Lake Filtration using Constructed Wetlands

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What are Total Suspended Solids?

TSS or total suspended solids, is a **unit of measurement of the total amount of insoluble solids which are present in the water**.

These solids may be organic or inorganic and TSS is a **primary measurement of water pollution** within a water body.

Key Fact: High TSS levels are a primary indicator of water pollution in Urban Lakes

Figure 1: Urban Stormwater runoff carrying suspended solids into waterbodies

Effects of TSS in Urban Lakes

Impervious Surfaces
Urbanisation increases roads, pavements and rooftops, which prevent rainwater from being absorbed by the soil, forcing it to runoff at the surface

Rain Event Runoff
During rain events, runoff collects pollutants, sediments and debris from streets and open areas, channelling them into stormwater drain systems.

Urban Lake Pollution
Stormwater drains discharge into lakes, increasing TSS levels and degrading water quality, harming aquatic systems

Scope of Study

Aim

Showcase methods to make urban lakes **cleaner and unpolluted** through the use of Constructed Wetlands

Objective

- Improve Water Quality in Urban lakes
- Reduce Total Suspended Solids (TSS)
- Use Constructed Wetlands as Natural Filtration System
- Provide a cost effective and sustainable solution

Focus

- Impact of Stormwater runoff on Urban lakes
- Role of Constructed Wetlands in pollutant removal
- Comparison of wetland design variations

Methodology

- Selected Urban Lake as case study
- Mapping and analysis using ArcGIS
- Identified stormwater inflow points
- Designed wetland integration zones
- Modelled Filtration and Flow Behaviour

Figure 2: Impact of untreated stormwater runoff on lake water quality

What are Constructed Wetlands

Man-made structures designed to filter water using plants and natural systems.

- Mimic **natural wetland processes**
- Use vegetation, soil and microbial activity for filtration
- Contain **macrophytes** such as Cattails, Lotus, Water Lettuce.

Working Principle

- Removal of suspended and dissolved pollutants

Combination of:

- **Physical processes (Sedimentation)**
- **Biological processes (Plant + microbial action)**
- **Chemical processes (adsorption, transformation)**

Figure 3: A Horizontal Flow Constructed Wetland (CW), with cattail planted

Treatment Mechanisms

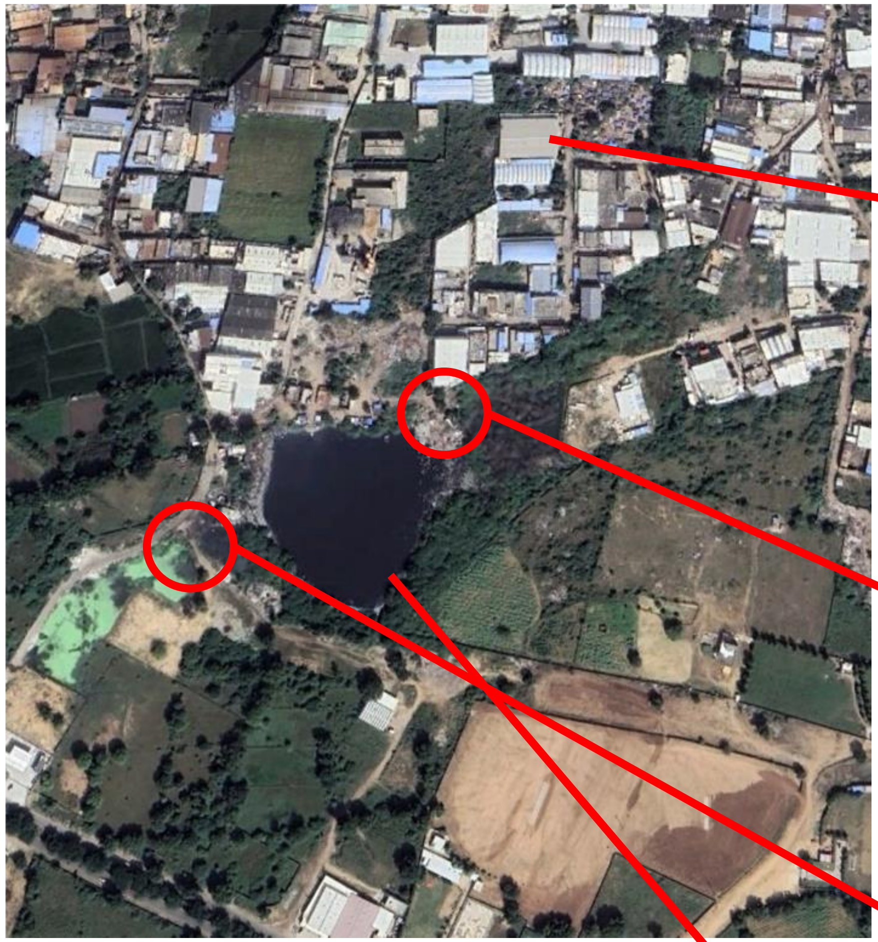
Sedimentation:
Settling of suspended solids (TSS) in low velocity zones
Biological Treatment:
Microbial activity in root zones breaks down pollutants
Nutrient Uptake:
Plant absorb nitrogen, phosphorous and excess nutrients
Filtration:
Substrate + roots trap fine particles

Figure 3: Location of Lake in Ahmedabad, Gujarat

Site Location

For our study, we decided to take a case-study of a semi-urban lake nearby Ahmedabad city. Through google maps, we identified this lake nearby **Santej Town, in Gandhinagar District.**

We chose this lake due to its situation in an urban and industrial environment, thus, it would accurately represent how polluted stormwater infiltration due to urbanization would affect a lake.



Factory Buildings: The entire upstream section of the lake consists of factories exculsivley. Direct dumping was not observed however.

Stormwater Inlet: The stormwater inlet consists of direct runoff from the drain into the lake, with no filtration of any kind.

Water Outlet: This outlet consists of just a weir made out of earthen materials.

The Lake: It's a small sized lake, located in the urban periphery, nearby an industrial area.

Site Observations

The lake primarily consists two main inlets due to runoff from rainfall and a stormwater inflow. It has one main outlet which follows into a stream.

From **HEC-HMS analysis** we have found that the lake occurs along a natural stream, which suggests that it might be a human-made lake, made by creating a bund on the stream. This shows that the water doesn't stagnate easily, especially during the monsoon season, where the water is recycled constantly.

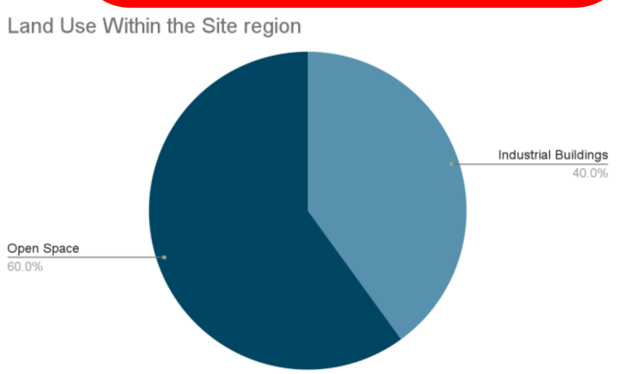


Figure 3: Pie chart showing the land use within the site area

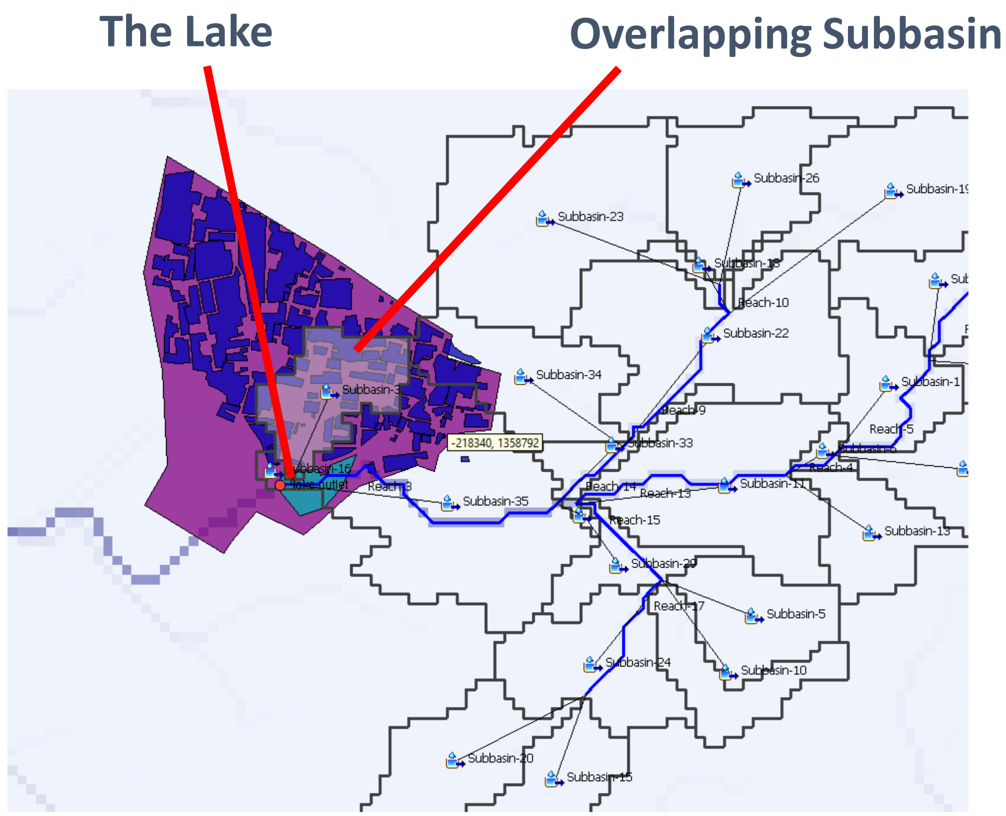


Figure 6: Hydrological Analysis of the Lake Using HEC-HMS

Hydrological Analysis

Using a DEM of the region and HEC-HMS, we were able to perform a little hydrological analysis of the site. From this data, we are able to see that the lake, lies on a steam line, which has multiple inlets and sub-basins. It was also found that our site area, coincides with one of the sub-basins, showing that stormwater outflow, drains into this lake.

However, for the purpose of this study, we will consider only the site area, as an inflow of pollutants due to simplicity and that a continuous stream of any kind was not observed on site and hence, the other sub-basins are unlikely to affect the lake in any meaningful way during normal rainfall events.

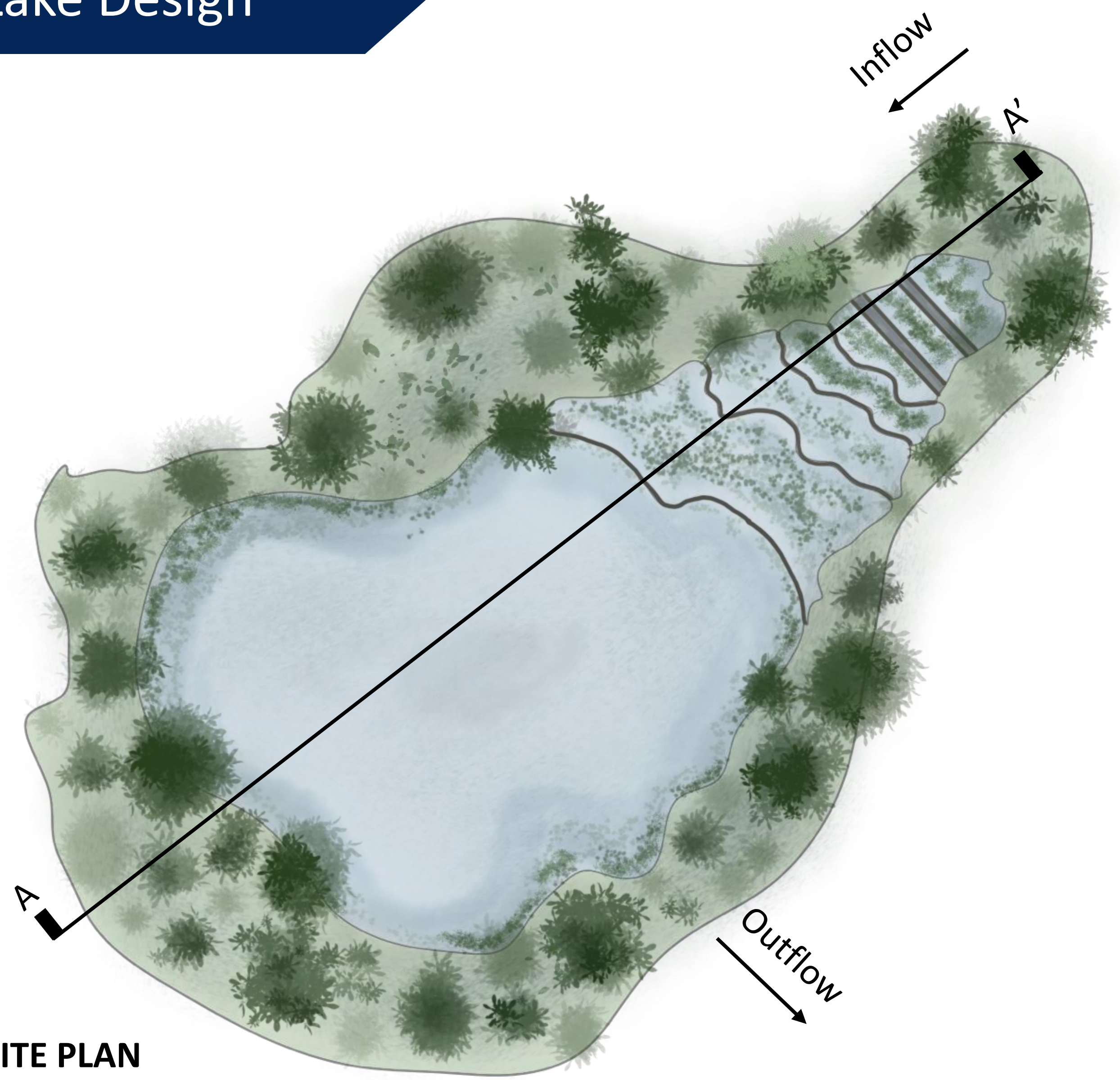
Figure 7: Slum Located on the Banks of the Lake

Figure 8: Garbage Thrown in and Around the Lake Premises

Figure 9: Stagnant and Garbage Infested Water of the Lake.

Site Conditions

After visiting the site in person, we found that the area was heavily polluted by both industrial and civilian waste. There was a slum that was located on the banks of the lake, most likely responsible for dumping a lot of organic waste as well as inorganic waste into the water body.

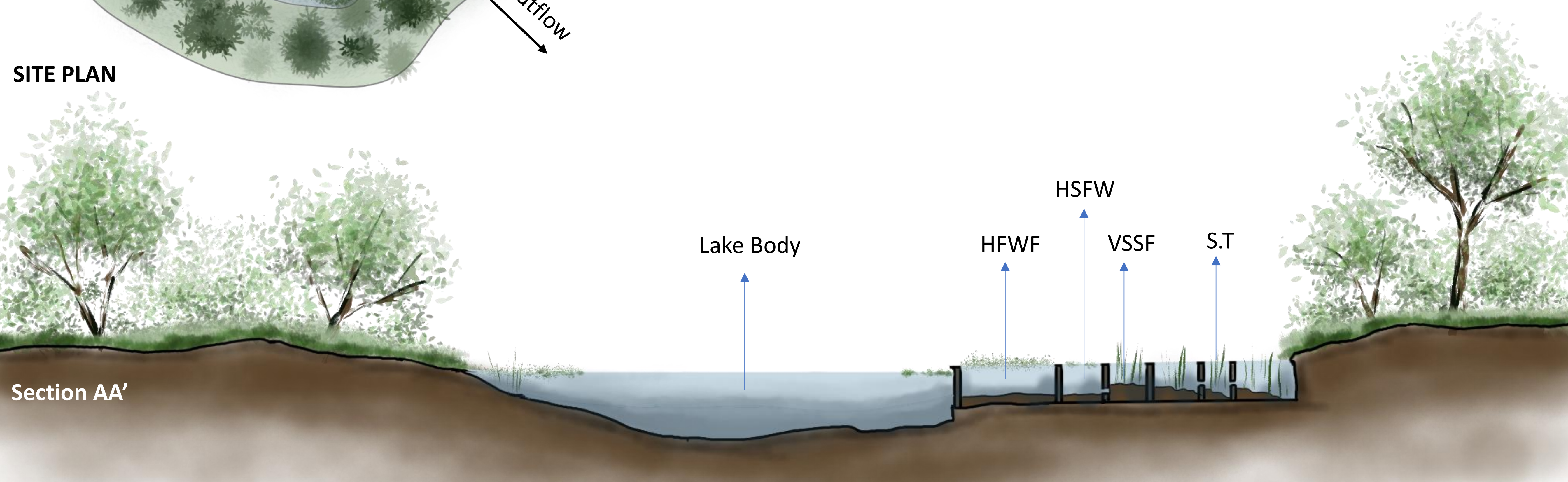


SITE PLAN

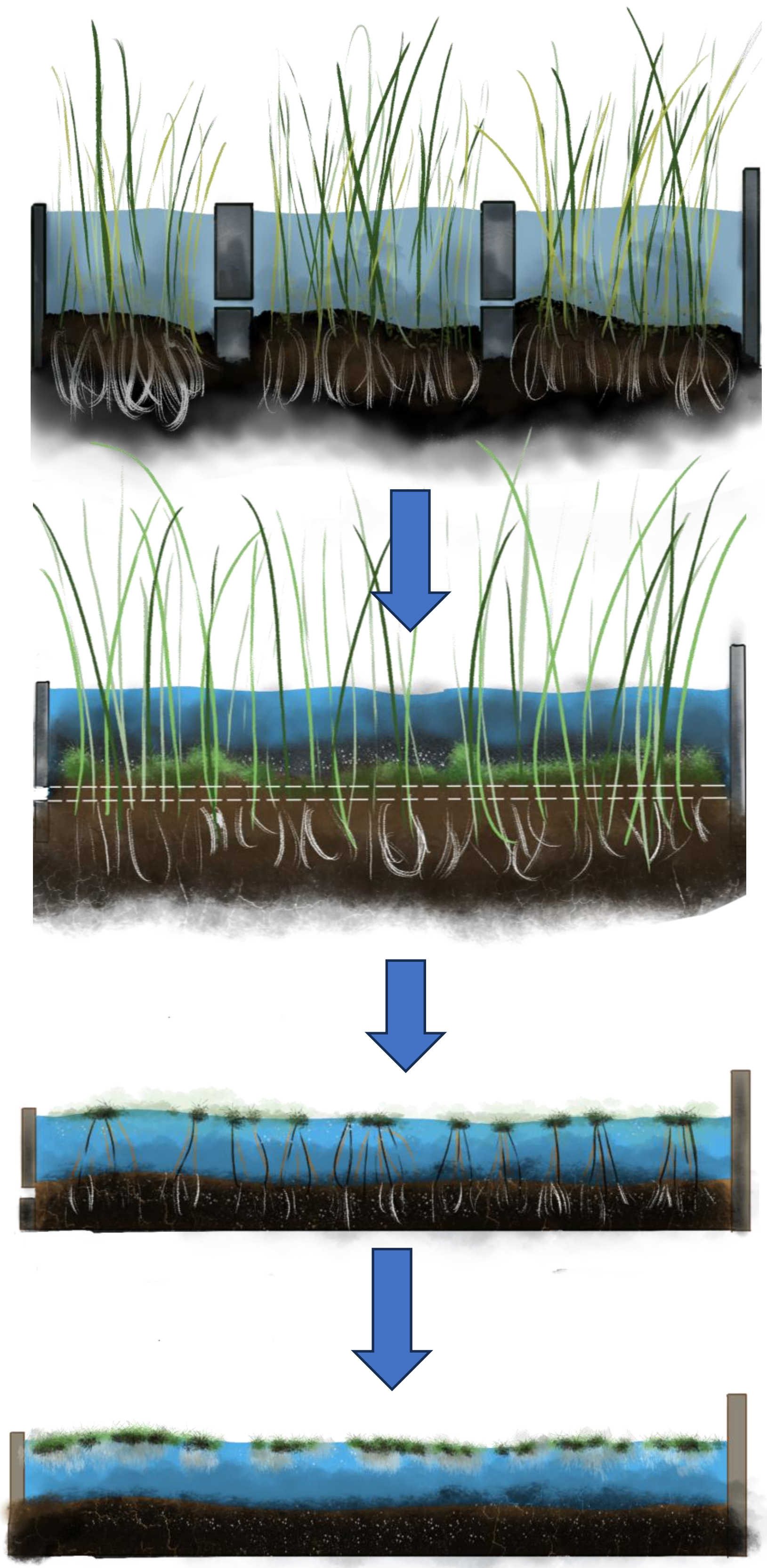
Redesigning the Lake Around Using CW's

We redesigned the lake with the intention of using the flood plain region of the lake as the region on which we will design the CWs.

The CW's have been designed in series with their size increasing as they extend outwards towards the lake. They have been designed to accommodate an increase in HRT and surface area according to the variation in CW used.



Section AA'



Sedimentation Tank

Capacity = 4000 m^3
Design HRT = 24hrs
Useful in TSS Removal

Vertical Subsurface Flow

Capacity = 4000 m^3
Design HRT = 24hrs
Useful in TSS and Nitrogen Removal

Horizontal Subsurface Flow

Capacity = 4000 m^3
Design HRT = 24hrs
Useful in TSS and BOD Removal

Horizontal Free Water Flow

Capacity = 4000 m^3
Design HRT = 24hrs
Useful in Removal of BOD

Utilizing CWs in Series

In our design We have utilized the different CWs in series so that each of their unique contributions can be felt by all the water passing through the system.

The sedimentation tank and the VSSF are the main CW's that focus on TSS reduction of the stormwater. Further filtration of possible BOD, COD and smaller TSS contamination occur in the following modules of HSSF and HFWF.

These modules can easily be redesigned in various sizes if we vary the HRT or base parameters.

Boundary Demarcation & Clearance
Removing illegal settlements and precisely marking the project boundaries to secure the site for development.

Lake Remediation
Comprehensive cleaning of garbage from the lake and desilting to restore the water body's health and depth.

Hydraulic Structure Demarcation
Comprehensive cleaning of garbage from the lake and desilting to restore the water body's health and depth.

Wetland Construction
Building the constructed wetland cells, starting with sedimentation tanks and progressing to horizontal flow treatment zones.

Community Engagement & Amenities
Integrating gathering spaces like parks, benches, and meeting areas to enhance community involvement and ownership.

Methodology

- Analysing Site Terrain Using ArcGIS & Google Earth
- Measuring Flow Hydrograph Using HEC-HMS
- Designating HRT Based on Space and Inflow Considerations
- Calculating TSS Load Through ESG Calculations.

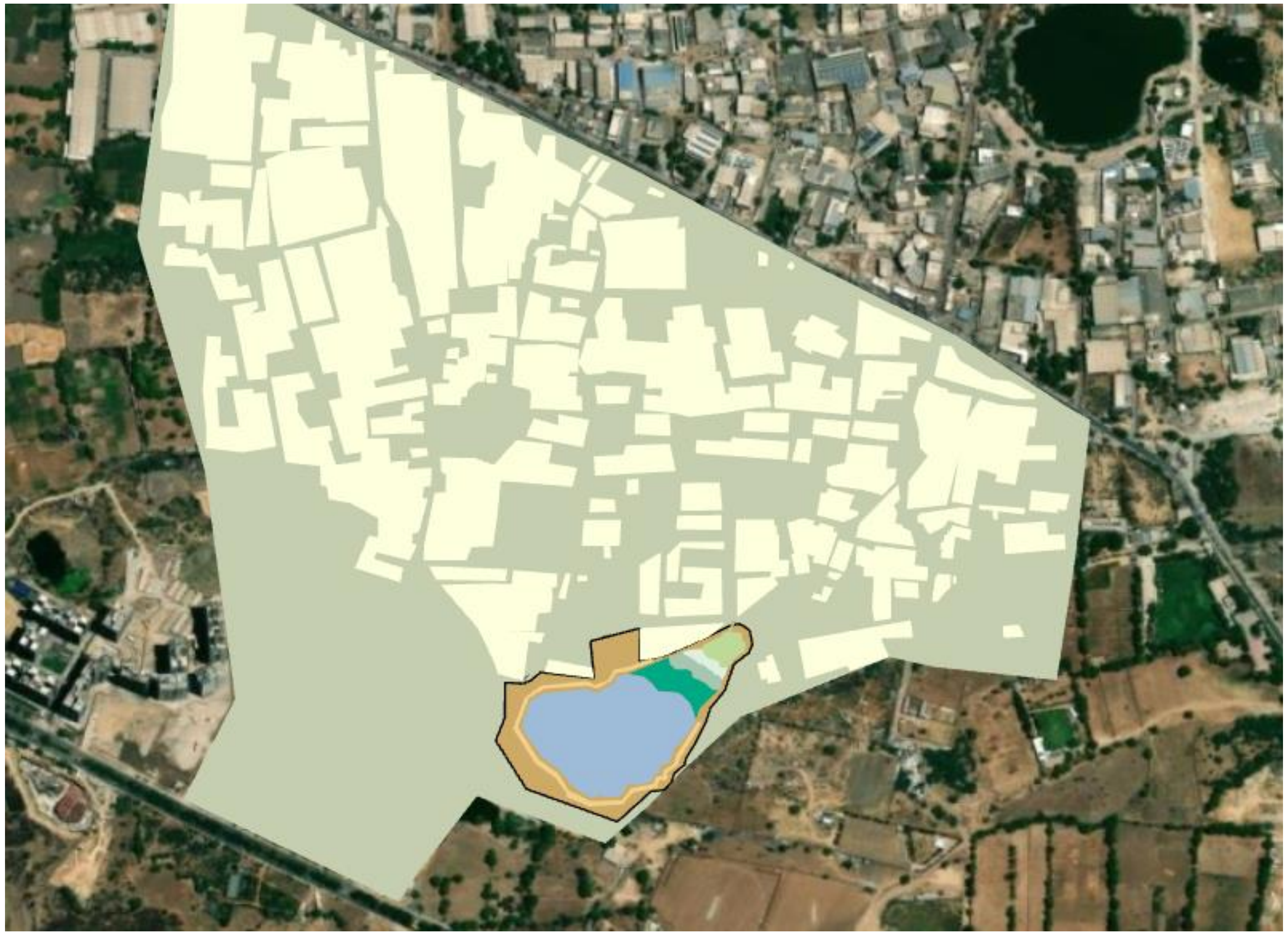


Figure: Using ArcGIS to Find LULC of the Site Region.

Site Area (m^2)	Building Area (m^2)	Open Area (m^2)	Runoff C
792638	323973	468665	0.427

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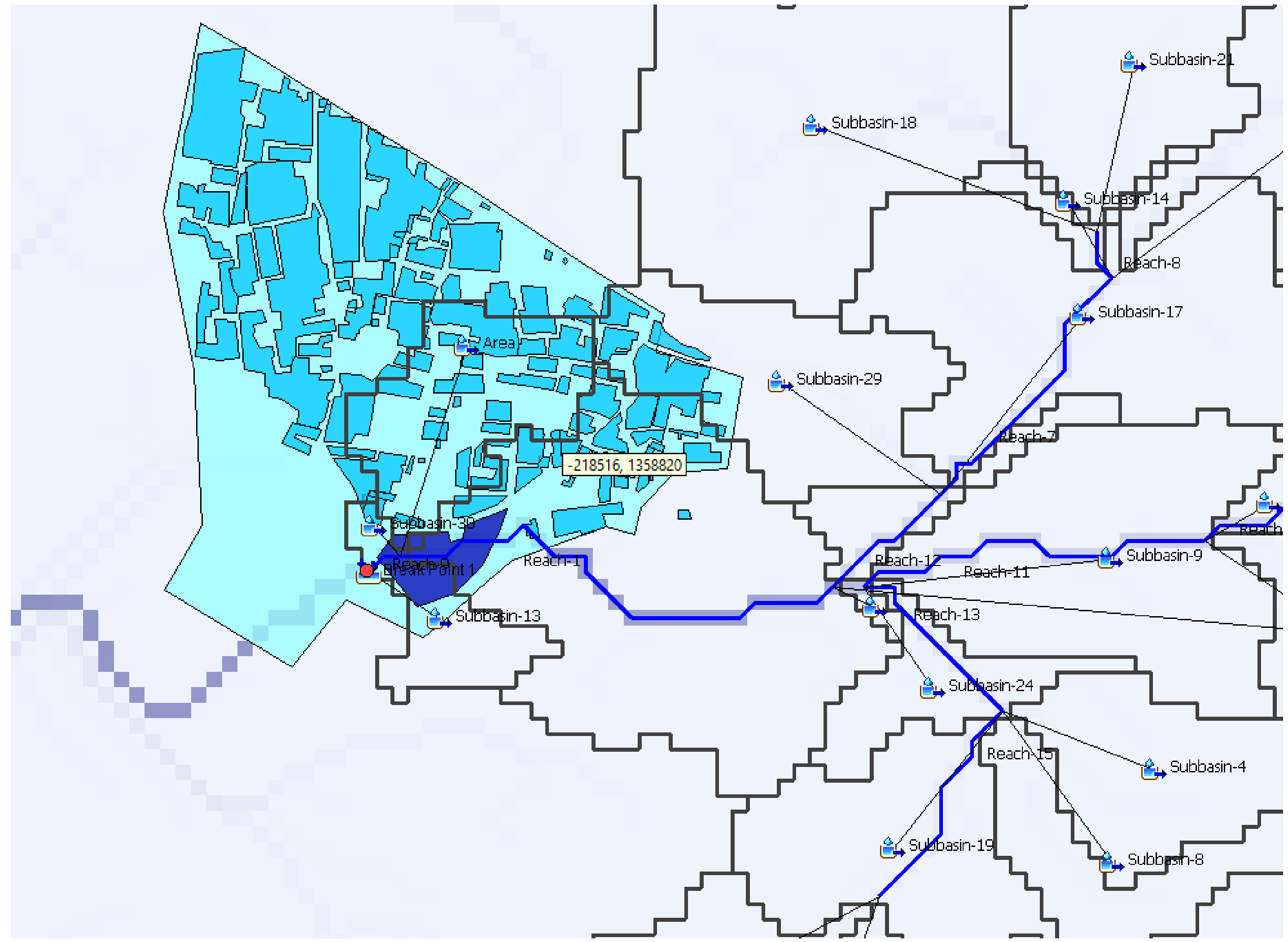

Figure: Using HEC-HMS to find the Inflow Hydrograph Into the Lake

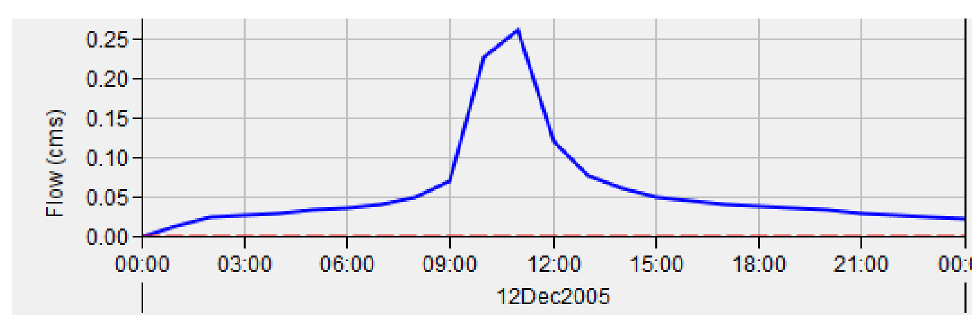

Figure: Inflow Hydrograph into the Lake

Methodology

Analysing Site Terrain Using ArcGIS & Google Earth

Measuring Flow Hydrograph Using HEC-HMS

Designating HRT Based on Space and Inflow Considerations

Calculating TSS Load Through ESG Calculations.

Inflow Considerations

From the previous step, we found the inflow hydrograph. Using this we can find the cumulative inflow into the lake for the example storm.

It is found that the cumulative value of inflow is 3240 m^3. From rough drawings we have found that the dimensions possible for each CW is around 4000 m^3.

Hence, to keep a buffer, we have kept the HRT at 24hrs for all CW's, reducing the efficiency of each module.

Adjusting HRT's and Efficiency

S No.	CW Name	Design HRT	Adjusted HRT	Design Efficiency	Adjusted Efficiency
1	Sedimentation Tank	24	24	60%	0.6
2	VSSF	72	24	70%	0.28
3	HSSF	72	24	60%	0.24
4	HFWF	72	24	50%	0.2

Methodology

Analysing Site Terrain Using ArcGIS & Google Earth

Measuring Flow Hydrograph Using HEC-HMS

Designating HRT Based on Space and Inflow Considerations

Calculating TSS Load Through ESG Calculations.

TSS Load

To find the TSS load, we calculated the TSS increase, due to the runoff by multiplying the inflow with the ESG value for an industrial region at 150mg/L.

However, for a 6 hrs. storm, TSS value reduces with time due to most of the loose sediment washing out within the first rainfall. This reduction in TSS is reflected by using a decay factor of 0.2 in the calculations.

We found the total TSS load to be 5356kg.

TSS Reduction

Using the efficiency's found in the previous slide and adding the TSS reduction, due to the CW's being in series, we achieve the following result.

TSS Left After S.T (kg)	TSS Left After VSSF (kg)	TSS Left After HSSF (kg)	TSS Left After HFWF (kg)
2142.72	1542.7584	1172.496384	937.9971072

We find a decrease of 82% in TSS values, resulting in the lake having a TSS concentration of 140.89 Mg/L, which is well within normal levels.

CW's have a longer HRT and have lower efficiency compared to traditional STP plants. However, they have virtually no energy utilization and their maintenance requirements are much lower, requiring monthly desilting and plant trimming to continue within the same efficiency.

CW's also enrich the local lake, with a variety of plants and habitats for fish, birds and insects, increasing the local biodiversity and environmental wealth of the area.

CW's can enhance the lakes environment with a green area, providing a good point of visual interest for lake goers, thus improving the local communities value and interest for the lake.

CW's do much more than just remove TSS quantities in a lake. They take up BOD pollution coming from untreated sewage and also excess nitrogen or organic compounds from entering into the lake. These quantities were not measured in this study and hence, and accurate measurement of the lake's efficiency was not able to be calculated here.

Through my calculations, the CW's functioned to remove 82% of all TSS load entering into the system providing a healthy 140.2 mg/L as the final concentration within the main lake body.

Figure 15: A Constructed Wetland that Includes Different Modules for FIltration

Source: https://www.vesienviro.com/preview/integrated-constructed-wetlands/icws-for-biodiversity/