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# Urban Stormwater Management and Sustainable Design

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***Abstract:*** Urban storm water drainage systems in India have historically been secondary to water supply and sewerage, a situation worsened by rapid urbanization and migration that strains existing infrastructure. This contributes to urban floods when heavy rainfall overwhelms drainage capacity. Mega cities, with their long history of municipal drainage dating back to the British era, often rely on antiquated, combined sewage and storm water systems, making upgrades and separation projects technically and financially challenging.

## I. INTRODUCTION

### STORM WATER DRAINAGE

Storm water drainage involves managing excess precipitation from urban surfaces using systems like storm drains. While structural measures like reservoirs and channels exist, non-structural approaches such as flood forecasting are also employed. Urban development, with its increase in impervious surfaces, significantly alters the natural water cycle, increasing runoff and pollutant transport. Technologies like infiltration basins, rain gardens, and porous pavements are used to manage storm water, promoting infiltration and improving water quality. Storm sewers transport runoff to water bodies, sometimes untreated, while combined sewer systems, which carry both sewage and storm water, can lead to pollution from overflows. As cities become denser, increased wastewater volumes necessitate greater drainage capacity and sewer systems

### CAUSES OF URBAN FLOODING

Several factors contribute to frequent urban flooding in India, even during light rainfall. High annual rainfall concentrated during the monsoon season, as seen in cities like Mumbai, is a significant factor. Storm drainage systems in India are often designed for low-frequency rainfall events, making them inadequate for higher intensity storms. Uncontrolled urbanization increases impervious surfaces, leading to greater runoff and flooding. Challenges in storm runoff disposal are amplified by flat terrain, coastal tidal influences, and blockages in hilly areas. Climate change also plays a role by increasing the frequency of high-intensity rainfall events. A lack of systematic and comprehensive storm water management planning leaves urban areas vulnerable, even to moderate rainfall.

## EFFECTS OF URBAN FLOODING

Urban flooding has several negative consequences,

- including loss of life and property,
- disruptions to transportation and power services,
- increased risk of epidemics during the monsoon season,
- and significant economic and
- Infrastructure damage to business

## STORM DRAINAGE SYSTEM

A storm drainage system is a network of structures, channels, and pipes designed to transport rainwater away to bodies of water like ponds, lakes, streams, and rivers. This system, comprising both public and private components, is crucial for managing the quantity, quality, timing, and distribution of storm runoff. Unlike sanitary sewer systems which carry wastewater to treatment plants, storm drains do not connect to these facilities. Effective stormwater drainage design is a vital part of overall stormwater management. Good design aims to work with existing drainage patterns, prevent flooding of property and infrastructure during design storms, and minimize environmental impacts from runoff. Stormwater collection systems should ensure adequate surface drainage while also supporting other management objectives such as improving water quality, protecting waterways and habitats, and promoting groundwater recharge.

## DRAINAGE SYSTEM COMPONENT

Urban areas typically have two interconnected stormwater drainage systems: the minor and major systems, designed with flooding, public safety, and water quality in mind. The minor system is intended for frequent, smaller storms, focusing on removing water from streets and sidewalks for public safety. It also includes less obvious paths like overflow swales and temporary ponding areas, serving as a backup if the minor system is overwhelmed or fails, ensuring overland flow doesn't damage property. The major/minor concept represents two distinct but linked networks that must be designed together, alongside structural controls and the overall stormwater management plan.

## STORM WATER MANAGEMENT

Stormwater management encompasses efforts to control and direct runoff from rain or melting snow in urban areas, streets, lawns, and homes to enhance water quality and mitigate the adverse impacts of flooding caused by agriculture and urban development. In natural environments like forests, much of this water infiltrates into the ground or evaporates, with soil absorbing significant amounts and plants retaining water, resulting in minimal runoff.

**Key aspects of stormwater management:**

- **Planning and Design:**
  Stormwater management plans (SWMPs) outline how runoff will be managed, treated, and discharged. This includes considering factors like runoff volume, peak flow, and pollutant removal.
- **Structural Controls:**
  These include engineered systems like retention ponds, detention basins, and permeable pavements, which help to store, filter, or infiltrate stormwater.

- **Operational Practices:**
  These include measures like street sweeping, proper fertilizer use, and avoiding dumping pollutants into storm drains.
- **Green Infrastructure:**
  Utilizing natural areas and green spaces like urban forests, rain gardens, and urban wetlands to absorb and treat stormwater.
- **Water Quality Improvement:**
  Stormwater management aims to reduce the amount of pollutants, such as sediment, nutrients, and chemicals, that enter waterways through runoff.
- **Flood Control:**
  By managing runoff volume and flow rates, stormwater management helps to reduce the risk of flooding and its associated damages.
- **Erosion Control:**
  Effective stormwater management prevents soil erosion and the transport of sediments into waterways.
  Importance of Stormwater Management:
- **Protecting Water Quality:**
  Stormwater runoff can carry pollutants, which can harm aquatic ecosystems and make water unsafe for human use.
- **Reducing Flood Risk:**
  Unmanaged stormwater runoff can overwhelm drainage systems and cause flooding, leading to property damage and economic losses.
- **Protecting Natural Resources:**
  Stormwater management helps to preserve natural habitats and biodiversity by minimizing the impacts of runoff on waterways.
- **Improving Urban Environments:**
  Green infrastructure and other stormwater management practices can enhance the aesthetics and quality of life in urban areas.

## I. RESEARCH METHODOLOGY

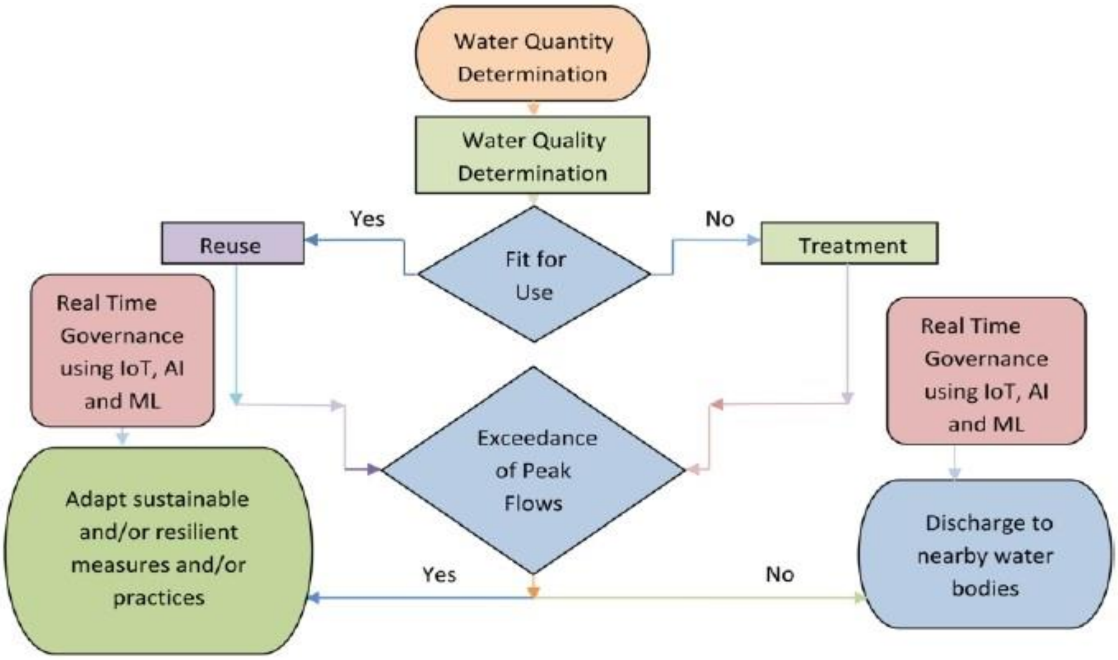
A robust research methodology for urban stormwater management and sustainable design involves a combination of quantitative and qualitative approaches, including modeling, case studies, stakeholder engagement, and experimental designs. This methodology aims to understand the complexities of stormwater, develop sustainable solutions, and evaluate their effectiveness.

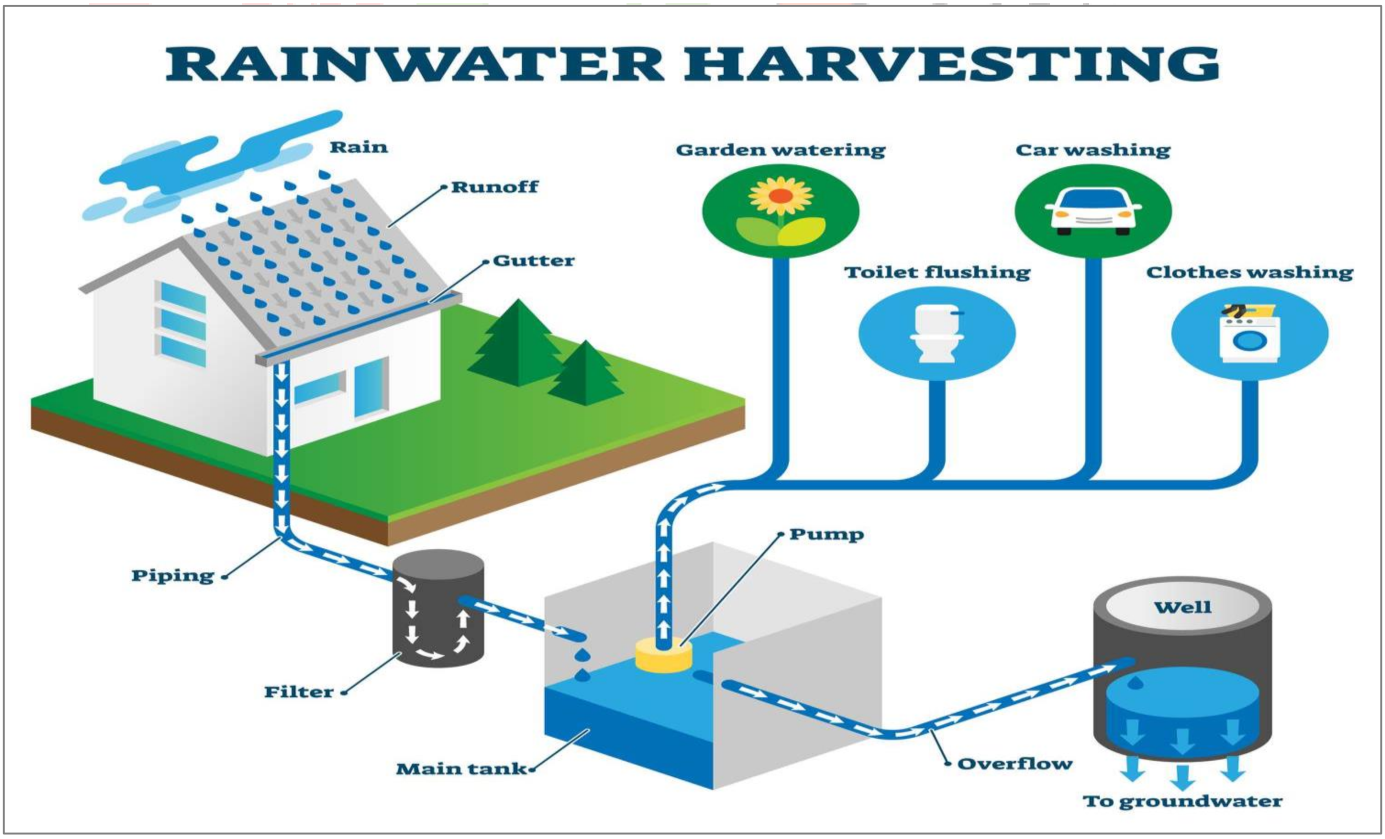
This research builds upon existing stormwater management reviews by offering a novel perspective focused on enhancing sustainability and resilience in urban contexts. It examines various urban stormwater management approaches, including Low Impact Development (LID), Best Management Practices (BMP), Sustainable Urban Drainage Systems (SUDS/SuDS), and Stormwater Control Plans (SCP), identifying knowledge gaps and suggesting future research directions. The study incorporates real-time governance and water reuse options to advance current practices. Furthermore, it comprehensively analyzes the impacts of climate change and urbanization on urban hydrology, ecology, and water quality, proposing improvements for existing measures to be more sustainable and resilient. The review utilizes tables and figures for clarity and identifies key drivers of integrated urban stormwater management, ultimately providing a thorough and novel examination of the field, highlighting challenges.

**Low Impact Development (LID) AND BEST MANAGEMENT PRACTICES**
refers to principles and techniques that integrate urban activities while preserving natural processes and resources. Various studies have explored the application of LID and BMP, with effective options including pervious pavements and bioretention. While bioretention is effective, its implementation should consider hydrologic, water quality, and environmental factors. Approaches exist to implement LID and integrate them as BMPs, although challenges remain in integrating LID with novel techniques for broader application and enhanced performance. Combining LID with models like StormWater Management Models (SWMM) has been used to reduce catchment imperviousness through methods such as rain barrels, permeable walkways, or bioretention reservoirs. In the context of Sponge Cities, SWMM has been integrated with algorithms like

the preference-inspired co-evolutionary algorithm using goal vectors (PICEA-g) for LID practices. An approach combining SWMM with the multi-objective antilon optimization algorithm (MOALOA) has been applied to identify stormwater control measures (SCMs) as LID for managing runoff and mitigating floods.

Storm water drainage design is crucial for managing runoff, preventing flooding, and minimizing environmental impacts. It involves analyzing topography, site conditions like soil and vegetation, and planning systems that align with natural drainage patterns while ensuring safe discharge and handling potential blockages or excess flows. The goal is to protect property, infrastructure, and the environment by effectively collecting and conveying storm water.



**General planning and Design procedure for stormwater management**

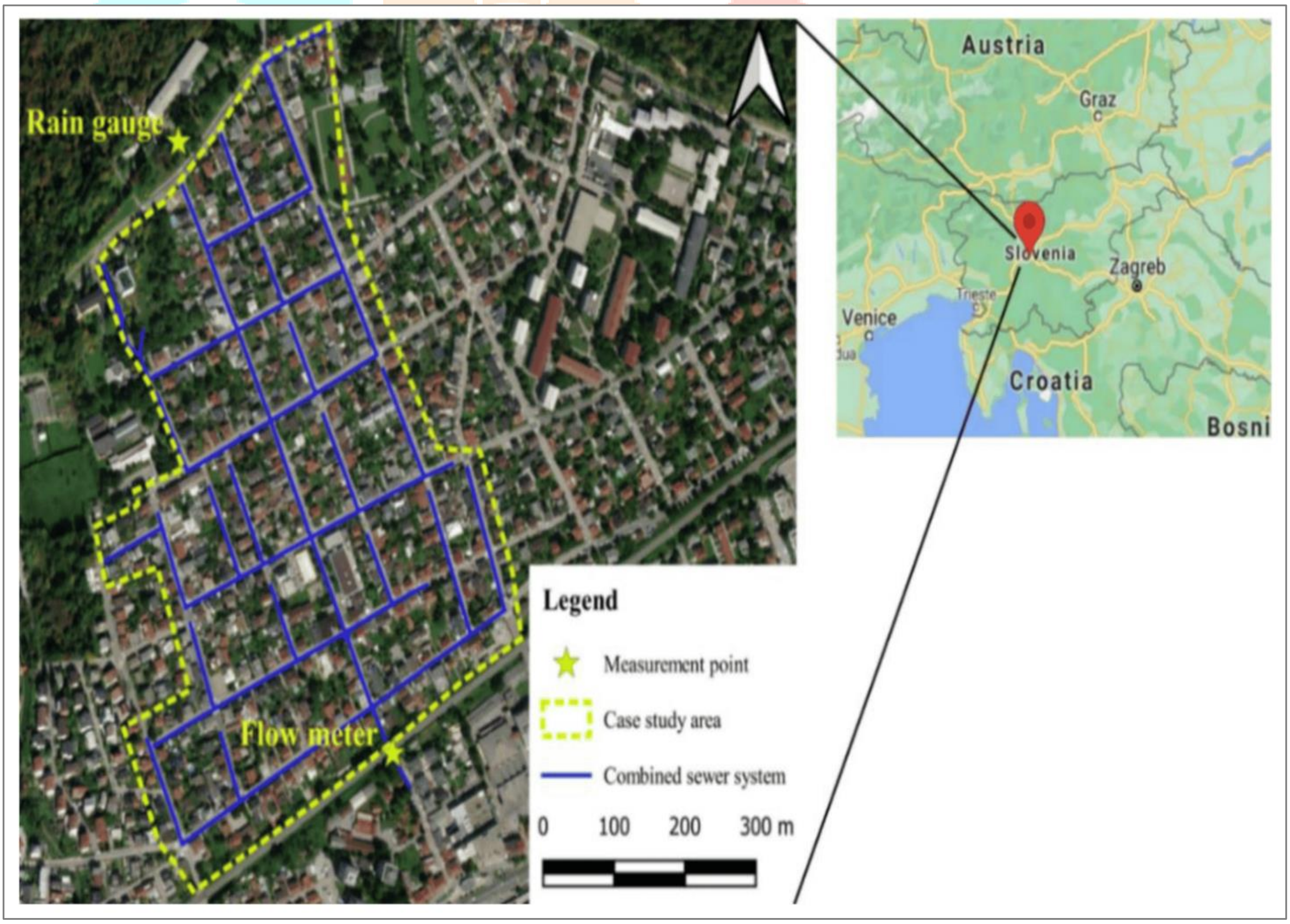
A standard approach for developing a drainage system on a site involves several key steps.

**Analyzing Topography**:

This starts by understanding the existing drainage patterns both on and off the site, identifying where water enters and exits. Next, the on-site topography is examined to determine surface runoff, potential storage areas, and infiltration zones. This includes mapping high points, ridges, valleys, and natural drainage paths like streams and swales to understand water flow. Overlaying a grading plan helps define watershed areas, calculate their size, and pinpoint areas of water concentration and low points. Finally, potential drainage outlets are assessed, including on-site options like structural controls or receiving waters, off-site possibilities such as highways or existing storm drains, natural drainage systems like swales, and pre-existing drain pipes.

**Analyzing Other Site Conditions:**

Several other factors influence drainage design. Existing land use and physical obstructions like walkways, driveways, parking areas, and landscaping elements can impact flow. The soil type is critical as it dictates how much water can infiltrate. Additionally, the type and density of vegetative cover influence the maximum permissible slope without causing erosion.




SewerGEMS offers flexible platform options to suit various workflows and user preferences. It can be utilized as a standalone Windows application for straightforward access and optimal performance. For integration with geographic information systems, users can work within ArcGIS, enabling thematic mapping and data publishing. MicroStation provides a bridge between geospatial planning and engineering design, while AutoCAD allows for convenient CAD layout and drafting. This multi-platform compatibility allows modeling teams to leverage the expertise of engineers from different disciplines and helps reduce the learning curve by allowing engineers to work in familiar environments.

**CASE STUDY (VASAI AREA)**

Rapid urbanization in the Vasai-Virar region has contributed to increased flood susceptibility over the past decade. Following recent heavy rainfall and subsequent flooding in Vasai and Virar, urban planners have attributed the issues to inadequate planning and a disregard for geographical and environmental factors during construction. As real estate values in Mumbai surged, the surrounding suburbs experienced a rise in unregulated and poorly monitored construction for both residential and commercial purposes over the last ten years. Experts believe the consequences of this development are now evident in these areas.

"Uncontrolled development" is identified as a primary cause of such flooding. Drainage channels that naturally convey water from higher elevations to the sea are becoming obstructed by excessive construction, and civic authorities are not adequately clearing them. It's pointed out that in many development plans, these crucial channels are not designated, and topography is often overlooked, creating significant problems not only in the Vasai-Virar area but in other places as well.

Situated between the Arabian Sea and the Sahyadri mountain range, Vasai holds a unique geographical position in Maharashtra. The Western Railway line and the Mumbai-Ahmedabad Highway traverse the area, with four busy station areas – Naigaum, Vasai, Nalasopara, and Virar – spanning approximately 10 kilometers before entering the Palghar district, which borders Gujarat. In many aspects, Vasai can be considered one of the earliest examples of a planned modern city with a history and heritage extending over 500 years. Its history predates that of modern Mumbai, as the latter's development is often linked to Vasai (formerly Bassein).

The city is located on the northern bank of Vasai Creek, part of the Ulhas River estuary, and is adjacent to the Tungareshwar Wildlife Sanctuary. Approximately 50-60 km from downtown Mumbai, Vasai includes a tehsil (taluk) and a Gram Panchayat, and falls under the jurisdiction of the Vasai-Virar City Municipal Corporation (VVCMC). It is also part of the Mumbai Metropolitan Region (MMR). With an estimated population of 13-15 lakh, it is one of the fastest-growing Mumbai suburbs. The significant floating population further strains the existing infrastructure.

A major contributing factor to flooding is the recent practice of construction entities dumping sand and debris in wetland areas. Vasai and Virar have numerous lakes and small ponds that serve as vital channels for directing rainwater to nullahs and the sea. Unchecked dumping has eliminated these natural reservoirs for rainwater, leading to waterlogging in residential areas. In fact, some residents have reclaimed these wetlands and built houses on them. A section of the Ulhas River, known locally as the Sopara river, which originates in the eastern hills of Vasai and flows into the Vasai creek, has also been encroached upon and diverted. The existing drainage culvert carrying water from the city is too narrow and requires widening, with the need for two new culverts. However, this culvert is located on railway land.

**HISTORY**

Vasai, known historically and alternatively as Bajipur in Marathi and Mahratti, and Bassein in English and Baçaim in Portuguese, is a historical location and city near Mumbai's western suburbs, situated in the Palghar district, which was formed by partitioning Thane district in 2014. It is part of the Vasai-Virar twin cities within the Konkan division of Maharashtra, India. The Portuguese in Goa and Damaon constructed the Bassein Fort to protect their colony and participate in the lucrative spice trade and the silk route that converged in the area. A significant portion of Portuguese Bombay and Bassein was seized by the Marathas during the Peshva rule, following the Battle of Vasai in 1739.

**CLIMATIC CONDITION**

Vasai experiences a tropical climate, specifically a tropical wet and dry climate (Aw) according to the Köppen climate classification. The year is characterized by seven dry months and a peak in rainfall during July. This moderate climate features numerous high rainfall days and few days with extreme temperatures. The cooler season runs from December to February, followed by the summer season from March to June. The period from June to approximately the end of September marks the southwest monsoon season, while October and

November constitute the post-monsoon season. The driest periods occur in winter, with the wettest days in July. Between June and September, the region is heavily influenced by the southwest monsoon rains. Pre-monsoon showers are received in May. Occasionally, monsoon showers occur in October and November. The average total annual rainfall ranges between 2,000 and 2,500 mm (79 and 98 in). Annually, over 80% of the total rainfall is received between June and October. The average humidity

## IV. RESULTS AND DISCUSSION

The Entire study zone is divided with considering geographical condition of this area and elevations. In SewerGEMS various aspects were related and considered. All the required data for SewerGEMS is provided and outputs collected. Detail Results are shown in this chapter. Month Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Year Average high °C (°F) 28.4

## II. CONCLUSION

The Vasai area is experiencing challenges with its stormwater drainage system due to population growth and increasing infrastructure development. The primary cause of inundation in the study area is the blockage of drains at various points, highlighting the critical need for regular maintenance of the existing drainage network. Google Earth proves a useful tool for readily determining area, perimeter, and elevation differences. Both the Rational method and SewerGEMS software have been successfully applied in this study to estimate stormwater discharge in the Vasai area. The findings from this research can serve as a valuable resource for designing storm drainage pipes in other locations.

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