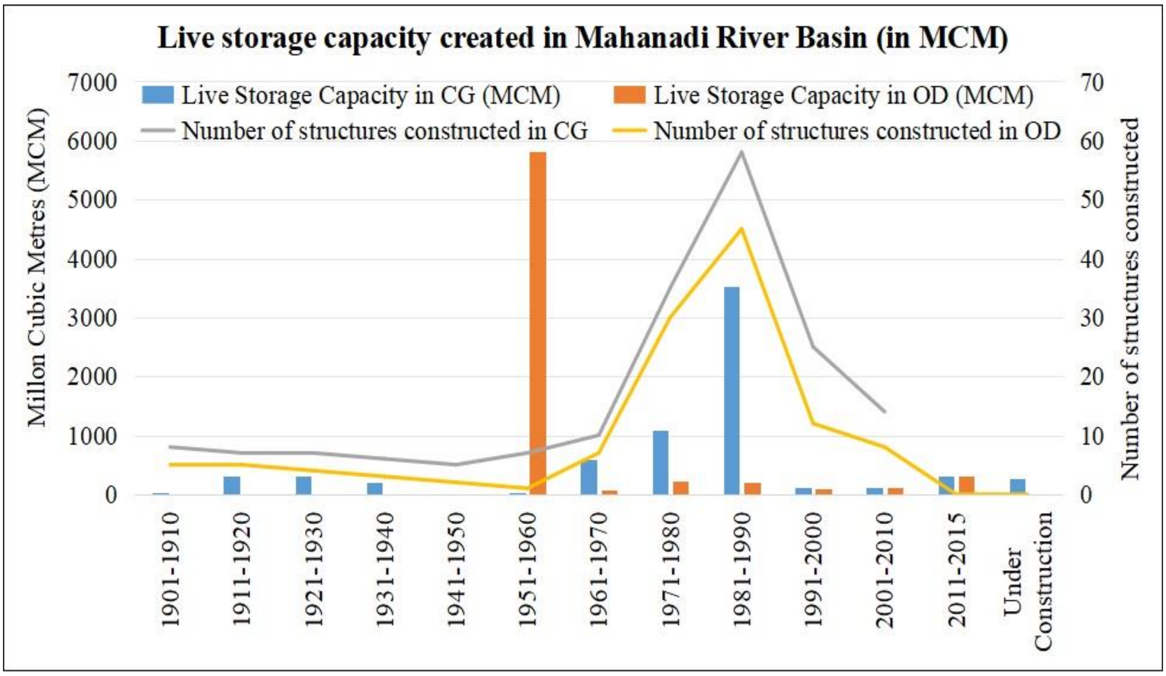


Figure 11 Live storage capacity in the Mahanadi River Basin.

(Source: Central Water Commission, 2014; Water Resources Department of Chhattisgarh, 2015; Central Water Commission, 2016b)

The Hirakud Dam (5818 MCM), completed in 1957, is Odisha's largest dam, serving Bargarh, Sambalpur, and Sonepur districts. Odisha experienced significant dam construction between 1970 and 1990, while Chhattisgarh expanded infrastructure in Kanker, Rajnandgaon, and Koriya districts of the Upper Hasdeo Basin. Since 1990, no major projects exceeding 1000 MCM live storage have been completed (Figure 11). The most recent large project is the Lower Indravati Dam (314 MCM). The Upper Indravati Project, an inter-basin transfer system, irrigates Kalahandi district. The Central Water Commission records 253 dams and 24 barrages/weirs/anicuts in the Mahanadi Basin, including 74 major or medium irrigation projects. The basin's gross irrigable area is 32.8 lakh hectares 15.4 lakh hectares in Odisha and 17.4 lakh hectares in Chhattisgarh covering 40% of the 82.3 lakh hectares gross cropped area.

2.5 Large dams and major irrigation projects in the Mahanadi River Basin (Chhattisgarh and Odisha)

The Chhattisgarh part of the Mahanadi basin developed its water resources before Odisha. Before independence, several dams were built there, including the Tandula Tank (1920), the Murrum Silli (1923), and the Maniyari (1930) and Kharang (1931) dams on the Seonath, which is the Mahanadi's main tributary. Major projects include Hirakud, Minimata Bango, and the Lower Indravati Dam (314 MCM). The Upper Indravati Project facilitates inter-basin water transfer for irrigation in Kalahandi.

The basin features 22 major irrigation projects, 54 medium irrigation projects, and 5 hydroelectric projects (Table 11), with a total live storage capacity of 14.244 BCM. 21.32% of the average annual flow and 28.4% of dependable, utilizable water. Of this, 12.799 BCM is completed, and 1.465 BCM is under construction. An additional 10.094 BCM is proposed, potentially increasing storage to 36% of average flow and 50% of dependable flow. The distribution of completed storage is almost evenly between Odisha (52%) and Chhattisgarh (48%).

Table 11 Large dams and major irrigation projects in the Mahanadi River Basin (MRB).

Aspects	Chhattisgarh	Odisha
Historical Development of Water Resources	Developed earlier with several smaller dams	Development came later, focused on large projects like Hirakud
Major Dams & Projects	Tandula Tank (1920), Murrum Silli (1923), Maniyari (1930), Kharang (1931), Minimata Bango, Mahanadi Reservoir Complex, Lower Indravati Dam, Upper Indravati Project.	Hirakud Dam
Total Live Storage Capacity	7.45 BCM (52% of the completed storage).	7.35 BCM (48% of the completed storage)
Irrigation Projects	22 major, 54 medium irrigation projects	74 major/medium irrigation projects (CWC)
Gross Irrigable Area	17.4 Lakh Ha	15.4 Lakh Ha
Hydroelectric Projects	5 hydroelectric projects	-
Water Diversion Projects	13 barrages and weirs, including Arpa-Bhaisajhar, 7 pick-up weirs for industrial use	Odisha raises concerns over the impact of Chhattisgarh's water diversion projects

The Mahanadi basin contains 253 dams, 24 barrages, and weirs, with 74 major or medium irrigation projects covering a gross irrigable area of 32.8 lakh hectares, 40% of the 82.3 lakh hectares of gross cropped area. Additionally, 3839 tanks provide surface water storage, crucial for irrigation and domestic use in both states.

Recent surface water developments have fueled disputes between Chhattisgarh and Odisha, particularly over 13 barrages and diversion weirs, including the Arpa-Bhaisajhar Barrage Project and seven pick-up weirs under construction in Chhattisgarh. Odisha has also raised concerns about the Pairy-Mahanadi Intra-State Link Project and the Tandula Reservoir Augmentation Scheme. These projects primarily serve industrial needs, with an estimated 1258.16 MCM allocated annually for industries, supplying over 45 power plants in Chhattisgarh.

Smaller structures like weirs, anicuts, and barrages have replaced large dams in the post-liberalization era, reflecting the shifting priorities in water resource development.

2.6 Key Issues

As is the case with many other states, Chhattisgarh too faces a range of issues related to its water resources and their management. Some of these issues include the rapid growth of population and industries, over-abstraction of water resources, unplanned urban development, and pollution. The development of new infrastructure, the maintenance and operation of existing infrastructure, and the increasing threats to the resource base from pollution and unplanned development, which exacerbate existing climatic risks such as droughts and floods, pose numerous challenges. Waterlogging, salinization, and increased levels of toxic elements in the water are serious concerns. Industries are depleting significant water resources, particularly groundwater, leading to a decline in groundwater tables in the state.

2.7 Existing/On-Going Initiatives

A comprehensive master plan for the state, for optimum use of water resources, is under preparation. The state is moving ahead with a more integrated and sustainable approach to water resources management. In 2012, the State developed a new Draft State Water Resources Development Policy, which aims to achieve the following primary objectives:

- We must develop water resources in a planned manner that is environmentally sustainable.
- It is technically feasible to make every possible effort for the development of water resources in the drought-affected and rain shadow areas.
- We aim to provide water for drinking, agriculture, and industries at affordable prices, ensuring that we can cover at least our maintenance costs.
- Given the need for significant investment in the development of water resources, we should encourage private-sector investment.
- Leaders of water users should participate in the development and maintenance of water resources.

- The goal is to guarantee water security for the entire population by establishing suitable institutional and legal structures in the water sector to supply water to different users.
- To improve water management efficiency by:
    - All relevant institutions and organizations have united and coordinated their efforts to create a policy framework that plans water resources, enhances them, and utilizes them effectively.
    - Users actively participate in the development and management of the state's water resources.
    - The goal is to increase the productivity of water by fixing the standards of infrastructure services and ensuring utilization efficiency.
    - Reducing the climatic risks and improving rain-fed agricultural productivity.
- To enhance the accessibility and effectiveness of irrigation water,
    - Realizing optimum irrigation potential under major, medium, and minor irrigation projects; and
    - Improving the performance of irrigation projects by narrowing the gap between potential created and utilization.
- To maintain and sustain the ecological balance,
    - Conserving and protecting the water bodies and wetlands through regulation and enforcement of standards for water infrastructure, uses, and waste disposals.
    - The regulation of land uses near water bodies is crucial.
    - Enforcing the recycling of industrial effluents and water disposal.

Key elements of the Draft 2012 State Policy of Water Resources Development include (a) water resources planning; (b) water resources development; (c) water resources management; (d) rationalization of water rates; and (e) water conservation.

2.8 Short-Term (Five Years) Strategies

The CSAPCC recognizes that scientific knowledge and evidence based on the impacts of climate change on the water sector is limited. Therefore, the CSAPCC will undertake a thorough analysis of climate vulnerability. As a complementary activity, a comprehensive water database in the public domain and an assessment of the impact of climate change on water resources through the various agencies responsible for different aspects of water resource management in the state will be developed, updated, and analyzed on an ongoing basis. Strategies towards this will include:

- The network of hydrological observation stations is being reviewed.
- The network of automatic weather stations and automated rain gauge stations is being reviewed.
- Collection of necessary additional hydro-meteorological and hydrological data for proper assessment of the impact of climate change on the

The state, including other improvements required in hydrometric networks to appropriately address the issues related to climate change, is being addressed.

Such data will include hydrological and hydro-meteorological data in low-rainfall areas.

- Improved network for collection of evaporation and rain gauge data using automated sensors.
- The establishment and strengthening of groundwater monitoring and geohydrology networks is currently underway.
- Collection of data about river morphology for monitoring erosion and carrying capacity; and
- Surface and groundwater quality data collection, etc.

2.9 Long-Term (Beyond The 12th FYP Period) Strategies

- Physical sustainability of groundwater resources will be accorded high importance, and intensive programs for groundwater recharge in over-exploited areas will be taken up.
- The State will implement measures to improve the quality of drinking water, particularly in rural areas. Additionally, it aims to enhance water efficiency in urban water supply systems by promoting water-efficient techniques, technologies, and management. This includes the effective and timely operation and maintenance of water resource projects and infrastructure assets across all water sub-sectors in the State.
- Steps will also be taken to foster integrated water resources development and management planning.
- A water resources and climate change "cell" will be set up for the necessary coordination and monitoring mechanisms.
- Documenting sectoral responses, learning what worked and what did not, dialogue, sharing data and information, etc. will be carried out as essential functions either by the individual agencies involved or collectively by a nominated agency.
- The gender dimensions of water use and management are well documented. For example, the gender and environment literature has long noted that women and girls typically take on the primary responsibility of collecting water for drinking, cooking, washing, hygiene, and raising small livestock, while men use it for irrigation, livestock farming, and industrial purposes.
- In the context of climate change, the imperative will be to ensure that policies and programs draw on the existing body of knowledge on gender and water to inform interventions and scale these up. To support the integration of gender knowledge into policy and planning.
- The private sector has considerable experience, expertise, technologies, and innovation capabilities, as has been demonstrated in many other states in terms of increasing private sector involvement in the water sector, especially by way of PPPs and other projects.

3. Infrastructure

The Mahanadi River Basin (MRB) features an extensive hydraulic infrastructure critical for water resource management and regional development. Significant projects have been developed to harness its water resources (Figure 12). Table 12 shows a summary of the basin's main infrastructure. It has about 282 dams of different sizes, with 10–15 major dams used for things like flood control, irrigation, and hydropower generation. Prominent structures include the Hirakud Dam in Odisha, one of Asia's largest earthen dams, providing irrigation, flood control, and hydroelectric power. Similarly, the Hasdeo Bango Dam in Chhattisgarh supports irrigation, hydroelectric generation, and water supply for industries and urban areas. The MRB also includes several dozen medium and over 200 minor irrigation projects.

Powerhouses associated with these dams significantly contribute to regional energy supply, such as the Hirakud Dam (347.5 MW installed capacity) and the Hasdeo Bango Dam (120 MW). While data on smaller projects is limited, these facilities highlight the basin's importance for hydropower. Figure 12 shows the locations of major powerhouses. Additionally, barrages and weirs regulate river flow, support irrigation, and maintain water levels. This comprehensive infrastructure requires integrated basin management to balance competing water demands and address potential environmental impacts.

Some other major dams, barrages, weirs, and structures in the Mahanadi River Basin:

In Chhattisgarh:

- **Hasdeo Bango Dam:** A major irrigation project providing water to several districts in Chhattisgarh, significantly contributing to agricultural productivity in the region.
- **Mand Dam:** A significant dam on the Mand River, contributing to irrigation and hydropower generation, supporting both agriculture and industries.
- **Ghumariya Barrage:** A crucial structure for irrigation in the Rajnandgaon district, ensuring water supply for crops.
- **Hasdeo Barrage:** A key component of the Hasdeo Bango Project, regulating water flow and managing irrigation.
- **Kodar Barrage:** A significant irrigation project in the Mahasamund district, providing water for agriculture and rural development.

In Odisha:

- **Naraj Barrage:** A major irrigation project in the Cuttack district, supporting agriculture and rural livelihoods.
- **Munduli Barrage:** Another important irrigation structure in the Cuttack district, contributing to irrigation and water supply.
- **Birupa Barrage:** A key component of the Mahanadi Delta Irrigation Project, ensuring water availability for agriculture in the delta region.
- **Titlagarh Barrage:** A significant irrigation project under construction in the Balangir district, expected to boost agricultural production.
- **Ong Weir:** A crucial structure for irrigation in the Balangir district, regulating water flow for irrigation purposes.

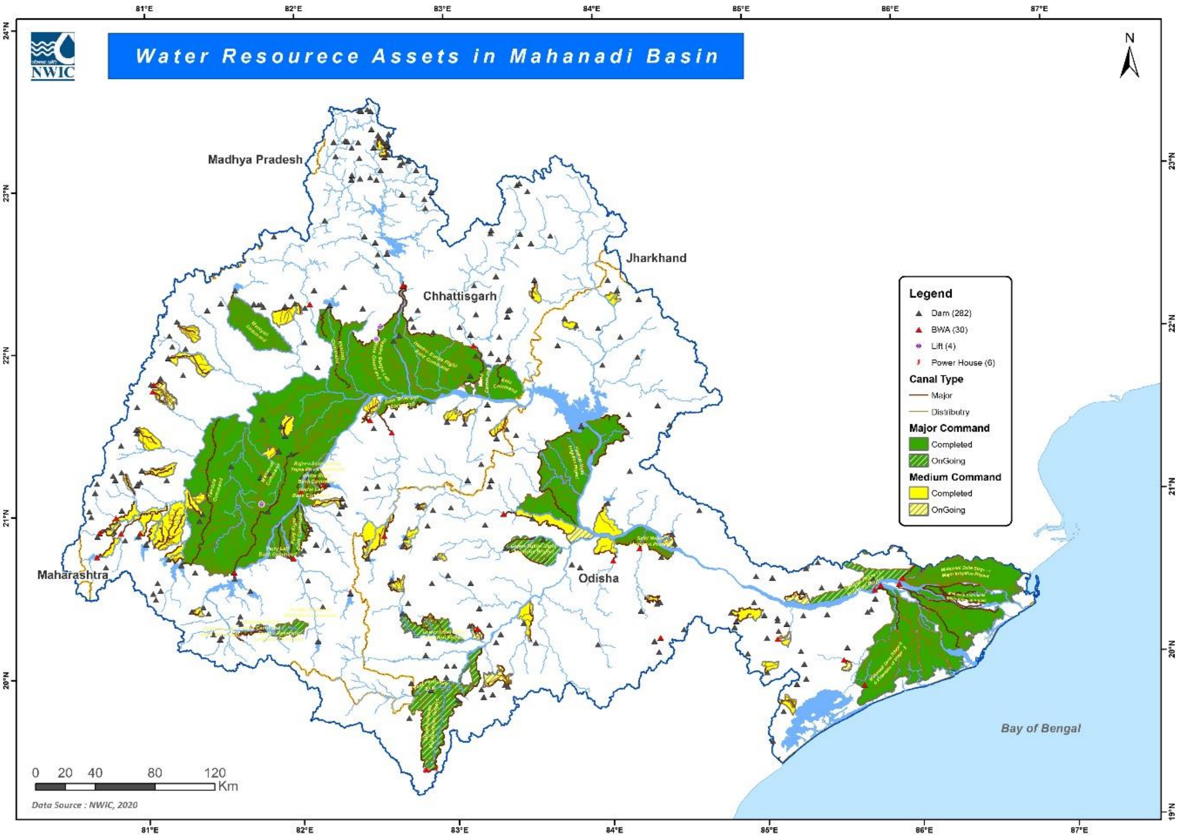


Figure 12 Major Infrastructure of the Mahanadi River Basin.

(Source: NWIC, 2020)

Table 12 Major Hydraulic Infrastructure in Mahanadi River Basin.

Infrastructure Name	Type	River/ Tributary	State	Operational Characteristics	Primary Purpose(s)	Location (Approximate)
Major Dams						
Hirakud	Composit e dam	Mahanadi	Odisha	Largest earthen dam in IndiaReservoir capacity: 8.1 BCM	Flood control, Irrigation, Hydropower	Sambalpur
Hasdeo Bango	Concrete gravity dam	Hasdeo	CG	Reservoir capacity: 3.5 BCM	Irrigation, Hydropower, Water supply	Korba district
Gangrel (Ravishankar Sagar)	Dam	Mahanadi	CG	Significant irrigation project	Irrigation, Water supply	Dhamtari district
Tandula	Dam	Tandula (tributary of Shivnath)	CG	Major irrigation project	Irrigation	Balod district
Rengali	Dam	Brahmani (partially influences Mahanadi basin)	Odisha	Major multipurpose project	Irrigation, Hydropower, Flood control	Angul district

Upper Indravati Project	Dam (and complex of structure s)	Indravati (diverted to Mahanadi basin)	Odisha	Hydropower generation (through diversion)	Hydropower	Kalahandi district
Medium/Smaller Dams						
Dudhawa	Dam	Mahanadi	CG	Medium irrigation project	Irrigation	Dhamtari district
Sondur	Dam	Sondur (tributary of Mahanadi)	CG	Medium irrigation project	Irrigation	Dhamtari district
Kodar	Dam	Kodar (tributary of Seonath)	CG	Medium irrigation project	Irrigation	Mahasamund district
Kharang	Dam	Kharang	CG	Used for irrigation and water supply	Irrigation, Water supply	Bilaspur district
Maniyari	Dam	Maniyari	CG	Primarily for irrigation	Irrigation	Mungeli district
Paralkot	Dam	-	CG	Medium irrigation project	Irrigation	Kanker district
Lower Indra	Dam	Indra	Odisha	Primarily for irrigation	Irrigation	Nuapada district
Pitamahal	Dam	-	Odisha	Medium irrigation project	Irrigation	Sundargarh district
Barrages						
Mahanadi	Barrage	Mahanadi	Odisha	Diversion structure with gates	Irrigation, Water diversion	Near Cuttack
Birupa	Barrage	Mahanadi	Odisha	Regulates water flow	Irrigation	Cuttack
Munduli	Barrage	Mahanadi	Odisha	Regulates water flow	Irrigation	Athagarh, Cuttack
Naraj	Barrage	Kathjuri (distributar y of Mahanadi)	Odisha	Regulates water flow	Irrigation	Cuttack
New Rudri	Barrage	Mahanadi	CG	Regulates water flow	Irrigation	Dhamtari
Bagh	Barrage	Bagh (tributary of Tel)	Odisha	Diversion structure	Irrigation	Bauda
Hasdeo	Barrage	Hasdeo	CG	Diversion structure	Irrigation	Katghora, Korba
Jonk	Barrage	Jonk	CG	Diversion structure	Irrigation	Near Pendra Road
Karra Nalla	Barrage	Karra Nalla	CG	Diversion structure	Irrigation	Kawardha, Kabeerdham
Kodar	Barrage	Kodar Nalla	CG	Diversion structure	Irrigation	Mahasamund

Mongra	Barrage	Shivnath	CG	Diversion structure	Irrigation	Raj Nandgaon
Sukha Nalla	Barrage	Sukha Nalla	CG	Diversion structure	Irrigation	Raj Nandgaon
Titlagarh	Barrage	Jamuna Jore	Odisha	Under construction	Irrigation	Titlagarh, Balangir
Weirs						
Ballar	Weir	Jonk	CG	Diversion structure	Irrigation	Kasdol, Raipur
Dahuka	Weir	Dahuka	Odisha	Diversion structure	Irrigation	Nayagarh
Jonk	Weir	Jonk	CG	Diversion structure	Irrigation	Kasdol, Raipur
Kharkhara	Weir	-	Odisha	Diversion structure	Irrigation	Nuapada
Mand	Weir	Mand	CG	Diversion structure	Irrigation	Kharsia, Raigarh
Matia Motinalla	Weir	Motinalla	CG	Diversion structure	Irrigation	Raj Nandgaon
Ong	Weir	Ong	Odisha	Diversion structure	Irrigation	Balangir
Pairi	Weir	Pairi	CG	Diversion structure	Irrigation	Bindra Nawagarh, Raipur
Rajua	Weir	-	Odisha	Diversion structure	Irrigation	Khordha
Salki	Weir	Salki	Odisha	Diversion structure	Irrigation	Bauda
Shivnath	Weir	Shivnath	CG	Diversion structure	Irrigation	Raj Nandgaon
Silhati	Weir	-	CG	Diversion structure	Irrigation	Kabeerdham
Uttei	Weir	Uttei	Odisha	Diversion structure	Irrigation	Baligurha, Kandhamal

These infrastructure projects have played a crucial role in the development of the Mahanadi River Basin. They have provided numerous benefits, including:

- **Irrigation:** These structures have significantly increased agricultural productivity in the region by providing reliable water supply. For example, the Hirakud Dam irrigates over 1.5 million hectares of land in Odisha and Hasdeo Bango Dam irrigate approx half million hectares of land in Chhattisgarh.
- **Hydropower generation:** Dams like Hirakud have contributed to the power generation capacity of the region.
- **Flood control:** Dams and barrages have helped to mitigate the impact of floods, protecting lives and property.
- **Drinking water supply:** Intake wells and canals have ensured the availability of drinking water for millions of people. Canals like the Mahanadi Delta Irrigation Canal provide drinking water to many villages and towns.
- **Industrial development:** Water from the river has been used for industrial purposes, contributing to economic growth. Industries in the region, such as steel and textile, rely on water from the Mahanadi River.

However, these projects have also had some negative impacts:

- **Environmental degradation:** Construction of dams and barrages can lead to habitat loss, alteration of river flows, and sedimentation.
- **Social displacement:** Many people have been displaced due to the construction of these projects.
- **Water quality issues:** Pollution from industrial and domestic sources can degrade the water quality of the river.

To mitigate these negative impacts, it is important to adopt sustainable water management practices and to carefully consider the environmental and social consequences of future infrastructure projects.

3.1 Physical infrastructure

3.1.1 Transport

Chhattisgarh has extensive road connectivity, including 11 national highways spanning 2,184 km, such as NH 6, NH 16, NH 43, and others. State highways and district roads add 8,031 km to the network. By 2012, 6,635 passenger vehicles operated on 2,316 roads, managed through 22 computerized transport offices. Plans include establishing a motor and driving school. The state's rail network, covering 1,108 km, falls under the Southeast Central Railway Zone, headquartered in Bilaspur. There is limited air connectivity, with only Swami Vivekananda Airport in Raipur offering scheduled commercial services. In 2013, the government signed an MoU with the Airports Authority of India to develop Raigarh Airport as a second domestic airport.

Odisha's robust transport network supports its economic growth. Key national highways, including NH 16 and NH 53, enhance interstate connectivity. Major railway hubs like Bhubaneswar, Sambalpur, and Rourkela facilitate passenger and freight movement, especially in mineral-rich regions. Biju Patnaik International Airport in Bhubaneswar serves as the primary air gateway, supplemented by Jharsuguda Airport and upcoming expansions in Jeypore and Rourkela. Additionally, Odisha is enhancing inland water transport, with Paradip and Dhamra ports playing vital roles in exports.

3.1.2 Irrigation

At the time of Chhattisgarh's formation, the irrigation potential was 13.28 lakh hectares, or 23% of the total sown area. Estimates suggest an expansion to 43 lakh hectares, with 33.8 lakh from surface sources and 9.2 lakh from groundwater. The government prioritized increasing the average irrigation coverage to 48.9% post-formation. In 2008–09, water resource development and irrigation enhancement were key priorities. By 2011–12, irrigation potential expanded by 0.35 lakh hectares, reaching a total of 18.44 lakh hectares (33.15% of the sown area). As of March 2012, 8 major, 33 medium, and 2,347 minor irrigation projects were completed, with 3 major, 6 medium, and 412 minor projects still under construction. Between 2011 and 2012, 26 departmental tube well projects added 25,500 hectares of irrigation potential, while private tube wells contributed 2,990 hectares.

Only 10% of the total cultivated area in Chhattisgarh receives irrigation. Despite having numerous perennial rivers (Mahanadi, Indrawati, Sheonath, etc.), these sources irrigate only 20% of the land, with the rest relying on rainfall. Groundwater potential remains largely untapped, though water is available at depths of 50–150 feet along river belts. Canals are the primary irrigation source, providing three-fourths of the total, followed by tube wells (8%), tanks (6%), and wells (4-5%). By March 2006, 4 major, 33 medium, and 2,199 minor irrigation projects had been completed, with 5 major, 9 medium, and 312 minor projects under construction.

3.1.3 Power

Chhattisgarh is one of the few states of India where the power sector is effectively developed. The Chhattisgarh State Electricity Board (CSEB) is in a strong position to meet the electricity requirement of the state. Chhattisgarh provides electricity to several other states because of surplus production and its power hubs are Korba and Bilaspur. In Chhattisgarh, NTPC has a thermal plant with a capacity of 2100 MW at Sipat, Bilaspur, while CSEB's units have a thermal capacity of 1780 MW and a hydel capacity of 130 MW. Apart from NTPC and CSEB, there are several private generation units of large and small capacity. As per a study made by the Power Finance Corporation Ltd., New Delhi, the state has the potential of 61000 MW of additional thermal power in terms of availability of coal for more than 100 years and more than 2500 MW hydel capacity.

3.1.4 Telecommunication

As of June 2024, Chhattisgarh's tele-density stands at 69.50%, indicating that approximately 69.5% of the population has telephone connections (Press Information Bureau). In efforts to enhance connectivity, Vodafone Idea (Vi) has upgraded 4G services by deploying 900 MHz spectrum on 3,043 sites in Madhya Pradesh and 1800 MHz band on 11,772 sites in Chhattisgarh, aiming to boost indoor 4G connectivity (Tele.net). The BharatNet project has made significant strides in the state, with optical fiber cables laid across 40,376 km and 4,074 Gram Panchayats made service ready as of April 2019 (www.slideshare.net). Additionally, the insurgency-hit Bastar region has seen the installation of over 500 mobile towers, improving communication and contributing to socio-economic development (The Print).

The Controller of Communication Accounts (CCA) in Chhattisgarh, a field unit of the Department of Telecommunications, manages various functions, including licensing, revenue management, and pension settlements, contributing to the sector's efficient operation. Despite these advancements, challenges persist, particularly in rural areas where connectivity remains limited. Ongoing efforts aim to bridge the digital divide, ensuring equitable access to telecommunication services throughout the state.

3.1.5 Urban Infrastructure

The Mahanadi River Basin (MRB) is integral to Chhattisgarh's urban infrastructure, influencing water supply, agriculture, and industrial activities. Spanning approximately 75,136 km^2 within the state, the Mahanadi River traverses 357 kilometers of Chhattisgarh's terrain, serving as a crucial resource for its cities and towns.

Urban centers such as Raipur, Bilaspur, and Durg depend heavily on the Mahanadi and its tributaries to meet their water needs. The basin has seen the construction of over 250 water conservation structures, including dams and reservoirs, to meet these demands. Notable among these are the Ravishankar Sagar dam, Dudhawa dam, and Murumsilli dam, which play pivotal roles in regulating water flow and ensuring a consistent supply for urban consumption, irrigation, and industrial processes.

Urban development in Odisha is progressing rapidly under initiatives like the Smart City Mission, with Bhubaneswar and Rourkela leading the way in urban planning, e-governance, and sustainable living practices. Smaller cities are witnessing significant infrastructure upgrades through programs such as AMRUT (Atal Mission for Rejuvenation and Urban Transformation), which focuses on improving water supply, sanitation, and public transportation. Additionally, housing schemes like the Pradhan Mantri Awas Yojana (PMAY) are addressing the issue of urban housing shortages, ensuring access to affordable homes for residents.

3.1.6 Industrial Infrastructure

Chhattisgarh is among India's richest states in mineral wealth, with 28 major minerals, including diamonds. It ranks second in mineral production. It holds a significant portion of India's coal deposits, enabling surplus power production. Notably, it is the only state in India with tin ore reserves. Chhattisgarh produces about one-fifth of the country's iron ore, with the Bailadila mines in southern Chhattisgarh featuring world-class deposits that are exported to Japan and other countries. The state also has abundant bauxite, limestone, dolomite, and corundum, supporting low-cost cement and aluminum production. In 2009-10, it contributed 14.09% of national mineral revenue.

Chhattisgarh has made significant investments in industrial infrastructure. The Chhattisgarh Industrial Development Corporation (CSIDC) has established four Industrial Growth Centres, five Industrial Parks, and 12 Integrated Infrastructure Development Centres (IIDCs). The state has three notified Special Economic Zones (SEZs). Chhattisgarh is becoming an industrial powerhouse and a top investment destination thanks to its rich resources, good rail and road connections, direct air links to major metros, 30 MMSCDM natural gas pipeline network, good power supply, and policies that encourage investment, such as the Industrial Policy 2009–14 and the SEZ Policy. Key industries include mining, iron and steel, cement, power, IT, biotechnology, food processing, and gems and jewellery. Other growth sectors include apparel, aluminum, handicrafts, automotive, and engineering.

The state is a national hub for iron and steel production. The Bhilai Steel Plant of SAIL produces over 3 million tonnes of iron and steel annually, supplemented by significant private-sector capacities.

- Chhattisgarh contributes 28% of India's sponge iron production with 91 plants.

- It ranks third among iron-ore-producing states.
- In 2008-09, it produced 32.9 million tonnes of iron ore.

Chhattisgarh hosts industrial parks in Bhilai, Korba, Borai (Durg), Urla (Raipur), Siltara, and Sirgitti (Bilaspur), managed by the CSIDC. These estates are near major cities and provide essential infrastructure. The state has also developed software technology parks in Bhilai and Korba. Key industrial areas include Urla, Sarora, Bhanpuri, Rawabhata, and Tifra.

Odisha is strategically located along India's eastern coast, with rich reserves of iron ore, bauxite, and coal, establishing itself as an industrial hub. Core sectors include steel, aluminum, cement, power, petrochemicals, and IT, with major players like Tata Steel, Jindal Steel, Vedanta, NTPC, and Hindalco. Industrial hubs such as Kalinganagar (steel), Jharsuguda (power and aluminum), and Angul (heavy industries) drive growth. The Paradip Port supports domestic and international trade, while upcoming SEZs focus on export-oriented industries. Odisha's Industrial Development Plan aligns with the "Make in India" initiative, offering incentives and ease of doing business to attract investors. Despite economic and employment gains, the state prioritizes eco-friendly practices, emission controls, and afforestation to mitigate industrialization's environmental impacts.

3.2 Social infrastructure

3.2.1 Education sector

Educational Institute (pre-primary, primary, middle, high, higher secondary school) is 59432 in the state (Statistical pocketbook of Chhattisgarh 2010-11). Concerning literacy, the state fared just below the national average. The recent estimates from the Census (2011) depict a literacy rate of 71 percent (81.4% Males and 60.5% Females), which is close to the all-India literacy rate of 74 percent.

Odisha's education system combines government and private institutions, offering diverse opportunities for learning and skill development. Higher education is spearheaded by renowned universities such as Utkal University, Sambalpur University, and NIT Rourkela, with emerging institutions like IIT Bhubaneswar and IIM Sambalpur enhancing the academic landscape. Government programs, including Mo School Abhiyan and Samagra Shiksha, have significantly improved school infrastructure and literacy rates, particularly in rural areas. To align education with industrial needs, skill development, and vocational training programs are actively promoted, while initiatives like Odisha Adarsha Vidyalayas focus on delivering quality education to economically disadvantaged communities.

3.2.2 Health Infrastructure

The state's health infrastructure has historically been inadequate, with only one medical college in Raipur until recently. Sub-centers, Primary Health Centers (PHCs), and Community Health Centers (CHCs) were insufficient due to sparse populations, difficult terrain, and dense forests. Initial efforts prioritized expanding infrastructure to improve accessibility and health indicators. Over the past decade, district hospitals increased from six to 16, CHCs from 114 to 148, PHCs from 512 to 757, and sub-health centers from 3,818 to 5,112. Approved Anganwadi Centers (AWCs) rose from 20,289 in 2001 to 43,763 in 2011, while mini-AWCs grew from 836 to 6,548, catering to remote populations. The Integrated Child Development Services (ICDS) beneficiaries doubled, with 9,000 new AWCs and 4,200 mini-AWCs established during the Eleventh Plan. Traditional medicine systems, including Ayurveda, Unani, Siddha, and homeopathy, remain prevalent.

In Odisha, health services have improved with AIIMS Bhubaneswar and multiple government medical colleges enhancing tertiary care. Rural healthcare relies on district hospitals, CHCs, and PHCs, supported by schemes like the Biju Swasthya Kalyan Yojana, which provides free medical services. However, remote areas face shortages of specialists and emergency facilities. The National Health Mission (NHM) is addressing these gaps through telemedicine and mobile health units. Odisha also prioritizes maternal and child health through initiatives like the Mamata Scheme and targeted nutrition programs.

4. Waste Management Infrastructure and Sanitation Plan

The waste management infrastructure and sanitation initiatives adopted by the state play a pivotal role in influencing the quality and biodiversity of the Mahanadi River basin, as they directly affect waste generation, resource consumption, and disposal practices. The Swachh Bharat Mission portal, as of 12 January 2025, provides a detailed overview of Chhattisgarh's efforts in this domain as depicted in Figure 13. This government initiative emphasizes capacity building and showcases significant advancements in waste processing, plastic management, and sanitation infrastructure across urban and rural regions, presenting a clear segmentation of efforts in waste management and sanitation.

Chhattisgarh has made significant progress in waste management infrastructure under the Swachh Bharat Mission. The state currently has 1,23,949 community compost pits and 1,42,108 community soak pits to facilitate the processing of organic and wastewater at the community level. Additionally, households have contributed with 1,67,760 household compost pits and 1,65,651 household soak pits. A total of 62 plastic waste management units and 191 faecal sludge management plants are operational across the state, supporting efforts to manage solid and liquid waste effectively. To enhance collection and segregation, 20,613 waste collection and segregation sheds have been established, and 24,865 vehicles have been deployed for waste transportation.

The state has constructed 35,57,124 individual household latrines (IHHLs) and 13,380 community sanitary complexes to improve sanitation access. Chhattisgarh has also promoted sustainable energy solutions through biogas plants, with 381 registered plants, of which 284 are functional. Household biogas initiatives have resulted in 2,048 household biogas units. The state is also fostering compressed biogas (CBG) infrastructure, with 19 plants registered, although only one is currently functional. Furthermore, household kitchen gardens, totalling 4,65,663, exemplify the integration of waste reuse with sustainable living practices. This comprehensive infrastructure development indicates the state's commitment to enhancing public health, sustainability, and environmental management.

Figure 13 Waste management infrastructure and sanitation initiatives in Chhattisgarh state.

(Source- Swachh Bharat Mission portal, 12 January 2025)

4.1 Wastewater Management Infrastructure in Chhattisgarh

Chhattisgarh faces significant wastewater management challenges due to a substantial gap between sewage generation and treatment capacity. The "National Inventory of Sewage Treatment Plants, March 2021" (CPCB) says that the state makes about 1,203 MLD of sewage but can only treat 73 MLD of it, so there is a 1,130 MLD capacity gap (Figure 14). Only 6% of the total generated sewage utilizes this capacity. Although all facilities are operational, only 6 MLD of the installed capacity is utilized, indicating inefficiencies in the system.

The state operates three sewage treatment plants (STPs), all using Activated Sludge Process (ASP) technology. The lack of natural treatment systems suggests an opportunity to diversify approaches for greater sustainability. However, with no STPs under construction or planned, the need for infrastructure investment is critical.

Figure 15 compares Chhattisgarh's installed capacity with other states like Maharashtra and Gujarat, showing that Chhattisgarh lags significantly, with its capacity far below industrialized states. Nationally, similar issues exist urban sewage generation increased from 7,067 MLD in 1978 to approximately 62,000 MLD by 2014-15, while treatment capacity rose from 2,758 MLD to 23,277 MLD (Figure 14). Chhattisgarh's situation reflects this disparity, highlighting inadequate planning and resource allocation. Immediate action is necessary to plan, fund, and execute wastewater management projects.

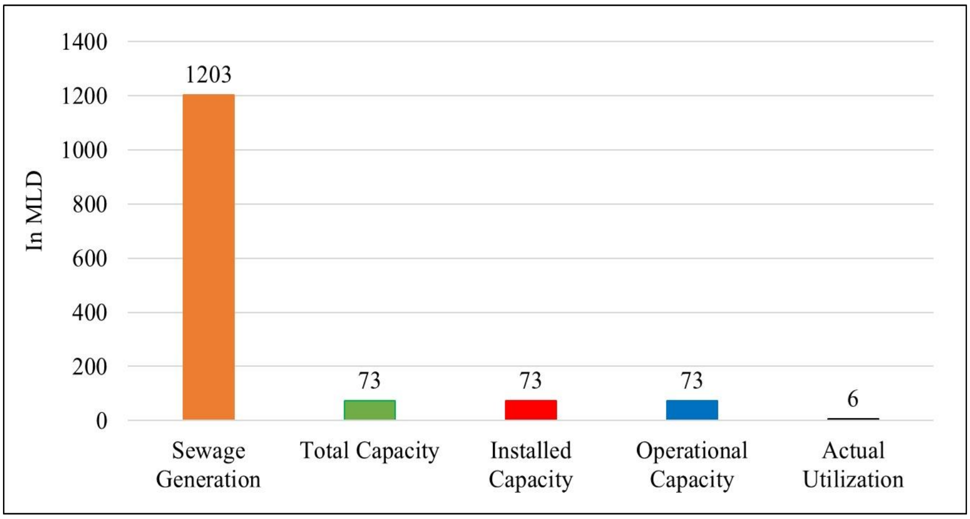


Figure 14 Wastewater management infrastructure in Chhattisgarh.

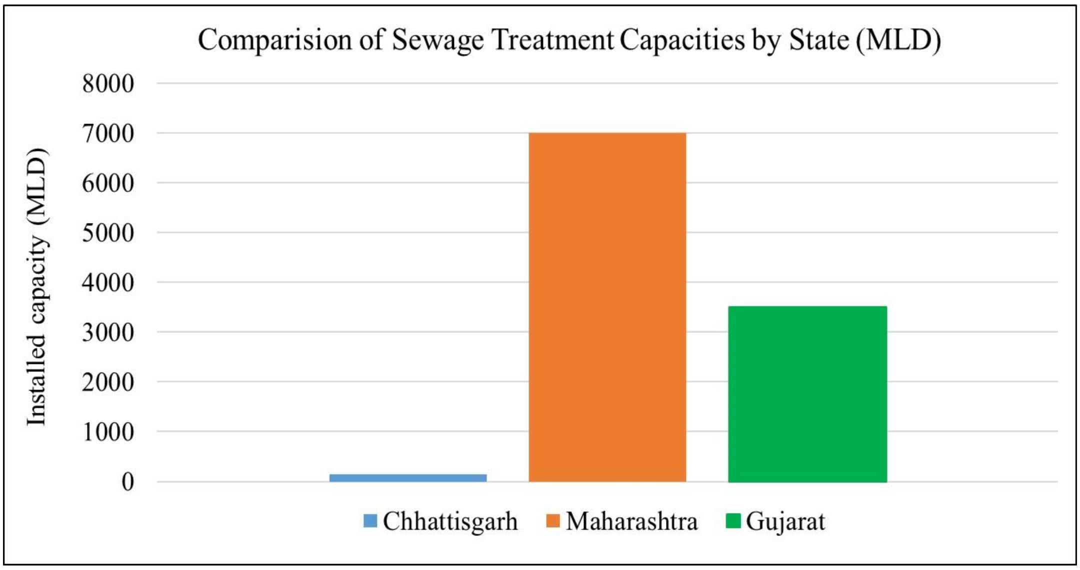


Figure 15 Installed treatment capacities.

4.2 Status of Solid Waste Management in Chhattisgarh

Chhattisgarh has achieved notable progress in solid waste management, earning the title of India's cleanest state in the Swachh Survekshan 2020. The state implemented 100% door-to-door garbage collection across all 166 urban local bodies (ULBs), with source-level waste segregation. This initiative processes approximately 1,650 metric tonnes of waste daily, converting wet waste into compost and recycling dry waste. The system has integrated over 9,000 women, known as 'Safai Didis,' enhancing efficiency and providing employment. Despite these advancements, significant challenges persist, particularly in the Mahanadi River basin. As of March 2023, Chhattisgarh generated around 600 million liters per day (MLD) of sewage, with 70.23% untreated. Additionally, 28.2% of the 3,871 tonnes of daily solid waste remained unprocessed. The National Green Tribunal (NGT) has mandated the state to allocate ₹1,000 crores to improve solid and liquid waste management systems.

Chhattisgarh has demonstrated efficiency in waste processing, achieving a 90% processing rate for 1,650 metric tonnes of waste daily in 2019, positioning it as one of the more efficient states. Cement, iron, steel, fertilizer, aluminum, power plants, waste processing units, and mine workshops are the primary sources of hazardous waste in Chhattisgarh. These facilities produce wastes like used oil, oil sludge, cathode residues, tar residue, and lead and zinc ash. As per the Hazardous and Other Wastes (Management and Transboundary Movement) Rules, 2016, the Chhattisgarh Environment Conservation Board (CECB) completed an inventory of hazardous waste generators. In April 2019, the Chhattisgarh Environment Conservation Board (CECB) issued 359 authorizations for waste management activities, approximately 314,903 MT of hazardous waste (Table 13).

Table 13 Summary of Hazardous Waste Management in Chhattisgarh.

S. No.	Type of waste	Quantity in (MT)
1	Landfillable Waste	31594.26
2	Recyclable Waste	259821.31
3	Incienerable Waste	23487.73
Total		**3,14,903.00**

(Source: https://www.enviscecb.org/)

4.3 Community Sanitation Programs in Chhattisgarh

Chhattisgarh has achieved significant progress in sanitation, particularly in the Mahanadi River Basin, through community-driven initiatives and government-supported programs. A key strategy has been the adoption of the Community-Led Total Sanitation (CLTS) approach, which prioritizes behavior change to eliminate open defecation and promote sustainable sanitation practices.

In 2011, 85% of Chhattisgarh's rural population practiced open defecation. A 2012-13 survey found over one million defunct toilets, many from earlier, poorly maintained schemes. CLTS, first implemented in Rajnandgaon and Raigarh, raised awareness of the health risks of open defecation and encouraged collective action. Community involvement, particularly through 'Nigrani Samitis' (monitoring committees), has been vital to sustaining Open Defecation Free (ODF) status. Communities are incentivized to maintain ODF status for three months, promoting accountability. Aligned with the Swachh Bharat Mission (SBM), the state integrated water and sanitation projects, constructed 160,000 toilets within nine months, and transformed 1,123 villages into ODF zones, including one entire block in Rajnandgaon. The Mahanadi River Basin, critical to the state's water resources and economy, benefited from reduced open defecation, improved public health, and enhanced water quality.

Chhattisgarh plans to establish over 18,300 community sanitation activities under the 15th Finance Commission (2023-24), emphasizing collective ownership and inclusivity. Women, particularly through self-help groups (SHGs), play a central role in these initiatives. Financial incentives, such as Rs. 12,000 per household for toilet construction, have further driven change. Capacity-building programs have trained local leaders to ensure effective implementation. The state's sanitation efforts extend beyond toilet provision, incorporating environmental sustainability through initiatives like Mission Jal Raksha, waste-to-art programs, fecal sludge treatment plants (FSTPs), and plastic waste management units (PWMUs). Over 67% of villages now adhere to the ODF Plus Model, with the goal of declaring all villages ODF Plus by December 2024.

4.4 Infrastructure Related to Sanitation and Hygiene in Chhattisgarh

This section evaluates sanitation and hygiene infrastructure in Chhattisgarh, focusing on household access, practices, drainage systems, and institutional facilities, which are vital for public health and environmental sustainability. The analysis reveals substantial gaps, rural-urban disparities, and challenges affecting marginalized groups, particularly in the Mahanadi River Basin.

Chhattisgarh's sanitation infrastructure lags national averages. According to the 2011 Census, 74% of households lacked toilets, compared to 46.9% nationally. The situation is worse in rural areas, where 85.2% of households lack toilets, compared to 21% in urban areas. Open defecation is practiced by 55.6% of households, rising to 61.2% in rural areas, with Scheduled Tribes (69.6%) and Scheduled Castes (58.6%) being the most affected (RSOC 2013-14). Improved sanitation facilities are available to only 24% of households (NFHS 2015-16), with rural areas and marginalized groups, such as SC (20.8%) and ST (15.6%) households, facing the most significant disparities. Only 35.4% of households have functional public sanitation facilities, such as Anganwadi toilets, which is marginally above the national average of 25.3%.

Efforts under the Swachh Bharat Mission (SBM) have shown progress, with toilet coverage increasing from 36.6% in 2014-15 to 57.52% in 2015-16. However, only 21.2% of households reported access to sanitary toilets, and just 19.9% used them regularly (Swachh Survekshan Gramin 2016).

Inadequate drainage systems and household bathing facilities further exacerbate issues. Only 31.1% of households have closed drainage systems, compared to 51.4% nationally, with rural areas faring worse (17.5% vs. 54.1% in urban areas). While school sanitation has improved, only 53.4% of girls' toilets are functional (ASER 2016, Figure 16), limiting their effectiveness.

Addressing these deficits requires investments in infrastructure, equitable resource distribution, maintenance, and behavioral change campaigns to ensure sustainable improvements in sanitation and hygiene.

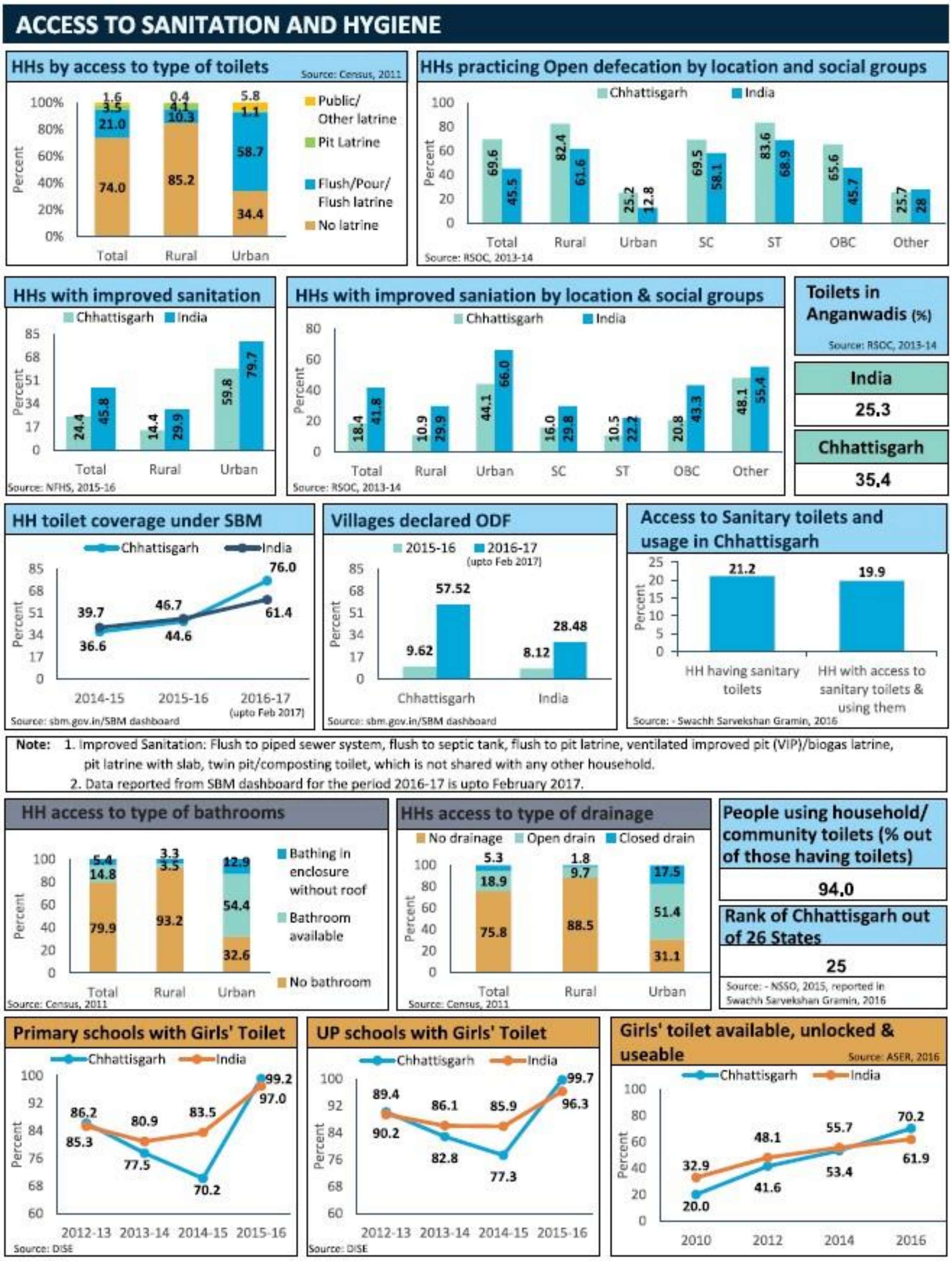


Figure 16 Community sanitation and hygiene in Chhattisgarh region.

4.5 Public toilets in Chhattisgarh

Chhattisgarh has made notable progress in improving sanitation and hygiene, particularly through various initiatives under the Swachh Bharat Mission (Figure 17). The state has constructed numerous public and community toilets to address the lack of in-home toilet facilities. Despite these efforts, challenges remain, particularly in rural areas where access to clean and functional toilets is still limited.

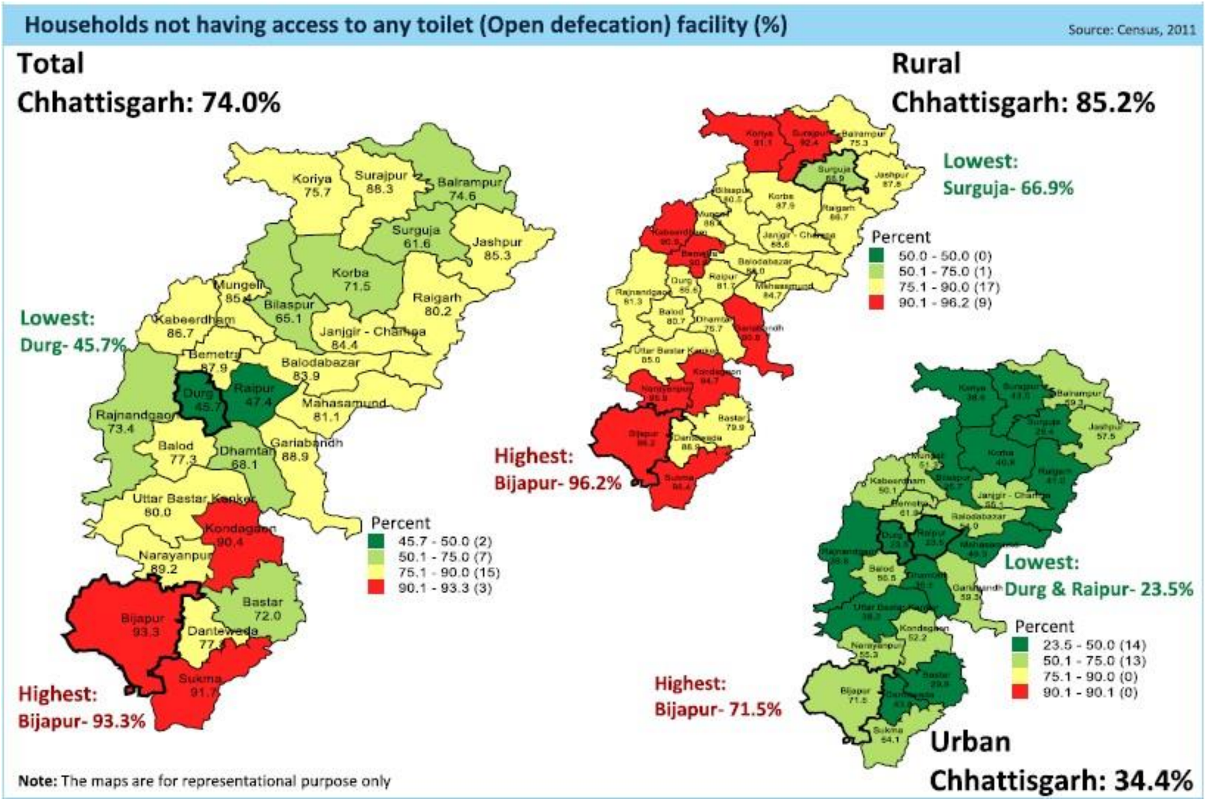


Figure 17 Household not having access to any toilet (open defecation).

As of recent data, Chhattisgarh has approximately 56.5 lakh households and a population of around 255.45 lakh. Around 36 lakh rural households have access to toilet facilities, and over 13,127 community toilets have been constructed across the state. The state had a target to build 85,000 toilets in urban areas by 2019 (Figure 17). While the state has made strides, issues like lack of water facilities and preference for open defecation persist in rural areas. In some villages, toilets have even been converted into storage spaces. In urban areas, the government has launched schemes to finance the construction of toilets, aiming for 100% coverage. Beneficiaries are expected to contribute a portion of the cost, with financial assistance from both the state and central governments.

Despite the construction of numerous toilets, several gaps remain. One of the most significant challenges is the lack of water supply, which leaves many toilets unused. Moreover, despite the availability of toilets, some villagers continue to prefer open defecation due to cultural habits or lack of awareness about the importance of sanitation. The maintenance of toilets is another issue, as many facilities fall into disrepair over time. In some remote areas, access to toilets remains limited, and women often face safety concerns when using public toilets.

Chhattisgarh is continuously working to address these gaps and improve sanitation across the state. The government is committed to achieving an Open Defecation Free (ODF) Plus status, which includes not just the construction of toilets but also their proper maintenance, ensuring access, and promoting hygienic practices. This is part of a broader initiative to improve public health and sanitation for all residents (Figure 18).

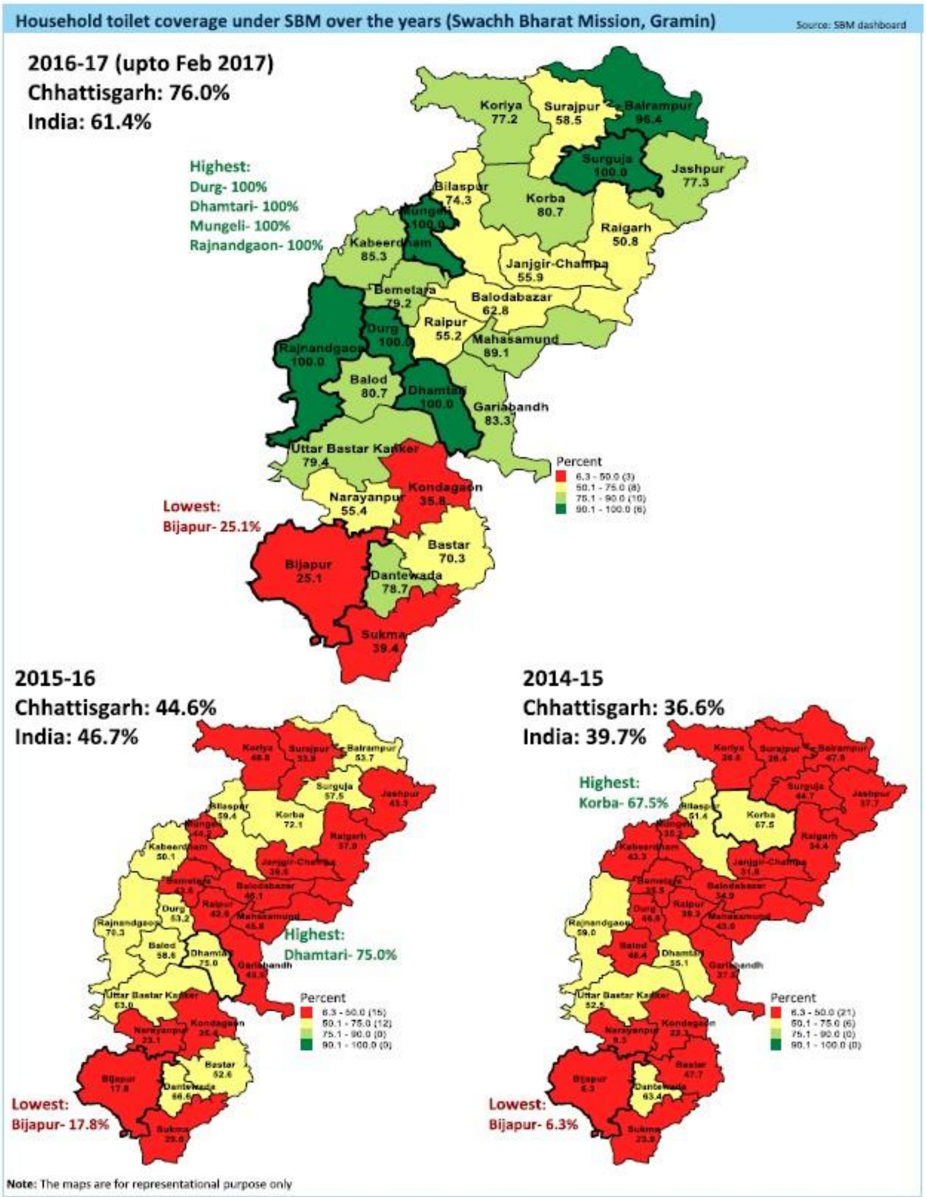


Figure 18 Household coverage under SBM.

5. Urban Development

With an urban population of 23.24, Chhattisgarh stands as the ninth least urbanized state. It is also the ninth lowest in terms of percentage decadal growth of the urban population. The Census 2011 data also reveals that the percentage growth of the urban male population was 40.09, compared to 30.06 for India, and the percentage growth of the urban female population was 43.69, compared to 33.73 for India. The data also reveals that, while the State experienced a total percentage decadal growth of 22.59 during 2001-2011, the corresponding figure for the urban population in the State was significantly higher at 41.83, indicating a dramatic increase in urbanization.

5.1 Urban Agglomerations and Population Growth

In 2011, Chhattisgarh had 182 towns, including 168 statutory towns and 14 census towns. It comprised 10 municipal corporations, 32 municipal councils, and 126 Nagar Panchayats, with an urban population of 59,36,538. The largest urban centers are Raipur, Durg, Bhilai, Bilaspur, Korba, Rajnandgaon, and Raigarh.

Figure 19 presents key demographic and household statistics, categorized by agro-climatic divisions. The state has 56,50,724 households, with 77% in rural areas and 23% in urban areas. The total population is 2,55,45,198; it is equally split between males and females. Socially, 56% of the population are Scheduled Tribes (ST), 13% are Scheduled Castes (SC), and 31% belong to other categories. The distribution of households across agro-climatic divisions shows that the Southern Region has 76% rural and 12% urban households, the Mahanadi Basin has 73.3% rural and 13.4% urban households, and the Northern Region has the highest rural concentration with 85.2% rural and 7.4% urban households (Figure 19).

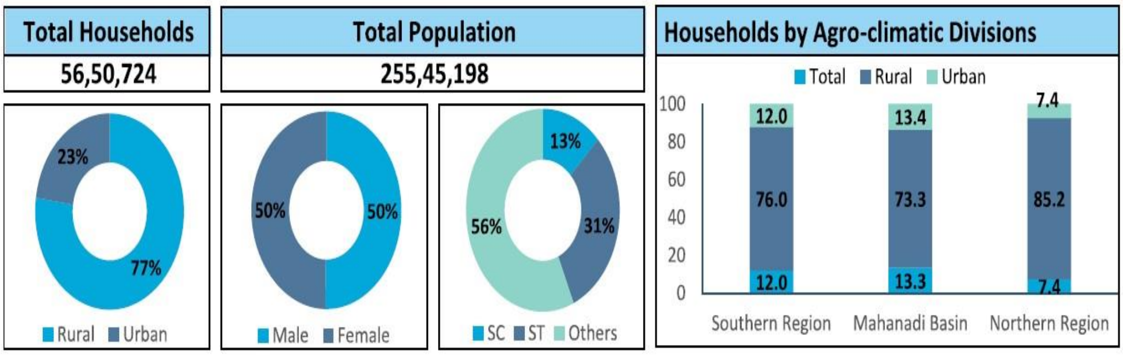


Figure 19 Urban agglomerations and population growth.

5.2 Urban Infrastructure and Services

Urban local bodies (ULBs), including municipal corporations, municipalities, and Nagar Panchayats, are responsible for urban services and public asset maintenance. The Service Level Benchmarking (SLB) conducted by the Ministry of Urban Development for 43 cities and towns in Chhattisgarh reveals significant service deficits in water supply, sewerage, solid waste management, and stormwater drainage. For instance, water supply typically lasts only 2 to 4 hours.

The SLB data highlights common challenges faced by ULBs in Chhattisgarh: inadequate budgets for water treatment plant operations, a shortage of managerial and technical staff, and a need for staff training in modern water utility management. Revenue from water sales is insufficient to cover operational costs, and the lack of water meters complicates billing for commercial and high-water users. There is no incentive to reduce water waste, and high non-revenue water (NRW) levels exacerbate the issue. ULBs must improve accounting practices and implement billing systems to ensure adequate revenue for water services.

5.3 Key Issues

The state's urban development sector faces several challenges. Rapid urban population growth is likely to worsen the existing infrastructure deficit, increasing risks unless urgent action is taken. Despite reforms, the financial health of urban local bodies (ULBs) remains concerning. Urban road congestion and traffic management are major issues, and a large urban poor population (5.45 lakh BPL families, including 2.5 lakh in slums) adds to the vulnerability of those seeking employment. Many works in the unorganized sector and live in unhygienic slums, exacerbating their situation.

A major challenge is the acute shortage of resources, with smaller towns receiving only Rs. 498 per capita, compared to Rs. 4,030 for rural areas. Programs like JNNURM support Raipur and Naya Raipur, while UIDSSMT assists Bilaspur, Raigarh, and Kondagaon. IHSDP provides partial housing support in 17 towns. To ensure balanced regional development, increased resources and technical support are needed for infrastructure and living conditions.

With future grants for ULBs expected to decline, internal resource mobilization is crucial. Strengthening ULBs' capacity to raise and manage funds, along with urban sector reforms, will be key to securing central funding and achieving self-sufficiency. Effective service delivery, infrastructure maintenance, and resource generation will determine funding access.

As recommended by the Thirteenth Finance Commission, the Second ARC, and the Planning Commission, states should devolve functions and finances to ULBs, allowing them to manage responsibilities. Initial support for planning and resource generation through tolls, taxes, and levies will be essential for sustainable urban development.

5.4 Existing/On-Going Initiatives

5.4.1 Naya Raipur

The State is developing Naya Raipur, a new greenfield city as the 4th new planned capital city in the country after Chandigarh, Gandhinagar, and Bhubaneswar, with a total area of 8000 ha. The construction of the city is taking place in three phases, spanning 21 sectors, with a planned density of 250 people/hectare and an expected average population of 16,000, expect the city to boast a comprehensive planned water supply, sewer network, planned road networks, telecom infrastructure, including a fibre optic network, an excellent power supply, and a robust social infrastructure, which includes designated areas for hospitals, educational institutes, and recreation. The city will also have large city parks, water bodies, jungle safaris, and a botanical garden. The World Bank is supporting the implementation of a Bus Rapid Transit System (BRTS) as a demonstration city for the Sustainable Urban Transport Project. The proposal also included a light rail transit system (LRTS). Other plans for Naya Raipur include a pedestrian corridor, a golf course, luxury hotels, convention centers, shopping malls, multiplexes, a cricket stadium, and demarcated areas for Special Economic Zones (SEZs), townships, etc (Figure 20).

Figure 20 Overview of Naya Raipur.

5.4.2 Integrated Municipal Solid Waste Management

Raipur has implemented a pilot project for integrated municipal solid waste management. The project entails door-to-door garbage collection, covered transportation, re-segregation, and disposal following appropriate treatment; it ensures a minimum of 80 percent recycling of the collected waste, with the use of engineered landfills not exceeding 20 percent. The project is operational in Raipur since January 2021.

5.4.3 Rapid Mass Transport Solutions: Metro Rail

Greater Raipur (Raipur, Naya Raipur, Durg, and Bhilai) is fast emerging as a metropolitan city. This gives urgency to appropriate mass rapid transport solutions. One option under exploration is Metro Rail. We estimate the track length between Rajnandgaon and Raipur to be around 93 km. The state has engaged the Delhi Metro Rail Corporation (DMRC) to conduct a pre-feasibility study of the Metro Rail project in the state. The State is forming an Urban Metropolitan Transport Authority (UMTA) to facilitate and support efforts to realize mass rapid transport solutions for Greater Raipur.

5.4.4 Urban Water Supply on 24 x 7 Basis

Water supply is on the special focus list of four municipal services in the state. The ideal scenario would be to transition to a 24 x 7 water supply with the appropriate quantity (135 lpd per capita) and quality. The Water Augmentation Scheme is about to launch a pilot on the EPC mode in outer Raipur. The supply volume is 150 mld.

5.4.5 Under Ground Urban Sewerage System

Drainage/sewerage is on the special focus list of four municipal services in the state. The state has developed plans for the recycling and reuse of wastewater. An underground sewerage scheme (UGS) pilot project is under implementation in Bilaspur under the UIDSSMT scheme of the Government of India. The estimated investment is 280 Cr. The project entails the development of infrastructure facilities that gather wastewater from various sources, channel it into a trunk underground sewerage system for proper treatment, and subsequently dispose of the treated effluent. The Bilaspur Municipal Corporation has taken on the responsibility of recycling reusable water back in the city.

5.4.6 Other Initiatives

Urban areas have introduced the Sarovar Dharohar Yojana program to renovate, revitalize, deepen, and beautify ponds and water bodies for environmental improvement. We undertook the task of renovating 50 ponds in the fiscal year 2011-12. Renovation of schools in urban areas of the state. The Gyanansthli Yojana program renovates schools in urban areas of the total sanctioned for 986 school buildings, 846 have successfully undergone construction. The program for protecting existing playgrounds and creating new ones, known as Unmukt Khel Maidan Yojna, is also underway. So far, 164 projects have received approval, with 112 already completed. We are implementing a range of programs like the Mukhyamantri Swavalambhan Yojana and Mahila Samriddhi Bazar Yojana to alleviate urban poverty and provide employment.

Eight urban bodies have initiated the Transport Nagar Yojana, which aims to simplify and streamline the state's transport system. Two projects have completed two projects and are currently working on the remains have started the Bhagirathi Nal-Jal Yojna, a new program to provide improved water supply service levels through piped water to nearly 2.5 lakh poor families living in slums situated in various urban centres at no cost. The state is undertaking a range of other such initiatives.

6. Riverbank Protection for the Mahanadi River Basin

6.1 Initiatives on River Bank Protection for the Mahanadi River Basin

The Mahanadi River Basin, one of the largest river systems in India, plays a vital role in the socio-economic and ecological well-being of the regions it traverses. However, riverbank erosion has emerged as a significant challenge, threatening agricultural lands, habitats, infrastructure, and local livelihoods. To address this, a multi-pronged approach combining afforestation, soil conservation measures, engineering interventions, and community-based initiatives has been adopted.

6.1.1 Plantation and Afforestation Initiatives

To mitigate riverbank erosion and stabilize the riverbanks, large-scale afforestation programs have been implemented in the Mahanadi River Basin. These initiatives aim to enhance soil retention, reduce runoff, and maintain the river's flow regime. Under these programs:

- In 2014-15, plantation activities were carried out over 1,276 hectares, with site preparation on 350 hectares and maintenance of 1,264 hectares of older plantations.
- In 2015-16, the plantation extended to 350 hectares, and 2,301 hectares of older plantations were maintained.

The Paudha Praday Yojana and Hariyali Prasar Yojana in Chhattisgarh have played pivotal roles in promoting urban and agroforestry. These schemes provide free saplings to urban residents and subsidized plants to rural communities for afforestation on fallow lands. The species prioritized for plantation include Bamboo (Bambusa spp.), Teak (Tectona grandis), Amla (Embilica officinalis), and Moringa (Moringa oleifera), which are selected based on their ecological and economic value.

6.1.2 Engineering Measures for Erosion Control

In addition to afforestation, structural measures are essential for riverbank protection. The Chhattisgarh government has implemented numerous engineering interventions, including:

a) **Construction of Water Augmentation Structures**

To enhance soil moisture and groundwater levels, structures such as check dams, stop dams, dykes, and loose boulder check dams have been constructed. These measures also reduce the velocity of river flow, preventing bank erosion.

- In 2019-20 and 2020-21, over 25 lakh groundwater augmentation structures were constructed at a cost of ₹370 crores, covering 7.04 lakh hectares across 1,995 drains.
- Specific focus was given to drains in protected areas, including:
  - 58 drains in the Indravati Tiger Reserve
  - 42 drains in Guru Ghasidas National Park
  - 28 drains in the Achanakmar Tiger Reserve

Narva Development Scheme: As part of the Narva Garuwa Ghurwa Baari Vikas Yojana, the revival of 1,089 forested drains has been undertaken. This initiative aims to rejuvenate groundwater reservoirs across 4,28,827 hectares of forest land, supported by funds from the Compensatory Afforestation Management and Planning Authority (CAMPA).

b) Bamboo Regeneration for Bank Stabilization

Bamboo has proven to be a highly effective species for riverbank stabilization due to its fast growth, extensive root systems, and economic benefits. The National Bamboo Mission promotes the regeneration of degraded bamboo forests along the wetlands and riverbanks of the Mahanadi Basin. Key activities include clearing dead and damaged bamboo, soil enrichment, and rhizome mounding. These efforts increase bamboo forest productivity, enhance groundwater recharge, and provide sustainable livelihoods for local communities.

c) Community Participation and Employment Generation

Community-based approaches have been central to riverbank protection efforts. Local populations, including farmers and forest-dependent communities, are actively involved in afforestation, maintenance, and soil conservation activities. The initiatives under CAMPA and other schemes have generated significant rural employment:

- Over 20 lakh man-days were created through afforestation and riverbank protection works.
- Approximately 50 lakh man-days of employment opportunities were generated through the Narva Development Plan.

d) Ecosystem Services Improvement Project (ESIP)

The Ecosystem Services Improvement Project (ESIP) complements these efforts by focusing on sustainable land and ecosystem management. The project aims to:

- Enhance forest and tree cover.
- Improve ecosystem services, including carbon sequestration and biodiversity conservation.
- Support livelihoods for small and marginal farmers through sustainable practices.

Under ESIP, degraded forestlands and non-forestlands are rehabilitated using selective investments, strengthening sustainable forest and land management practices across the Mahanadi River Basin.

6.2 Initiatives on the Riverfront Development Plan

Riverfront development balances urban growth with environmental sustainability by protecting riverbanks, enhancing public spaces, and restoring ecosystems. Techniques such as embankments, vegetation, and bioengineering stabilize riverbanks, prevent erosion, and mitigate flooding while safeguarding communities and infrastructure. Additionally, riverfronts transform underutilized areas into recreational spaces with parks, gardens, and promenades, fostering social interaction and improving urban life. Walkways promote active lifestyles and connectivity between urban and green spaces. Ecological restoration efforts include native vegetation planting and wildlife habitat creation.

Table 14 highlights key riverfront projects in Chhattisgarh, focusing on aesthetics, ecology, and recreation. The Kharun Riverfront in Raipur (2023) emphasizes beautification, recreation, and conservation, while the Mahanadi Riverfront in Janjgir-Champa (2023) prioritizes tourism and eco-restoration. The Hasdeo Riverfront in Korba (2024) plans urban parks, pathways, and ecological preservation.

Ongoing projects include the Seonath Riverfront in Durg-Bhilai (2022), featuring green spaces and public recreation; the Arpa Riverfront in Bilaspur (2022), integrating stabilization, eco-tourism, and recreation; and the Kelo Riverfront in Raigarh (2023), focusing on landscaping, water conservation, and tourism. These initiatives collectively harmonize urban development with environmental sustainability, ensuring ecosystem conservation while enhancing local economies and quality of life.

Table 14 Key riverfront development projects in Chhattisgarh.

Riverfront Project	River	Location	Status	Year	Remarks
Kharun	Kharun	Raipur	Ongoing/ Proposed	2023 (Proposed)	Beautification, recreational spaces, and conservation of the Kharun River.
Mahanadi	Mahanadi	Janjgir-Champa	Proposed	2023 (Proposed)	Tourism development, landscaping, eco-restoration, and beautification.
Hasdeo	Hasdeo	Korba	Proposed	2024 (Planned)	Urban riverfront development with parks, pathways, and ecological preservation.
Seonath	Seonath	Durg-Bhilai	Ongoing	2022	Beautification, green spaces, and public recreational facilities.
Arpa	Arpa	Bilaspur	Ongoing	2022	Beautification, riverbank stabilization, eco-tourism, and recreational zones.
Kelo	Kelo	Raigarh	Ongoing	2023	Landscaping, walking tracks, water conservation, and tourist attractions.

6.3 Existing Initiatives for Ecological Restoration of the Mahanadi River Basin

The Mahanadi River Basin is vital for ecological, cultural, and economic purposes. However, challenges like deforestation, habitat degradation, pollution, and unsustainable land-use practices have prompted the need for comprehensive ecological restoration efforts. These efforts, guided by national policies, state government initiatives, engineering interventions, and community participation, aim to restore the ecological health of the basin.

6.3.1 Afforestation and Biodiversity Conservation

Afforestation remains a core strategy for the ecological restoration of the Mahanadi Basin. Several government programs, including the Compensatory Afforestation Management and Planning Authority (CAMPA) and the National Afforestation Programme (NAP), are facilitating large-scale plantation activities to improve soil retention, reduce runoff, and bolster biodiversity conservation.

Under CAMPA, areas such as the Achanakmar Tiger Reserve and Indravati Tiger Reserve have been prioritized for restoration efforts, focusing on habitat regeneration and eco-sensitive zone development. The Chhattisgarh government's Paudha Praday Yojana and Hariyali Prasar Yojana have been instrumental in distributing free saplings to urban residents and subsidized plants to rural communities, encouraging afforestation of fallow lands and promoting sustainable forest cover.

The National Bamboo Mission (NBM) has been particularly effective in promoting bamboo cultivation along riverbanks and degraded lands. Bamboo species like Teak (Tectona grandis), Amla (Embilica officinalis), and Moringa (Moringa oleifera) are being planted for both their ecological benefits and economic potential. These efforts align with the State Forest Policy, which emphasizes the restoration of degraded ecosystems through the establishment of multi-layered near-natural forests and ensuring biodiversity conservation in critical areas.

6.3.2 Water Resource Management and Pollution Control

Water management and pollution control are central to restoring the ecological health of the Mahanadi Basin. Programs like the National River Conservation Plan (NRCP) and National Water Mission (NWM) are essential in implementing strategies for pollution control, equitable water distribution, and ecosystem rejuvenation.

Inspired by the Namami Gange Program, comprehensive strategies are being adopted to tackle issues such as untreated sewage, industrial effluents, and solid waste, which contribute to pollution in the Mahanadi River. The Chhattisgarh government's Narva Garuwa Ghurwa Baari Vikas Yojana (NGGB) has successfully revived over 1,000 forested drains, contributing to groundwater recharge and soil conservation, vital for restoring the basin's ecological balance. The deployment of Real-Time Water Quality Monitoring Systems (RTWQMS) is enabling the prompt detection of pollution incidents and ensuring better water quality management. The

State Forest Policy highlights the importance of integrated watershed management and the protection of water bodies, both of which are being implemented through these water management and pollution control initiatives.

6.3.3 Engineering and Structural Measures

Addressing the issue of riverbank erosion and stabilizing the river system has been a priority. The Mahanadi Riverbank Erosion Control Project has introduced several engineering measures such as check dams, stop dams, embankments, and loose boulder structures. From 2019-20 to 2020-21, over 25 lakh groundwater augmentation structures were constructed at a cost of ₹370 crores, benefiting 7.04 lakh hectares of agricultural land across 1,995 drains. Special efforts have been focused on protected areas like Guru Ghasidas National Park, where sediment control and hydrological balance are being addressed through targeted interventions. These initiatives are aligned with the State Forest Policy's goals of addressing soil erosion and enhancing hydrological stability through structural measures that mitigate riverbank degradation and support water retention.

6.3.4 Community Participation and Employment Generation

Community engagement is a cornerstone of the restoration initiatives. Programs like MGNREGA (Mahatma Gandhi National Rural Employment Guarantee Act) and CAMPA have provided substantial rural employment through afforestation, soil conservation, and watershed management activities.

More than 20 lakh man-days were generated from afforestation and riverbank stabilization projects. Eco-clubs and public awareness campaigns are educating local communities about the importance of sustainable practices and river conservation, fostering a collective effort towards ecological restoration. The State Forest Policy places a strong emphasis on community-driven conservation and livelihood generation, which is in harmony with the ongoing efforts to empower local populations through job creation and awareness-building programs.

6.3.5 Urban and Industrial Waste Management

To prevent pollution from urban and industrial waste, integrated waste management systems are being introduced in cities such as Raipur and Cuttack. The Central Pollution Control Board (CPCB) mandates industries to install Effluent Treatment Plants (ETPs) to reduce industrial pollution in the river.

6.3.6 Sustainable Agriculture and Livelihood Programs

The Ecosystem Services Improvement Project (ESIP), supported by the World Bank, is enhancing forest cover, improving carbon sequestration, and providing eco-friendly livelihood options for small and marginal farmers. Sustainable practices like organic farming and agroforestry are being promoted to reduce agricultural runoff and support biodiversity. These strategies are supported by the State Forest Policy's goals of integrating agricultural practices with ecological restoration, promoting sustainable agriculture, and reducing negative impacts on the river ecosystem.

6.3.7 Monitoring and Research

Ongoing studies are critical for assessing the ecological health of the Mahanadi Basin. Collaborative research efforts between the government, academic institutions, and research organizations have facilitated the development of data-driven strategies for restoration. The Mahanadi Basin Assessment Studies, led by NIT Raipur, focus on water quality monitoring, pollution control, and ecosystem services. Long-term monitoring frameworks ensure adaptive management and resilience-building to address emerging environmental challenges. The State Forest Policy underlines the need for scientific monitoring and adaptive management of ecosystems, ensuring the long-term success of restoration efforts.

7. Critical Issues and Hotspots in the Mahanadi River Basin

The Mahanadi River has witnessed fast changes during the last two decades, especially after the formation of the new state of Chhattisgarh. The Mahanadi River is considered the lifeline of Chhattisgarh state and constitutes almost 55 percent of the state's total geographical area. While the region was part of Madhya Pradesh, there were major developments in the river and its pattern has changed recently. As in the case of Chhattisgarh, the other riparian state Odisha also places equal importance on its waters for its development. Studies also show that the river itself is changing the precipitation in its catchment, and the water resources and their utilization resulting from human interventions and climatic changes (Central Water Commission 2014).

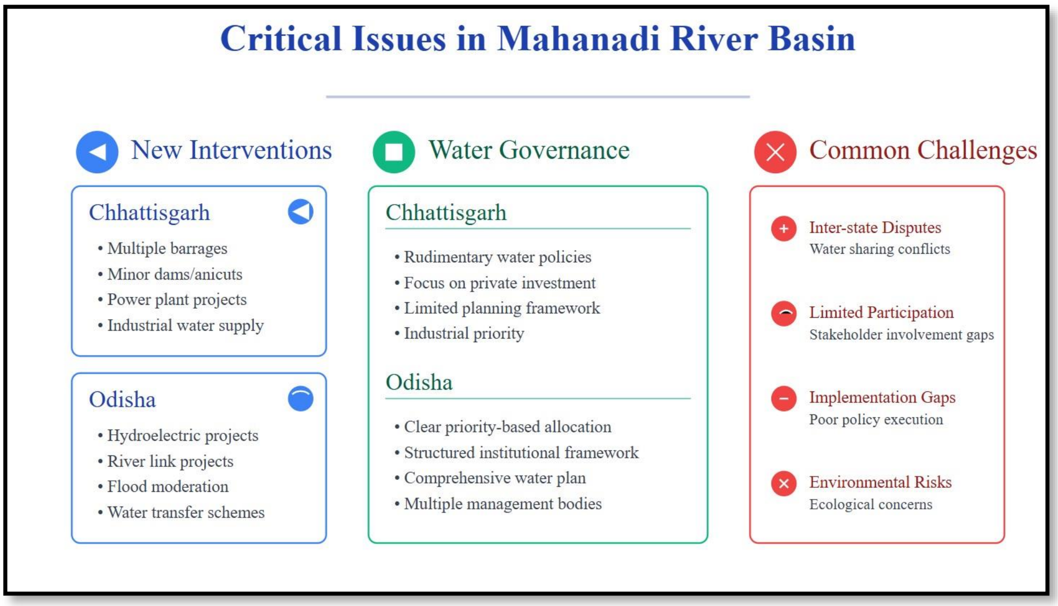


Figure 21 Critical issues in the Mahanadi River Basin.

While developmental aspirations are justifiable as various socio-economic indicators in the basin population are low, the path selected to achieve these puts a lot of stress on natural resources such as water and extractive mineral resources by both the riparian states and hence problematic. The thrust on privatization, not only of the mineral resources but even of water and rivers, as we see in the case of Chhattisgarh, is going to impact the Mahanadi in a big way in the long run. At present the river looks like it has sufficient water and has year-round flows in some stretches, but it won't take much time for it to undergo the same fate as many other rivers in the country. Hence these issues and hotspots must be identified and acted upon for ushering in a strategy for its sustainable management and development.

In the present section, we highlight the main issues or hotspots which have a bearing on river management. Some of these issues are depicted in the Figure 21. These are interlinked issues ranging from assessment and planning of the resources to sectoral allocations including the requirement for maintaining the river's health and water quality as well as conflicts around allocation across sectors and states. However, these issues/ hotspots at present are not dispersed across the basin, but in various pockets where one or the other issue is becoming crucial. In the long run, there are chances that the basin will suffer from most of these problems.

7.1 New Interventions

The development of surface water resources in the Mahanadi basin is a major point of contention between Odisha and Chhattisgarh. Several interventions, including barrages, dams, and diversion projects, are emerging in Chhattisgarh's sub-basins (Table 15).

Table 15 Recent Developments in Surface Water Resources in the Mahanadi Basin (Chhattisgarh and Odisha).

Aspects	Chhattisgarh	Odisha
New Water Projects	Numerous barrages (e.g., Samoda, Sheorinarayan, Basantpur, Kalma, Kudari), minor dams/anicuts (e.g., Amamuda, Salka, Lachhanpur), major projects (e.g., Kelo, Arpa-Bhaisajhar), Pairy-Mahanadi Intra State Link Project, Tandula Reservoir Augmentation Scheme.	Hydroelectric Projects (e.g., Salki, Barmul), Mahanadi-Brahmani River Link Project, Tel Integrated Project.
Purpose of Projects	Primarily to provide water for industries (power plants), with some Kharif irrigation.	Hydroelectric power generation, inter-basin water transfer, flood moderation
Water Allocation for Industries	Arpa River, once perennial, now becomes a dry bed in many stretches in summer.	-
Legal and Statutory Clearances	Some projects (e.g., Arpa-Bhaisajhar, Rajiv Samoda-Nisda) began without statutory technical/environmental clearances.	Projects like the Mahanadi-Brahmani Link are subject to statutory processes.
Private Sector Involvement	Private companies (especially thermal power plants) play a key role in funding and	-

	managing water resource projects (e.g., barrages).	
Water Privatization Mechanism	Private companies fund the construction of barrages, with water allocated based on investment. The government charges water use fees with a hike post-construction.	-
Inter-State Water Sharing Disputes	The new water projects (e.g., Arpa-Bhaisajhar, Kelo) exacerbate disputes over Mahanadi water allocation with Odisha.	Concerns regarding the impact of Chhattisgarh's projects on Odisha's water supply.

These projects, such as the Kelo and Arpa-Bhaisajhar projects, mainly supply water to industries. According to an analysis, eight new barrages and one anicut will give about 1258.16 MCM of water a year to more than 45 power plants in three districts, as well as some water for Kharif irrigation (Goyal, 2014).

Similarly, Odisha is developing multiple projects, including the Salki and Barmul Hydroelectric Projects, the Mahanadi-Brahmani River Link Project, and the Tel Integrated Project (Table 15). The Mahanadi-Brahmani River Link aims to optimize Hirakud reservoir spill water while mitigating floods. The proliferation of small and medium structures in sub-basins is significantly altering river flow. For instance, the Arpa River, once perennial, now runs dry for several stretches during the summer. However, some projects, such as Arpa-Bhaisajhar and Sukhanala, commenced without mandatory clearances. Many smaller projects bypass statutory requirements, raising concerns about their environmental and hydrological impact, particularly on downstream regions.

A critical issue is private companies, particularly thermal power plants, financing and using these water projects. Industries fund the construction of barrages as an advance payment for future water consumption, and post-construction water tariffs triple. Companies extract water directly from rivers in non-monsoon seasons, reinforcing water privatization trends (Yadav, 2014, as cited in Goyal, 2014). These developments not only exacerbate inter-state water disputes but also fuel conflicts over sectoral water allocation within Chhattisgarh. The impact of these projects on river ecology, livelihoods, and equitable water distribution requires further scrutiny.

7.2 Development Plans/Policies for Water Governance of Chhattisgarh State by Government Agencies/NGOs

Chhattisgarh, a newly formed state, faces significant challenges in water resource management due to underdeveloped legal and institutional frameworks. Compared to Odisha, its water policies remain rudimentary, with limited focus on planning and projections. The Chhattisgarh State Water Resources Development Policy (SWRDP) prioritizes drinking water and agriculture but lacks clear guidelines for balancing competing demands from industry and power generation. A master plan for medium and large water projects is yet to be developed, with the

State Water Resources Utilization Committee and district-level committees responsible for allocation decisions. However, the Water Resources Department (WRD) retains overall authority, making decisions on a project-by-project basis.

The state promotes private sector investment through Public-Private Partnerships (PPP) for industrial water supply, as emphasized in both the State Water Policy and Industrial Policy. However, regulatory mechanisms for private sector participation remain underdeveloped.

Chhattisgarh continues to rely on outdated laws from Madhya Pradesh, such as the Madhya Pradesh Irrigation Act (1931) and the Regulation of Waters Act (1949), which centralize control but provide limited guidance on managing water use across agriculture, industry, and domestic needs. In times of scarcity, district collectors prioritize drinking water, but broader intersectoral allocation issues remain unaddressed. The Chhattisgarh Participatory Irrigation Management (PIM) Act (2006) aims to involve Water Users Committees (WUAs) in decision-making, but these committees lack real authority due to WRD resistance.

Groundwater regulation under the Chhattisgarh Groundwater (Regulation and Control of Development and Management) Bill (2012) remains nascent, and basin-level management is lacking. The non-transparent development of Basin Master Plans, such as for Hasdeo and Seonath, weakens governance. Fragmented policies and unclear allocation mechanisms have intensified conflicts within Chhattisgarh and with Odisha. Growing industrial demands and privatization risks further strain water access, while the absence of a priority framework complicates dispute resolution. Strengthening legal, institutional, and participatory mechanisms is essential for sustainable water management and conflict mitigation in Chhattisgarh.

7.3 Development Plans/Policies for Water Governance of Odisha State by Government Agencies/NGOs

Odisha's Water Policy prioritizes water allocation in the following order: drinking water and domestic use, ecology, irrigation and agriculture, hydropower, industries (including agro based), navigation, and other uses like tourism. The Odisha Water Resources Consolidation Project (OWRCP) has reinforced this policy by introducing a structured institutional framework under the Department of Water Resources (DoWR).

Key agencies include the Odisha Water Planning Organization (OWPO) for macro-level planning; the Water Resource Board (WRB) for policy formulation; the Water Allocation Committee (WAC) for allocation oversight; and River Basin Organizations (RBOs) for managing water resources at the river basin level. Water Users' Associations (WUAs), or Pani Panchayats, handle local irrigation management. The WRB, as the highest authority, formulates policies, with the OWPO serving as its secretariat. However, these bodies face criticism for being techno-bureaucratic, lacking stakeholder representation, and limiting community participation. Notably, an RBO exists only for the Baitarani River basin.

Odisha's State Water Plan outlines resource management, sectoral demands, allocation, and institutional frameworks. It includes a basin-scale analysis of industrial water requirements but suffers from unreliable baseline data, affecting demand projections. Legal instruments guiding water governance include the Orissa Irrigation Act, 1959 (with amendments), and the Orissa Pani Panchayat Act, 2002, which now involves fisherfolk in water management. Groundwater is regulated under the Orissa Groundwater (Regulation and Control) Bill, 2011, requiring users to register structures and restricting abstraction in notified areas.

Despite these frameworks, Odisha's water governance struggles with poor implementation, lack of democratic decision-making, and limited stakeholder participation. The absence of transparent guidelines results in ad-hoc decision-making and secrecy, undermining the effectiveness of the institutional and legal frameworks.

8. Gaps and shortcomings in initiatives and plans for the Mahanadi River Basin

The Mahanadi River Basin, vital for central and eastern India, faces major challenges due to rapid urbanization, inadequate infrastructure, and resource mismanagement. Key issues include outdated water supply systems with leakage losses of up to 50% and poor coordination between urban planning and water resource management. Unplanned urban growth has encroached on ecologically sensitive areas, reducing groundwater recharge and increasing flood risks. Inefficient stormwater drainage systems further exacerbate urban flooding and economic disruptions.

Urban centers like Raipur and Bilaspur in Chhattisgarh, as well as Sambalpur and Cuttack in Odisha, struggle with inadequate water distribution. Studies show leakage losses between 30–50%, worsening supply issues (Figure 22). The lack of integration between urban planning and water management results in networks misaligned with demographic expansion. For instance, Raipur, despite its proximity to water sources, faces chronic summer shortages, highlighting inefficiencies in resource utilization.

Urban expansion often disregards zoning regulations, leading to encroachments on wetlands and floodplains. In Bhubaneswar, rapid sprawl has significantly impacted wetlands like Ekamra Kanan and Chandaka, crucial for groundwater recharge. Reports indicate a 200% rise in impervious surfaces over two decades, reducing groundwater replenishment and increasing flood risks. Additionally, unregulated development undermines sustainability by converting agricultural and conservation zones into residential and industrial areas. Addressing these challenges requires coordinated planning, infrastructure modernization, and strict enforcement of zoning regulations to ensure sustainable water management in the basin.

Stormwater drainage systems in the Mahanadi Basin are outdated and poorly maintained, making them ineffective against increasingly intense rainfall due to climate change. Inadequate desilting worsens urban flooding, as seen in Cuttack and Bhubaneswar during the 2023 monsoon, highlighting the urgent need for climate-resilient stormwater management.

Wastewater management is another critical issue. The Mahanadi and its tributaries receive treatment for less than 30% of urban wastewater. Industrial effluents and domestic sewage from cities like Sambalpur and Raipur significantly degrade water quality, with high levels of pollutants posing severe health risks. Insufficient investment and weak enforcement of pollution control regulations exacerbate this problem.

Solid waste management also remains inadequate. Cities such as Bhilai, Durg, and Puri generate about 6,000 metric tons of waste daily, but only 60% is collected and 20% properly processed. Dumping much of the waste in open areas contaminates water bodies and degrades riparian habitats. Informal waste-picking, though providing livelihoods, lacks integration into formal systems, further reducing efficiency.

Sanitation initiatives have fallen short, despite programs like the Swachh Bharat Mission improving toilet coverage. Infrastructure-focused efforts have overlooked behavioral change, and open defecation persists in rural and peri-urban areas, especially among marginalized groups in Balangir and Nuapada. Insufficient community participation hinders long-term impact.

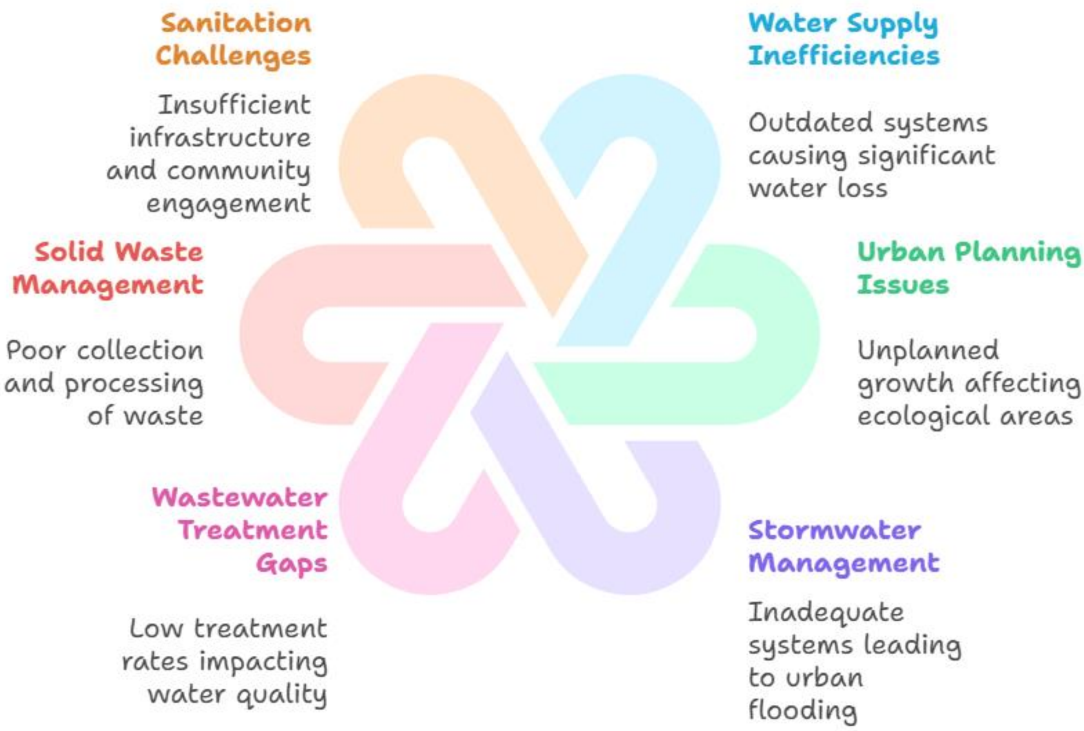


Figure 22 Gaps and shortcomings in initiatives and plans for the MRB.

Recreational space development and riverbank protection are lacking. The Mahanadi's banks suffer from encroachments, pollution, and erosion due to unregulated sand mining and deforestation. Proposed projects, such as Cuttack's riverfront development, face land-use conflicts and poor coordination. About 15% of the basin's riverbanks experience severe erosion, requiring urgent intervention.

Limited financial, technical, and human resources further compound these challenges. Budgetary allocations are often insufficient, with funds diverted to immediate crises rather than long-term planning. Municipal corporations in Odisha and Chhattisgarh report deficits in waste and water management budgets, while weak governance structures and poor interdepartmental coordination hinder effective implementation.

Water resource management suffers from inefficiencies and conflicts among agricultural, industrial, and domestic sectors. Overextraction, especially in Raigarh and Jharsuguda, depletes groundwater, while climate change exacerbates stress on water availability. Despite these issues, integrated water resource management (IWRM) remains underutilized, with sectoral approaches prevailing. Addressing these challenges requires a comprehensive, sustainable approach. Investments in modern infrastructure, such as smart water grids and decentralized wastewater treatment, can improve efficiency. Integrated urban planning and nature-based stormwater solutions, like green roofs and permeable pavements, can mitigate urban flooding.

Enhancing waste management through formalized waste-picking and circular economy principles will improve efficiency. Community-driven sanitation efforts should emphasize behavioral change and facility maintenance. Riverbank restoration through bioengineering and afforestation can preserve the ecological and cultural significance of the Mahanadi. Therefore, stronger resource allocation and governance are essential. Increased infrastructure funding, technical training, and improved interdepartmental coordination will enhance implementation and monitoring. Multi-stakeholder collaboration is necessary for holistic and integrated management of the basin.

8.1 Data Gaps

Figure 23 illustrates the data gaps identified in the Mahanadi River Basin (MRB), highlighting areas where critical information is lacking for comprehensive analysis and effective decision-making.

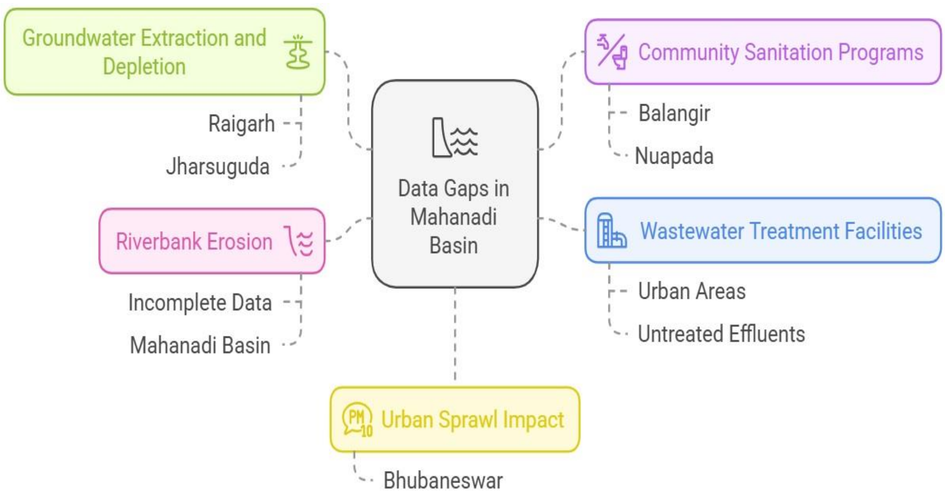


Figure 23 Data gaps in Mahanadi River Basin.

The key data gaps observed during the preparation of the present reports includes:

- Insufficient data on the exact extent of groundwater extraction and depletion across all regions in the basin, specifically in areas like Raigarh and Jharsuguda.
- Limited data on the effectiveness of existing community sanitation programs, especially in rural and peri-urban areas like Balangir and Nuapada.
- Lack of detailed data on the impact of urban sprawl on groundwater recharge and wetland encroachment, particularly in cities like Bhubaneswar.
- Missing data on the exact status of wastewater treatment facilities in various urban areas and the proportion of untreated effluents being discharged into the river system.
- Incomplete data on the level of riverbank erosion across the entire Mahanadi basin, with statistics available for only certain areas.

8.2 Data Uncertainties

Figure 24 illustrates the data uncertainties in the Mahanadi River Basin (MRB), highlighting the variability and potential gaps in the available datasets critical for accurate analysis and modeling.

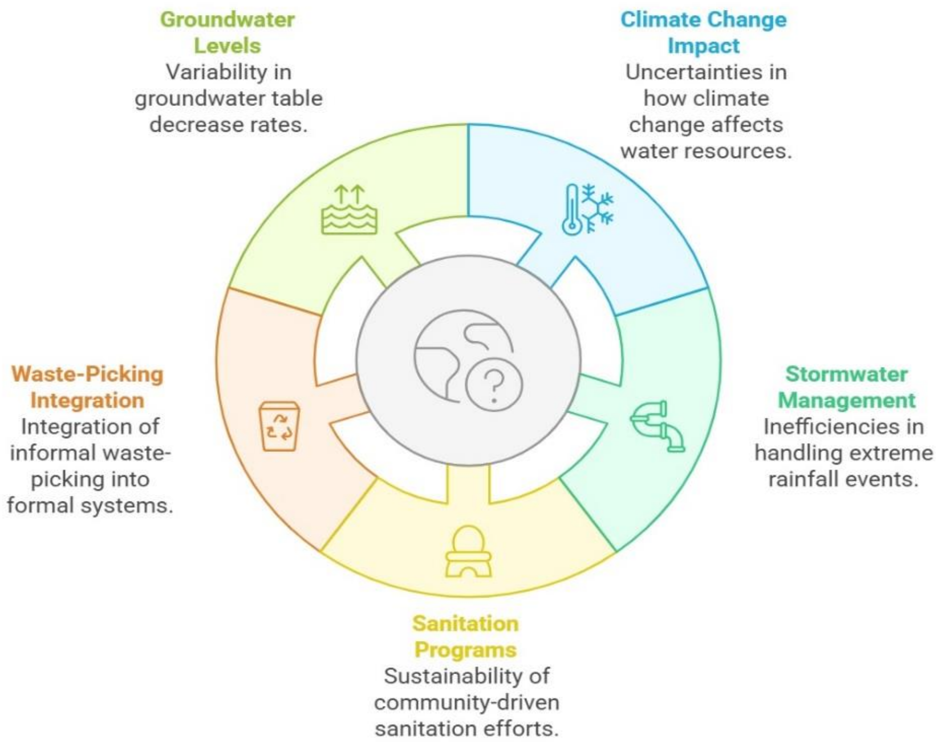


Figure 24 Data uncertainties in MRB.

The key uncertainties observed during the preparation of the present reports includes:

- The extent of the impact of climate change on water resources, including altered precipitation patterns and increased evapotranspiration rates, remains uncertain.
- The full scope of stormwater management inefficiencies, such as the capacity of drainage systems to handle future extreme rainfall events, is not fully understood.
- The long-term effectiveness and sustainability of community-driven sanitation programs, particularly in terms of behavioral change and local engagement, are still uncertain.
- The exact level of informal waste-picking activities and their potential integration into formal waste management systems needs further investigation.
- The rate of decrease in groundwater tables in different parts of the basin, such as Raigarh and Jharsuguda, remains uncertain, affecting future water availability projections.

8.3 Utility of the Data

Figure 25 illustrates the data utility in the Mahanadi River Basin (MRB), highlighting its application and significance in the context of the study.

- Data on infrastructure systems like water supply networks and stormwater drainage reveal gaps in service delivery and resource management, highlighting areas for improvement.
- Information on urban expansion and the loss of ecologically sensitive areas guides better land-use planning and zoning regulations and highlights the impacts of unplanned urban growth.
- Information about water quality, inefficient wastewater treatment, solid waste management, and riverbank erosion shows that treatment facilities need to be updated, waste management needs to be improved, and riverbank protection needs to be strengthened.

Figure 25 Data utility in the MRB.

8.4 Suggestions for Future Improvements of the Reports

For future improvements in the Mahanadi River Basin, a multifaceted approach is required that prioritizes sustainability, resilience, and equity. Modernizing infrastructure is crucial, particularly in water supply systems, wastewater treatment, and stormwater management. Investment in smart water grids and decentralized treatment facilities can significantly improve resource use efficiency and reduce waste. Figure 26 illustrates the suggestions for future improvements of the reports in the Mahanadi River Basin (MRB), highlighting key areas for enhancing the accuracy, comprehensiveness, and usability of the documentation.

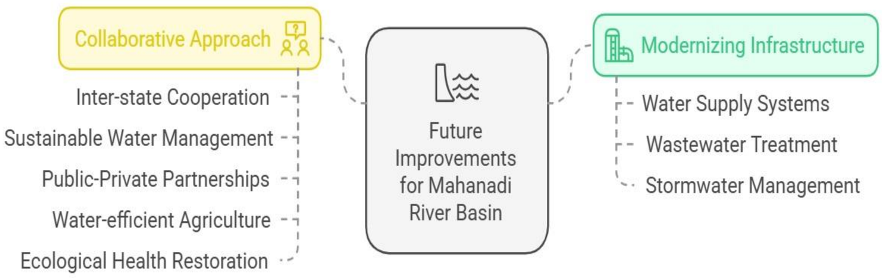


Figure 26 Importance of Stakeholder Engagement and Addressing their Needs in Reports.

The report emphasizes that improving the Mahanadi River Basin requires a collaborative approach involving multiple stakeholders. Figure 27 illustrates the significance of stakeholder engagement and the importance of addressing their needs in the infrastructure planning report within the Mahanadi River Basin (MRB). Key recommendations include:

- Strengthening inter-state cooperation for water governance.
- Prioritizing sustainable and equitable water resource management.
- Enhancing urban infrastructure and sanitation through public-private partnerships.
- Expanding irrigation and promoting water-efficient agriculture.
- Protecting riverbanks and restoring ecological health through afforestation, pollution control, and community-based initiatives.

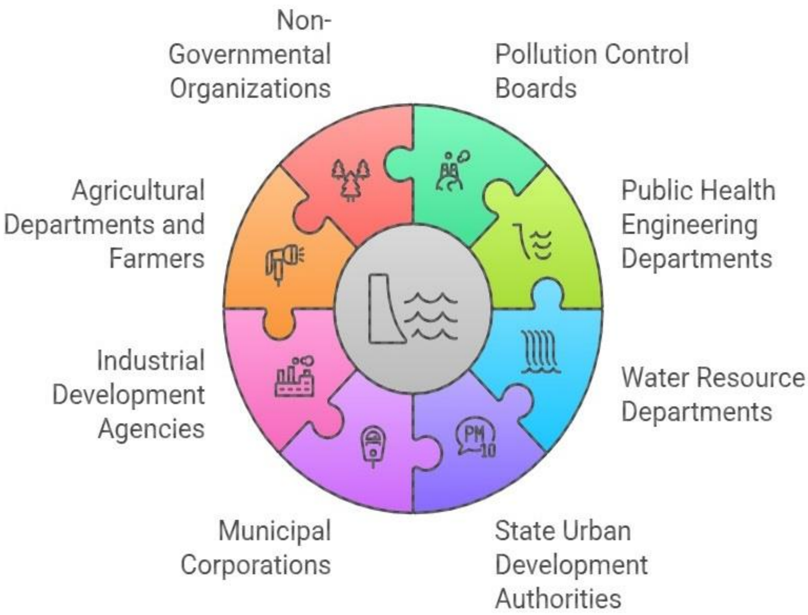


Figure 27 Significance of stakeholder engagement and the importance of addressing their needs in reports within the MRB.

a) **Pollution Control Board (PCB)**

The report will play a crucial role in pinpointing the pollution sources that impact the health of the river. **Pollution Control Board** can use the data on industrial effluents, urban runoff, and agricultural practices as a guide to monitor compliance with environmental regulations, enforce stricter pollution control measures, and develop strategies for restoring river ecosystems. This is essential for mitigating the adverse effects of pollution on public health and biodiversity.

b) **2. Public Health Engineering (PHE) Departments**

Public Health Engineering Department can benefit from insights into water supply infrastructure gaps highlighted in the report. By understanding the current state of water quality and sanitation facilities, PHE departments can prioritize investments in safe drinking water projects and wastewater treatment systems, addressing critical public health issues in both urban and rural areas.

c) **Water Resource Departments (WRDs)**

The **Water Resource Departments (WRDs)** of Chhattisgarh and Odisha will need the reports thorough analyses to make good water management policies. Findings of inefficient irrigation and over-exploitation of groundwater will help WRDs make targeted changes to improve resource sustainability. These changes will include improving watershed management and optimizing irrigation practices to make sure everyone has equal access to water resources.

d) **State Urban Development Authorities (SUDA)**

State Urban Development Authorities (SUDA) can utilize the report to address urbanization challenges within the basin. The insights into urban infrastructure needs, including waste management systems and stormwater drainage, will assist SUDA in developing integrated urban plans that accommodate population growth while safeguarding environmental integrity. This is crucial for preventing urban flooding and ensuring sustainable urban development.

e) **Municipal Corporations**

Municipal Corporations are at the forefront of implementing local infrastructure projects. The report provides them with essential data on wastewater management deficiencies, enabling municipalities to plan for new sewage treatment facilities or upgrades to existing ones. This is particularly important for improving sanitation services and reducing pollution entering the river system.

f) **Industrial Development Agencies**

Industrial Development Agencies can utilize insights from the report to promote sustainable industrial practices. By understanding the implications of industrial water use on local resources, these agencies can encourage industries to adopt cleaner technologies that reduce water consumption and minimize environmental impacts.

g) **Agricultural Departments and Farmers**

Agricultural Departments can leverage the findings related to irrigation potential and agricultural water use efficiency. By promoting best practices for sustainable agriculture, these departments can enhance crop productivity while minimizing water wastage. The report's recommendations on expanding irrigation coverage will be particularly beneficial for farmers who rely heavily on agriculture for their livelihoods.

h) **Non-Governmental Organizations (NGOs)**

Non-Governmental Organizations (NGOs) engaged in community development can use the report as a foundation for advocacy efforts aimed at improving local water management practices. The emphasis on community participation in sustainable practices provides NGOs with a framework for designing impactful programs that enhance local resilience against climate change impacts.

i) **Academia and Research Organizations**

Academic Institutions and Research Organizations can draw upon this comprehensive dataset for further research initiatives focused on hydrology, environmental science, and sustainable development within the Mahanadi Basin. The report serves as a rich resource for developing innovative solutions to address pressing challenges faced by the basin.

9. Conclusions

The Mahanadi River Basin (MRB) is a critical water resource for Chhattisgarh and Odisha, supporting irrigation, industrial growth, power generation, and drinking water supply. However, sustainable development requires addressing challenges in infrastructure, water utilization, and equitable distribution.

While both states have abundant water resources, disparities exist in irrigation coverage, groundwater use, and infrastructure. Despite having abundant surface water, Chhattisgarh underutilizes its irrigation potential, leaving much of its land dependent on rainfall. Odisha, though more advanced in irrigation, faces imbalances in regional development and underperformance in industrial and drinking water sectors. These disparities highlight the need for an integrated water management framework across the basin.

Key infrastructure projects, such as dams, barrages, and lift irrigation schemes, reflect the states' efforts to harness the Mahanadi's potential. However, these projects have led to environmental and social concerns, with industrialization, privatization of water resources, and inter-sectoral water allocation creating conflicts. Odisha's opposition to Chhattisgarh's upstream projects over concerns about downstream water availability highlights the need for transparent water-sharing agreements. Environmental sustainability is crucial, with infrastructure impacts, reduced tributary flows, and ecosystem degradation threatening the basin's health. Balancing development with environmental assessments, restoration projects, and community engagement is essential.

The differing governance approaches of Chhattisgarh and Odisha reveal opportunities for improvement. Odisha's structured river basin organizations contrast with Chhattisgarh's reliance on outdated legal frameworks. Both states face challenges in stakeholder participation, transparency, and adaptive management. Strengthening institutional capacities and fostering inter-state cooperation can align water development with socio-economic and environmental goals.

Future strategies should focus on equitable water distribution, efficient irrigation, and sustainable industrial growth while maintaining ecological integrity. To deal with new problems and protect the Mahanadi's role in the region's growth and the environment, it is important to take a basin-wide approach that includes technology, inclusive planning, and strong legal frameworks.

10. Recommendations

We recommend several measures to improve the sustainable management of water resources in the Mahanadi River Basin (MRB) and address challenges in Chhattisgarh and Odisha. Chhattisgarh has 41,720 MCM of surface water and 11,960 MCM of groundwater potential, but currently irrigates only 16% of its cultivable land. With the potential to expand irrigation to 75%, the state should focus on improving irrigation efficiency. Odisha has 43.07 lakh hectares that could be irrigated by 2020. To close the 19% gap between created and used capacity, systems need to be improved and projects like the Lower Suktel Project and Gangadhar Meher Lift Canal System need to be finished.

Chhattisgarh has built 74 irrigation projects and 253 dams, but disparities exist. For example, Dhamtari has achieved 131% of its irrigation potential, while districts like Dantewada and Korba remain under 7%. Investments should target underperforming regions. Odisha, with 82.841 BCM of annual surface water and 16.69 BCM of groundwater resources, should focus on improving inter-district irrigation and adopting modern technologies.

Chhattisgarh industries consume 1,258.16 MCM of water annually, highlighting the need to address growing industrial demand, which impacts agriculture and drinking water. Both states should improve water governance and explore public-private partnerships. Odisha, with 1,184.5 MW of hydroelectric potential, should balance power generation with ecological conservation through initiatives like the Tel Integrated Project and Mahanadi-Brahmani River Link Project.

Revitalization efforts, such as the Kharun Riverfront in Chhattisgarh and beautification projects in Odisha, should integrate ecological restoration with community development. With 7.45 BCM and 7.35 BCM of live storage capacities in Chhattisgarh and Odisha, respectively, expanding storage projects and constructing 27 proposed barrages are critical. Resolving disputes, like those over the Arpa-Bhaisajhar barrage, requires collaborative interstate mechanisms.

Ultimately, sustainable water resource development in MRB depends on expanding infrastructure, ensuring equitable distribution, preserving ecology, and engaging stakeholders to support agriculture, industry, and livelihoods.

Acknowledgment

The Centre for Mahanadi River Basin Management and Studies (cMahanadi), NIT Raipur, and NIT Rourkela express their sincere gratitude to the following agencies and institutions for their invaluable support and contributions in the preparation of the "**Infrastructure and Planning Report**" for the Mahanadi Basin: We extend our thanks to the following agencies for providing data and support in the preparation of the report –

- Revenue & Disaster Management Department, Government of Chhattisgarh
- Data Centre, Water Resource Department, Govt. of Odisha
- Environment and Forest Department, Government of Chhattisgarh
- Central Pollution Control Board (CPCB)
- Water Resource Department Government of Chhattisgarh
- Chhattisgarh State Electricity Board Government of Chhattisgarh
- State Urban Development Agency Government of Chhattisgarh
- Environment Conservation Board Government of Chhattisgarh
- Public Health Engineering Department Government of Chhattisgarh
- Chhattisgarh Housing Board Government of Chhattisgarh
- Chhattisgarh Transport Department Government of Chhattisgarh
- Indian Audit and Accounts Department Government of Chhattisgarh
- Department of Higher Education Chhattisgarh Government of Chhattisgarh
- Town and Country Planning, Atal Nagar, Raipur Government of Chhattisgarh
- Special Economic Zones Government of Chhattisgarh
- National Health Mission Government of Chhattisgarh
- Pradhan Mantri Awas Yojana Government of Chhattisgarh
- Atal Mission for Rejuvenation and Urban Transformation Government of Chhattisgarh
- National Water Mission Government of India
- Narva Garuwa Ghurwa Baari Vikas Yojana Government of Chhattisgarh
- National Afforestation Programme Government of India
- Swachh Bharat Mission Government of India

References

- Central Water Commission (2011). Mahanadi. Retrieved on June 2017, from Water Resources Information System: http://india-wris.nrsc.gov.in/wrpinfo/index.php?title=Mahanadi
- Central Water Commission (2012). Integrated hydrological data book (non-classified river basins). CWC, Government of India.
- Central Water Commission (2013). Water and related statistics. CWC, Government of India. Retrieved June 24, 2017, from http://www.cwc.nic.in/main/downloads/Water%20and%20 Related%20Statistics-2013.pdf
- Directorate of Economics and Statistics, Ministry of Agriculture (2014). Land use, cropping, and irrigation statistics (1993-94 to 2013-14). Retrieved from DES, Ministry of Agriculture and Farmers Welfare, Government of India: http://eands.dacnet.nic.in/
- Government of Chhattisgarh (2014) Industrial Policy 2014-19. Retrieved December 2016 from, Department of Commerce & Industries, Government of Chhattisgarh: https://industries. cg.gov.in/pdf/policy2014-19/Industrial%20Policy%202014-19%20Translated%20 12Feb2016.pdf
- Gupta, S.K. and Deshpande, R.D. (2004). Water for India in 2050: first-order assessment of available options, Current Science, 86 (9), pp: 1216-1214.
- Ministry of Water Resources (2014). Mahanadi basin report. MoWR, Government of India. Retrieved June 24, 2017, from http://www.india-wris.nrsc.gov.in/Publications/ BasinReports/Mahanadi% 20Basin.pdf
- Central Water Commission (2016a). Major and medium projects in the Mahanadi River basin. Retrieved from Water Resources Information System of India (WRIS): http://www.India wris.nrsc.gov.in/wrpinfo/index.php?title=Major_Medium_Irrigation_Projects_in_Mahanadi_Basin
- Goyal, A. (2014). Seven new barrages: Giving birth to many conflicts. Internship report submitted to Forum for Policy Dialogue on Water Conflicts in India. Available at, water conflict forum, org/lib_docs/INT_RPT_AG_Seven_New_Barrages.pdf
- Central Water Commission (2016b). Minutes of the Meeting of Hon'ble Chief Ministers of Odisha and Chhattisgarh held under the Chairmanship of Hon'ble Minister of MoWR to consider various water resource issues in the Mahanadi Basin on 17-09-2016. Ministry of Water Resources, Government of India
- Government of India (2012) National Water Policy, Retrieved from, Ministry of Water Resources, GoI: http://wrmin.nic.in/writereaddata/NationalWaterPolicy/NWP2012Eng6495132651.pdf accessed in December 2016
- Ministry of Water Resources (2014). Mahanadi basin report. MoWR, Government of India. Retrieved June 24, 2017, from http://www.india-wris.nrsc.gov.in/Publications/ BasinReports/Mahanadi% 20Basin.pdf
- Ministry of Water Resources (2016). Draft National Water Framework Bill. MoWR, Government of India
- Central Water Commission (CWC) 2014. Mahanadi Basin, Version 2.0.

- Chhattisgarh State Center for Climate Change (CSCCC), 2019. Water Resource Management for Improved Climate Resilience in Chhattisgarh part of Mahanadi River Basin. http://cgclimatechange.com/wp-content/uploads/ 2019/05/WRM-Full-Report-V1-min.pdf India-WRIS. (n.d.). Retrieved April 20, 2023, from https:/ /indiawris.gov.in/wris/#/
- Central Water Commission (2016b). Major and medium projects in the Mahanadi River basin. Retrieved from Water Resources Information System of India (WRIS): http://www.india wris.nrsc.gov.in/wrpinfo/index.php?title=Major_Medium_Irrigation_Projects_in_Mahanadi_Basin
- Central Water Commission (2014). National register for large dams. Retrieved from http://www.cwc.nic.in/main/downloads/New%20NRLD.pdf
- Department of Water Resources, Government of Chhattisgarh (2015). Allocations of water to industries from planned barrages on Mahanadi River.
- https://nihroorkee.gov.in/sites/default/files/uploadfiles/Env-Flows.pdf
- https://www.globalwaters.org/resources/blogs/swp/water-and-ecosystems-importance-environmental-flows
- https://www.futurewater.eu/expertise/river-basin-management/
- https://waterconflictforum.org/lib_docs/Environmental%20flows%20in%20River%20Basin%20Planning_revised%20draft%2018122017.pdf
- https://www.researchgate.net/publication/232413713_Implication_of_environmental_flows_in_river_basin_management
- https://wires.onlinelibrary.wiley.com/doi/10.1002/wat2.1565
- https://waterconflictforum.org/env-flows