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Research Article

Design of Storm Sewer System for Mass City Using Bentley SewerGEMS Software

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Abstract

Erbil has been undergoing rapid urbanisation and population growth for the last ten years. The impervious surface areas increased, so the volume of runoff generated from stormwater increased. For this reason, the storm sewer system is faced with additional runoff from the urban areas, and the existing sewer system is inadequate. This study focuses on the storm sewer system design using SewerGEMS and AutoCAD Software in Mass City, which is located in the east of Erbil. The topographic map of the study area was created using Civil 3D software and the total station in surveying, and rainfall storm data were collected from Erbil Meteorology Station and the General Directorate of Water and Sewage. Geometric design and hydraulic modelling were done using AutoCAD and SewerGEMS, respectively. The results show hydraulic design parameters such as flow velocity, sewer pipe size, slopes, manholes, pipe profiles, hydraulic grade line, minimum depth of excavation, and the minimum number of drops. Such a model allowed the project to be accomplished in a short time, with high efficiency and low costs; the model effectively demonstrated its ability to improve design and analysis by examining hydraulic performance.

1. Introduction

Designing a stormwater drainage network plays a crucial role in urban planning and management, particularly in rapidly growing cities such as Erbil. Proper management of rainwater drainage not only improves public safety but also helps mitigate the risk of flooding and minimises environmental and property damage. In addition, climate change has emerged as a significant challenge faced by many regions. Flooding, as one of the consequences of climate change, has severely impacted Erbil and its inhabitants. For these reasons, the need for effective stormwater management has become even more pressing [1]. As cities expand, municipalities must construct essential public infrastructure such as drinking water pipelines, wastewater systems, street lighting, storm sewer systems, and roadways [2]. Expanding impervious land cover results in an increase in stormwater runoff, which disrupts the balance of other components within the hydrologic cycle. Moreover, stormwater transports hazardous pollutants from urban surfaces directly to downstream storm sewer systems [3]. Nowadays, water management in urban areas presents significant challenges due to population growth, urban development, and climate change. Consequently, water authorities must develop plans that consider economic, social, and environmental factors. This is achieved through the analysis of scenarios involving these factors and their impact on the urban water cycle, using specialised software [4]. A storm sewer system is an underground network infrastructure composed of manholes, inlets, and sewers. Its primary function is to convey stormwater from catchments to an outfall location. To facilitate the construction of such a sewer system, conducting storm sewer modelling studies is essential. The conventional design of stormwater networks is time-consuming and laborious and demands extensive geospatial data to establish system flow loading. Any modifications to the design necessitate recalibrating all loadings from scratch.

Numerous up-to-date numerical models are available for conducting stormwater network flow loading. One of these widely used software programs is SewerGEMS, specifically tailored for analysing and designing sewage systems. It offers built-in hydraulic tools and provides a streamlined environment for experts to analyse, plan, design, and operate sewer systems [5]. Additionally, it is compatible with AutoCAD tools. SewerGEMS offers many unique benefits, including:

- Time and effort savings: The program allows hydraulic analyses to be conducted quickly and accurately, reducing the need for redesigns and complete reloads from scratch.
- Accuracy in analyses: SewerGEMS allows users to analyse data accurately and reliably, aiding in crucial decisions regarding network design and maintenance.
- Integration with GIS: Engineers can use available geographical data in the GIS system for network analysis and design, enhancing the accuracy of results and the efficiency of work.
- Ease of Use: The program features a simple and user-friendly interface, making it suitable for sewage and stormwater engineers at various levels of expertise [6].

SewerGEMS can be used for the following applications:

1. Hydrologic modelling: This involves taking rain data and converting it to runoff flow.
2. Hydraulic analysis: SewerGEMS includes 1D/2D hydraulic analysis capabilities that allow a better understanding of surface flood depth and velocity, flood hazard, and inundation times.
3. Scenario management: SewerGEMS allows users to configure, evaluate, visualise, and compare an unlimited number of scenarios within a single file.

4. Data integration: SewerGEMS allows users to use CAD drawings, GIS data, databases, and spreadsheets to jumpstart the model-building process [7].

SewerGEMS has the following benefits:

1. Improved efficiency: SewerGEMS streamlines the modelling process, allowing users to spend more time-solving storm and wastewater engineering problems.
2. Better decision-making: SewerGEMS permits users to analyse and evaluate multiple scenarios, allowing for better decision-making.
3. Increased accuracy: SewerGEMS provides accurate modelling results, allowing for more precise design and operation of sewer systems.
4. Improved communication: SewerGEMS allows users to easily share and communicate modelling results with stakeholders.
5. Cost savings: SewerGEMS allows the identification of cost-effective solutions to stormwater engineering problems, potentially saving money on construction and operation costs.

SewerGEMS is a powerful software tool that allows the efficient and accurate modelling of sewer systems, permitting users to make informed decisions and identify cost-effective solutions to wastewater engineering problems [7].

Numerous research studies have investigated the capabilities and features of the SewerGEMS software in sewerage network analysis and design. This software provides researchers and designers with an efficient solution to tackle the complexities associated with sewerage network design. For instance, in 2020, Manoj Tonde and his team employed Bentley SewerGEMS software to design and analyse the storm drainage system in the Bhilarewadi Village, India. The study involved a thorough examination and analysis of the sewerage system in Bhilarewadi Village, located in the Pune District of Maharashtra. Hydraulic modelling was used to calculate parameters such as total flow, pipe diameters, slopes, manholes, and outfalls. The accuracy and efficiency of the SewerGEMS software proved to be an effective and time-saving approach for sewer network design. Consequently, the final results were presented in a DWG file format, which can be easily accessed and read by various applications [8].

R. Chinmoy completed an MSc thesis in 2019 at Jadavpur University on the storm sewer water drainage system in Haldia, West Bengal. The thesis examines the challenges of urbanisation in India, specifically the growing volume of stormwater runoff caused by impermeable surfaces in the study area. It highlights the disparity between water supply and drainage development in Indian cities, resulting in inadequate drainage systems. The study assesses the drainage system in Rajarhat, using SewerGEMS software to identify construction, management, and design issues. SewerGEMS software enables efficient and cost-effective project completion. The thesis suggests appropriate measures to alleviate the negative impacts on the drainage system, ensuring sustainable service to the area and planning for future drainage infrastructure needs [9].

In 2021, Noori and Singh conducted a study in Kabul, Afghanistan, using ArcGIS and SewerGEMS software tools to assess the feasibility of implementing a decentralised sewerage collection system in the fifth district of the city. By using land-use and land-cover data, digital elevation models, and satellite imagery, the network's geometry was created within the ArcMap environment. Hydraulic simulation and modelling were performed using SewerGEMS software, with variables adjusted in accordance with conventional wastewater topology guidelines. The analysis of hydraulic outputs indicated that a decentralised wastewater collection system would be the most appropriate option for the area. The successful development and implementation of the hydraulic model suggest its potential applicability in future wastewater master planning endeavours for the city. After conducting numerous simulations across various scenarios, the hydraulic model design for two research zones within the fifth district, based on maximum discharge, was finalised using the SewerGEMS program. The evaluation of control parameters such as flow rate, pipeline diameters, slopes, and profiles confirmed the successful development and operation of the hydraulic model [10].

Abhishek Pawar and others conducted a study in 2021 to design a sewer system using SewerGEMS for Vake Village in the Malegaon Taluka, Dist-Nashik, Maharashtra, India. The findings are presented in a tabular format, including details such as length, slope, section type, material, and diameter. The results show that the software is user-friendly and provides visual and tabular results, thereby saving time [11]. Shraddha Tiwari and Mangesh Bhorkar conducted a study in 2020 on the design of an underground drainage system in a rural area using SewerGEMS software. They discovered that SewerGEMS is equipped with the capacity to generate drawings directly, which can subsequently be exported as AutoCAD drawings. Moreover, it allocates conduit attributes and uses distinct colours that correspond to different diameters, enhancing the visual presentation and facilitating effortless identification of elements within the sewer system. SewerGEMS also touts superior accuracy in comparison to manual sewer design, thus minimising the necessity for manual adjustments to achieve desired outputs [12].

In 2022, Bassma and others conducted a study in Egypt titled "Comparison of Urbanization, Climate Change, and Drainage Design Impacts on Urban Flashfloods in an Arid Region." The results indicate that rapid urbanisation has significantly contributed to heightened surface runoff due to inadequate planning. This oversight has neglected the incorporation of natural floodplains, resulting in the expansion of impervious surfaces that exacerbate runoff volumes and strain the drainage infrastructure. Furthermore, recent rainfall patterns have been influenced by climate change, leading to a 17% increase in the frequency of extreme rainfall events between 2000 and 2020 compared to pre-1999 patterns [13]. In 2022, Hazem Ramadan and his team conducted a study on the increasing flood risk caused by climate change in Aswan, Egypt, which recently experienced severe rainstorms that resulted in significant damage. The objective of the study was to reduce the impact of flooding and improve flood resilience in Aswan. Cutting-edge modelling tools such as WMS, ArcGIS, HEC-HMS, SewerGEMS, and HEC-RAS were used to analyse the contributing watersheds, assess meteorological data, determine peak flows, and simulate flood events. The study considered various flood protection measures, both external and internal. As for internal protection, priority was given to implementing storm drainage networks to safeguard highly urbanised areas from heavy rainfall, using SewerGEMS software [14].

In 2022, Rutuja Kendre and his team undertook a study to design a sewerage system for managing storm and wastewater in Hyderabad, India. They used design software including Civil 3D, Power Civil, and SewerGEMS to simulate the current flow of the catchment in the initial phase. In the second phase, they assessed the capacity of the stormwater system. In the third phase, they designed and optimised the sewer system to tap and redirect sewage flow, using SewerGEMS software. This optimised flow was then directed to the sewage treatment plants for processing [15]. Murilo Camilo and his team conducted a study on the computational modelling of urban drainage in Brazil in 2020. The study focused on modelling the urban drainage network in the sub-basin formed by the intersection of Guaiapo and Palmares avenues in Maringá. It aimed to evaluate the current state of the drainage system and explore the effectiveness of using SewerGEMS software. The study conducted scenario simulations to assess the performance of the urban drainage network. The findings revealed that the existing network, represented in Scenario 1, is insufficient to effectively manage stormwater runoff. Therefore, the study proposed implementing compensatory measures in Scenarios 2, 3, and 4. The results highlight the effectiveness of computational modelling in evaluating different scenarios and suggest that such approaches can inform municipal urban management strategies.

By providing insights into an adequate and efficient system of stormwater management, this study offers valuable support for urban planning and infrastructure development in Maringá, Paraná. [16]. Prajakta Wanjari and his team conducted a study on the analysis and design of the sewerage network in the Gadchiroli district, Maharashtra, India in 2023. They used SewerGEMS and found that the use of software for design significantly enhanced the efficiency of the entire process in terms of time and reliability. This software enables designers to complete design tasks efficiently and at a low cost. It also facilitates the redesign of existing network systems, particularly aiding in repair works that are frequently undertaken, allowing users to differentiate between existing and proposed network elements. The evaluation of sewerage systems in the Gadchiroli district was based on the overall flow of the system. The cost savings achieved in network design will have a significant impact on the overall cost of the network. By optimising network redundancy, costs were reduced by 2-90 lakhs, depending on the length of the network. This optimisation involved providing an optimal number of manholes to serve the entire network and selecting appropriate channel diameters to significantly reduce costs. The software offers various tools for scheduling, optimisation, modification, visualisation, and evaluation. It facilitates calculations for different models and provides longitudinal sections, reports, and cross-sections to understand the design of hydraulic networks for sewers and storm sewers. Economies are achieved by reducing conduit length by 15% and decreasing the number of manholes by 5.09% as per proposed requirements. The overall savings from optimising the number of manholes and conduit diameters amount to 89.67 lakhs. The design in this case study prioritises economical gravity-assisted flow, eliminating the need for pumps [17].

In 2024, Aly and her team conducted a study at Ain Shams University on the management of sewage networks in the Zamalek area of Egypt. The study proposed hydraulic modelling using SewerGEMS software to analyse and enhance the management of the sewage network, addressing the limitations of manual design methods. Hydraulic modelling with SewerGEMS provides valuable information about the condition and performance of the network, supported by surveillance cameras that record its performance. Cracks and fractures were detected in certain sections of the network, totalling approximately 6,451 metres. The hydraulic study also identified some reversed branches (manual design errors) that necessitated corrective re-excavation. Geographic information systems, in conjunction with SewerGEMS, were employed to offer comprehensive data on the network in the area, including the number of manholes, lengths of sewer lines, and calculation of the actual network behaviour. This approach significantly enhanced the design capacity of the project. The study successfully demonstrated the potential of an integrated engineering framework for the effective management and analysis of sewage networks [18].

In Erbil, traditional methods have been used for designing infrastructure, without the use of analysis software. This has resulted in design errors such as overlapping lines and blockages. The city's diverse terrain, which includes streets with varying levels and significant slopes, further complicates the design process. Additionally, the combined rainwater drainage and sewerage system in Erbil exacerbates these issues, leading to road floods, blockages, and traffic accidents. To address these concerns, this research aims to develop and identify a network plan for a reliable storm sewer system in the study area, using SewerGEMS software for design purposes. This software allows the design and analysis of the network's parameters, enabling the formulation of an effective rain network design. By determining crucial design parameters such as pipe diameters, flow velocities, and excavation depths, this research will assist in the construction of a successful rainwater drainage system. The goal is to mitigate flooding and improve road safety in Erbil's urban landscape. The study project uses SewerGEMS and AutoCAD software to design a storm sewer system in Mass City, Erbil. Unlike traditional manual design processes, these tools save time and ensure performance based on climatic data. The study aims to deliver an efficient storm sewer system using modern design software, thereby contributing to the resilience of the urban infrastructure in Mass City. The objectives of this study include conducting a primary survey of the study area, performing a literature review, and designing a sewer system using the hydraulic and hydrology tools provided by the SewerGEMS software.

1.1 Description of Study Area

Erbil is the capital of the Iraqi Kurdistan Region; its population is estimated at two million. After 2014, a large number of displaced people were forced to come to Erbil from inside and outside Iraq (Syria); as refugees. Also, a large number of people came to Erbil from other cities looking for jobs. Therefore, the urban expansion caused an increased ratio of land cover by concrete and asphalt, and Erbil was frequently exposed to flash floods. The study area of Mass City, which is located in the east of Erbil, consists of four zones: A, B, C, and D. The storm sewer design for Zone C is used in the current research. The study area of Zone C shown in Figure 1 is about 22 hectares.

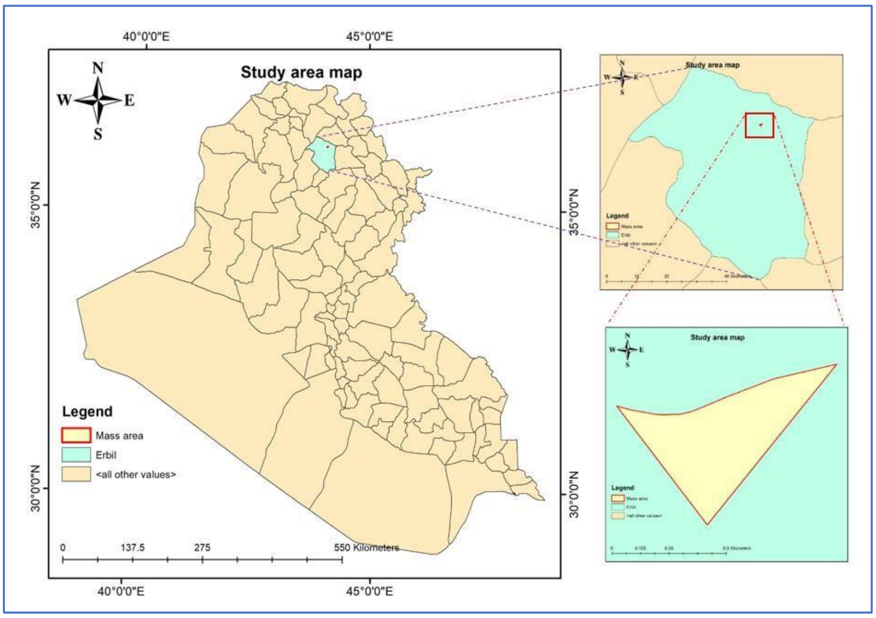

Figure 1. Location of the study area of Mass City

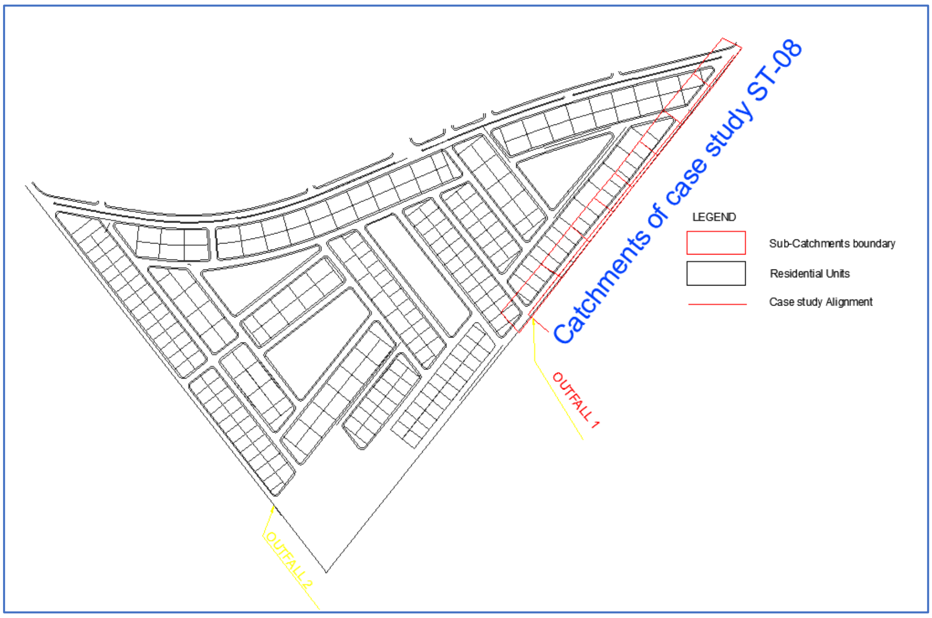

Figure 2. Site plan of the study area and catchment area of sewers

The study area covers the plain and undulating area, according to the site plan, shown in Figure 2, and the design study model has been developed for storm sewer system design for the first alignment line as a case study. The total area for the case coverage case study is about 14,719.58 m²; see Table 3.

2. Materials and Methods

The rainfall data required to carry out the current study were collected from the General Directorate of Meteorology and Seismic Monitoring [19]. Table I shows the maximum daily rainfall data for the Erbil station, and the intensity-duration-frequency (IDF) curve for Erbil derived by Dawood and Mawlood [20] is shown in Figure 3. Topographic surveying for the study area was done by the total station to get contour maps and drawing profiles by Civil 3D software. The site plan design was obtained from Mass Company [21], and the geometric design of the sewer alignments was performed in coordination with the road designer for the road design formation profile and sections in each road line. The next step was using SewerGEMS and AutoCAD to design a rainfall storm drainage network through geometry creation (adding alignment of sewer, distribution of manholes and inlets according to road design, catchment area estimation from the site plan for each manhole, and connection with outfall). The simulation of the model and drawing of the design profile were done according to standard criteria for infrastructures of storm drainage network design [22].

Table 1. Maximum daily rainfall data at the Erbil station [19].

Year	Max daily rainfall mm	Year	Max daily rainfall mm	Year	Max daily rainfall mm	Year	Max daily rainfall mm
1980	57.6	1991	62.4	2002	32.3	2013	71.8
1981	40.9	1992	15.7	2003	59.2	2014	51
1982	38.1	1993	79	2004	41.4	2015	37.6
1983	32.9	1994	41.7	2005	34	2016	55.8
1984	42.7	1995	75.7	2006	103.9	2017	36.4
1985	72.7	1996	22.3	2007	38	2018	51.1
1986	73.6	1997	35.8	2008	37.8	2019	59.5
1987	31.8	1998	36.8	2009	41	2020	36.8
1988	37.2	1999	25.8	2010	33.8	2021	16
1989	48.4	2000	46.4	2011	67		
1990	35.8	2001	48.3	2012	21		

Then, for estimating rainfall design, depth, intensity, and duration, the IDF curve of Erbil derived by [20] was used, as shown in Figure 3.

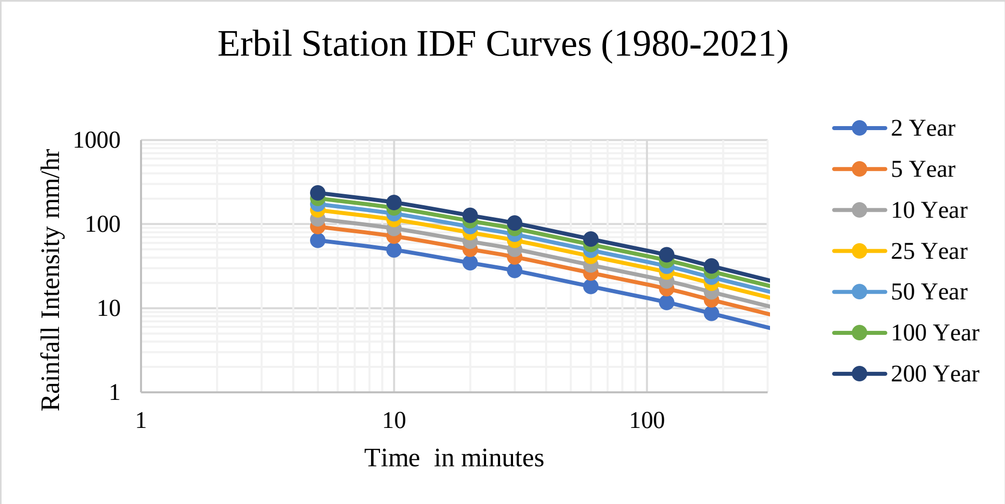

Figure 3. Intensity-duration-frequency curves for the Erbil station

3. Results and Discussion

3.1. Design Criteria

The design approaches described here involve non-uniform flow inside each segment of a storm sewer. This means that the velocity and flow depth are independent of both time and distance. The flow at each inlet varies in actual storm sewer systems according to the sub-catchment area and surface slope. the typical hydrologic method used in the design discharge of storm sewer drains is a rational formula [23].

The rational formula is shown below:

$$Q = C * I * A/3.6 \quad (1)$$

Where: Q = water flow (m^3/s)

C = coefficient of runoff

I = design intensity (mm/hr)

A = area (km^2) [23]

The hydrologist uses his experience to choose the proper runoff coefficient C. Table 2 shows the runoff coefficient according to the drainage area [24].

Table 2. Coefficient of runoff

Type of Drainage Area	**Runoff Coefficient C**
Downtown areas	0.7-0.95
Residential	0.3-0.5
Heavy areas	0.6-0.9

Because the land surface of the catchment area for each manhole is built of concrete and asphalt, the estimated C value is 0.87.

For the design, the storm intensity used the data adopted by the General Directorate of Water and Sewage, Kurdistan Regional Government [19] and according to the IDF curve 80mm/hr for the storm sewer system design, at a return period of 50 years and duration of 30 minutes, and from Table 1. The maximum daily rainfall depth is 103.9 mm/d, which means 103.9 mm for 24 hours, so the intensity of 80mm/hr is more acceptable for design. For the calculation of the flow, we used a rational formula. Then the data were used in a hydraulic model by SewerGEMS to design the storm drainage network.

3.2. Catchment Area

The small catchment area contributing to the stormwater collection for each manhole in the sewer system was measured from topographic maps and field surveys. The selected design sample in the current research is the first alignment as shown in Figure 2 and Table 3. The area distribution for each manhole in the first alignment is calculated by SewerGEMS as the contributing area for each manhole.

Table 3. Catchment area distribution for each manhole in the first alignment

Label	Runoff Method	Scaled Area (m^2)	Use Scaled Area?	Time of Concentration (min)	Runoff Coefficient (Rational)	Outflow Element
CA-01	Rational Method	1,868.57	TRUE	10	0.87	MANHOL9
CA-02	Rational Method	1,879.41	TRUE	10	0.87	MANHOL2
CA-03	Rational Method	1,579.97	TRUE	10	0.87	MANHOL5
CA-04	Rational Method	1,618.00	TRUE	10	0.87	MANHOL7
CA-05	Rational Method	1,301.00	TRUE	10	0.87	MANHOL6
CA-06	Rational Method	1,548.00	TRUE	10	0.87	MANHOL3
CA-07	Rational Method	1,981.13	TRUE	10	0.87	MANHOL8
CA-08	Rational Method	2,943.50	TRUE	10	0.87	MANHOL4
Sum		**14,719.58**				

3.3. Assumptions Used in Storm Sewer Design Practice

The following assumptions were used in the design:

1. The flow in the sewer system is designed to flow freely due to gravity.
2. The pipes are concrete, the diameter equals or is greater than 300 mm, and the Manning roughness coefficient is 0.013.
3. The selected diameter of the sewer pipe has a flow capacity equal to or greater than the design flow.
4. The sewer pipe must be placed at a depth of at least 1.2 m.
5. The connection of sewers at junctions in manholes is crown to crown.
6. The minimum permissible flow velocity is 0.75 m/s and the maximum permissible flow velocity is 5 m/s, to prevent scouring.

7. At the downstream manhole, the sewer cannot be smaller than any of the upstream sewers at that junction because of the accumulation of discharge from catchments.

For sewer design, we used the first alignment, which has a length of 440 m, consists of eight manholes, and is connected to an outfall, as shown in Figure 4. Manning n = 0.013, I = 80 mm/hr, storm duration = one hour, time of concentration = 10 minutes, as appropriate to the urban nature of the catchment area, and slopes are considered to obtain minimum velocity [22].

3.4. Modelling

In the geometric model, the location of the manholes, inlets, and main network paths are done in a sewer network in the first alignment of the study area.

For the determination of the cross-sectional area, the hydraulic radius and wetted perimeter for each sewer segment in the sewer system used Manning's equation, as shown in Figure 4. Using SewerGEMS:

$$Q = A * R^{0.67} * S^{0.5}/n \quad (2)$$

Where: Q = flow in m^3/sec

A = the cross-sectional area of pipe or channel in m^2

S = the bottom slope of the channel or pipe in m/m (dimensionless)

n = Manning roughness coefficient

R = the hydraulic radius = A/P

P = the wetted perimeter in metres [23]

3.5. Results

Water velocity in sewer pipes is a control parameter controlled through SewerGEMS. The velocity limitation in the sewer design range is 0.75 – 5.0 m/sec. Figure 4 shows the design size, length, and slope for the storm sewer system.

SewerGEMS plays a pivotal role in overseeing specific control parameters. Table 4 and Figure 5 visually depict the inverted elevation of the design and the top elevation of the ground surface. The components of invert level, manholes, drops, inlets, and pipe diameter collectively shape both the physical arrangement and hydraulic performance of the sewer system. In this framework, invert levels are instrumental in determining pipe slopes, guaranteeing smooth flow dynamics, and averting sediment accumulation. Manholes facilitate maintenance and inspection access, with their placement strategically orchestrated for effective system management. Drops serve as mechanisms to navigate shifts in elevation, thereby curbing excessive water velocities. Inlets serve as reservoirs for runoff capture, with accurate sizing pivotal in forestalling localised inundation. The diameter of pipes directly influences the flow capacity and velocity, necessitating a delicate equilibrium for optimal operational efficiency.

Table 4. Controlling the design parameters by SewerGEMS

Start Node	Stop Node	Material	Invert (Start) (m)	Invert (Stop) (m)	Elevation Ground (Stop) (m)	Length (Scaled) (m)	Diameter (mm)	Slope (Calculated) (m/m)	Size
MANHOL (Point)-1	MANHOL (Point)-9	Concrete	516.35	515.95	517.45	46	300	0.009	300
MANHOL (Point)-9	MANHOL (Point)-2	Concrete	515.95	515.54	517.04	53.9	300	0.008	300
MANHOL (Point)-2	MANHOL (Point)-5	Concrete	515.44	515	516.6	48.9	400	0.009	400
MANHOL (Point)-5	MANHOL (Point)-7	Concrete	515	514.08	515.68	54.5	400	0.017	400
MANHOL (Point)-7	MANHOL (Point)-6	Concrete	514.08	512.55	514.15	48.3	400	0.032	400
MANHOL (Point)-6	MANHOL (Point)-3	Concrete	512.55	510.44	512.04	48.3	400	0.044	400
MANHOL (Point)-3	MANHOL (Point)-8	Concrete	510.44	508.42	510.02	65.6	500	0.031	500
MANHOL (Point)-8	MANHOL (Point)-4	Concrete	508.32	507.55	509.25	70	600	0.011	600
O-1	MANHOL (Point)-4	Concrete	507.05	507.55	509.25	35.4	600	-0.014	600

Velocity (m/s)	Depth/Rise (%)	Slope (Maximum) (m/m)	Slope (Minimum) (m/m)	Velocity (Maximum) (m/s)	Velocity (Minimum) (m/s)	Manning's n	Capacity (Full Flow) (L/s)	Flow / Capacity (Design) (%)	Cover (Average) (m)
0	31.8	0.1	0.005	2.50	0.75	0.013	90.14	0	1.2
1.3	63	0.1	0.005	2.50	0.75	0.013	84.37	69.2	1.2
1.64	67.9	0.1	0.005	2.50	0.75	0.013	197.60	58	1.2
2.26	78.4	0.1	0.005	2.50	0.75	0.013	270.47	59.3	1.2
3.05	85.8	0.1	0.005	2.50	0.75	0.013	370.66	55.7	1.2
3.59	90.8	0.1	0.005	2.50	0.75	0.013	435.28	55.9	1.2
3.24	64.5	0.1	0.005	2.50	0.75	0.013	662.64	43.3	1.1
2.28	70.5	0.1	0.005	2.50	0.75	0.013	643.91	53	1.1
2.60	69.6	0.1	0.005	2.50	0.75	0.013	729.75	57.5	1.1

Velocity, slope, total flow, and Manning's coefficient wield significant influence. Velocity impacts sediment transport, while slope delineates flow velocity and direction. For concrete sewers, Manning's coefficient typically rests at 0.013. The introduction of these parameters into SewerGEMS permits engineers to model flow patterns, discern zones characterised by excessive velocity, pinpoint potential sediment accumulation zones, and unravel capacity-related challenges.

The selection of appropriate sewer material, particularly concrete, demands an intricate assessment of durability, resistance to corrosion, and financial implications. This choice exerts a profound impact on the system's longevity and the prerequisites for its maintenance.

Within this design, stop nodes emerge as pivotal players, orchestrating the flow direction. These nodes can be strategically positioned at intersections, drop structures, or diversion points to thwart overloading and exercise command over water movement throughout the system.

Considering ground elevation, maximum and minimum depth of excavation, and soil cover is paramount. Ground elevation influences the layout of pipes and the calculations for slope. Determining the upper and lower limits of excavation depths necessitates a contemplation of factors like gradient mandates, utility depths, and groundwater levels. This meticulous consideration ensures the functional integrity of the pipes, facilitates maintenance access, and buffers against external pressures. Adequate soil cover assumes a protective mantle, warding off external stresses and environmental elements. Achieving this balance among cover depth, pipe dimensions, and diameter is pivotal for sustaining structural integrity.

Table 5. Ground and inverted elevation of manholes

Label	ID	Elevation (Rim) (m)	Elevation (Invert) (m)	Flow (Total In) (L/s)	Flow (Total Out) (L/s)	Depth (Out) (m)	Hydraulic Grade Line (Out) (m)	Hydraulic Grade Line (In) (m)
MANHOL (Point)-1	30	517.85	516.35	0	0	0	516.35	516.35
MANHOL (Point)-9	38	517.45	515.95	60.13	60.13	0.19	516.14	516.14
MANHOL (Point)-2	31	517.04	515.44	120.61	118.1	0.25	515.69	515.69
MANHOL (Point)-5	34	516.6	515	168.94	165.34	0.3	515.3	515.3
MANHOL (Point)-7	36	515.68	514.08	217.4	212.85	0.33	514.41	514.41
MANHOL (Point)-6	35	514.15	512.55	254.71	250.61	0.35	512.9	512.9
MANHOL (Point)-3	32	512.04	510.44	300.43	295.53	0.37	510.81	510.81
MANHOL (Point)-8	37	510.02	508.32	359.28	351.47	0.4	508.72	508.72
MANHOL (Point)-4	33	509.25	507.55	446.19	432.04	0.44	507.99	507.99

3.6. Implementation of Storm Sewer System

Designing a storm sewer system is a complex process that requires careful consideration of multiple factors to ensure effective stormwater management and minimise the risk of flooding and infrastructure damage. Using tools like SewerGEMS, engineers can simulate and analyse various design parameters to create an optimised storm sewer network. The design profile and results by Bentley SewerGEMS in Figure 4 show the pipe size, length, minimum depth, minimum number of drops, slope, manholes, energy grade line (EGL), and HGL hydraulic grade line (HGL).

Local regulations, environmental concerns, and site-specific conditions also influence design decisions. Collaborating with experienced professionals, using advanced software for sustainable design, and adhering to engineering standards are essential to creating a robust storm sewer system that effectively manages stormwater runoff and contributes to resilient urban infrastructure. We therefore used SewerGEMS in the study.

Figure 4 shows the design profile of the critical path with parameters. Also, the result of the design can be displayed from separate tables and program reports. The HGL and total EGL in the manholes and sewer show the best hydraulic performance.

3.7. Validation of the Results

The validation process typically comprises several steps, including comparing model parameters such as pipe roughness coefficients and HGL. Assessing the storm sewer system behaviour performance evaluation entails analysing various criteria such as flow capacity, pipe size, slope, velocity, invert level, and surcharge levels to identify potential issues such as high velocities, excessive pressures, or inadequate capacity. The results are depicted in Table 6.

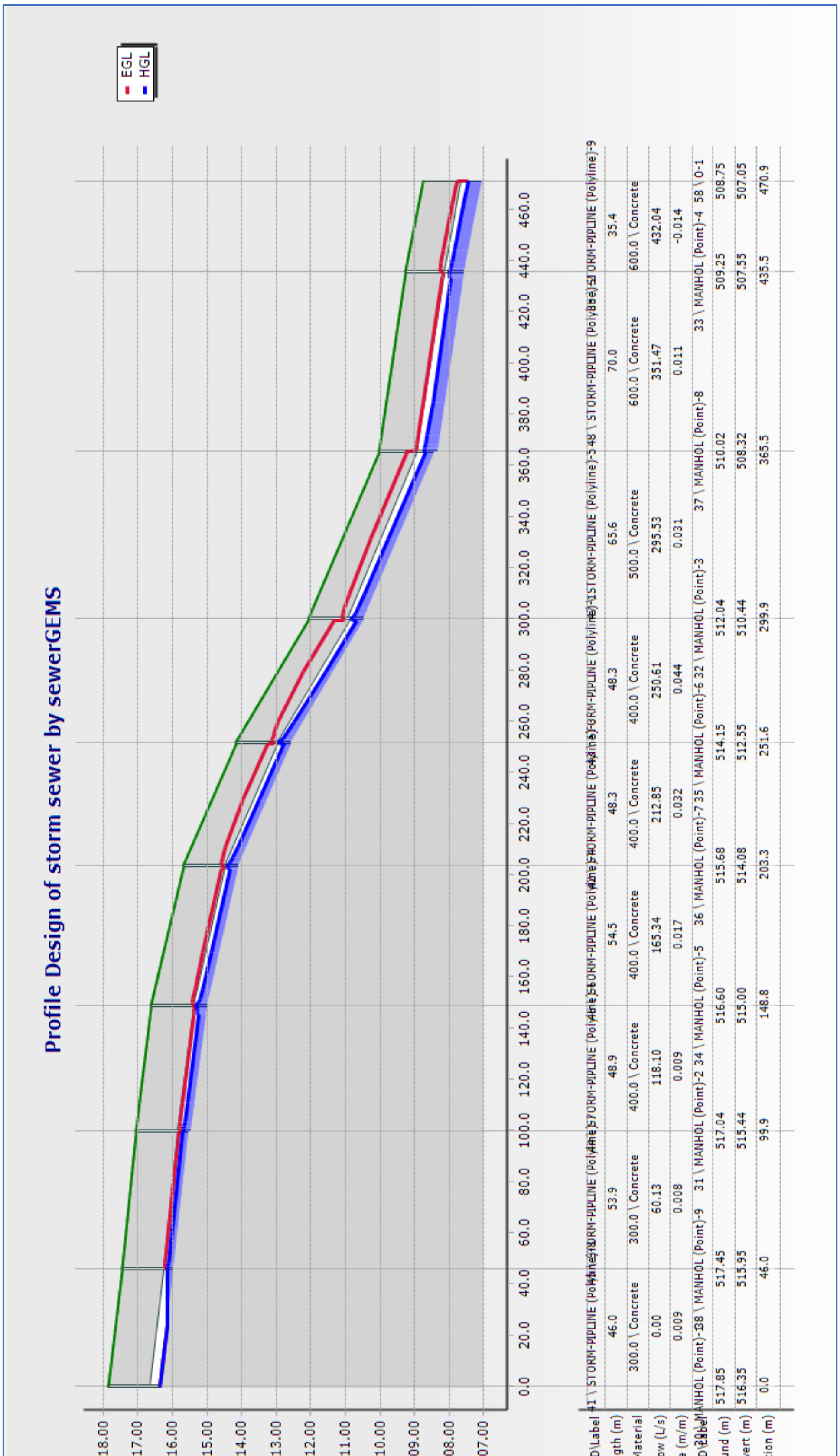

Figure 4. Profile design of storm sewer by SewerGEMS

Table 6. Validation of storm sewer system results with past research studies

Research	Location	Methodology	Comparison
Abhishek et al [11]	Vake Village, Malegaon Taluka, Dist-Nashik, Maharashtra, India	Design and analysis using SewerGEMS and ArcGIS	Good match at testing HGL
Shraddha Tiwari and Mangesh Bhorkar [12]	Rural area, India	Design and analysis using SewerGEMS	Good match at flow capacity, velocity, pipe size, and surcharge levels
Mohammad Alhumaid et al [25]	Buraydah, a city in the Saudi Arabian Kingdom	Design and analysis using SewerGEMS and actual survey	Good match at flow capacity, velocity, pipe size, and surcharge levels
Murugesh et al [26]	Municipal area, India	Design and analysis using SewerGEMS and AutoCAD	Good match at table for manhole and conduit

4. Conclusion

The design of the storm sewer system was done for study area Zone C in Mass City. The hydraulic design was done by SewerGEMS software. Hydraulic analysis of the system was done, and analysis control parameters pipe size, velocity, slope, and profile were then performed by SewerGEMS to check the results, as shown in Table 4 and 5. As is obvious from the control parameters, HGL, and total EGL, the water velocity in sewers is in the range of permissible velocity. The hydraulic model of the design drainage system has succeeded and such models are applicable in the study area. SewerGEMS software makes it easy to accurately design and modelling storm sewer systems and saves time, so this sustainable design is now under construction in the study area.

In comparison, the traditional design method by hand with the use of Bentley SewerGEMS software in the design of a storm sewer system for Mass City offers several benefits. The software streamlines the modelling process, facilitates optimal urban sewer planning, provides advanced hydraulic analysis capabilities, supports scenario management, and integrates existing data sources. These features contribute to efficient and effective stormwater engineering, enabling engineers to design and operate storm sewer systems that are sustainable, resilient, and capable of mitigating flood risks. The use of Bentley SewerGEMS software has been demonstrated in the case study, where engineers were able to recommend the optimal system for future use, resulting in considerable capital cost savings and environmental benefits. The use of Bentley SewerGEMS software in the design of a storm sewer system for Mass City is a valuable tool for stormwater engineers, providing a comprehensive solution for designing and operating storm sewer systems that are sustainable, efficient, and effective.

Table 6 offers a concise overview of the validation process and helps to establish the credibility and reliability of the storm sewer system design by comparing it to previous research findings.

Even if the implementation and capacity of the rain drainage sewer network are excellent, not cleaning the storm drainage system regularly and not performing maintenance work lead to blockage, overflow, and floods at low points in cities and towns. Therefore, the storm drainage system should be cleaned and maintained periodically.

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