Water Sensitive Urban Design of Wah Cantt City

Session 2019-2023

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Final Year Design Project Thesis Report

Project ID	12	Number Of Members	04

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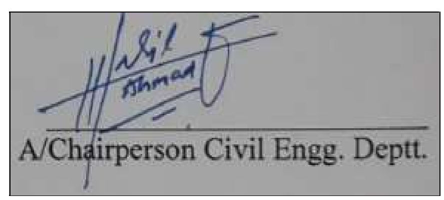

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Acknowledgement

We are thankful to Allah Almighty for successful completion of our project. Our special thanksto our supervisor **Mr. Salman Zaidi** for giving his supervision. We are grateful to our supervisor who gave his precious time and guiding us in project completion and all faculty members who helped us with their advices and comments. We are thankful to the administration of Civil Engineering Department WEC for allowing us to use the lab equipment as per requirement.

Abstract

Water Sensitive Urban Design (WSUD) is a technique of planning our cities that can minimize water runoff and ensure the least amount of damage that may arise due to runoff. It is about wise use of rainwater that can help to improve our urban environment. WSUD is an alternative land development method that is recommended to replace traditional rainwater collection design. In this project we have recommended Water Sensitive Urban Design Wah Cantt City. The main objective of application of WSUD over Wah Cantt city is to reduce the impact of land development on water demand by the efficient use of rainwater management practices by collecting, harvesting and reusing rainwater. In the first phase of the project, we have work on water sensitive urban design in which we have collected data including soil samples, elevation, and coordinates to draw the contour map of the area, and by identifying the lowest elevated areas we have suggested the suitable locations for ponds to collect runoff water. We have worked on water budget by using precipitation, infiltration and evaporation data that is collected from Pakistan Metrological Department (PMD) to calculate the exact amount of storm water we can store in those ponds during whole year. We have also recommended the detail design of Quaid Ave Road, Parking lots, Roofs and Paved Areas by the help of simulations using EPA Storm Water Management Model (SWMM) version 5.2.

The most significant impact of the application of Water Sensitive Urban Design (WSUD) is that it reduces the risk of flooding by efficient and proper management of storm water. The water stored through WSUD can be utilized for different purposes including, construction and irrigation purposes with no or minimal requirement of filtration. This will also help to reduce the water and environment pollution. Implementation of WSUD reduces the load on natural ground water resources, thus effective management not only increases the quantity of natural ground water, but also improves the quality of water. This will help to sustain natural habitats that depend on aquifers and also maintain the ground water table.

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Chapter # 1
Introduction

1.1 Introduction

Wah Cantt is a city located in the Punjab province of Pakistan. It is situated in the Pothohar region, near the border of the Khyber Pakhtunkhwa province, and is approximately 45 kilometers (28 miles) from Islamabad, the capital of Pakistan. The city is situated in the northern part of the country, in a valley surrounded by hills and mountains. The Margalla Hills to the south and the Kala Chitta Range to the north provide a picturesque backdrop to the city. The area is known for its scenic beauty and is a popular tourist destination. Wah Cantt is located on the Grand Trunk Road, which is an ancient trade route that runs through South Asia, connecting the region to Central Asia and the Middle East. The city is also situated near the historic city of Taxila, which was an important center of Buddhist learning and a hub of trade and commerce during the ancient times. Overall, Wah Cantt is a geographically significant city in Pakistan, owing to its strategic location and proximity to important trade routes and historical sites.

Wah Cantt city is facing numerous challenges related to water resources management, including water scarcity, flooding, and water pollution. These challenges are primarily caused by urbanization and the unsustainable use of water resources. To address these challenges, the implementation of Water Sensitive Urban Design (WSUD) can be a suitable solution.

WSUD is an approach to urban design that integrates the management of water resources into the planning, design, and management of urban areas. It aims to mimic natural water cycles and processes in urban areas, thus reducing the impact of urbanization on the water environment. The implementation of WSUD in Wah Cantt city can help to achieve several objectives:

Enhance water resource management: WSUD can help to reduce water consumption, promote rainwater harvesting and reuse, and treat and recycle wastewater.

Mitigate flooding: WSUD can help to reduce the volume and velocity of stormwater runoff, thus reducing the risk of flooding.

Improve water quality: WSUD can help to treat stormwater and wastewater before discharging it into water bodies, thus reducing pollution. Enhance livability and resilience: WSUD can create more attractive and sustainable urban spaces, which can enhance the livability and resilience of the city.

The implementation of WSUD in Wah Cantt city can help to mitigate the adverse impacts of urbanization on water resources and the environment, while also enhancing the livability and resilience of the city. Therefore, this thesis will explore the feasibility, benefits, and challenges of introducing WSUD in Wah Cantt city and provide recommendations for its implementation.

1.2 Climatic condition

Wah Cantt is a city located in the Punjab province of Pakistan. The climatic conditions in Wah Cantt are typical of the region, with hot summers and cool winters. During the summer months of May to August, the average high temperatures range from around 35 to 40 degrees Celsius (95 to 104 degrees Fahrenheit), while the average low temperatures range from around 25 to 30 degrees Celsius (77 to 86 degrees Fahrenheit). These months are also characterized by high humidity levels, which can make the weather feel even hotter. In contrast, the winter months of December to February are relatively cooler, with average high temperatures ranging from around 16 to 20 degrees Celsius (61 to 68 degrees Fahrenheit) and average low temperatures ranging from around 5 to 10 degrees Celsius (41 to 50 degrees Fahrenheit). These months are also relatively dry, with lower humidity levels compared to the summer months.

Overall, Wah Cantt experiences a hot and humid climate during the summer and a cool and relatively dry climate during the winter.

1.3 Topography

Wah Cantt is situated in the northern part of the Punjab province in Pakistan. The city is located at an altitude of about 475 meters (1558 feet) above sea level and is surrounded by the Margalla Hills to the north and the Haro River to the south. The natural topography of Wah Cantt can be divided into three distinct regions: the Margalla Hills, the Potohar Plateau, and the Soan River Valley. The Margalla Hills form the northern boundary of Wah Cantt and are a part of the Himalayan Mountain range. The Margalla Hills are characterized by their steep slopes, which rise to an altitude of around 1600 meters (5249 feet) above sea level at their highest point. The Margalla Hills are covered by dense vegetation, including forests of oak, pine, and other species of trees. The hills provide a habitat for a variety of wildlife, including leopards, monkeys, and a range of bird species.

To the south of the Margalla Hills lies the Potohar Plateau, a vast and arid plain that stretches across much of northern Punjab. The Potohar Plateau is characterized by its flat terrain, with occasional rocky outcrops and shallow valleys. The plateau is covered by scrub vegetation, including thorny bushes, acacia trees, and grasses. The Soan River Valley lies to the east of Wah Cantt and is formed by the Soan River, which originates in the foothills of the Himalayas. The Soan River Valley is characterized by its rugged and rocky terrain, with steep cliffs and gorges. The valley is also home to a range of wildlife, including wild boar, jackals, and various bird species. Overall, the natural topography of Wah Cantt is characterized by a mix of rugged and arid plains, dense forests, and rocky hills and valleys. This diverse landscape provides a habitat for a range of flora and fauna and contributes to the scenic beauty of the region.

POF and WEC is also located in Wah Cantt. Pakistan Ordnance Factory (POF): POF is a state-owned defense corporation located in Wah Cantonment, Punjab, Pakistan. It was established in 1951 to produce small arms, ammunition, and explosives for the Pakistani military. Today, POF has become a leading supplier of military equipment and is recognized as one of the largest defense industrial complexes in Pakistan. Wah Engineering College (WEC): WEC is a higher education institution located in Wah Cantonment, Punjab, Pakistan. It was established in 1981 as an engineering college, and it has since grown to become a renowned university offering undergraduate and graduate programs in engineering, management, and computer science. The college is affiliated with the University of Wah and has a strong reputation for producing highly skilled engineers.

POF and WEC Partnership: POF and WEC are closely linked, with POF being a major employer of WEC graduates. POF provides internships, research opportunities, and job placements for WEC students, and the college offers continuing education programs for POF employees. This partnership helps to strengthen the defense industry in Pakistan by fostering innovation and collaboration between academia and industry.

1.4 Existing drainage system of Wah Cantt

Wah Cantt is a city located in the Punjab province of Pakistan. The city has a well-developed drainage system that includes a network of drains, sewer lines, and storm water management infrastructure. The city's drainage system is managed by the Wah Cantonment Board, which is responsible for ensuring that the system functions effectively to prevent flooding and waterlogging during monsoon seasons. The system is regularly maintained, and any issues or blockages are promptly addressed.

Wah Cantt's drainage system is divided into two parts: the internal drainage system and the external drainage system. The internal drainage system comprises a network of underground sewer lines and surface drains that collect and transport wastewater from residential and commercial areas to treatment plants. The external drainage system comprises a network of canals, embankments, and sluice gates that control the flow of stormwater and prevent flooding. In addition to these systems, the city has several detention ponds and reservoirs that serve as temporary storage for excess stormwater. These ponds and reservoirs help to prevent flooding and reduce the risk of damage to property and infrastructure.

Overall, the drainage system of Wah Cantt is well-designed and efficiently managed, which helps to prevent flooding and ensure the safety and well-being of the city's but there is more betterment is required for its more effective and good working.

1.5 Geology

Wah Cantt is a city located in the Punjab province of Pakistan, near the border with the Khyber Pakhtunkhwa province. The geology of the area is primarily composed of sedimentary rocks, with some igneous and metamorphic rocks also present. The oldest rocks in the area are the Precambrian-age metamorphic rocks, which are found in the Margalla Hills to the west of Wah Cantt. These rocks consist of gneiss, schist, and marble, and were formed from the intense heat and pressure of the Earth's interior. Above the Precambrian rocks are the Paleozoic sedimentary rocks, which were deposited during the Cambrian to Carboniferous periods. These rocks consist of sandstone, shale, limestone, and conglomerate, and were formed from the erosion of older rocks and the accumulation of sediment in shallow seas.

The Mesozoic and Cenozoic sedimentary rocks are also present in the area, and were deposited during the Jurassic to Quaternary periods. These rocks consist of sandstone, shale, and limestone, and were formed from the erosion of older rocks and the accumulation of sediment in rivers, lakes, and seas.

In addition to the sedimentary rocks, some igneous rocks are also present in the area. These rocks were formed from the cooling and solidification of magma or lava, and include basalt and andesite. Overall, the geology of Wah Cantt is complex and diverse, reflecting the varied geological history of the region.

The soil conditions in Wah Cantt are influenced by the underlying geology, as well as climate, vegetation, and human activities. The soils in the area are primarily classified as Inceptisols and Entisols.

Inceptisols are soils that have only minimal development of soil horizons, or layers, and are found on young, recently deposited sediments. In Wah Cantt, Inceptisols are found on the youngest sedimentary deposits, such as alluvial fans and floodplains. These soils are typically well-drained, moderately fertile, and have a relatively high content of coarse fragments such as gravel and sand.

Entisols are soils that are relatively undeveloped and lack well-defined soil horizons. They are typically found on steep slopes, recently deposited materials, or areas with low organic matter content. In Wah Cantt, Entisols are found on the steeper slopes of the Margalla Hills, where erosion has removed much of the soil cover. These soils are generally poor in nutrients and organic matter, and have a low water-holding capacity.

The soil conditions in Wah Cantt can also be affected by human activities such as land use, agriculture, and construction. In areas where land has been converted to agriculture, the soil may be more fertile due to the addition of organic matter and nutrients.

1.6 Water sensitive urban design

1.6.1 Significance of water sensitive urban design:

Water sensitive urban design (WSUD) is a comprehensive approach to urban planning and development that seeks to integrate water management into the design and function of urban landscapes. The goal of WSUD is to create more sustainable, resilient, and livable urban environments by reducing the negative impacts of urbanization on the water cycle. WSUD recognizes that urbanization often leads to increased stormwater runoff, which can cause flooding, erosion, and pollution of waterways. By incorporating features such as rain gardens, green roofs, permeable pavements, and water harvesting systems into urban design, WSUD can help to capture, treat, and reuse stormwater, reducing the burden on traditional infrastructure and mitigating the impacts of urbanization on the natural water cycle.

In addition to its practical benefits, WSUD can also have social and aesthetic benefits. For example, green infrastructure features like rain gardens and green roofs can provide habitat for wildlife, enhance urban biodiversity, and create attractive public spaces. Overall, WSUD is an important tool for creating more sustainable and livable cities that can adapt to the challenges of climate change and urbanization while protecting and enhancing our natural water resources.

1.6.2 Application of Water sensitive urban design

WSUD is being applied in different countries around the world. Here are some examples:

Australia: WSUD has been extensively applied in Australia, where water scarcity and drought are major issues. The city of Melbourne has implemented a range of WSUD measures, including green roofs, rain gardens, and permeable pavements, to reduce stormwater runoff and improve water quality.

Singapore: Singapore has also implemented WSUD measures to address its water scarcity issues. The city-state has developed an integrated water management system that includes rainwater harvesting, water recycling, and desalination.

United States: In the United States, WSUD is being used to mitigate the impact of urbanization on water resources. For example, the city of Philadelphia has implemented a Green City, Clean Waters program, which includes the use of green infrastructure such as rain gardens, green roofs, and permeable pavements to reduce stormwater runoff.

China: China is also implementing WSUD measures to address its water scarcity issues. The city of Tianjin has developed a sponge city program that includes the use of green roofs, permeable pavements, and wetlands to manage stormwater runoff.

South Africa: WSUD is being used in South Africa to address water scarcity and improve water quality. The city of Cape Town has implemented a range of WSUD measures, including rainwater harvesting, stormwater management ponds, and wetlands.

Overall, WSUD is becoming increasingly popular as a means of addressing water scarcity, improving water quality, and reducing the impact of urbanization on the water cycle in different countries around the world.

According to our research work are also representing presenting proper design of storm water management and its proper drainage system to store water in small dam to improve ground water table recharge and use this water for other useful purposes.

1.7 Component of WSUD

Some common components of water sensitive urban design include:

1.7.1 Green infrastructure:

This refers to the use of natural systems such as trees, green roofs, and permeable pavements to capture and manage rainwater runoff. Green infrastructure helps to reduce the amount of stormwater entering the sewer system and can also improve the quality of water entering natural waterways.

1.7.2 Water-efficient landscaping:

This involves using plants that require less water and designing landscapes to capture and reuse rainwater. Water-efficient landscaping can help to reduce water consumption and promote biodiversity.

1.7.3 Rainwater harvesting:

This involves capturing and storing rainwater for later use. Rainwater harvesting systems can range from simple rain barrels to complex systems that store and treat large volumes of rainwater.

1.7.4 Water-sensitive streets:

This involves designing streets to capture and manage rainwater runoff. Water-sensitive streets can include features such as bioswales, which are landscaped areas designed to capture and treat stormwater runoff.

1.7.5 Integrated water management:

This involves coordinating the management of water resources across different sectors and levels of government. Integrated water management seeks to balance the competing demands for water from different users and ensure that water is used efficiently and sustainably.

1.8 Ponds in WSUD

Ponds can play an important role in water sensitive urban design (WSUD) by helping to manage stormwater runoff and improve water quality in urban areas. In WSUD, the aim is to mimic the natural water cycle by incorporating green infrastructure and sustainable drainage systems (SuDS) into urban design. Ponds are one example of a SuDS measure that can be used to capture, store and treat stormwater runoff.

When rain falls on impervious surfaces such as roads, roofs, and pavements, it can quickly runoff into nearby waterways, causing flooding and pollution. Ponds are designed to capture this runoff, allowing it to slowly filter into the ground or be slowly released back into the environment. This helps to reduce the amount of runoff entering the stormwater system and improve water quality by filtering out pollutants.

Ponds can also provide additional benefits such as creating habitats for wildlife, improving aesthetics and providing recreational opportunities for communities.

However, it is important to note that ponds must be properly designed and maintained to ensure they function effectively and do not pose a safety risk. This includes considering factors such as the size of the pond, its location, and the type of vegetation used to enhance its effectiveness.

Overall, ponds can be a valuable component of WSUD, providing a sustainable and effective solution for managing stormwater runoff and improving water quality in urban areas.

CHAPTER # 2
Literature Review

2.1 Storm water management

Stormwater management is a critical aspect of urban planning and development, aiming to effectively manage and control stormwater runoff within urban areas. It involves the implementation of various strategies and techniques to mitigate the adverse impacts of urbanization on the natural water cycle. Through the use of green infrastructure, such as rain gardens, bioswales, and permeable pavements, stormwater management systems can help reduce the volume and velocity of runoff, improve water quality by removing pollutants, and enhance groundwater recharge. Additionally, these systems can contribute to the overall resilience of urban areas by minimizing the risks of flooding and erosion. Numerous studies have highlighted the effectiveness of different stormwater management practices, providing valuable insights into their performance, cost-effectiveness, and applicability in different urban contexts. Understanding the benefits and limitations of these approaches is crucial for developing sustainable stormwater management strategies that can withstand the challenges posed by urbanization and climate change.

2.2 conventional storm water system:

A conventional stormwater system refers to a network of structures and facilities designed to manage the runoff of rainwater or stormwater in urban or developed areas. It aims to collect, convey, and treat stormwater to prevent flooding, erosion, and pollution of water bodies. Here's a detailed description of a conventional stormwater system.

2.2.1 Catchment Area Identification:

The first step in designing a stormwater system is to identify the catchment area, which is the land area that contributes runoff to a specific location. This area is typically determined based on topographic surveys and land-use mapping.

2.2.2Collection System:

The collection system consists of various components designed to collect stormwater runoff from the catchment area. These components may include:

- **Catch Basins:**
  Catch basins are grated structures located at low points to collect surface runoff and direct it into the stormwater system. They are typically placed along roads, parking lots, and other paved surfaces.
- **Inlets:**
  Inlets are openings in curbs or sidewalks that allow stormwater to enter the storm drain system. They are designed to capture runoff from paved surfaces and direct it into the collection pipes.
- **Storm Drains:**
  Storm drains are underground pipes that transport stormwater from catch basins and inlets to larger conveyance systems, such as culverts or open channels.

2.2.3 conveyance system:

The conveyance system carries the collected stormwater from the collection points to suitable discharge points. It consists of various components, including:

- **Culverts:**
  Culverts are large pipes or structures that carry stormwater underneath roads, railways, or other obstructions. They are designed to maintain the flow capacity and prevent blockages.

- **Open Channels**:

  Open channels, such as ditches or canals, are used to convey stormwater in areas where underground pipes are not feasible. They are often lined with concrete or vegetated to prevent erosion.
- **Detention and Retention Ponds:**

  Detention and retention ponds are constructed to temporarily store excess stormwater during heavy rainfall events. Detention ponds release the stored water slowly, reducing the peak flow downstream, while retention ponds permanently retain water for groundwater recharge or recreational purposes.

2.2.4 treatment facilities:

Stormwater runoff often carries pollutants, such as sediments, oils, heavy metals, and nutrients. To mitigate the environmental impact, conventional stormwater systems may include various treatment facilities, including:

- **Sedimentation Basins:**

  Sedimentation basins or settling ponds are designed to remove sediment and other suspended solids from stormwater. The water is detained in the basin, allowing sediments to settle to the bottom, and then discharged.
- **Filtration Systems:**

  Filtration systems, such as sand filters or bioretention cells, are used to remove pollutants through physical and biological processes. Stormwater is directed through filter media, which captures pollutants before the water is discharged.
- **Oil/Water Separators**:

  Oil/water separators are devices designed to remove oil and grease from stormwater runoff, particularly in areas with significant vehicular traffic. They use gravity and buoyancy to separate oil and grease from the water.

The stormwater system ultimately discharges into receiving water bodies, such as rivers, lakes, or the ocean. Outfall structures, such as energy dissipators, are often employed to prevent erosion and minimize the impact of the discharged water.

2.2.5 Maintenance and Inspection:

Regular maintenance and inspection of the stormwater system are crucial to ensure its proper functioning. This includes cleaning catch basins, removing sediment from sedimentation basins, inspecting and repairing pipes and structures, and monitoring water quality.

2.3 Urban runoff and pollution control measures

Urban runoff, which occurs when rainfall or snowmelt flows over urban surfaces and enters water bodies, carries pollutants that can harm the environment. To address this issue, various pollution control measures can be implemented. One effective approach is the use of green infrastructure, such as rain gardens and vegetated swales, which absorb and filter rainwater, reducing runoff and removing pollutants. Another method is the use of permeable pavement that allows water to infiltrate the ground, minimizing runoff and promoting groundwater recharge. Detention and retention basins temporarily store stormwater, allowing sediments and pollutants to settle before discharge. Similarly, stormwater management ponds and wetlands provide natural treatment systems.

Regular street sweeping helps remove debris, preventing it from entering storm drains. Best management practices, public education, and strict regulations for industrial and commercial facilities are essential for pollution prevention. Monitoring stormwater quality and enforcing regulations play a crucial role, as does land use planning that incorporates stormwater management strategies.

By adopting these measures, urban runoff can be controlled, minimizing pollution and protecting water resources.

2.4 Green infrastructure and Water Sensitive Urban Design technique

Green infrastructure refers to a holistic approach to urban planning and development that focuses on integrating natural elements into the built environment. It involves the use of environmentally friendly techniques and technologies to minimize the impact of human activities on the surrounding ecosystems. One important component of green infrastructure is low-impact development (LID), which is a set of strategies and practices aimed at managing stormwater runoff and reducing the strain on existing infrastructure.

Water Sensitive Urban Design technique

LID techniques aim to mimic natural hydrological processes by capturing, storing, and treating stormwater on-site, rather than allowing it to flow into traditional storm drains and water bodies. These techniques include the use of permeable pavements, such as porous concrete or interlocking pavers, which allow rainwater to infiltrate into the ground. By doing so, they reduce the volume of runoff and help replenish groundwater resources.

Another LID technique is the implementation of green roofs and walls. Green roofs involve the installation of vegetation on the rooftops of buildings, which can absorb rainfall and release it slowly, reducing the peak flow of stormwater. Green walls, on the other hand, consist of plants and vegetation grown vertically on the sides of buildings, helping to absorb and filter rainwater while providing additional benefits like improved air quality and energy efficiency.

Rain gardens and bioswales are also commonly used LID practices. Rain gardens are shallow depressions planted with native vegetation that collect and filter stormwater runoff. They help remove pollutants and recharge groundwater. Bioswales are vegetated channels or ditches that slow down and filter stormwater as it flows through, removing contaminants and allowing for infiltration.

In addition to managing stormwater, LID techniques offer numerous environmental benefits. They help mitigate the urban heat island effect by reducing surface temperatures and providing shade. They promote biodiversity by creating habitats for various plant and animal species. Furthermore, they contribute to air purification, noise reduction, and overall improved aesthetics in urban areas.

Overall, the implementation of green infrastructure and low-impact development techniques is crucial for creating sustainable, resilient cities. By integrating nature into the urban landscape and effectively managing stormwater runoff, these approaches contribute to a healthier environment, improved water quality, and enhanced quality of life for residents.

2.5 Socio economic benefits and community engagement

This approach not only offers environmental benefits but also provides significant socio-economic benefits and fosters community engagement. By integrating WSUD principles into urban planning and design, cities can enhance their resilience, sustainability, and livability while addressing water-related challenges.

One of the key socio-economic benefits of WSUD is the potential for cost savings. Traditional stormwater management systems, such as underground pipes and large-scale detention basins, can be expensive to construct and maintain. In contrast, WSUD emphasizes decentralized and nature-based solutions, such as green roofs, permeable pavements, and rain gardens, which are often more cost-effective to implement. These approaches not only reduce infrastructure costs but also minimize the need for ongoing maintenance and repair, resulting in long-term financial savings for municipalities and communities.

Furthermore, WSUD promotes water resource conservation and efficiency. By capturing and treating stormwater runoff on-site, WSUD practices help recharge groundwater aquifers, mitigate flood risks, and reduce the strain on traditional water supply systems. This can lead to enhanced water security, particularly in regions prone to water scarcity or experiencing rapid population growth. Additionally, the integration of WSUD features within urban landscapes can create attractive green spaces and improve overall aesthetic quality, contributing to community well-being and enhancing property values.

Community engagement plays a crucial role in WSUD implementation. Unlike conventional stormwater management systems that are often hidden or disconnected from public spaces, WSUD features are designed to be visible, interactive, and educative. Rain gardens, bioswales, and wetlands not only serve as functional elements but also provide opportunities for recreational activities and environmental education. By involving the community in the planning, design, and maintenance of WSUD projects, residents develop a sense of ownership and pride in their neighborhoods, fostering social cohesion and community empowerment.

Moreover, WSUD projects can create employment opportunities and support local economies. The construction and maintenance of green infrastructure elements require specialized skills and expertise, providing job prospects in landscaping, horticulture, and stormwater management sectors. Additionally, the increased demand for WSUD-related products and services can stimulate local businesses and promote innovation in sustainable water management practices.

The adoption of water-sensitive urban design brings about not only environmental advantages but also significant socio-economic benefits and community engagement. The cost savings, water resource conservation, and improved aesthetics associated with WSUD contribute to the overall well-being of communities. By actively involving residents in the planning and implementation of WSUD projects, cities can foster a sense of community ownership, encourage environmental stewardship, and support local economies.

2.6 Challenges and barrier in implementing water sensitive urban design

Implementing water-sensitive urban design (WSUD) poses several challenges and barriers that need to be overcome to ensure its successful adoption. One of the primary challenges is the existing urban infrastructure, which is often outdated and not designed to accommodate WSUD principles. Retrofitting the infrastructure to incorporate WSUD features can be costly and time-consuming, requiring significant investments and coordination among various stakeholders.

Another barrier is the lack of awareness and understanding among urban planners, engineers, and decision-makers about the benefits and importance of WSUD. Many traditional approaches to urban development prioritize conventional drainage systems and overlook the potential of WSUD to mitigate flood risks, improve water quality, and enhance overall environmental sustainability. Educating and raising awareness about WSUD's advantages is crucial to gain support and promote its widespread implementation.

Furthermore, integrating WSUD into existing regulatory frameworks and urban planning policies can be challenging. These frameworks often have rigid guidelines that do not account for innovative and sustainable approaches like WSUD. Updating and revising these regulations to include WSUD principles and practices require collaboration between government agencies, policymakers, and water management authorities.

Securing adequate funding for WSUD projects is another significant barrier. Implementing WSUD features, such as green roofs, rain gardens, or permeable pavements, requires financial resources that may not be readily available. Governments, private sector entities, and community organizations need to collaborate and explore funding options, such as public-private partnerships, grants, and incentives, to overcome the financial challenges associated with WSUD implementation. Additionally, community engagement and participation play a vital role in the successful implementation of WSUD. Public acceptance and involvement are crucial to ensure the long-term sustainability of WSUD initiatives. However, engaging and educating the community about WSUD concepts and benefits can be challenging, as it requires effective communication and outreach strategies.

Lastly, monitoring and evaluating the performance of WSUD projects is essential to assess their effectiveness and make necessary adjustments. However, establishing monitoring systems and collecting data can be complex and require technical expertise. Adequate resources and capacity building efforts are needed to monitor the impact of WSUD projects and ensure their continuous improvement. In summary, the challenges and barriers in implementing water-sensitive urban design include outdated infrastructure, lack of awareness and understanding, integrating WSUD into existing regulatory frameworks, securing funding, community engagement, and monitoring and evaluation. Overcoming these obstacles requires collaboration, education, policy changes, financial support, and active community participation to enable the widespread adoption of WSUD principles and practices.

2.7 International perspective on water sensitive urban design

Water-sensitive urban design (WSUD) has gained significant attention and recognition as an effective approach to managing water resources in urban areas from an international perspective. This innovative design approach focuses on integrating sustainable water management practices into the planning and development of urban environments. By considering the entire water cycle, including stormwater, wastewater, and water supply, WSUD aims to achieve multiple objectives such as flood mitigation, water conservation, improved water quality, and enhanced urban livability.

From an international perspective, various countries have embraced WSUD principles and implemented them in their urban planning processes. In Australia, for instance, WSUD has been widely adopted and promoted as a means to address water scarcity and enhance urban resilience. The use of techniques such as rainwater harvesting, permeable pavements, and constructed wetlands has become increasingly common in Australian cities.

Similarly, in Singapore, a city-state known for its innovative urban planning, WSUD plays a crucial role in their sustainable water management strategy. The country has implemented an extensive network of water-sensitive infrastructure, including rain gardens, green roofs, and bioswales, to manage stormwater runoff and improve water quality. Singapore's integrated approach to water management has become a model for other cities facing similar challenges.

In Europe, WSUD has gained traction as a response to urbanization and the need for sustainable water management. Countries like Germany and the Netherlands have embraced WSUD principles by incorporating features such as green roofs, rainwater retention basins, and sustainable drainage systems (SuDS) into their urban landscapes. These measures not only contribute to efficient water management but also provide additional benefits such as urban cooling, biodiversity promotion, and aesthetic enhancements.

Beyond these examples, WSUD principles have been applied in various other regions, including North America, Asia, and Africa, as part of efforts to address water scarcity, reduce pollution, and enhance urban sustainability. Localized approaches and adaptations have emerged to suit the specific climatic, geographical, and socio-economic conditions of different areas.

2.8 Multi-disciplinary approaches in water sensitive urban design

Water sensitive urban design (WSUD) relies on a multi-disciplinary approach that brings together experts from various fields to tackle the complex challenges of sustainable water management in urban areas. This integrated approach involves collaboration between urban planners, civil and environmental engineers, landscape architects, hydrologists, ecologists, social scientists, community engagement experts, and governance professionals. Urban planners and designers work on incorporating WSUD principles into the overall urban fabric, considering factors like land use and building design. Civil and environmental engineers implement sustainable stormwater management systems, such as green infrastructure and decentralized wastewater treatment. Landscape architects contribute their expertise in designing outdoor spaces with water-sensitive elements like permeable pavements and green roofs. Hydrologists and water resources managers assess water quantity and quality, while ecologists focus on preserving or creating urban habitats. Social scientists engage with communities and raise awareness about water management, and governance experts develop policies and regulations to support WSUD implementation. Through the collective efforts of these disciplines, WSUD projects can achieve sustainable water management, improved water quality, reduced flood risk, and increased community resilience, among other benefits.

CHAPTER # 03

METHODOLOGY

3.1 FLOW CHART OF METHODOLOGY

1. Topographical study (Contouring, Co-ordinates Collection etc.)
2. Soil investigation
3. Study of pavements and types of material
4. Estimation of Water Budget equation
   (Including Precipitation, Evaporation and Infiltration Data)
5. Tests performed
6. Data Assessment and Compilation
7. Design Recommendation (including Drawings)

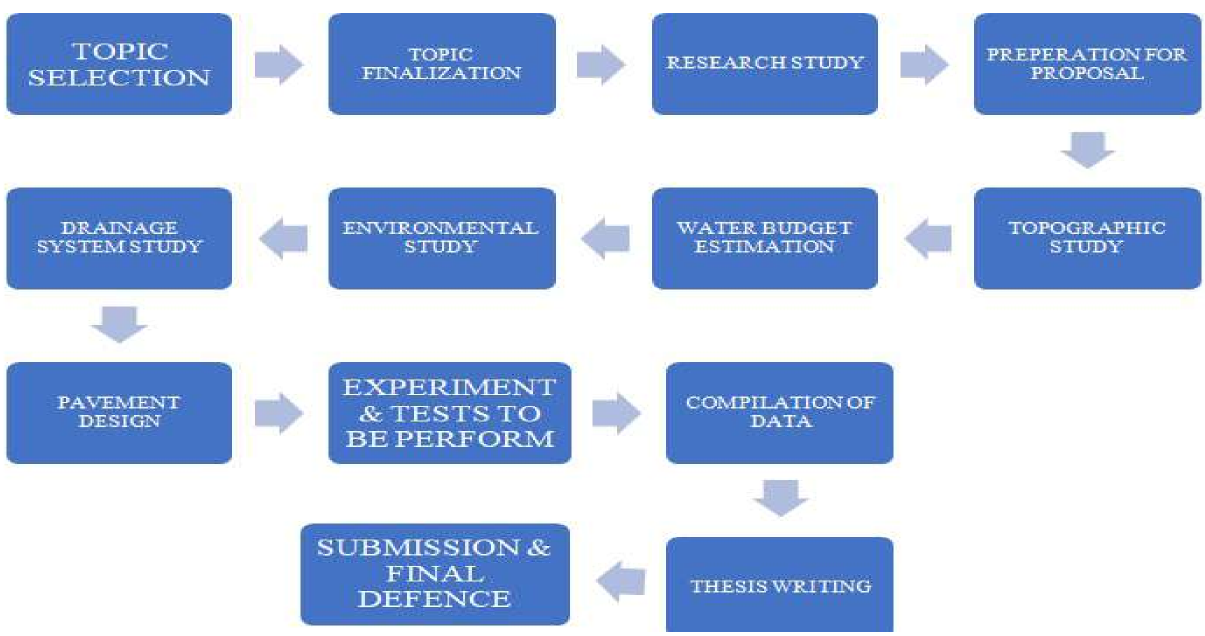


Figure 3.1: Methodology of Work

3.1 Topographical Study

Wah Cantt, short for Wah Cantonment, is a city located in the Punjab province of Pakistan. Situated in the northern part of the country, Wah Cantt is nestled in the picturesque Potohar Plateau, which forms part of the larger Himalayan foothills. The city's topography is characterized by undulating terrain, with rolling hills and shallow valleys interspersed throughout the region.

Surrounded by scenic beauty, Wah Cantt is known for its lush greenery and natural landscapes. The hills and ridges in the area add a unique charm to the city, providing breathtaking views from various vantage points. The Margalla Hills, a prominent mountain range, can be seen in the distance, further enhancing the picturesque setting.

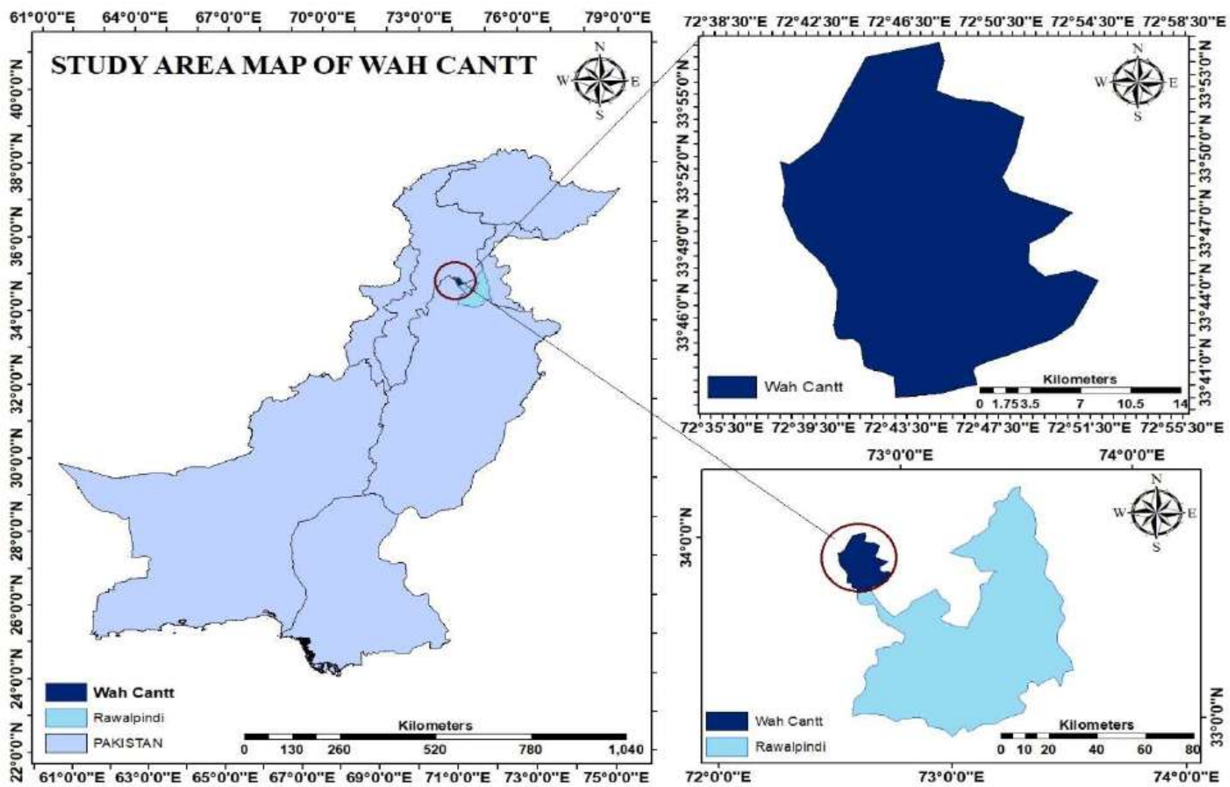


Figure 3.2: Study area of Wah Cantt

3.1.1 TECHNIQUES USED IN TOPOGRAPHICAL STUDY:

Generally, there are 5 types of techniques used in topographical studies i.e.

1. Remote sensing
2. Passive sensor methodologies
3. Photogrammetry
4. Field survey
5. Active sensor methodologies

In our project field survey technique is used because we have to perform work by surveying in the field and find coordinates with the help of Global Positioning System (GPS), by walking at different points of the housing society.

3.2 TOPOGRAPHIC SURVEY:

This is a Survey which collects data at the elevation of points on a piece of land & presents them as contour lines on a plot.

3.2 CONTOURING:

In field of surveying, it is the determination of elevation of various points on the ground & to fix points which have same horizontal positions in contour map.

3.2.1 Elevation:

The height above the level of a sea or altitude.

3.2.2 Contour Line:

A contour line is a line that passes through all points on a map that has the same elevation.

3.2.3 Contour Interval:

It is a constant vertical distance between two consecutive contours.

3.2.4 Index Contour Line:

Heavy, dark contour lines that usually have the elevation written.

3.2.5 Horizontal Equivalent:

It is a horizontal distance between any two adjacent contours.

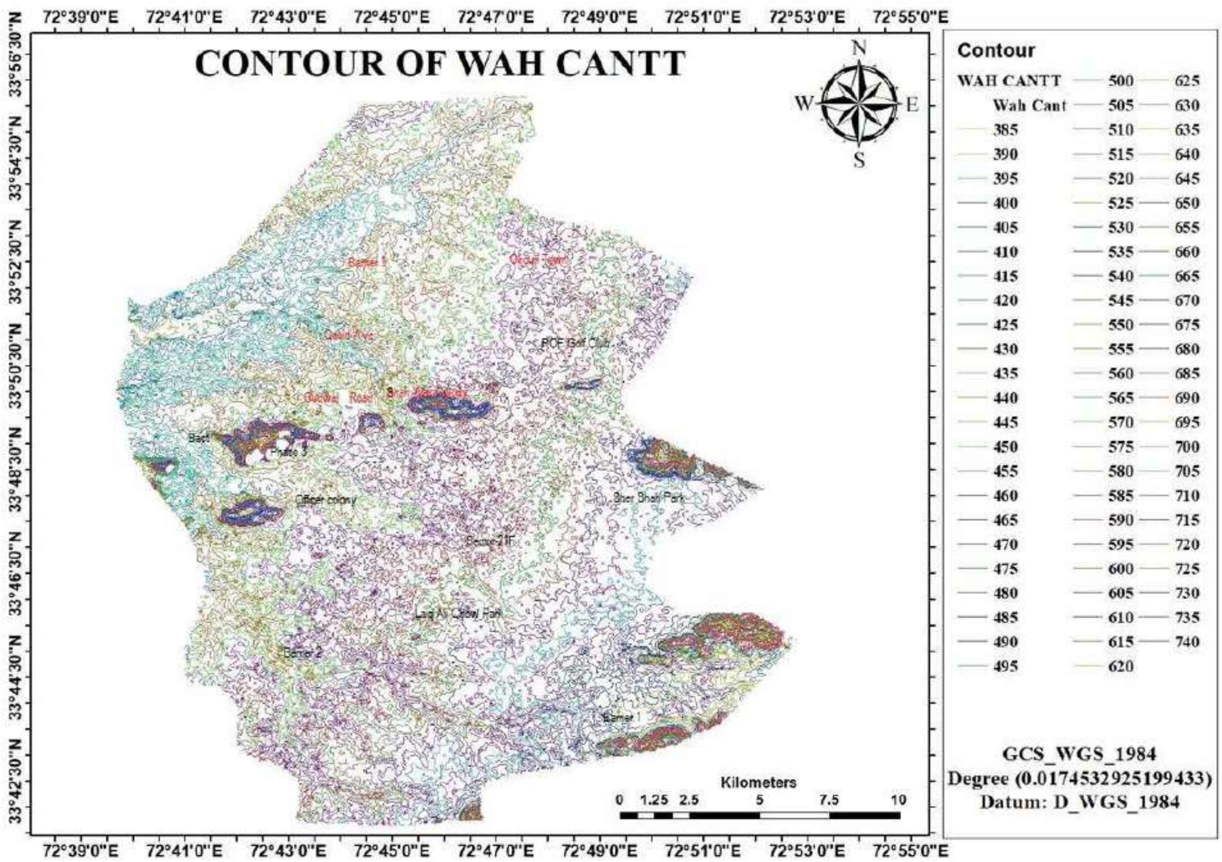


Figure 3.3: Contour Map of Wah Cantt City

3.3 SOIL SAMPLING

A soil sample for sieve analysis is collected to determine the particle size distribution of the soil. This analysis helps in understanding the soil's texture and its engineering properties. To collect a soil sample for sieve analysis, several steps need to be followed.

Firstly, select the sampling location based on the area of interest or the specific soil profile you want to analyze. Ensure that the location represents the larger area accurately. Clear any debris or vegetation from the surface of the soil to obtain a clean sample.

Next, determine the sampling depth based on the project requirements. Typically, soil samples for sieve analysis are collected from the topsoil, usually up to a depth of 6-8 inches. However, if you are interested in specific soil horizons, you may need to collect samples from different depths. Use a soil probe, auger, or shovel to collect the soil sample. Insert the tool into the ground to the desired depth, and then extract the soil while keeping the sample intact. If using a shovel, dig a small hole and collect the soil from the side, ensuring you capture the required depth.

After collecting the soil sample, transfer it into a clean container. Ensure that the container is free from any contaminants that may affect the analysis. Label the container with the sampling location, depth, and any other relevant information. It is crucial to avoid cross-contamination between samples, so use separate containers for each location or depth.

Once you have collected the soil samples, you can proceed with the sieve analysis. This involves passing the soil through a set of sieves with different mesh sizes. The sieves separate the soil particles into various size fractions. Each fraction is then weighed, and the weight percentages are used to determine the particle size distribution.

Remember to handle the soil samples with care to maintain their integrity. Any loss of moisture or disturbance to the sample may affect the analysis results. If necessary, follow specific guidelines provided by laboratories or testing facilities for packaging and shipping the soil samples for sieve analysis.

- We took soil samples from 9 different points as the interval of approx. 1km. Collection points are:

  i. Barrier one

  ii. Nashiman school

  iii. In front of POF hospital

  iv. Main Gate POF Factory

  v. Jamia Masjid

vi. Near Ordinance Club

vii. Park Explosive Factory gate

viii. POF Guest House

ix. C.B Ground Barrier no 3.

Figure 3.4: Soil Sample Collection

3.4 Sieve analysis

Sieve analysis is a method used to determine the particle size distribution of a granular material. It is commonly employed in civil engineering, geotechnical engineering, and material science to evaluate the gradation of soils, aggregates, and other granular material. The process involves passing a sample of the material through a series of sieves with progressively smaller openings. These sieves are stacked on top of each other, with the largest sieve at the top and the finest at the bottom. The sample is placed on the top sieve, and the stack is then mechanically or manually shaken for a specific duration to facilitate the separation of particles.

After shaking, the material retained on each sieve is weighed. The weight of the material retained on each sieve is divided by the total weight of the sample to determine the percentage of material retained on each sieve. This information is used to construct a particle size distribution curve.

The results of a sieve analysis can provide valuable insights into the characteristics of the material being tested. It helps determine the amount of material present within specific size ranges and provides information on the uniformity or heterogeneity of the sample. These findings can be used to assess the suitability of the material for various applications, such as construction, filtration, or grading requirements.

Figure 3.5: Taken during Sieve Analysis of soil sample

3.5 Hydraulic Conductivity Test

In science and engineering, hydraulic conductivity, is a property of porous materials, soils and rocks, that describes the ease with which a fluid can move through the pore space, or fractures network. Hydraulic Conductivity test was performed in Geo-Tech Lab on the sample already taken from eight different sites mentioned above. Hydraulic conductivities ranges from 0.0005 to 10 m / day.

- Hydraulic Conductivity of soil sample was found to be = 0.015 mm/day

Figure 3.6: Hydraulic conductivity test

3.6 Infiltration test

A double-ring infiltrometer is a commonly used tool to measure the infiltration rate of soil, which indicates how quickly water can penetrate the soil surface. It consists of two concentric metal rings, typically made of stainless steel, with the inner ring serving as the infiltration ring and the outer ring as the collection ring. Here's a step-by-step guide on how to conduct an infiltration test using a double-ring infiltrometer:

Site Selection:

Choose a representative area within the study site where you want to measure the infiltration rate. Ensure that the soil in the selected area is undisturbed and free from compaction or surface irregularities that could affect infiltration.

Equipment Setup:

Assemble the double-ring infiltrometer by placing the smaller inner ring (infiltration ring) inside the larger outer ring (collection ring). Ensure that both rings are leveled and firmly fixed in place to prevent water from seeping through gaps.

Pre-test Preparation:

Dig a hole in the ground slightly larger than the diameter of the outer ring. Place the assembled double-ring infiltrometer in the hole, ensuring that the rings protrude slightly above the soil surface. Gently compact the soil around the rings to minimize potential bypass flow.

Initial Measurements:

Measure and record the initial water level in the inner ring (infiltration ring). This can be done using a graduated measuring stick or a transparent tube attached to the ring. Fill the inner ring with water, ensuring that it completely covers the soil surface within the ring. Allow the water to infiltrate into the soil for a few minutes until a steady infiltration rate is achieved.

Measurement Collection:

Start the timer and record the time ($t = 0$) when the water in the inner ring reaches a specific reference level, such as the top of the ring or a marked line. Continuously monitor the water level in the inner ring at regular time intervals, e.g., every minute, and record the corresponding time and water level.

Data Analysis:

Plot a graph of cumulative infiltration (depth of water infiltrated into the soil) against time. Calculate the infiltration rate by dividing the slope of the graph by the surface area of the inner ring. The infiltration rate can be expressed in units of length per time, such as centimeters per hour Double ring infiltrometer is used for performing infiltration test.

Figure 3.0-7: Double Ring Infiltrometer

Chapter # 04

Results and Discussions

By closely resembling the natural water cycle, water sensitive urban design (WSUD) prevents stormwater from entering our rivers by reusing it in urban planning and design.

4.1 Climate Data of Wah Cantt City

Graphical representation of Climate data including Rainfall, Evaporation and Temperature for Wah Cantt City taken from Pakistan Metrological Department (PMD) is shown below.

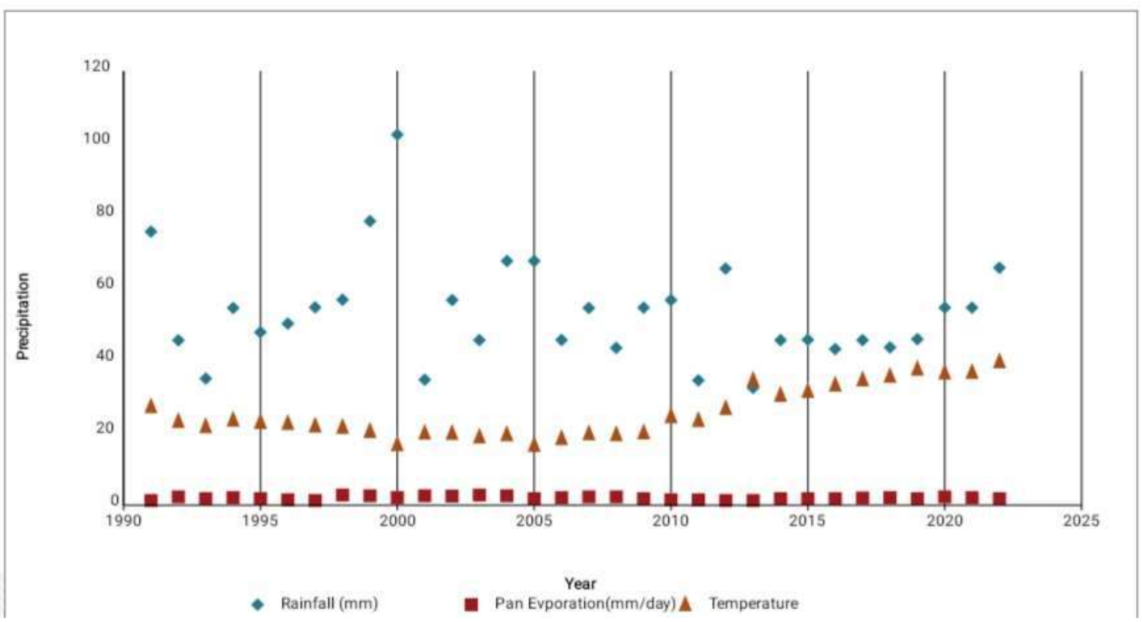


Figure 4.1: Climate Data of Wah Cantt from 1990-2022

We can observe the temperature, evaporation, and rainfall statistics with regard to the years in the graphic depiction.

4.2 Infiltration Test Performed (ASTM D 3385-9)

Infiltration tests basically include creating a hole, filling it with water, and tracking the water level decline over time. The infiltration test is conducted using a double ring infiltrometer.

Analyzing Data

TIME	HEIGHT(cm)	INFILTRATION(cm)
2:10	29.6	0
2:30	24.3	3.3
2:50	23.3	1
3:10	21.1	2.2
3:30	20	1.1
3:50	18.16	1.84
4:10	17.2	0.94

Table 1. Infiltration result table with respect to time

- **The infiltration rate is 6.5 cm per hour in the first hour.**
- **The rate of infiltration is 4.74 cm per hour in the second hour.**

4.3 Hydraulics Conductivity Test

Hydraulic conductivity, in science and engineering, is a property of porous materials, such as soils and rocks, that explains how easily a fluid may pass through the pore space or cracks network.

- Between 0.0005 and 10 m/day of hydraulic conductivity can be used with it.
- Our soil's hydraulic conductivity is 0.015 millimeters per day.

4.4 Estimation of Water Budget

A water budget is a breakdown of all the water entering and leaving a project area.

"Ss =P+ Qin -Qout +Qg -Es -Ts - I"

- P represents precipitation.
- Qin is the amount of surface water entering the system.
- Surface water flow out of the system is measured by Qout.
- Qg is the amount of groundwater entering the stream.
- Es stands for surface evaporation.
- Ts represents transpiration.
- I am the intruder.
- Ss is the modification in water storage.
- By using the inverse distance approach, we may find precipitation.

Wah Cantt's entire area is 58.27 km2.

Wah Cantt's typical annual rainfall is 1042.85 mm, or 1.04 meters.

Wah Cantt experiences 60.60 million gallons of total annual precipitation.

Soil hydraulic conductivity is 0.015 millimeters per day.

2.45 million gallons of water evaporate each year.

	mm/day	mm/year
INFILTRATION	0.015	0.000041
PRECIPITATION	2.84	0.007
EVAPORATION	0.00043	0.0000017

Table 2 .Final calculation of 3 tests

Delta S which is change in storage was found to be = 2.82455 mm/day. This is the amount of water that can be

4.5 SWMM Model Analysis

In order to examine the quantity and quality of flow in metropolitan settings, storm water management simulate (SWMM), a dynamic precipitation flow simulation model, can be used for either single events or long-term (continuous) simulation places known as sub-catchments that gather rainwater, produce runoff, and contaminate the environment. A network of pipelines, channels, storage and treatment facilities, pumps, and regulators is used by the SWMM's routing component. SWMM keeps track of each sub-catchment's flow quantity and quality as well as the depth, speed, and water quality of each pipe and channel.

4.5.1Modelling Components

Numerous hydrological phenomena that influence urban runoff are taken into account by SWMM. One of them changes over time is rainfall. Rainwater from depression storage is removed through rainwater collection and static surface water evaporation.

Seepage water penetrates into the groundwater layer, rainwater seeps into the saturated soil layer, and the groundwater-drainage system interflows.

4.5.2 Sub-catchment Developing

Watersheds are a type of hydrological unit. If it doesn't evaporate, every precipitation drop that enters the catchment will eventually flow into the same river that empties into the sea. The sub-catchment is a drainage system that mimics how a particular land area would be drained. Each sub-basin generates a runoff water level, which is typically sent to ponds or downstream river segments. It is also possible to utilize the sub catchment area to explain rain that falls directly on the pond's surface.

Processing steps

- Import map of study area
- Marked the catchment and sub catchment of study area
- Import the series data of precipitation

- Locate the gauging station
- Import the infiltration Data
- Rainfall Model Processing
- Set-up Flow routing
- Kinematic wave model
- Setting simulation model
- Check out summery details
- Enter time series analysis

4.6 Drainage Area of Wah Cantt

Drainage area is marked and analyze in SWMM as shown below.

Figure 4.2: Drainage Area in SWMM

4.6.1 Collection of storm water points

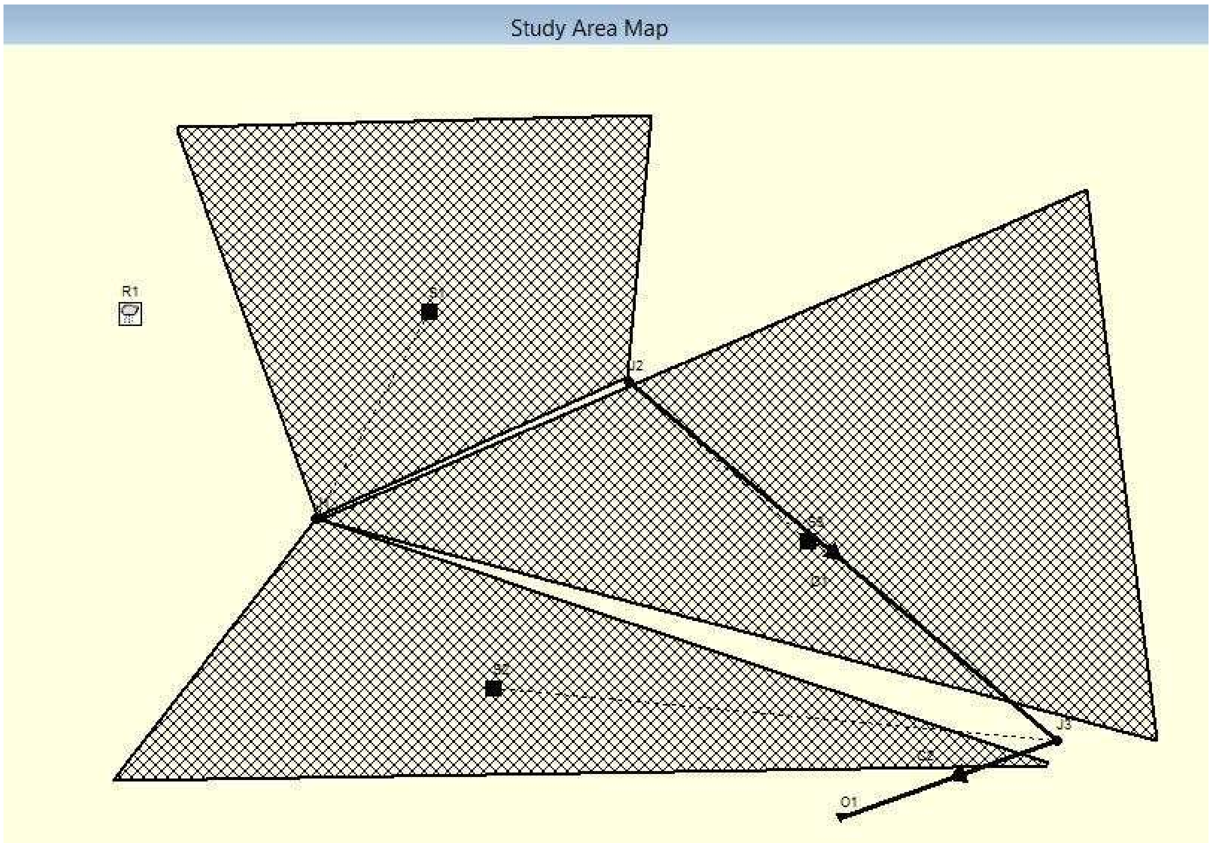


Figure 4.3: Strom Water Points Collection in SWMM

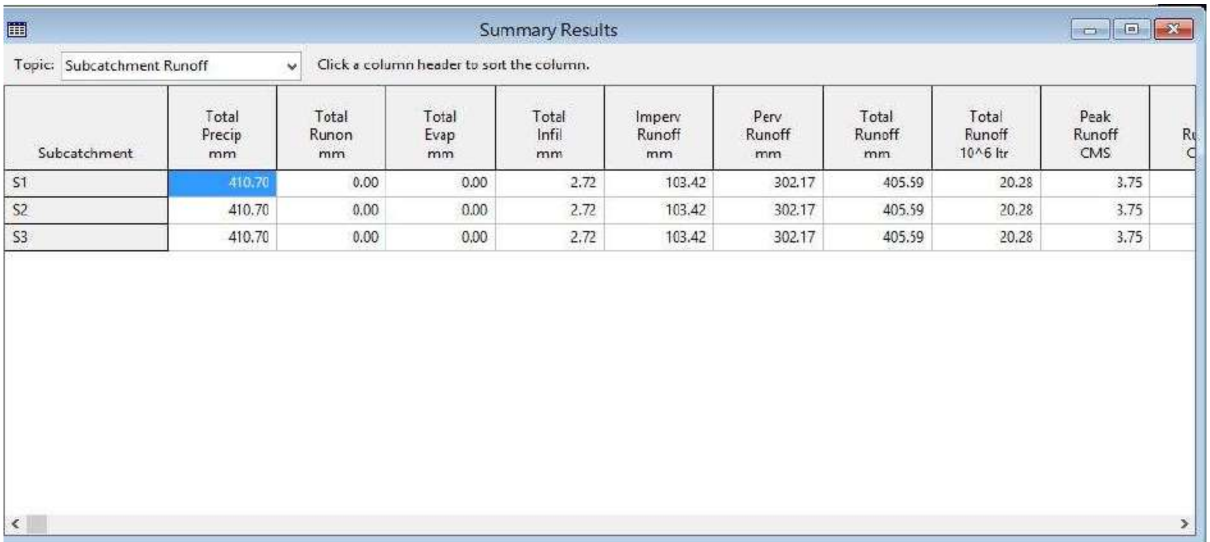
4.7 SWMM Results

- In each of the three sub-catchments, the sewage pipelines in the study area have appropriate slopes at the intermediate connections and pipelines. For rainfall events over a 30-year period, the runoff generated by the main sub-basins of the study area.

- These hydrological process lines help to understand how rainfall runoff interacts with sub-catchments, which are the result of various rainfall occurrences. Studies have shown that heavy rainfall with higher rainfall intensity has the largest peak runoff and time to reach the peak.

-

Runoff Results in SWMM

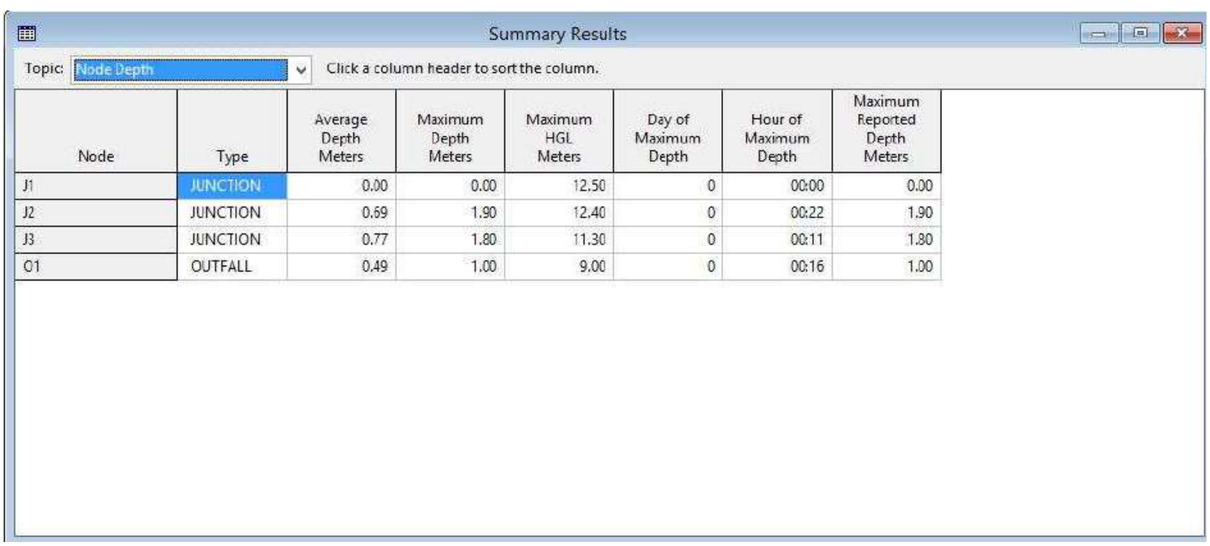


Summary Results

Topic: Subcatchment Runoff — Click a column header to sort the column.

Subcatchment	Total Precip mm	Total Runon mm	Total Evap mm	Total Infil mm	Imperv Runoff mm	Perv Runoff mm	Total Runoff mm	Total Runoff 10^6 ltr	Peak Runoff CMS
S1	410.70	0.00	0.00	2.72	103.42	302.17	405.59	20.28	3.75
S2	410.70	0.00	0.00	2.72	103.42	302.17	405.59	20.28	3.75
S3	410.70	0.00	0.00	2.72	103.42	302.17	405.59	20.28	3.75

Depth of runoff in SWMM



Summary Results

Topic: Node Depth — Click a column header to sort the column.

Node	Type	Average Depth Meters	Maximum Depth Meters	Maximum HGL Meters	Day of Maximum Depth	Hour of Maximum Depth	Maximum Reported Depth Meters
J1	JUNCTION	0.00	0.00	12.50	0	00:00	0.00
J2	JUNCTION	0.69	1.90	12.40	0	00:22	1.90
J3	JUNCTION	0.77	1.80	11.30	0	00:11	1.80
O1	OUTFALL	0.49	1.00	9.00	0	00:16	1.00

Total flow volume in SWMM

Summary Results

Topic: Node inflow — Click a column header to sort the column.

Node	Type	Maximum Lateral Inflow CMS	Maximum Total Inflow CMS	Day of Maximum Inflow	Hour of Maximum Inflow	Lateral Inflow Volume 10^6 ltr	Total Inflow Volume 10^6 ltr	Flow Balance Error Percent
J1	JUNCTION	3.749	3.749	0	05:00	20.3	20.3	0.000
J2	JUNCTION	3.749	3.749	0	05:00	20.3	20.3	-0.000
J3	JUNCTION	3.749	5.307	0	05:00	20.3	33.6	0.000
O1	OUTFALL	0.000	2.055	0	05:13	0	18.6	0.000

Maximum Flood Record

Summary Results

Topic: Node Flooding — Click a column header to sort the column.

Node	Hours Flooded	Maximum Rate CMS	Day of Maximum Flooding	Hour of Maximum Flooding	Total Flood Volume 10^6 ltr	Maximum Ponded Volume 1000 m3
J2	1.69	2.190	0	05:00	6.975	0.000
J3	2.08	3.398	0	05:00	15.107	0.000

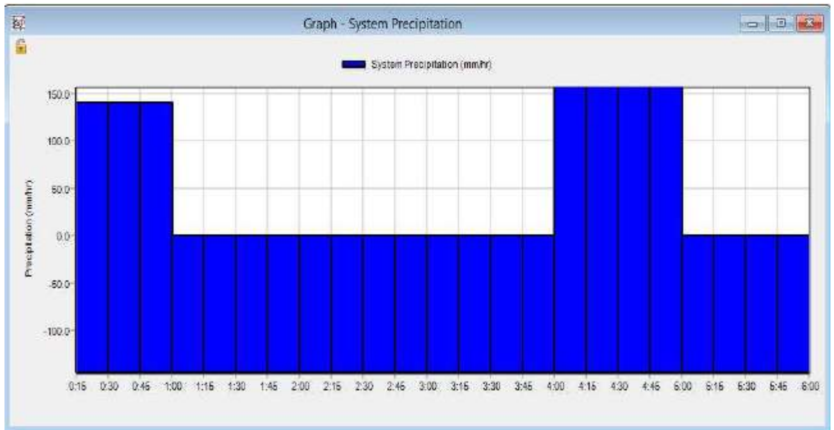
Summary Result in SWMM

Summary Results

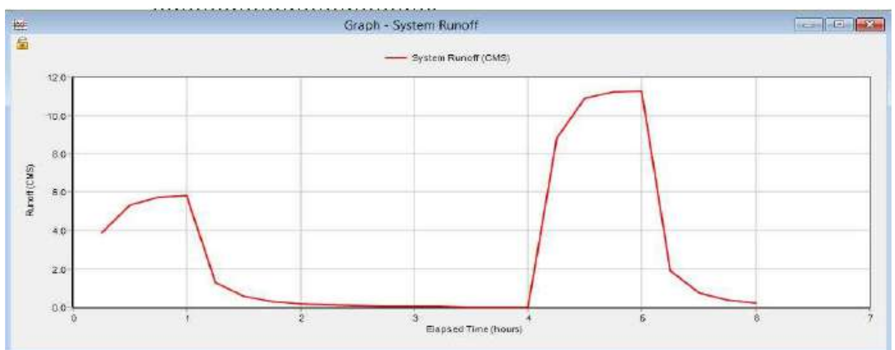
Topic: Link Flow — Click a column header to sort the column.

Link	Type	Maximum |Flow| CMS	Day of Maximum Flow	Hour of Maximum Flow	Maximum |Velocity| m/sec	Max / Full Flow	Max / Full Depth
C1	CONDUIT	1.687	0	00:32	2.64	1.08	1.00
C2	CONDUIT	2.055	0	05:13	3.04	1.08	1.00

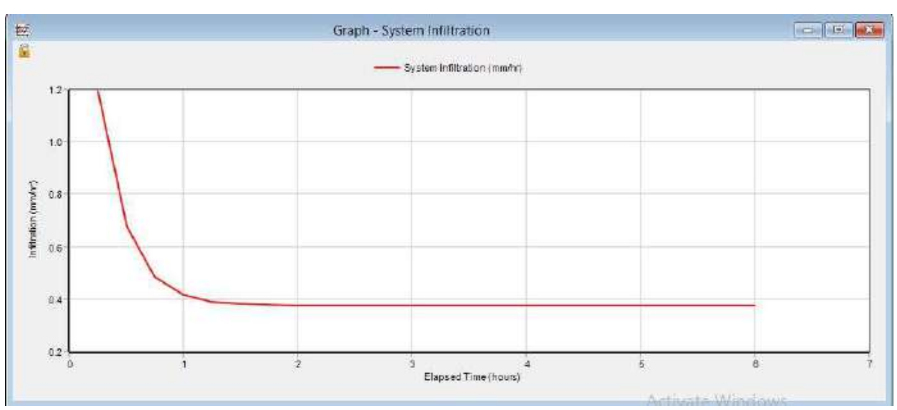
Precipitation records during flood in SWMM



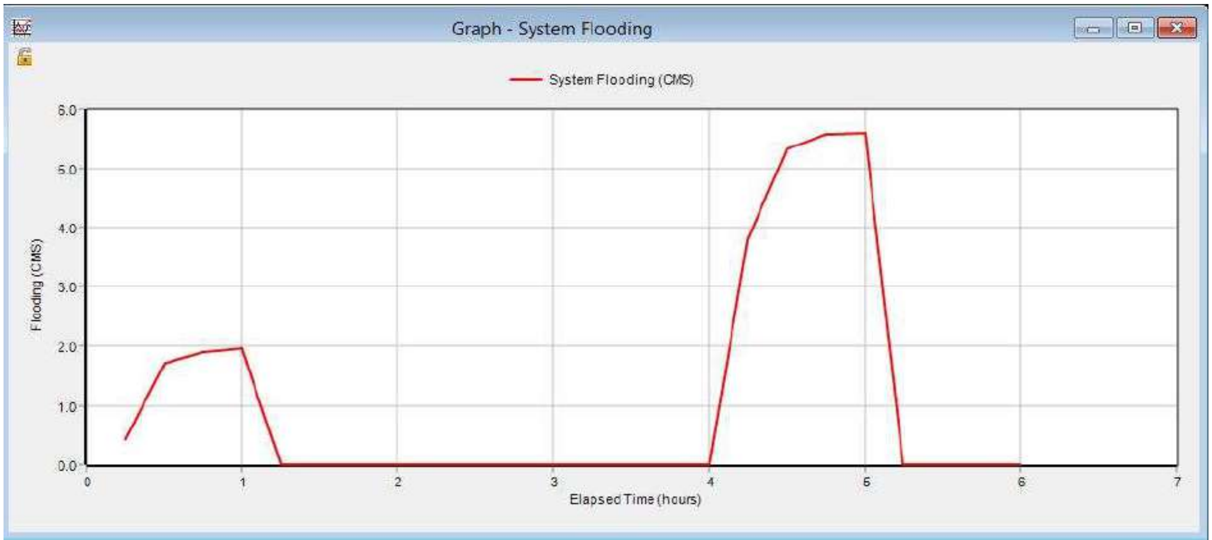
Runoff Hydrograph of Study Area in SWMM



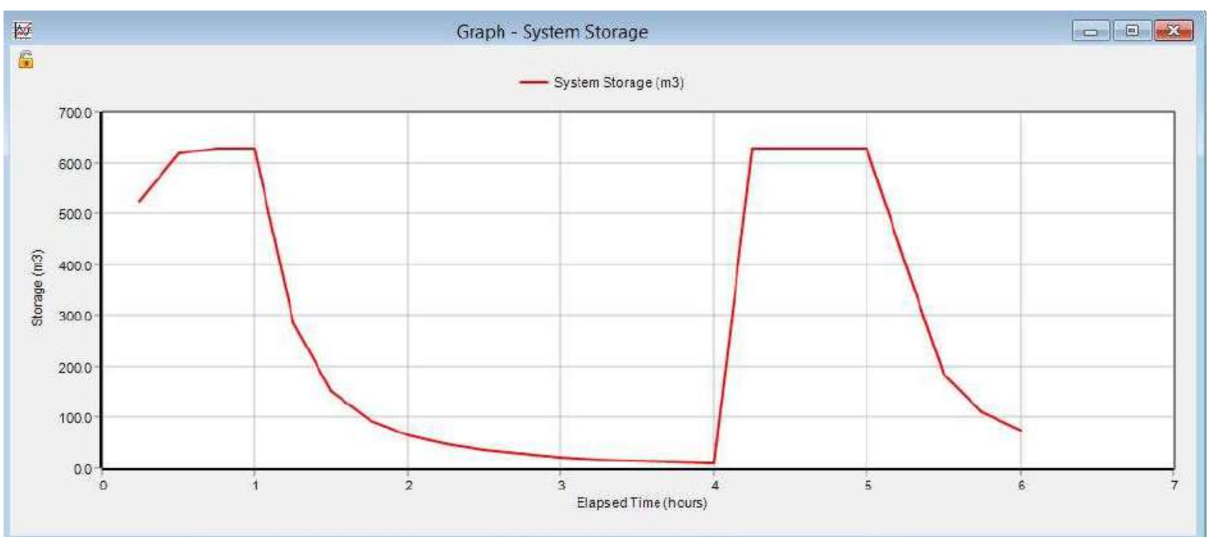
Infiltration of Study Area in SWMM



Graphical representation of Flood in SWMM



Graphical representation of pond storage time in SWMM



Results of Study area from SWMM

- **Types**
- **Runoff coefficient**
- **Built up area**

0.66-0.88

- **Densely Residential area**

0.56-0.71

- **Sparkly residential area**

0.4-0.65

- **Populated area**

0.32-0.54

SWMM is particularly well adapted for urban catchments, as the case study of Wah Cantt Taxila demonstrates, particularly when simulated as a single watershed under unfavorable circumstances. It may be calculated using both pre- and post-catchment characteristics.

The SWMM offers watershed responses to peak flow and runoff volume, which are the most essential catchment responses in urban drainage design, by stating that no nodes in the whole catchment are inundated and that no overflow sections occur. As a result, the campus storm network system is well-designed and capable of handling simulated rains.

Chapter # 05

Conclusion & Recommendation

Water Sensitive Urban Design is relatively a new approach. WSUD is an alternative land development method to replace rainwater management and has been recommended to replace traditional rainwater design. The main purpose of WSUD is to reduce the impact of development on water-related issues through the use of rainwater management practices that infiltrate, evaporate or collect and use rainwater where it falls. The most important result of WSUD is to greatly reduce the negative impact on the environment, return rainwater runoff and effective base flow, thus actively managing not only the quantity of natural water, but also the quality of water. This will help maintain natural habitats attached to aquifers and also maintain the ground water table.

WSUD include bioretention design, parking lot design, street scape design, infiltration trench design and permeable layer design. By adopting these all techniques, we not only save the storm water but also recharge the ground water table. These all techniques are environment friendly and also have a favorable effect on our natural ecosystem.

5.1 Recommended Drawings

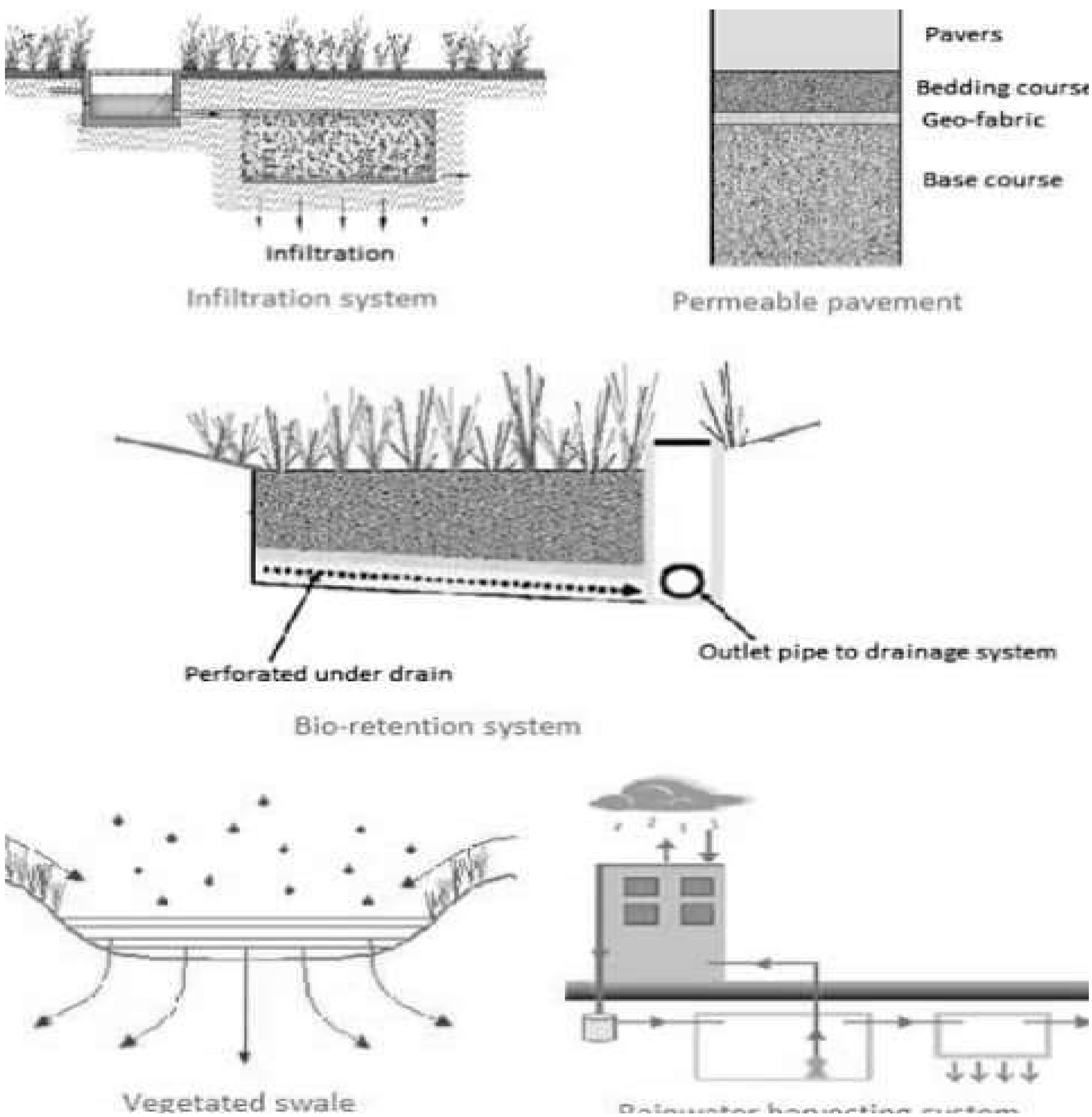


Figure 5.1 Bio Retention System

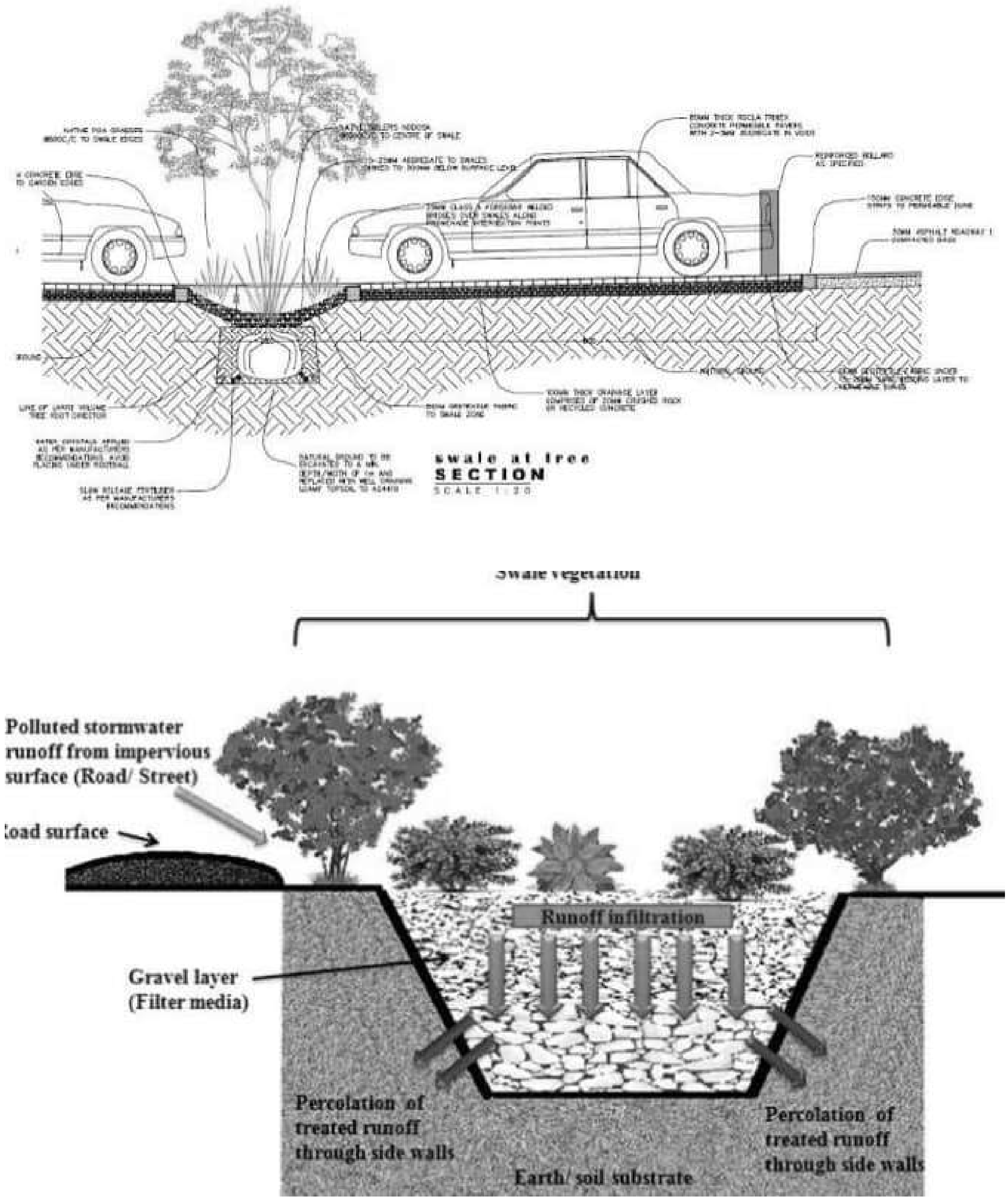


Figure 5.2 Road Cross Section

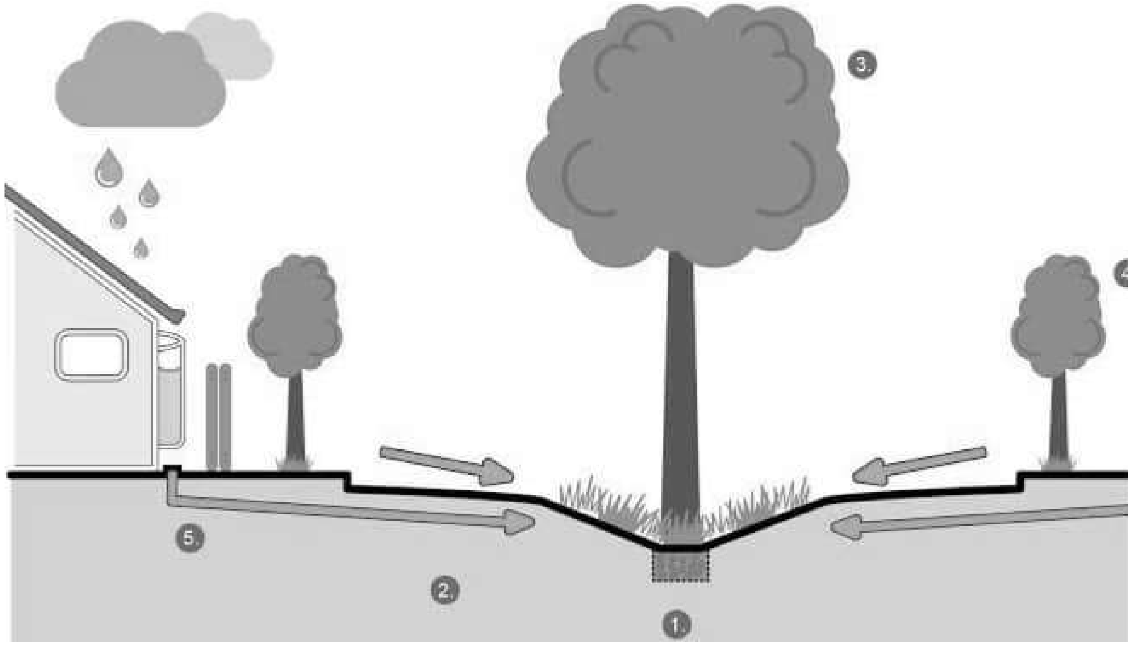


Figure 5.3 Collection of Water

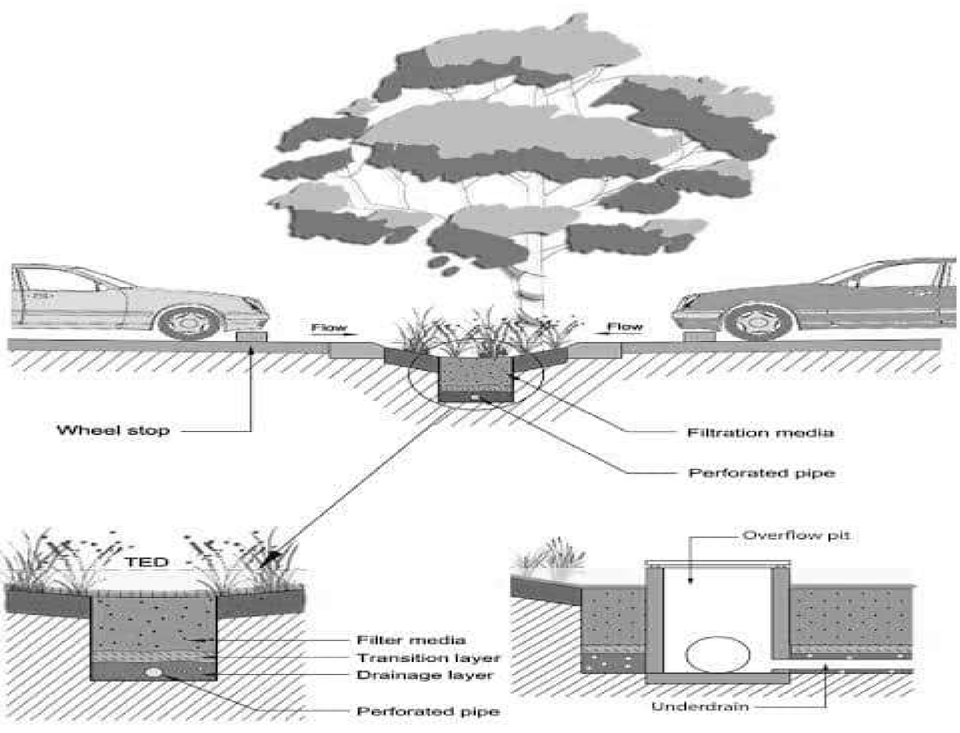


Figure 5.4 Working of Perforated pipe

5.2 Recommended Model for Wah Cantt City

Figure 5. 5 Presentation of Model of Wah Cantt City in "Open House and Job Fair 2023"

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