Evaluation of Existing Storm Water Drainage System of Aba-Geda Sub-City in Adama City, Ethiopia

Emebet Fetene Negash

A Thesis Submitted to the Department of Water Resources Engineering
School of Civil Engineering and Architecture

Office of Graduate Studies
Adama Science and Technology University

Presented in Partial Fulfilment of the Requirement for the Degree of Master ‘s in Water Resource Engineering (Specialization in Water Supply and Environmental Engineering)

February, 2024
Adama, Ethiopia

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Advisor: Andinet Kebede (PhD)

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Declaration

I hereby declare that this Master Thesis entitled "**Evaluation of Existing Storm Water Drainage System of Aba-Geda Sub-City, Adama, Ethiopia**" is my original work. That is, it has not been submitted for the award of any academic degree, diploma or certificate in any other university. All sources of materials that are used for this thesis have been duly acknowledged through citation.

Emebet Fetene	___________________	________________
Name of student	Signature	Date

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I, the advisor of this thesis, hereby certify that I have read the revised version of the thesis entitled "**Evaluation of Existing Storm Water Drainage System of Aba-Geda Sub-City, Adama, Ethiopia**" prepared under my guidance by Emebet Fetene submitted in partial fulfillment of the requirements for the degree of Mater's of Science in Water Resource Engineering (Specialization In Water Supply and Environmental Engineering). Therefore, I recommend the submission of the Thesis to the department for further review and evaluation.

Andinet Kebede(PhD) ________________________ ______________

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Approval Page of M.Sc. Thesis

I the advisor of the thesis entitled "Evaluation of Existing Storm Water Drainage System of Aba-Geda Sub-City, Adama, Ethiopia" and developed by Emebet Fetene, hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

Andinet Kebede(PhD)	________________________	_______________
Major Advisor	Signature	Date

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We, the undersigned, members of the Board of Examiners of the thesis open defense Emebet Fetene have read and evaluated the thesis entitled "**Evaluation of Existing Storm Water Drainage System of Aba-Geda Sub-City, Adama, Ethiopia**" and examined the candidate. This is, therefore, to certify that the thesis has been accepted in partial fulfillment of the requirement of the degree of Master of Science in Water Resource Engineering (Specialization In Water Supply and Environmental Engineering).

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Abbreviations

BMP	Best management practice
DEM	Digital elevation model
EPA	Environmental Protection Agency
GIS	Geographical Information System
(HGL)	Hydraulic Grade Line
IDF	Intensity-Duration-Frequency
LULC	Land use land cover
MCDA	Multi-Criteria Decision-Making
NRCS	Natural Resources Conservation Service
ERA	The Ethiopian Road Authority
GPS	Global Positioning System
TOC	Time of concentration

Abstract

Improper management of urban runoff poses a significant threat to cities worldwide. It stems from a combination of various factors, including hydrological elements, urbanization, climate change, and inadequate infrastructure. This issue can lead to devastating consequences, such as property damage, the destruction of critical infrastructure, and even loss of life. Many cities around the world have been facing with this disastrous trait, which arises due to the complexity and uncertainty surrounding these interconnected factors. It is crucial for cities to address and tackle this issue promptly to mitigate its detrimental effects on society and the environment. During the rainy season in Adama city of Aba-Geda Sub City often experience frequent flooding. The abundance of rainfall, combined with the absence of proper drainage systems and inadequate solid and liquid waste management practices, contribute to this issue.This paper focuses on the challenges of storm water drainage management in Adama city of Abageda Sub-city, Ethiopia. The study highlights the need for an integrated early warning system for flood risk management and ongoing improvement in analysis, mitigation, and management of flood damages. The objective of this study is to assess the existing storm water drainage system in Adama, specifically for Aba-Geda Sub-City drainage line. The data collection process involved gathering both primary and secondary data were subsequently analyzed and presented. Landsat imagery from 2018 and 2022 was utilized for land use and land cover classification. Geographic information system (GIS) software was employed to classify the land use and land cover map based on ground truth observation. Additionally, an accuracy assessment was conducted to verify the consistency of the classified map with the ground truth data. This involved comparing the classified map with actual on-site observations to ensure the reliability and precision of the classification results. The frequency analysis of rainfall was computed using the Gumbel distribution, which is commonly used to analyze extreme value data, such as rainfall. The intensity-duration-frequency (IDF) curve was developed to understand the relationship between rainfall intensity, rainfall duration, and return period. The peak discharge flowing in the main catchment up to the final outlet point was calculated using the rational method, which is a widely used method for estimating peak discharges in small watersheds. These methods and analyses provided valuable insights into the characteristics of rainfall and its impact on the drainage system. The comparison of the model results with the existing hydraulic capacity of the channels revealed that, the channels from CH-8 to CH-14, known as Mebrat Hayil to Posta Bet, as well as the channels from CH-15 to CH-16, surrounding Bekele Mola to Posta Bet, and the channels from CH-17 to CH-26, from Sar Tera to Franco, are all experiencing a lack of hydraulic capacity to handle the runoff water they receive. Similarly, the channels from CH-27 to CH-30, from Franco to Pan-Africa, are also inadequate in carrying the contributed runoff water. These channels are currently ill-equipped to manage the runoff generated by a 25-year return period design discharge. The primary issue in this area stems from the insufficient capacity of the channels and the incorrect sizing of the inlet culverts, which were not appropriately designed considering the contributing catchment area of 220ha.Therefor, BMP's will help in solving the problem.

Keywords: Aba-Geda Sub-City, drainage system, Stormwater, Urbanization , Best Management Practicess

1. INTRODUCTION

1.1. Background

Storm drainage is an essential part of the urban environmental system, and it is crucial to ensure that storm drainage planning and design are compatible with comprehensive regional plans. To achieve this, a master plan for storm drainage should be developed and maintained up-to-date for each urbanizing drainage watershed in the region. The planning for drainage facilities should be coordinated with planning for open space and transportation to identify new opportunities that can assist in the solution of drainage problems(Biabanaki et al,2012.)

Urbanization is characterized by a marked increase in built structures such as streets, walkways, parking lots, and rooftops creating sealed surfaces. Drainage networks are an important part of the infrastructure of any society. The main purpose of providing the drainage network is to carry away sanitary waste and stormwater from a municipal area in such a way that it does not cause any public health-related problems. Both stormwater and wastewater need to be considered for the drainage system planning and design. Stormwater is the water generated from rainfall, it infiltrates the ground surface and joins with the groundwater table or contributes to subsurface flow, and the remaining portion ends up as surface runoff which ultimately joins with the streams, rivers, etc. Under natural conditions, most of the stormwater gets infiltrated into the soil due to higher permeability of the surface. Stormwater is rainwater or melted snow that runs off streets, lawns, and other sites. When stormwater is absorbed into the soil, it is filtered and ultimately replenishes aquifers or flows into streams and rivers. Urbanization is characterized by a marked increase in built structures such as streets, walkways, parking lots, and rooftops creating sealed surfaces. Drainage networks are an important part of the infrastructure of any society. The main purpose of providing the drainage network is to carry away sanitary waste and stormwater from a municipal area in such a way that it does not cause any public health-related problems. Both stormwater and wastewater need to be considered for the drainage system planning and design. Stormwater is the water generated from rainfall, it infiltrates the ground surface and joins with the groundwater table or contributes to subsurface flow, and the remaining portion ends up as surface runoff which ultimately joins with the streams, rivers, etc. Under natural conditions, most of the stormwater gets infiltrated into the soil due to higher permeability of the surface. Stormwater is rainwater or melted snow that runs off streets, lawns, and other sites. When stormwater is absorbed into the soil, it is filtered and ultimately replenishes aquifers or flows into streams and rivers(Zinabie & Kebede, 2020).

Urban stormwater drainage systems are part of the urban infrastructure basics and stormwater is rain, snowmelt, and rising water that temporarily runs off the ground surface. In towns with many impermeable surfaces, large quantities of stormwater storage are designed. Drainage problems in urban areas consist of flooding, deterioration of roads, land degradation, sedimentation, blockage of drainage facilities, and water logging(Tadesse et al, 2021).

The storm water drainage system was designed to drain excess rain water from impervious surfaces such as paved streets, car parks, parking lots, footpaths, sidewalks, and roofs. In modern cities, the storm water drainage system was an essential part of the urban infrastructures. Basically, the most important use of the storm water drainage system was to carry the excess rain water in the monsoon season from the roads, streets and roofs and make the city free from the problems of back flow and also from the flood. In developing countries, the factors which affected the storm water drainage system were classified into two categories: natural and human activity (Zinabie, 2018).

The pattern of urbanization and modernization in Ethiopia increased densification along with urban infrastructure development. This led to deforestation, use of corrugated roofs and paved surfaces. The combined effect of this resulted in higher rainfall intensity and consequently accelerated and concentrated runoff in the urban areas. Due to inadequate integration between road and urban storm water drainage infrastructure provision, many areas were exposed to flooding problems and road damages in urban roads. (Dagnachew, 2011).

In Ethiopia, floods have posed a significant natural hazard, particularly in Adama City, leading to substantial risks and damage. The city has experienced devastating floods in 2008, 2009, and 2016, resulting in significant costs and widespread impact. Adama City's susceptibility to flooding is attributed to its location and rapid urbanization. The absence of an integrated early warning system for flood risk management has contributed to escalating social, economic, and ecological flood damages over time. This deficiency underscores the need for ongoing improvements in analysis, mitigation, and management practices to effectively address the challenges posed by the lack of an integrated system(Tesema et al., 2017).

A well planned, operated and maintained storm water system drained storm water runoff effectively during normal periods and during floods. However, with rapidly expanding cities, unanticipated problems from changing land usage, system overloading, pollution and deteriorating environment caused problems to storm water assets and contributed to its failure. These issues were more problematic in larger and older cities where replacement was costly.

Urban storm water drainage facilities were part of the urban infrastructure elements and design of these facilities required due attention. In Ethiopian context, where watersheds of many urban centres received significant amount of annual rainfall and where rainfall intensity was generally high, control of runoff at source, flood protection, and safe disposal of excess water/runoff through proper drainage facilities became essential (Asfaw, 2016)
The renovation of older residential areas for stormwater management, pollution reduction, and ecosystem restoration is a complex task in urban water management. In many old towns, the original plans may not be found, and the low willingness of residents for change can make the process more challenging. Furthermore, the involvement of multiple government agencies, such as water conservancy bureaus, housing and construction bureaus, and municipal engineering departments, can further complicate the process(Zhang et al. 2020).

The main focus of the study was to assess the challenges of urban drainage infrastructures and its provision in the developing towns of Ethiopia, considering Adama city as a case study of Aba-Geda Sub-City. The study discussed the coverage of drainage system, its current status and the impacts due to poor drainage system at the case study area.

1.2. Statement of the Problem

The insufficient management of urban stormwater drainage is a prevalent issue in many urban centers of Ethiopia, often leading to resident complaints and worsening with rapid urbanization. The lack of proper planning and implementation of stormwater protection structures further worsens this problem. The increasing rate of urbanization, along with the densification and permeability of the urban landscape, has contributed to the deterioration of existing drain systems and the lack of on-site stormwater management. Urbanization has been directly linked to major drainage failure causes, often resulting from man-made debris and increased impervious surfaces(Asfaw, 2016).

Adama City, one of the rapidly growing and flood-vulnerable urban areas in Ethiopia, has been significantly impacted by flooding, leading to a demand for proper stormwater management and spatial-temporal information related to the interaction between urbanization and the city's hydrological characteristics. The city's high flood vulnerability is attributed to factors such as unplanned urbanization in low-lying areas, rapid population growth, and the absence of comprehensive flood vulnerability assessments. The absence of an integrated early warning system for flood risk management has contributed to the increasing social, economic, and ecological flood damages in Adama City. Therefore, there is a pressing need to prioritize the establishment of an integrated early warning system, conduct comprehensive flood vulnerability assessments, and implement effective stormwater management strategies to mitigate the adverse impacts of floods and restore the ecosystem function and biodiversity in Adama City(Bulti & Abebe, 2020).

In Adama context, floods at a time of alot high rainy days over flowing of the flood on the top of the drainage system the normal flood ways and created a lot of disaster to the residents, also Aba-Geda Sub-Cities of Adama Cities in Ethiopia are frequently flooded during the rainy season due to heavy rainfall, lack of drainage systems, and poor solid and liquid waste management practices. The flooding risk in Aba-Geda Sub-Cities is a significant concern, and a comprehensive flood vulnerability assessment and local management strategy are needed to mitigate the adverse impacts of floods. The problem over flowing of the flood on the top of the drainage system, blockage of drainage facilities, and filling of water in some of the drainage areas is also a concern, and wastes that flow along the drainage system have a bad smell and create an unwelcoming environment. The efficient management of stormwater is essential to protect the health, happiness, and safety of the public, conserve water, and try for a suitable environment. The involvement of multiple government agencies further complicates the task of addressing the cities flood vulnerability and implementing sustainable urban water management practices. Therefore, there is a pressing need to prioritize the establishment of an integrated early warning system, conduct comprehensive flood vulnerability assessments, and implement effective stormwater management strategies to mitigate the adverse impacts of floods and restore the ecosystem function and biodiversity in Aba-Geda Sub-City of Adama City.

1.3 Research Objective

1.3.1 General objective

The main objective of this study is to evaluate the existing storm water drainage system in Adama, specifically for Aba-Geda Sub-City drainage line.

1.3.2 Specific objectives

To realize the general objective, the following specific objectives were used as the operational steps.

- To evaluate the adequacy of the existing drainage system in the study area
- To identify the major challenges in the storm water drainage management
- To map and Identify flood prone areas
- To propose appropriate best management practice (BMP) to alleviate the problem

1.4, Research Questions

The research tried to find answers to the following questions:

1. What is the status, in terms of adequacy, of the existing drainage of the study area?
2. What are the major challenges in managing the storm water drainage in the study area?
3. Which part of the study area is more sensitive to flooding problems, and why?
4. What are appropriate best management practices (BMP) to alleviate the problem?

1.5, Scope of the project

The Thesis aims to cover field observation of flood-prone areas of Aba Geda Sub City, assessment, and identification of problems in the sub city that need immediate short-term solutions, and proposals of possible short and long-term flood mitigation mechanisms for the current rainy season.

1.6, Limitations of the study

The study faced several limitations, including the lack of a well-organized existing drainage data in the Municipality's Office. This made the data collection process laborious and time-consuming. The absence of a comprehensive and organized drainage data set made it difficult to obtain necessary information about the drainage system. Due to the lack of available data in the municipality's, the research had to rely on collecting information from the ground, which was time-consuming and labour-intensive.Limitation of personal experience with StormCAD has shown that the effectiveness of assessing existing storm water drainage systems heavily relies on the skills and training of the tutorial.

1.7, Significance of the Study

This study on the evaluation of existing stormwater drainage systems in Aba-Geda Sub-City holds great significance for various stakeholders, identify potential vulnerabilities and weaknesses. Improving these systems minimize flooding occurrences, protecting homes, businesses, and infrastructure, and enhancing the overall resilience of the community. Inadequate drainage systems lead to stagnant water, which can become breeding grounds for mosquitos and other disease-carrying vectors. Evaluating and improving the drainage infrastructure is help prevent waterborne diseases, ensuring better public health and safety for the residents of Aba-Geda Sub-City. Proper stormwater management plays a crucial role in protecting the environment. Implementing sustainable drainage measures can help mitigate these environmental impacts and preserve the natural resources in the area.The findings of this study can inform the Municipality's future planning and development strategies. Improving the stormwater drainage infrastructure lead to efficient land use, reduced property damage, and control food problem. It can also contribute to the overall attractiveness and livability of the sub city. By providing comprehensive insights into the condition of the existing stormwater drainage systems, this study can assist government authorities in formulating effective policies and regulations. It can aid in allocating resources appropriately, prioritizing maintenance and upgrades, and ensuring a sustainable and resilient urban environment. Overall, this study has the potential to bring about positive changes for the community, public health, Municipality, and government by addressing the challenges associated with stormwater drainage systems in Aba-Geda Sub-City and paving the way for informed decision-making and improvements.

2. LITERATURE REVIEW

2.1, Storm Water and Urban Drainage System

2.1.1, Storm water

Stormwater is the water that accumulates from various infrastructures, such as rooftops, roadways, and parking lots, following rainfall events. It then flows over the Earth's surface and drains into drainage lines, ultimately joining nearby water bodies. The properties of stormwater, in terms of quantity and quality, are influenced by the nature and characteristics of both the rainfall and the catchment area. Factors such as rainfall patterns (frequency, intensity, duration), landscape, and land use play a significant role in determining the behavior of stormwater (Hawaz, 2020).

Stormwater, which contains impurities and pollutants, is the result of rainfall and snowmelt. In urban environments, the presence of impervious surfaces such as roads and rooftops prevents stormwater from infiltrating the ground, leading to increased runoff. This phenomenon can cause flooding and water pollution. However, when managed effectively, stormwater can be a valuable source of fresh water. To achieve this, it is essential to control both the quality and quantity of stormwater through a combination of structural and operational practices. Integrated water management is a critical aspect of urban environments, as it allows for the comprehensive management of water resources, including stormwater (Teshome & Sewnet,2020).

2.1.2, Urban drainage system

The urban drainage system is a system that is both social and technical in nature, located in a large-scale urban environment combining many other subsystems to create a complete system. These sub systems (e.g. Roads, buildings, pipe, surface water) all intimately associate in different ways. However, each subsystem has its own ways of operation, functions, and interactions with factors, can therefore lead to conflicts in the relationships. These relationships and association cause the system complexity, making it complicated to understand and predict the interactions between subsystems and factors.

Urban drainage is concerned with the collection and conveyance of wastewater and storm water from urban areas. An important social aspect is to maintain public health and safety; hence an efficient drainage of storm water and wastewater is essential to avoid impact of flooding on life and property. In addition, the current environmental awareness involves the protection of the receiving waters from the pollutants that may be dragged by water flowing in the surface during heavy rain events (Siragi, 2019).

For a long time, urban drainage systems have existed as a vital city infrastructure to collect and convey storm water and wastewater away from urban areas. Despite development over the years, it remains a significant challenge to design an effective functioning drainage system (Zhou, 2014).

Urban storm water drainage system needs to be designed properly because it is an essential part of any urbanization. Its proper operation and performance insures the safe discharge of run off to the required place. Urban drainage models are required to design these infrastructures for the specific demands of the planed urban area. Consistent maintenance methodology is required after construction to guarantee the proper functioning of the system and to facilitate the remedial works and optimize the allocation of resources (ABRAHIM & Kebede, 2022).

2.1.3, Urbanization effects on storm water drainage system

Urbanization is negative impact on urban drainages system in unplanned city. Most of densely populated town and cities are facing water logging and flooding problem during heavy rainfall. Urban drainage replaces one part of the natural water cycle and, as with any artificial system that takes place of a natural one, it is important that the full effects are understood (Leta, 2020).

Urbanization has impacted the processes of the urban hydrological cycle in several ways. The expansion of impermeable surfaces, such as sidewalks and buildings, has increased surface runoff and reduced groundwater recharge, lowering surface roughness by reducing the vegetation distribution and flattening the surface, which may accelerate the surface runoff process (Chen et al 2022).

As population grows, demand for housing and commercial amenities naturally follows. The urbanization adds roads, rooftops, parking lots, sidewalks, and other imperviousness to the landscape. In recent years, researchers have reported that imperviousness is an effective predictor of environmental degradation. Land surface is covered by buildings and pavement; do not allow rain and snowmelt to soak into the ground. Instead, most developed areas rely on storm drains to carry large amounts of runoff from roofs and paved areas to nearby waterways. The level of economic also has implications to urban hydrology and storm water management in other ways. For instance, the increasing use of the car and other forms of road transport results in a significant increase in impervious areas for the road surfaces and areas for parking (Bajracharya et al 2015).

2.2, Storm Water Drainage System and Its Function

2.2.1, Storm water drainage system

Storm water drainage is the process of draining excess water from streets, sidewalks, roofs, buildings, and other areas. The systems used to drain storm water are often referred to as storm drains. Many cities and towns have carefully planned storm water drainage systems that consist of inlets, outlets, and pipes. The inlets of storm drains are often covered by protective grates that help to ensure that large items don't fall in while water can enter freely. Since it's important for large amounts of water to flow into these drains, the bars of the grates must be spaced some distance from each other. This concession means that some smaller objects do fall into the drain (Tefera 2020).

Urban storm water drainage facilities are part of the urban infrastructure elements and the design of these facilities requires due attention. In Ethiopia context, where watershed of many urban centres receive a significant amount of annual rainfall and where rainfall intensity is generally high, control of runoff at the source, flood protection, and safe disposal of excess water/runoff through proper drainage facilities becomes essential (Tariku, 2022)

2.2.2, Function of storm water drainage system

One of the most important facilities in preserving and improving the urban water environment is an adequate and properly functioning storm water drainage system (Pavan et al., 2015).The function of the storm water drainage system is to direct runoff from precipitation events such as rain or snow melt away from our property. We have altered the landscape as we have developed and grown as a City. Our business and home roofs, sidewalks, streets, and parking lots are not the vegetated areas they once were. When vegetated, land largely absorbs storm water. But when developed, the amount of impervious area (hard surface area that does not absorb storm water) increases. Without the storm water drainage system, there would be nothing in place to direct storm water runoff away from our homes and businesses. The storm water drainage system is designed according to the layout of the land (i.e. low points and high points) and the impervious area surrounding it.

2.3, Storm Water Best Management Practice (BMP's)

Best management practice (BMP) is a term used for structural and engineering measure of storm water management which have a paramount importance in preventing flood in urban areas. BMP is management technique mainly for surface water through the use of natural drainage in conjunction with technologies and policies. BMPs used to reduce or prevent storm water negative effects through structural, vegetative or managerial practices (Teshome & Sewnet, 2020).

BMP means a practice, or combination of practices, that is determined to be an effective and practicable (including technological, economic, and institutional considerations) means of preventing/ reducing the amount of pollution generated by nonpoint sources to a level compatible with water quality goals (Jain 2019).

2.3.1, Goals of storm water Best Management Practice

Storm water management is the control and use of storm water runoff. It includes planning for runoff, maintaining storm water systems, and regulating the collection, storage, and movement of storm water. Storm water management also considers drainage in the design of cities and housing developments (Shelton et al. 2015).

The goals of storm water management include protecting our environment; reducing flooding to protect people and property; reducing demand on public storm water drainage systems; supporting healthy streams and rivers; and creating healthier, more sustainable communities. Effective storm water management provides environmental, social, and economic benefits to local communities. When storm water management is done well, streams, rivers, and lakes are cleaner; flood risks are reduced; costs due to flood damage decrease; and community quality of life increases (Fleischmann 2014).

2.3.2, Benefits of using BMPs for storm water management

The benefits of managing storm water runoff don't end with reducing pollutants. Storm water BMPs can reduce the threat of flooding, create whole new ecosystems, and provide economic benefits.

- Economic benefits: The economic benefits of storm water management include increased economic development, more green jobs, and increased land and property values.
- Improved water quality: Removing pollutants from water improves water quality, both for humans and for the ecosystem as a whole.

- Better flood control: Flood risks are mitigated as a large amount of runoff is diverted to BMPs. It can be held there temporarily and released gradually to keep water levels manageable.

- Creates environmental amenities: Ponds, basins, rain gardens, and marshes can create stopover sites for migrating waterfowl like herons and egrets. They can also provide permanent habitat for other wildlife, creating new ecosystems. For humans, they can provide spots for hiking, fishing, swimming, and other recreational activities.

The benefits of BM’s (United states EPA 2022)

- Promotes the natural movement of water, instead of allowing it to wash into streets and down storm drains.
- Can blend in with the landscape and infrastructure.
- Can be infrastructure, such as a permeable parking lot.
- Can provide aesthetic effects.
- Can reduce the amount of pollutants entering the water collection system.
- Can improve water quality and the water treatment process at water treatment plants.

2.3.3, Factors influencing best management practice

The objective of storm water BMPs is to prevent or reduce the movement of sediment, nutrients, pollutants, or debris from land to surface or ground waters. The natural drivers of such movement are highly dependent on the interaction among entities such as soil, vegetation, land use, storm and runoff characteristics, and processes such as runoff formation, infiltration, erosion, and sediment transport. The natural factors that guide these processes are dependent on topography, geology, soil-geomorphology, and the hydrometeorology of the region (Gautam et al. 2010,).

The management and regulation of stormwater in the United States is faced with many challenges that make improvement or reform a difficult task. The challenges that face stormwater management today are typically related to funding, public awareness, institutional organization, regulation implementation, and monitoring (Jiang, et al.2018).

2.4, Hydrology and Hydraulic Design

The hydrologic and hydraulic design requirements for drainage systems are described below. This information supplements the policies, objectives, and design considerations of Development services schemes and their components, including aspects affecting aesthetics and soft engineering. This section includes details on the design of drainage systems, focusing on hydrologic and hydraulic aspects.

Hydrology also deals with estimating flood magnitudes as the result of precipitation. In the design of roadway drainage structures, floods are usually considered in terms of peak runoff or discharge in cubic meters per second (m^3/s) and hydrographs as discharge per time.

The Rational Method is widely used for determining design flow rate in storm sewer design. The Rational Equation, and estimation of its parameters to calculate Q, will be covered here because of its key role in hydraulic design of storm sewers. The Rational Method is used for other purposes also, especially with relatively small drainage areas (Bondeson 2021).

The Rational Method predicts the peak runoff according to the formula: Q = CiA,

*Where: **Q** is the peak runoff rate for a specified return period, cfs**

C is the runoff coefficient that is the fraction of rainfall which becomes runoff. The value of C is dependent upon the land use of the drainage area. It is dimensionless

i is the design rainfall intensity, in/hr

A is the sub catchment area,

A Hydraulic Grade Line (HGL) analysis is required for all designs to ensure water flows through underground pipes and overland flow systems in the manner intended. The finished surface level of developed land is a primary consideration when determining hydraulic grade requirements.

The first step in the hydraulic design of a length of storm sewer is typically determination of a design flow rate for that length of pipe. For storm sewers the design flow rate is based on the runoff from a design storm for the site of the storm sewer system.

For the purpose of the hydraulic analysis, a hydraulic model has been developed that will simulate the runoff conditions of the storm water drainage system, using the Bentley Storm CAD software package. While developing the model, first the parameters of the main elements are examined, such as: manholes and catch basins; channels; links (pipes); outfalls; main collector; urban surface border and catchment areas.

2.5 Flood Hazard Maping

Flood hazard mapping is a critical component of flood-prone land use planning and mitigation. It involves the use of ArcGIS 10.2 software tools to perform the mapping. Multi-criteria decision analysis (MCDA) is recognized as an important tool for analyzing complex decision problems that often involve incommensurable data or criteria. The flood hazard mapping was taking into account various factors such as slope, rainfall distribution, land use and land cover (LULC) pattern, and the distance from the river. The Digital Elevation Model (DEM) from ALOS PALSAR and rainfall data from the Department of Hydrology and Meteorology were utilized to create individual maps for each factor. This comprehensive approach allowed for the integration of multiple criteria in the flood hazard mapping process, enabling a more forceful and accurate assessment of flood risk. (Adhikari, 2020).

All studies, despite their different methodologies, have highlighted the effectiveness of Geographic Information System-Multi-Criteria Decision Analysis (GIS-MCDA) as a forceful tool for identifying flood hazard areas. The overall process for identifying flood-prone areas involves several steps: defining specific criteria, conducting a ranking process through standardization, assigning weights to each criterion, and overlaying the criteria to generate the final result. To ensure the reliability of the outcome map, a sensitivity analysis was performed. The ultimate outcome of the GIS-MCDA approach is the categorization of areas into five classes based on their vulnerability to future flooding: "Very high," "High," "Moderate," "Low," and "Very low"(Ajjur and Mogheir, 2020).

3. MATERIALS AND METHODS

3.1 Description of the Study Area

3.1.1 Location

Adama city is one of the fast-growing urban areas in Ethiopia. It is located at 8.554222°,8.547855°,8.542893° & 8.539383°,N latitude and 39.265095°,39.281048°,39.279046° & 39.258993°E longitude. Located 99 kilometers south-east of Addis Ababa on the Ethio-Djibouti corridor, Adama is one of the country's key import-export routes and business hubs. However, compared to its investment, trade and logistical importance, its march to industrialization started relatively recently, and included the opening of the first phase of the industrial park, which has 19 sheds and cost ETB4.1 billion.The city is suited in Rift Valley, on flat topography characteristics and surrounded by mountains and ridged topography. The latest approved land use plan of the city was prepared in 2004(Bulti & Abebe, 2020). The growth rate of population of Adama city from 2004 to 2016 is about 9%. Hence, time series analysis of Land use land cover (LULC) in the city administration from 1997 to 2022 is deemed appropriate to provide enhanced picture of the impacts of urbanization on hydrological characteristics of the area.

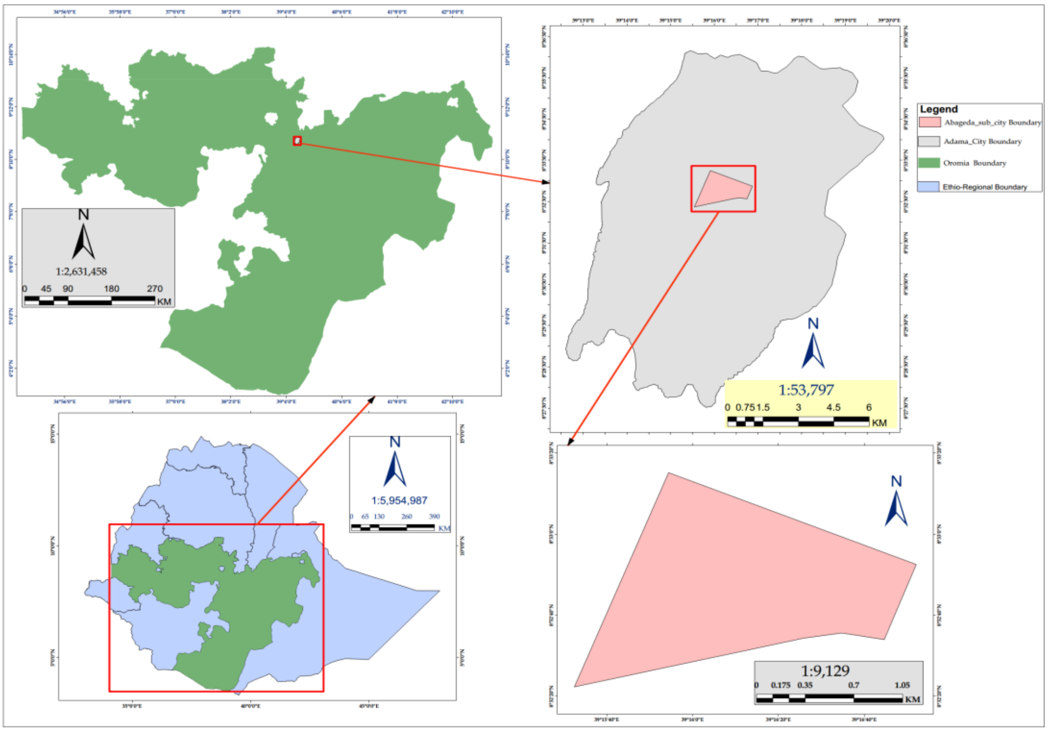

Figure 3.1 location map of study area

3.1.2 Topograph of Aba-Geda Sub Cities

The Elevation map of Aba-Geda Sub Cities in Adama city, provides a visual representation of the range of elevation in the area using different colors. The map was generated using elevation data from NASA's 12.5m resolution SRTM data and provides an idea of the topography and contour of Adama, Ethiopia. The map is displayed at different zoom levels and. The Aba-Geda Sub Cities topographic map shows the minimum, and maximum elevation of the area, which is 1,637 m and 1,617 m respectively. Adama is located in the East Shewa Zone of the Oromia Region of Ethiopia, at an elevation of 1,712 meters, 99 km southeast of Addis Ababa.

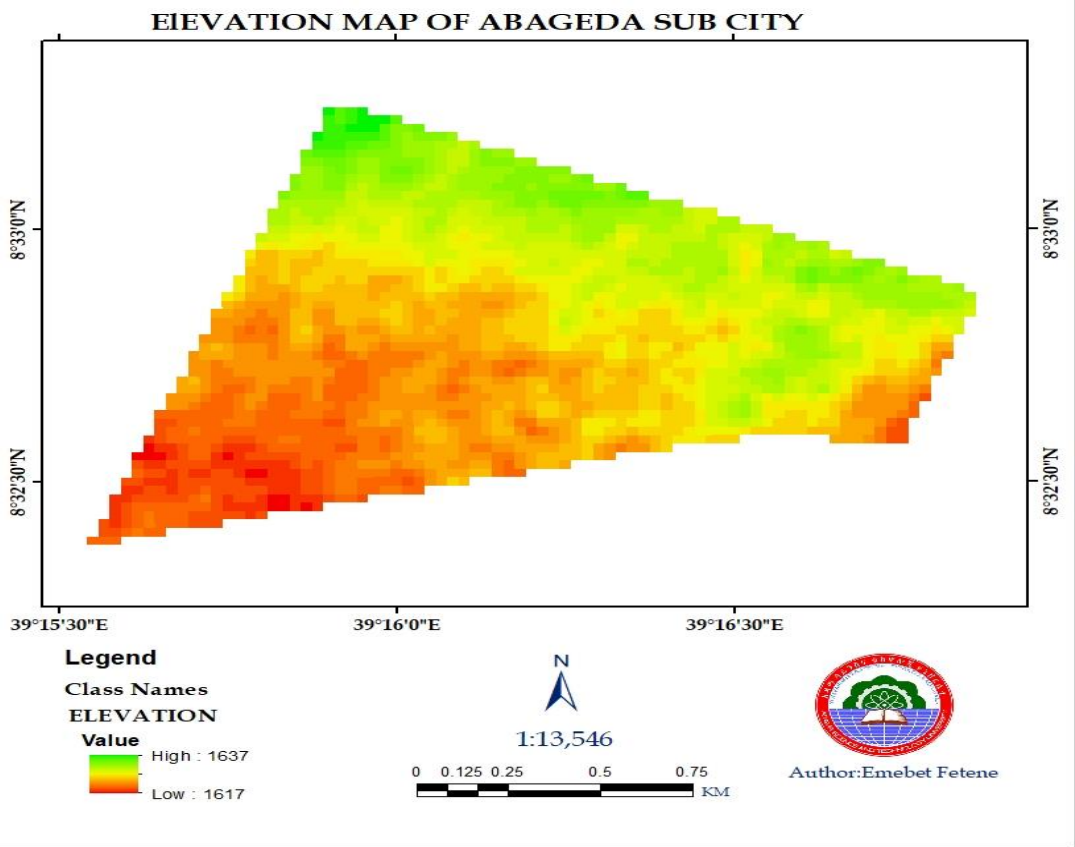

Figure 3.2 Topographic map of the study area

3.1.3 Land Use Land Cover

A Land Use and Land Cover (LULC) assessment was conducted for the Aba-Geda Sub-Cities area, utilizing satellite image interpretation, the master plan map of the Adama city, and field observations. The area was found to be covered by five types of land cover: asphalt, commercial, residential, Institutional, and recreational. This assessment provides valuable insights into how the land is being utilized and the physical characteristics of the area.

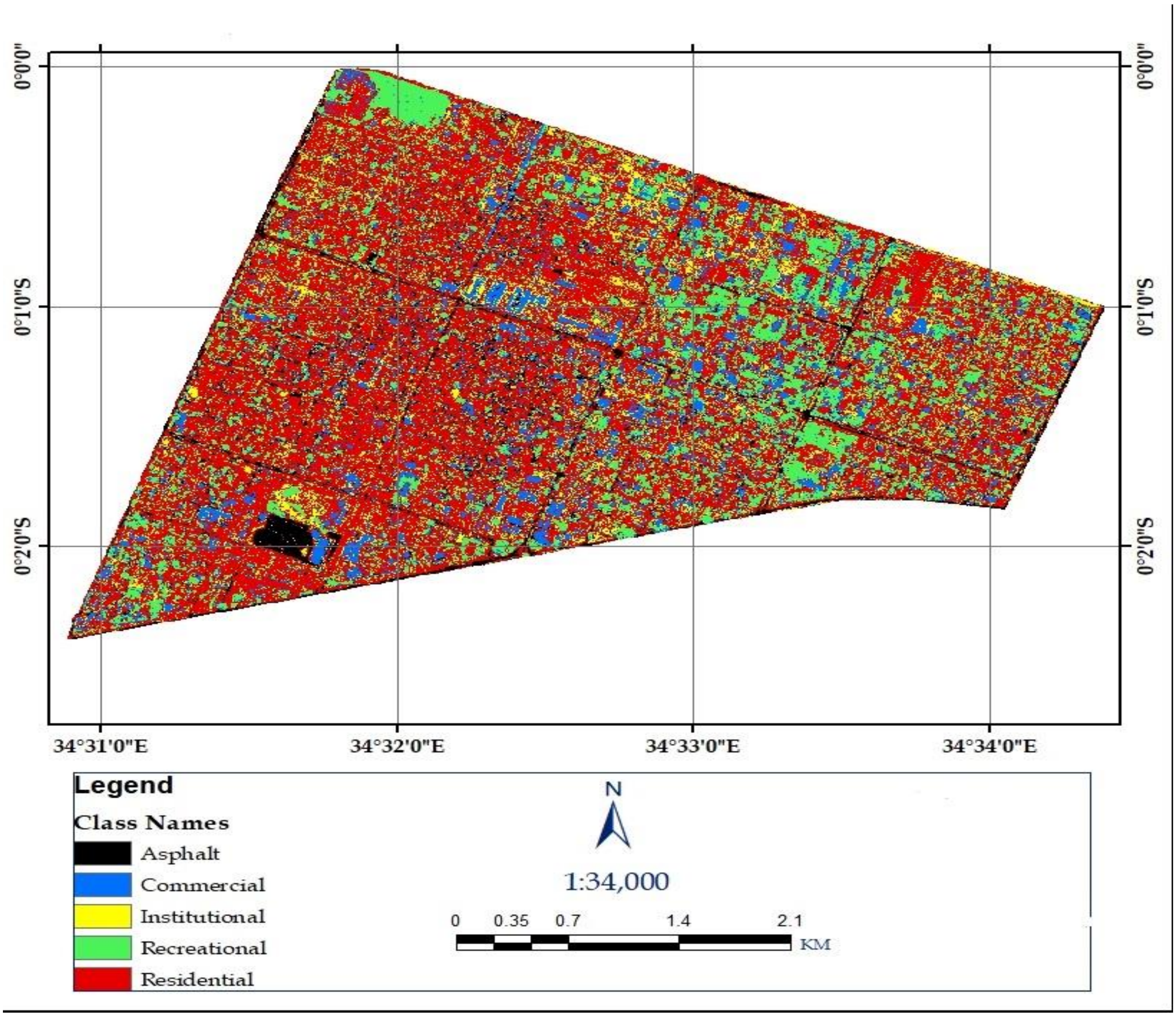

Figure 3.3 land use land cover of the study area

3.1.4 Existing Drainage Network

The network of Aba-Geda Sub City is currently non-existent within the municipality.From detailed field observation undersand that the channel's structure constructed using masonry techniques and the shape of the drainage is rectangular. The channel network data is obtained from Google Earth and try to show the figure.

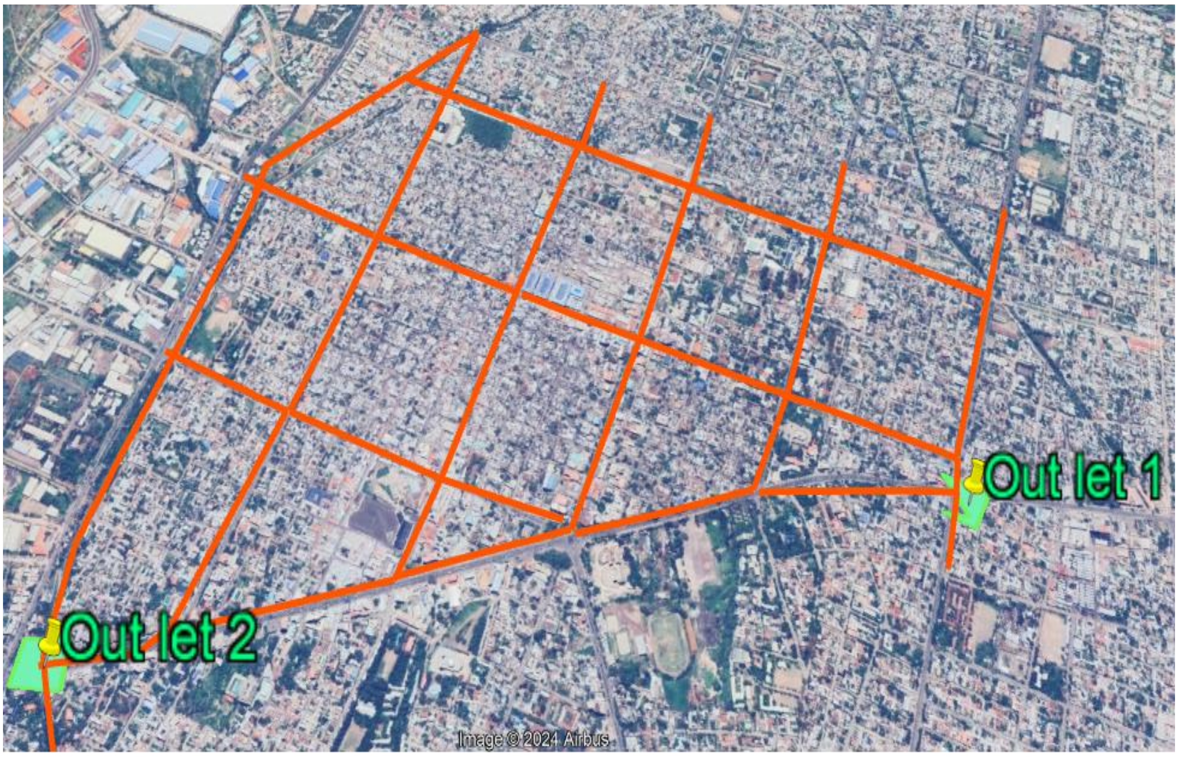

Figure 3.4 Existing Drainage Network of Aba-Geda Sub City

3.2 Materials and Data Sources

3.2.1 Materials

The following materials were used for this research:

- ARC-GIS to obtain hydrological and physical parameters and spatial information of the catchments of the study area.
- DEM data is used as an input data for ARC-GIS software for catchment delineation and estimation of catchment characteristic.
- Google Earth Software to verify water shed and divides of catchments of the study area.
- Digital camera, GPS device, and measuring tape.
- Hydrological and meteorological data and etc.

3.2.2 Data sources

The study employed various methodologies to gather primary data, including conducting a field survey and making observations within the study area. Additionally, different scenarios related to drainage issues were captured through pictures to depict an accurate representation of the study area. In parallel, secondary data sources such as meteorological data (specifically rainfall data) from the Meteorological Service Center for eastern and central Oromia, as well as the master plan, existing literature, and relevant reports, were utilized as valuable resources for this research.In a similar evaluation of the effectiveness of drainage systems in tackling future scenarios and implementing flood prevention measures, data on the study area's drainage network, digital elevation model (DEM), land use/land cover, and rainfall.

3.3 Methodology

Assessing urban stormwater drainage systems is a challenging undertaking that calls for a thorough approach. A comprehensive methodology is essential to effectively evaluate these systems.Two types of methodologies were employed in this research. The descriptive approach was utilized to delineate the challenges and factors that delayed the performance of the stormwater drainage system. On the other hand, the exploratory method was specifically used to investigate the current condition of urban stormwater drainage facilities in the Aba-Geda Sub-City and to identify the best management practices for the existing drainage problems. The assessment of the drainage system's performance in response to future scenarios and flood mitigation measures was conducted using the Stormcad software. Additionally, the evaluation of existing flooding issues on a project site is a crucial first step in designing a project that complies with stormwater regulations. These diverse methodologies, including descriptive and exploratory approaches, along with the use of the StormCad, collectively contributed to the comprehensive assessment of the existing stormwater drainage system.

3.3.1 To evaluate the adequacy of the existing drainage system in the study area

To evaluate the adequacy of the existing drainage system in the study area, can be employed various methodologies. Here are a few commonly used approaches:

3.3.1.1 Field survey

Conducting visual inspections and field surveys provide valuable insights into the condition of the drainage infrastructure and identify any visible insufficiencies or blockages.A few sample roads and corresponding pavement types in the study sites were physically surveyed (or measured) including depth, width, pavement type & cross-sectional profile of roads, in parallel, the length, type (open/closed), geometry (trapezoidal and rectangular), dimensions and construction materials of drains were physically measured. The registrations were supplemented with photos (Adugna, 2019)

The assessment aimed to evaluate the adequacy of the existing drainage system of Aba-Geda Sub city in Adama City in transferring stormwater from various sub-catchments. To conduct the assessment, applied the Manning equation (Equation 3.1). This equation enables the calculation of the maximum discharge capacity of a channel based on its planned shape and characteristics. By applying the Manning equation, determined whether the current drainage system could effectively handle the stormwater runoff from all areas of the Sub City.

$$Q = \frac{1}{n} * A * R^{\frac{2}{3}} * 1 \text{ -------------- } Eq\ 3.1$$

Where: Q=flow discharge in m^3/s

n=manning roughness coefficient

A=cross-sectional area in m^2

that derived from recorded flow depth (m) with given

drainage dimensionless

R=hydraulic radius in m

3.3.1.2 Hydraulic Modeling

StormCAD, a hydraulic modeling software by Bentley Systems, is used to calculate catchment runoffs, inlet capacities, and pipe network flows within storm sewer systems. The software uses various methods and equations to perform these calculations, including the Rational Method, the SCS Method, and the Manning's equation for open channels.

The input data required by StormCAD typically includes information about the watershed, such as drainage areas, slopes, rainfall data, Manning's n, runoff coefficients, and land use. Additionally, the software needs details regarding the stormwater infrastructure, such as pipe/Channel network geometry, node properties (e.g., inlets, outfalls, manholes), pipe/channel material, and flow boundary conditions like inflow hydrographs and water levels. The output obtained from StormCAD includes various results and analyses related to stormwater drainage systems. This can include pipe/channel flow rates, velocities, and capacities, as well as hydraulic grade lines, water surface profiles, storage volumes, time of concentration, and peak flows. The software often provides graphical representations, tabular data, and summary reports to aid in interpreting and utilizing the results.To calibrate StormCAD models, compare the model results with historical data, to ensure that the model response is accurate. The calibration process typically involves adjusting the model parameters to achieve a good fit between the model results and the historical data.

In this thesis, the hydraulic capacity of the existing drains was evaluated by computing the transit/total areas and elevation of each drain using Storm CAD. ArcGIS was also used to determine the areas and elevation of each drain and to map infiltration areas based on their degree of imperviousness using GIS-based editing tools and zonal statistics. The Rational Formula was used to determine peak runoff, which expressed peak runoff as Q = CiA, where Q was the peak runoff, C was the runoff coefficient, i was the rainfall intensity, and A was the drainage area. The formula assumes that the rainfall intensity is homogeneous across the entire catchment area, and that the duration of the storm event is less than the time of concentration for the catchment. It is a simplified approach and may not yield accurate results for complex or larger watersheds.

3.3.1.3 Hydrological Analysis

By performing a hydrological analysis, one can gain an understanding of the catchment area's features, such as rainfall patterns and runoff volumes. This data is valuable for assessing whether the drainage system is suitably designed to manage the expected water volume. The effective rainfall during a specific period contributes to runoff at a later time, and the volumetric relationship between rainfall and runoff is a crucial factor in hydrological analysis.

3.3.1.3.1 Rainfall Data

In order to conduct this thesis, the primary data needed is rainfall data. Specifically, rainfall data can be acquired solely from the Meteorological Service Centre for Eastern and Central Oromia. The dataset encompasses the recorded daily rainfall precipitation for a period of 30 consecutive years, spanning from 1992 to **2022.** It is crucial to note that this particular station serves as the exclusive source for obtaining the necessary rainfall data for this thesis.

The rational method was commonly utilized in hydrology to compare and establish relationships between results. One important term in this field was the return period, also known as the recurrence interval. It referred to the average time lapse between the occurrences of storms and floods of a specific magnitude. The choice of the modeling return period flexble on finding an economic balance between the costs of periodically repairing or replacing structures, the potential flood hazard to property, the expected level of service, budgetary constraints, as well as the magnitude and risk associated with damage from larger flood events. In cases where structures faced potential damage or required stringent operational conditions, a higher modeling recurrence interval was employed.

One important aspect of effective drainage structure design and analysis is having rainfall intensity duration data for shorter durations. The gauging station records rainfall depths over a 24-hour duration. However, in order to meet the necessary requirements, it is crucial to have data on rainfall intensity for shorter durations. The Ethiopian Roads Authority (2013) suggests the use of Gumbel method analysis for deriving appropriate Intensity-Duration-Frequency (IDF) data for shorter durations.

Gumbel method analysis

The Gumbel distribution methodology is commonly used for flood probability analysis due to its simplicity and focus on extreme events, such as maximum values or peak rainfalls. This method involves calculating the 2, 5, 10, 25, 50, and 100-year return intervals for each duration period, requiring multiple calculations(Elsebaie, 2011).

$$P_T = P_{avg} + \mathbf{K} * \mathbf{Sy} \text{--------------------- Eq 3.2}$$

Where K is Gumbel frequency factor given by:

$$K = -\frac{\sqrt{6}}{\pi}\left[0.5772 + ln\left[ln\left[\frac{T}{T-1}\right]\right]\right] ----------- Eq\ 3.3$$

where Pave is the average of the Maximum precipitation corresponding to a specific duration. In utilizing Gumbel's distribution, the arithmetic average in Eq. (1) is used:

$$P_{ave} = \frac{1}{n}\sum_{i-1}^{n} Pi ----------- Eq\ 3.4$$

where p i is the individual extreme value of rainfall and n is the number of events or years of record. Thestandard deviation is calculated by Eq. 3.5 computed using the following relation:

$$S = \left[\frac{1}{n-1}\sum_{i-1}^{n}(p_{i-p_{ave}})2\right]1/2 - - - - - - - - - - - - - - Eq\ 3.5$$

Where S is the standard deviation of P data. The frequency factor (K) (given in Table: Appendix), whichis a function of the return period and sample size, when multiplied by the standard deviation gives thedeparture of a desired return period rainfall from the average. Then the rainfall intensity, I (in mm/hr) for return period T is obtained from:

$$I_{t}= \frac{P_T}{T_d} - - - - - - - - - - - - - - - Eq\ 3.6$$

In this thesis the used intensity-duration-frequency (IDF) curves, also known as rainfall frequency curves, to estimate the intensity and frequency of rainfall events of different durations. These curves provided important information for engineering and infrastructure design, flood analysis, water resource management, and other related fields. The application of IDF curves ranged from assessing rainfall events to classifying climatic regimes, and also utilized these curves to derive more reliable IDF curves, which were essential for various design and analysis tasks, particularly in the context of drainage and flood management. The IDF curves played a crucial role in understanding the probability of different average rainfall intensities occurring within specific periods of time, and they were instrumental in making informed decisions related to infrastructure and water management.

Estimation of shorter duration Rainfall

The rainfall intensity is defined as the average rainfall rate in millimeters per hour for a duration equal to the time of concentration for a selected return period. Once a specific return period has been chosen for design and the time of concentration has been calculated for the catchment area, the rainfall intensity can be obtained from Rainfall-Intensity-Duration curves(ERA, 2013).The rainfall intensity at any required time using the 24-hour rainfall depth, which was known as a rainfall intensity-duration-frequency (IDF) relationship. The equation used for this purpose was

$$R_{Rt} = \frac{1}{24}\frac{(b+24)^n}{(b+t)^n} - - - - - - - - - Eq\ 3.7$$

Where:- RRt is rainfall depth ratio Rt: R24

Rt is rainfall depth in a given duration t

R24 is 24 hr rainfall depth

Coefficients b=0.3 & n=0.78-1.09

After rearrangement, the above formula has the following form.

$$R_{t=}\frac{t(b+24)^n}{24(b+t)^n}.R_{24}--------Eq\ 3.8$$

After substituting to estimate intensity (It=Rt/t) , the above formula has the following form thi is the ERA method.

$$It=\frac{R_{24}(b+24)^n}{24\ (b+t)^n}-------------Eq\ 3.9$$

3.3.1.3.2 Runoff volume

To determine the amount of water that flowed over the ground surface during a rain event, the runoff volume is calculated. This is a critical factor in designing proper stormwater drainage systems. The calculation of runoff volume involves considering various factors such as rainfall intensity, duration, catchment area, and surface conditions. The most commonly used method to calculate runoff volume is the Rational Method, which incorporates the formula Q = 0.278*C * I * A, where Q represents the runoff volume (in cubic units), C denotes the coefficient of runoff, A represents the catchment area (in square units), and i indicates the rainfall intensity (in units of length per time) . To calculate runoff volume using the Rational Method, the coefficient of runoff (C) is determined, which represents the fraction of rainfall that becomes runoff. This coefficient is based on land use and surface conditions, such as vegetation, slope, and soil type. The calculation of runoff volume is an essential aspect of hydrological analysis, as it helps in designing effective stormwater drainage systems and assessing the impact of urbanization on the water cycle. The catchment area (A) was the total area contributing runoff to a particular point of interest, such as a watershed, a parking lot, or any other area where water runoff needed to be managed. Lastly, the rainfall intensity (i) was the rate at which rain fell on the catchment area, which obtained from local weather stations or rainfall intensity-duration-frequency (IDF) curves. By plugging in the appropriate values and units into the equation, calculated the runoff volume (Q) for a specific stormwater drainage system.

The runoff coefficient (C) is the variable of the Rational Method least susceptible to precise determination and requires judgment and understanding on the part of the designer. A typical coefficient represents the integrated effects of many drainage basin parameters. The following discussion considers the effects of soil groups, land use, and average land slope(ERA, 2013). Table 3.1 was used to assign the C values for each LULC in their particular sub catchments using the weightage approach, Then, using Eq. 3.1, composite runoff coefficients were calculated for each sub catchment.

Table 3.1 Runoff coefficient(Sources ERA 2013).

Description of Area	**Runoff Coefficients**
Business:Downtown areas	0.70-0.95
Neighborhood areas	0.50-0.70
Residential:Single-family areas	0.30-0.50
Residential:Multi units,detached	0.40-0.60
Residential:Multi units,attached	0.60-0.75
Suburban	0.25-0.40
Residential(0.5 hectar lots or more)	0.30-0.45
Apartment dwelling areas	0.50-0.70
Industrial:Light areas	0.50-0.80
Industrial:Heavy areas	0.60-0.90
Parks,cemeteries	0.10-0.25
Playgrounds	0.20-0.40
Railroad yard area	0.20-0.40
Unimproved area	0.10-0.30

The high C-value means low infiltration capacity of the surfaces and increases the risk for urban flash/surface flooding.

$$C_{weigted} = \frac{\sum A_i C_i}{A_T} \text{---------------} Eq\ 3.10$$

Where; C i- runoff coefficient for a given hydrologic soil group area

Ai -area under each hydrologic soil group and

AT-total catchment area considered

The time of concentration is a critical parameter in hydrological analysis, as it influences the peak runoff rate and volume, which are essential for designing effective stormwater management systems and assessing the impact of urbanization on drainage and runoff patterns. The calculated the time of concentration (TOC) for this area was Identify the drainage area and divide it into sub-areas based on the type of surface, Calculate the time of concentration for each sub-area using appropriate equations or methods, such as the Kirpich (1940) and NRCS (1997) methods, or the average velocity method and add the time of concentration for each sub-area to obtain the total time of concentration for the entire drainage area.Use the calculated time of concentration to estimate the peak runoff rate and volume for a given rainfall event.

$$Tt = \frac{[0.091 * (nL)^{0.8}]}{(P^2)S^{0.4}}$$ -----------------------Eq 3.11 Sheet flow

$$Ttravel = \frac{L}{(60 * V)}$$ -------------------------- Eq 3.12,

$$V = 4.9178 * S^{0.5}$$ ------------------------------Eq 3.13 for unpaved area

$$V = 6.1961 * S^{0.5}$$ --Eq 3.14 for Paved area

$Tc = T_t + T_{travel}$ ------------------------------------Eq 3.15

The table 3.2 presents the design constraints of the study area, including the minimum and maximum values for velocity, cover, slope, spread in sag, and gutter depth in sag. These constraints are essential for understanding the physical parameters of the area and are valuable for various planning and development purposes. These constraints are derived from the Drainage Design Manual 2013 and are crucial for ensuring the proper design and implementation of drainage systems in the area.

Table 3.2 design constraints of the study area

Design constraint components	Minimum	Maximum
Velocity (m/s)	0.6	3
Cover (m)	0.8	2.5
Slope (%) 1	1	10
Spread in Sag (m)	N/A	4
Gutter Depth in Sag (m)	N/A	2

3.3.2 The major challenges in the storm water drainage management

To identify the major challenges in the stormwater drainage management system of Aba-Geda Sub-City involve various approaches. These include:

Field Surveys and Observation: According to (Chocat et al, 2001) Many problems remain, others arise, depending on the local urban geography and population expectations Conducting field surveys and observations to assess the existing condition of the drainage system and identify specific challenges related to stormwater management.

Interviews and Communication: Engaging in interviews with local authorities, professionals, and residents to gather firsthand information about the challenges faced in stormwater drainage management within the Sub-City.

Research and Data Analysis: To analyze the existing stormwater management system, research methods were utilized, including the evaluation of the hydraulic capacity of existing drain systems and the identification of management challenges. Problems associated with runoff quantity. Increased runoff volumes and peak flows, causing environmental and property damages, and in extreme cases even the loss of life; decreased low flows in rivers, depressed groundwater tables, leading to subsidence of urban land and structural damages; and channel and erosion damaging habitat in urban streams. Some of these problems may be further exacerbated by climate change(Chocat et al, 2001).

3.3.3 To map the areas those are highly sensitive to flooding

Field Surveys: Conducting: A field survey is crucial for ground-trothing and validating the findings from remote sensing and modelling approaches. Experts can visit the identified flood-prone areas to measure water levels during flood events and collect additional data, such as soil type, vegetation coverage, or infrastructure conditions, to refine the flood-risk assessment.

Hydrological Modelling: Developing hydrological models using hydrologic data and rainfall records can simulate flood events and predict flood-prone areas. These models typically use parameters such as land cover, soil type, precipitation data, and topography to generate flood-inundation maps.

To map the areas that are highly sensitive to flooding, various methodologies and tools can be employed. In this study the methodology use Geographical Information System (GIS) to map the area those are highly sensitive to flooding. Geographical Information System (GIS): GIS tools can be used to map the topography of the study area, identify flood-prone areas, and assess the integration of urban stormwater drainage infrastructure with road provision.

DEM is a three-dimensional (3D) representation of a terrain's surface, created from terrain elevation data. It can be represented as a raster or as a vector-based TIN. The DEM map of the district is filling to create free of sinks/depression less DEM, and then, the flow direction (the direction the stream flows in each cell) map was derived from the filling DEM map. Next, the flow accumulation raster map is creating from the flow direction map. Filling the DEM map, creating flow direction, and computing flow accumulation were performed using Hydrology tools such as Fill, Flow Direction, and Flow Accumulation, respectively, in the Spatial Analyst Tools of ArcGIS software (Negese, Worku et al.2022)

3.3.4 Appropriate best management practice (BMP) to alleviate the problem

Stormwater management is the process of controlling the stormwater runoff that comes primarily from impervious surfaces like parking lots, driveways, and rooftops. Stormwater management aims to reduce runoff volumes and improve stormwater quality through the use of green infrastructure and other approaches and technologies. This includes capturing and reusing stormwater to maintain or restore natural hydrologies. The goals of stormwater management include protecting the environment, reducing flooding, supporting healthy streams and rivers, and creating healthier, more sustainable communities. Effective stormwater management provides environmental, social, and economic benefits to local communities.

The step calls for a preliminary analysis of the site in order to obtain the most relevant BMPs adapted to the case. Afterwards, the alternatives for consideration are analysed, including individual BMPs and possible combinations. Next, the stakeholder analysis is needed, during which relevant stakeholders are identified and data are collected for determining criteria priorities and for calculating the social performance of the different BMPs. The next step consists in the application of Multi-Criteria Decision-Making (MCDA) methods themselves, providing a final ranking of the different BMP alternatives for each stakeholder. The final step consists in an analysis of these results, including the sensitivity analysis, in order to draw conclusions on the most appropriate MCDA method and recommended BMP alternative(s) (Aceves & Fuamba, 2016).

The thesis will be focusing on performance assessment of drainage systems on abageda sub-city in Adama city. Therefore, the data's will be gathered and analysed critically and the final data will be analysed by the Statistical tools and presented with suitable forms such as tabular, diagrammatic, graphical etc., approach with the summary and recommendation to each problems rise in the research.

3.4 Research framework

A research framework is a systematic and organized approach that guides a research study, providing a clear and coherent structure for the research process.

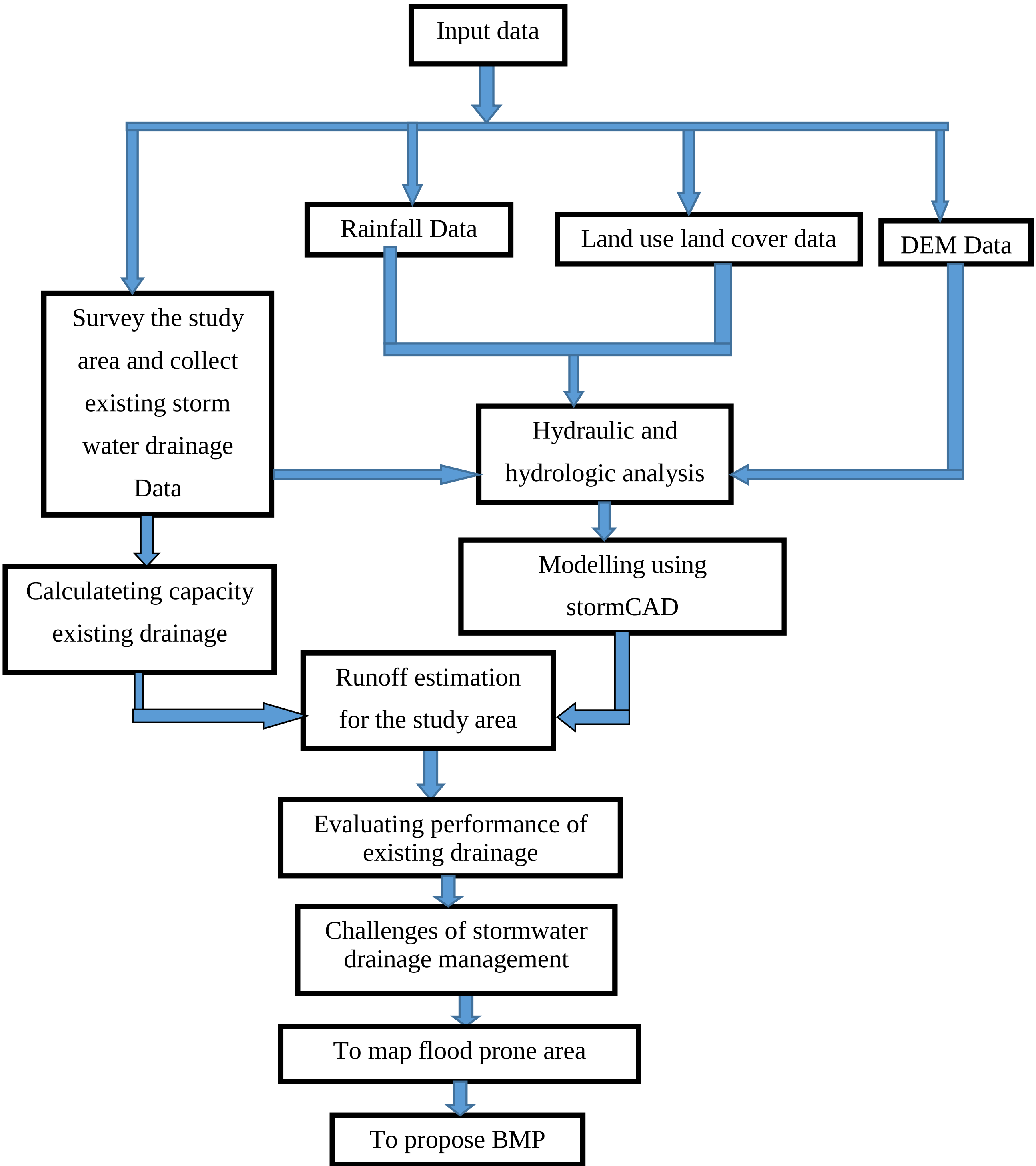

Figure 3.5 Conceptual frame work

4 Results and Discussion

4.1 Capacities of the existing drainage system of the study area

The hydraulic capacity of the drainage system in Aba-Geda Sub City is crucial for a drainage system to effectively collect and convey stormwater away from the area to prevent flooding and ensure proper water management. To evaluate this capacity, involved a combination of various methods, including detailed field surveys and the utilization of Storm CAD software. The evaluation of the hydraulic capacity of the drainage system was conducted using a simulation model. The model incorporated various key hydraulic parameters to evaluate the performance of the system, including flood volume, surface runoff, channel flows, flood water depths, and velocities.

The evaluation was fundamental for ensuring the efficient management of stormwater and the mitigation of flooding. The findings from this evaluation provided valuable insights into the performance of the existing drainage systems and identified areas for potential improvement, thereby contributing to the overall resilience of the stormwater management system in the study area. After conducting a field survey, it was crucial to volume of discharge conveyed in the existing drainage system and the constructed material of the channel is massonary and roughness coefficient(n) is 0.032.This information was obtained through the application of Manning's formula, as shown in Table **4.1.**The calculations presented in the table provide a sample estimation of the discharge conveyed through the current drainage system.

Table 4.1 Capacity of existing drainage system

No	Flow direction	W (m)	D (m)	A (m2)	P (m)	R (m)	S (m/m)	n	Q(m3/s)
1	CH1-CH2	0.6	0.6	0.4	1.8	0.2	0.002	0.032	0.17
2	CH2-CH3	0.6	0.6	0.4	1.8	0.2	0.002	0.032	0.17
3	CH3-CH4	0.6	0.6	0.4	1.8	0.2	0.002	0.032	0.17
4	CH4-CH5	0.6	0.6	0.4	1.8	0.2	0.002	0.032	0.17
5	CH5-CH6	0.6	0.6	0.4	1.8	0.2	0.012	0.032	0.42
6	CH6-CH7	0.5	0.5	0.3	1.5	0.17	0.011	0.032	0.25
7	CH7-CH8	0.5	0.5	0.3	1.5	0.17	0.017	0.032	0.31
8	CH8-CH9	0.8	0.8	0.6	2.4	0.27	0.017	0.032	1.08
9	CH9-CH10	0.8	0.8	0.6	2.4	0.27	0.016	0.032	1.04
10	CH10-CH11	0.8	0.8	0.6	2.4	0.27	0.016	0.032	1.04
11	CH11-CH12	1	1.2	1.2	3.4	0.35	0.001	0.032	0.59
12	CH12-CH13	1	1.2	1.2	3.4	0.35	0.001	0.032	0.59
13	CH13-CH14	1	1.2	1.2	3.4	0.35	0.001	0.032	0.59
14	CH14-CH15	1	1.2	1.2	3.4	0.35	0.025	0.032	2.95

15	CH15-CH16	1	1.2	1.2	3.4	0.35	0.015	0.032	2.29
16	CH16-CH17	1	1.2	1.2	3.4	0.353	0.003	0.032	1.02
17	CH17-CH18	1	1.2	1.2	3.4	0.353	0.003	0.032	1.02
18	CH18-CH19	1	1.2	1.2	3.4	0.353	0.029	0.032	3.18
19	CH19-CH20	1	1.2	1.2	3.4	0.353	0.03	0.032	3.23
20	CH20-CH21	1	1.2	1.2	3.4	0.353	0.015	0.032	2.29
21	CH21-CH22	1	1.2	1.2	3.4	0.353	0.014	0.032	2.21
22	CH22-CH23	1	1.2	1.2	3.4	0.353	0.015	0.032	2.29
23	CH23-CH24	1	1.2	1.2	3.4	0.353	0.015	0.032	2.29
24	CH24-CH25	1	1.2	1.2	3.4	0.353	0.004	0.032	1.18
25	CH29-CH30	1.5	1.2	1.8	3.9	0.462	0.004	0.032	2.12
26	CH30-O2	1.8	1.8	3.24	5.4	0.6	0.001	0.032	2.27
27	CH25-CH26	1.5	1.5	2.25	4.5	0.5	0.001	0.032	1.40
28	CH26-CH27	1.5	1.5	2.25	4.5	0.5	0.013	0.032	5.04
29	CH27-CH28	1.5	1.5	2.25	4.5	0.5	0.004	0.032	2.79
30	CH28-CH29	1.5	1.5	2.25	4.5	0.5	0.007	0.032	3.70

4.1.1 Formulation of IDF curve for Aba-Geda Sub-City

The IDF curve for the Aba-Geda Sub City, created using the Gumbel Type I distribution method, is based on 30-year rainfall data from the Meteorological Service Centre for Eastern and Central Oromia. The curve demonstrates that rainfall intensity decreases as the duration of the storm increases, and if the return period is large, rainfall of any specific duration shows a higher intensity, which aligns with the study by (Shamkhi et al.,2022). The maximum rainfall intensity of 246.76 mm/hr occurred at a duration of 0.08 hr with a return period of 100 years, while the minimum rainfall intensity of 1.72 mm/hr occurred at a duration of 24 hr with a return period of 2 years. The results are displayed in Table 4.2 and curve is illustrated in Figure 4.1. which showed that the intensity of rainfall increases with the increment in return periods but decreases with the increment in duration

Table 4.2 Duration of rainfall against their corresponding average intensity

Duration (m)	Intensity for given return periods(mm/hr)					
	2 years	5 years	10 years	25 years	50 years	100 years
5	75.04	121.01	151.45	189.91	218.44	246.76
10	47.27	76.23	95.41	119.64	137.61	155.45
15	36.07	66.40	72.81	91.30	105.02	118.63
30	22.73	41.83	45.87	57.51	66.16	74.73
60	14.32	20.12	28.89	36.23	41.68	47.08
12	9.02	12.67	18.20	22.82	26.25	29.66
720	2.73	3.84	5.51	6.91	7.95	8.98
1440	1.72	2.42	3.47	4.35	5.01	5.66

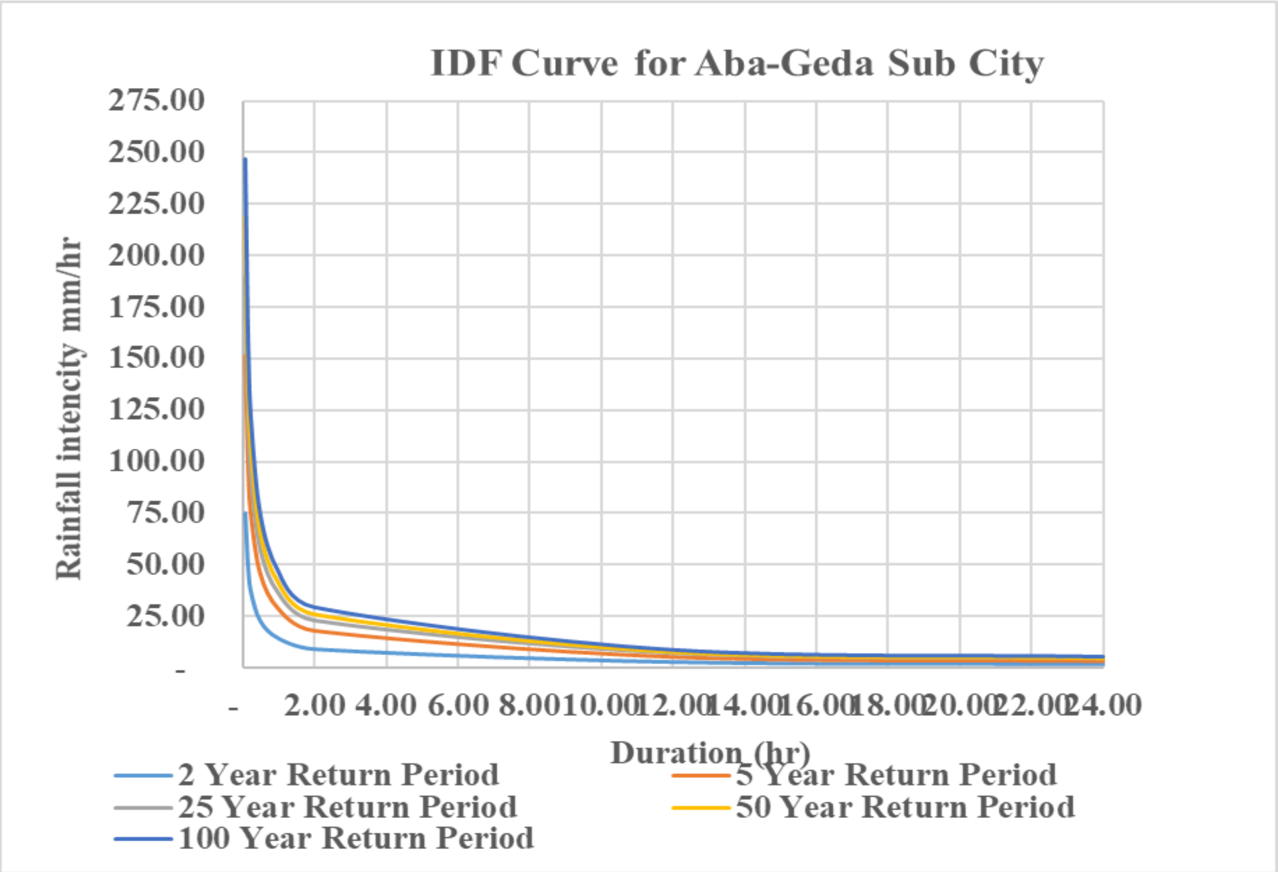

Figure 4.1 IDF Curve of Aba-Geda Sub City

4.1.2 Model results for channel

The StormCAD model as showed the fig 4.3 covered a total area of 220 hectares, consisting of sub-catchments with impervious surfaces such as roofs or roads. All the existing data was input into StormCAD, and the simulation was carried out by computing network flows using built-in numerical models. The sub-catchment data included cathement area, percent impervious, width, elevation, types of channel, shapes of channel and time of concentration. The entire catchment area was divided into sub-catchments that formed the designated units for data. The design process involved modeling the gutter shape for capture in the catch-basin properties when designing roadside drainage. The design also included selecting the appropriate cross-section type, such as trapezoidal or rectangular, and defining the side slopes and other channel properties. The channel element was used to model the flow of water through the drainage channels. The design was analyzed to ensure the system was functioning correctly and meeting the desired performance criteria. The simulation was carried out by inputting all the existing data into StormCAD. The design process involved introducing gutters in the network and designing the whole network at once.

Table 4.3 Model result for channels

No	Flow direction		Flow (m^3/s)	Velocity (m/s)
1	CH-1	CH-2	0.65	3.25
2	CH-2	CH-3	0.65	3.25
3	CH-3	CH-4	0.65	3.25
4	CH-4	CH-5	0.65	3.25
5	CH-5	CH-6	0.65	3.25
6	CH-6	CH-7	0.34	1.68
7	CH-7	CH-8	0.34	1.68
8	CH-8	CH-9	0.57	3.76
9	CH-9	CH-10	0.57	3.75
10	CH-10	CH-11	0.57	1.88
11	CH-11	CH-12	0.57	2.34
12	CH-12	CH-13	0.57	2.34
13	CH-13	CH-14	0.57	2.34
14	CH-14	CH-15	0.57	2.34
15	CH-15	CH-16	0.84	1.45
16	CH-16	CH-17	0.84	0.91
17	CH-17	CH-18	0.38	0.41
18	CH-18	CH-19	0.37	1.61
19	CH-19	CH-20	0.37	1.65
20	CH-20	CH-21	0.37	0.51

21	CH-21	CH-22	0.37	1.2
22	CH-22	CH-23	0.37	1.25
23	CH-23	CH-24	0.36	0.39
24	CH-24	CH-25	0.36	0.39
25	CH-29	CH-30	2.03	2.2
26	CH-30	O2	2.02	2.19
27	CH-25	CH-26	0.77	0.84
28	CH-26	CH-27	0.77	0.83
29	CH-27	CH-28	1.66	1.8
30	CH-28	CH-29	1.65	1.79

4.1.3 Comparison of hydraulic capacity model runoff

To determine the hydraulic capacities of open channels in the study area, Flow Master was used. The peak rate of runoff and hydraulic capacities of the constructed channel were computed, and the obtained sample result was presented in Table:4.3 Since there is no recorded data about the dimensions of these drainage systems, a field survey was conducted to measure the dimensions of the drainage system. This survey is necessary to determine the hydraulic capacity of the existing drainage system.

Table 4.4 Comparision of peak runoff rate and hydraulic capacity of channels

No	Flow direction	W	D	A	P	R	S	n	Observed Runoff	Simulated Runoff	Simulated runoff - Observed Runoff
1	CH1-CH2	0.6	0.6	0.36	1.8	0.20	0.002	0.032	0.17	0.65	0.48
2	CH2-CH3	0.6	0.6	0.36	1.8	0.20	0.002	0.032	0.17	0.65	0.48
3	CH3-CH4	0.6	0.6	0.36	1.8	0.20	0.002	0.032	0.17	0.65	0.48
4	CH4-CH5	0.6	0.6	0.36	1.8	0.20	0.002	0.032	0.17	0.65	0.48
5	CH5-CH6	0.6	0.6	0.36	1.8	0.20	0.012	0.032	0.42	0.65	0.23
6	CH6-CH7	0.5	0.5	0.25	1.5	0.17	0.011	0.032	0.25	0.34	0.09
7	CH7-CH8	0.5	0.5	0.25	1.5	0.17	0.017	0.032	0.31	0.34	0.03
8	CH8-CH9	0.8	0.8	0.64	2.4	0.27	0.017	0.032	1.08	0.57	- 0.51
9	CH9-CH10	0.8	0.8	0.64	2.4	0.27	0.016	0.032	1.04	0.57	- 0.47
10	CH10-CH11	0.8	0.8	0.64	2.4	0.27	0.016	0.032	1.04	0.57	- 0.47
11	CH11-CH12	1	1.2	1.2	3.4	0.35	0.001	0.032	0.59	0.57	- 0.02
12	CH12-CH13	1	1.2	1.2	3.4	0.35	0.001	0.032	0.59	0.57	- 0.02
13	CH13-CH14	1	1.2	1.2	3.4	0.35	0.001	0.032	0.59	0.57	- 0.02
14	CH14-CH15	1	1.2	1.2	3.4	0.35	0.025	0.032	2.95	0.57	- 2.38
15	CH15-CH16	1	1.2	1.2	3.4	0.35	0.015	0.032	2.29	0.84	- 1.45
16	CH16-CH17	1	1.2	1.2	3.4	0.35	0.003	0.032	1.02	0.84	- 0.18
17	CH17-CH18	1	1.2	1.2	3.4	0.35	0.003	0.032	1.02	0.38	- 0.64
18	CH18-CH19	1	1.2	1.2	3.4	0.35	0.029	0.032	3.18	0.37	- 2.81
19	CH19-CH20	1	1.2	1.2	3.4	0.35	0.03	0.032	3.23	0.37	- 2.86
20	CH20-CH21	1	1.2	1.2	3.4	0.35	0.015	0.032	2.29	0.37	- 1.92
21	CH21-CH22	1	1.2	1.2	3.4	0.35	0.014	0.032	2.21	0.37	- 1.84

22	CH22-CH23	1	1.2	1.2	3.4	0.35	0.015	0.032	2.29	0.37	-	1.92
23	CH23-CH24	1	1.2	1.2	3.4	0.35	0.015	0.032	2.29	0.36	-	1.93
24	CH24-CH25	1	1.2	1.2	3.4	0.35	0.004	0.032	1.18	0.36	-	0.82
25	CH29-CH30	1.5	1.2	1.8	3.9	0.46	0.004	0.032	2.12	2.03	-	0.09
26	CH30-O2	1.8	1.8	3.24	5.4	0.60	0.001	0.032	2.27	2.03	-	0.24
27	CH25-CH26	1.5	1.5	2.25	4.5	0.50	0.001	0.032	1.40	0.77	-	0.63
28	CH26-CH27	1.5	1.5	2.25	4.5	0.50	0.013	0.032	5.04	0.77	-	4.27
29	CH27-CH28	1.5	1.5	2.25	4.5	0.50	0.004	0.032	2.79	1.66	-	1.13
30	CH28-CH29	1.5	1.5	2.25	4.5	0.50	0.007	0.032	3.70	1.65	-	2.05

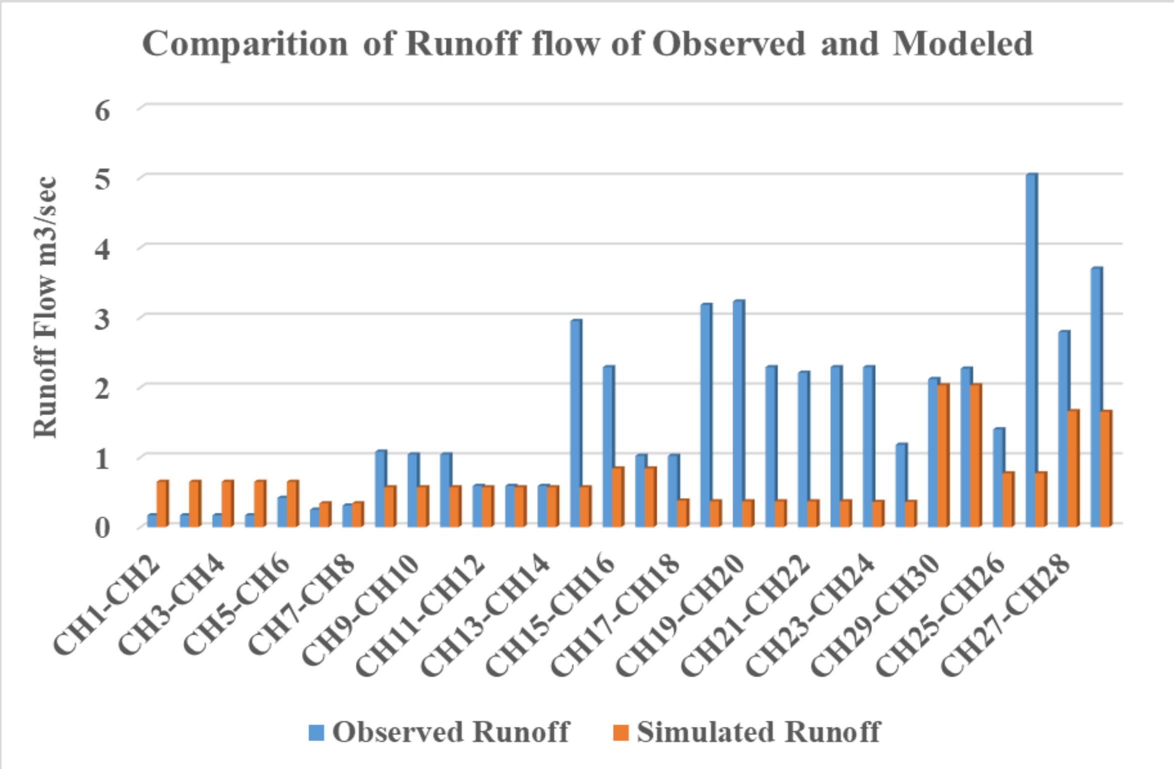

Figure 4.2 Comparition of Runoff flow of Observed and Modeled

During heavy rainfalls, some of the existing drainage systems become overwhelmed, causing flooding in road side drains, walkways, and even the asphalt. This flooding can occur even during average storms. According to Table 4.4 the hydraulic capacity of the channels in the study area is insufficient to handle the runoff generated by a 25-year return period design discharge. The channels from CH8 to CH14 (mebrat hayil to posta bet), CH15 to CH16 (Around bekele mola to posta bet), CH17 to CH26 (Sar tera to Franco), and CH27 to CH30 (Franco to Pan-africa) have inadequate hydraulic capacity to carry the runoff water contributed to them. The hydraulic parameters used to assess the differences in performance of the drainage system included flood volume, surface runoff, channel flows, flood water depths, and velocities. The evaluation of the hydraulic capacity of existing drainage systems was crucial for effective stormwater management and flood mitigation. The findings from this evaluation provided valuable insights into the performance of the existing drainage systems and identified areas for potential improvement, thereby contributing to the overall resilience of the stormwater management system in the study area. The study's results emphasize the importance of regular maintenance and upgrading of the drainage system to ensure its effectiveness in managing stormwater and mitigating flooding problems in low-lying areas.The main issue in this area lies in the insufficient capacity of the channels and the incorrect sizing of inlet culverts, which were not designed based on the contributing catchment area of 220ha. To overcome this problem, resizing both the drainage system's inlets and channels is essential. To reduce flooding issues in the study area, changing the section of the channels could be considered as an alternative solution. The obtained sample result was presented in Table 4.4. The evaluation of the hydraulic capacity of existing drainage systems is essential for effective stormwater management and flood mitigation.

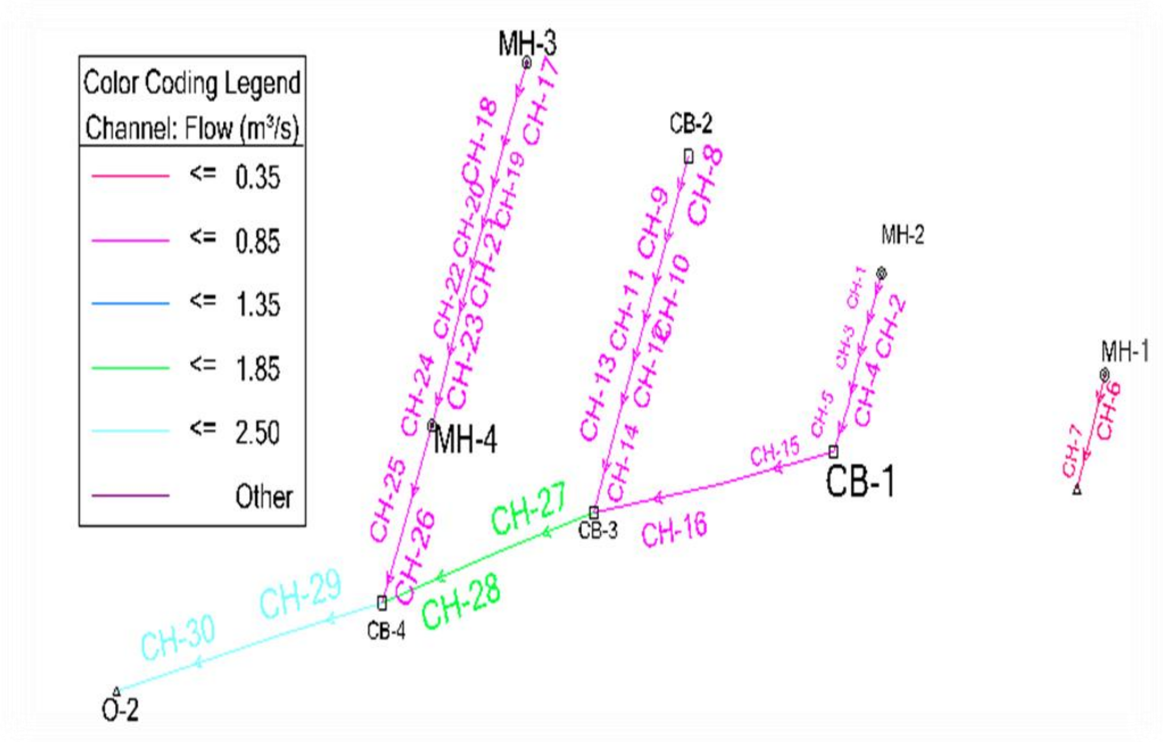

Figure 4.3Drainage network

4.1.4 Bentley storm cad simulation results for catchments

In this study, the runoff generated from the drainage basin was determined based on the Ethiopian Roads Authority Drainage Design Manual recommended by the urban storm water drainage design manual of the country. The manual recommends the rational method for drainage basin areas less than 50 ha. The peak rate of runoff was simulated using Bentley Storm cad. The study area was divided into 9 sub-catchment areas for modelling with Bentley Storm cad software. The required parameters were determined for each sub-catchment to input for running the simulation. The obtained sample results are indicated in Table 4.5. The design of a storm drainage system requires a balance among public safety, capital costs, operation and maintenance costs, public convenience, environmental enhancement, and other design objectives. The drainage design manual provides a general process of design for roadway drainage systems, including the selection of a recurrence interval, hydrologic analysis, hydraulic analysis, and environmental considerations. The Rational Method is a widely used approach for estimating the peak rate of runoff at a specific location in a watershed. This method estimates the peak rate of runoff as a function of the average rainfall rate during the time of concentration.

Table 4.5 Simulated catchement characteristics result

No	Label	Outflow Element	Area (User Defined) (ha)	Runoff Coefficient (Rational)	Time of Concentration (hours)	Flow (Total Out) (m^3/s)
1	SC-1	MH-1	27.85	0.707	15	0.34
2	SC-2	MH-2	25.287	0.69	8	0.65
3	SC-3	O-1	9.12	0.702	14	0.11
4	SC-4	CB-1	21.67	0.702	10	0.39
5	SC-5	CB-2	21.69	0.706	8	0.57
6	SC-6	MH-3	25.93	0.706	12	0.38
7	SC-7	CB-3	25.799	0.693	7	0.71
8	SC-8	MH-4	31.18	0.693	10	0.64
9	SC-9	O-2	31.439	0.678	24	0.26

According to Table 4.5, the total flow of the catchement is 4.05 m3/s during 25 years return period, the catchment with the highest flow output of 0.71 m^3/s is catchment number 7 (from mebrathayle to sartera, sartera to franco, franco to posabet and from postabet to mebrathayil) with an area of 25.799 hectares. On the other hand, the catchment with the lowest output of 0.11 m^3/s is catchment number 3 (from hani cake to Alem hotel, Alem hotel to Mariam cherch,Mariam church to Bekele Mola hotel) with an area of 9.12 hectares. Stormwater overflow happened in this area is most likely occurring due to several factors, including: Poor drainage systems, unsound construction, and negligent solid and liquid waste management, Poorly maintained drainage systems can contribute to stormwater overflow.This information is crucial for propose and designing an effective BMP of storm drainage management system that can handle the runoff generated by each catchment area. The peak flow rate of runoff is essential for effective stormwater management systems and assessing the impact of urbanization on the water cycle.

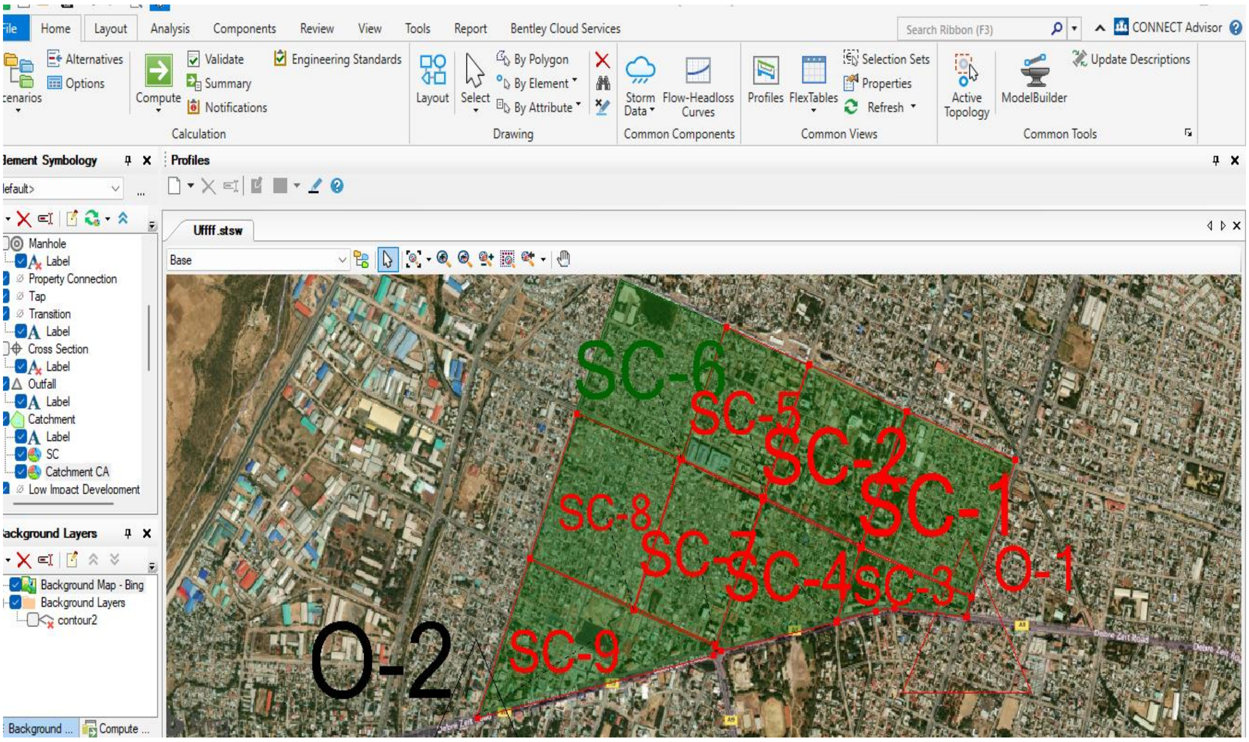

Figure 4.4 StormCAD Modeling of Stormwater Networks

4.2 The major challenges in the stormwater drainage

Storm water drainage management in Adama city of Aba-Geda Sub-City, faces several challenges. This challenges were also studed in Assosa town, where similar case studies have been observed. During the site investigation, it was observed that the existing drainage system in the study area mainly consists of open ditches with rectangular cross-sections. Most of the ditches are open and covered by eucalyptus trees. The drainage structures, including ditches, manholes, canals, and outfall dimensions, were measured, and GPS coordinates were taken at required points. However, almost all the drainage structures in the town, especially the open ditches, are filled with dry waste, which can cause blockages and overflow during heavy rainfall (Abdeta, 2020).

4.2.1 **Urbanization** and **Lack of planning**

The flow in urbanization has resulted in a rise in impervious surfaces such as roads, parking lots, and rooftops, leading to an increase in stormwater runoff. Additionally, the absence of planned separate wastewater management for grey water, stormwater, and sewerage has led urban local bodies to disregard the significance of stormwater drainage management. This oversight has contributed to the neglect of stormwater management, posing a significant challenge to urban areas. The lack of attention to stormwater drainage management has the potential to exacerbate flooding issues and compromise water quality, necessitating a reevaluation of current stormwater management practices and the implementation of more effective approaches to address these challenges.

4.2.2 Dumping of solid waste and liquid waste in the drainage system

The improper disposal of solid waste materials into drainages and streams presents a significant challenge to the stormwater drainage system. All types of Urban waste, also known as trash, debris, flotsam, jetsam, floatables, gross pollutants, rubbish, or solid waste, has emerged as a major problem in these areas(Adane, 2019).

Dumping solid waste materials into drainages and streams is a challenge that these systems face. This problem not only compromises the drainage system's functionality but also endangers water quality. The accumulation of urban waste in stormwater drains and conduits can hinder the proper functioning of the drainage system and lead to the contamination of receiving bodies of water. Additionally, the presence of organic debris, such as leaf litter, in urban stormwater systems during rain events can result in nutrient spikes in the receiving bodies of water. Therefore, addressing the issue of urban waste in stormwater drainage systems is crucial for maintaining the system's effectiveness and preventing adverse environmental impacts This dumping of solid waste materials into drains blocks the drainage system and causes flooding over streets and walkways. The following are some of the impacts of urban waste on storm water drainage systems:

- Clogging of drainage systems: Dumping solid waste materials into drainages and streams clogs the drainage system and causes flooding over streets and walkways.
- Water pollution: Urban waste can also pollute water bodies, which can have adverse effects on aquatic life and human health.
- Infrastructure damage: The improper disposal of solid waste materials into drainages and streams improves this challenge, compromising the functionality of the drainage system and disrupt operations.

Public education and outreach about the impact of storm water on urban waste management is crucial in tackling the issue of waste accumulation in storm drainage systems. When proper management practices are not implemented, trash tends to build up in storm drains, leading to system blockages and subsequent pollution of local waterways.Therefore, proper management of solid waste materials is necessary to prevent clogging of drainage systems and water pollution.

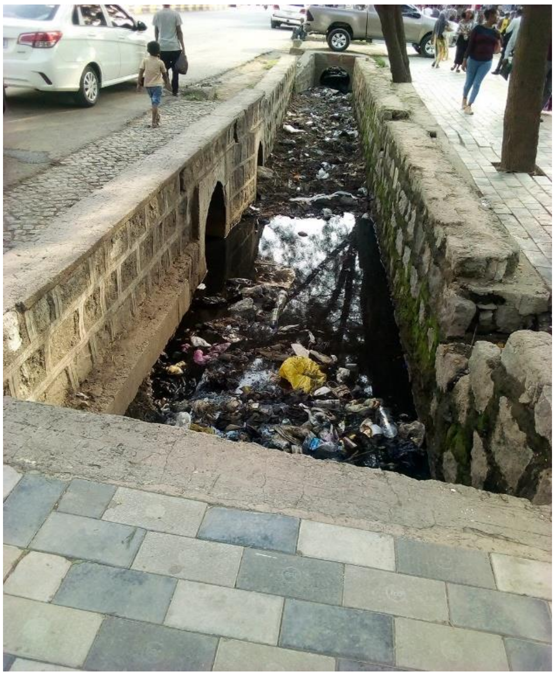 

Figure 4.5 The improper disposal of liquid and solid waste into the drainage system.

4.2.3 The lack of frequent clearance in the drainage system

Aba-Geda Sub Cities in Adama city is facing a disruption in its drainage system due to the infrequent clearing of drainage lines. The lack of regular maintenance has reduced the drainage lines out of service. This issue is prevalent in the city and requires immediate attention to restore proper functioning of the drainage system. The neglect of clearing the lines has led to the disruption of drainage services of Aba-Geda Sub-Cities in Adama city. Sediment load and solid wastes have blocked most of the drainage system, and without scheduled clearance, the service life of those ditches could be out of their life span. Figure 7 shows blocked ditches in the study area. There are several consequences that arise when drainage lines are not regularly cleared. There are several consequences that arise when drainage lines are not regularly cleared:

- Clogging of drainage systems: The lack of frequent clearance of drainage lines has led to the clogging of the drainage system, which can cause flooding over streets and walkways.
- Infrastructure damage**:** The clogging of drainage systems can also damage infrastructure and disrupt operations.
- Reduced service life: Without scheduled clearance, the service life of drainage systems could be out of their life span.

To prevent the clogging of drainage systems due to the lack of frequent clearance of drainage lines, the following measures can be taken:

- Scheduled maintenance: Regular maintenance and scheduled clearance of drainage lines can prevent the clogging of drainage systems.
- Proper disposal of solid wastes: Proper disposal of solid wastes can prevent the accumulation of solid wastes in drainage systems.
- Public education and outreach: Public education and outreach on the importance of proper disposal of solid wastes and the need for scheduled maintenance of drainage systems can help prevent the clogging of drainage systems.

In conclusion, the lack of frequent clearance of drainage lines has led to the clogging of drainage system in Adama city of Aba-Geda Sub-City. Regular maintenance and scheduled clearance of drainage lines, proper disposal of solid wastes, and public education and outreach are some of the measures that can be taken to prevent the clogging of drainage systems.

Figure 4.6 Lack of frequent clearance in the drainage system

4.2.4 A damaged drain line

The majority of infrastructure development in Adama city of Aba-Geda Sub-City, has less concern for the drainage system. For example, housing construction, water supply lines, and telephone line installation and expansion have been damaging drainage lines. Most of the time, after construction, they didn't care enough to maintain what they damage. The following are some of the impacts of the lack of concern for the drainage system during infrastructure development:

- Clogging of drainage systems: Damage to drainage lines during infrastructure development can lead to the clogging of the drainage system, which can cause flooding over streets and walkways.
- Infrastructure damage: Damage to drainage lines during infrastructure development can also damage infrastructure and disrupt operations.
- Reduced service life: Damage to drainage lines during infrastructure development can reduce the service life of drainage systems.

To prevent damage to drainage lines during infrastructure development, the following measures can be taken:

- Proper planning: Proper planning of infrastructure development projects can prevent damage to drainage lines.
- Proper maintenance: Proper maintenance of drainage lines during and after infrastructure development can prevent damage to the drainage system.
- Public education and outreach: Public education and outreach on the importance of proper planning and maintenance of drainage lines during infrastructure development can help prevent damage to the drainage system.

In conclusion, the lack of concern for the drainage system during infrastructure development in Adama city, has led to damage to drainage lines, which can cause the clogging of the drainage system, infrastructure damage, and reduced service life of drainage systems. Proper planning and maintenance of drainage lines during and after infrastructure development, as well as public education and outreach, are some of the measures that can be taken to prevent damage to the drainage system.

Figure 4.7 Damaged drain line

4.3 Map of flood prone area

To map and identify flood-prone areas, there are several tools and resources available. The following are some of the resources that can be used to map and identify flood-prone areas:

1. Satellite Imagery Analysis: Analysing remotely sensed data, such as satellite imagery, can help identify flood-prone areas. By examining historical imagery, researchers can detect patterns of flooding, including the expansion and contraction of water bodies, and identify areas at higher risk.

2**.** Topographic Analysis: Terrain analysis using digital elevation models (DEMs) can reveal the natural drainage patterns and low-lying areas prone to flooding. By analysing slope, elevation, and flow accumulation, researchers can identify areas more susceptible to floods.

3. Community Engagement: Engaging with local communities, residents, and authorities is essential to gather anecdotal evidence of past flooding incidents. This information helps validate and supplement the mapping and modelling efforts, providing a more comprehensive understanding of flood-prone areas.

4. Historical Data Analysis: Analysing historical flood records and disaster management reports can provide valuable insights into past floods, their impacts, and areas prone to recurring flooding. This data can be combined with other methods to identify flood-prone zones.

7. Stakeholder Collaboration: Collaboration with governmental entities, water management agencies, urban planners, and along with other pertinent stakeholders. is crucial for sharing information and expertise. This collaborative approach helps create a holistic flood-risk map, incorporating local knowledge and expertise. By employing these methods in combination, policymakers, urban planners, and researchers can effectively map and identify flood-prone areas in Adama City Aba-Geda Sub-City, and develop strategies for flood risk management and mitigation.

To effectively map and identify flood-prone areas, a combination of resources and methods is essential. Flood maps can show the relationship between a property and the areas with the highest risk of flooding. By using these resources, communities can develop strategies for reducing their risk and make more informed decisions about how to reduce or manage their risk.

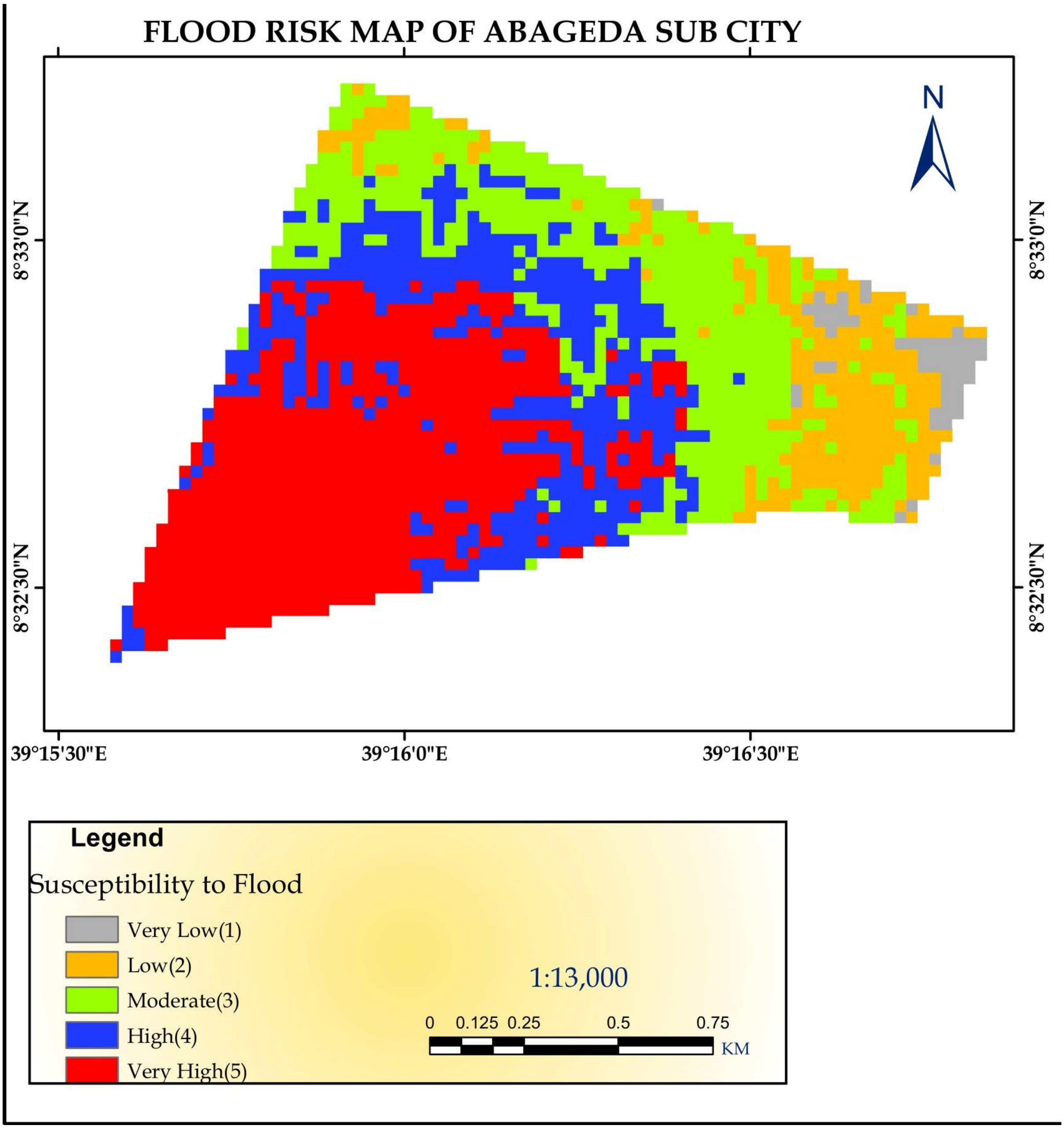

Figure 4.8 Flood risk map

4.4 Proposed best management practice

Best Management Practices (BMPs) are a set of practices that are used to manage land and activities to mitigate environmental impacts. The effect of cost during the selection of Best Management Practices (BMPs) for stormwater management is a significant factor. Due to the number of available BMPs, competing selection strategies, and physical site constraints, more efficient strategies and tools are required to ensure that the most appropriate BMPs are selected after weighing these criteria (Hodges, 2016).

1) source control BMPs:- Source control Best Management Practices (BMPs) refer to a set of practices implemented to prevent pollution by minimizing potential pollutants at their

origin points prior to their interaction with stormwater. These measures are aimed at addressing pollution prevention at its source, before it can enter the stormwater system. The implementation of source control BMPs effectively reduces the likelihood of pollutants coming into contact with stormwater, thus mitigating environmental contamination. By applying source control BMPs, pollution can be intercepted and minimized, ensuring a cleaner and healthier stormwater system and

2) treatment control BMPs:- while treatment controls, as the name implies, are methods to treat or remove pollutants from stormwater(Dc, 2004).

In order to effectively mitigate flood impacts, non-structural stormwater management strategies emphasize preventive measures and depend heavily on altering behaviors. These strategies are of utmost importance, especially in tropical climates within low-income communities. Such changes in approach are particularly relevant for flood prevention and reduction.(Parkinson, 2003).

4.4.1 Source control BMPs

Source control BMPs are practices that prevent pollution by reducing potential pollutants at their sources before they come into contact with stormwater. a listing of source control BMPs(Dc, 2004)

Table 4.6 Source control BMP's (Armitage et al., 2013).

No	Method	General description	Advantages	Limitations	Operation and maintenance
1	**Green roof**	Urban stormwater controls are vital for managing runoff in densely populated areas.	Enhances building conditions, regulates temperature, improves air quality, and boosts amenity and biodiversity.	Implementing waterproofing and plant features in green roofs can be expensive. However, the detention of water within the green roof storage layers may lead to waterproofing membrane failure, potentially causing leaks or increasing the risk of roof collapse.	recommends 3-4 annual inspections for vegetation issues, occasional irrigation during establishment and dry periods, and periodic fertilizer application.
2	**Rainwater harvesting**	Water can be used for non-drinking purposes, such as toilets and gardens, reducing stormwater and being common in developing countries.	promote water conservation, pollution reduction, and stormwater reuse.	The water quality must be monitored. Above-ground rainwater storage facilities may appear unattractive. Domestic-scale rainwater reuse is currently expensive, primarily due to the high cost of rainwater tanks.	General maintenance includes monitoring the first flush diverter, cleaning roof gutters, and removing sediment from the storage tank.
3	**Soakaways**	Soakaways are underground storage areas filled with porous material, through which stormwater is released slowly into the surrounding soil.	a design life of up to 20 years, effectively reduces both the volume and rate of runoff, helping remove pollutants from stormwater runoff.	may not be suitable for regions where infiltrating water can harm nearby structures. Additionally, it is limited to smaller connected areas and may not function well on steep slopes. Over time, sedimentation can also reduce its storage capacity.	Soil types like silts and clays need thorough inspection and maintenance. Clogged soakaways can attract mosquitoes, vectors, and unpleasant odors due to stagnant water. To resolve this, replacing the backfill material may be required.
4	**Permeable pavements**	Permeable paving uses a gravel sub-base to store stormwater and recharge groundwater by allowing it to infiltrate the underlying stratum. Suitable climates and low traffic are ideal for its construction.	Permeable pavements utilize roads, driveways, and parking lots for stormwater drainage, increasing usable space and recharging groundwater.	sites with slopes below 5%, It is not recommended for high traffic volumes or speeds exceeding 50 km/hr as it may not be suitable. While permeable pavements have lower pollutant removal capabilities.	To prevent blockage, the fine stone aggregate in PCBP joints and slots should be replaced periodically. Regular maintenance involves vacuuming and/or high pressure jet-washing the surface every 3 months or 4 times a year.

Acording to the study of Performance Evaluation of Stormwater Drainage System: The Case of Hawassa City and Evaluation of Drainage system in Kebena stream catchment, Addis Ababa Best management practice selection criteria is less limitaions from all proposed best management practice (Yidinekachew, 2019) and (Eskedar, 2013). From the above table 8 of source control BMP's the conclusion their limitations it can be understood that storm water harvesting BMP's is the best acceptable limitations and that involves the collection and use of stormwater for various beneficial purposes, such as irrigation, toilet flushing, and groundwater recharge.This practice is considered an effective stormwater management strategy due to Its potential to reduce stormwater runoff and associated problems, such as flooding and water pollution. By capturing and utilizing stormwater, this BMP helps to conserve potable water supplies and reduce the strain on traditional water sources. Additionally, stormwater harvesting can contribute to the sustainability of water systems by providing an alternative water supply for non-potable uses. Stormwater harvesting systems, an effective method of integrated water resources management and climate-resilient urban planning, utilize various components such as storage tanks, infiltration basins, and green infrastructure. By capturing and storing stormwater for later use, these systems play a crucial role in sustainable water management. This approach is gaining recognition for its ability to address climate challenges in urban areas.

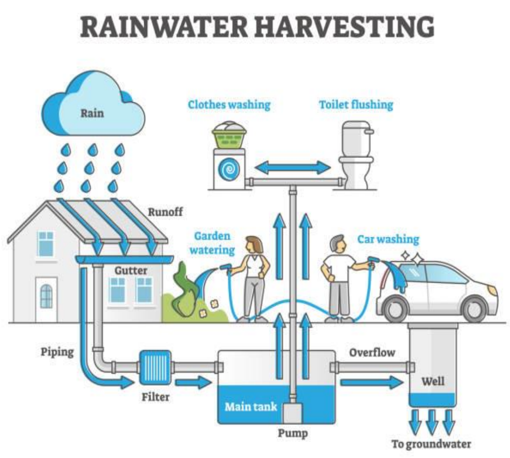

Figure 4.9 some examples of Rainwater harvesting

4.4.2 Treatment control BMPs

while treatment controls, as the name implies, are methods to treat or remove pollutants from stormwater. filter strips emerge as the superior choice among various stormwater management practices. With their low installation and maintenance costs, filter strips prove to be a cost-effective solution. Moreover, their ability to complement natural landscapes makes them an ideal option for recreational purposes, ensuring a harmonious integration with the environment.

Table 4.7 Treatment control

No	Method	General description	Advantages	Limitations	Operation and maintenance
1	**Filter strips**	in managing shallow overland stormwater runoff through filter strips, which are maintained grassed areas that undergo filtration processes like buffer strips.	low installation and maintenance costs, flexible layouts, attenuate flood peaks, integrate well with the landscape, and provide open spaces for recreation.	They can be ineffective in removing fine sediments and dissolved pollutants, and they have minimal stormwater runoff storage capacity. Additionally, they are not very effective at treating high-velocity flows and are not suitable for steeply sloping landscapes.	requires periodic checks, cleaning of litter, removal of sediment, re-levelling, and planting new vegetation. Vegetation replacement is also necessary for areas affected by erosion or excess sediment.
2	**Swales**	Swales are grass channels used as an alternative to kerbs and gutters in residential areas, needing ample space to work properly.	Vegetated swales are cost-effective and visually appealing alternatives to kerbs and channels. They help manage runoff by absorbing water and capturing pollutants, reducing stormwater volume and flow.	Swales require more land space, have limited pollutant removal capabilities, and are not suitable for properties with steep slopes. Additionally, standing water in swales can attract mosquitoes and create unpleasant odors.	The most important maintenance period is first two years, known as the plant establishment period, are crucial and require frequent weed control and replanting. Special attention should be given to the inlet and outlet areas of the swale to prevent erosion.
3	**Infiltration trenches**	Infiltration trenches are trenches filled with rock or void forming products, separated from surrounding soil by geotextile.	These systems help increase groundwater recharge, reduce flooding frequency, remove pollutants fromstormwater, and can be implemented in urban areas, including older or modified sites.	unsuitability for unstable or steep areas, potential groundwater contamination, and the risk of failure if sediment or debris clogs the gravel.	In the first year, inspect the trench after each heavy rainfall for sediment, debris, and stormwater quality. Afterwards, conduct inspections every three months.

4	**Bio-retention areas**	Bio-retention areas are used to manage stormwater runoff in various locations, including between houses, parking lots, roadsides, and large paved areas.	Bio-retention areas are effective in removing stormwater pollutants and can be easily integrated into different landscapes. They are suitable choices for retrofitting and can also enhance aesthetics.	this system is not practical in hilly areas, unsuitable for areas with shallow water tables, requires frequent maintenance for visual appeal, prone to clogging if surrounding areas are not well maintained, and tends to be more expensive compared to other options.	Key maintenance steps are regular debris removal, yearly weeding and replacement of soil/mulch layers, replacing damaged vegetation, pruning, treating diseased plants, and sediment removal.
5	**Sand filters**	filter stormwater runoff using a sedimentation chamber and an underground filtration chamber with sand or other media. The filtration process involves both the sand bed and microbial action to remove pollutants from the runoff.	It can be used in limited space areas under paved surfaces. The cleaned water can be reused for various non-drinking purposes like toilet flushing, dish washing, and watering gardens.	In summary, sand filters can easily become clogged, are unappealing without vegetation cover, and are costly compared to other Sustainable Drainage System (SuDS) alternatives.	Sand filters require frequent maintenance compared to other SuDS options. It is important to prioritize regular maintenance in the management plans of sand filters during the design stage of their application.

Acording to the study of Performance Evaluation of Stormwater Drainage System: The Case of Hawassa City and Evaluation of Drainage system in Kebena stream catchment, Addis Ababa Best management practice selection criteria is less limitaions from all proposed best management practice (Yidinekachew, 2019) and (Eskedar, 2013). From the above table 9 of source control BMP’s the conclusion their limitations it can be understood that Filter strips BMP’s have emerged as a more choice among the other stormwater management practices due to several reasons: Low installation and maintenance costs, Cost-effectiveness, Environmental compatibility,Compatibility with other practices and Wide applicability.Overall, filter strips BMP’s offer a cost-effective and environmentally friendly solution for managing stormwater runoff, making them a popular choice for homeowners, municipalities, and developers.

Figure 4.10 some examples of filter strips BMP’s

5 Conclusion and Recommendation

5.1 Conclusion

This study aims to determine the effectiveness of the drainage network in Aba-Geda Sub-Cities of Adama City, identify major challenges in the management of storm water drainage, map flood prone area and recommend best management practices.

Based on the search results, the following are some ways to improve the drainage network in Aba-Geda Sub-Cities of Adama City:

- The existing drainage system in the Aba-Geda Sub-Cities of Adama City was observed, and the potential environmental impacts of urban drainage discharges were forecasted. This analysis aimed to understand the existing drainage infrastructure and anticipate its effects on the environment due to urban discharge.

- Consider holistic considerations of other integral parts and deal with problems associated with storm water in an integrated approach so that the effects of individual problems can be reduced in downstream areas.
- Provide information regarding the current status of the drainage system for effective planning and management of flood hazards in the study area.
- Implement integrated solid waste and liquid waste management practices in the city to reduce the amount of waste that can clog the drainage system.
- Address drainage issues in the urban landscape by better classifying, surface drains, and structural drainage pathways.

In summary, improving the drainage network in Aba-Geda Sub-Cities of Adama City can be achieved by analysing the existing drainage system, considering holistic considerations of other integral parts, providing information regarding the current status of the drainage system, implementing integrated solid waste and liquid waste management practices and addressing drainage issues in the urban landscape.

5.2 Recommendation

To improve the drainage systems in the study area and create a better and sustainable urban storm water drainage system, the following recommendations are made:

- Conduct educational campaigns: Governmental and non-governmental organizations should organize awareness campaigns at the community level. These campaigns should provide information on the benefits of adopting best management practices. The information provided should be aimed at stimulating behavioral change at the community level to achieve proper solid and liquid waste management
- Engage community leaders: Municipalities should work closely with community leaders to promote the use of drainage systems and proper waste management. These leaders can help spread the message within their communities and encourage residents to adopt sustainable practices.
- Provide training and workshops: Governmental and non-governmental organizations should organize training sessions and workshops to educate community members on the importance of drainage system usage and waste management. These sessions can also provide information on the various best management practices available and how to implement them.
- Collaborate with schools and educational institutions: Storm water management and sustainable drainage practices should be included in the curriculum of schools and educational institutions. This will help install the importance of responsible drainage system usage and waste management from a young age.
- Develop partnerships: Collaboration between governmental and non-governmental organizations working on storm water drainage and related activities, including consultation with the municipality, is crucial for effective community engagement. By working together, these organizations can pool resources and expertise to implement awareness programs and promote the use of drainage systems.
- Involve the public in decision-making processes: The community should be involved in the planning and decision-making processes related to the expansion and management of the city's drainage systems. Public consultations and meetings can be organized to discuss future plans and obtain feedback from residents.

- Conduct regular inspections and maintenance: The municipality should establish a system for regular inspections and maintenance of the drainage systems. This will ensure that the systems are in good working condition and can serve their intended lifespan.

- Further research and analysis on the economic benefits of stormwater management, urbanization effects relative to the damping of solid, have been conducted to assess the potential advantages, such as increased economic development, green job opportunities, and enhanced land and property values.

- Improve water quality by implementing measures to remove pollutants from storm water, benefiting both human health and the ecosystem.

By implementing these strategies, the community will become more aware of the importance of proper drainage system usage and waste management. This will help extend the lifespan of the drainage systems and contribute to a cleaner and healthier environment.

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Appendix

Appendix A: Runoff Coefficient

	Land Use	A	%	C	CA	Cweigted
Area 1	Commercial	11.9506	42.9111	0.825	9.85925	
	Institutional	3.6962	13.272	0.825	3.04937	
	Asphalt	5.9354	21.3123	0.825	4.89671	
	Residential	3.8729	13.9064	0.3	1.16187	
	Recreational	2.3946	8.5983	0.3	0.71838	0.7068502
	Total	27.8497	100		19.6856	
Area 2	Commercial	9.0727	35.8793	0.825	7.48498	
	Institutional	3.3545	13.2659	0.825	2.76746	
	Asphalt	6.3746	25.2093	0.825	5.25905	
	Residential	4.4195	17.4776	0.3	1.32585	
	Recreational	2.0654	8.16793	0.3	0.61962	0.6903611
	Total	25.2867	100		17.457	
Area 3	Commercial	4.35224	47.7219	0.825	3.5906	
	Institutional	0.64008	7.01842	0.825	0.52807	
	Asphalt	1.99457	21.8702	0.825	1.64552	
	Residential	1.20571	13.2205	0.3	0.36171	
	Recreational	0.92741	10.1689	0.3	0.27822	0.7022055
	Total	9.12	100		6.40411	
Area 4	Commercial	10.3413	46.7878	0.825	8.5316	
	Institutional	1.52089	13.9028	0.825	1.25474	
	Asphalt	4.73928	16.7202	0.825	3.90991	
	Residential	2.86488	13.1111	0.3	0.85946	
	Recreational	2.20361	9.47806	0.3	0.66108	0.7022055
	Total	21.67	100		15.2168	
	Commercial	10.1483	48.2055	0.825	8.37233	
	Institutional	3.01552	12.0485	0.825	2.4878	
	Asphalt	3.62662	12.2586	0.825	2.99196	
	Residential	2.84379	14.6788	0.3	0.85314	
	Recreational	2.05579	12.8086	0.3	0.61674	0.7064071
Area 5	Total	21.69	100		15.322	
	Commercial	12.1321	48.5673	0.825	10.009	
	Institutional	3.605	13.0918	0.825	2.97412	
	Asphalt	4.33556	13.0918	0.825	3.57683	
	Residential	3.3997	12.5241	0.3	1.01991	
	Recreational	2.45766	12.6287	0.3	0.7373	0.7064071
Area 6	Total	25.93	99.9038		18.3171	
	Commercial	12.6845	43.6287	0.825	10.4647	
	Institutional	3.0522	12.9908	0.825	2.51807	
Area 7	Asphalt	3.786	15.3248	0.825	3.12345	0.6978131

	Residential	3.1035	14.528	0.3	0.93105	
	Recreational	3.221	13.5277	0.3	0.9663	
	Total	25.8	100		18.0036	
	Commercial	15.1432	48.5673	0.825	12.4931	
	Institutional	4.112	13.0918	0.825	3.3924	
	Asphalt	4.082	13.0918	0.825	3.36765	
	Residential	3.905	12.5241	0.3	1.1715	
	Recreational	3.9376	12.6287	0.3	1.18128	0.6929477
Area 8	Total	31.1798	99.9038		21.606	
	Commercial	13.7165	43.6287	0.825	11.3161	
	Institutional	4.0842	12.9908	0.825	3.36947	
	Asphalt	4.818	15.3248	0.825	3.97485	
	Residential	4.5675	14.528	0.3	1.37025	
	Recreational	4.253	13.5277	0.3	1.2759	0.6777074
Area 9	Total	31.4392	100		21.3066	

Appendix B: Time of concentration

Area	L	S	L^0.77	n	0.091*(nL)^0.8	P2*s^0.4	P2	Tt	V	T travel	Tc
A1	530	0.013	125.23	0.032	0.88	0.30	1.72	2.89	0.71	12.50	15.40
A2	467	0.041	113.60	0.032	0.79	0.48	1.72	1.65	1.25	6.20	7.86
A3	555	0.017	129.75	0.032	0.91	0.34	1.72	2.70	0.81	11.45	14.15
A4	583.9	0.035	134.92	0.032	0.95	0.45	1.72	2.10	1.16	8.40	10.50
A5	411	0.037	102.96	0.032	0.71	0.46	1.72	1.55	1.19	5.75	7.30
A6	513.4	0.032	122.19	0.032	0.85	0.43	1.72	1.97	1.11	7.72	9.69
A7	410.4	0.024	102.83	0.032	0.71	0.39	1.72	1.85	0.96	7.13	8.97
A8	510	0.031	121.57	0.032	0.85	0.43	1.72	1.98	1.09	7.79	9.77
A9	1153	0.021	227.83	0.032	1.63	0.37	1.72	4.45	0.90	21.40	25.85

Appendix C: The highset daily peak Rainfall Data

S.No	Year	Highest Daily Peak mm
1	1992	41.1
2	1993	70.0
3	1994	51.0
4	1995	77.5
5	1996	47.5
6	1997	61.4
7	1998	59.8
8	1999	41.5

9	2000	82.2
10	2001	44.3
11	2002	82.2
12	2003	70.4
13	2004	43.3
14	2005	42.3
15	2006	62.8
16	2007	55.1
17	2008	72.5
18	2009	54
19	2010	56.1
20	2011	46.9
21	2012	69.6
22	2013	59.4
23	2014	46.6
24	2015	52.6
25	2016	56
26	2017	68.4
27	2018	56.4
28	2019	56.3
29	2020	57
30	2021	69.1
31	2022	45.4