ASSESSMENT OF FUNCTIONAL DEFICIENCIES THROUGH HYDRAULIC NETWORK MODELLING OF EXISTING SEWERAGE SYSTEM

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Abstract

The sewage collection system acts as a vital part in the infrastructure sector which also supports the environment. The system is to convey the domestic liquid wastes from the habited areas so as to stop producing any health-related issues. Also, nowadays, awareness for the treatment of wastewater is increasing due to the rise in damage and pollution of the environment. The underground sewerage scheme functions based on the quantity of flow and the gradient of the pipes. The functional deficiencies majorly caused by the higher or lower quantity of flow generated against the designed flow. The defects in laid pipelines or pipeline vertical alignments also impacts the conveyance of the sewage. A case study with analytical procedures on the existing sewer network in the commanding area of Mathulampettai pumping station at Kumbakonam Municipality is being considered. This Project study aims to assess the working conditions of the existing pipelines and to carry out Performance assessment of the system through Hydraulic network modelling.

Introduction

The management of Sewage in town or city is essential because of unhygienic to the environment. The local bodies manage it through a sewage collection system in their area for a certain design life period and the forecasted population. Such collection system which includes Manholes, Sewer Pipes etc., becomes deficient over the period. To avoid such deficiency, the system requires proper operation and maintenance in order to sustain. Further it is required to study the existing system and identify the gaps in the performance of the system. Based on the study, the system has to be improved so as to attain the safe and proper conveyance of the sewage generated in the respective areas. Therefore, this project represents an assessment on an area where sewage collection system is existing and functioning. The Municipal town of Kumbakonam is having a sewerage scheme commissioned in the year 2007. This scheme evolved in early 2000s covered habited areas at that time. Since then, the development added more populated areas. This resulted in the present scenario of having a large number of uncovered areas as far as sewerage is concerned. The health benefit of investment to implement sewerage scheme is defeated if a few areas are left out and unhygienic condition prevails. This problem is being faced by the Municipal Administration. If this problem is not get rectified, the hygiene and health of the inhabitants will be seriously affected. Important impact of leaving some area without hygienic facilities is rendering a vast area under the risk of epidemic outbreak.

Kumbakonam Municipality is a pilgrimage center in Eastern part of Tamilnadu which is having a sewer length of about 200 Km with 7000 manholes. The system is having 8 Pumping stations and 8 numbers of lifting stations (without Pretreatment).

This study mainly focusses on one of the Pumping stations and its commanding areas which is called Madulampettai Pumping station. The commanding area comprises of 10.2 Km and 365 Manholes. The objective of the Project is to perform an Assessment of the existing sewerage system with in the commanding area of Madhulapettai Pumping station. Collecting all the required existing data and perform the hydraulic network modelling and identify the issues in conveyance of the Sewage generated from the population with in the commanding area.

Table 1 Salient Details of Kumbakonam Municipality

S. No	Details	Information
1	Total Number of Wards	45 Nos.
2	Total Number of Existing Pumping Stations	7 Nos.
3	Total Number of Existing Lifting Stations	3 Nos.
4	Total Existing Sewer length	174 Km
5	Total Number of Manholes	7230 Nos.
6	Existing STP	17 MLD
7	Population – as per 2011 Census	140113
8	Population – as per latest approved DPR (2018)	144835

Methods

Data Collection

The existing sewage collection system details are collected from the Kumbakonam Municipality. The related data are the salient details of the local body, population, Floating Population, present condition of the System etc., are collected. Materials of the pipe lines, Construction materials of the manholes are also collected. The salient details of the project area collected are as per the table 2 shown below.

Table 2 Salient Details of the Project Area

S.No	Details	Information
1	Wards covered	5 wards - 39,40,41,42 (full) &26 (Part)
2	Total Existing Sewer length	10.21 Km
3	Total Number of Manholes – Existing	365 Nos.
4	Pipe Material	Stoneware, RCC
5	Pumping Station	174 Km
a.	Screen Well – 1	Dia- 2.65m
b.	Grit Well – 1	Dia- 5.65m
c.	Suction Well – 1	Dia- 5.65m
d.	Pump set – 1 No. (2DWF)	22 HP
e.	Pump set – 2 Nos (1DWF)	11 HP

Data Processing

The population data and other related data such as present collection system drawings, Town maps and ward maps, previous approved detailed project report, as built drawings were listed and the data were verified for the completeness and correctness for further activities. The population has been considered as per the approved DPR which is the basis for the entire project work. The details collected for the streetwise existing collection system has been entered in the Sewer GEMS software. The activities after the data processing have been approached in the following step by step procedures.

Population

The population is for the base year of 2018 and projected in four different methods

Table 3 Population Projection

S.No	Method of Projection	2018	2033	2048
1	Arithmetical Increase Method	144835	154954	165073
2	Incremental Increase Method	140946	131944	108234
3	Geometrical Progression Method	141450	144358	147325
4	Method of Least Square	237372	300941	364510

Considering the ground conditions, different decadal growths of the town it was concluded to adopt the Arithmetical Increase method. Hence the final design population as per the previous data available is as shown in the Table 4.

Table 4 Design Population

Year	Population Projection by Arithmetical Method
2018	144835
2033	154954
2048	165073

Population for this Project

Considering the population as per the above Table 4, the ward wise projections made and the population contributing the generation of the sewage flow to the Madhulampettai Pumping station is taken as 22861 in 2018. The population growth for the 15 years from 2018 to 2033 is 6.5%. Hence growth per year is works out to 0.43 %. The population adopted for the assessment of the existing system on the year 2022 within the project area is 22861 + (22861 x 0.43% x 4 years) = 23254 persons

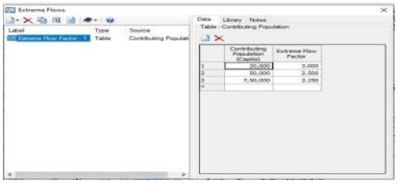
Problems in the Existing Network

The existing system was commissioned in the year 2007 and the age of the system is around 15 years. The town has two rivers flowing towards west to east which are River Cauvery in the north side and River Arasalar in the south side. Hence the entire town is having the sandy soil strata. Also, there are huge fluctuations in ground water table which results in the seepage and structural damages in both brick and RCC manholes. The structural damage and uplift and tilting of Manholes causes the pipe damage and dislocations which results in obstruction of flow.

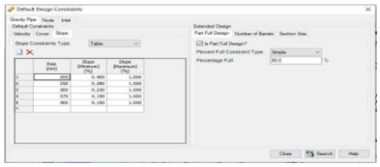
Hydraulic Network Modelling

Inputs

The collected data from the municipality has been entered in the software. The details entered are Population, Per capita Sewage flow, Standard Velocity and Slope details etc.,



Peak Factor as per CPHEEO Norms



Slope of the pipe as per CPHEEO norm

Figure 1 Input Data

Population

The nodal population was entered for all the Manhole nodes. The population was calculated as 23254 persons for a length of 10205 m sewer pipe. The per meter population contribution was calculated and it was applied to the length of the pipe between manholes. The population contributing the sewage generation for single pipe line is added to the respective upstream manhole node. The nodal population entered as per the below Table 7. The Population entered were input to the software and further designs were done. The population was multiplied by the Per capita sewage generation of 110 LPCD and flow is arrived for each pipe line and the capacity analysis were performed.

Collection System Pipes

The existing Collection System Pipelines comprises of both Stoneware pipes and RCC pipes to a total length of 10.203 Km. All the lateral pipes, starting pipes and smaller flow pipes are of 200 mm diameter and pipes carrying the cumulative flow nearer to the pumping station reached up to 400 mm diameter.

Table 4 Existing pipe lines

S.No	Diameter	Material	Length in m
1	200	Stoneware	8327
2	250	Stoneware	607
3	300	Stoneware	64
4	375	Stoneware	50
5	400	RCC	1158
	Total		10203

Collection System Manholes

The manholes with in the Commanding area are 363 numbers which are ranging from 1.2 m depth and 4.96m depth. The deepest manholes are nearer to the pumping station. The manholes within 2.5 m depth, constructed with Brick masonry are 216 numbers and the balance 147 numbers are above 2.5m depth and constructed in RCC.

Modelling

After entering all the data, the software was running though. It validates the data for any loops present in the data, any nodes or pipes are isolated without connections etc.

Outcomes of the Modelling

Velocity

As per CPHEEO norms the minimum velocity required is 0.6 m/s. The result of the modelling shows that there are 277 pipes out of 363 pipes are having the self-cleansing velocity below the requirement. The velocity in such pipes is ranging between 0.1 m/s to 0.59 m/s. This minimum velocity occurs due to the minimum flow at the starting stretches. After the accumulation of the flow, the velocity gets increased above the minimum value of 0.6 m/s.

Slope

The slopes of the pipe lines having to be applied for smooth conveying of the sewage by gravity. CPHEEO recommended the slope for various diameters of the pipelines. In the outcome of the modelling, various pipes do not meet the slope constraints. Out of total 363 pipes, 66 No. of pipes are not meeting the slope criteria. During execution, based on the ground condition, there are requirements to adjust the slope. Such adjustments result in not meeting the slope constraints.

Carrying Capacity

Table 5 Inadequate Pipe Lines

Pipe No.	From Node	To Node	Pipe Material	Dia in mm	Length in m	Capacity of Pipe Lps	Design Flow in LPS	% of flow
220	264	299	Stoneware	250	30	20.98	24.5	116.8
1	377	PS	RCC	400	24	76.07	87.21	114.7
224	260	261	Stoneware	250	29	21.53	23.34	108.4
222	262	263	Stoneware	250	27	22.13	23.9	108.0
225	259	260	Stoneware	250	26	21.82	23.1	105.8
221	263	264	Stoneware	250	25	22.91	24.13	105.3
223	261	262	Stoneware	250	26	22.51	23.66	105.1
226	258	259	Stoneware	250	30	21.82	22.84	104.7

The sewer pipe design is for partial flow and to a maximum of 80% of the actual capacity. The Modelling outcome clearly indicates that there are 8 numbers of pipes which are inadequate to cater the present flow. The flow is more than 80% which results in reduction of velocity and minor inundation with in the manholes.

Assessment

Hydraulic Modelling

Velocity

As per CPHEEO norms the minimum velocity required is 0.6 m/s. The result of the modelling shows that there are 277 pipes out of 363 pipes are having the self-cleansing velocity below the requirement. The velocity in such pipes are ranging between 0.1 m/s to 0.59 m/s. The velocity can be increased by increasing the slope of the pipe or increasing the flow of the pipe. As the collection system is existing and in live by conveying the sewage flow, the slope and flow has to be remained unchanged. Hence the velocity of the flow cannot be changed.

Slope

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Carrying Capacity

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Table 6 Inadequate Pipe Lines

S.No	Pipe No.	Pipe Material	Actual Existing Diameter in mm	Modified Existing Diameter in mm
1	1	RCC	400	450
2	220	Stoneware	250	300
3	224	Stoneware	250	300
4	222	Stoneware	250	300
5	225	Stoneware	250	300
6	221	Stoneware	250	300
7	223	Stoneware	250	300
8	226	Stoneware	250	300

Causes Increase in Diameters

Generally, in the Manning equation, the velocity of the flow is dependent upon the Hydraulic mean radius which is the Area divided by the wetted perimeter. As the diameter of the pipe increases the hydraulic radius increases therefore the velocity will increase. The other variable in that equation is the slope of the gradient. If the Hydraulic radius increases the slope can decrease and still maintain the minimum scouring velocity required. By decreasing he slope we can go longer distances without having to go that much deeper in excavation.

Here in our existing system, the starting invert level and the ending invert level of the pipes are fixed. The Flow generated and the presently getting conveyed by the pipe line is also almost fixed. Hence it is clearly understood that, since the quantity and slope is fixed and the increase in diameter results in the variation in velocity. But the increase in diameter results in higher discharge.

Comparison of Results

Velocity

The velocity has been compared between the existing and newly modified diameters and the results are as follows

Sl. no	Pipe No.	From Node	To Node	Pipe Material	Actual Existing Diameter in mm	Modified Diameter in mm	Present velocity	New velocity
1	1	377	PS	RCC	400	450	0.69	0.73
2	220	264	299	Stoneware	250	300	0.54	0.56
3	224	260	261	Stoneware	250	300	0.50	0.53
4	222	262	263	Stoneware	250	300	0.50	0.53
5	225	259	260	Stoneware	250	300	0.48	0.53
6	221	263	264	Stoneware	250	300	0.52	0.55
7	223	261	262	Stoneware	250	300	0.49	0.54
8	226	258	259	Stoneware	250	300	0.53	0.56

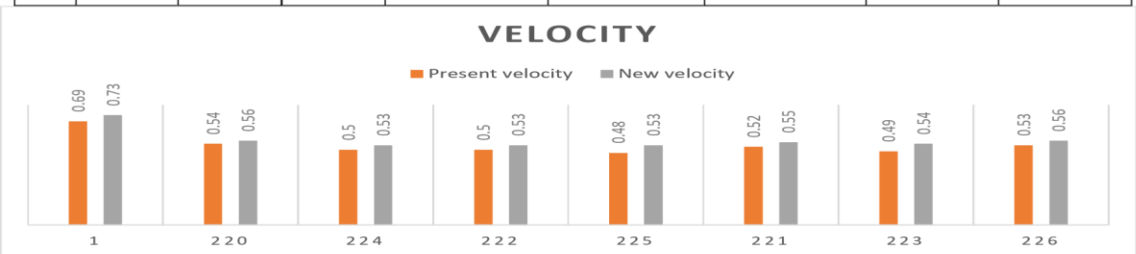

Figure 2 Comparison of Velocity

Carrying Capacity

The Carrying Capacity has been compared between the existing and newly modified diameters and the results are as follows

Table 7 Comparison of Carrying Capacity

S. No	Pipe No.	Actual Existing Diameter in mm	Modified Existing Diameter in mm	Actual Existing Carrying Capacity in %	Modified Carrying Capacity in %
1	1	400	450	114.7	83.7
2	220	250	300	97.9	60.2
3	224	250	300	104.7	64.4
4	222	250	300	105.8	65.1
5	225	250	300	108.4	66.7
6	221	250	300	105.1	64.7
7	223	250	300	108.0	66.4
8	226	250	300	105.3	64.8

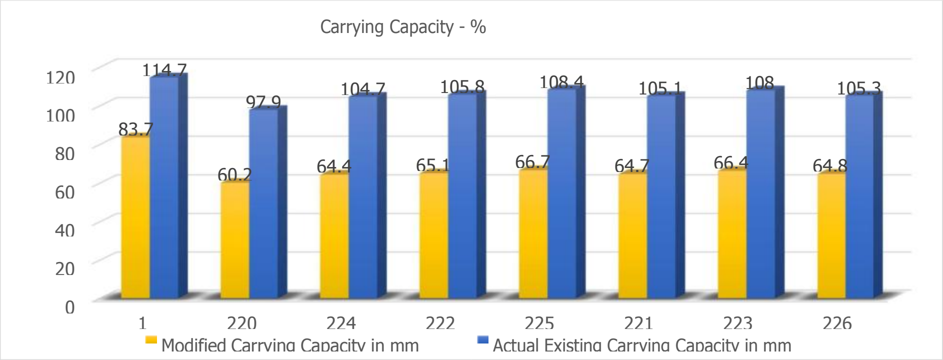

Figure 3 Comparison of Carrying Capacity

Conclusions

In order to improve the present system for better performance in conveying the generated sewage in the existing system, it is recommended that the sewer pipes in certain stretches needs to be replaced with higher diameters. Such replacements will improve the carrying capacity of the pipe and the functioning of the existing system will be more effective.

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