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Design of Sewer Network for Gwalior, Ward no. 60 using SewerGEMS V8i Software with different load distribution methods

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Abstract — ***Efficient sanitation system is a fundamental key to environment sustainability. Our aim is to design economic sewer network for a Ward. The present study includes the use of SewerGEMS V8i software for the design and analysis of the sewage system for the Gwalior city, Ward no. 60 situated in Madhya Pradesh. SewerGEMS V8i is computer software specifically developed for the purpose of design and analysis of the sewer networks in a short time with high efficiency and low costs. In the design of a sewerage system the sewer network is the basic unit occurring repeatedly in the design process. Bentley SewerGEMS v8i is the first and only fully-dynamic, multi-platform (GIS, CAD and Stand-Alone) sanitary and combined sewer modeling solution. Any savings during the design of this unit will affect the overall cost of the sewerage system.***

Keywords- Sewer Network, Sewage, Sewergems V8i, CAD and Microstation, Gwalior city, Ward no. 60

I. INTRODUCTION

Sewerage systems are vital part of the infrastructure of any society. The main aim of providing the sewer network is to carry away sanitary waste from a municipal area in such a way that it does not cause any public health related problems. Sewerage network setup conveys wastewater used by individuals, commercial and industrial establishments to wastewater treatment facilities, ultimately to be returned to the natural environment. Since earlier times, manual design of conveyance system was practiced and from the recent past, it has switched to advanced design practices adopting well organized computer aided design software which has been widely used is 'SewerGEMS' developed by Bentley's products. Out of the latest technologies, in the present study, focus has been made on 'SewerGEMS'. In the proposed paper, 'SewerGEMS' software is adopted for the design & analysis of underground drainage system. The cost of sewerage schemes is so high but this issue can be solved by computer software SewerGEMS. An analysis of waste water management of Gwalior, Ward no. 60 is carried out with respect to population and its forecasting. In SewerGEMS software, the program selects automatically pipe diameters by considering the flow in the pipe velocity and gradient requirements. Parameters like discharge, velocity, ground level, invert level and depth are calculated using the software. The computer software package SewerGEMS is the most helpful tool as compare to manual methods of the purpose of designing an economic sewer network since it can give the optimum cost and practically feasible layout which can handle a large network.

II. GENERAL DETAILS ABOUT THE SOFTWARE

A. MicroStation Mode

This gives you access to all of MicroStations drafting and presentation tools, while still enabling us to perform Bentley SewerGEMS V8i modeling tasks like editing, solving, and data management. This relationship between Bentley SewerGEMS V8i and MicroStation enables extremely detailed and accurate mapping of model features, and provides the full array of output and presentation features available in MicroStation. This facility provides the most flexibility and the highest degree of compatibility with other CAD-based applications and drawing data maintained at any organization.

B. GIS Mode

Each mode provides access to differing functionality certain capabilities that are available within GIS mode may not be available when working in the Bentley SewerGEMS V8i Stand-alone Editor. All the functionality available in the Stand-alone Editor are however available in GIS mode.

C. AutoCAD Mode

This gives you access to all of AutoCAD's drafting and presentation tools, while still enabling you to perform Bentley SewerGEMS V8i modeling tasks like editing, solving, and data management. This relationship between Bentley SewerGEMS V8i and AutoCAD enables extremely detailed and accurate mapping of model features, and provides the

full array of output and presentation features available in AutoCAD. This facility provides the most flexibility and the highest degree of compatibility with other CAD-based applications and drawing data maintained at your organization.

D. SewerGEMS V8i

Bentley SewerGEMS V8i is the first and final completely powerful, multi-stage clean and joined sewer demonstrating arrangement. The computer software package SewerGEMS is the most helpful tool as compare to manual methods of the purpose of designing & analysis of underground drainage system an economic sewer network since it can give the optimum cost and practically feasible layout which can handle a large network.

E. Microsoft Excel

The manual calculations were carried out adopting 'Microsoft Excel' spread sheet for the design of sewer attributes such as - full discharge, velocity at peak flow conditions and d/D ratio by utilizing various design formulae and design constraints as approved by CPHEEO guidelines. Further comparison was done for the software results & Excel results. For the result comparison, the basic data for slope, diameter & flows were taken from 'SewerGEMS' results. Utilizing these data, analysis was performed to simulate hydraulic conditions of sewers. In order to assess compatibility to accept the outputs of the software results; manual calculations are carried out with the aid of 'Microsoft Excel'. The results are found in similar nature with slight variations in physical values.

III. GENERAL INFORMATION ABOUT GWALIOR CITY, WARD NO. 60

A. Geography

Gwalior is located at 26.22°N Latitude and 78.18°E Longitude in northern Madhya Pradesh 300 km (186 miles) from Delhi. It has an average elevation of 197 metres (646 feet). The city comprises three townships - Lashkar, Old city and Morar. Old Gwalior is surrounded by hills particularly in West, Southwest and southern part of the city's urban spread. The municipal area of Gwalior city is 177.3 sq. km and is divided into 60 WARDS and 20 sanitary zones.

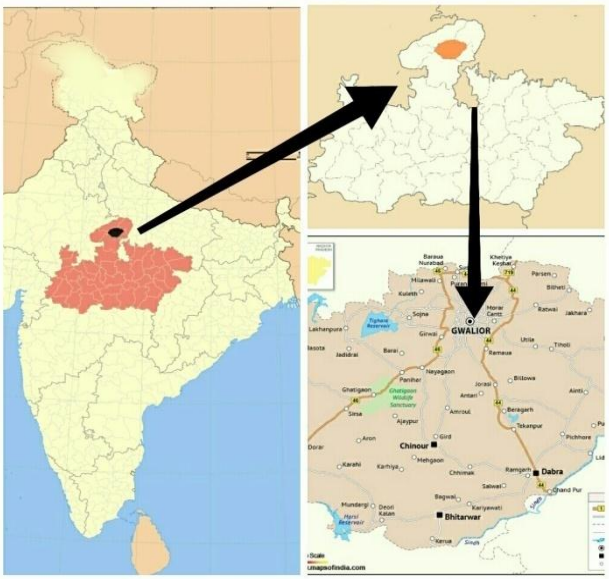

Figure 1. Key map of Gwalior city, Madhya Pradesh

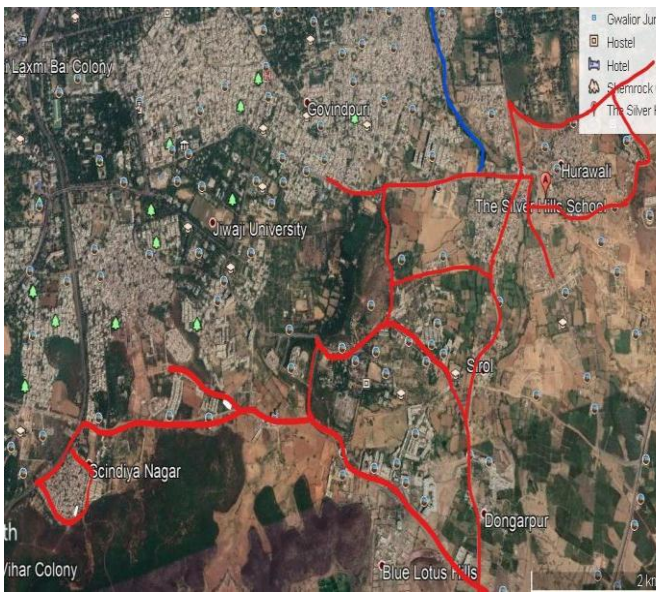

Figure 2. Google earth map of Gwalior, Ward 60

B. *Demographics*

Total Area of Gwalior, Ward No. 60 (Study Area) is 3.736 m. sq. It is Gwalior city's 10th most populous ward, located in Gwalior (Gird) sub-district of Gwalior district in the state Madhya Pradesh in India. Fig. 2 shows the google earth map of study area.

IV. MATERIALS AND METHODS

A. *Data Collection*

For designing a Sewer network of Gwalior city, Ward 60 the following data were obtained from Radical Engineering Firm :
1) Collection of the population of last 4 decades of Gwalior City, Ward no. 60
2) Topographical map of Gwalior, Ward 60.
3) Road map of Gwalior, Ward 60.

B. *Population Forecast*

There are 4501 households in the Ward no. 60 and an average 5 persons live in every family. Population of the ward has increased by 61% in last 10 years. In 2001 census total population here were about 15 thousand and according to Population Census 2011, it has population of about 24,000. The population has been forecasted for the design period of 30 years using incremental increase method.
The projected populations for the design horizons for 2020, 2030, 2040 and 2050 are 30540, 40975, 53852 and 69181 respectively.

C. *Survey*

The detailed topographical survey was carried out for the ward 60. The roads were identified and represented in AutoCAD as shown in Figure 3

Figure 3. Topographical map of Gwalior, Ward 60 in AutoCAD

V. ANALYSIS AND DESIGN CRITERIA

We have optimize the network using two different load distribution method for above forecasted population :

1) Length wise load distribution
2) Area wise load distribution

Design of sewer system as per CPHEEO manual includes the following design parameters :

A. Design Period

The length of time up to which the capacity of a sewer will be adequate is referred to as the design period. The sewerage system of the selected area has been designed for the period of 30 years.

B. Peak Factor

The flow in sewers varies from hour to hour and seasonally. However, for the purpose of hydraulic design estimated peak flows are adopted. The peak factor is the ratio of maximum to average flows depends upon contributory population. The peak factor was adopted as 3.

C. Per Capita Sewage Flow

The entire spent water of a community is normally contributing to the total flow in a sanitary sewer. However, the observed dry weather flow quantities usually are slightly less than the per capita water consumption. The assumption has been made that the supply of the water to the city at a uniform rate of 108 lpcd. The rate of sewage generation was taken as 80% of the water supply.

D. Depth Of Flow

The sewers shall not run full as otherwise the pressure will rise above or fall below the atmospheric pressure and condition of open channel flow will cease to exist. Moreover, from consideration of ventilation, sewers should not be designed to run full for the ultimate design period, the sewers are designed flowing 80% full (d/D = 0.8)

E. Velocity Of Flow

For the hydraulic design, minimum velocity has to be maintained in the sewers even during minimum flow conditions. At the same time the velocity should not be excessive to cause erosion. For design of sewer minimum velocity should be 0.3 m/sec. And for velocity less than 0.3 m/s flushing tanks are provided. To avoid erosion in the sewer network, velocity more than 3.0 m/sec will not be allowed.

F. Minimum Depth Of Cover

The starting manhole depth of the proposed sewers ranges from 1m to 1.5 m depending upon the topography and details of road planning network available. The minimum depth of cover depends on the depth of the starting manhole and subsequent ground level of the road along the sewer. The minimum depth of cover of 1m has been provided.

G. Recommended Slopes For Minimum Velocity

For sewers running partially full, for a given flow and slope, velocity is influenced by pipe diameter. The recommended slopes as per design manual for minimum velocity have been adopted.

Table 1. Adopted slope for minimum velocity

Sewer size (in mm)	**Minimum slope**	
	As percent	**As 1 in**
150	0.6	170
200	0.40	250
250	0.28	360
300	0.22	450
375	0.15	670
450	0.12	830
≥525	0.10	1000

H. Size And Shape Of Sewers

The circular pipes were adopted for the trunk mains and branch sewers. The study area having present base year population of less than 1 lakh, so the minimum diameter of 200 mm has been adopted.

I. Selection Pipe Material

Over the years almost all types of pipe materials have been tried and tested for sewerage application. Though there are numerous factors to be considered in designing a Sewerage System, mainly three basic factors influence the ideal choice of pipe material.

1) Hydraulic and structural design.
2) Nature of the effluent to be carried and the soil / ground water condition.
3) Ability to encounter sewage related corrosion and abrasion.

We have made design using HDPE and RCC pipe materials.

J. Manholes

Manholes form one of the essential structures in any Sewerage System. They are generally provided at every road junction, at every change of alignment or gradient of sewers at every junction of two or more sewers at head of all sewers or branches, wherever there is a change in size of sewer and at regular intervals in the Sewerage System. They are used for inspection, cleaning and repairing of sewers and other maintenance operations.

VI. DESIGN OF SEWER NETWORK AND METHODOLOGY

A. Laying Out A Network

SewerGEMS V8i is an extremely efficient tool for laying out a sanitary sewer network. It is easy to prepare a schematic or scaled model and let SewerGEMS V8i take care of the link-node connectivity. In constructing the network for this lesson, you do not need to be concerned with assigning labels to pipes and nodes, because the software assigns labels automatically. The preparatory work for design engineer is to carry out field examination and further to study carefully the characteristics of study area pertaining to the street network pattern, projected population, invert level of pipe at manhole, existing network, land topography, natural barrier, existing and proposed land use, uncertainly proposed site for sewage treatment plant and the outfall etc. trunk sewer arrangement has been proposed by considering the geography of the city and major deterrents like national highway and railway track. Zoning has been done such that trunk sewer line has to cross NH and railway line at very least points. Based on this entire Gwalior city is isolated into 60 wards, and we have made design for ward no. 60

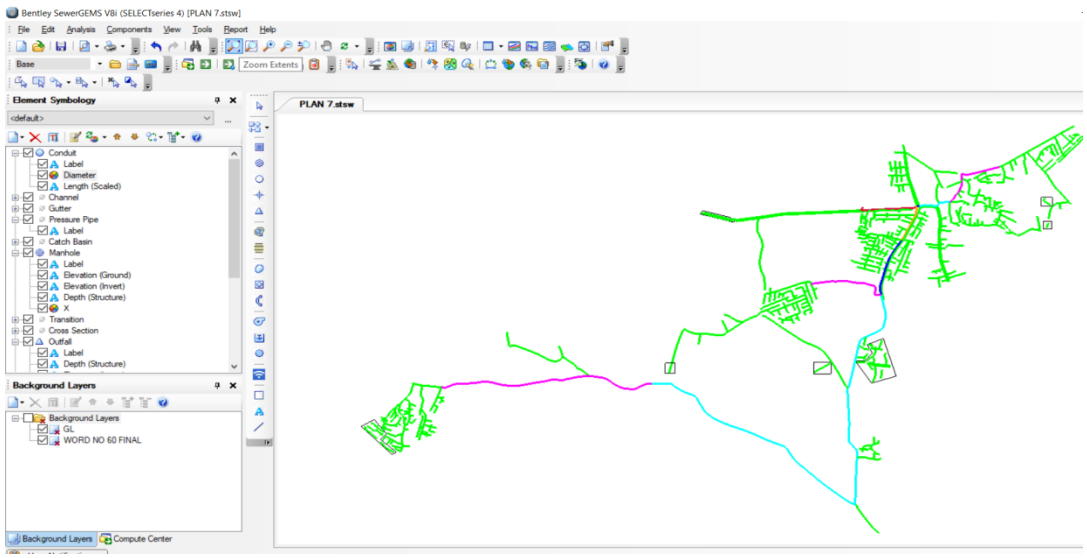

Figure 4. Layout of Gwalior, Ward no. 60

B. Methodology

In the flowchart of methodology given below, describes the systematic procedure of the proposed work.

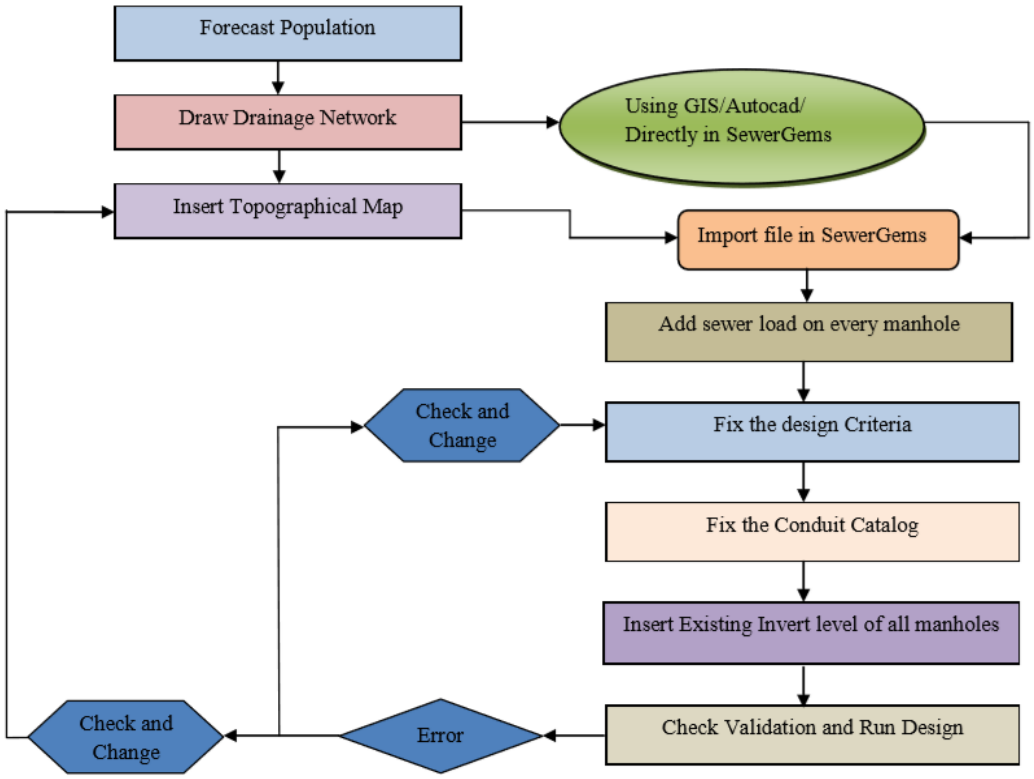

Figure 5. Flowchart of steps used in Design

VII. RESULTS AND DISCUSSION

Bentley SewerGEMS V8i is the first and final completely powerful, multi-stage clean and joined sewer demonstrating arrangement. The computer software package SewerGEMS is the most helpful tool as compare to manual methods of the purpose of designing & analysis of underground drainage system an economic sewer network since it can give the optimum cost and practically feasible layout which can handle a large network. Less time spent to create the drawings by using the tools for labelling the system parts, updating data automatically for layout & longitudinal Profile with the modifications make along the designing process, calculating the pipe diameters automatically, using the features for creating the plotting drawings. A map containing pipe details, velocity, elevations & flow can be directly obtained from SewerGEMS v8i. The conditions for maintaining the minimum & maximum velocity are assigned to SewerGEMS v8i.

A. Results By Length Wise Load Distrubtuion Method:

The results obtained from the software were represented in terms of percentages of design parameters with respect to their manholes as shown in table.

Table 2. Details of depth wise manhole

Sr. No.	Depth Of MH (m)	Number Of MH	Percentage
1.	1.0 – 2.0	1134	58.2%
2.	2.1 – 3.0	293	15.04%
3.	3.1 – 4.0	215	11.04%
4.	4.1 – 5.0	174	8.93%
5.	5.1 – 6.0	78	4.07%
6.	6.1 – 7.0	53	2.72%

From the above table, obtained from design simulation shows that 58.2 % of the manholes have a depth between 1 to 2 m and 15.04 % have depth between 2.1 to 3 m, 11.04% depth between 3.1 to 4 m, 8.93 % have depth between 4.1 to 5 m, 4.07 % have depth between 5.1 to 6 m, and remaining 2.72 % of the manholes have depth between 6.1 to 7.0 m. The results were compared with diameter and depending length as shown in Table 3.

Table 3. Details of diameter along with length of sewer lines

Sr. No.	Diameter (mm)	Length (m)	Percentage
1.	200	39,800	82.70%
2.	250	2,880	6.15%
3.	300	4,110	8.50%
4.	400	510	1.06%
5.	450	310	0.64%
6.	560	460	0.95%

The total length of pipes of all diameters together is 48,070 m. It was observed that about 82.70 % of the pipes were of 200 mm diameter, 6.15 % was of 250 mm diameter, 8.5 % of the pipes were 300 mm, 1.06 % of the pipes were of 400 mm diameter, 0.64 % of the pipes were of 450 mm diameter, and remaining 0.95 % of the pipes were of 560 mm diameter.

Table 4. Details of velocity in the sewer lines

Sr. No.	Velocity (m/s)	Number of MH	Percentage
1.	<0.30	417	21.41%
2.	0.31 – 0.60	836	42.95%
3.	>0.60	694	35.64%

The outcome from the design simulation results from Table 4, shows that 21.41 % of the manholes had a velocity <0.3m/s, about 42.95% fell between 0.31-0.6m/s and 35.64 % has a velocity >0.6m/s. The lower velocity of less than 0.3m/s is caused due to lack of load generated at the starting of the branches and less load contributed for the successive manholes. Around 79% of the manholes have velocities more than 0.3m/s which are acceptable by the departments.

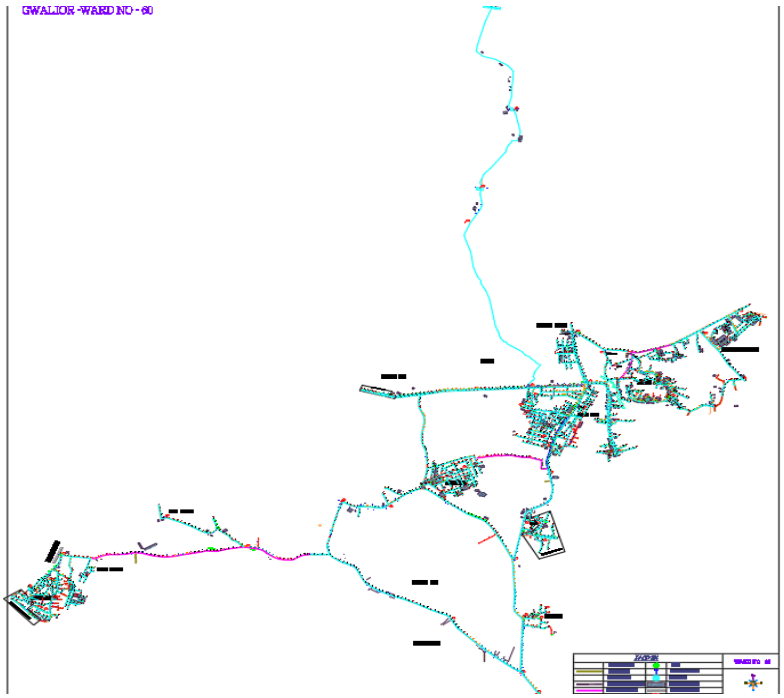

Figure 6. Sewer Design Network for Gwalior, Ward no. 60

B. Results By Area wise Load Distrubtuion Method:

Table 5. Details of depth wise manhole

Sr. No.	Depth Of MH (m)	Number Of MH	Percentage
1.	<1	12	0.67
2.	1 to 2	727	40.77
3.	2.1 to 3	309	17.33
4.	3.1 to 4	225	12.62
5.	4.1 to 5	227	12.73
6.	5.1 to 6	141	7.91

From the above table, obtained from design simulation shows that 0.67 % of manholes have depth of less than 1 m. 40.77 % have a depth between 1 to 2 m and 17.33 % have depth between 2.1 to 3 m, 12.62 % have depth between 3.1 to 4 m, 12.73 % have depth between 4.1 to 5 m, 7.91 % of the manholes have depth between 5.1 to 6 m. The results were compared with diameter and depending length as shown in Table 6.

Table 6. Details of diameter along with length of sewer lines

Sr. No.	Diameter (mm)	Length (m)	Percentage
1.	200	38,973.70	88.54
2.	250	3,272.20	7.43
3.	300	832.6	1.89
4.	350	834.6	1.90
5.	450	107.3	0.24

The total length of pipes of all diameters together is 44,020.4 m. It was observed that about 88.54 % of the pipes were of 200 mm diameter, 7.43 % was of 250 mm diameter, 1.89 % of the pipes were 300 mm, 1.90 % of the pipes were of 350 mm diameter, 0.24 % of the pipes were of 450 mm diameter.

Table 7. Details of velocity in the sewer lines

Sr. No.	Velocity (m/s)	Number of MH	Percentage
1.	< 0.3	29	1.63
2.	0.3 to 0.6	1329	74.54
3.	0.6 to 1	407	22.83
4.	1 to 2	18	1.01

The outcome from the design simulation results from Table 7, shows that 1.63 % of the manholes had a velocity <0.3m/s, about 74.54% fell between 0.3-0.6m/s, 22.83% has a velocity between 0.6 to 1m/s and around 1.01 % have velocity more than 1 m/s.

VIII. CONCLUSION

The following conclusions were drawn based on the work carried out on network design for sewerage system for Gwalior, Ward 60:

- In this project, the main objective is to form base map to prepare sewer network with help of SewerGEMS v8i.
- In SewerGEMS V8i, less time spent to create the drawings by using the tools for labeling the system parts, updating data automatically for layout and longitudinal profile with the modifications we make along the designing process, calculating the pipe diameters automatically, using the features for creating the plotting drawings as compared to ‘Microsoft Excel’. ‘Microsoft Excel’ consumes lot of time.

- A map containing pipe details, velocity, elevations and flow can be directly obtained from SewerGEMSV8i.
- d/D ratio is lower than 80 % for all pipes in both methods. So both the designs are suitable and can be recommended for sewer network.
- For velocities below 0.60 m/s flushing manholes can be adopted or recommended to increase self cleansing velocity. 80 % of velocity in sewer lines falls in more than 0.30 m/s, considering the execution point of view; hence, it is presently acceptable.
- By considering all the above points, SewerGEMS V8i will give feasible and optimal results. Hence, the results obtained from SewerGEMS V8i can be recommended for the entire sewer network.

IX. ACKNOWLEDGEMENT

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