Assessment and Modeling of the Sewerage Network Using SewerGEMS Software in the City Center of Karbala, Iraq

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Abstract—The sewerage system is a vital element of urban infrastructure. Environmental pollution can be attributed to the presence of floodwater caused by pipe blockages, pipe breaks, or inadequate drainage capacity. In recent decades, there has been a significant surge in both the population size and the pace of population growth. As a result, urbanisation and industrialization have experienced a rise. Recent patterns indicate a growth in urban areas. As cities grow, it becomes necessary for the Municipality to provide essential public service infrastructure, like drinking water pipelines, sewer systems, street lighting, and roadways. An example of a public service institution is sewer networks, which play a crucial role in maintaining public health and cleanliness. The future entails the implementation of an efficient drainage system to mitigate the risk of flooding caused by abrupt population surges during festivals or religious visits. In this research, we conduct a modeling of the sewerage network previously implemented in the historic city center of Karbala - Iraq, using sewer gems. This region is characterized by attracting many visitors to its religious shrines and since this network was implemented during the year 1980 for a limited number of residents, this area suffers from frequent sewage overflows during the pilgrim because it cannot accommodate the increasing numbers of residents, which also causes environmental pollution and obstruction of traffic[reference: Karbala Sewerage Directorate].

Keywords—Sewer Network, Sewege overflow, SewerGEMS, manhole, population, Karbala

I. Introduction

Sewerage systems are an essential component of the infrastructure of any society. The primary objective of implementing a sewer network is to efficiently transport sanitary waste from an urban region, ensuring that it does not pose any public health concerns. The installation of a sewerage network transports the wastewater generated by individuals, business enterprises, and industrial establishments to facilities where it can be treated before being released back into the natural environment [1]. The expense associated with sewerage projects is considerable, but this problem can be solved through the use of computer software such as SewerGEMS.A sewage network model was developed in the city center of Karbala, Iraq, to address the growing population during the Pilgrim season. The model predicts the amount of people and the timing of wastewater collection based on the area's zoning rules.The SewerGEMS software automatically determines pipe diameters based on the flow velocity and gradient needs of the pipe. The software is used to determine parameters such as discharge, velocity, ground level, inversion level, and depth of cut. The computer software package SewerGEMS is superior to manual approaches for building an economical sewer network. It provides an optimal cost and practical plan that can accommodate a vast network.

II. Literature Review

The sewerage network serves as the fundamental component in the design. Cost savings made during the design phase of this unit will have an impact on the total cost of the sewerage system. Bentley SewerGEMS v8i is a unique and comprehensive software that enables dynamic modelling of sanitary and combined sewer systems across several platforms, including GIS and CAD [2]. SewerGEMS is a software that simplifies the modelling process by allowing more time to solve wastewater engineering challenges. It also increases capacity and reduces sewer overflows, helping utilities meet sewer design criteria established by regulatory authorities. The software offers sophisticated engineering capabilities for the design, planning, maintenance, and operation of sanitary sewage systems [3].

Comparing the SewerGEMS computer software to manual design methods reveals its economic advantages, as it offers cost optimisation and realistic planning capabilities for sewerage networks [4], [5]. The SewerGEMS software is versatile, allowing the creation of a numerical model of the sewage system using geographic information systems [6]. In addition, I utilise SewerGEMES in conjunction with AutoCAD to assess the functionality of a sewage network system and propose appropriate corrective actions [6]. Nishant Sourabh [7] similarly examined the hydraulic state of the SVNIT campus, identifying areas of excessive flow and offering recommended solutions and measures.

III. Methodology

This paper will present a modeling work for the sewerage network implemented in the past in the center of the historic religious city of Karbala, using the SewerGEMS for the purpose of treating the recurring occurrence of sewage overflows during the Pilgrimage because it does not accommodate the excess drainage resulting from the population increase for which the network was designed. Fig. 1, shows the work steps.

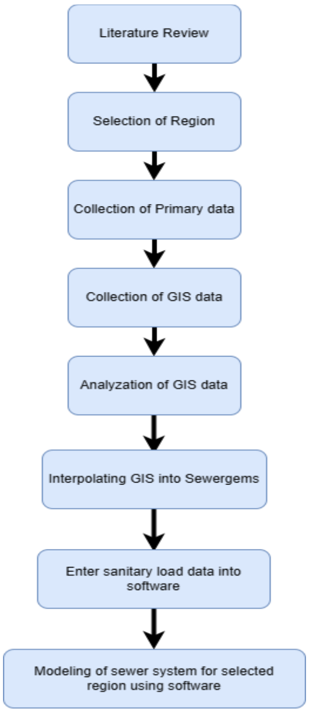

Fig. 1. The stages of research methodology work

IV. Description of the Study Area

Karbala, spanning 5,034 square kilometres, is a city in Iraq situated approximately 100 kilometres (62 miles) southwest of Baghdad. Its precise geographical coordinates are Latitude: 32°36'51" N, Longitude: 044°01'29" E. Karbala consists of two districts, namely "Old Karbala" and "New Karbala". The residential district encompasses Islamic schools and government facilities. The city centre of Karbala has an approximate population of 495,411, whereas the entire Karbala Governorate has a population of 975,000 (City Population, 2018) [8]. Fig. 2 depicts a map of Iraq, specifically highlighting the city of Karbala along with neighbouring cities.

Karbala is renowned as a significant religious city that attracts Muslims worldwide at specified annual periods. The city experiences the highest influx of visitors during the Arbaeen visit, which occurs on the twentieth day of the month of Safar in the Hijri calendar. Fig. 3, displays the visitor count to the governorate over a period of twenty days (from 1st Safar to 20th Safar) for the past seven years [9].

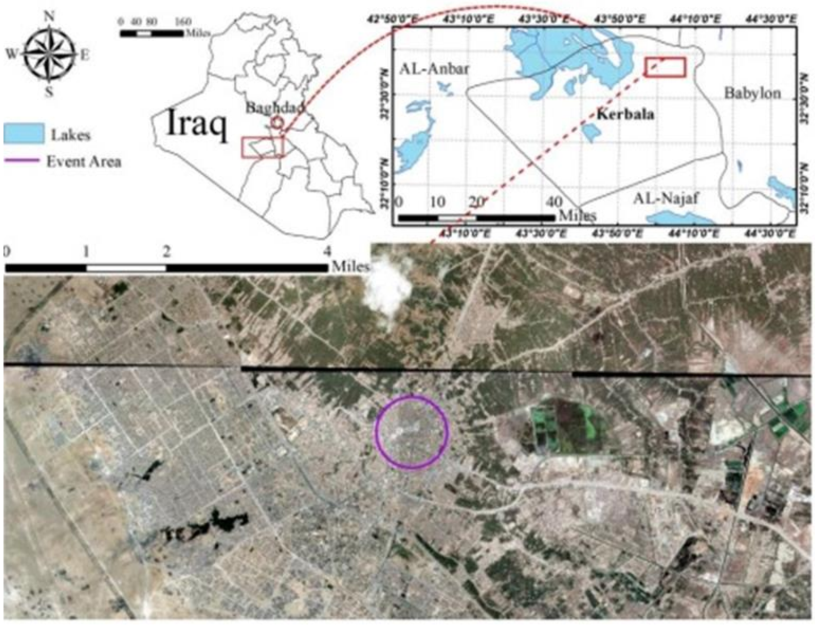

Fig. 2. the location of Karbala Governorate on a map of Iraq

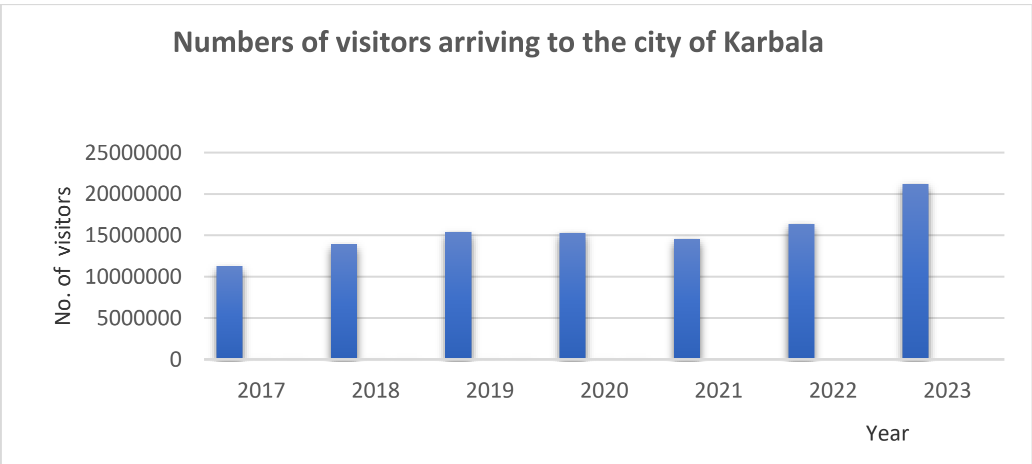

Fig. 3. The number of visitors arriving to the city of Karbala

In 1980, sewage networks were established in the city centre of Karbala, utilising pipes of varying diameters. The network comprises primary and secondary pipelines, as depicted in Fig. 4. These pipelines are linked to concrete manholes, which come in round and rectangular forms, with varying intervals between each manhole.

Fig. 4. Aerial photo showing Karbala city center with sewage networks

Due to the aging of the city's sewage network and its design to accommodate a limited number of residents, sewage overflow occurs in many locations, as in the Fig. 1, affecting the environment and traffic during the period of religious visitation.

Fig. 5. Sewage overflow in a number of locations in the city center of Karbala

V. PROJECT NECESSITY

The necessity of the project is to establish a new sewage network that is compatible with the huge amounts of drainage during the period of religious visits to the city to prevent recurring sewage overflows and preserve the environment from pollution.

VI. SEWERGEMS

SewerGEMS simplifies the modelling process, allowing us to allocate more time to address wastewater engineering challenges such as enhancing capacity and mitigating sewer overflows. This eventually enables utilities to adhere to sewer standards established by regulatory authorities. SewerGEMS offers experts an advanced engineering tool for the planning, design, maintenance, and operation of sanitary sewage systems. This tool encompasses the following aspects [10].

1-Utilise the what-if scenario management tools of SewerGEMS to gain insights into the functioning of your wastewater system, enhancing decision making and reducing reaction time more effectively.

2-Enhanced model accuracy: A properly calibrated model reduces the likelihood of making suboptimal decisions and guarantees the utilisation of the most reliable data provided to it. The inclusion of SCADA connectivity in SewerGEMS calibration tools allows experts to have confidence in the accuracy of their model findings.

3-SewerGEMS facilitates the efficient exchange of information across utilities' design, engineering, GIS, and operation departments, as well as their consultants, through its comprehensive GIS, CAD, and SCADA interoperability. This enhanced information mobility is cost-effective and enables seamless sharing and flow of data. Users may utilise the data that the utility has invested in once and reuse it across several departments.

SewerGEMS offers engineers a user-friendly platform to analyse, design, and manage sanitary or combined conveyance sewer systems. It includes advanced hydraulic and hydrology features, as well as various wet weather calibration methods, making it suitable for tasks ranging from urban sewer planning to overflow remediation analysis to optimised best management practices design. SewerGEMS utilises Bentley CONNECT services by linking a hydraulic model with a CONNECT project [10]. This facilitates seamless sharing access to the model for all team members.

7-Hydraulic modeling and analysis

The primary goal of a hydraulic analysis of the network is to scrutinise the architectural model that was previously constructed in the Arc map environment. Hydraulic models are the most successful methodology in various types of sewer network study [11]. The objective of the control system is to utilise the available capacity of the pipes in order to minimise overflow in the wastewater system. The primary objectives of hydraulic design are to ascertain the necessary diameter of sewer pipes, compute and regulate the slope, and manage the flow velocity within the sewer pipes. Velocity plays a crucial role in fluid dynamics and is subject to specific limitations based on design criteria. Additionally, the sewer pipes are intentionally built with incomplete filling, necessitating the specification of the fullness-to-emptiness ratio in hydraulic calculations. The model was subjected to a load using the "area load" method in this investigation. The dispersion of discharge in the pipelines has also been achieved utilising “Equal Flow Distribution.” The distribution of flow in all pipelines is proportional to the area occupied by each pipeline. Given that certain pipelines may have varying numbers of loads, this situation will not actually occur in actuality. This approach is referred to as the optimal loading framework, as it was specifically designed to assess the feasibility of modelling. The following design scenario was considered for the hydraulic design:

a) The type of pipe material selected is,Polyvinyl chloride (PVC).

b) Pipeline’s diameter range is between 30 to 1800 cm.

c) The high and low-velocity limits are assumed 500-30cm/sec.

d) Depth of burial of pipelines according within 100 to 500cm

e) The slope for piping was set among 0.5 and 10%percent.

f) All pipelines are considered (75%) full.

The generated model has undergone validation to assess the input data and design settings scenario. Upon completion of the validation procedure, the model was executed to conduct hydraulic analysis. The software quantifies and evaluates numerical and analytical factors.

8-Presenting and Evaluating the Results

The SewerGEMS programme provides multiple techniques for displaying the results of the research. The "design report" offers a succinct summary of the scrutinised network. The relevant information comprises the designer's specifications, project title, organisation name, analysis date, and design. Furthermore, it offers succinct information regarding the particular case that was utilised to construct the model. It precisely represents the exact amount of each element used in the network. This analysis employs a grand total of 863 pipes and manholes, which encompasses three outfall structures. Furthermore, it furnishes the precise measurements of the lengths and diameters for every range of pipeline diameters employed in the model (Fig. 6). A total of 49,070.9 metres of pipelines were used in this modelling project.

Hydraulic Model Inventory: sewer net.16-12.stsw

Title	Sanitation network for the city center of Karbala - Iraq
Engineer	Ihsan Kadhim Abed
Company	
Date	12/7/2023
Notes	

Scenario Summary

ID	1
Label	Base
Notes	
Active Topology	Base Active Topology
User Data Extensions	Base User Data Extensions
Physical	Base Physical
Boundary Condition	Base Boundary Condition
Initial Settings	Base Initial Settings
Hydrology	Base Hydrology
Output	Base Output
Infiltration and Inflow	Base Infiltration and Inflow
Rainfall Runoff	Base Rainfall Runoff
Water Quality	Base Water Quality
Sanitary Loading	Base Sanitary Loading
Headloss	Base Headloss
Operational	Base Operational
Design	Base Design
System Flows	Base System Flows
SCADA	Base SCADA
Energy Cost	Base Energy Cost
Surface Definition	Base Surface Definition
Solver Calculation Options	Base Calculation Options

Network Inventory

Conduits	863	Outfalls	6
-Circle	863	Catchments	0
-Box	0	Low Impact Development Controls	0
-Ellipse	0	Ponds	0
-Virtual	0	Pond Outlet Structures	0
-Irregular Channel	0	Headwalls	0
-Trapezoidal Channel	0	Pumps	0
-Triangular Channel	0	Wet Wells	0
-Rectangular Channel	0	Pressure Junctions	0
-Pipe-Arch	0	SCADA Elements	0
Laterals	0	Pump Stations	0
Channels	0	Variable Speed Pump Batteries	0
Gutters	0	Air Valves	0
Pressure Pipes	0	Grids	0
Catch Basins	0	Surface Polygons	0
Manholes	863	Surface Polylines	0
Property Connections	0	Boundary Lines	0
Taps	0	Boundary Points	0

Circle Inventory			
Circle - 0.3 m	21,094.0 m	Circle - 1.0 m	763.5 m
Circle - 0.4 m	3,772.0 m	Circle - 1.2 m	2,142.5 m
Circle - 0.5 m	3,682.6 m	Circle - 1.3 m	276.3 m
Circle - 0.6 m	4,427.4 m	Circle - 1.5 m	3,101.8 m
Circle - 0.7 m	2,897.4 m	Circle - 1.8 m	5,126.1 m
Circle - 0.8 m	1,254.3 m	Total Length	49,070.9 m
Circle - 0.9 m	533.0 m		

sewer net.16-12.stsw
12/23/2023

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SewerGEMS
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Fig. 6. Summary of hydraulic design

The software allows for the presentation of distinct tables, enabling the examination of design specifics to obtain further information regarding manholes and pipelines. The programme report can illustrate the materials used in the pipeline design, the length of each branch, and all the necessary information. An alternative approach to visualise the outcomes is through diagrammatic representation. The graph depicting the temporal aspects of different model components can be utilised to elucidate the fluctuations within each component within the framework of a map. The variation in the "hydraulic gradient" within a manhole during a 24-hour period is seen in Fig. 7. By implementing the extended time strategy in the design example, a definitive result is achieved.

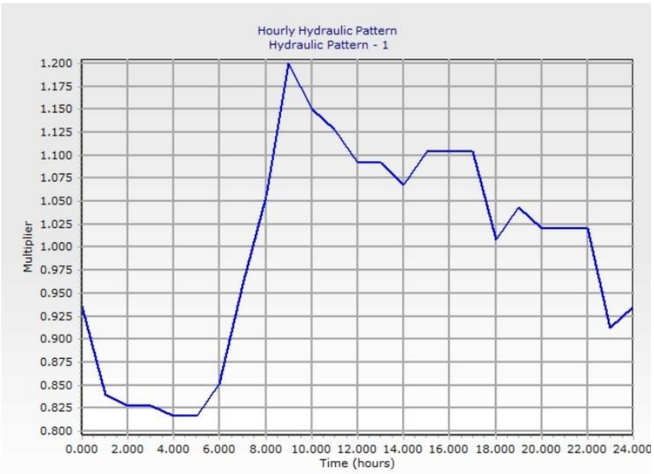

Fig. 7. Hydraulic gradient for manhole 259

Displaying the sewer network profile is an essential component. The comprehensive analysis of all pipelines is crucial for the successful execution of sanitation initiatives. The crucial path, also referred to as the farthest path, is observable. The profile may encompass surface elevation, manhole depth, invert elevation, pipeline gradient, width, and any other necessary data.

VII. Control of Parameters

Certain modules can serve as control parameters to evaluate the accuracy and exactness of the design and hydraulic analysis. One component that can be analysed is the velocity, which refers to the speed of flow. The velocity limitations for sewage networks range from 30 to 500 cm/s, with an optimal range of 60 to 180 cm/s, as determined by the design requirements. Therefore, it can be concluded that in wastewater collection modelling, the velocity must fall within the appropriate range, otherwise the ideal level. The flow velocity in all tubes ranged from 30 to 487 cm/s. Similar to the conventional practice of incorporating pipeline diameters from the software library, other variables can be monitored, verified, and quantified based on the flow volume. Upon executing the programme, the selection of all diameters was determined according to the pipe diameter that is commonly accessible, as indicated in the diameter column. SewerGEMS can also be utilised to validate factors associated with manholes. The elevation of the ground and the vertical distance of the manholes, known as invert altitude, are two crucial factors to take into account while dealing with manholes.

VIII. Conclusion

The objective of this project was to develop a model for upgrading an existing sewage drainage network, originally designed for restricted capacity, to handle a significantly larger volume of drainage during pilgrimages. Shapefiles were generated separately for pipelines and manholes within the ArcMap framework to construct the architectural model. The existing architectural model is imported into the SewerGEMS software and modified to create a hydrological model.The hydraulic assessment of the model was conducted using SewerGEMS software. The geometric modelling and hydraulic analysis demonstrate that wastewater collection systems are feasible and suitable solutions for the city of Karbala. However, after creating numerous simulations of different situations, the hydraulic model design for the city was ultimately finished using the SewerGEMS programme, taking into account the highest possible discharge. The successful development and operation of the hydraulic model can be deduced from the study of hydraulic findings and the evaluation of control parameters such as flow rate, pipeline diameters, slopes, and profiles. These models can be used to analyse the sizes of cities at the district level. The absence of a coherent urban design poses challenges in developing such models; this analysis seeks to incorporate supplementary tools into the gravity system for both planned and unplanned scenarios geographical areas.

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