

# “Case Study & Design Underground Sewerage Network on SewerGems Software for Expansion of Solapur City”

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**Abstract:** Rapid urban expansion in Solapur City has significantly increased wastewater generation in newly developed areas, while the absence of a properly designed underground sewerage network and the inadequacy of the existing system have led to frequent overflows, environmental pollution, and public health risks. This study presents a case study and design of an underground sewerage network for Solapur's expansion areas using SewerGEMS software to develop a hydraulically efficient, cost-effective, and regulatory-compliant system capable of handling present and projected wastewater loads. Essential data such as topography, ground levels, groundwater table, road alignment, population projections, and water supply details are collected, and sewage generation is estimated using per capita consumption and peak factor analysis as per CPHEEO guidelines. The sewer network is modeled in SewerGEMS by incorporating manholes, gravity sewers, junctions, and outfall points, followed by steady-state and peak flow simulations to evaluate velocity, flow depth ratio ( $d/D$ ), hydraulic grade line (HGL), and surcharge conditions. The proposed work focuses on hydraulic optimization, validation of design parameters, and comparison with conventional manual design methods. The expected outcomes include an optimized network layout with adequate pipe diameters, self-cleansing velocities, minimized excavation depth, reduced overflow risk, improved hydraulic reliability, and enhanced design accuracy, thereby supporting sustainable and future-ready urban wastewater management for Solapur City.

**Keywords:** Underground Sewerage Network Design, SewerGEMS Hydraulic Modeling, Urban Wastewater Management, Population Forecasting, Sewage Load Estimation, Hydraulic Grade Line Analysis, Peak Flow Factor, Gravity Sewer Optimization, CPHEEO Standards, Sustainable Urban Infrastructure

## Introduction

Rapid urbanization and sustained population growth have significantly increased wastewater generation in expanding cities, exerting considerable pressure on existing sewerage infrastructure. In many developing urban regions, sewer networks were originally designed for smaller populations and lower discharge rates, making them inadequate under present and future loading conditions. Hydraulic insufficiency, pipe blockages, and structural deterioration frequently result in surcharge, backflow, and surface flooding, posing environmental and public health risks [Xiaojie Wang et al., 2025; Umair Iqbal et al., 2024]. The situation becomes more critical in newly developed expansion areas where underground sewerage systems are either absent or poorly planned.

Urban drainage performance is further influenced by increasing impervious surfaces, erratic rainfall patterns, and climate variability. Research indicates that intensified storm events and improper drainage planning significantly increase peak discharge and overflow frequency in urban catchments [Arati Reddy Nilap et al., 2025]. Numerical simulations have demonstrated that clogged or undersized sewer conduits substantially elevate inundation depth and reduce hydraulic efficiency, emphasizing the need for

scientifically designed networks capable of handling both average and peak flows [Xiaojie Wang et al., 2025].

Conventional manual design approaches rely heavily on empirical assumptions and simplified hydraulic calculations, which may not fully represent real-time flow variations, network interactions, and surcharge behavior. Such limitations can lead to overdesign or underdesign of sewer components, affecting both cost efficiency and system reliability. Advanced hydraulic modeling techniques provide improved predictive capability and allow comprehensive analysis of flow dynamics within complex sewer networks [Candace Agonaifir et al., 2023]. These approaches enhance decision-making by enabling engineers to evaluate multiple design scenarios and optimize network performance.

Recent advancements in intelligent water infrastructure management, including artificial intelligence (AI), Internet of Things (IoT) sensors, and predictive modeling, have significantly improved the monitoring and operational efficiency of sewer systems. Smart monitoring technologies enable real-time detection of blockages, water levels, and surcharge conditions, thereby supporting proactive maintenance strategies [Guangtao Fu et al., 2022; Aung Khaing Min et al., 2024]. Although monitoring enhances operational performance, effective

long-term planning still depends on accurate hydraulic design and simulation during the planning stage.

In this context, hydraulic modeling software such as SewerGEMS provides an integrated platform for designing, analyzing, and optimizing underground sewerage networks. The software enables steady-state and peak flow simulations, hydraulic grade line (HGL) evaluation, velocity analysis, and verification of flow depth ratios ( $d/D$ ), ensuring compliance with design standards. By incorporating projected population growth, sewage generation rates, and topographical data, a reliable and future-ready sewer network can be developed. Therefore, the application of software-based hydraulic modeling is essential for designing a technically sound, efficient, and sustainable underground sewerage system for the expansion areas of Solapur City.

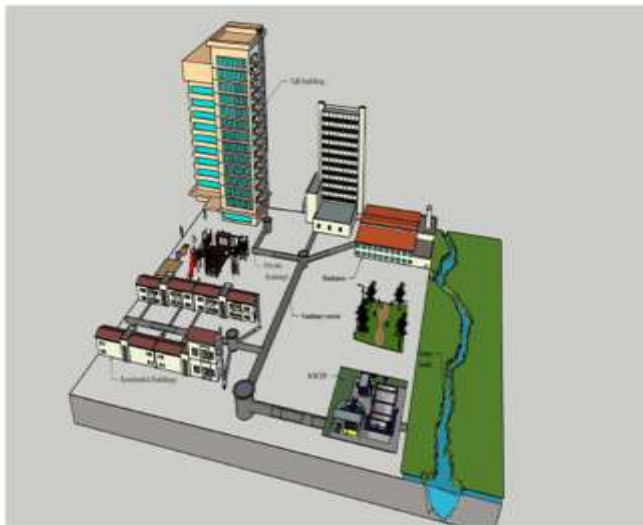


Figure1.1: Integrating the Design of Tall Building, Wastewater Drainage Systems into the Public Sewer Network: A Review of the Current State of the Art

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**Background of Urban Sewerage Systems** Urban sewerage systems are fundamental components of municipal infrastructure, designed to collect, convey, and safely dispose of domestic and commercial wastewater. Efficient sewer networks protect public health, prevent environmental contamination, and support sustainable urban development. However, rapid urbanization, increasing population density, and aging infrastructure have placed significant stress on conventional sewer systems, often resulting in hydraulic overloading, surcharge, and surface flooding [Xiaojie Wang et al., 2025; Umair Iqbal et al., 2024]. Studies highlight that inadequate drainage capacity and blockages significantly reduce system performance, especially during peak flow and extreme rainfall events [Arati Reddy Nilap et al., 2025]. Modern urban water management therefore emphasizes the adoption of advanced hydraulic modeling tools and smart monitoring techniques to enhance reliability, optimize design, and improve long-term operational efficiency [Guangtao Fu et al., 2022].

**Need for Underground Sewerage in Expanding Cities** Expanding urban areas frequently develop faster than the supporting sanitation infrastructure, resulting in unplanned drainage systems, open channels, and septic overflow issues. Such conditions contribute to groundwater contamination, environmental degradation, and increased health hazards. Research indicates that undersized or poorly designed drainage networks significantly increase flood risk and hydraulic instability under peak loading conditions [Umair Iqbal et al., 2024; Xiaojie Wang et al., 2025]. Additionally, increasing impervious surfaces and climate variability intensify runoff and wastewater generation in newly urbanized zones [Arati Reddy Nilap et al., 2025]. These challenges highlight the urgent need for scientifically designed underground sewerage systems that

incorporate accurate flow estimation, peak factor analysis, and hydraulic simulation to ensure long-term sustainability and compliance with regulatory standards.

**Overview of Solapur City Expansion Areas** Solapur City, located in Maharashtra, has experienced significant spatial and demographic growth in recent years, leading to the development of new residential and commercial expansion zones. Many of these newly developed areas lack a properly planned underground sewerage network, while the existing system in older parts of the city is often undersized for current and projected wastewater loads. The absence of a hydraulically efficient sewer network increases the risk of overflow, localized flooding, and environmental pollution. Considering projected population growth and urban development trends, it is essential to design a sustainable and optimized sewerage system capable of handling future sewage loads. The adoption of hydraulic modeling tools enables accurate assessment of network performance and supports the development of a reliable underground sewerage infrastructure for Solapur's expansion areas.

### Fundamentals of Wastewater Collection Systems

Wastewater collection systems form the backbone of urban sanitation infrastructure, ensuring the safe conveyance of domestic, commercial, and institutional sewage to treatment facilities. These systems typically operate under gravity flow conditions, utilizing a network of laterals, branch sewers, trunk mains, and manholes designed to maintain hydraulic efficiency and structural stability. Proper sewer design must prevent surcharge, minimize infiltration and inflow (I/I), and maintain adequate self-cleansing velocity to avoid sediment deposition and blockages. Research indicates that undersized or clogged drainage systems significantly increase overflow frequency and urban flood risk, especially during peak flow conditions and extreme rainfall events [Xiaojie Wang et al., 2025; Umair Iqbal et al., 2024]. Modern wastewater management therefore emphasizes hydraulic simulation, predictive assessment, and resilience-based planning to improve long-term system performance [Candace Agonafir et al., 2023].

**Design Criteria as per CPHEEO Guidelines** The Central Public Health and Environmental Engineering Organisation (CPHEEO) provides standardized technical guidelines for the planning and design of sewerage systems in India. These guidelines define design period, population forecasting methods, per capita water demand, sewage return factors, peak flow estimation, minimum pipe diameters, slope requirements, and velocity limits. Adherence to CPHEEO standards ensures hydraulic safety, structural durability, and regulatory compliance in urban sewer infrastructure. Scientific design criteria are essential to accommodate projected urban growth and climate variability, which significantly influence wastewater generation and hydraulic loading [Arati Reddy Nilap et al., 2025].

**Per Capita Water Demand** Per capita water demand represents the average daily water supply per individual and serves as the primary basis for sewage flow estimation. As per CPHEEO norms, residential water demand generally ranges between 135–150 liters per capita per day (lpcd) for urban areas. Accurate estimation of per capita demand is crucial for calculating average daily flow (ADF) and designing pipe capacity for future population growth. Population growth trends and urbanization patterns directly impact water consumption and wastewater generation rates, necessitating reliable forecasting techniques [Candace Agonafir et al., 2023].

**Sewage Generation Factors** Typically, 80–85% of supplied water is assumed to return as sewage, accounting for losses such as evaporation, gardening, and consumption. In addition to domestic wastewater, infiltration and inflow (I/I) from groundwater and stormwater connections can significantly increase total sewer load. Studies have shown that uncontrolled inflow and infiltration contribute to hydraulic overloading and system instability during peak rainfall events [Xiaojie Wang et al., 2025]. Therefore, appropriate allowance for I/I must be incorporated into design

calculations to prevent surcharge and overflow conditions.

**Peak Flow Estimation Methods** Sewer systems are designed for peak discharge rather than average flow to ensure reliability during maximum loading conditions. Peak flow is estimated by applying a peak factor to the average daily flow, commonly using empirical relationships such as the Harmon formula. Research demonstrates that inadequate peak factor consideration leads to increased overflow risk and reduced hydraulic performance in expanding urban catchments [Umair Iqbal et al., 2024]. Accurate peak flow estimation is therefore essential to prevent hydraulic failure and ensure resilience against variable demand patterns.

**Self-Cleansing Velocity Criteria** Maintaining self-cleansing velocity is essential to prevent sediment accumulation and maintain hygienic sewer conditions. CPHEEO guidelines recommend a minimum velocity of approximately 0.6 m/s under partial flow conditions to avoid deposition, while maximum velocities are controlled to prevent pipe erosion. Studies highlight that improper velocity control contributes to blockage formation and reduced system efficiency [Aung Khaing Min et al., 2024]. Therefore, hydraulic design must balance slope, pipe diameter, and roughness to achieve optimal velocity performance.

**Hydraulic Principles of Gravity Sewer Design** Gravity sewer systems operate based on open channel and partially filled pipe flow principles. Hydraulic design involves determining pipe diameter, slope, roughness coefficient, and flow capacity to ensure safe and efficient conveyance of wastewater. Accurate hydraulic modeling allows engineers to evaluate flow distribution, energy levels, and surcharge risks under varying loading conditions [Guangtao Fu et al., 2022]. The application of computational modeling enhances prediction accuracy and supports optimized infrastructure planning.

**Conventional Manual Design Methods** Traditional sewer design relies on manual hydraulic calculations, empirical formulas, and iterative pipe sizing based on assumed slopes and discharge values. Although effective for small networks, manual methods are time-consuming and may not accurately represent dynamic interactions within large interconnected systems. Studies indicate that reliance solely on conventional approaches can result in underestimation of surcharge risks and inefficient design optimization [Umair Iqbal et al., 2024]. Hence, advanced modeling tools are increasingly preferred for complex urban sewer planning.

**Application of Software in Sewer Network Design** Hydraulic modeling software enables comprehensive simulation of sewer networks under steady-state and peak flow conditions. These tools allow evaluation of velocity distribution, flow depth ratios, surcharge risk, and hydraulic grade line profiles across interconnected systems. The integration of computational modeling improves prediction accuracy, reduces design time, and supports scenario-based planning for future population growth [Candace Agonafir et al., 2023; Guangtao Fu et al., 2022]. Software-based analysis significantly enhances decision-making and infrastructure resilience.

**Overview of SewerGEMS Software** SewerGEMS is an advanced hydraulic modeling software widely used for planning, analysis, and optimization of gravity and pressure sewer systems. It integrates terrain data, GIS mapping, and population projections to develop accurate hydraulic simulations. The platform supports steady-state and dynamic analysis, enabling detailed evaluation of network performance under varying loading conditions.

**Features and Capabilities** Key features of SewerGEMS include automated pipe sizing, hydraulic grade line profiling, scenario management, capacity analysis, cost optimization support, and integration with CAD/GIS environments. These capabilities allow engineers to assess system efficiency, detect surcharge conditions, and optimize network design parameters for long-term sustainability [Guangtao Fu et al., 2022].

**Hydraulic Modeling Approaches** SewerGEMS supports steady-state analysis for average and peak flow assessment as well as dynamic simulations for time-varying flow conditions. Advanced modeling approaches enable verification of velocity criteria, d/D ratios, and HGL profiles to ensure compliance with design standards. The adoption of such software-based modeling techniques significantly enhances accuracy, efficiency, and reliability in urban sewerage system design [Candace Agonafir et al., 2023].



**Figure 1.2: Sewer Network Modeling, Analysis & Design with OpenFlows SewerGEMS: A Comprehensive Approach**  
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## Research Gap Identification

Despite significant advancements in urban drainage modeling and intelligent monitoring systems, several research gaps remain in the planning and design of underground sewerage networks for rapidly expanding cities. Recent studies have focused extensively on flood prediction, blockage detection, and climate-resilient drainage systems using AI and numerical simulations [Xiaojie Wang et al., 2025; Guangtao Fu et al., 2022]. However, limited research has addressed the practical integration of hydraulic modeling software in the detailed design of sewer networks for medium-tier Indian cities experiencing rapid spatial growth. Most existing studies emphasize stormwater modeling rather than comprehensive wastewater collection system design incorporating projected population growth and CPHEEO-based regulatory compliance [Arati Reddy Nilap et al., 2025]. Furthermore, while intelligent monitoring techniques and IoT-based blockage detection systems have demonstrated effectiveness in operational management [Aung Khaing Min et al., 2024], fewer studies focus on optimizing sewer network geometry, pipe sizing, and slope configuration during the planning stage using simulation tools. The majority of traditional designs in developing urban regions still rely on manual calculations, which may not fully account for dynamic peak flow conditions, infiltration, and surcharge risk [Umair Iqbal et al., 2024]. There is also a lack of comparative evaluation between conventional manual design approaches and software-based hydraulic modeling in terms of accuracy, cost optimization, and system reliability.

Additionally, case-specific studies addressing expansion areas of cities like Solapur are scarce in the literature. Many research works provide generalized modeling frameworks but do not incorporate localized topographical data, groundwater considerations, and long-term population forecasting for practical implementation [Candace Agonafir et al., 2023]. Therefore, a comprehensive, software-based hydraulic design study tailored to Solapur's expansion zones—integrating CPHEEO standards, peak flow analysis, hydraulic grade line assessment, and network optimization—addresses a critical research gap and contributes to sustainable urban wastewater

infrastructure planning.

### Study Area Description

The present study focuses on the New Vidi Gharkul area of Solapur City, Maharashtra, which is identified as a rapidly developing residential expansion zone. The area has witnessed significant urban growth due to increasing housing developments and infrastructure expansion under municipal planning initiatives. However, the underground sewerage infrastructure in this locality is either inadequate or not systematically designed to accommodate future wastewater loads, necessitating a scientifically planned and hydraulically optimized sewer network. The project work area is strategically located approximately 7 km from Solapur Airport and around 9 km from the proposed Hotgi IT Park, indicating strong potential for future residential and commercial growth. The proximity to these major infrastructural developments is expected to increase population density and wastewater generation in the coming years. Therefore, designing a sustainable and capacity-adequate underground sewerage network for New Vidi Gharkul is essential to ensure efficient wastewater collection, prevent environmental contamination, and support long-term urban development in Solapur City.

**Table 1.1: Particular Population**

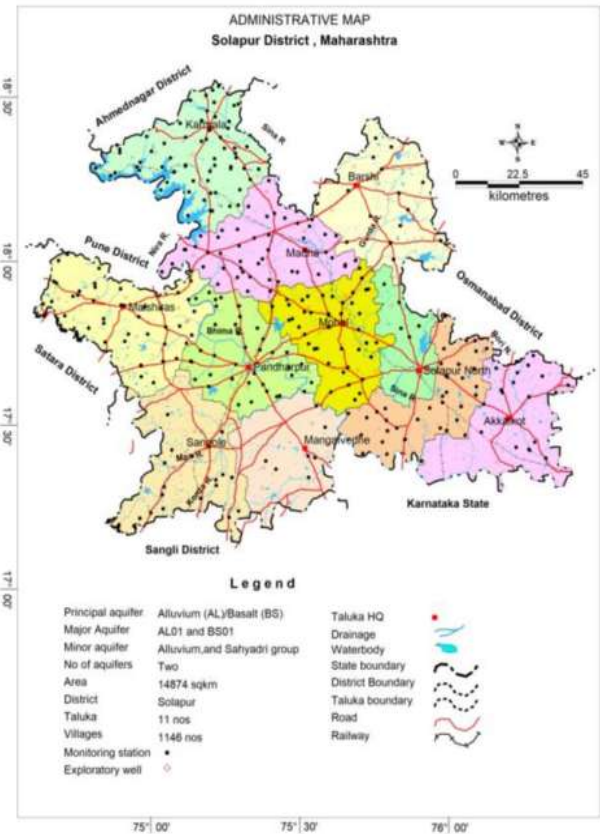
| Particular                | Fixed population | Floating population |
|---------------------------|------------------|---------------------|
| city population (in 2011) | 952000           | 47600               |
| city population (in 2025) | 1170000          | 58500               |
| city population (in 2050) | 1706000          | 85300               |

|                               |       |
|-------------------------------|-------|
| Area of city                  | 100   |
| Population per sq. km. (2025) | 12285 |
| Population per sq. km. (2050) | 17913 |



**Figure1.3: Location Map[a]**

<https://maps.app.goo.gl/mrbx2CLPCTTuouVh6>



- Located in the developing extension zone of Solapur, New Vidi Gharkul represents a fast-growing residential settlement requiring planned urban infrastructure.
- The area lies approximately 7 km from Solapur Airport, indicating strategic connectivity and increasing urban importance.
- It is about 9 km from the proposed Hotgi IT Park, suggesting future commercial growth and population influx.
- The locality consists mainly of newly developed housing schemes with limited or no underground sewerage infrastructure.
- Rapid urbanization and anticipated economic activity in surrounding areas are expected to significantly increase wastewater generation in the coming years.
- The terrain characteristics, road network layout, and plot development pattern make it suitable for hydraulic modeling using SewerGEMS for optimized sewer network planning.
- The study area offers a practical case for designing a future-ready, cost-effective, and hydraulically efficient underground sewerage system aligned with expansion planning of Solapur City.

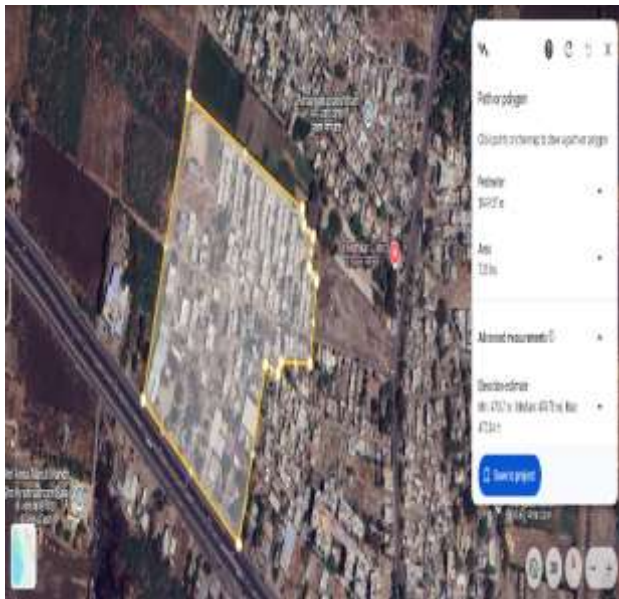


Figure1.4: Location Map [b]

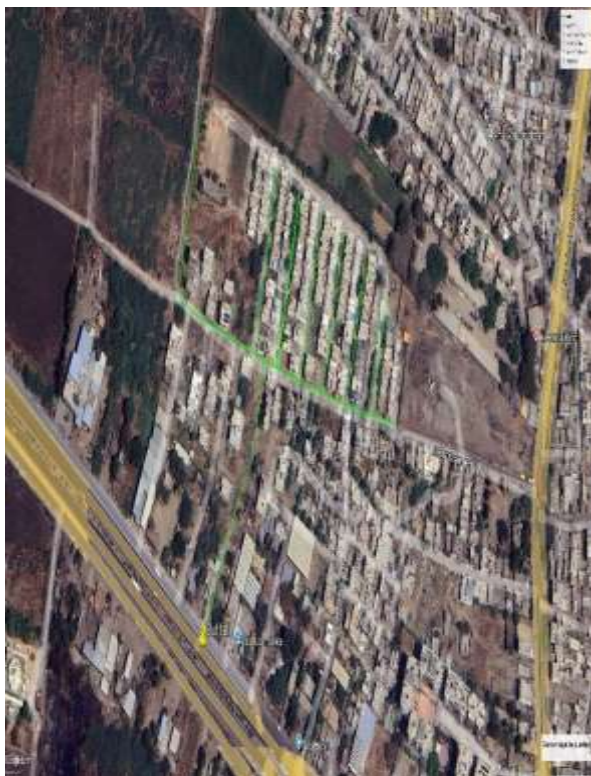


Figure1.5: Location Map[c]



Figure 1.6: Location Map [d]

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Figure 1.7: Location Map [e]

<https://maps.app.goo.gl/bMWLEJxppdrNGpJD9>

Table 1.2: Design Input Parameters

| Parameter | Description |
|-----------|-------------|
|-----------|-------------|

|                           |                                          |
|---------------------------|------------------------------------------|
| Topography Data           | Ground levels, contours, road elevations |
| Population Data           | Present and projected population         |
| Water Demand              | 135–150 lpcd (CPHEEO standards)          |
| Sewage Factor             | 80–85% of water supply                   |
| Peak Factor               | Based on population (Harmon formula)     |
| Infiltration/Inflow       | Additional allowance included            |
| Pipe Material             | RCC / PVC with defined roughness         |
| Manning's Coefficient (n) | Typically, 0.011–0.015                   |
| Minimum Velocity          | $\geq 0.6$ m/s (self-cleansing)          |
| Design Period             | 20–30 years                              |

**Tabel 1.3: Designed Output Parameters**

| Parameter                  | Description                         |
|----------------------------|-------------------------------------|
| Pipe Diameter              | Optimized sizes based on flow       |
| Flow Velocity              | Within permissible limits           |
| Discharge                  | Average and peak flow values        |
| Flow Depth Ratio (d/D)     | Maintained within 0.5–0.8           |
| Hydraulic Grade Line (HGL) | Stable without surcharge            |
| Slope of Pipe              | Designed for gravity flow           |
| Manhole Depth              | Based on ground and invert levels   |
| Invert Levels              | Calculated for proper alignment     |
| Network Efficiency         | No overflow or backflow             |
| Cost Optimization          | Reduced excavation and material use |

## Result and Discussion


**Graph1: scenario: Base**

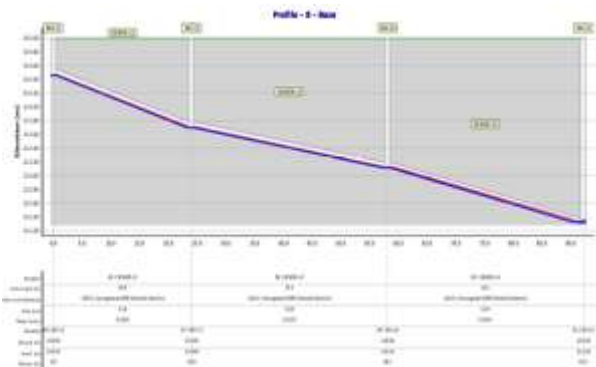
The graph represents the base scenario layout of the proposed underground sewerage network modeled in SewerGEMS. It shows the main trunk sewer line with multiple lateral branch connections collecting wastewater from different zones and conveying it toward the outlet. The network configuration ensures systematic flow collection and hydraulic efficiency for the expanded area of Solapur.


**Graph2: Profile S1 To S11**

The profile graph shows the longitudinal section of the main sewer line under the base scenario in SewerGEMS. It illustrates the gradual decrease in invert levels along the pipeline, ensuring gravity flow throughout the network. The profile confirms adequate slope and depth are maintained to achieve smooth and hydraulically efficient wastewater conveyance.


**Graph3: Profile S7 To S10**

The longitudinal profile (Profile-1: Base) illustrates the variation of ground level and sewer invert level along the main trunk line. The consistent downward slope indicates proper gravity flow conditions without any backflow risk. The close alignment of design parameters confirms that the network is hydraulically stable and meets the required slope and depth criteria.

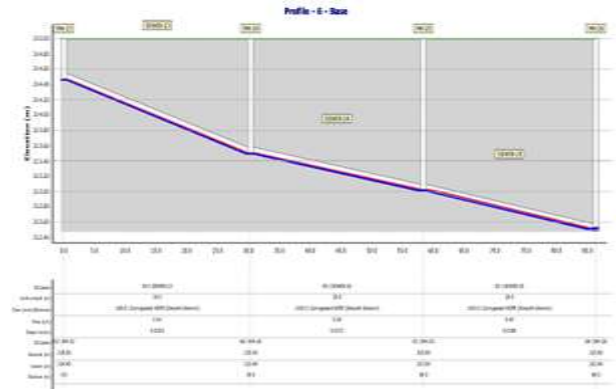

**Graph4: Profile S12 To S14**

The longitudinal profile graph shows a continuous downward slope from the upstream to downstream manholes, ensuring gravity-based sewage flow without pumping. The hydraulic grade line closely follows the pipe profile, indicating adequate capacity and proper flow conditions under design load. This confirms that the proposed sewer alignment in SewerGEMS is hydraulically efficient and free from surcharge conditions.



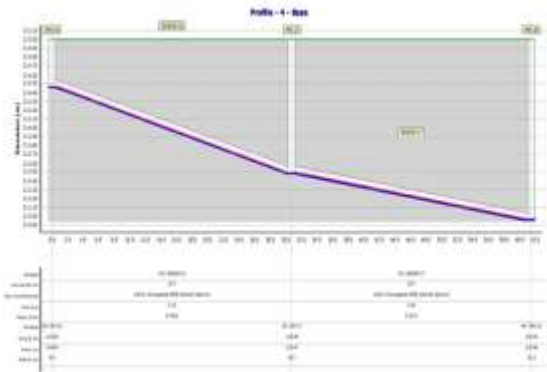
**Graph5: Profile S15 To S31**

The profile illustrates the longitudinal section of the sewer network under base conditions, showing ground level and pipe invert level along the alignment. The pipe follows a consistent downward gradient, ensuring gravity flow and maintaining hydraulic stability. The gradual slope indicates adequate design to achieve self-cleansing velocity without causing surcharge conditions.



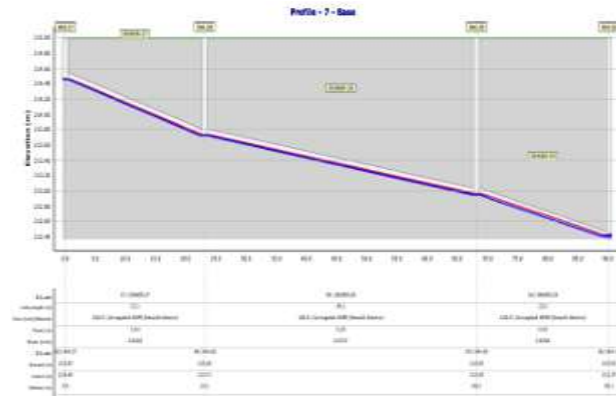
**Graph8: Profile S23 To S25**

The profile illustrates the longitudinal alignment of the sewer line under base flow conditions, displaying ground level and pipe invert level across successive manholes. A consistent downward slope is maintained, ensuring gravity-driven flow and adequate self-cleansing velocity. The hydraulic profile indicates smooth energy distribution without any signs of surcharge or backflow, confirming stable system performance.



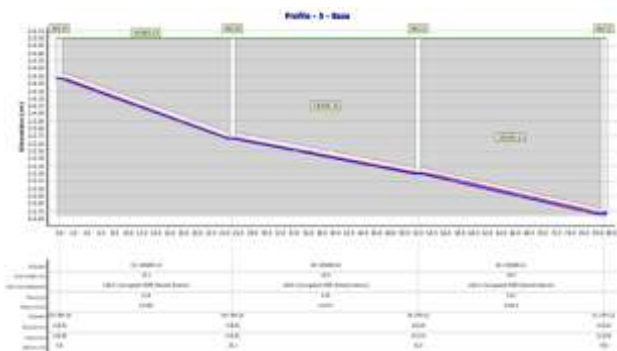
**Graoph6: Profile S16 To S17**

The profile shows the longitudinal section of the sewer line under base condition, illustrating ground level and pipe invert level along the alignment. A uniform downward slope is maintained throughout the stretch, ensuring smooth gravity flow and adequate velocity. The profile indicates stable hydraulic performance without any signs of backflow or surcharge.



**Graph9: Profile S27 To S29**

The profile shows the longitudinal section of the sewer network under base conditions, indicating ground level and invert level along the alignment. The pipeline maintains a steady downward gradient, ensuring smooth gravity flow and maintaining adequate velocity throughout the stretch. The hydraulic profile confirms stable operation without surcharge, reflecting proper slope and pipe sizing design.



**Graph7: Profile S19 To S21**

The profile represents the longitudinal section of the sewer network under base flow conditions, showing ground level and invert level variations along the alignment. The pipeline follows a continuous downward gradient, ensuring efficient gravity flow and maintaining adequate self-cleansing velocity. The smooth hydraulic profile indicates stable operation without surcharge or overflow risks.



**Graph10: Profile S32 To S36**

The profile represents the longitudinal section of the sewer line under base flow conditions, showing a nearly uniform and gentle slope along the alignment. The invert level consistently remains below the ground level, ensuring safe gravity flow. The gradual gradient indicates stable hydraulic performance with no risk of surcharge or overflow in the designed stretch.

## Conclusion and Future Work

The study successfully developed a hydraulically efficient underground sewerage network design for the New Vidi Gharkul area of Solapur City using SewerGEMS modeling. The proposed system satisfies CPHEEO design criteria by maintaining adequate self-cleansing velocity, permissible flow depth ratio ( $d/D$ ), and a stable hydraulic grade line (HGL) under peak flow conditions, with no observed surcharge or overflow risks. The software-based approach enhanced design accuracy, optimized pipe sizing and slopes, reduced manual calculation errors, and ensured the network can accommodate projected population growth for sustainable urban sanitation. Future work may include dynamic rainfall–runoff interaction analysis, integration of GIS-based asset management and IoT-enabled real-time monitoring systems, along with cost optimization, life-cycle assessment, and climate resilience evaluation to further improve the long-term performance and adaptability of the sewerage infrastructure.

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