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DESIGN OF STORM WATER DRAINAGE SYSTEM FOR URBAN AREA

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Abstract: Urban storm water drainage systems have got priority in India only after drinking water supply and sewerage projects in majority of the cases. Due to fast pace of urbanization and migration of people from rural areas to urban areas in quest of livelihood and better education, there has been immense pressure on urban infrastructure, worsening the problem of urban drainage systems in India. Urban floods are the floods occurring in urban areas, and are primarily caused by heavy rainfall overwhelming the drainage capacity.

The megalopolises (mega cities) have a long history of municipal drainage perceptions since the British era. Most of the underground drainage facilities within core clusters of these mega cities are usually century old antiquated brick masonry conduits. The existing storm water collection network in these cities is mainly designed to serve as a combined system for sewage as well as storm water runoff. Augmentation and rehabilitation including separation of storm water from sewage in such facilities invite highest level of challenges for municipal engineers and financial resources.

1.INTRODUCTION

1.1 Storm water drainage

Storm water drainage is the process of draining excess water from streets, sidewalks, roofs, buildings and other areas. The system used to drain storm water are often referred to as storm drains and are also called storm sewers and drainage wells (Harshil. H. Gajjar, 2006). Storm water can be any precipitation, such as rain, snow and sleet that falls on the surface of the earth. Structural measures to control storm water include storage reservoirs, flood embankments, drainage channels, antierosion works, channel improvement works, detention basins and non-structural measures include flood forecasting, flood plain zoning, flood proofing, disaster preparedness etc.(Dieter H. Lindner,2013). In areas with natural, unaltered ground water, about 10% of the precipitation becomes runoff and about 50% infiltrates into the soil to form or replenish ground water and flows into streams. Evaporation and uptake by plants accounts to the remaining 40%.When natural conditions change due to development, land use and other activities, this water cycle becomes altered .As the land becomes more covered with impervious surfaces, more precipitation converts as runoff. This runoff carries the dust, other loads, and pollutants. When the development is more as much as 55% may become runoff (JNNURM Project, 2006).Technologies for storm water infiltration, such as infiltration basins and trenches, soak away pits, bioretention systems (rain gardens) and porous pavements are well developed (Mikkelsen PS ,1996), (Pagotto C, 2000). Rain gardens use vegetated soil media to improve storm water quality (Bratières k, 2008), attenuate flow rates (Hunt WF, 2009) and, depending on the design, promote infiltration and evapotranspiration (Hamel P, 2011). Where infiltration is not possible, they can be built with an under drain which discharges treated water directly to the storm water system (and thus the receiving water), at a rate controlled to match the pre-development low-flow regime (Hunt, 2009). Storm sewers (also storm drains) are large pipes or open channels that transport storm water runoff from streets to natural bodies of water, to avoid street flooding. Storm drains vary in design from small residential dry wells to large municipal systems. Many storm drainage systems are designed to drain the storm water, untreated, into rivers or streams. A combined sewer is a type of sewer system that collects sanitary sewage and storm water runoff in a single system. Combined sewers can cause serious water pollution problems due to combined sewer overflows, which are caused by large variations in flow between dry and wet weather. Any storm drain in the area may be discharging different quantity of water and also the type of pollutants it contributes. Since the cities becoming densely populated, the per-household volumes of waste water exceed the infiltration capacity of local soils and hence require greater drainage capacity and the introduction of sewer systems.

1.2 CAUSES OF URBAN FLOODING

Some of the major causes leading to frequent flooding even in light rainfall in urban areas of India are as under:

1. The average annual rainfall in many important cities in the country receives high rainfall during four months of monsoon. The cities like Mumbai receive annual average rainfall of order of 2,932 mm. High intensity rainfall in such cities is responsible for frequent flooding.
2. Storm drainage systems are currently designed in India for rainfall intensities of once in one year to once in two years return periods. In case, rainfall records are not available, rainfall intensity is usually adopted in the range of 12 mm/hr – 20 mm/hr. Therefore, 'Accommodation & Transportation' capacities of such hydraulically configured drainage facilities are easily overwhelmed, whenever rain storms of higher frequencies are experienced.
3. Unplanned urbanization causes considerable increase in impervious areas, thereby, leading to enhanced surface runoff and frequent flooding.
4. The problem of disposal of storm runoff is compounded in the cities having flat terrain, tidal fluctuations in coastal areas and blockage of streams / drains due to landslides in hilly areas.
5. Global climate change resulting in changed weather pattern and increased occurrence of high intensity rainfall events further aggravate the risk of flooding in towns and cities.
6. The absence of systematic approach to formulate and implement a holistic storm water drainage scheme within specified planning horizon has turned urban areas and cities so vulnerable now that even rain of light and medium intensity causes urban flooding.
7. The problem of illegal disposal of Construction and Demolition waste / municipal solid waste coupled with poor maintenance of existing drainage system often obstructs the storm runoff causing localized flooding in the areas.

1.2.1 EFFECTS OF URBAN FLOODING

Urban flooding leads to undesirable effects such as:

- Loss of life and property;
- Disruptions to transport and power;
- Incidences of epidemics during the monsoons;
- Severe economic and infrastructure loss to industry and commerce.

1.3 STORMDRAINAGESYSTEM

It's a network of structures, channels and underground pipes that carry stormwater (rain water) to ponds, lakes, streams and rivers. The network consists of both public and private systems. It's an integral part of the system in the county that is designed to control the quantity, quality, timing and distribution of storm runoff. It's not part of which carries water and waste from drains (sinks, bathtubs, showers, etc.) and toilets to a treatment plant to be treated and filtered. Stormwater does not flow to a treatment plant.

Stormwater drainage design is an integral component of both site and overall stormwater management design. Good drainage design must strive to maintain compatibility and minimize interference with existing drainage patterns; control flooding of property, structures and roadways for design flood events; and minimize potential environmental impacts on stormwater runoff. Stormwater collection systems must be designed to provide adequate surface drainage while at the same time meeting other stormwater management goals such as water quality, streambank channel protection, habitat protection and groundwater recharge.

1.3.1 DRAINAGE SYSTEM COMPONENT

In every location there are two stormwater drainage systems, the minor system and the major system. Three considerations largely shape the design of these systems: flooding, public safety and water quality. The minor drainage system is designed to remove stormwater from areas such as streets and sidewalks for public safety reasons. The minor drainage system consists of inlets, street and roadway gutters, roadside ditches, small channels and swales, and small underground pipe systems which collect stormwater runoff and transport it to structural control facilities, pervious areas and/or the major drainage system (i.e., natural waterways, large man-made conduits, and large water impoundments). Paths taken by runoff from very large storms are called major systems. The major system (designed for the less frequent storm up to the 100-yr level) consists of natural waterways, large man-made conduits, and large water impoundments. In addition, the major system includes some less obvious drainageways such as overload relief swales and infrequent temporary ponding areas. The major system includes not only the trunk line system that receives the water from the minor system, but also the natural backup system which functions in case of overflow from or failure of the minor system. Overland relief must not flood or damage houses, buildings or other property. The major/minor concept may be described as a system within a system for it comprises two distinct but conjunctive drainage networks. The major and minor systems are closely interrelated, and their design needs to be done in tandem and in conjunction with the design of structural stormwater controls and the overall stormwater management concept and plan.

1.4 STORM WATER MANAGEMENT

Storm water management is the effort aimed at reducing and channeling rainwater runoff or melted snow from urban areas, streets, lawns, and homes to improve water quality. It also helps to reverse the negative effects of urban and rural storm water flooding caused by agriculture and human activities such as infrastructural constructions.Stormwater is water that comes from rain or melting snow and ice. In a natural situation, the stormwater is supposed to infiltrate to the ground or evaporate. In habitats like forests, for instance, the soil absorbs considerable amounts of stormwater and plants help hold significant amounts, ensuring that very little runs off.

1.5 PRROBLEM STATEMENT

The Vasai city is located on the north bank of Vasai Creek, part of the estuary of the Ulhas River and settled next to the Tungareshwar Wildlife Sanctuary. Located 50-60 km from downtown Mumbai, Vasai has tehsil (or taluk), a Gram Panchayat, and there is also the Vasai-Virar City Municipal Corporation (VVCMC). And it is part of the Mumbai Metropolitan Region (MMR). The population – estimated to be 13-15 lakh – makes it the fastest growing Mumbai suburbs. There is a large floating population as well, and the pressure on infrastructure is high.

Extensive urbanisation in the Vasai-Virar belt has made it more prone to floods over the last decade. The drainage channels that take water from higher level to the sea level get blocked due to excessive construction. Generally in development plan, such channels are not marked, or even topography is not considered, which a major issue becomes.

The drainage culvert carrying water from the city is very narrow. It needs to be enlarged and two new culverts need to be built. Hence Storm water management is possible with the help of proper designing of drainage system.

1.7 OBJECTIVES & EXPECTED OUTCOME

- To understand existing drainage system and relevant problems of Vasai.
- To understand the rainfall pattern and respective runoff generation by analyzing previous years data.
- To analyse and design the drainage system of Vasai.

2 METHODOLOGY AND STUDY AREA

2.1 GENERAL

Storm water drainage design is an integral component of both site and overall storm water management design. Good drainage design must strive to maintain compatibility and minimize interference with existing drainage patterns; control flooding of property, structures and roadways for design flood events; and minimize potential environmental impacts on storm water runoff.

Storm water collection systems must be designed to provide adequate surface drainage while at the same time meeting other storm water management goals such as water quality, streambank channel protection, habitat protection and groundwater recharge.

2.2 DRAINAGE PLANNING AND DESIGN

The following is a general procedure for drainage system design on a development site.

2.2.1 ANALYZE TOPOGRAPHY

2.2.1.1 Check off-site drainage pattern. Where is water coming onto the site? Where is water leaving the site?

2.2.1.2 Check on-site topography for surface runoff and storage, and infiltration

a) Determine runoff pattern; high points, ridges, valleys, streams, and swales. Where is the water going?

b) Overlay the grading plan and indicate watershed areas; calculate square footage (acreage), points of concentration, low points, etc.

2.2.1.3 Check potential drainage outlets and methods

1. On-site (structural control, receiving water)
2. Off-site (highway, storm drain, receiving water, regional control)
3. Natural drainage system (swales)
4. Existing drainage system (drain pipe)

2.2.2 ANALYZE OTHER SITE CONDITIONS

a) Land use and physical obstructions such as walks, drives, parking, patios, landscape edging, fencing, grassed area, landscaped area, tree roots, etc.

b) Soil type determines the amount of water that can be absorbed by the soil.

c) Vegetative cover will determine the amount of slope possible without erosion.

2.3 GENERAL DRAINAGE DESIGN CONSSIDERATIONS

2.3.1 Stormwater systems should be planned and designed so as to generally conform to natural drainage patterns and discharge to natural drainage paths within a drainage basin. These natural drainage paths should be modified as necessary to contain and safely convey the peak flows generated by the development.

2.3.2 Runoff must be discharged in a manner that will not cause adverse impacts on downstream properties or stormwater systems. In general, runoff from development sites within a drainage basin should be discharged at the existing natural drainage outlet or outlets. If the developer wishes to change discharge points he or she must demonstrate that the change will not have any adverse impacts on downstream properties or stormwater systems.

2.3.3 It is important to ensure that the combined minor and major system can handle blockages and flows in excess of the design capacity to minimize the likelihood of nuisance flooding or damage to private properties. If failure of minor systems and/or major structures occurs during these periods, the risk to life and property could be significantly increased.

2.3.4 In establishing the layout of stormwater networks, it is essential to ensure that flows will not discharge onto private property or roadways during flows up to the major system design capacity.

2.4 ABOUT SEWERGEMS

From urban sewer planning to overflow remediation analysis to optimized best management practices designs, SewerGEMS provides an easy-to-use environment for engineers to analyze, design, and operate sanitary or combined conveyance sewer systems, using built-in hydraulic and hydrology capabilities, and a variety of wet-weather calibration methods. SewerGEMS takes advantage of Bentley CONNECTservices by associating a hydraulic model with a CONNECT project.

With SewerGEMS, utilities and consultants can choose to model from within four platforms, while accessing a single, shared, project data source.

These platforms include:

- Windows stand alone for ease of use, accessibility, and performance
- ArcGIS for GIS integration, thematic mapping, and publishing
- MicroStation for bridging geospatial planning and engineering design environments
- AutoCAD for convenient CAD layout and drafting

Modeling teams can leverage the skills of engineers from different departments, and engineers can flatten learning curves by choosing the environment they already know and provide results that can be visualized on multiple platforms.

2.5 CASE STUDY (VASAI AREA)

Rampant urbanisation in the Vasai-Virar belt has made it more prone to floods over the last decade. As Vasai and Virar areas saw flooding after heavy rainfall on Tuesday, urban planners pointed fingers at poor planning coupled with ignoring geographical and environmental factors while construction is carried out in the area. As the real estate prices in the Maximum City skyrocketed, suburbs adjoining Mumbai saw a spike in unchecked and poorly monitored construction activities for residential and commercial spaces in the last decade. The effect of the same is now visible in these cities, feel the experts.

"Rampant development" is one of the key factors for such flooding. "The drainage channels that take water from higher level to the sea level get blocked due to excessive construction and civic authorities do not clear them," she said. She pointed out, "Generally in development plan, such channels are not marked, or even topography is not considered, which becomes a major issue in all cases; not just Vasai-Virar area."

Nestled along the Arabian Sea on one side and the majestic Sahyadri ranges on the other sides, Vasai is a unique place in Maharashtra. In between passes the Western Railway line and the Mumbai-Ahmedabad Highway – with four busy station-localities on the way – Naigaum, Vasai, Nalasopara and Virar, over a stretch of nearly 10 kms, and thence into Palghar district that touches the Gujarat border.

In many respects, Vasai could well be one among the first planned modern cities that can claim to have a history and heritage of over 500 years, as well. Vasai's history is older than that of Bombay, now Mumbai, or rather, the modern history of Mumbai started from Vasai or Bassein.

Figure 2.1 Vasai Region Map

The city is located on the north bank of Vasai Creek, part of the estuary of the Ulhas River and settled next to the Tungareshwar Wildlife Sanctuary. Located 50-60 km from downtown Mumbai, Vasai has tehsil (or taluk), a Gram Panchayat, and there is also the Vasai-Virar City Municipal Corporation (VVCMC). And it is part of the Mumbai Metropolitan Region (MMR). The population – estimated to be 13-15 lakh – makes it the fastest growing Mumbai suburbs. There is a large floating population as well, and the pressure on infrastructure is high.

The main reason is that a lot of construction bodies have recently started dumping sand and debris in the wetland areas. We have a lot of lakes and small ponds in Vasai and Virar, which serve as important channels to carry rain water to the nullahs and the sea. Due to the unchecked dumping, there is no natural reservoir for the rain water, causing townships to choke. In fact, several residents have reclaimed these wetlands and built houses over them," Part of the Ulhas river, locally known as Sopara river, which starts from the hills in the eastern part of Vasai and ends in the Vasai creek, has also been encroached, and diverted The drainage culvert carrying water from the city is very narrow. It needs to be enlarged and two new culverts need to be built. But, the culvert is on railway land.

2.5.1 HISTORY

Vasai in Maharashtri Konkani and Marathi pronunciation: [ʋəsəi], (formerly and alternatively Mahratti; Bajipur,[5] English: Bassein; Portuguese: Baçaim), is a historical place and City near Mumbai (Bombay)'s western suburbs, located in Palghar district which was partitioned from the Thane district in 2014. It also forms a part of Vasai-Virar twin cities in the Konkan division of Maharashtra, India.

The Portuguese in Goa and Damaon built the Bassein Fort to defend their colony and participate in the lucrative spice trade and the silk route that converged in the area. Much of Portuguese Bombay and Bassein was seized by Marathas during the period of Peshva rule, after the Battle of Vasai in 1739.

This process is used to compensate for the sharp discontinuities that will inevitably occur between adjacent linear models at the leaves of the pruned trees. This is a particular problem for models constructed from a small number of training samples. Smoothing can be accomplished by producing linear models for each internal node, as well as for the leaves at the time the tree is built. Experiments show that smoothing substantially increases the accuracy of prediction. Details of Model tree can be seen in Quinlan (1992).

2.5.2 CLIMATIC CONDITION

Vasai has a tropical climate, specifically a tropical wet and dry climate (Aw) under the Köppen climate classification, with seven months of dryness and peak of rains in July. This moderate climate consists of high rainfall days and very few days of extreme temperatures. The cooler season from December to February is followed by the summer season from March to June. The period from June to about the end of September constitutes the south-west monsoon season, and October and November form the post-monsoon season. The driest days are in winter while the wettest days occur in July.

Between June and September, the south-west monsoon rains lash the region. Pre-monsoon showers are received in May. Occasionally, monsoon showers occur in October and November. The average total annual rainfall averages between 2,000 and 2,500 mm (79 and 98 in). Annually, over 80% of the total rainfall is experienced during June to October. Average humidity is 61-86%, making it a humid climate zone.

The temperature varies from 22–36 °C (72–97 °F). The average temperature is 26.6 °C (79.9 °F), and the average precipitation is 2,434 mm (95.8 in). The average minimum temperature is 22.5 °C (72.5 °F). The daily mean maximum temperature range from 28.4 to 33.4 °C (83.1 to 92.1 °F), while the daily mean minimum temperature ranges from 17.5 to 26.4 °C (63.5 to 79.5 °F). In winter, temperature ranges between 12–25 °C (54–77 °F) while summer temperature ranges from 36–41 °C (97–106 °F).

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Average high °C (°F)	28.4	29.2	31.2	32.7	33.4	32.1	29.6	29.4	29.7	32	31	30.2	30.7
	(83.1)	(84.6)	(88.2)	(90.9)	(92.1)	(89.8)	(85.3)	(84.9)	(85.5)	(90.0)	(88.0)	(86.4)	(87.4)
Daily mean °C (°F)	22.9	23.8	26.3	28.3	29.9	29.1	27.2	26.9	26.9	27.7	26.4	24.4	26.6
	(73.2)	(74.8)	(79.3)	(82.9)	(85.8)	(84.4)	(81.0)	(80.4)	(80.4)	(81.9)	(79.5)	(75.9)	(80.0)
Average low °C (°F)	17.5	18.4	21.4	24	26.4	26.1	24.9	24.5	24.2	23.5	20.9	18.6	22.5
	(63.5)	(65.1)	(70.5)	(75.0)	(79.5)	(79.0)	(76.8)	(76.1)	(75.6)	(74.3)	(69.6)	(65.5)	(72.5)
Average rainfall mm (inches)	0.3	0.4	0	0.1	11.3	493.1	840.7	585.2	341.4	89.3	9.9	1.6	2,434
	(0.0)	(0.0)	(0.0)	(0.0)	(0.4)	(19.4)	(33.1)	(23.0)	(13.4)	(3.5)	(0.4)	(0.1)	(95.8)

Table 2.1 Climate Data for Vasai

3. REESULTS & DISCUSSION

The Entire study zone is divided with considering geographical condition of this area and elevations. The measured depth details cross –section and all the length were compared with existing maps of storm network. In SewerGEMS various aspects were related and considered. All the required data for SewerGEMS is provided and outputs collected. Detail Results are shown in this chapter.

3.1 RESULTS & SEWEGEMS OUTPUT

Study Area is selected with the help of Google earth in collaboration with SewerGEMS which is shown in figure no 4.1

Figure 3.1

3.2.1 RESULTS OF CONDUIT TABLE IS SHOWN IN TABLE NO.

Label	Start Node	Stop Node	Length (Scaled) (m)	Elevation Ground Start (m)	Elevation Ground Stop (m)	Invert Start (m)	Invert Stop (m)	Manning's n	Dia (mm)	Slope (Calculated) (%)	Flow (L/s)	Velocity (m/s)	Cover (Avg.) (m)	Depth / Rise (m)
CO-10	MH2-20-4	MH2-20-3	28.7	19.98	20.247	17.74	17.654	0.011	300	0.300	31.62	0.45	2.117	100
PIPE-49(2)	CB2-41-4	IN2-41-3	85.39	18.91	18.957	16.738	16.482	0.011	300	0.300	0.55	0.01	2.024	100
PIPE-66(2)	CB2-41-2	IN2-41-1	24.23	18.989	18.927	16.423	16.35	0.011	300	0.301	8.75	0.12	2.272	100
PIPE-453(2)	CB1-11-6-2	IN1-11-6-1	45.02	21.597	21.266	19.582	19.447	0.011	300	0.300	43.12	0.99	1.617	59
PIPE-375(2)	IN2-16-1A-5	IN2-16-1A-4	27.58	19.123	19.01	17.232	17.149	0.011	300	0.300	18.17	0.26	1.576	100
CO-12	MH1-9-3	MH1-9-2	83.69	21.273	21.776	18.726	18.475	0.011	300	0.300	6.43	0.57	2.624	21.8
CO-13(1)	MH2-6-9	MH2-6-8	98.69	19.214	19.317	16.312	15.905	0.012	400	0.412	38.45	0.31	2.757	100
CO-13(2)	MH2-6-8	MH2-6-7	72.77	19.317	18.957	15.905	15.604	0.012	400	0.414	38.54	0.31	2.983	100

CO-15	MH2-6-7-2	MH2-6-7-1	35.47	18.87	18.976	16.071	15.964	0.011	300	0.300	56.38	0.80	2.606	100
CO-16	MH2-41	MH2-40	76.8	18.903	19.374	16.3	16.07	0.011	300	0.299	2.93	0.04	2.654	100
PIPE-581	IN2-15-7-1	MH2-15-7	5.61	19.006	18.887	16.541	16.524	0.012	400	0.303	35.35	0.28	2.014	100
CO-17	MH2-15-7	MH2-15-6	94.95	18.887	19.378	16.524	16.237	0.012	400	0.302	32.06	0.26	2.352	100
CO-19	MH2-15-1	MH2-15	117.93	19.156	19.287	14.656	14.55	0.012	600	0.090	99.57	0.35	4.018	100

3.2.2 Results of Manhole table is shown in figure 3.2

Label	Elevation Ground (m)	Elevation Invert (m)	Depth Structure (m)	Flow (Total Out) (L/s)
MH-79	20.379	15.64	4.74	21.39
MH1-1	20.127	15.73	4.4	22.09
MH1-11-1	22.164	18.255	3.91	78.7
MH1-11-2	22.069	18.39	3.68	85.13
MH1-11-3	22.372	18.573	3.8	70.58
MH1-11-4	22.117	18.802	3.32	70.46
MH1-11-5	21.996	19.016	2.98	65.6
MH1-11-6	21.401	19.373	2.03	54.56
MH1-9-1	21.577	18.34	3.24	8.31
MH1-9-2	21.776	18.475	3.3	9.33
MH1-9-3	21.273	18.726	2.55	6.86
MH2-1	20.346	13.458	6.89	158.95
MH2-10	19.338	13.795	5.54	135.94
MH2-11	19.185	13.808	5.38	138.33
MH2-12	19.387	13.83	5.56	139.07
MH2-13	19.59	13.847	5.74	141.61
MH2-14	19.293	13.895	5.4	143.84
MH2-14-1	19.175	15.872	3.3	59.71
MH2-14-2	18.874	16.163	2.71	37.39
MH2-15	19.287	13.944	5.34	140
MH2-15-1	19.156	14.656	4.5	99.59
MH2-15-1-1	18.921	15.614	3.31	61.59
MH2-15-1-2	19.012	15.908	3.1	54.13

Table 3.2 Manhole Table

3.2.3 Results of Outfall table is shown in figure 3.3

Label	Elevation (Ground) (m)	Elevation (Invert) (m)	Flow (Total Out) (L/s)	Hydraulic Grade (m)	Population (System Sanitary) (Capita)
MH1-11	22.2	18.242	78.18	18.457	(N/A)
MH1-9	21.58	18.324	8.23	18.389	(N/A)
OF-1	20.361	15.61	21.38	18	(N/A)
OF-2	20	13.45	158.95	18.147	(N/A)

Table 3.3 Outfall Table

3.2.3: Figure 3.4 shows the Main line profile.

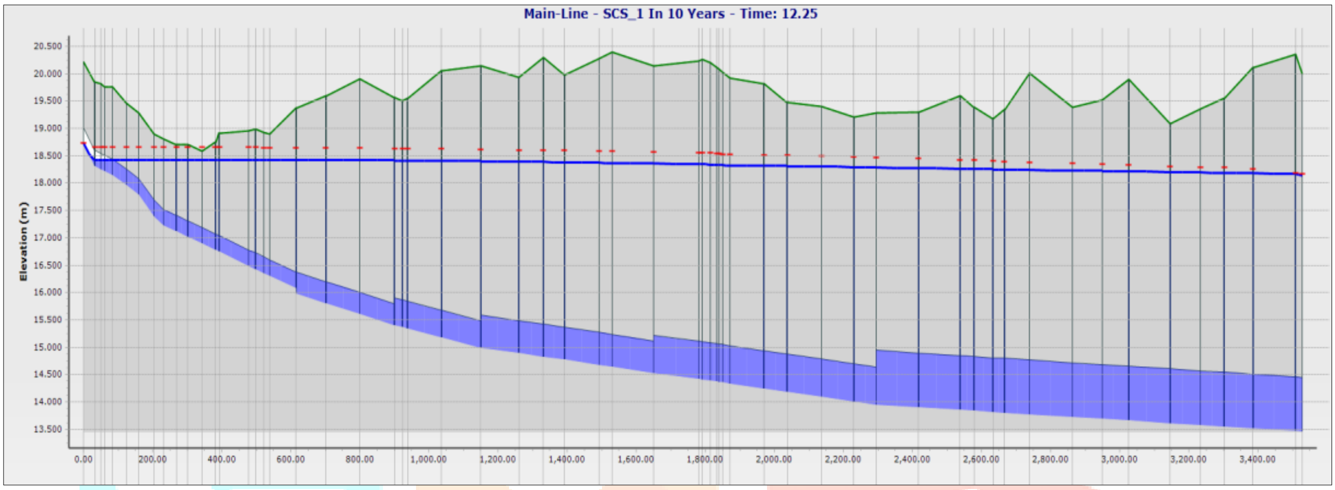

Figure 3.4 Main line Profile

4. CONCLUSION

Vasai area is facing storm water drainage problem due to increasing population and infrastructural activities. The inundation of the study area is mainly due to the blockage of the drains in different points; therefore periodical maintenance of existing drains is essential. Google earth is software in which we can easily find area, perimeter and elevation different. Rational method and using sewer gem software has been successfully used for the estimation of storm wise discharge in Vasai area. This study can be helpful to design storm drainage pipe at other places.

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