URMP Report Muzaffarpur

May 2026

Project title: Preparation of Urban River Management Plan for Six Cities in Bihar

Submitted to -

National Mission on Clean Ganga

National Institute of Urban Affairs

Submitted by Project Consultants - Consortium of

All India Institute of Local Self Government

ICF Consulting, India Private Limited

ACKNOWLEDGEMENTS

This report is a collaborative effort of NMCG and NIUA along with Muzaffarpur Municipal Corporation for the preparation of Urban River Management Plan for cities in Bihar.

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Disclaimer: The interventions proposed in this Draft URMP document (Version 1) are prepared in consultation with city stakeholders, NIUA, and NMCG as project concepts. For its implementation, a Detailed Project Report (DPR) needs to be prepared.

Publication Year – 2026

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GLOSSARY

Abbreviation	Full Form
AMRUT	Atal Mission for Rejuvenation and Urban Transformation
BOD	Biochemical Oxygen Demand
BSDMA	Bihar State Disaster Management Authority
BSPCB	Bihar State Pollution Control Board
BSAPCC	Bihar State Action Plan on Climate Change
BUIDCO	Bihar Urban Infrastructure Development Company
CGWB	Central Ground Water Board
CMMU	City Mission Management Unit
COD	Chemical Oxygen Demand
CPHEEO	Central Public Health and Environmental Engineering Organization
CPCB	Central Pollution Control Board
DGCs	District Ganga Planning Committee
DEP	District Environment Plan
DEWATS	Decentralized Wastewater Treatment System
DO	Dissolved Oxygen
DPR	Detailed Project Report
EO	Executive Officer
FPZ	Flood Plain Zoning
GDDP	Gross District Domestic Product
MNN	Muzaffarpur Nagar Nigam
IHHL	Individual Household Toilets
MoEF&CC	Ministry of Environment, Forest & Climate Change
MoHUA	Ministry of Housing and Urban Affairs
MSL	Mean Sea Level
MSWG	Multi-Stakeholder Working Group
NDVI	Normal Difference Vegetation Index
NGT	National Green Tribunal
NIC	National Informatics Centre
NIUA	National Institute of Urban Affairs
NMCG	National Mission on Clean Ganga
NWIC	National Water Informatics Centre
OHT	Over Head Tank
PHED	Public Health and Engineering Department
RCD	Road and Construction Department
SBM	Swachh Bharat Mission
SDRF	State Disaster Response Force
SPVs	Special Purpose Vehicles

Abbreviation	Full Form
STP	Sewage Treatment Plant
UDHD	Urban Development and Housing Department
ULB	Urban Local Bodies
URMI	Urban River Management Index
URMP	Urban River Management Plan
WRD	Water Resource Department

EXECUTIVE SUMMARY

EXECUTIVE SUMMARY

The Urban River Management Plan (URMP) for Muzaffarpur has been prepared under the guidance of the National Mission for Clean Ganga (NMCG) and the National Institute of Urban Affairs (NIUA) with the objective of mainstreaming river-sensitive planning within the city's development trajectory. The Burhi Gandak River forms the ecological spine of Muzaffarpur, shaping its historical growth, land use patterns, and socio-cultural practices. The river, along with its network of ponds, wetlands, and natural drainage channels, has traditionally supported groundwater recharge, agriculture, and local livelihoods. However, over time, increasing urbanisation, expansion of built-up areas, and inadequate infrastructure provisioning have disrupted this delicate river–city relationship. The resulting pressures have manifested in declining water quality, encroachment into floodplains, obstruction of natural drainage, and heightened flood vulnerability, particularly in low-lying and densely developed parts of the city.

The URMP has been developed through a structured, data-driven, and consultative process anchored by the Multi-Stakeholder Working Group (MSWG), which brought together representatives from Muzaffarpur Municipal Corporation, district administration, and key line departments, including WRD, PHED, BSPCB, BUIDCO, and others. The first MSWG meeting established a common understanding of existing conditions, institutional roles, and priority issues, while the second meeting focused on validating findings, refining interventions, and identifying convergence opportunities with ongoing schemes.

Muzaffarpur's Burhi Gandak River has long been the ecological and cultural backbone of the city, supporting agriculture, groundwater recharge, and community practices. Rapid urbanisation, however, has weakened this relationship. Untreated wastewater from major drains, encroachment into floodplains, and solid waste dumping have degraded water quality and riparian buffers. Altered drainage patterns have increased waterlogging and flood vulnerability, especially in densely populated areas. The absence of formal floodplain zoning and weak enforcement mechanisms further compound these risks, placing the city at a critical juncture where ecological assets remain but are under mounting stress.

The Urban River Management Index as per the URMP framework places Muzaffarpur at a moderate performance level, but with significant weaknesses in floodplain management. Lack of demarcation, poor enforcement, and inadequate monitoring systems are key drivers of low scores. While embankments and scattered green patches provide partial safeguards, they are insufficient to address the scale of challenges. Institutional coordination remains weak, wastewater and solid waste systems are underdeveloped, and floodplain areas are increasingly fragmented, reducing their natural buffering capacity. These gaps highlight the urgent need for integrated planning and governance reforms.

Muzaffarpur's Burhi Gandak River has historically shaped the city's ecology, land use, and socio-cultural practices. Yet rapid urbanisation and weak infrastructure have disrupted this balance. Key issues identified include:

- **Water quality decline** from untreated wastewater (Chandwara Nallah, Sikanderpur outfall).
- **Floodplain encroachment** and obstruction of natural drainage.
- **Solid waste dumping** in nallahs, ponds, and riverbanks, with riparian buffer degradation.
- **Recurring waterlogging and flooding** in low-lying areas.
- **Absence of floodplain zoning** and weak enforcement mechanisms.

URMP-Muzaffarpur is organized around the ten-point URMP agenda, translating baseline insights into tangible and practical actions. Interventions range from planning/ policy measures (zoning, guidelines, institutional arrangements) to on-ground projects which can be implemented by various agencies, Actions are phased as short-, medium-, and long-term to enable pragmatic delivery while building institutional capacity.

Each intervention carries a defined phasing (short/medium/long term) with responsible agencies (e.g., BUIDCO , Pollution Control Board, Forest, Agriculture, Disaster, Fisheries, Tourism, Urban Development PHED, NMCG) specified for delivery, enabling alignment with funding, approvals, and DPR preparation.

Proposed interventions include strengthening sewage treatment infrastructure, improving solid waste management, protecting riparian buffers through native plantations, restoring interconnected water bodies, and regulating development along the floodplain. In addition, eco-sensitive riverfront improvements along selected ghats aim to enhance public access while preserving the ecological integrity of the river corridor. Through these initiatives, Muzaffarpur envisions a future in which the Burhi Gandak is revitalized as a clean, vibrant, and resilient urban river. By integrating environmental restoration with cultural heritage and sustainable planning practices, the URMP aims to ensure that the river continues to nurture the ecological health, social life, and economic vitality of the city

Following is the key summary of interventions prepared based on a detailed baseline assessment, identification of issues and challenges and aligning with the objectives of URMP framework and city's vision.

Summary of key interventions proposed by Muzaffarpur URMP

Objective 1: Regulation of Activities in the Floodplain

	Intervention	Responsible agency	Potential Funding Source	Estimated budget
1.1	Floodplain Zoning Integration into the Master Plan	Town and Country Planning Department, UDHD-Bihar, Muzaffarpur Municipal Corporation	UDHD Bihar, State funding	Master Plans are currently being prepared under the AMRUT GIS-based Master Plan funding initiative.

Objective 2: Pollution Free River

	Intervention	Responsible agency	Potential Funding Source	Estimated budget
2.1	Interim Septage Treatment and Pollution Control System – Septage Pre-Treatment & Dilution Unit	Muzaffarpur Municipal Corporation in coordination	SBM-U 2.0, AMRUT 2.0, State Urban Infrastructure	₹ 0.5 – 1 Cr (for 35 KLD Pre Treatment FSTP incl. land, civil works & O&M setup)

		with PHED / State Urban Development Department	Funds, PPP (O&M model)	
2.3	In-Situ Bioremediation & Eco-Restoration of Urban Nalahs – Chandwara Nallah and Furdoo Nallah	Muzaffarpur Municipal Corporation, PHED, State Pollution Control Board (SPCB)	NMCG, AMRUT 2.0, State Environment Funds, World Bank / ADB assisted urban projects	₹ 6.5 Cr (bio-enzymes, aeration units, phytoremediation, monitoring & landscaping)
2.4	Riverfront Cleanliness & Public Sanitation Improvement	Muzaffarpur Municipal Corporation, Multi Stakeholder Working Group, PHED, State Pollution Control Board (SPCB)	Muzaffarpur Municipal Corporation, PHED, State Pollution Control Board (SPCB)	₹3.5 Cr (policy formulation, staff engagement, eco-toilets, twin dustbins, GIS mapping, monitoring wells, enforcement & capacity building)

Objective 3: Rejuvenation of inland water bodies

	Intervention	**Responsible agency**	**Potential Funding Source**	**Estimated budget**
3.1	Comprehensive GIS-based inventory and water quality monitoring system for all waterbodies	Muzaffarpur Municipal Corporation (Lead), WRD Bihar (Support)	City's Annual Budget CSR	₹60-80 Lakhs (GIS platform, baseline surveys, sensors, lab testing & capacity building)
3.2	Ecological restoration of Sikanderpur Lakefront	Muzaffarpur Municipal Corporation (Lead), Bihar State Pollution Control Boa (Support), WRD (support)	AMRUT 2.0, 15th Finance Commission Grants, NPCA (Wetlands Scheme), State Urban Development Fund, CSR Funding, Municipal Budget	₹ 10 Cr (Edge treatment, aerators, Constructed Wetlands and Smart Dhobhi Ghaat System)
3.3	Rejuvenation of Sahu Pokhara	Muzaffarpur Municipal Corporation (Lead), Bihar State Pollution Control Boa (Support), WRD (support)	AMRUT 2.0, 15th Finance Commission Grants, NPCA (Wetlands Scheme) ,	₹ 1.25 – 1.80 Cr (Edge treatment, aerators, Constructed Wetlands and Smart Dhobhi Ghaat System)

			State Urban Development Fund , CSR Funding, Municipal Budget	

Objective 4: Enhancing Riparian Buffer

	Intervention	**Responsible agency**	**Potential Funding Source**	**Estimated budget**
4.1	Riparian Buffer Restoration for 4.3 Km stretch of the Burhi Gandak	Muzaffarpur Municipal Corporation (Lead), with technical support from Forest Department	CAMPA Funds CAMPA Funds, Muzaffarpur Municipal Corporation (own fund), Forest department	Included in Objective 7
4.2	Riverfront Linear Parks and Public Interface Development			

Objective 5: Increased Reuse of Treated Wastewater
Objective 6: Maximum Good quality return flow

	Intervention	**Responsible agency**	**Potential Funding Source**	**Estimated budget**
5.1	Preparation of a City-level Strategy for Reuse of Treated Used Water	Muzaffarpur Municipal Corporation, BUIDCO	Urban Local body Bihar Pollution Control Board	₹ 60 lakh
5.2	River Health and Water Bodies Monitoring and Public Reporting System	Muzaffarpur Municipal Corporation, BUIDCO	Urban Local body Bihar Pollution Control Board	₹ 50 lakh

Objective 7: Eco-friendly Riverfront Projects
Objective 8: Leveraging Economic Potential of the River

	Intervention	**Responsible agency**	**Potential Funding Source**	**Estimated budget**
7.1	Eco-sensitive Ghat Redevelopment & Public River Access Improvement	Muzaffarpur Municipal Corporation (Lead), WRD Bihar, Forest & Department	Namami Gange, AMRUT 2.0, CAMPA (green buffers), State Plan Funds	6.2 Cr – 8.2 Cr (CAPEX) 90 lakh – 1.3 Cr / year (OPEX)

7.2	Ecological River Edge Restoration & Linear Park Development along the 4.3 Km of the Burhi Gandak	Muzaffarpur Municipal Corporation (Lead), WRD Bihar, Forest & Department	Namami Gange, AMRUT 2.0, CAMPA (green buffers), State Plan Funds	₹18 - 20 Cr (eco-edge treatment, riparian plantation, access improvements, safety measures)
7.3	Litchi Experience Park - at Namami Gange Siddhi Ghat	Muzaffarpur Municipal Corporation (Lead), Tourism Department Bihar, Department of Culture	Swadesh Darshan 2.0, PRASHAD, Namami Gange, CSR	₹33 - 48 Cr (temporary structures, cultural spaces, riverbed activation, livelihood kiosks, ecological safeguards)

Objective 9: River Sensitive Behavior among Citizens
Objective 10: Citizen engagement in river management

	Intervention	**Responsible agency**	**Potential Funding Source**	**Estimated budget**
9.1	River sensitization program for Muzaffarpur city – • Door-to-door river health campaigns • Community Platforms , Empowering RWAs, Ghat committee market associations and SHGs • City wide narratives (2-5 years) scale up through schools, temples, media and cultural institutions	Muzaffarpur Municipal Corporation (Lead), BSPCB, Education Department, Local NGOs	SBM-U 2.0 (IEC), Namami Gange (Public Awareness), State Urban Development Grants, CSR	₹1–1.5 Cr (citywide IEC campaigns, school & college programs, media outreach, training modules)
9.2	Community-led River Stewardship – Muzaffarpur (Burhi Gandak) • **Initiation (0–6 Months):** Form River Stewardship Groups, onboard stakeholders, launch IEC campaigns. • **Pilot (6–18 Months):** Test stewardship in priority stretches	GMC (Lead), District Administration, Tourism & Culture Department	Namami Gange, Swadesh Darshan 2.0 (CSR), State	₹ 1.5 – 2.0 (River Day events, clean-up drives, cultural programs, volunteer mobilization & logistics)

	with source segregation, ghat recovery points, citizen monitoring, and "Nadi Seva Days." • **Scaling & Institutionalisation (18–60 Months):**			

INTRODUCTION

1. INTRODUCING URBAN RIVER MANAGEMENT PLAN FOR MUZAFFARPUR

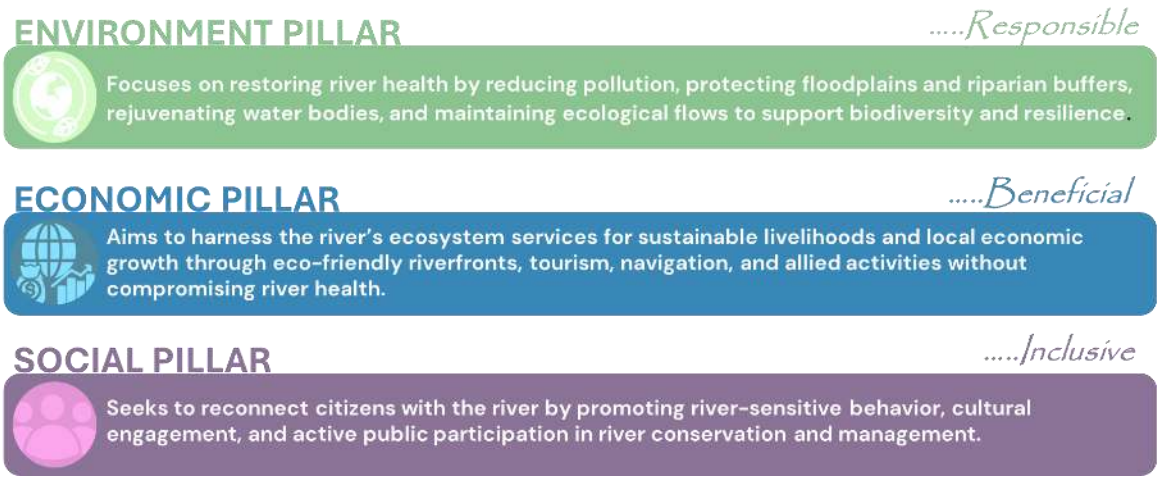
1.1 Concept, Vision and Pillars of URMP

The core concept of the URMP is to integrate river-sensitive thinking into mainstream urban planning and governance. Rather than treating the river as a residual drain or a standalone beautification project, the URMP positions the river as a living ecological system and a shared urban asset that supports biodiversity, livelihoods, cultural practices, and city resilience. The URMP framework promotes a shift from fragmented, project-based interventions to a holistic, basin-aware, and outcome-oriented approach that aligns with existing statutory plans such as the Master Plan, City Sanitation Plan, and City Development Plan.

Importantly, the URMP is designed as a living document, allowing cities to monitor progress, learn from implementation, and recalibrate actions over time.

The URMP is anchored in the three pillars of sustainable development: Environmental, Economic, and Social. These pillars collectively guide the vision, objectives, and interventions proposed under the plan.

Figure 1: Elements of the URMP Framework



The Urban River Management Plan envisions a future where urban rivers function as healthy ecological systems, support sustainable economic activities, and are valued and celebrated by citizens. The vision emphasizes river-sensitive urban development that enhances environmental resilience, urban liveability, and socio-economic productivity while maintaining the ecological integrity of the river. The URMP operationalises this vision **through ten objectives** covering environmental, economic, and social dimensions. The URMP's vision shall be achieved through a set of ten objectives, six of which are environmental, and two each for the economic and social visions. Each objective is unique and addresses a niche aspect of urban river management. The URMP also indicates a phase-wise (short-term, medium-term, long-term) implementation plan for these interventions.

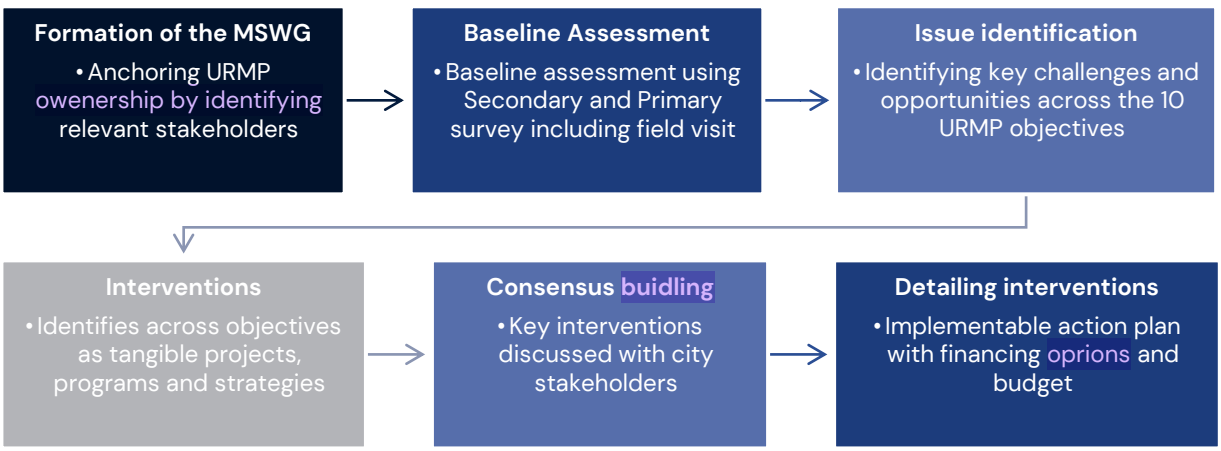
Figure 2: Objectives across the 3 elements of the URMP Framework

1.2 Process for preparation of URMP Muzaffarpur

Following process was followed for the preparation of URMP Muzaffarpur:

- Step 1 –Setting up a core working group of relevant stakeholders to anchor the ownership of the URMP
- Step 2 – Conducting a thorough baseline assessment of the relevant parameters to establish the current status and the baseline score
- Step 3 – Identifying key challenges and issues and preparing SWOT
- Step 4 – Identifying tangible interventions for each objective of the URMP framework
- Step 5 – Consensus building on the interventions via stakeholder workshops with City officials
- Step 6 – Preparation of a detailed plan for prioritized implementation of the interventions, and linking each intervention to probable institutional and financing option, along with a monitoring framework

Figure 3: Steps for preparation of URMP Muzaffarpur



1.3 URMP Muzaffarpur - Working Group

The preparation of the Urban River Management Plan (URMP) for Muzaffarpur is being led by the Muzaffarpur Municipal Corporation under the guidance of the Municipal Commissioner, with active participation from relevant line departments and key stakeholders.

To ensure inclusive stakeholder engagement and coordinated planning, a Multi-Stakeholder Working Group (MSWG) was constituted, comprising representatives from the municipal corporation, district administration, relevant state departments, and associated agencies**.**

1.3.1 First MSWG Meeting

The first Multi-Stakeholder Working Group (MSWG) meeting (17th September 2025) introduced the Urban River Management Plan (URMP) framework and initiated inter-departmental coordination for Muzaffarpur. Representatives from municipal departments, state agencies, and technical institutions participated.

The MSWG was formally **constituted on 10th October 2025** under the chairpersonship of the Municipal Commissioner, with members from key departments including PHED, Water Resources, Pollution Control Board, BUIDCO, and district administration. The group serves as the primary platform for coordinated planning, data sharing, and implementation of URMP interventions.

Figure 4: First MSWG Meeting held on 17 September 2025

Key issues identified:
Discussions during the meeting helped consolidate the city's priority issues, which directly informed the URMP proposals:

- **Untreated wastewater discharge** into the Burhi Gandak River due to limited sewerage and treatment infrastructure
- **Solid waste dumping in nallahs and river edges**, leading to flow obstruction and pollution
- **Encroachment along riverbanks and drainage channels**, reducing natural flood-carrying capacity
- **Frequent urban flooding and waterlogging** linked to inadequate and clogged drainage systems

- **Groundwater stress** due to over-reliance on borewells and lack of surface water integration
- **Degradation of riparian ecosystems and biodiversity loss**
- **Underutilised riverfront potential**, despite strong cultural and livelihood linkages (ghats, rituals, local economy)

Vision Identified for the Muzaffarpur URMP:

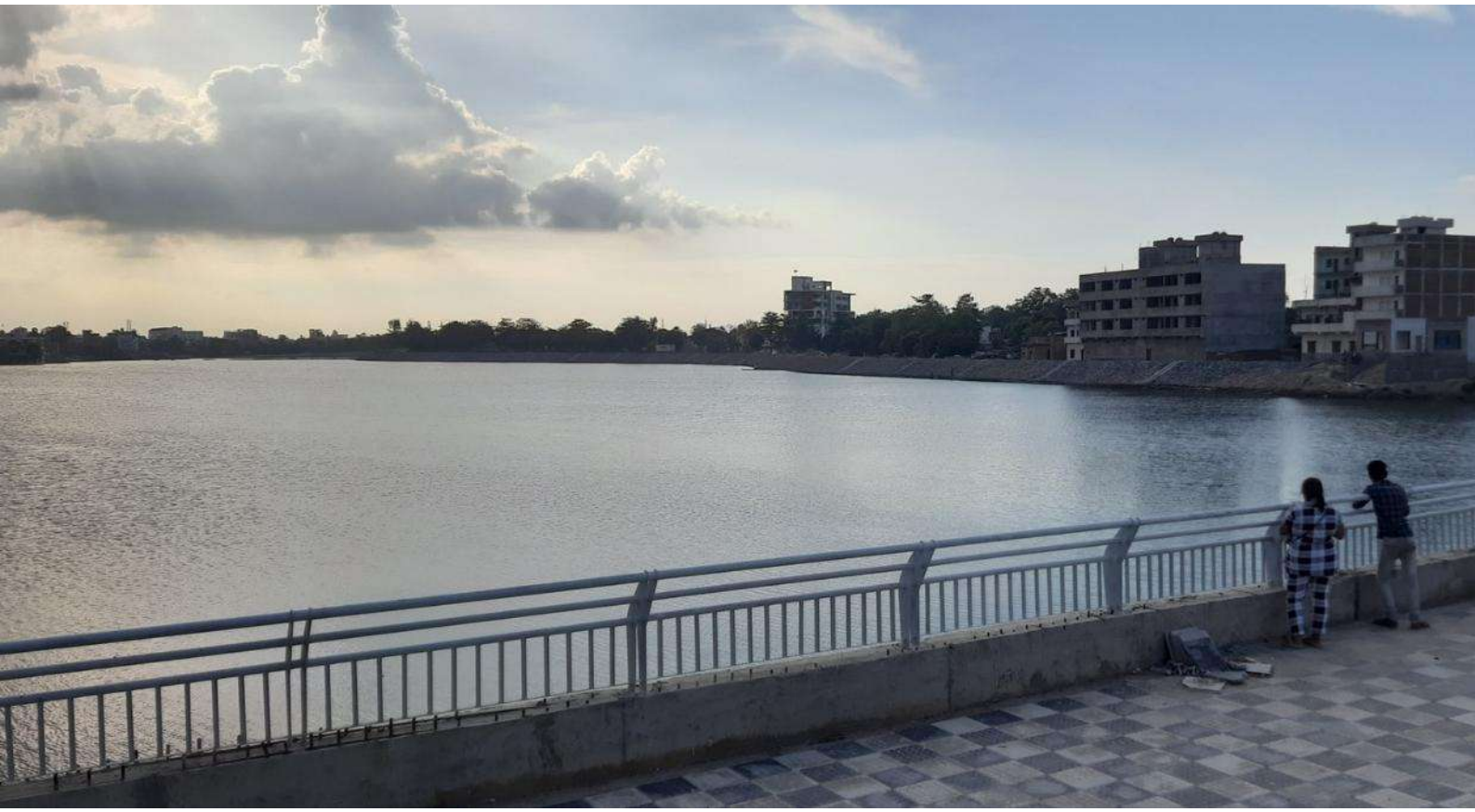
Reviving Muzaffarpur through river-sensitive planning that celebrates its agro-heritage, while promoting a river-centric social, cultural, and economic renewal in the city

1.3.2 Second MSWG Meeting

The 2nd Multi-Stakeholder Working Group (MSWG) meeting for Muzaffarpur was convened under the chairmanship of the Municipal Commissioner, with participation from representatives of key departments. Based on stakeholder inputs and deliberations, the following key directions emerged from the meeting:

- Strengthening of project costing, including desilting of major nallahs and incorporation of detailed O&M costs
- Exploration of convergence opportunities, particularly with NCAP for plantation and riparian buffer development
- Adoption of a context-sensitive approach for Sikanderpur Lake, ensuring minimal disruption to existing communities
- Requirement for detailed technical inputs, including BOD levels and O&M estimates for constructed wetlands
- Integration of existing DPRs, including riverfront development proposals, into the URMP framework
- Inclusion of clear implementation mechanisms, defined responsibilities, and long-term maintenance strategies across all interventions

Figure 5 : Second MSWG Meeting held on 17 March 2026



MUZAFFARPUR - URMP BACKGROUND

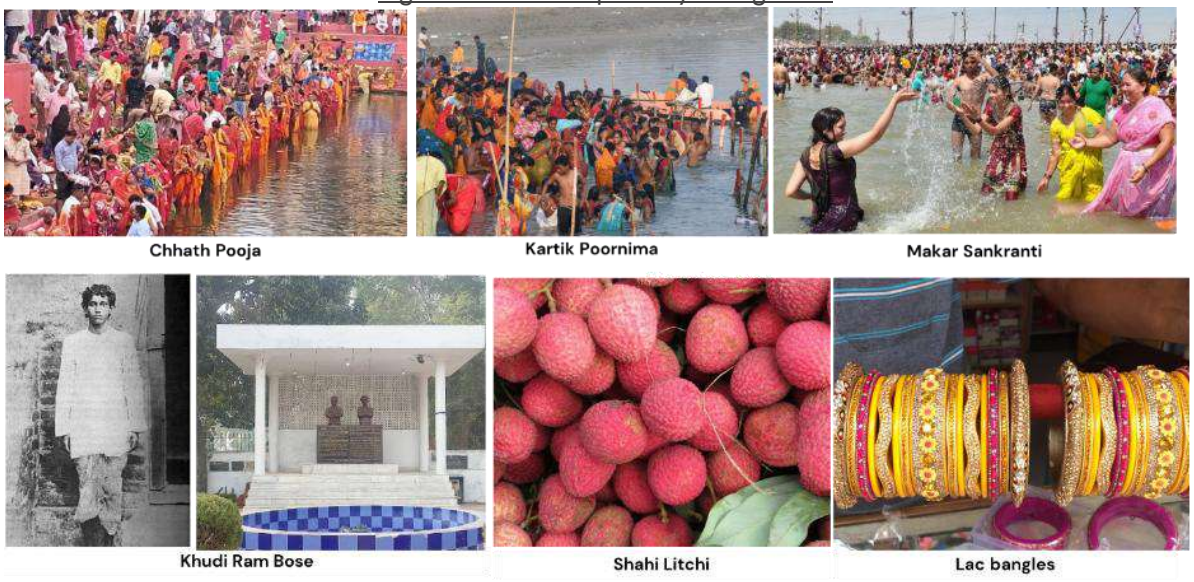
2. MUZAFFARPUR – BACKGROUND

2.1 City Profile

Muzaffarpur, located in the fertile plains of north Bihar, has a rich cultural identity shaped by its association with the Burhi Gandak River and the broader Gangetic civilisation. Historically, the city has been a centre of trade, agriculture, and learning, with its culture deeply rooted in Maithili traditions, festivals, and river-based practices.[1]

The city is known for several culturally significant sites, including the revered Garibnath Temple, a major pilgrimage centre dedicated to Lord Shiva that attracts devotees from across the region, especially during Shravan where, thousands of Kanwariyas visit the temple to offer holy water to the Shiva Lingam. Other important religious and cultural landmarks such as Ramna Devi Mandir and local ghats along the Burhi Gandak contribute to the city's spiritual landscape. Seasonal festivals like Chhath Puja, Durga Puja celebrated on riverbanks and water bodies, further highlight the cultural centrality of water in Muzaffarpur.[2] The region is famous globally for its premium *Shahi Litchi* variety which are GI tagged product of the region, making it a massive contributor to the state's agricultural exports. The city is also famous for production of *lac bangles (locally referred as "Lahati").* Its major industrial hubs—such as Bela and Bariyarpur—support manufacturing, dairy, and textiles, while Motijheel and Sutapatti act as bustling central markets.
Historically, the city was established in 1875 and grew as an administrative center. The city played a pivotal role in the British freedom struggle, most notably with the 1908 Muzaffarpur Conspiracy Case involving young revolutionaries Khudiram Bose and Prafulla Chaki. The Khudiram Bose Memorial in Muzaffarpur, Bihar located in Company bagh near the Burhi Gandak River and the former central jail where he was martyred is a place of historical importance.

Figure 6: Muzaffarpur city at a glance



Muzaffarpur Municipal Corporation covers an area of approximately **26.63 sq. km** and has a population of 3.54 lakh[3] , distributed across 49 wards, with a population density of nearly 13,310 persons/sq. km *(Refer Map 2- Administrative boundary).* The population is estimated to have

[1] District Gazetteers, Muzaffarpur, Government of Bihar.

[2] Bihar State Tourism Development Corporation – Muzaffarpur.

[3] Census of India, 2011

increased to around **4 lakh by 2026** and projected to increase to **5.2 lakh by 2045**.[4] The Muzaffarpur planning area, currently under master plan preparation, extends to approximately **265.71 sq. km.** Such anticipated urban expansion is expected to place increasing pressure on urban infrastructure, drainage systems, and riverfront areas. The Burhi Gandak riverfront within the municipal area extends for nearly **4.3 km**, forming a critical ecological and urban interface.

The city has developed around a dense network of roads, railway corridors, water bodies, and mixed land uses. Residential and mixed-use areas dominate the urban core, while industrial clusters are concentrated primarily toward the southern and southeastern parts of the city along major transport corridors. Pockets of green areas, water bodies, and peri-urban agricultural land remain along the city edges and near the Burhi Gandak floodplain, highlighting the transitional character between the urban core and the surrounding rural landscape. (*Refer Map 1: Muzaffarpur city Base map)* The Burhi Gandak River, a perennial tributary of the Ganga, has historically shaped Muzaffarpur's growth, ecology, and socio-cultural identity. Flowing through the fertile alluvial plains of North Bihar, the river has supported agriculture, trade, groundwater recharge, and settlement development for centuries. The riverbanks continue to function as important public and cultural spaces where communities engage in daily activities, religious rituals, and festivals. During these events, large numbers of devotees gather along the ghats and riverbanks, reinforcing the strong social and spiritual relationship between the city and the river.

Figure 7 Burhi Gandak - Post Monsoon

[4] Muzaffarpur Drainage DPR, Tirhut Division, BUIDCo, Bihar

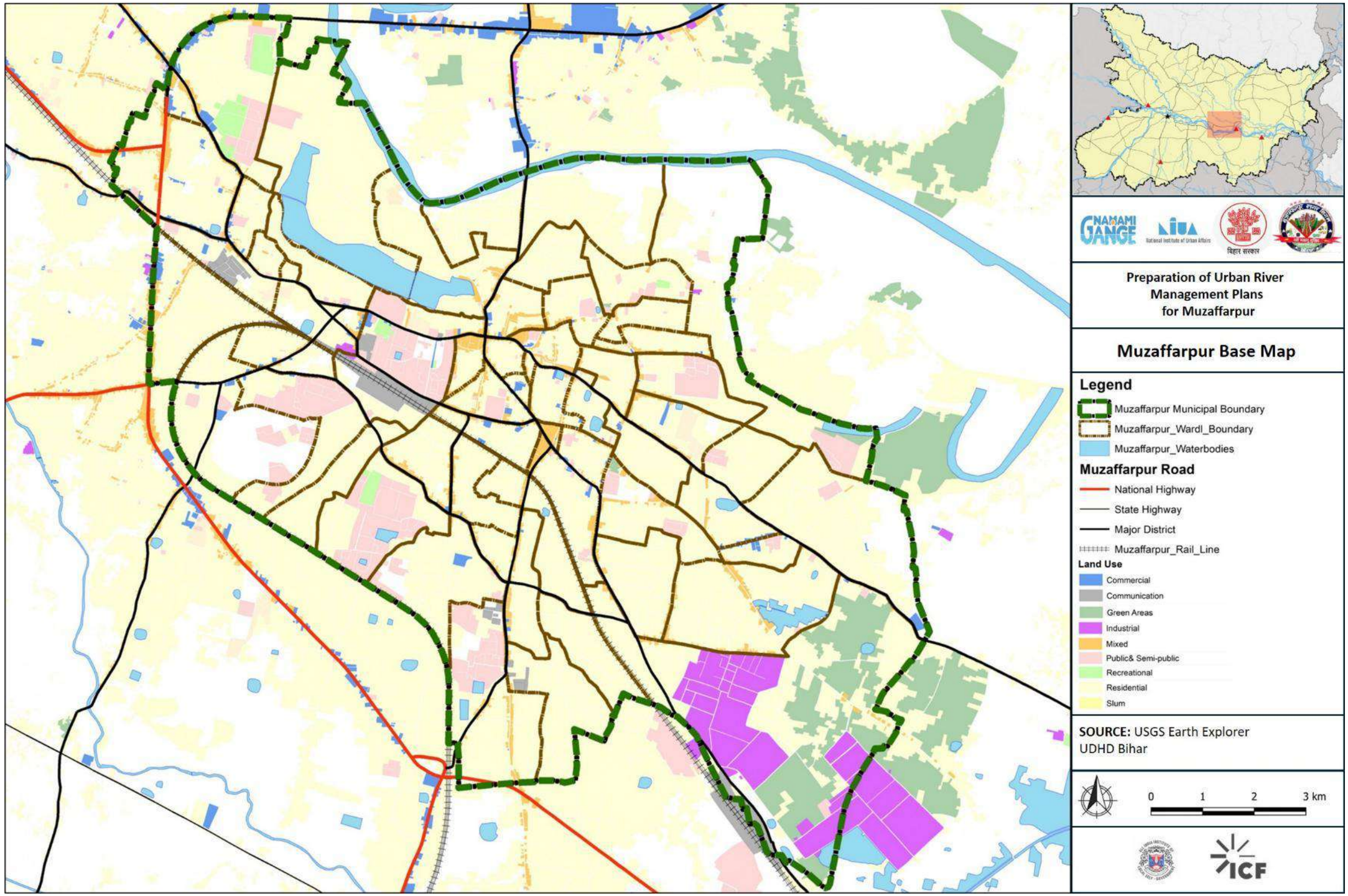
Figure 8 Burhi Gandak during the lean season (March – May)

Source: Primary Survey

Ecologically, the river corridor supports diverse riparian habitats and wetlands that contribute to urban biodiversity. Vegetation along the riverbanks helps stabilize soil, reduce erosion, and filter pollutants from urban runoff. These natural buffers also provide habitats for aquatic species, birds, and small wildlife while supporting fisheries and other livelihood activities for local communities. Historically, the river and its connected ponds, wetlands, and canals formed an integrated hydrological network that regulated water flows and maintained ecological balance across the urban landscape. In recent decades, however, the river has come under increasing environmental stress due to rapid urbanisation. Untreated sewage discharge through city drains, solid waste dumping, loss of riparian vegetation, and encroachments along the floodplain have contributed to declining water quality and degradation of riverine ecosystems. The absence of adequate wastewater treatment infrastructure and increasing pressure on urban land have further intensified these challenges.

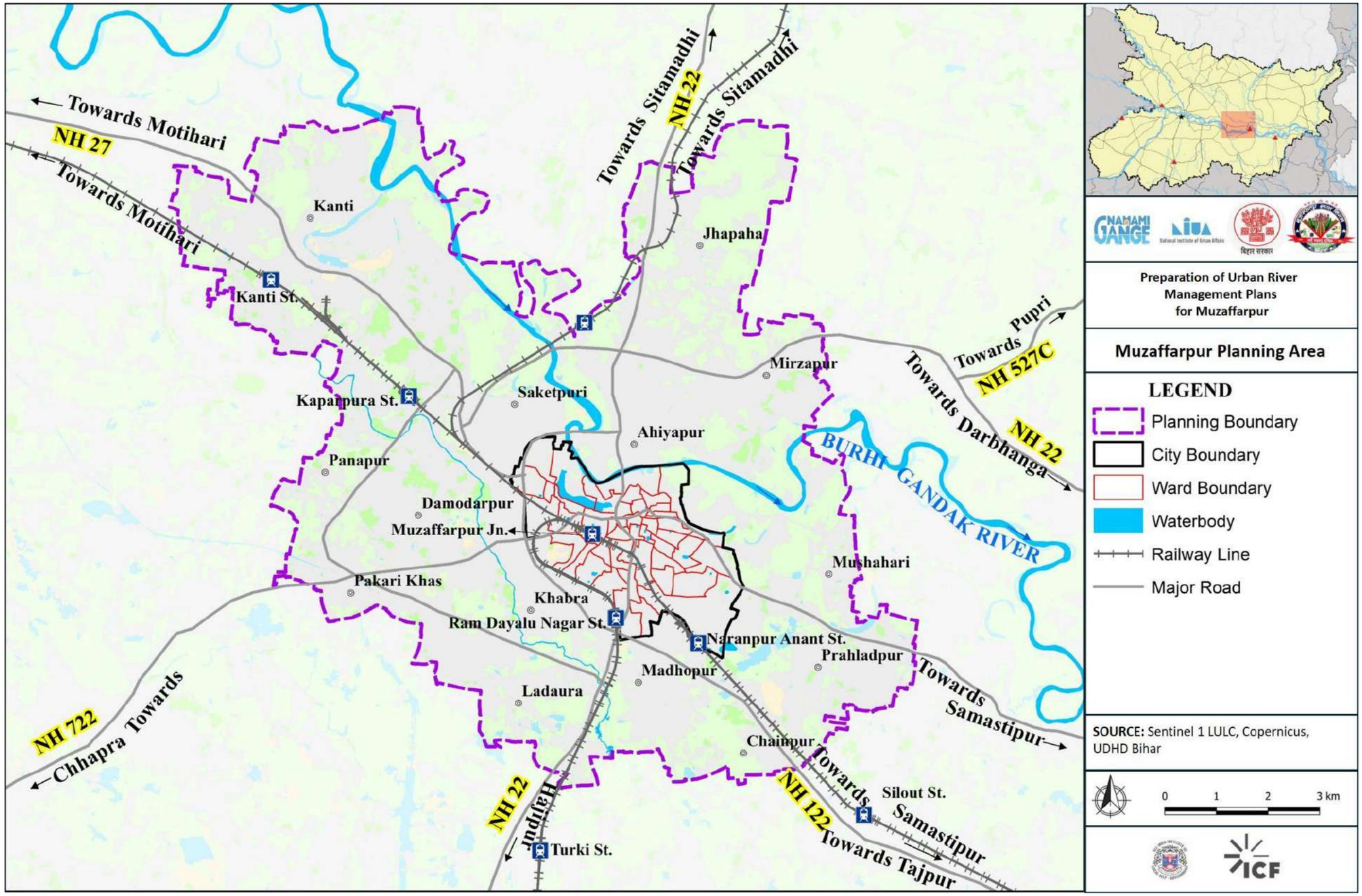
Recognising the importance of restoring and safeguarding this vital river–city relationship, the Urban River Management Plan (URMP) for Muzaffarpur seeks to promote an integrated approach to river conservation and urban development. By integrating environmental restoration with cultural heritage and sustainable planning practices, the URMP aims to ensure that the river continues to nurture the ecological health, social life, and economic vitality of the city.

Map 1: Basemap with landuse



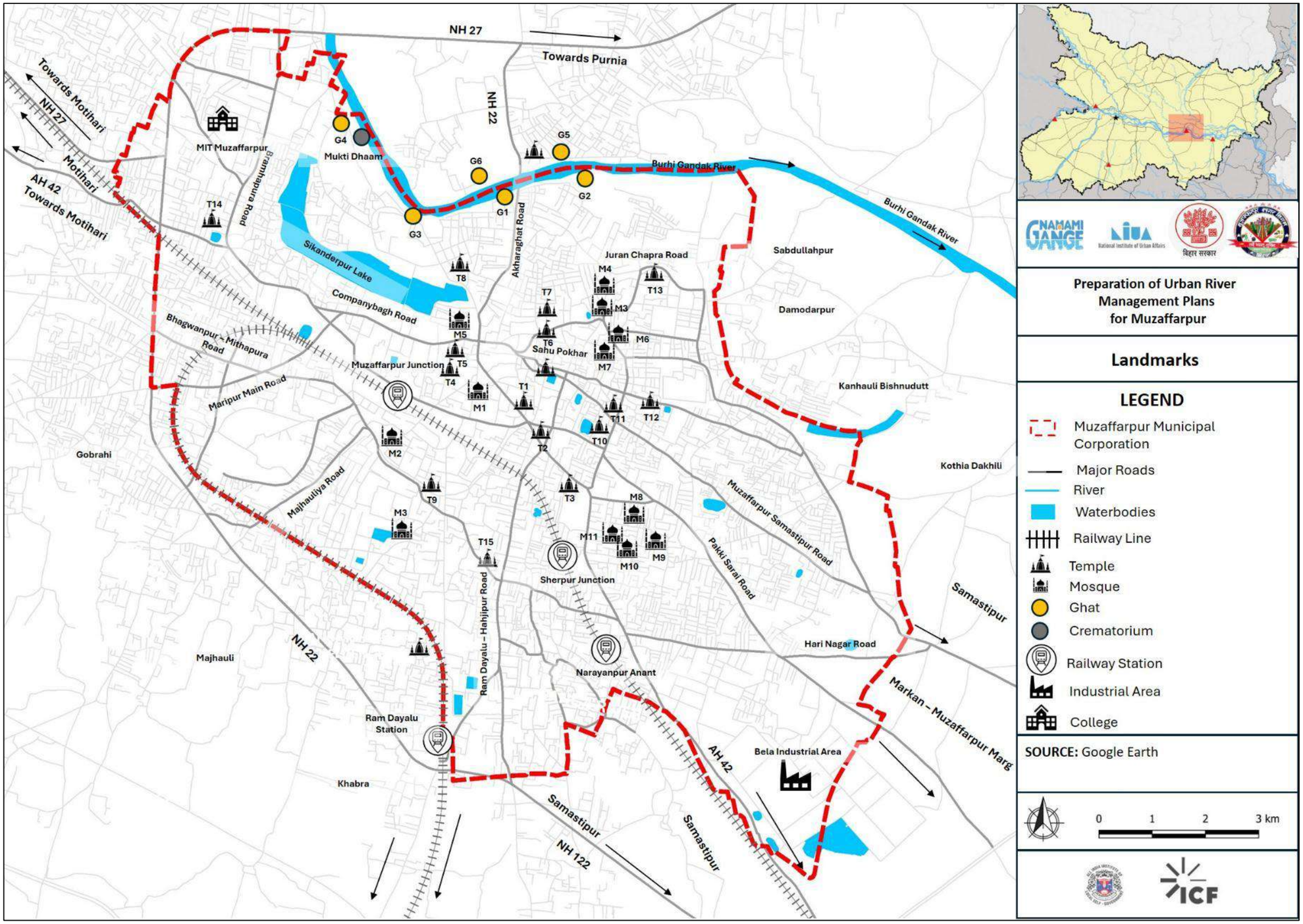
Source: UDHD Bihar

Map 2 : Administrative boundary



Source: UDHD Bihar

Map 3 : Major landmarks



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Key landmarks

Figure 9 :Key landmarks- Muzaffarpur city

Sikanderpur lake

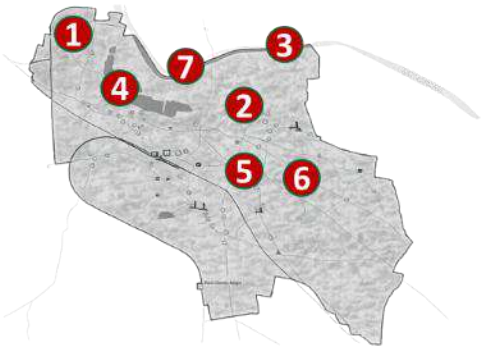
Sahu Pokhara

Akhara Ghat

Khudiram Bose Smarak

Baba Garibnath Mandir

Chaturbhuj Sthan



Seedhi ghat

2.2 Muzaffarpur and its relationship with Burhi Gandak

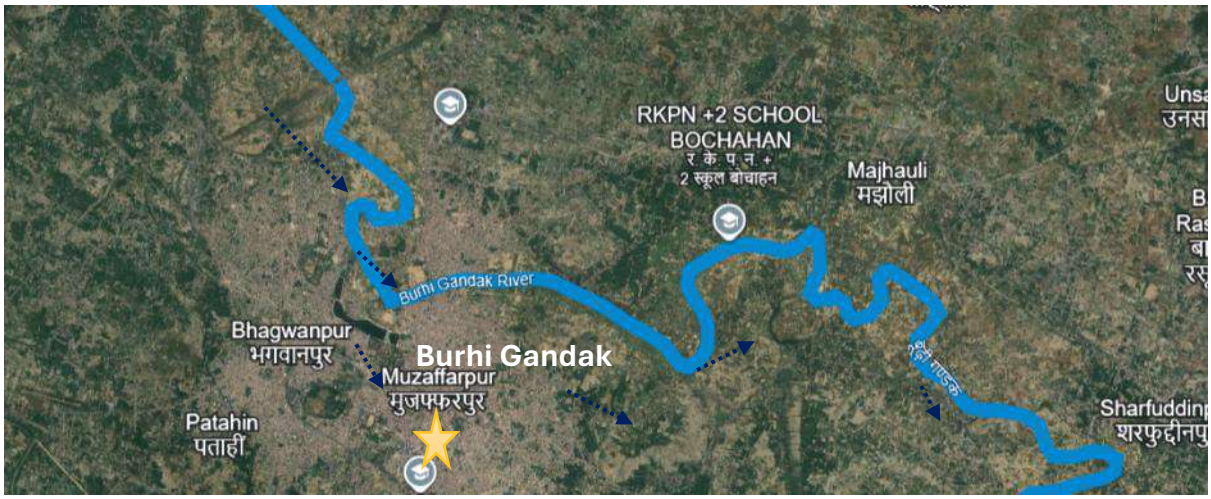
The Burhi Gandak sub-basin covers an area of nearly 12,500 square kilometres, of which about 2,350 square kilometres lie within Nepal. It is bounded by several major river systems, including the Bagmati River, the Gandak River–Ganga system, and the Bagmati–Kosi basin. The basin is also well connected by transportation infrastructure, including major roads and railway networks, with Muzaffarpur serving as an important urban and commercial centre in the region.

The Burhi Gandak River originates from the Chautarwa Wetlands, western Champaran district of Bihar at an elevation of approximately 300 meters above mean sea level. From there, the river flows southward into the plains of Bihar and eventually joins the Ganges River near Khagaria. The river is characterised by a meandering course and is largely embanked along many sections. Although it carries a high silt load due to sediment deposition from the upper catchment, it generally has relatively low flash-flood potential compared with other Himalayan rivers. Outside the embankments, extensive cultivated floodplains and densely populated settlements occupy the surrounding landscape.

Figure 10 Burhi Gandak Basin

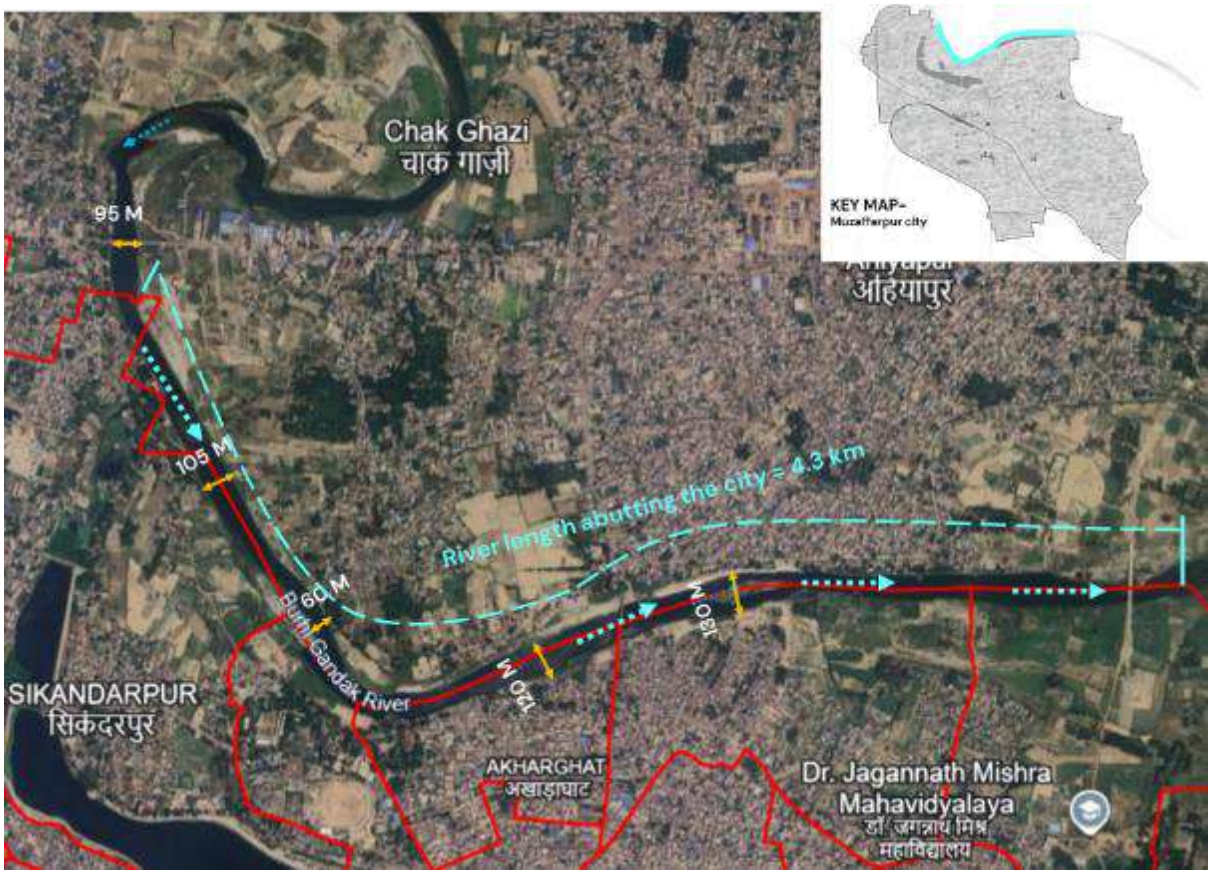
Source: Asian Development Bank & Department of Water Resources, River Development & Ganga Rejuvenation, Government of India (2015). Basin Flood Management Plan for Burhi-Gandak (Vol. 3 – Final, December 2015). DFID/ADB/Deltares, in association with RMSI & JPS

Figure 11: Path of the Burhi Gandak River Along Muzaffarpur



Source: Google Earth

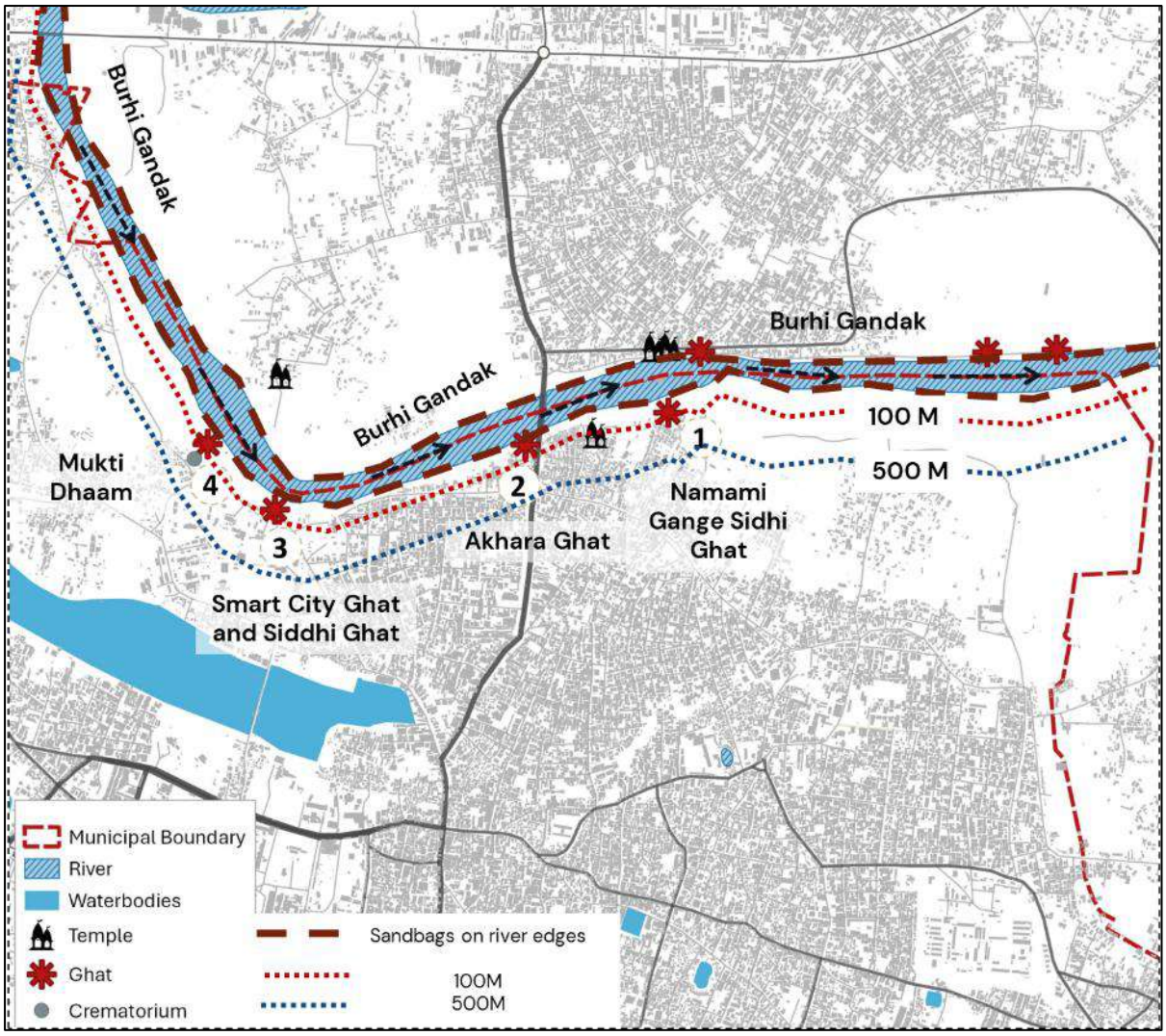
Figure 12 : Burhi Gandak and the city



- **Length of the riverfront – 4.3 Km** in the ULB**. 8.6 km,** including both sides **(North and South)**
- **Ghats –** 4 ghats, including a Muktidham (crematorium)
- **Direction of River Flow:** The river flows **from east to west** along the northern boundary of Muzaffarpur before curving northwards downstream.
- **Embankment Details:** The riverbanks are protected using temporary sandbag embankments along both edges, primarily for flood protection and bank stabilization.
- **Information for Both Banks:**

- ***Southern Bank (City Side):*** *Contains major public ghats including* ***Namami Gange Sidhi Ghat, Akhara Ghat, and Smart City Ghat****, along with religious nodes and dense urban settlements.*
- ***Northern Bank:*** *Comparatively less urbanised with scattered development and floodplain areas*, functioning as a buffer during high-flow conditions

Figure 13 : River edge in the city



The riverfront currently lacks dedicated cultural and recreational public spaces, resulting in minimal everyday engagement by citizens. As a result, the river is largely perceived as a utilitarian or ritual landscape rather than an urban asset, with public interaction largely limited to festivals and religious occasions. Outside these periods, the riverfront remains underutilized and disconnected from the city's public life. Ritual activities such as bathing, ablutions, idol immersion, and offerings intensify during major festivals, leading to increased organic load, nutrient enrichment, and solid waste deposition in the river and adjacent ponds. Prominent sites like Baba Garibnath Mandir and Sahu Pokhar attract large crowds, placing additional stress on water quality and surrounding infrastructure. Continuous use of ghats and riverbanks contributes to localised erosion, disturbance of riparian ecology, and deterioration in water quality, including reduced Dissolved Oxygen (DO) levels and increased coliform presence.

2.3 Muzaffarpur-Physical features

2.3.1 Elevation and Topography:

Muzaffarpur is characterised by a predominantly flat alluvial terrain with very gentle elevation variations, typical of the middle Gangetic plains. As shown in *Map 7: Topographic Map of Muzaffarpur City*, the municipal area largely ranges between low-lying floodplain surfaces and marginally elevated urban ridges formed through long-term fluvial deposition by the Burhi Gandak River and its drainage system.

The city's slope conditions are also extremely gentle, with the majority of the municipal area falling within the **0–3° slope category**, as seen in *Map 5 : Slope Map of Muzaffarpur City*. The absence of significant natural gradients limits rapid surface runoff and results in slow drainage movement across the urban area. Consequently, stormwater tends to accumulate in low-lying depressions, natural drainage channels, ponds, and wetland pockets, increasing the city's vulnerability to seasonal waterlogging and urban flooding during intense rainfall events.

2.3.2 Hydrology, Natural Drainage and watershed

The hydrological structure of Muzaffarpur is intrinsically linked to the Burhi Gandak River, which forms the primary drainage spine of the city. Located within the alluvial plains of North Bihar, the city is characterised by low topographic gradients, a dense network of natural drainage channels, and a **highly groundwater-dependent urban system**. In the absence of adequate surface water infrastructure, groundwater remains the primary source for domestic, commercial, and institutional water supply across the city.[5]

The natural drainage network of Muzaffarpur exhibits a well-defined hierarchical structure, comprising streams of varying orders that ultimately discharge into the Burhi Gandak River. (Map Natural drainage Map of Muzaffarpur)

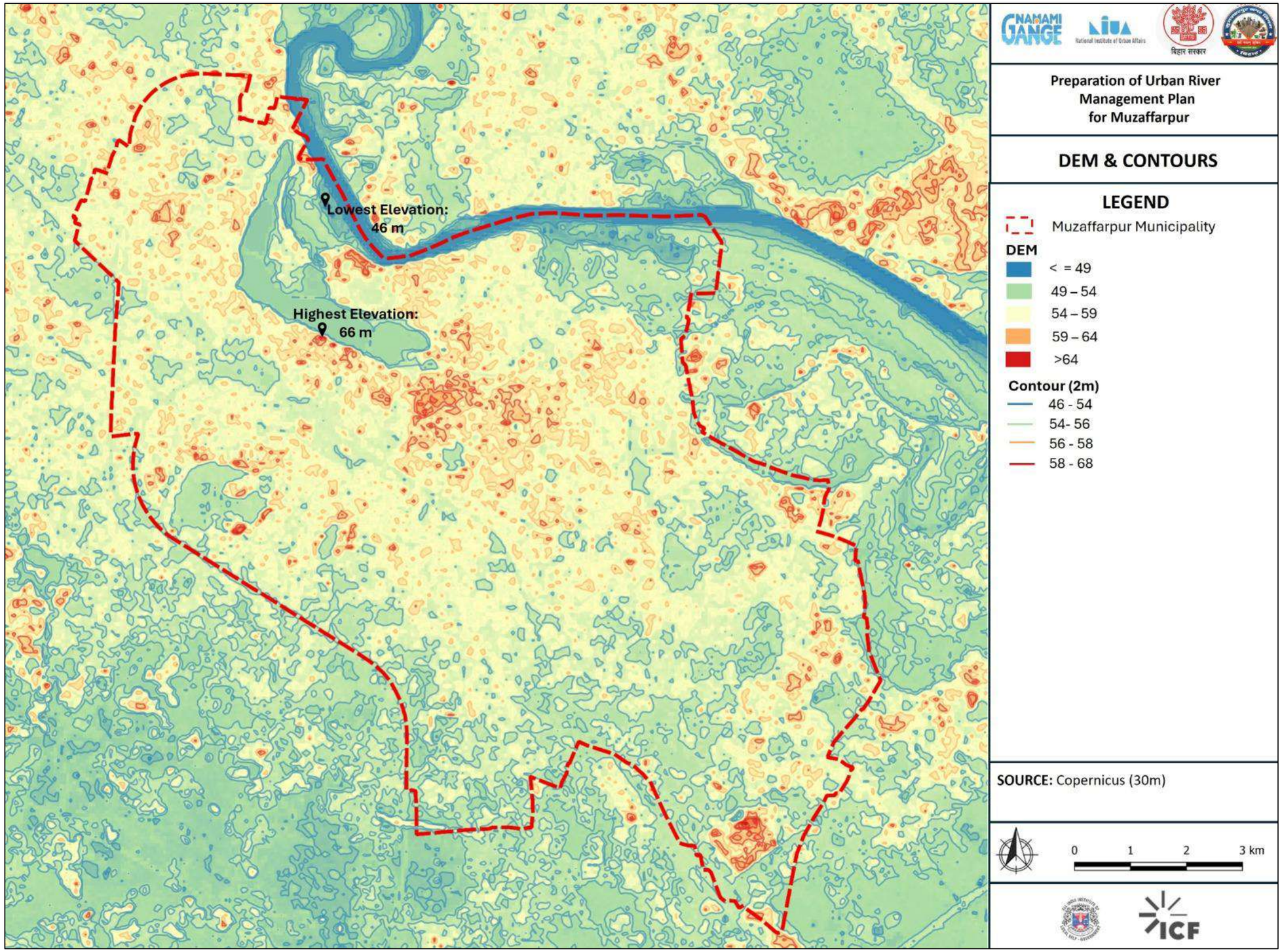
Key Observations

- The Burhi Gandak functions as a **6th order stream**, receiving multiple 3rd to 5th order tributaries.
- Drainage is predominantly oriented towards the north, indicating natural slope direction.
- Several natural channels now function as urban nallahs, traversing dense built-up areas.
- Waterbodies act as intermediate retention systems but are spatially fragmented.
- The city comprises **multiple micro-catchments**, resulting in distributed runoff patterns.
- Sub-watersheds vary in size and degree of urbanisation.
- Localised depressions within sub-catchments contribute to waterlogging during peak rainfall events.

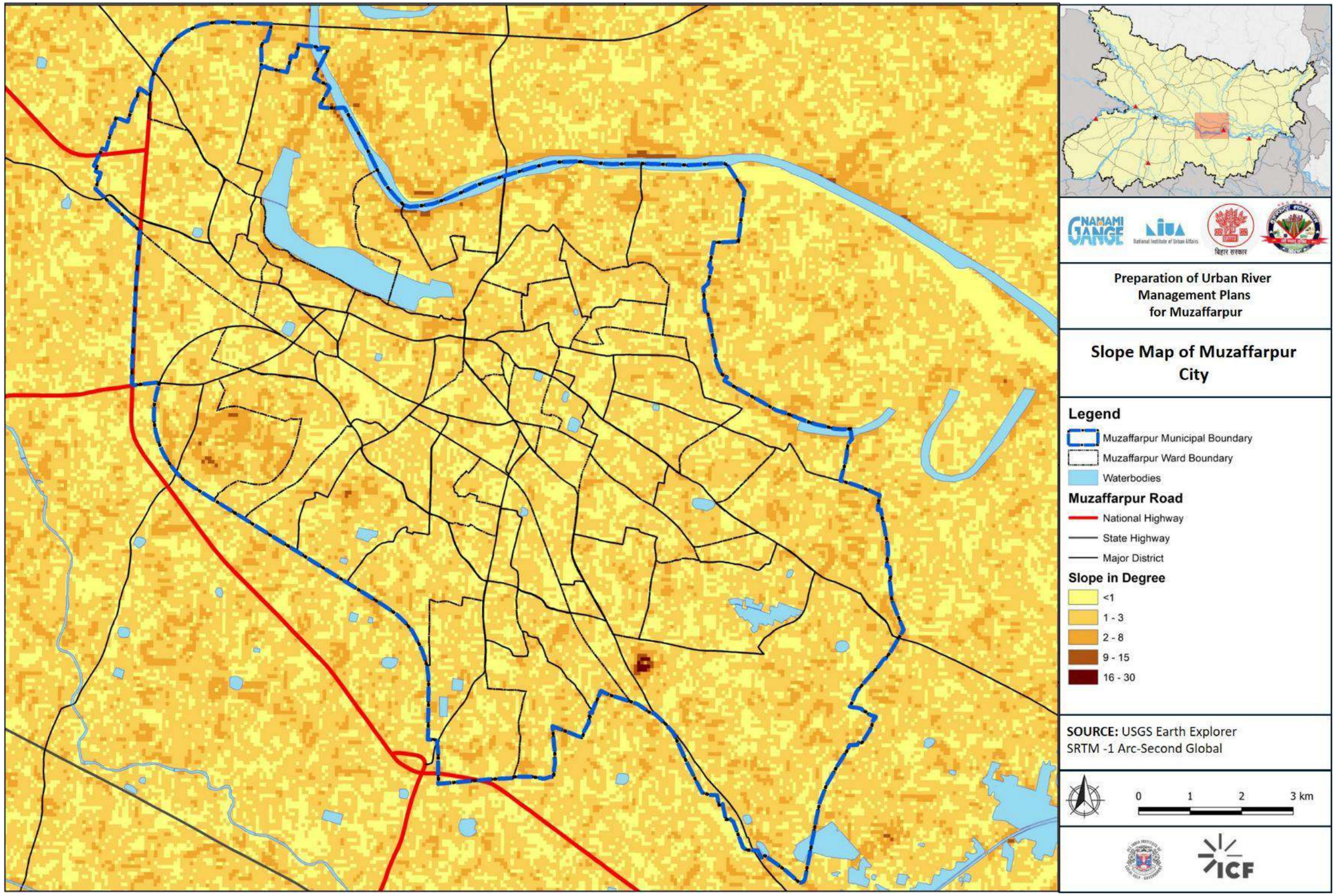
This fragmented watershed structure highlights the need for decentralised drainage and treatment interventions.

[5] Central Ground Water Board (CGWB), Ground Water Year Book – Bihar, Ministry of Jal Shakti, Government of India.

Map 4 : Muzaffarpur Elevation Map

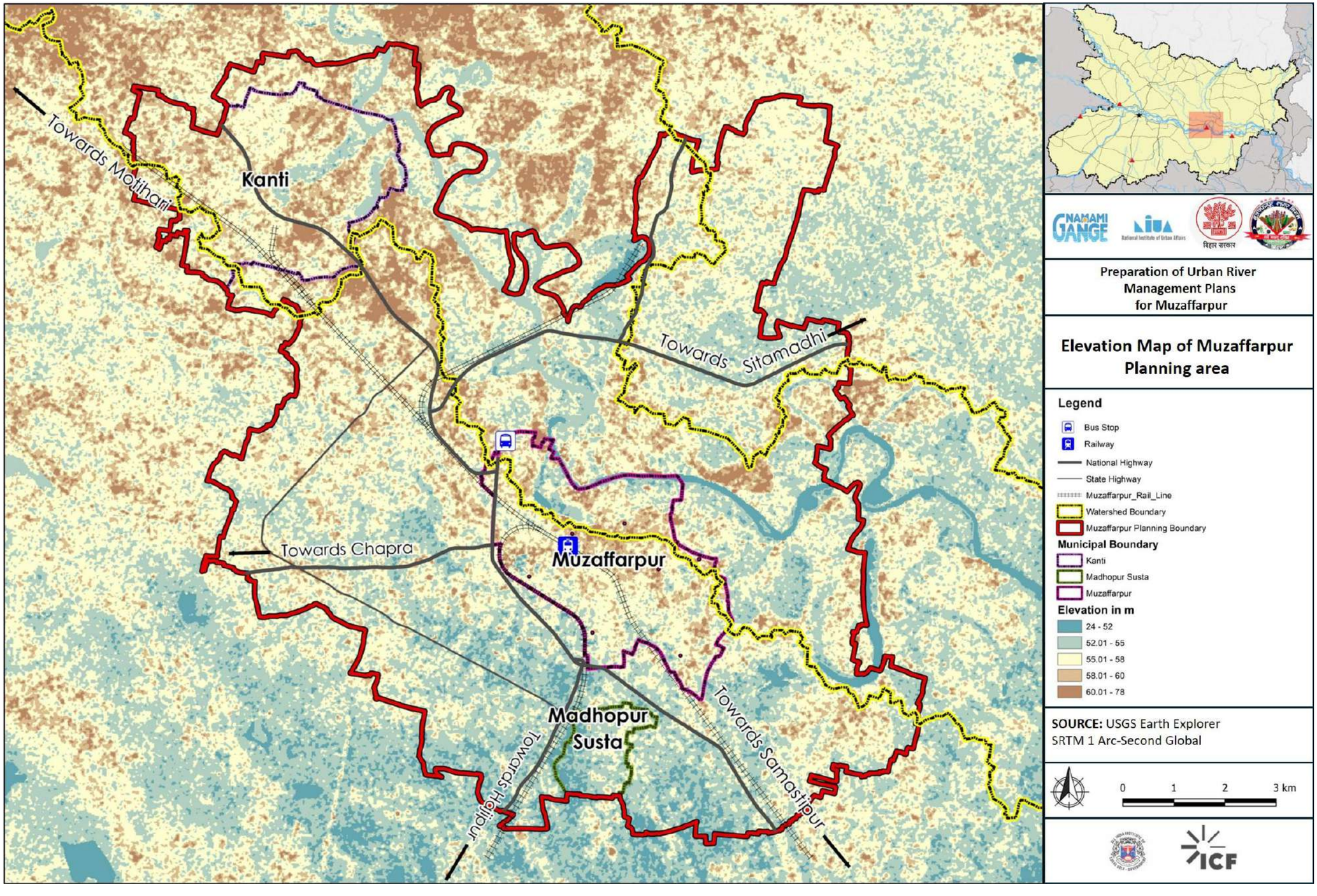


Map 5 : Muzaffarpur city- Slope Map



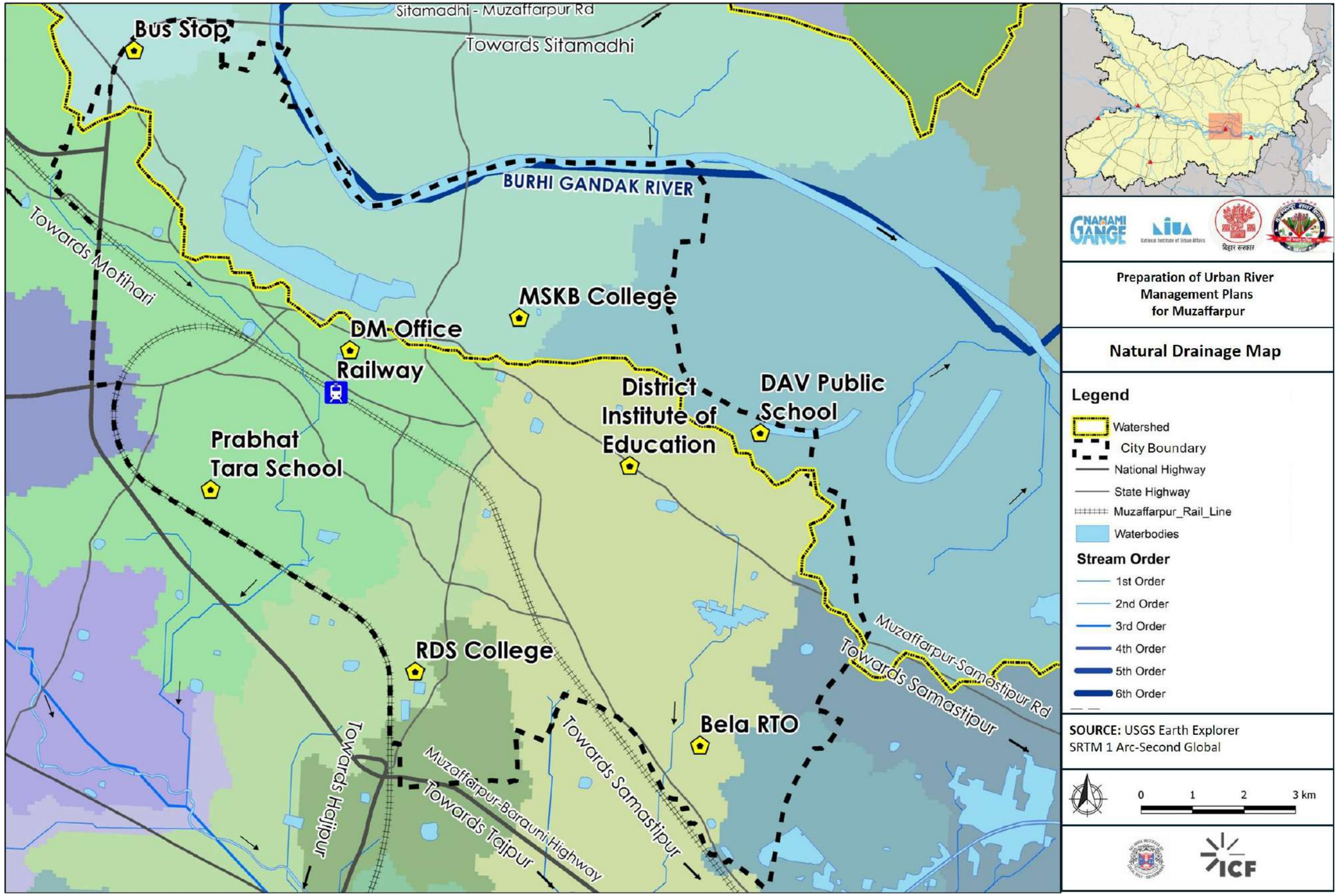
Source: USGS

Map 6: DEM- Muzaffarpur Planning Area



Source: USGS, SRTM 1 Arc-Second Global

Map 7 : Drainage and watershed



Source: USGS, SRTM 1 Arc-Second Globe

BASEMENT ASSESSMENT-SUMMARY

3. BASELINE ASSESSMENT-SUMMARY

3.1 URMP Index for Burhi Gandak- Muzaffarpur city

Summarising the score achieved across the 10 objectives:

No	URMP Objective	Indicator/ score	Score achieved
1	Regulation of activities in Flood planning and	Flood plain management score	1
2	Pollution-Free River	Net dissolved oxygen score	3
3	Rejuvenation of Waterbodies	Waterbody revival score	2
4	Enhancing riparian buffer	Riparian buffer score	3
5	Increased reuse of treated wastewater	Wastewater reuse score	1
6	Maximum Good Quality Return Flow*	Return flow score	X
7	Eco-friendly riverfront projects	Eco-friendly riverfront score	3
8	Leveraging the economic potential of the river	River economy score	5
9	River Sensitive Behaviour Among citizens	Citizen sensitisation score	2
10	Engage Citizens in River management	Citizen engagement score	2
	TOTAL		**22**

URM index = (1+3+2+3+1+X+3+5+2+2) /9* = 22/9 = 2.44

***In this case, the city has not committed the annual return flow, the score could not be calculated for objective 6. Hence, we will average the score by 9**

URM Index for Muzaffarpur city = 2.44 (Elementary Level of river management)

As per URMP Framework, Muzaffarpur city has an Elementary level of urban river management, scoring between 1.6 to 2.5

Overall, Muzaffarpur's baseline assessment indicates a city at a critical inflexion point: one where ecological risk, if left unmanaged, could intensify rapidly, but where strategic planning, regulatory clarity, and integrated investments could unlock significant environmental, economic, and social gains under the URMP. Muzaffarpur's score profile highlights a high-risk, high-opportunity city. With targeted interventions in floodplain zoning, wastewater reuse, waterbody restoration, and structured citizen engagement, the city has the potential to significantly improve its URMP performance in subsequent assessment cycles.

3.2 SWOT analysis

Based on the baseline assessment and consultations with city stakeholders, the following SWOT analysis has been prepared for the Burhi Gandak and its associated water bodies in Muzaffarpur. This provides a diagnostic basis for identifying intervention areas under the URMP.

ENVIRONMENTAL

Key focus: Treatment of wastewater, groundwater quality improvements, trunk infrastructure creation, flood plain management, pollution control, rejuvenation of inland water bodies and drains

STRENGTHS

- Perennial river system with existing water bodies supporting ecological balance
- Potential for boating and river-based economic activities

WEAKNESS

- Untreated sewage discharge degrades the river and nallah water quality
- Loss and degradation of riparian buffers due to encroachment and dumping

OPPORTUNITY

- Wetland restoration and green buffer development for ecological improvement
- Scope for nature-based solutions to enhance river health and resilience

THREATS

- High flood risk due to low-lying terrain and poor drainage conditions
- Increasing climate variability is impacting river flows and urban flooding

ECONOMIC

Key focus: Leveraging the economic potential of the riverfront and other economic activities

STRENGTHS

- Strong Shahi Litchi economy with regional and global recognition
- Potential for boating and river-based economic activities


WEAKNESS

- Poor riverfront infrastructure is limiting economic utilisation.
- Prevalence of informal and unregulated riverbank activities


OPPORTUNITY

- Development of riverfront economy through tourism and local markets
- Leveraging agriculture and river identity for economic branding


THREATS

- Urban Flooding damage impacting livelihoods and the local economy
- Increasing land pressure, reducing the scope for planned development


SOCIAL

Key focus: Citizen sensitization and awareness on the importance of the river and mobilisation of community led efforts in managing river's health

STRENGTHS

- Strong cultural connection to the river through ghats and ritual practices
- Presence of traditional community engagement with river systems

WEAKNESS

- Low awareness regarding river conservation and sustainable practices
- Encroachment pressure driven by informal settlements and usage

OPPORTUNITY

- Scope for community stewardship and citizen-led river monitoring
- Potential for behaviour change through awareness and engagement programmes

THREATS

- Continued neglect of river systems leading to public health risks
- Degrading river conditions weaken cultural and social connections

INTERVENTIONS

4. INTERVENTIONS

4.1 Objective 1: Regulation of Activities in the Floodplain

Objective 1 *aims to regulate activities within the floodplain to safeguard river health. This includes ensuring land-use compliance, preventing encroachment, and aligning development with river-sensitive planning and zoning norms.*

4.1.1 Existing Condition

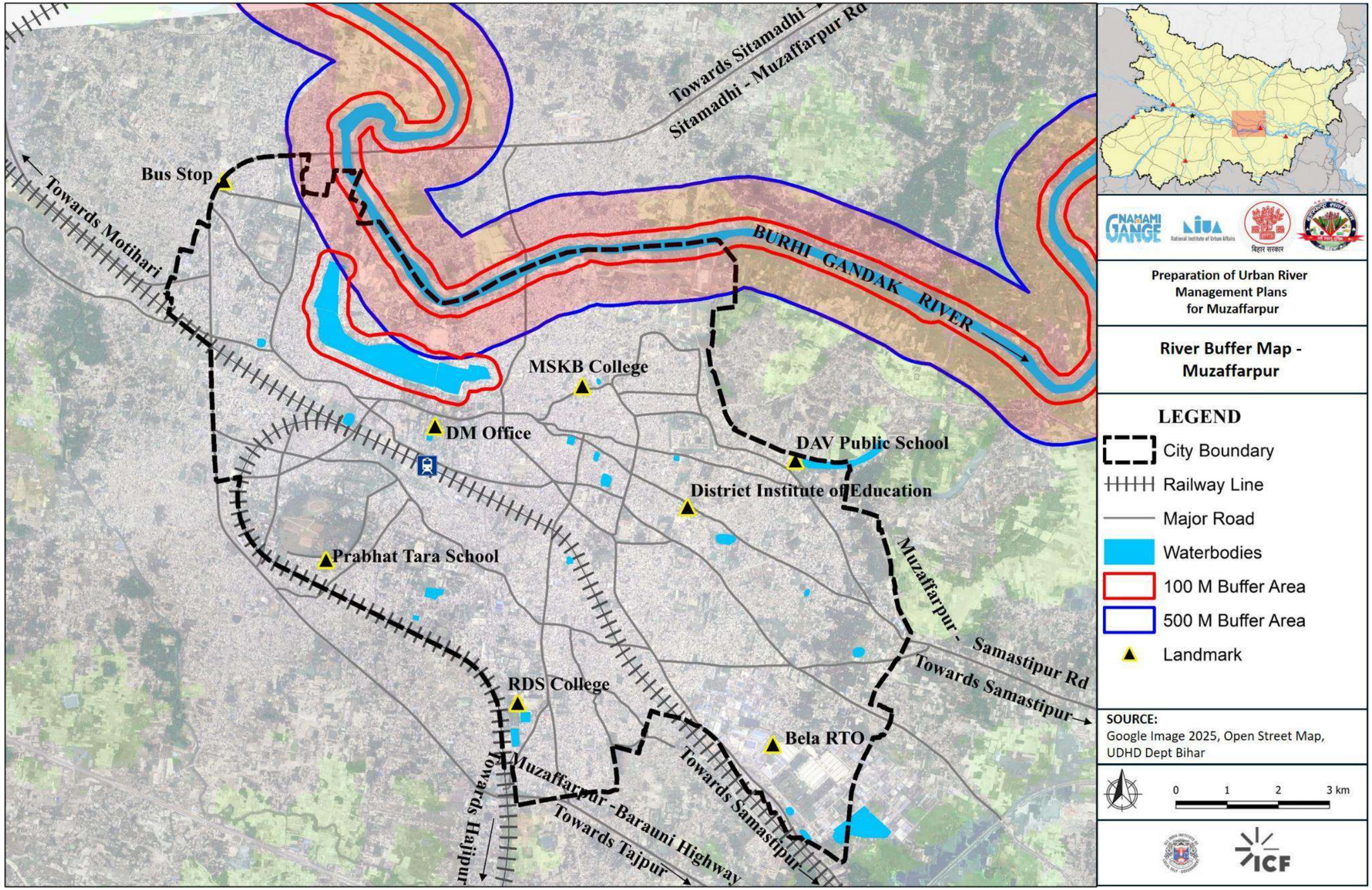
Floodplain management in Muzaffarpur operates within a multi-layered policy framework comprising national environmental legislation, judicial directives, and evolving state-level guidelines. National frameworks such as the *Environment (Protection) Act, 1986*, *Water Act, 1974*, and the *River Ganga (Rejuvenation, Protection and Management) Authorities Order, 2019* establish broad principles for regulating pollution, restricting construction, and protecting river ecosystems. Guidelines from the Central Water Commission (CWC), National Disaster Management Authority (NDMA), and the National Mission for Clean Ganga (NMCG) further emphasise the integration of floodplain zoning into urban planning. The National Green Tribunal (NGT) has reinforced these provisions through directives mandating floodplain demarcation, removal of encroachments, and prohibition of waste dumping within river buffers. However, in the absence of a notified floodplain zoning law in Bihar, implementation remains limited and fragmented.

At the state level, flood management continues to rely primarily on structural measures such as embankments and flood protection works undertaken by the Water Resources Department. While initiatives such as the *Jal Jeevan Hariyali Mission* promote water conservation and climate resilience, there remains a significant gap in regulating land use within floodplain areas. Enforcement by agencies such as the Bihar State Pollution Control Board is constrained, and floodplain zoning has not yet been formally integrated into statutory planning frameworks. At the local level, Muzaffarpur largely follows a reactive approach to flood management, centred on emergency response and relief operations, with limited regulatory control over construction, encroachments, or land use along the river.

The absence of clearly defined floodplain boundaries, development control regulations, and enforcement mechanisms has led to incremental, unregulated expansion toward the river edge. Encroachments near ghats, expansion of built-up areas, and increasing pressure on the riparian corridor have weakened the river system's natural buffering capacity. At the same time, competing land uses—including agriculture, urban development, and infrastructure—continue to occupy flood-prone areas without adequate consideration of hydrological processes.

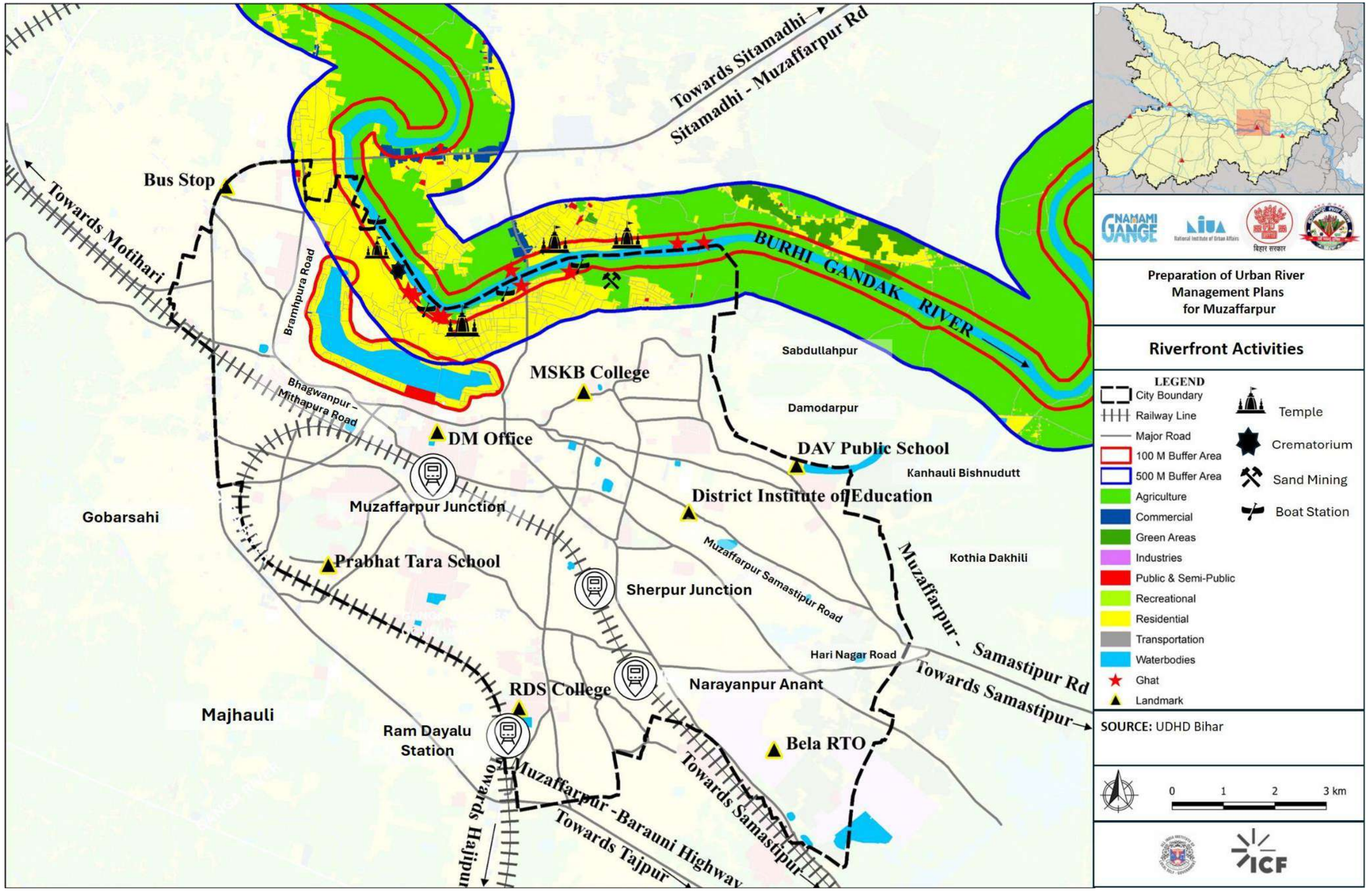
These conditions highlight the need for a structured floodplain regulation framework that moves beyond reactive flood management toward proactive land-use planning. Integrating floodplain zoning into the Master Plan, establishing clear development controls, and strengthening institutional coordination will be essential to ensure long-term flood resilience, ecological protection, and sustainable urban growth in Muzaffarpur.

Map 8 : River Buffer analysis



Source: Google Image 2025, Open Street Map and UDHD Dept Biha

Map 9 : Riverfront activity map



Map 10 : Sikandarpur Lake -riverfront activities

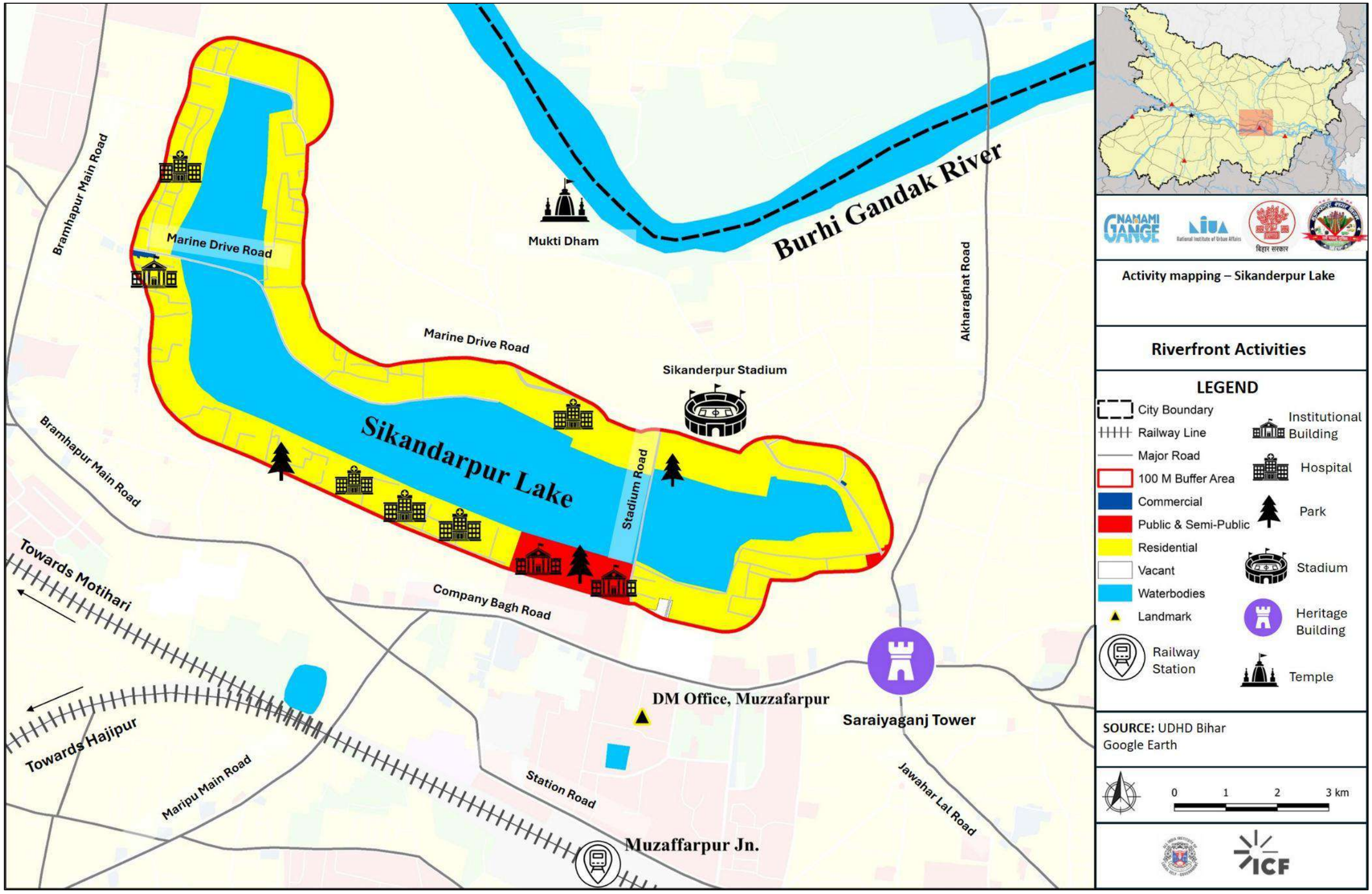


Figure 14 Dense urban development on the floodplain on Bandh Road, Muzaffarpur

Source: Primary Survey

Figure 15 Unauthorised construction on the river floodplain

Source: Primary Survey

Figure 16 Agricultural area on the Muzaffarpur floodplain

Source: Primary Survey

4.1.2 URMP Score

The Floodplain Management Score for Muzaffarpur is **24/100**, indicating weak regulatory control and limited enforcement. While structural measures such as embankments exist and land-use data is available, there is **no formal floodplain demarcation, NDZ, or monitoring mechanism** in place, leading to continued encroachment and solid waste dumping along riverbanks. **Based on the URMP framework, as the total score is below 30, the final URMP score for this objective is 1**, reflecting a poor level of floodplain management.

4.1.3 Flood Susceptibility and Floodplain Delineation

Flood susceptibility in Muzaffarpur is closely linked to its low-lying terrain and proximity to the Burhi Gandak River. The city's **High Flood Level (HFL) is 54.59 m**, representing the maximum recorded floodwater level and forming the basis for delineating flood-prone areas. Areas lying at or below this elevation, particularly along the river and within natural drainage corridors, are highly susceptible to flooding. As seen in the LULC map, the riverfront is predominantly built-up, especially along the central and western stretches of the Burhi Gandak, where dense urban development extends up to the river edge. Only fragmented patches of agriculture and green areas are visible, primarily in the eastern and northeastern fringes. This high degree of built-up encroachment along the riverfront reduces natural floodplain storage, restricts lateral water spread, and increases the risk of waterlogging and urban flooding in adjacent areas.

Flood susceptibility assessment is used to guide floodplain zoning, where the **HFL (54.59 m)** acts as a critical threshold for regulating development and prioritising flood mitigation measures in Muzaffarpur. Flood susceptibility refers to the intrinsic tendency of a terrain to experience inundation based on its physical, hydrological, environmental, and anthropogenic characteristics.

Flood susceptibility in Muzaffarpur has been assessed using a combination of key parameters:

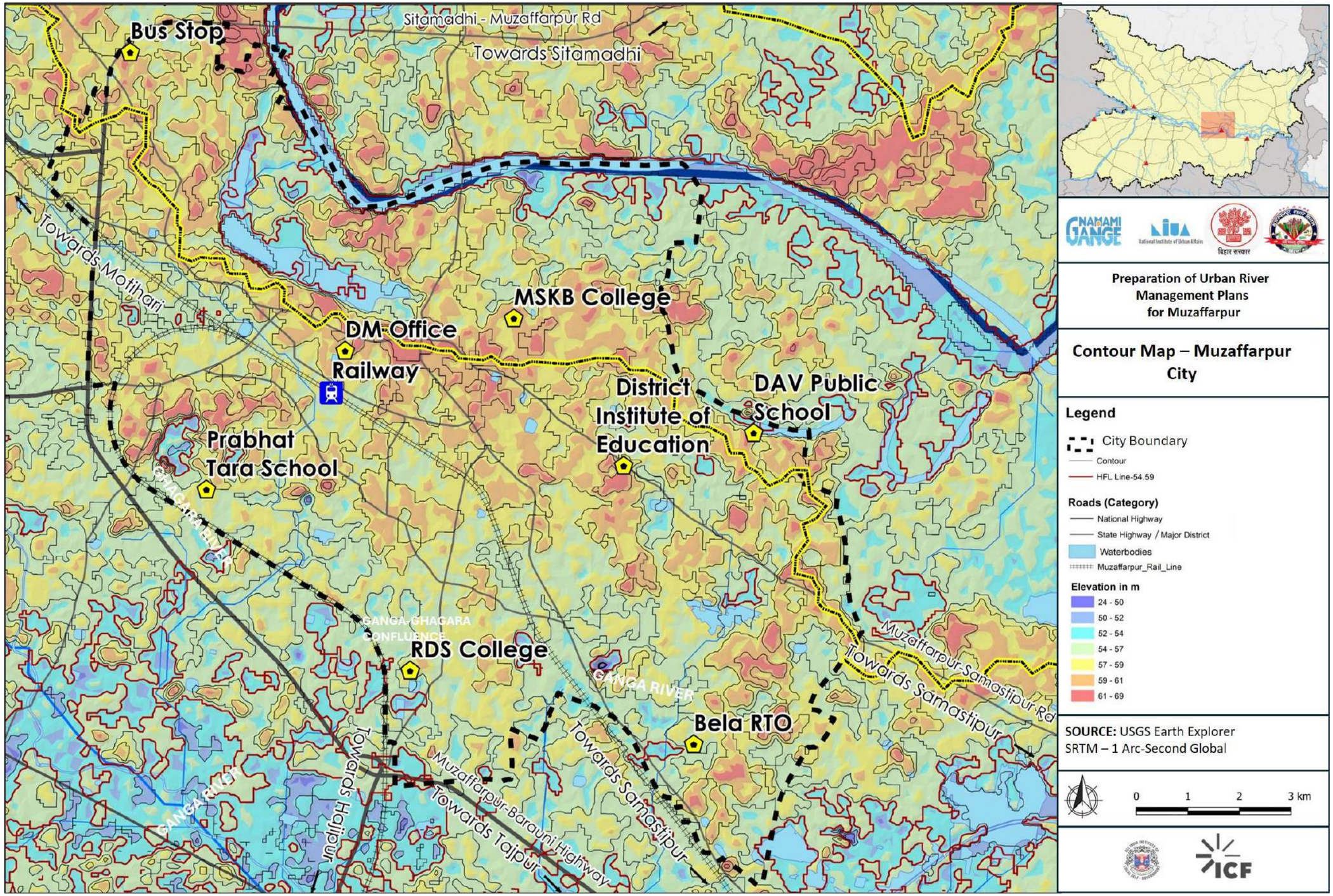
- Topographic Wetness Index (TWI)
- Drainage Density
- River Proximity (Buffer)
- Elevation and Slope
- Land Use Land Cover (LULC)
- Soil Characteristics
- Vegetation Index (NDVI)
- Road and Railway Buffers

The analysis indicates that:

- TWI and Drainage Density (18.2% each) are the most influential parameters for flooding
- River buffer (14%) captures flood exposure along the Burhi Gandak
- Elevation and slope (~21%) influence runoff and stagnation
- LULC, soil, and NDVI determine infiltration and permeability
- Infrastructure buffers act as localised flow barriers

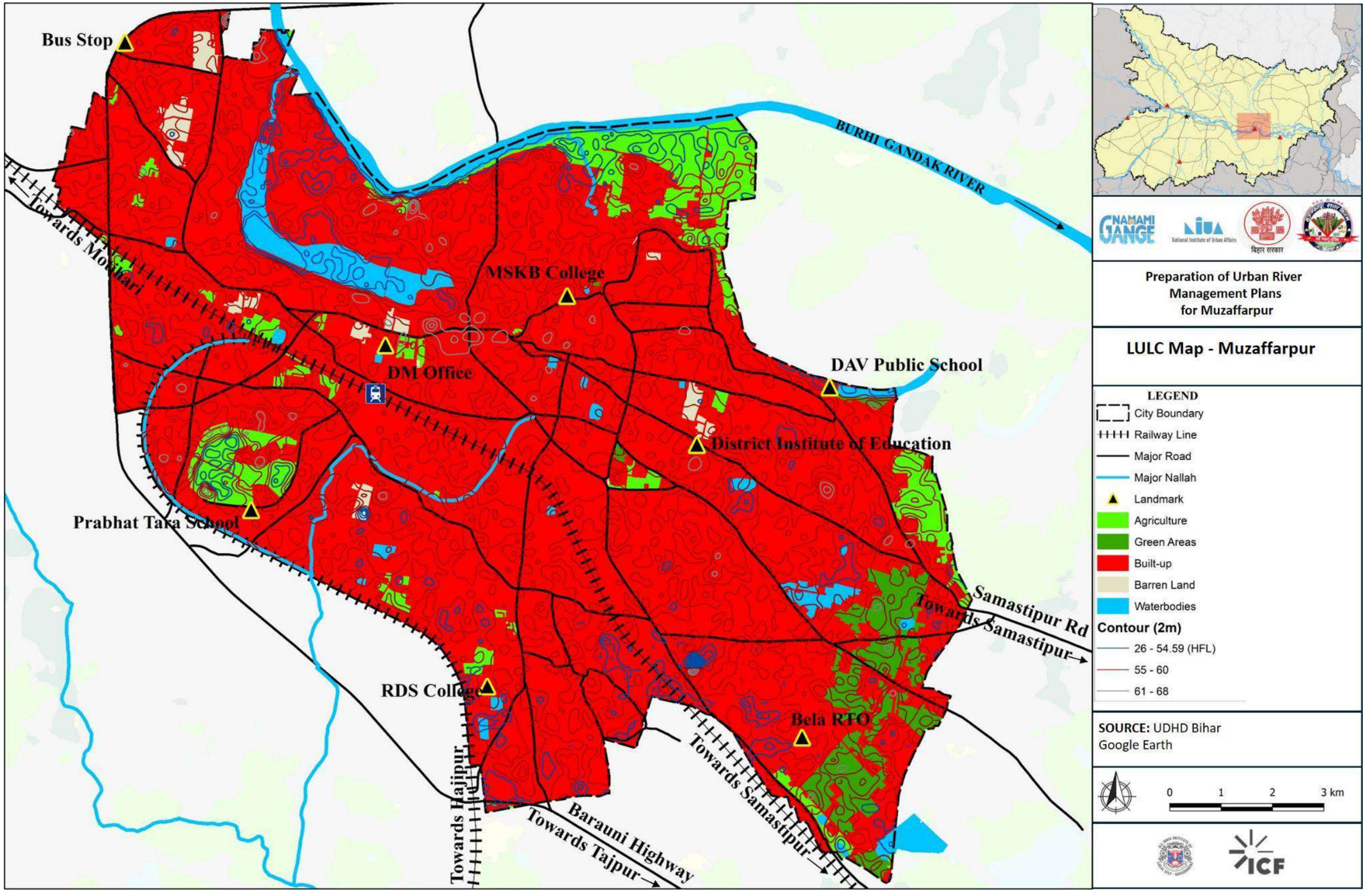
The methodology of calculating the Flood Susceptibility is detailed in **Annexure 3**

Map 11: Contour Map of Muzaffarpur- with 54 m HFL



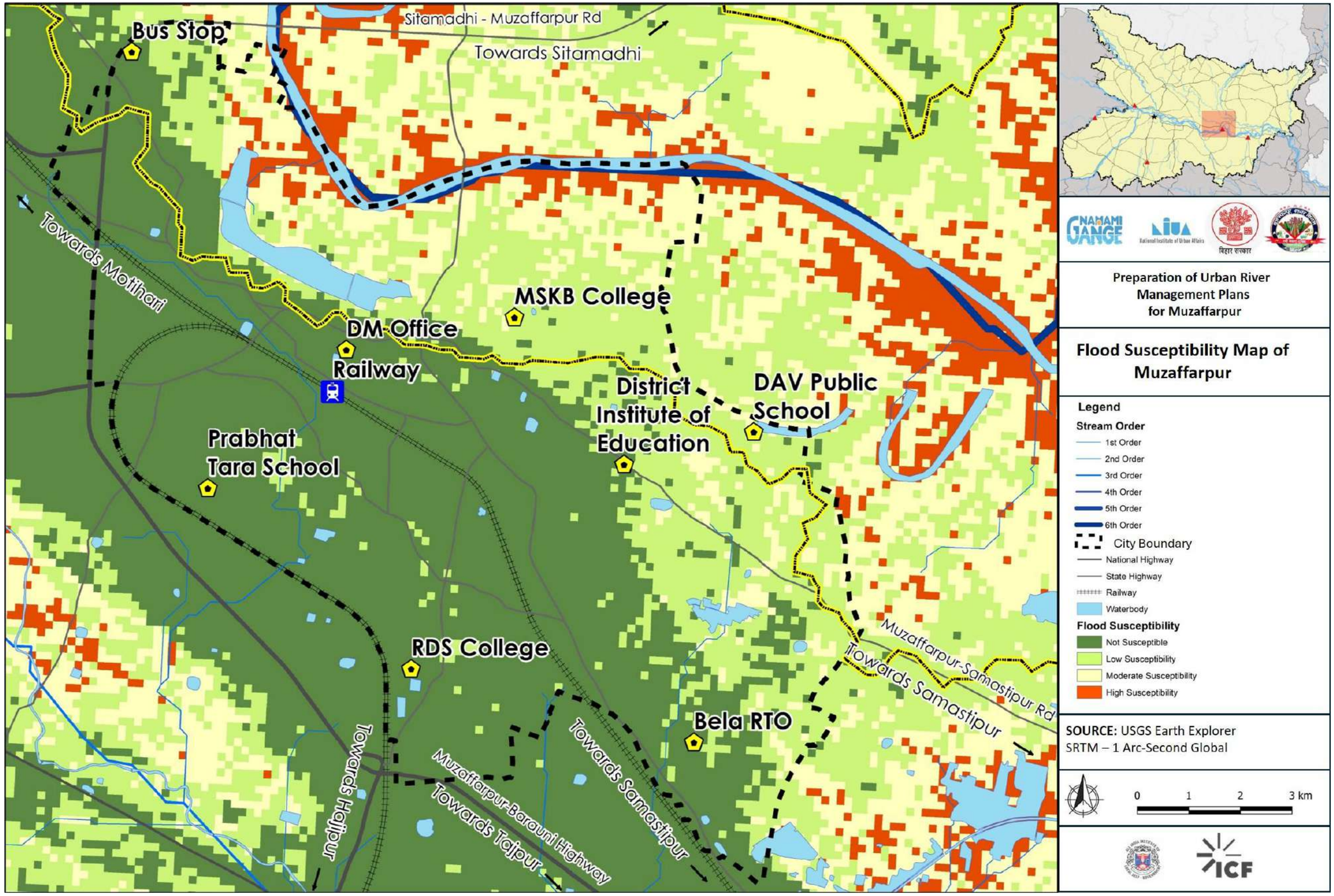
Source: USGS Earth Explorer and SRTM-1 ARC Second Global

Map 12 : LULC Map with Contours



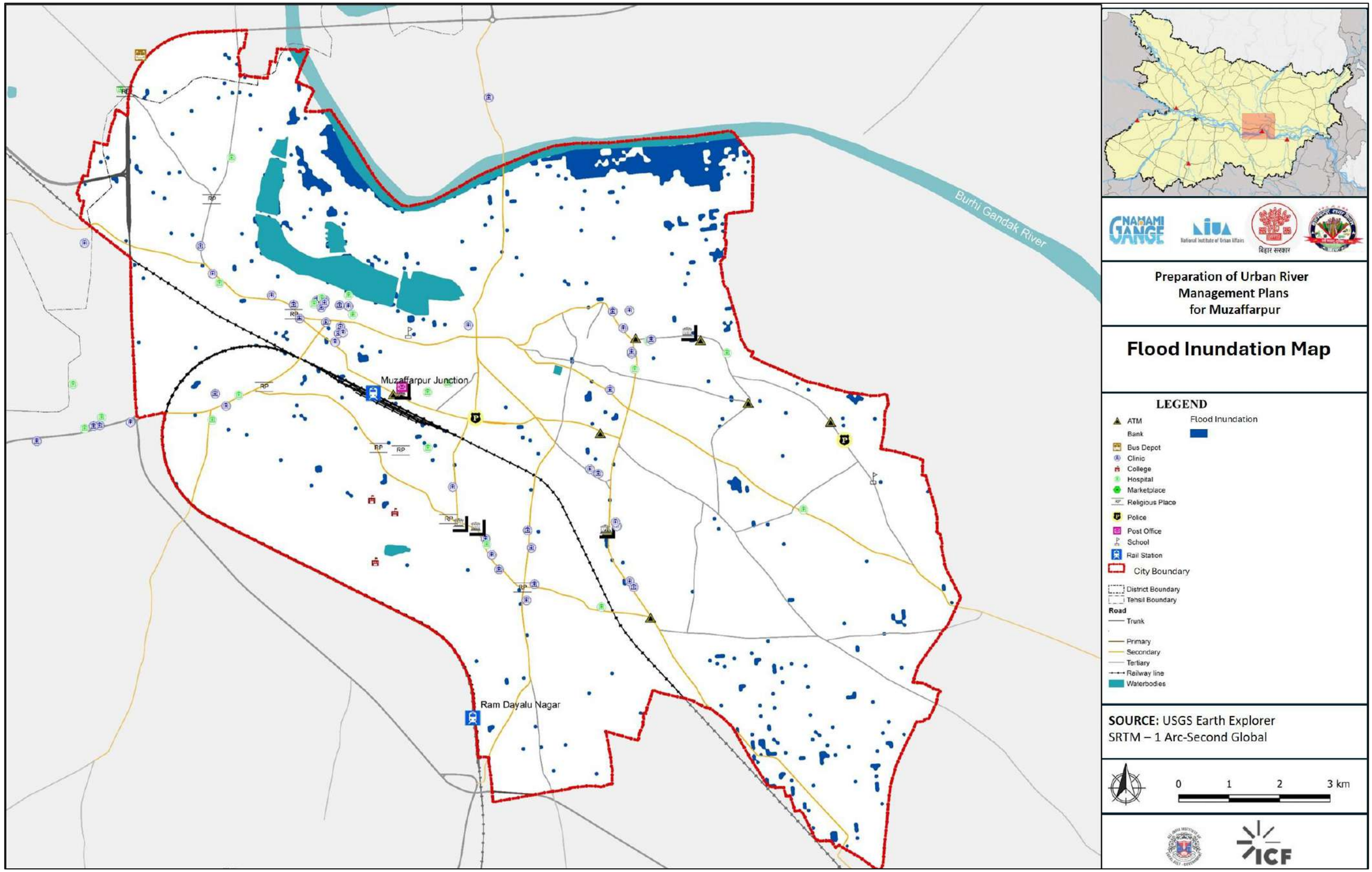
Source: UDHD Bihar and Google Earthl

Map 13: Flood Susceptibility map



Source: Consultant analysis. Methodology mentioned in Annexure

Map 14 : Flood inundation map



4.1.4 Interventions- Objective 1

Interventions 1.1: Flood plain Zoning Integration into the Master Plan

The Master Plan for Muzaffarpur is currently under preparation/proposal stage and does not comprehensively address floodplain management, river-sensitive planning, or ecological restoration along the Burhi Gandak River and its drainage network.

Several stretches of the Burhi Gandak riverfront and adjoining nallah corridors are characterised by dense built-up development, encroachments, unregulated dumping of solid waste, and degraded drainage conditions. Although parts of the river corridor and peripheral floodplain remain semi-natural, particularly in agricultural and low-density areas, the absence of a comprehensive floodplain zoning framework has resulted in increasing encroachment and pressure on drainage infrastructure. The lack of river-sensitive development controls limits opportunities to strengthen flood resilience and restore ecological buffers along the Burhi Gandak and associated drains.

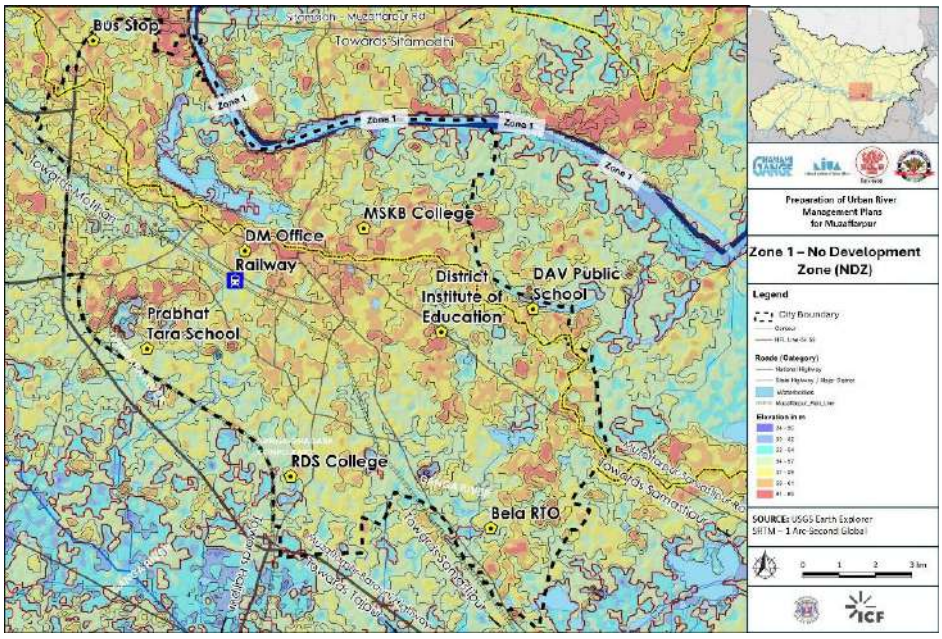
Figure 17 : Process for Floodplain zoning integration into Master plan

Step 1: Delineate and Zone the Floodplain

Zone 1 – No Development Zone (NDZ): Active River Corridor and Drainage Network

The active river corridor of the Burhi Gandak River, including low-lying flood-prone areas **below the High Flood Level (HFL) of 54.59 m,** major nallahs, wetlands, and natural drainage channels, shall be designated as the No Development Zone (NDZ). This zone shall function as a strict ecological and hydraulic buffer where permanent construction, landfilling, waste dumping, and encroachments shall not be permitted.

Map 15 : Proposed flood plain zoning- ZONE 1



The delineation of this zone shall be based on HFL contours, natural drainage patterns, existing water channels, and observed seasonal flow behaviour. Limited non-intrusive and temporary activities such as eco-restoration, riverfront greening, cultural uses, and seasonal public access may be permitted, provided they do

not obstruct drainage flow or alter the floodplain character. All temporary installations must remain removable before the monsoon season.

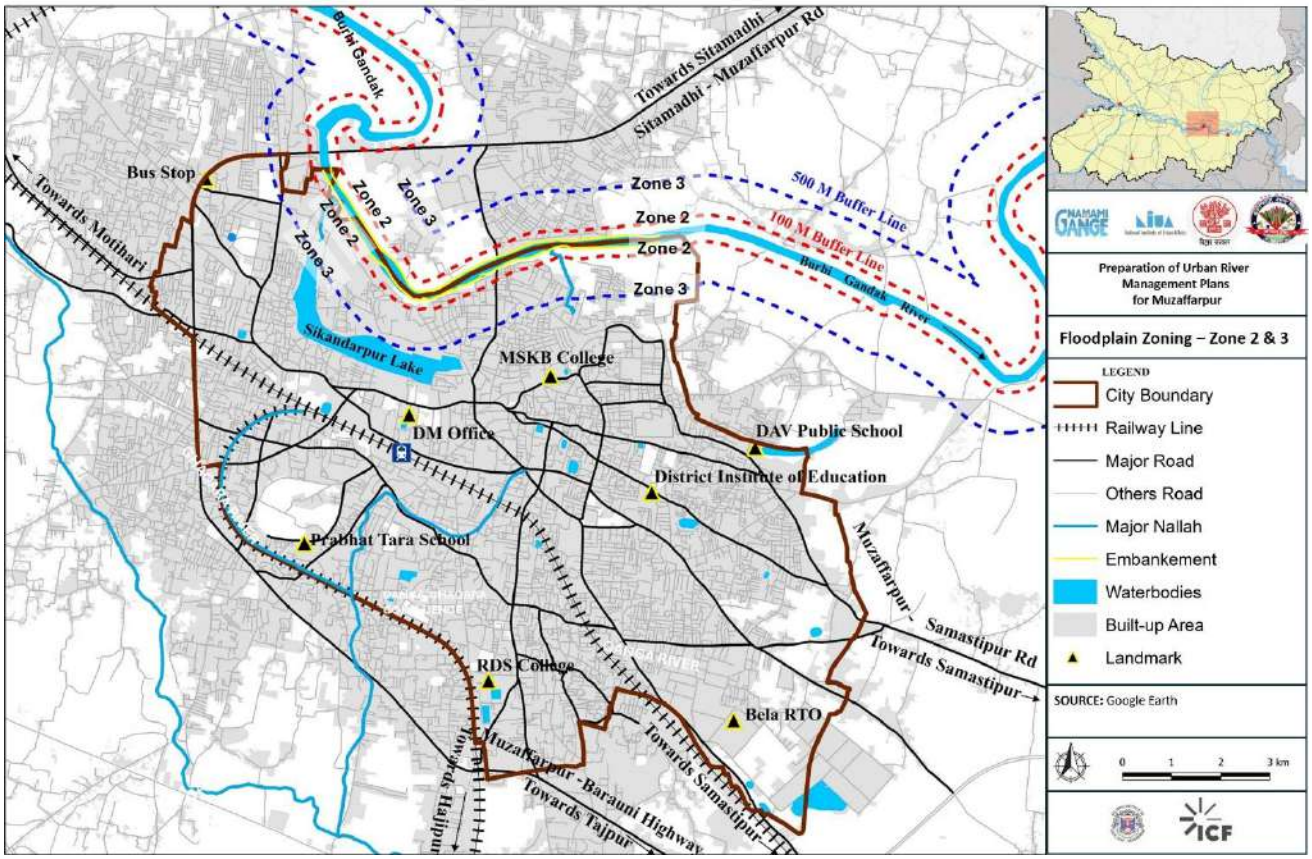
Zone 2 – Regulated Development Zone (RDZ): Riparian and Flood Buffer

A regulated buffer zone along the river edge and major drainage corridors shall be designated as the Regulated Development Zone (RDZ). This zone broadly corresponds to areas vulnerable to periodic flooding, drainage congestion, and waterlogging, including densely built-up pockets adjoining the Burhi Gandak and major nallah systems.

The planning approach within this zone shall focus on regulating further urban intensification while improving flood resilience in existing developed areas. Development controls shall include restrictions on ground coverage, mandatory plinth heights, permeable surfaces, drainage improvements, and setbacks along drains and water bodies. Buffer areas shall also function as strict no-dumping zones to prevent drain blockage and a reduction in carrying capacity.

Agricultural and open areas within this zone should integrate vegetative buffers and plantation belts to reduce runoff, stabilise riverbanks, and improve infiltration. The objective is to reduce long-term flood risk while improving environmental performance within the urban fabric.

Map 16 : Proposed flood plain zoning- ZONE 2,3



Zone 3 – Special Regulation Zone (SRZ): Urban Transition and Controlled Development Area

Zone 3 shall function as a Special Regulation Zone (SRZ) requiring area-specific planning and customised Development Control Regulations (DCRs). This zone includes existing urban areas beyond the primary flood buffer that continue to experience indirect flood impacts due to inadequate drainage, high built-up density, and altered runoff patterns.

Development within the SRZ shall be guided through flood-sensitive urban planning measures, including controls on FAR, ground coverage, built form, and stormwater management. Infrastructure upgrades, climate-responsive urban design, and flood-compatible development typologies shall be prioritised within this zone. The SRZ will act as a transition interface between the active floodplain and the urban core, balancing development needs with long-term flood resilience, drainage management, and ecological sustainability.

Step 2: Modify Relevant Development Control Regulations (DCRs)

The DCRs accompanying the Master Plan should define land-use controls and environmental safeguards within each floodplain zone. Regulations should focus on:

- Protection of drainage channels and nallah networks
- Prevention of solid waste dumping along rivers and drains
- Restriction of construction within designated buffers
- Flood-resilient building regulations
- Preservation of low-lying agricultural and open areas as flood retention zones

Building regulations within flood-prone areas should include:

- Minimum plinth height above flood level
- Controlled ground coverage and FAR
- Flood-resilient building design
- On-site stormwater management
- Mandatory setbacks along drains and nallahs

Muzaffarpur's urban flooding is strongly linked to altered drainage patterns, encroachments, inadequate waste management, and increasing built-up intensity in low-lying areas. Mandatory buffer zones should therefore be created along the Burhi Gandak, major nallahs, ponds, and water bodies, within which dumping, encroachment, and permanent construction shall be prohibited. Differential DCRs should regulate built form and site coverage based on flood susceptibility to reduce long-term flood risk while maintaining urban functionality.

Table 1 : List of Permissible Activities

Activity Type	No Development Zone (100 m)	Regulated Development Zone (500 m)
Permanent residential housing	✕ Prohibited	✕ Prohibited
Agriculture (organic/natural)	✓ Permitted	✓ Permitted
Chemical-intensive farming	✕ Prohibited	△ Strongly discouraged
Grazing/pasture	✓ Permitted	✓ Permitted

Table 2: Zone wise permissible activities

Activity Type	No Development Zone (100 m)	Regulated Development Zone (500 m)
Religious activities (Chhath, rituals)	✓ Permitted (temporary)	✓ Permitted
Permanent religious structures	✕ Prohibited / △ Regulated	✕ Prohibited
Ghats (eco-sensitive design)	✓ Permitted	✓ Permitted
Cremation grounds	✓ Permitted	✓ Permitted
Parks, open spaces	✓ Permitted	✓ Permitted
Commercial/industrial activity	✕ Prohibited	✕ Prohibited
Solid waste dumping	✕ Prohibited	✕ Prohibited
STPs / river works	✕ Prohibited	△ Strongly discouraged

Legend: ✓ Permitted △ Conditional ✕ Prohibited

The following should be permitted across zones, subject to safeguards:

- Bridges, embankment repairs, flood protection works
- Water supply pipelines, power transmission lines
- Outfalls, river conservation works under NMCG

Note:

The proposed floodplain zoning framework provides a structured basis for regulating development along the Burhi Gandak while improving flood resilience. Its **effectiveness will depend on formal notification, integration with the Master Plan, and enforcement through clear institutional roles**. A **phased approach is recommended** to address existing land uses, supported by community engagement and convergence with ongoing projects. Continuous monitoring and periodic updates will be essential to ensure long-term sustainability and risk reduction.

Step 3: Physically Demarcate the Floodplain Boundaries

Once the floodplain zones are delineated, they should be physically demarcated on-site to improve enforcement and prevent future encroachments along the Burhi Gandak River and major nallah corridors. This can be achieved through:

- Installation of boundary pillars, signage, and visual markers along the NDZ and RDZ boundaries
- Use of embankments, roads, and drainage edges as reference lines wherever applicable, supported by signage indicating regulatory status
- Protection and marking of major drainage channels and outfalls to prevent blockage and dumping
- Periodic verification and monitoring through GIS mapping and field surveys to ensure compliance and update floodplain boundaries where required

Physical demarcation should also be integrated with green buffer development and riverfront improvement measures to strengthen long-term floodplain protection and public awareness.

4.2 Objective 2: Pollution Free River

Objective 2 *aims to assess the existing situation of citywide waste management systems with a focus on both liquid and solid waste streams and their impact on river health. The scope of this assessment covers the entire value chain, starting from sources of generation to final disposal, while also considering institutional arrangements, service delivery mechanisms, and ongoing or planned interventions. The central premise of this indicator is that, at the least, the city should ensure that the* ***quality of water leaving the city should be the same as entering the city***.

4.2.1 Existing Condition

Groundwater and drinking water context

Muzaffarpur is almost entirely dependent on groundwater for domestic, commercial, and institutional water supply. Groundwater in the city occurs at relatively shallow depths, with pre-monsoon water levels ranging between **2.18 to 5.61 metres below ground level (mbgl)** across the district. In central urban areas such as Muzaffarpur Sadar (Mushahari block), groundwater levels are typically even shallower, generally ranging between 2–4 mbgl. Groundwater levels rise post monsoon significantly because of rainfall recharge and interaction with the Burhi Gandak River, often approaching near-surface conditions in low-lying areas and contributing to seasonal waterlogging. Despite this apparent abundance, groundwater resources are under increasing stress, with the district recording a groundwater **extraction stage of approximately 73.83%, placing it in the semi-critical category**. Elevated nitrate concentrations and contamination risks in parts of the district further indicate growing groundwater quality concerns.[6] [7]

Table 3 : Gaps in water supply

Total Water Supply Demand for Population	Total Water Supply(Provisioned)	Gap In Water Supply
41.24 MLD	29.97 MLD	11.27 MLD

Source: PHED Muzaffarpur and Drainage DPR from BUIDCO

The city currently relies on 15 municipal tube wells producing approximately **29.97 MLD** and operating for about 13 hours per day, supplemented by nearly 482 hand pumps. Pumping capacities range from 113–151 KLD/hr, indicating significant extraction pressure on aquifers.

Against a **total demand of 41.24 MLD, the city faces a present and persistent supply gap of 11.27 MLD,** leading to increasing dependence on private borewells and further stressing groundwater resources. Water quality is generally within permissible limits for pH and conductivity; however, elevated BOD and coliform presence indicate contamination risks within the distribution system, compounded by the absence of advanced treatment facilities beyond chlorination. The levels are given in the table below.

[6] Central Ground Water Board (CGWB), Ground Water Year Book – Bihar, Ministry of Jal Shakti, Government of India.

[7] Central Ground Water Board (CGWB), Aquifer Maps and Management Plan of Muzaffarpur District, Bihar, 2023

Table 4 Groundwater quality

Parameter	Observed Value in Muzaffarpur	Acceptable / Safe Range (IS 10500:2012 / CPCB)	Status
pH	7.05 – 8.35	6.5 – 8.5	Within permissible limits
Conductivity	256 – 1032 µmhos/cm	Generally acceptable below 1500 µmhos/cm	Within permissible limits
BOD	6.6 mg/L	< 3 mg/L desirable for potable source water	Exceeds acceptable limit
Total Coliform	2 – 120 MPN/100 ml	0 MPN/100 ml desirable for drinking water	Indicates contamination risk

Source: Preparation of DPR for Stormwater Drainage Scheme for Muzaffarpur Bihar, Tirhut Division, BUIDCO.

The city's storage and distribution infrastructure remains outdated and inefficient. Muzaffarpur has seven Overhead Tanks (OHTs), with a combined storage capacity of approximately 29.5 MLD, many dating back to 1952, along with a 72 km long pipeline network primarily consisting of old cast-iron pipes prone to leakages. This results in high non-revenue water (~40%) and reduced service efficiency. Coverage remains limited, with only about 60% of the population served and approximately 26.28% household connections, while per capita supply stands at 77 LPCD. The system further suffers from intermittent supply (~8 hours/day), absence of metering, and weak cost recovery (~40%), highlighting systemic inefficiencies.[8]

Rapid urbanisation, encroachment along natural drains, and declining recharge areas have significantly altered the city's hydrological regime. As a result, Muzaffarpur presents a paradox of simultaneous groundwater abundance and vulnerability, characterised by shallow water tables, recurring waterlogging, and increasing pressure on both groundwater quantity and quality. The city's continued dependence on groundwater in a semi-critical aquifer condition underscores the urgent need for source diversification, aquifer recharge measures, demand management, reduction of distribution losses, and integrated urban water resource planning.

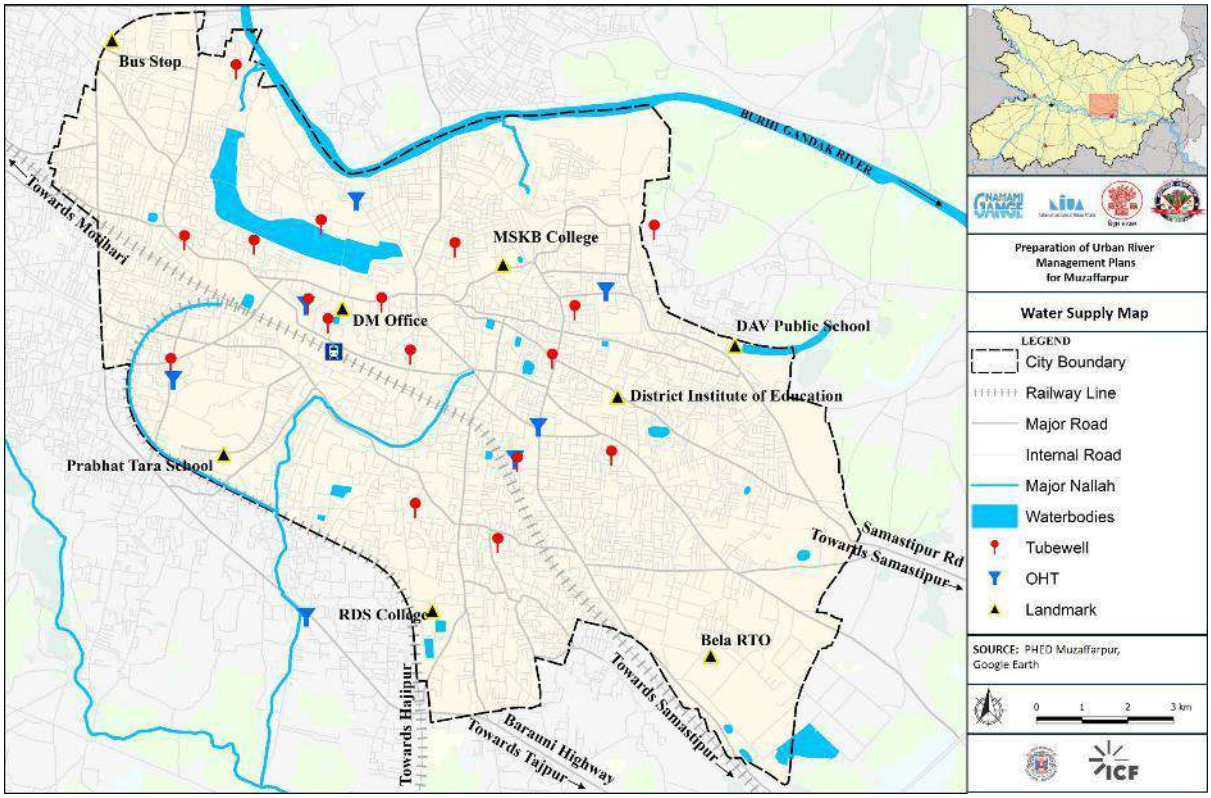
Table 5 List of Overhead Tanks in Muzaffarpur

Sl. No.	Location of OHT	Capacity (ML)	Status
1	Company Bagh	0.35	Functioning
2	Sikanderpur Stadium	0.45	Functioning
3	Jail Road	0.45	Functioning
4	Zilla School	0.35	Functioning
5	Imli Chatti	0.45	Functioning
6	Circuit House	0.45	Functioning
7	Khabra	0.45	Functioning

Source: PHED Muzaffarpur

[8] Preparation of DPR for Stormwater Drainage Scheme for Muzaffarpur Bihar, Tirhut Division, BUIDCo.

Map 17 : Location of OHTs and Tube wells



Sewerage network

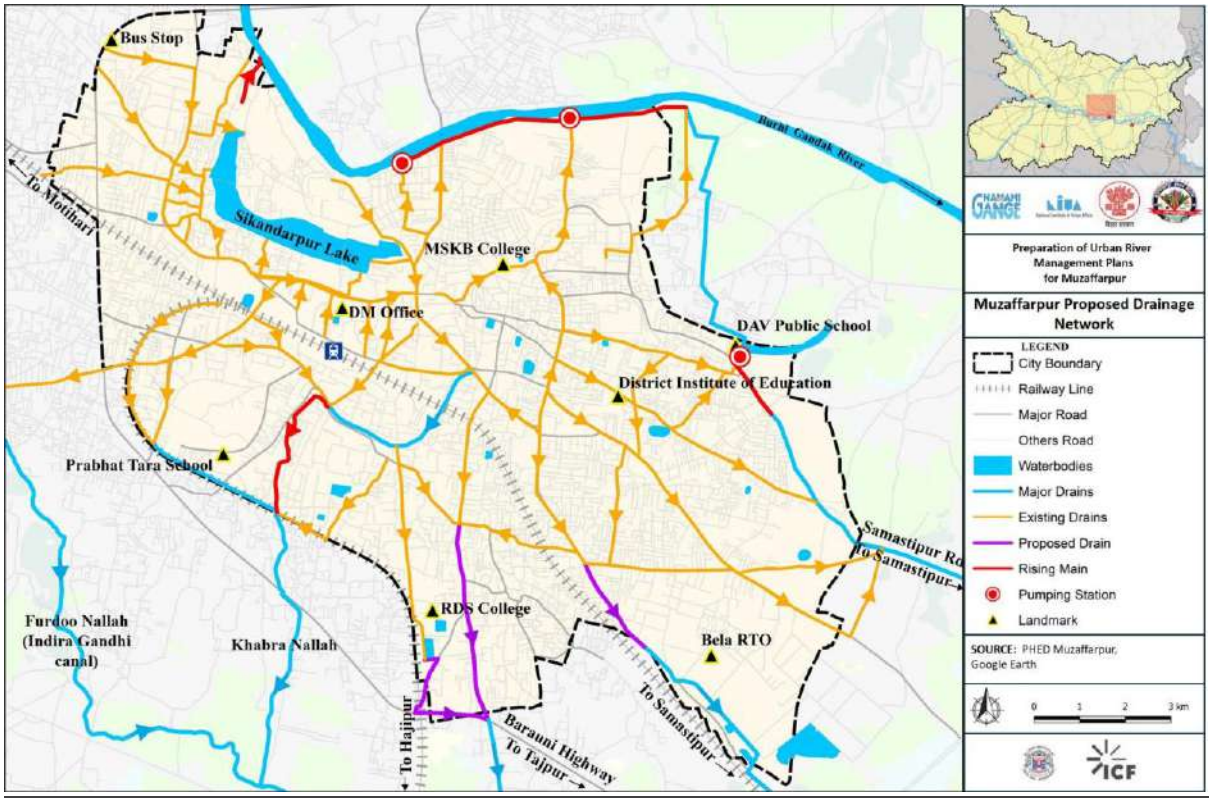
Muzaffarpur currently lacks an organised sewerage system, with no underground network for the collection, conveyance, or treatment of wastewater. As a result, sewage is managed primarily through on-site sanitation systems, engineered and un-engineered nallahs, leading to unsafe disposal and direct discharge into natural drainage channels and eventually into the Burhi Gandak and Furdoo Canal. As per DPR estimates, the city is projected to generate nearly **57 MLD of sewage by 2030**, most of which currently remains untreated.

In the absence of a sewer network, stormwater drains function as de facto combined drains, carrying domestic wastewater during dry periods and mixed sewage–stormwater flows during the monsoon. This often results in flooding of contaminated water in low-lying areas and increases pollution loads entering the river system. The city has a road network of nearly **550 km**, but only about **137.17 km of drains**, resulting in drainage coverage of approximately **25%**. Most drains are open, shallow, and hydraulically inadequate, with severe siltation and solid waste accumulation further reducing carrying capacity.

Drainage Basins and Catchments

The city has been delineated into multiple drainage basins based on topography and outfall locations, draining into the Burhi Gandak, Sikanderpur Lake (Bramhpura Basin), Furdoo Nallah (Indira Gandhi Canal), Manika Mann (Oxbow-shaped lake and wetland), and local nallas. *Refer Map 18, 19 – Proposed drainage network and catchment areas)*

Map 18: Proposed Drainage Network



Source: Government of Bihar (2017). DPR for Storm Water Drainage Scheme, Muzaffarpur, Package-2 (Tirhut), BUIDCO

Table 6 : Zone wise drainage catchment

Zone	Zone Name	Catchment Area (ha)	Length of Major Drains (km)	Outfall
1	Brahmpura Lake Zone (Sikanderpur)	370.70	13.00	Burhi Gandak
2	Local Pokhra Zone	70.54	2.48	Railway Track
3	River Burhi Gandak-1	34.33	0.81	Major Outfall
4	River Burhi Gandak-2	198.30	3.12	Major Outfall
5	River Burhi Gandak-3	41.36	0.43	Major Outfall
6	River Burhi Gandak-4	143.33	1.08	Burhi Gandak
7	Shahdallpur Lake Zone	491.80	13.88	Major Outfall
8	Industrial Area (Bela Road)	280.40	6.18	Tirhut Canal
9	Katchi Pakki Road Zone	315.36	6.70	NH-28 / Madhual Nala
10	Furdoo River Zone-1	459.26	16.41	Furdoo River
11	Furdoo River Zone-2	74.10	3.90	Furdoo River
12	Manika Maun Outfall	1.07	9.35	Manika Maun
Total	—	2,480.55	77.32	—

Source: Government of Bihar (2017). DPR for Storm Water Drainage Scheme, Muzaffarpur, Package-2 (Tirhut), BUIDCO

Treatment Infrastructure and Industrial Linkages

Proposal: To address these issues, BUIDCo has proposed a comprehensive drainage DPR along with an Interception and Diversion (I&D) project for the Burhi Gandak and associated drains. The proposed system aims to intercept major wastewater outfalls and convey sewage to **three proposed STPs** for treatment before discharge. However, there are currently no proposals for a citywide underground sewerage network or Faecal Sludge Treatment Plant (FSTP), creating a significant gap in long-term sewage and septage management.[9]

To address the treatment gap, **22 MLD and 2.5 MLD STPs are under construction (≈80% complete)** and expected to be operational by September 2026, while a **16 MLD STP is proposed** for the southern part of the city *(Refer MAP – 18, 19- Drainage network and catchment areas)*. However, the absence of sewer connectivity limits their effectiveness. Industrial activity, primarily concentrated in the Bela Industrial Area, further compounds pollution due to the lack of a **Common Effluent Treatment Plant (CETP)**. In many cases, untreated industrial effluents are discharged into low-lying areas or municipal drains, eventually reaching the Burhi Gandak and Furdoo rivers. **Key Issues**

- Absence of a sewerage network leading to direct discharge of untreated sewage
- Drains functioning as combined sewers, causing sewage-laden flooding
- Large treatment gap despite ongoing STP projects
- High solid waste accumulation reduces drain efficiency
- Direct discharge of polluted flows into rivers
- Lack of CETP and poor industrial effluent management
- Weak institutional integration across water, sewerage, drainage, and pollution management sectors

Table 7 Gap Analysis of Liquid Waste

Year	Population	Sewage Generation in MLD (Water Supply*0.8)	Proposed Infrastructure (MLD)	Gap (MLD)
2011	3,43,724	37.12	41	-3.88
2015	3,70,000	39.96	41	-1.04
2030	4,40,000	47.52	41	6.52
2035	5,17,500	55.89	41	14.89
2045	5,20,000	56.16	41	15.16

Source: Drainage DPR

[9] Preparation of DPR for Stormwater Drainage Scheme for Muzaffarpur Bihar, Tirhut Division, BUIDCo

Figure 18 Images of the under construction STPs

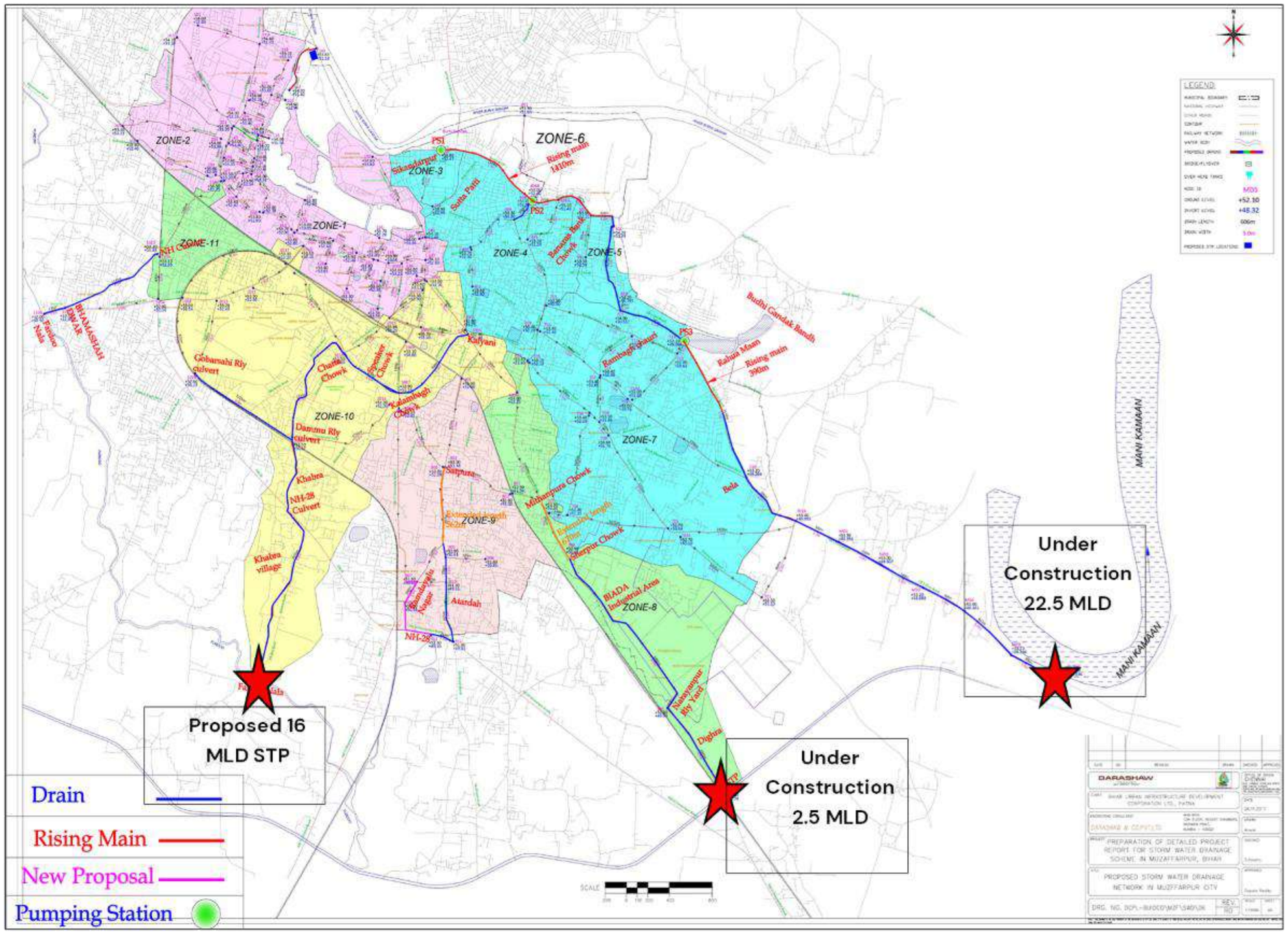
Faecal Sludge

The ULB currently operates **three faecal sludge suction vehicles of 3000 litres capacity each** for the collection and transportation of septage from on-site sanitation systems. However, the city presently lacks a designated treatment or safe disposal facility for faecal sludge, resulting in a major gap in septage management and increasing the risk of unsafe disposal into drains, low-lying areas, and water bodies.

Water quality monitoring data from the Bihar State Pollution Control Board (BSPCB) indicate fluctuating but persistent organic pollution in the Burhi Gandak River within Muzaffarpur. BOD levels recorded at monitoring locations near Akharaghat Road Bridge and NH Road Bridge generally range between **1–3.5 mg/L**, with occasional higher values in earlier years, indicating moderate organic pollution loads entering the river through urban drains. Dissolved Oxygen (DO) levels mostly remain within acceptable ranges, although local fluctuations reflect seasonal variations in flow and pollution intensity. The data highlights the continued impact of untreated wastewater discharge and inadequate drainage infrastructure on the river's water quality.[10]

[10] Bihar State Pollution Control Board

Map 19: Proposed Drainage catchment and STP location



4.2.2 Solid Waste Management

Muzaffarpur generates approximately **120 TPD of municipal solid waste, with about 80% collection efficiency,** leaving a significant portion uncollected and often entering drains and waterbodies. The waste has a high organic content (60–65%), which increases the risk of leachate formation and organic pollution. The city currently lacks scientific processing, segregation, and sanitary landfill facilities, and all collected waste is dumped in an open, low-lying site at Dadar/Rautiniya. This unengineered dumping leads to leachate seepage, groundwater contamination, and direct pollution of nearby drains that ultimately discharge into the Burhi Gandak River.

Solid waste management practices across the city are fragmented and inefficient. There is no segregation at source, limited door-to-door collection coverage, and inadequate primary storage infrastructure, resulting in widespread open dumping along streets, riverbanks, and nallahs. Stormwater drains frequently act as conduits for waste transport, especially during the monsoon, leading to clogging, reduced carrying capacity, and sewage-mixed flooding. Additionally, waste transportation is largely carried out in uncovered vehicles, causing spillage and continuous leakage into the urban environment.

Key Issues

- Direct dumping of solid waste into drains and riverbanks, necessitating trash interception systems at nallah outfalls and along the river edge
- Absence of segregation and processing, leading to mixed waste entering waterways and increasing pollution load
- Open dumping near drainage channels, causing leachate flow into river systems—highlighting the need for scientific landfill and waste processing facilities
- Clogging of drains due to waste deposition, reinforcing the need for regular desilting, drain protection, and waste capture mechanisms
- Poor sanitation and waste accumulation along riverbanks, indicating the need for riverfront sanitation infrastructure and regulated waste disposal systems
- Inadequate collection and transportation systems, requiring strengthening of door-to-door collection and covered transport

4.2.3 Pollution Hotspot Analysis

The pollution hotspot analysis for Muzaffarpur highlights a concentration of contamination sources along the Burhi Gandak River corridor, particularly within the 100 m and 500 m buffer zones. These hotspots are primarily associated with direct discharge of untreated sewage, solid waste dumping, and drain outfalls, which collectively contribute to a high pollution load entering the river system. Key stretches within the central urban area show a clustering of both liquid waste discharge points (nallah outfalls) and solid waste accumulation zones, indicating critical pressure points on river health. The analysis further reveals that many hotspots coincide with dense built-up areas and informal dumping sites along riverbanks, where waste is directly deposited or washed into the river during rainfall events. Additionally, low-lying areas and agricultural lands near the river edge are impacted by wastewater inflows, creating pathways for pollutant transport. These findings underline the need for targeted interventions such as trash interception at drains, interception and diversion of sewage flows, and improved sanitation infrastructure along riverbanks, to reduce pollution loads and restore the ecological integrity of the Burhi Gandak.

MAP 1 Pollution Hotspot Analysis Map of Muzaffarpur

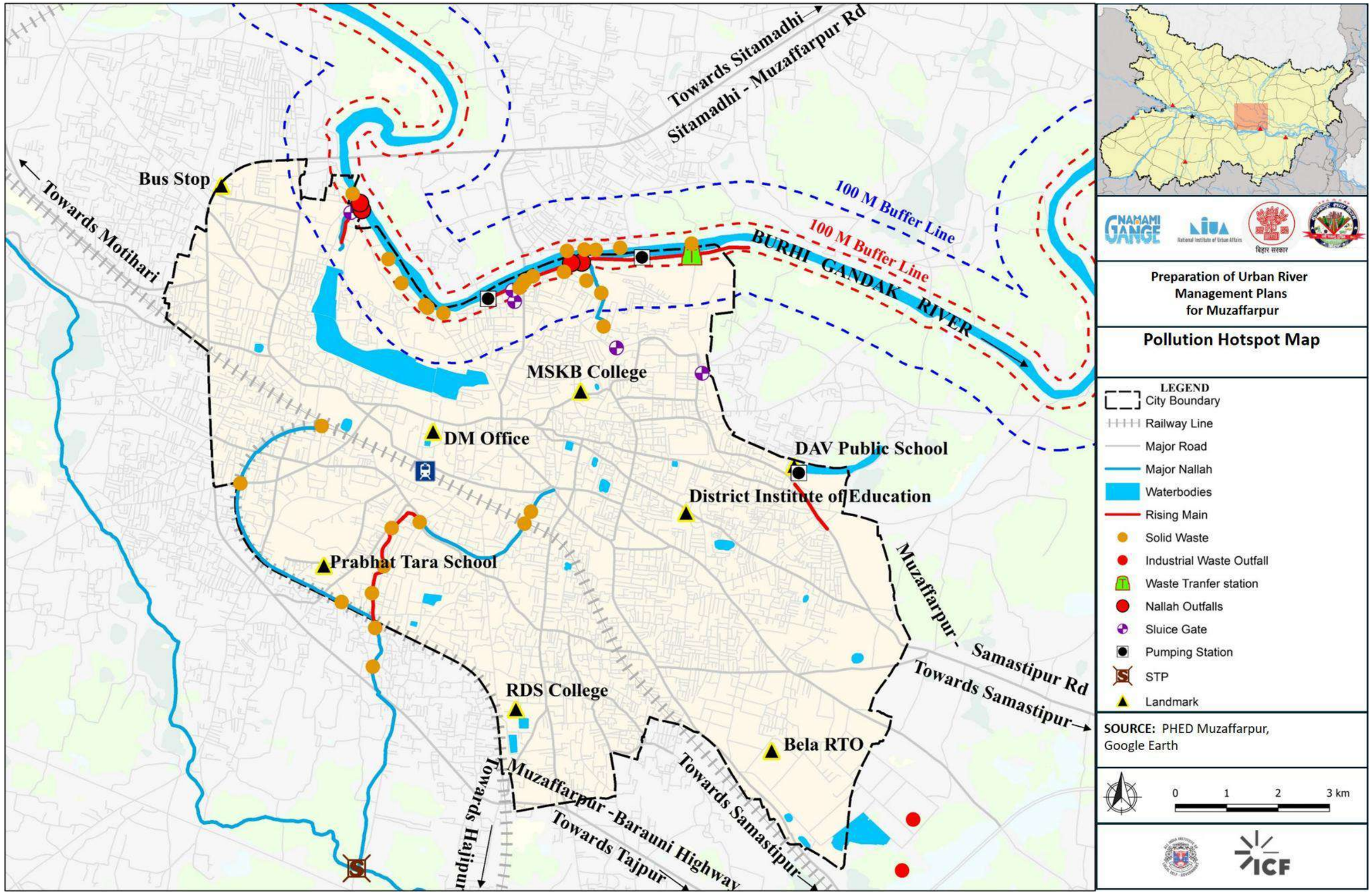


Figure 19 Major Outfall of the Chandwara Nallah near Siddhi Ghat

Source: Primary Survey

Figure 20 Rautiniya Dumpsite 13km from the city

Source: Primary Survey

Figure 21 Nallah Outfalls of Natural drains

Source: Primary Survey

Figure 22 Solid waste dumping sites near Smart City Ghat

Source: Primary Survey

4.2.4 URMP Score

As per the URMP framework, to understand the pollution levels in the river, the Net Dissolved Oxygen Score is measured. Since the SPCB- Bihar has published data on Dos. The net DO is DO outlet (-) DO inlet / DO inlet x 100. The difference is – 4.05, indicating an **average score of 3**. This may not show the true nature of the water quality due to the high flow rate of water; the water quality is diluted.

4.2.5 Interventions

Intervention 2.1 Interim Septage Treatment and Pollution Control System - Septage Pre-Treatment & Dilution Unit

Muzaffarpur is a predominantly on-site sanitation-dependent city, where a significant proportion of households rely on septic tanks and pit-based systems. In the absence of a sewerage network, faecal sludge and septage (FSS) generated across the city is either improperly disposed of into drains, low-lying areas, or directly into water bodies, contributing to severe river pollution.

Case Study – The Kargi STP
The Kargi STP, Dehradun (Uttarakhand) demonstrates a successful model of septage co-treatment under FSM guidelines.

Key Features:
STP Capacity: 68 MLD
Septage Co-treatment: ~130 KLD
Dedicated septage receiving and pre-treatment facility
Controlled mixing of septage with sewage before biological treatment
Process:
Septage unloading station
Screening & grit removal
Settling/equalization
Dilution with sewage
Treatment in STP
Key Learning:
Septage must be pre-treated and diluted before entering STP
Prevents shock loading and process failure
Enables cities to leverage existing infrastructure instead of building new FSTPs

While STPs are being developed, they are designed for sewage treatment and not for high strength septage, creating a critical gap in the safe management of faecal sludge. In this context, the proposed Septage Pre-Treatment & Dilution Unit aims to enable co-treatment of septage at STPs, ensuring safe, controlled, and environmentally compliant disposal.

Rationale

- The city generates high-strength septage (BOD: 2000–20000 mg/L), which cannot be directly treated in conventional STPs
- Existing STPs (~41 MLD) are designed only for sewage and lack septage receiving facilities
- Unregulated desludging and disposal practices are leading to:
    - Direct discharge into **nallahs and rivers**
    - Contamination of **groundwater and low-lying agricultural areas**
- Co-treatment through pre-treatment + dilution is a cost-effective and scalable solution, avoiding the need for standalone FSTPs

The intervention ensures:

- Controlled mixing of septage with sewage
- Prevention of shock loading in biological treatment systems
- Improved overall treatment efficiency and river water quality

Key Gaps in Sewage Management in Muzaffarpur

- No infrastructure for septage receiving and treatment
- 100% dependence on on-site systems, but no FSS management chain
- STPs not designed to handle septage → system incompatibility
- Unregulated desludging and informal disposal
- Direct discharge of untreated wastewater into the Burhi Gandak & Furdoo River

Proposed Intervention

The intervention involves setting up a Septage Pre-Treatment Unit (35 KLD capacity) at/near STPs, comprising:

- Septage receiving station
- Screening and grit removal
- Settling/equalisation tank
- Controlled dilution with sewage
- Pumping to STP inlet

Table 8 Calculation of Faecal Sludge generated per day

Parameter	Value	Unit
Design Year	2045	
Population	5.2	Lakh
Sanitation Coverage	100	%
On-site Sanitation Coverage	95	%
Faecal Sludge Generation Rate (CPHEEO)	0.14	L/person/day
Desludging Frequency	3	Years
Safety Factor	25	%

Source: CPHEEO Guidelines

Note on Transportation Capacity of the ULB:
The ULB currently operates a fleet of **three desludging vehicles of 3000 L capacity each**, supplemented by approximately **2–4 private vehicles of similar capacity**. At present, the combined operational capacity of the existing fleet is estimated at around **15,000 L/day**. However, with improved operational scheduling and an average of **three trips per vehicle per day**, the collection and transportation capacity can potentially be scaled up to approximately **45,000 L/day**, enabling the proposed septage pre-treatment facility to operate closer to its intended capacity. While the current fleet is broadly adequate for servicing the existing population on a demand basis, Muzaffarpur will require significant augmentation of desludging infrastructure and operational systems in the future to support scheduled desludging and safely cater to the city's growing population and wastewater generation.

Note on Site Feasibility:
The larger proposed STP sites at Manika Maan (22.5 MLD) and Furdoo Nallah/Khabara Village (13 MLD) are considered suitable for integrating septage pre-treatment and dilution facilities due to their higher treatment capacities, comparatively larger land allocations, and location along major drainage corridors. The use of compact SBR technology, which has lower land requirements, may allow integration of auxiliary septage receiving and pre-treatment infrastructure within the proposed STP campuses. Their peripheral locations and connectivity to major roads also improve access for desludging vehicles and reduce transportation distances.

Given Muzaffarpur's lack of sewerage infrastructure and the direct discharge of wastewater into open drains and the Burhi Gandak River, co-treatment of septage at these larger STPs can help reduce untreated pollution loads entering the drainage system.

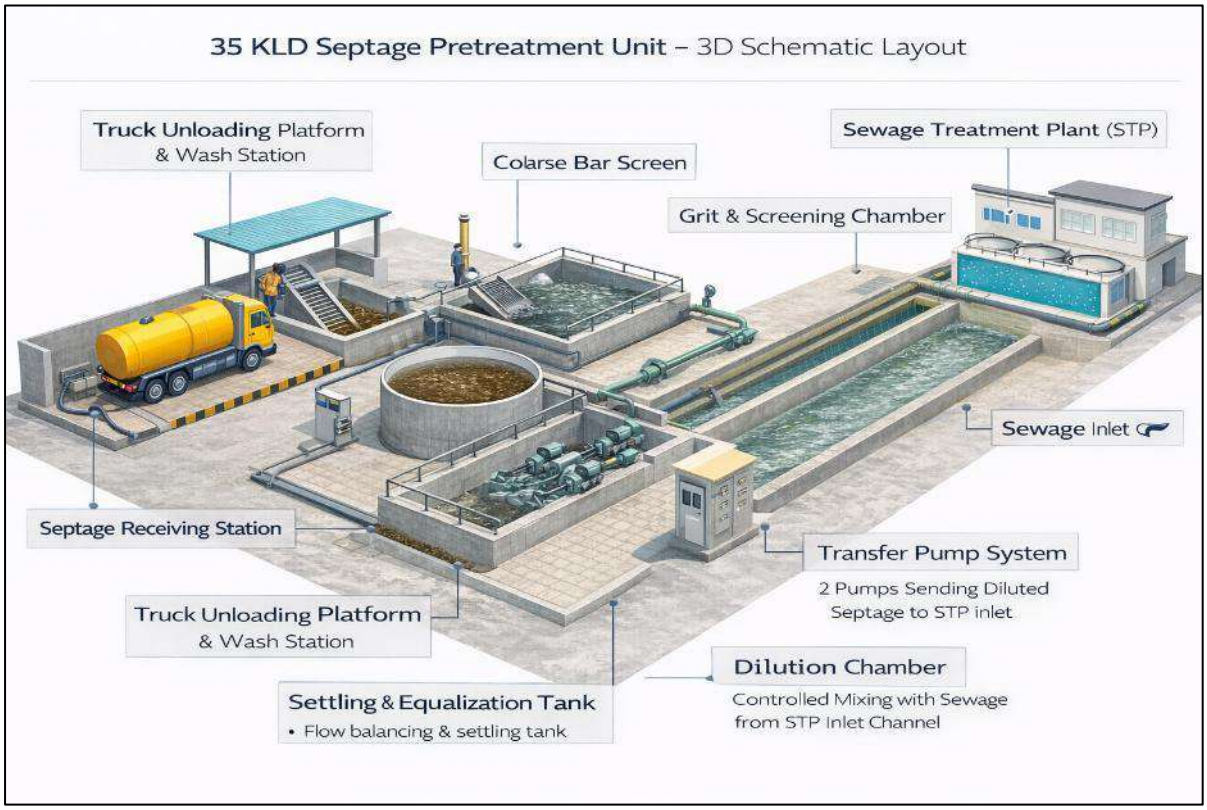
However, detailed site-level feasibility assessments should be undertaken prior to implementation to evaluate land suitability, hydraulic compatibility, expansion requirements, access, and operational constraints. In case adequate space is not available within the STP campuses, decentralised pre-treatment units may be developed at nearby locations, with treated effluent conveyed through connecting pipelines into the drainage/I&D system leading

Table 9 Calculation on the Capacity of the Pre-Treatment Unit

Sl. No.	Calculation Component	Formula	Value	Unit
1	Population dependent on on-site sanitation	5,20,000 × 0.95	4,94,000	persons
2	Daily faecal sludge generation	4,94,000 × 0.14	69.160	litres/day
3	Annual faecal sludge generation	69.160 × 365	2,52,43,400	litres/year
4	Sludge collected per year (desludging once in 3 years)	2,52,43,400 ÷ 3	8,414,466	litres/year
5	Average daily sludge load to FSTP	8,414,466÷ 365	2,804	litres/day
6	Average daily load	—	28	KLD
7	Additional capacity (25% safety factor)	28 × 0.25	7	KLD
8	Total required FSTP capacity	28 + 7	35	KLD

Source: CPHEEO Guidelines

Figure 23 Schematic Layout of the Pre-Treatment Unit



Source: Faecal Sludge and Septage Co-treatment Design Guidebook, NIUA

Table 10 Estimated Cost of Septage Pre-Treatment Unit (35 KLD)

Component	Purpose	Qty	Cost (₹)
1. Septage Receiving Station	Truck unloading + washing facility	1	6 Lakh
2. Screening Unit	Removal of large solids (bar screen)	1	4 Lakh
3. Grit Chamber	Removal of sand & heavy particles	1	3 Lakh
4. Settling / Equalisation Tank (40–50 m³)	Flow balancing & partial solids removal	1	10 Lakh
5. Dilution & Mixing Chamber	Controlled mixing with sewage before STP	1	5 Lakh
6. Transfer Pump System	Pumping treated flow to STP inlet	2 Pumps	4 Lakh
7. Pipeline & Valves	Connection to STP inlet channel	Lump sum	3 Lakh
8. Odour Control System	Biofilter/ventilation system	Lump sum	2 Lakh
9. Electrical & Control Panel	Plant operation & automation	Lump sum	3 Lakh
10. Civil Works	Foundation, tanks, platforms	Lump sum	12 Lakh
Grand Total			**50 Lakh**

Source: CPHEEO Guidelines

Funding Sources and Applicability for CAPEX Investment for the Pre-Treatment Unit

- **SBM-U 2.0 –** Core FSSM infrastructure and operational support
- **NMCG (Namami Gange Programme)** – River pollution abatement and wastewater management interventions
- **AMRUT 2.0 –** Sewerage systems, co-treatment infrastructure, and reuse components
- **15th Finance Commission Grants –** Tied grants for urban sanitation and performance-based O&M support
- **State Urban Development Fund –** Gap funding for infrastructure development

O&M Framework (Odisha SHG Model)

Institutional Model

Operation by SHGs (Self Help Groups) under ULB supervision
Convergence with NULM for livelihood generation
Technical oversight by ULB / PHED

Table 11 Estimated Monthly O&M Cost

Component	Details	Monthly Cost (₹)
Plant operators (2–3 staff)	Skilled / semi-skilled	40,000
Lab assistant (highly skilled)	Water quality monitoring	25,000
Cleaning & maintenance staff (SHG)	Sweeping, gardening	20,000
Electricity & consumables	Pumps, lighting, chemicals	15,000
Desludging vehicle support	Fuel + engagement	25,000
Miscellaneous & repairs	Minor O&M	10,000
Total Estimated O&M Cost		~1.35 – 1.50 lakh/month

Source: Odisha FSSM Model

O&M Responsibilities

- SHGs: Cleaning, upkeep, basic operations
- ULB: Monitoring, contracts, compliance
- Private operators: Desludging & transport
- Lab assistant: Quality testing and reporting

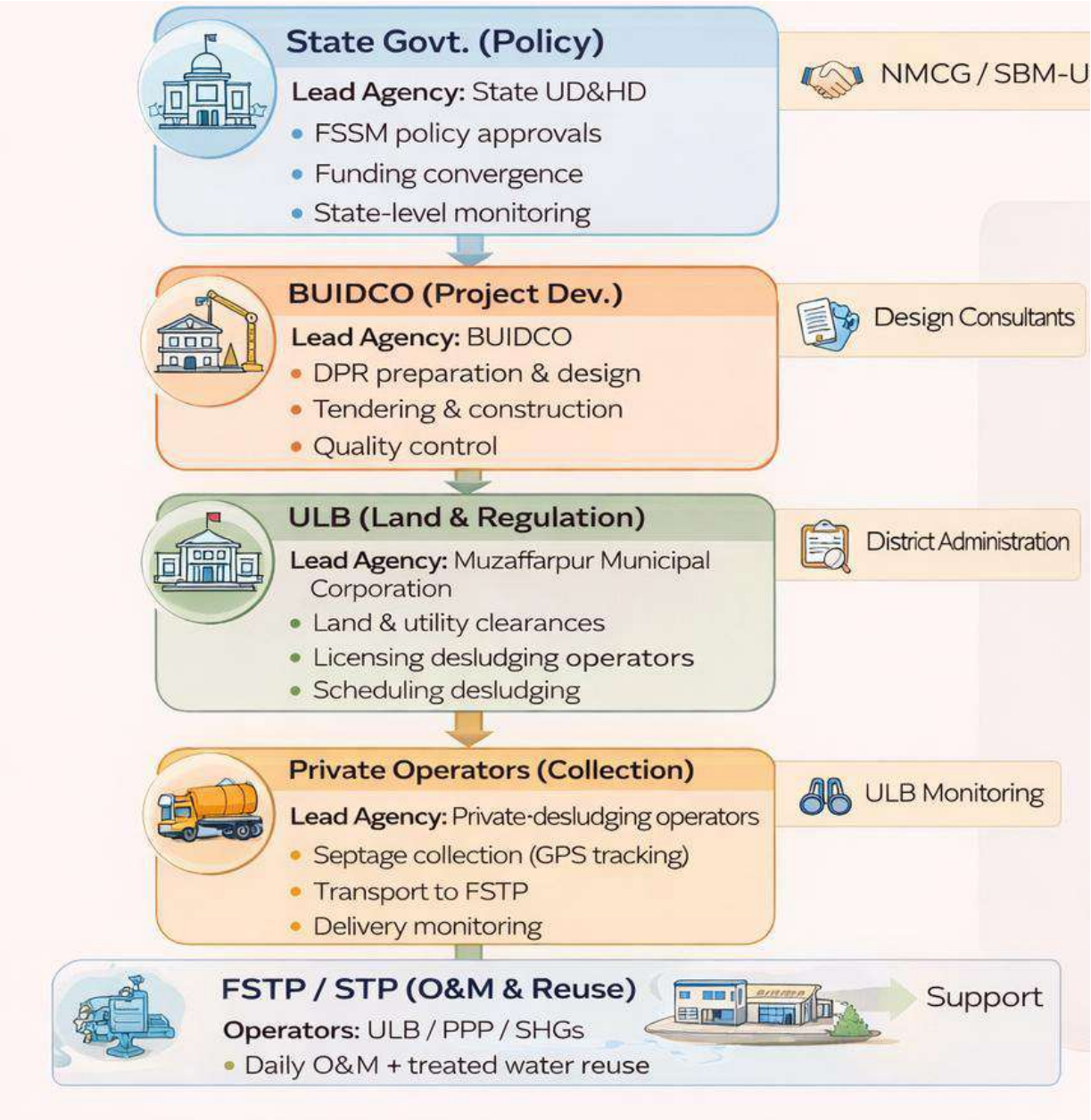
For O&M (Convergence Approach)

- **SBM-U 2.0** – Support for FSSM operations and service delivery
- **NULM (National Urban Livelihood Mission)** – SHG-based workforce for plant operations, cleaning, and maintenance
- **User Charges (Desludging Fees)** – Primary revenue stream for sustaining O&M
- **ULB Budget** – Viability gap funding and administrative support
- **PPP Model (Optional)** – Improved efficiency and professional O&M service

Institutional Framework

The institutional framework establishes a coordinated structure across state, city, and private stakeholders for the effective implementation and management of septage treatment. It ensures clear roles for policy, infrastructure development, regulation, service delivery, and O&M, enabling seamless integration of FSSM within the urban water management system.

Figure 24 Institutional Framework



Source: Odisha FSSM Model

Intervention 2.2 Eco-Restoration of Polluted Urban Drains Chandwara and Furdoo Nallah

Urban drains (nallahs) in Muzaffarpur function as primary carriers of untreated wastewater, greywater, and solid waste, ultimately discharging into the Burhi Gandak River. Field assessments and pollution hotspot mapping have identified Chandwara Nallah and Furdoo Nallah as critical pollution pathways, contributing significantly to the deterioration of river water quality.

Given the limited sewerage coverage and the time-intensive nature of centralised infrastructure development, in-situ bioremediation and eco-restoration of nallahs is proposed as a decentralised and immediately implementable solution. The intervention focuses on pollution interception at source, in-channel treatment, and ecological stabilisation, ensuring that untreated flows are minimised before reaching the river.

Objectives

The key objectives of this intervention are:

- To intercept solid and floating waste at upstream and intermediate locations
- To reduce organic and suspended pollutant loads through decentralised treatment
- To improve hydraulic efficiency and reduce clogging of drains
- To stabilise nallah edges and prevent erosion and sediment inflow
- To restore ecological functions through nature-based solutions
- To ensure that only treated or partially treated water enters the river system

Key components:

- Vegetated bioswales.
- Stabilisation of drain edges.
- Pollution load reduction via natural barriers.
- Integration with STP/STBM projects.

Project Coverage

The intervention covers two major urban nallahs:

Table 12 Project Coverage

Nallah	Length	Catchment Characteristics	Key Issues
Chandwara Nallah	~0.9 km	Dense urban + river edge	Direct discharge, dumping, sediment load
Furdoo Nallah	~2.2 km	Dense + semi-urban stretches	Greywater inflow, encroachments, and solid waste

Source: Drainage DPR Muzaffarpur, BUIDCo

Intervention Framework for Chandwara and Furdoo Nallahs

Chandwara Nallah – Node-based Intervention for Chandwara Nallah

Figure 25 Location of Nodes for Eco Nallah restoration

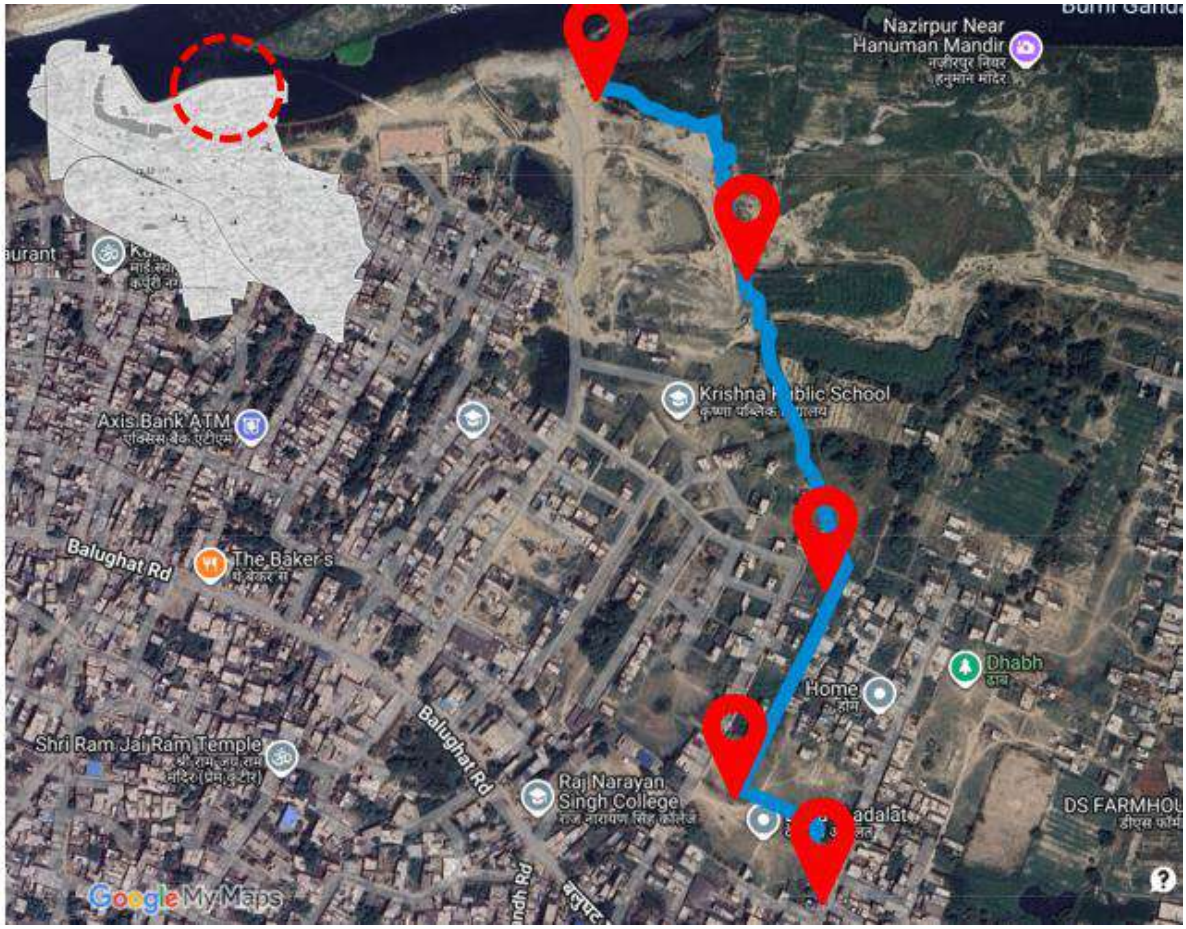


Table 13 Key Interventions for Chandwara Nallah

Node	Location Type	Key Interventions
Node 1	Upstream entry	Trash rack, desilting chamber
Node 2	Mid-reach / junction	Bio-filtration module, vegetation
Node 3	Road crossing	Trash rack, maintenance platform
Node 4	Downstream stretch	Secondary treatment + stabilization
Node 5	Outfall	Trash boom, sediment trap, monitoring

Figure 26 Sections for the 5 nodes of Chandwara Nallahs

Figure 27 Conceptual Images of Chandwara Nalla

BEFORE

AFTER

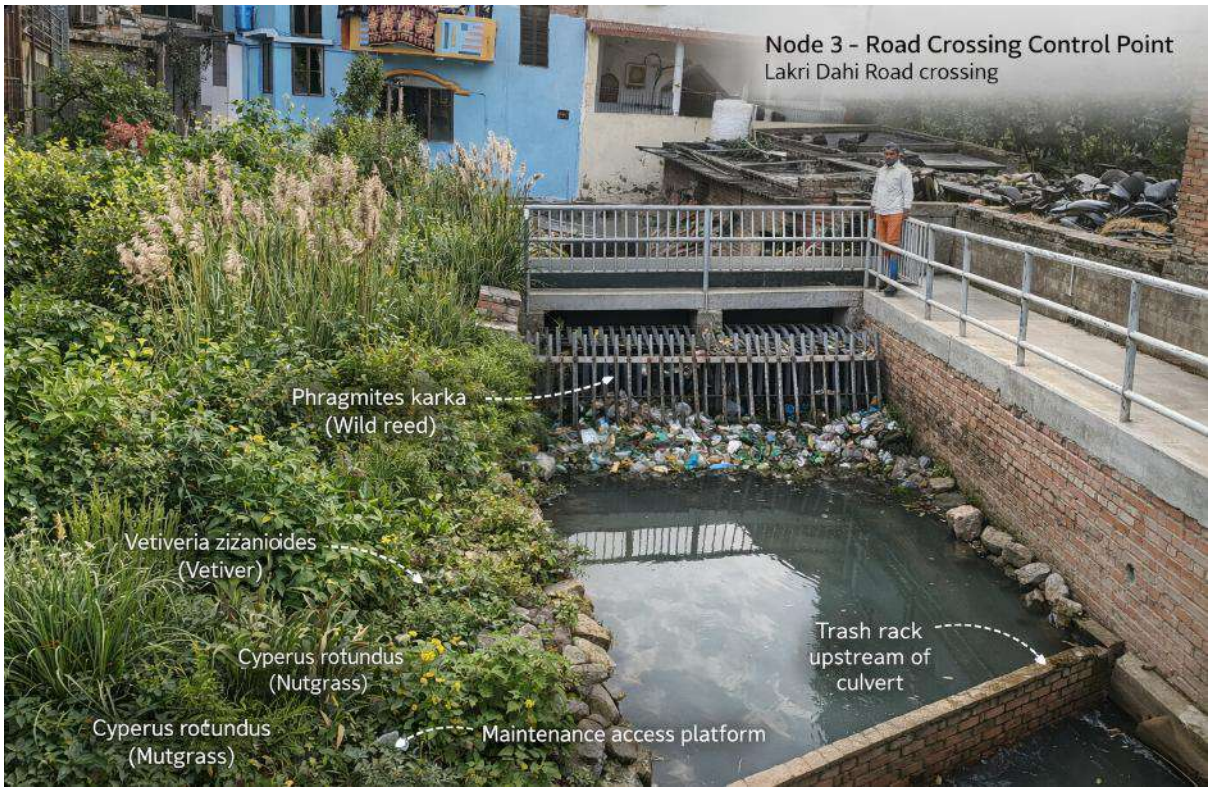


Table 14 Node-Based Treatment Systems

Sl. No.	Item Description	Unit	Qty	Unit Rate (₹)	Amount (₹ Lakhs)	Basis / Reference
1	Trash rack with civil frame (MS + concrete)	No.	3	2,50,000	7.5	CPHEEO + SBM SWM DPR norms
2	Desilting chamber (brick masonry + RCC base)	No.	1	4,50,000	4.5	Standard drain chamber design
3	Modular bio-filtration unit (coir + gravel + microbial media)	No.	2	15,00,000	30.0	CSIR-NEERI / NMCG drain treatment
4	Maintenance platform (RCC + railing)	No.	1	3,00,000	3.0	PWD schedule rates
5	Trash rack at culvert crossing	No.	1	2,50,000	2.5	CPHEEO guidelines
6	Trash boom at outfall (HDPE floats + anchoring)	No.	1	12,00,000	12.0	NMCG river interception projects
7	Monitoring platform + sampling point	No.	1	6,00,000	6.0	CPCB monitoring norms

Table 15 Linear Ecological Restoration Works (900 m Stretch)

Sl. No.	Item Description	Unit	Qty	Unit Rate (₹)	Amount (₹ Lakhs)	Basis / Reference
1	Riparian vegetation stabilisation (bioengineering + planting)	km	1.8	10,00,000/km	18.0	MoEFCC / river restoration norms
2	Coir roll bank protection	m	900	1,200/m	10.8	Coir Board / NBSS&LUP
3	Native vegetation plantation	km	1.8	4,00,000/km	7.2	Horticulture Dept. schedule
4	Channel regrading & minor earthwork	m	900	800/m	7.2	PWD SOR (earthwork)
5	Phytoremediation pockets (constructed wetland cells)	No.	4	1,50,000	6.0	NMCG wetland modules

Table 16 Sediment & Desilting Infrastructure

Sl. No.	Item Description	Unit	Qty	Unit Rate (₹)	Amount (₹ Lakhs)	Basis / Reference
1	Desilting chambers (additional)	No.	2	3,00,000	6.0	Drainage DPR standards

2	Silt traps at junctions	No.	3	2,00,000	6.0	Urban drain design manuals
3	Outfall sediment trap basin	No.	1	8,00,000	8.0	NMCG guidelines
4	Initial desilting & sludge removal	LS	1	10,00,000	10.0	ULB tender benchmarks

Table 17 Monitoring & Community Components

Sl. No.	Item Description	Unit	Qty	Unit Rate (₹)	Amount (₹ Lakhs)	Basis / Reference
1	Water quality monitoring station	No.	1	8,00,000	8.0	CPCB norms
2	IEC signage & awareness boards	No.	5	50,000	2.5	SBM IEC norms
3	Community waste bins	No.	10	15,000	1.5	SBM SWM guidelines

Table 18 Summary Cost (Chandwara Nallah)

Component	Cost
Node Treatment Systems	₹1.00 Cr
Ecological Restoration	₹1.07 Cr
Sediment Management	₹0.56 Cr
Monitoring & IEC	₹0.21 Cr
Total Estimated Cost ≈ ₹2.3 – ₹2.8 Cr	

Furdoo Nallah Restoration Framework

The restoration strategy for Furdoo Nallah is structured as a **typology-based intervention framework**, recognising the variation in urban form, land use, and pollution load along its course. Instead of a one-size-fits-all approach, the nallah is divided into three functional stretches—dense urban, semi-urban, and peripheral—each requiring context-specific interventions. This approach ensures that solutions are technically appropriate, spatially efficient, and aligned with on-ground realities of Muzaffarpur.

The framework integrates **waste interception, ecological treatment, and channel restoration measures** to improve water quality, reduce solid waste inflow, and enhance the overall ecological performance of the drain before it discharges into the Burhi Gandak River.

1. Upstream Urban Entry Control (Dense Urban Stretch)
This stretch corresponds to highly built-up areas near markets and residential zones, where the nallah first receives a significant load of solid waste and silt. The primary objective in this section is to intercept pollutants at source and prevent their downstream movement. Interventions such as trash interception racks, desilting chambers, and floating debris booms are proposed to capture plastics, floating waste, and sediments at entry points.

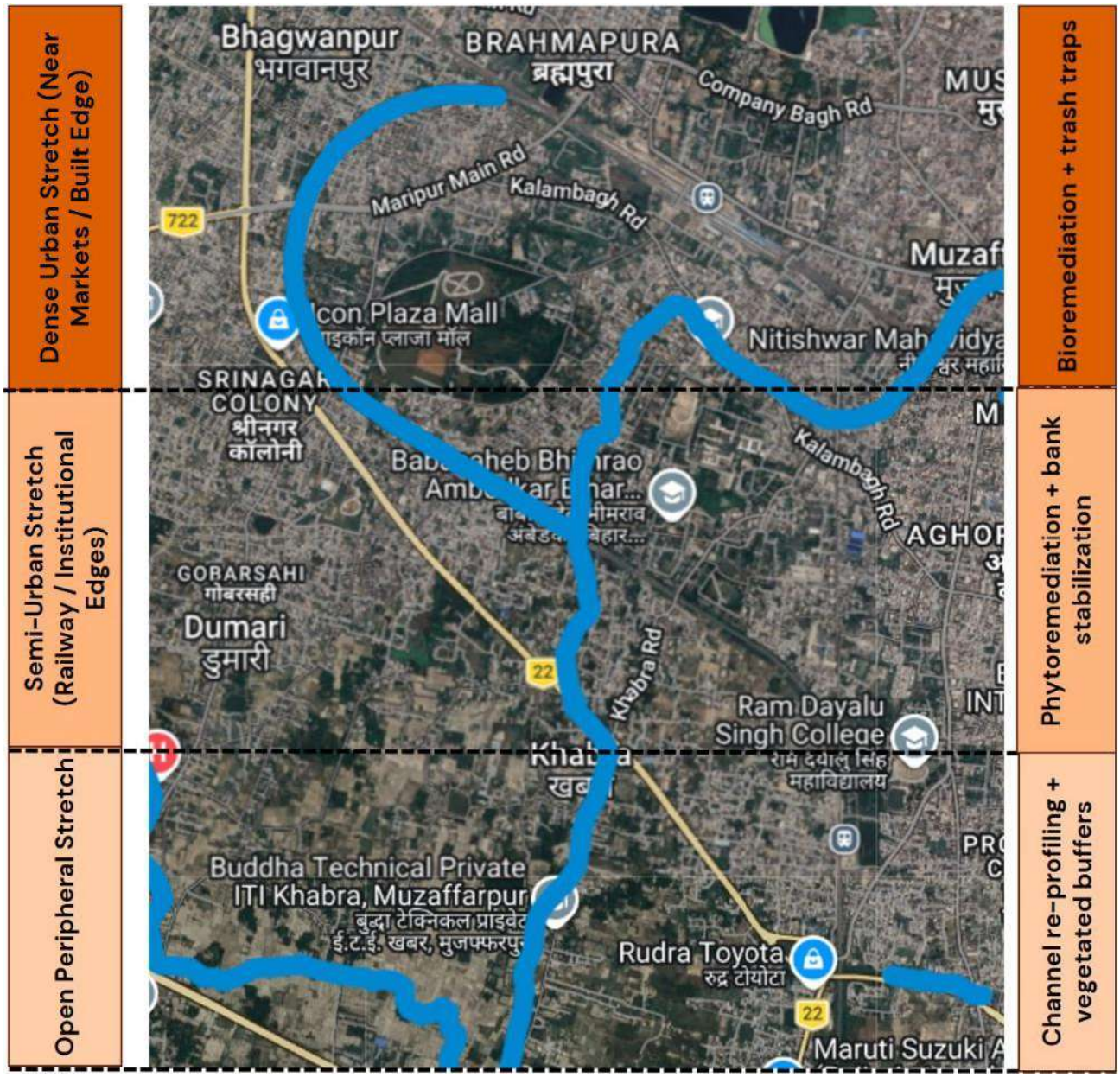
Given the constrained right-of-way and high waste generation, the focus is on mechanical and modular systems that can function within limited space while requiring regular maintenance. These interventions help reduce clogging, improve flow conditions, and prevent the accumulation of waste in downstream stretches, thereby addressing one of the key issues observed in the city—solid waste entering the river system through drains.

2. Neighbourhood Drain Junction Treatment (Semi-Urban Stretch)
In this stretch, multiple smaller drains discharge into Furdoo Nallah, contributing to increased organic load and nutrient pollution. The strategy here shifts from interception to in-situ treatment and ecological stabilisation. Bio-filtration modules using layered media (coir, gravel, microbial substrates) are introduced at junction points to treat incoming wastewater before it enters the main channel.
Additionally, riparian edge stabilisation using native vegetation such as vetiver, canna, and colocasia is proposed to enhance bank stability and promote natural filtration. Small phytoremediation pockets further aid in reducing BOD and nutrient loads. This combination of engineered-natural systems improves water quality while enhancing the ecological character of the nallah corridor, making it more resilient and self-sustaining over time.

3. River Outfall Polishing Zone (Downstream Stretch)
The downstream stretch near the confluence with the Burhi Gandak River acts as the final opportunity for improving water quality before discharge. Interventions in this zone focus **on** final polishing and monitoring. Trash booms are installed at the outfall to prevent floating waste from entering the river, while sediment trap basins allow for the settling of residual solids.
This stretch also incorporates water quality monitoring points to track improvements and support long-term management. The aim is to ensure that the discharge entering the river is relatively cleaner, thereby reducing pollution load on the Burhi Gandak. Functionally, this zone acts as a buffer that combines sediment control, waste interception, and data-driven monitoring to support regulatory compliance and river health improvement.

Together, these three typologies create a **sequential treatment system along the nallah**, where pollution is progressively reduced from source to outfall. The approach balances **engineering solutions with nature-based interventions**, ensuring both immediate impact and long-term sustainability. It also aligns with URMP objectives of improving river water quality, restoring ecological functions, and strengthening the urban–river interface in Muzaffarpur.

Figure 28 Conceptual Map of Furdoo Nallah Restoration



Source: Google Earth

Figure 29 Sections of Furdoo Nallahs

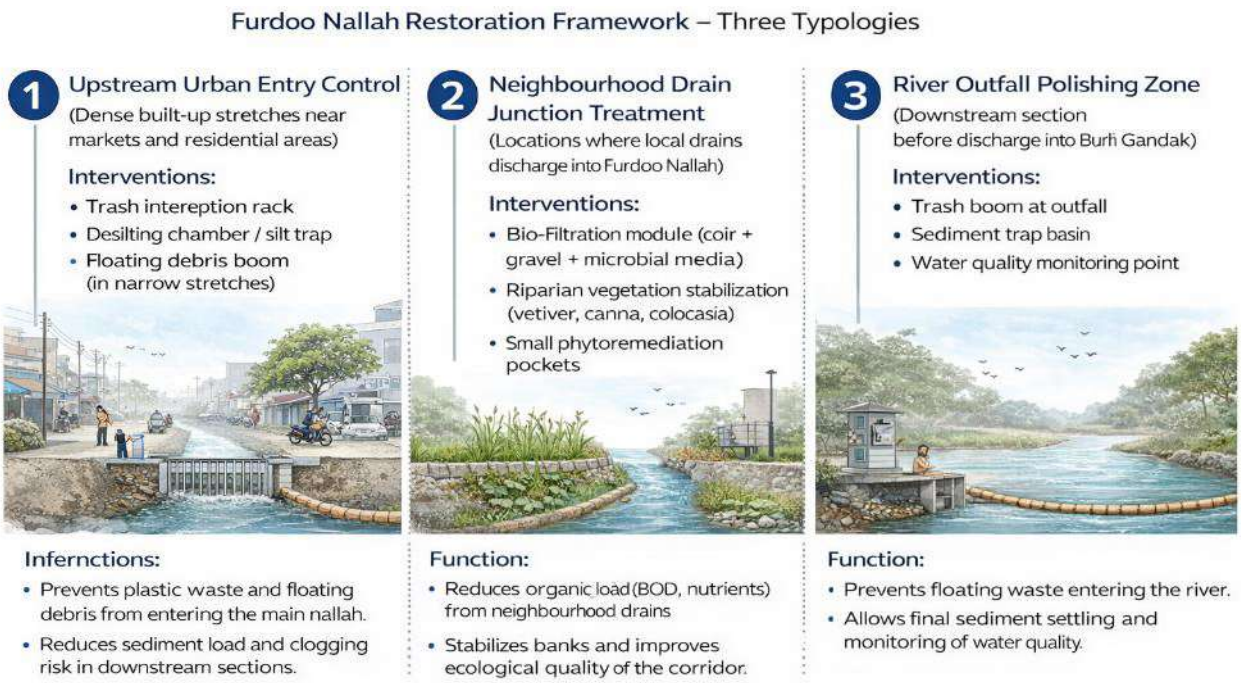


Figure 30 Before and Conceptual After Images of Furdoo Nallah

BEFORE

Source: Primary Survey

AFTER

Table 19 Upstream Entry Control & Interception Systems

Sl. No.	Item Description	Unit	Qty	Unit Rate (₹)	Amount (₹ Lakhs)	Basis / Reference
1	Trash interception racks (MS + civil frame)	No.	6	2,50,000	15.0	CPHEEO / SBM SWM
2	Desilting chambers (RCC + brick masonry)	No.	6	3,00,000	18.0	Drainage DPR norms
3	Floating debris booms (narrow stretches)	No.	3	4,00,000	12.0	NMCG river projects

Table 20 Neighbourhood Drain Junction Treatment

Sl. No.	Item Description	Unit	Qty	Unit Rate (₹)	Amount (₹ Lakhs)	Basis / Reference
1	Modular bio-filtration units (coir + gravel + microbial media)	No.	6	4,00,000	24.0	CSIR-NEERI / NMCG
2	Riparian vegetation stabilisation (bioengineering)	m	2,200	4,000/m	88.0	MoEFCC / eco-restoration
3	Phytoremediation pockets	No.	6	2,00,000	12.0	Constructed wetland modules

Table 21 River Outfall Polishing Zone

Sl. No.	Item Description	Unit	Qty	Unit Rate (₹)	Amount (₹ Lakhs)	Basis / Reference
1	Trash boom at river outfall	No.	2	5,00,000	10.0	NMCG guidelines
2	Sediment trap basin	No.	2	8,00,000	16.0	Standard sedimentation design
3	Water quality monitoring station	No.	2	2,00,000	4.0	CPCB norms

Table 22 Linear Ecological Restoration (Full Stretch – 2.2 km)

Sl. No.	Item Description	Unit	Qty	Unit Rate (₹)	Amount (₹ Lakhs)	Basis / Reference
1	Coir roll bank protection	m	2,200	1,200/m	26.4	Coir Board standards
2	Native riparian plantation	km	4.4	4,00,000/km	17.6	Horticulture norms
3	Channel regrading & minor earthwork	m	2,200	800/m	17.6	PWD SOR
4	Grass turfing & slope stabilization	m	2,200	500/m	11.0	Bioengineering norms

Table 23 Sediment Management & Desilting (System Strengthening)

Sl. No.	Item Description	Unit	Qty	Unit Rate (₹)	Amount (₹ Lakhs)	Basis / Reference
1	Additional silt traps at junctions	No.	6	2,00,000	12.0	Urban drainage manuals
2	Periodic desilting infrastructure (access ramps, chambers)	LS	1	15,00,000	15.0	ULB O&M integration
3	Initial desilting & sludge clearance (full stretch)	LS	1	20,00,000	20.0	Tender benchmarks

Table 24 Monitoring, Access & Community Infrastructure

Sl. No.	Item Description	Unit	Qty	Unit Rate (₹)	Amount (₹ Lakhs)	Basis / Reference
1	Maintenance platforms & access walkways	No.	4	3,00,000	12.0	PWD SOR
2	IEC signage & awareness boards	No.	10	50,000	5.0	SBM IEC
3	Community waste bins	No.	20	15,000	3.0	SBM SWM

Table 25 Summary Cost (Furdoo Nallah)

Component	Cost
Upstream Interception	₹0.45 Cr
Junction Treatment	₹1.24 Cr
Outfall Polishing	₹0.30 Cr
Ecological Restoration	₹0.73 Cr
Sediment Management	₹0.47 Cr
Monitoring & Access	₹0.20 Cr
Total Estimated Cost – Furdoo Nallah ≈ ₹3.8 – ₹4.0 Cr	

Desilting & Sediment Management Strategy

Existing Issues

Irregular desilting practices
High sediment accumulation reduces flow capacity
Re-entry of sludge into the drainage system
Proposed Approach

The proposed approach is -

A. Annual Desilting Plan
Chandwara Nallah (~0.9 km)
Furdoo Nallah (~2.2 km)

Frequency: Pre-monsoon (primary) + post-monsoon (secondary)

B. Structural Provisions
Desilting chambers at upstream nodes
Silt traps at key junctions
Sediment trap basins at outfalls
Maintenance access platforms

C. Institutional Mechanism
Integration into ULB annual O&M plan
Ward-wise scheduling and monitoring
Use of geo-tagged records and maintenance logs

Operation & Maintenance Framework

O&M Process Flow
Waste Entry → Trash Interception → Cleaning → Desilting Chamber → Sludge Removal → Bio-treatment → Vegetation Maintenance → Outfall Control → Monitoring

Roles and Responsibilities

Table 26 Roles and Responsibility Distribution for O&M

Activity	Frequency	Agency
Trash removal	Daily	ULB sanitation team
Desilting chamber cleaning	Monthly	ULB / contractor
Vegetation maintenance	Quarterly	Horticulture team
Full desilting	Annual	ULB
Water quality monitoring	Monthly	Pollution Control Board

O&M Guidelines for Key Components

- **Trash racks & booms:** Daily cleaning; prevent clogging and overflow
- **Desilting chambers:** Cleaning every 30–45 days; proper sludge disposal
- **Coir stabilization:** Inspect post-monsoon; replace after 3–5 years
- **Vegetation:** Periodic trimming, replanting, invasive removal
- **Bio-filtration units:** Media replacement every 2–3 years
- **Monitoring:** Monthly water quality testing and reporting

Table 27 Annual O&M Cost Estimation

Activity	Frequency	Agency	Unit Cost Basis	Annual Cost (₹)
Trash removal	Daily	ULB sanitation team	~₹2,000/day (labour + transport)	₹7.30 Lakhs
Desilting chamber cleaning	Monthly	ULB / contractor	~₹15,000 per cleaning × 12	₹1.80 Lakhs
Vegetation maintenance	Quarterly	Horticulture team	~₹50,000 per cycle × 4	₹2.00 Lakhs
Full desilting (entire stretch)	Annual	ULB	Lump sum (machine + labour)	₹15.00 Lakhs
Water quality monitoring	Monthly	Pollution Control Board	~₹10,000/sample × 12	₹1.20 Lakhs
Total Estimated Annual O&M Cost ≈ ₹27–28 Lakhs				

Edge Stabilisation Plantation (Riparian & Bioswale Species)

To support in-situ bioremediation and long-term channel stability, native riparian vegetation and bioswale species are proposed along Chandwara and Furdoo Nallah. These species are selected based on their soil-binding capacity, pollutant uptake, flood tolerance, and ecological benefits, as well as their suitability for urban drain conditions.

Table 28 Recommended Plant Species for Edge Stabilisation

Scientific Name	Common Name	Application / Function
Vetiveria zizanioides	Vetiver (Khus grass)	Strong root system; ideal for bank stabilisation and erosion control
Saccharum spontaneum	Kans grass	Native riparian species; supports bank protection and habitat creation
Cyperus rotundus	Nutgrass	Suitable for wet–dry transition zones along drain edges
Desmostachya bipinnata	Kusha grass	Effective for upper slopes and dry bioswale edges
Phragmites karka	Wild reed	Helps in nutrient uptake and filtration; supports bird habitats
Typha angustifolia	Cattail	Ideal for phytoremediation zones and shallow water edges

Source: Biodiversity Expert

Plantation Strategy

Continuous vegetated buffer along both banks (minimum 1–2 m width where feasible)
Layered planting approach:

- Toe zone: Typha, Phragmites

- Mid-slope: Vetiver, Cyperus
- Upper bank: Kans grass, Kusha grass

Integration with coir roll stabilisation and bioengineering techniques

Plantation to be combined with phytoremediation pockets at low-flow zones

Enhances bank stability, pollutant filtration, and biodiversity (bird/reptile habitats)

Funding Sources for Nallah Restoration

The proposed intervention integrates ecological restoration, pollution control, and urban infrastructure, enabling convergence across multiple national and state schemes.

A. National Clean Air Programme (NCAP) – Afforestation Component

Suggested by Forest Department

Applicable for:

- Riparian plantation
- Urban green buffers along nallahs

B. Namami Gange / NMCG

Applicable for:

- Drain treatment (bio-remediation modules)
- Trash traps, sedimentation structures
- River outfall management

Strong alignment with:

- Drain interception and pollution abatement objectives

C. AMRUT 2.0

Applicable for:

- Urban waterbody rejuvenation
- Drainage and stormwater management

Can support: Channel improvement + ecological restoration works

D. Swachh Bharat Mission (Urban) 2.0

Applicable for:

- Solid waste management (trash racks, bins)
- IEC and community engagement

Useful for:

- Waste interception at source

E. Smart City Mission / State Urban Development Funds

Applicable for:

- Pilot stretches (high-visibility areas)
- Monitoring systems and smart infrastructure

F. CAMPA / State Forestry Schemes

Applicable for:

- Large-scale plantation and biodiversity enhancement

Supports:

- Riparian afforestation and ecological restoration

Expected Outcomes

- Reduction in BOD, COD, and suspended solids
- Prevention of solid waste entry into the river
- Improved drain flow and reduced clogging

- Stabilised banks and reduced erosion
- Creation of green, ecologically functional corridors
- Strengthened urban river health and resilience

Conclusion

The proposed in-situ bioremediation and eco-restoration of Chandwara and Furdoo Nallahs provides a cost-effective, scalable, and nature-based solution to address urban river pollution in Muzaffarpur. By focusing on pollution interception at the drain level, this intervention reduces the burden on downstream infrastructure while significantly improving river water quality. Integrated with solid waste management and FSSM interventions, it forms a key component of achieving a Pollution-Free River under URMP.

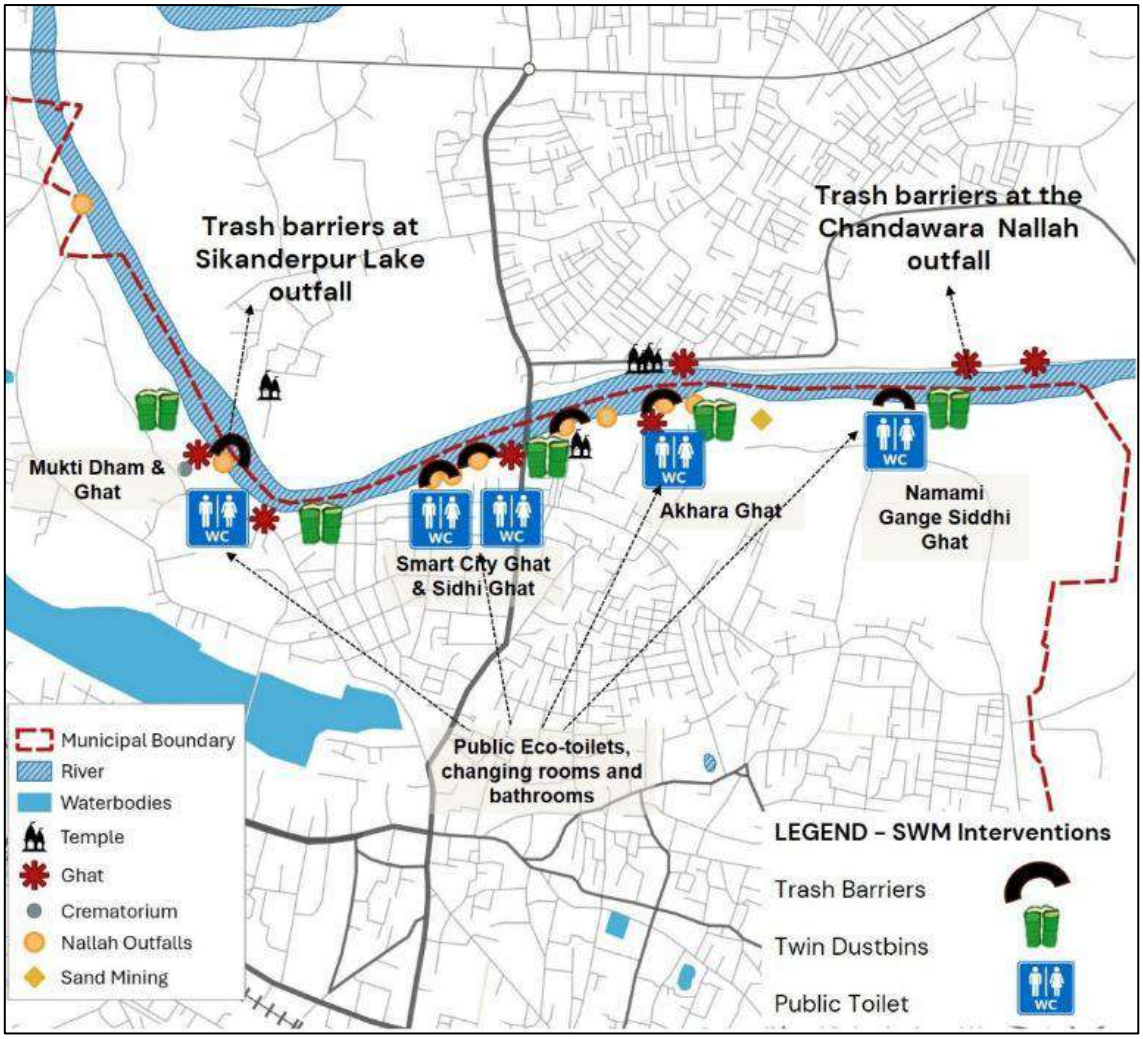
Intervention 2.3 Riverfront Cleanliness & Public Sanitation Improvement

In response to the increasing solid waste generation (projected to reach ~234 TPD by 2045) and the existing infrastructure gap, the intervention adopts a source-to-river approach, focusing on preventing waste leakage into drains and the Burhi Gandak. The strategy integrates decentralised waste management, riverfront sanitation, and drain-level interception systems, ensuring that solid waste is managed at source and along its flow pathway.

The intervention is structured across two complementary components: (i) riverfront cleanliness and public sanitation infrastructure, and (ii) drain and nallah-based pollution control measures. Together, these aim to establish a zero-waste-to-river system, while strengthening municipal operations and community participation.

Riverfront Cleanliness & Public Sanitation Infrastructure

Figure 31 Conceptual Map of Riverfront Cleanliness and Public Sanitation Infrastructure



This component focuses on managing waste generation at high-footfall locations along the river corridor, including ghats, temples, and residential edges.

- Installation of **segregated twin dustbins at 100–150 m intervals** along the 4.3 km river stretch (~30–35 bin clusters)
- Development of **5 public toilet complexes (10 seats each)** at major ghats to eliminate open defecation
- Provision of **ghat-level waste storage and secondary collection points**, integrated with the municipal SWM system
- Deployment of **daily mechanised sweeping and waste collection services** along the riverfront
- Implementation of a **caretaker-based O&M model (PPP / SHG-led)** for toilets and bin management
- Establishment of **festival waste management protocols**, including temporary bins and intensified collection during peak events

Drain & River Protection (Eco-Nallah Integration)

This component targets the interception of waste entering the river through urban drains and nallahs, addressing one of the primary pollution pathways.

- Installation of **trash traps/barriers at 6 major nallah outfalls**, including Chandwara and Sikanderpur
- Development of a **scheduled desilting framework (pre- and post-monsoon)** to prevent clogging and overflow
- Integration of **bio-buffer vegetation and edge stabilisation measures** at outfall zones
- Provision of **localised waste storage systems near drain junctions** to prevent informal dumping
- Strengthening of **floodplain dumping surveillance and enforcement mechanisms**
- Convergence with **eco-restoration interventions (bio-remediation of nallahs)** to ensure combined liquid and solid waste management

Phased Implementation Approach

- **Short-term (0–2 years):** Bin infrastructure, trash traps, public toilets, immediate riverfront cleaning
- **Medium-term (3–5 years):** Expansion of waste processing capacity, strengthening collection systems
- **Long-term (5+ years):** Full integration with city-wide SWM system and sustained O&M

Cost Estimates

Table 29 Riverfront Cleanliness & Public Sanitation Infrastructure (CAPEX)

Sl. No.	Item Description	Unit	Qty	Unit Rate (₹)	Amount (₹ Lakhs)	Basis / Reference
1	Twin dustbin sets (segregated)	No.	34	15,000	5.1	SBM (U) norms
2	Public toilet complexes (10 seats each)	No.	5	40,00,000	200.0	SBM / CPHEEO
3	Ghat-level waste storage units	No.	10	1,50,000	15.0	ULB benchmarks
4	Mechanised sweeping equipment (shared)	LS	1	25,00,000	25.0	ULB tender data
5	Secondary collection & transport setup	LS	1	20,00,000	20.0	SWM DPR norms
Total					**265**	

Table 30 Drain & River Protection (Waste Interception Systems – CAPEX)

Sl. No.	Item Description	Unit	Qty	Unit Rate (₹)	Amount (₹ Lakhs)	Basis / Reference
1	Trash barriers at major nallah outfalls	No.	6	5,00,000	30.0	NMCG guidelines
2	Trash racks at secondary drains	No.	10	2,50,000	25.0	CPHEEO
3	Floating debris booms	No.	3	4,00,000	12.0	River projects
4	Waste storage at drain junctions	No.	8	1,00,000	8.0	ULB norms
Total					**75**	

Table 31 Operation & Maintenance (O&M) Cost – Annual

Sl. No.	Activity	Description	Frequency	Unit Cost Basis	Annual Cost (₹ Lakhs)
1	Riverfront sweeping (2 cycles)	Manual + mechanised sweeping of 4.3 km stretch	Daily (2 times)	~₹1,200/km/cycle	37.7
2	Waste collection & transport	Secondary collection from ghats & bins	Daily	Lump sum	15.0
3	Public toilet O&M	Cleaning, caretaker, water & electricity (5 complexes)	Daily	₹3 lakh/toilet/year	15.0
4	Trash barrier & rack maintenance	Cleaning of traps at nallah outfalls	Daily–Weekly	Lump sum	8.0
Total					**75**

Table 32 Summary Cost Table

Sl. No.	Component	Cost (₹ Cr)
1	Capital Cost (CAPEX) – Infrastructure	3.40
2	Annual O&M Cost	0.75
3	5-Year O&M Cost	3.75

Funding Sources for SWM Intervention

Primary Funding Sources

- **Swachh Bharat Mission (Urban) 2.0 (SBM-U)** - Dustbins, public toilets, IEC, waste systems
- **15th Finance Commission (Tied Grants)** - Riverfront cleanliness, sanitation infrastructure
- **AMRUT 2.0** - Drainage improvement, waste interception infrastructure

Secondary / Convergence Funding

- State Urban Development Funds (UD&HD) - Gap funding, capital works
- CSR (Corporate Social Responsibility) - Public toilets, riverfront amenities, awareness campaigns
- Smart City Mission (if applicable) - Pilot stretches, smart monitoring

O&M Funding Sources

- User charges (toilets, services)
- Municipal budget allocation
- Advertisement rights (riverfront assets)
- PPP / SHG-based management models

Regulatory & Supporting Institutions

- **BSPCB / CPCB** → Compliance and monitoring
- **Water Resources Department (WRD)** → Drain coordination
- **District Administration** → Enforcement

4.3 Objective 3: Rejuvenation of Waterbodies and Wetlands

Objective 3 *aims to gauge the existing condition of inland water bodies within the city to assess their potential for rejuvenation and their "acceptable" condition. All water bodies more than 1 acre are considered for study, as otherwise advised by the city.*

4.3.1 Existing Condition

Muzaffarpur's water bodies, including ponds, wetlands, lakes, and the Burhi Gandak River system, play an important role in urban drainage, groundwater recharge, flood buffering, and maintaining ecological balance. Several wetlands and oxbow water bodies within the city, such as **Sikandarpur Lake** and **Kanhauli Maan wetland**, have originated from the historical shifting and meandering course of the Burhi Gandak River, reflecting the city's strong geomorphological relationship with the river floodplain.

However, rapid urbanisation, encroachment, wastewater discharge, and inadequate solid waste management have led to the degradation of many water bodies, reducing their storage capacity and deteriorating water quality. These pressures highlight the need for integrated conservation, restoration, and long-term management strategies.
The spatial distribution of water bodies categorises water bodies into **good, average, and poor condition** based on field-level observations and environmental indicators. The assessment was carried out using the following parameters:

- Absence of solid waste dumping in and around the water body
- Absence of wastewater discharge into the water body
- Presence of boundary protection or edge treatment
- Absence of visible eutrophication
- No significant reduction in water volume compared to the previous year

Each parameter was assigned a score of **1** where conditions were satisfactory and **0** where issues were observed. Based on the cumulative score, water bodies scoring below **33%** were categorised as **poor**, those scoring between **33–66%** as **average**, and those scoring above **66%** as **good condition**.

For example, **Sikandarpur Lake** has boundary protection and a developed waterfront, but continues to fall within the **average category** due to the discharge of drains into the lake, the presence of solid waste along the edges, and visible eutrophication. This reflects the broader condition of several urban water bodies in Muzaffarpur, where physical improvements exist but ecological health remains compromised due to continued pollution and inadequate wastewater management.

4.3.2 URMP Score

As per URMP, if water body revival factor is 40 - 59, **then water body revival score is 2**

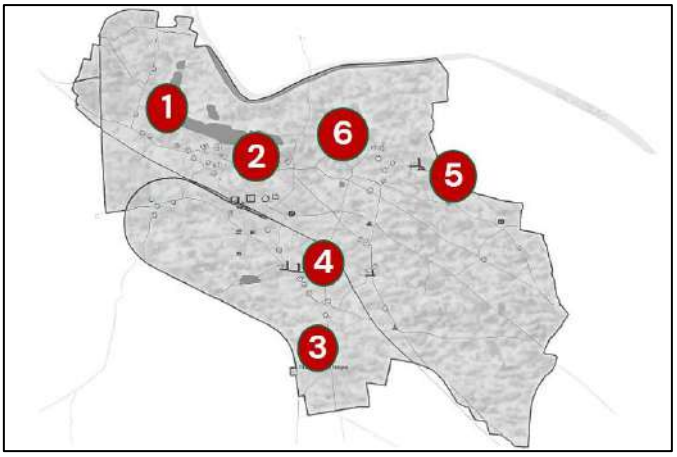


Table 33 Major waterbodies in Muzaffarpur

1. Sikanderpur Lake

2. Sahu Pokhar


3. RDS College Pokhar

4. Padav Pokhar

5. Kanhauli Mann

6. Pond Near Rajkiya Vidyalaya

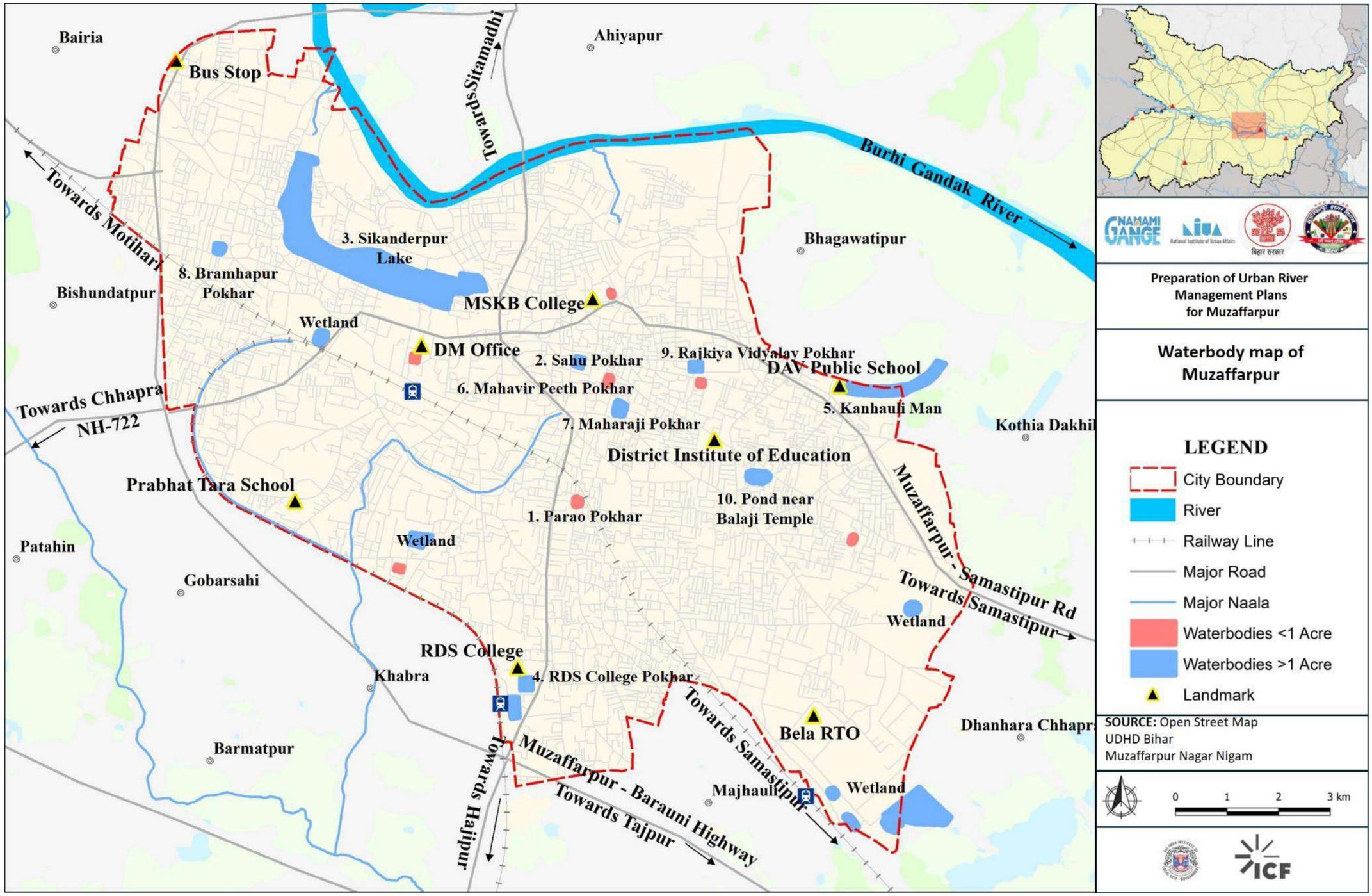
Source: Primary Survey

Table 34 Water Body Inventory

Sl. No.`	Name of Water Bodies	Primary Use	Area (Acres)	Plant Species	Year of Rejuvenation	No presence of Solid Waste in and around the water body	No discharge of wastewater in the water body	Presence of a boundary protection around a water body	No visible eutrophication in the water body	Minimum DO (mg/L)	Water Volume Change vs. Last Year
1.	Padav Pokhar	Religious Activities	1.03	Nil		No	No	Yes	Yes	4 ≥	Reduced
2.	Sahu Pokhar	Religious Activities	1.61	Nil	2018-19	Yes	Yes	No	Yes	4 ≥	Reduced
3.	Sikanderpur Marine Drive	Recreational/ Pisciculture	74.7	Water Chestnut	2023	No	No	Yes	Yes	≥ 8	Reduced
4.	RDS College Pokhar	Recreational	1.51	Water Chestnut		No	Yes	Yes	Yes	≥ 4	No reduction
5.	Kanhauli Mn	Pisciculture	5.50	Water Chestnut		No	No	Yes		≥ 8	No reduction
6	Mahaveer Peeth Pokhar	Religious Activities/ Recreational	1.13	Nil		Yes	No	Yes	No	≥ 4	Reduced
7	Maharaji Pokhar		2.98	advanced eutrophication		No	Yes	No	No	2 - 3	Reduced
8	Bramhpura Pokhar	Religious Activities	1.23	Nil	2021 - 22	Yes	Yes	Yes	Yes	≥ 4	No reduction
9	Rajkiya Vidyalay Pokhar		1.4			No	Yes	No	No	≥ 4	No reduction
10	Pond near Balaji Hanuman Temple	Religious	1.2	Nil		No	Yes	Yes	Yes	≥ 4	No reduction

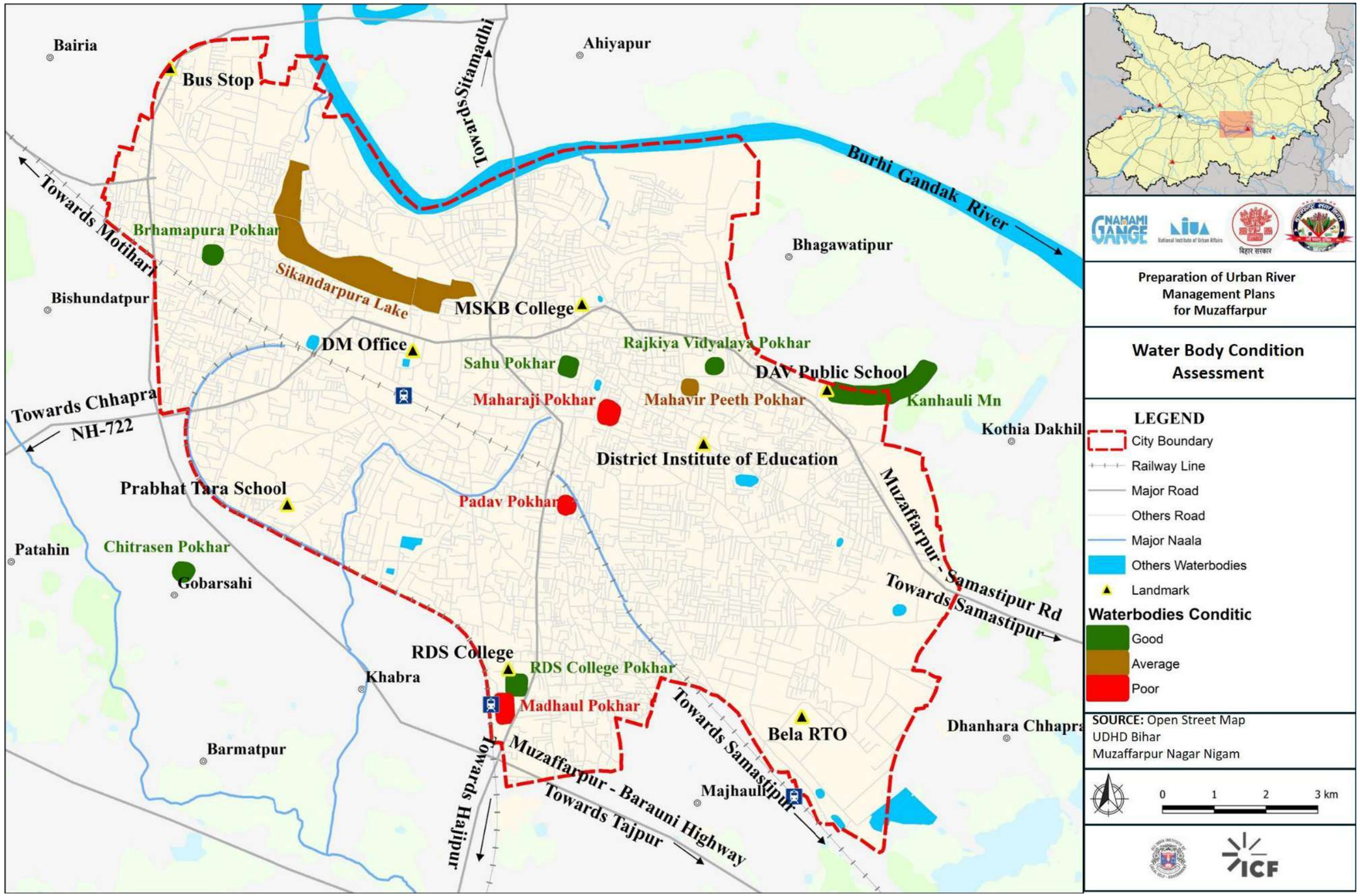
Source: Primary Survey

Map 20 : Inland water bodies- Muzaffarpur



Source: Primary Survey

Map 21: Condition of Water bodies



Source: Primary Survey

4.3.3 Interventions

Intervention 3.1: Develop a GIS-Based Waterbody Inventory, Wetland Remediation Mapping, and Water Quality Monitoring System for Muzaffarpur

Case Study: GIS-Based Lake Monitoring and Restoration in Kolkata

Kolkata has adopted a GIS-based approach for the mapping, monitoring, and management of urban water bodies and wetland systems, particularly within the **East Kolkata Wetlands (EKW)** and the city's network of ponds and lakes. The initiative was implemented through agencies such as the **Kolkata Municipal Corporation (KMC)**, the **East Kolkata Wetlands Management Authority (EKWMA)**, and the **West Bengal Pollution Control Board (WBPCB)**, with technical support from remote sensing and urban planning institutions. Funding for restoration and monitoring activities has been supported through a combination of **state government schemes, AMRUT, wetland conservation programmes, and municipal funds**.
Using GIS and remote sensing tools, water bodies were inventoried and mapped to assess changes in surface area, encroachments, drainage connectivity, pollution inflows, and surrounding land-use change. The GIS database enabled authorities to identify degraded water bodies, prioritise restoration works, and strengthen enforcement against illegal filling and dumping.

The monitoring framework also supported periodic assessment of water quality, wetland extent, and hydrological linkages, helping integrate lake conservation with flood management and urban planning strategies. Restoration measures included desiltation, edge protection, wastewater diversion, ecological landscaping, and community-led awareness initiatives.

The Kolkata experience demonstrates how a GIS-enabled inventory and monitoring framework can support long-term protection and management of urban water bodies. A similar approach can be adopted in Muzaffarpur for monitoring ponds, wetlands, oxbow lakes, and drainage-linked water bodies such as Sikandarpur Lake and Kanhauli Maan wetland, improving ecological health, flood resilience, and urban water governance. [11] [12] [13]

A comprehensive GIS-based inventory and water quality monitoring system is essential for the sustainable management, protection, and rejuvenation of urban and peri-urban water bodies in Muzaffarpur. Rapid urbanisation, encroachment, and pollution have significantly degraded key assets such as Sikanderpur Lake, Sahu Pokhar, Mahavir Peeth Pokhar, and associated wetlands across the city. To address these challenges, a centralised, spatially enabled decision-support system is proposed to map, monitor, and manage all water bodies and wetlands within the municipal boundary.

The system will create a georeferenced digital inventory using high-resolution satellite imagery, drone surveys, and field-based ground truthing. Each waterbody and wetland will be assigned a

[11] East Kolkata Wetlands Management Authority (EKWMA), Government of West Bengal. Management and Conservation of East Kolkata Wetlands.
[12] Kolkata Municipal Corporation (KMC). Urban Water Body Restoration and Drainage Improvement Initiatives under AMRUT.
[13] West Bengal Pollution Control Board (WBPCB). Wetland and Urban Water Quality Monitoring Reports.

unique identification code and mapped within a GIS platform, capturing attributes such as location, surface area, storage capacity, ownership, hydrological connectivity, catchment characteristics, inflow and outflow structures, surrounding land use, and encroachment status. Seasonal variations in water spread and storage will also be monitored to assess hydrological performance and climate resilience.

A key addition to this intervention is the development of a **Wetland Remediation Map**, which will spatially identify degraded wetlands, pollution hotspots, and priority zones for ecological restoration. This map will integrate layers such as water quality status, sedimentation levels, encroachment extent, inflow pollution sources, and proximity to drains/nallahs. Based on this analysis, wetlands will be categorised into intervention typologies—phytoremediation zones, sediment-removal areas, buffer-plantation zones, and conservation zones—enabling targeted, site-specific restoration strategies.

Aligned with national best practices and frameworks promoted by NIUA, the inventory and remediation mapping will be integrated into a digital waterbody management platform or mobile-based application. This will enable standardised data collection, visualisation, and real-time updating by Muzaffarpur Municipal Corporation (MMC) and relevant departments. Field officials will be able to upload geo-tagged photographs, inspection reports, and status updates, improving transparency and inter-agency coordination.

A critical component of the system is water quality monitoring. Regular sampling will be conducted for key parameters such as pH, dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), turbidity, and nutrients. Monitoring stations—both manual and sensor-based—will be strategically located across major water bodies to capture pollution inflows and seasonal variations. The collected data will be integrated into the GIS platform for spatial and temporal analysis.

Suggested On-Ground Implementation Steps (Integrated with GIS Outputs)

Based on the GIS-based assessment and Wetland Remediation Map, the following **phased, site-specific interventions** are recommended:

Short-Term Actions (Immediate Restoration & Cleaning)

- Desilting and deepening of identified water bodies to restore storage capacity
- Removal of solid waste and floating debris
- Cleaning and restoration of inlet and outlet structures
- Mapping and baseline assessment of all wetlands and ponds

Mid-Term Actions (Pollution Control & Ecological Strengthening)

- Construction of interceptor drains to prevent sewage inflow into water bodies
- Establishment of proper drain connections and diversion systems
- Development of bio-fencing and green buffer zones around water bodies
- Plantation of native wetland vegetation for natural filtration and bank stabilisation
- Creation of constructed wetlands and natural filtration beds in high-pollution zones

Long-Term Actions (Sustainability & Monitoring)

- Continuous water quality monitoring using sensor-based and manual systems

Biodiversity enhancement through bird habitat zones and ecological corridors
Encroachment prevention through demarcation, fencing, and regulatory enforcement
Periodic assessment of ecological health and hydrological performance

Ecological Restoration Strategy (City-Wide Lakes & Wetlands)

The intervention further incorporates a city-wide ecological restoration approach, including:

- Constructed wetlands and nature-based treatment systems
- Plantation of native wetland species
- Development of bird habitat and biodiversity zones
- Long-term conservation through monitoring and regulatory frameworks

Institutional Framework

- **Lead Agency:** Muzaffarpur Municipal Corporation (MMC)
- **Supporting Agencies:** Bihar Urban Development Department, State Wetland Authority, Forest Department, Irrigation Department
- **Stakeholders:** Ward Committees, Local NGOs, Community Groups

Intervention 3.2: Ecological restoration of Sikanderpur Lakefront

Sikanderpur Lake, covering approximately **35 hectares including connected wetlands**, is one of the most significant urban water bodies in Muzaffarpur. While partial lakefront development has been undertaken, the ecological functioning of the lake system remains severely compromised. The lake currently receives **untreated wastewater inflows from surrounding catchments**, resulting in elevated organic pollution levels. Field observations indicate **encroachment on wetland edges**, lack of vegetation along walkways, and unregulated activities such as dhobi ghats contributing to detergent pollution. Hydrological disconnection of wetlands due to road infrastructure has further reduced the lake's natural filtration capacity.

Figure 32 Images of Sikanderpur Lake

Key Issues

- High organic pollution load (BOD: 3–15.6 mg/L)
- Direct inflow of untreated wastewater and drain discharge
- Encroachment and fragmentation of wetland systems
- Absence of natural filtration zones and buffer vegetation
- Unregulated dhobi ghat leading to detergent contamination
- Poor microclimate and lack of shading along the lakefront
- Lake functioning as a pollution sink instead of an ecological buffer

Case Study: Neknampur Lake Constructed Wetland System, Hyderabad

A relevant example of a decentralised wetland-based wastewater treatment system is the Neknampur Lake restoration project in Hyderabad, Telangana. The project was implemented through collaboration between the Greater Hyderabad Municipal Corporation (GHMC), local citizen groups, and environmental organisations to address untreated wastewater inflows, eutrophication, and ecological degradation affecting the urban lake.

The intervention adopted a constructed wetland and natural treatment approach for improving water quality before discharge into the lake. The treatment system included:

- Inlet screening and trash removal
- Sedimentation and settling zones
- Reed-bed and gravel filtration systems
- Free water surface wetlands
- Aeration and polishing ponds
- Riparian plantation and ecological edge restoration

The project demonstrated significant improvements in reducing suspended solids, organic pollution, and nutrient loads entering the lake, while also enhancing biodiversity and restoring ecological functions. The wetland system operates as a low-energy, nature-based treatment solution requiring comparatively lower operational costs than conventional STPs.

The Hyderabad example is relevant for Muzaffarpur's proposed Constructed Wetland Treatment System near the Burhi Gandak outfall, as both contexts involve urban drains carrying mixed stormwater and wastewater into ecologically sensitive water bodies. The case highlights how decentralised wetland systems can improve water quality, restore hydrological connectivity, and create multifunctional ecological landscapes within dense urban environments.

(Source: Greater Hyderabad Municipal Corporation (GHMC). *Urban Lake Restoration and Wetland Management Initiatives*.)

Rationale

Sikanderpur Lake has the potential to function as a natural urban wetland system, providing water purification, flood buffering, and recreational value. However, this requires a shift from cosmetic lakefront development to integrated ecological restoration.

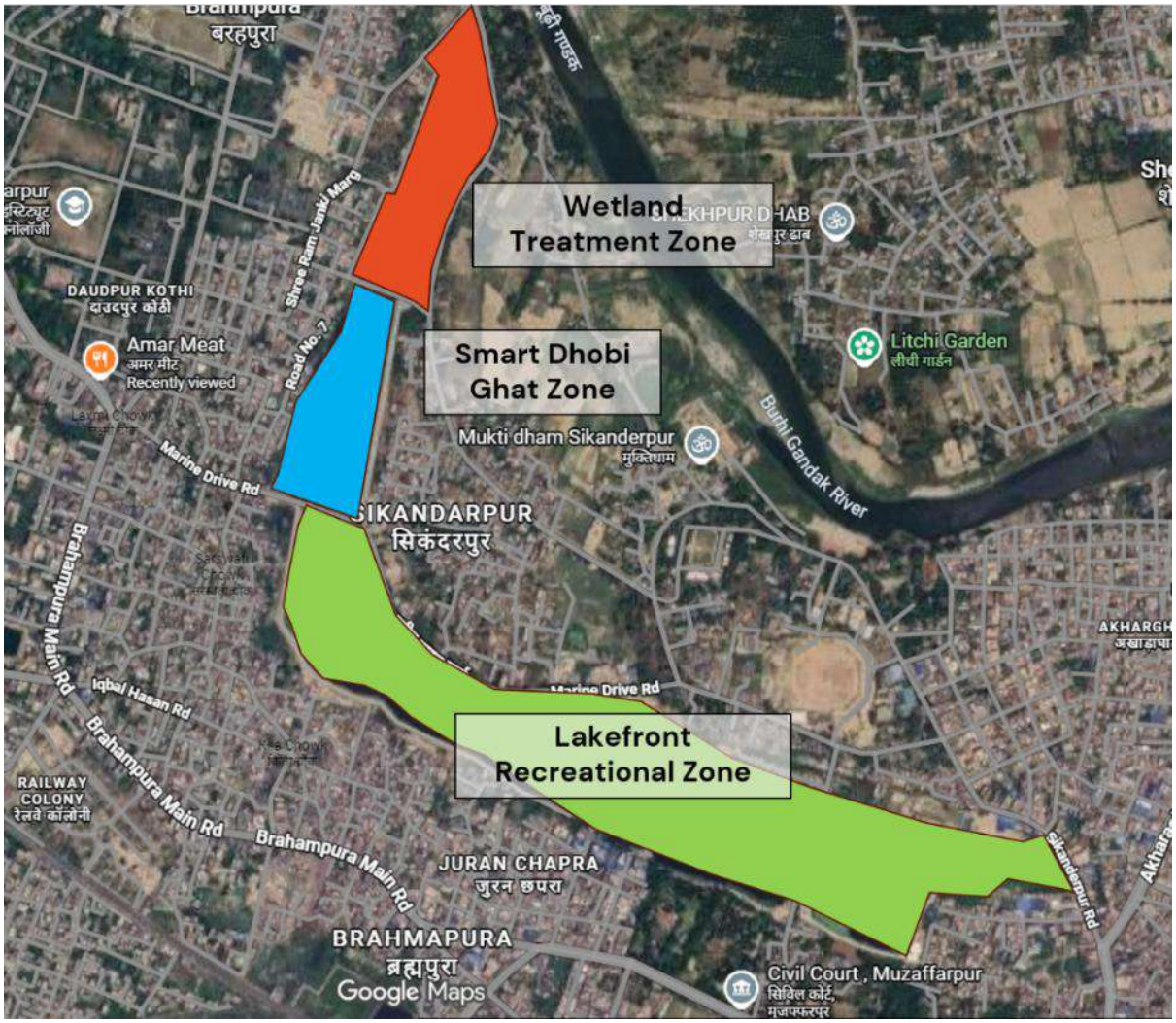
The proposed intervention adopts a nature-based, multi-zone approach, combining:

- Wetland-based treatment systems
- Pollution source control
- Hydrological restoration
- Public realm enhancement

Proposed Intervention Strategy: Integrated 3-Zone Restoration Approach

Zone	Area	Intervention Focus
Zone 1: Lakefront Ecological Zone	~35 ha	Aeration, edge treatment, public realm
Zone 2: Smart Dhobi Ghat Zone	~6.79 ha	Controlled washing + greywater treatment
Zone 3: Wetland Treatment Zone	~5.6 ha	Constructed wetlands + filtration

Figure 33 Zoning of the Sikanderpur Lake Ecological Restoration



Source: Primary Survey

Zone 1: Lakefront Ecological Enhancement

Interventions:

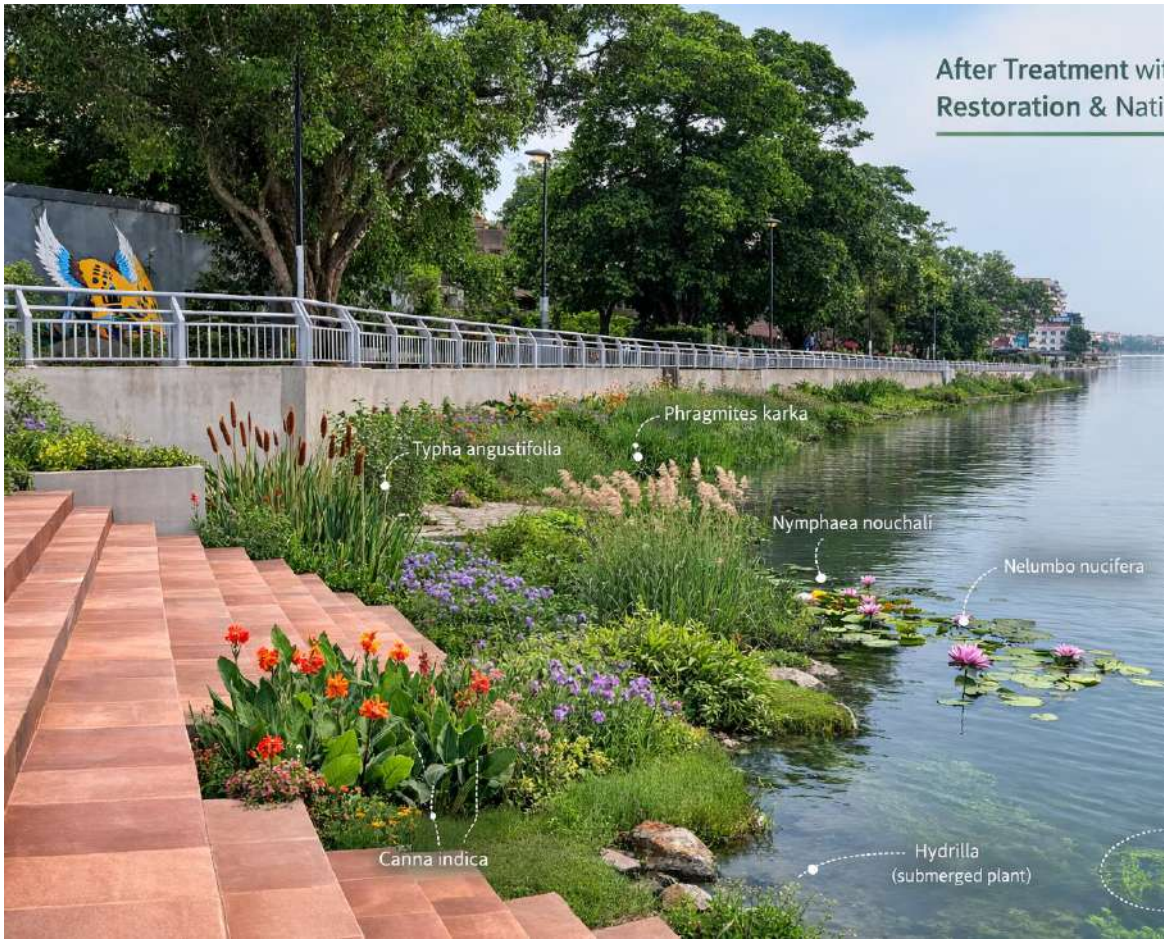
- Floating and diffused aerators for DO improvement
- Riparian vegetation and bio-engineered edges
- Constructed wetland buffers along the lake edge
- Shaded pedestrian corridors with native plantation
- Aquatic vegetation (lotus, hydrilla, etc.)

Expected Outcomes:

- Improved oxygen levels and reduced eutrophication

- Enhanced biodiversity and habitat creation
- Improved recreational and microclimatic conditions

Figure 34 Before and After Images of the Sikanderpur Lake edge control



Zone 2: Smart Dhobi Ghat System

Area: ~6.79 ha

Interventions:

- Designated washing platforms
- Multi-stage greywater treatment system:
  - Grit chamber
  - Settling tank
  - Oil & grease trap
  - Bio-filtration + polishing pond
- Treated water reuse system
- Controlled discharge into the wetland system

Benefits:

- Reduction in detergent and organic pollution
- Formalisation of informal livelihood
- Improved hygiene and working conditions

Figure 35 Conceptual Image of the Smart Dhobhi Ghat

Zone 3: Constructed Wetland Treatment System

Area: ~5.6 ha (at lake outfall towards Burhi Gandak)

Interventions:

- Inlet chamber with trash rack
- Sedimentation basin for TSS removal
- Multi-stage wetland system:
  - Anaerobic wetland cells
  - Free water surface wetlands
  - Planted gravel/reed filtration

- Polishing pond with aeration
- Culverts for restoring hydrological connectivity
- Riparian buffer plantation

Expected Outcomes:

- 30–60% reduction in BOD
- 40–70% reduction in COD
- Improved nutrient removal before discharge

Institutional Framework

Table 35 Institutional Framework for the Sikanderpur Lakefront development

Component	Lead Agency	Supporting Agencies	Role
Project Implementation	MMC	State UD&HD	DPR, execution
Wetland & Hydrology	WRD	Forest Dept.	Flow & ecological design
Water Quality Monitoring	BSPCB	MMC	Compliance
Dhobi Ghat Management	MMC	SHGs / PPP Operator	O&M
Public Realm & Landscaping	MMC	Tourism Dept.	Activation

O&M SOP

The long-term performance of the Sikanderpur Lake ecological restoration system is critically dependent on a robust and well-defined Operation & Maintenance (O&M) framework. Unlike conventional infrastructure, constructed wetlands function as living systems, where hydraulic efficiency, vegetation health, and pollutant removal capacity must be continuously maintained.
The proposed O&M strategy adopts a zone-based approach, recognising the distinct functional roles of the lakefront, dhobi ghat system, and constructed wetland treatment zone. It combines routine maintenance, ecological management, and water quality monitoring, with clearly defined responsibilities across municipal agencies, technical departments, and operators.

A structured Standard Operating Procedure (SOP) ensures that maintenance activities are carried out at appropriate frequencies—ranging from daily cleaning to annual desilting—thereby preventing system clogging, maintaining treatment efficiency, and sustaining ecological balance. This approach ensures that the intervention remains resilient, self-sustaining, and effective in achieving long-term water quality improvement and ecosystem restoration goals.

Zone-wise O&M Framework

Table 36 Zone 1: Lakefront Ecological Zone

Activity	Frequency	Agency
Vegetation trimming	Quarterly	Horticulture
Aerator maintenance	Monthly	Contractor
Debris removal	Daily	ULB

Table 37 Zone 2: Smart Dhobhi Zone

Activity	Frequency	Agency
Platform cleaning	Daily	Operator

Sludge removal (settling tank)	Monthly	Contractor
Oil & grease trap cleaning	Weekly	Operator
Water reuse system check	Weekly	MMC

Table 38 Zone 3 Constructed wetland

Activity	Frequency	Agency
Inlet trash cleaning	Daily	ULB
Sedimentation basin desilting	Quarterly	Contractor
Wetland vegetation management	Quarterly	Horticulture
Invasive species removal	Monthly	MMC
Hydraulic flow inspection	Monthly	WRD
Water quality testing	Monthly	BSPCB

SOP (Step-wise)

Daily

- Remove floating waste at inlet
- Check flow continuity

Weekly

- Inspect clogging in channels
- Check dhobi ghat discharge

Monthly

- Water quality testing (BOD, COD, DO)
- Minor vegetation pruning

Quarterly

- Sediment removal
- Replanting damaged vegetation

Annual

- Major desilting
- Structural inspection

CAPEX Costing

A. Lakefront Ecological Zone

Table 39 Lakefront Ecological Zone costing

Component	Cost (₹ Lakhs)
Floating wetlands & aerators	130
Edge treatment & vegetation	100
Boardwalk & public realm	75
Landscaping & plantation	52
Lighting & street furniture	40
Subtotal A ≈ ₹4.0 Cr	

B. Smart Dhobi Ghat

Table 40 Smart Dhobhi Ghat Costing

Component	Cost (₹ Lakhs)
Washing platforms & infrastructure	80
Greywater treatment system (Decentralised Moving Bed Biofilm Reactor – MBBR)	120
Utilities & drainage	50

Subtotal B ≈ ₹2.5 Cr

C. Constructed Wetland System

Table 41 Constructed Wetland System

Component	Cost (₹ Lakhs)
Wetland cells & basins	150
Filtration zones & plantation	100
Culverts & hydraulic structures	30
Pathways & interpretation	40

Subtotal C ≈ ₹3.5 Cr

Total CAPEX ≈ ₹10 Cr

O&M Cost (Annual)

Table 42 O&M Cost Annual

Component	Annual Cost (₹ Lakhs)
Aeration system O&M	25
Wetland maintenance	20
Dhobi ghat O&M	30
Landscaping & cleaning	20
Monitoring & inspections	10

Total Annual O&M ≈ ₹1.05 Cr

Table 43 Lifecycle Cost

Component	Cost
CAPEX	₹10 Cr
5-Year O&M	₹5.25 Cr

Total Lifecycle Cost ≈ ₹15.25 Cr

Funding Sources

- **AMRUT 2.0** → Lake rejuvenation & infrastructure
- **15th Finance Commission Grants** → Public realm & greens
- **NPCA (Wetlands Scheme)** → Wetland restoration
- **State Urban Development Fund** → Dhobi ghat & utilities
- **CSR Funding** → Landscaping, public amenities
- **Municipal Budget** → O&M

Implementation Phasing

Short-term (0–2 years): Desilting, aeration, dhobi ghat construction
Mid-term (2–5 years): Wetland system development, plantation
Long-term (5+ years): Monitoring, ecosystem stabilisation

Ecological Plantation Strategy & Habitat Design

The plantation strategy for Sikanderpur Lake adopts a multi-layered ecological approach, integrating bank stabilisation, wetland filtration, and faunal habitat creation. The design ensures that vegetation is not ornamental but functional—supporting biodiversity, water purification, and erosion control. The detailed suggestions for

Table 44 Plantation Zonation Strategy

Zone	Plantation Type	Function
Bioswale / Transition Zone	Native grasses + ground flora	Filtration, habitat corridors
Wetland Treatment Zone	Aquatic + emergent plants	Water purification

Table 45 Shrubs and Understory (Bioswale & Edge Habitat Layer)

Scientific Name	Common Name	Ecological Function
Carissa carandas	Karonda	Dense thorny cover for mongoose & reptiles
Clerodendrum infortunatum	Bhant	Shelter for snakes & reptiles
Calotropis procera	Akanda	Structural cover in dry edges
Dodonaea viscosa	Hopbush	Soil binder; stabilizes slopes
Lantana camara (controlled use)	Wild sage	Shelter (use only native variants)
Vitex negundo	Nirgundi	Snake habitat; bank stabilizer
Woodfordia fruticosa	Dhataki	Dense shrub layer
Ziziphus mauritiana	Ber	Fruit source for birds & fauna

Table 46 Native Grass (Edge Control and Bioswale Stabilisation)

Scientific Name	Common Name	Application
Vetiveria zizanioides	Vetiver	Primary erosion control (steep banks)

Saccharum spontaneum	Kans grass	Riparian edges
Cyperus rotundus	Nutgrass	Wet-dry interface
Desmostachya bipinnata	Kusha grass	Upper bioswale
Phragmites karka	Wild reed	Large swales & bird habitat
Typha angustifolia	Cattail	Wet edges & shallow zones

Table 47 Wetland & Aquatic Plants (Constructed Wetland System)

Scientific Name	Common Name	Function
Nymphaea nouchali	Blue water lily	Surface shading
Nelumbo nucifera	Lotus	Bird habitat
Hydrilla verticillata	Hydrilla	Fish habitat
Ludwigia octovalvis	Water primrose	Amphibian support
Ipomoea aquatica	Water spinach	Shallow stabilization
Alternanthera sessilis	Sessile joyweed	Edge vegetation
Azolla pinnata	Mosquito fern	Nutrient uptake
Ceratophyllum demersum	Hornwort	Fish nursery

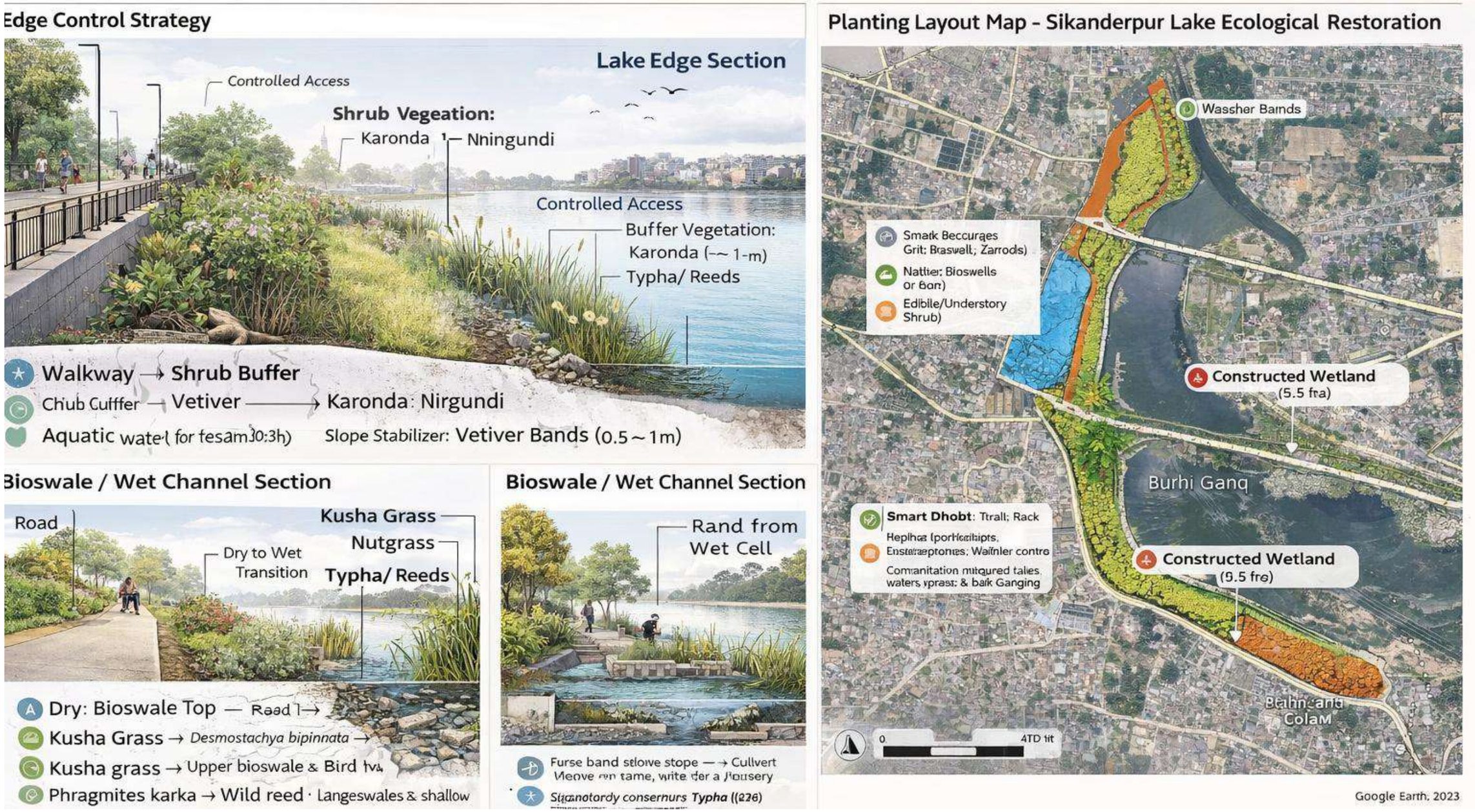
Table 48 Ground Flora / Herbaceous Layer

Scientific Name	Common Name	Function
Boerhavia diffusa	Punarnava	Moisture retention
Evolvulus alsinoides	Shankhpushpi	Ground cover
Asystasia gangetica	Groundcover	Erosion control
Aerva lanata	Knotgrass	Reptile movement
Leucas aspera	Thumbai	Pollinator support

Edge Control Strategy (Key Design Note)

- Primary stabilizer: Vetiver grass (continuous bands)
- Secondary buffer: Shrub layer (Karonda, Nirgundi)
- Wet edge stabilizer: Typha + Phragmites
- Transition zone: Cyperus + ground flora

Figure 36 Ecological Restoration and plantation strategy



References for Costing (CAPEX & O&M)

Table 49 References for costing for CAPEX and O&M

Source / Guideline	Key Components Covered	Application in Project
NMCG DPR Guidelines	Constructed wetlands, bio-remediation, riverfront works	Wetland systems, aeration, riparian plantation
AMRUT 2.0 Toolkit (MoHUA)	Lake rejuvenation, desilting, edge development	Lakefront works, pathways, public realm
CPHEEO Manual	Greywater treatment, settling tanks, treatment units	Smart dhobi ghat system design & costing
Bihar SOR / CPWD DSR	Civil works, landscaping, electrical items	BOQ rates for construction & infrastructure
NPCA (MoEFCC)	Wetland restoration, biodiversity interventions	Wetland plantation & habitat restoration
SBM (Urban) 2.0	Sanitation systems, O&M models	Dhobi ghat sanitation & O&M benchmarking
Smart Cities Mission Projects	Lakefront, public realm, landscaping benchmarks	Cost benchmarking (boardwalks, lighting, amenities)
NIUA URMP Toolkit	Nature-based solutions, integrated planning	Structuring intervention & cost logic
CPCB / BSPCB Guidelines	Water quality monitoring systems	Monitoring infrastructure & O&M costs
DPR Case Studies & Market Benchmarks	Aerators, floating wetlands, treatment units	Unit rate validation & practical costing

Intervention 3.3: Rejuvenation of Sahu Pokhar

To transform Sahu Pokhar into a clean, ecologically functional, and culturally vibrant urban waterbody, balancing its religious significance with nature-based water treatment systems, while enabling safe public use and community stewardship.

The proposal adopts a hybrid NbS + engineered intervention model, structured around:

- Water Quality Restoration through in-situ treatment and controlled inflows
- Ritual Management System to reduce pollution load
- Edge Reconfiguration to improve ecological interface
- Public Realm Enhancement with controlled access and shading
- Institutional + Community Stewardship Framework

Key Issues

- Stagnant waterbody with no inflow–outflow system
- High organic load due to ritual activities and idol immersion
- Fully concretised edges with no ecological buffer
- Absence of aeration and treatment mechanisms
- Lack of green/public comfort infrastructure
- No structured O&M or stewardship system

Figure 37 Key Issues of Sahu Pokhar

Figure: Completely concretised edges near the water body and surrounded by built-up area no space to expand

Figure: Ritual and solid waste

Figure: Very high footfall during festivals

Figure: Waterbody used only for rituals

Source: Primary Survey

Proposed Interventions

Water Quality Improvement System

- Installation of floating treatment wetlands (FTWs) with native species
- Phytoremediation rafts placed along edges and stagnant zones
- Diffused aeration system to improve DO levels
- Creation of circulation flow using low-energy pumps
- Periodic desludging plan with sediment traps

Ritual Activity Segregation System (Critical Intervention)

- Construction of a designated RCC-lined ritual tank/immersion zone within the pond edge
- Hydraulic separation from main waterbody (controlled overflow + filtration)
- Dedicated idol immersion platform + waste collection nets
- Provision of ritual washing ghats to avoid direct contamination

Edge Reconfiguration & Ecological Buffer

- Retrofitting portions of hard edge into soft ecological ledges (where feasible)
- Introduction of planter-based phytoremediation strips (since space is constrained)
- Installation of shaded trellis walkways with climbers (Aparajita, Madhumalti)
- Plantation of Neem, Peepal, and native shade trees in available pockets

Public Realm & Cultural Interface

- Development of 2 m wide circumferential walkway (select stretches)
- Seating zones integrated with shaded structures
- Smart lighting for festival use and safety
- Drinking water kiosks and changing areas near ritual zones
- Designated festival congregation zones

Solid Waste & Ritual Waste Management

- Installation of floating trash barriers and collection booms
- Dedicated ritual waste bins + organic waste segregation system
- Integration with Swachh Bharat Mission (SBM-U 2.0)
- Daily cleaning protocol during peak events

Smart Monitoring & Display

- Real-time water quality display board (DO, BOD indicators)
- CCTV-based monitoring during festivals
- Public awareness signage (IEC boards on sacred water protection)

Community Stewardship Model

- Formation of **"Sahu Pokhar Management Committee"**:
  - MMC + Temple Trust + Ward Committee + NGOs
- Volunteer-led festival management system
- Citizen engagement through "Adopt-a-Pond" initiatives

Figure 38 Conceptual Map of the Sahu Pokhar Intervention

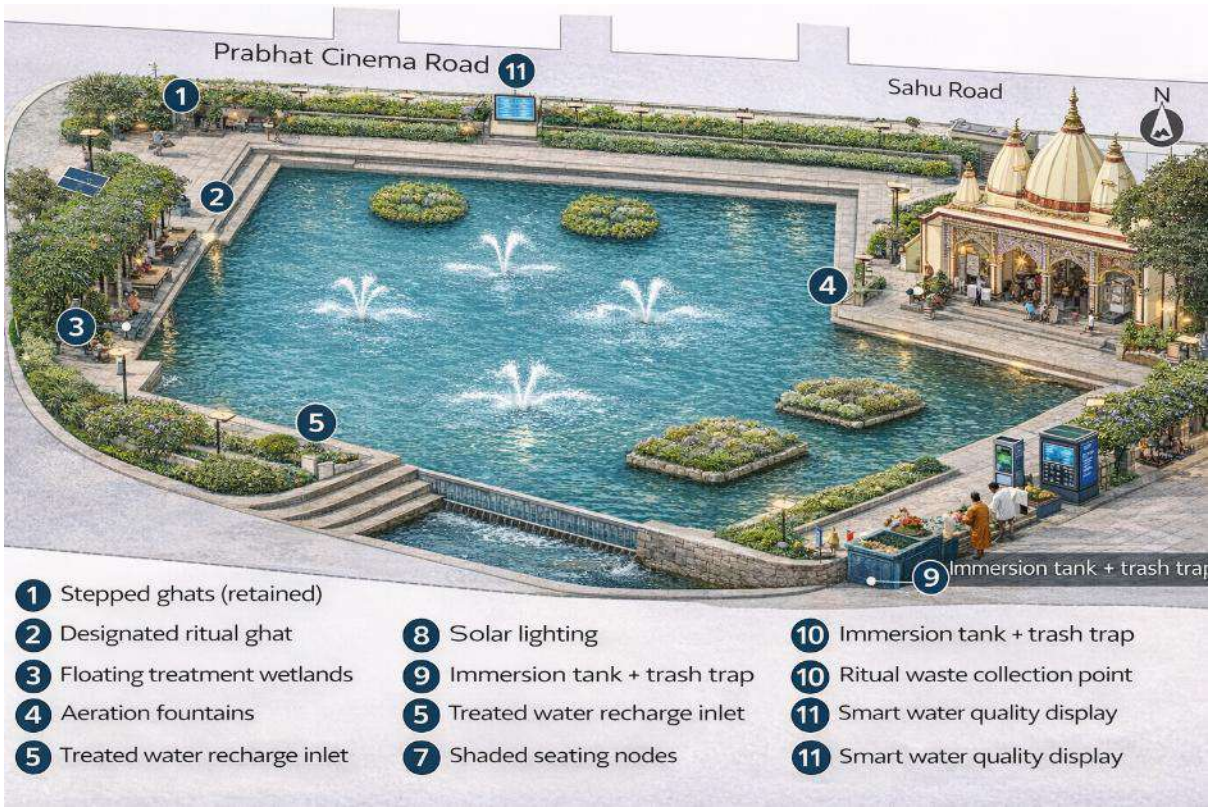
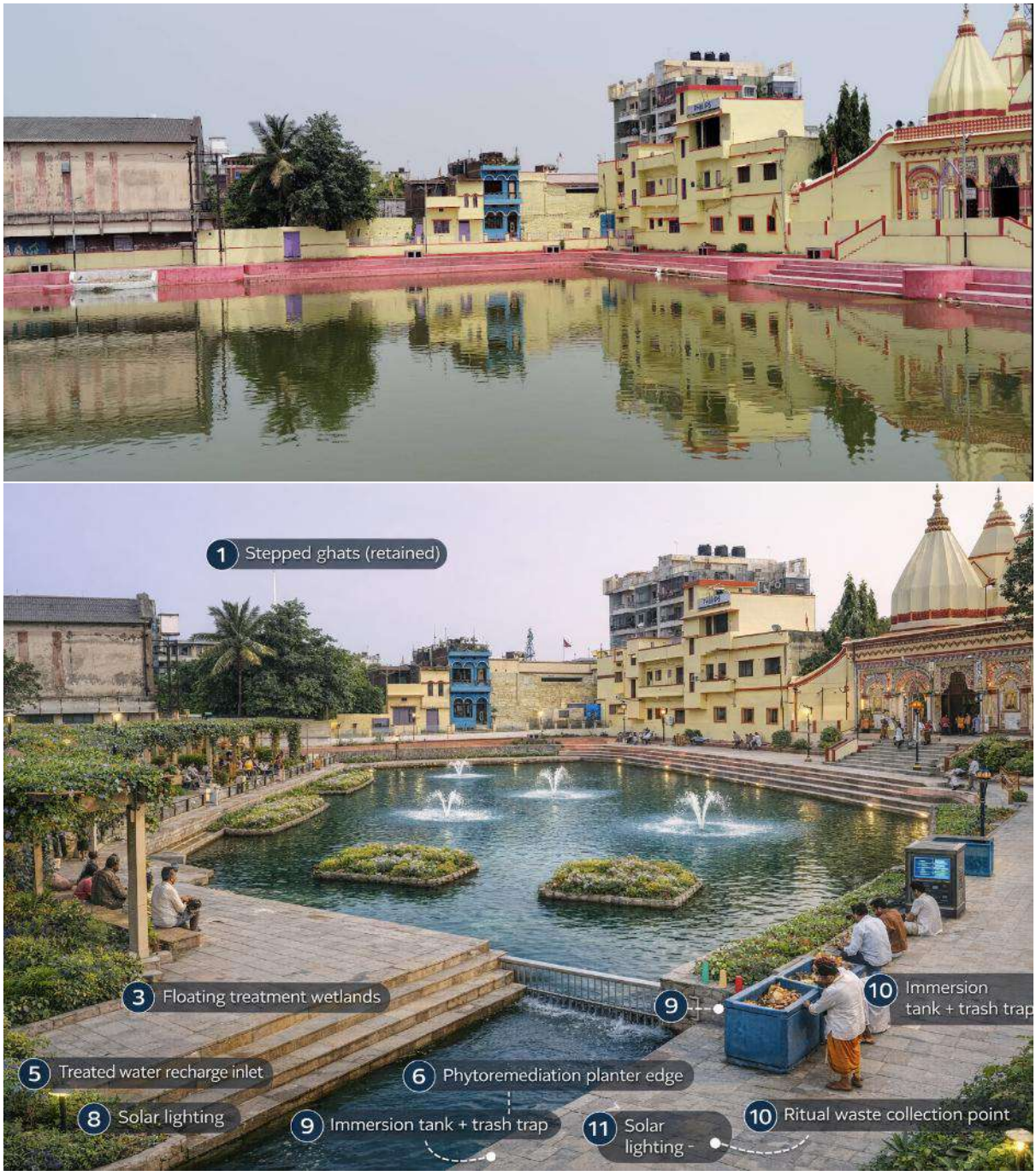


Figure 39 Sahu Pokhar before and after interventions of Sahu pokhar interventions

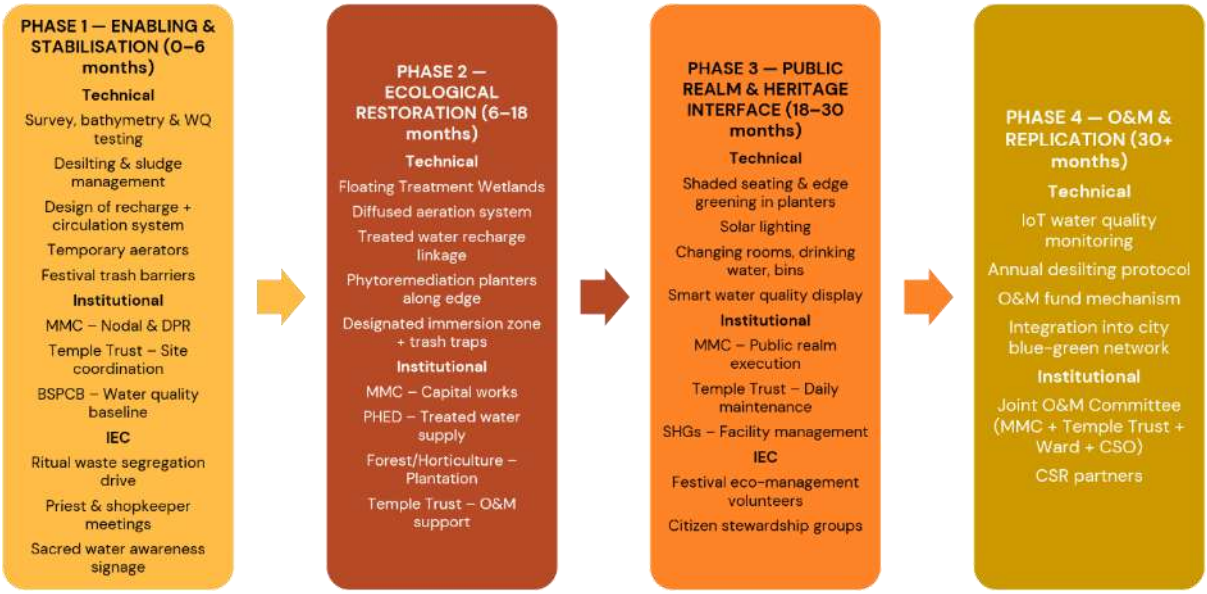


Phasing Strategy

The rejuvenation of Sahu Pokhar is structured through a **phased implementation strategy aligned with the URMP framework**, ensuring a systematic transition from immediate stabilisation to long-term sustainability. The process begins with **Phase 1 (0–6 months)** focusing on baseline assessments, desludging, and temporary measures to arrest further degradation. This is followed by **Phase 2 (6–18 months)**, which prioritises core ecological restoration through installation of treatment systems, aeration, and the critical ritual segregation infrastructure. **Phase 3 (18–30 months)** integrates public realm improvements, including walkways, shading, and cultural interfaces, enhancing usability without compromising ecological health. Finally, **Phase 4 (>30 months)** institutionalises operations through monitoring systems, annual maintenance protocols,

and community-led stewardship, ensuring the long-term resilience and functionality of the waterbody.

Figure 40 Phasing Strategy



Costing for Sahu Pokhar rejuvenation

CAPEX Costing

Table 50 CAPEX BOQ- Sahu Pokhar

S. No.	Component	Description	Estimated Cost (₹ lakh)	Lead Agency	Supporting Agency
1	Desilting & sludge management	Removal of silt, sediment traps, disposal	20–30	MMC	Temple Trust
2	Floating Treatment Wetlands (FTWs)	Modular floating islands with native plants	18–25	MMC	Forest Dept.
3	Diffused Aeration System	Aerators + circulation pumps	12–18	PHED	MMC
4	Water circulation & recharge	Pump-based circulation system	25–35	PHED	MMC
5	Ritual segregation tank (RCC)	Dedicated immersion tank with filtration	20–30	Temple Trust	MMC
6	Edge retrofitting & planters	Phytoremediation edge + planter strips	15–20	MMC	Forest Dept.
7	Walkway & public realm	2m walkway, seating, shading structures	20–28	MMC	Smart City (if applicable)
8	Solid waste management system	Trash barriers, bins, collection points	5–7	MMC	SBM Cell
9	Smart display & lighting	Water quality display + smart lighting	3–5	MMC	BSPCB

10	IEC & signage	Awareness boards, ritual waste messaging	2–3	MMC	NGOs

Total Estimated CAPEX: ₹1.25 – 1.80 Cr

Table 51 O&M BOQ

S. No.	Component	Activity	Frequency	Annual Cost (₹ lakh)	Responsible Agency
1	Aeration system	Operation & maintenance	Monthly	4–6	Contractor / PHED
2	FTWs maintenance	Plant trimming, replacement	Quarterly	3–4	Horticulture Dept.
3	Desilting	Minor desludging	Annual	3–5	MMC
4	Solid waste management	Daily cleaning & disposal	Daily	4–6	MMC / SBM
5	Water quality monitoring	Testing & reporting	Monthly	2–3	BSPCB
6	Public realm upkeep	Cleaning, lighting, repairs	Monthly	2–3	MMC
7	Festival management	Temporary staff, logistics	Seasonal	2–3	Temple Trust + MMC

Total Annual O&M: ₹18 – 24 lakhs

Funding Strategy

Table 52 Funding Strategy Matrix

Component	Potential Funding Source	Remarks
Desilting & water restoration	15th Finance Commission Grants	Water & sanitation tied grants
FTWs & ecological restoration	AMRUT 2.0 / CSR	NbS-focused funding eligible
Aeration & circulation	AMRUT 2.0 / Urban Infra Funds	Core infrastructure
Ritual segregation tank	Temple Trust + CSR	High cultural relevance
Walkways & public realm	Municipal Budget / Smart City	Urban improvement
Solid waste management	SBM-U 2.0	Direct convergence
Smart monitoring & IEC	AMRUT / CSR	Awareness + innovation
O&M funding	User-based / Municipal revenue	Long-term sustainability

Institutional Framework

Table 53 Institutional Framework

Function	Nodal Agency	Key Responsibilities
Project planning & execution	Muzaffarpur Municipal Corporation (MMC)	DPR, tendering, implementation
Ritual management	Temple Trust	Immersion management, crowd control
Water infrastructure	PHED	Aeration, circulation systems
Ecological systems	Forest / Horticulture Dept.	Plantation, FTWs maintenance
Water quality monitoring	BSPCB	Testing, compliance
Solid waste management	MMC / SBM Cell	Collection & disposal
Community engagement	SHGs / NGOs	IEC, volunteer mobilisation
CSR convergence	District Administration	Partner onboarding

Special Governance Mechanism

Formation of "Sahu Pokhar Management Committee"

- Members: MMC + Temple Trust + Ward Committee + BSPCB + NGOs

Joint O&M Model:

- Temple Trust → Ritual zone management
- MMC → Infrastructure & cleaning
- Community → Stewardship & vigilance

4.4. Objective 4: Enhancing Riparian Buffer

Objective 4 *seeks to restore and strengthen riparian buffers as natural shields that protect rivers from urban pressures and flooding. By developing continuous stretches of native vegetation along riverbanks, cities can stabilise soils, filter pollutants, and create ecological corridors.*

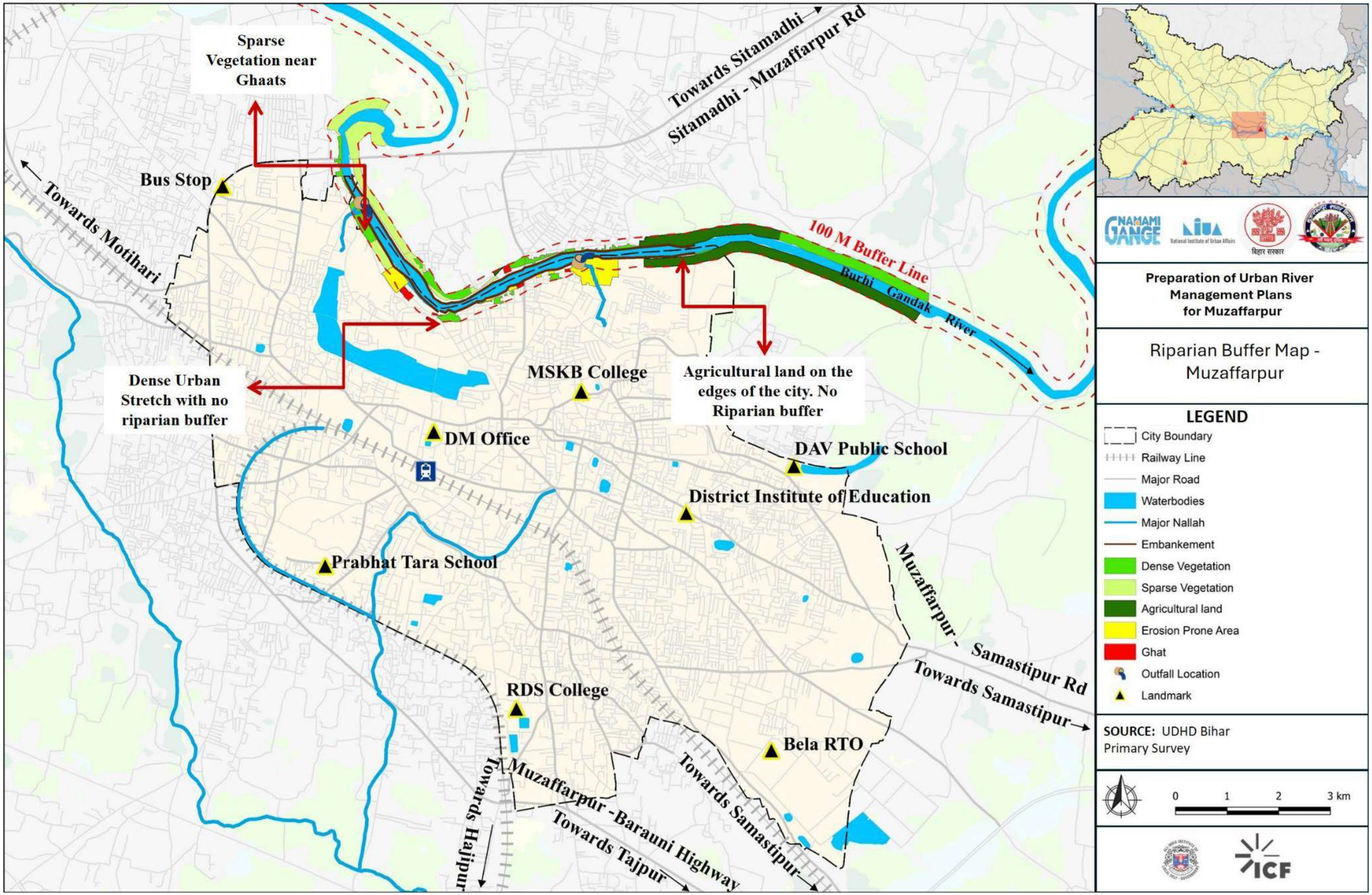
4.4.1 Existing Condition

The existing condition of the riparian buffer along the river reflects a highly fragmented and unregulated edge, limiting its ecological and hydrological functions. The absence of a notified buffer zone under WRD or municipal regulations has led to ad-hoc development and progressive encroachment, resulting in a narrowed and discontinuous buffer. A significant portion of the riparian stretch is dominated by residential land use, leaving minimal space for natural vegetation or flood absorption. Additionally, hard infrastructure at cultural nodes, such as ghats, cremation areas, and access paths, has introduced extensive concretisation along the river edge. These interventions disrupt natural processes, reduce infiltration, and increase surface runoff, further weakening the buffer's role in flood mitigation, pollution control, and ecological continuity.

4.4.2 URMP Score

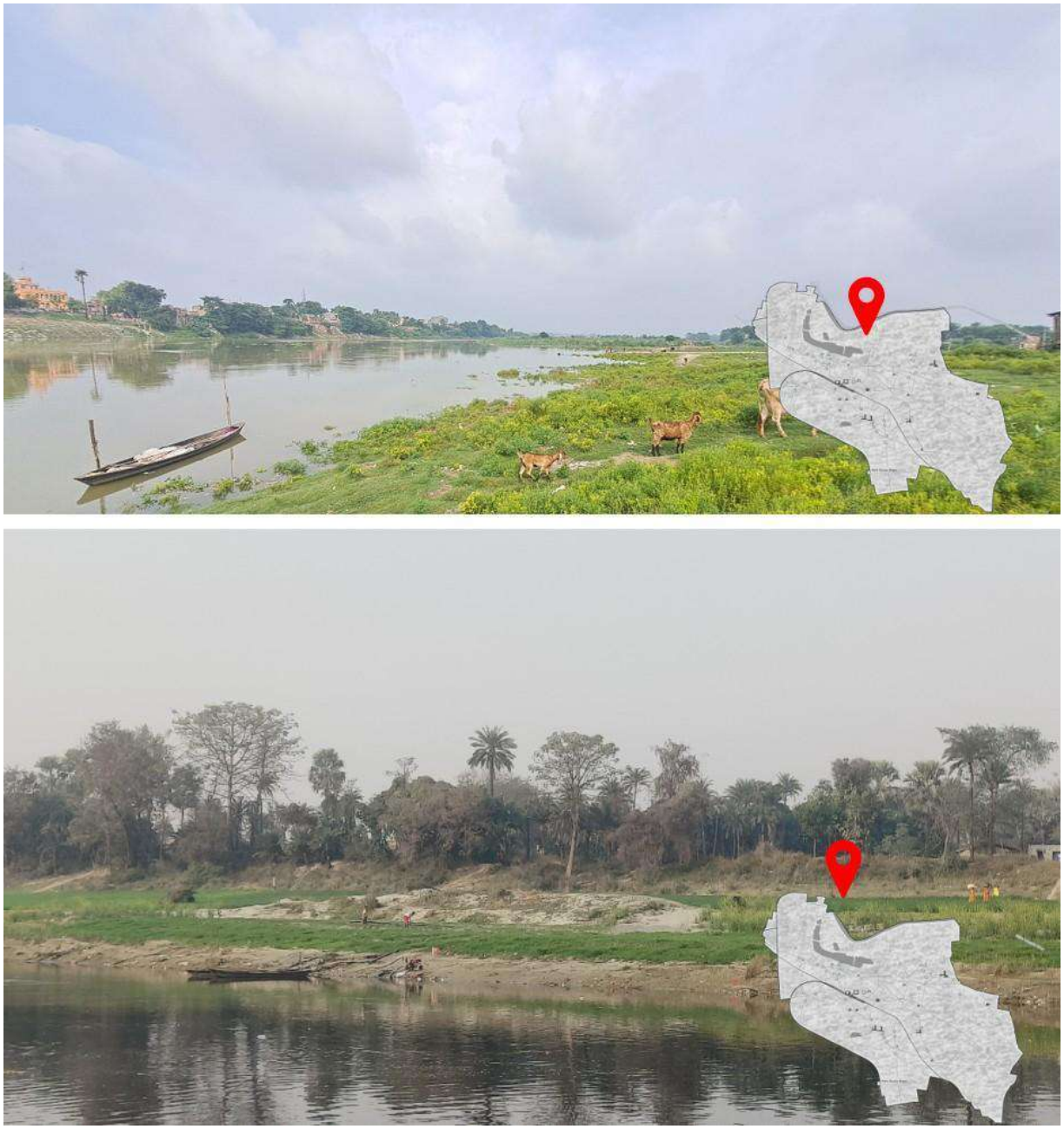
55.69% of the Riparian buffer is not covered by built up area. As per URMP, if the riparian buffer factor is 50-69, then the **riparian buffer score is score is 3.**

Map 22 : Riparian buffer along Burhi Gandak



Source: Primary Survey

Figure 41 Images of Existing Riparian Buffer

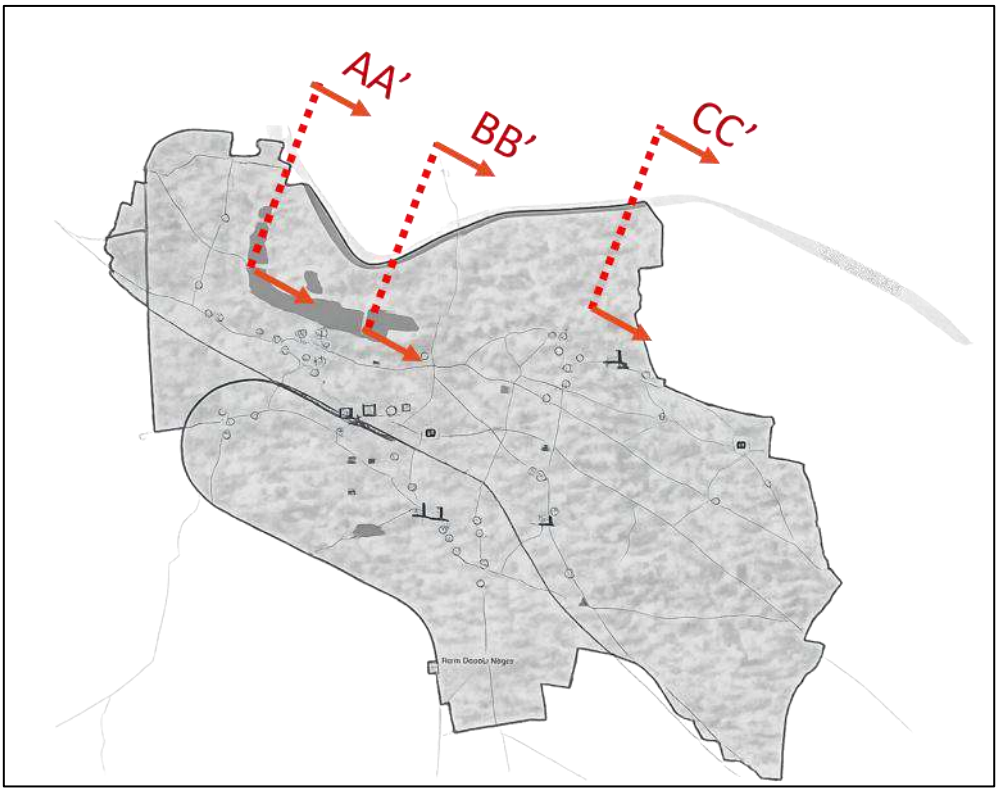


Source: Primary Survey

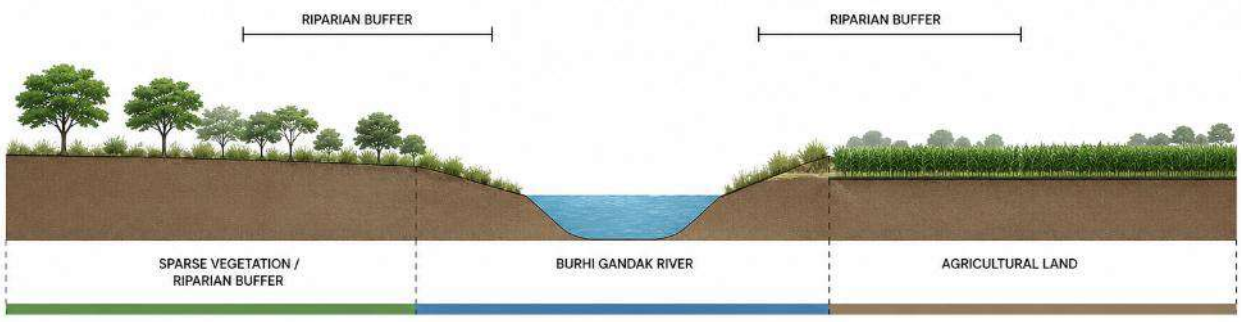
The Riparian Buffer Map of Muzaffarpur highlights the varying ecological conditions and urban interface along the Burhi Gandak River corridor within the municipal area. The analysis indicates significant variation in riparian vegetation, with stretches of dense and sparse vegetation interspersed with agricultural land, erosion-prone edges, ghats, embankments, and highly urbanised riverfront segments. While some peripheral stretches retain natural or semi-natural riparian buffers, several urban sections—particularly near dense built-up areas—lack adequate buffer zones due to encroachment, road development, and direct edge modification along the river. Agricultural activity is also visible along parts of the eastern river edge, where natural buffers are fragmented or absent. To further illustrate the relationship between the river and surrounding urban fabric, three representative sectional profiles have been prepared at key locations near the **NH-22 Bridge, Bandh Road, and Akharaghat Bridge**. These sections demonstrate the changing

riparian conditions, including dense urban edges, sparse vegetation zones, agricultural interfaces, and varying slope and embankment conditions along the Burhi Gandak riverfront

Figure 42 : Key sections along the Burhi Gandak



Section AA'



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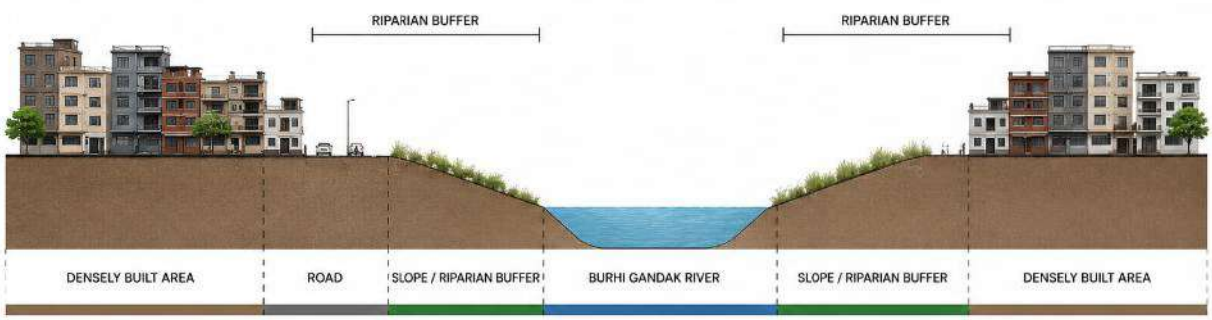

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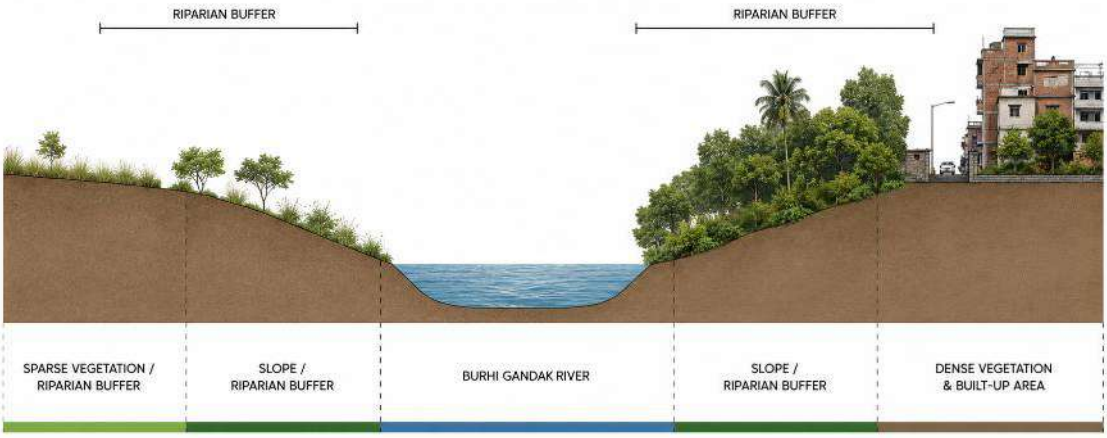

RIPARIAN BUFFER
RIPARIAN BUFFER
SPARSE VEGETATION / RIPARIAN BUFFER
SLOPE / RIPARIAN BUFFER
BURHI GANDAK RIVER
SLOPE / RIPARIAN BUFFER
DENSE VEGETATION & BUILT-UP AREA

4.4.3 Interventions- Objective 4

Intervention 4.1: Riparian Buffer Restoration- 4.3 km of riverfront stretch

Case Study: Sabarmati River Riparian Plantation and Ecological Buffer Restoration, Ahmedabad

A relevant example of layered riparian restoration can be observed along selected ecological stretches of the Sabarmati River in Ahmedabad, where riverbank stabilisation and biodiversity enhancement measures were integrated with flood management and landscape restoration initiatives. While the central riverfront is highly engineered, peripheral stretches and restoration zones incorporated multi-layered native plantation strategies to improve ecological performance and reduce erosion along river edges.

The restoration approach adopted a gradient-based planting system similar to the proposed Burhi Gandak riparian strategy. Lower riparian zones incorporated aquatic and wetland vegetation for filtration and water retention, while mid-slope grass layers using species such as Vetiver were used for slope stabilisation and erosion control. Upper banks included shrubs and native tree species to improve biodiversity, create shaded microclimates, and strengthen long-term bank stability.

The project demonstrated the role of layered riparian vegetation in:

- Reducing soil erosion and bank degradation
- Improving stormwater filtration and runoff quality
- Enhancing urban biodiversity and habitat connectivity
- Increasing flood resilience through soft-edge stabilisation
- Creating climate-responsive riverfront landscapes

The Ahmedabad experience highlights how ecological restoration can function alongside urban river management by combining hydrological performance with biodiversity enhancement and public landscape improvement. The approach is relevant to Muzaffarpur, particularly along stretches of the Burhi Gandak where fragmented riparian buffers, erosion-prone edges, and urban encroachments require low-impact, nature-based restoration strategies.

(Source: Sabarmati Riverfront Development Corporation Ltd. (SRFDCL). Environmental and Landscape Management Initiatives.)

To establish a continuous and ecologically functional riparian buffer along the Burhi Gandak River through native vegetation restoration, erosion control, habitat enhancement, and flood-resilient landscape management. This proposal focuses on restoring degraded river edges and strengthening the ecological function of the floodplain through nature-based interventions and policy-led protection measures.

Key Policy Measures

- Notification and demarcation of Riparian Buffer Zones under municipal and WRD frameworks
- Restriction of permanent construction within the buffer zone
- Regulation of hard embankments and edge modifications
- Integration of riparian buffer guidelines into Master Plan and DPRs
- Protection of natural drainage channels and erosion-prone stretches

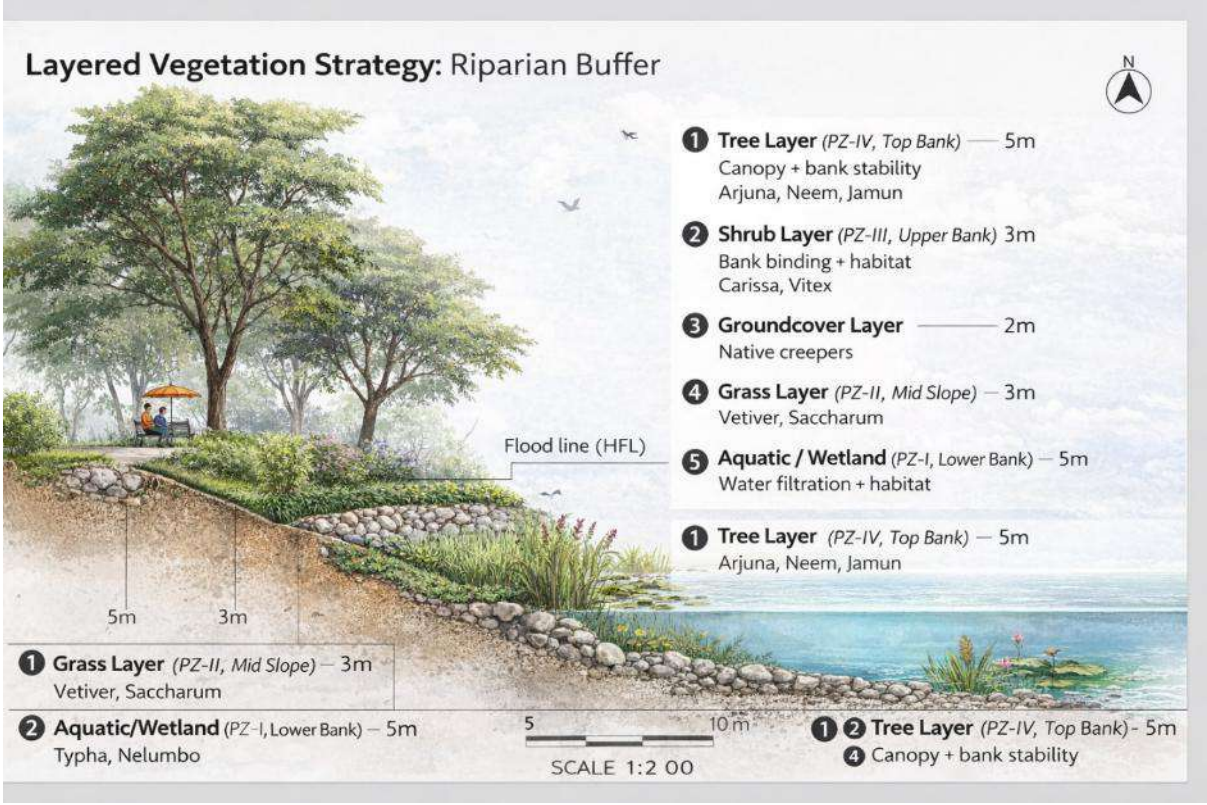
Ecological Restoration Strategy

The riparian edge is designed as a **multi-layered ecological gradient**, transitioning from aquatic to terrestrial zones. At the **lowest edge (PZ-I)**, emergent and floating species such as *Typha* and *Lotus* act as **biofilters**, improving water quality and supporting aquatic biodiversity. Moving upward, the **grass layer (PZ-II)** comprising *Vetiver* and *Saccharum* stabilises slopes and reduces erosion during flood fluctuations.

The **shrub layer (PZ-III)**, including *Carissa* and *Vitex*, strengthens the bank while creating **microhabitats for fauna**. Above this, the **tree layer (PZ-IV)** with species like *Arjuna*, *Neem*, and *Jamun* provides **canopy cover, temperature regulation, and long-term bank stability**. Groundcover vegetation is integrated across upper zones to ensure **soil protection and moisture retention**.

This layered system ensures that the riparian buffer functions as a **hydrological filter, biodiversity corridor, and climate-responsive landscape**, while remaining adaptable to seasonal flooding. A detailed list of species, Fauna-habitat matrix, restoration strategy and KPIs is given in Annexure.

- **Aquatic Layer (Lower Bank):** Typha, Lotus for filtration and aquatic habitat
- **Grass Layer (Mid-Slope):** Vetiver, Saccharum for slope stabilisation and erosion reduction
- **Shrub Layer (Upper Bank):** Carissa, Vitex for habitat creation and bank strengthening
- **Tree Layer (Top Bank):** Arjuna, Neem, Jamun for canopy cover, microclimate regulation, and long-term bank stability.



Spatial Interventions

- Riparian plantation using native species
- Removal of invasive vegetation (Prosopis, Lantana, etc.)
- Bio-swales and seasonal wetland pockets for runoff filtration
- Soft-edge bank stabilisation using vegetative techniques
- Restoration of ecological connectivity along fragmented river edges

Phasing Strategy

Phase	Focus
Short-term (0–1 yr)	Buffer demarcation, invasive species removal, pilot plantation
Medium-term (1–3 yr)	Riparian vegetation establishment, bank stabilisation
Long-term (3–5 yr)	Habitat maturation, ecological monitoring, adaptive management

Institutional Framework

Function	Nodal Agency	Key Role
Buffer demarcation & regulation	WRD + District Administration	Flood line and land regulation
Ecological restoration	Forest Dept. / Horticulture Dept.	Species selection and plantation
Monitoring & compliance	BSPCB	Environmental monitoring
Community stewardship	NGOs / SHGs / Ward Committees	Awareness and maintenance

Funding Sources

- Namami Gange
- State River Conservation Schemes
- CAMPA / Forest Department schemes
- 15th Finance Commission grants

Intervention 4.2: Riverfront Linear Parks and Public Interface Development

To develop low-impact public open spaces and ecological linear parks along selected urban stretches of the Burhi Gandak River while maintaining flood compatibility and river sensitivity. The proposal focuses on improving public access to the river through soft landscape interventions rather than intensive riverfront development. Priority stretches include urban edges near ghats and accessible public zones such as Sidhi Ghat and Mukti Dham.

Key Planning Measures

- Development of controlled-access public spaces along designated stretches
- Promotion of flood-compatible landscape planning
- Restriction of heavy permanent structures within flood-prone areas
- Integration of public spaces with ecological restoration measures

Linear Park Components

- Permeable walking trails (non-RCC pathways)
- Native shaded seating zones
- Interpretation signage on biodiversity and flood awareness
- Controlled access ghat interfaces
- Open green spaces and passive recreation areas
- River viewing decks using eco-sensitive materials

Urban Design Strategy

The linear parks are designed as “soft-access” public interfaces that maintain hydrological permeability and minimise disturbance to the river ecosystem. The proposal avoids continuous

concretised promenades and instead promotes landscape-based public spaces integrated with vegetation and seasonal flood behaviour.

Implementation Strategy

Pilot-based development at selected stretches
Integration with ward-level open space planning
Partnerships with local communities and citizen groups
Annual plantation and stewardship drives

Institutional Framework

Function	Nodal Agency	Key Role
Planning & implementation	Muzaffarpur Municipal Corporation	DPR preparation and execution
Landscape development	Horticulture Dept.	Planting and maintenance
Community engagement	NGOs / SHGs / Ward Committees	Stewardship and awareness
Funding convergence	District Administration	Scheme integration

Funding Sources

Component	Funding Source
Linear parks	AMRUT 2.0 / Municipal Budget
Public amenities	CSR / 15th Finance Commission
Plantation & landscape	CAMPA / Forest schemes
O&M	Municipal + community-based models

4.5 Objective 5 & 6: Increased Reuse of Treated Used Water & Maximum Good Quality Return Flow

Objective 5 *aims to reduce dependency on freshwater withdrawals and ease stress on rivers by maximising reuse of treated wastewater. The wastewater treated must conform to the quality standards prescribed by CPCB for that stretch of the river flowing through the city*

Objective 6 *promotes the city's responsibility to contribute to maintaining environmental flow in the river. Return flows must be proportional to withdrawals and treated to meet quality standards before release. Key actions include assessing urban drains, balancing reuse with discharge, and ensuring that stormwater and wastewater outfalls enhance rather than degrade river health.*

4.5.1 Existing Status of Wastewater Reuse

Muzaffarpur currently has no operational system for treated wastewater reuse and remains in a transitional stage, with infrastructure under development but not yet functional.

- 22.5 MLD (Musahari) and 2.5 MLD (Narayanpur) STPs are under construction (~80% complete)
- 16 MLD STP is proposed under AMRUT
- The sewerage network is not yet fully connected
- No FSTPs are present

As a result, no treated wastewater is generated or reused, and most wastewater flows untreated through drains such as Chandwara Nallah and the Sikanderpur system into the Burhi Gandak and Furdoo Rivers. Projected wastewater generation by 2030 is ~57 MLD, while planned capacity (41 MLD) leaves a ~16 MLD deficit, indicating continued untreated discharge if gaps persist.

Policy and Regulatory Context

While city-level reuse policies are absent, national and state frameworks provide direction:

- National guidelines mandate 50% reuse of treated wastewater
- Bihar Low Carbon Action Plan promotes reuse in agriculture and landscaping
- CPCB standards (BOD ≤ 30 mg/L, TSS ≤ 100 mg/L) define reuse quality

However, these remain unimplemented due to a lack of operational systems.

Reuse Potential and Demand Context

Muzaffarpur has strong potential for reuse, supported by its land-use pattern:

- Peri-urban agricultural lands along the Burhi Gandak floodplain
- Urban parks and green spaces (Jubba Sahani Park, Sikanderpur Lake)
- Construction demand in transit corridors
- Waterbody recharge and replenishment
- Large open and agricultural areas near the river provide immediate reuse opportunities, but require infrastructure, stakeholder acceptance, and water quality assurance.

Key Issues

- No operational treatment or reuse system
- Incomplete sewerage network
- Treatment capacity deficit (~16 MLD)
- Direct discharge of untreated wastewater into drains and rivers
- Absence of reuse infrastructure and distribution systems
- Lack of institutional and policy framework

- Limited awareness and acceptance
- No monitoring of treated water quality

4.5.2 Existing Status of Maximum Good Quality Return Flow

Muzaffarpur's hydrology is defined by the Burhi Gandak River, floodplains, and a network of natural and man-made drains, including:

- Brahmapura Nallah
- Sikandarpur–Khabra Nallah
- Pandai/Tilave system
- Chandwara Nallah (major pollution source)

These drains discharge untreated wastewater into the river, forming the primary pollution pathway.

Water Quality Status

The Burhi Gandak River shows high organic pollution and ecological stress:

- Elevated BOD and COD from untreated wastewater
- Low DO levels, especially during lean flow
- Pollution hotspots near drain outfalls and dense settlements
- Seasonal deterioration during non-monsoon periods

This confirms that drain discharge and sanitation gaps are the primary drivers of river pollution.

Groundwater and Waterbody Linkages

Muzaffarpur's urban hydrological system is strongly dependent on groundwater, with the city relying almost entirely on aquifers for domestic and municipal water supply. The seasonal groundwater maps (*Map 25: Pre-Monsoon Groundwater Levels* and *Map 26: Post-Monsoon Groundwater Levels*) indicate that groundwater levels remain relatively shallow across much of the planning area, particularly near the Burhi Gandak River, Sikandarpur Lake, urban ponds, and floodplain zones that function as important natural recharge systems.

During the pre-monsoon period, groundwater levels within the municipal area are generally observed in the range of **5–6 mbgl**, reflecting intensive extraction and reduced recharge conditions. Post-monsoon levels rise significantly to nearly **1.4–3 mbgl** in several parts of the city due to rainfall infiltration, floodplain interaction, and recharge from connected water bodies. This seasonal fluctuation highlights the importance of preserving natural recharge systems for maintaining groundwater availability and supporting return flows within the urban water cycle.
However, the quality and sustainability of these recharge systems are increasingly under stress due to rapid urbanisation, encroachment on ponds and wetlands, discharge of untreated wastewater into drains and water bodies, and the loss of permeable surfaces. Key recharge features such as **Sikandarpur Lake, floodplain areas, and urban ponds** are gradually losing their hydrological function because of siltation, pollution, and fragmented integration with the drainage network.

The maps further indicate that areas with shallow groundwater levels correspond closely with low-lying floodplain and wetland systems, reinforcing their role in groundwater recharge and maintaining environmental flows. Protecting and restoring these water bodies and floodplain corridors is therefore essential not only for groundwater sustainability but also for improving the quality of urban return flows entering the Burhi Gandak River system.

Flooding and Hydrological Stress

Muzaffarpur experiences recurrent urban flooding and waterlogging due to its predominantly flat alluvial terrain, low surface gradients, and location within the Burhi Gandak floodplain system (*Map 27: Geomorphology Map*). The geomorphology map indicates that large parts of the city fall within older floodplain zones, while the active floodplain is concentrated along the northern river corridor adjacent to the Burhi Gandak River. These floodplain landscapes naturally retain water during high rainfall and river overflow events, increasing the susceptibility of nearby urban areas to inundation. The identified waterlogging hotspots (*Map 28: Waterlogged Area*) are concentrated within the dense urban core near the DM Office and central market areas, where inadequate drain capacity, encroachment on natural drainage paths, and high built-up density restrict stormwater movement. Frequent flooding is also observed along the railway corridor, where railway embankments and limited cross-drainage openings obstruct the natural east–west flow of stormwater, creating localised ponding during monsoon periods.

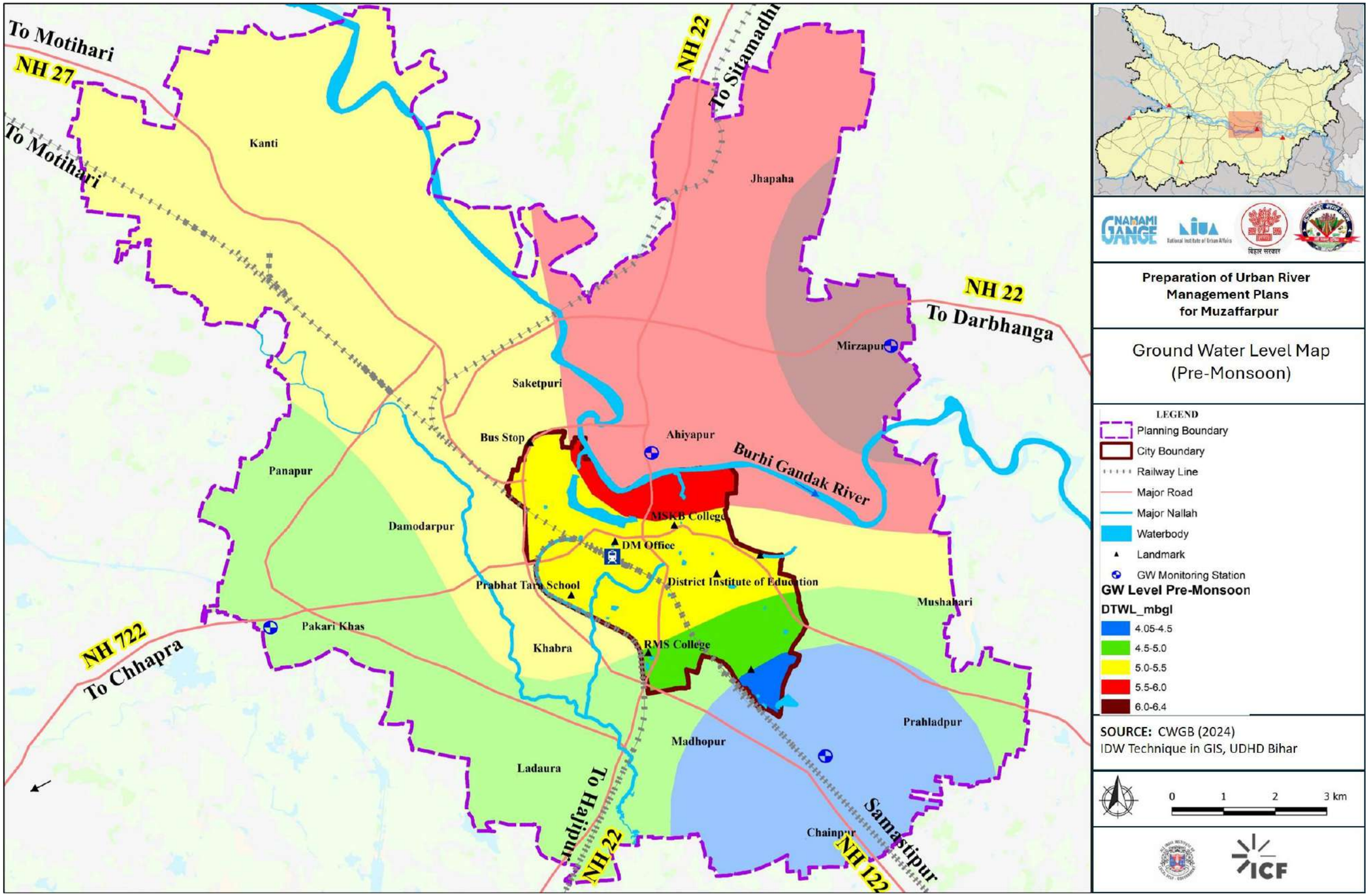
The pattern of inundation closely corresponds with the city's floodplain geomorphology. Areas located within or adjacent to the active and older floodplain zones experience prolonged water retention due to their low elevation, shallow groundwater table, and reduced natural drainage gradients. During peak monsoon conditions, backflow from the Burhi Gandak and surcharge in major nallahs result in temporary flooding of floodplain edges and low-lying urban pockets. The loss of wetlands, natural depressions, and floodplain storage areas due to urbanisation has further reduced the city's capacity to absorb and gradually release stormwater.

Many drains remain silted, discontinuous, or hydraulically undersized, while natural retention areas have been encroached upon or disconnected from the drainage network. The city currently lacks fixed dewatering or pumping stations, resulting in delayed flood recession and recurring inundation in vulnerable neighbourhoods during the monsoon season.

Key Issues

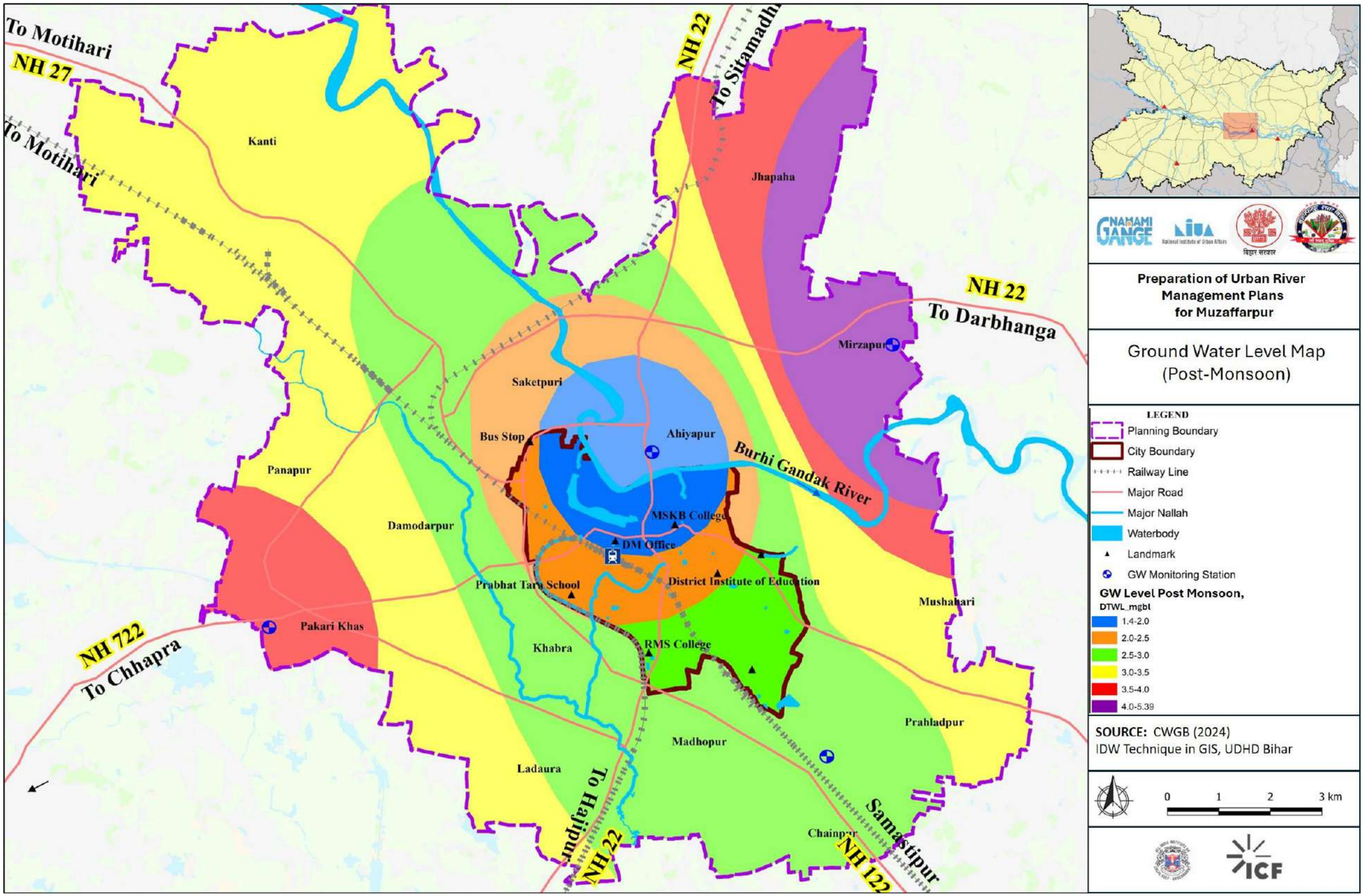
- Untreated wastewater discharge through drains
- Under-capacity and fragmented drainage network
- Pollution hotspots at major outfalls (e.g., Chandwara Nallah)
- Lack of interception and treatment systems
- Encroachment and degradation of waterbodies and floodplains
- Declining groundwater recharge
- Recurrent urban flooding
- Absence of integrated monitoring and management systems
- Weak linkage between riverfront development and ecological systems

Map 23 : Ground water levels (pre-monsoon)



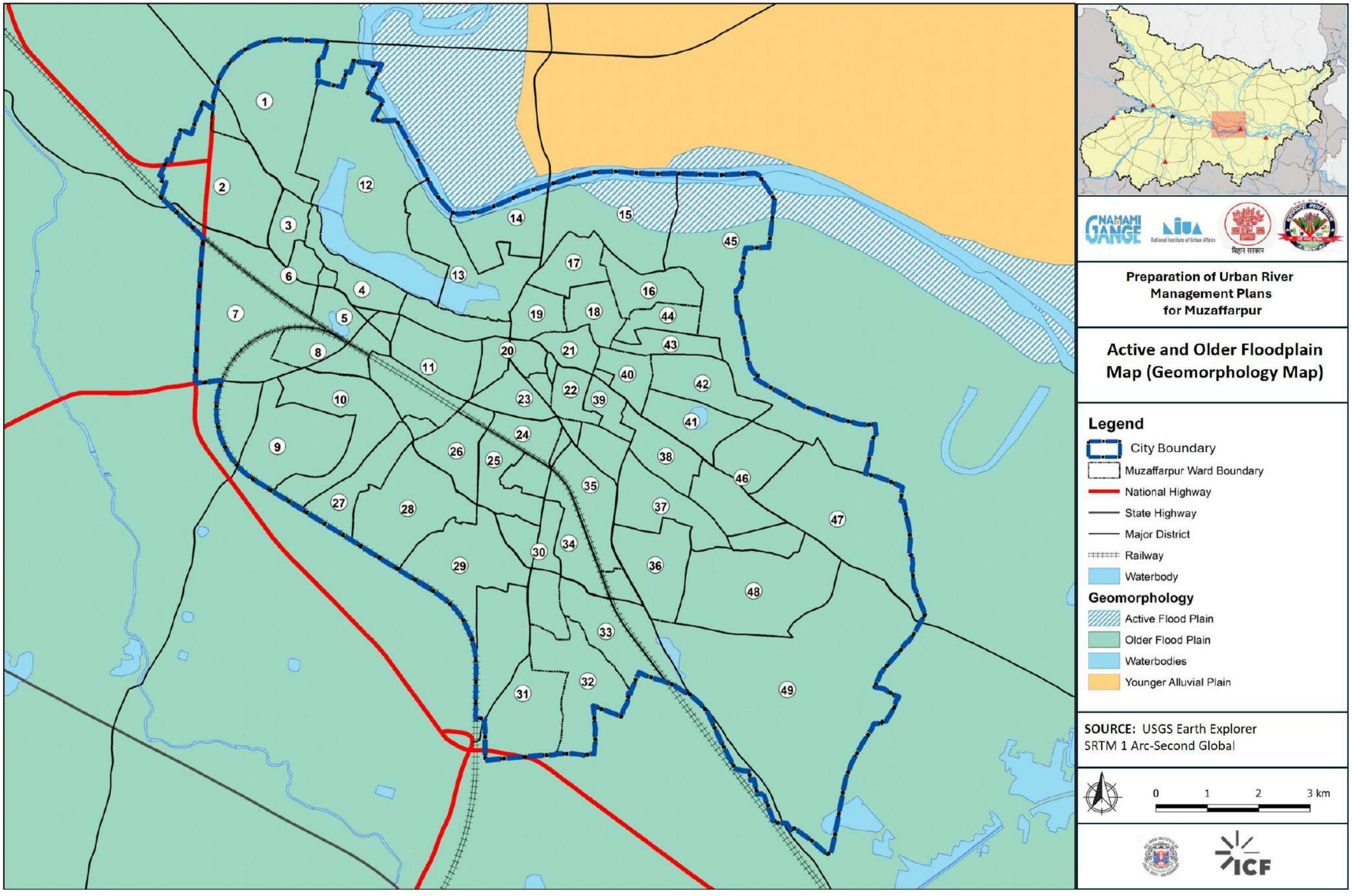
Source: CWGB (2024), IDW Technique in GIS, UDHD Bihar

Map 24: Groundwater levels (post monsoon)



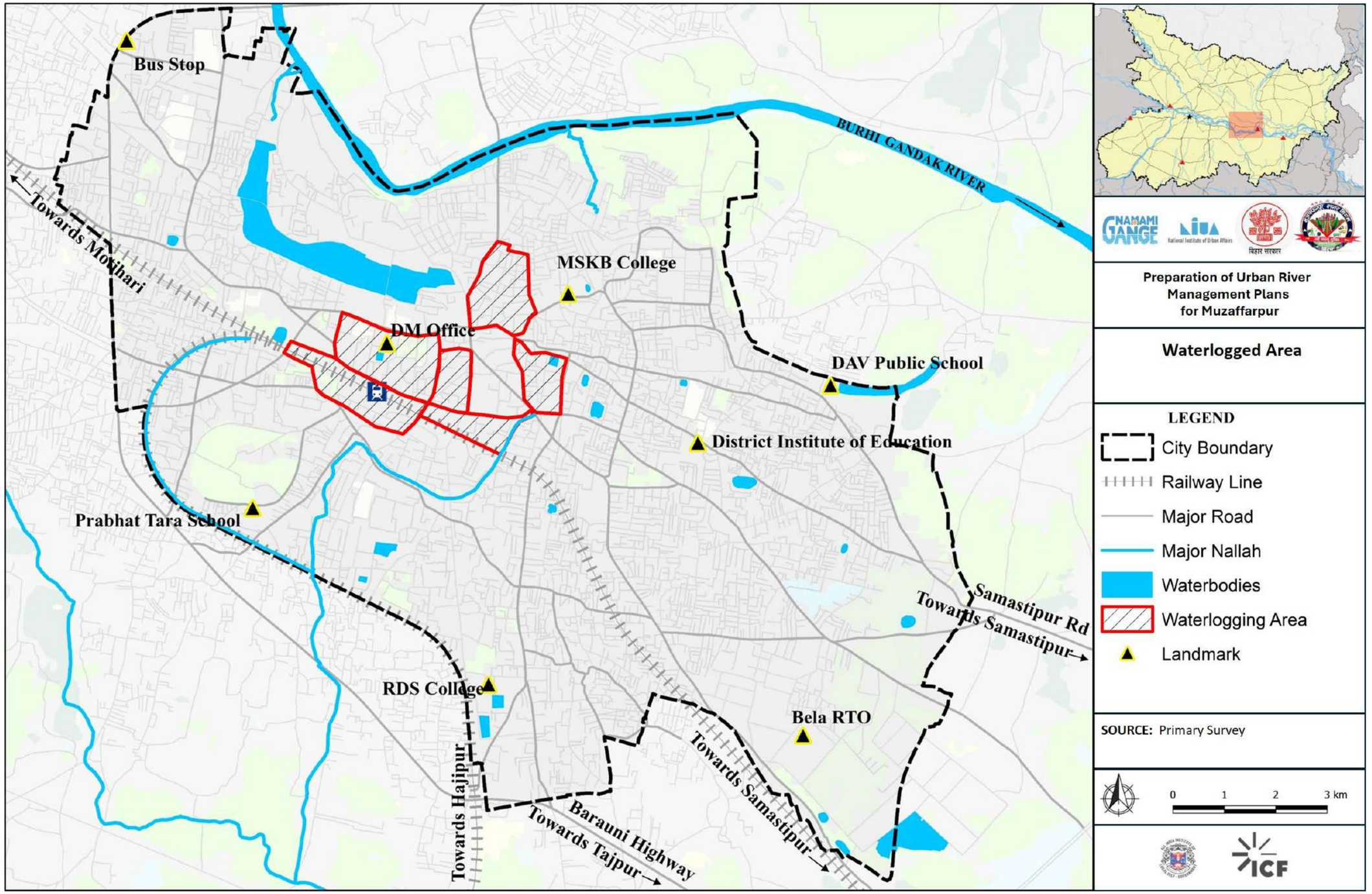
Source: CWGB (2024), IDW Technique in GIS, UDHD Bihar

Map 25 : Geomorphology map- Muzaffarpur city



Source: USGS Earth Exploreer, SRTM 1 Arc-second Global

Map 26 : Water logged areas in the city



Source: Primary Survey

4.5.3 URMP Score

As per URMP, if as there 0% reuse of water, **Increased Reuse of Treated Used Water score for Muzaffarpur is 1**.
And for **Maximum Good quality Return flow the score cannot be calculated** at the moment as the city does not have any commited return flow for the city.

4.5.4 Interventions

Muzaffarpur currently faces a significant gap between wastewater generation and treatment, with most sewage flowing untreated through major drains such as Chandwara Nallah and the Sikanderpur system into the Burhi Gandak River. Given that the sewerage network is yet to be fully operational and the treatment infrastructure is still under development, a phased and adaptive approach is required to address pollution while building long-term reuse capacity.

The proposed strategy focuses on **interception, decentralised treatment, and gradual integration with upcoming STPs**, ensuring early reduction in pollutant loads while establishing a framework for treated wastewater reuse. Simultaneously, a **city-level monitoring and reporting system** is essential to track river health, guide decision-making, and improve accountability.

Intervention 5.1 Preparation of a City-Level Treated Wastewater Reuse Strategy for Muzaffarpur

Muzaffarpur currently lacks an operational wastewater reuse system due to the absence of functional treatment infrastructure. However, with the proposed STPs at Manika Man, Furdoo Nallah, and Tirhut Canal under the BUIDCo sewerage and I&D project, the city has an opportunity to establish a **direct treated wastewater reuse network** linked to urban landscape restoration, industrial demand centres, and peri-urban irrigation zones.
This intervention proposes the development of **dedicated tertiary-treated reuse infrastructure** at selected STPs, including:

- Tertiary treatment and chlorination units
- Reuse storage reservoirs
- Pumping stations and distribution pipelines
- Dual-use irrigation outlets for parks and plantations
- Metered non-potable supply connections for industries and construction activities

Priority implementation zones identified for direct reuse include:

- **Linear parks and riparian buffer restoration stretches** along the Burhi Gandak near Akharaghat, Bandh Road, and Siddhi Ghat
- **Urban green spaces and public landscapes** such as Jubba Sahni Park and the Sikandarpur Lake precinct
- **Peri-urban agricultural belts** along the eastern floodplain edge for seasonal irrigation reuse
- **Industrial areas in southern and south-eastern Muzaffarpur**, where treated wastewater can substitute groundwater for non-potable industrial applications

The intervention includes the preparation of a phased reuse pipeline network connecting nearby STPs to identified demand clusters. Initial pilot reuse systems can be implemented near the Manika Man and Furdoo STPs, where large landscape and irrigation demand exists within feasible conveyance distance.

A similar approach has been implemented under the **Sabarmati Riverfront Development Project, Ahmedabad**, where treated wastewater is reused for maintaining public landscapes and riverfront plantations, reducing freshwater demand. Cities such as **Nagpur** have also operationalised treated wastewater supply for industrial reuse through dedicated conveyance infrastructure and reuse agreements.

By creating physical reuse infrastructure and identifying end-use networks, this intervention directly supports groundwater conservation, reduces freshwater dependency, minimises untreated discharge into the Burhi Gandak, and advances a circular urban water management framework for Muzaffarpur.

Table 54 Intervention Details

Intervention	Responsible Agency	Intervention Type	Estimated Budget	Potential Funding Sources	Timeline
Preparation of City-Level Treated Wastewater Reuse Strategy	BUIDCo (Lead), MMC, PHED	Policy / Planning	INR 60 lakh	NMCG, AMRUT 2.0, State Plans	Long-term (5–10 years)

Intervention 5.2 River Health and Water Bodies Monitoring and Public Reporting System

At present, water quality monitoring in Muzaffarpur is fragmented and largely confined to regulatory functions, with limited integration into urban planning and public decision-making. This intervention proposes the establishment of a **GIS-enabled river and urban waterbody monitoring system** combining both **manual sampling** and **selective real-time sensor-based monitoring** at critical pollution locations.

The proposed system will monitor the Burhi Gandak River, major drains, and priority urban water bodies through a network of approximately **10 monitoring stations**, including:

- 3 river monitoring stations along the Burhi Gandak:
    - Upstream (near NH-22 bridge entry point)
    - Midstream (Akharaghat/Bandh Road stretch)
    - Downstream (towards eastern municipal edge)
- 4 drain outfall monitoring locations at major pollution entry points including Chandwara Nallah, Furdoo Nallah, and key outfalls discharging into the river
- 3 urban waterbody stations, including Sikandarpur Lake, Kanhauli Man wetland, and one major urban pond within the municipal area

The intervention proposes:

- Manual monthly water quality sampling at all stations
- Real-time sensor-based monitoring units at high-impact locations such as major river outfalls and polluted drains
- Integration of monitoring data into a GIS dashboard and Urban Water Information System for public disclosure and planning support

The monitoring framework will adopt standardised parameters including **pH, BOD, COD, DO, TSS, and coliform levels**, aligned with CPCB and BSPCB standards. The system will support pollution

hotspot identification, intervention prioritisation, and periodic "River Health Report Cards" for public transparency and institutional accountability.

Table 55 Intervention Details

Component	Description	Estimated Cost (INR Lakhs)
Manual Water Quality Monitoring Equipment	Portable kits for pH, DO, BOD, COD, TSS testing, sampling bottles, GPS-enabled field survey equipment	6
Real-Time Monitoring Stations	Installation of 3 sensor-based monitoring stations at major river/drain outfalls with telemetry and data transmission	15
Laboratory Testing & Baseline Sampling	Initial laboratory analysis for river, drain, and waterbody monitoring (including coliform testing)	5
GIS Dashboard & Public Reporting Platform	Development of GIS-enabled monitoring dashboard, database integration, public portal, and visualisation tools	8
Field Surveys & Mapping	Mapping of drains, outfalls, monitoring points, and periodic field verification	3
Data Management & Technical Support	Data processing, analytics, report preparation, and technical consultancy support	4
Awareness & Public Disclosure	River Health Report Cards, citizen outreach material, workshops, and public display systems	2
Annual O&M Provision (1 year)	Sensor maintenance, calibration, field sampling, data hosting, and operational expenses	7
Total Estimated Cost		INR 50 Lakhs

Source of Costing: Indicative costing derived from CPCB river monitoring systems, Smart City environmental monitoring dashboards, AMRUT urban water quality programmes, and Namami Gange river monitoring projects.

4.6 Objective 7 & 8: Eco-Friendly Riverfront Projects Leveraging Economic Potential of River

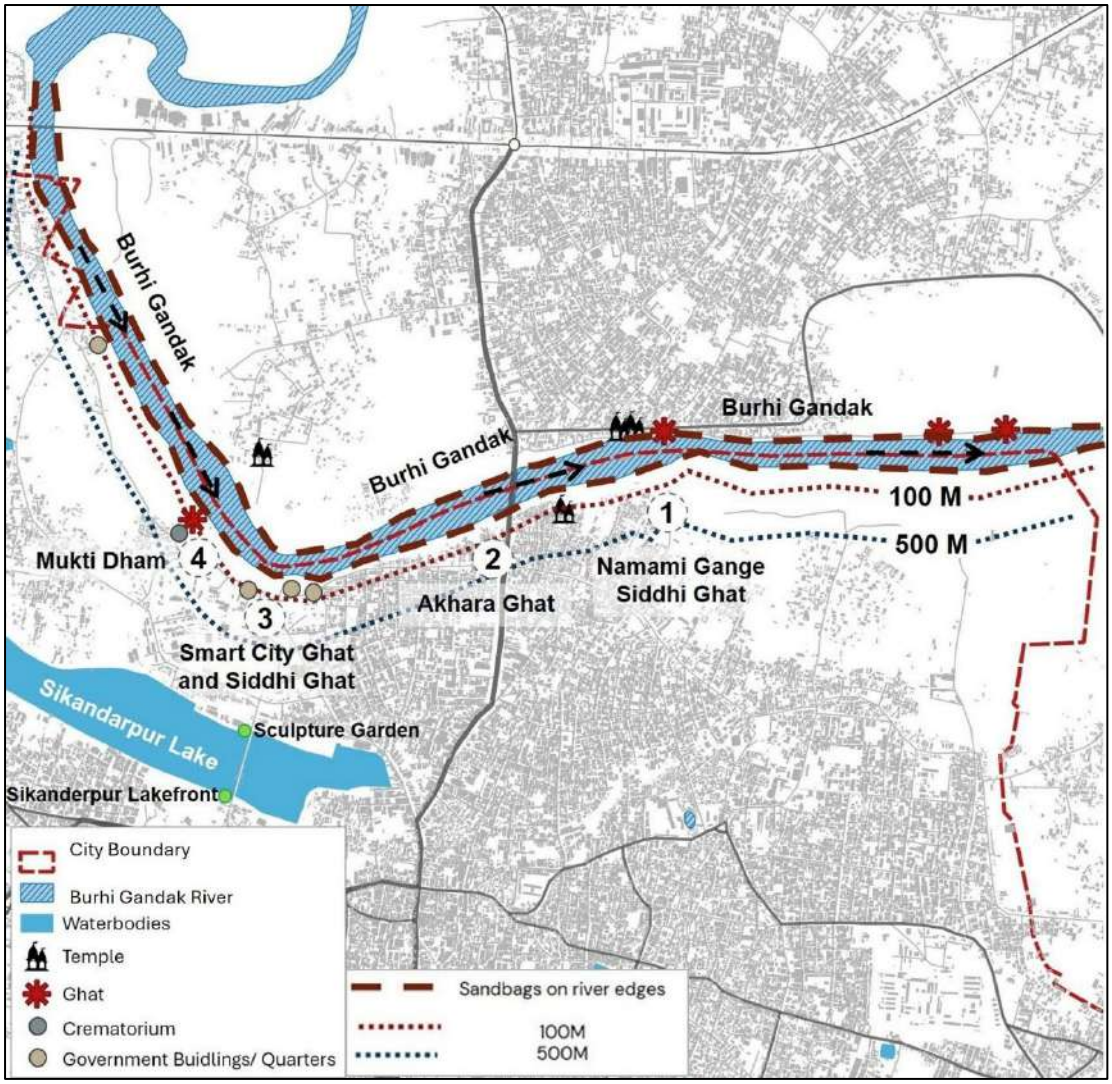
Objective 7 *- Eco-friendly riverfronts reconnect citizens with rivers while promoting recreation, culture, and sustainable tourism. Objective 7 encourages the development of people-centric spaces without compromising ecological integrity. The emphasis is on smaller, scalable interventions that improve aesthetics, enhance access, and stimulate local economies.*

Objective 8 *focuses on assessing and promoting sustainable river-linked economic activities while ensuring that interventions respect the carrying capacity of the ecosystem. It highlights the potential of rivers as economic assets that can drive inclusive urban growth.*

4.6.1 Existing Condition of Riverfront

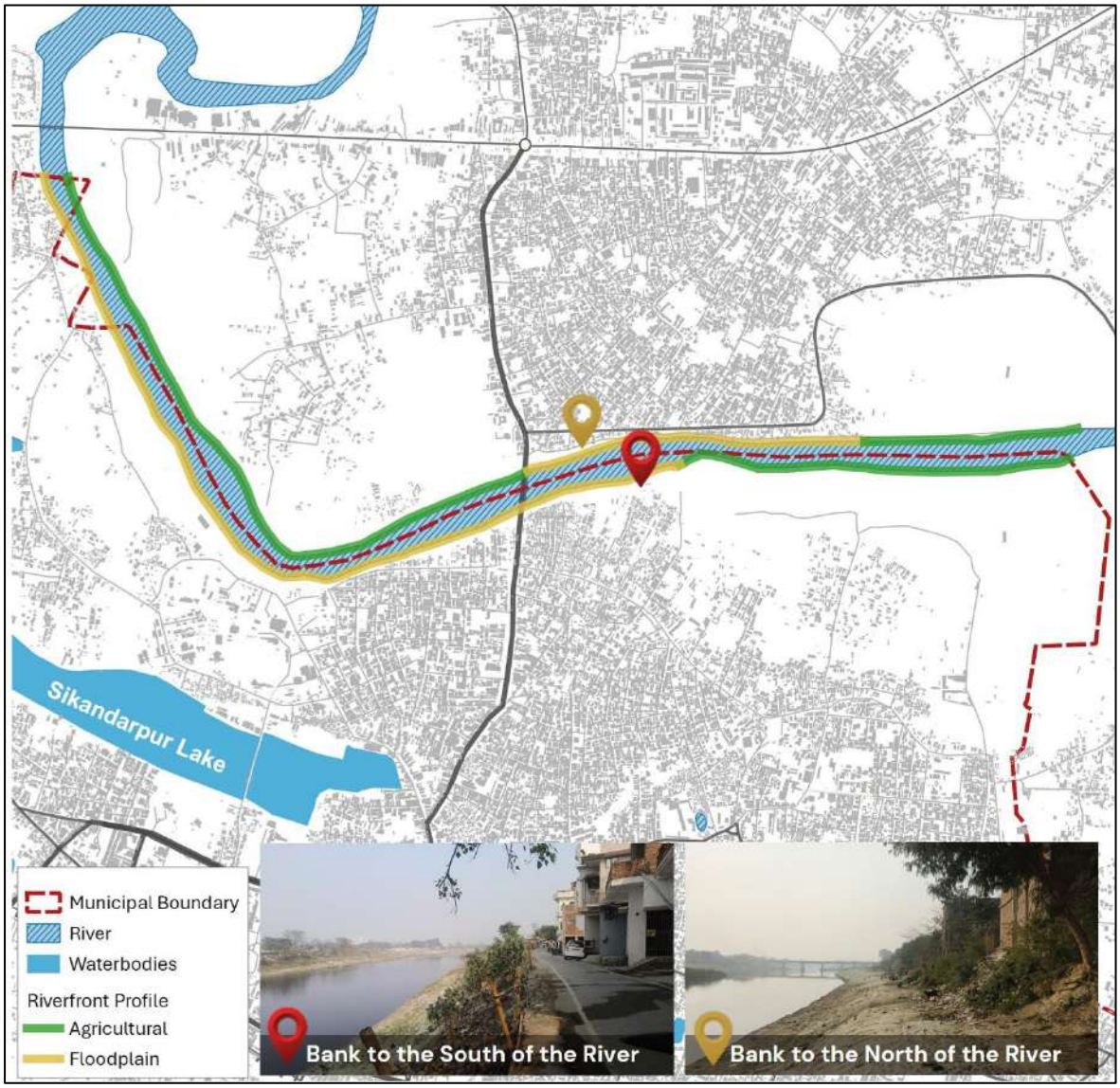
The riverfront within the municipal boundary extends approximately 8.6 km (both banks), with the southern bank forming the primary urban interface and the northern bank largely comprising agricultural and floodplain areas. The river exhibits a dynamic morphology, flowing east to west before curving northward, with wide sandy stretches and seasonal floodplains.

Map 27 : Riverfront ghats and key activities



Source: Primary Survey

Figure 43 : Riverfront profiling



Source: Primary Survey

Currently, the riverfront is partially developed with isolated engineered ghats, while large stretches remain unstructured and ecologically degraded. The banks are predominantly stabilised using temporary sandbag embankments, indicating a lack of permanent, ecologically sensitive edge treatment. The riparian buffer is fragmented, with limited native vegetation and increasing anthropogenic pressure.

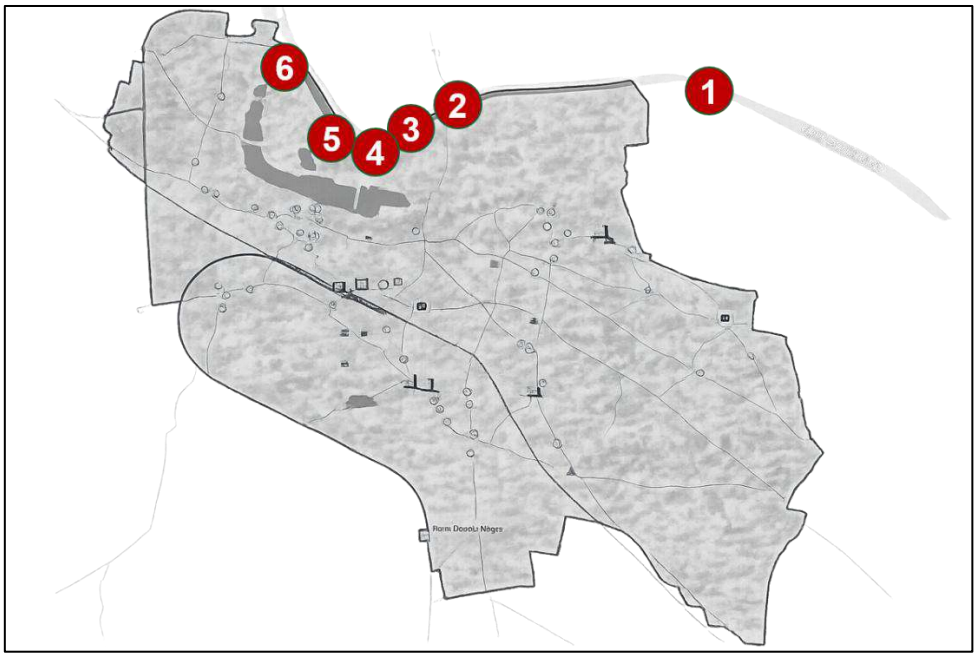
The southern bank is characterised by dense urban settlements, cultural nodes, and religious ghats, whereas the northern bank functions as a natural buffer with relatively low urbanisation. However, across both banks, the river system is impacted by untreated wastewater discharge, solid waste dumping, and poor accessibility, limiting its ecological and social potential.

Key Issues for Eco-Friendly Riverfront Development

- Fragmented Ecological Buffer: Discontinuous riparian zones with minimal native vegetation reduce flood absorption, filtration, and habitat functions.
- Unregulated Edge Development: Absence of notified buffer regulations has led to encroachments, ad-hoc construction, and narrowing of floodplains.

- Hardscape Cultural Interfaces: Concretised ghats and access points disrupt natural river–land interaction and increase surface runoff.
- Poor Water Quality & Pollution Load: Untreated nallah discharge and solid waste accumulation degrade water quality with no treatment systems in place.
- Unsustainable Bank Stabilisation: Reliance on temporary sandbag embankments fails to address long-term erosion and flood dynamics.
- Limited Accessibility & Public Interface: Unplanned and encroached access routes limit safe, inclusive, and eco-sensitive engagement with the river.
- Underutilised Northern Floodplain: The northern bank remains an unstructured ecological asset without a defined conservation or restoration strategy.
- Lack of Integrated Governance: Fragmented institutional roles result in the absence of a coordinated riverfront management framework.

Figure 44 Riverfront Activities



1. Chandwara Bridge

2. Akhara Ghat Bridge

3. Namami Gange Sidhi Ghat

4. Smart City Ghat

5. Mukti Dham and Crematorium

6. Agricultural Land

Source: Primary Survey

4.6.2 Existing Condition of Economic Potential of the River

The riverfront of Muzaffarpur presents a fragmented and largely informal interface, shaped by a mix of cultural, residential, and agricultural uses. While select stretches on the southern bank are developed with isolated ghats, the overall edge lacks continuity, ecological planning, and integrated public infrastructure. The river economy is predominantly unregulated, with activities such as dhobi ghats, vending, and ritual use operating without adequate wastewater or solid waste management systems. Untreated nallah outfalls and visible waste accumulation further degrade water quality. Accessibility to the river remains limited and unstructured, often through encroached or poorly maintained pathways. In contrast, the northern bank retains floodplain and agricultural characteristics, but remains underutilised and lacks a defined ecological or recreational framework. Overall, the riverfront reflects high cultural significance but low environmental performance and weak institutional governance, limiting its potential as a sustainable urban asset.

River Economy – Key Issues

- Informal & Unregulated Economy: River-based activities operate without formal systems, resulting in weak revenue capture.
- Limited Amenities at Ghats: Ghats lack integrated design and facilities beyond ritual use.
- Unmanaged Dhobi & Vendor Activities: Absence of wastewater and solid waste systems leads to direct pollution.
- Lack of Governance Framework: No structured system for licensing, fee collection, or footfall management.
- Underutilised Economic Potential: High festival footfall is not leveraged for sustainable revenue generation.

4.6.3 URMP Score

As per the URMP framework, If **Eco-friendly Riverfront Point = 40 – 59 the score is 3** which is an average score. And under the objective for **Leveraging the Economic Potential of the river the city scores a very good score of 5**.

4.6.4 Interventions

Intervention 7.1: Eco-sensitive Ghat Redevelopment & Public River Access Improvement

This intervention focuses specifically on retrofitting and upgrading existing ghats along the Burhi Gandak into safe, inclusive, and multifunctional public spaces while preserving their cultural and religious significance. Unlike conventional concrete-heavy riverfront projects, the proposal promotes eco-sensitive and flood-compatible ghat development integrated with public amenities, green buffers, and waste management systems.

The intervention builds upon the DPR-proposed access infrastructure and pathways while improving the environmental quality, accessibility, and functionality of existing ghats such as Akharaghat, Siddhi Ghat, Mukti Dham Ghat, and Smart City Ghat.

Key Interventions

- Retrofitting existing ghats with eco-sensitive materials
- Integration of shaded seating, green buffers, and permeable surfaces
- Universal accessibility improvements (ramps, safe steps, handrails)
- Solid waste and wastewater management systems near ghats
- Controlled vending and activity zones
- Lighting, signage, and public safety infrastructure
- Designated ritual, boating, and cultural activity spaces

Table 56 Functional Transformation Strategy

Existing Condition	Proposed Transformation
Ritual-only use	Multi-functional public space
Hard concrete edges	Green-integrated interfaces
Lack of amenities	Toilets, bins, lighting, seating
Poor accessibility	Inclusive and universal access
Unregulated activities	Managed public-use zones

River Economy Integration

The intervention also supports sustainable river-based livelihoods through:

- Formalised boating zones
- Seasonal cultural markets and vending areas
- Festival-linked activity spaces
- User-based maintenance and revenue systems

Expected Outcomes

- Improved public access and safety along ghats
- Reduced pollution and unmanaged waste disposal into the river
- Enhanced cultural and recreational value of the riverfront

- Better integration between ecological restoration and public use
- Strengthened river-based local economy and tourism potential

Implementation Framework

- **Lead Agencies:** MMC, WRD, PHED
  Supporting Agencies: Tourism Department, BSPCB, NGOs/SHGs
  Funding Sources: SBM, AMRUT 2.0, Namami Gange, CSR, Municipal Fund

Table 57 Capital Cost Estimate (CAPEX) – Eco-sensitive Ghat Redevelopment & Public River Access Improvement

Component	Description	Estimated Cost (₹ Crore)	Cost Basis / Source
Ghat Retrofitting & Step Improvement	Repair of steps, eco-sensitive surfacing, flood-compatible edge treatment	1.50 – 2.00	Based on SBM-U 2.0 public sanitation infrastructure costs and comparable riverfront ghat upgradation projects under Namami Gange
Universal Accessibility Infrastructure	Ramps, handrails, tactile paving, safety railings, accessible pathways	0.60 – 0.80	CPWD Schedule of Rates (SOR) 2024 and Harmonised Guidelines for Universal Accessibility
Green Buffers & Landscape Development	Native plantation, shaded seating areas, permeable paving, soft landscaping	0.80 – 1.00	AMRUT landscape development benchmarks and State Horticulture Department plantation costs
Public Amenities	Toilets, drinking water kiosks, seating, changing rooms, bins, signage	0.90 – 1.20	SBM-U 2.0 sanitation unit costs and Smart City public amenity benchmarks
Lighting & Safety Infrastructure	Street lighting, CCTV, signage, emergency access infrastructure	0.70 – 0.90	Bihar Urban Infrastructure Development Corporation (BUIDCo) urban streetscape estimates
Waste & Wastewater Management	Solid waste collection points, drain screens, wastewater interception near ghats	0.80 – 1.00	CPCB/Namami Gange indicative costs for riverfront pollution management systems
Boating & Activity Zones	Defined vending areas, boating access improvements, cultural activity spaces	0.50 – 0.70	Comparable riverfront public space development projects in Varanasi and Patna
Contingency & Project Management	DPR refinement, supervision, contingencies, IEC activities	0.40 – 0.60	Standard 5–8% project contingency provision
Total Estimated CAPEX		6.20 – 8.20 Crores	

Table 58 Annual Operation & Maintenance (O&M) Cost Estimate

Component	Key Activities	Annual Cost (₹ Lakh/year)	Source Basis
Cleaning & Waste Management	Daily sweeping, waste collection, drain cleaning	20 – 30	SBM-U O&M benchmarks
Public Amenities Maintenance	Toilet cleaning, water supply, electricity, repairs	15 – 20	AMRUT public utility maintenance norms
Landscape & Green Buffer Maintenance	Plantation care, irrigation, pruning, replacement planting	10 – 15	State horticulture maintenance schedules
Lighting & Safety Systems	Electricity, CCTV maintenance, repairs	10 – 15	Municipal street infrastructure O&M standards
Security & Crowd Management	Guards, festival/event management support	15 – 20	Comparable urban riverfront management costs
Minor Repairs & Desilting	Repair of paving, railings, seasonal desilting	20 – 30	WRD and municipal maintenance estimates
Total Annual O&M		90 Lakh – 1.30 Crores/year	

Indicative Cost References

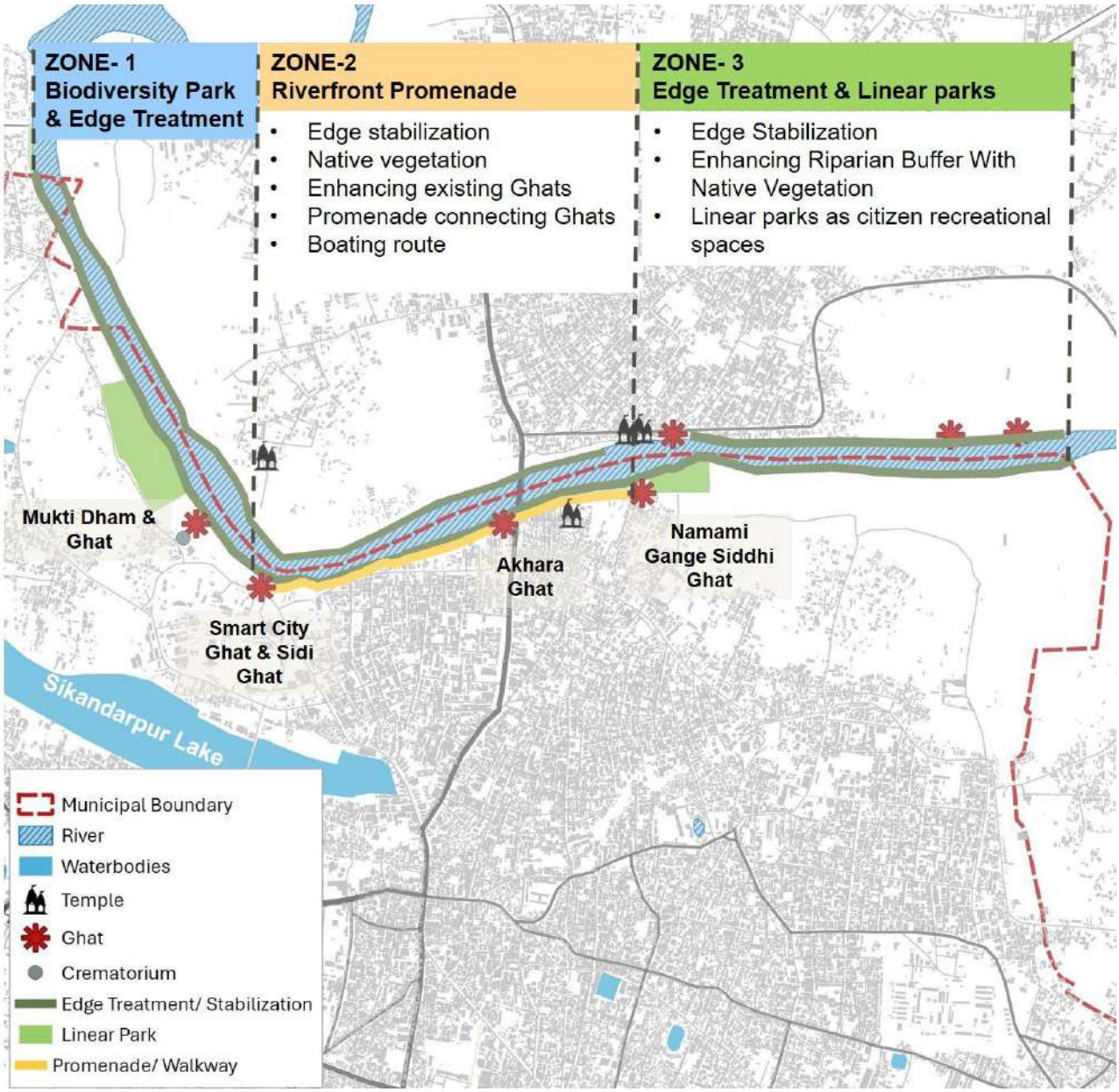
- Swachh Bharat Mission – Urban (SBM-U 2.0) Guidelines, MoHUA
- AMRUT 2.0 Toolkit and Urban Greenspace Development Framework
- CPWD Schedule of Rates (SOR), 2024
- Namami Gange riverfront development project benchmarks (Varanasi, Patna, Kanpur ghats)
- BUIDCo urban infrastructure and streetscape cost benchmarks
- Smart Cities Mission public realm and waterfront development estimates

Figure 45 Conceptual Images of Ghat Redevelopment

Intervention 7.2 Ecological River Edge Restoration & Linear Park Development

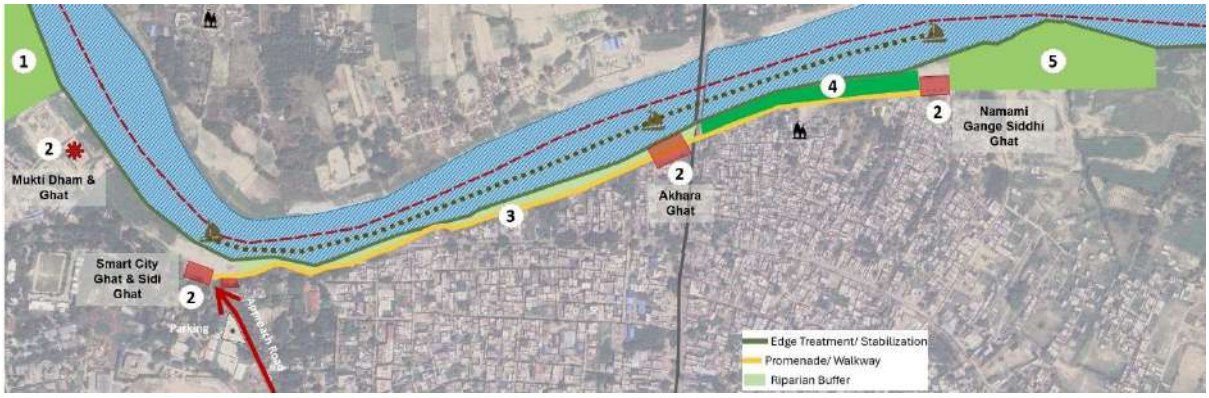
This intervention focuses on restoring the 4.3 km Burhi Gandak river edge as an ecologically resilient and flood-compatible public landscape through nature-based solutions (NbS). The proposal prioritises riverbank stabilisation, riparian buffer restoration, eco-nallah integration, and development of low-impact linear parks while avoiding excessive hardscaping along the riverfront.

Figure 46 : Zoning plan- proposed for the riverfront



Source: Primary Survey

Figure 47 Map of the proposed rivefront projects



Source: Google Earth

The intervention complements the DPR-led riverfront infrastructure by strengthening the ecological performance of the river corridor and improving flood resilience, biodiversity, and public access. The proposal is divided into three ecological stretches:

- **Zone 1 – Biodiversity Park & Edge Restoration (Western Stretch):**
  Riparian buffer restoration, habitat creation, bank stabilisation, and controlled access pathways.
- **Zone 2 – Eco-sensitive Urban River Interface:**
  Integration of native vegetation, shaded public spaces, and ecological edge treatment near dense urban areas.
- **Zone 3 – Linear Ecological Parks (Eastern Stretch):**
  Floodplain-compatible green corridors with seasonal-use landscapes and minimal built infrastructure.

Table 59 Key Components

Component	Description
Natural Edge Treatment (~4.3 km)	Bioengineering-based bank stabilisation using coir rolls, vetiver grass, and native planting
Riparian Buffer Development	Continuous vegetation corridor for filtration, erosion control, and habitat creation
Eco-Nallah Systems (8–10 drains)	Constructed wetlands, sedimentation zones, and bio-remediation channels before river discharge
Linear Parks & Soft Landscapes	Flood-compatible public spaces with permeable pathways and shaded seating
Public Amenities Support	Toilets, bins, lighting, and basic landscape infrastructure

Ecological Restoration Strategy

The river edge will be restored through a layered vegetation system comprising:

- **Aquatic Layer:** Typha, Lotus for filtration and habitat support
- **Grass Layer:** Vetiver, Saccharum for slope stabilisation
- **Shrub Layer:** Carissa, Vitex for bank strengthening and habitat creation
- **Tree Layer:** Arjuna, Neem, Jamun for canopy cover and long-term stability
- **Expected Outcomes**
- Reduced erosion and sediment loss

- Improved river-edge filtration and ecological health
- Enhanced biodiversity and riparian habitat connectivity
- Flood-compatible public open spaces
- Reduced untreated drain discharge into the Burhi Gandak

Implementation Framework

- **Lead Agencies:** MMC, WRD, Forest/Horticulture Department, BSPCB
- **Funding Sources:** Namami Gange, AMRUT 2.0, 15th Finance Commission, CAMPA, CSR

Table 60 Capital Cost Estimate (CAPEX) – Ecological River Edge Restoration & Linear Park Development

Component	Description	Estimated Cost (₹ Crore)	Cost Basis / Source
River Edge Stabilisation	Bioengineering measures including coir rolls, vetiver grassing, slope stabilisation, erosion control	2.00 – 2.50	Based on WRD riverbank protection works and National Mission for Clean Ganga (NMCG) eco-restoration projects
Riparian Buffer Restoration	Native plantation, shrub layers, grass buffers, habitat restoration along ~4.3 km stretch	1.20 – 1.60	CAMPA plantation norms, Forest Department afforestation benchmarks, AMRUT greenspace costs
Eco-Nallah Integration Systems	Constructed wetlands, sedimentation basins, bio-remediation channels at major drain outfalls	2.50 – 3.50	CPCB and NMCG decentralised wastewater treatment and wetland treatment system benchmarks
Linear Park Development	Soft landscape parks, shaded seating, walking/cycling trails, permeable pathways	1.80 – 2.50	AMRUT 2.0 public open space development benchmarks and Smart City riverfront projects
Public Amenities	Toilets, benches, drinking water points, signage, bins, solar lighting	0.80 – 1.20	SBM-U 2.0 and Smart Cities Mission public realm infrastructure costs
Ecological Interpretation & Public Interface	Biodiversity signage, viewing decks, educational nodes, nature trails	0.40 – 0.60	Urban biodiversity park and eco-park development benchmarks
Monitoring & Environmental Sensors	Water level gauges, water quality sensors, ecological monitoring setup	0.40 – 0.70	BSPCB/CPCB monitoring infrastructure estimates
Project Management & Contingency	DPR detailing, supervision, contingency, IEC activities	0.80 – 1.00	Standard contingency provision (5–8%)
Total Estimated CAPEX		9.90 – 13.60 Crores	

Table 61 Annual Operation & Maintenance (O&M) Cost Estimate

Component	Key Activities	Annual Cost (₹ Lakh/year)	Source Basis
Riparian Plantation Maintenance	Watering, pruning, replacement plantation, invasive species removal	20 – 30	Forest Department and urban greenspace O&M norms
Linear Park Maintenance	Grass cutting, pathway upkeep, seating and lighting repairs	25 – 35	AMRUT and Smart City parks maintenance benchmarks
Wetland & Eco-Nallah Systems	Wetland cleaning, sludge removal, vegetation management	20 – 30	Constructed wetland O&M benchmarks under NMCG projects
Public Amenities Maintenance	Toilets, bins, utilities, cleaning	15 – 20	SBM-U O&M benchmarks
Environmental Monitoring	Sensor calibration, sampling, reporting	10 – 15	CPCB/BSPCB monitoring estimates
Security & Community Stewardship	Guards, awareness activities, community management support	10 – 15	Urban riverfront management projects
Minor Repairs & Flood Damage Restoration	Seasonal repairs after monsoon events	15 – 25	WRD floodplain maintenance estimates
Total Annual O&M		1.15 – 1.70 Crores/year	

Indicative Cost References

- National Mission for Clean Ganga (NMCG) – Riverfront Development & River Rejuvenation Guidelines
- Central Pollution Control Board (CPCB) – Constructed Wetland and Bio-remediation Cost Benchmarks
- AMRUT 2.0 Toolkit for Urban Greenspaces and Open Space Development
- CAMPA Afforestation and Riparian Plantation Cost Norms
- CPWD Schedule of Rates (SOR), 2024
- Water Resources Department (WRD), Bihar – Riverbank Stabilisation and Flood Protection Works
- Smart Cities Mission public realm and waterfront development benchmarks
- Case references: Sabarmati Riverfront (Ahmedabad), Adyar Eco-restoration (Chennai), East Kolkata Wetlands restoration projects

Figure 48 Before and After images of the Riverfront promenade with viewing decks

Figure 49 Before and After images of Edge Treatment and Stabilization

O&M Components and Activities

Table 62 O&M Activity Framework

Component	Key Activities	Frequency
River Edge & Riparian Buffer	Plantation care, replanting, erosion checks, invasive species removal	Monthly / Seasonal

Ghat Areas	Cleaning, minor repairs, desilting of steps, safety checks	Daily / Monthly
Eco-Nallah Systems	Wetland maintenance, sludge removal, flow monitoring	Monthly / Quarterly
Public Amenities	Toilets, bins, lighting maintenance	Daily / Weekly
Solid Waste Management	Collection, segregation, disposal	Daily
Safety & Surveillance	Guards, lighting checks, signage upkeep	Daily
Public Spaces (soft landscape)	Grass cutting, irrigation, pruning	Weekly / Seasonal

Institutional Responsibilities

Table 63 Roles & Responsibilities

Agency	Responsibility
Muzaffarpur Municipal Corporation (MMC)	Overall O&M management, ghat maintenance, waste management, revenue collection
Water Resources Department (WRD)	Structural stability of river edges, flood-related interventions
PHED	Drainage systems, eco-nallah maintenance, wastewater management
Forest / Horticulture Dept.	Plantation, biodiversity maintenance, riparian buffer
BSPCB	Water quality monitoring and compliance
Private Operators / SHGs	Maintenance of toilets, kiosks, vending zones
NGOs / Community Groups	Awareness, monitoring, participatory upkeep

Revenue Model for Sustainable O&M

Primary Revenue Sources

- User Charges
- Entry fees (select ghats / zones)
- Boating and activity charges
- Vending & Kiosk Rentals
- Regulated vending zones near ghats: Seasonal markets
- Event-Based Revenue: Festivals, cultural programs
- Parking Fees
- Designated parking near access points
- CSR & PPP Support
- Maintenance sponsorships
- Public amenity upkeep

Intervention 7.3: Litchi Experience Park – at Namami Gange Siddhi Ghat

The proposed Muzaffarpur Riverfront Biodiversity & Public Recreation Park is envisioned as an ecological riverfront restoration and public open space initiative along the Burhi Gandak River near Siddhi Ghat. The intervention seeks to transform degraded sand-mined and underutilised floodplain land into a resilient ecological landscape that integrates biodiversity enhancement, riverfront restoration, climate-responsive public spaces, and community-oriented recreation.

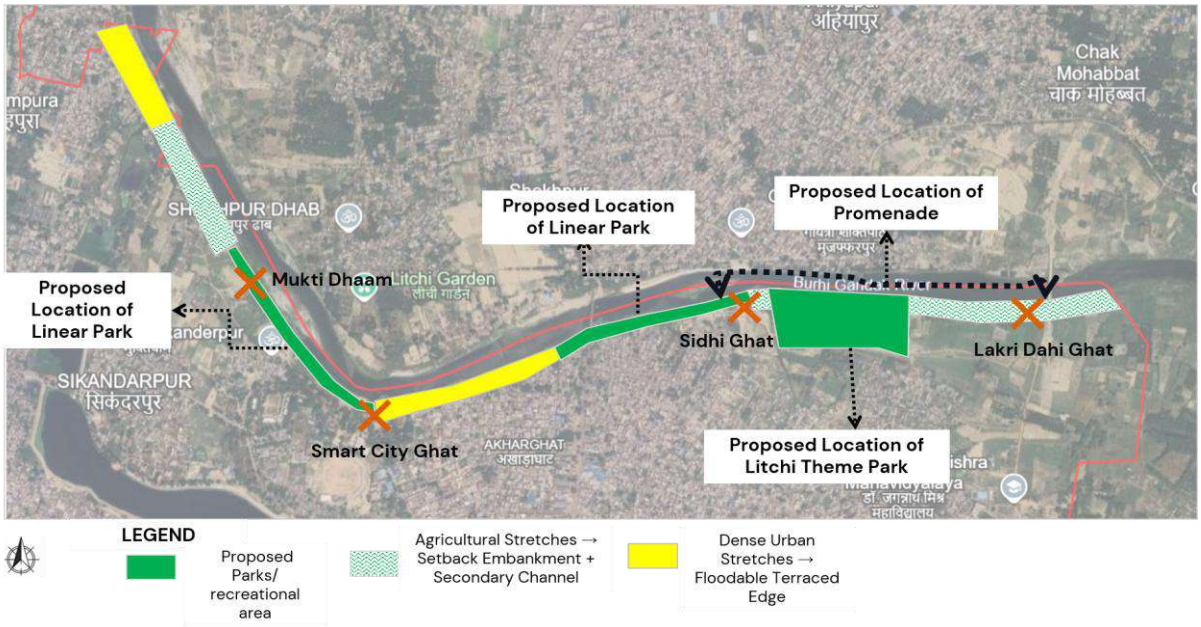
Located within the active river influence zone, the project adopts a "landscape-first" and low-impact development approach, prioritizing ecological restoration over intensive built infrastructure. The proposal aims to strengthen the river-city relationship while improving environmental quality, enhancing public accessibility, and creating multifunctional open spaces along the urban river corridor.

Site Context

The proposed site is located along the Burhi Gandak riverfront near Siddhi Ghat within the Muzaffarpur municipal area. The site presently consists of degraded floodplain land characterized by sand deposition, disturbed topography, sparse vegetation, and localized waterlogging pockets resulting from riverine processes and previous extraction activities.

The surrounding areas comprise dense urban settlements, transport corridors, institutional uses, and fragmented green patches. Due to its strategic riverfront location and ecological significance, the site presents an opportunity for developing a multifunctional public landscape integrated with floodplain-sensitive planning principles.

Map 28 : Location of the proposed Litchi park



Source: Google Earth

Planning Approach

The proposal is based on the following planning principles:

- Ecological restoration of degraded floodplain landscapes
- Minimal permanent construction within the river influence zone
- Flood-compatible and water-sensitive landscape design
- Enhancement of biodiversity through native plantation systems
- Integration of public recreation with ecological functions
- Creation of climate-responsive and inclusive open spaces
- Strengthening riverfront accessibility and environmental awareness

Figure 50 Existing Site Pictures

Source: Primary Survey

Figure 51 Conceptual Zoning Plan of Litchi Park

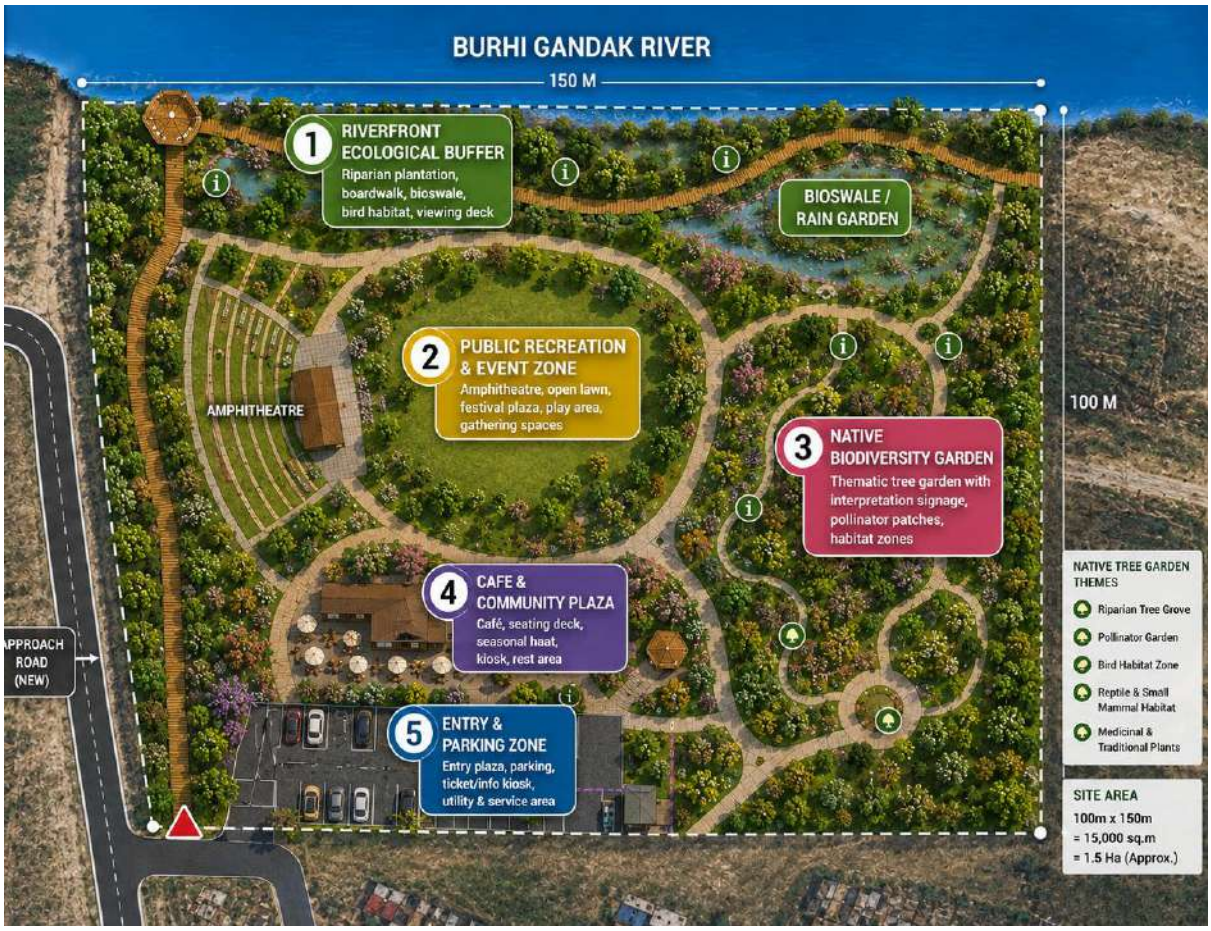
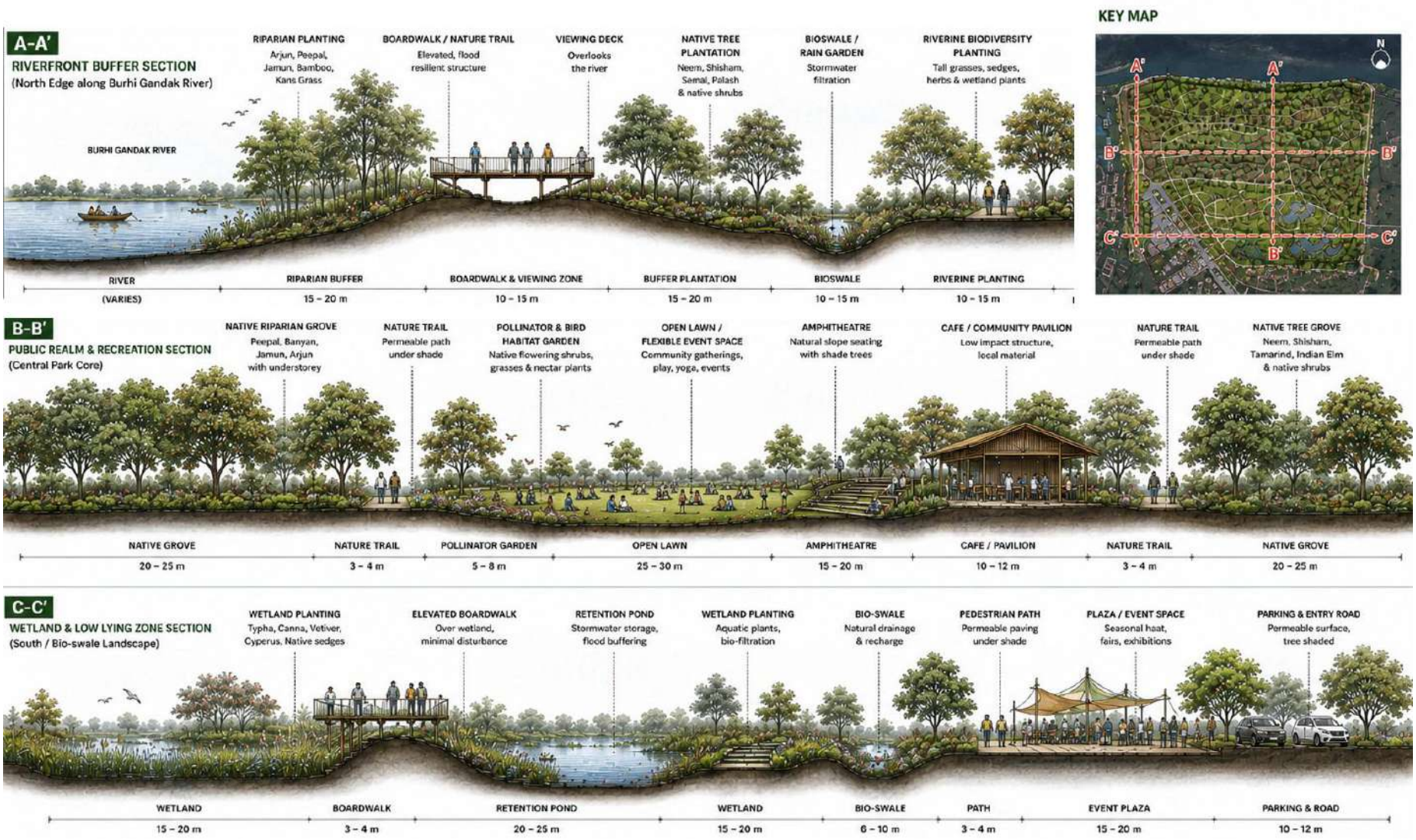


Figure 52 Site Sections



Key Components of the Proposal

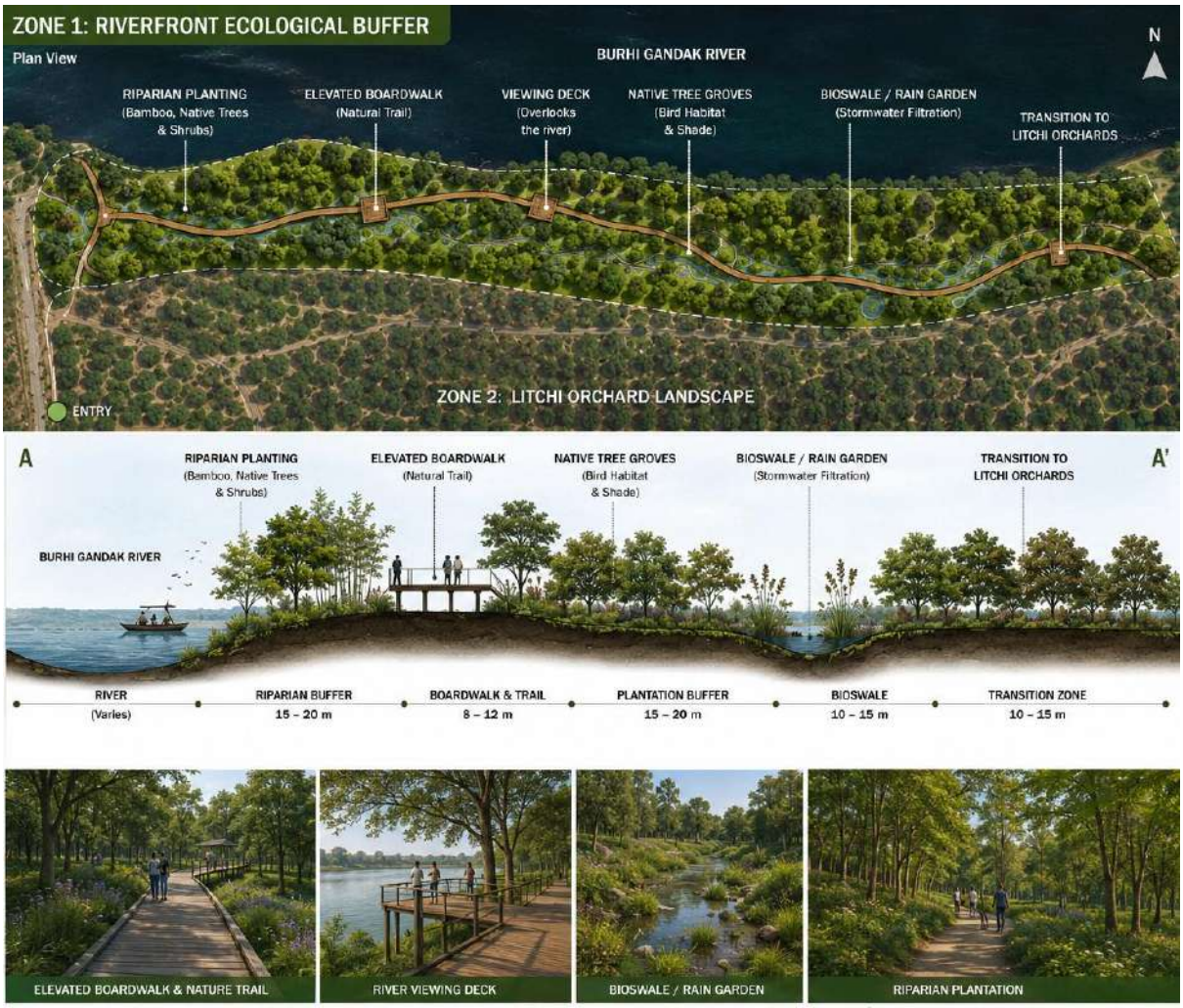
1. Riverfront Ecological Buffer

A continuous riparian buffer is proposed along the river edge comprising native floodplain plantation, bioswales, rain gardens, and ecological trails. The buffer will function as a biodiversity corridor while stabilizing the riverbank and improving stormwater filtration.

Proposed Elements

- Riparian plantation
- Elevated boardwalks
- Viewing decks
- Bioswales & rain gardens
- Nature interpretation trails
- Bird & pollinator habitat zones

Figure 53 Plan of Zone 1



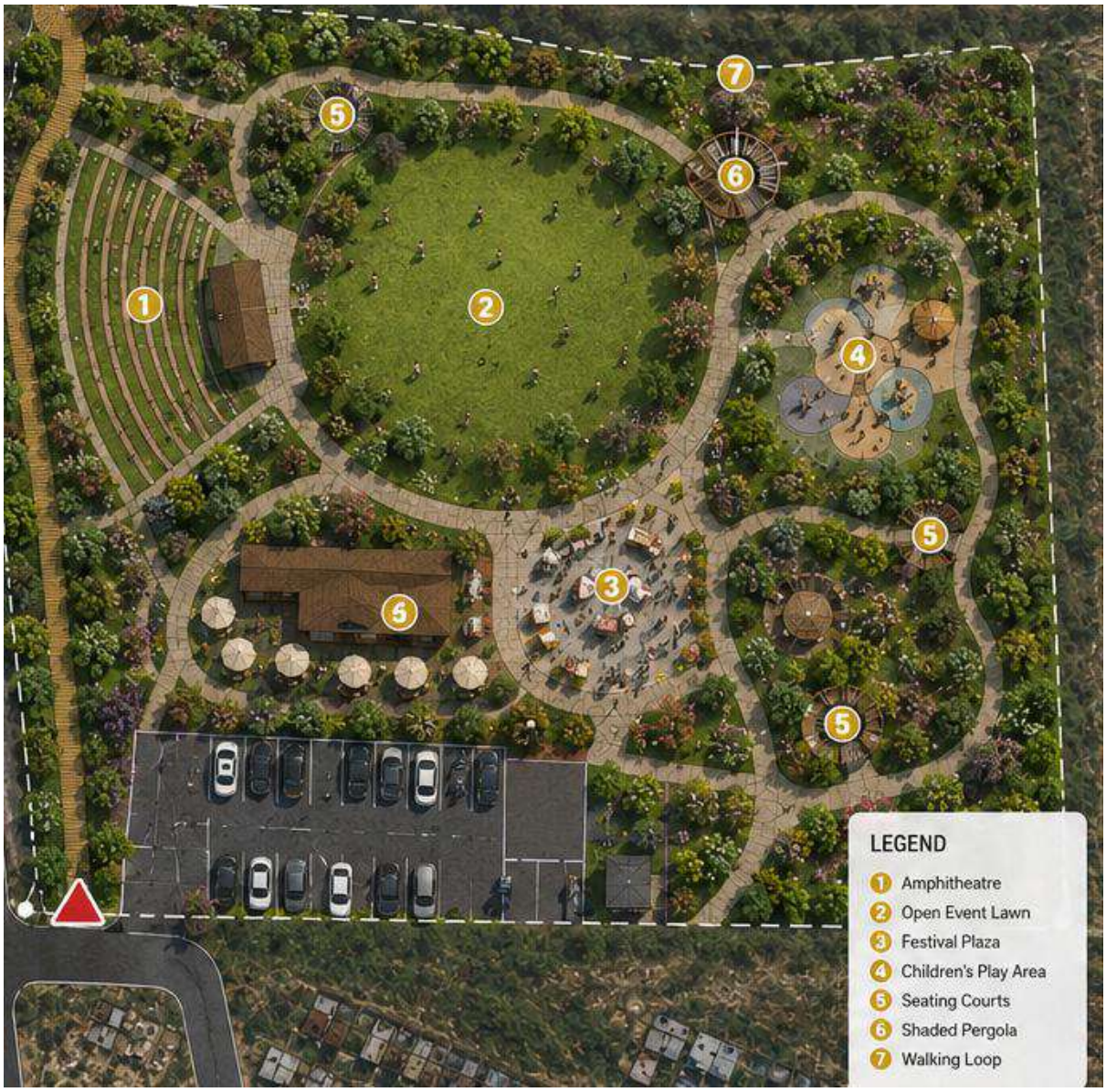
2. Public Recreation & Event Zone

The central public realm of the park is designed as a flexible recreation and event landscape accommodating community activities, cultural events, and everyday public use.

Proposed Elements

- Amphitheatre
- Open event lawns
- Festival plaza
- Children's play area
- Seating courts & shaded spaces
- Walking loops & recreational pathways

Figure 54 Plan of Zone 2



3. Native Biodiversity Garden

A thematic biodiversity garden is proposed to showcase native riparian and floodplain species of the Burhi Gandak ecosystem. The zone will function as an environmental education and ecological interpretation landscape.

Proposed Elements

- Native tree groves
- Pollinator gardens
- Butterfly habitat areas

- Medicinal plant gardens
- Ecological interpretation signage

Nature learning trails

Indicative Native Species

- Peepal (Ficus religiosa)
- Banyan (Ficus benghalensis)
- Jamun (Syzygium cumini)
- Arjun (Terminalia arjuna)
- Neem (Azadirachta indica)
- Shisham (Dalbergia sissoo)
- Palash (Butea monosperma)
- Semal (Bombax ceiba)

Figure 55 Plan of Zone 3

4. Café & Community Plaza

A low-impact community plaza integrated with landscape features is proposed to support leisure activities, visitor amenities, and small-scale public gatherings.

Proposed Elements

- Café pavilion
- Outdoor seating decks
- Seasonal kiosks
- Community plaza
- Public seating areas

Figure 56 Plan of Zone 4

5. Entry & Parking Zone

The entry zone will provide controlled access and essential visitor infrastructure integrated with the landscape character of the park.

Proposed Elements

- Entry plaza
- Parking area
- Information kiosk
- Public amenities
- Landscape edge plantation

Figure 57 Before and After pictures of Sidhi Ghat

BEFORE

AFTER

Floodplain Sensitivity & Resilience

Considering the flood-prone nature of the Burhi Gandak corridor, the proposal adopts flood-compatible planning measures including:

- Minimal permanent construction
- Elevated and permeable pathways
- Water-sensitive landscape systems
- Native flood-resilient plantation
- Retention depressions and bioswales
- Flexible open-use landscapes

The intervention is designed to work with the natural hydrological character of the floodplain while minimizing disturbance to river processes.

Implementation Strategy

The project may be implemented in phases through convergence of funding under:

- Namami Gange / NMCG
- AMRUT 2.0
- Urban green space initiatives
- CSR & PPP partnerships
- State urban development programs

A multi-agency implementation structure involving Muzaffarpur Municipal Corporation, state agencies, environmental institutions, and local stakeholders is recommended for long-term management and maintenance of the park.

Indicative Cost Estimate

Total Estimated Cost: ₹ 5.5 – 6.0 Cr

Table 64 Proposed Implementation Phasing

Component	Estimated Cost (₹ Cr)
Ecological restoration & plantation	1.00
Recreation & public realm	1.50
Biodiversity garden	0.60
Café & community plaza	0.80
Entry & parking infrastructure	0.55
Utilities, signage & lighting	0.45
Contingency & PMC	0.60

Note: Cost for land acquisition not considered on the budget

Figure 58 Conceptual images of Litchi Park

4.7 Objective 9 & 10: River-Sensitive Behaviour among Citizens and Engagement in River Management

Objective 9 *aims to foster river-sensitive values through education, media campaigns, school programs, and innovative outreach such as festivals and digital tools. The focus is on building a shared culture of stewardship where citizens recognize the benefits of healthy rivers and their role in protecting them.*

Objective 10 *calls for citizens to become active participants in river management. Community groups, NGOs, and volunteers can be mobilized for monitoring, clean-up, and stewardship activities. By embedding citizen participation in governance frameworks, cities can build long-term ownership and collective responsibility for river systems.*

4.7.1 Existing Condition

Muzaffarpur's engagement with environmental stewardship has largely evolved through sanitation-driven awareness initiatives, particularly under Swachh Bharat Mission (Urban), which have indirectly contributed to reducing pollution entering the Burhi Gandak. These efforts—ranging from ward-level campaigns and door-to-door outreach to decentralised waste management systems—have created a foundation of citizen participation and behavioural awareness. However, the absence of a dedicated river-centric Information, Education, and Communication (IEC) framework has limited the translation of these efforts into direct river stewardship and ownership.

While institutional capacity is gradually strengthening through training programs and emerging riverfront planning initiatives, citizen engagement in river governance remains fragmented and indirect, embedded within broader urban cleanliness narratives rather than focused on river ecology, floodplain management, or water quality. With increasing investments in riverfront development and drainage infrastructure, there is a critical opportunity to mainstream river-sensitive behaviour across households, communities, and citywide platforms, ensuring that infrastructure interventions are supported by sustained behavioural change and community stewardship.

Key Issues

- **Absence of Dedicated River-Centric IEC Framework:** Existing awareness campaigns focus on sanitation, with limited emphasis on river health, ecology, and floodplain dynamics.
- **Indirect and Fragmented Citizen Engagement:** Participation is largely embedded within cleanliness drives, lacking structured platforms for river stewardship.
- **Low Institutionalisation of River Sensitisation:** No formal systems such as river-focused websites, campaigns, or dedicated observance days exist.
- **Limited Community Participation in River Governance:** Citizens are not actively involved in monitoring, decision-making, or river management processes.
- **Minimal Use of Diverse Communication Channels:** Traditional and digital media are underutilised for river-specific messaging and outreach.
- **Lack of School and Youth Engagement:** Absence of structured programs for river literacy, eco-clubs, or citizen science initiatives.
- **Weak CSR and Stakeholder Convergence:** Limited private sector and NGO involvement in river-related awareness and engagement activities.
- **Fragmented Institutional Coordination:** Multiple agencies operate in silos without a unified framework for citizen-led river stewardship.

4.7.2 URMP Score

As per URMP framework, if the river sensitization point is 20-27 the **citizen sensitization score is 2**

As per URMP, if the city get one answer as Yes in modality of citizen engagement, then the **Citizen engagement score is 2**

4.7.3 Interventions

Intervention 9.1 River-Based Sensitisation Program

Rationale

To foster long-term behavioral change and community stewardship for river conservation by transitioning from awareness-driven campaigns to institutionalised practices, ensuring sustainable management of riverfront and water systems.
The intervention adopts a three-tier engagement strategy, moving from household-level awareness to citywide behavioral transformation, with strong integration of community institutions and cultural platforms.
Awareness → Behaviour Change → Shared Stewardship → Institutionalisation

Program Structure

Phase 1: Household-Level Engagement (0–1 Year)
Focus on **direct citizen outreach and behaviour change at the source**
Key Actions:

- Door-to-door "River Health Campaigns"
- Awareness on:
- Eliminating **drain dumping**
- Scheduled **desludging practices**
- Safe **septic tank maintenance**
- **Source segregation of waste**

Phase 2: Community & Neighbourhood Platforms (1–3 Years)
Strengthening **local institutions as custodians of river health**
Target Groups:

- RWAs, Ghat Committees, Market Associations, SHGs

Capacity Building Focus:

- Festival waste management protocols
- Maintenance of eco-friendly ghats
- Monitoring of drains and waste hotspots
- Sensitisation of floodplain farmers for organic practices

Phase 3: Citywide Campaigns & Public Narratives (3–5 Years)
Scaling up through **mass communication and cultural integration**
Key Strategies:

- Engagement of media, temples, schools, anganwadis as multipliers
- Festival-specific IEC campaigns:
    - **Chhath:** Waste-free ghats
    - **Shraddh / Pitru Paksha:** Eco-friendly rituals and offerings

Institutional Framework

Function	Nodal Agency	Supporting Agencies
Program design & coordination	MMC	District Administration
IEC & outreach	SBM Cell (ULB)	NGOs / CBOs
Community mobilisation	Ward Committees	SHGs / RWAs
School & institutional engagement	Education Dept.	Anganwadi network
Monitoring & evaluation	BSPCB	MMC

. Implementation Mechanism

- Integration with Swachh Bharat Mission (SBM-U 2.0) and IEC funds
- Formation of Ward-level River Steward Groups
- Use of mobile apps / grievance systems for reporting dumping and maintenance issues
- Incentivisation through "Clean Ghat / Clean Ward" rankings

Estimated Annual Cost: ₹1.0 – 1.5 Cr

Table 65 Costing for the River-sensitisation program

Component	Cost (₹ lakh/year)
IEC campaigns & materials	30 – 40
Community training & workshops	20 – 30
Outreach staff & volunteers	20 – 25
Media & events	15 – 25
Monitoring & reporting systems	10 – 15

Funding Sources:

- SBM-U 2.0 (IEC component)
- AMRUT 2.0 (awareness integration)
- CSR (campaigns & branding)

Intervention 9.2: Community-led River Stewardship – Muzaffarpur (Burhi Gandak)

To establish a community-driven river governance model that enables citizens to act as active custodians of river health, ensuring long-term sustainability through participation, monitoring, and livelihood integration.

The intervention adopts a phased, bottom-up stewardship model, integrating citizen groups, local institutions, and municipal systems to move from pilot initiatives to citywide river governance and economic integration.

Program Structure (Phasing Strategy)

Phase 1: Initiation & Institutional Setup (0–6 Months)

Focus on **building the foundation for community participation**

Key Actions:

- Stakeholder onboarding: MMC, ward committees, SHGs, youth groups, temple committees, recyclers
- Formation of **River Stewardship Groups (RSGs)** at ward/ghat level

- Training modules on:
    - Source segregation
    - Drain–river linkage awareness
    - Flood-season waste management
- Launch of **IEC campaigns** aligned with SBM and Namami Gange

Phase 2: Pilot Implementation (6–18 Months)
Testing stewardship models in **priority riverfront stretches**
Key Actions:

- **Segregation-at-source systems** for river-edge households and vendors
- Establishment of **Ghat-level Material Recovery Points (MRPs)**
- Citizen monitoring of:
    - Dumping
    - Drain choking
      (via mobile reporting/ward registers)
- Monthly **"Nadi Seva Days"** (clean-ups + awareness events)
- Formation of **school and college river clubs**
- Integration with municipal sanitation workforce

Phase 3: Scaling Along River Corridor (18–36 Months)
Expansion to **all riverfront wards and integration with systems**
Key Actions:

- Expansion of RSGs across the entire river corridor
- Linkage with **decentralised composting and dry waste value chains**
- Launch of **"Adopt-a-Ghat" programme** (CSR / institutions / market associations)
- City-level campaigns:
    - Pre-monsoon River preparedness
    - Chhath and festival-specific cleanliness drives
- Development of **data dashboards** tracking:
    - Cleanliness
    - Waste segregation
    - Citizen participation

Phase 4: Long-Term Governance & River Economy Link (3–5 Years)
Institutionalising stewardship into **governance and livelihoods**
Key Actions:

- Establishment of **River Stewardship Cell within MMC**
- Introduction of **performance-based incentives** for citizen groups
- Integration with **riverfront O&M contracts**
- Promotion of **green livelihoods**, including:
    - Compost marketing
    - Recyclables aggregation
    - Eco-guides and ghat management services

Institutional Framework

Table 66 Institutional Framework

Function	Nodal Agency	Supporting Stakeholders
Overall coordination	MMC	District Administration
Community mobilisation	Ward Committees	SHGs, NGOs
Waste management integration	SBM Cell	Sanitation Workers
Monitoring & reporting	MMC + BSPCB	Citizen groups
CSR convergence	District / MMC	Private sector

Cost & Funding Strategy

Table 67 Cost and Funding strategy

Component	Cost (₹ lakh/year)
Training & capacity building	30 – 40
IEC & campaigns	25 – 35
Monitoring systems & dashboards	20 – 30
Community incentives	30 – 40
Program management	25 – 35

Estimated Annual Cost: ₹1.5 – 2.0 Cr

Funding Sources:

- SBM-U 2.0 (IEC + community engagement)
- Namami Gange (convergence for river stewardship)
- CSR (Adopt-a-Ghat, campaigns)
- Municipal budget (O&M integration)

5. Annexures

5.1 Annexure 1

5.1.1 The Technical Guidelines on Flood Plain Zoning (July 2025)

The *Technical Guidelines on Flood Plain Zoning (July 2025)*, issued by the Ministry of Jal Shakti through the Central Water Commission, provide a structured framework for regulating developmental activities within floodplains across India. The guidelines serve as a reference for States and Union Territories to identify, demarcate, and regulate the use of floodplain areas, thereby minimizing risks to life, property, and ecosystems while preserving the natural functions of rivers.

Key Provisions Relevant to This Study

1. Immediate Restrictions: Until floodplain identification and demarcation are completed, **no activity is permitted within 100 meters of the river edge**, designated as a *No-Development/Construction Zone*. States and UTs may be given phased compliance, with exceptions permitted for essential infrastructure such as railway lines, bridges, and public utilities.
2. Defining River's Edge: For enforcement purposes, the "river edge" may be determined by adopting either the maximum dry-season waterline or the maximum flood line recorded during the past **five years**.
3. Waste and Pollution Control:
    - Direct disposal of municipal solid waste, e-waste, or biomedical waste into the river or floodplain is prohibited.
    - No dumping or landfill sites are allowed within **500 meters** of the river edge (or as defined under State/municipal byelaws, whichever is more stringent).
    - Monitoring of effluents from treatment facilities is mandatory under Section 21 of the Water (Prevention and Control of Pollution) Act, 1974.
4. Encroachment Management:
    - Floodplain zones downstream of dams and barrages must be demarcated, with encroachments mapped by nodal agencies.
    - Phased action plans for removal of encroachments should be prepared with district administrations and State Disaster Management Authorities (SDMAs).
    - Governments may declare themselves free of liability for flood-related damages in such areas to encourage relocation of vulnerable populations.
5. Revenue Records: State revenue departments must update official records once floodplain zoning work is completed, ensuring long-term integration of demarcations into land-use management.
6. Floodplain Zoning in Urban Contexts
    - **Protected Zone**: Most vulnerable; no activities allowed other than essential services.

- **Regulatory Zone**: Between **1-in-5 and 1-in-25-year floods**; limited, regulated activities allowed.
- **Warning Zone**: Between **1-in-25 and 1-in-100-year floods**; most activities may be permitted, subject to vulnerability mapping and flood-risk safeguards.

Table 6.1 below summarises the flood frequency intervals used for zoning:

Zone	Flood Frequency Interval	Applicability
Protected Zone	Up to 1-in-5 years	Rural & Urban Areas
Regulatory Zone	1-in-5 to 1-in-25 years	Rural & Urban Areas
Warning Zone	1-in-25 to 1-in-100 years	Urban Areas only

Environmental Safeguards in Floodplains

- Existing landfill sites or dumps in active floodplains must be removed through municipal or panchayat interventions.
- Regular community awareness programs and flood preparedness campaigns must be conducted in identified zones.
- In hilly and mountainous regions, where floodplains differ due to slope and topography, zoning should adopt adaptive approaches based on slope angles, highest flood levels, and flood frequency analysis.

5.1.2 Guidelines Emerging from the Status Report on Delhi Flooding (OA No. 537/2023)

The *Status Report of the Environment Department, GNCTD (2023)*, prepared in response to severe flooding along the Yamuna, highlights the urgent need to rethink Delhi's Master Plan 2041. The report underscores how unregulated urbanisation, encroachment on floodplains, and inadequate stormwater management have magnified flood risks. The recommendations function as de facto urban river management guidelines, stressing the integration of flood resilience, ecological safeguards, and land-use regulation into planning.

Key Provisions Relevant to Urban River Management

1. Floodplain Zoning and Restrictions
    a. Mandatory demarcation of the floodplain, with clear no-construction zones to prevent encroachments.
    b. Immediate restrictions on development within ecologically sensitive floodplain belts until zoning is finalized.
2. Integration of Blue–Green Infrastructure
    a. Recognition of wetlands, waterbodies, and natural drains as critical flood buffers.
    b. Guidelines recommend restoring and linking these systems to reduce urban flooding and recharge aquifers.
3. Stormwater and Drainage Management
    a. Mandates integration of city stormwater drains with the natural hydrology of the Yamuna.

   b. Encourages nature-based solutions such as bioswales and retention ponds to manage runoff.
4. Pollution and Waste Control
   a. Prohibition of solid waste dumping, landfill siting, or untreated sewage discharge within the floodplain.
   b. Strict monitoring of wastewater treatment facilities under provisions of the Water (Prevention and Control of Pollution) Act, 1974.
5. Disaster Risk Reduction
   a. Flood-prone zones must be mapped using historical flood records and climate projections.
   b. Encroachment removal and relocation of vulnerable settlements are to be implemented through phased action plans in coordination with SDMAs.
6. Institutional Coordination
   a. Development Authority (DDA), Urban Local Bodies, and disaster management agencies must operate through a multi-stakeholder mechanism.
   b. Revenue records and land-use plans must be updated to integrate floodplain demarcations, ensuring long-term enforcement.

Floodplain Management

- Protected Zones (High-Risk Flood Areas): No permanent activity permitted, except essential public utilities.
- Regulatory Zones (Moderate Risk): Limited, regulated activities allowed, with mandatory safeguards.
- Urban Context Emphasis: In densely built areas, warning zones are defined where activities may continue, but with vulnerability mapping, preparedness measures, and design modifications to withstand floods.

Environmental and Social Safeguards

- Removal of existing solid waste dumps from active floodplains through coordinated municipal action.
- Promotion of community-based awareness and preparedness programs in flood-vulnerable settlements.
- Adoption of adaptive flood management approaches in hilly terrain adjoining river valleys, considering slope, peak flood levels, and flood recurrence intervals.

Permissible Activities in Floodplains

- Agriculture, horticulture, and pastures (seasonal cropping, grazing).
- Parks, gardens, and open green buffers.
- Forestry and plantations.
- Playgrounds, sports fields, and recreational open spaces.
- Roads on raised structures or embankments (if approved).
- Essential utility lines (water supply mains, sewers, electric/telecom lines) with flood-resistant design.
- Fisheries and aquaculture in low-lying zones.
- Eco-tourism and biodiversity parks (low-impact, non-permanent structures).
- Riverfront promenades are designed without obstructing flood flows.

Non-Permissible Activities in Floodplains

- Permanent residential, commercial, or industrial construction.
- Hazardous industries, storage of toxic/inflammable materials.
- Solid waste dumping, landfills, and debris disposal.
- Construction of colonies, farmhouses, hotels, banquet halls, or religious structures.
- Mining, excavation, or sand removal beyond regulated limits.
- Infrastructure that blocks natural drainage or alters flood flow (e.g., embankments, roads without culverts).
- Parking yards, transport terminals, and large impermeable paved surfaces.
- Encroachments by unauthorised settlements or private development.

5.1.3 WRD Bihar Notification on Floodplain zoning (March 2025)

बिहार सरकार
जल संसाधन विभाग

संचिका संख्या– यो०मो०–4 (विविध)07–372/2020 पार्ट–II- 143 /पटना, दिनांक– 06/3/2025

–: आदेश :–

विषयः– बिहार राज्य अंतर्गत तटबंधित नदियों के लिए Flood Plain Zoning लागू किए जाने के संबंध में।

1. माननीय राष्ट्रीय हरित अधिकरण (National Green Tribunal), नई दिल्ली में विचाराधीन OA No-200/2014, OA No-673/2018 एवं अन्य मामले में पारित आदेशों के आलोक में नदियों के प्राकृतिक, आर्थिक एवं पर्यावरणीय लाभकारी मूल्यों का संरक्षण, प्रदूषण की रोकथाम तथा नदी पारिस्थितिकी तंत्र (River Ecosystem) का संरक्षण एवं जीर्णोद्धार के उद्देश्य से Flood Plain Zoning राज्यों द्वारा लागू किया जाना है।
2. जल शक्ति मंत्रालय, भारत सरकार द्वारा बाढ़ प्रबंधन कार्यक्रम (Flood Management Program) के तहत वित्त पोषण प्राप्त करने हेतु राज्यों को Flood Plain Zoning कानून अथवा किसी उपयुक्त कार्यकारी आदेश के माध्यम से लागू किये जाने की भी पात्रता निर्धारित की गयी है।
3. बिहार बाढ़ के दृष्टिकोण से अत्यधिक संवेदनशील राज्य है, जहाँ बाढ़ प्रवण क्षेत्र देश के बाढ़ प्रवण क्षेत्र का लगभग 17.2 प्रतिशत है। राज्य के कुल 94.16 लाख हेक्टेयर भौगोलिक क्षेत्र का 68.80 लाख हेक्टेयर क्षेत्र बाढ़ प्रवण है, जो कुल भौगोलिक क्षेत्र का लगभग 73 प्रतिशत है। बिहार के कुल 68.80 लाख हेक्टेयर बाढ़ प्रवण क्षेत्र में से 50.45 लाख हेक्टेयर बाढ़ प्रवण क्षेत्र उत्तरी बिहार तथा 18.35 लाख हेक्टेयर बाढ़ प्रवण क्षेत्र दक्षिणी बिहार में पड़ता है। यहाँ की भौगोलिक स्थिति तथा गंगा, कोसी, गंडक, बागमती जैसी प्रमुख नदियों के कारण राज्य को बार–बार बाढ़ की विभीषिका का सामना करना पड़ता है।
4. बाढ़ के संरचनात्मक प्रबंधन हेतु जल संसाधन विभाग द्वारा नदियों पर तटबंधों का निर्माण एवं मरम्मति/रखरखाव तथा आवश्यक बाढ़ सुरक्षात्मक कार्य कराया जाता है। बिहार राज्य में विभिन्न नदियों पर लगभग 3800.41 किलोमीटर तटबंध का निर्माण किया जा चुका है, जिसमें 3606.02 किलोमीटर उत्तर बिहार

तटबंधों के निर्माण से कुल 39.96 लाख हेक्टेयर क्षेत्र को बाढ़ से सुरक्षित किया गया है।

5. राज्य अंतर्गत प्रथम चरण में Flood Plain Zoning तटबंधित नदियों के लिए लागू करने का निर्णय लिया गया है। गैर तटबंधित नदियों के लिए Flood Plain Zone के निर्धारण हेतु आवश्यक अध्ययनोपरान्त अग्रेत्तर कार्रवाई की जायेगी।

6. उपर्युक्त वर्णित परिपेक्ष्य के दृष्टिगत राज्याधीन तटबंधित नदियों के लिए Flood Plain Zone का निर्धारण निम्नवत् किया जाता है:–

   (क) जिन नदियों के दोनों किनारों पर तटबंध निर्मित है, उन नदियों के लिए दोनों किनारे पर निर्मित तटबंध के मध्य के क्षेत्र को Flood Plain Zone निर्धारित किया जाता है।

   (ख) जिन नदियों के एक हीं किनारे पर तटबंध निर्मित है, उन नदियों के लिए तटबंध से लेकर नदी की चौड़ाई होते हुए नदी के दूसरे किनारे से 500 मीटर तक की चौड़ाई के क्षेत्र को Flood Plain Zone निर्धारित किया जाता है।

   (ग) उपरोक्त कंडिका– क एवं ख में निर्धारित Flood Plain Zone को Prohibited Zone अंतर्गत रखा गया है।

7. (क) Prohibited Zone में निम्नांकित गतिविधियां अनुमान्य होगी :–
   - i. पारंपरिक जैविक और प्राकृतिक खेती, जिसमें किसी भी प्रकार के कृषि रसायन या भारी मशीनरी का उपयोग न हो।
   - ii. पार्क, खेल के मैदान, बगीचे, मनोरंजक गतिविधियाँ आदि, जिनमें किसी स्थायी संरचना का निर्माण/अधिष्ठापन न हो।
   - iii. पारंपरिक मछली पालन, जिसमें रसायनों, विषाक्त पदार्थों, विस्फोटकों या बिजली के कनेक्शन का उपयोग न हो।
   - iv. पशुओं को चराने हेतु चारागाह।
   - v. घरेलू तथा अन्य गैर–व्यावसायिक उपयोग के लिए हैन्डपंपों से भूजल की निकासी।
   - vi. संबंधित सक्षम प्राधिकार से अनुमति लेकर डिफेन्स संबंधित अस्थाई/चलंत संरचनाओं का निर्माण।
   - vii. बाढ़ सुरक्षा संबंधित संरचनाओं का निर्माण।
   - viii. आवश्यक सेवाओं के लिए निर्माण जैसे गैस/पेट्रोलियम पाइपलाइन, बिजली लाइन ट्रांसमिशन टावर, जल आपूर्ति पाइपलाइन, पुल और बैराज।

ix. प्राकृतिक आपदाओं और आपदा प्रबंधन जैसी विशेष परिस्थितियों के लिए अस्थाई/चलंत संरचनाओं एवं आवासन का निर्माण।
x. शहरों या कस्बों से घरेलू अपशिष्ट जल का उपचारित होकर निर्धारित मानकों के अनुसार निस्सरण।
xi. धार्मिक और सामाजिक–सांस्कृतिक गतिविधियाँ (जैसे कुंभ मेला, पूजा अनुष्ठान आदि) और उनसे संबंधित पूर्ण रूप से अस्थाई/चलंत संरचनाएँ, लेकिन केवल गैर–मानसून मौसम में।
xii. अस्थाई/चलंत घाट एवं रिवरफ्रन्ट के निर्माण।
xiii. पर्यावरण–अनुकूल पर्यटन गतिविधियाँ, जिनमें स्थायी संरचनाओं का निर्माण न हो और प्रकृति अनुकूल प्रैक्टिस जैसे गैर–डीजल मोटरबोट का उपयोग शामिल हो।
xiv. पर्याप्त सुरक्षा के साथ रेलवे के आधारभूत निर्माण जैसे नए तटबंध/पुलों का निर्माण।
xv. स्थानीय वृक्ष/झाड़ का व्यावसायिक उपयोग के लिए वृक्षारोपण।
xvi. पर्यावरण, वन एवं जलवायु परिवर्तन, भारत सरकार के दिशा–निर्देशों तथा राज्य सरकार के समय समय पर निर्धारित नियमों के अनुसार Regulated Sand/ Stone/ sediment/ river borne material mining की अनुमति।
xvii. पूर्व से निर्मित भवनों का अतिआवश्यक मरम्मती का कार्य, परंतु इसमे कोई विस्तारीकरण/नवनिर्माण निषिद्ध होगा।
xviii. STP, Conservation तथा NMCG से संबंधित कार्य।
xix. नदी के वर्तमान किनारे को दृष्टिगत रखते हुए नदी–तट से 250 मीटर के दूरी को छोड़ कर बाकी चौड़ाई में ऐसे पूर्ण रूप से अस्थाई/चलंत भवन, आवास एवं संरचना का निर्माण जो अनफोल्ड कर अथवा यथास्वरूप स्थानांतरित किया जा सके।

(ख) Prohibited Zone मे निम्नांकित गतिविधियाँ प्रतिबंधित होगी:–

i. सभी प्रकार के स्थायी निर्माण।
ii. किसी भी प्रकार की किसी भी मौजूदा संरचना के फर्श क्षेत्र या ऊंचाई में कोई वृद्धि।
iii. ठोस अपशिष्ट का डंपिंग/लैंड फिल का निर्माण।
iv. अत्यधिक अस्थिर, ज्वलनशील, विस्फोटक, विषाक्त पदार्थों का भंडारण।
v. बड़े पैमाने पर वाणिज्यिक या औद्योगिक सुविधाओं की स्थापना।
vi. कंडिका 'क' में उल्लेखित अनुमत गतिविधियों को छोड़कर नदी चैनल के प्राकृतिक मार्ग को बाधित करने वाले निर्माण कार्य।

8. Prohibited Zone में मूलभूत सुविधाएँ यथा स्कूल, अस्पताल, सड़कें तथा आंगनवाड़ी केंद्र इत्यादि को स्थापित करने हेतु अस्थाई/चलंत संरचना, जो

अनफोल्ड/यथास्वरूप स्थानान्तरित किए जा सके को उपयोग में लाया जा सकता है।

9. Flood Plain Zoning के कार्यान्वयन/विनियमन से संबंधित गतिविधियों की निगरानी एवं समन्वय संबंधित जिला प्रशासन द्वारा किया जायेगा। साथ ही Flood Plain Zoning की स्वीकार्यता के उद्देश्य से ग्रामवासियों को तटबंध से बाहर बसने के लिए जिला प्रशासन द्वारा प्रोत्साहित/प्रशिक्षित किया जायेगा। राज्याधीन सभी संबंधित विभागों के जिला स्तरीय पदाधिकारियों द्वारा जिला प्रशासन को Flood Plain Zoning के कार्यान्वयन/विनियमन हेतु सहयोग किया जायेगा।
10. Flood Plain Zoning के कार्यान्वयन की नियमित समीक्षा की जायेगी तथा बदलते पर्यावरणीय एवं सामाजिक–आर्थिक परिदृश्यों के अनुसार इसे सशक्त बनाने हेतु आवश्यक कार्रवाई की जायेगी।
11. उक्त पर माननीय मंत्री का अनुमोदन प्राप्त है।

5/3/25

(संतोष कुमार मल्ल)
प्रधान सचिव
जल संसाधन विभाग

ज्ञापांक–यो०मो०–4 (विविध)07–372/2020 पार्ट–II-143 पटना, दिनांक– 06/3/2025

प्रतिलिपिः–सभी जिला पदाधिकारी को सूचनार्थ एवं आवश्यक कार्रवाई हेतु प्रेषित।

5/3/25

प्रधान सचिव
जल संसाधन विभाग

ज्ञापांक–यो०मो०–4 (विविध)07–372/2020 पार्ट–II-143 पटना, दिनांक– 06/3/2025

प्रतिलिपिः–अभियंता प्रमुख, मुख्यालय/सिंचाई सृजन/बाढ़ नियंत्रण एवं जल निस्सरण, जल संसाधन विभाग, बिहार सरकार को सूचनार्थ एवं आवश्यक कार्रवाई हेतु प्रेषित।

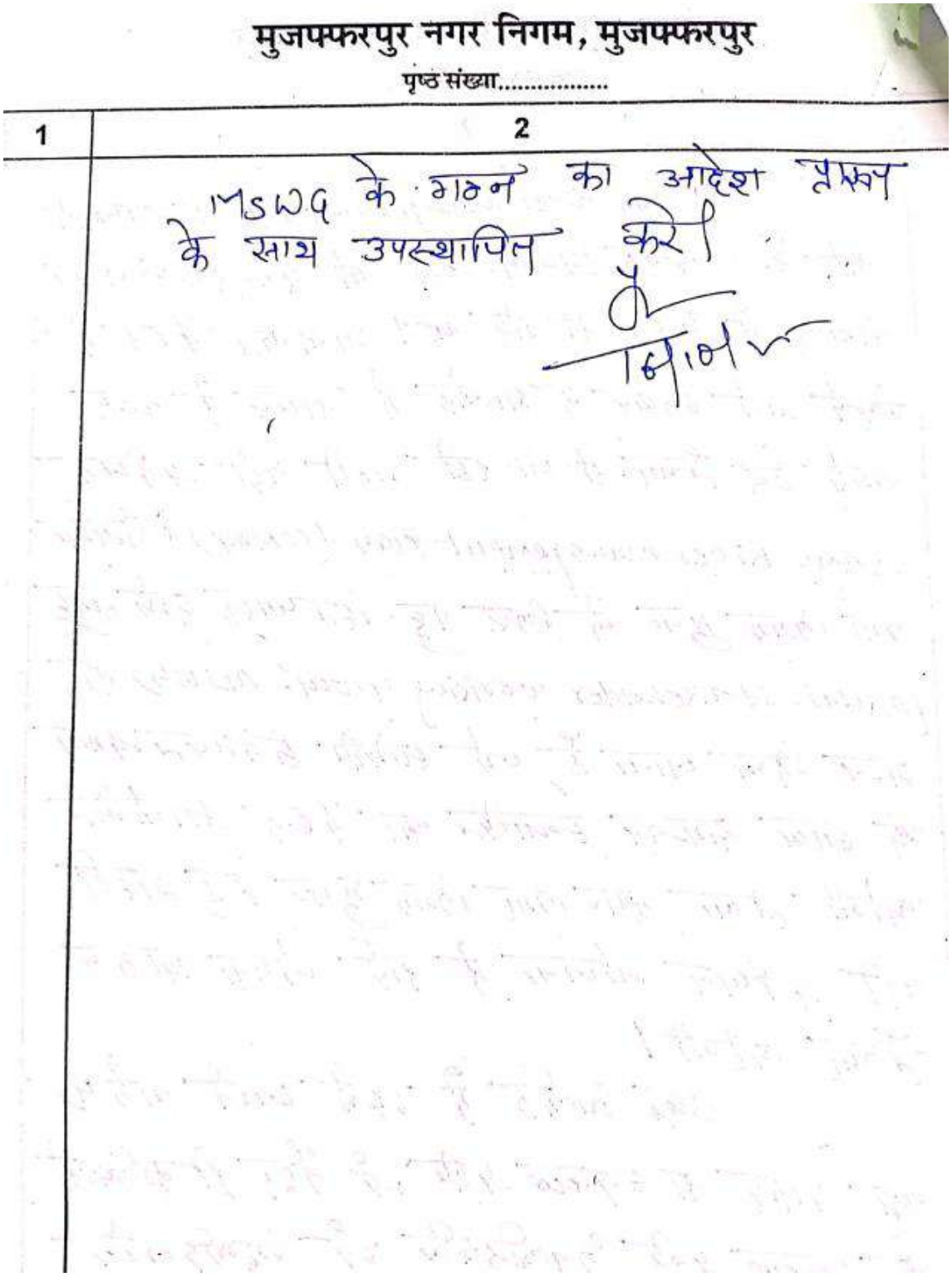
5/3/25

प्रधान सचिव
जल संसाधन विभाग

5.2 Annexure 2- Notification- Formation of Muzaffarpur MSWG

पृष्ठ संख्या.....17.......

1	2	3
	Urban River Management Plan के क्रियान्वयन की बैठक दिनांक 17-09-2025 को प्रधान सचिवालय स्थित सभागार में आहूत की गई थी। आयोजित बैठक के बिन्दु, निर्णय के आलोक में राज्य के बड़े नगरों हेतु तैयार की जा रही शहरी नदी प्रबंधन योजना Urban River Management Plan-(URMP) के अंतर्गत मास्टर प्लान मुजफ्फरपुर के लिए बहु-हितधारक कार्य समूह (Multi-Stakeholder Working Group- MSWG) का गठन किया जाना है, जो समिति से संबंधित विभागों के साथ समन्वय स्थापित कर बैठक आयोजित करेगी तथा मुजफ्फरपुर मास्टर प्लान हेतु शहरी नदी प्रबंधन योजना के कार्य योजना प्रारूप तैयार करेगी।	
	उक्त आलोक में दिये जाने वाले पत्र का प्रारूप का स्वच्छ प्रति एवं बैठक की कार्यवाही के स्वच्छ प्रति अवलोकनार्थ एवं हस्ताक्षरार्थ उपस्थापित।	
	Aadya 14/10/25	
	उप नगर आयुक्त	
	उपरोक्त टिप्पणी के आलोक में बैठक की कार्यवाही एवं 'बहु-हितधारक कार्य समूह (MSWG) का गठन किया जा चुका है।	
	14.10.25	
	नगर आयुक्त बैठक हो चुकी है।	



मुजफ्फरपुर नगर निगम, मुजफ्फरपुर

पृष्ठ संख्या.....

1	2
	MSWG के गठन का आदेश प्रस्ताव के साथ उपस्थापित करें।

कार्यालय, मुजफ्फरपुर नगर निगम, मुजफ्फरपुर
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पत्रांक– ..... दिनांक ...../2025

कार्यालय आदेश

दिनांक–17.09.2025 को आयोजित बैठक के क्रम में राज्य के छः नगरों हेतु तैयार की जा रही शहरी नदी प्रबंधन (Urban River Management Plan - (URMP) के अंतर्गत नगर निगम, मुजफ्फरपुर के लिए बहु–हितधारक कार्य समूह (Multi-Stakeholder Working Group – MSWG) का गठन किया जाता है। उक्त समिति के सदस्यों का विवरण निम्नवतः–

1. नगर आयुक्त, मुजफ्फरपुर नगर निगम, मुजफ्फरपुर।	–	अध्यक्ष
2. वन प्रमंडल पदाधिकारी, मुजफ्फरपुर।	–	सदस्य
3. जिला सांख्यिकी पदाधिकारी, मुजफ्फरपुर।	–	सदस्य
4. जिला कृषि पदाधिकारी, मुजफ्फरपुर।	–	सदस्य
5. जिला भू–अर्जन पदाधिकारी, मुजफ्फरपुर।	–	सदस्य
6. क्षेत्रीय पदाधिकारी, बिहार राज्य प्रदूषण नियंत्रण पर्षद, मुजफ्फरपुर।	–	सदस्य
7. कार्यपालक अभियंता, लोक स्वास्थ्य अभियंत्रण प्रमंडल, मुजफ्फरपुर।	–	सदस्य
8. कार्यपालक अभियंता, लघु सिंचाई विभाग, मुजफ्फरपुर।	–	सदस्य
9. कार्यपालक अभियंता, पथ निर्माण विभाग, मुजफ्फरपुर।	–	सदस्य
10. कार्यपालक अभियंता, जल संसाधन विभाग, मुजफ्फरपुर।	–	सदस्य
11. कार्यपालक अभियंता, नगर विकास प्रमंडल, नगर निगम, मुजफ्फरपुर।	–	सदस्य
12. परियोजना निदेशक, बुडको, मुजफ्फरपुर।	–	सदस्य
13. सहायक अभियंता, बिहार राज्य जल पर्षद, मुजफ्फरपुर।	–	सदस्य
14. सहायक नगर योजना (टाउन प्लानिंग) पर्यवेक्षक, मुजफ्फरपुर नगर निगम, मुजफ्फरपुर।	–	सदस्य
15. सहायक लोक स्वच्छता एवं अपशिष्ट प्रबंधन पदाधिकारी, मुजफ्फरपुर नगर निगम, मुजफ्फरपुर।	–	सदस्य
16. नगर प्रबंधक, मुजफ्फरपुर नगर निगम, मुजफ्फरपुर।	–	सदस्य

उक्त समिति संबंधित विभागों के साथ समन्वय स्थापित कर बैठक आयोजित करेगी तथा मुजफ्फरपुर नगर निगम, मुजफ्फरपुर हेतु शहरी नदी प्रबंधन योजना के कार्य योजना का प्रारूप तैयार करेगी।

विश्वासभाजन

(विक्रम विरकर, भा.प्र.से.)
नगर आयुक्त,
मुजफ्फरपुर नगर निगम, मुजफ्फरपुर।

5.3 Annexure 3 – Flood susceptibility methodology

Flood susceptibility refers to the intrinsic tendency of a terrain to experience inundation based on its physical, hydrological, environmental, and anthropogenic characteristics. The approach adopted in this study follows a multi-criteria decision analysis (MCDA) framework using the Analytical Hierarchy Process (AHP) integrated with GIS-based weighted overlay analysis. The methodology is structured into two sequential components:

1. Preparation of Flood Susceptibility Map using terrain, hydrological, land surface and proximity-based parameters.
2. Delineation of floodplain by combining the susceptibility output with High Flood Level (HFL) contour and modification using hydraulic barriers such as roads, railway embankments, dams and ghats.

The entire workflow is designed to be technically defensible and suitable for use in EIA studies, urban planning, disaster management plans, and regulatory submissions.

Data Used and Sources

The study utilises only authoritative and standard datasets to ensure the reliability of outputs:

- **Digital Elevation Model (DEM)**
  Source: SRTM Arc 1 Second Global
  Resolution: ~30 m
  Purpose: Terrain analysis, slope, elevation, drainage, TWI
- **Satellite Imagery**
  Source: Landsat 9 OLI, dated 15 November 2025
  Resolution: 30 m
  Purpose: NDVI and LULC preparation
- **Soil Data**
  Source: WRIS India Portal
  Type: Vector thematic
  Purpose: Soil texture and infiltration characteristics
- **River, Road, Railway layers**
  Source: AIILSG
  Type: Vector GIS layers
  Purpose: Proximity analysis and hydraulic barrier identification
- **Contour Data**
  Source: Derived from DEM
  Resolution: 1 m / 5 m interval
  Purpose: Identification of 112 m HFL contour

All datasets were projected to a common coordinate system (UTM, WGS 84 datum) and resampled to a uniform spatial resolution of 30 m to maintain consistency in raster-based analysis.

Pre-processing of Datasets

The DEM obtained from SRTM Arc 1 Second Global was subjected to sink filling to remove spurious depressions using hydrological correction tools. This step is critical for ensuring reliable derivation of hydrological parameters such as flow direction, flow accumulation, drainage network, and TWI. Landsat 9 imagery was radiometrically corrected and atmospherically normalised. Cloud-free scenes were selected and clipped to the study area boundary. Soil and vector layers (river, road, railway) were cleaned for topology errors and clipped to the study area.

All thematic layers were converted into raster format at 30 m resolution for integration in the weighted overlay stage.

Derivation of Flood Conditioning Parameters

Elevation
Elevation was directly derived from the DEM. Lower elevation areas generally exhibit higher flood susceptibility due to gravitational flow accumulation. The elevation raster was classified into five susceptibility classes using natural breaks, where lower elevation zones were assigned higher susceptibility ranks.

Slope
Slope was generated from the DEM using standard slope algorithms in degrees. Gentle slopes favour water stagnation and prolonged inundation, whereas steep slopes promote rapid runoff. Accordingly, slope values were reclassified such that low slope classes received higher flood susceptibility ranks.

Drainage Density
Drainage density represents the ratio of total stream length to the area of a drainage basin. Flow direction and flow accumulation were derived from the DEM, followed by stream network extraction using a suitable accumulation threshold. Sub-watersheds were delineated, and drainage density was calculated for each sub-watershed. The resulting drainage density map was then interpolated and rasterised for spatial analysis. Higher drainage density zones were considered more flood-prone due to increased runoff concentration.

Topographic Wetness Index (TWI)
TWI was derived from the DEM using the equation:
TWI = ln (As / tan β)
Where *As* represents the upslope contributing area and β represents the local slope. Flow accumulation and slope layers were used to compute TWI. Areas with high TWI values indicate zones of water convergence and saturation potential and were therefore assigned higher susceptibility ranks.

Buffer from the River
The river network obtained from AIILSG was used to generate multiple buffer zones (e.g., 0–100 m, 100–250 m, 250–500 m, >500 m). Proximity to river channels directly influences flood exposure. Areas closer to rivers were assigned higher susceptibility rankings.

Land Use Land Cover (LULC)
LULC classification was performed using supervised classification on Landsat 9 imagery. Major classes such as built-up, agricultural land, barren land, water bodies, vegetation, and wetlands were identified. Impervious surfaces such as built-up areas and barren land were ranked higher due to reduced infiltration and increased surface runoff, while dense vegetation areas were ranked lower.

NDVI
NDVI was computed using Landsat 9 bands:
NDVI = (NIR – Red) / (NIR + Red)

Lower NDVI values represent sparse vegetation and higher runoff potential, thus receiving higher flood susceptibility ranks. Higher NDVI areas indicate dense vegetation and improved infiltration, therefore receiving lower ranks.

Soil

Soil texture data from WRIS was reclassified based on infiltration characteristics. Clayey soils with low infiltration capacity were assigned higher susceptibility ranks, while sandy and loamy soils with better drainage characteristics were assigned lower susceptibility ranks.

Buffer from Road and Railway

Road and railway layers from AIILSG were used to generate proximity buffers. These parameters were included not only for susceptibility but also because transport corridors influence surface drainage, obstruct natural flow paths, and create artificial embankments.

AHP-Based Flood Susceptibility Assessment

Flood susceptibility in Muzaffarpur has been assessed using a combination of key parameters:

- Topographic Wetness Index (TWI)
- Drainage Density
- River Proximity (Buffer)
- Elevation and Slope
- Land Use Land Cover (LULC)
- Soil Characteristics
- Vegetation Index (NDVI)
- Road and Railway Buffers

The relative importance of these parameters was determined using the AHP method based on Saaty's pairwise comparison scale.

Table 68 Pairwise Comparison Matrix (Saaty Scale)

Criteria	TWI	Drainage Density	River Buffer	Elevation	Slope	LULC	Soil	Road Buffer	Railway Buffer	NDVI
TWI	1.00	1.00	2.00	3.00	3.00	4.00	4.00	6.00	6.00	5.00
Drainage Density	1.00	1.00	2.00	3.00	3.00	4.00	4.00	6.00	6.00	5.00
River Buffer	0.50	0.50	1.00	2.00	2.00	3.00	3.00	5.00	5.00	4.00
Elevation	0.33	0.33	0.50	1.00	2.00	3.00	3.00	5.00	5.00	4.00
Slope	0.33	0.33	0.50	0.50	1.00	2.00	2.00	4.00	4.00	3.00
LULC	0.25	0.25	0.33	0.33	0.50	1.00	2.00	3.00	3.00	2.00
Soil	0.25	0.25	0.33	0.33	0.50	0.50	1.00	3.00	3.00	2.00
Road Buffer	0.17	0.17	0.20	0.20	0.25	0.33	0.33	1.00	2.00	0.50
Railway Buffer	0.17	0.17	0.20	0.20	0.25	0.33	0.33	0.50	1.00	0.50
NDVI	0.20	0.20	0.25	0.25	0.33	0.50	0.50	2.00	2.00	1.00

Table 69 Normalised AHP Matrix and Derived Weights

Criteria	Weight	% Influence
TWI	0.182	18.20%
Drainage Density	0.182	18.20%
Buffer from the River	0.140	14.00%
Elevation	0.115	11.50%
Slope	0.095	9.50%
LULC	0.080	8.00%
Soil	0.070	7.00%
NDVI	0.060	6.00%
Buffer from Road	0.040	4.00%
Buffer from the Railway	0.036	3.60%
Total	**1.000**	**100%**

The analysis indicates that:

- **TWI and Drainage Density (18.2% each)** are the most influential parameters
- **River buffer (14%)** captures flood exposure along the Burhi Gandak
- **Elevation and slope (~21%)** influence runoff and stagnation
- **LULC, soil, and NDVI** determine infiltration and permeability
- **Infrastructure buffers** act as localised flow barriers

The weighted overlay was used to generate the Flood Susceptibility Index (FSI):

FSI = Σ (Wi × Ri)

The output was classified into five categories: Very Low, Low, Moderate, High, and Very High susceptibility.

5.4 Annexure 4 – Suggested tree/ plant species for riparian buffer and river edge

1. **Native Tree Species (Riparian Buffers / River Edges)**

Support: shade, nesting, thermoregulation, fruit/seed availability, perches for owls & pelicans.

Species (Scientific Name)	*Common Name*	*Habitat Support*

Ficus religiosa	Peepal	Excellent canopy cover; squirrels, birds, owls
Ficus benghalensis	Banyan	Habitat for squirrels, owls, mongoose
Syzygium cumini	Jamun	Fruit attracts birds, deer for shade
Terminalia arjuna	Arjun	Classic riparian stabilizer; tortoise basking shade
Dalbergia sissoo	Shisham	Soil-binding; mongoose & deer shelter
Tamarindus indica	Tamarind	Dense foliage, food for squirrels
Butea monosperma	Palash	Bird attractor (doves, owls nearby)
Bombax ceiba	Semal	Perch/nesting sites for pelicans and owls
Holoptelea integrifolia	Indian Elm	Fast-growing shade, reptile movement corridors
Azadirachta indica	Neem	Chemical-free refuge; owl perches

2. Shrubs & Understory Plants (For Mongoose, Monitor Lizard, Vipers, Deer)

Create cover, hiding spots, prey habitat, and are essential for bioswale edges.

Scientific Name	Common Name	Faunal Benefit
Carissa carandas	Karonda	Dense thorny cover mongoose, small reptiles
Clerodendrum infortunatum	Bhant	Shrub cover for vipers & reptiles
Calotropis procera	Akanda	Good structural cover for reptiles
Dodonaea viscosa	Hopbush	Soil binder; reptile corridors
Lantana camara (native variants only)	Wild sage	Used for mongoose & small mammal shelter (use with caution)
Vitex negundo	Nirgundi	Snake habitat-friendly; stabilizes banks
Woodfordia fruticosa	Dhataki	Dense shrub for reptiles & small mammals
Ziziphus mauritiana	Ber	Fruit for deer, birds

3. Native Grasses (Bioswales / Bank Stabilization / Reptile Habitats)

Provide microhabitats for lizards, snakes, tortoise movements.

Scientific Name	Common Name	Notes
Vetiveria zizanioides	Vetiver	Exceptional for bioswales & soil stabilization
Saccharum spontaneum	Kans grass	Classic riparian grass; reptile habitat
Cyperus rotundus	Nutgrass	Wet–dry transition zones
Desmostachya bipinnata	Kusha grass	Ideal for dry bioswale tops
Phragmites karka	Wild reed	Bird shelter; good for wide swales
Typha angustifolia	Cattail	Wet bioswales and shallow wetlands

4. Wetland & Aquatic Plants (For Pelicans, Tortoise, Amphibians, Waterbirds)

Support fish habitat, prey availability, nesting for wetland birds, and shade/cooling.

Scientific Name	Common Name	Ecological Role
Nymphaea nouchali	Blue water lily	Food & shading for aquatic fauna
Nelumbo nucifera	Lotus	Supports aquatic birds; nesting cover
Hydrilla verticillata	Hydrilla	Fish habitat for pelican feeding
Ludwigia octovalvis	Water primrose	Supports amphibians and reptiles
Ipomoea aquatica	Water spinach	Shallow-water stabilizer
Alternanthera sessilis	Sessile joyweed	Shallow wetland margins
Azolla pinnata	Mosquito fern	Water cover, supports turtles (tortoise)
Salvinia molesta (Native? Use carefully)	Floating fern	Habitat structure, but avoid overgrowth
Ceratophyllum demersum	Hornwort	Pelican feeding grounds (fish nursery)

5. Ground Flora / Herbaceous Plants (Cover for Snakes, Lizards, Mongoose)

Low-growing species that enrich soil, provide cover, and attract insects.

Scientific Name	Common Name	Benefit
Boerhavia diffusa	Punarnava	Ground moisture retention
Evolvulus alsinoides	Shankhpushpi	Ground cover near swales
Asystasia gangetica	Ganges groundcover	Excellent erosion control

Aerva lanata	Mountain knotgrass	Supports reptile ground movement
Leucas aspera	Thumbai	Attracts insects → bird foraging

6. Fauna–Vegetation Compatibility Matrix - summarised

Fauna	Habitat Needs	Best Plant Types
Monitor Lizard	Open sun + shrub cover	Shrubs, vetiver, Terminalia arjuna
Barking Deer	Shade + fruit	Ficus spp., Syzygium, Ziziphus
Palm Squirrel	Trees with canopy	Ficus, Neem, Tamarind
Mongoose	Dense shrubs	Carissa, Vitex, Hopbush
Tortoise	Wetland fringe, basking spots	Arjuna, Typha, lotus, lilies
Russell's Viper	Thick undergrowth	Kans grass, Vetiver, Nirgundi
Spot-billed Pelican	Wetlands + fish habitat	Phragmites, Hydrilla, lotus
Spotted Dove	Tall trees & shrubs	Banyan, Neem, Semal
Indian Eagle Owl	Perches + open ground	Semal, Arjuna, rocky shrub zones

5.5 Annexure 5 – Fauna- vegetation mix suggested

1. Fauna–Vegetation Compatibility Matrix - summarised

Fauna	Habitat Needs	Best Plant Types
Monitor Lizard	Open sun + shrub cover	Shrubs, vetiver, Terminalia arjuna
Barking Deer	Shade + fruit	Ficus spp., Syzygium, Ziziphus
Palm Squirrel	Trees with canopy	Ficus, Neem, Tamarind
Mongoose	Dense shrubs	Carissa, Vitex, Hopbush
Tortoise	Wetland fringe, basking spots	Arjuna, Typha, lotus, lilies
Russell's Viper	Thick undergrowth	Kans grass, Vetiver, Nirgundi
Spot-billed Pelican	Wetlands + fish habitat	Phragmites, Hydrilla, lotus
Spotted Dove	Tall trees & shrubs	Banyan, Neem, Semal
Indian Eagle Owl	Perches + open ground	Semal, Arjuna, rocky shrub zones

2. Comprehensive Species Matrix – Riparian Zones × Multilayer Vegetation Structure

Riparian Zone	Trees (Upper Canopy)	Shrubs (Understory)	Grasses (Bank Stabilizers)	Wetland/Aquatic Species	Groundcover / Herbs	Fauna Supported
PZ-I: Active Channel Zone (0–5 m, waterlogged)	— *(trees usually not planted in active channel)*	— *(not suitable)*	*Cyperus rotundus*, *Scirpus lacustris*	*Typha angustifolia*, *Phragmites karka*, *Nymphaea nouchali*, *Nelumbo nucifera*, *Hydrilla verticillata*, *Ceratophyllum demersum*	*Alternanthera sessilis*, *Ipomoea aquatica*	Pelicans, tortoise, amphibians, fish-feeding birds
PZ-II: Wet Riparian Buffer (5–20 m, moist soils)	*Terminalia arjuna*, *Syzygium cumini*, *Holoptelea integrifolia*	*Vitex negundo*, *Carissa carandas*, *Clerodendrum infortunatum*	*Vetiveria zizanioides*, *Saccharum spontaneum*	*(Occasional overflow zone) Typha*, *Phragmites*	*Boerhavia diffusa*, *Evolvulus alsinoides*	Monitor lizard, tortoise, vipers, mongoose, deer
PZ-III: Mid Riparian Slope (20–50 m, well-drained)	*Ficus religiosa*, *Ficus benghalensis*, *Azadirachta indica*, *Bombax ceiba*	*Dodonaea viscosa*, *Woodfordia fruticosa*	*Desmostachya bipinnata*, *Vetiveria*	—	*Asystasia gangetica*, *Evolvulus alsinoides*	Owls, doves, palm squirrels, mongoose
PZ-IV: Upland Dry Buffer (50+ m toward urban edge)	*Tamarindus indica*, *Ziziphus mauritiana*, *Butea monosperma*	*Calotropis procera*, *Aerva lanata*	*Desmostachya bipinnata*, *Dichanthium annulatum*	—	*Boerhavia diffusa*, *Leucas aspera*	Spotted dove, deer, mongoose, small mammals

3. Layer-Wise Integration Summary (Cross-Mapping)

Vegetation Layer	Primary Zones Used	Representative Species	Ecological Functions
Tree Layer	PZ-II, PZ-III, PZ-IV	*Ficus religiosa*, *Terminalia arjuna*, *Azadirachta indica*, *Syzygium cumini*, *Ziziphus mauritiana*	Shade, perches for owls/pelicans, seed sources, canopy linkage
Shrub Layer	PZ-II, PZ-III, PZ-IV	*Vitex negundo*, *Carissa carandas*, *Dodonaea viscosa*, *Woodfordia fruticosa*	Refuge for reptiles, mongoose habitat, bank reinforcement
Grass Layer	PZ-I, PZ-II, PZ-III	*Vetiveria zizanioides*, *Saccharum spontaneum*, *Desmostachya bipinnata*, *Cyperus rotundus*	Bioswale stabilisation, erosion control, reptile microhabitats
Wetland/Aquatic Layer	PZ-I, lower PZ-II	*Typha angustifolia*, *Phragmites karka*, *Nymphaea nouchali*, *Nelumbo nucifera*, *Hydrilla*	Habitat for pelicans, turtles, amphibians; water filtration
Groundcover Layer	PZ-II, PZ-III, PZ-IV	*Boerhavia diffusa*, *Evolvulus alsinoides*, *Asystasia gangetica*, *Leucas aspera*	Soil protection, insect attraction, and foraging for ground birds

PHASED RESTORATION STRATEGY — TABLE FORMAT (1–3–5–10 YEAR CYCLE)

Phase	Timeline	Objectives	Key Activities / Actions
Phase 1	0–1 Year	Initial Stabilization	• Invasive species removal (Prosopis, Ipomoea, Lantana non-native) •Soil preparation, mulching, contouring •Establish wetland strip (Typha, Phragmites, lilies) •Pilot planting of shrubs & grasses •Install habitat structures (rocks, logs for reptiles) • Temporary fencing for protection
Phase 2	1–3 Years	Establishment of Vegetation	•Full-scale multilayer planting (trees, shrubs, grasses) •Expand bioswale grass systems •Create habitat corridors •Add perching poles, rock piles, basking mounds • Survival monitoring & monsoon replanting
Phase 3	3–5 Years	Habitat Structuring	•Canopy developing in PZ-III & PZ-IV •Wetland vegetation fully rooted • Understory shrubs forming thickets (refuge for reptiles/mongoose) •Increased pollinator activity • Early bird nesting and faunal return
Phase 4	5–10 Years	Ecological Maturity	•Full canopy closure and soil stabilization •Reptile, amphibian, mammal populations stabilize •Predator species return (owls, mongoose) •Hydrological balance improves (reduced erosion) • Community stewardship & low-maintenance regime

COMPREHENSIVE TABLE — Maintenance Plan + KPIs

Phase / Year	Maintenance Actions	Monitoring Indicators	Key Performance Indicators (KPIs)
Year 0–2 (High Maintenance)	• Weed control every 2 months • Mulching & watering in dry periods • Replace plant mortality >30% • Protect wetland plantations from trampling • Strengthen fencing & signage	• Monthly plant survival survey • Soil moisture check • Wetland vegetation establishment • Photographic documentation	Vegetation: >70% survival of planted species Wetland: 60–70% establishment of Typha/Phragmites Hydrology: Initial reduction in bank erosion visible by Year 2 Fauna: Early sightings of amphibians, small reptiles
Year 2–5 (Moderate Maintenance)	• Grass cutting twice a year • Light de-silting of wetlands once a year • Annual soil testing • Enrichment planting where needed • Repair habitat structures (logs, rocks)	• Annual vegetation density survey • Water quality sampling • Wetland depth & turbidity check • Faunal presence tracking	Vegetation: 60% shrub thicket formation Grasses: >80% bioswale grass cover Hydrology: 10–15% reduction in sediment load Fauna: Return of monitor lizard, mongoose, and increased bird foraging
Year 5–7 (Low Maintenance)	• Annual pruning & canopy health check • Wetland health audit • Community stewardship monitoring • Removal of any invasive recolonization	• Canopy closure measurement • Annual faunal diversity count • Community participation log	Vegetation: Full canopy development in PZ-III & PZ-IV Wetland: Stable hydrology Fauna: Return of predators such as eagle owl & mongoose Community: 100+ volunteers; zero-dumping compliance
Beyond Year 10 (Sustained Stewardship)	• Minimal maintenance • Focus on monitoring ecological performance • Continued citizen science programs	• Long-term biodiversity index • Riparian bank stability index • Water retention capacity	Vegetation: Stable native ecosystem Fauna: Balanced trophic structure Socio-ecological: Active community-managed riparian corridor

END OF REPORT