Design, Modelling, and Analysis of Floodwater Management and its Purification for Hindamata and MPT Sewri Mumbai

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Abstract: Almost all of the flooding which seriously disrupts the communication and the activity of the Mumbai city, with increasing regularity, are located within the large fill area bounded by the old islands. Not only the ground levels are low but the island of hard basalt rock form natural boundaries to the drainage areas. The low-lying topography and meteorological and hydrological conditions of the Hindamata make it vulnerable to floods and stormwater. Various measures have been conducted for the mitigation of flood and inundation damages, but the drainage problem is still one of the major tasks. The flooding inflicted serious damage over the past half century; these floods have become both more extensive and more severe as experienced in recent storms. Development in the suburbs has taken place very rapidly in recent years. The drainage system is large of open 'nalas' based on the original natural drainage channels. The system has not in all places been extended symmetrically to keep pace with development and indeed in many places development has encroached into the drainage channel thus reducing their capacity as the flows they receive have increased. To address the problem, different engineering works were utilized to provide flood protection and reduce flood damages. One alternative flood control measure is the provision of underground storage tanks for the reduction of the peak discharge of floods. Based on the hydrological, topographic, and flooding information gathered from government institutions, an underground storage tank facility with a new drain network is proposed as an alternative flood control measure in the study area to reduce the flood level and identify the volume of the proposed storage tank. The conceptual simplified model for underground storage tank simulation model has been used to simulate the operation of the tanks and to evaluate the performance of the proposed structure. Though there are many flooding spots in Mumbai, the Hindamata flooding spot is intensively affected. As the major traffic carrying road passes through this an area, it gives a serious call to look into this matter. The project deals with finding a proper solution that can be adopted for solving the flooding scenario of the Hindamata flooding spot of F/South ward, Mumbai.

I. Introduction

Water is one of the basic needs of living beings which is very essential for life. But sometimes nature strikes and makes the living lives harder by making the pure water scarce and by flooding. Though the major causes of floods are all-natural but human activities such as blocking of channels or aggravation of drainage channels, improper land use, deforestation in headwater regions, etc. also majorly contribute to the flood. We cannot control nature and repairing the mistakes of humans would take years or even decades. But there arises an emergency of preventing the rainwater to flood the roads at least in the economical cities.

In this paper, we have found a solution through which we can reduce the flood water by creating an effective system in targeted areas that are usually prone to flood (Here targeted areas are Hindamata, Worli, Sion, and Wadala in Mumbai as Mumbai is an economical city and gets adversely affected by food every year). The problem does not come to an end. As we know that during floods the water which is usually supplied to our houses is mostly muddy and undrinkable while in some areas the water is unavailable. The water which is supplied muddy can be purified at home with many methods but the problem arises for those who do not get the water itself. One of the major reasons for this is the industries which take up the water supplied to the people of the city for their use. So there arises a need for drinking water as well. Purifying the flood water comes up first in our mind since we are reducing the floodwater. But purifying the flood water for common people becomes rather difficult than purifying it to an extent where it can be supplied to the industries for various processes such as keeping the machine parts cool by using water as a coolant, using it for spraying in the green areas of the industries, etc. This supply chain of purified flood water to the industries will reduce the scarcity of water for common people to a certain extent.

Flooding due to rainfall is a severe problem for Mumbai City which is inundated for several hours mainly due to the drainage congestion. Mumbai metropolitan area has experienced waterlogging for the last couple of years. Even a little rain causes a serious problem for certain areas so that parts of Mumbai are inundated for several days. The water depth in some of the areas may be as much as 1-1.2m, which creates large infrastructure problems for the city and a huge economical loss in production for the city together with large damages to existing property and goods. Rainfall-induced flooding, meaning floods in Mumbai City caused by local rainfall occurs in the built-up areas of the city several times a year on various scales. Inadequate existing drainage channels and their improper operation and management mainly cause these floods. The severe waterlogging occurred in June and July of 2005. Some important street intersections were inundated and many of the important business and government offices of the city suffered the most from the flooding. Flood is in itself abbreviated – **Finally, Loss Occurred after Opportunities Denied**.

Flood is influenced by various factors rainfall, river flow, and tidal-surge, topography, a measure of flood control, and alterations due to infrastructural. Some floods grow and discharge gradually, while others can develop in just a few minutes and recede quickly such as a flash flood. Flood events are happening for the last many years and centuries. Urban flooding is caused by heavy rainfall and overwhelming drainage capacity. It already has large economic and social impacts. These are very likely to increase if no changes are made to the management of urban drainage. Urban floods are a great disturbance of daily life in the city. Roads can be blocked; people can't go to work or schools and economic damages are also high. Thus, this paper does not focus only on the reduction of the flood water but also on its purification.

II. Objectives of System

- The challenges inspired us a lot and made us think to generate mechanisms for the reduction and purification of floodwater.
- To reduce the floodwater.
- To purify the floodwater.
- To supply the flood water to industries.
- To supply the rejected water from purifiers to perform activities such as washing vehicles, cleaning roads, etc.
- Eco-friendly system that does not produce any pollution.
- Converting the wastewater into a useful one.
- These prototypes can be readily manufactured and put to use in all flood-prone areas.
- Better and less complicated way to reduce and purify the floodwater.

III. Methodology

1. **Study of Current Situation**
   Many highly populated cities in the developing countries that are located on the coast, for example, Mumbai is highly susceptible to urban flooding one of the main reasons cited for this is the fast development going on in various areas i.e., rapid urbanization which causes changes in landscape owing to the construction of urban infrastructure and changes in runoff conveyance network
2. **Topographical Survey**
   Urbanization significantly changes the characteristics of a catchment as natural areas are transformed into impervious surfaces such as roads, roofs, and parking lots. The increased fraction of impervious surfaces leads to changes to the stormwater runoff characteristics, whilst a variety of anthropogenic activities common to urban areas generate a range of pollutants such as nutrients, solids, and organic matter.
   Hindamata is low laying saucer-shaped area. From MMGS road to Hindamata, the drains are flowing under

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gravity due to a downward slope. From Hindamata to P. Guruji road the drains are flowing backward which causes accumulation of stormwater over the roads which cause major serious traffic.

3. **Hydrological Survey**

   The occurrence of the extreme rain event on 26th July 2005 subsequently elicited the inadequacy of having only two rainfall-recording weather observatories (at Colaba and Santacruz) set up by IMD. Data obtained from IMD and BMC (in mm/day), by studying this data we plotted an average rainfall intensity graph. (Source IMD and BMC).

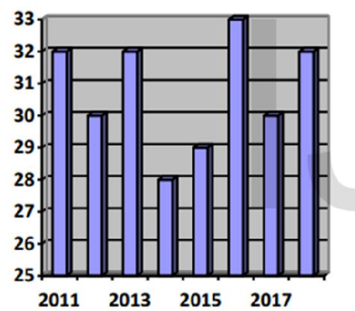

Figure 1: Average Rainfall Intensity Graph
(Source IMD and BMC)

Considering average rainfall intensity of 30 mm/hr.

Drainage Survey

The following figure shows drain detail at Hindamata chowk

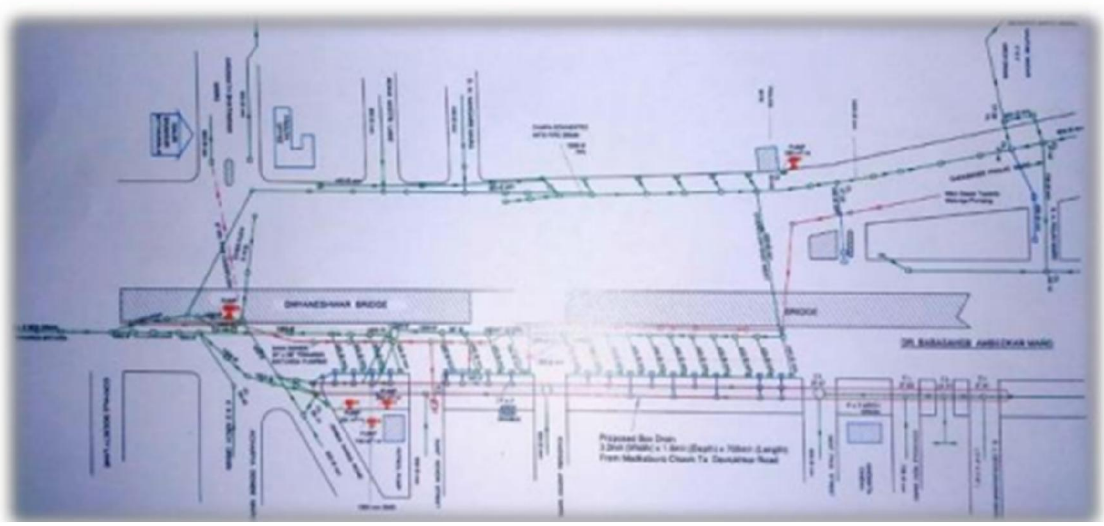

Figure 2: Drain Detail at Hindamata Chowk

Analysis of Current Situation

According to our analysis, we came to know that the accumulation of surplus water on the road surface is because of its saucer shape topography. In the graph shown below, the depth of accumulated water varies from year to year (1995 to 2010).

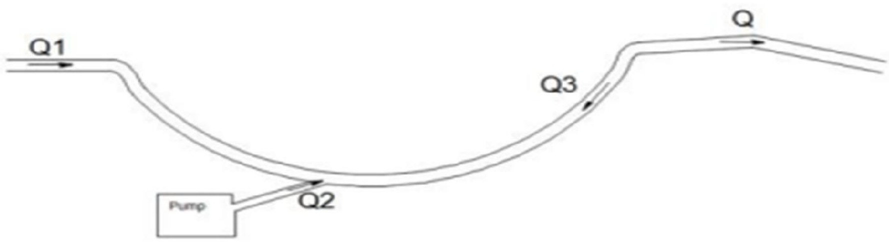

Figure 3: Saucer Shaped Area of Hindamata Chowk

By analyzing the current situation, we observed that the drain network up to Hindamata is flowing under gravity. A submersible pump was installed at Hindamata Chowk of capacity 300 m^3 /hr. to flow water through a drain at a higher velocity. There is a continuous rise in slope from Hindamata to Parmar Guruji Marg, due to this slope water flows in reverse direction i.e., towards Hindamata which decreases net discharge flowing through the existing drain network.

Let,

Q1 be the discharge through the existing drain network under gravity.

Q2 be the discharge due to a submersible pump installed at Hindamata Chowk.

Q3 is the discharge through the existing drain network due to the upward slope.

Q be the net discharge flowing through the existing drain.

Q = (Q1 + Q2) - Q3

Forward Discharge (Q1+Q2) = 3.15 m3 /sec
Backward discharge (Q3) = 2.77 m3 /sec
Therefore, the capacity of the existing drain
Net Discharge (Q) = 0.38 m3 /sec = 1350 m3 /hr.
Net velocity = 0.15 m/sec
Approximate calculation of the volume of waterlogging:
According to available data,
Catchment area :1.017km2
Average rainfall intensity: 30mm/hr.
Therefore, Total volume of water on the catchment=1.017x106 x30x10-3 = 30510m3 /hr.
Assuming 2.5mm/hr Infiltration (GREEN-AMPT parameter)
Runoff water =30510 - 2542=27968 m3 /hr
Total surplus water = 27968-1350 = 26618 m3 /hr.
Proposing Solutions for Flooding

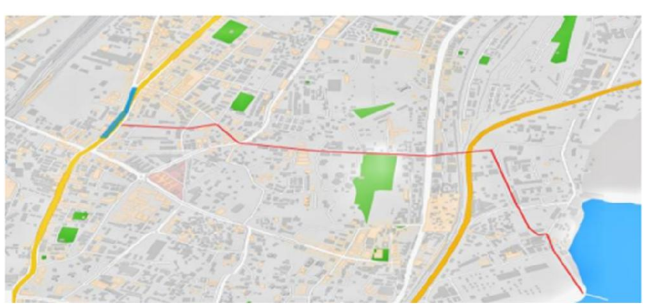

Figure.4: Proposed Drain Network

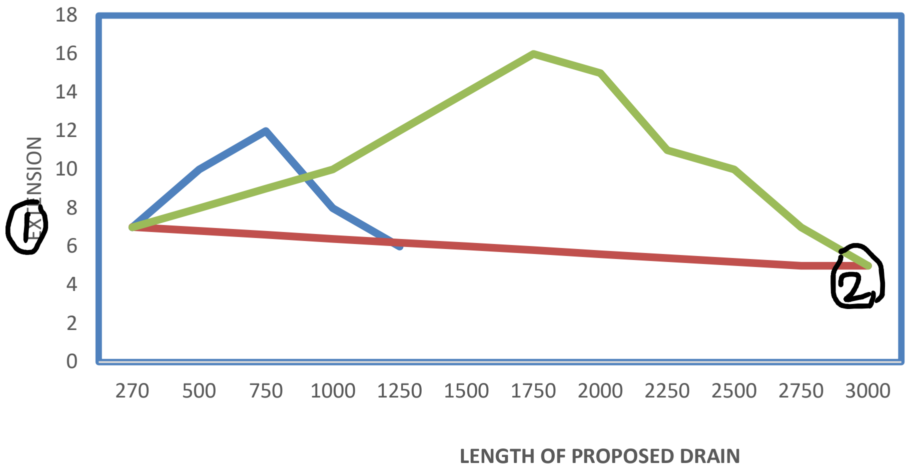

Figure 5: Length of Proposed Drain

1. Hindamata
2. MPT Sewri

Design of Main Drain Network

Diameter of pipe: 1.8 m

Length of drain: 2.8 km

The head difference available for the proposed drain is approximately 3m.

Velocity by Manning's Equation V = (1/n) *(D/4) 2/3 *(S) ½

Discharge = Q = 3.26 m3 /sec = 11726 m^3 /hr.

Total surplus water remaining after proposed drain = 26618– 11726 = 14892 m/hr

Underground Storage Tanks

Underground storage tanks are provided below public grounds or parks of sufficient depth. Storage tanks collect and store Stormwater runoff during a storm event, then release it at controlled rates to the downstream drainage system, thereby attenuating peak discharge rates from the site.

Design of Proposed Storage Tank

Here we are going to design a storage tank below the public garden so that it cannot affect the present scenario under any roads in the city from the current situation in our study area few grounds are available some of them are listed below with their area:

1. Naigaon parade ground: Area: 6260 m^2
   Assuming 3 m depth for our proposed storage tank.
   Volume =18780 m^3
2. Sadakant Dhavan ground: Area: 4180 m^2
   Assuming 3 m depth for our proposed storage tank
   Volume =12540 m^3
   Total storage tank capacity= (Volume of 1) +(Volume of 2) = 18780 + 12540 = 31320 m^3

For maintaining flow in both tanks, a submersible pump of 6 m^3 /sec. (pumps are provided for both the tank).
This study will focus on the waterborne pathogenic microorganism covering the types, source of the microorganism, size, and the disease brought by them. It is important to identify the waterborne pathogenic for facilitating the process of filtration and sanitation and also to avoid the infections because the presence can be harmful to the user if not removed.

To ensure the water is clean and safe from the waterborne pathogenic, the filtration system needs to have a pore size below 20 to 25 nm to ensure all the pathogens including the Norovirus are clear from the water before entering the body for drinking and cooking.

Floodwater Quality

Floods could influence water quantity by affecting quality in one of two ways. Floods will either increase contaminants and sediments from urban and agricultural runoff during high rainfall causing a decrease in water quality [7-9]. The drinking water supply will be affected by contamination as the result of the extreme water caused by the weather events [10]. Everybody knows that floodwater is full of contaminants and carries animal waste from fields and forests and it has been shown the bacterial count in floodwater is extremely high. Even though it knows, that almost victims use the water for daily use because of the lack of clean water. Once it rises, it will flow to structures and at the same time bring the disease to an organism. That's why the quality of water produced by the floodwater is the worst one (2013). As can see, there are two and a half billion people suffer from insufficient access to improved sanitation of water, and each year, the world awakened with more than 1.5 million children dying from diarrhea diseases. Even hitting the water can get diseases, rather than drinking the floodwater.

Other than that, the flood water or any surrounding area is not safe unless the local or state authorities have been declared it safe to use especially the clean water tank because of worry if it also contaminated by flood water. In case no safe water for essential use advised boiling the water for at least 10 minutes to ensure the quality of water. Also, be alert to chemically contaminated floodwater at the industrial site to avoid the chemicals on the body.

Wastewater Treatment

Some treatment has been researched or conducted to purify the floodwater into clean water and safe for drinking or cooking. As been mention above, there are many bacteria, viruses, or parasites in flood water that give dangerous diseases if not carefully using the water. Some nations which expose to flood disaster season, have to get ready with the purification water system to avoid any disease to the victim. One of the treatments is electrolysis which oxygen ions was used to disinfect water, and hydroxyl and hydronium are produced to move the liquid (floodwater) from one electrode to another. They will react with it chemically to eliminate the bacteria and turns the floodwater into clean water. Another treatment that has been introduced in Indonesia which faced a lot of potential flood disasters places with clean water problems is MSWT, Mobile Surface Water Treatment. It is such a modular process with a combination of existing technologies and pieces of literature that comes in a compact design and is equipped with mobile features for easier operation. The technology used is microfiltration (MF) or ultrafiltration (UF) for filtration and followed a by UV lamp for of disinfection the microorganism. Any mixture of chemical substances utilized in the MSWT. Once have the advantages in otherwise it capacity only around 22kg weight and ideal for the small quantity.

Based on the treatment above, electrolysis and MSWT have the potential to kill the microorganism also waterborne pathogens because the tool used is capable of removing all the bacteria until the smallest one. Electrolysis is one of the experimental methods to disinfect flood water by using the power supply to generate hydroxyl ions during the container of floodwater is subjected to the electrode plated with nickel. That ion will react chemically to eliminate the bacteria while across the floodwater.

In MSWT, filtration is used level by level. Starting with MF which can filter the bacteria with a pore size of 0.1 – 10 µm and only part of the viral contamination is caught up in the process, followed by UF which can remove the particles of 0.001 – 0.1 µm from fluids. The final level which UV light as a system that exposes water to light at just the right wavelength for killing microbes. It's a way to kill bacteria, viruses, fungi, protozoans, and cysts that may be present in the water. The effectiveness of UV treatment depends on the strength and intensity of the light, the amount of time the light shines through the water, and the bill of particles present in the water.

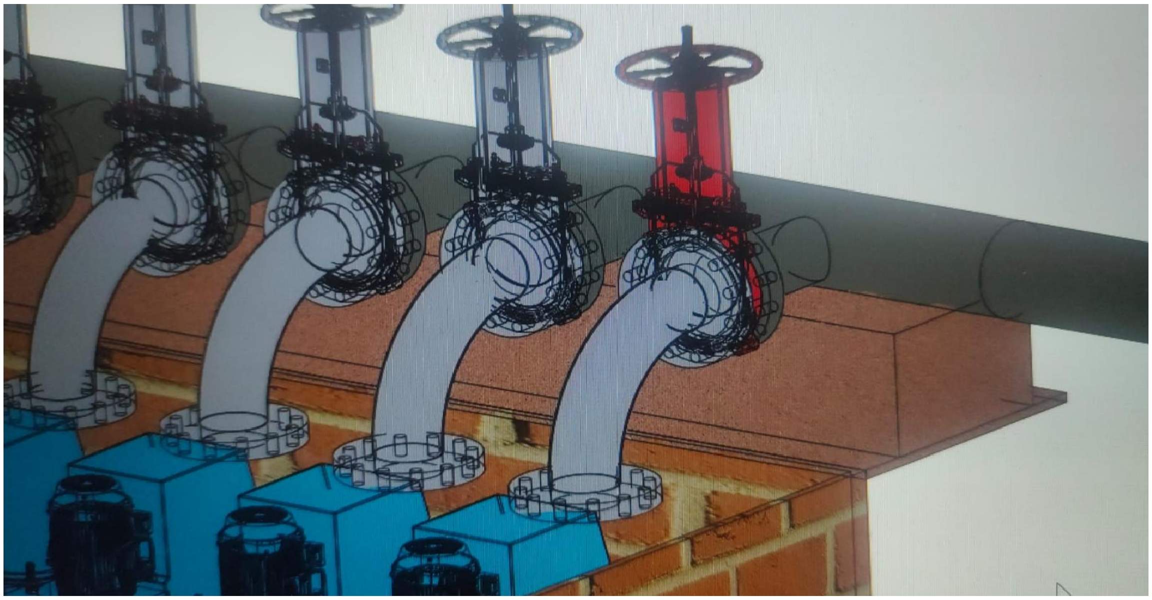

Figure 6: Wireframe Model: Hindamata Tank Assembly

The dimension of the delivery pipe of the submersible slurry pump is of diameter 600 mm while that for the main pipe which is coloured dark grey is of diameter 900 mm.

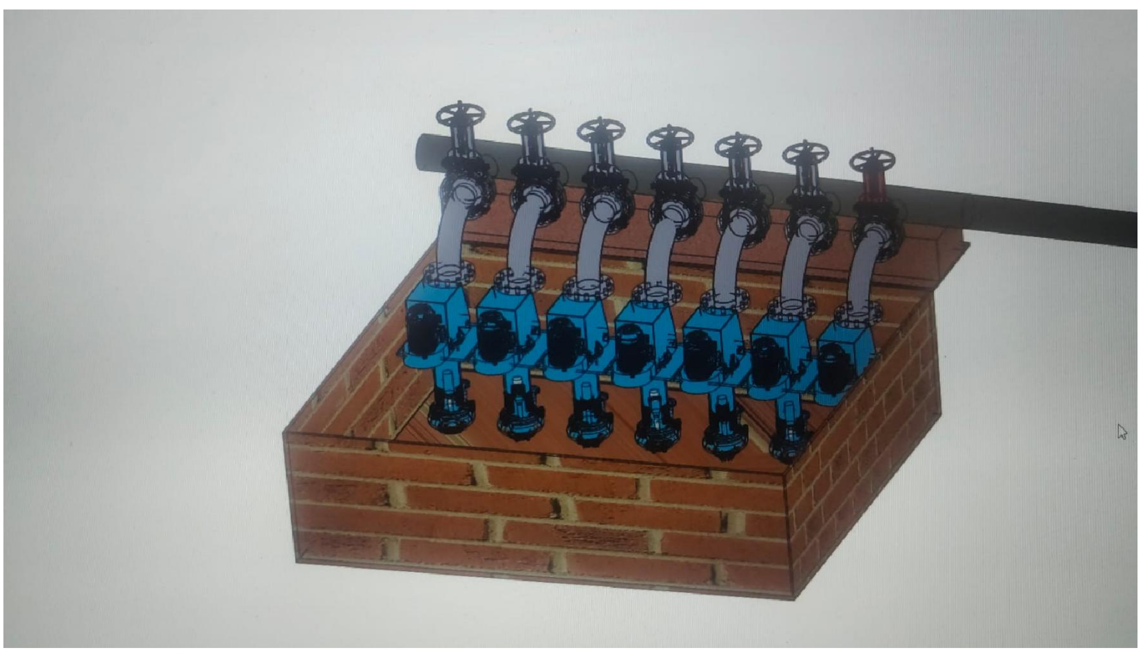

Figure 7: Hindamata Tank Assembly

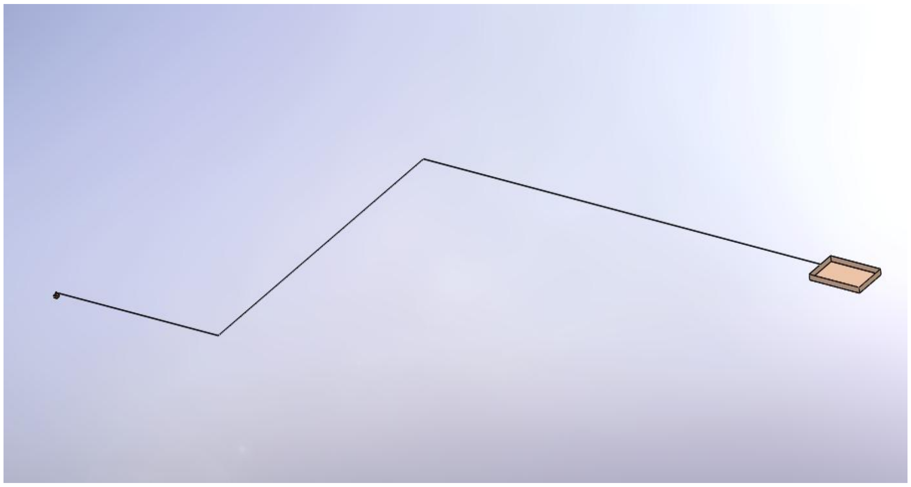

Figure 8: Final 3D Assembly

The Hindamata Sump is on the left while the P.M. Garden underground storage tank is on the right. The total distance from Hindamata Sump to P.M. Garden underground storage tank is 3 km.

IV. Solid Work Analysis

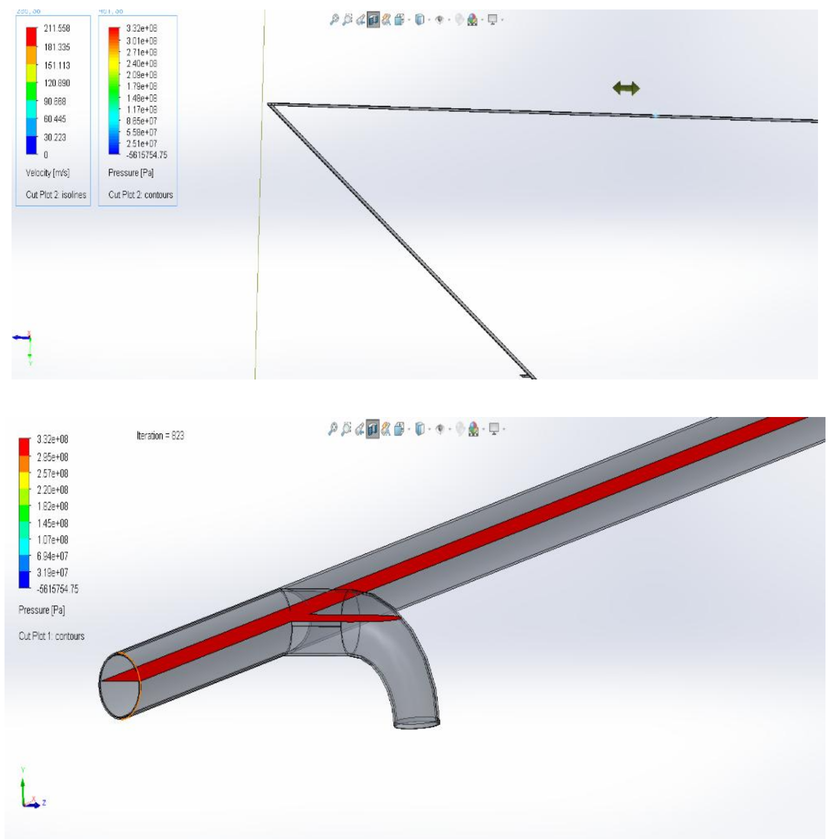

Figure 9: Pressure Analysis at the Inlet of Hindmata Sump

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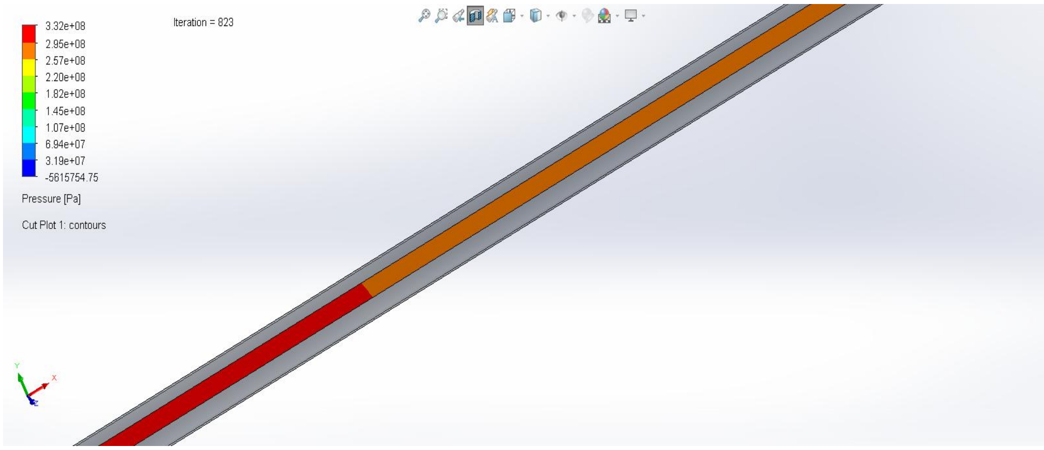

Figure 10: Pressure Analysis of the Pipe at a Section Ahead of the Inlet

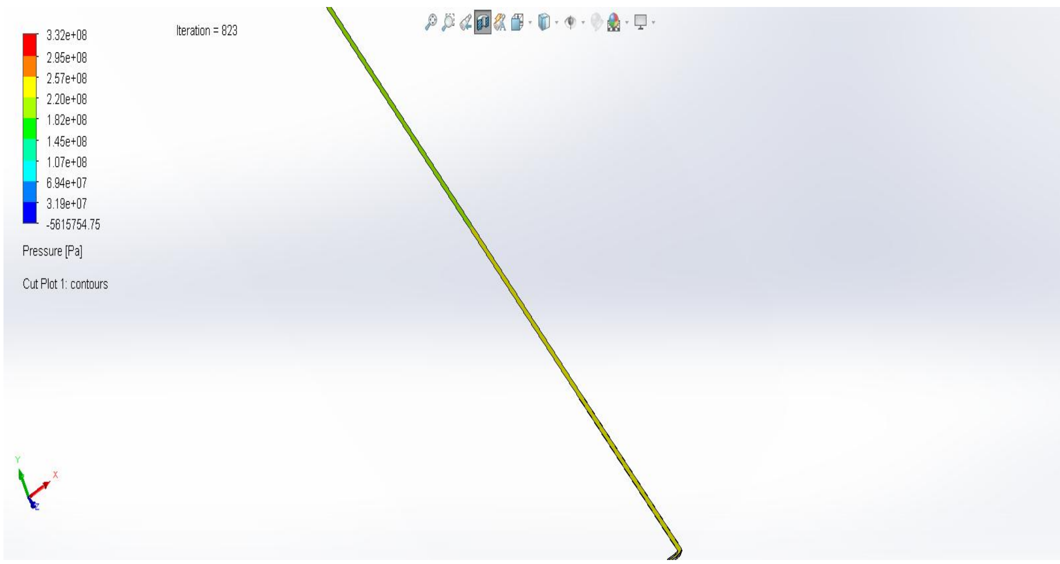

Figure 11: Pressure Analysis of the Pipe After the First Elbow

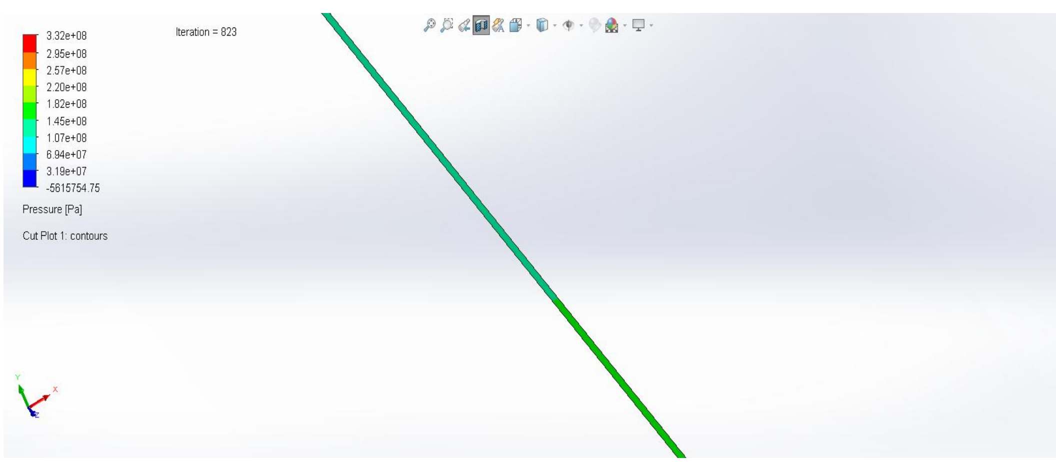

Figure 12: Pressure Analysis of the Pipe After the First Elbow

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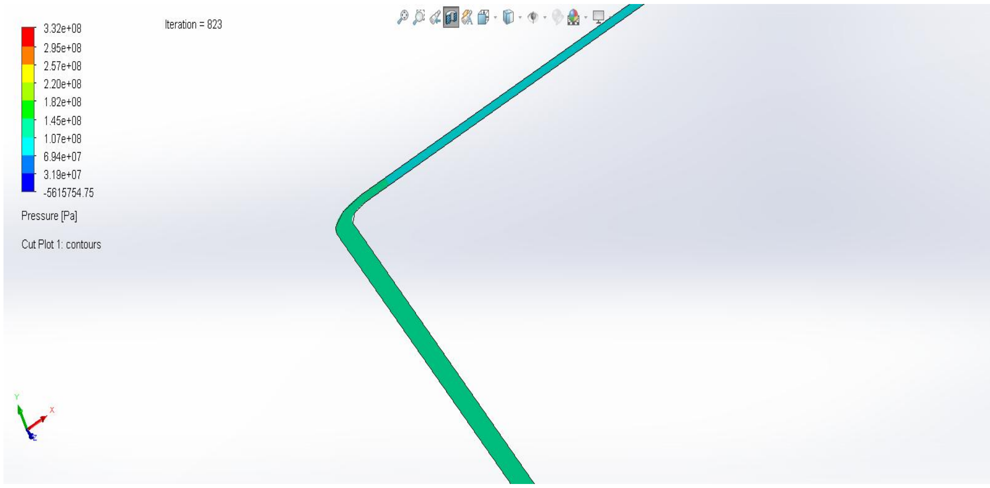

Figure 13: Pressure Analysis of the Second Elbow

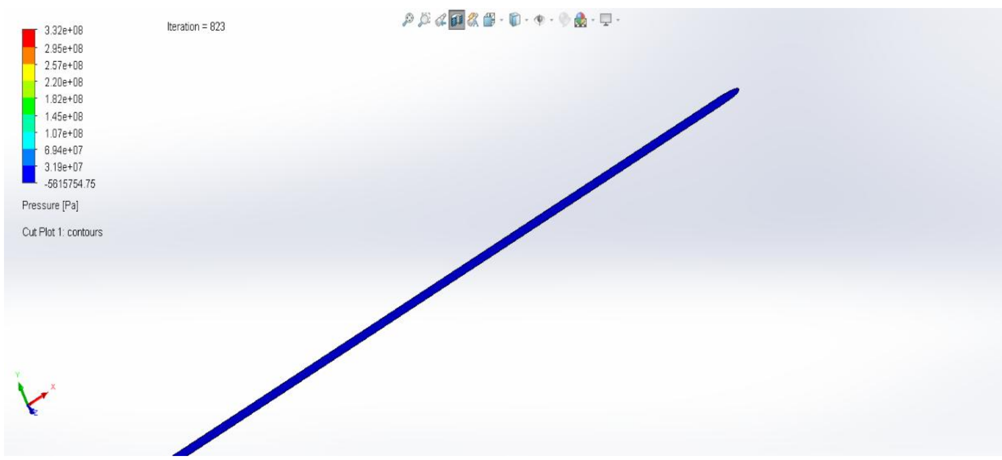

Figure 14: Pressure Analysis of the Pipe After the Second Elbow at the Outlet (INLET OF P.M. GARDEN UNDERGROUND STORAGE TANK)

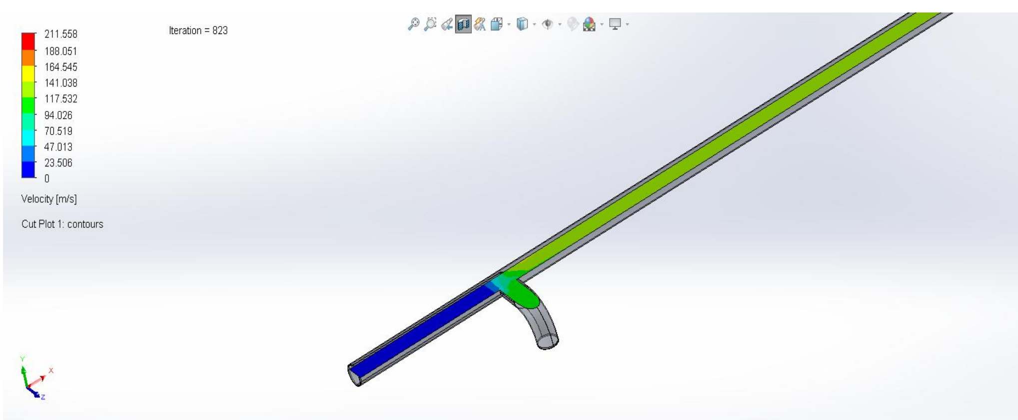

Figure 15 [1]: Velocity Analysis at the Inlet of Hindmata Sump

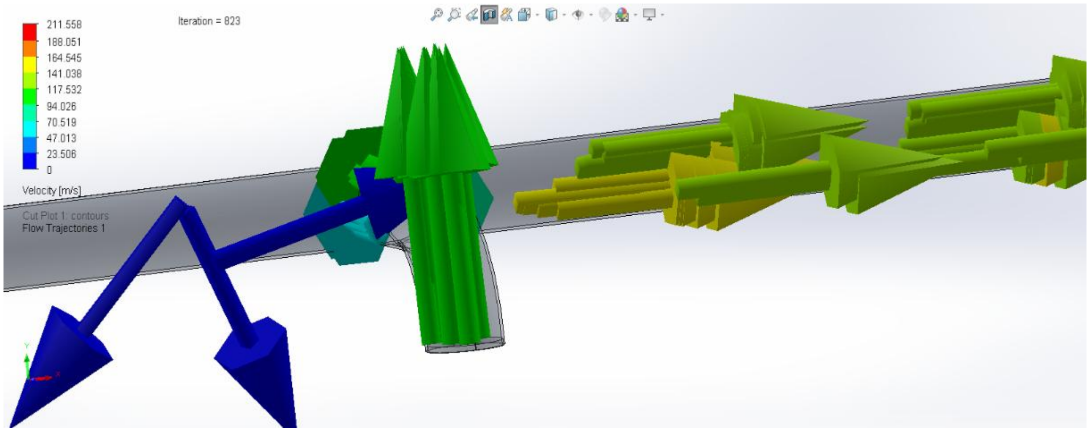

Figure 15 [2]: Velocity Analysis at the Inlet of Hindmata Sump

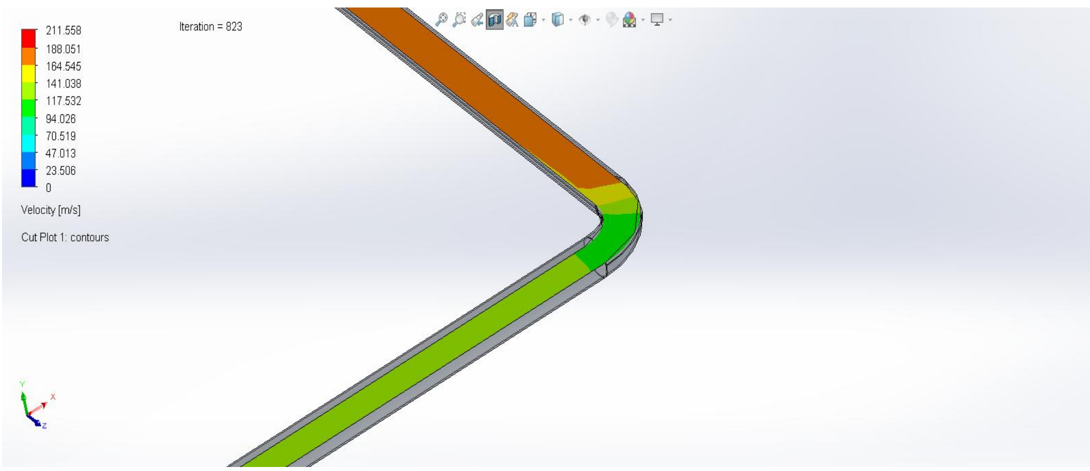

Figure 16 [3]: Velocity Analysis of the Pipe at the First Elbow

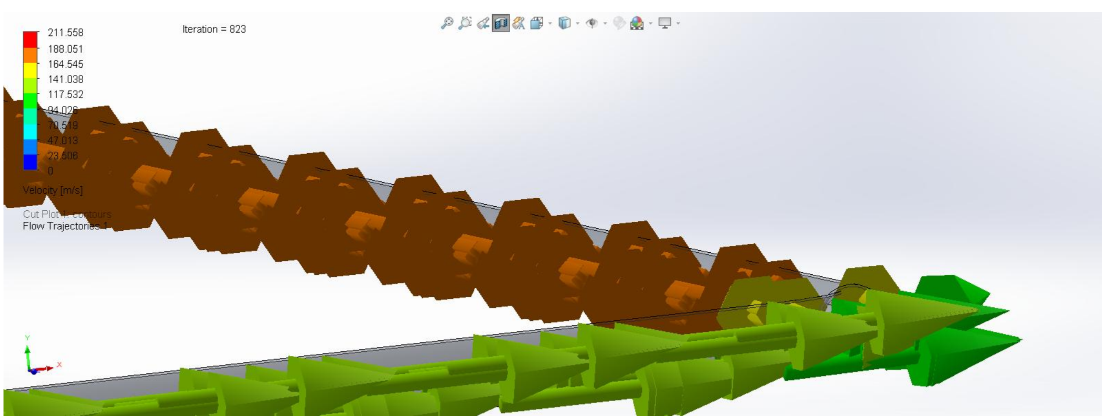

Figure 16 [4]: Velocity Analysis of the Pipe at the First Elbow

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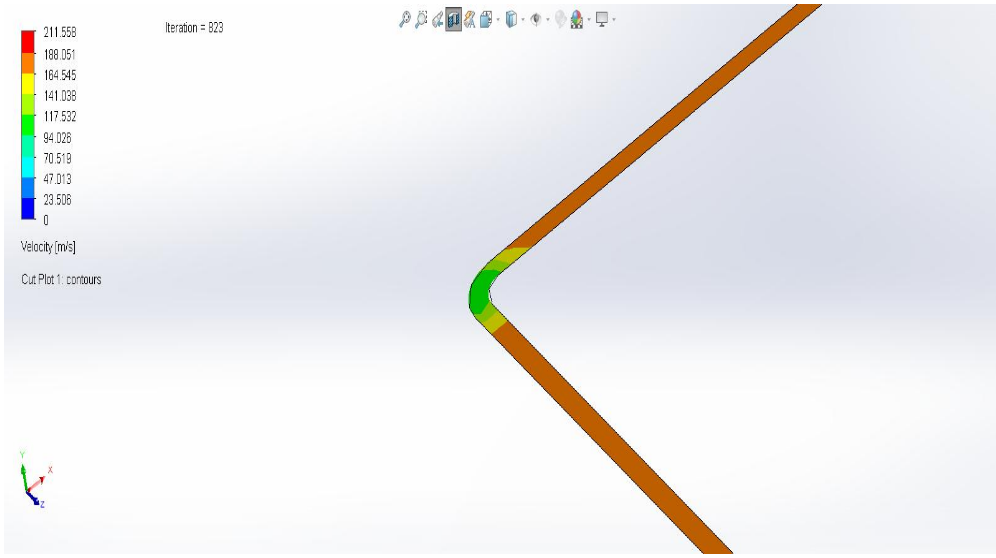

Figure 17 [5]: Velocity Analysis of the Pipe at the Second Elbow

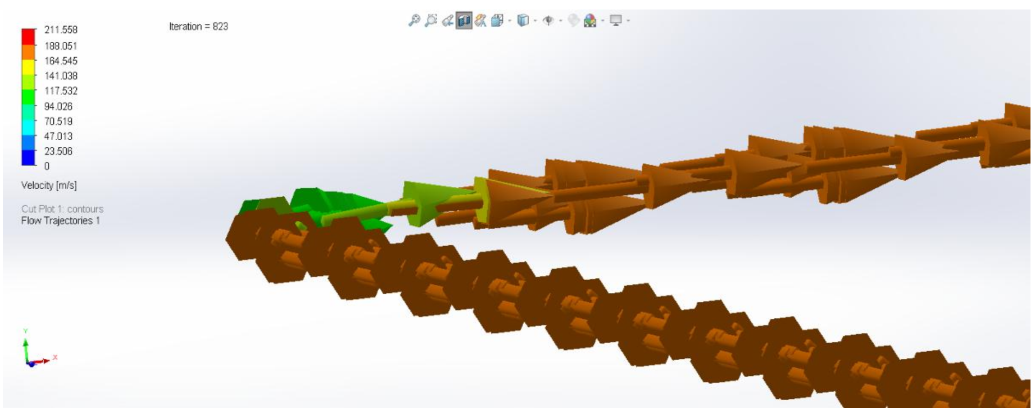

Figure 17 [6]: Velocity Analysis of the Pipe at the Second Elbow

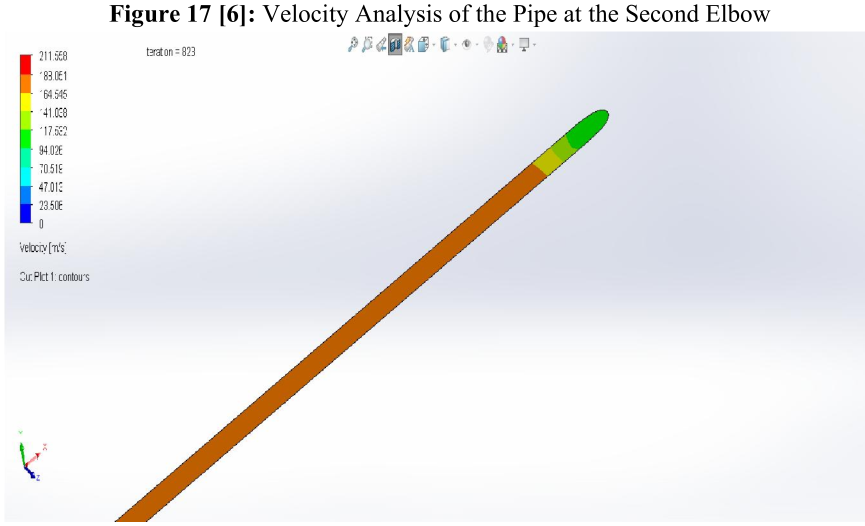

Figure 18 [7]: Velocity Analysis of the Pipe at the Outlet

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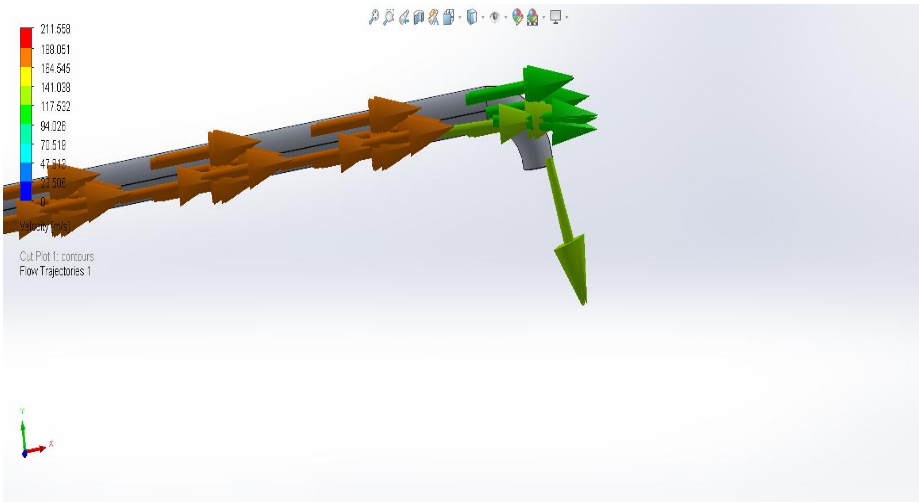


Figure 18 [8]: Velocity Analysis of the Pipe at the Outlet

V. Analysis Calculation

Considering the diameter of the pipe to be 900 mm throughout the length of 3 km. From the above analysis, taking the pressure and the velocity at the outlet as 3 x 10^7 Pa and 188.051 m/sec.

Volume of pipe = $\pi \times r^2 \times l$

= $\pi \times 0.45^2 \times 3000$

= 1908.52 m^3

Area of pipe = $\pi \times l \times d$

= $\pi \times 3000 \times 0.9$

= 8482.3 m^2

Discharge of flood water through pipe at P.M. Garden = A x v

= 8482.3 x 188.051

= 1.6 x 10^6 m^3/sec

Time to carry flood water from Hindamata to P.M. Garden = Discharge / Volume

= 1.6 x 10^6 / 1908.52

= 838.34 seconds

= 14 min (approx)

VI. Purification

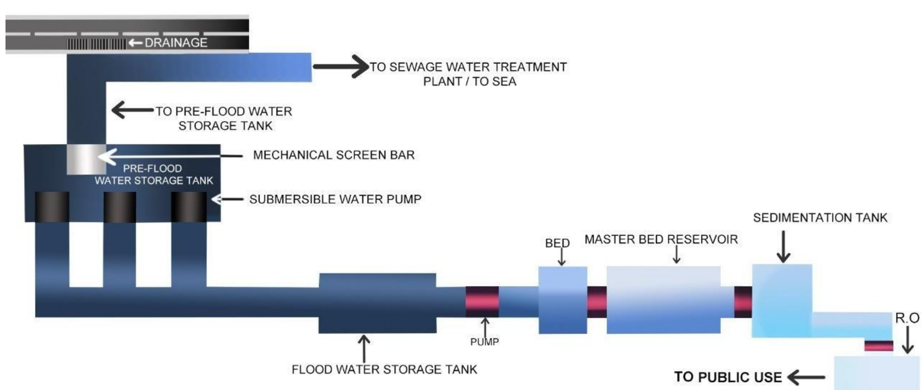


Figure 19: Flow Diagram of Floodwater Reduction

Filterer Consists of: -

- **Pre-Treatment Pressure Sand Filter in bed-** It purifies physical impurities.
- **Activated Carbon Filter in bed-** It improves the taste of the water and removes bad odor.
- **Sedimentation Tank-** Here the flood water
- **FRP Membrane Pressure Vessels-** It is used in purifying mainly brackish and salty water.
- **TDS Controller-** It maintains the TDS of the water.
- **RO Technology-**It has a membrane of pore size 0.0001 micron with auto-flush to remove the wastewater.
- The membrane filters out most of the harmful viruses and bacteria like salmonella, shigella, Vibro cholera, etc.
- **Micron Cartridge Filter-** It filters water to a designated micron rating.
- **High-Pressure Pump.**
- **Alkaline Cartridge-** It makes the water perfectly alkaline (Maintains the Ph of the water)

The purified water then goes into a **Filtered Water Tank** and the wastewater which has been auto-flushed from the RO process is stored in **Waste Water Storage Tank**.

The filtered water is then used for cooking, drinking, and other household activities while the wastewater is used in flushing toilets.

The filtered water can also be used for industrial purposes which might save the water of common people which industries use for green zones.

The overflow of the wastewater is then passed on to the Sewage Water Treatment Plant or directly into the sea.

VI. Conclusion and Result

After adequate research and experiments, we come up with the conclusion that this project will lead to a better future for countries since it is cheap and it can reduce the flood water. By studying and analyzing the current situation we are proposing the following solutions:

1. The main drain of diameter (1.8m) from Hindamata chowk to Sewer outfall which is about 2.8km.
2. The storage tanks can store the surplus water for some duration of time during heavy rainfall. A submersible pump of 6 m3 /sec is to be provided to transfer surplus water into proposed storage tanks.
3. A sub drains of diameter (1.2m) from Hindamata chowk to storage tanks to transfer surplus water.

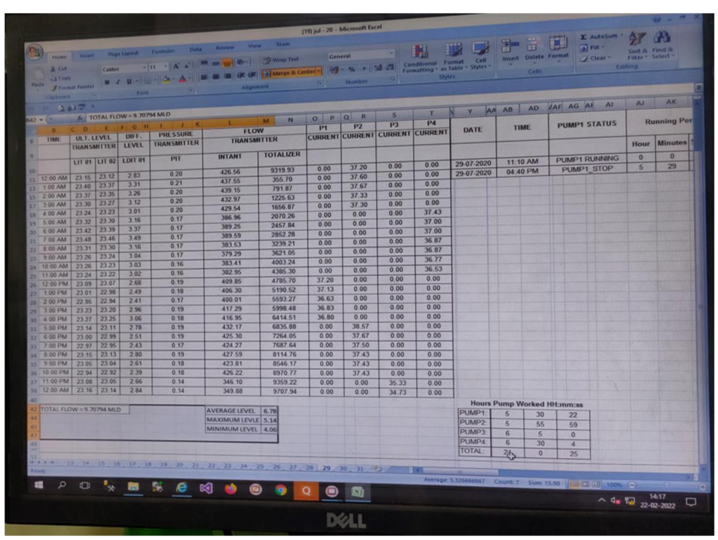
If rainfall intensity of 30mm/hr for 4hrs	The volume of surplus water at Hindamata Chowk (m^3)
Before proposing solution	1,11,872
After proposing solution	28,248

4. Results of the flood water samples from the laboratory.

WATERBORNE PATHOGENS (BACTERIA)	SOURCE	SIZE	EFFECTS
Salmonella	Fecal-oral route and occasionally found in groundwater Primarily foodborne (beef, poultry, milk, eggs), but also transmitted by water.	0.7 -1.5 µm in width and the length is 2-5 µm.	Typhoid and diarrheal.
Shigella	Human feces, transmitted by contaminated food, water, recreation	They are short, gram-negative rods, about 2-4 µm in length x 0.6µm in breadth	Gastroenteritis, dysentery, reactive arthritis. diarrheal (often bloody), fever, cramps, 24--48 hours after infection.

Vibrio Cholerae	Primarily aquatic bacteria. Human feces and freshwater zooplankton. Transmitted by water and food; rarely by direct contact.	0.5- 0.8 µm by 1.5- 2.5 µm .	Cholera, diarrheal. circulatory collapse and dehydration with cyanosis.
Escherichia coli	Human feces, the feces of breast-fed infants. Contaminated food and water as poor sanitation.	It is rod-shaped 2.5 µm long and 0.8 µm in diameter.	Gastroenteritis, Haemolytic Uraemic Syndrome, and bloody diarrheal may cause acute kidney failure and death cause.
Giardia Lamblia	Presence in water and animal feces, contaminated food and water.	8 to 12 µm.	Giardiasis (chronic gastroenteritis). Continuous diarrheal, and intestinal malabsorption.
Cryptosporidium	Water, human and other mammal feces, contaminated water, and food.	Spherical shape with 4 to 6 microns in diameter.	Acute diarrheal is fatal for immunocompromised individuals.
Rotavirus	Human feces.	65 -75 nm in diameter.	Gastroenteritis, diarrheal, intestinal enterocyte.
Norovirus	Human feces. contaminated food or water.	26 to 35- nm.	Gastroenteritis, diarrheal, vomiting, abdominal pain, nausea.
Naegleria fowleri	Freshwater such as rivers and lakes.	8 µm to 15 micrometers in size.	Headache, fever, nausea and vomiting, and encephalitis. Most are dead after 1 week of symptoms.

This Project has discussed the crisis of clean water during floods and has inspired us to innovate a system of purification based on the size of the waterborne pathogens in the contaminated water to generate clean and safe water to use for drinking water. After the size of the smallest pathogen can be detected, it has become a small matter to find the best solution to remove the bacteria and purify the contaminated water. This project will contribute to solving the problem of water sanitation and avoid many people from getting an infection by the waterborne pathogenic disease during floods due to water quality control and drinking water treatment.



5. According to the research and report provided below, the Chinchpokli Sewage Water Pumping Station has a capacity of 30 MLD while the maximum volume that the plant has experienced is 9.70794 MLD. So we can divert the flow of flood from Britannia Pumping Station to the Chinchpokli Sewage Water Pumping Station and other pumping stations located in the catchment area of Hindamata.

We can construct sponge cities by taking up the area of mills that are not in use and building an underground water storage tank and building malls or commercial buildings with rainwater harvesting facilities. By this construction, the cost which was invested will be returned as the commercial buildings will provide us with good economic returns.

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