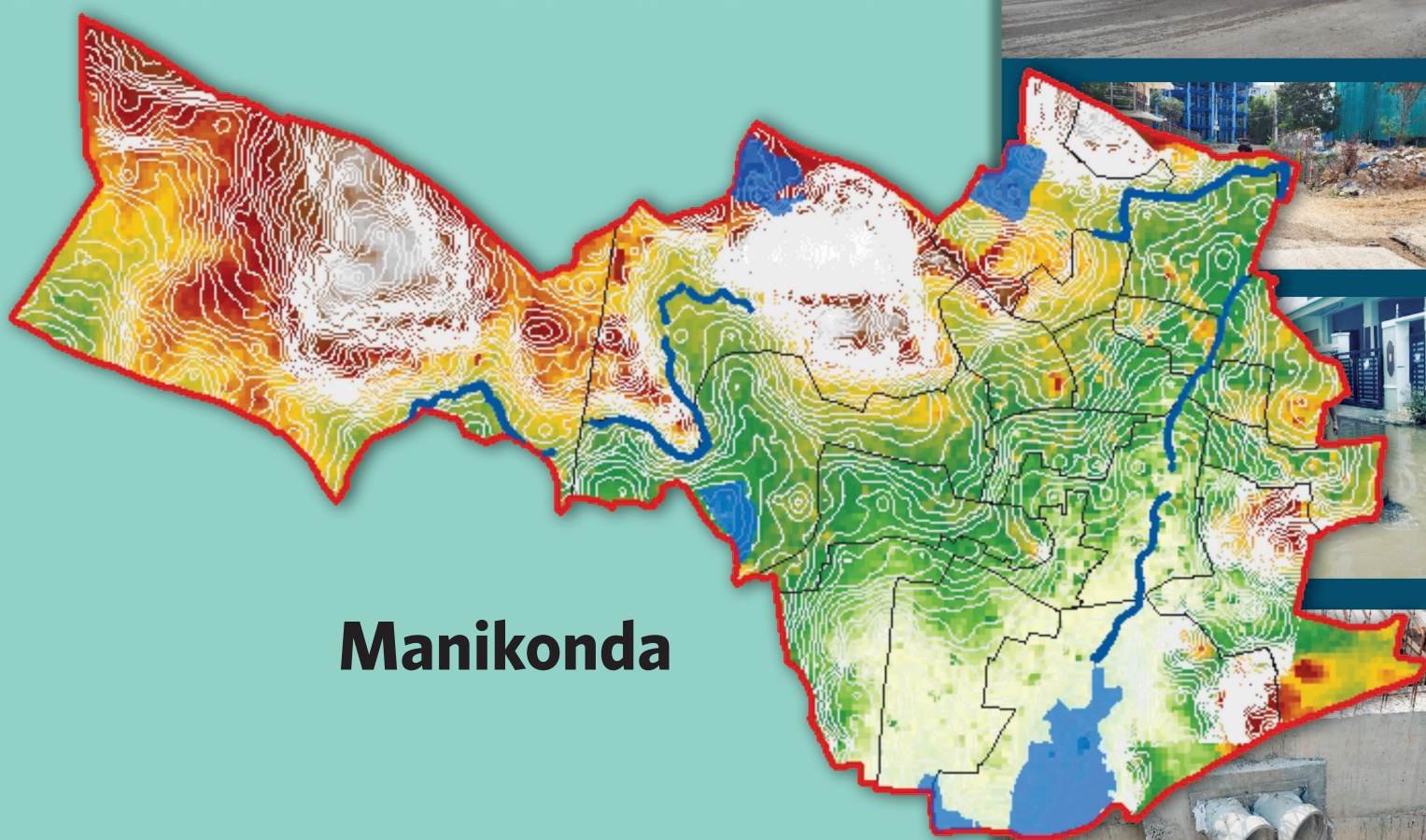




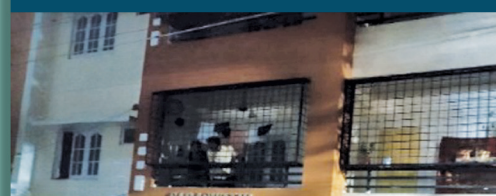
Resilient India - Disaster free India



Development of Flood Risk Assessment Framework and a Roadmap for Making Cities Resilient



Manikonda





Development of Flood Risk Assessment Framework and a Roadmap for Making Cities Resilient

Manikonda

National Institute of Disaster Management

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Development of Flood Risk Assessment Framework and a Roadmap for Making Cities Resilient: Monikonda

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FOREWORD

Urban flooding has become one of the most pressing challenges confronting India's rapidly growing cities. With changing climate patterns intensifying extreme weather events and unplanned urbanization straining existing infrastructure, flood risks have escalated dramatically—impacting millions of lives, livelihoods and critical urban systems. In this context, the need for robust, science-based flood risk assessment and resilient urban planning has never been more urgent.

National Institute of Disaster Management (NIDM) is committed to strengthening the country's disaster preparedness and resilience through research, capacity building and strategic partnerships. This study on Flood Risk Assessment and Roadmap for Making Cities Resilient: Case Study of Manikonda, undertaken in collaboration with the Resilience Innovation Knowledge Academy (RIKA), Walter P Moore and IIT Guwahati, represents a significant milestone in advancing India's urban flood resilience agenda.

The study has been carried out as part of the NIDM-GIZ grant agreement on "Enabling Cities on Disaster Risk Reduction (DRR) and Climate Change Adaptation (CCA) for Sustainable Urban Development in India", a sub-project under the Sustainable Urban Development – Smart Cities II (SUDSC-II) programme. This initiative is jointly implemented by GIZ and

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Ministry of Housing and Urban Affairs (MoHUA), Government of India on behalf of the German Federal Ministry for Economic Cooperation and Development (BMZ).

Manikonda City is facing increasing vulnerability to urban flooding—a complex challenge that threatens lives, livelihoods, infrastructure and overall urban resilience. This comprehensive study offers timely and critical analysis of the city’s flood vulnerabilities. It highlights several pressing issues—including drainage obstructions caused by construction debris and encroachments on major water channels. The study not only assesses these risks in detail but also provide need of proactive infrastructure planning and risk-informed development. It underscores the importance of integrating data-driven approaches with established national guidelines such as those issued by NDMA, and global frameworks like the Sendai Framework for Disaster Risk Reduction. The findings and recommendations presented in this study will serve as a valuable resource for policymakers, urban planners, disaster managers, and all stakeholders involved in building resilient cities.

I hope that this work will encourage continued collaboration and commitment toward safeguarding India’s urban future from the risks of floods and other disasters.

I congratulate the entire team for their dedication and insightful contributions and encourage all cities to adopt and adapt these learnings to strengthen their disaster preparedness.



(Madhup Vyas)

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(Dr. Garima Aggarwal)

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ABBREVIATIONS

BIS	Bureau of Indian Standards
BL	Base Line
CBOs	Community Based Organisations
CCA	Climate Change Adaptation
CSR	Corporate Social Responsibility
DDMPS	District Disaster Management Plans
DA	Drainage Area
DM	Disaster Management
DRM	Disaster Risk Management
DRR	Disaster Risk Reduction
DSS	Decision Support System
EIA	Environmental Impact Assessment
FGD	Focus Group Discussions
HRVA	Hazard Risk and Vulnerability Assessment
KII	Key Informant Interview
GIS	Geographic Information System
GHMC	Greater Hyderabad Municipal Corporation
GPS	Global Positioning System
HFL	High Flood Level
ICT	Information and Communication Technology
IDF	Intensity-Duration-Frequency
IoT	Internet of Things

IMD	India Meteorological Department
LIDAR	Light Detection and Ranging
MAH	Major Accident Hazard
MIS	Management Information System
MLD	Million Liters Per Day
NDMA	National Disaster Management Authority
NDMP	National Disaster Management Plan
NbS	Nature-based Solution
NGO	Non-governmental Organisation
PPP	Public-Private Partnerships
UAV	Unmanned Aerial Vehicle
SDMP	State Disaster Management Plan
SDGs	Sustainable Development Goals
SDMP	State Disaster Management Plan
SFDRR	Sendai Framework for Disaster Risk Reduction
SHGs	Self-Help Groups
SIA	Social Impact Assessment
SNDP	Strategic Nala Development Programme
TPD	Tonnes Per Day
WSEL	Water surface elevation level

EXECUTIVE SUMMARY

Flooding has emerged as a critical challenge in India, affecting over 40 million hectares of flood-prone regions across states and union territories, with significant economic impacts. Rapid urbanization and climate change have exacerbated flood risk by intensifying precipitation, altering soil and vegetation conditions and impacting drainage capacities. Recent extreme events, such as the 2023 Delhi floods and the 2022 Bengaluru Flood, illustrate how rapid urban expansion, inadequate planning and human intervention have weakened urban resilience. In response, the National Disaster Management Authority (NDMA) established guidelines for a more proactive approach to urban flooding management, focusing on disaster preparedness, resilience-building, and policy alignment with frameworks such as the Sendai Framework for Disaster Risk Reduction (SFDRR).

This study, commissioned by the National Institute of Disaster Management (NIDM) and implemented by the Resilience Innovation Knowledge Academy (RIKA) in collaboration with Walter P Moore and IIT, Guwahati, aimed to develop a Flood Risk Assessment Framework and a Roadmap for resilient city planning. It is a stepping stone to bolster the flood resilience of urban centres in India through activities ranging from the development of a flood risk assessment framework, undertaking detailed consultations and surveys to identify capacity gaps, development of responsibility matrices, capacity building exercises and identifying suitable recommendations for future development. Focusing on the city of Manikonda (Telangana), the study assessed the unique urban flood challenges, existing capacity, and opportunities for mitigation and adaptation, addressing policy gaps, climate vulnerabilities, and infrastructure deficiencies. This is significant as the city has been experiencing multiple incidents of urban flooding over the years. Through consultations and sample surveys it was observed that, the city faces flood risks due to dumping of waste in drainage network, excess of construction and demolition waste and urban encroachment. Lack of robust city-specific disaster management frameworks further exacerbates the threat to infrastructure, livelihoods, and public health.

The methodology designed for this flood risk assessment project emphasized an inclusive approach integrating hydrological and hydraulic modelling with stakeholder insights. Primary and secondary data were sourced from multiple channels, including historical rainfall records, topographic data, and past flood incidents. A Systematic Literature Review (SLR) provided a foundation of knowledge on urban flood patterns, climate impacts, and risk management strategies specific to the Indian context. Stakeholder engagement and local consultation meetings were held with municipal officials, development authorities, disaster management authorities, community leaders and vulnerable population representatives. In Manikonda, residents from high-risk zones (like Panchavati Colony, Sai Gautham Colony, Spectrum Villas) participated, sharing ground realities on drainage issues and community awareness. Gender and Social Inclusion (GESI) integration for inclusion of the vulnerable demographic groups (e.g., women, elderly, disabled) were identified, and their unique needs were incorporated into the data collection, and planning process, ensuring that flood mitigation efforts are equitable and comprehensive. In light of projected climate change impacts, it was realized

that the city requires a strong framework that integrates modern data-driven methodologies for comprehensive flood risk mitigation.

Using HEC-RAS 1D modelling, the study analysed water surface elevations, depth, and extent of inundation for different storm return periods (10-years, 25-years and 100-years) and climate change scenarios. This provided an understanding of future flood risks for Manikonda through assessments under projected climate change scenarios. Soil hydrological groups (e.g., HSG-C/D with high runoff unless drained) were assessed, offering insight into water retention capacity and drainage functionality. Specific drainage channels (nallahs) were evaluated to identify flood hotspots and obstructions from encroachments or silt build-up. Intensity-Duration-Frequency (IDF) curves were analysed for Manikonda to project rainfall impacts over different return periods. The study assessed how future rainfall patterns could worsen urban flood risks in light of climate change, especially in high-density residential areas with limited natural drainage.

Stakeholder capacities and gaps were assessed by Key Informant Interviews (KIIs) with government officials and the community to assess local capacities for flood management and response. The study identified that there are staff for response and relief but there is potential for improvement on aspects of waste management mechanisms; training of staff in disaster risk management, nature-based solutions, maintenance of drainage systems; awareness campaigns with vulnerable communities; mobilizing volunteer networks, and participation from NGOs and SHGs. Risk communication and early warning mechanisms were assessed by reviewing current methods and technologies, such as the reliance on Twitter for flood updates was highlighted by the Manikonda municipality.

Findings from Manikonda reveal the specific gaps in flood risk mitigation. A deeper look into the specific findings suggests that in Manikonda drainage obstructions caused by construction and demolition waste, encroachment on drainage channels, particularly around Sheikhpeth nallah (referred to as Nallah-1 in the study), limit water flow, causing challenges during heavy rain. Key hotspots like Panchavati Colony and Spectrum Villas experience recurrent flooding due to blocked drains, and inadequate drainage channel sizes. Flood return period analysis using hydraulic modelling for different flood return periods (10-years, 25-years, and 100-years) reveals that certain areas, such as Aparna Zenon, are affected under extreme scenarios. In the 100-years return period, flooding extends to new zones, highlighting the need for proactive flood management in vulnerable areas. Main roads and access roads such as Lanco Hills Lake Road and Golden Temple Road are frequently submerged, thus disrupting transportation. One major hospital, Shobha Hospital, lies close to a flood zone, increasing risks of disruption in essential healthcare services. Public awareness and institutional support are limited and inadequate hindering the effectiveness of flood response. While social media (mainly Twitter) is used for updates, there is no structured system to disseminate early warnings through broader, more accessible channels. The low engagement of Community-Based Organisations (CBOs) and Self-Help Groups (SHGs) were reported by both municipal offices and households. The assessment highlights minimal participation of SHGs and women's networks in flood management efforts, particularly in awareness campaigns and relief support. According to the data from consultations frequent cases of diseases (e.g., malaria, cholera) in flooded areas, especially in high-density wards like 10, 15 and 16. The absence of adequate sanitation and health infrastructure heightens vulnerability to disease outbreaks, especially water-borne diseases.

The data analysis suggests an increased water surface extents for the 100-years return period storm events and under climate change conditions. This trend indicates that current stormwater infrastructure and drainage systems need to be strengthened to handle future climate impacts. A recurring theme across the wards of the city is limited participation of NGOs, SHGs and volunteer networks in flood response and management. Limited waste management and lack of comprehensive sewerage systems contribute to heightened public health risks. Additionally, community awareness campaigns are rare, especially on topics like waste segregation and sanitation, which are critical to reducing flood risks. Based on the findings, there is a need for critical interventions in the flood resilience planning of the urban system of Manikonda. This can be achieved by formulating phase-wise key recommendations laid down. The following give a brief summary of the general and city-specific recommendations for short (0-2 years), medium (2-5 years) and long (5-10 years) terms.

MANIKONDA

Short-term Recommendations

- Install Advanced Warning Systems (AWS) in flood-prone areas for timely alerts. Prioritize installation of AWS in high-risk wards 1, 3, 7 and 17.
- Mentorship of municipal staff by C&D waste management experts for advisory and hand-holding support on the improvement of waste management.
- Regular aerosol spraying and channelization of stagnant water bodies in the city to prevent malaria spread.
- Identify volunteer groups in each ward to undertake capacity-building activities on flood risk management, solid waste management, etc.
- Initiate interventions and improvement in solid waste management practices; hence policy guidelines/SOPs should be in place to address safe collection, handling, and disposal.

Medium-term Recommendations

- Preparation of water management plan with reference to existing water bodies (including health of water bodies etc.) in wards 3, 7 and 12 and integrate with urban planning projects.
- Develop ward-level disaster management plans with clear roles for municipal staff, SHGs and community volunteers.
- Mobilize SHGs, Accredited Social Health Activists (ASHA) and Auxiliary Nurse Midwives (ANMs) and Resident Welfare Associations (RWAs) to head the flood risk awareness and monitoring in localities as they hold influence over residents and can support grassroots-level outreach.
- Launch departmental capacity needs assessment and develop training programs for staff on flood risk management.

Long-term Recommendations

- Ensure appropriate land use planning using detailed zonation is undertaken guided by micro-zonation studies.
- Establish dedicated emergency funds within ward offices that can lead to involving communities in budgeting processes to ensure funds are allocated to the most needed flood resilience projects.
- Prepare guidelines for retrofitting government workplaces to be flood-resilient, ensuring businesses can continue operations during floods.
- Promote preparation of periodic environmental and social impact assessment reports of development projects.

The future of disaster resilience in Manikonda hinges on a coordinated, multi-stakeholder approach that incorporates community awareness, infrastructure improvement, and robust policy frameworks. Policy makers and decision-makers could consider the phase-wise recommendations for improving the overall resilience of the city. Implementing the recommended actions within the designated timelines will enhance urban resilience to future climate impacts, support sustainable growth, and protect critical infrastructure. This could be achieved by prioritizing and focusing on low-performing parameters through targeted action plans. Besides, the good aspects could be further strengthened and to showcase good practices. Further, comprehensive flood mitigation master plans could also be formulated in this regard. Municipal authorities are encouraged to initiate these changes in collaboration with state agencies, NGOs, and local communities, leveraging the outlined responsibility matrix to ensure accountability and sustained action.



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1

INTRODUCTION

1.1 BACKGROUND

India is geographically located in a high disaster-prone region and has been under the continuous impact of natural hazards, which include floods, cyclones, landslides, earthquakes, heatwaves and tsunamis. In India, out of 28 states and 8 union territories, around 27 are disaster-prone and more than 40 million hectares (mha) out of 329 mha of India is flood-prone (NDMA, 2019). A total of 5,161 urban local bodies are prone to urban flooding. (NDMA, 2023). Recent years have seen severe cyclonic activity in the Arabian Sea and Bay of Bengal due to global warming leading to concentrated heavy rainfall leading to urban floods. Some of the most devastating floods like in Mumbai (2005), Chennai (2015) and Srinagar (2014) were caused by periods of intense rainfall. Additionally, human intervention in the environment creates a greater chance of urban floods. Rapid development and change in land use directly influence the vegetation cover and slow down water flow, reduce water-retention capacity, etc leading to increased chances of urban flooding. Urban flood increases the flood peaks from 1.8 to 8 times and flood volumes by up to 6 times. Every year an estimated damage to houses and public utilities of Rs. 1805 crores is caused due to floods only (NDMA, 2019). Despite urban flooding being a problem for decades, there has been insufficient attention paid to planning specific initiatives to address it. The Mumbai floods of 2005 paved the way for specific actions and guidance for urban flooding in India. Because of the extent of the disruption caused by these urban floods, the authorities realized that many factors contribute to urban flooding, necessitating the development of effective response plans. National Disaster Management Authority (NDMA) developed the National Guidelines for the Management of Urban Flooding in order to enhance national efforts to manage urban flood disasters and fortify the goal of adopting a more proactive, mitigation-focused approach to pre-disaster preparedness.

Intergovernmental Panel on Climate Change (IPCC) Report suggests an increase in the number of extreme disaster events in India. Now not only more disasters are occurring, but they are also getting more complex and multifaceted. Some of the recent urban flooding incidents were in Hyderabad in 2020 and 2021, Delhi in July 2023, Bengaluru and Ahmedabad in 2022, and Chennai in November 2021 (Singh, 2022). Hyderabad faced over 33 life losses in the 2020 floods (Somasekhar, 2020), Bengaluru experienced a stoppage of water supply in many parts during the 2022 floods as pumping stations were completely submerged and in Delhi over 25,000 people had to be relocated during July 2023 floods (Sphere India, 2023). These events have caused irreparable damage to life, property, livelihoods, and infrastructure. Such flooding events can be linked to the rapid growth in urbanization, anthropogenic impacts on the environment like construction on the beds of rivulets, rivers, and lakes, encroachment on natural drainage etc. For instance, the built-up cover has increased by 41% in 0-20 km of the city center in Hyderabad and by over 65% in 0-20 km of the city centre in Bengaluru between a span of only 15 years between 2000 to 2015 (WRI, 2020). This has led to a major challenge of decreased water-retention capacity thus exacerbating the risks of flooding.

Rapid population expansion has intensified the demands on infrastructure services in Indian cities, of which many are already operating beyond their capacity. In Tier II cities like Guwahati and Pune increased imperviousness, siltation and surface runoff attribute to urban flooding incidents (Sarmah, 2018; Kumar, 2021). Imperviousness is increased by features such as paved spaces like large parking lots, roads and underpasses that lead to frequent and severe waterlogging. Instances of overwhelmed drainage systems, uncontrolled dumping of solid waste and increased wastewater discharged into existing stormwater drains/rivers can lead to disruption of the flow of waste water and reduced carrying capacity. Such incidents have occurred in the past leading to flooding and epidemics during the monsoon in cities like Siliguri (Sarmah, 2018).

The projected impact of climate change like altered frequencies and severity of hydro-meteorological hazards such as floods are giving rise to complex and cascading urban risks in the cities. It is aggravated by the pressure of urbanization on cities. Under such complex risk scenarios, fragile urban systems often break in, triggering cascading impacts on other inter-connected urban systems and services. The increasing incidence of climate change-induced events has compounded urban challenges, manifesting in recurrent flooding and exacerbated urban heat island effects. Thus, there is a need for an evidence-based framework that undertakes a holistic and multi-dimensional systems approach to understand and manage evolving flood risks being faced by Indian cities. There is also significant potential in a comprehensive assessment of urban flood risks due to limited consideration of critical aspects such as operational concepts, structural evolution of urban flood resilience, and benefits of nature-based solutions (NbS) like green infrastructure design in past assessments (Prashar et. al., 2023).

The Sustainable Urban Development Smart Cities II (SUDSC-II) project is being jointly implemented by GIZ on behalf of the German Federal Ministry of Economic Cooperation and Development (BMZ) and Ministry of Housing and Urban Affairs (MoHUA). The project aims to develop climate-induced disaster-resilient sustainable habitats. It supports MoHUA and partner cities in resilient, sustainable approaches and solutions for urban development including infrastructure that considers Disaster Risk Management (DRM) and the leave-no-one behind principle. Through the sub-project 'Enabling cities on Disaster Risk Reduction (DRR) and Climate Change Adaptation (CCA) for Sustainable Urban Development in India' under SUDSC-II) National Institute of Disaster Management (NIDM) has assigned the task of conducting a study on 'Development of Flood Risk Assessment Framework and a Roadmap for Making Cities Resilient' to the consortium of Resilience Innovation Knowledge Academy (RIKA) India Pvt. Ltd., Walter P. Moore (WPM) and Indian Institute of Technology Guwahati (IIT-G). This project was undertaken in two cities: Guwahati and Manikonda.

In collaboration with the municipal offices at Manikonda, the current study engaged departments set up to maintain various services in the city, like urban local bodies, town planning and allied departments to understand their capacities for management of flood risks. After analysis of existing datasets and reports on urban flooding, planning and rainfall patterns flood risk at ward and zonal levels within the city was assessed. Multiple rounds of stakeholder consultations at Manikonda and the NIDM office, in Delhi were conducted. It was identified that, historically, flood disaster management strategies were mostly focused on riverine floods, but it was recognized that the

causes of flooding in Manikonda is due to excessive concretization and change of land use. It was observed that the overall resilience of the community has weakened as a result of the effects of population expansion and environmental deterioration. It suggested that the only appropriate course of action to mitigate and manage the potential effects of disaster and climate change is through the integration of disaster risk reduction and climate change adaptation into development initiatives. This has to be done in all varied sectors and in all development projects and programmes across these crucial sectors. This study was developed based on the existing challenges and capacities to provide a set of actionable recommendations.

1.2 OBJECTIVES

With the overall aim of enhancing the capacities and building the resilience of urban centres against climate and disaster risks, particularly those of floods, the following are the key objectives of the current assignment:

- 1 Developing a flood risk assessment framework for Indian cities
- 2 Developing a roadmap for building the resilience, particularly to urban floods

1.3 SCOPE AND LIMITATIONS

The current study aims to achieve the broad outcome of enhancing the resilience of cities against urban flood risks. In this regard, the project team was required to develop a flood risk assessment framework, a roadmap for building resilience, particularly to urban floods, a training module on the risk assessment towards flood mitigation and imparting training(s) for the relevant stakeholders from the identified cities/states. The scope of work under the assignment includes:

- 1 Background study & study area profiling — Review of literature, policy documents, relevant stakeholders, existing datasets, tools development (literature informed)
- 2 Flood risk assessment in study area — Underlying causes, hydraulic and hydrologic analysis, ground truthing, conditions of vulnerability of population & assets in hotspots, experience & capacity of local governance, existing initiatives, potential solutions
- 3 Roadmap setting & capacity building — Evidence-based Flood Risk Assessment (FRA) framework, recommendations on risk management, a roadmap for resilience building, training/capacity building sessions on developed resources

The study has a specific focus on floods, particularly urban floods in the study areas of Manikonda. Manikonda municipality comprises areas of Manikonda Jagir & Pupalaguda under the Rajendranagar Mandal and formed a municipality only in 2019. It is a fast-developing commercial hub marked with multiple lakes, and wetlands and is a suburban area near Hyderabad, Telangana. Details of the study areas are shared in Figure 1. This study will help to promote and localize some of the priorities for action laid down under the Sendai Framework for Disaster Risk Reduction (SFDRR).

The study is fast-paced and short-term study which included the collection of specific primary and secondary information and datasets. Some significant limitations and measures undertaken for them were:

- Lack of unavailability of recent datasets with the urban local bodies. Some data from secondary sources were used to fill data gaps, however being a new municipal body not many secondary resources are available for Manikonda. Consultations and reports were relied on for the latest information.
- Few datasets could not be used due to resolution and accuracy challenges. E.g. coarse resolution soil data, inadequate information on invert levels, outfall locations etc. The best available datasets were used in these cases.
- The reluctance of the community to share information. Data gaps were filled from information available in secondary sources like published reports, plans etc.
- Due to the short duration of study, the most suitable 1D modelling was used to obtain results. A detailed topographical survey, higher resolution HEC-RAS modelling and household survey of the entire city could be explored in future interventions.

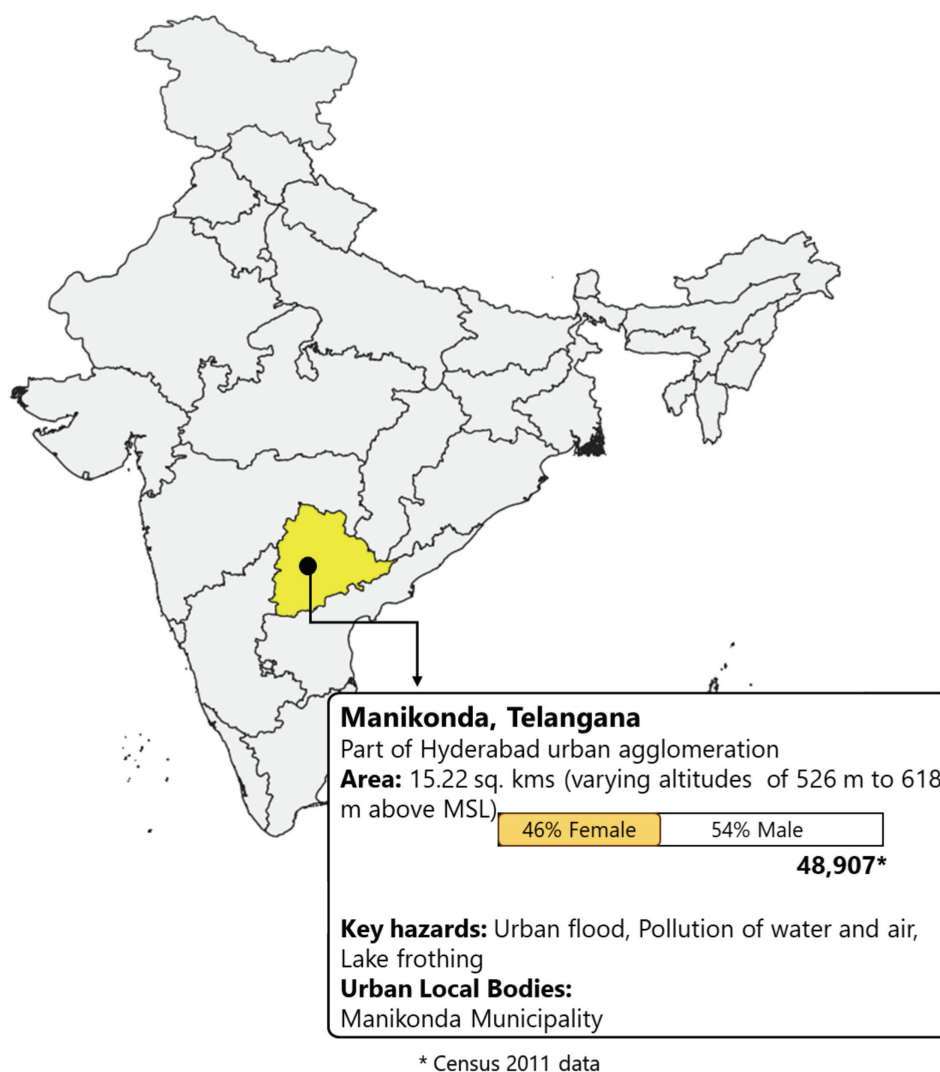


Figure 1. Study Area

2

LITERATURE REVIEW

Once a rare event, urban flooding is now a serious problem that occurs frequently in India's largest cities. Climate change intensifies urban flooding episodes, causing unexpected and severe impacts. The IPCC report AR6 highlights the negative effects of human-caused climate change on the Indian subcontinent, such as increased dry spells, more extreme rainfall and a surge in heatwaves and cyclonic events. Given that disasters have increased fivefold over the previous fifty years, the World Meteorological Organisation (WMO) and the United Nations Office for Disaster Risk Reduction (UNDRR) emphasize that climate change increases the likelihood of catastrophes and diminishes community resilience. This indicates that without effective disaster management strategies, urban systems can fail or come to a standstill.

Events in Guwahati (2022), Hyderabad (2020), Patna (2019) and Kochi (2018) have brought attention to the urgent need for all-encompassing plans that combine better flood risk reduction with specific consideration to the condition of drainage networks and solid waste management. Floods in Chennai (2015), Kashmir (2014), Surat (2006) and Mumbai (2005) show how persistent this issue is. Cities with an increasing urban population like Chennai, Guwahati and Hyderabad face challenges where their aging sewage system, designed for a much smaller population, struggles to cope with the city's current demands. Storm intensity and urban waste accumulation in these cities have increased, necessitating an integrated strategy for disaster management, ecological preservation, and urban design. Taking into account this problem of flood risk, the Indian government has started several important projects to reduce urban flooding. National Disaster Management Authority (NDMA) formulated the National Guidelines on 'Management of Urban Flooding' in 2010 in response to the growing risk of urban floods. These guidelines provide a list of preparatory and mitigation measures meant to increase urban areas' measures against floods. These guidelines also highlight the necessity of integrated approaches to urban management. The government for the Urban Flood Risk Management Programme (UFRMP) has allocated approximately Rs. 2500 crore, targeting seven major cities—Mumbai, Chennai, Kolkata, Hyderabad, Ahmedabad, Bengaluru and Pune focused on sectors of urban infrastructure, improving drainage systems that are frequently clogged by waste and implementing advanced early warning systems.

The following sections detail the existing conditions, opportunities to strengthen interventions, good practices, and various aspects necessary for the flood risk assessments for urban areas.

2.1 STATUS OF DRAINAGE SYSTEM IN INDIA

Currently, stormwater drainage in India is considered lower in priority than drinking water and sanitation. However, to protect metropolitan areas from urban flooding in a phased fashion, compatible with the availability of resources, storm water drainage systems need to be designed and built in an organized manner, considering many aspects of design, operation and

maintenance, and economics. Some of the prominent factors responsible for the drainage conditions in India are:

- Cities' natural drainage systems are in peril, leading to increasing flooding due to inadequate storm water drainage infrastructure. The flooding situation has worsened due to the non-availability of properly engineered stormwater drainage infrastructures (CPHEEO 2019). The problems are compounded by encroachment and rampant dumping of garbage and solid waste into drains on the one hand and a lack of preventive maintenance on the other.
- Underground drainage facilities in core areas of megacities are often century-old brick masonry pipes. The present storm water collection network in these cities is primarily intended to function as a combined system for sewage and storm water runoff. Augmentation and restoration, including the separation of storm water from sewage in such facilities, present the highest level of obstacles for municipal engineers and financial resources.
- According to the Report on Indian Urban Infrastructure and Services published by the former Ministry of Urban Development (MoUD) in March 2011, the storm water drainage network covers only about 20% of the road network and catchments. This is insufficient to address storm water disposal in today's cities.
- The Manual on Storm Water Drainage System by CPHEEO suggests that urban flooding issues are exacerbated due to the widespread dumping of garbage and solid waste in the drains. Illegal disposal of construction and demolition waste along with poor maintenance of existing drainage systems often obstructs the storm water runoff causing localized flooding.

2.2 TECHNO-LEGAL INSTRUMENTS

After the Disaster Management Act of India was passed in 2005, the disaster risk management process underwent a substantial evolution. The prime authority for disaster management in India is the National Disaster Management Authority (NDMA), which is led by the Prime Minister. The Disaster Management Act of 2005 governs the institutional framework used by authorities at the state and district levels for disaster management. The National Disaster Management Plan and the National Policy on Disaster Management, 2009 offer the government agencies at all levels a structure and guidance. The Disaster Management Act, 2005 was also imposed during the COVID-19 response as it envisaged the role of all ministries and agencies in the measures to be taken for the response to the emergency situation.

The Disaster Management Act, 2005 provides the legal and institutional framework for "the effective management of disasters and for matters connected therewith or incidental thereto". It provides for the establishment of National Disaster Management Authority (NDMA), State Disaster Management Authority (SDMA) and District Disaster Management Authorities (DDMA) at the National, State and District levels with financial and administrative powers. The act also provides guidelines for the creation of the National Disaster Response Fund and National Mitigation Fund, the establishment of funds by State Government and the allocation of funds by Ministries and Departments for Emergency Procurement. The act also provides for the establishment of the National Disaster Response Force (NDRF). Some of the other plans and policies that directly or indirectly influence flood risks are reviewed in Table 1 below:

Table 1. Opportunities and Gaps in Policies

Document Reviewed	Key Features	Opportunities to Strengthen w.r.t. Flood Hazard
National Disaster Management Policy, 2009	- Expanding the scope of disaster management activities to build a resilient and safe India. - Covering institutional, legal and financial arrangements related to all stages of DM. - Development of techno-legal regulations for safe building, municipal practices and compliance. - Multi-hazard strategy, in consideration of cooperation, partnership and technological interventions. - Addresses the concerns of all sections of society through community-based disaster management. - Focus on last-mile integration of the policy, plans and execution. - Cooperation with national, regional and international agencies. - Capacity building and training for personnel in DM. - Promotes multi-sectoral synergy.	- Various flood risk typologies especially urban flood management need to be highlighted. - Promotion of data collection, analysis and dissemination systems to support evidence-based decision-making. - A component of cascading risks is absent.
National Environment Policy, 2006	- Regulatory reforms for effective environmental management. - A streamlined process for environmental and forest clearances. - Development of environmental standards based on scientific research. - Promotion of clean technologies and innovation for sustainable development. - Emphasis on environmental awareness, education and information dissemination. - Encouragement of partnerships and stakeholder involvement in environmental conservation.	- Institutionalize watershed management plans. - Integrating disaster risk assessment and mapping. - Promoting sustainable land use planning and zoning regulations. - Implementing awareness and promotion of nature-based solutions and watershed development.

Document Reviewed	Key Features	Opportunities to Strengthen w.r.t. Flood Hazard
National Disaster Management Plan, 2019	▪ Framework and direction for all government agencies to mainstream responsibilities and intervention strategies with consideration to all phases of the DM cycle. ▪ Founded on the DM Act and NPDM 2009 and integrates mandates from SFDRR, SDG and Paris Agreement.	▪ Timeframe for periodic O&M of drainage systems. ▪ Solid-waste containment, prevention of release and management guidance. ▪ Interconnection of drainage network. ▪ Mechanisms to limit extreme expansion of human footprint in cities. ▪ Clear delineation of responsibilities of state and parastatal agencies.
National Action Plan on Climate Change, 2008	▪ Integrates a vision for green and ecologically sustainable development into all facets of national development, including urban areas, agriculture, industry and ecological systems.	▪ The mission on sustainable water is adaptive and lacks quantified targets. ▪ Limited convergence of mission on sustainable habitats with existing AMRUT due to multi-departmental and sectoral approaches, respectively.
National Urban Policy Framework, 2018	▪ Takes a comprehensive and consistent approach with two axes of philosophical perceptions and ▪ Functional aspects of urban space and management. ▪ The component of environmental sustainability highlights the need for planners to adapt to the local environmental landscape while protecting natural drainage and contours. ▪ Highlights the need for risk financing mechanisms at all levels with a focus on local institutions.	▪ Mechanisms for consideration of environmental impact assessment in urban planning. ▪ Potential for integration of watershed management and consideration. ▪ Emphasis on nature-based solutions in addressing urban flood.

Document Reviewed	Key Features	Opportunities to Strengthen w.r.t. Flood Hazard
City Disaster Management Plan – Greater Hyderabad	▪ Incorporates aspects about risks and how they affect human life and property in the greater Hyderabad area.	▪ Integration of early warning and detailed mitigation for urban flood. ▪ Lack of segregated data on damage and loss caused by various types of flooding. ▪ Emphasize strategies for the maintenance of drainage channels, sewerage systems, etc. ▪ Specific directions to address cascading and compounded risks. ▪ Timeline on maintenance of critical infrastructure, storm water drainage, dams and embankments, could be included. ▪ Gender-inclusive DRR practices.
Urban Flood Action Plan – Greater Hyderabad Municipal Corporation, 2021	▪ Incorporates the key types of floods and relevant activities necessary for flood risk management including warning mechanisms.	▪ Planning on expert evaluation of dam and embankment structure. ▪ Highlight on managing pollutants during urban floods. ▪ Consideration of safe evacuation for elderly, pregnant and lactating women.

Source: Developed from Disaster Management Plans at country, state, district, city levels and other relevant policy documents.

2.3 GOOD PRACTICES

To achieve sustainable urban development, action-oriented planning with a strong mobilization strategy, capacity building and monitoring mechanisms are essential to provide a safe and secure habitat. Integration of the practice of risk management within the governance, planning, and operations of local authorities like municipal bodies and allied departments can effectively accomplish urban disaster risk reduction. The local-level disaster risk reduction activities such as risk-sensitive land use plans are important for strengthening disaster risk governance at the micro level. Certain exemplary practices that have been followed around the world are discussed in the following paragraphs. The characteristics or practices observed in the case can form the base criteria for delivering suitable strategies for risk and resource management and future land use planning and can serve as a basis for development goals to be implemented by the municipality of Manikonda to ensure resilience. The practices discussed are not necessarily global best practices but best-suited practices in relatable conditions or can guide in building the roadmap for making cities more resilient.

Multi-layer Approach and NbS in The Netherlands

More than half of the Netherlands is below sea level, prompting the country to seek creative water management techniques while shifting focus to mitigating flooding as part of sustainable urban design. Protective dikes along the coastline and rivers are examples of proactive and preventive steps taken by the country to combat the ongoing threat of flooding. The Flood Protection Act, now called the Water Act since 2009, establishes flood protection standards and has introduced a 6-years assessment of the flood defenses. The country takes a multi-layer approach as shown in Figure 2 where prevention, protection, and planning are integral parts. It functions on prevention from granting building permits in its high flood-prone areas, planning on what to do when flooding occurs, and spatial planning measures like compartmentalization to address nature conservation, recreation and infrastructure E.g. implementation has been done on the island of Dordrecht, known as “Self-reliant Island of Dordrecht”.

Delta Program of Netherlands is an approach to flood risk management, with a system of dams barriers, dikes, and other protective measures. The program focuses on integrated water management strategies, such as sustainable drainage systems, water storage facilities, and water reuse activities. This leads to better water resource management, less water shortages, and greater resistance to climate change impacts. It also encourages Nature-based solutions and ecosystem restoration activities, such as wetland rehabilitation, river restoration, and habitat conservation e.g. ‘Wide green dike’ as a nature-based solution against flooding. ‘Wide green dike’ is

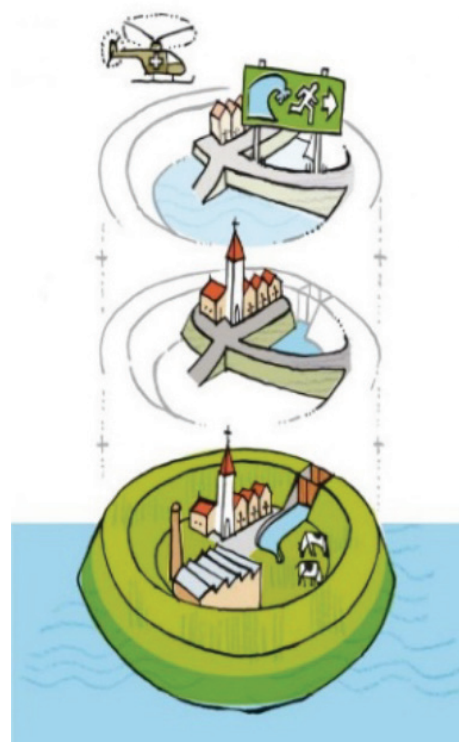


Figure 2. Multi-layer Approach of Netherlands on Safety, Prevention, Sustainable Spatial Planning and Disaster Management

Source: Beleidsnota Waterveiligheid 2009-2015

a historical design that uses solely natural materials, such as clay covered in grass, and has a gently sloping seaward face blending into the adjacent salt marsh. This has been significant in bringing together experts on water management, civil society, and authorities from all levels of government. The program targets to identify barriers and drivers in implementing NbS to flooding so that regions with similar geography can replicate it.

Institutional Mechanisms and Flood Early Warning Technology in Japan

Japan underwent rapid development economically and militarily during the late 19th and early 20th century where the municipal body now plays a central role in disaster management. According to the Disaster Countermeasure Basic Act, the municipal body is responsible for establishing a local disaster management plan, emergency operations such as warning systems, issuing evacuation recommendations and orders and relief activities. The approach to risk assessment chosen is based on risk type and local characteristics, while also taking into account different stakeholders' requirements. Another aspect considered important is the capacity building of the city's residents. The Life Safety Learning Center is developed by the Tokyo Fire Department at different locations in the city of Tokyo to provide an experiential facility to share disaster preparedness knowledge. The center has earthquake simulations, drills for typhoons, and flood information sharing with evacuation knowledge.

Low-cost Automated Flood Early Warning System (FEWS)

Dependence on manual systems for last-mile dissemination of early warning has led to delays in response to flooding incidents in Japan. Most FEWS, especially for small rivers, are manual which makes risk identification difficult, particularly in remote areas. Low-cost, on-site FEWS systems have been earlier installed by Yamagata Prefecture by the Ministry of Water Resources, Japan. These use carbon and magnesium inside a water battery which when dipped in water undergo a chemical reaction magnesium oxidizes and releases electrons and carbon facilitates reduction leading to the flow of electrons that generates electric current which triggers off signals. It is an automated, and low-cost on-site solution that uses flood water to generate electricity which further powers emergency evacuation light signals and alarms. It is useful, particularly in areas where a systematic early warning system is missing. When connected to an electric source and the internet, the advanced version can relay the generated signals through an IT network for wider transmission or can be integrated with other dissemination channels. This system has been tested at a pond at Keio University, Japan with different variations. A modified version of a similar water battery-powered Flood Early Warning Dissemination System (FEWDS) is being installed and tested in Uttarakhand by the RIKA team.

The Act on Sediment Disaster Countermeasures 2001 provides the base for the development of land use zoning in the area. The non-structural measures like identification of hazardous areas and provision of information for decision-making are based on this act. The act highlights the designation of warning and special warning areas for sediment-related disasters, which are prime for land use zoning. This highlights the need for risk-sensitive planning for land use. The zonation is done by "red" and "yellow" for special warning areas as shown in Figure 3. Red zone residents are at severe risk to

their lives and health whereas yellow are at moderate. The act also aims to enable residents to share information for their decision-making. The City Planning Act mentions a criterion of delineation of the urbanization promotion area and the urbanization control area based on vulnerability to floods, tsunamis and storm surges.

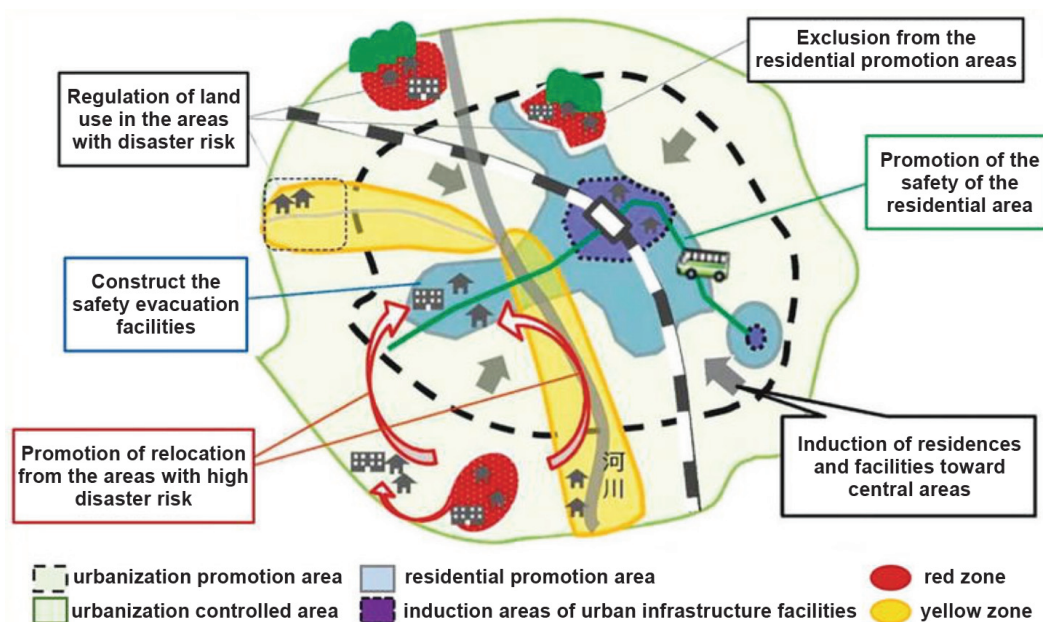


Figure 3. Countermeasures for Disaster Mitigation Risk-sensitive Planning

Source: Karashima, K. & Ohgai, A., 2022

Local disaster management plans are formed by the local Disaster Management Council which has a representation of local government and line departments. The national government provides essential help to local governments while the city government facilitates consensus among stakeholders through the Disaster Management Council. Wherever practicable, solutions include multi-functional systems that offer benefits beyond flood risk management. It is also vital to create and implement clear governance systems. At the center of each NbS project, is the community that plays a vital role (Sharma, S. and Ayuba, D., 2024; International Bank for Reconstruction and Development, 2022).

Some initiatives across the globe were reviewed from the perspective of NbS in flood mitigation as summarized in Figure 4. Japan displays technologically advanced systems for disaster risk reduction and thus is an important center for technical knowledge sharing with the world. Nature-based solutions such as the sites East Kolkata Wetlands and integrated storm water drain in Chennai have varied costs associated based on scale. These solutions are comparatively efficient and cheaper than data-driven early warning system establishment or formation of underground storage of stormwater. The reviewed practices indicate that developing resilient infrastructure, such as flood barriers and green spaces is beneficial for mitigating flood risk. Restoring wetlands and floodplains can reduce the impact of floods while promoting biodiversity. Reliable early warning systems enhance preparedness and response to flood events, saving lives and reducing damage. In addition, building capacities of local communities in flood risk management ensures better understanding, compliance, and resilience.

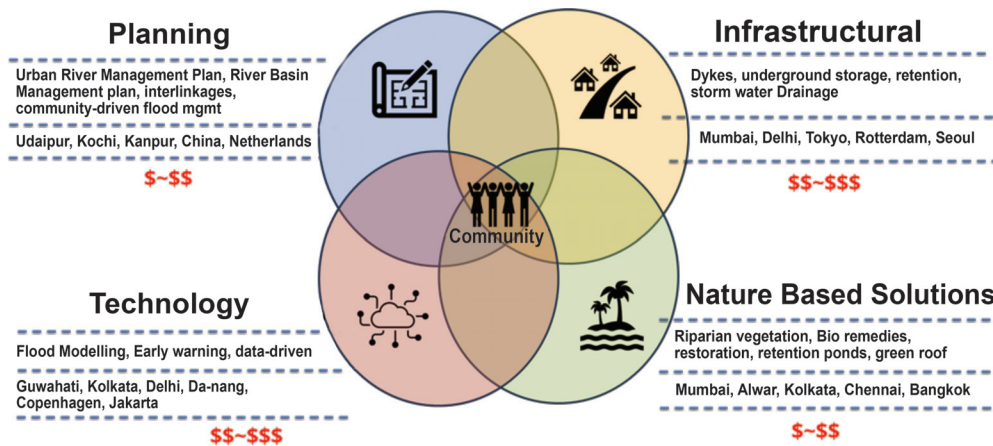


Figure 4. Other Examples of Initiatives to Improve Flood Resilience

Source: Authors' compilation

2.4 COMPONENTS OF FLOOD RISK ASSESSMENT

Many plans, policies, research articles, scientific papers and journals were reviewed in a systemic manner using keyword searches indicating prominent aspects of the flood risk assessment. The process of risk assessment majorly uses the frequency of events, exposure, and vulnerability. It can look into hazard intensity, which is the spatial distribution of the measurable negative consequences of a particular hazardous phenomenon. It was observed that for assessing different hazards and their domino effects the systematic hazard interaction and their classification have been used in previous studies (Liu, et al., 2015; Marzocchi, et al., 2009). From the perspective of **hazard assessment**, utilizing satellite imagery, meteorological data and geographical data has been made easier and more effective by the application of GIS techniques. Studies in the past have given consideration for cascading risks with spatial and temporal aspects being used to analyse information (L.F. Guimarães et.al. 2021, Li. J. et. al. 2023). In addition, water depth and return period are the most commonly used components to assess flood hazards (Rangari et. al. 2021). Thus, based on the literature, hazard intensity and frequency along with the systemic hazard interactions have been incorporated into the flood risk assessment framework as shared in the following section.

For the **exposure assessment**, aspects such as the percentage of impermeable ground (%), built-up area, road density (paved roads), number of protected buildings, critical infrastructure and groundwater level have been considered by studies related to flood risk assessment (Kumar et. al. 2021, Garrote et. al. 2020, Chang H, et. al. 2021, Kramer et. al. 2016). Although the effects of physical structure on people during disasters have been investigated, further research is necessary to fully understand the impact of social, economic, and environmental issues. The degree of risk induced through floods depends on various social, physical, institutional, natural and economic factors that vary from one area to another (in this study, ward and division). Hence, the degree of risk induced varies for each area.

Füssel, 2010 states two approaches for calculating vulnerability to flood risk: theory-based and data-based approaches (Füssel, 2010). Data-based approaches are extremely specific to situations and have constraints on data availability. Reclassification, indexing, modelling and multi-criteria approach are some of the commonly used techniques for risk assessment (Pathak et. al. 2020, Sarmah et. al. 2020, Ahmed et. al. 2024, Sundaram et. al. 2021). This study thus uses a theory-

based approach by assigning weights to selected indicators. Although there might be uncertainties, the weighing of variables has proved effective in studies (Lein, 2010). Expert knowledge and system characteristics play an important role in the approach of using vulnerability indicators and have been found to be more effective than computer modelling and other methods (Nasiri, et. al., 2016). The approach for vulnerability assessment for Manikonda uses weights to estimate the vulnerability for all the floods and other hazards.

Physical considerations directly affect the structures in the event of natural hazards and further define their vulnerability. The physical components in the vulnerability assessment study generally include the type of buildings, kind of roof, wall and floor. In addition, covers the physical characteristics of roadways, building styles, vital infrastructure (such as water and electricity supplies) and medical facilities (such as fire departments and ambulances) (Winrock International India, n.d.). The damage to physical structures like buildings, roads, bridges and public utilities can be caused by lateral pressure or velocity forces, erosion of foundations gradual weakening due to waterlogging, and other effects (World Bank, 2016). Construction type is an important function while determining the dead weight. Brick houses, wooden houses, and masonry flood retaining walls can cause differential levels of damage and hence variation in weight is given accordingly. The factors encompassed in this study consider the elements that are either directly or indirectly connected to the location and kind of the built environment. These are referred to as physical factors.

The degree of growth in terms of human development metrics and the general well-being of people, communities, and society is correlated with **social** factors. It covers things like common areas, literacy rates and collective organisational methods and traditional values. Access to money and fundamental socioeconomic infrastructure are examples of **economic** considerations. The study employed many indicators under the heading of economic aspects, such as the source of income, annual income, access to insurance schemes, financial institution accessibility and industry areas. Studies have established the exposure and vulnerability aspects are equally important while approaching the vulnerability concept (Bohle, 2001). According to United Nations, flood risk vulnerability is scored from 0 to 1 i.e., no damage to full damage (United Nations, 1982). Managing flood with the goal of the safety and well-being of the public and minimizing loss is one of the main responsibilities of city authorities in flood prone areas. Studies consider different sides of flood risk assessment and have also included the aspect of sensitivity of population using indicators like population density, gender, and age (Murillo-Garcia, et al., 2015). The type of building that could be damaged is another major criterion to assess the vulnerability (World Bank, 2016).

Through the literature review following were the key components identified for consideration in order to design the flood risk assessment framework as shown in Section 3.

- Flooding variables considered: Water depth, return period
- Exposed elements: Humans, Buildings, Animals
- Cascading hazard: Spatial and temporal aspect
- Physical dimension: Percentage of impermeable ground (%), Built-up area, Road density (Paved roads), Number of protected buildings, Critical infrastructure, Groundwater level
- Social dimension: Population density, hospitals, Number of registered volunteers
- Economic and political dimension: GDP, subsidy after disaster
- Natural dimension: Green infrastructure
- Assessment: Reclassification, indexing, modelling

2.5 FRAMEWORK FOR FLOOD RISK ASSESSMENT

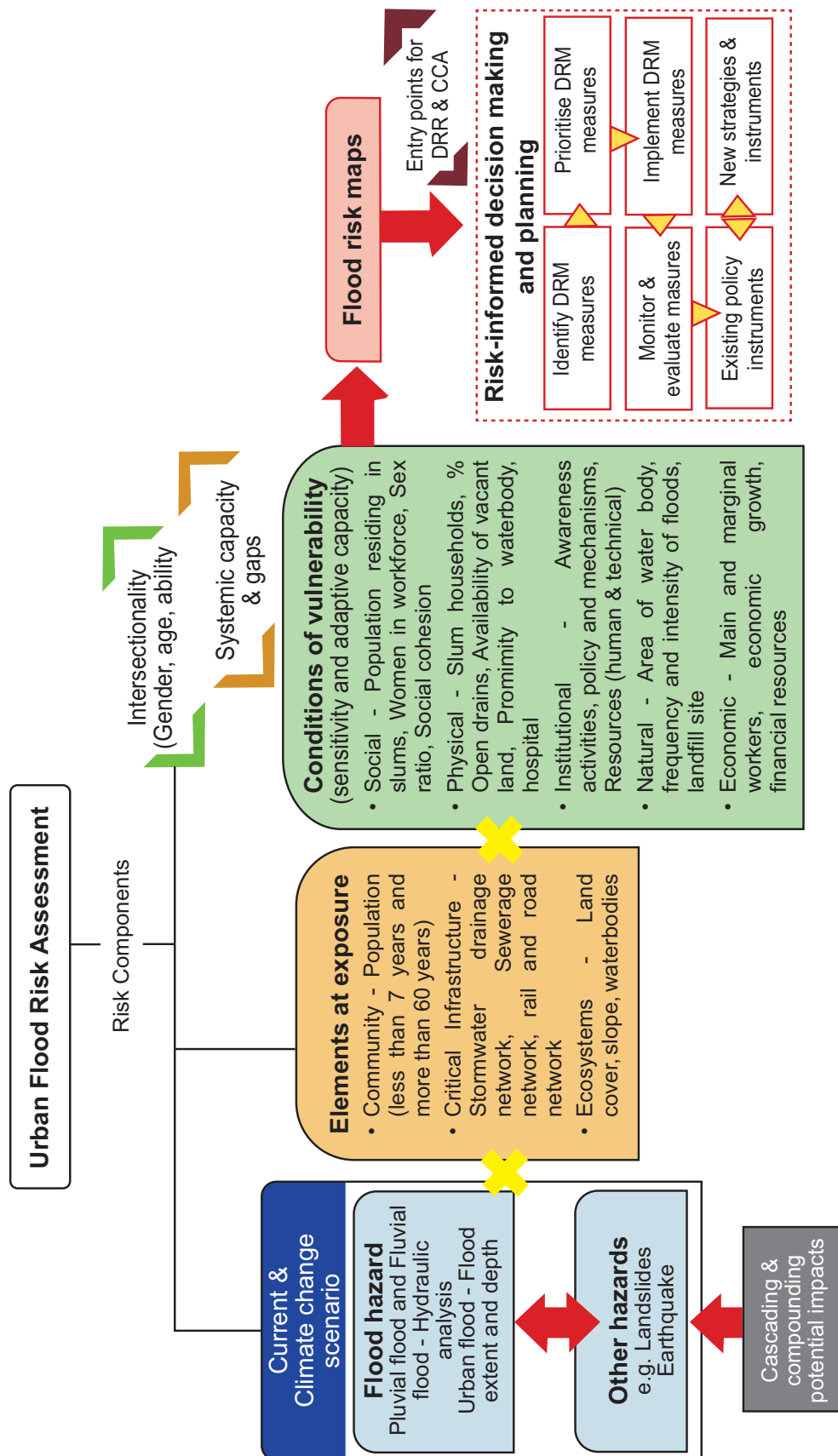


Figure 5. Conceptual framework for flood risk assessment

3

APPROACH AND METHODOLOGY

Disaster risk is context-specific (UNDRR, 2019). While it can be driven by local, national, regional, or global factors, disaster risk demonstrates varied local and specific characteristics that are shaped by local patterns and interplay of exposure, vulnerability, adaptive capacities, and resilience. The non-linear changes in the intensity and frequency pattern of the natural and biological hazards make the risk more dynamic over time and scale. Such changes can be better gauged and perceived at a local level wherein the local government, local communities and other key stakeholders like Community-Based Organisations (CBOs), Non-Governmental Organisations (NGOs), private sector, etc. are actively engaged and have an instrumental role in the disaster risk reduction (DRR) and disaster risk management (DRM) processes. In line with the paradigm shift brought forth by the Sendai Framework, the focus of the plans should be on disaster risk management rather than only disaster management.

Climate change is expected to adversely impact the progress and processes targeted at strengthening resilience and adaptation. Key aspects to be considered for addressing climate-induced disaster risks and resilience in cities are: (a) Increasing focus on working at the local level — a shift from central government to local government and community level (b) Increasing focus on multi-disciplinary, multi-stakeholder approach (c) Evolution from theory to practice i.e., from technology to implementation. The pressures of urbanization, along with the expected impact of climate change, which is very likely to affect the frequency and intensity of hydrometeorological hazards such as floods, are creating complex and cascading urban risks in cities. In such complicated risk circumstances, fragile urban systems frequently break in, resulting in cascading effects on other interconnected urban systems and services.

The Sendai Framework for Disaster Risk Reduction (SFDRR) 2015-30 echoes the need for the same, supported by strengthening the existing mechanisms for disaster risk governance at all levels while being mindful of new and emerging risks. In this regard, the role of local government and community is immense not only as first responders but also as well aware, risk-informed and resilient stakeholders for disaster risk management. One of the guiding principles of the SFDRR lays great emphasis on “empowering local authorities and local communities to reduce disaster risk, including through resources, incentives and decision-making responsibilities, as appropriate”. At the national level, the paramount importance of engaging with and enhancing the capacities of local government and local communities is also resonated by the Prime Minister’s 10 Point Agenda on Disaster Risk Reduction. It calls for building on local capacities and initiatives for enhancing disaster risk reduction (DRR). It further underscores that such efforts not only lead to risk reduction but also create opportunities for local development and sustainable livelihoods along with duly imbibing the traditional good practices and indigenous knowledge.

3.1 OVERALL APPROACH

The approach for this assignment as shown in Figure 6 is guided by the Global Risk Assessment Framework (GRAF) (UNDRR, 2019) and Words into Action Guidelines on National Risk Assessment and Local DRR and Resilience Strategies, in which risk assessment is central to ensuring risk-informed, disaster-resilient and sustainable planning and processes at a city level; thereby furthering the efforts of local administration and other stakeholders towards the four Priorities for Action (PFA) laid down under the SFDRR, namely, understanding disaster risk, strengthening disaster risk governance, investing in DRR for resilience building and enhancing disaster preparedness for better response and ensuring “building back better” through post-disaster response and recovery.

The aspect of “whole-of-government” approach as emphasized by the 2021 United Nations Climate Change Conference (COP26) to act on risks and opportunities from climate change has been considered. The technical approach of local DRR and resilience lays down that the local government should be playing a leading role in developing and implementing the local DRR and resilience strategies with an active engagement of the local community while other stakeholders like government at a higher level, private sector and academia should be playing a supporting role.

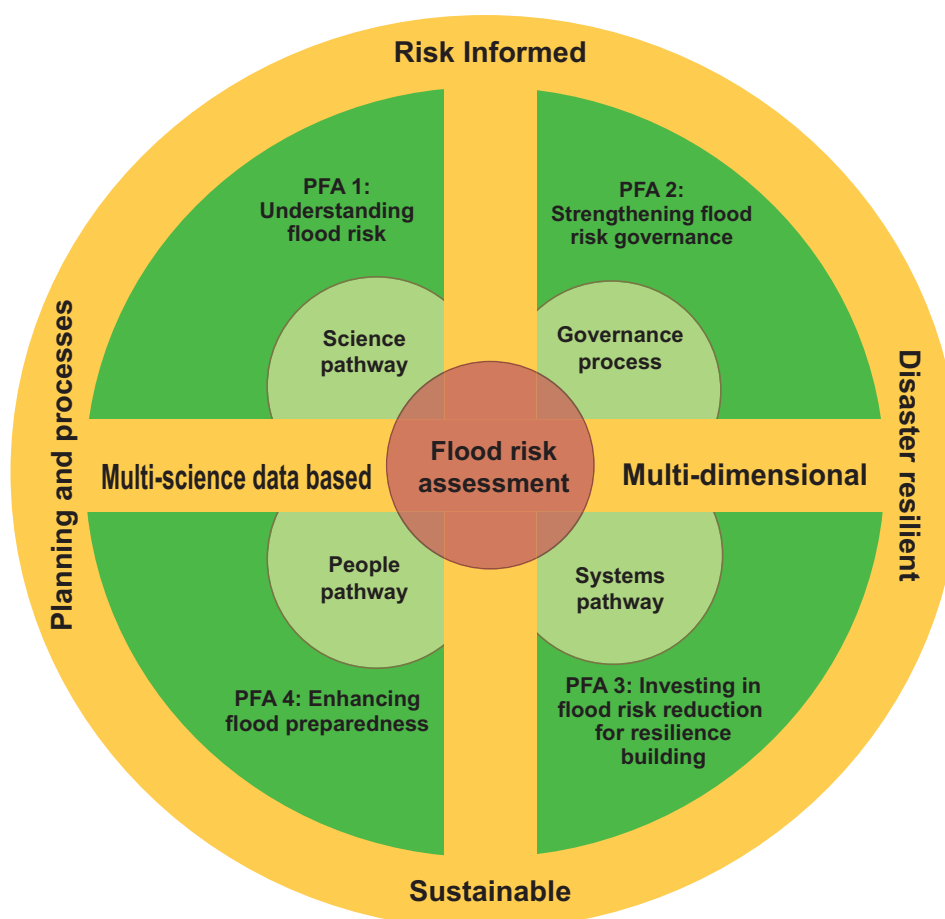


Figure 6. Approach for the Project

In addition, according to the National Disaster Management Plan 2019, specific aspects like the need for early warnings, mapping vulnerable and at-risk populations, developing a stakeholder engagement strategy, and efficient interagency and stakeholder cooperation have been highlighted.

It calls for the preparation of an accountability matrix and outlining methods for monitoring, assessing, and revising plans (NDMA, 2019). These have been crucial in helping state and district administrations in India to control urban floods. Contextualising these guidelines locally is crucial, to guarantee their efficient maintenance and building of resilience. As of now, only a few cities—like Chennai's Chennai Climate Action Plan (CCAP) and Mumbai's Mumbai Climate Action Plan, March 2022 — have included urban flood management in their climate action plans. There is a scope to establish a formalised governance structures and plans for managing urban flooding.

Approach: Under this approach, flood risk assessment is central to ensuring risk-informed, disaster-resilient and sustainable planning and processes at a city level; thereby furthering the efforts of local administration and other stakeholders towards the four Priorities for Action (PFA) laid down under the SFDRR. Under this, the flood risk assessment will be guided by multi-hazard (all types of prominent hazards in an urban context), multi-component (beyond hazard — understanding conditions of exposure, vulnerability & capacity and underlying complex interactions) and multi-dimensional (lenses of social, economic, physical, structural and ecological considerations for understanding vulnerability & capacities) approaches. Figure 6 highlights the key elements of GRAF including causal pathways people, science and systems and governance.

Science pathway/component: Understanding the existing status of and gaps within the prevalent flood risk assessment methodologies. It enabled the project team to design a robust flood risk assessment framework that addresses the identified gaps and is informed by field-based evidence and existing and emerging tools and technologies. It uses the lens of coverage, interoperability, standards, availability and accessibility for doing so. It also considers the science behind the hazards and conditions of exposure using principles of multiple disciplines such as hydrology, geoinformatics, climate science, etc.

Systems Pathway/Component: Fostering systems thinking in the design and implementation of the flood risk assessment by focusing on the interconnections, inter-dependencies and correlations across and in between different urban systems including the urban ecosystems. It leads to gauging inter-dependencies across & within varied components of urban systems e.g. critical infrastructures.

People Pathway/Component: Comprehending contexts and needs of at-risk populations; differential vulnerabilities (all-of-society & intersectionality approach) are underpinned in the design and implementation of the flood risk assessment framework and resilience building roadmap. It helps understand and map the differential conditions of exposure and vulnerabilities experienced by different sections of populations residing in varied pockets of Manikonda.

Governance Component: Understanding gaps/enablers in existing institutional frameworks and instruments; maps, tools, plans and guidelines, challenges & opportunities faced by urban local bodies, and other government stakeholders in using them (All-of-government approach). It helps the project team to have a representative understanding of the needs and usage for different end-users including the city administrators and other key stakeholders. It further led the team to map the ongoing initiatives and efforts in this regard which resulted in laying down well informed and duly streamlined city-specific resilience-building roadmap and training module.

Overall, an effective risk assessment and resilience-building strategy should envisage working towards the management of disaster risks rather than just the management of disasters. It should be laid with a long-term perspective and considerations for existing & emerging and complex

risks and not just for the ad-hoc management of a single disaster event. Further, with sustainable development as one of its key guiding principles, the local DRR and resilience strategy should strive to integrate and make DRR inherent to development planning.

The study reflects the four dimensions of risk—hazard, exposure, vulnerability and capacity through a comprehensive review of literature, both national and global, along with other scientific literature. The hazard considerations in this study includes possibility of a physical event, trend, or physical impact that could result in death, serious injury, or other health effects, as well as destruction or loss of property, infrastructure, livelihood, ecosystems and environmental resources. It refers to physical events or impacts related to climate change. Exposure refers to the existence of individuals, livelihood, species or ecosystems, infrastructure, environmental services, functions and resources, as well as economic, social, or cultural assets, in locations and circumstances where they may suffer negative effects. Vulnerability is the tendency or inclination to experience negative consequences. A multitude of ideas and components are included in the same, such as sensitivity or susceptibility to injury and the inability to cope.

3.2 GENDER EQUALITY AND SOCIAL INCLUSION (GESI) INTEGRATION

The concept of gender sensitivity has been developed as a way to reduce barriers to personal and economic development created by societal constructs. Incidents like the Indian Ocean Tsunami of 2004 impacted women severely with 70 percent of fatalities being women in Banda Aceh, and 91 percent of fatalities after Cyclone Gorky in Bangladesh in 1991 were women (Carlsson, R., Helene, M., Trohanis, Z. E., 2012). These highlighted how disasters impact gender groups differently. The need and importance of including gender in DRR and understanding vulnerabilities of gender groups and the ways important to bring gender equality in DRR.

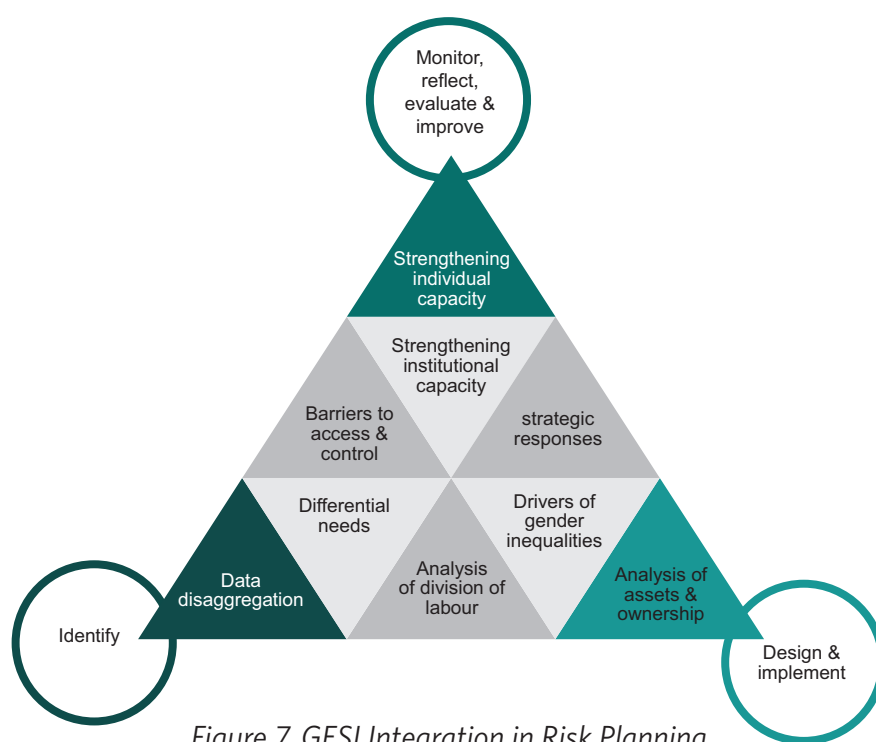


Figure 7. GESI Integration in Risk Planning

Source: Adapted from CRIDF, 2019 & ADB, 2022

The existing socio-cultural norms related to gender influence the decision-making capacity and access to resources. Such inequalities are structurally embedded into societies. As a result, women bear the brunt of a disaster in a much-aggravated way than men. One example is when the disaster-induced loss of livelihood acts as a catalyst to increase domestic violence (Daalen et. al. 2022).

As represented in Figure 7, GESI integration has to be considered at all stages of disaster risk planning from identification to design and implementation and monitoring and evaluation.

In this regard, for the present study the following considerations were made:

- **Identification of vulnerable gender groups** and their differential needs. Data disaggregation is important to analyse the condition in detail. The approach targeted to understand cross-cutting issues (class, caste, religion, age, ability, literacy, employment, etc.) and intersectionalities prevalent.
- Considerations pertained to **identifying specific vulnerabilities** or reasons that magnify the vulnerabilities, specifically information on the literacy of women, the employment status of women, and their representation and engagement in flood management and decision-making. E.g. the data collection tool gathers information on literacy levels that vary between women, young adults and elderly women and can be representative of their access to information.
- The information was captured through stakeholder consultations where women-stakeholder **participation** provided in-depth information on barriers to access.
- In the study gender representation, aspects of strengths and weaknesses along with vulnerabilities are analysed based on **data collected from women** for household information and awareness.

Table 2 highlights the GESI-specific considerations used in this project to ensure inclusivity in the study. Details of the same are present in data collection tools as Annexure 1.

Table 2. The GESI Checklist Used in this Study

Type	Considerations in Primary Data Collection
GESI Specific Indicators	The extent of engagement of women networks, SHGs in flood risk management, training, etc.
	% of women in the workforce
	Availability of funds for women and women-led businesses affected by flood
	Separate capacities of officials of different genders
Participation and Reflection	Engaging different stakeholders in meaningful ways (ensuring listening to what they have to say)–Female government employees, community members included.
	Disaggregation of groups for data collection
	Transparent and responsible data collection
	Opportunity to report and reflect upon their engagement in the intervention

3.3 METHODOLOGY

Urban flooding is a common occurrence in major cities with high economic activity, such as Bengaluru, Chennai, Mumbai and Gurugram. A comparatively higher number of people have been exposed to the risks and vulnerabilities associated with natural hazards, global warming, and climate change-related phenomena like heat waves, droughts and flash floods as a result of urbanisation. These risks and vulnerabilities are made worse by underdeveloped infrastructure, a shortage of affordable housing, and the rise in informal settlements, which are frequently found in dangerous or low-lying areas (MoHUA 2020).

Cities are the primary locations for the usage of resources and the largest producers of waste. The solid waste profile of urban regions includes garbage from homes, waste from building and demolition projects, e-waste and other sources, all of which are predicted to worsen and expand in the upcoming decades due to rapid urbanisation (MoHUA, 2020). There are open landfills dispersed around the cities as a result of the low capability for collecting solid waste. Building resilience in cities requires a far-sighted vision and rigorous policy frameworks. To mainstream urban resilience and risk reduction strategies, long-term planning procedures must incorporate both existing and emerging climate hazards.

In this regard, the methodology for the assignment is **evidence-led conceptualisation** as illustrated in Figure 8. These include the key steps of systematic literature review, conceptualisation, and field testing of the flood risk assessment framework. Through this, the evidence-led conceptualisation of the envisaged flood risk assessment framework has been undertaken along with proposing a resilience-building roadmap and evidence-based recommendations for mitigation, preparedness, and NbS. The methodology also highlights the steps for flood risk assessment using both primary and secondary datasets along with multiple stakeholder consultations. GIS tools were used to form a composite overlay of pieces of information: hazards, exposure, and vulnerabilities, highlighting the high-risk areas in the city. A thorough roadmap with a focus on aspects of localization, integration with development planning, monitoring, and regulatory mechanisms, multi — and cross-sectoral engagements, risk communications, local actions, etc., as a part of the study, ascertain steps to build a resilient city. The final findings and capacity building of the government stakeholders were also integral to the successful completion of the study.

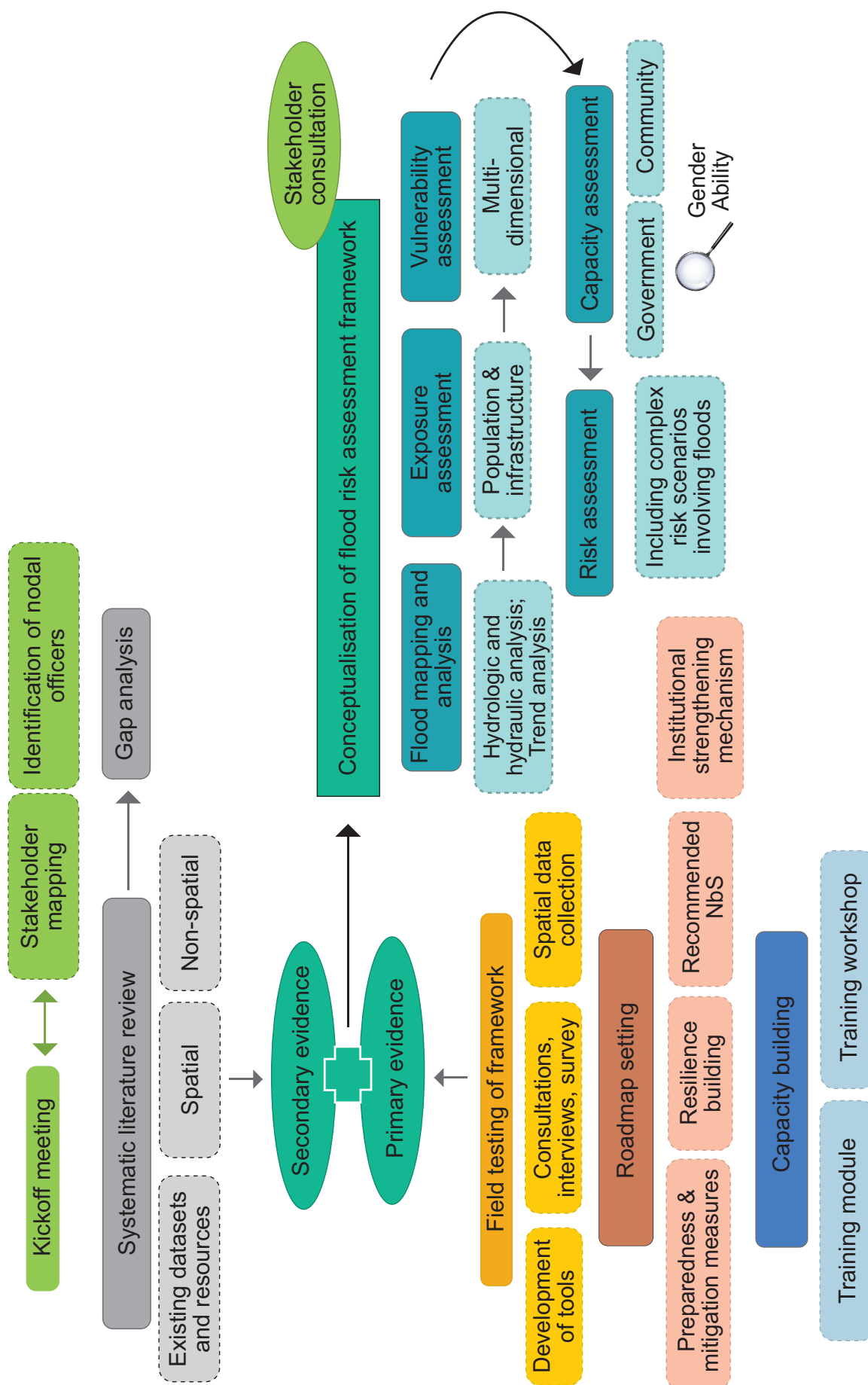


Figure 8. Detailed Methodology for Evidence-based Conceptualisation of Risk Assessment

Source: Authors' compilation

3.3.1 SYSTEMATIC LITERATURE REVIEW

After the Disaster Management Act of India was passed in 2005, the disaster risk management process underwent a substantial evolution. The prime authority for disaster management in India is the National Disaster Management Authority (NDMA), which is led by the Prime Minister. The Disaster Management Act of 2005 and amendment 2025, the institutional framework used by authorities at the state and district levels for disaster management. The National Disaster Management Plan and the National Policy on Disaster Management, 2009 offer the government agencies at all levels a structure and guidance. The existing plans and policies at all levels have some opportunities for improvement which were studied in detail through a SWOT analysis process.

Existing frameworks and tools for flood risk assessment and flood resilience assessment were reviewed in detail to identify and map the key dimensions and indicators. This included an in-depth study of existing guidelines, frameworks, plans and reports of similar assessments being done by other cities through a study of web portals of relevant government bodies and departments along with relevant academic papers on the topic through keyword searches on reputed academic search engines as shown in Figure 9.

For the study following plans and policies were reviewed in detail:

- National Disaster Management Policy, 2009
- National Disaster Management Plan, 2019
- National Environment Policy, 2006
- National Action Plan on Climate Change, 2008
- National Urban Policy Framework, 2018
- City Disaster Management Plan – Greater Hyderabad, 2021
- Urban Flood Action Plan – Greater Hyderabad Municipal Corporation

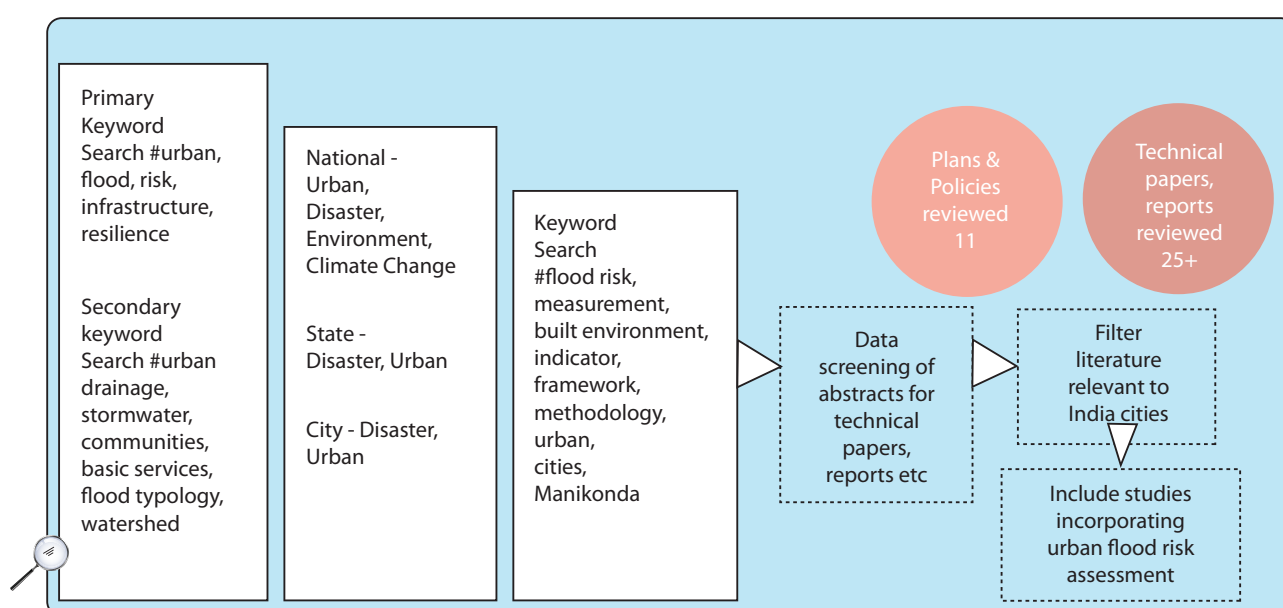


Figure 9. Literature Review Process

A renewed sense of urgency and necessity for strengthening disaster risk governance and enhancing resilience through well-integrated and risk-informed policies, plans, programmes and budgets at all levels of governance was infused among the member nations by the Sendai Framework for Disaster Risk Reduction (2015–2030) (SFDRR). In order to achieve the goals directed by the SFDRR, the DRM systems must specify the goals and particular objectives for lowering disaster risks along with relevant activities. To mainstream their implementation, policies must be linked to strategies for sustainable development and climate change adaptation as shared in the opportunities to strengthen flood considerations discussed in Chapter 2. The principle of increasing disaster resilience through targets for vulnerability reduction and capacity building is also embodied in the Sustainable Development Goals (SDGs). By strengthening the institutions and weakening the factors of risk like poverty, gender discrimination, food insecurity and social disparity, the SDGs can promote resilience. Early warning, risk mitigation, and management of hazards are indirectly prioritised through SDG 1, 11, 13, which is especially relevant given the flooding scenarios in Manikonda.

3.3.2 FRAMEWORK: FLOOD HAZARD & EXPOSURE ANALYSIS

Flood hazard and exposure analysis is a crucial process for assessing and managing flood risks to communities and infrastructure. It involves the potential for flooding in a specific area by considering factors such as historical flood data, topography, rainfall patterns and river basin characteristics as shown in Figures 10 and 11 below. The methodology and the technical aspect are based on the Storm Water Drainage Systems Manual, Volume 1 by the Central Public Health and Environment Engineering Organization (CPHEEO). Figure 10 involves steps of data collection involving collecting Digital Elevation Models (DEMs) and rainfall records spanning 30 years (1994-2023) for the

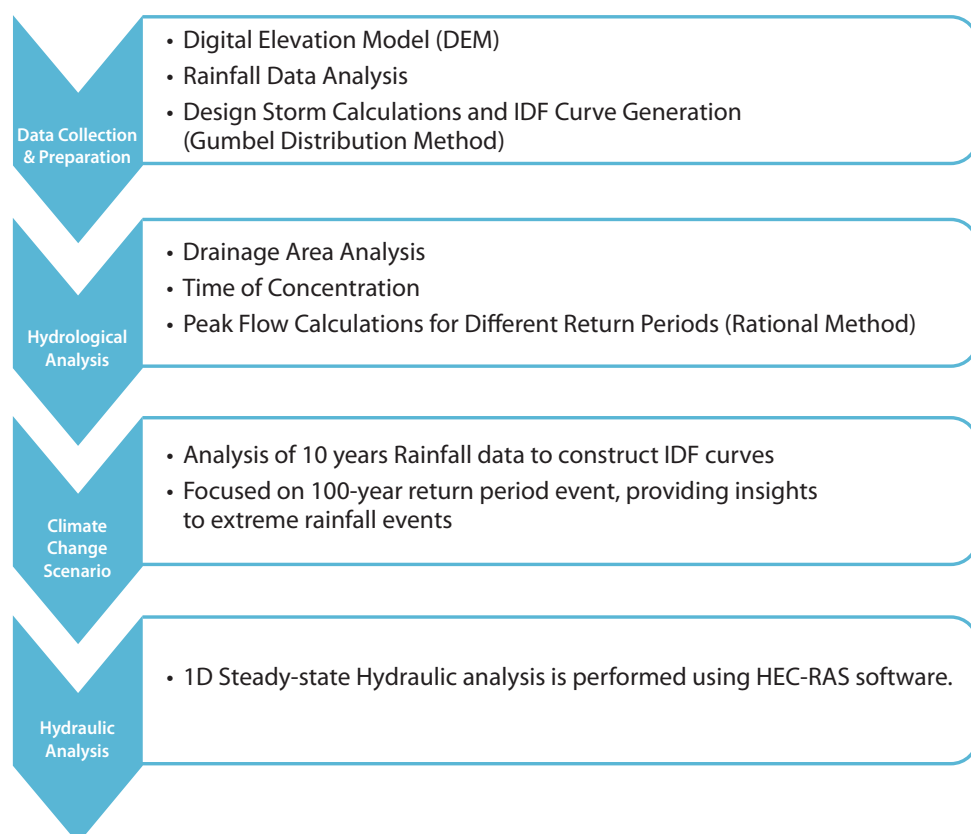


Figure 10. Framework Designed for Flood Hazard Analysis

analysis and Intensity-Duration-Frequency (IDF) curves generation using the Gumbel distribution method. The hydrological analysis includes drainage area delineation and the time of concentration calculation. It also involves peak flow calculations using the Rational method for different return period rainfall events and the climate change scenario. A climate change scenario analysis considers examining 10 years of rainfall data (2014-2023) to construct corresponding IDF curves, with a specific focus on a 100-years return period. Hydraulic analysis includes the 1D steady state analysis, as it simplifies the modeling of flow in open channels, making it computationally efficient and easier to implement, to assess the flood risk to Manikonda. Additionally, it also involves assessing the vulnerability of buildings, transportation networks, utilities and people to flood impacts. This analysis helps in understanding the potential consequences of flooding on both human and material resources.

The process of flood hazard and exposure analysis is detailed below:

- **DEM (Topography/Terrain):** Data is obtained from ISRO's Bhuvan website, and used for catchment delineation in ArcGIS software.
- **Rainfall Analysis:** According to Central Public Health and Environment Engineering Organisation (CPHEEO) guidelines, the Gumbel distribution method is utilised transform the highest 24-hour rainfall recorded over the past 30 years.
- **Intensity-Duration-Frequency (IDF) Curves:** It determines rainfall intensities for specific durations based on desired return frequencies.
- **Hydrologic Analysis:** Modelling involves rainfall-runoff modelling. The process determines the volume of water from a given storm event that will transform into runoff on the landscape.
- **Catchment Delineation:** It is the process of identifying and mapping the geographical boundaries of an area that contributes water flow to a particular point of a river.
- **The Longest Flow Path:** Signifies the route from a headwater, typically the ridge line of the drainage area, to the outlet, which is longer than all other flow paths in length within the drainage area and is used in the calculation of T_c .
- **Time of Concentration (TC):** An important component of peak flow calculations. It is required to obtain the corresponding rainfall intensity from IDF curves. The time of peak runoff is dependent on the time of concentration (Annexure 2).
- **Peak Flow:** It is the main output of the hydrologic analysis. It is defined as the maximum flow of the entire catchment, contributing to its outlet. This will occur when the given intensity of rainfall begins instantaneously and continues until the time of concentration. (**Rational Method** is used in the Calculations: $Q=CIA$) (Annexure 2).
- **Climate Change Scenario:** Assessment follows the Storm Water Drainage Systems Manual, Volume 1 by CPHEEO. The method used to assess changing trends in rainfall intensity involves analyzing 10 years of rainfall data (2014-2023) and constructing the corresponding IDF (Intensity-Duration-Frequency) curve. The analysis will focus on a 100-year return period.
- **Hydraulic Analysis:** It is used to determine the flood risk to the project site by understanding the water surface elevation, depth, and extent of the inundation. Peak flows are used as input. 1D-steady hydraulic analysis is performed using HEC-RAS version 6.4.1. Multiple cross-sections are analysed to assess flood risk. Steady flow conditions are described using energy and Manning's equations. The results include water surface elevations and extent of inundation for different return period events. (Detailed calculations are shared in Annexure 2)

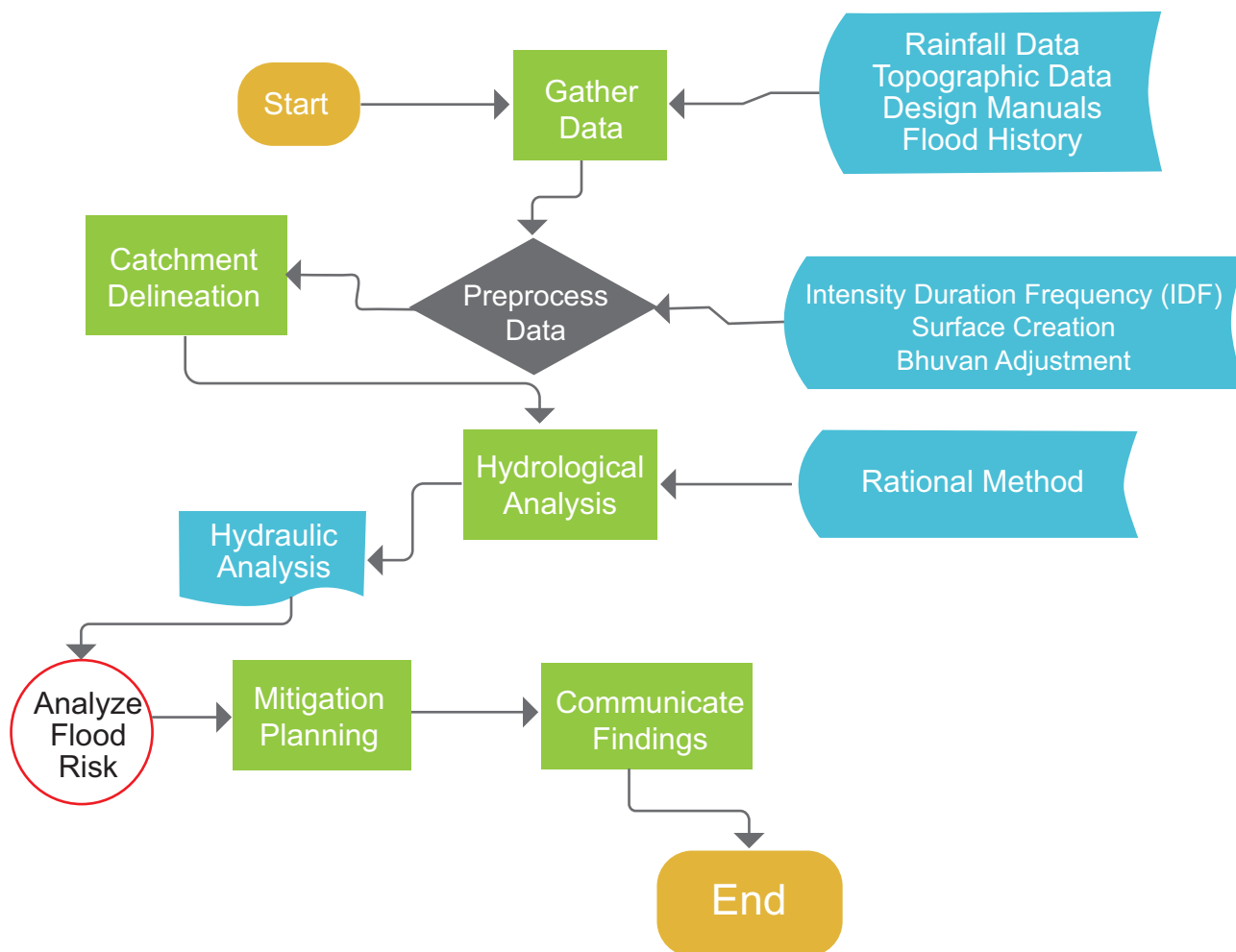


Figure 11. Framework Designed for Flood Hazard and Exposure Analysis

3.3.3 FRAMEWORK: FLOOD VULNERABILITY & CAPACITY ANALYSIS

The flood vulnerability and capacities are evaluated using the SPINE framework as shown in Figure 12 which uses specific considerations:

- **Social Inclusion:** Acknowledge that some residents in a city have received preferential treatment than others due to various underlying factors. Therefore, the risk assessment should take into account the needs and experiences of individuals from all socioeconomic backgrounds, as well as those who are diverse in terms of gender, age, colour, religion and ethnicity.
- **Physical Infrastructure Safety:** Disaster impacts are aggravated when infrastructures are weak or poorly maintained. This can lead to compounding effects and multiplied damages.
- **Institutionally Responsive:** Ensure that policies and services are designed, planned and managed based on the needs of residents and address local and emerging hazards.
- **Natural Integrity:** The resources (natural) are judiciously used. Encroachments can lead to flooding incidents, not maintaining building bye-laws can lead to further waterlogging, hamper drainage flows, etc.
- **Economically Viable:** Identify monetary conditions at the household-level and the availability of funds and budget at the institutional level to identify and implement measures to fix issues.

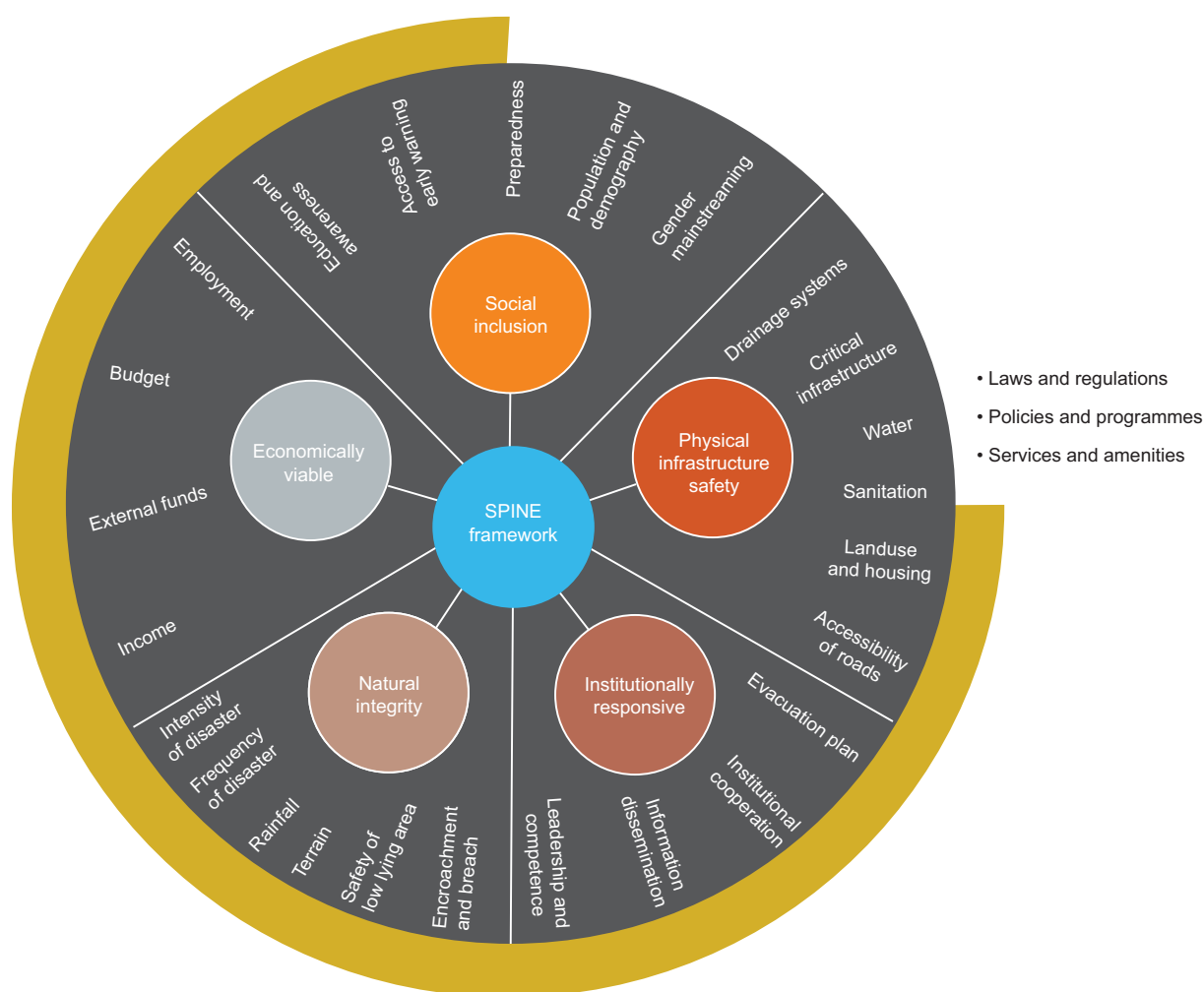


Figure 12. Framework Designed for Vulnerability and Capacity Analysis

The identified dimensions and parameters were used to design the data collection tools as shared in the next subsection. Some challenges evident throughout the city were reflected in the information shared. Ratings on stakeholder inputs allowed us to identify highly vulnerable areas. All the parameters were normalised by bringing them to a common scale. For this, the min-max normalisation was used to make them unit-free. The normalisation is based on the functional relationship of the parameters with risk such that the value assigned is 1 where the condition is poor or vulnerability is high and 5 where the condition is good and vulnerability is low as shown in Figure 13. The list indicates the 5 dimensions and parameters under each dimension along with the number of indicators marked in brackets against each parameter.

The process involved the selection of indicators based on a detailed relevant literature review, and stakeholder consultation, followed by data collection at ward and division levels. However, due to the unavailability of certain datasets, some indicators had to be excluded from the computation for each city. These absent datasets are attributed to various reasons like limited monitoring setup and insufficient data collection processes with urban local bodies. The list of complete indicators, including those excluded, is part of the data collection tools provided in Annexure 1. The data gaps may impact the replicability of the risk assessment as some indicators important for Manikonda may not be relevant for other cities and vice versa.

Social	Physical	Institutional	Natural (Environmental)	Economic
Demographic condition (5) Access to information (5) Disaster preparedness and capacity (5)	Land use and housing condition (7) Water and sanitation condition (7) Road condition and accessibility (5) Critical infrastructure (7) Drainage system capacity (5)	Competence in DRM (5) Knowledge sharing and collaboration (5)	Disaster frequency and intensity (4) Land use change (1)	Employment and income condition (5) Budgetary allocation (5)

Indicator rating for qualitative data

Very poor condition	Poor condition	Moderate	Good condition	Very good condition
1	2	3	4	5

Figure 13. Dimensions and Parameters (No. of Indicators) Developed for Vulnerability Analysis

The following two considerations are part of the risk assessment framework's vulnerability component:

- Sensitivity is the degree to which climatic fluctuation affects a system in a positive or in a negative way.
- Adaptive capacity, or the capacity of humans, institutions, or systems, to react to climatic or anthropogenic causes and adapt to possible harm, or consequences.

3.3.4 TOOLS OF PRIMARY DATA COLLECTION

The data collection tools are specific survey formats and guiding questions for the stakeholder and household level interviews are shared in Annexure 1. All questions were asked to the respondents and only the questions which were answered were considered for the evaluation and further reflection. The pool of questions can be considered as a master document that can be used with variations for different cities and requirements. Table 3 shows the detailed tools used and the level of engagement along with the specific dimension it corresponds to based on the previous subsection.

Table 3. Tools for Data Collection

Tool	Purpose	Level of Engagement	Dimensions Used
Questionnaires for consultation	Vulnerability & capacity assessment; gap analysis	State and district officials	Primarily institutional
	Vulnerability & capacity assessment; gap analysis	Division and ward officials	Social, Physical, Institutional, Natural (Environmental), Economic
Guide for FGDs/KII	Vulnerability & capacity assessment; awareness	Household/Community	Social, Economic, Physical, Natural (Environmental)
Guide for visual survey	Vulnerability & capacity assessment	Houses, drainage channels & networks at hotspots	Physical, Environmental

The collected data are assessed at the ward-level for Manikonda as guided by NIDM and other stakeholders in the Stakeholder Consultation meeting in May, 2024. The primary and secondary data were used for risk calculations as detailed in Annexure 2.

3.3.5 INFORMATION VALIDATION: VULNERABILITY & CAPACITY ANALYSIS

Through consultation with various stakeholders, the project team was able to identify priority areas for flood risk mitigation and adaptation in the short, medium, and long-term and lay down the actionable items and the resilience-building roadmap for each of the identified priority areas. At multiple levels, the perception and challenges varied and allowed for a holistic understanding of key pressures. A brief distribution of consultations at both urban local bodies is shared in Table 4, further details of which are shared in Annexure 4.

Table 4. List of Consulted Agencies and Stakeholders

Stakeholders Consulted	Manikonda
State Level Agencies	No. of Consultations
State Disaster Management Authority (SDMA)/ State Disaster Response Department	1
Department of Housing & Urban Affairs (DoHUA)/ Municipal Administration & Urban Development	1
Telangana Urban Finance Infrastructure Development Corporation Limited	1

District Level Agencies	
District Disaster Management Authority/Disaster Management Cell	1
City Level Agencies	
Urban Local Body – Commissioners, Assistant Commissioners	1
Engineering and Works Staff	3
Development Authority — Town Planner & Planning Staff	1
Community Level	
Community Members/Households	20 HH

Figure 14. Data Collection Activities Conducted at (a) Municipal Office (b) Household in Manikonda

Images: RIKA India



The method used for the household data collection is shared in Figure 15. It considers the identification of flood hotspots based on stakeholder consultation followed by consideration of Water Surface Elevation Level (WSEL) landmarks calculated by the project team out of which the 5 landmarks with high WSEL were identified and considered for ground data collection. Locations common to both the list of hotspots and 5 high WSEL were considered along with those specific landmarks that showed up in the WSEL list.

From these, only the residential areas were selected. Further consultation with ULB highlighted the most suitable locations from the list of residential areas to conduct data collection. The data collection was continued till repetitive responses were received.

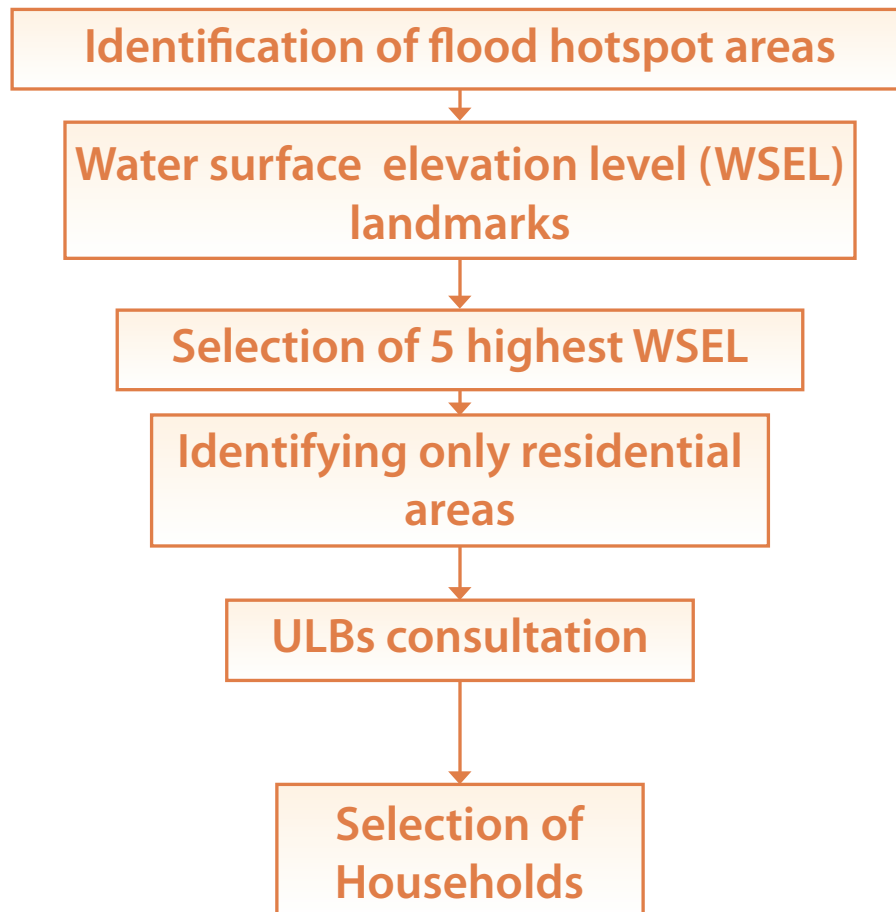


Figure 15. Sampling Process for Household-level Data Collection

3.3.6 DATA SOURCES FOR THE ANALYSIS

The data used for the study includes datasets shared by government agencies at both sites and available online resources. Table 5 details some of the data used and their corresponding sources. Other than these data sources reports and past studies were referred which are cited in this report. These were also used for the cross-verification of primary data collected based on the tools shared in Table 4. Based on the data received, the following are the pre-analysis assumptions for the methodology of the study:

- The coordinate system is considered as WGS_1984_UTM_Zone_44N for Manikonda.
- Bhuvan topographic data for Manikonda city is adjusted as per the contour levels provided by the government.
- The major structures on the rivers and nallahs are assumed to be already constructed for more than 100-year return period rainfall events. Hence, will not impact the hydraulic analysis of the study. Sufficient information was not available for the smaller structures; hence they are excluded from the analysis.

Table 5. Sources of Datasets Used for Analysis

Categories	Data	Source
Social	Population Density	Manikonda Municipality
	Availability of Health Facilities	Health Department Data, Manikonda Municipality
	SC/ST Population	Manikonda Municipality
	Extent of Engagement of Women Groups	Manikonda Municipality
Physical	Ward and City Boundaries	Manikonda Municipality
	Land use Land Cover	(Bhuvan — Indian Geo-Platform of Indian Space Research Organisation (ISRO))
	Stormwater Drainage Network	Manikonda Municipality
	Proximity to Water Bodies	Project Team Analysis Based on Topographical Maps
	Solid Waste Management	Manikonda Municipality
	Damage to Infrastructure in the Past	Manikonda Municipality, Town and Country Planning Office, District Disaster Management Authority
	Vacant Land Information	Manikonda Municipality
	Change in Built-up Area.	Project Team Analysis based on the Bhuvan Dataset
Institutional	Presence of AWS, EOC	Manikonda Municipality
	Members of the Emergency Team	Manikonda Municipality
	Presence of Evacuation Shelters	Manikonda Municipality

Categories	Data	Source
Natural	Rainfall Data	India Metrological Department (IMD) Grid (0.25°x0.25°) through MATLAB Code for Specific Latitude and Longitude of the Site, India-Water Resource Information System (WRIS)
	Topographic Data	Bhuvan Digital Elevation Model (DEM) Data (30 m x 30 m Resolution; Cartosat-1 Version-3) - (Bhuvan - Indian Geo-Platform of Indian Space Research Organisation (ISRO)) Survey Data (from Client)
	Flood History	Specific Site State Water Resources Department Website
	River Discharge Data	India-Water Resource Information System (WRIS), https://vedas.sac.gov.in/hydro/index.html
	Design Manuals	Central Public Health and Environment Engineering Organisation (CPHEEO) Manual, Volume 1 Part A: Engineering Design
Economic	Workforce Engagement (Including Women Participation)	Manikonda Municipality
	Budgetary Allocations	Manikonda Municipality

3.3.7 TOOLS OF DATA ANALYSIS

In the study, open-source software and tools were used to ensure interoperability and ease of access as shown in Table 6.

Table 6. Software and Tools for Data Analysis

Tool	Purpose
Google Earth Engine	Enables aerial view analysis, location identification, elevation profiling, and Street View access.
QGIS and ArcGIS	Geospatial tools for raster analysis (DEM) and vector creation/modification aid in catchment delineation processes. Analysis of information on hazards, exposure, and vulnerabilities using geoprocessing tools, overlay analysis, etc. for classification and evaluation of risks.
US Army Corps-HEC-RAS (Hydrologic Engineering Center - River Analysis System)	Hydraulic modelling of rivers and channels to simulate water flow and assess flood risk.
US Army Corps-HEC-HMS (Hydrologic Engineering Center — Hydrologic Modelling System)	Simulating rainfall-runoff processes and analyzing watershed response to precipitation events.

4

CITY PROFILE, STATUS OF DRAINAGE, RISK ASSESSMENT AND RESILIENCE ROADMAP

4.1 INTRODUCTION

Manikonda is a municipality in the Rangareddy district of Telangana. Constituted in 2019, Manikonda municipality was formulated from two villages Manikonda Jagir & Pupalaguda under the Rajendranagar Mandal. Located towards the west of Hyderabad, Manikonda was impacted by past flood incidents in 1954, 1970, 2000, 2001, 2002, 2006, 2008 (220.7m in 36 hours) that highly affected the city of Hyderabad. It is marked by numerous lakes and wetlands along with multiple housing complexes. It covers an area of 15.22 sq. kms distributed in 20 wards (as shared by the Manikonda municipality office during consultation). The city has majorly high-rise buildings and has only one prominent informal settlement at Aminnagar. The population of the city was 16,989 during the Census 2011 and is now estimated at 2,61,450 (as shared by the Manikonda municipality office during consultation). The population is primarily engaged in the Information Technology sector, government staff, and informal sector.

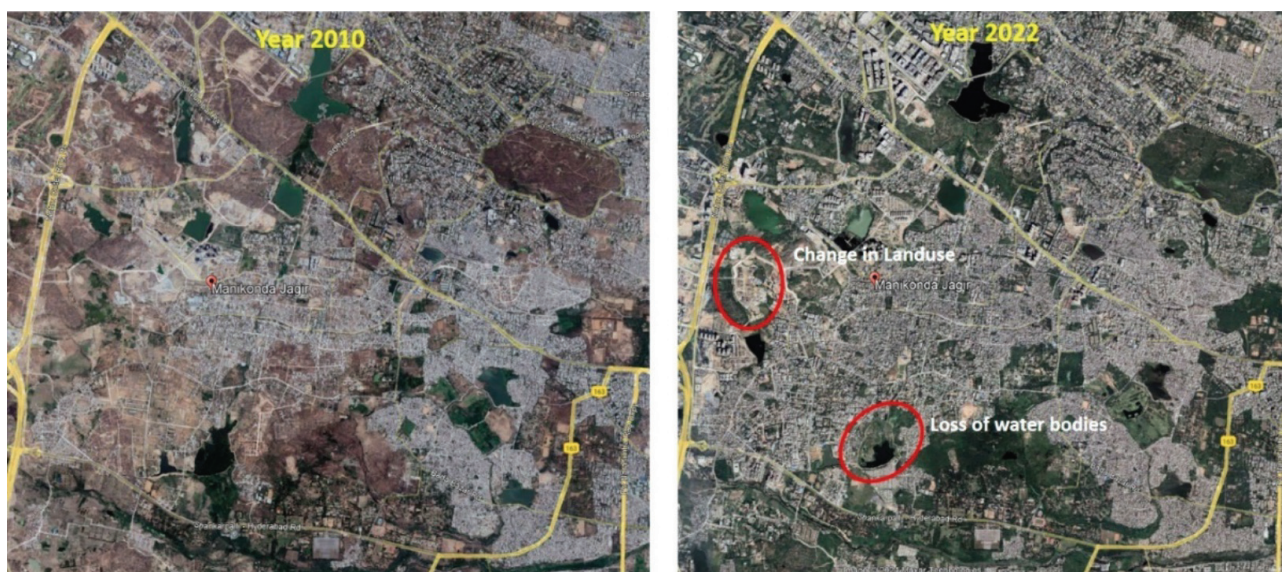


Figure 16. Changes in Manikonda Due to Urbanization

Source: RIKA consortium's analysis from Google Earth imagery accessed in June 2024

The city has experienced significant changes in the past 20 years, including the construction of new buildings and apartments, improvements in road connectivity, the development of stormwater drains, and the creation of parks. The city has 64% coverage of concrete cement roads and over 20 km length of stormwater drains with each household connected to a drainage network (as shared by Manikonda municipality office during consultation). The municipality has witnessed a significant increase in the population which is indicated by an increase in the requirement for drinking water, generation of excess waste, and lessening in the overall area of water bodies in the city. Telangana State Pollution Control Board (TSPCB) reported multiple cases of encroachment of lakes and

contamination of water bodies by residents. Historical satellite images in Figure 16 support this claim with visible shrinkage in the perimeter of water bodies and their numbers due to an increase in built-up areas in the past decade.

Figure 17 shows the vicinity of Manikonda city, including the surrounding features and prominent localities. The municipality does not have many prominent critical infrastructures such as Primary Health Centers, District Hospitals, Medical Colleges but has school infrastructures and residential colonies that get inundated due to heavy rainfall causing urban floods. In addition, the municipality lacks a sewage treatment plant and relies on the neighbouring Hyderabad area for the same. The city has one natural heritage site namely Rock Park Hillock. It is a satellite town that is undergoing fast-paced real estate development to cater to spillover urbanization from Hyderabad. The land cover map as shown in Figure 18 shows that the majority of the city is covered in build-up.

Manikonda is located in the western part of Hyderabad and features relatively flat terrain as shown in Figure 19. It has 5 prominent water bodies Manikonda (Yellamma) Cheruvu in Ward 1; Mushkin Cheruvu in Ward 10; Neknampur (Chinna) Cheruvu in Ward 8; Khajaguda lake in Ward 12; Ibrahim Bagh (Pedda) lake-Ward 7. The southern part of Manikonda has a lower elevation as shown in Figure 19 and is reported to have frequent waterlogging incidents. The spillover of urbanization in Hyderabad has led to the illegal commercial development of the Manikonda Lake buffer zone; thereby severely affecting the biodiversity of the area.

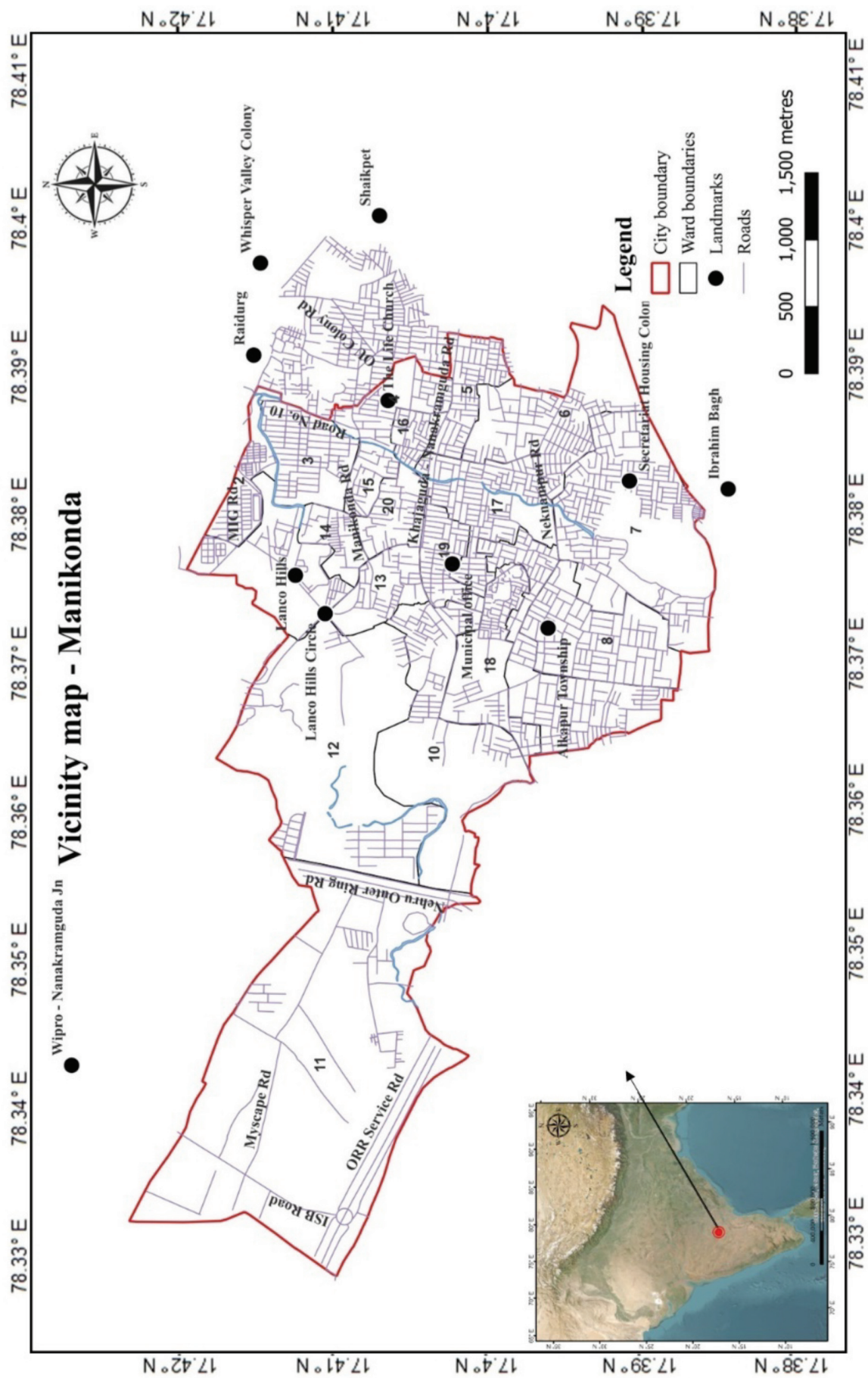


Figure 17. Location and Vicinity Map of Manikonda

Source: Developed from municipal data and satellite imagery

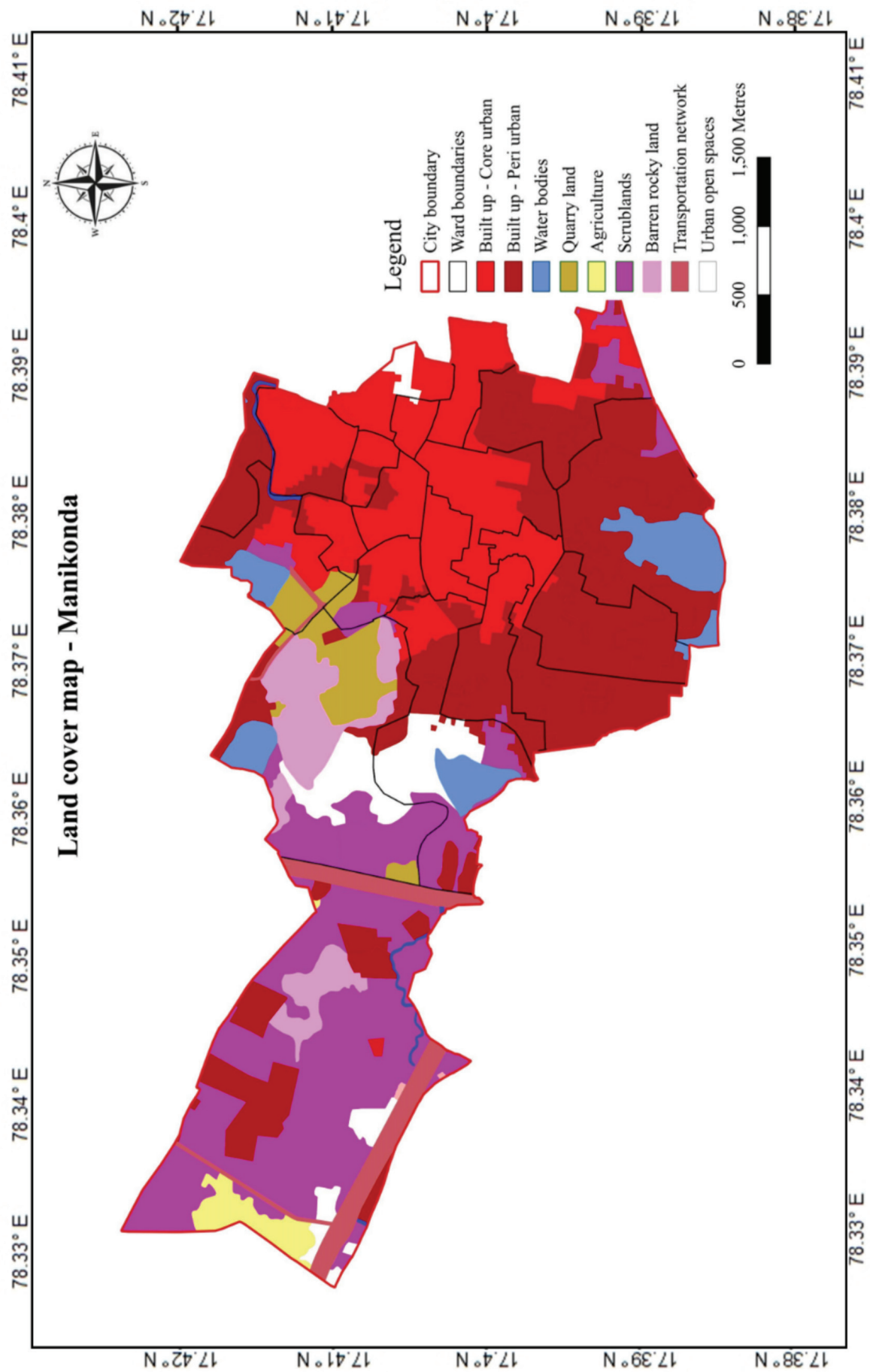


Figure 18. Land Cover Map of Manikonda

Source: Developed from ISRO (SIS DP 2018-23) datasets for this project

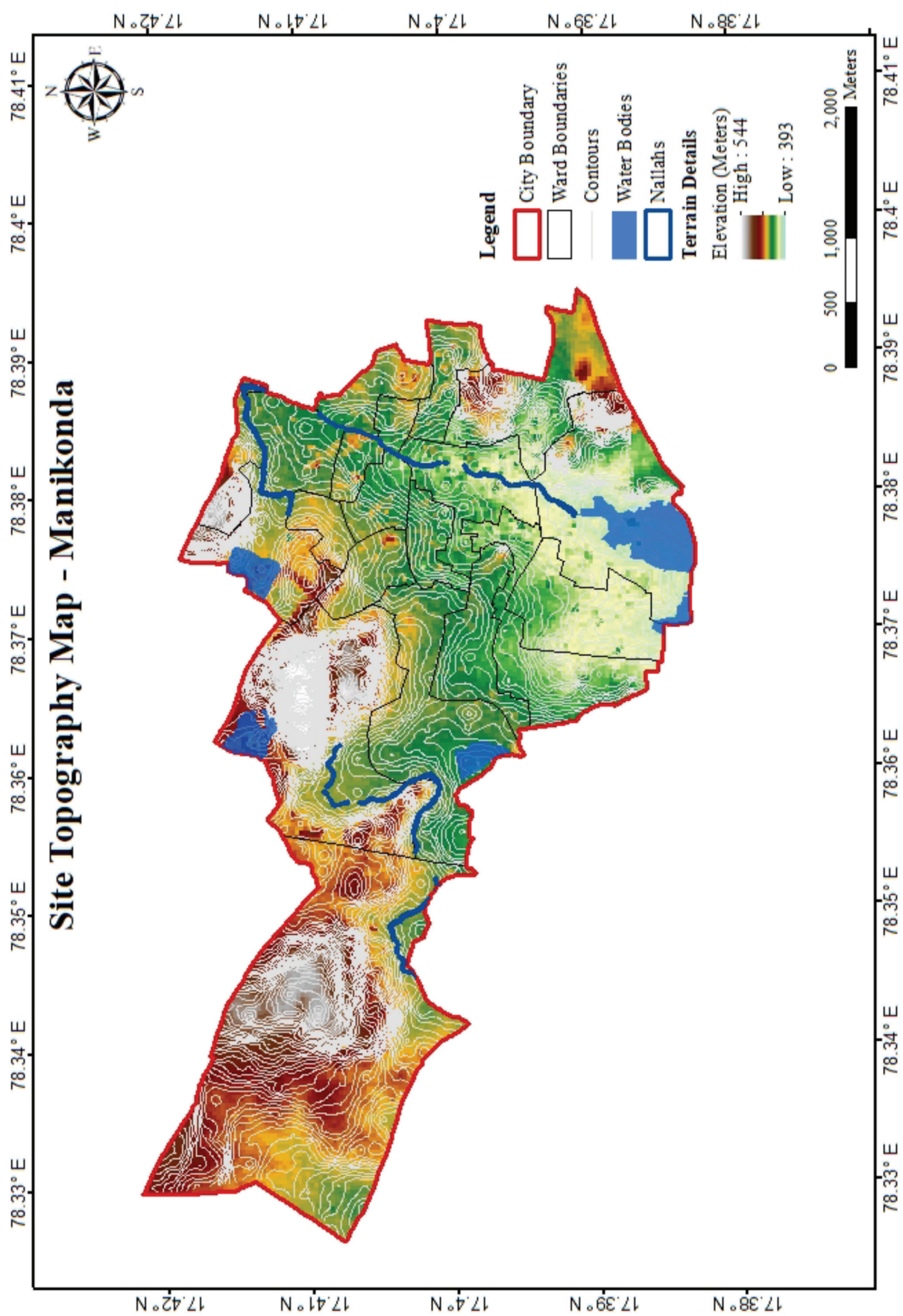


Figure 19. Topographic Details of Manikonda with Prominent Water Bodies

Source: Developed from datasets provided by Manikonda municipality and ISRO for this project

4.2 STATUS OF DRAINAGE SYSTEM

Administrative change and jurisdiction marked the change in rapid development in the Manikonda area. This affected the type of developmental activities. The water bodies were reported to be polluted and encroached. Under the Strategic Nalah Development Programme (SNDP) the municipality has constructed stormwater drainage network in Ward No. 5, 12, 19 and invested funds to the scale of 1.5 Cr from the municipal funds for the development of a stormwater drainage system (as per municipal data Annexure 5). Toll Free Number (1077) is active during the rains and SNDP within the municipal limits lowered incidents of flooding in 2023. Activities like the construction of box drains and culverts at Lanco Hills were undertaken.

As the municipality receives wastewater from the upstream Greater Hyderabad Municipal Corporation (GHMC) area through the Sheikhpeta nallah also called the GHMC nallah, a high amount of wastewater from GHMC area directly impacts the drainage channels in Manikonda. There are four categories of drains in Manikonda as shown in Table 7. Covered drains have perforated covers as shown in Figure 20 for preventing waterlogging. Drains with various widths 450 mm, 600 mm, 900 mm and 1200 mm as shown in Figure 21 are present across the municipality. Other than these the natural nallahs are present which are wider and carry wastewater. The municipality report suggests a length of 19 kms of drains out of which 12 kms are kaccha nallahs including the GHMC nallah. The existing stormwater drainage network in Manikonda is categorized into natural, cemented, and masonry drains. The majority length of drains is kaccha however almost all residential areas are connected to the drainage system except Ward Numbers 11, and 12 as shown in Figure 21. Dewatering pumps, motors and stoppers are used by the municipality to divert stormwater during incidents of urban flooding.

Table 7. Length of Stormwater Drains in Manikonda

Particulars	Drain length
Total Length of Drains	19.00 kms
Concrete Cement Drains	5.00 kms
Masonry Drains	2.00 kms
Kachha Drains	12.00 kms

Source: Manikonda Municipality City Profile Report



**Figure 20. Existing Drainage Network Situation (a) Perforated Design for Drain Covers
(b) C&D Waste Affecting Nallah**

Image Source: RIKA India

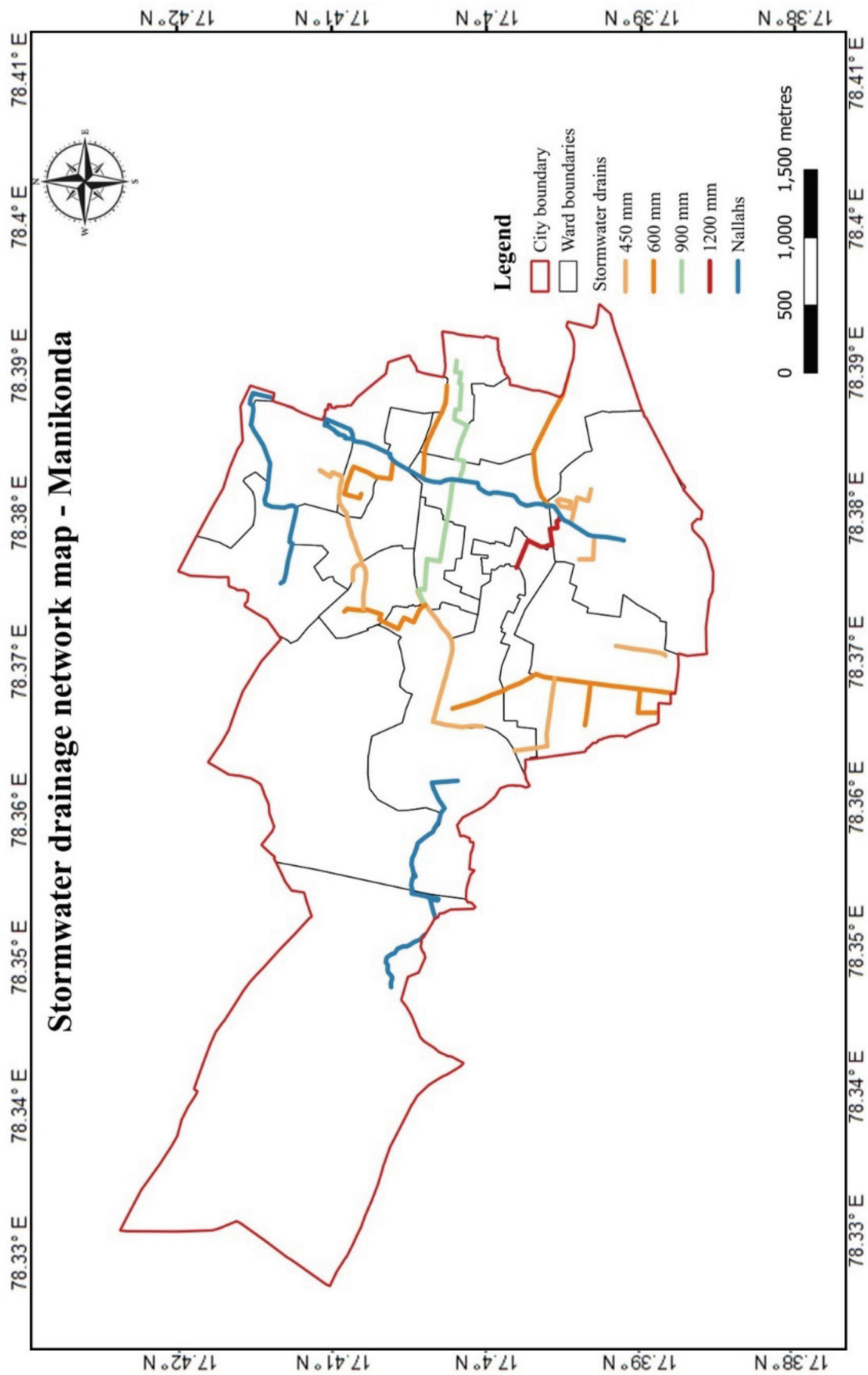


Figure 21. Drainage Network Categories Manikonda

Source: Developed from data shared by Manikonda Municipality

Manikonda experiences heavy rains during the south-west monsoon season (June–October) and most of the low-lying areas get affected by floods. The issue has also been associated with an overflow of nallahs caused by the accumulation of debris, sediment, and waste, waterlogging and improper waste management. Urban flooding in Manikonda highly affects the ward 3, 5, 8, 10, 11 and 12. The gradual flow of wastewater from GHMC area is a prominent reason for flooding issues in the Manikonda due to the specific areas of Neknampur Lake and nearby colonies like Venkateshwara colony. Construction and demolition waste from the upcoming high-rise buildings affect the runoff.

Defending Pollution of Drainage Network by Floating Treatment Wetlands at Neknampur Lake

The wastewater flowing in the drainage channels from the Manikonda area severely pollutes the water bodies in the city. Weed-choked concoctions of household sewage and chemical contaminants from the growing number of homes that sprung up along the lake border affect the health of lakes. Lack of land for a Sewage Treatment Plant in the municipal limit due to space issues and has continuously led to the contamination of lakes in the city. Neknampur Lake is one such 450-year-old water body, which covers 108 acres and has frequently made news for its persistent pollution.



Figure 22. Wastewater Management Solution — Floating Wetland — Neknampur Lake

ce: *Telangana Today*

“Floating Treatment Wetland” incorporating phytoremediation techniques into restoration plans was released into Neknampur Lake in 2016 jointly by NGO Dhruvansh under supervision and support from the State Irrigation Department, Rangareddy District Collector, Hyderabad Metropolitan Development Authority, Telangana State Pollution Control Board, Telangana Fisheries Department and the Telangana State Biodiversity Board. This has been able to reduce the levels of pollution in the water body.

Rapid urbanization has led to specific challenges in the area such as a significant increase in municipal waste and its accumulation in drainage channels. Encroachment on low-lying areas and changes in drainage channels as further studied in Section 5.3. Blocked stormwater drains and new developments have additionally altered natural water flow patterns. As per municipal data waste generated was 35 TPD in 2021 but now is over 95 TPD in 2024.

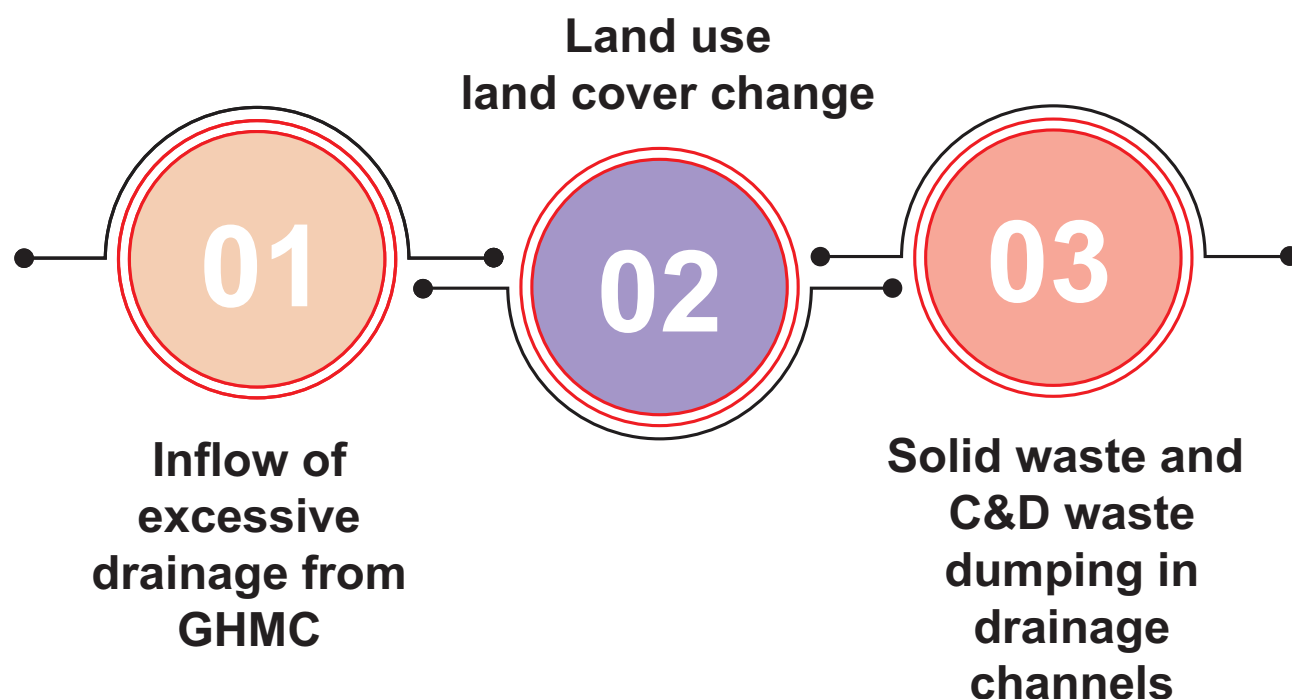


Figure 23. Identified Pressures on the Stormwater Network in Manikonda

Source: Developed based on preliminary consultation with city officials

Waste composting facilities have been initiated by the municipality in some of the government parks however the coverage is less than 70% (as per consultation with Manikonda Municipality). Neknampur Lake and Mushkin Cheruvu locations have been affected by wastewater and dumping of garbage. Some of the priority pressures on the stormwater drainage system in Manikonda are listed in Figure 24. The municipality is now focussed on lake rejuvenation where collaborative efforts for cleaning along with NGO are being undertaken. Additionally, reforms for optimizing waste management are being planned with support from bilateral agencies which are at the ideation stage.

4.3 FLOOD RISK ASSESSMENT

Over the years, urban development has increased in Manikonda, leading to encroachment upon nallahs. This has restricted their natural flow capacity significantly. This reduction in space has resulted in frequent flooding problems for nearby housing complexes and colonies, as the nallahs are unable to efficiently channel water during heavy rainfall events. In Manikonda, in July 2023, 80 colonies (Panchavati Colony, Secretariat Colony, Alkapur Township, Tulip Colony and many more) faced a perennial problem of inundation (according to municipal officials).

4.3.1 RAINFALL ANALYSIS USING INTENSITY-DURATION-FREQUENCY CURVES

The maximum 24-hour rainfall for the past 30-years (1994-2023) is obtained from India Meteorological Department (IMD) Grid (0.25°x0.25°) through MATLAB Code for specific latitudes and longitudes of the site. It is plotted to understand the maximum, minimum, and average rainfall that occurred at that location. This rainfall data is analysed further to obtain the IDF curves.

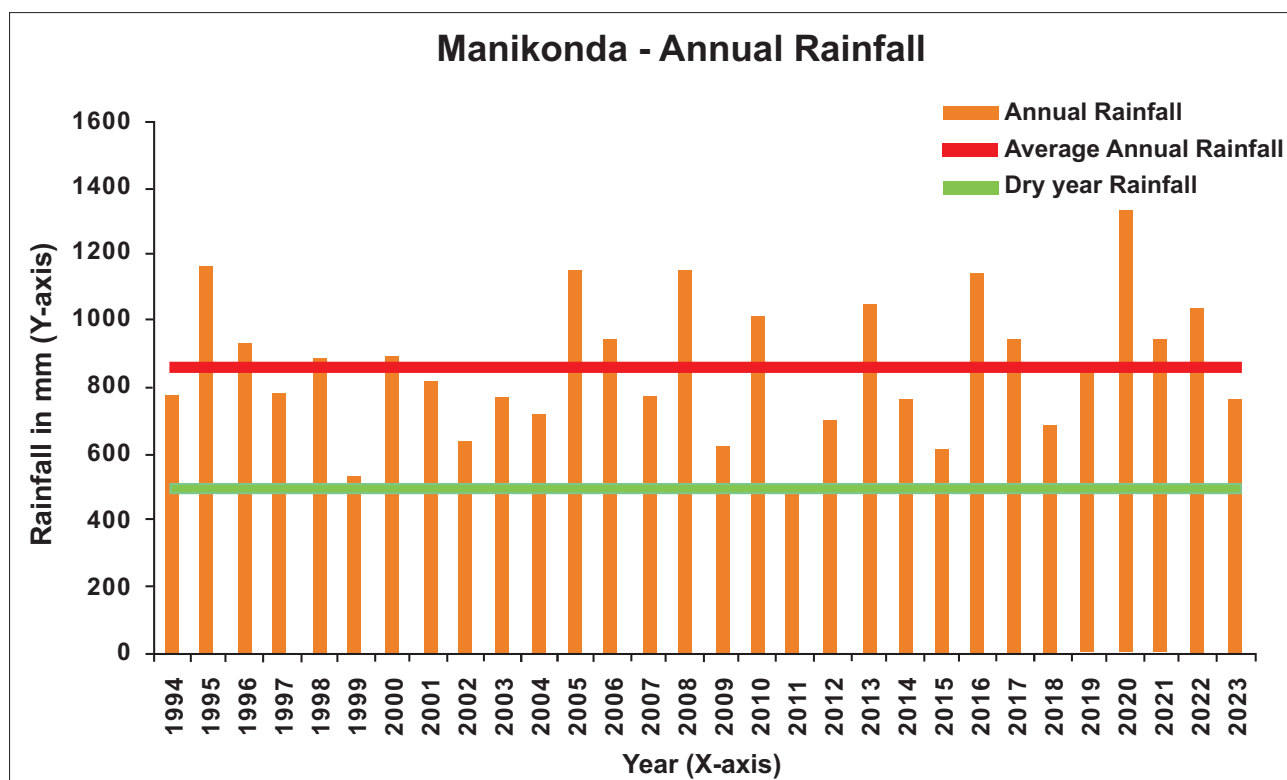


Figure 24. Statistical Representation of Manikonda Rainfall Data

Manikonda, located on the Deccan Plateau in the central stretch of the eastern seaboard of the Indian Peninsula, exhibits a distinctive rainfall pattern based on a comprehensive analysis of 30 years of meteorological data. The city experiences an average annual rainfall of 861.14 mm (red line). It was observed that for the last 5 years consistently rainfall has been more than the average rainfall, showing the climate change effect while dry year rainfall (green line) of 500 mm occurred in year 2011. Over this period, the maximum recorded rainfall reached approximately 1332 mm, highlighting significant variability in precipitation levels. While dry-year rainfall (denoted by the green line) of 503.09 mm occurred in the year 2011. It was observed that for the last five years, consistent rainfall has been around the average rainfall, showing the climate change effect. Figure 24 presents a bar chart displaying the annual rainfall data for this period, including the average annual rainfall and the rainfall during the dry year for Manikonda. Figure 25 shows the IDF curve for design storm events for 5, 10, 25 and 100-year periods.

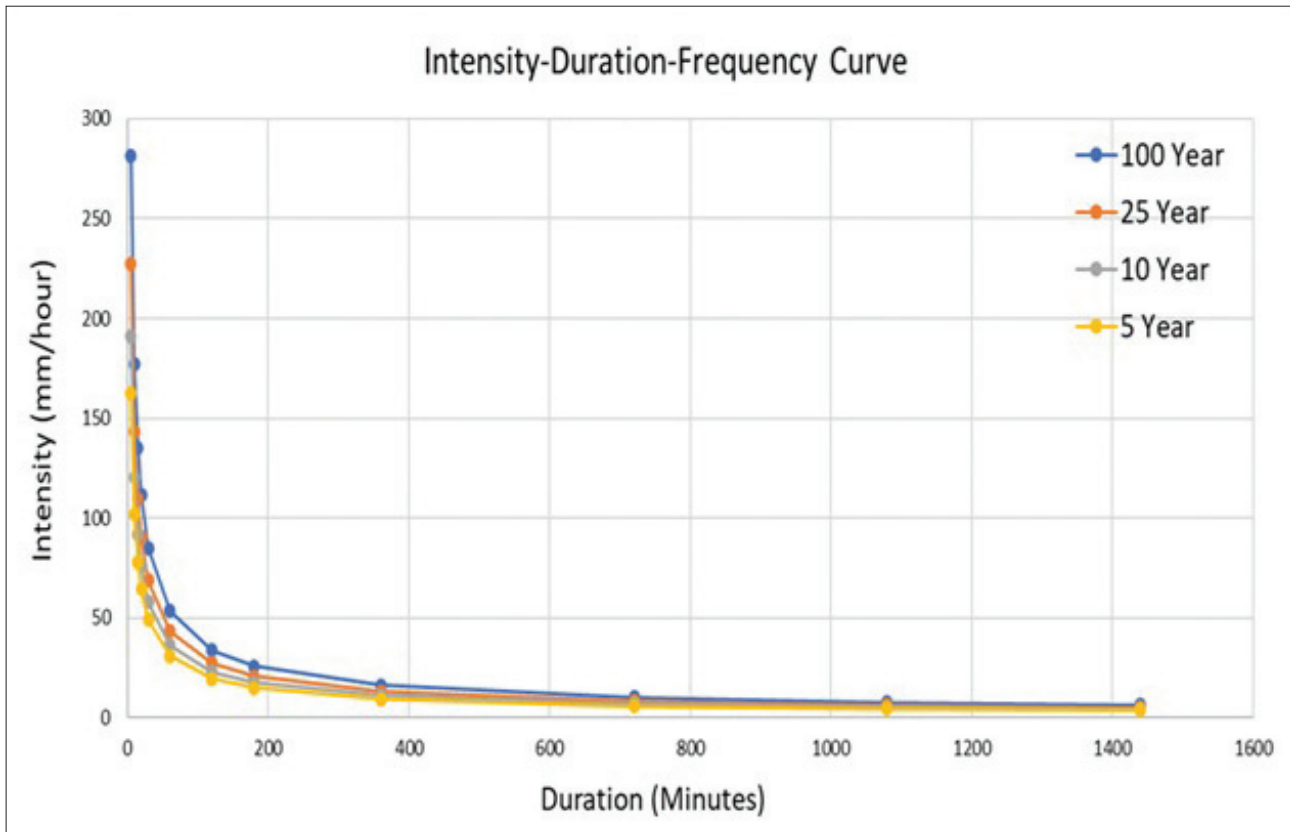


Figure 25. IDF Curve for Design Storm Events of Manikonda

Source: Rainfall Data from IMD

4.3.2 CLIMATE CHANGE SCENARIO

In the context of climate change, more intense rainfall events are expected due to warmer temperatures and altered atmospheric circulation patterns, leading to increased rainfall intensities for specific durations and return periods (Trenberth, 2011). The assessment is conducted following the guidelines outlined in the CPHEEO manual which involves analysing the past 10 years of rainfall data (2014-2023) and constructing corresponding IDF curves and will focus on a 100-year return period event (Figure 26). This approach helps understand the impact of climate change on extreme rainfall events and informs infrastructure planning and resilience measures accordingly. The x-axis represents rainfall duration (minutes), the y-axis denotes rainfall intensity (mm/hr), and different curves on the graph signify varying return periods or frequencies of rainfall events.

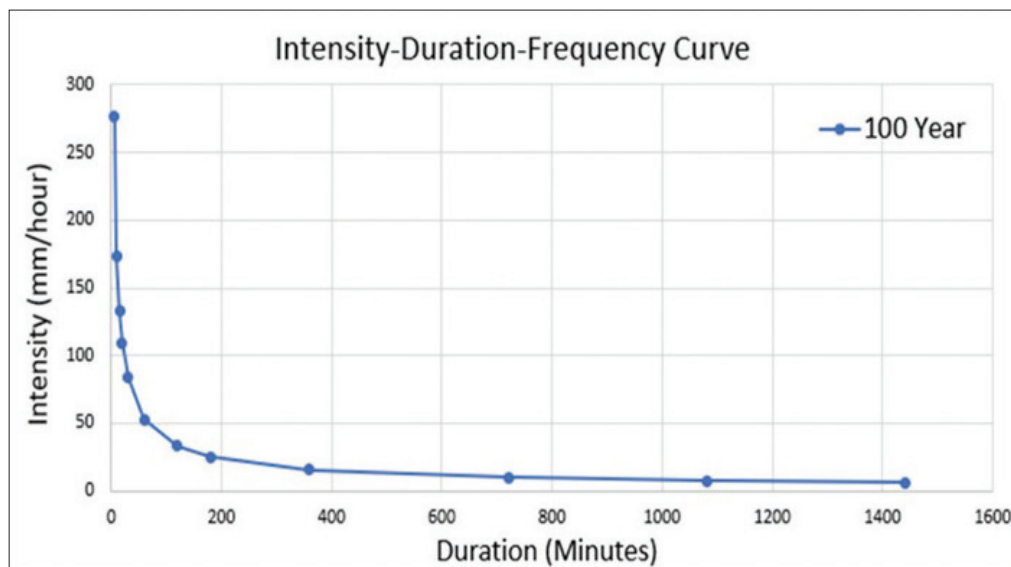


Figure 26. Graphical Representation of the IDF Developed for Climate Change Scenario for 100-year Return Period Event at Manikonda

Source: Rainfall data from IMD

4.3.3 DRAINAGE AREA ANALYSIS

The Drainage Area (DA) analysis is performed using the DEM with 30m x 30m grid resolution obtained from Bhuvan. As shown in Figure 32 Nallah-1 and Nallah-2 flow through Manikonda City. It discharges into the Musi River the south of Manikonda City. DA Nallah-1 and DA Nallah-2 are delineated for the streams flowing through Manikonda to understand the amount of surface runoff flowing toward the streams. Drainage areas DA Nallah-1 and DA Nallah-2 cover approximately 8.77 Sq.km (2167.81 ac) and 29.15 Sq.km (7202.25 ac), respectively as shown in Figure 27. These Nallahs flow from north to south and the drainage areas are majorly residential areas. Longest flow paths (marked in blue) are identified for each drainage area using the flow accumulation generated using the DEM required to calculate the time of concentration. Flow direction in the city is from North to South, draining into the Musi River flowing in the south of the city in directions west to east.

Soil type data is analysed using HYSOGs250m data¹. This dataset represents a globally consistent, gridded dataset of hydrologic soil groups (HSGs) with a geographical resolution of 1/480 decimal degrees, corresponding to a projected resolution of approximately 250 m. HSGs for Nallah-1 and Nallah-2 drainage areas are derived as described in the U.S. Department of Agriculture-Natural Resources Conservation Service (USDA-NRCS) National Engineering Handbook (USDA, 2009). The DA Nallah-1 and DA Nallah-2 consist of soils classified into HSG C, D, C/D, and D/D categories. HSG-C has moderately high runoff potential (typically contains <50% sand and 20-40% clay). HSG-D has high runoff potential (<50% sand and >40% clay). HSG-C/D has high runoff potential unless drained (<50% sand and 20-40% clay) and HSG-D/D has high runoff potential unless drained (<50% sand and >40% clay). DA Nallah-1 and DA Nallah- 2 mainly consist of HSG D.

The Time of concentration for DA Nallah-1 is 57.25 min (0.95 hr) and for DA Nallah-2 is 78.45 min (1.31 hr) i.e. the total time taken for rainwater to travel from the farthest point of the drainage area to the outfall.

¹ Global Hydrologic Soil Groups (HYSOGs250m) for Curve Number-Based Runoff Modelling (ornl.gov)

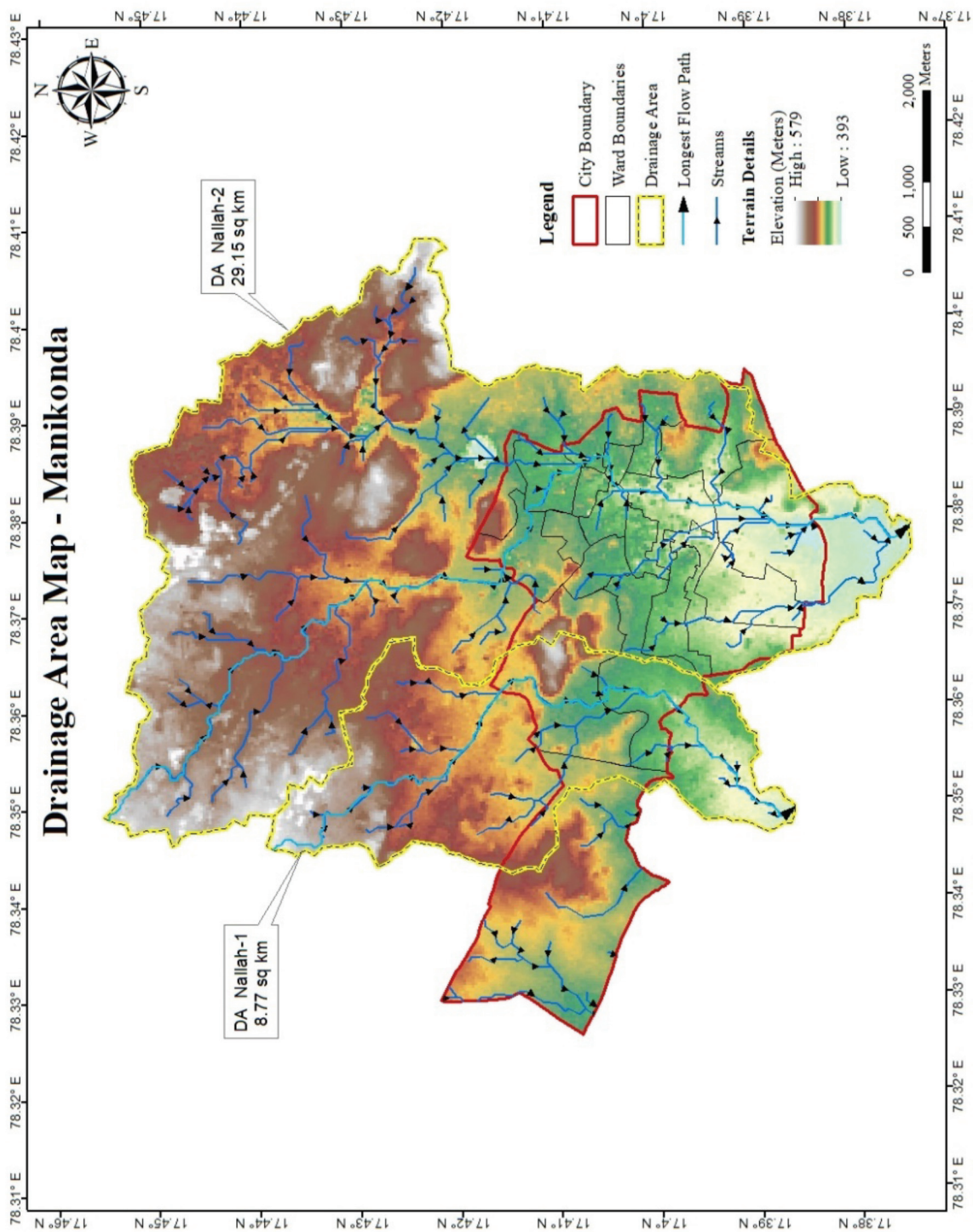


Figure 27. Drainage Area Analysis - Manikonda

Source: Developed from satellite imagery and datasets from IMD, ISRO

4.3.4 PEAK FLOW ANALYSIS

The peak flow from the offsite drainage area is estimated using the Rational Method. The methodology is based on the Storm Water Drainage Systems Manual, Volume 1 by the Central Public Health and Environment Engineering Organisation (CPHEEO). The Runoff Coefficients 'C' for the Nallah-1 and Nallah-2 drainage areas, DA Nallah-1 and DA Nallah-2 in Manikonda are used as 0.60 and 0.70 respectively considering the areas as a high-density residential catchment. On average 80% increase in the 100-year rainfall intensity and the peak flows are estimated to show the climate change scenario. This indicates the need for action with specific considerations for long-term changes in the area. Tables 8 and 9 show the various hydrological estimations for different storm events and climate change scenarios. In the 100-year return period the estimated flow increases by 1.5 times the 10-year return period for DA Nallah-2.

Table 8. Hydrological Estimations for the Drainage Areas for Different Storm Events for Manikonda

Drainage Area	TC (hrs)	C	Area (sq. km)	Intensity (mm/hr)			Estimated Flow (m ³ /sec)		
				10-year	25-year	100-year	10-year	25-year	100-year
DA Nallah-1	0.95	0.60	8.77	38.43	45.73	56.52	56.18	66.86	82.64
DA Nallah-2	1.31	0.70	29.15	32.31	38.45	47.53	183.14	217.94	269.38

Table 9. Hydrological Estimations for the Drainage Areas for Climate Change Scenario for Manikonda

Drainage Area	TC (hrs)	C	Area (sq. km)	Intensity (mm/hr)	Estimated Flow (m ³ /sec)
				100-year	100-year
DA Nallah-1	0.95	0.60	8.77	87.12	127.38
DA Nallah-2	1.31	0.70	29.15	74.05	419.65

4.3.5 ONE-DIMENSIONAL HYDRAULIC MODELLING

Hydraulic analysis for Manikonda City is performed considering the terrain low elevations obtained from Bhuvan terrain data and aerials. Historical imagery on Google Earth shows that the Nallahs were visible in earlier years but have since been obscured by encroachment. The oldest historical imagery available on Google Earth was from the year 1985, followed by imageries from the year 2010 onward. Historical imageries from all the years between 2010 and 2024, along with the year

1985 imagery were observed. In the historic imagery of the year 1985, the Nallahs were visible. However, in the imageries from the year 2010 to 2024, increasing encroachment on the Nallahs was observed over the years. Nallahs are modelled as per the older aerials and the older Nallahs locations.

The hydraulic analysis of the Nallahs involves obtaining multiple cross-sections sequentially drawn from the left side over the river bank to the right. The cross-sections were cut perpendicular to the flow path of Nallah-1 and Nallah-2 flowing within Manikonda city. This approach is used to assess the flood risk due to the Nallahs in terms of the Water Surface Elevation and the extent of flooding in the city. This was done aligning with the direction of flow of the Nallah-1 and Nallah-2 flowing within the Manikonda city. These cross-sections are meticulously positioned perpendicular to the flow path and subjected to analysis utilizing 1D steady-state techniques. Land cover assumptions were established through Google satellite imagery. Manning's roughness (n) values were assigned to the Nallah-1 and Nallah-2 cross-sections based on the land cover according to the CPHEEO manual (Annexure 2).

The hydraulic analysis is used to determine the flood risk to the project site by understanding the water surface elevation, depth, and extent of the inundation. A 1D HEC-RAS model is developed considering a stretch of nallahs/rivers covering the extent of the city. Multiple cross-sections are obtained sequentially from left to right, aligning with the direction of flow of the Nallah-1 and Nallah-2 flowing within the Manikonda city, to assess flood risk at the Manikonda. The Nallahs are modelled from north to south, starting from the north city boundary to the south and draining into the Musi River. There is a minor increase in the extent of floods in 10, 25 and 100-year return periods. For the hydraulic model, the peak flow corresponding to the 10-year, 25-year and 100-year return period storm event is employed as the upstream boundary condition for the Nallahs. The downstream boundary condition in the hydraulic model is defined by a normal depth. Figure 28 visually depicts the extent of the 1D model of the Nallah-1 and Nallah-2. The green lines represent the cross-sections.

As a result of the hydraulic analysis, the Water Surface Elevation Level (WSEL) and extent of inundation for 10-yr, 25-yr and 100-yr return period rainfall events are obtained at each of the considered cross-sections are shown in Figure 29, 30, 31 respectively. The water surface elevation for different storm events shows an increasing trend from the 10-year to the 25-year and then to the 100-year return periods. Under the climate change scenario (100-year) WSEL is higher than the 100-year design storm event, as indicated in Table 10 for different cross-sections at key landmarks in Manikonda. Climate change intensifies the risk profile of vulnerable urban cities in India by altering the frequency and severity of flood-related hazards. Therefore, adopting integrated climate change risk management is essential for understanding extreme events and incorporating disaster risk reduction into local development policies. The climate change scenario assessment is conducted following the guidelines outlined in the Storm Water Drainage Systems Manual, Volume 1 by the Central Public Health & Environmental Engineering Organization (CPHEEO). This timeframe captures current trends and variations in rainfall patterns influenced by climate change. Focusing on recent data allows for a more accurate assessment of extreme rainfall events.

Table 10. Water Surface Elevations (WSEL) for Different Storm Events and Climate Change Scenarios at Various Cross-sections Manikonda (a) Nallah 1 (b) Nallah 2**(a)**

Cross-Section ID	Landmark	WSEL (m)			
		Design Storm Events			Climate Change Scenario
		10-yr	25-yr	100-yr	
1	Khajaguda Lake Entrance	562.30	562.42	562.59	562.98
2	Khajaguda Lake	559.12	559.15	559.20	559.32
3	ORR Service Rd — Lanco Hills Link Road	545.42	545.50	545.61	545.87
4	J Block, Aparna Zenon	540.02	540.08	540.17	540.43
5	Sai Gautam Colony Road, near Mushkin Cheruvu	537.84	537.93	538.05	538.32
6	Muppas Road	531.86	531.89	531.93	532.10
7	Narsing Nanakramguda Service Road	528.37	528.46	528.57	528.84
8	NCC Urban Club House	525.27	525.33	525.40	525.56

(b)

Cross-Section ID	Landmark	WSEL (m)			
		Design Storm Events			Climate Change Scenario
		10-yr	25-yr	100-yr	
1	Between Khajaguda Talab and Khajaguda-Nanakramguda Road	554.42	554.51	554.65	554.93
2	Jain Housing and Constructions Ltd.	552.50	552.66	552.85	553.32
3	Manikonda Cheruvu	550.44	550.53	550.67	551.02
4	Duplex Chitrapuri Hills near Malkam Cheruvu Road	545.29	545.40	545.54	545.87
5	Eldritch Residency Road Number 51	541.17	541.30	541.46	541.86
6	Shaikpet Main Road Nallah	533.38	533.55	533.79	534.41
7	Hyderabad Presidency College and PG Centre	527.10	527.26	527.45	527.91
8	Community Hall, Secretariat Hills	522.95	523.07	523.22	523.59
9	Ibrahim Cheruvu	519.81	519.93	520.09	520.47
10	Vessella Meadows Park 2	516.35	516.51	516.69	517.10

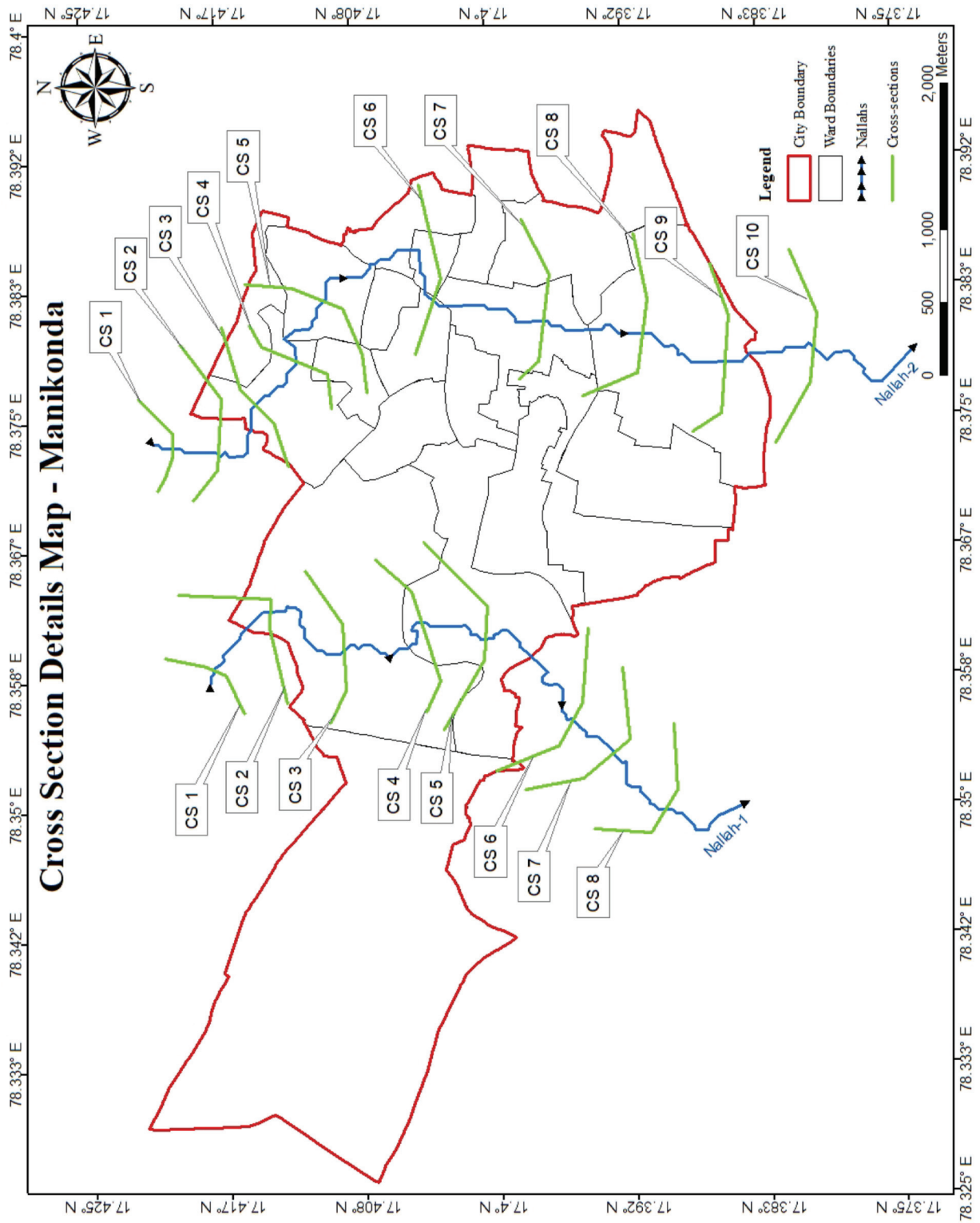


Figure 28. Cross-section Details of Manikonda

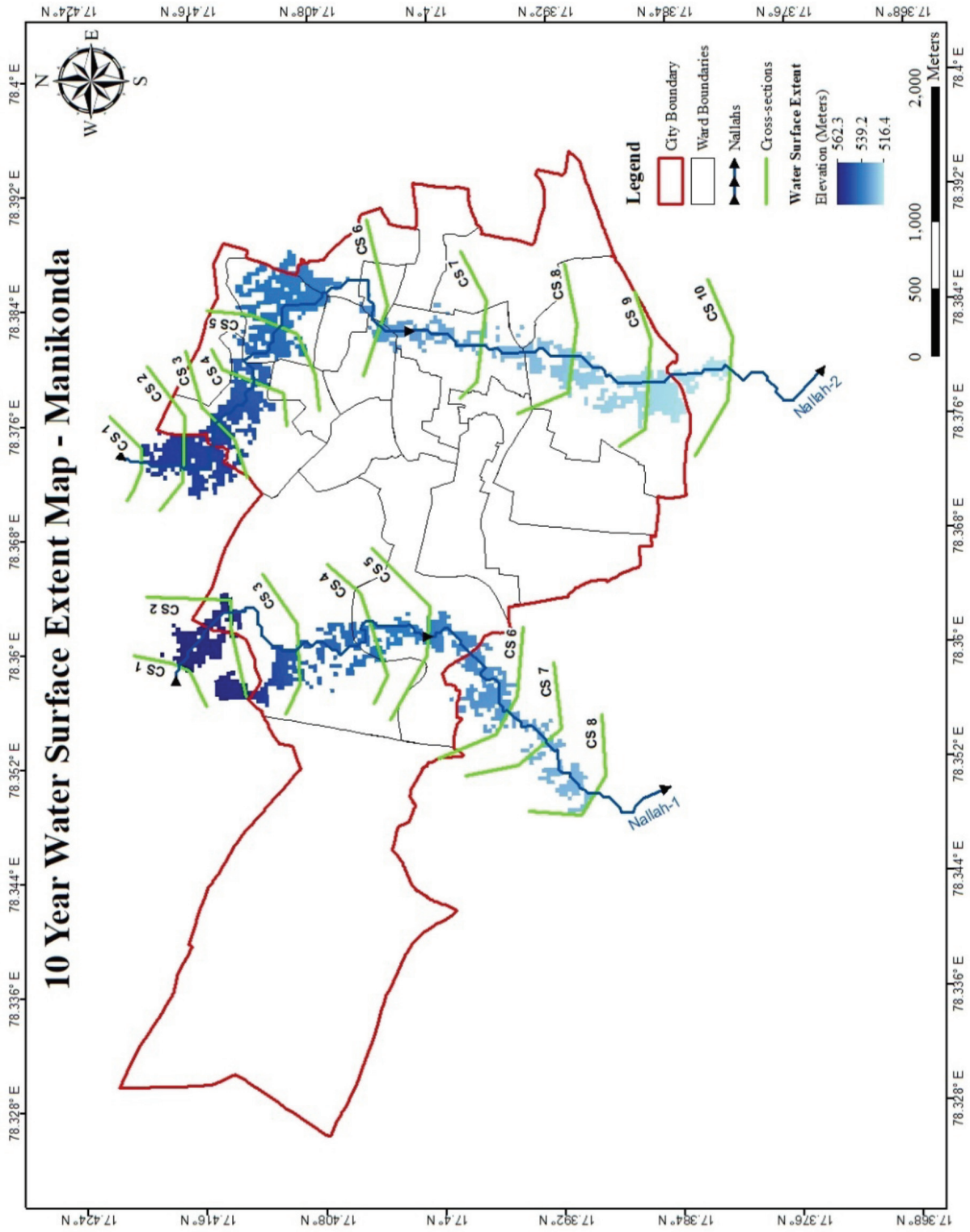


Figure 29. Flood Water Surface Extent at 10-year Return Period – Manikonda

Source: Developed from IMD, ISRO, municipal office datasets and field visits

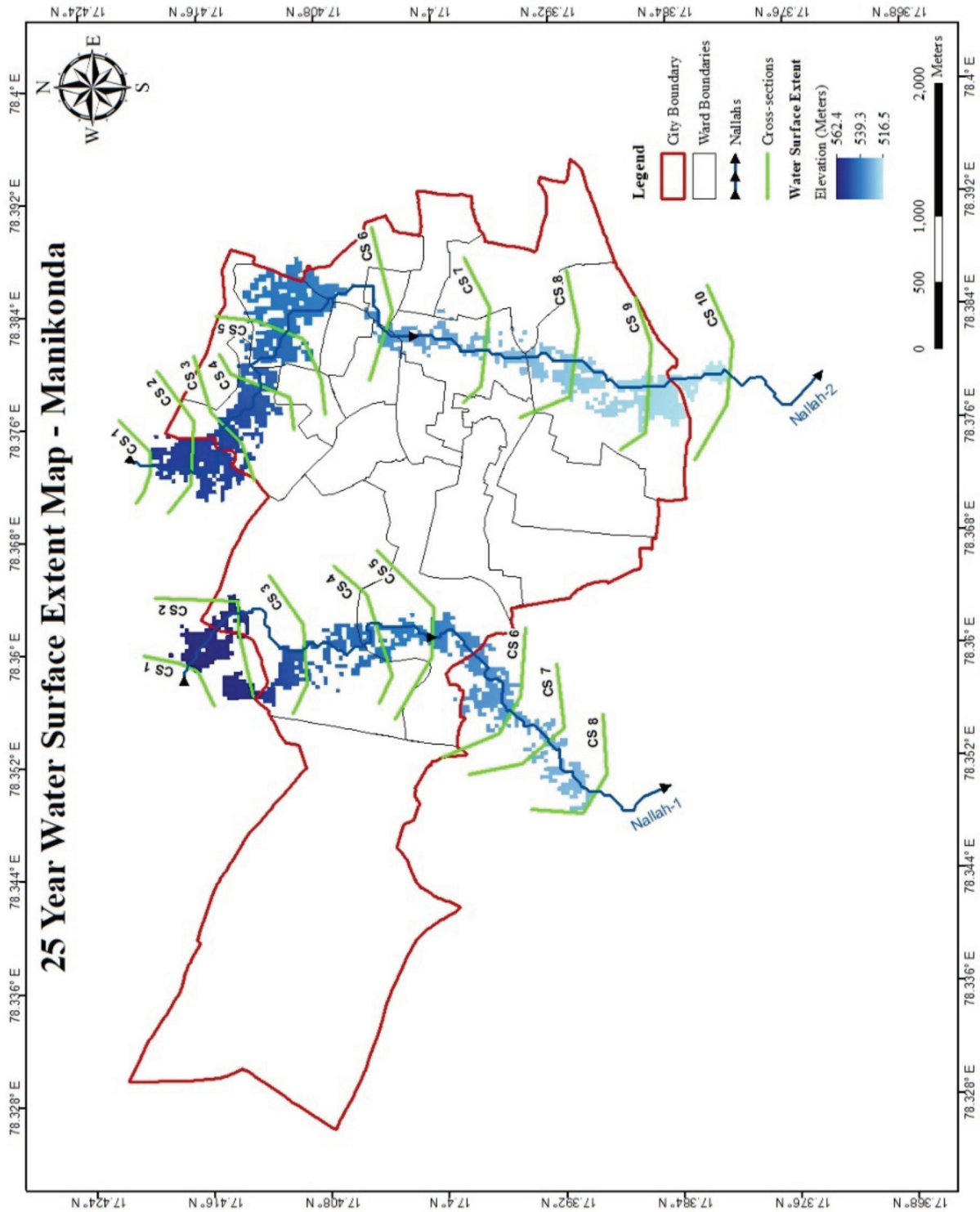


Figure 30. Flood Water Surface Extent at 25-year Return Period - Manikonda

Source: Developed from IMD, ISRO, municipal office datasets and field visits

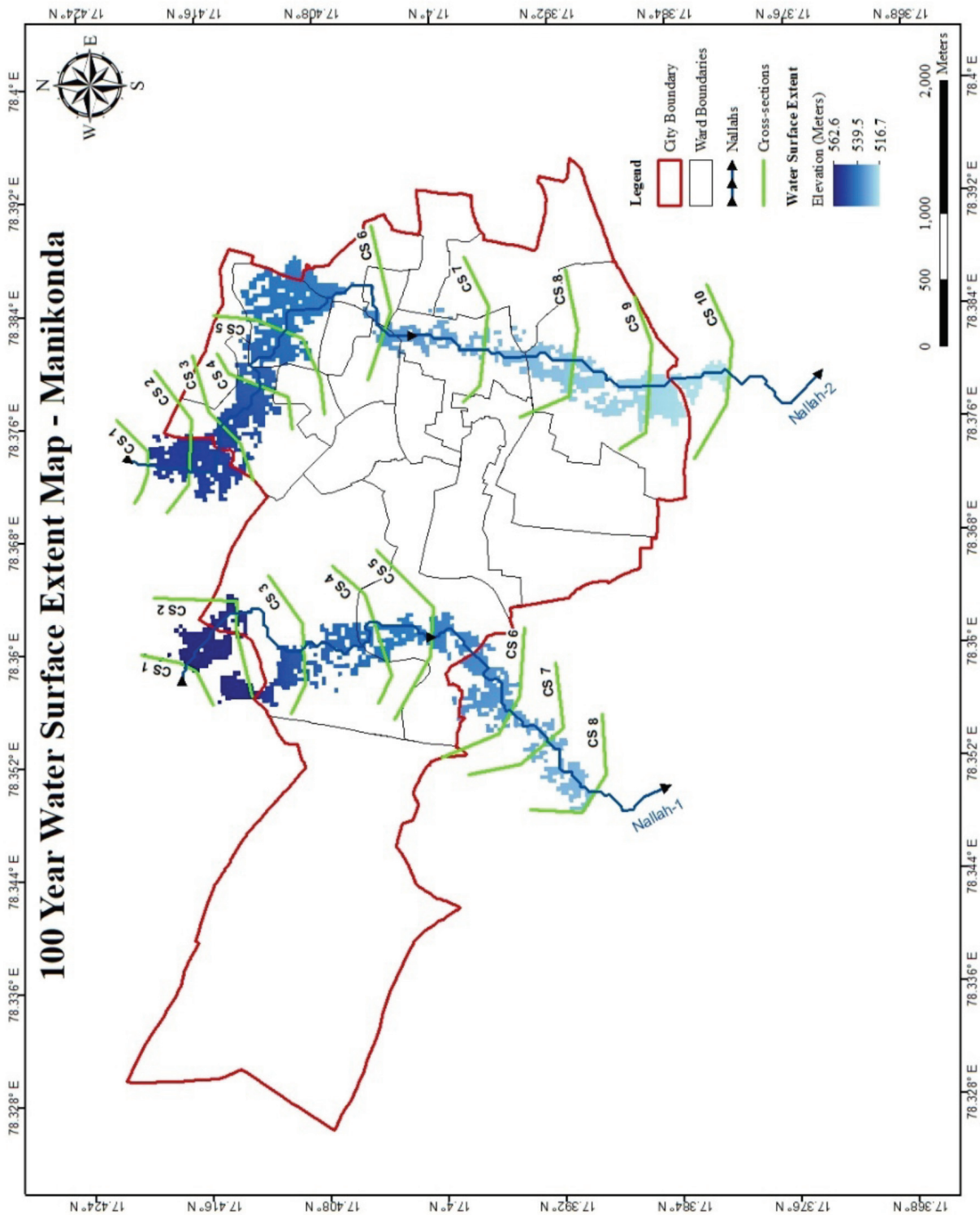


Figure 31. Flood Water Surface Extent at 100-year Return Period – Manikonda

Source: Developed from IMD, ISRO, municipal office datasets and field visits

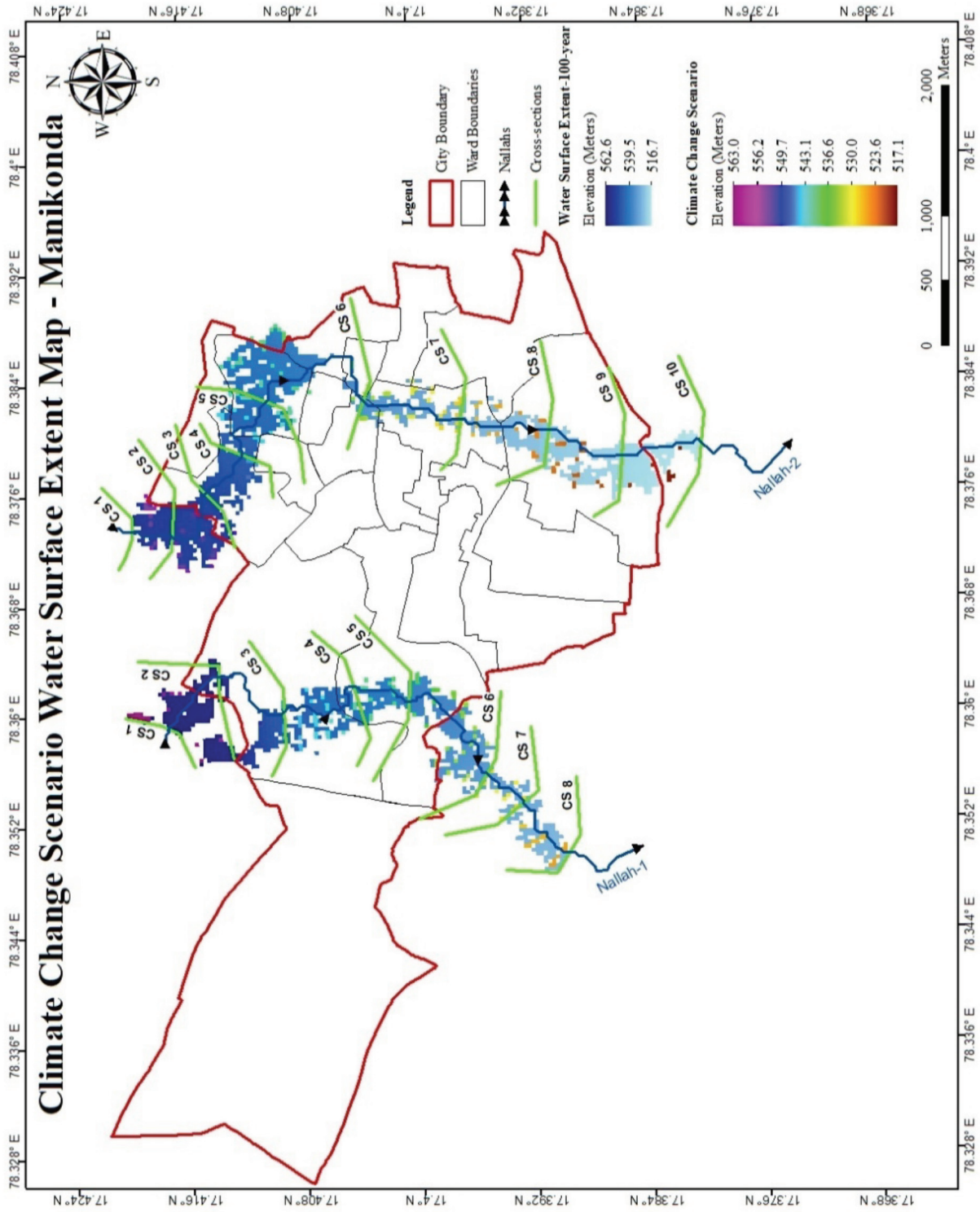


Figure 32. Flood Water Surface Extent at Climate Change Scenario – Manikonda

Source: Developed from IMD, ISRO, municipal office datasets and field visits

Based on the findings of the 1D steady analysis of the Nallahs, it can be inferred that Panchavati Colony, Golden Temple Secretariat Colony, Spectrum Villas and Trails Villa Ward No.3 experienced flooding due to Nallah-2. These are among some of the critical areas as provided by the Manikonda Municipality — Action Plan-2024 and local area files shared which are prone to flood. It is observed through Google Earth that the Nallahs are largely covered by encroachments and constructions. Figures 29 to 32 show that, for the 100-year return period, the water surface extends to Road Number 13, Road Number 14, Road Number 15 and Enigma Digi. These are some of the areas which are not impacted by the 25-year return period results. In the climate change scenario, the water surface extends to Golden Temple Road, Neknampur Road, Aparna Zenon, etc. areas that are not affected in the 100-year return period. For further analysis, consideration of the water surface extent from the climate change scenario is considered suitable for providing solutions that are holistic in nature and cater to the majority of the city.

4.3.6 IMPACT OF RIVERINE FLOOD ON URBAN FLOODS

The analysis conducted for a 100-year return period rainfall event for the Musi River shows that the 100-year water surface does not extend up to Manikonda city as shown in Figure 33. Thus major urban flooding incidents in Manikonda city like in September 2024, September 2023 and October 2020 were due to the Nallahs which are largely covered with encroachments and hinder the water management during heavy rainfall in the city. Similar observations are made during the RICA site visit and discussions. As noted in Section 5.2, flooding at specific critical locations in Manikonda is attributed to factors such as the overflow of stormwater drains, insufficient capacity, improper grading, substantial silt accumulation and indiscriminate garbage disposal.

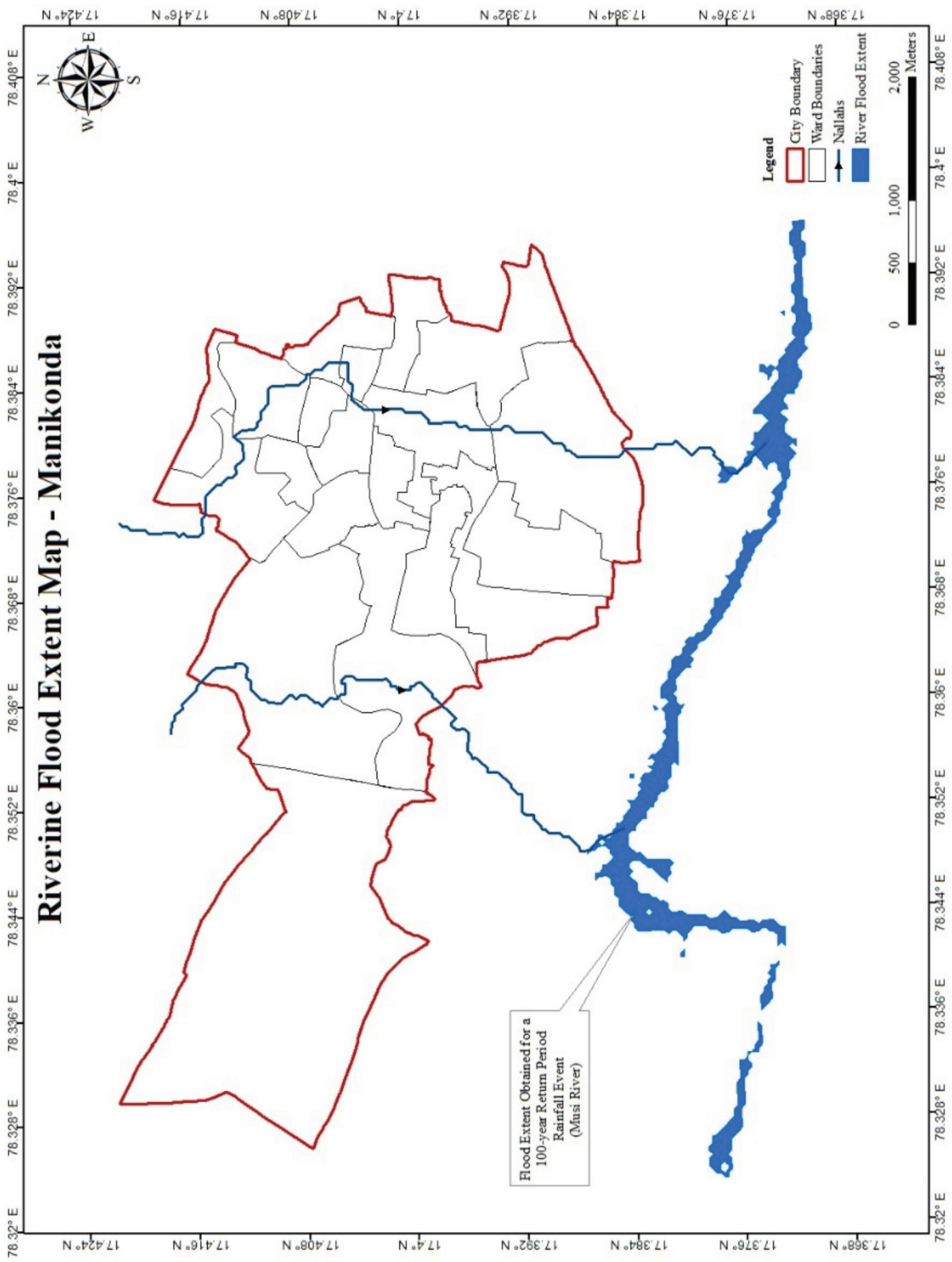


Figure 33. Impact of Musi River Flooding on Urban Floods

Source: Developed from IMD datasets

4.3.7 FLOOD HOTSPOTS

The flooding hotspots identified through hydraulic analysis are the areas marked in yellow are the critical areas flooded because of the Nallahs in Manikonda. It was observed through site visits and consultations that some waterlogged areas are not impacted by Nallahs (marked in cyan color) as shown in Figure 34. The information through analysis was verified through stakeholder consultations and it was identified that the areas of Anjali Garden, Lamma Gardens, Panchavati Colony, Krinns Villas and Manikonda Gardens have been frequently inundated during heavy rainfalls. Spatial information correlates with the information provided by the municipality regarding issues of urban flooding in these locations. Inundation issues are caused by disjointed nallas like Pandan Wagu Nala and blocked natural flow. Panchavati colony and Vinayak Nagar colony are frequented by debris and sediment flow.

Preliminary consultations with the works inspector, engineer, and Municipal Commissioner suggested the increase in construction and demolition waste which is a significant challenge needing priority attention. In addition to urban flooding, India Metrological Department, (IMD) hazard maps suggest the Manikonda region comes under the high damage risk zone for cyclonic storms. Manikonda being situated around 500 km away from the coastline, is susceptible to impacts of cyclonic storms which may arise in the Bay of Bengal from time to time.

The identified wards such as 3, 5, 7, 10, 11 15, 17 and 19 which include the flood hotspots as shown in Figure 34 are considered for the immediate actions for improving the flood resilience. The critical flood locations identified from the hydraulic analysis overlap with the on-ground information acquired as marked in blue and yellow in Figure 34. The waterlogging locations outside the natural drainage channel inundation areas are due to factors like clogging of drains, and lower elevation than neighbouring areas.

4.3.8 IMPACT ON CRITICAL INFRASTRUCTURE

Flooding issues have not affected critical infrastructures like schools, hospitals, electric substations, bus terminals and railway stations in the past. However, there have been frequent hindrance to transportation due to waterlogging at arterial roads. The specific critical infrastructures that are at risk of being inundated in the city are majorly located along the GHMC nallah (Nallah- 2). It was observed from spatial data and the hydrological analysis that some of the arterial roads like Panchavati Colony Road, Lanco Hills Lake Road, Road No. 1, Aparna Main Road, Golden Temple Road, Mushkin Cheruvu Road, would be impacted in situations of flooding in future. As per the analysis, only one hospital Shobha Hospital is at risk of being inundated as shown in Figure 35. None of the schools lie in the critical flood areas but two schools namely Mandal Parishad Primary School Government School and Footprints Pre School are in close proximity to the critical flood area. The electric substations in the city are at a safe distance from the critical flood area. It was observed that there are no police stations or fire stations within the city limits and the nearest facilities are Raidurgam Police Station and Fire Station, Film Nagar respectively.

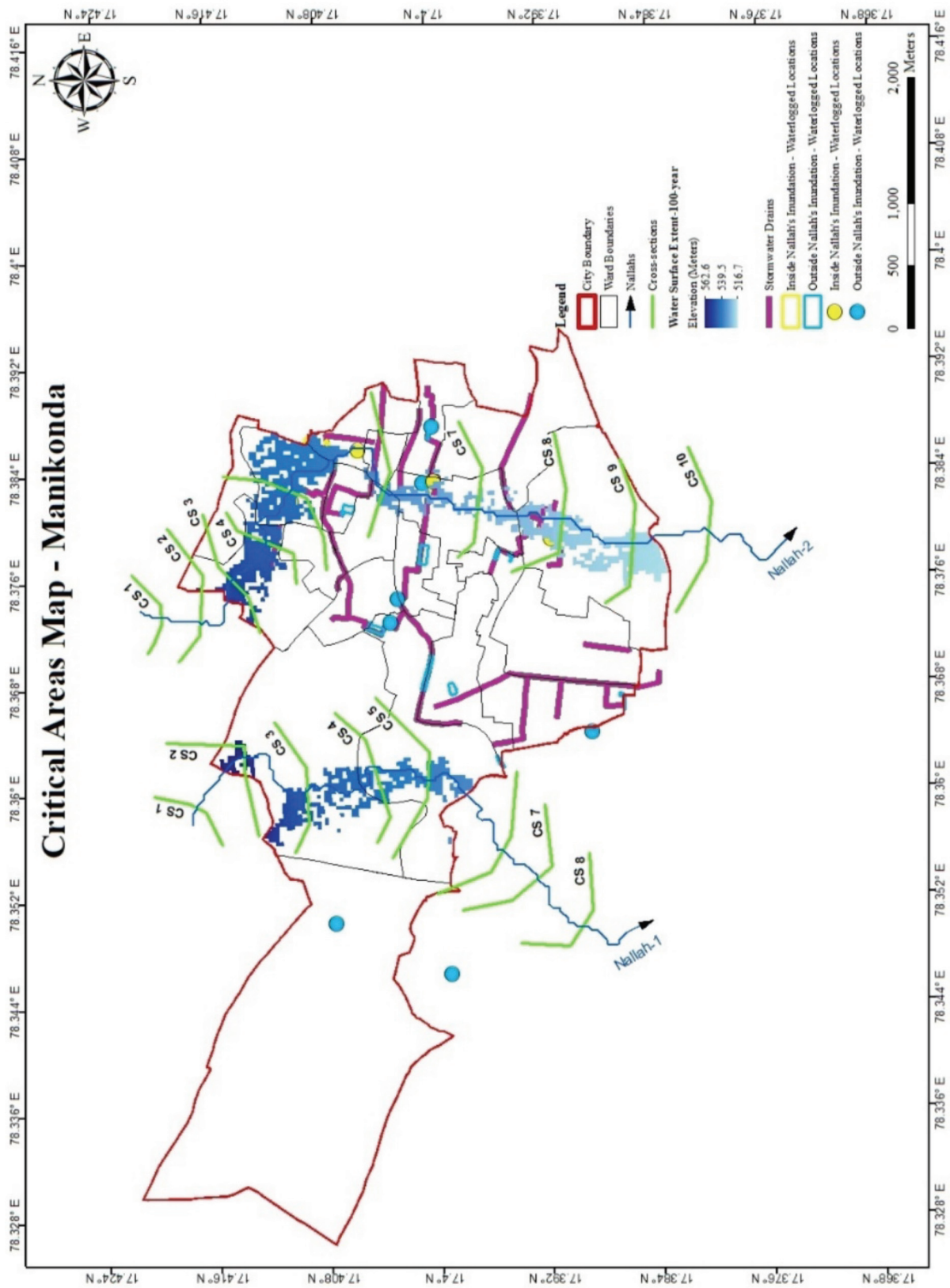


Figure 34. Critical Flood Locations in Manikonda

Source: Developed from IMD, ISRO, Municipal Office datasets and field visits.

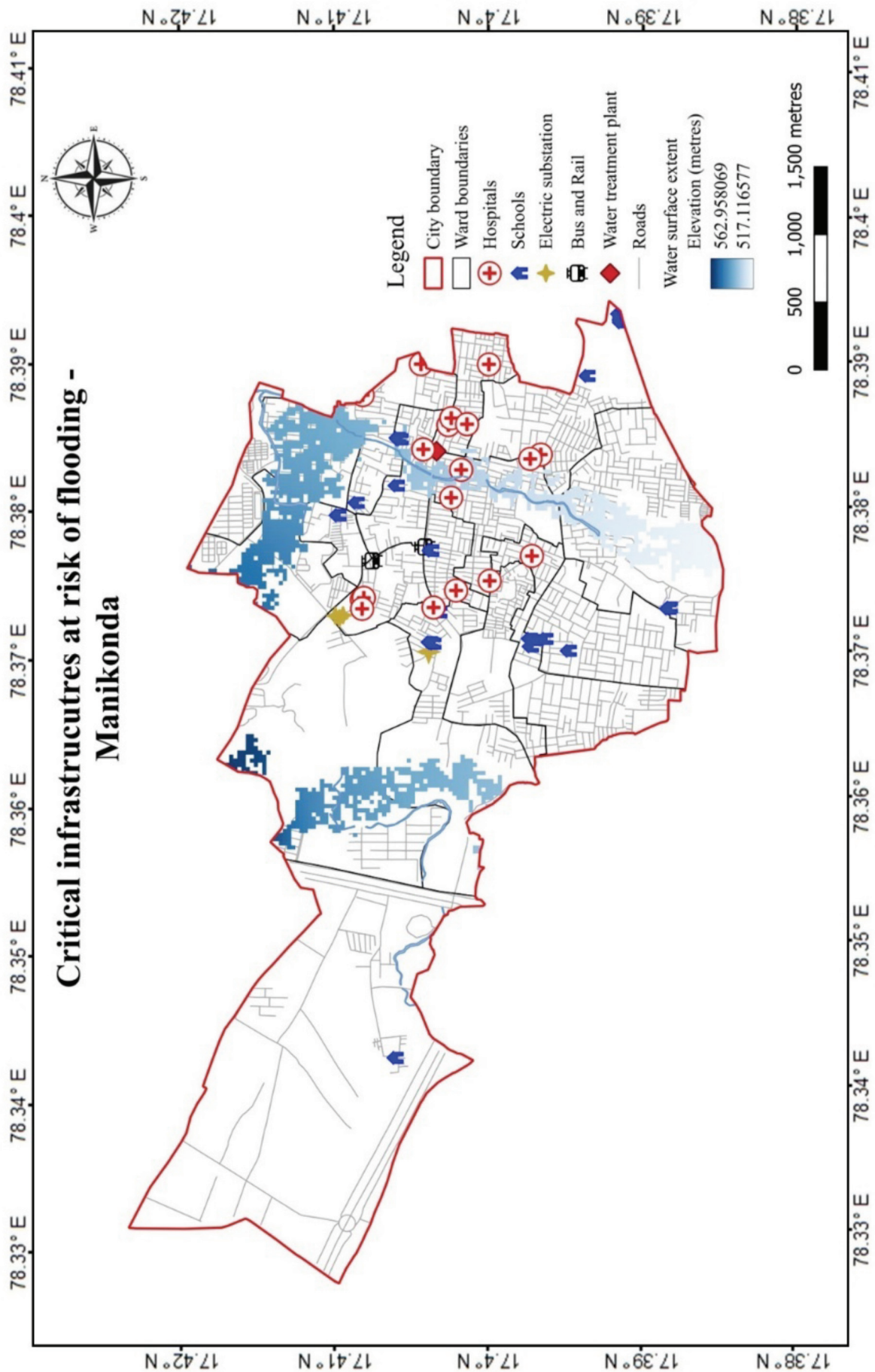


Figure 35. Critical Infrastructure at Risk of Flooding in Manikonda

Source: Municipal Office datasets and field visits.

4.3.9 STRENGTHS AND WEAKNESSES

4.3.9.1 SOCIAL

Manikonda has a major population working in the IT industry with one or more earning members in the family. Household level interactions in the flooding hotspots (in areas of Eldritch Residency Road Number 51, Between Khajaguda Talab and Khajaguda-Nanakramguda Road, Jain Housing and Constructions Ltd., Trails Villa Ward No. 3, Spectrum Villas, Sai Gautham Colony Road, near Mushkin Cheruvu, Duplex Chitrapuri Hills near Malkam Cheruvu Road) suggest that majority of the households are personally owned with land title. The surveyed information suggested internet access through social media, FM radio, etc., is present yet the effectiveness of the same for communication of emergency information and early warning depends on the usage and understanding of the local community. It was highlighted that Twitter is used as a mode of communicating grievances to municipal offices during the time of floods. Although ward officials are well aware of their roles during floods, public knowledge about flood threats varies, with some wards showing less awareness.

Minimal to no engagement of women networks or SHGs in flood risk management and training was observed through consultation and household data collection. Ward No. 16 reports comparatively low literacy rates which indicates poor capacity and a high population density which indicates higher vulnerabilities. Concerns like existing systems for drainage being inadequate and the need for more stormwater drains (SWDs) were highlighted in wards like 10, 11. Several wards along the SNDP-GHMC nallah: Wards 15, 4, 20, 16, 17, 6 and 7 reported recurring water-borne diseases like malaria, and cholera, highlighting gaps in public health measures. The residents informed that there was a limited support from NGOs, CBOs or religious organisations received post-floods. The ward-wise analysis of social conditions based on consultations and data collection tools is shared in Figure 36. This is based on data collected using the data collection tools detailed in Annexure 1 and methodology as highlighted in Chapter 4.

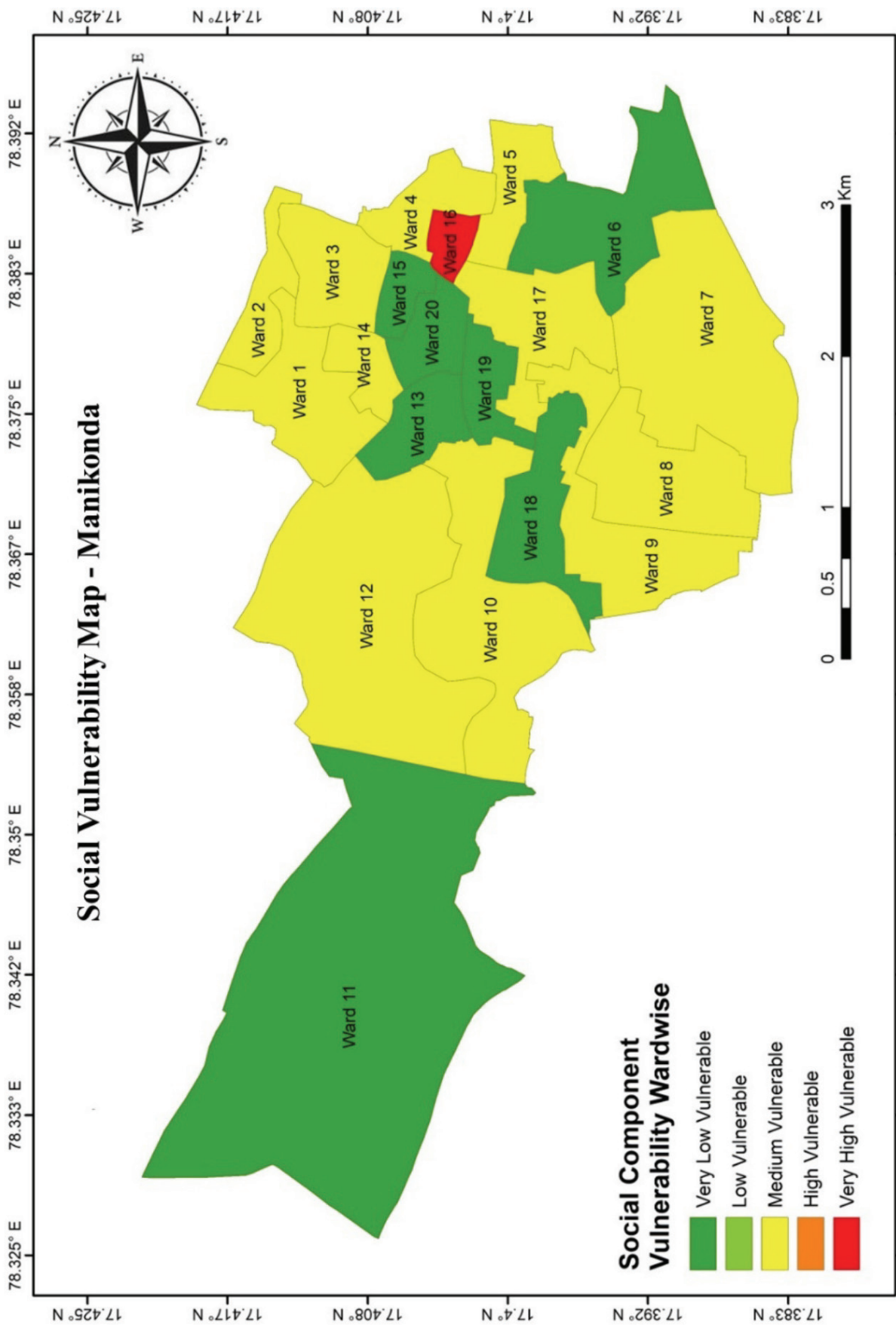


Figure 36. Social Vulnerability Map Manikonda

Source: Developed from Municipal datasets, field data, and consultation

4.3.9.2 PHYSICAL

Wards 7, 8, 9, 11, 12 have high built-up areas causing reduced areas for groundwater recharge. All wards have less than 20% coverage of green infrastructures such as permeable pavements. A high percentage of home ownership suggests stability, but it is crucial to ensure that all owned properties meet flood-resistant standards. 394 such residential units lie in proximity to nallahs and have the potential to be impacted by overflow of drains during monsoon. In areas of Ward No. 7 the culvert often gets inundated, rendering the road non-functional for 3-4 hours. This causes major disruptions for residents and commuters who rely on this road. Residents undertake some activities to mitigate the flood impact, such as clearing debris from near their houses however these are not sufficient for mitigating future risks. Many areas in the ward are particularly prone to flooding due to their low-lying positions, with numerous residences situated below road level.

Every day solid waste collection is reported from the household studied; however, the municipal officials informed the regular door-to-door collection is not yet monitored by them. There is some segregation of approximately 30% (*as reported by government officials*) of waste which is insufficient and causes blocked drains. Waste is collected using 83 autos and 1 tipper vehicle. All wards have good road connectivity with all-weather roads; however, proximity to water bodies, culverts over nallahs, and accessibility during floods remain significant concerns.

According to the municipal office, no hospitals are at risk of flooding, but the condition of culverts near Spectrum villas (Ward No. 7) is poor and needs detailed hydraulic study to improve the culvert dimensions. Geethanjali school area (Ward No. 10) has around 0.3m of inundation during flood situations causing hindrance to access. It was reported that public buildings do not use flood-resistant designs, indicating a significantly high vulnerability. The ward-wise analysis of physical conditions is shared in Figure 37. This is based on data collected using the data collection tools detailed in Annexure 1 and methodology as highlighted in Chapter 4.

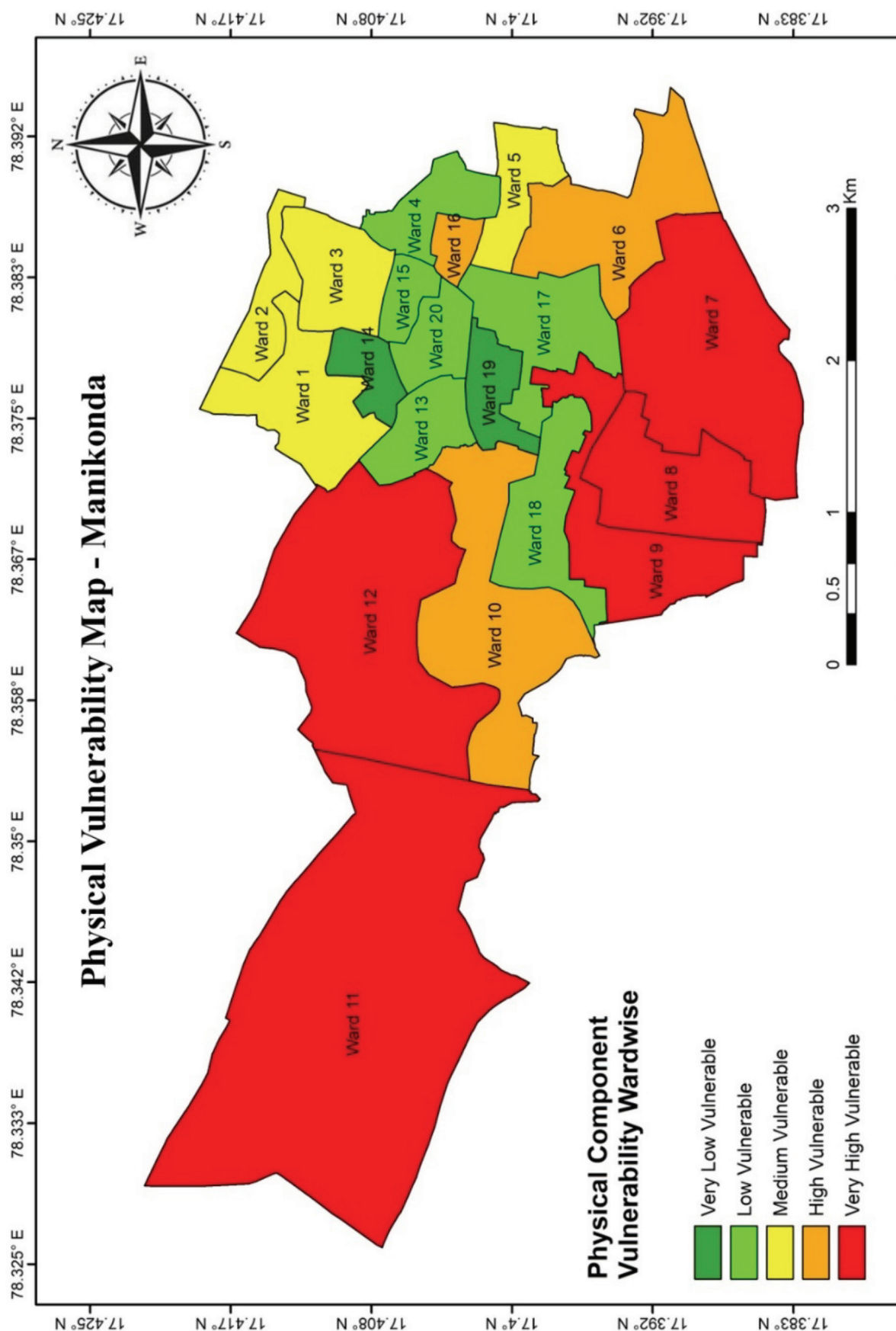


Figure 37. Physical Vulnerability Map Manikonda

Source: Developed from Municipal datasets, field data, and consultation

4.3.9.3 INSTITUTIONAL

The stakeholder consultations and secondary literature indicated that institutional strength in all wards has a scope for improvement as there are no disaster management plans. The residents are generally updated on urban floods through social media and Twitter. There are no regular flood awareness trainings for the community however Disaster Response Force consisting of 8 members was initially trained by GHMC and is equipped with customized vehicles, machinery and a workforce trained to tackle floods. They are prompt in managing the waterlogging situation as communication with the community is good in the area. Except for wards 11 and 12, disaster drills are conducted less than once every six months, indicating room for more frequent engagement in all wards.

Approximately 950 buildings have installed Rainwater Harvesting (RWH) pits, there is a significant need to increase public awareness about it. In all of the municipality areas, none of the buildings reported using flood-resistant designs (as per municipal data). Rainwater harvesting is a mandatory provision however community had limited knowledge of the condition and functionality of rainwater harvesting in the buildings. 6 out of 20 households suggested moderate strength of community cooperation whereas others suggested good cooperation levels. It was also reported by officials that despite generating significant revenue from property taxes, the municipality has struggled to address issues of flooded roads and poor sanitation, affecting the daily lives of residents.

There is a scope for enhancing community-level cohesion as very less of the members are interested in sharing information. Since waste segregation in the city is at 30% there is a need for the municipality to strengthen capacities and establish a community-based mechanism to oversee the implementation and efficacy of preparedness measures. Insufficient resources (books, leaflets, manpower, campaigns) hinder the effective dissemination of flood awareness information to the residents. The municipal officials and community highlighted the absence of multiple channels of early warning dissemination for vulnerable communities such as the elderly, women, and children who may not have mobile phones. This indicates that a lack of targeted communication channels could lead to higher vulnerability for these groups during floods.

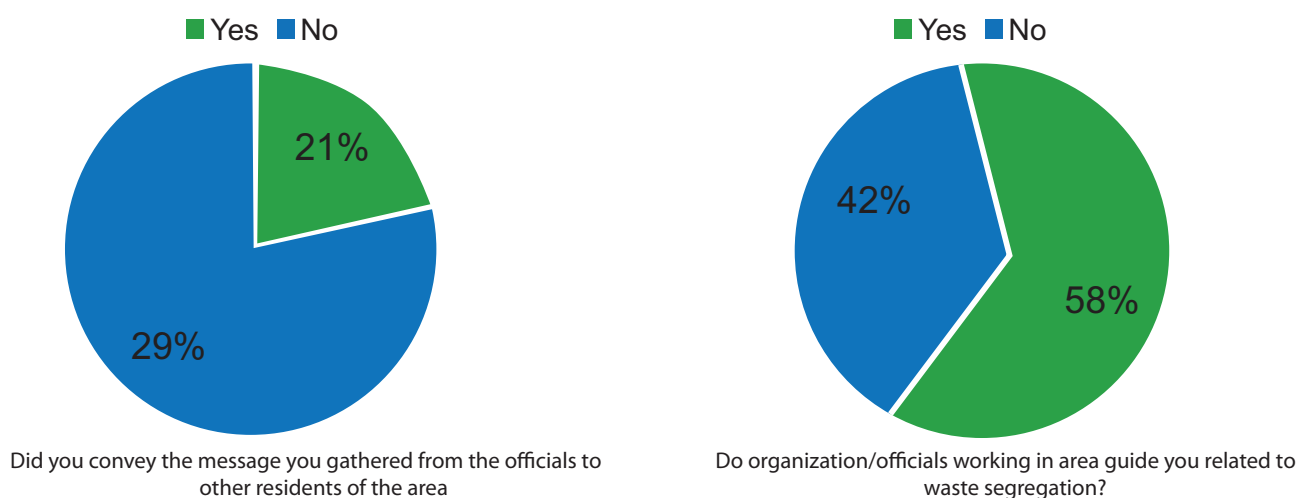


Figure 38. Some Prominent Findings from Household Data Collection

Source: Field data and consultation

4.3.9.4 NATURAL

Consultations indicated that Wards 3 and 7 have a probability of high intensity of floods, while other wards reported high to moderate intensity. High and very high urban flood intensity can lead to significant disruptions, damage and potential loss of life and property. There are no riverine floods in the area and Ward No. 7 have high-intensity flooding of nallah. Consultations suggested that several wards like 3, 5, 7, 8, 9, 10, 11 and 12 experience urban flooding or waterlogging every year, indicating a frequent recurrence that has the potential to lead to severe economic losses, and health hazards, and affect daily life. Out of these wards 3, 5, 7, 10 and 11 are also key flood hotspots identified through field visits as mentioned in Sub-section 5.3.7. Wards 3 and 7 reported a significant loss of urban water bodies due to rampant development and illegal encroachment on drainage channels and water bodies. More than 10 water bodies were lost in the last 10 years as shared by municipal office and evident from satellite imagery. Loss of urban water bodies reduces natural flood buffers, increases flood risk, and impacts local biodiversity. Although disruption of ecosystems and displacement of species have not been reported it can have long-term ecological consequences. Figure 39 shows the wards with severely high natural vulnerabilities based on consultations and field data.

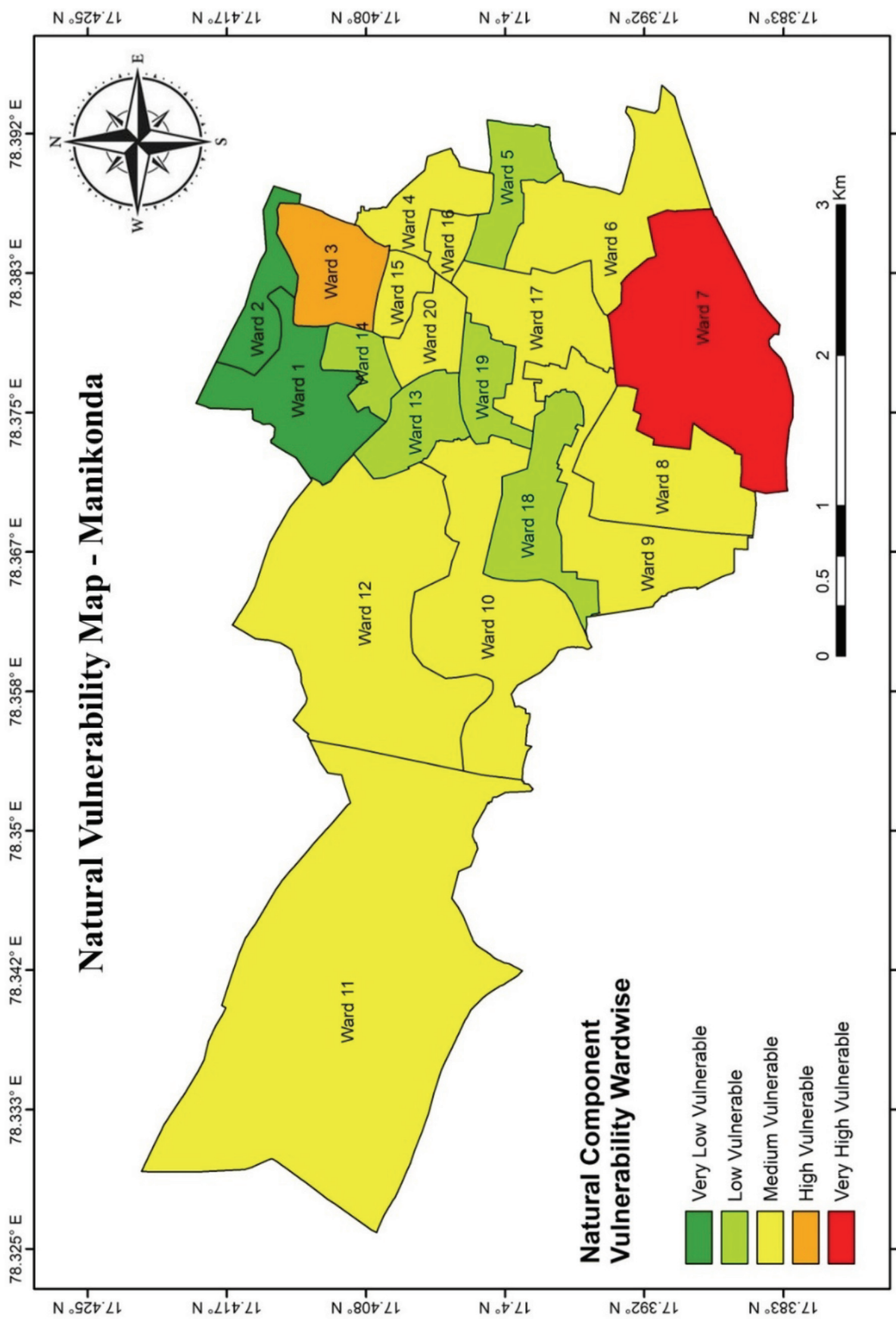


Figure 39. Natural Vulnerability Map Manikonda

Source: Developed from Municipal datasets, field data, and consultation

4.3.9.5 ECONOMIC

In the city, over 60-80% of households rely on a single source of income as shared in the consultation with the municipal office. Women in the workforce are estimated to be 40-50% in the majority of the wards and more than 60% of households depend on one income source. Sufficient funding options are available with the municipal body which are distributed to wards for development purposes as reported by the municipal officials. However, only 20-40% of community members generally have insurance schemes. Wards 5, 8, 9, 10, 11 and 12 face incidents of urban floods that lead to economic losses in households as shared by residents in these areas. Household information identified that less than 20% of affected households got government incentives which they have used to rebuild, suggesting limited availability or awareness of support programs. There is no specific funding or subsidies available for urban poor or low-income groups and during floods. It was highlighted by the municipal officials that the availability of funds for women and women-led businesses is inadequate with some wards reporting no funds both during normal times and during times of flood. In addition, there are no prominent schemes in the city that support reconstruction and revival from damage caused by floods/other disasters. Figure 40 shows the detailed economic vulnerabilities in each of the wards of Manikonda municipality based on consultations and field data.

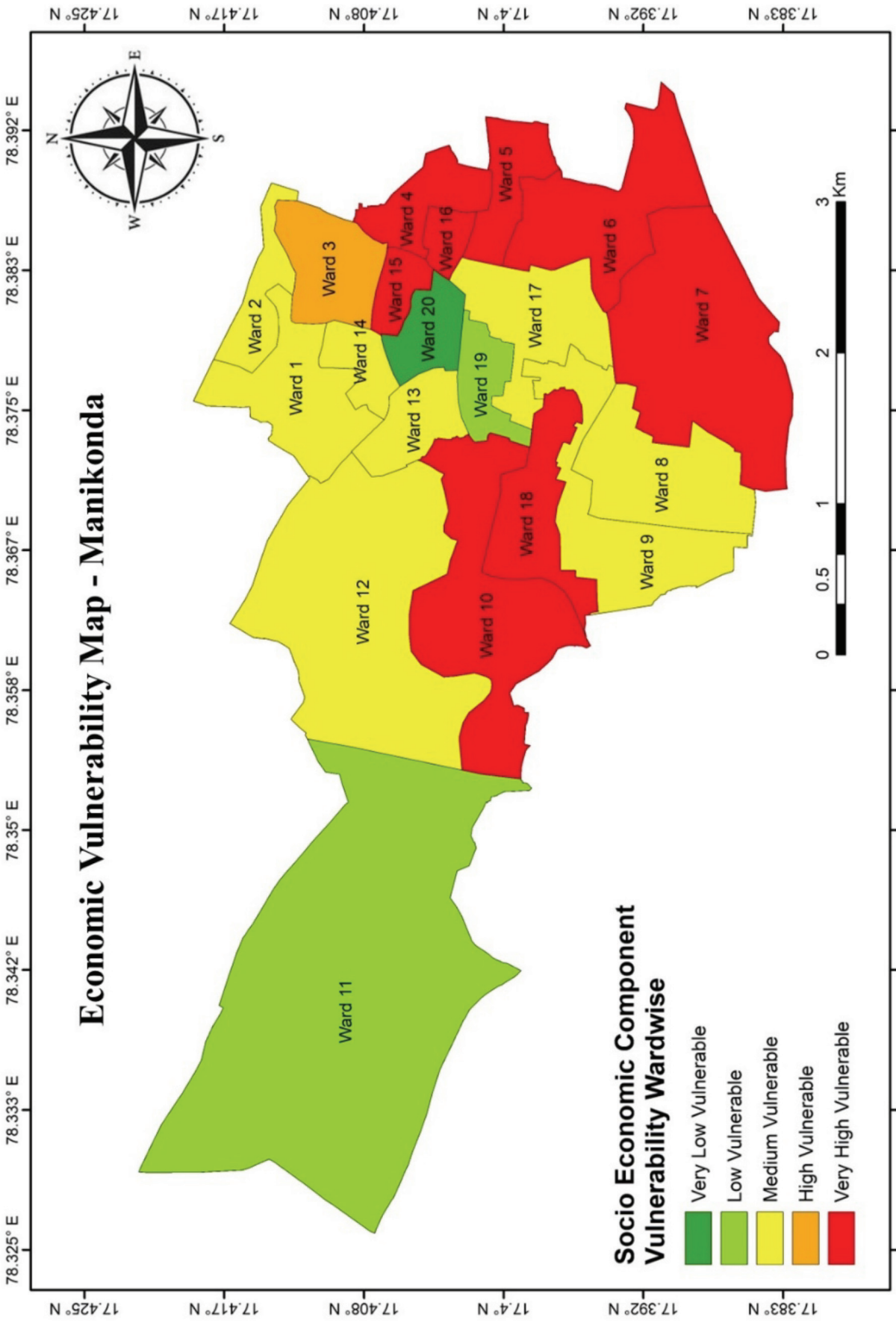


Figure 40. Economic Vulnerabilities in Manikonda

Source: Developed from Municipal datasets, field data, and consultation

4.3.9.6 EMERGENT RISKS IN MANIKONDA

The urban flood risk index was computed at the administrative ward level for Manikonda Municipality. Based on scores, five categories were created using the natural breaks: very high, high, medium, low and very low risk. Hazard map information includes the hydraulic analysis, flood hotspot and probable inundation area information. It also considers the residential areas under the water surface elevation extents marked in blue as shown in Figure 41. This information was considered in the calculations of vulnerability analysis shared in the previous subsection. Residential units in the vicinity area of Nallahs, are prone to urban flooding incidents and are at threat of being exposed to diseases such as malaria. A total of 394 such residential units have been identified with the majority being apartments in wards 1, 3, 7, 12, 16, 17 and 20. A large number of water supply network flows along the road and are in proximity to stormwater drains which pose a risk of contamination during the time of waterlogging. Consultations and ground truthing information suggested a correlation in the critical locations identified from the hydraulic analysis. The hazard and exposure information at the ward level is shown in Figure 42. The composite overlay of hazard and exposure highlights the key areas such as Wards 1 and, 3 which are highly exposed to impacts of urban flooding, followed by Wards 7, 10 and 17. The detailed observations from the flood hotspots are shared in Annexure 3.

Risk maps are presented in Figure 43. The computations of risks by using hazard, exposure and vulnerability components revealed that Wards 1, 3, 7, 10, 16 and 17 along the GHMC nallah were under very high risk, followed by the Lanco Hills Area, which fell in the high-risk category. They were followed by Wards 5, 6, 8, 9, 11, 15 and 18 all falling in the moderate risk category. Followed by the Wards 2, 13, 14 were in the very low-risk category. The urban flood risk profiling will help the Manikonda Municipality prioritise the interventions and identify the relevant stakeholders and types of interventions needed for managing floods. This would be useful to establish a robust framework for regular monitoring and strategizing development initiatives with consideration of the risks in the area. As the Manikonda municipality is comparatively new the detailed ward-level risk information can strengthen the potential work that should be undertaken by newly identified ward officers along with enforcing land-use planning to prevent construction on floodplains, enforcement of building codes, and enhance data collection on informal settlements and flood-prone areas in future. The overall flood risk assessment for Manikonda indicates the following key aspects needing attention from the urban local body and key stakeholders:

- Manikonda being a newer city has infrastructure in good condition however the mechanisms for services such as solid waste management (especially management of C&D waste) and sewage network are not robust. This can aggravate damages caused by urban flooding in the long term when rainfall patterns change.
- The hydraulic analysis for the city suggests an increase in water surface extents from a 10-year to 100-year scenario.
- The municipality does not have a detailed stormwater drainage plan with information on gradients and projected increases in stormwater flow which makes it difficult to monitor. This can lead to an increase in damage due to aggravated waterlogging incidents in the future.
- Many residential areas are at risk of inundation. This exposes the residents to an increase in several challenges like loss of assets, vector and waterborne diseases, limited access, loss of work, etc.
- The residential areas in the city are increasing which poses a threat of encroachment on wetlands and waterbodies.
- A rise in temperatures globally and reports from city administration indicate that there could be a water shortage in the future which will need measures like rainwater harvesting.

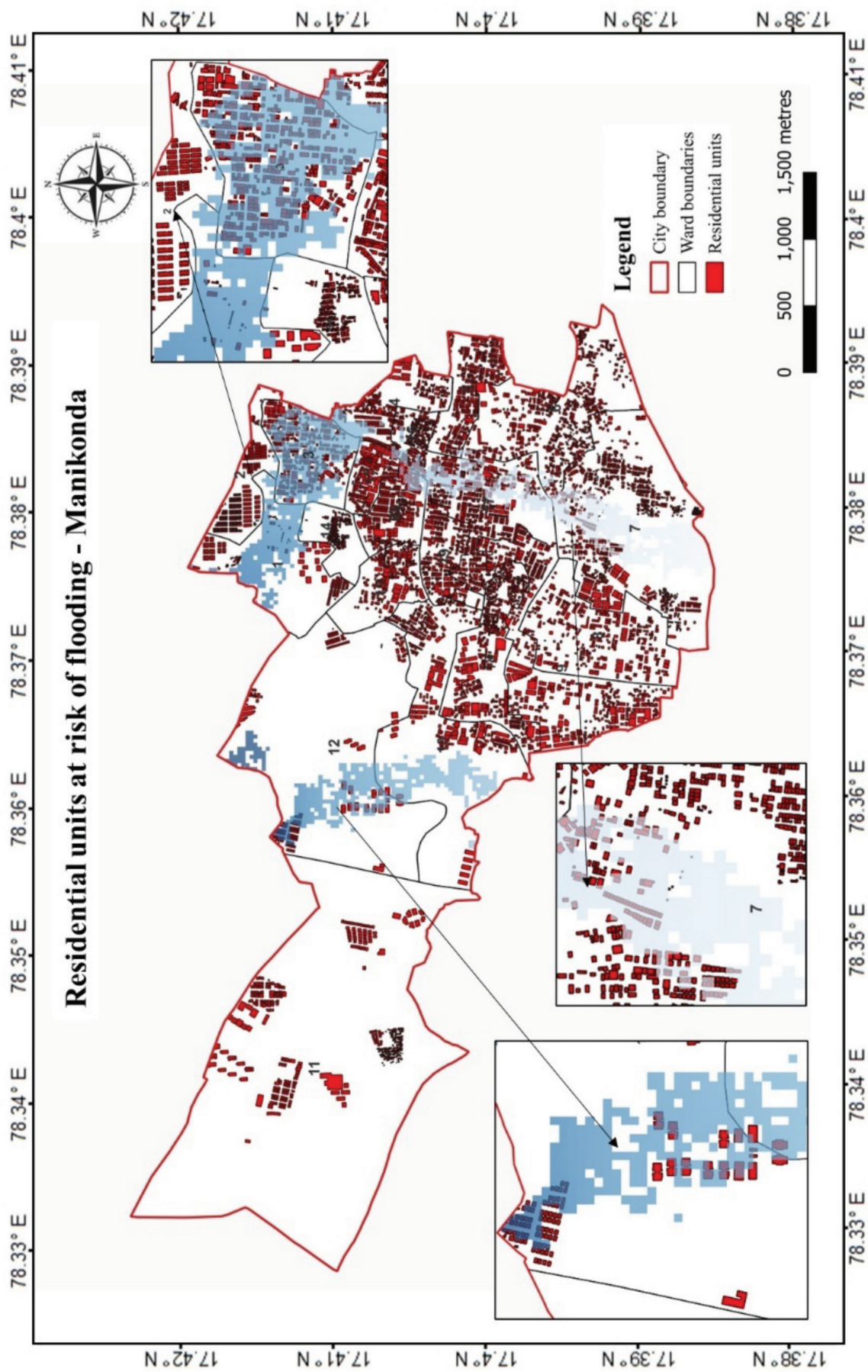


Figure 41. Residential Units Exposed to Flooding in Manikonda

Source: Developed from Municipal datasets, field data, and consultation

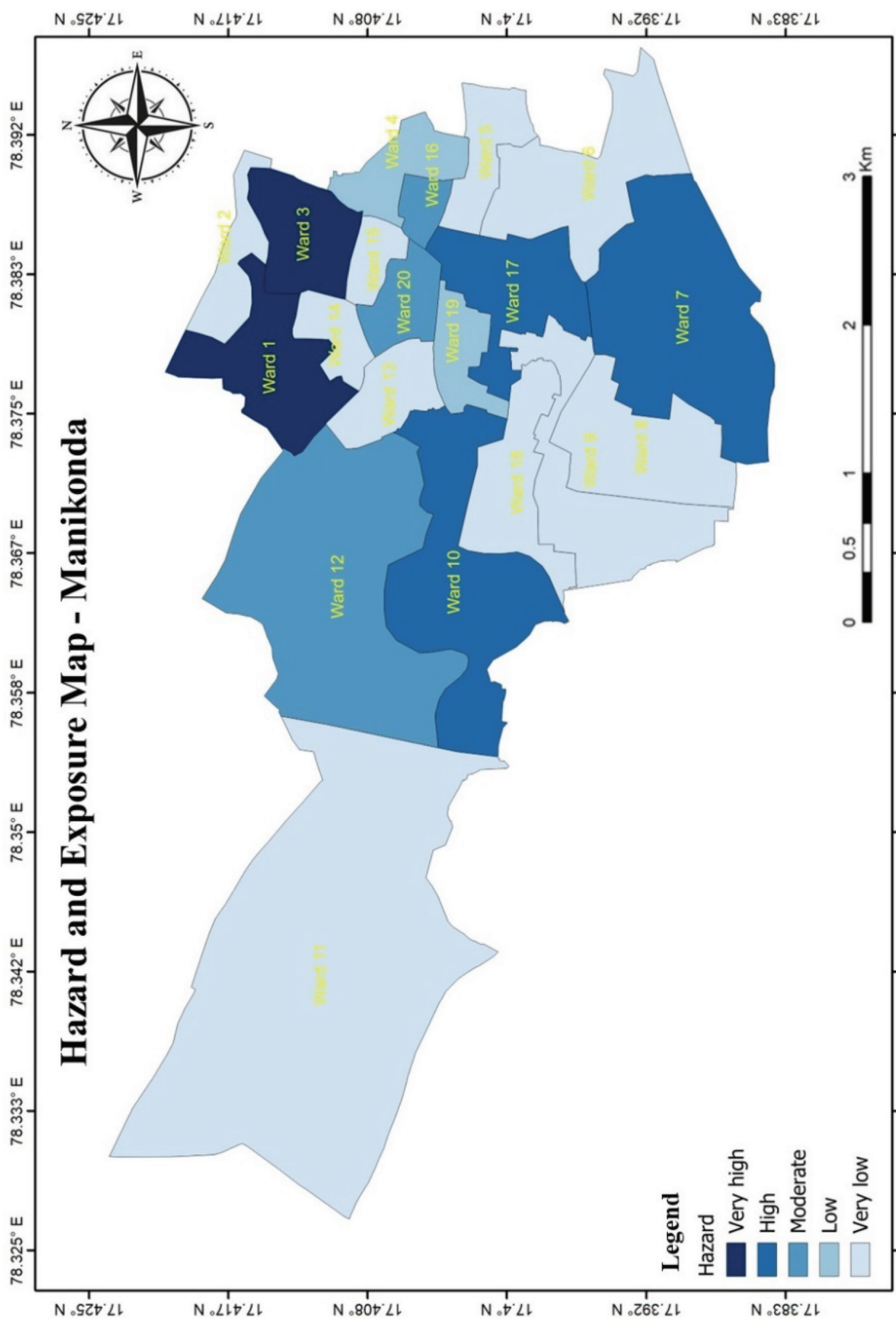
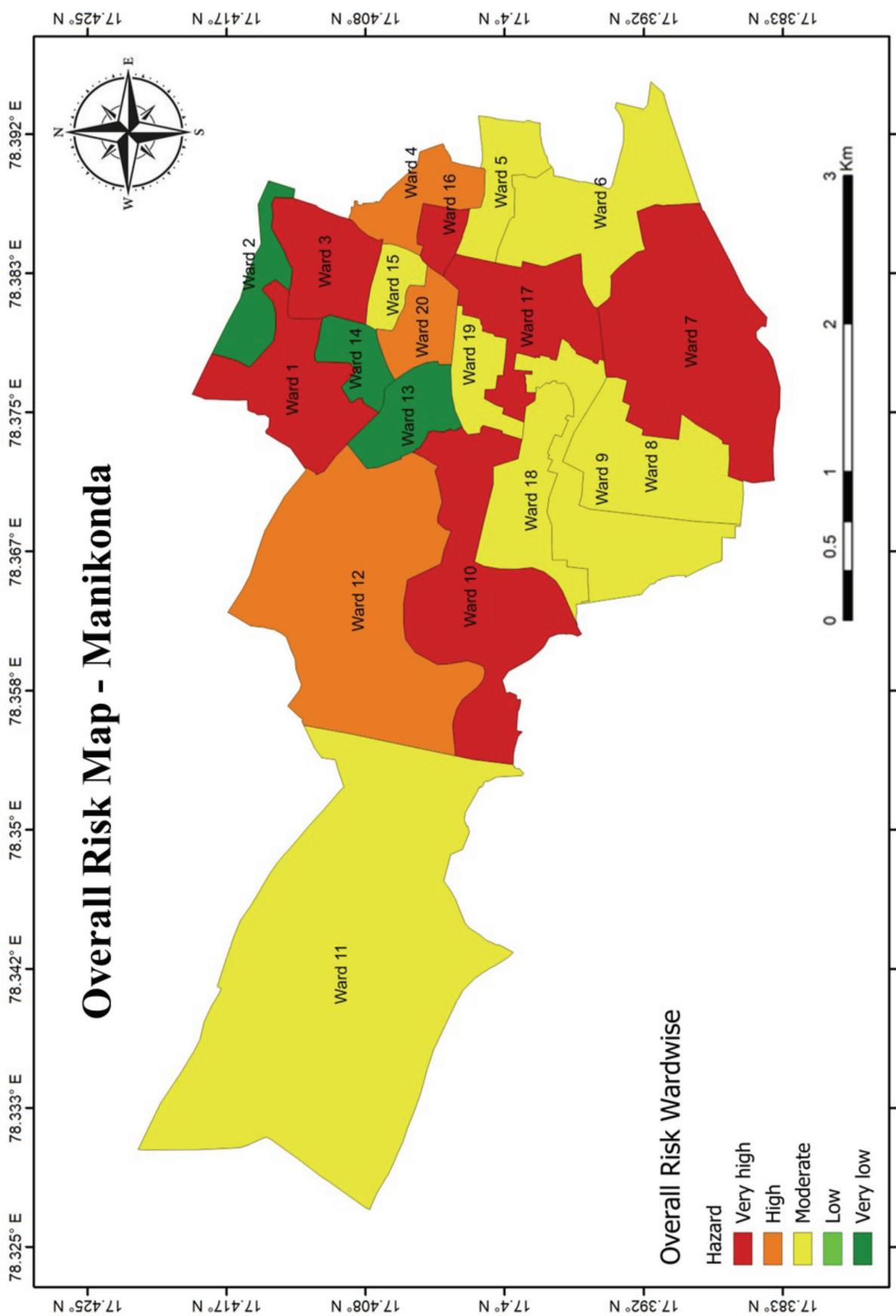


Figure 42. Hazard and Exposure Map of Manikonda

Source: Developed from Municipal datasets, field data and consultation



Source: Developed from Municipal datasets; field data and consultation

Figure 43. Risk Map of Manikonda

4.4 RECOMMENDATIONS AND ROADMAP FOR IMPLEMENTATION

Based on the findings from the risk assessment process supported by consultations there is a need for critical interventions in the flood resilience planning of the urban system of Manikonda. The roadmap for implementation of interventions in Manikonda follows the identification of issues or existing conditions as detailed in the previous section, the actions required in the form of recommendations and potential organizations for action. This can be achieved by formulating phase-wise key recommendations laid down to be undertaken at different disaster phases of preparedness, mitigation, response and recovery. The recommendations are a combination of specific interventions for high-risk localities and city-level interventions. The following section gives detailed recommendations based on the identified strengths, weaknesses, and overall risks in the city. The recommendations were generated for short (0-2 years), medium (2-5 years) and long-term (5-10 years). These timeframes are considered to align with the timeframes of SDGs and the National Disaster Management Plan. Table 11 elaborates the recommendations for Manikonda including both structural and non-structural measures that could be implemented to effectively mitigate and adapt to flood risks. As the city has specific challenges with early warning, waste management, capacity development and mainstreaming of flood risk reduction following key recommendations would enhance the resilience of the city:

Table 11. Roadmap with Short-Medium and Long-Term Recommendations for Flood Risk Management in Manikonda

Components	Existing Conditions	Recommendations	Potential Organisation for Action
Short-term Recommendations (0-2 years)			
Early Warning	There is the high-risk status of specific wards and frequent urban flooding in Wards 3, 7, 9. However, there is only one AWS station at Manikonda.	There should be a prioritization of installing AWS in high-risk wards. As per the World Meteorological Organisation (WMO) norms, there should be at least one AWS for 10–20 sq km (IMD n.d). Wards like Ward 7, and 9 should be considered for precise and timely early warning alerts.	Manikonda Municipality, District Disaster Management Authority.
Risk Assessment	There is no disaster management plan for Manikonda or hazard-risk vulnerability assessment (HRVA)	Preparation of ward-level disaster management plans for high-risk wards and City Disaster Management Plan to prioritise the development of appropriate mitigation actions.	Manikonda Municipality — Ward Office.

Components	Existing Conditions	Recommendations	Potential Organisation for Action
Risk Communication Mechanism	Twitter is used by municipal offices to post about urban flooding. However, the municipal office considers that there is a need for a robust mechanism for communication of risks.	- Establish robust communication platforms/groups for ensuring a continuous flow of knowledge and prompt dissemination of early warnings and alerts, for example, via WhatsApp groups. - Significant outreach activities and programmes need to be undertaken to popularize these communication channels through interactive events/campaigns.	Manikonda Municipality, Citizen groups, NGOs.
Solid Waste Management	- Low level of waste segregation at only 30% of total waste generated. - Collection and disposal of construction and demolition (C&D) waste is a challenge for the municipality as the disposal site is over 45km away which leads to increased carbon footprint.	- Install features such as traps, and trash racks in the drainage system to reduce the amount of solid waste going into the stormwater channels in upstream Wards 3, 12 and 15. - Launch door to door-to-door campaign to spread awareness about source segregation under the Swachh Bharat Mission (Urban). This step is very important, as it establishes continuous contact with the participants, facilitates feedback, and help to build a strong bond between the government and the beneficiaries. - Mentorship of municipal staff by C&D waste management experts for advisory and hand-holding support on the improvement of waste management. - Improve stormwater drainage systems to install innovative solutions to reduced C&D waste through Atal Mission for Rejuvenation and Urban Transformation (AMRUT).	Manikonda Municipality – Engineering, Stormwater, Public Health and Sanitation Department.

Components	Existing Conditions	Recommendations	Potential Organisation for Action
Rainwater Harvesting	Manikonda Municipality has only some residential units with installed Rainwater Harvesting (RWH) pits that are functional, approximately 950, and there is a significant need to increase public awareness.	- Encourage stakeholders to adopt RWH on sites where RWH units have already been installed. - Manikonda Municipality has to regularly monitor RWH in all new upcoming urban infrastructure. - Incorporate RWH in public and semi-public buildings through Jal Shakti Abhiyan. - Incorporate the concept of rain gardens when planning open spaces like parks and on-site stormwater management for larger colonies. This can be done in Ward 7, 17 and 19 which are at high risk.	Manikonda Municipality – Engineering, Public Works Department.
Operation and Maintenance of Drainage	- Drains are being cleaned and desilted once every year, which is not enough. - Clogging of perforated stormwater drain covers due to waste requires the attention of the response force. - During and post-monsoon cleaning is irregular and done as required. - De-silting of the nullahs is done at a small scale only.	- A detailed schedule to ensure periodicity of cleaning drains based on the local conditions is required. - Prompt disposal of waste from major drainage channels instead of allowing it to dry in proximity of drainage channels. - Regular aerosol spraying and channelization of stagnant water bodies in the city to prevent malaria spread particularly in high density wards 1, 3, 7, 12. - Sensitizing and engaging the community for the detection of Anopheles breeding places and their elimination. - Follow the CPHEEO (Manual on Storm Water Drainage Systems 2019b) in cleaning shallow surface drains.	Manikonda Municipality – Engineering, Stormwater, Public Works, Water Supply, Public Health and Sanitation Department.

Components	Existing Conditions	Recommendations	Potential Organisation for Action
Volunteer Group Formation	Only an eight-member team from municipality are engaged in disaster response with no NGOs and civil societies support. To ensure mainstreaming participation of volunteer groups, women SHGs in the overall flood management could be done.	▪ Municipality can encourage residents to constitute and be a part of volunteer groups on floods. Inclusion of women, ex-servicemen and retired police could be beneficial. ▪ Mobilize SHGs, accredited social health activists (ASHA) and auxiliary nurse midwives (ANMs) and resident welfare associations (RWAs) to head the flood risk awareness and monitoring in localities as they hold influence over residents and can support grassroots level outreach.	Manikonda Municipality, NGOs.
Regular Mock Drills	Frequency varies across different wards.	▪ Periodic trainings in high and very high-risk zones should be prioritized. ▪ Emergency mock drills involving ULB staff, community-based organisations and volunteer groups should be conducted.	Manikonda Municipality, Fire Department.
Medium-term Recommendations (2-5 years)			
Installation of Flood Early Warning	Currently no flood early warning devices are there in the municipality.	▪ Cost-effective early warning systems installation like water batteries (as discussed in Sub-section 2.3) on the nullahs that are in close proximity to residential areas and flood hotspots identified in wards 3, 7, 12 and 16. ▪ Initiate plantation and riparian buffer restoration through Pattana Pragathi Programme.	Manikonda Municipality, District Disaster Management Authority.

Components	Existing Conditions	Recommendations	Potential Organisation for Action
High-resolution Mapping	▪ Gradient maps are not regularly updated and low-resolution contour are used. ▪ Panchavati colony SWD work is on-going and Spectrum villas near the culvert need to raise the level has been identified during laying of pipes.	▪ A thorough topographical analysis needs to be done for entire city drainage network planning. ▪ Designing of stormwater drainage system considering the run-off coefficient, land use change from GIS and remote sensing information. ▪ Improve and expand drainage infrastructure to handle heavy rainfall and prevent waterlogging, especially in Ward 8, 9, 12.	Manikonda Municipality - Engineering, Public Works Department, Academia.
Detailed Vulnerability Analysis	There is no specific disaster management plan and HRVA for the city.	▪ Perform detailed mapping of vulnerable population based on data collection tools and assessment framework developed in the study. ▪ Identify the scope for appropriate public-private partnership (PPP) models for delivering insurance and financing structural measures required to mitigate floods.	Manikonda Municipality, District Disaster Management Authority.
Master Plan Preparation and Revision	Manikonda does not have a complete up-to-date master plan for the city.	▪ Develop a strategic and action-oriented master plan linked to the budget which should be updated every 2 years. ▪ Plan preparation should be participatory with consideration of diverse stakeholder views.	Manikonda Municipality, Housing and Urban Development Department, Town and Country Planning.

Components	Existing Conditions	Recommendations	Potential Organisation for Action
Runoff Management	Manikonda has several lakes however, only Neknampur lake has managed to enable ecosystem benefits such as curbing water pollution through floating wetlands. Over 10 waterbodies have been deeply affected by construction.	▪ Mainstreaming of water recharge and proper flow using nature-based solutions as mentioned can be done. Porous pavements, rain gardens, reviving water bodies, and the creation of retention areas could be useful. Details in Section 9.3. ▪ Prepare a water management plan with reference to existing water bodies (including the health of water bodies etc.) and integrate with urban planning projects through Jal Shakti Abhiyan. ▪ Enhance sewer and drainage systems to handle higher water volumes, develop flood barriers, and use advanced flood prediction and monitoring systems. This should be undertaken through Strategic Nala Development Programme.	Manikonda Municipality –Public Works, Water Supply, Department.
Planning for Comprehensive Flood Risk Management	▪ SNDP focuses majorly on SWD construction with limited consideration to climate change and no specific committees is there for flood risk management in the city. ▪ There is no transboundary collaboration with Hyderabad Municipal Corporation for the management of GHMC nallah.	▪ Constitution of expert committee including hydrologists, environmentalists, planners, NGOs for developing of comprehensive flood risk management strategy. ▪ Mobilize ward officers and create ward-level committees along with volunteers to prepare ward-level flood risk reduction plans. ▪ Harness the risk assessment to initiate a discussion with Hyderabad for the management of shared resources like nallahs, healthcare etc. during monsoon and flood. ▪ Establish inter-agency coordination centers and regular meetings.	Manikonda Municipality, District Disaster Management Authority, Forest Department.

Components	Existing Conditions	Recommendations	Potential Organisation for Action
Institutional Capacity Development	The disaster response force have received training only once. Municipal officers reported need for support for information on the emerging impacts of climate change. Specific issues like heat wave, water scarcity are becoming prominent in the municipality.	Department-specific capacity need assessment and the development of a charter has to be done. The response force should have periodic training every year with other trainings for SWM section on the operation and maintenance of nullahs, engineering section on new designs, spatial tools, IoT for managing urban floods need to be provided.	All government departments in the city.
Long-term Recommendations (5-10 years)			
Mainstreaming Flood Resilient Designs	Government buildings are not completely equipped with RWH, use of weatherproof roofing etc. Only the new municipal office building has provision for RWH as reported by officials.	▪ Retrofit government workplaces to be flood-resilient, ensuring businesses can continue operations during floods. ▪ A strategy for promoting the construction of flood-resilient housing, particularly in vulnerable areas of Ward 7, 8, 9, 16 and 20 could be developed. ▪ Schemes for interest-free loans or grants for flood mitigation measures in homes and businesses can be considered. ▪ Raise the lowest storey of new buildings above the normal minimum flood level of the adjoining area.	Manikonda Municipality – Engineering, Public Works Department, NGOs, Academia.

Components	Existing Conditions	Recommendations	Potential Organisation for Action
Periodic update of Land use Information	The updated land use plan or city master plan document is not there.	- Ensure appropriate land use planning using detailed zonation is undertaken guided by micro-zonation studies. - Risk-sensitive planning for land use can be incorporated as shown in Subsection 2.3. - Ensure all new constructions strictly comply with building codes, standards, IRC specifications and the latest techno-legal regime including NBC, BIS Codes, guidelines, town planning bylaws, land-use zoning, development control regulations and other regulations and model codes for civil works and infrastructure.	Manikonda Municipality, Housing and Urban Development department, Town and Country Planning.
Dedicated Budgetary Allocation	At the ward-level, the allocation of the budget to flood management activities are not segregated. No external agencies like NGOs, community groups, SHGs, or private sector collaboration is present for flood risk management. Only awareness activities have been supported in the past.	- Establish dedicated emergency funds within ward offices specifically for flood prevention and recovery. Utilize State Disaster Mitigation Fund (SDMF) for mitigation related activities. - Ensure a fixed percentage of local budgets is allocated to flood preparedness and response activities. - Involve communities in budgeting processes to ensure funds are allocated to the most needed flood resilience projects. - Provide targeted subsidies for low-income groups and women-led businesses in order to build resilience against floods. This can help in further collaborations for flood risk management through National Urban Livelihood Mission and Mission for Elimination of Poverty In Municipal Areas.	Manikonda Municipality, District Disaster Management Authority, NGOs.

5

CONCLUSIONS AND WAY FORWARD

The increase in urbanization in Indian cities has fundamentally altered the risks faced. Urban flooding risks are increased due to more impermeable surfaces, fewer green areas and insufficient drainage systems. At the same time, poor solid waste management makes these issues even more difficult. Uncollected waste, frequently choked drainage systems, increasing the danger of flooding during periods of heavy precipitation since storm water has nowhere to go. The detailed analysis suggest that thematic actions with consideration of climate change and the need for planning and development interventions is required in Manikonda. The analysis suggests an increase in water surface extents from a 10-year to 100-year scenario and in the future there will be a severe impact on critical infrastructures due to floods. This can also lead to cascading incidents such as a fire at industrial sites, landslides in hilly areas, etc. The absence of well connected stormwater drainage network with scientifically calculated future projection of stormwater flow can impact decisions during future floods. Based on the findings from the risk assessment and consultations there is a need for critical interventions in the solid waste management and flood resilience planning of Manikonda.

Institutional conditions indicate that despite significantly high literacy rates there is lack of avenues for community engagement in risk management activities, especially engagement of women networks, SHGs in flood risk management, training, etc. is negligible. Irregularities in solid waste management with excess of construction and demolition waste highlight the need for decentralized waste management systems. The lack of updated disaster management plans for the city and its infrastructures like schools, hospitals, and electric substations indicates the need for mainstreaming of disaster risk management. The rise in temperatures globally indicates that there could be a water shortage in the future which will need measures of rainwater harvesting, which is presently not followed in Manikonda. Allocation of dedicated resources, manpower, and budget for risk reduction is necessary, which is not emphasised at present. In addition, despite frequently facing issues of urban flooding, nature-based solutions have not been explored to their full potential. These challenges may not be unique to Manikonda as many Indian cities are now at risk of flash floods that overwhelm existing infrastructure because of multiple hazards as well as unpredictable extreme weather conditions brought on by climate change.

Manikonda being a rapidly developing area in Hyderabad urban agglomeration will face unsustainable pressures from the growing issues of urbanisation, if proper action is not undertaken, thus increasing the danger of flooding and other environmental problems. To protect future urban living conditions, state must proactively establish mitigation and adaptation policies, risk-sensitive planning, and mechanisms that address urban floods. Some of the actions to guide the ambition of becoming disaster resilient in changing climatic conditions are preventing new risks, reducing existing ones, and managing residual risks. Potential national, state and local-level actions that can enhance the resilience of cities in India have been discussed in the following subsections.

5.1 POLICY-LEVEL INTERVENTIONS

Based on the systemic review of existing techno-legal frameworks as listed in Chapter 2 the following are the priority opportunities that need interventions from the perspective of policies and plans:

- Even while disaster management plans are in place on paper, putting them into practice is still difficult. The majority of the plans approach disaster management from a relief-centric perspective rather than taking a proactive prevention, mitigation and preparedness approach, despite the government's insistence on a paradigm change to a preparedness approach.
- A prominent aspect of preparedness measures for various flood typologies needs to be highlighted in disaster management plans. Area-specific challenges need to be addressed using localized solutions for which thorough flood risk assessments should be conducted.
- Cascading and compound risks are generally not considered a part of disaster management plans. The risks related to climate change have to be considered in a more holistic way along with the need for mainstreaming those with the current development planning policies.
- The plans at national, state, district and city levels do not include aspects of regularizing or defining periodicity for the operation and maintenance of services such as drainage, water supply, and solid waste management which is integral to urban flood management.
- With respect to infrastructure, there is a need to strengthen resilient building practices for rapidly growing urban settlements which need to be made disaster-resilient.
- Inclusivity with respect to gender is limited to only capacity building in most of the disaster management plans whereas it should be integral in all stages of DRR.
- Activities aimed at reducing risk are less visible in all of the plans. The accountability systems needed to guarantee that departments take DRM considerations into account when they aim to mainstream their initiatives which are not institutionalised in the existing frameworks. As a result, rather than being guided by the long-term strategies in State Disaster Management Plans, risk-reduction initiatives are led by external programmes and schemes.
- A prominent scope of collaborative strategy that recognises the roles of academia, corporations, government, civil society and communities and encourages all parties to work together to achieve disaster resilience is lacking in bringing together the many stakeholders.

Thus, despite the existence of policies and guidelines, several anticipated outcomes, such as the incorporation of disaster risk reduction into development planning, remain unfulfilled. Therefore, in order to accomplish the integration of the identified aspects, it is essential to design policies and procedures within the pertinent context.

5.2 INSTITUTIONAL MECHANISM

As is evident from the previous sections, mainstreaming of disaster risk management needs to be strengthened in policies at local as well as national, and state levels along with well-defined roles and responsibilities for the relevant stakeholders. Currently, methods to ascertain a suitable periodicity for maintenance of stormwater drainage, stringent implementation of building codes and standards, regular collection of C&D waste from all areas and adequate and recurring workshops on awareness of segregation of waste is yet to be done. These factors can magnify urban flooding in the future

due to siltation, deteriorated condition of RCC drains, and risk of contamination of waterbodies is not would be useful. The study highlights some key activities that should be undertaken by the stakeholders to ensure the resilience of cities. Table 12 shares the roles and responsibilities of various government stakeholders which might be adapted in existing and new urban local bodies to streamline the flood risk management and overall resilience of cities.

Table 12. Responsibility Matrix

Key Actions	Coordinating Departments
- Implementation of strengthening and retrofitting activities for critical infrastructures as per the recommendation of safety audits. - Restrict building permissions to the site within the limits of the highest watermark. - Ensure flood-resistant rainwater harvesting features in the planning and construction of new residential, commercial, or industrial projects. - Construction of shelters at safe zones.	Municipal Corporation/ Municipality – Engineering Department
- Repair and monitor maintenance of damaged drain and drainage networks in the flood-affected wards/zones. - Ensure periodicity in de-silting activities and make emergency desilting and drain cleaning action plan for critical drains. - Prepare zone-wise detailed network maps and flood action plan and submit them to the municipal office and disaster management authority. - Install high-capacity pumps in all low-lying areas and regularly pump out submerged areas.	Municipal Corporation/ Municipality – Stormwater Department
- Ensure regular and proper desilting/dredging, cleaning and other suitable measures in water bodies of the wards. - Ensure compliance is maintained when new infrastructure is built. - Undertake studies on flood line mapping, vulnerability analysis and risk mapping. - Demarcation of low-lying, vulnerable settlements and waterlogging areas in the ward. - Discourage reclamation of low-lying land. - Ensure proper functioning of communication networks. - Ensure solid waste removal from open drains and regular de-silting procedures are undertaken. - Ensure the flood-proofing of critical infrastructure, bridges, etc., within the ward. - Provide emergency kits, and amenities to people residing in flood banks after early warning.	Municipal Corporation/ Municipality – Ward Office/Zonal Office

▪ Strengthening up an emergency operation centre (EOC) to continuously monitor the flood situation, sending alerts to citizens. ▪ Coordination with NDRF, SDRF and civil defense for check of the necessary equipment in each ward. ▪ Strengthening and upgrading the current flood forecast and early warning system using devices based on IoT. ▪ Coordinate with local task forces/volunteer groups to generate awareness for urban floods. ▪ Design relief packages for vulnerable populations based on damage assessment and departmental action reports. ▪ Organize capacity building, mock drills for flood, ensuring rescue material at the local level—awareness program.	Disaster Management Cell, District Disaster Management Authority
▪ Conduct training to doctors, psychologists, health educators and ASHA workers on pre and post-disaster mental health care. ▪ Issue health cards to vulnerable groups like women, elderly and disabled persons. ▪ Coordinate with EOC for vector control and fogging. ▪ Assign mobile hospital units in flood zones for safe delivery. ▪ Provide alerts to private and public sector hospitals for support. ▪ Undertake measures to disinfect zones that have got contaminated.	Public Health Department, NGOs
▪ Undertake regular checks to confirm infrastructure remains in operational condition during flooding. ▪ Demarcate proper evacuation routes to ensure accessibility of safe shelters. ▪ Prepare emergency structures (levees etc.) to control flood risk. ▪ Regularly monitor dilapidated structures and update it with municipal body.	Public Works Department
▪ Install water supply outlets above flood level at identified hotspots. ▪ Ensure adequate sources of alternate water supply, water tankers etc. ▪ Map groundwater resources to identify areas resistant to disaster impacts. ▪ Restoration of all water supply infrastructure after floods to a functional condition. ▪ Identify specific points of contamination of drinking water and ensure measures to prevent it in the future.	Water Supply Department
▪ Identification of extreme fire-prone areas and industrial sites and ensure maintenance of equipment and vehicles nearby. ▪ Evacuate stranded persons from the affected area. ▪ Coordination with other agencies for rescue and relief.	Fire Department

5.3 IMPLEMENTATION OF NATURE-BASED SOLUTIONS

The International Union for Conservation of Nature (IUCN) defines NbS as “actions to protect, sustainably manage, and restore natural and modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits.” These solutions can range from low human intervention, which involves less disruption to ecosystems, to high human intervention, which involves more intrusive management of ecosystems, or even the creation of new ecosystems. NbS not only addresses immediate water management needs but also contributes to broader environmental and social benefits as evident from Figure 44. It shows that diverse NbS can be used in diverse landscapes to adapt to the threats of climate change. Consequently, it is critical to think about the main weaknesses and use NbS to its fullest capacity in order to strengthen community resilience.

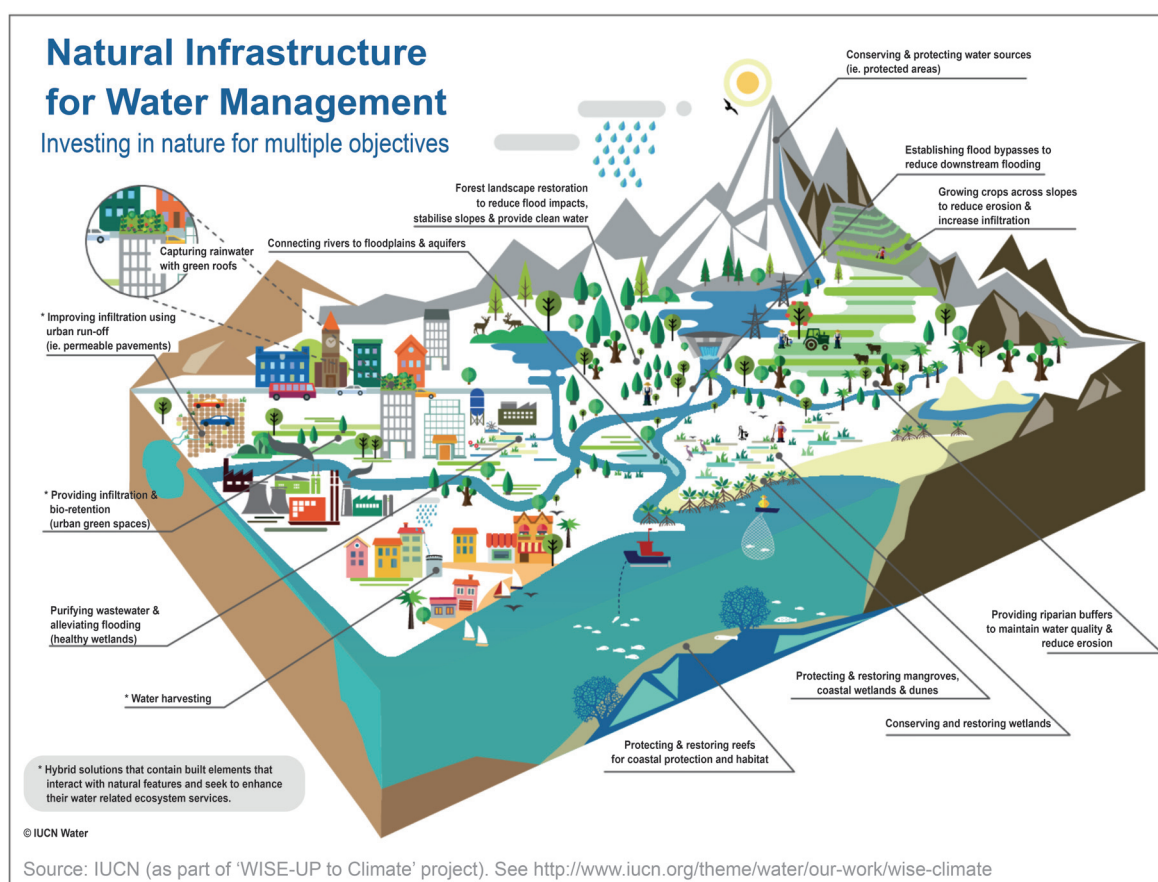


Figure 44. Nature-based Solutions for Water Management

Source: IUCN

Despite having implemented nature-based solutions for managing water pollution (floating wetland in Manikonda), the interventions are piecemeal in nature and have not been adopted throughout the city. Interventions such as practices like agroforestry to improve water infiltration and retention, riparian buffers and urban green spaces have been highlighted as recommendations in Sub-sections 5.4. Nature-based Solutions can be promoted to mitigate the rising temperature, soil erosion and curb the effects of pollution caused by landfill sites in proximity to eco-sensitive zones. Table 13 highlights some of the NbS interventions that can be useful for newly formed municipalities like Manikonda or old municipal corporations with larger populations.

Table 13. Nature-based Solutions for the Management of Urban Floods in Cities

Focus Area of Nature-based Solution	Description
Reduce the Risk of Urban Flooding.	▪ The capacity of traditional drainage infrastructure is usually exceeded by heavy rainfall events due to drainage networks being either too small or too old to handle the increasing urbanisation and changing patterns of precipitation. While traditional drainage systems typically rely on underground pipes and concrete channels, which can increase runoff and cause flooding, improved drainage systems use natural components to manage stormwater more sustainably. ▪ Permeable pavements, rain gardens, and vegetated swales are a few examples of these elements. During times of heavy rainfall, natural features such as ponds, wetlands and retention basins can be utilised to retain and hold excess runoff. These characteristics not only lessen flooding but also improve biodiversity, water quality and recreational opportunities.
Promote Biodiversity	▪ Green roofs, or the technique of growing vegetation on building rooftops, have various benefits, such as increased biodiversity, temperature control and rainfall retention. Green roofs efficiently manage stormwater by collecting precipitation, lowering surface runoff and keeping drainage systems from overloading during heavy rainfall events. On green roofs, rainwater is gathered and held by the vegetation, which acts as a natural sponge to release water gradually. Furthermore, the process of plant evapotranspiration helps to cool the surrounding area. E.g. Singapore's Green Roof initiative integrates policy support with an intervention that provides insights into stormwater retention, energy savings and biodiversity enhancement.

Focus Area of Nature-based Solution	Description
Improve Water Quality	▪ Creating a green river-like connection between wetlands, consists of improving biodiversity and natural assets, recreation, sediment trapping and water purification. High-biodiversity wetlands offer organic water treatment capabilities. Before runoff from the land reaches open water, it filters out pollutants, excess nutrients and silt. ▪ The restoration and preservation of natural habitats through NbS bolster ecosystem resilience and biodiversity, sustaining diverse plant and animal communities that contribute to the preservation of water quality and natural filtration services. Biofiltration systems and vegetated areas further remove excess nutrients like nitrogen and phosphorus from runoff, curbing nutrient loading in aquatic ecosystems and averting eutrophication and algae blooms.
Mitigate the effect of Climate Change	▪ Urban forests and green corridors are examples of green infrastructure features that control microclimates, act as a buffer against climatic unpredictability and lessen the impact of the urban heat island effect, all of which lessen the vulnerability of cities to flooding brought on by climate change. ▪ Another initiative that has been useful in flood-prone cities is Sponge City Initiative which promotes modernising the current infrastructure while incorporating natural solutions into urban development initiatives, such as built wetlands, permeable pavements and green roofs. Additionally, planning for sustainable land use and community involvement are crucial. ▪ Stakeholders must encourage partnerships with the commercial sector, integrate nature-based solutions into urban planning procedures, and strengthen local implementation and maintenance capabilities. The accumulated findings highlight the need for expanding the initiative's reach, improving processes for monitoring and evaluating its effectiveness, and incorporating natural solutions into more all-encompassing climate adaption measures.

5.4 WAY FORWARD

This study “Development of Flood Risk Assessment Framework and Roadmap for Resilient Cities” is the first document of its sort created for Manikonda. A thorough analysis was conducted to recommend flood risk management strategies; however, there are certain nuances that should be detailed and taken into account while carrying out future risk assessment studies. Among them are:

- Manikonda is rapidly expanding with increase in residential and commercial buildings, leading to notable shifts in land use from green cover. As the city’s built-up area grows, the natural drainage systems will become even more obstructed. There will be a greater demand for sewer infrastructure as the city expands in both area and population. Although it has been determined that stormwater drains and sewerage channels must be kept apart, other city-specific plans, such as a master plan for drainage, must also take these conclusions and recommendations into consideration.
- Urban flooding is a consequence of excess of construction waste and improper management of regular solid waste in Manikonda. The practices ought to emphasise the value of community involvement, especially among women, and contain measures to increase public awareness of the detrimental effects of solid waste and C&D waste accumulation in the drains, which clog pipes and worsen local flooding.
- The study was stipulated to a short timeframe and could be further strengthened by detailed assessment using sufficient high-resolution data, detailed survey elevations, frequency for discharges to support a more detailed hydrologic and hydraulic analysis. The availability of internal city drainage network details (such as invert levels, pipe sizes, outfall locations, gradients, etc.) can help in detailed drainage modelling to understand and project the future capacity of the drainage networks.
- Future studies can consider a detailed topographical survey to identify the present extent of natural drainage channels which may not be similar to the satellite imagery as the drainage channels visible in earlier years’ imagery may have since been obscured by encroachment.
- Along with this, a detailed household survey can ensure that community-level vulnerabilities are minutely assessed.
- To ascertain that the recommendations mentioned in the previous chapter can be easily implemented financially, a feasibility evaluation must be conducted. Determining the funding sources e.g. from the central, state, or municipal governments—is also necessary.

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ANNEXURES

ANNEXURE 1 – DATA COLLECTION TOOLS

Stakeholder guiding questions - Consultations to understand the vulnerabilities of the city and wards.

These are the list of guiding questions to support interaction with the key stakeholders at city-level Consultant would collect information based on these questions.

Name and Designation of Official:

Date and Time of Interaction:

Physical

1. Which are the most flood affected wards in the city?

Riverine Flood-

Urban Flood-

2. Are there natural barriers (e.g., hills, wetlands) that provide protection from flooding to the city?

3. What types of provisions are available for flood defence (floodwalls, dams etc.)? Are they effective?

4. What kind of changes in the landuse have occurred in past 20 years? Mention examples of specific issues related to encroachment and damage to urban forests and lakes?

5. What % of the city has well connected stormwater drainage system? Mention examples of urban flooding challenges and how are stormwater drains affected?

Social

1. What were the impacts of previous floods on the community, infrastructure, and economy?

2. What lessons have been learned from past flood events, and how have they influenced risk reduction measures?

3. Are there barriers to communication such as low access to mobile phones, network connectivity in the city that affect dissemination of early warning information? How do the women, LGBTQ+, elderly get affected due to such issues like language or limited access to technology?

4. Do women have access to resources such as education, healthcare, and economic opportunities prior to the disaster?

5. Are there specific risks or vulnerabilities that women face during flood situation or evacuation, such as increased risk of gender-based violence or separation from family members? Share with example from past incidents.

Economic

1. What type of economic losses associated with flood events, including damage to property, crops, and livelihoods? Which wards have faced high economic losses due to flood?

2. What type of capacities available with local businesses and industries to recover from flood-related disruptions?

3. Are there any prominent schemes in city which support reconstruction and revival from damage caused by flood/other disasters? What % of population opts for Govt. schemes, funding options to rebuild houses, business establishment etc. impacted by floods?

Institutional

1. Who are the key collaborators in flood risk management other than government. In what aspects do neighbouring cities, NGOs CBOs etc. collaborate.
2. How has the existing mechanisms strengthened resilience and promote gender equality in disaster risk reduction and response efforts?
3. What mechanisms are used to ensure trust in local authorities and response agencies in situations of flooding
4. What measures are taken to promote gender-responsive planning and programming in disaster management initiatives? What more can be done?
5. What opportunities exist for enhancing capacity through investments in infrastructure, education, and livelihood diversification?

Natural

1. What % of city area is vulnerable to floods of different types? What are the other prominent hazards?
2. What are the factors such as deforestation or urbanization exacerbating flood vulnerability of the city? How has climate change influenced the flooding patterns there?
3. What are the critical infrastructures (e.g. hospital, fire brigade, power lines, water treatment plant etc.) that have been severely affected by flooding? If possible, provide ward-wise information?
4. What are the prominent nature based solutions being implemented in the city to address issues of flooding like plantation, lake rejuvenation, watershed development etc. Have these solutions helped in curbing impact of floods. And how?
5. How are pollution levels influenced by the flooding? Are there recurrent patterns of water-borne diseases, change in water quality etc. after floods?
6. Are hazard maps considered during development planning in the city? What type of steps are taken to ensure the consideration?

Stakeholder Guiding Questions – Capacity Component

Use these set of questions to understand the capacities available with the key departments (Municipal Corporation/Municipality, Metropolitan Development Authority, State Disaster Management Authority, Public Health Engineering Department (Phed), Water resources, and any other department important for flood risk management.

A. Institutional Capacity

1. Key role of your department with regards to the following, if any, along with details of the role. Please include any other role with respect to any Emergency Support Functions, if not listed below.

Flood risk assessment	
Early warning generation	
Early warning dissemination	
Flood risk mitigation (including those related to nature-based solutions, if any)	
Preparedness & capacity building	
Flood response	
Flood relief & compensation	
Damage and loss assessment	
Flood recovery	

2. What are the existing institutional mechanism and instruments within your department that support fulfilling the above identified roles?
(e.g. Task Forces, Committees, etc. mandated to perform such a role or legal instruments backing such a role such as any SOP, manual, guidelines, plans, etc.)
3. Which are the key external stakeholders (outside your department) whose support is crucial to fulfill the above mentioned roles & responsibilities? List down and explain each of them to help develop a network of closely associated stakeholders.
4. How is the coordination and communication with these stakeholders undertaken? What are the associated gaps?
5. What is the mechanism of to and fro flow of information with the city/municipality EOC/Control Room/Command & Control Centre? Associated gaps? Key technologies leveraged?
6. Any reporting and documentation mechanism that are currently in place that smooth the functioning of department for flood related roles?

7. What are the key datasets available with the department such as maps, demographic data, climatic data, public utilities network data, spatial data, hazard monitoring software/technologies, record of past disasters that are utilised/can be utilised for the above mentioned roles?

B. Human Resources

1. Details of nodal officer, if any, designated for DRM or flood related roles (listed above).
2. List and details of officials and staff trained on different aspects of DRM, particularly, flood related.

(e.g. EOC operator, GIS staff in dept, staff performing specific roles on flood mitigation and management such as pre-monsoon clearance of drainage, removing of vulnerable branches, trees, hoardings, O&M staff of different critical services, etc.)
3. Provide details of technical staff/skills available with the department that can be leveraged for any of the above mentioned roles with respect to flood risk assessment, mitigation and management.

C. Physical Capacity

1. Key physical resources (infrastructure, assets) associated with your departments that are/can be utilised for flood risk mitigation and management (Particularly those help fulfilling the above roles). Do include the critical infrastructure associated with your departments.

(E.g. Dewatering pumps, flood early warning systems, flood shelters, boats, life jackets, medicines, health facilities, drainage network, STP, etc.)

What are the additional resources that can further enhance your functioning with respect to the above roles?
2. Are there any instances of disruption in continuity of services your provide or functioning of any of your critical infrastructure during past disasters, particularly floods? How were these cases managed at that time and what measures have been undertaken since then to prevent their re-occurrence in future or mitigating their impacts?
3. Share past examples where additional physical resources had to be deployed from your counterparts departments in neighbouring cities/districts/states?

D. Financial Resources

1. What are the key sources of funds that support the fulfilling the above mentioned roles, procuring & maintaining the mapped resources and HR, etc. ? (Differentiate national, state and local sources or schemes/initiatives which are leveraged for such funding)?
2. Are there instances of CSR or philanthropy fundings for undertaking any flood risk mitigation or management measures?
3. What are the key challenges associated with existing financial mechanisms?
4. What more can be done to enhance the functioning of these mechanisms (in terms of timeliness, adequacy, reporting, etc.)?

Q1. What sources do you trust for information about Urban flooding and other disasters? How frequent do you use these sources?

Q2. Which measures have you taken to address issues of urban flooding?

Q3. How did you organize the staffing to address the urban flooding?

Q4. What actions were taken to mitigate flooding risks? Frequency of O&M.

Q5. What actions did you take to address urban floods? Do you have SoPs and how frequently are they revised? Are there tasks beyond the SoPs that have to be addressed?

Stakeholder Consultation-Ward/Zone Data Collection

Use these set of questions to understand the capacities available with the ward/zone level officials. Specific information based on their assessment to be included.

Ward no. / name	
Ward officer name	
Total population of ward (disaggregated)	
Area of ward	
Date	

Physical	
1.1 Land use and housing	
1.1.1 % of building constructed following building code (1= less than 20%, 2= 20-40%, 3=40-60%, 4=60-80%, 5=80-100%)	
1.1.2 type % area of informal settlements (5= less than 20%, 4= 20-40%, 3=40-60%, 2=60-80%, 1=80-100%)	
1.1.3 % of houses above normal/ flood water logging/low-lying areas (1= less than 20%, 2= 20-40%, 3=40-60%, 4=60-80%, 5=80-100%)	
1.1.4 Total % of the ward's population living in proximity (less than 50m) to the river/ water body (1= more than 50%, 2=30%-50%, 3=20-30%, 4=10-20%, 5= less than 10%)	
1.1.5 % of house with ownership (1= less than 20%, 2= 20-40%, 3=40-60%, 4=60-80%, 5=80-100%)	
1.1.6 Rate of increase in built-up area every 5 year in the ward (1=50% or more, 2=20-50%, 3=10-20%, 4= 5-10%, 5= less than 5%)	
1.1.7 % area having temporary structures (5= less than 20%, 4= 20-40%, 3=40-60%, 2=60-80%, 1=80-100%)	
Water and sanitation	
1.2.1 % levees, embankments, bunds, dams, and floodwalls in good condition (1= less than 20%, 2= 20-40%, 3=40-60%, 4=60-80%, 5=80-100%)	
1.2.2 % of area frequently waterlogged (1= more than 40%, 2=30%-40%, 3=20-30%, 4=10-20%, 5= less than 10%)	
1.2.3 % of the population having access to drinking water - tap connection at the house (1= less than 50%, 2= 50-60%, 3=60-70%, 4=70-80%, 5=80% above)	
1.2.4 % population having access to sanitation (1= less than 20%, 2= 20-40%, 3=40-60%, 4=60-80%, 5=80-100%)	
1.2.5 % area from where solid waste is collected everyday (1= less than 20%, 2= 20-40%, 3=40-60%, 4=60-80%, 5=80-100%)	
1.2.6. % area affected by water supply disruption (1=more than 50%, 2=30-50%, 3=15-30%, 4=5-15%, 5=5% or less)	
1.2.7 % of solid waste collected 48 hours after a disaster (1=less than 10%, 2= 10-30%, 3=30-60%, 4=60-80%, 5=80-100%)	
Roads and accessibility	
1.3.1 % of roads are all weather road, RCC roads (1= less than 20%, 2= 20-40%, 3=40-60%, 4=60-80%, 5=80-100%)	

1.4 Critical infrastructure	
1.4.1 % of hospitals in the ward at risk of flooding (1= more than 40%, 2=30%-40%, 3=20-30%, 4=10-20%, 5= less than 10%)	
1.4.2 % of bridges in flood prone/waterlogged area (1= more than 40%, 2=30%-40%, 3=20-30%, 4=10-20%, 5= less than 10%)	
1.4.3 % of buildings more than 20 years old (1= more than 40%, 2=30%-40%, 3=20-30%, 4=10-20%, 5= less than 10%)	
1.4.4 % of public building structures use flood resistant designs (1=none, 2=less than 20%, 3=20-40%, 4=40-60%, 5= above 60%)	
1.4.5 How many electric sub stations were affected in past floods (1= more than 8, 2=6-8, 3=4-6, 4=1-3, 5=none)	
1.4.6 % of schools at risk of flooding (1= more than 40%, 2=30%-40%, 3=20-30%, 4=10-20%, 5= less than 10%)	
1.4.7 How many high-value assets (industry, heritage) in the flood-prone area of ward (1= more than 8, 2=6-8, 3=4-6, 4=1-3, 5=none)	
1.5 Drainage system	
1.5.1 How many bottlenecks or areas of insufficient capacity within the drainage network? (1 = more than 10 identified spots, 2=7-9, 3= 4-6, 4= 1-3, 5=none)	
1.5.2 Frequency of maintenance of drainage pipelines (1= never, 2 = once in 5 years, 3= once every year pre-Monsoon, 4 = every 6 months, 5=every 3 months or more frequent)	
1.5.3 What is the capacity of the drainage system to handle high levels of rainfall(more than 65mm per day)? (1=very poor, 5= very good)	
1.5.4 What % of drainage system incorporating green infrastructure (e.g., rain gardens, permeable pavements) to enhance drainage capacity? (1= none, 2= 1-20%, 3=20-40%, 4=40-60%, 5= more than 60%)	
1.5.5. What % of construction in the ward is on drainage catchment and natural drainage channel that is prone to localized flooding? (1=more than 50%, 2=30-50%, 3=15-30%, 2=5-15%, 1=less than 5%)	
Social	
Population and demography	
2.1.1 % of population under 14 and over 64 (1= more than 40%, 2=30%-40%, 3=20-30%, 4=10-20%, 5= less than 10%)	
2.1.2 Literacy rate of population (1= less than 20%, 2= 20-40%, 3=40-60%, 4=60-80%, 5=80-100%)	
2.1.3 % of population live in slum area/urban informal settlement /urban poor areas (1= more than 40%, 2=30%-40%, 3=20-30%, 4=10-20%, 5= less than 10%)	
2.1.4 Population density per square kilometre (1= very high, 5= very low)	
2.1.5 % population living below poverty line (1= more than 40%, 2=30%-40%, 3=20-30%, 4=10-20%, 5= less than 10%)	
Awareness	
2.2.1 % of ward officials aware of roles and responsibilities during flood, urban flood (1= less than 20%, 2= 20-40%, 3=40-60%, 4=60-80%, 5=80-100%)	
2.2.2 Awareness or knowledge of population about the threat and impacts of flooding (1= less than 20%, 2= 20-40%, 3=40-60%, 4=60-80%, 5=80-100%)	
2.2.3 How often does the city authority organize public awareness program/disaster drills (1= never, 2= no schedule, 3= once a year, 4= once every 6 months, 5= every 3 months or more frequent)	
2.2.4 % Population has access to internet (1= less than 20%, 2= 20-40%, 3=40-60%, 4=60-80%, 5=80-100%)	

2.2.5 % population affected by water-borne diseases every year (1= More than 30%, 2= 20-30%, 3=10-20%, 4=5-10%, 5=5%or less)	
Preparedness	
2.3.1 How often is community participation in monitoring and reporting drainage issues, such as localized flooding or blocked drains? (1= never, 2= rarely, 3= during specific season, 4= most of the times, 5=always)	
2.3.2 Extent of engagement of women networks, SHGs in flood risk management, training etc. (1= never, 2= rarely, 3=once every year, 4=once every 6 months, 5= regularly or 3 months)	
2.3.3 % of population needing shelter after recent floods (1= More than 30%, 2= 20-30%, 3=10-20%, 4=5-10%, 5=5%or less)	
2.3.4 Availability of sufficient dewatering pumps and equipment	
2.3.5 Extent of support from NGOs/ CBOs/volunteer groups or religious organisations for floods	
Economic	
3.1 Employment & income	
3.1.1 % of population having employment (1= less than 20%, 2= 20-40%, 3=40-60%, 4=60-80%, 5=80% above)	
3.1.2 % of women in workforce (1= less than 20%, 2=30-40%, 3=40-50%, 4= 50-60%, 5= more than 60%)	
3.1.3 % of households depending on only one income source (1= more than 80%, 2=60-80%, 3=40-60%, 4=20-40%, 5=less than 20%)	
3.1.4 % of business activities (informal sector) affected due to floods in the ward (1= above 50%, 2= 20-50%, 3=10-20%, 4=1-10%, 5= none)	
3.1.5 % of affected households required govt. incentives to rebuild after flood (1= more than 80%, 2=60-80%, 3=40-60%, 4=20-40%, 5=less than 20%)	
3.2 Funds and budget allocation	
3.2.1 Availability of sufficient funds with ward offices to prevent floods (1=very low, 2= low, 3= moderate, 4= good, 5=very good)	
3.2.2 Access of credit facility with ward office to face/prevent floods (1=very low, 2= low, 3= moderate, 4= good, 5=very good)	
3.2.3 Effectiveness of funding/subsidies for urban poor or low -income groups during floods (1=very low, 2= low, 3= moderate, 4= good, 5=very good)	
3.2.4 Availability of funds for women and women led businesses affected by flood (1=very low, 2= low, 3= moderate, 4= good, 5=very good)	
3.2.5 % of residential units under any sort of insurance scheme (1= less than 20%, 2=20-40%, 3=40-60%, 4=60-80%, 5=80% above)	
Institutional	
4.1 Effectiveness of flood risk management (1=poor, 5=good)	
4.1.1 Existence of sufficient members in emergency team during a flood (1=poor, 5=good)	
4.1.2 Effectiveness of emergency team during a disaster (leadership /competence) (1= poor, 5 = good)	
4.1.3 Availability of sufficient evacuation centres (e.g community centres, school)	
4.1.4 regularity in testing and updation of disaster management plans	
4.1.5 Existence and readiness of multiple channels of early warning dissemination for vulnerable communities like elderly, women, children who may not have mobile phones	
4.2 knowledge sharing	

4.2.1	Effectiveness of staff in learning from previous disasters (1=poor, 5=very good)	
4.2.2	Availability of regular disaster training programmes for staff (1= never, 2= once in 5 years, 3= once every 2 year, 4=every year, 5= every 6 months or more frequent)	
4.2.3	Frequency of flood risk awareness programmes (disaster education) for communities (1= never, 2= once in 5 years, 3= once every 2 year, 4=every year, 5= every 6 months or more frequent)	
4.2.4	Capacity for ward office for sharing of flood awareness (books, leaflets. Manpower, campaigns) (1=very poor, 2=poor, 3=moderate, 4=good, 5=very good)	
4.2.5	Interconnectedness and cooperation for transfer of information between key stakeholder, NGOs, nearby city etc. (1=poor, 5=very good)	
Natural		
5.1.1	Intensity of riverine flood (1=very high, 2=high, 3=moderate, 4=low, 5=very low)	
5.1.2	Intensity of urban flood (1=very high, 2=high, 3=moderate, 4=low, 5=very low)	
5.1.3	Frequency of riverine flood (1=every 6 months, 2=every year, 3= every 2year, 4= every 5 year, 5 = every 10 year or less)	
5.1.4	Frequency of waterlogging/urban flood (1=every month, 2=every 3 months, 3= every year, 4= every alternate year, 5 = once every 3 year or less)	
5.1.5	Loss of urban water bodies (encroachment on lakes ponds drainage etc) due to development of infrastructure, housing etc. over the last 10 years (1=more than 10, 2=7-9, 3=4-6, 4=1-3, 5=none)	

Household Survey

Use in Locations that are Frequently Inundated in the City

1. Name	
2. Gender and Age	
3. Total Members in HH	
4. Age Group (<5 yrs, 5-18 yrs, 18-60 yrs, >60 yrs)	
5. Education (Illiterate = 1, Primary (1 to 7 grade) = 2, Secondary (8-10 grade) = 3, Higher Secondary (10-12 grade) = 4, University or Higher = 5, Others = 6)	
6. Health Status (Pregnant/Lactating = 1, Differently Abled = 2, Bedridden/Special Care = 3, Others = 4)	
7. Employment Status (Salaried = 1, Daily Wager = 2, Self-employed = 3, Pension = 4, Unemployed = 5, Students = 6, Others = 7)	
8. Do you live in your own house with title or in rented accommodation (Own house with title = 1, Rented accommodation = 2, Friends/relatives = 3, Others = 4)	
9. Who is the service provider for solid waste disposal and collection system? (Government = 1, Private Agency = 2, Community-driven = 3, Others = 4)	
10. How many floors are there in the house? (Ground floor only = 1, Ground+1 = 2, Ground+2 = 3, More than ground+2 = 4)	
11. Does the house have a water connection? (Yes = 1, No = 2)	
12. Does the house have a toilet and washroom? (Only washroom = 1, Both washroom and toilet = 2, None = 3)	
13. Distance from low lying area in metres (<300 = 1, 300-500 = 2, 500-1000 = 3, >1000 = 4)	
14. Near open area of waste disposal (4) in metres (<300 = 1, 300-500 = 2, 500-1000 = 3, >1000 = 4)	
15. Do the key sources of water get polluted/flooded during rainfall, floods? (Yes = 1, No = 2)	
16. What is the strength of community cooperation during urban floods? (Very Poor = 1, Poor = 2, Moderate = 3, Good = 4, Very Good = 5)	
17. Did you have to shift to safe shelters during floods?	
18. Do you have regular community meetings to discuss local issues, challenges, etc.? (Yes = 1, No = 2, Not Aware = 3)	
19. Does your family discuss preparedness measures and plan of action for disasters? (Yes = 1, No = 2)	
20. What do you discuss about — safe shelters, how to strengthen housing, emergency stock, evacuation plan etc.	
21. How was your family/household affected by past urban floods?	
22. What all key disruptions in critical services were faced during past urban floods?	
23. How do you protect your houses/assets from being flooded/cyclone?	

Baseline for Public Awareness (Y/N/Na Type Questions)

1. Has there been damages in the area (human/asset etc.) due to urban flooding in the past?	
2. Were you informed about the precautions to take during urban flooding by the municipality?	
3. Were you aware of when waterlogging issues will occur?	
4. Do you get information on urban flooding from: TV, Social Media, Whatsapp?	
5. Did you find any advisory posters in the community regarding the same?	
6. Were the posters posted in accessible places in the area?	
7. Did elderly of your household read the posters?	
8. Did the municipality convey information on what to do next and in case of emergency?	
9. Did they inform whom to contact in case of emergency?	
10. Did you convey the message you gathered from the officials to other residents of the area?	
11. Do all residents of community adhere to guidelines as mentioned?	
12. Do organisation/officials working in area guide you related to waste segregation?	
13. Do organisation/officials working in area guide you related to rain water harvesting?	
14. Do you wish to invest time in the workshops/trainings for disaster and urban flood related capacity building?	
15. What government initiative should be taken in the area so as to increase awareness of the public?:	

ANNEXURE 2 - METHODOLOGY FOR RISK ANALYSIS

Hydrological and Hydraulic

The hydrological analysis, conducted following the methodology detailed in the Storm Water Drainage Systems Manual, Volume 1 by the Central Public Health & Environmental Engineering Organisation (CPHEEO), utilized a DEM developed using the terrain information obtained from Bhuvan. This analysis elucidates surface runoff patterns directed toward the project site, delineating drainage areas, flow directions, and pathways for both the onsite and the offsite.

The time of concentration (TC) is when rainwater travels from the farthest point of the drainage area to the outfall. The time of concentration was determined for the drainage area using a combination of the equation developed by the Corps of Engineers and Manning's equation to obtain the time of travel in surface flow (T_o) and conduit flow (T_f), respectively. As shown in equation 1, the time of concentration is a summation of T_o and T_f .

$$T_c = T_o + T_f \quad \text{Eq. (1)}$$

The time of travel for surface flow (T_o) was calculated by an equation developed by the Corps of Engineers:

$$T_o = \frac{0.994(1.1-C)L^{0.5}}{S^{0.333}} \quad \text{Eq. (2)}$$

Where,

T_o = Time of surface flow (min)

C = Runoff Coefficient

L = Length of sheet flow (m)

S = Surface slope (%)

The time of travel for the conduit (T_f) was calculated by Manning's equation:

$$V = \frac{1}{n} R^{0.67} S^{0.5} \quad \text{Eq. (3)}$$

$$T_f = \frac{L_{ch}}{60 \times V} \quad \text{Eq. (4)}$$

Where,

V = Velocity in the channel (m/sec)

n = Manning's roughness coefficient of the channel

R = Hydraulic radius (m)

S = Slope of the channel

L_{ch} = Length of the channel (m)

Utilizing the aforementioned equations, the time of concentration is computed as the sum of the time required for surface and conduit flow.

The resulting time of concentration (T_c) for Manikonda is estimated to be 57.25 min (0.95 hr) for DA Nallah-1, and 78.45 min (1.31 hr) for DA Nallah-2 under existing conditions.

Table 14. Manning's 'n' Values at Different Cross-Sections at Nallah-1 in Manikonda

Cross-Section	'n' Value		
	Left Over Bank	Channel	Right Over Bank
1	0.1	0.04	0.1
2	0.1	0.04	0.1
3	0.1	0.1	0.1
4	0.1	0.1	0.1
5	0.1	0.1	0.1
6	0.1	0.1	0.1
7	0.1	0.1	0.1
8	0.1	0.04	0.1

Table 15. Manning's 'n' Values at Different Cross-Sections at Nallah-2 in Manikonda

Cross-Section	'n' Value		
	Left Over Bank	Channel	Right Over Bank
1	0.1	0.04	0.1
2	0.12	0.12	0.12
3	0.1	0.04	0.1
4	0.1	0.1	0.1
5	0.15	0.15	0.12
6	0.12	0.12	0.12
7	0.1	0.04	0.1
8	0.1	0.04	0.1
9	0.1	0.04	0.1
10	0.1	0.1	0.1

Rational Method

Detailed data for applying the Soil Conservation Service (SCS) unit hydrograph method was not available, and the available soil data was too coarse and insufficient for thorough analysis. Given the time constraints, the Rational method emerged as the most suitable option. The Rational method can be applied with limited data, and can quickly provide estimates of peak discharge. Additionally, it accounts for various types of losses beyond just soil-related losses.

The peak flow from the offsite drainage area is estimated using the Rational Method. The methodology is based on the Storm Water Drainage Systems Manual, Volume 1 by the Central Public Health and Environment Engineering Organisation (CPHEEO). The Runoff Coefficient 'C' depends on the surface type of a catchment. The Runoff Coefficients 'C' for the Nallah-1 and Nallah-2 drainage areas, DA Nallah-1 and DA Nallah-2 in Manikonda are used as 0.60 and 0.70 respectively considering the areas as a high-density residential catchment. The peak flow for 10-year, 25-year and 100-year

events are calculated using the Rational Method Formula:

$$\text{Peak Runoff } Q = C \times \text{Intensity} \times \text{Drainage Area} \quad \text{Eq. (5)}$$

Hydraulic Analysis

Hydraulic analysis encompasses the study of fluid flow behavior in rivers, channels, and other hydraulic structures (culverts, bridges, etc.,). It involves predicting water surface elevations, flow velocities, and other hydraulic parameters under various conditions, including flood events and channel modifications.

The Hydrologic Engineering Center's River Analysis System (HEC-RAS), developed by the US Army Corps of Engineers is a powerful software tool widely used for the hydraulic analysis of open channels. HEC-RAS employs various computational methods, including one-dimensional (1D) steady flow, 1D unsteady flow, and two-dimensional flow simulations, to accurately model complex hydraulic processes. The software facilitates the setup of detailed geometric models, including river channels, floodplains, and other hydraulic structures, using GIS data or manual input. By defining boundary conditions such as flow rates, and water surface elevations, users can simulate different flood scenarios and analyse their impacts on the surrounding environment. HEC-RAS provides comprehensive output data, including water surface profiles, flow velocities, inundation maps, and floodplain delineations, enabling engineers to assess flood risk, evaluate the performance of existing infrastructure, and design effective flood control measures. Overall, HEC-RAS is a valuable tool for hydraulic analysis and plays a crucial role in flood risk management.

Hydraulic analysis is used to determine the flood risk to the project site by understanding the water surface elevation, depth, and extent of the inundation. A (1D) steady-state hydraulic analysis is performed using the HEC-RAS software, version 6.4.1, to derive the flood level in the nallahs/ rivers. The objective of the hydraulic model is to understand the flood extent and the water surface elevation (WSEL), for the area within and around the city for different return period storm events. To account for the above characteristics of the site and determine the risk, a 1D modelling approach is used.

One-Dimensional Hydraulic Modelling

In HEC-RAS, 1D hydraulic modelling involves dividing the river or channel into a series of cross-sections and computing the flow properties along the length of the channel. Each cross-section is characterized by its geometry, including channel width, depth, and slope, as well as hydraulic properties such as roughness coefficients. The software solves the 1D Saint-Venant equations, which govern the flow of water in open channels, to calculate water surface elevations, flow velocities, and other hydraulic parameters. This allows engineers to simulate various scenarios, such as different flow rates or channel configurations, and assess the impact on flood risk, water levels, and flow velocities within the river system.

A 1D HEC-RAS model is developed considering a stretch of nallahs/rivers covering the extent of the city. The peak flows obtained from the rational flow method are used as input to the upstream cross-section of the HEC-RAS model. The Bhuvan terrain is used to obtain the elevation information

for all cross-sections of the river. The details of the structures (Bridge and culverts) are requested to the client, which are required for modelling on the river to understand their impact on the water surface elevation. However, due to insufficient information obtained for the client, the structures are excluded from the hydraulic analysis, also with an assumption that the major and new structures on the rivers and nallahs are already designed for more than a 100-year return period rainfall events. As a result of the hydraulic analysis, the WSEL and extent of inundation for 10-yr, 25-yr, and 100-yr return period rainfall events are obtained at each of the considered cross-sections.

Steady flow describes conditions in which depth and velocity at a given channel location do not change with time. Basic computational procedure is based on an iterative solution of the energy equation: The Energy equation and Manning's equation are written as follows:

$$Z_1 + Y_1 + \frac{\alpha_1 V_1^2}{2g} = Z_2 + Y_2 + \frac{\alpha_2 V_2^2}{2g} + h_e \quad \text{Eq. (6)}$$

Where,

α_1 = Velocity weighting coefficients

h_e = Energy head loss (m)

Z_1, Z_2 = Elevation of the main channel inverts (m)

Y_1, Y_2 = Depth of water at cross-section (m)

V_1, V_2 = Average velocity (m/s)

g = Gravitational acceleration (m/s²)

$$Q = \frac{1}{n} R^{0.67} S^{0.5} A \quad \text{Eq. (7)}$$

Where,

V = Velocity in the channel (m/sec)

n = Manning's roughness coefficient of the channel

R = Hydraulic radius (m)

S = Slope of the channel

L_{ch} = Length of the channel (m)

Q = Flows (m³/s)

Water surface elevation (WSE) was computed at the cross-section by solving the Energy equation with an iterative procedure called the standard step method.

Hazard, Vulnerability and Exposure Calculations

The degree of risk induced by floods depends on various social, physical, institutional, natural and economic factors that vary from one ward or division to another. So, the degree of risk induced by flooding is expected to vary significantly as identified from consultations. Following a series of consultations and discussions were held with various officials within Manikonda Municipality, and other relevant departments. Hazard indicators were based on the rainfall and storm events, the final indicator list of exposure and vulnerability were reflected in the final data collection tools using the SPINE framework (described in Sub-section 4.3.2) to include the aspects of socioeconomic,

physical, institutional and behavioural indicators among others that are impacting the risk directly or inversely. All the indicators were normalised by bringing them to a common scale of 1-5. For this, the min-max normalisation technique was used where risk was classified such that with an increase in the value of the indicator the risk is reduced.

This was followed by a semi-quantitative approach for assigning weights that allowed for stakeholder engagement in determining the relative weights of the indicators being compared. Multi-criteria decision modelling tools were reviewed that are widely applied within vulnerability and flood risk assessment studies (Hoque et. al. 2019, Hasanuzzaman et. al. 2022) Although for this study, responses suggested that most of the indicators have equal importance i.e. indicators are equally significant with respect to the project objective.

Risk Calculation Components

Hazard	Exposure	Vulnerability
▪ Flood inundated areas/ hotspots ▪ Projected water surface elevations ▪ Frequency of waterlogging	▪ Land cover characteristics ▪ Slope ▪ Population density ▪ Stormwater network coverage	▪ SPINE Framework indicators (data collection tool) ▪ Research & Documentation

ANNEXURE 3 - FIELD DATA COLLECTION

Table 16. Flood Location Information of Manikonda — Household and Community Interview

Area Name	Profile of the Area	Key Challenges	Supporting Photographs
Panchavati Colony Road No. 10 Ward 3	Panchavati Colony is a residential area predominantly inhabited by professionals working in corporate companies. The residents generally have a high socio-economic status, which contributes to their awareness and proactive measures in dealing with environmental issues, including flooding.	▪ <i>Frequent Flooding:</i> Despite the preparedness of the residents, Panchavati Colony experiences frequent flooding, especially during the monsoon season. ▪ <i>Water Logging:</i> Prolonged water logging after rainfall causes significant inconvenience to the residents, disrupting daily activities and mobility. ▪ <i>Frequent Inundation:</i> During rainfall, the colony experiences a minimum inundation depth of 0.3 meters, which exacerbates the inconvenience and disruption caused by water logging. ▪ <i>Drainage Maintenance:</i> There is a notable lack of maintenance of the drainage systems, particularly those with retaining walls on the left bank. This poor maintenance results in overflows during floods, contributing significantly to the flooding issues. ▪ <i>Funding Gaps:</i> Insufficient funding for infrastructure improvements and regular maintenance activities hampers efforts to effectively address the flooding issues.	  Water Logging point of recent rain on June 2nd 2024 at Panchavati colony near SNDP Nallah. ▪ The SNDP Box culvert size is 4.5m*1.5m with 282m length. Latitude: 17°24'30.92N ; Longitude: 78°23'11.52E 

		▪ <i>Ongoing Infrastructure Work:</i> The ongoing Strategic Nallah Development Project (SNDP), which involves the construction of a box culvert nallah, is in its final stages of completion. Once finished, this project is expected to significantly reduce water logging problems.	 Panchavati colony SWD outflow to SNDP-GHMC nallah
Vinayk Nagar Colony Ward 10		▪ <i>Frequent Flooding:</i> Vinayak Nagar experiences frequent flooding, particularly during the monsoon season. This causes significant inconvenience to residents. ▪ <i>Water Logging:</i> Prolonged water logging is a common issue, causing disruption to daily life and posing health risks due to stagnant water. ▪ <i>Drainage Infrastructure:</i> A grating with a depth of 0.9 meters, width of 0.6 meters, and length of 6 meters has been laid to divert stormwater drainage (SWD) during floods.	 Latitude: 17°23'54.97N ; Longitude: 78°22'03.56E The pictures below illustrate the current conditions and ongoing efforts to mitigate the flooding issue in Vinayak Nagar Colony.  Perforated drains  Ongoing drainage network work 

Lalamma Gardens Ward 5	Lalamma Gardens is a residential community comprising several apartment buildings. The residents are primarily middle-class families, many of whom work in various professional sectors. The socio-economic status of the residents is moderate, and they are generally well-informed about the risks associated with flooding. The community is proactive in mitigating the impact of floods, with residents maintaining motors and pumps to clear water from flooded areas.	▪ <i>Low-Level Basements:</i> The basements of the apartment buildings in Lalamma Gardens are situated below the road level. During heavy rains, the underground parking areas are prone to flooding, causing damage to vehicles and property stored in these areas. ▪ <i>Stormwater Inconvenience:</i> Despite having motors and pumps to remove floodwater, residents face considerable inconvenience due to the volume of stormwater that enters the basements. The continuous need to pump out water is a significant disruption to daily life. ▪ <i>Debris and Clogging:</i> Floodwaters often carry debris and other waste materials into the apartment premises, exacerbating the flooding problem. The entry of this debris clogs drains and complicates the cleaning process, posing a major challenge for the residents. ▪ <i>Infrastructure Improvement Needs:</i> There is a need for infrastructural improvements to address the flooding issue more effectively. Without significant upgrades, the community continues to struggle with recurrent flooding and its associated problems.	 Latitude: 17°24'00.37N; Longitude: 78°23'13.50E
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		Community Efforts: The residents of Lalamma Gardens are proactive in managing flood risks. They use motors and pumps to clear water, participate in cleaning efforts, and raise awareness about proper waste disposal to prevent blockages. However, these efforts alone are insufficient without broader infrastructural support.	
Spectrum Villas near Culvert Road Ward 7	Spectrum Villas is a residential area located near Culvert Road in Ward 7. The residents are predominantly middle to upper-middle-class families with a moderate level of socio-economic status. They are generally aware of the flood risks in their area and undertake various measures to mitigate the impact of floods.	<i>Low-Level Culvert:</i> The culvert on Culvert Road is positioned at a low level, which becomes a significant problem during rainfall. The culvert often gets inundated, rendering the road non-functional for 3-4 hours. This causes major disruptions for residents and commuters who rely on this road. <i>Road Accessibility:</i> During and after heavy rainfall, residents and others in the vicinity find it difficult to cross the culvert road due to the inundation, leading to safety concerns and mobility issues.	 Specific locational challenges of the flood location being informed by resident to project team member.

	These measures include cleaning and maintaining local drainage systems and participating in community initiatives to address flood-related issues.	▪ <i>Stormwater Intrusion:</i> During heavy floods, stormwater enters the Spectrum Villas, reaching depths of up to 0.3 meters. This not only causes property damage but also poses health risks due to waterborne diseases. ▪ <i>Proposal for Infrastructure Improvement:</i> Although local officials have raised a proposal to increase the height of the culvert road to mitigate the flooding issue, this project has not yet been implemented. The delay in infrastructure improvement continues to exacerbate the flooding challenges faced by the residents. ▪ <i>Community Efforts:</i> While residents undertake various activities to mitigate the flood impact, such as clearing debris from drains and raising awareness about proper waste disposal, the community efforts alone are insufficient without significant infrastructure upgrades.	
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ANNEXURE 4 – LIST OF OFFICIALS CONTACTED

Table 17. Key Government Officials Consulted in Manikonda

S. No.	Official Designation	Official Name	Meeting Date	Data Provided
1	Municipal Commissioner, Manikonda Municipality	Sri G. Pradeep Kumar	27-05-2024 18-06-2024	Given permission to provide data and allotted Dy. Executive Engineer
2	Dy. Executive Engineer	Smt. Divya Jyothi	27-05-2024 18-06-2024 20-06-2024	Shared details pertaining to SWM, ongoing work in SNDP, allotted engineers to provide necessary data
3	Engineer	Sri Nithin	27-05-2024	Gave ward boundary, shapefiles for analysis
4	Environment Engineer	Sri Mahender	27-05-2024 to 29-05-2024	Provided information for stakeholder questionnaire
5		Sri Sampath	27-05-2024 to 29-05-2024	Provided all Wards information and support for interaction at household level
6	Work Inspector	Sri Anil	29-05-2024 20-06-2024	Shared stormwater drainage network details
7	Ex-Municipal Commissioner (currently Adm Manager, TUFIDC)	Sri Phalgun Kumar	21-06-2024	Gave information on formation of Manikonda, temporal changes in flooding patterns
8	Assistant Engineer, EVDM Hyderabad	Sri Ajesh	29-05-2024 21-06-2024	Shared disaster management plan, inputs on gaps in addressing floods

ANNEXURE 5 – STORMWATER DRAINAGE WORK DETAILS MANIKONDA

	PROCEEDINGS OF THE MUNICIPAL COMMISSIONER, MANIKONDA MUNICIPALITY Present: Sri. K. Phalgun Kumar, Municipal Commissioner

Work Order No. E1/ 732 /MC/MNK/2022-23	Date: 15.06.2022
To, M/s. VSR Infra, H.No.8-3-169/60/1376/32, Rajiv Gandhi Nagar, Yousufguda Ph:7013304181	
Gentlemen,	
Sub:	Manikonda Municipality –“LAYING OF SWD LINE AT LALAMMA GARDEN IN FRIENDS COLONY IN WARD NO.05 IN MANIKONDA MUNICIPALITY UNDER MUNICIPAL GENERAL FUNDS 2022- 23”- Work Order– Issued – Reg.
Ref:	1. Council Resolution No. 931/2022-23, Date:27-04- 2022 2. Tender Notice No. E1/356/2021-22, dt: 28-05-2022 3. e Procurement Tender Id No.323731 4. LOA issued on dt: 08-06-2022
	@@@
<u>ORDER:</u>	
Administrative Sanction	: Rs. 50,00,000.00
Amount of ECV	: Rs. 39,95,619.00
Tender Premium	: (-) 28.22% Less
Amount of Contract	: Rs. 28,68,055.32
Period of Completion	: 3 Three Months
You are here by informed to start this work immediately duly obtaining mark out from Municipal Assistant Engineer, subject to terms & conditions as laid down in the tender and also time to time instructions of the technical authorities besides under signed.	
The work should be completed within stipulated period of time from the date of receipt this work order, failing which action will be initiated against the Contractor/ agency under the provisions of T.S. Municipal Act. 2019 of Authority of Contract (Sl.No.55) Telangana Gazette Extraordinary and other related orders / provisions.	
 COMMISSIONER MANIKONDA MUNICIPALITY 8/6/22 15/06/22	
Copy to Dy. Executive Engineer, Manikonda Municipality with instructions to supervise the work in all respects.	
Copy to Assistant Executive Engineer with instructions for markout and execute the work in all respects.	



PROCEEDINGS OF THE MUNICIPAL COMMISSIONER, MANIKONDA MUNICIPALITY

Present: Sri. K. Phalgun Kumar,
Municipal Commissioner

WORK ORDER No. E1/412-04/MC/MNK/2022-23, Date: - -2023

To,
Sri. VSR INFRA, Firm No. (3861 of 2017),
(Formerly Sri Varikuppala Ramesh),
H No.8-3-169/60/1376/32, Rajiv Gandhi Nagar, SPR Hills,
Yousufguda, Hyderabad - 500045.
Ph:

Gentlemen,

Sub: Manikonda Municipality -"Laying of SWD from Keerthi Residency to AR Residency in Friends Colony in ward no.5 in M1anikonda Municipality Under Municipal General Funds 2022-23"- WORK ORDER - Issued - Reg.

Ref: 1. Council Resolution No.1110/2022-23, Dt:30-11-2022
2. Technical Sanction No.1544/2022-23, Dt:19-12-2022
3. Tender Notice No.E1/412-04/2022-23, Dt:31-12-2022
4. LOA No. E1/412-04/MC/MNK/2022-23, Date:07-01 -2023

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ORDER:

Administrative Sanction	:	Rs. 40,00,000.00
Amount of ECV	:	Rs. 32,49,008.00
Tender Premium	:	(-) 1.22% Less
Amount of Contract	:	Rs. 32,09,370.10
Period of Completion	:	01 One Month

You are here by informed to start this work immediately duly obtaining mark out from Municipal Assistant Engineer, subject to terms & conditions as laid down in the tender and also time to time instructions of the technical authorities besides under signed.

The work should be completed within stipulated period of time from the date of receipt this work order, failing which action will be initiated against the Contractor/ Agency under the provisions of T.S. Municipal Act. 2019 of Authority of Contract (Sl.No.55) Telangana Gazette Extraordinary and other related Orders /Provisions.

**COMMISSIONER
MANIKONDA MUNICIPALITY**

Copy to Dy. Executive Engineer, Manikonda Municipality with instructions to supervise the work in all respects.

Copy to Assistant Executive Engineer with instructions for markout and execute the work in all respects.



**PROCEEDINGS OF THE MUNICIPAL COMMISSIONER,
MANIKONDA MUNICIPALITY**

Present: Sri. K. Phalgun Kumar,
Municipal Commissioner

WORK ORDER No. E1/429-06/MC/MNK/2023-24, Date: - -2023

To,
Sri. K MAHENDER REDDY, S/o Yella Reddy (Late),
H.No.13-6-434/C/19/1, Maruti Nagar, Ring Road Karwan,
Pillar No.86, Golkonda, Langer House, Hyderabad - 500008.
Ph: 9346386084.

Gentlemen,

Sub: Manikonda Municipality -" Laying of SWD from Armani Avenue to Prathap
enclave in Ward no.19 in Manikonda Municipality under Municipal General
Funds 2023-24" - WORK ORDER - Issued - Reg.

Ref: 1. Council Resolution No.1231/2023-24, Dt:29-03-2023
2. Technical Sanction No.4/2023-24, Dt:06-04-2023
3. Tender Notice No.E1/429-6/2023-24, Dt: 12-04-2023
4. LOA No. E1/429-06/2023-24, Dt: 19-04-2023

@ @ @

ORDER:

Administrative Sanction	: Rs. 50,00,000.00
Amount of ECV	: Rs. 39,95,213.00
Tender Premium	: (=) Equal
Amount of Contract	: Rs. 39,95,213.00
Period of Completion	: 03 Three Months

You are here by informed to start this work immediately duly obtaining mark out from
Municipal Assistant Engineer, subject to terms & conditions as laid down in the tender and also time
to time instructions of the technical authorities besides under signed.

The work should be completed within stipulated period of time from the date of receipt this
work order, failing which action will be initiated against the Contractor/Agency under the provisions
of T.S. Municipal Act. 2019 of Authority of Contract (Sl.No.55) Telangana Gazette Extraordinary and
other related Orders/Provisions.

**COMMISSIONER
MANIKONDA MUNICIPALITY**

Copy to Dy. Executive Engineer, Manikonda Municipality with instructions to supervise the work in
all respects.

Copy to Assistant Executive Engineer with instructions for mark out and execute the work
in all respects.



PROCEEDINGS OF THE MUNICIPAL COMMISSIONER,
MANIKONDA MUNICIPALITY

Present: Sri. K. Phalgun Kumar,
Municipal Commissioner

WORK ORDER No. E1/375-09/MC/MNK/2022-23, Date: - -2022

To,
Sri. TANDRA YADAGIRI,
H.No.10-8-6/4, L B S Nagar, Balanagar,
Medchal - Malkajgiri, Telangana - 500042.
Ph: 9346386084.

Gentlemen,

Sub: Manikonda Municipality -" Laying of SWD line in Ward No.12 in Manikonda Municipality under Municipal General Funds 2022-23 (Reserved for SC)" - WORK ORDER - Issued - Reg.

Ref: 1. Council Resolution No.1001/2022-23, Dt:18-07-2022
2. Technical Sanction No.542/2022-23, Dt:08-08-2022
3. Tender Notice No.E1/375-09/2022-23, Dt:19-08-2022
4. LOA No. E1/375-09/2022-23, Dt: 23-09-2022

ORDER:

Administrative Sanction	: Rs. 12,00,000.00
Amount of ECV	: Rs. 9,52,363.00
Tender Premium	: (-) 21.3% Less
Amount of Contract	: Rs. 7,49,509.68
Period of Completion	: 03 Three Month

You are hereby informed to start this work immediately duly obtaining mark out from Municipal Assistant Engineer, subject to terms & conditions as laid down in the tender and also time to time instructions of the technical authorities besides under signed.

The work should be completed within stipulated period of time from the date of receipt this work order, failing which action will be initiated against the Contractor/Agency under the provisions of T.S. Municipal Act. 2019 of Authority of Contract (Sl.No.55) Telangana Gazette Extraordinary and other related Orders/Provisions.

COMMISSIONER
MANIKONDA MUNICIPALITY

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