URBAN STORM WATER DRAINAGE MANAGEMENT SYSTEM AND ITS CHALLENGES (THE CASE OF BISHOFTU TOWN), ETHIOPIA

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DR.SITOTAW HAILE

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Declaration

I declare that this thesis entitled

"Urban storm water drainage management system and it challenges (the case of bishoftu)."Is my own work and has not been submitted to any university for similar purpose. The references used in this thesis are duly recognized by proper citations.

Alemayehu Jiraa ______________________ ___________________

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LIST OF ABBREVIATIONS.

AACRA: Addis Ababa City Roads Authority

ArcGIS: Architectural Geographical Information System

BMP: Best Management Practices

CAD: Computer Assisted Design

DEM Digital Elevation Models

FUPI: Federal Urban Planning Institute

FGD Focal Group Discussion

GTZ: German Technical Cooperation

Km: Kilometer

M: Meter.

Masl; Meter above sea level

mm: Millimeter

NGOs: Non-Government Organizations

NUPI: National Urban Planning Institute

UN: United Nation

USWD: Urban Storm Water Drainage

ABSTRACT

Ethiopia's rapid urbanization, which is exacerbated by global climate change, is causing major challenges for major cities, such as increased storm runoff and flooding. Runoff coefficients are higher in urban areas than in rural areas, where vegetation cover and agricultural land help to absorb or infiltrate rainfall, reducing storm runoff. However, in urban areas, paved surfaces and built-up areas increase storm runoff, reducing infiltration rates (Berndtsson et al., 2019). The main aim of this research is to investigate the current storm water management system and its challenges in Bishoftu town. In order to achieve the objective exploratory mixed research design and descriptive research types that involved both quantitative and qualitative analysis were developed. A questionnaire was conducted to households chosen from the site using a random sampling technique. Supplementary data was also gathered through selected key informant interviews, field observation, and by consulting secondary data sources. And data were analyzed by using arc cad ,auto cad & Excel software are used . Based on the result of the study, most of the drainage ditches are filled with solid waste and sewerage resulting in formation of sewage ponds in the channel as well as on the road. Reuslt of the study revealed that the majority of the road in the study area are deteriorated and degraded occurred due to the absence of adequate urban storm water drainage infrastructure that discharges the flood generated safely in to the final receiving systems. Likewise, the major provision challenges of the stormwater management system are topography and geological formation, inadequate coverage of drainage lines, inappropriately designed drainage structures, disposal of solid waste into natural waterways and drainage facilities, low community participation and others. These practices decrease environmental degradation. Furthermore, results obtained from field observation indicated that very serious environmental degradation due to the inadequacies of drainage along most streets, lack of green space, and the result of poor stormwater management. Therefore, the recommendations of the study are; the municipality should applying Sustainable urban stormwater management proposed strategies through inviting different stakeholders to create awareness and technically support the community in how they start stormwater management practice. This study also strongly recommends the implementation of the planned and designed urban drainage. The use of porous structures like grassing on compounds and road sides instead of pavements will contribute valuable advantages towards the sustainable urban drainage management.

Key word: Storm water,* Urbanization*, Runoff & rainfall.

CHAPTER ONE

1. INTRODUCTION

1.1 Background

Today, urban areas house more than 55% of the world's population, and the number is expected to rise to 68% by 2050 (United Nations, 2018). As urbanization continues to increase, the amount of urban infrastructure covering the surface area of cities is also rising. This has led to an increase in compacted soils and impermeable surfaces (Berndtsson et al., 2019). Furthermore, alongside the expansion of urbanization, drainage systems are becoming increasingly inundated and unable to cope with heavy rainfall. Improperly designed infrastructure and impermeable structures associated with urbanization are significant contributors to flooding in numerous developing urban areas (Belete, 2009).

On top of that, as the process of urbanization accelerates, the hydrological cycle of cities will be interrupted, reducing infiltration capacity, decreasing groundwater recharge, and increasing evaporation (Qiao, 2019). Increased urbanization will affect the hydrological makeup by obstructing natural streams and/or diminishing the surface's water absorption capacity (Chen, et.a., 2015). Increased impervious surfaces result in increased storm water runoff volume and shorter time to peak flow, which can increase the risk of urban flooding and water-logging in urban areas (Mahaut & Andrieu, 2019).

Storm water has long been seen as a primary contributor in urban flooding due to its severe consequences on the living and non-living environments. Around the world, vegetation and topsoil are removed to create space for houses, roads, other infrastructure, and drainage networks. (Saraswat et al. 2016). Following that, storm water can overflow sewerage or municipal drainage lines, resulting in urban flooding that can harm numerous environments (Jha et al., 2011).

The urban drainage system both influences and is influenced by the city expansion process, which is often chaotic (Francisco et al., 2020). Poor drainage system can lead to flooding, resulting in property loss and even forcing people to relocate to escape floodwaters. The issue with urban storm water drainage networks is also another

Barrier in urban settings, because run-off produced in a specific urban area could not safely be discharged in to the final receiving system (Muzamil, et.al., 2020). As a result, this could be the source of environmental concerns like as erosion, pollution, over topping, traffic barriers, and other issues.

Urban drainage systems play a significant part in the complex ecosystem of cities and are frequently subject to obstacles that impede their operation, such as city expansion dynamics, system maintenance, urban area vulnerability, public policies, and investments (Francisco, et.a., 2022) . Urban storm water management is the management of the quantity and quality of storm water (Rathnayke, & Srishantha, 2017). It has focused especially on reducing peak flows, pollution and downstream flooding (Donofrio et al., 2009). Additionally, it is a method to manage the total water cycle into the urban development process through integrating urban planning and design (Noordhoek, 2014). The general advantages of stormwater management include mitigation the damage to the property, protection of the natural water bodies from pollution, to provide the economic benefits, and to promote public health (Rathnayke, & Srishantha, 2017).Urban storm water management and drainage system facilities are part of the urban infrastructure, and their design requires consideration (Beniyam, 2016). In the Ethiopian context, where many urban watersheds receive large yearly rainfall and rainfall intensity is generally high, control of runoff at source, flood protection, and safe disposal of excess water/runoff through suitable drainage facilities becomes critical.

Due to the presence of an inefficient, unscientific, and poorly maintained drainage infrastructure, Ethiopia's major cities mostly suffer from localized flooding and water pollution. The urbanization development of Bishoftu town, like in many other cities, has increased impervious surfaces, resulting in considerable flood threats. Unfortunately, street flooding, over topping, and other environmental issues are frequent in this Bishoftu town. This is especially acute in areas where road infrastructure looks to be lacking suitable rainwater drainage infrastructure. In addition, liquid and solid waste are also the biggest challenges in contributing for the over flow by blocking the drainage systems. Therefore, the purpose of this research is to evaluate the urban storm water drainage system and its challenges in the town of Bishoftu.

1.2. Statement of the problem.

Ethiopia's urbanization and modernization pattern has resulted in significant densification and urban infrastructure development .Excess storm water flow over the road in Ethiopia's urban centers, including Bishoftu, has been caused due to expansion of urban construction without provision of drainage system and poor management. A lack of urban storm water drainage management is one of the most prominent sources of complaint among people in many Ethiopian cities, including Bishoftu, and the problem is worsening as urbanization progresses. (Mitiku and Mekdes, 2017).

Bishoftu twon is one of the dynamic business centers because of its hospitable and beautiful climate, natural resources, proximity to Addis Ababa, and transport access both road and rail. So the study on urban drainage and storm water management in the town has due attention for the topographic nature of the Bishoftu town and lack of proper planning in storm water management & construction.

Heavy rains and excessive runoff in Bishoftu town cause flooding in a number of areas. During the rainy season, a large area of the town is vulnerable to floods. This has resulted in significant loss of human life and property. There is also an issue with overtopping, drainage facility blockage, erosion and water logging in some drainage areas, which has a major impact on both road access and strength. Runoff generated during the rainy season can transport wastes that have a poor odour and create an unwelcoming environment. This has a negative impact on the community's health. In the town settlements built on the steep slope area and low-lying areas are frequently affected by uncontrolled runoff.

The drainage lines in many parts of town are clogged with solid waste and siltation. The town's existing drainage system comprises of a significant length of open masonry ditches, covered drains, and earthen channels with various cross-drainage structures that do not maintain suitable slope design in flat areas. Furthermore, drop structures have not been designed to limit excessive velocity on steep slopes. The culvert size is inadequate, and some of them are not in an appropriate place.

The insufficient drainage system, inadequate flood protection, poor storm water management, rough topography, and high coverage of an impervious surface increased the runoff, resulting in very serious damages and the destruction of several properties in Bishoftu town.

Nowadays, few studies have been conducted in Bishoftu town relating to urban drainage and flooding. One study undertaken by Dagnachew (2011) focused on the assessment of the urban road and drainage infrastructure in Bishoftu town including the available resources and the related problems. Another study conducted by Biruk (2018), analysis of the causes and consequences of flash flood and design for flood resilient neighborhood in Kebelle 02 of Bishoftu town. In these studies, however, no sufficient exploration was made with regards to the overall challenges of urban storm water management system and the mitigation strategies in the context of Bishoftu town. This has created a knowledge gap on the major challenges of urban storm water management system and this study is intended to contribute to filling these knowledge gaps. Therefore, the study tries to identify the major urban storm water drainage challenges and proposes the strategies to enhance sustainable urban storm water management system for Bishoftu town.

Flooding from the bare Gara Beru, Babo Gaya & Kidanemihret hill side Mountain and improper management of the urban drainage system due to various reasons is the major problem driving force to undertake this work in the aforementioned particular in Bishoftu.

1.3. Objectives

1.3.1 General objectives.

The main objective of the study is to assess urban storm water drainage management system and its challenges in case of Bishoftu town.

1.3.2 Specific objectives.

- To analyses the existing condition of drainage system in the case study area
- To identify the challenges of stormwater management system in the town
- To propose strategies to enhance sustainable urban stormwater management system

1.4. Research Questions.

The research will attempt to assess the following questions.

1. What is the current state of the town's urban drainage system?
2. What are the challenges of stormwater management system in Bishoftu town?
3. How to enhance sustainable urban stormwater management system in Bishoftu town?

1.5. Significance of the study.

Generally, managing urban storm water drainage system has a significant role for sustainable environment management by keeping the service life of urban utilities like roads, buildings, telephone lines, power supply lines, water supply lines and the existing rivers. But, due to lack of proper environmental management on the surrounding mountainous and built-up areas and due to inadequate integration between Road and Urban Storm Water Drainage infrastructure there exists poor urban storm water drainage management in Bishoftu , as a whole. Thus, this research is expected to address/reverse the above mentioned problems at twon and then, at twon level and to the down catchment environment. Furthermore, this study will contribute paramount advantages by creating a good opportunity to keep the aesthetic and recreational value of rivers and improves the environmental condition of the surrounding areas, as a whole. Besides, it will have a greater advantage by enabling the ground water to recharge itself. This study will also enable the Bishoftu city and any environmentally concerned body to use it as a reference for future decision making and planning purposes. The residents will also be benefited from the sustainable environmental values added by this study. Last not least, this study enables the researcher to have an in-sighted understanding and further knowledge towards urban drainage system management and planning, and will open good and additional opportunities to the researcher's future research studies and capabilities.

1.6. Scope of the Study.

The thematic scope of research was focusing on the implication of urban stormwater management by recommending the concept of sustainable urban stormwater management. The study covers the challenges of the urban stormwater management system and suggestion strategies for sustainable urban stormwater management. The spatial scope of the study is Bishoftu town kebele.

1.7. Limitation of the study.

The researcher faced three major constraints; these are lack of interest on the respondents' side, political instability and time constraints. When the researcher conducted the household survey, the target groups were not willing to fill questionnaires, by presuming that the result of this research does not have impact for the area. After convincing those on the significance of the research in flagging the problems and suggesting possible solutions to bring resilience in the study area, they become willing to fill it. During the time of data collection there was turmoil in the study area. This has an adverse effect in collecting the filed data on the planed time.

1.8. Organization of the study.

This study is organized into five chapters to enable ease of access through contents of each chapter. Chapter one deals with is introduction part that discusses the background of the study, research problems, research objectives and questions, scope and significance, limitations and organizations of the study. Chapter two incorporates review of study related literatures. Chapter three discusses selection of research methodology, data collection and analysis tools. Chapter four is in which socio-economic, result and discussion of the study are presented. The last Chapter presents conclusions and recommendations of the study.

CHAPTER TWO

2. LITERATURE REVIEW

2.1. Introduction

In this chapter, the significant literature reviewed was discussed. It was prepared to support the objective of defining by research questions. This includes the challenges of urban stormwater management system, and solution proposed to mitigate it.

2.2. History and Concept of Urban Storm water.

Stormwater is rain that falls on paved or other impermeable surfaces such as roofs, parking lots, roadways, and driveways and continues to flow onto and across the ground, in culverts, on pavement, and generally in drainage systems. It is also pure rainwater plus anything else the rain brings with it. Water that falls onto impervious surfaces during a rainstorm flows to the nearest storm drain or local water body. This water can come from sources other than rain, such as snow melt or street wash water, and is referred to as storm water (Hunt, 2011).

Rain that falls on our roofs or collects on paved areas such as driveways, roads, and footpaths in urban areas is taken away by a system of pipes that is separate from or mixed with the sewerage system. Storm water, unlike sewage, is not treated. Storm water that is not adequately drained can cause a great deal of discomfort, damage, and even health problems. Flooding is one of the most common problems associated with poor drainage, and can cause extensive damage to homes, businesses, and public infrastructure. In addition, standing water can lead to the growth of mold and mildew, which can cause respiratory problems for people with allergies or asthma (Elliott, & Trowsdale, 2007).

According to Basuah (2014) urban stormwater runoff is produced from built-up areas, construction sites, rooftops, roads, and highways. Through one area becomes more densely developed, a large part of the land is covered with hardened surfaces (Schutte & Sculze, 2017) this can make the rainstorm that would be absorbed by plants or filtered into groundwater aquifers instead flows into the local water path and storm drains. Also, in urban zones because of the increase in the water-resistant surface and disturbed natural soils and vegetation infiltration volume is decreased (Addisu, 2009). Some studies indicate as the extent of impervious surface increases, degradation is also likely to increase (Mezgebe, 2009). The effect of urban stormwater runoff from urban development and sprawl after any rainfall in the city surroundings efficiently takes areas that are impermeable surfaces (Tian, 2011).

Sewers were among the earliest cities. Archaeological excavations of settlements in the Indus and Tigris river basins have revealed the utilization of drainage conduits as far back as 3500 BC (Bruce, 1998). Romans were great builders of sewers, roads, and bridges. The greater sewer, cloaca maxima, built in the sixteenth century B.C. to drain the Forum in Rome, is still in use today (ibid). Since then, sewers have been built to drain only runoff from stormwater. Strictly speaking, this was enacted to specifically prohibit the entry of anything but rainwater in the sewer/drainage systems. Thus, sewers/drains were placed largely for convenience to minimize the detention of water on roadways and other surfaces in wet weather. London and Paris in the 1840s and the 1850s were converting storm sewers to combined sewers (ibid), and new sewers were designed to act as combined sewers because an epidemic broke out due to the increase in the number of urban people and the discharge of domestic waste everywhere. North America followed this practice. These combined sewers were discharging the wastes in to local/natural water courses (ibid), as a result these receiving water courses had got polluted, in addition to these ecological and aesthetic problems, the fecal contamination of surface waters further impaired the quality of surface water supplies. It was decided that the combined sewers should be treated before being discharged into natural water courses. The implementation of sewage treatment is confounded by a large number of combined sewer outfalls (pipes entering watercourses).

2.3. Significance of urban storm water management.

The management of urban stormwater has improved water sustainability (Nassar et al., 2017). According to Carmon and Shamir (2009), the following three Rs (Reduce) should be followed for improved urban stormwater management at all spatial levels, from a single lot and building block to a neighbourhood and the entire city:

1. Reduce the difference in runoff volume leaving the area after urban growth vs volume before it.
2. Reduce the change in discharge leaving the area following urban growth in comparison to the discharge before it.
3. Reduce the pollution load in runoff from urbanized areas.

Urban areas are defined by a large percentage of impervious surfaces used to quickly and efficiently move higher densities. However, these impervious surfaces generate problems when dealing with stormwater because the natural hydrology of the area is disturbed by urban development. The creation of cities alters natural hydrology in a series of steps, from clearing vegetation, installing roads, re-grading surfaces, and building actual structures (Jared, 2011).

Changes to water pathways from urban construction have led to important issues regarding stormwater, along with the creation and implementation of best management practices. Traditional stormwater management removes runoff from developed areas as quickly and completely as possible. The new alternative sustainable approach comprises a combination of the conventional approach (providing a drainage network and modifying existing watercourses) complemented or substituted by different concepts, including the recycling and reuse of stormwater (Gogate et al., 2017).

2.4. Urban Storm Water Management Challenges .

Rainfall, snowmelt, sea surge, and drainage and water system failure are all examples of natural phenomena that contribute to inner-city stormwater runoff. In urban environments, a key avenue for urban flooding is severe rainfall that exceeds a city's drainage holding capacity (Adugna, 2011). Increases in flood water sources are not the only factors contributing to increased flood hazard in the urban environment. Stormwater transportation towards urban areas and variables that reduce the ability to distribute stormwater are present.

As a result, some challenges to urban stormwater management include land-use change, increased urban expansion, and a lack of community awareness, as well as a decrease in the permeability of open spaces, a lack of well-implemented urban planning, a lack of maintenance of ageing infrastructure, and a lack or overload of drainage systems. The following are explained:-

A. Land use change

Land use change in urban areas can increase the threat of storm water by reducing the area's ability to absorb excess water (Schutte & Sculze, 2017). With the expansion of urban land use, new infrastructure will increase impervious surfaces (Haile & Worku, 2018). For example, transportation networks may introduce elevated structures that obstruct previous natural flow paths. In addition, more natural changes to land use can damage the sensitive water and land balance main, resulting in reduced storage and increased overland flow.

Another key factor influencing surface runoff is vegetation loss (Assefaw, 2016). Commercial, residential, and industrial uses are developed from open spaces and undeveloped land. This may result in a loss of land cover. Additionally, increased precipitation may result in increased river sedimentation, faster rainfall runoff, and environmental damage.

B. Absence of community participation

Stormwater pollution, flooding, and other consequences have a significant and growing negative impact on local economy, water quality, and public health across the country (United States Environmental Protection Agency, 2016). Therefore, creating beautiful cities that promote pleasant community wellness is one of the responsibilities of municipal governments. The failure of stormwater management in urban settings is caused by a lack of public knowledge, a lack of preventative actions taken by households and by city officials, and other factors. The district administration, Municipal Corporation, and Disaster Mitigation and Management Centre all have significant management responsibilities after and during stormwater flows, however despite their best attempts to educate the public on stormwater management practises, it appears that this is not the case. Quality of storm water is polluted mostly by household solid waste through dropped in the storm water drainage line and on street of urban areas (Bansal et al., 2015).

C. Poor urban planning implementation

When a city's structural plan or Local Development Plan is produced, it offers solutions to many urban concerns. However, due to a shortage of adequate public or private spaces in already developed places, implementing the recommended alternative open space, green area, and drainage master plans is problematic. Land use and infrastructure plans frequently do not designate urban sites for this use (Goldenfum et al., 2007).

D. Excess sediment and wastes

In developing countries, urban areas have huge amounts of exposed soil, which is prone to erosion and produces large amounts of silt. Building sites, whether in locations where the city is expanding or within the built urban area, do not typically have controls for erosion prevention or sediment retention so that it does not reach the streets, storm drains, and urban waterways. It is not an exaggeration to state that 10 to 15% of the urbanised territory in developing countries contributes significantly to sediment production and transport.

The amount of rubbish entering the drainage network is reduced, equal to a generation of 0.4 to 0.8% of total waste produced (Urgessa, 2016). The rate of rubbish accumulation in the streets is undoubtedly higher in developing countries, because the storm-drain network is employed for garbage disposal in some areas of cities. With these huge sediment and rubbish loads, no modern solution to urban drainage is conceivable without special retention structures upstream or intensive maintenance procedures with dredging or mechanical removal of the large amounts carried after every storm (Werkneh., 2017). This is a distinctive feature of developing countries that makes storm runoff control activities much more expensive to implement.

E. Inadequate maintenance of the infrastructure

Another factor that may exacerbate urban stormwater impacts is the failure to maintain ageing drainage lines (Qiao, 2019). This is typically the case in both developing and wealthy countries, and efficient upkeep of these infrastructures necessitates substantial sums of money on a regular basis, which may not be a priority for local management. According to (Megen, 2018), the lack of drainage maintenance in Oslo has resulted in the loss of 50% of drainage capacity owing to obstructions. The value of maintaining existing infrastructure to reduce flood risk is not often appreciated. Small acts made frequently can have a significant impact on flood risk.

F. Overload of drainage systems

Intense rainfall can generate urban stormwater overflow by overloading existing drainage systems. Today's urban drainage system may be hampered by insufficient water carrying capacity as a result of poor design and construction, as well as a lack of maintenance (World Meteorological Organisation, 2012). It could also be a rainfall event that exceeds the drainage system's design criteria. Because extreme events that surpass the capacity of the inner-city drainage structure are a primary cause of surface overflowing of rainwater, which can cause drainage systems to deteriorate in a short period of time.

2.5. Storm Water Management Program.

The sympathetic awareness for the storm water management need special attention because uncontrolled storm water and surface run off can cause significant environmental damage.

In fact most events of storm water were caused by exceptional events, which cannot be managed by a classical approach and sewer system the most appropriate way to deal with the risk of water is to have good organization. The question of organization in the case of water management concern two aspects (Wondimu A, 1998).Here management of storm water needs special attention on the geographical conditions and economic base of cities. If we take geographical conditions it includes topographic situation, totality of watersheds, slopes, rainfall, whereas economic base of the city is the ability to provide facilities to alleviate problems.

The basic understanding purpose of storm water management is to keep people from the water to keep the water from people, and to protect or enhance the environment while doing so. Keeping people from the water involves a wide-ranging number of non-structural damage mitigation measures, including zoning, flood plain management, home acquisition, flood proofing etc…keeping the water from people involves direct interference with the water through the use of flow amount or flow elevation reduction measures, such as detestation or detention storage facilities or channel enlargement.

2.6. Urban Storm Water Management and Sustainable Drainage System.

Definition of Storm water Storm water is the part of precipitation that accumulates on earth‟s surface, ditch of road side, in culvert, on pavement and generally in drainage system. Also, it is pure rain water plus anything the rain carries along with it's a way (Manual. Vol-I Revised, 2016). During rain storms, water that falls onto impervious surfaces flows to the nearest storm drain or local water body. This water can come from events other than a rain storm, such as a snow melt or street wash water, all of which are defined as storm water (Jared, 2011). Throughout this research, storm water runoff, will be synonymous with non-point source pollution. Storm water runoff problems are nothing new to local land-use decision-makers. However, the principal concern about runoff has always been safety, with the focus on directing and draining water off of paved surfaces as quickly and efficiently as possible (Jared, 2011). In urban areas, rain that falls on the roof of our house, or collects on paved areas like driveways, roads and footpaths is carried away through a system of pipes that separated or mixed from sewerage system. Unlike sewage, storm water is not treated. If storm water was not drained properly, it would cause inconvenience, damage, flooding and further health risks (Butler & Davies, 2000).

2.6.1 Storm water management Sustainability at local areas.

A) Best Management Practice for storm water management sustainability.

i. Reduce urban Run-off: The achievement of runoff reduction starts by recognizing that developing or redeveloping land within a watershed inherently increases the imperviousness of the areas and therefore the volume and rate of runoff and the associated pollutant load; and outlines various approaches to reduce or minimize this impact through planning and design techniques. The extent of impervious land covering the landscape is an important indicator of storm water quantity and quality and the health of urban watersheds. Impervious land coverage is a fundamental characteristic of the urban and suburban environment -- rooftops, roadways, parking areas and other impenetrable surfaces cover soils that, before development, allowed rainwater to infiltrate (Eskader, 2013).The technics that is related to reduce of urban run-off is encompasses manage watershed impervious area, minimize directly connected impervious areas to storm drainage system and consider coefficient of Runoff reduction areas.

Good housekeeping → source control → site controls → regional controls.

FIGURE **2-1: Flow chart for Urban Runoff Management (Sharma, 2008).**

ii. Protect the existing best management practice**:** The functions provided by BMPs may include volume reduction, treatment and slow release of the water quality capture volume (WQCV), and combined water quality/flood detention. Ideally, site designs will include a variety of source control and treatment BMPs combined in a "treatment train" that controls pollutants at their sources, reduces runoff volumes, and treats pollutants in runoff. Few Examples list of BMPs for urban storm water management are.

1. Wet Retention Pond: are a storm water control structure that provides retention and treatment of contaminated storm water runoff. By capturing and retaining storm water runoff, wet retention ponds control storm water quantity and quality. The ponds natural processes then work to remove pollutants. Retention ponds should be surrounded by natural vegetation to improve bank stability and improve aesthetic benefits.

2**.** Extended Detention basin (EDB): are storm water best management practices that provide general flood protection and can also control extreme floods such as a 1 in 100-year storm event. The basins are typically built during the construction of new land development projects including residential subdivisions or shopping centers. The ponds help manage the excess urban runoff generated by newly constructed impervious surfaces such as roads, parking lots and rooftops.

3**.** Permeable Pavement Systems (PPS): The term Permeable Pavement System, as used in this

Case, is a general term to describe any one of several pavements that allow movement of water into the layers below the pavement surface. Depending on the design, permeable pavements can be used to promote volume reduction, provide treatment and slow release of the water quality capture volume (WQCV), and reduce effective imperviousness, etc.

4. Sand Filter**:** are used as a step in the water treatment process of water purification. A sand filter is a filtering or infiltrating BMP that consists of a surcharge zone underlain by a sand bed with an underdrain system (when necessary). During a storm, accumulated runoff collects in the surcharge zone and gradually infiltrates into the underlying sand bed, filling the void spaces of

the sand. The under drain gradually dewaters the sand bed and discharges the runoff to a nearby channel, swale, or storm sewer.

5. Green Roof**:** Green roofs could be defined as "contained" living systems on top of human made structures. This green space can be below, at, or above grade involving systems where plants are not planted in the ground.

Grass swales are densely vegetated trapezoidal or triangular channels with low pitched side slopes designed to convey runoff slowly. Grass swales have low longitudinal slopes and broad cross-sections that convey flow in a slow and shallow manner, thereby facilitating sedimentation and filtering (straining) while limiting erosion. Berms or check dams may be incorporated into grass swales to reduce velocities and encourage settling and infiltration.

B. Sustainable Storm Water Management as Restoration.

The idea that urban watersheds can be restored to pre-development conditions is not realistic. Ecological restoration is a widely interpreted term. Restoration is “a singular word offering myriad meanings and rich rhetorical resources. The term is common language for developers, ecologists, academics, planners, environmentalists, and others. However, the term means different things to these different people in different professions and contexts (Alicia, 2009).

2.7 Internal and External Dimensions of Urban Drainage

Urban drainage is a complex system composed of technical organization and natural elements, interacting with combined system, waste and storm water are mostly managed by one service (Kebede D, 2005).

2.7.1 Internal dimension

This refers to the storm drainage system of the overall technical organization and natural element used to manage storm water.

2.7.2 External dimension

Refers to the internal actions of storm drainage system within the urban system. Every element in the urban system interacts with other even though the degree of interaction of storm water with solid waste, waste water, Road and housing system is known as external interaction, this interaction funds expressions in the impact of each elements on the function of the other and vice-versa, where the drainage system receives impacts from solid waste, housing, road system, etc…which facilitate or handicap its functioning it will have in turn effects on the urban system and ecosystem (Wondimu A, 1998).

2.8 Drainage facilities and problem with drainage

Drainage facilities; selection of drainage network should be depend on the economic capacity of the municipality, on the space consumption, Road standards. For example Open channel drainage network are relatively simple to construct and maintenance .the simplest open channel drain is a hard dig Unlined ditch. Though there are limitations on its use, they are cheaper than open channel lined with masonry or concrete.

Open channel drains take up space and pose a hazard to road users, especially if the drain is very wide or deep, or passes along a busy through fare. In such cases the drain can be covered with removable slabs. (http://www.oeconline.org)

Covered drains.

If excess widths are restricted, open drain may be covered, whilst there are less prone to blockage by rubbish, it is more difficult to clean them. In general, drains deeper than 400mm are a hazard to pedestrian and vehicles, but drainage smaller than 500mm wide should not be sufficiently orbits to resist super imposed/wads, whiles remaining light enough to be removed in order to allow cleaning to be effected.

Culverts.

Culverts are normally circular concrete pipes laid beneath the road to convey drained water from one side to the road to the other.

A culvert is defined as

- A structure used to convey surface runoff through embankments
- A structure that is usually designed hydraulically to take advantage of submergence to increase hydraulic capacity.

- A structure, as distinguished from bridges, that is usually covered with embankment and is composed of structural material around the entire perimeter, although some are supported on spread footings with the streamed serving as the bottom of the culvert.

For economic and hydraulic efficiency, culverts should be designed to operate with the inlet submerged during flood flows, if conditions permit.

Cross-drains are those culverts and pipes that are used to convey run off from one side of a highway to another.

Cross-Drainage-Culvert**:** It extends under a roadway and transport runoff from one side of a roadway and discharges the runoff at the other side of the roadway.

The design of a culvert is influenced by cost, hydraulic efficiency, purpose, and the topography at the purposed culvert site. Thus physical data must be integrated with engineering and economic considerations.

The primary purpose of a culvert is to convey surface water, but, properly designed, it may also be used to restrict flow and reduce downstream storm runoff pecks. In addition to the hydraulic function, a culvert must also support the embankment and roadway for traffic conveyance and protect the traveling public and adjacent property owner from flood hazards to the extent practicable and in a reasonable and prudent manner.

The type of drainage structure specified for a particular location is often determined based on economic consideration. The following can serve as a guide in the selection of the type of structure, proceeding from the most expensive. Note that bridges are included in the text of this section to allow for a more complete progression in the treatment of this topic. Bridges are used where they are more economic than a culvert, perhaps due to the need to bury a culvert under a high level of fill. They are also employed to satisfy land use requirement, to mitigate environmental harm possible with a culvert, to avoid floodway or irrigation canal encroachments, and to accommodate large debris.

Culvert are used where bridges are not hydraulically required, where debris is tolerable, and where they are more economical than a bridge. Culvert can be concrete box culvert, reinforced concrete pipe culverts, or corrugated metal culverts. Concrete box culverts are constructed with a square or rectangular opening, and with wing walls at both ends. They are usually specified for larger flows, where the area of the opening is larger than that available for manufactured concrete or metal pipe culverts.

They may also be used where the cost estimate indicates that concrete box culverts constructed on site are less expensive than manufactured and/or imported pipe culverts. An alternative sometimes employed is to use metal arch pipe, and for larger openings this can be more economic than concrete .Although metal pipe culverts are usually less expensive than concrete pipe culverts, a cost estimate may indicate that this is not the case. There are local concrete pipe culverts manufacturers producing pipe of varying quality, presently all metal pipes need to be imported.

2.9 Sub Sequential Effect of Storm Water Related Problems in Developing Countries.

The dramatic growth of the cities of the developing world has become something over relevant. The cost of providing satisfactory urban services for all area is of course huge. According to (Wondimu A, 1998), the question of water management holds one of the burning issued on the two grounds; these are resources and risks.

Risk

Faulty storm water management facilities and conveyance structures are dangers when there is flooding. People are injured or killed, and property is damaged by flooding, erosion, and pollution. One important community education and awareness role for urban storm water and floodplain managers is that of risk communication. For instance, the August 1998 flooding in Niger caused losses estimated at billion. (K(lesahle 28 Augest 1998)

In Addis Ababa alone, in each of 3 cyclical events in the last two decades, flooding affected 7000 in habitats, with loss of human life (12 fatalities in 1978/9 of 1995). Besides the site presents favorable topographic conditions, two factors aggravated the risk; precarious housing and river bank occupation (Hagos G.2003).).

The other hand the most crucial problem of cities is resources scarcity, with a doubting of the world population forecast for the coming 50yrs. The question of resource above all concerns land

and water, which have the two fundamental elements for human life. The futures of cities are determined by integrated management of land and water, in order to ensure the necessary water resources for consumption and to avoid or to minimize rate related problems (Wondimu A, 2001).

If we take case of Ethiopia, one of the problem facing urban area of Ethiopia is that of storm water management, because of the poor, improper, absence and/or inadequate drainage and accompany in facilities, manifold problem are encountered among the existent storm water management. For example in Nazareth town (Aug 21, 1990 & July16, 1993) submergence caused Sevier damage; properties and crops destroyed, also the event of 1972 in Awassa town, caused submergence of buildings, structures, road and gardens along the shore of the lake (Tesfaye Y, 1996).

Deforestation of fuel or for more urban expansion area reduced the water holding and flow retarding capacity of the catchments areas. Because of high urban land value flood prone areas may also be claimed for settlement. All these and others aggravate the drainage and drainage related problems of urban areas. In this and other respects, Ethiopia towns are no exception one of the major problems facing urban areas of Ethiopia is that of storm water management accompanying facilities, manifold problems are encountered.

2.10 Design and Construction Considerations in Planning Drainage Structure.

The design procedure involves calculation of the quantity of surface water or runoff characteristics of the area which is likely to result from rainfall.

1. Catchment area: the boundaries of drainage catchments' can be defined using a contoured plan of the site, given that in a gravity flows drainage system water flows downhill from a higher elevation to the lower elevation.

2. Time of Concentration (T): The time of concentration is the time in minutes taken by the remotest particles of water to arrive at the inlet of the structure

$$T_c = \frac{\text{distance of remote point}}{60 * \text{Average velocity}}$$

Where the average velocity depends on the topography and the vegetation of the

Catchments.

3. Storm Duration (D): it is the duration of rainfall occurrence

4. Intensity of Rainfall (I): the rainfall intensity represent a rate of rainfall and its magnitude depend up on the storm duration that is, the length of time for the Rainfall intercity being greater than or equal to a specific intensity.

5. Run-off coefficient (C): it is the proportion of rainfall which is transformed in to run- off. The coefficient C depends on the topography and type of vegetation.

The rational method: the simplest way of calculating the runoff from a given catchments' is by the rational method which state that.

$Q = 2.78CIA$……………………………………………………1

Where Q = run-off in litter per second.

C = volumetric run-off coefficient

I = Rainfall intensity of the storm in mm per hour.

A = Total area drained in hectares.

Many serious construction problems arise because important drainage and water-related factors were overlooked or neglected in the planning and location phases of the project. With proper planning, many factors can be avoided or cost effective solutions can be developed to prevent extended damages. Such factors include:

- Soil erosion,
- Sediment deposition,
- Drainage and landslide,
- Timing of project stages,

- Protection of irrigation systems and continued use during construction,
- Protection of streams, lakes, and rivers and
- Protection of wetlands.

Analysis of available data, scheduling of work, and other aspects involved in the early planning and location studies can alleviate many problems encountered in the construction of drainage structures (ERA, 2002).

2.10.1 Maintenance considerations.

Planning and location studies should consider potential erosion and sedimentation problems. If a particular location will require frequent and expensive maintenance due to drainage, alternate locations shall be considered, unless these maintenance costs can be reduced by special design. Local experience is the best indicator of maintenance problems and interviews with maintenance personnel and local residents are extremely helpful in identifying potential drainage problems. Reference to highway maintenance, flood reports, and damage surveys is also valuable in evaluating potential maintenance problems.

Channel changes, drainage modifications, and revisions affecting irrigation systems usually result in certain maintenance responsibilities by the agency constructing the highway. Potential damage from erosion and degradation of stream channels and problems caused by debris can be of considerable significance from a maintenance standpoint. . (Drainage design manual,2002)

2.11. Urban Storm Water Drainage Experience in Ethiopia.

In Ethiopian context, where watersheds of many urban centers receive significant amount of annual rainfall and where rainfall intensity is generally high, control of runoff at the source, flood protection, and safe disposal of the excess water/runoff through proper drainage facilities become essential (NUPI, 2000). Drainage problems in Ethiopian urban centers include flooding, deterioration of roads, land degradation, sedimentation, and blockage of drainage facilities, water logging and the like. With urbanization, impermeability increases with the increase in impervious surfaces (i.e. residential houses, commercial buildings, paved roads, parking lots, etc.), drainage pattern changes, overland flow gets faster, flooding and environmental problems such as land degradation increases. It is a crucial problem facing the existing and future environmental conditions of urban centers. After its inception, Federal Urban Planning Institute (FUPI) (the then NUPI) has been involving in planning and design of urban storm water drainage facilities as part of the Master/Development Plan of a city/town with the objective of keeping the life of urban infrastructure and to protect the urban environment like water pollution from non-point sources of storm water, Air pollution from stagnated water and Soil from erosion and degradation. Before the establishment of the National Urban planning institute (NUPI) some twenty years ago, there has been no formal working organization in the area of urban storm water drainage system. Even now a day the attention towards urban storm water system is at its immature stage that is why most of the urban storm water drainage structures get blocked with solid waste of various types after huge money has been invested on them. In some areas they by themselves are sources of environmental problems (FUPI, 2008). The Federal urban planning institute under the Ministry of Works and urban development has been trying to put a considerable effort in controlling run-off, which is produced as a result of urban structural pavements and external sources, like flooding from Gara Beru, Babo Gaya & Kidanemihret mountains in bishoftu . Generally, the urban storm water drainage system in Ethiopia is at its poor condition, some of the facts are:

- ✓ the unforgettable flooding event/problem, which were occurred in Diredawa some two years ago and
- ✓ the yearly repeated flooding problems in various parts of Addis Ababa, which have been resulting in congested traffic movement, property loss, soil and water degradation and other infrastructure, particularly around “Filwoha”, National bank of Ethiopia, Addis Ketema Comprehensive Secondary School, general vegetables market are some of the notable ones. The flooding and the sedimentation problem in Awassa Town and its lake resource is also the other significant problem which has been occurring due to inadequate urban storm water drainage provision and management.
- ✓ The land sliding and soil erosion problem in Dessie and Adigrat Towns.

The run-off water stagnation problem in Bahirdar due to inadequate USWD system is also the other big challenge in spreading malaria & water borne diseases. These and the other problems are the notable challenges of inadequate urban storm water drainage system in Ethiopia. The only mechanism in alleviating such environmental challenges is at the hand of urban storm water drainage system. The technologies in handling the environmental problems of urban storm water drainage in Ethiopia, which have ever been practiced, are not in a position to utilize the flood/runoff for various uses, like the treatment/sedimentation of runoff water, construction of detention ponds and other perforated structures for the water to be infiltrated in to the soil, rather the primary aim of urban storm water drainage system in the country is to safely discharge the storm/run-off out of the urban centers.

CHAPTER THREE

3. MATERIALS AND METHODS

3.1. Introduction

This chapter has focused on materials and methods, which were employed to address the indicated research objectives. Hence, research design, sampling and target population, sources of data, and method of data collection were explained. Likewise, data analysis technique and its tools were described under here.

An intensive literature survey was conducted, particularly, in designing the urban storm water drainage net-work which is appropriate and alternative option to handle the urban storm water drainage problem in a sustainable manner.

3.2. Description of the Study area.

Bishoftu town is located in central Ethiopia, Oromia National Regional State, East Shewa Zone, Adea woreda, at a distance of 44 Km from Addis Ababa. The geographical/astronomical/ location of the town is at 8044’40’’N latitude and 38059’9’’E longitude with an elevation between 1800-1995 meters above sea level. The town are in 1976 was 3280ha and currently increased to 20,574.45 hectares in 2022. This age old town is located on along the rapidly developing corridor of the country where huge socio-economic transformation is ongoing. However, its urban infrastructures planning and development do not match the socio-economic development and transformation the city is undergoing. Accordingly, storm water damage and problems has increased in intensity, frequency and severity in recent years.

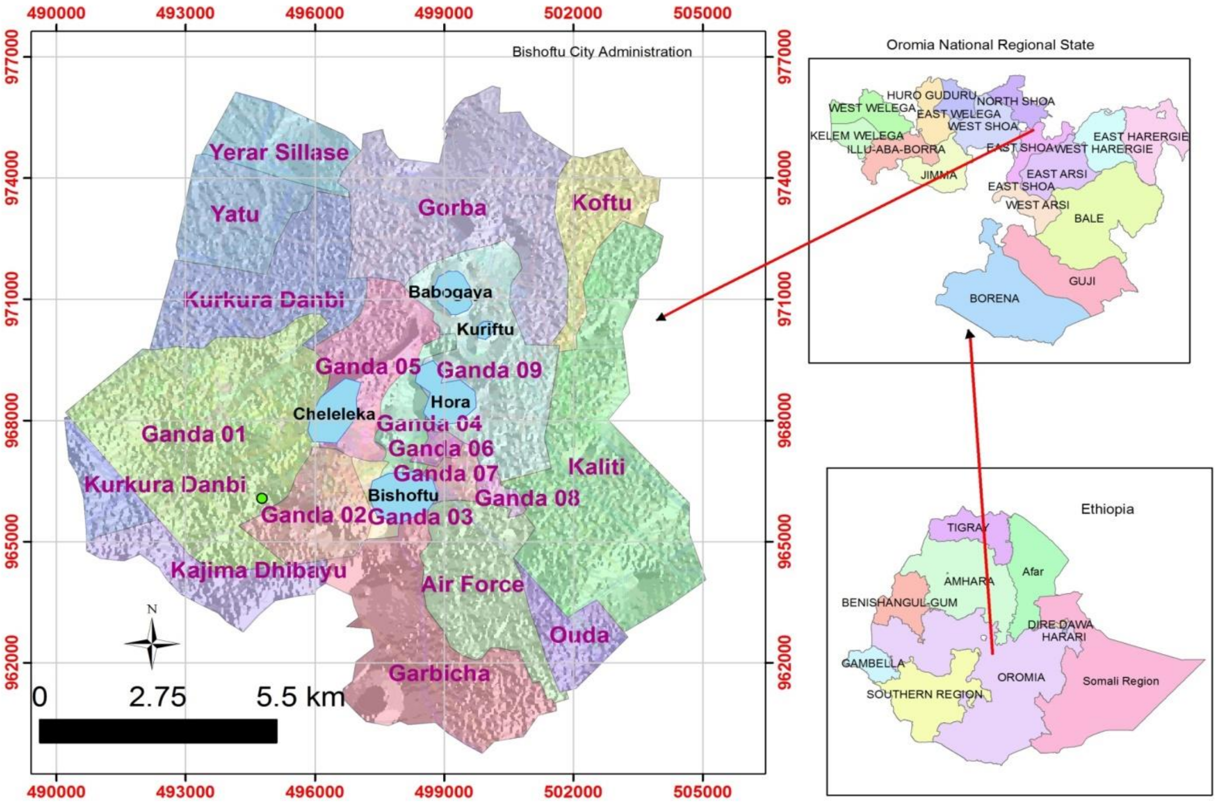

FIG.3.1: **Locational Map of Bishoftu City**.

3.2.1 Topography

The structural plan of the town describes the topography of landform of Bishoftu town and its environ comprising vast plain areas, swampy and water bodies, soft, rounded hips and hilly mountains, steep and rounded hills and associated undulating dissected areas. The southern portion of the town is largely associated and characterized by undulating and rugged terrains whereas the eastern is to a large extent plain area.

The topography and landform of Bishoftu town is also undulating that comprises several ups and downs, rivers and streams (both perennial and permanent), swampy and crater lakes of Hora Harsedi, Babo Gaya, Kuriftu, Cheleleka and Bishoftu and associated mountain hills such as Gara Beru, Babo Gaya, Kidanemihret, are hilly undulated areas. These are significant land features that obscured the development of the town on one hand and interrupted the continuity of developments on the other hand. Thus the expansion of the town is restricted in the southern end.

Flat areas constituted the largest proportion in terms of area coverage. Such areas are found in the eastern, northern and north-western expansion directions. The soft rounded hips found at the centre of the town (Kidanemihret Church area) observed accessible with both non-motorized and motorized transport modes.

The structural plan reported that those places with a slope of below 2% are considered as swampy and are not recommended for heavy developments as they are flood hazard prone areas. On the other hand, those places with a slope of greater than 10% are not considered for general developments as they are undulating, steep and very steep areas. The master plan report classified relief map of Bishoftu town is into five slope categories as in Figure below.

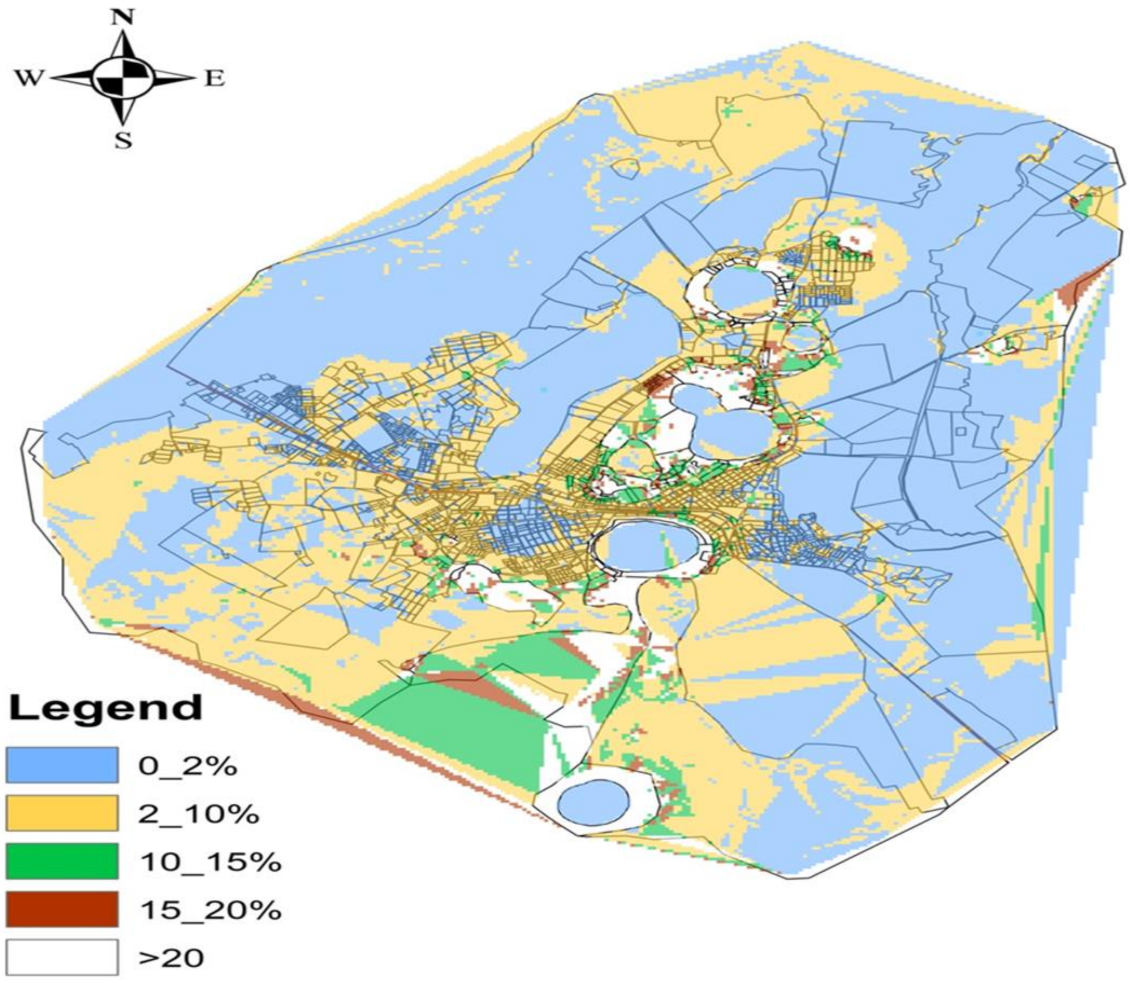

FIGURE 3-2**: Slope Characteristics of Bishoftu area.**

Most of the hills are located on the southern side of the town, these high ground formations of Sofa, Baru, Bubissa, Dhibaayu, and Wulabbo recharge flood that rush down towards the town part and causes damage to property. The structural Plan reports that kebele 02 and 06 are flood prone areas. The dawn stream plain areas of Cheleleka are also one susceptible to flooding. And, this is the current reality on the ground.

The elevation map of Bishoftu town and the surrounding catchment area is shown in figure 3.3 below.

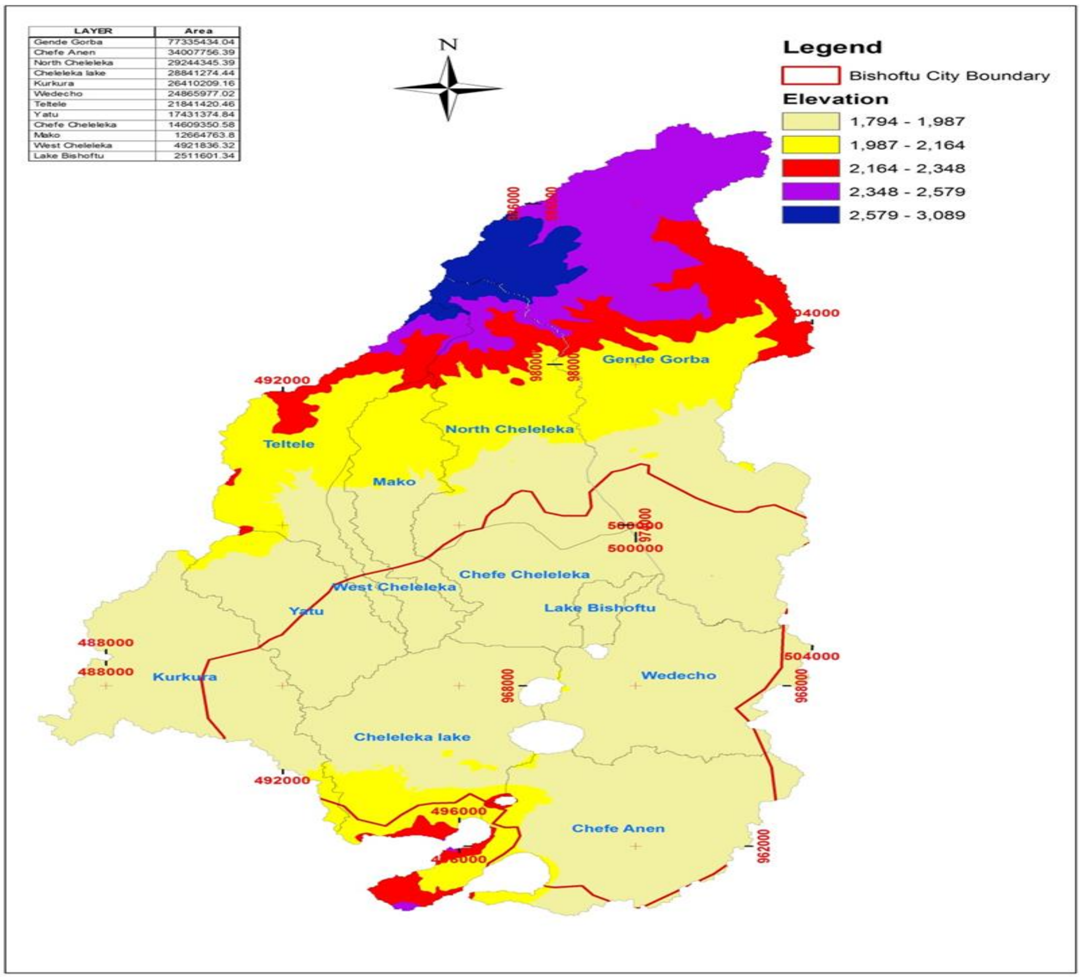

FIGURE 3-3: **Elevation of Bishoftu area.**

3.2.2 Climate

As per the Ethiopian customary climate classification, the town is classified as “Woina-Dega”; the average annual temperature and rainfall of the town are 19.3^{0}C and 854mm respectively. The monthly mean maximum temperature ranges from 24.2^{0}C (August) to 29.4^{0}C (May). The monthly mean minimum temperature ranges from 9^{0}C (December) to 13.9^{0}C (August). Whereas, the minimum and maximum annual temperature ranges from 12.0^{0}C to 26.9^{0}C that make an average of 19.3^{0}C

May and December are the warmest and coldest months; March and April are also warmer months next to May, where the highest maximum mean temperatures are observed during these three months. On the other hand, the lowest minimum mean temperatures mostly occur from November to February each year.

3.2.3. Rainfall

The town has five rainy months; from March to April and from June to September that make two rainy seasons of spring and summer respectively. Summer rain accounts for 50 to 90% of the annual rainfall in the area and is relatively stable when compared with other rainfall season. Winter is a dry season in Bishoftu town. The mean annual rainfall recorded over the ten years (2012-2022) has shown that the month of July is the highest rainy month with a mean annual rainfall of 244.5mm and in November least (4.5mm) recorded as per the master plan report. The mean annual rainfall is about 860.6mm.

Table : 3.1 Rainfall Data by Month in the year, 2022 of Bishoftu

Month	**Jun**	July	August	Sep	Oct	Nov	**Dec**	**Jan**	**Feb**	Mar	Apr	May	**Annual**
Rainfall	101.8	244.5	185.1	100.1	25.2	4.5	7.6	11.2	22	52.8	59.2	46.6	1190
Seasons	Summer /kiremt/			Spring /Tseday/			Winter /Bega/			Autumn /Meher/			

Source: Bishoftu Agricultural Research Institute 2023

3.2.4. Geology

From the aspect of general geology, Bishoftu area is part of the Ethiopian Main Rift, and it is thus founded on quaternary volcanic rocks underlain by tertiary and in some places sedimentary volcanic rocks, which are mostly encountered at the hilly areas. Alluvial and residual deposits are also available at the areas with relatively gentle slope and flat terrains. The alluvial deposit at the low-laying terrains constitutes of consolidated tuff (sandy silt and silt sand with little clay)

The Bishoftu area represents a transition zone between the Ethiopian Plateau and the Main Ethiopian Rift (MER). In this area the rift escarpment is not well defined, and the rift intersects the important E-W structure (the Yerer-Tullu Wellel Volcano Tectonic Lineament; Structural Report.)

3.2.5. Land Use

The existing land used plan of the city is revised and updated in the Structural plan of the City where additional rural kebeles and Peri-urban areas had been incorporated in to the city limits.

Land use planning is one of the most important planning tool for provision of municipal infrastructure and other facilities, it also helps for reducing urban problems and managing built up areas. Land in urban centres is an important element for urban drainage planning.

N	**General land use**	**Area (HA.)**	**Coverage by %**
1	Housing	5,557.87	27
2	Commerce	349.75	1.7
3	Service	642.65	3.1
4	Administration	15.46	0.1
5	Manufacturing	1,231.32	6
6	Environment	6,817.47	33
7	Road and transport	1,222.02	5.9
8	Water bodies	1,092.49	5.3
9	Special Function	968.07	4.7
10	Others	2,677.35	13
	Administration boundary	**20,574.45**	**100**

Source: *Bishoftu Finance & Economic Development Bureau, Profile Report, 2022*

Table: 3.2 Land Use of Bishoftu cities Administration

3.2.6. Soil Texture

As mentioned above, the topography of Bishoftu area varies from nearly flat to rolling, with some hills and old volcanic cones. Soil characteristics may be dependent upon the topographic setting of an area and type of parent material from which the soil originated and some other factors. Therefore, the soil in Bishoftu area can be the weathered product of the volcanic rock that formed the area and that alluvial type which may be washed down from the surrounding hills and settled at the lower flat surface. The soil around Bishoftu is primarily gray to very dark gray, or black clays or clay loams. In addition, some areas there are also brown to reddish brown clay soils. On the other hand, the slope of the hills are often reddish brown and in the lower areas, the soils are dark colored. 26 In general Bishoftu's soil type is characterized as dark clay and very dark gray clay with high organic content where this type of soil character is a good potential for agricultural production. Nevertheless, such type of soil has high swelling and shrinkage properties which is not comfortable for construction and development, therefore it is essential to put much consideration before any type of development. Such types of soil characters usually has low infiltration rate during intense rainfall and promotes rapid runoff (Hill, Verjee, & Barrett, 2010).

3.3. Research Design

Exploratory mixed-methods research design was used to study the existing conditions and challenges of storm water management system in the study area. An exploratory mixed-methods research design is a type of research that uses both qualitative and quantitative data collection and analysis methods (Johonson, 2017). This type of research design is often used when the researcher is not sure what the research questions are or how to best answer them. The qualitative data can be used to help the researcher develop the research questions and to gain a better understanding of the research problem. The quantitative data can be used to test hypotheses and to provide statistical evidence to support the findings of the research.

In this study, the qualitative data was collected through site observations, interviews with stakeholders, and document reviews. The quantitative data was collected through surveys and questionnaires. The researcher used the qualitative data to develop a better understanding of the existing condition of storm water management and to identify the challenges that can increase stormwater runoff. The researcher then used the quantitative data to quantify the existing conditions by taking existing drainage line, natural water ways and the general environment using base map and a check list and comparing with standards.

3.4. Research Approach

In this research, a descriptive research approach was used to describe the current state of the stormwater management system. Descriptive research approaches is used to describe the current state of things. It can be used to describe existing conditions or relationships, prevalent practices, held points of view or attitudes, and altered effects. Descriptive research can be advantageous because it can be used to obtain detailed data from a large number of respondents. It can also be used to describe the reality of what occurs within a situation with current practices (Siedlecki, S. 2020).

3.5. Data type and sources.

To achieve the intended objective this study used both primary and secondary data. Primary data was collected from the local community and experts though interview and questionnaires. .Observations and physical studies were also conducted using a checklist and camera to capture photos of the physical features. While, secondary data used for the study included various, articles, Google maps, Base map, couture map, structural plan of the town, books, and other significant documents. Primary data such as different manuals, photographs, and stormwater management related documents were also used for the study. The secondary data were collected from different library, website and Bishoftu City Administration.

3.6. Sampling size and Sampling Techniques.

Purposive sampling was employed in this research study to select the sample Keblels. Accordingly, out of 15 kebeles found in the town, this study was conducted only on two purposively kebeles. These two sample Kebeles were: 01/02(Mikael church area including Shi-Semaniya & Got 6 & 7 in Kebele 02 & Around Genesis area Got 21 of Kebele 01 of the twon.) The selection of these kebeles has done with the bishoftu municipal infrastructure & environmental protection team. The basic reasons to select these kebeles was that flooding is more pronounced in these kebeles.

To select flood vulnerable sites within the two Kebelle that are frequently affected by the storm water the researcher used a purposive sampling technique. Each Kebelle in Bishoftu town is divided into villages (‘Gotte’). Out of these villages, the Kebelle administration helped the researcher to purposively select the villages that are frequently affected by the storm water and those selected villages were categorized as high, medium and low exposure. Accordingly, seven villages namely villages 03, villages 06, villages 07, villages 08, villages 09, villages 19 and 23 were selected. Based on the information obtained from the kebele administration each village has a minimum of 100 households.

For this study 700 households are selected from the study area. The researcher used 12 % of the total affected as a representative for the house to house questionnaire survey. The sample size for this study was determined by employing a formula to calculate sample size from a finite population (Kothari, 2004). It is given by:

$$N= \frac{z^2 \, p.q.n}{e^2 \, (n-1) + z^2 \, .p.q}$$

Where: n= size of the sample;

p= reasonable estimate for the key proportion to be studied (12%);

q= 1-p;

n= Sample frame; (700)

z= standard variation at an acceptable confidence level; (1.96) and

e= acceptable error (0.05%).

$$N= \frac{1.96^2 \times 0.12 \times (1-0.12) \times 700}{0.05^2 \, (700-1) + 1.96^2 \times 0.12 \, (1-0.12)}$$

n=<u>132</u>

A total of 132 households were selected for household surveys from a population of 700 households. A proportional to size allocation method was used to obtain a representative sample size for each village. This method involves selecting subjects in proportion to their occurrence in the population. In this case, the sample per village was determined by the percentage contribution of households by each village to the total number of households (700) in the eight villages. Simple random sampling was used to select the sample households. This method involves randomly selecting households from each village. A table of random numbers was used to select the households from the registered list of households in each village.

3.7. Data collection instrument.

The data collection method used a variety of instruments, such as field observation, questionnaires, and interviews, to obtain important data on the Urban Storm Water Drainage Management System and its challenges.

Here is a more detailed explanation of each instrument:

- **Field observation:** This involved observing the physical environment and collecting data on things like the condition of roads and drainage systems, the presence of flooding, and the impact of stormwater runoff on the environment.

- **Questionnaires:** These were used to collect data from a variety of stakeholders, including residents, businesses, and government officials. The questionnaires asked questions about people's experiences with stormwater runoff, their perceptions of the effectiveness of the stormwater management system, and their suggestions for improvements.

- **Interviews:** These were conducted with a small number of key informants, such as experts in stormwater management and representatives of environmental organizations. The interviews were designed to get a deeper understanding of the challenges facing the stormwater management system and the potential solutions.

By using a variety of instruments, the researchers were able to collect a comprehensive set of data on the Urban Storm Water Drainage Management System and its challenges. This data has also used to develop recommendations for improving the system.

3.8. Method of data analysis .

The data collected from different sources were analyzed using different methods. The analyses of the collected data from different sources were organized into their representative categories in order to come up with logical results. Data from primary and secondary sources were analyzed qualitatively and quantitatively.

Quantitative analysis was used to investigate the current status of storm water management system and its effects on natural and built environments. Qualitative analysis was used to analyse and interpret data about challenges for stormwater management. This analysis was conducted using photographs (plats). Spatial analysis was used to analyze different data, such as land use of the area, topographic analysis, built up areas and others. This analysis was performed by GIS (Geographical information system), AUTOCAD, ARCHI CAD, adobe illustrator and Photoshop software. Finally, the analyzed data were presented using bar graphs, tables, charts, figures, plans/maps and visual photographs accompanied by textual discussions and interpretations.

3.9. Ethical Considerations.

The researcher explained the nature, goal, and aim of the research to the respondents. They would be able to ask questions about the research, and their confidentiality would be assured. Their names would not be attached to the questionnaires. The researcher would respect the culture, values, and views of the respondents and other people while gathering relevant information for the study. Safety measures were taken to avoid exposure to COVID-19, including social distancing. The researcher also acknowledged the work of others that he thought was useful for the research. Additionally, the researcher tried to avoid personal bias and stick to professional knowledge and ground reality. Based on this methodology, the researcher tried to present the findings and related discussions in Chapter 4, which is divided into the following parts:

Chapter Four

4. Results and Discussions.

In this Chapter, field observation, key informant interviews, and document review are presented, analyzed, and discussed. The findings, obtained from different sources employing multiple methods of data collection, triangulated in order to cross-check the validity of the data and generate in-depth in understanding of different issues were under investigation.in accordance with the established specific objectives.

4.1 The Existing condition of drainage system.

Based on the information obtained from interview and field observation, the existing drainage system covers most of the developed areas consists of a considerable length of open masonry, gutters and non-lined ditches, and cross-drainage structures (Figure 4.1). Most open drainage ditches are adequately designed but slopes are not adequately provided in flatter areas and drops at highly steep areas where excessive velocity is observed to cause damage on the channel. Most of the drainage ditches are filled with solid waste and sewerage resulting in formation of sewage ponds in the channel as well as on the road.

The municipality of the city has played a significant role in improving the drainage system of the town by maintaining the existing drainage facilities, constructing new drainage lines and structures along with the new roads. During the field visit indiscriminate dumping of solid waste in to storm lines is observed to be a major problem that compromises the functionality of the drainage facilities and seriously endanger the eco-system of the Cheleleka Wetland System. In addition, the main highway side drains are only planned to safely discharge the surface drain from the road surface. And, these drains are unable to accommodate arterial drainage lines connected to it at different locations. The side drains were totally blocked at some points and surface runoff overflows on the road surface.

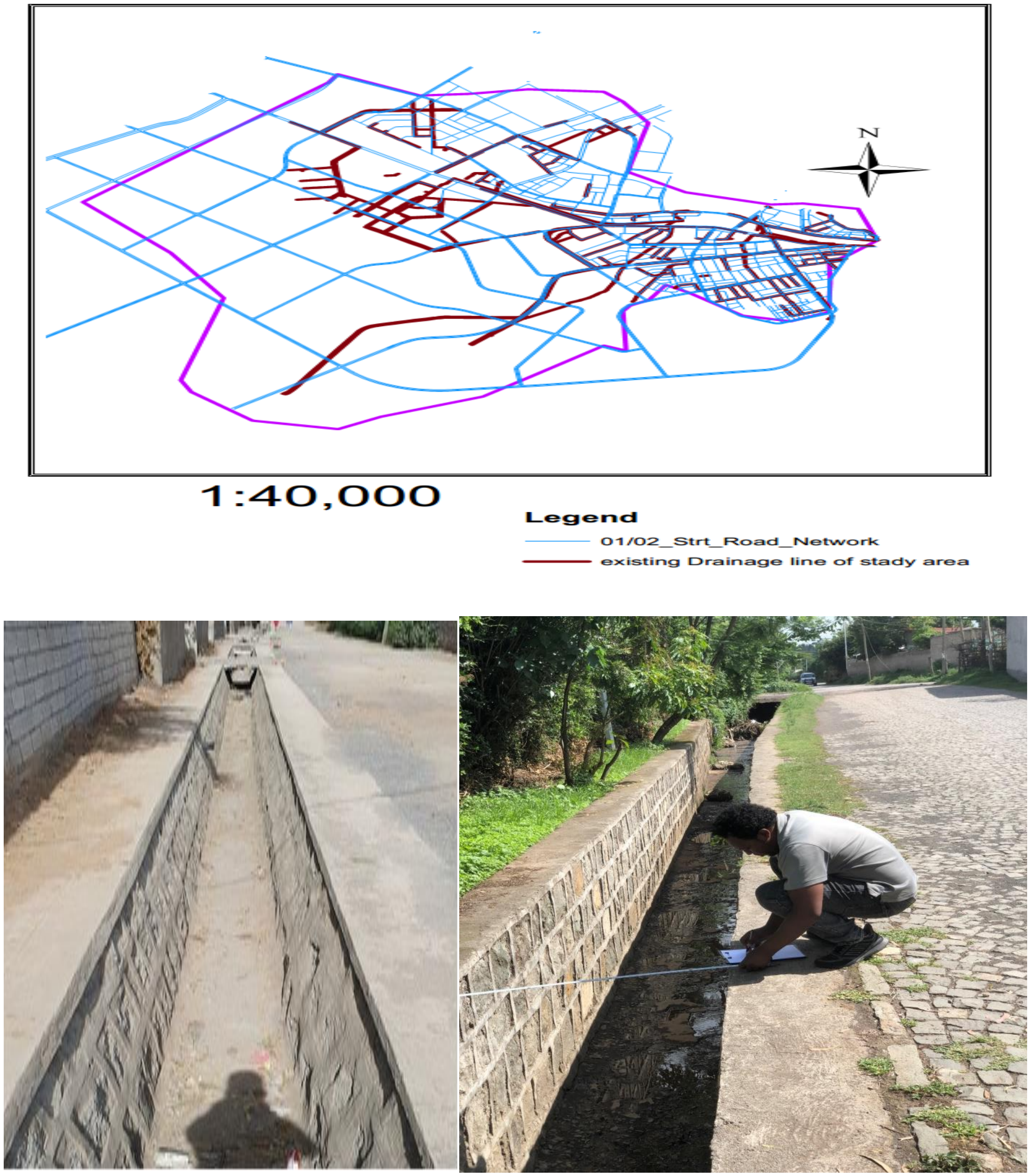

FIGURE**: 4.1. Bishoftu Existing Storm Drainage facilities (Source: field surveying and from GIS)**

4.1.1 Inventory of the Drainage Network.

There is a total 6.63kilometers of drainage line in in the study area of Bishoftu City; of which about1.1 Km of the drainage line is Open Masonry; followed by Closed Masonry Drain with a total length of 2.417 kilo meters. On the other hand; Open Concrete Line Drain, Piped Concrete Drain and Cobble Stone Lined Drain have a total length of 1.4, 0.413 and 1.3 kilometers respectively.

Table 4.1: Drainage Line Feature

No.	Drainage Category/Type	Total Actual Length in (m)	Coverage %
1	Trapezoidal	1062	16%
2	Rectangular	5155	78%
3	Circular	413	6.%
	Grand total	6630	100%

Source: field surveying and from GIS.

4.1.2. Existing Drainage Pattern of Bishoftu town

Based on the information obtained from the filed observation, the drainage pattern of the area which affects the city is from south to north. The storm water generated in the upper hilly catchment transcends downstream towards the city and cross the main Addis – Adama main road which passes through the Bishoftu City and the old railway and culminates at Cheleleka Lake and surrounding marshy areas. Only the eastern side of the City is connected to Major River. The interceptor drain constructed at the southern hilly area of the city drains to Bishoftu Lake.

Bishoftu have crater lakes and no surface or storm water is draining to them. The large marshy area of Cheleleka Lake receives most of the storm water coming from the south passing Bishoftu City as well as surface runoff from the northern and western directions.

There is no major river crossing Bishoftu City or drain into or out of the Lakes. The Bishoftu City drainage and flooding problem can be solved with proper storm water design, which is integrated to the existing and planned roads and other built-up structures such as commercial and residential houses. Due to existing infrastructure getting enough land space; appropriate flow direction and road, crossings without demolishing and affecting private or public property will be a big challenge.

FIGURE **4 2: Drainage Lines from DEM with Satellite Imagery**

Based on the information obtained from the field investigation and desk review, the major drainage outlets of the kebele 01/02 catchment crosses the main highway at three points that the road construction only provided cross drainage outlets in three points, and the physical location of these outlets totally overlaps with drainage lines.

In addition, the main highway side drains are only planned to safely discharge the surface drain from the road surface. And, these drains are unable to accommodate arterial drainage lines connected to it at different locations. The side drains were totally blocked at some points and the side drains jumps to road surface.

The field visit also established the indiscriminate dumping of solid waste in to storm lines is a major problem that compromises the functionality of the drainage facilities and seriously endanger the eco-system of the Chelelek Wetland System.

4.1.3 Physical Drainage Structures Constructed.

The first impression that would come to any professional or visitor taking a walk through survey or brainstorming site visit in Bishoftu would surely be the length of cobblestone road constructed in different parts of the city and masonry drainage channels. It is worth mentioning the commitments and efforts of the successive City Administrations that has resulted in improvements in major parts of the city (Figure 4.3 and 4.4.).

However, the presence of these structures did not prevent the flooding and storm water damaging both private and public infrastructure facilities. The causes of this are variable and several, and would require further elaboration in the study phase of this study; but preliminary assessment indicates to planning and management issues in storm drainage management system.

FIGURE **4. 3: Drainage & Road Infrastructure Development (Source: field surveying)**

FIGURE 4 .4**: Drainage & Road Construction (Source: field surveying).**

FIGURE 4 5: Culvert outlet with accumulated solid waste. (Source: field surveying).

4.1.4 Drainage problem across main asphalt road.

The main asphalt road passing through the town bisects the city from Northwest to southeast, the asphalt road cross drainage structures are also the outlets for upstream drainage basins of the city. The road covers over 6km for the western part of the town and catchment, but only three cross drainage structures are provided, and these structures are also the only outlets to siphon the upstream drainage. Moreover, the side drains provided are meant to collect and drain the surface drains from the asphalt surface and could not accommodate the additional drainage from the upland catchment connected to it via several drainage lines along the arterial roads across the town section.

The following pictures taken in recent trip (17th march 2023) to the city are clear manifestation of the storm drainage problem along the main asphalt road (Figure 4.6).

FIGURE **4 .6: No Surface and Side Drainage on main road around Lemlem area Source (Source : field surveying).**

FIGURE 4 **.7: Location of Outlets and Assessed Problem Hotspots**. (

FIGURE 4 .8 **challenge of existing drainage line (Source: field surveying).**

A: The side drain along the asphalt road is blocked with debris and the surface drain flows and stagnation is visible on the pre-cast slabs at junction to arterial road.

B: The side drain along the asphalt road is blocked with debris, vegetation & grass. And the storm water flows overland

C: The overland flow on the pedestrian re-join the road surface drain downstream again, but further blocked and the overland flow continues downstream (next junction pictures)

FIGURE 4 .9 **challenge of existing drainage line. (Source: field surveying).**

The road side drains upstream flows along the pedestrian and blocked side drain flows to the road surface at inlet of slab culvert at junction (J-3) (Figure 4.7).

Both the slab culvert connecting to the junction road and outlet of slab culvert is blocked. Effort to confine the storm water from over flowing road by placing stone barricade is.

The major outlets and culverts are those that are located in J-4, J-5 and J-6 (Figure 4.7). The entire drainage of the town upstream the road surface crosses to downstream via these outlets. If we divide the city along the Bishoftu-Hora Lake in to east and west zones, the entire western zone drains to Chelelek Lake. The western part of the city is drained by two major watersheds that crosses the road at Ziquala Junction and in front of Bus Station, and accordingly named Ziquala outlet and Meneharia Outlet for this assessment. The corresponding watersheds are also named as Ziquala Watershed and Meneharia Watershed.

A. Meneharia Catchment.

The catchment is the single biggest watershed that drains through Meneharia outlet in to Chelelek Lake. The total air distance of the catchment is about 6km and covers a total area of 12.662 Square Km (1,266ha).

The size of the catchment is significant to be drained via constructed channels without any natural channel. Moreover, to drain the same with only a single culvert in well-developed part of the city in almost flat hydraulic slope is cause of concern. The storm water has to pass through very narrow existing culverts on main road and old railway line.

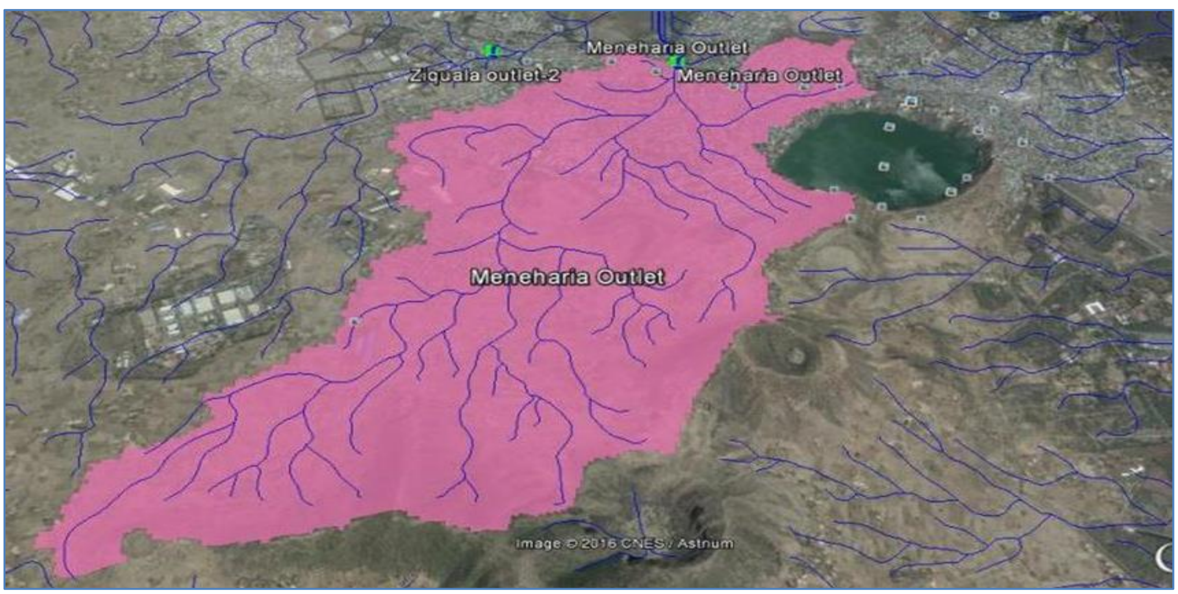

FIGURE 4 10**: Meneharia Outlet Catchment & Drainage Lines generated from DEM. Source Drainage Lines generated from DEM with GIS.**

B. Ziquala Catchment Outlets.

This catchment is about half the Meneharia catchment. The total are of the watershed is about 6,326 Square Km (633 ha). The major portion of the basin is drained via slab culvert at ziquala junction towards the low lying Chelelek Lake. There is another outlet that drains sub-catchment of the basin in front of Adea Flour factory, and the town then joins before passing through old railway culvert just in front of Adea Flour Factory.

FIGURE 4.11: **Critical Outlets condition of Ziquala Catchment at lower reaches. (Source: field surveying).**

4.1.5. The level of integration between Road and Urban Storm Water Drainage infrastructure.

Provision of Road and USWD infrastructure are indispensable, particularly, in an urban center for safe and easy reachability from one area to another and to protect flood damage on urban infrastructure and utilities as a result of pavement or imperviousness. There is a need to integrate Road and USWD infrastructure to elongate or keep the service life of other urban infrastructure and utilities like water supply lines, telephone lines, electric lines, buildings, and Roads by safely discharging the flood generated as a result of pavement of structures. But, during field survey it was observed that most of the roads surface and base have been degraded, water supply lines have exposed for external weathering as a result of erosion. These and the other related issues have been discussed in detail in following sections.

4.1.5.1. The existing condition and coverage of urban storm water drains in the study area.

With the help of a base map and check list the existing condition and coverage of the urban storm water drainage infrastructure have been surveyed one by one for the two sample kebeles to study whether the flood generated in the drainage system of the study area are safely discharged in to the final receiving natural water ways or not.

Table-4.2 Road and Drainage lines infrastructure deterioration scales/indicators.

Indicators classification Surface condition	Indicators classification Surface condition
Very good	Shapes of roads/USWD lines as still in original design condition
Good	No significant depressions, undulations and deformation
Light	Shape of the road/USWD lines deteriorate, but still sheds water
Severe	Total collapse of the road/USWD lines structure and barely passable

Source: GTZ, 2006.

Table-4.3 Summary of Urban storm water drainage lines in the study area

Drainage line type	Surface Condition				Kebele
	Good (m)	Light (m)	Severe(m)	Total	
Trapezoidal	168	273	114	555	01
Rectangular	478	1009	1014	2501	
Circular	16	65	78	159	
Sub-total	662	1347	1206	3215	
Trapezoidal	147	146	214	507	02
Rectangular	578	1018	1058	2654	
Circular	56	101	97	254	
Sub-total	781	1265	1369	3415	
Grand total	1443	2612	2575	6630	
Percentage from total	21%	40%	39%	100%	

Source: Field survey and GIS analysis, 2023.

From Table-4.3, of the total drains in the two sample kebeles about 39% is severely degraded, which has resulted in degradation of road and other urban utilities.

In summary, in kebele 01&02 the flood generated due to urbanization cannot safely be discharged in to the final receiving natural water ways but flows over the surface of roads and stagnated on open surfaces. During the event of rain fall it is common to see flood flowing over the surface of roads (Fig.-4.12), which is a big obstacle to vehicles and pedestrians. Both pedestrians and vehicles stand and wait until the flood stops.

FIG-4.12 **Flood over flowing on road surfaces kebele02 Source: Field survey, 2023.**

4. 1.5.2. The existing condition and coverage of Road infrastructure and its performance.

The existing condition and coverage of Road infrastructure have been fully surveyed and studied in the two sample kebeles to study whether the Road infrastructure in the study area are in a good performance or not, because Roads adequately integrated with storm water drains have a good performance with longer service life than those without storm water drains. The bases as well as surface degradation of roads will get down when there is a proper integration between road and urban storm water drains.

Accordingly, the existing condition and coverage of the Road infrastructure with their surface types for the two kebeles have been summarized and depicted in Table-4.4.

Table-4.4 Summary of road surface type and existing surface condition.

Kebele	Road surface type	Existing Surface condition (meters, m)					Total
		segments	V.good	Good	Light	Severe	
01	Asphalt	2	-	1475	1704	257	3436
	Cobble Stone	4	-	270	1241	418	1929
	Gravel	34	-	-	589	278	867
	Sub-total	40		1745	3534	953	6232
	Percent proportion			28%	56%	15%	100%
02	Asphalt	2	-	1008	1250	250	1520
	Cobble Stone	27	-	169	1578	270	1140
	Gravel	6	-	-	718	247	515
	Sub-total	35		1177	3546	767	5490
	Percent proportion			22%	64%	14.%	100%
Grand total				2922	7080	1720	11722
Percent proportion				25%	61%	14%	100

Source: Field survey and GIS analysis, 2023.

From Table-4.4 generally, of the total roads in the two sample kebeles 25% is good, 61% is light and 14% is severe. Light and severely degraded roads together comprises of 75%. As it was critically studied during field survey almost 90% of the deteriorated and degraded and/or eroded roads have occurred due to the absence of adequate urban storm water drainage infrastructure that discharges the flood generated safely in to the final receiving systems.

4.1.5.3. Integration of Road and Urban storm water drainage lines.

The integration of Road and Urban drainage lines has a greater significance in alleviating otherwise reducing the flood hazards which may occur as a result of reduced infiltration due to surface pavements, constructions and deforestation. Urban storm water drainage and road infrastructure should well be integrated so as to remove floods, which is generated within urban centers or coming from an external source, safely or with a minimum risk to the final receiving natural water ways. By so doing, the aesthetic (environmental situation), the condition of urban utilities (road bases, buildings, water supply lines, telephone lines, electric lines, railway bases) and quality of life of city residents will get improved. But, in the study area, due to inadequate integration of road and urban storm water drains the following major problems have been observed: road base and road surface degradation, widening of river banks, erosion on road bases and road surfaces, degradation of Urban utilities, blockage of urban drainage lines, inundation of rain water on vacant surfaces which may breed and/or harbor disease causing organisms. The existing integration of road and urban storm water drainage infrastructure is discussed hereunder:

I. <u>Kebele 01 /02</u>

Urban storm water drainage (USWD) density = $\frac{\text{Total drainage lines} * 100}{\text{Kebele built up area}}$ -------- (14)

6.630km/1448ha =

0.0046 of USWD line per hectare of area or 0.46%

Drainage line and Road integration = $\frac{\text{Total drainage lines.}}{\text{Total Road lines}}$ =6.6/11722

6.6km/11.722km =0.563 or 563meters

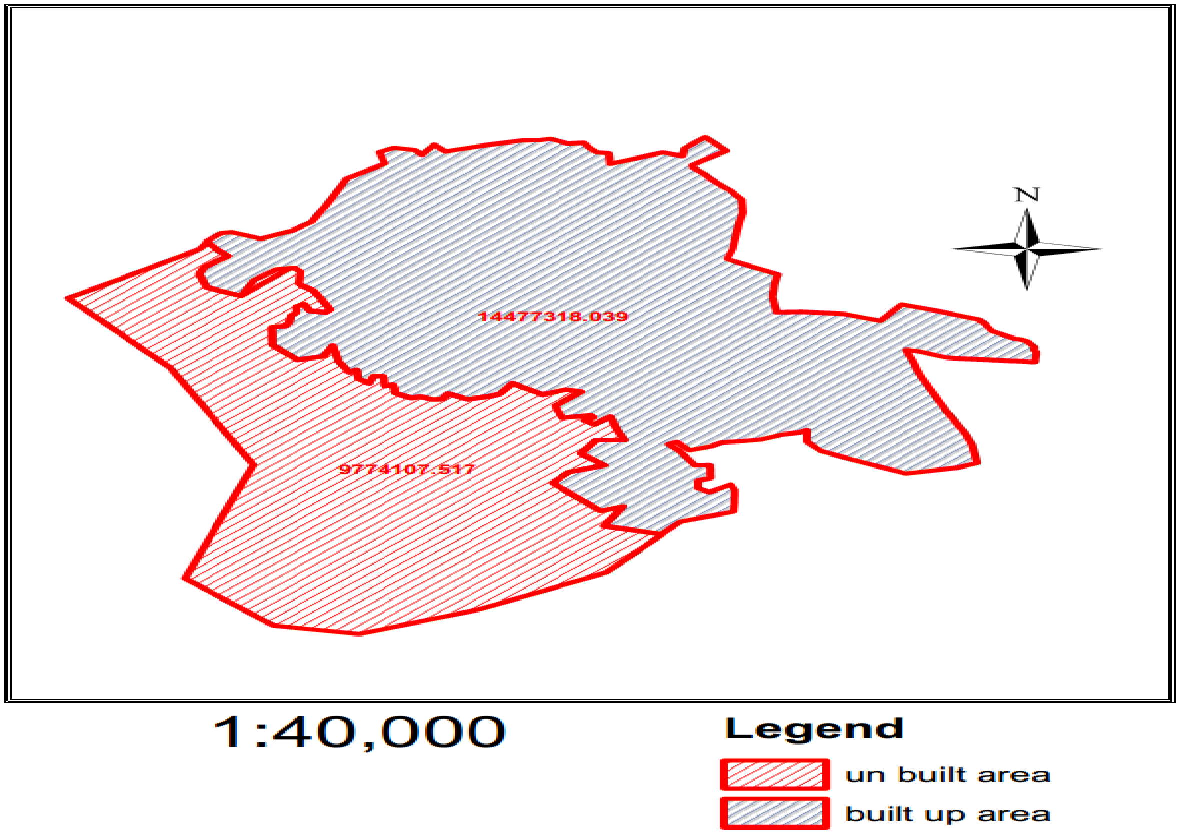

Fig-4.13 built-up and non-built up Study area of bishoftu city (source: own analysis)

Table 4-5 Summary of USWD density and Road and USWD integration in the study area

No.	Keble	Density (%) Road	USWD integration(m)
1	Average of kabele 01&02	0.46%	563meters
2	Bishoftu Average	**0.7**	**Not known**
3	World average	18	Not known

Source: field survey and GIS analysis, 2023 but Bishoftu and world average from literatures.

As depicted in Table-4-5, average USWD density and Road to USWD integration at kabele 01&02 city was found 0.46% and 563 meters respectively. Generally, the implications of the above discussions regarding the integration between road and urban storm drainage lines integration in the study area are:

- The flood generated within the study area could not safely be discharged in to the final receiving system.
- The problem of flood gets increased to excessive amount leading to environmental degradation like erosion and water pollution.
- The degradation of urban utilities and road increases to a larger amount.
- Inundation of storm water on vacant surfaces, which decreases the aesthetic value of the areas.

This study clearly showed that:

- ➢ the environmental impact of the drainage system has resulted in:
- Accelerated and concentrated runoff.
- Degradation of soil and water resources.
- The productive urban land shrinks due to erosion.
- Stagnation and/or inundation of rain water on vacant spaces.
- River bank degradation.
- ➢ There is a serious flood problem in kabele 01&02 because of inadequate integration between road and storm water drains.
- ➢ Urban utilities are vulnerable to degradation and may have shorter service life than expected.

4.2. Major challenges in urban drainage management system in the town.

The major challenges that cause urban stormwater management system problems in Kebele 01/02, Bishoftu City, have been identified based on information obtained from interviews, field observations, and questionnaires. These challenges are summarized below. :

4.2.1. Topography and Geological formation.

Based on the information obtained from filed observation and interview, topography and geological formation is the major challenges that cause urban stormwater management system problems in Kebele 01/02, Bishoftu City.

- Topography

The topography of Kebele 01/02 is characterized by steep slopes and narrow valleys. This makes it difficult to design and maintain stormwater management systems that can effectively capture and convey stormwater runoff.

- Geological formation

The geological formation of Kebele 01/02 is composed of a variety of materials, including clay, silt, sand, and gravel. These materials have different permeabilities, which can affect the rate at which stormwater infiltrates into the ground. In areas with low permeability, stormwater runoff is more likely to run off the surface and into the stormwater management system.

Based on the information obtained from the experts, the combination of topography and geological formation make it difficult to design and maintain stormwater management systems that can effectively capture and convey stormwater runoff in Kebele 01/02. This has led to stormwater runoff problems, such as flooding, erosion, and water pollution.

4.2.2 Inadequate coverage of drainage lines.

Availability of properly constructed drainage canals and other flood protection infrastructures in all parts of the city is very essential to prevent damages and destructions caused by heavy flooding. In spite of the continuous efforts by the Municipality, most parts of Bishoftu city does not have adequate road and drainage infrastructure. As a result, the main asphalt roads and the access roads in the city and much of the built up areas are exposed to inundation by heavy flooding every year during the rainy seasons. The fact that most steep areas lack drainage lines has allowed the flood to gallop down with great velocity and force, washing away everything in its way and cause extensive destruction upon the people living in the downstream kebeles.

As mentioned during FGD session, in some parts of the city it is difficult to drain out the flood even after the disaster is over. For example, one participant explained that whenever flood enters Kebele 02 it would stay there for weeks due to absence of outlets. Several instances in which the local community had to manually excavate temporary drainage ditches or use water pumps have been reported. The existing inadequate geographic distribution of drainage facilities would be further diminishes if we discount several kilometers of nonfunctional canals that are filled by silt.

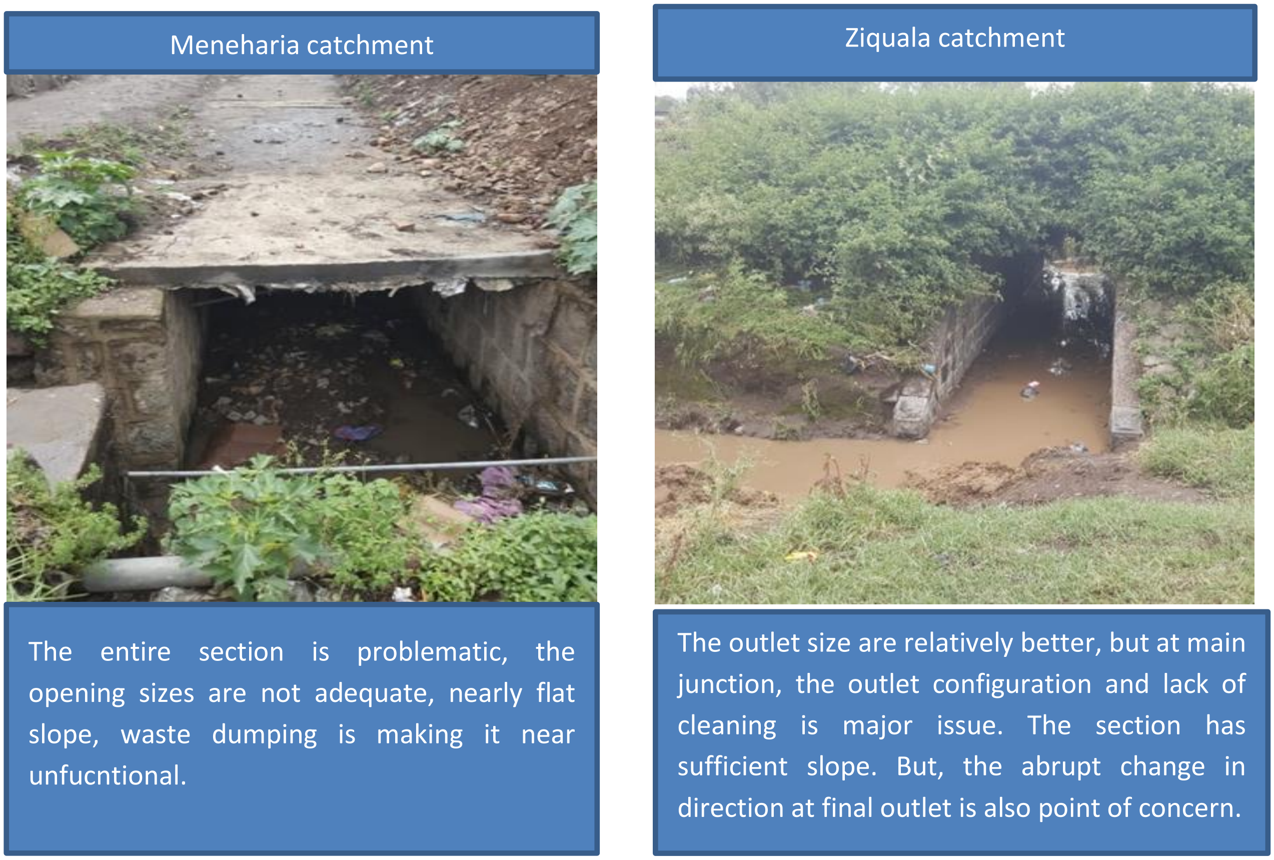

FIGURE **4.14: Critical Outlets condition of Ziquala Catchment at lower reaches (Source: field surveying)**

4.2.3 Inappropriately designed drainage structures.

Existence of drainage structures is necessary, but it does not guarantee the delivery of required results unless it is designed and constructed properly. The community representatives were found to have a good understanding of the design problems and have mentioned several instances of design related defects and poor workmanship. Some of the defects pointed out were:

When compared to the huge volume of flood, the existing drainage structures are under sized in in my study area. Mostly the drainage lines are shallow in depth and narrow in diameters resulting in flood overflowing to the unwanted directions instead of to its intended destination. The workmanship is also questionable as some drainages crumble in less than two years.

- It was reported that the size of the receptor lines is smaller than the size of the collector pipes in many places creating overflow into roads and houses

- In some areas, the drainages are short in length with no connection to any receiving line downwards, and simply release storm water on the low-lying communities often causing severe flooding. Drainage canals found in flat parts of the city lack adequate slop required to convey to downstream areas. As a result, stagnant water stays in the canals for more than a week pausing health and environmental risks to the population of the localities.

FIGURE 4. 15: Drainage & Slab Cover do not receive surface drain

FIGURE 4. 16: Faulty Construction

4.2.4 Disposal of solid waste into natural waterways and drainage facilities.

In addition to the contributing factors discussed above, the flood problem in kebale 01/02 has been compounded by a widespread practice of dumping different kinds of solid waste in the drainage ditches. This problem is observed in several parts of the town. People bring fertilizer bags full of garbage, dead animals, plastic bottles and all sorts of other solid wastes and throw them into the canals, thereby significantly reducing canal capacity to drain storm water. Such practices also contribute negatively to the public health and the study proposes that the City Administration should work hard to bring attitudinal changes.

Figure 4.17 Garbage dumping in drainages canals and inadequate out let

Source: field surveying.

FIGURE **4.18 Inlet of pipe Culvert totally blocked with solid waste Junction-A. (Source: field surveying and from GIS).**

J-4: is the second major outlet for all the upstream drainages for the north-western and western basins of the town. The junction is an intersection point for roads from five directions. In general the inlet and outlet conditions of all the roads at junction are deteriorated, and some of the inlets and outlets are nearly closed by dumping of all sort of solid wastes. The main cross drainage inlet at B and outlet at C are full of silt and debris that nearly the effective flow depth is consumed and the freeboard is the flow depth.

FIGURE **4 .19 the drainage line in front of bus station seriously blocked with silt-up of mud and waste (Source: field surveying)**

4.2.5. Low Community participation.

Based on the information obtained from key informant interview, lack of community awareness about stormwater management is a major challenge that causes urban stormwater management system problems in Kebele 01/02, Bishoftu City. This is because stormwater management is a complex issue that requires the cooperation of everyone in the community. Based on the information obtained from key informant interview, when residents are not aware of the importance of stormwater management or their role in preventing stormwater runoff problems, they are more likely to engage in behaviors that contribute to these problems. For example, they:

- Dispose of waste improperly, such as by dumping it in the street or waterway.
- Over water their lawns, which can lead to increased runoff.
- Leave their gutters and downspouts clogged, which can also lead to increased runoff.
- Build structures that obstruct stormwater flow, such as retaining walls and fences.

4.3. Proposed sustainable urban storm water management strategies

Due to increased runoff and flooding, urban planners and water experts will need to improve their strategies for dealing with storm water. Gupta (2015) proposed sustainable urban storm water management strategies that focus on improving the quality and reducing the volume of storm water runoff. These strategies include Water Sensitive Urban Design (WSUD) technical approaches that can be integrated into urban planning and design to reduce environmental degradation and improve sustainability and attractiveness.

The study area lacks an adequate plan and design for urban storm water management, and existing drainage systems cannot handle large amounts of storm water, resulting in overflows. This demonstrates the need for a storm water management method in the area.

The study area is prone to storm water runoff, which can cause flooding and other problems. To address this issue, a set of storm water management strategies are proposed. These strategies include infiltrating rainwater directly into the ground, passively directing storm water into amenity areas, and using structural and non-structural control facilities. The strategies are designed to be functional, safe, aesthetically acceptable, and environmentally friendly.

The strategies are based on the Urban Storm water Drainage Design Manual (2008), which provides guidance on storm water management practices. The manual recommends a variety of practices, including green roofs, rain gardens, and bio retention swales. These practices can help to reduce storm water runoff, improve water quality, and protect the environment.

The proposed storm water management strategies are a comprehensive and effective approach to addressing the storm water runoff problems in the study area. The strategies are designed to be functional, safe, aesthetically acceptable, and environmentally friendly. They are based on the latest research and best practices in storm water management. It is illustrated in Figure 4.20 the conceptual development of the proposed strategies.

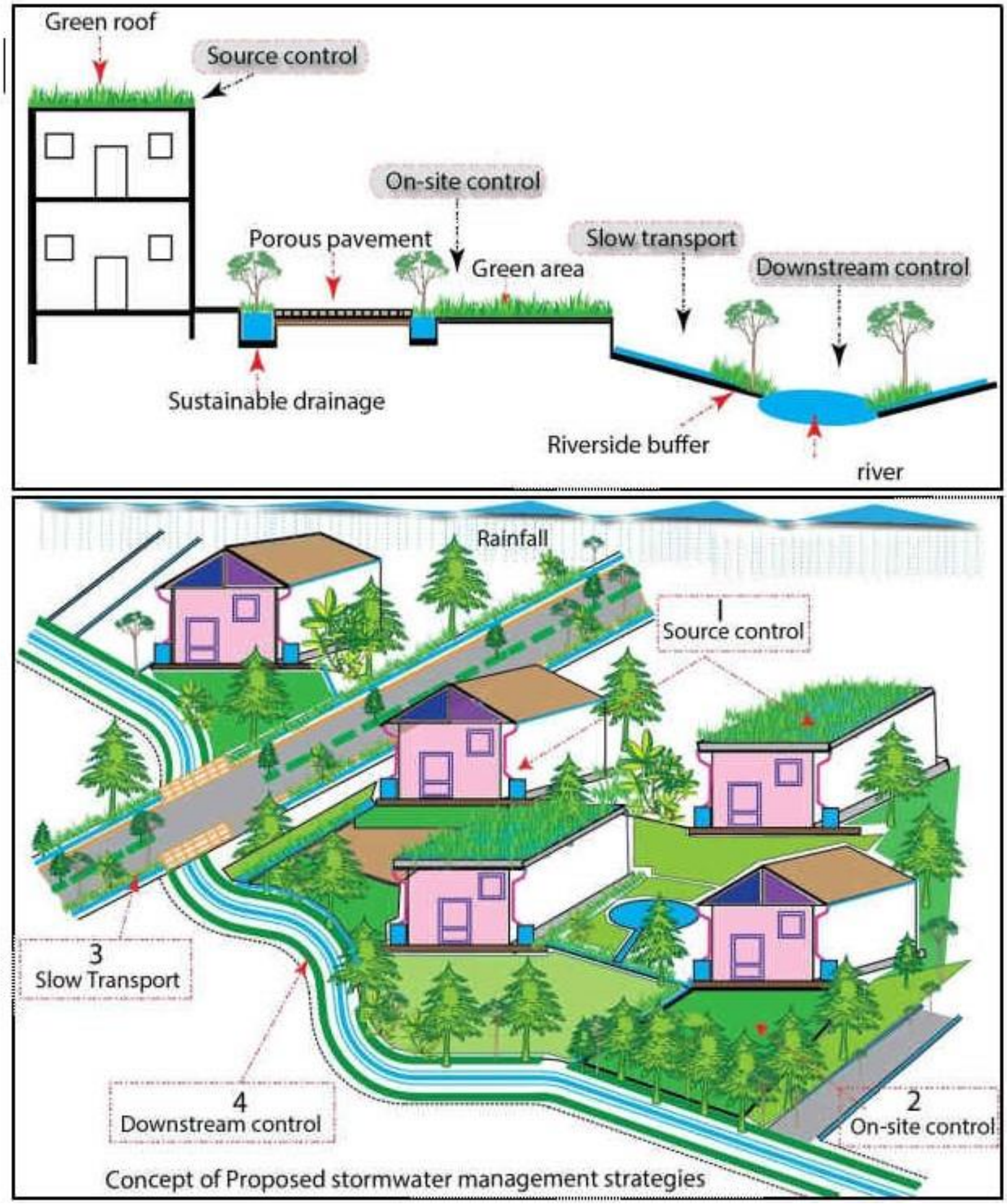

FIGURE **4.20: Conceptual development of Sustainable storm water management proposed strategies (Source: Author, 2023)**

Storm water runoff can degrade both the natural and built environments of a study area. Integrating sustainable urban storm water management plans with other planning mechanisms can help to reduce this degradation. This can be done by implementing source control, on-site control, multi-site control, slow transport control, and downstream control. These measures should be integrated to achieve sustainability in urban storm water management. The scale of application can range from individual houses to streetscapes, blocks, and entire urbanized catchments. The following are proposed strategies for sustainable urban stormwater management:

4.3.1. Source control Strategy (Plot level control).

Storm water source controls are small-scale measures that can be implemented at the lot level to prevent pollutants from entering storm water and accumulating at the source. This can affect the quality of stormwater and pollute the environment in residential, commercial, and industrial areas. The principle of source control is targeted toward low rainfall and expressed as the volume capture ratio of annual rainfall. Here are some examples of stormwater source controls:

- Green roofs: Green roofs are vegetated roofs that can help to reduce stormwater runoff, improve air quality, and provide a habitat for wildlife. They are especially beneficial in commercial areas where their aesthetic qualities can be a selling point.
- Rainwater harvesting: Rainwater harvesting is the collection and storage of rainwater for reuse. This can help to reduce stormwater runoff and provide a sustainable source of water for irrigation, washing, and other non-potable uses.
- Permeable and porous pavements: Permeable and porous pavements allow water to flow through them, which can help to reduce stormwater runoff. These pavements are made from materials such as concrete with voids, asphalt with aggregate, and porous concrete.
- Vegetable gardens and green areas: Vegetable gardens and green areas can help to reduce stormwater runoff by providing a place for rainwater to infiltrate into the ground. They can also help to improve air quality and provide a habitat for wildlife.
- Indigenous trees: Indigenous trees are trees that are native to a particular area. They are well-adapted to the local climate and conditions, and they can help to reduce stormwater runoff by providing shade and by intercepting rainwater.

- Redirecting roof leader discharges: Roof leader discharges are pipes that carry rainwater from roofs to storm drains. By redirecting these discharges to ponding areas or for reuse, we can help to reduce stormwater runoff and improve water quality.

These are just a few examples of stormwater source controls. There are many other measures that can be taken to prevent stormwater runoff and improve water quality. By implementing these measures, we can help to protect our environment and our communities.

4.3.2. On site control Strategy (Block level).

On-site stormwater control systems can be used to manage stormwater runoff from blocks and roads. These systems can provide reuse opportunities for households, improve water quality, and enhance the effectiveness of downstream treatment systems. Some of the ways to implement on-site stormwater control systems include:

- Retention and detention ponds: Retention and detention ponds are man-made bodies of water that are used to temporarily store stormwater runoff. They can help to reduce stormwater runoff by slowing down the flow of water and allowing it to infiltrate into the ground. Retention and detention ponds can also help to improve water quality by filtering pollutants out of stormwater runoff.
- Smart growth objectives: Smart growth objectives are a set of principles that can be used to promote compact, mixed-use development through vertical development. This can increase green space and reduce stormwater runoff. Smart growth objectives can be implemented by zoning for mixed-use development, providing incentives for developers to build compactly, and investing in public transportation.
- Rain gardens and open green areas: Rain gardens and open green areas are planted with vegetation that helps to filter stormwater runoff. Rain gardens are typically small, shallow depressions that are planted with native plants. Open green areas are larger areas of land that are planted with vegetation. Rain gardens and open green areas can help to improve water quality by filtering pollutants out of stormwater runoff.
- Permeable pavement: Permeable pavement is a type of pavement that allows water to flow through it. This type of pavement can help to reduce stormwater runoff by allowing water to infiltrate into the ground. Permeable pavement can be made from a variety of materials, including concrete with voids, asphalt with aggregate, and porous concrete.

- Different vegetation along a right of way: Different vegetation along a right of way can help to improve air quality and provide a habitat for wildlife. By planting a variety of trees and shrubs along a right of way, we can help to create a more diverse and healthy ecosystem.

4.3.3. Downstream or watershed scale control Strategy.

Stormwater runoff can cause pollution and damage to rivers and streams. Marsalek and Schreie (2018) found that wide riparian buffer zones and constructed wetlands can help to reduce stormwater runoff and mitigate pollution. These practices can also help to improve water quality and reduce flood risk. To reduce stormwater runoff damage in the case area, the following points are proposed:

- Urban agriculture and community parks: Develop urban agriculture and community parks along the river, with at least 50% of trees being fruit trees to support food security.
- Greenway: Develop a greenway, or urban riverside greenway, to protect rivers sides from further damage.
- Plants along riversides: Plant deep-rooted plants along riversides to protect the river bank and its immediate surrounding from erosion.
- Riverside buffer zone: Enhance the riverside buffer zone to 30m and categorize it into three distinctive zones:
    - A 6m riverside zone to protect the physical and ecological integrity of the river ecosystem.
    - An 18m middle zone from the outer zone of the zone one area of native vegetation protects.
    - A 6m outer zone immediately from the outer edge of zone two to protect the water quality of the river and reduce flood problems.
- Reforestation: Reforest the edges of the river by selecting appropriate tree species, preferably indigenous species, terracing, provision of retention or detention facilities or storage facilities.

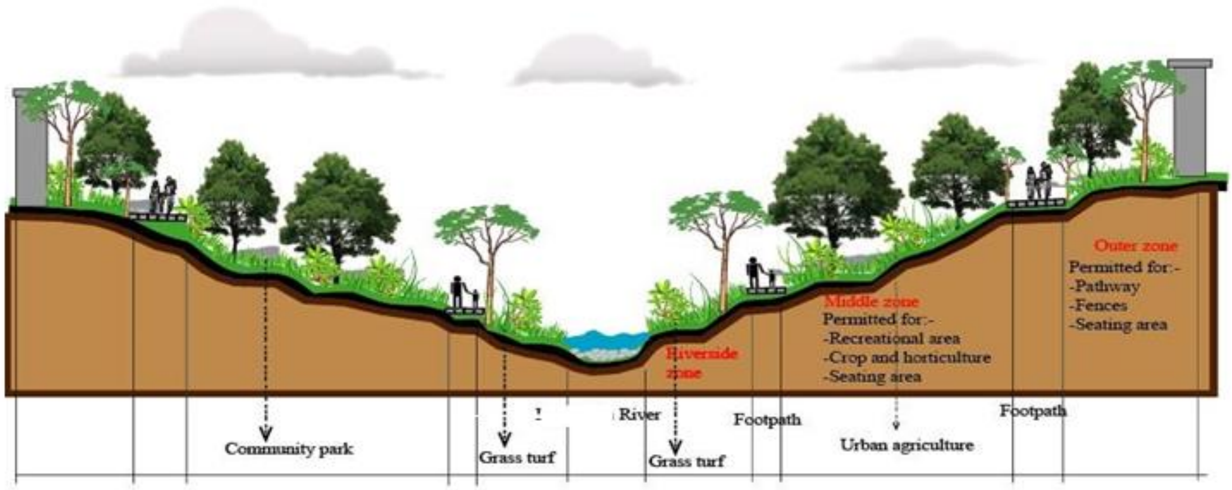

FIGURE **4.21: Proposed river side buffer plan and cross section.**

4.3.4. Urban storm water drainage network design options.

To safely remove flood generated in an urban center and to discharge it to final receiving system there should be a well-planned, designed and adequate urban storm water drainage network infrastructure. In light of this, based on the information gathered during field survey and challenges observed in the study area the following urban storm water drainage network option has planned and designed to properly manage the urban drainage system in the study area.

4.3.4.1 Design Criteria

This section describes the design criteria used for the design kebele 01/02 of Bishoftu storm drainage system in.

a) Surface Channels.

Surface channels are used to intercept runoff and conduct it to an adequate outfall. They should have adequate capacity for the design runoff. Channel linings shall be used where vegetation will not control erosion.

b) Drainage Inlets

Drainage inlets are sized and located to limit the spread on traffic lanes to tolerable widths for the design storm. Inlets shall be placed upstream of locations where the pavement cross slope reverses, such as on the high side of super elevated horizontal curves, to avoid concentrated flows crossing the carriageway.

c) Storm Drains

A storm drain is that portion of the storm drainage system that receives runoff from inlets and conveys the runoff to some point where it is then discharged into a channel.

4.3.4.2 Design Frequency of Drains.

Storm systems, culverts (Minor Drainage Systems) - 5 Year

Channels with outfalls (Major Drainage Systems) - 10 Year

Large Culverts - 25 Year

4.3.4.3. Runoff Coefficients.

The general guideline of runoff coefficients for different land uses in storm water drainage design is given in Table 4.20 as adopted from United States Federal Highway Administration HEC 19.

Table 4 .6: Recommended Runoff Coefficient C for Various Selected Land Uses.

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
Multi units, detached	0.40-0.60
Multi units, attached	0.60-0.75
Suburban	0.25-0.40
Residential (0.5 hectare lots or more)	0.30-0.45
Apartment dwelling areas	0.50-0.70
Industrial: Light areas	0.50-0.80
Heavy areas	0.60-0.90
Parks, cemeteries	0.10-0.25
Playgrounds	0.20-0.40
Railroad yard areas	0.20-0.40
Unimproved areas	0.10-0.30

Source: Hydrology, Federal Highway Administration, HEC No. 19, 1984

Design coefficients shall be used by using the above coefficients on a weighted run off method for both pre-development and post-development.

4.3.4.4. Velocity

Allowable velocity in the channels is recommended to protect channels from scouring in steep slopes; maximum velocity of 1.2 m/sec for earth channels and 3.0 m3/sec for masonry lined channels is adopted in this design. Drop structures are recommended when velocities exceed 3 m/sec to reduce the slope.

4.3.4.5. Hydraulic Design.

The rainfall excess (runoff) is transported to the design point through various flow processes. The flow in most elements of urban watershed has a free surface at atmospheric pressure and is generally classified as open-channel flow. Along a typical flow path, the rainfall excess will generally take the form of sheet flow over the roofs, lawns, driveways, and street pavements. This special type of open channel flow has a very small depth and is called overland flow. The rainfall excess will then reach a channel like street gutter, ditch, and drainage channel flowing partly full under the effect of gravitational forces and continue to move in the form of channel flow towards the watershed outlet.

Storm water drainage systems represent a significant portion of urban infrastructure. They are made up of many structures that require proper design, installation and maintenance. These drainage structures include street gutters, drainage inlets, manholes, culverts, drop structures energy dissipaters and surface drainage channels.

4.3.4.6 Surface Channels.

Open channels are often used to collect storm water runoff from urban areas and convey it to an outfall channel or to a storm water drainage inlet. Road side ditches, median channels, and storm water channels are example of surface drainage systems.

Open channels are preferred for use, especially in the major drainage system, and can have advantages in terms of cost, capacity, multiple use and flow routing storage. However, open channels have the disadvantages right-of-way needs and maintenance requirements.

Most open drainage channels are trapezoidal in cross section. Designing an open channel involves the selection of the longitudinal slope and the cross-sectional dimensions, namely the bottom width, side slope and the section depth. The longitudinal bottom slope is usually governed by topography, and the in-situ soil type dictates the side slopes (based on slope stability analysis).

Given the longitudinal slope and cross-section side slopes, the bottom width and the depth of the section can be determined so that the design discharge can be conveyed without exceeding the permissible shear stress on the channel bed.

Under design-storm conditions, the flow in surface drainage channel is neither steady nor uniform. However, in practice, the channels are designed for normal flow conditions assuming the flow is steady at the peak discharge. To account for deviation from normal flow conditions, a freeboard is added to the design flow depth in the channel section. The principles of open channel hydraulics are applicable to all drainage facilities including culverts.

The topography of the project area generally controls the channel alignment and bottom slope. The other factors that affects design of storm drainage channel includes width of right-of-way; location of existing channel; and adjacent existing structures, such as buildings, transportation facilities, utility structures, outlet for local drainage and tributaries. The bottom slope may be controlled by elevations of existing structures as well as by general topography, elevations at end of improvements, and hydraulic features (flow velocity, etc.).

The proper channel cross section for a given reach is the one that has adequate hydraulic capacity for a minimum cost of construction and maintenance. The economics must include the costs of right-of-way and structures such as culverts and bridges. In rural areas a trapezoidal cross section may be least costly, whereas in urban areas a rectangular cross section is often the least costly.

4.3.5. Proposed drainage system analysis.

4.3.5.1 General.

It is understood from the field survey and data collected on the existing drainage network an extensive work and a lot of effort is exerted by the City Administration. The major problem will arise from the topographic nature of the watershed area where runoff originates from the hilly areas in the southern direction flows towards and across the City to the natural lake of Cheleleka. As urbanization grows the paved area increase which results in increased runoff than infiltration. Usually sufficient space is not allowed to drain storm runoff hence runoff/flood interferes with development areas by inundating roads, houses and villages and occupying open spaces. In addition, sediment transported from upper watersheds is clogging channels and culverts and reduce their flow transporting capacity. Random solid waste disposal which is a major problem in all cities in Ethiopia is a major concern which blocks channels and culverts and contribute for water quality deterioration of the receiving lakes.

4.3.5.2 Base Map.

A general storm water drainage network (base map) is prepared and some priority channels are recommended to improve the network. A base map is prepared to cover all drainage networks for the master plan of Bishoftu City Administration indicated in Figure 6.3. The area covered under this master plan covers most of the developed part of the City. The detail drainage network is shown in the base map. The base map is prepared on the City's structural plan map considering the natural topography for the flow directions. The Arc GIS software is used to prepare the map and the channel network database.

4.3.5.3 The proposed Drainage System.

There exists one interceptor drain channel which drains to Bishoftu Lake. Because of its location Bishoftu Lake is better located to intercept the hill runoff from reaching the city center. Watershed management at the southern hills such as planting trees, terracing and contour bonding will be important to reduce erosion and transported sediment and increase infiltration also contribute to some extent reducing flood. An interceptor drain at the bottom of the hill draining to Bishoftu Lake will be mandatory. Stilling basins/forebay is also recommended to collect solid waste and sediment before discharging to the Lakes.

There is no option except providing enough space for storm runoff to travel to its destination and conveyance channels and culverts should be adequately designed and properly constructed. Diverting storm from one place to another will not be a solution unless integrated from upstream to downstream upto disposal site. Lacking a well-conceived drainage masterplan which was integrated with city. Development and road network was a major shortcoming. It is well observed that the existing drainage design and construction are under optimum because of in adequate size of culvert and channels, slope, and in some cases in appropriate locations.

4.3.5.4 Drainage Channel.

Design of the proposed kabele01/02 of Bishoftu drainage channels have been made based on the design criteria stipulated in the above section and hydraulic computation and hydraulic capacity design and is shown in Annex-A & B.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

This study has been carried out with the help of base map and checklists to study the overall drainage system, the impact of Gara Beru, Babo Gaya, Kidanemihret mountain, the integration between road and urban drainage infrastructure, the existing condition of natural water ways and related issues in kebele 01 and 02 Bishoftu sub-city, particularly in kebele 01and 02. These kebeles were selected due to the fact that they are representative to address the objectives of this research study

The data collected with the help of base map and checklists were transferred in to AutoCAD and then to GIS software. The existing road infrastructure was digitized to analyze the existing condition, and pavement of roads. Whereas Shape files were created on the ArcCatalog and then the collected data concerning the urban storm water drainage lines along with their conditions, types and pavements were transferred into ArcMap for a simplified analysis. This is because the drainage lines were not present on the base map and hence to make the analysis easier.

The urban drainage design option was carried out with the help of Microsoft excel to properly plan and design the urban drainage net-work with all necessary techniques. Generally, the following major points have drawn as conclusions in line with the objectives of this study:

- Most of the existing drainage channels and structures have adequate cross-section with a few exceptions but are not in good condition and needs proper maintenance.
- Existing drainage channels and structures are highly misused and mismanaged mainly due to dumping of solid waste by residents, necessary cleaning will keep the structures efficient.

- The design of the drainage system is based on the available funding, so efforts has been paid to make the system safe and economic with the provision of rectangular channels and culverts where needed.

- Problems due to scouring effects cause failure of structures; the provision of protection measure has to be made so that the effect will be controlled where lined ditches will have long life. Outfall structure at the culvert outlet of main road crossings has to be considered.

- Stilling/sedimentation basin will be useful to filter solid wastes and garbage entering the natural lakes of Chelelека and Bishoftu.

- Most of the construction sites including housing construction, water supply lines, electric lines and telephone lines installation do not consider the effect of such infrastructure and utility development on the general environment.

The major challenges of the stormwater management system are topography and geological formation, inadequate coverage of drainage lines, inappropriately designed drainage structures, disposal of solid waste into natural waterways and drainage facilities, low community participation, and others. Therefore, the study concludes well sustainable urban stormwater management is needed to a very high extent as a permanent solution. That includes different alleviation measures and applicable to both developed and redeveloped areas. Such as; source control (stormwater harvesting, green roof), on-site control (permeable pavements, retention ponds), and downstream stormwater control through the riverside buffer and green area are proposed strategies for minimizing the stormwater runoff destructive effects of the study area

5.2 RECOMMENDATIONS

After a thorough analysis and evaluation of the existing situation in line with this design, the following recommendations are drawn:

- The implementation of the proposed storm water drainage design will prevent the flooding problem which affects the study parts of the city. Dumping of solid waste and debris in the drainage ditch must be avoided by the community.
- Using the corresponding return period the channels require major maintenance such as providing adequate slope in flatter areas drop structures at the steep sections and each channel should be maintained and cleaned before every rainy season begins and should be supervised at least twice during the duration of the rainy seasons.
- Introducing fast growing indigenous trees, shrubs and grasses to increase the forest coverage of Gara Beru, Babo Gaya, Kidanemihret Mountain so that flooding problem and environmental degradation on the lower catchment areas will get minimized.
- Grassing and use of permeable structures on gardens, vacant areas, river and road sides to increase infiltration and reduce flooding hazards.
- By providing adequate transfer sites equitably to each locality to encourage solid wastes to be damped only in to authorized places.
- Through awareness creation not to damp solid wastes and other toxic chemicals in to unauthorized places like rivers, vacant areas and drainage lines.
- River buffer zone and bank development through the participation of private sectors will facilitate the sustainable development of rivers and will increase their aesthetical.
- Development of storm water drainage system is not possible in isolation from other infrastructure and environmental sectors. Thus, Coordination is necessary between, different; departments, government, NGOs and other stakeholders.

- Use of gabion retaining walls to prevent river bank erosion instead of paved retaining walls to allow root penetration and soil trapping.

- The use of rain water harvesting technologies should highly be encouraged to reduce flooding hazards, to recharge the ground water, to keep soil moisture, to reduce natural resource degradation, to solve the problem of water shortage for planted seedlings and other water requiring activities .

- Roof water harvesting should be introduced for rain water harvesting which can be employed for domestic uses, gardening and related activities. In doing so it will reduce the peak runoff discharge and the problem of environmental degradation.

- The newly designed urban drainage infrastructure shall be implemented so that the flood generated within each kebele can safely be discharged in to the final receiving systems.

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APPENDIX A: HYDRAULIC COMPUTATIONS

Drain_ID	Block_ID	CA (km2)	Max_E (m)	Min_E (m)	CL_m	S	Tc (min)	C	I_{10} (mm/hr)	Q_{10} (m3/sec)
DA1	A	1938	1904	0.59	2022	1908	2047	0.06	21	0.5
DA2	A	1986	1972	4	2074	1972	2828	0.04	32	0.5
DA3	A	1970	1955	4.45	2074	1955	3999	0.03	45	0.5
DA4	A	1968	1958	0.35	1982	1958	1679	0.01	30	0.6
DA5	A	1972	1962	0.49	2032	1962	1152	0.06	13	0.6
DA6	A	1954	1888	5.548	2074	1954	4939	0.02	57	0.5
DA7	A	1988	1984	0.26	1988	1984	754	0.01	24	0.6
DA8	A	1922	1888	0.32	2044	1888	3100	0.05	30	0.6
DA9	A	1919	1898	0.03	1920	1898	789	0.03	13	0.6
DA10	A	1886	1885	0.04	1900	1885	841	0.02	16	0.6
DA11	A	1884.5	1884	0.16	1884.5	1884	554	0.001	38	0.5
DA12	A	1956	1904	0.08	1956	1904	1085	0.05	14	0.6
DA13	A	1916	1912	0.032	1916	1912	288	0.014	8	0.6
DA14	A	1912	1887	0.21	1922	1887	1072.957	0.03	16	0.6
DA15	A	1910	1894	0.035	1910	1894	471	0.03	8	0.6
DA16	A	1988	1986	6.2	2074	1986	5200	0.02	68	0.5
DA17	A	1985.7	1984	6.4	2074	1984	5661	0.02	75	0.5

Drain_ ID	Block_ ID	CA (km2)	Max_E (m)	Min_E (m)	CL_ m	S	Tc (min)	C	I_{10} (mm/ hr)	Q_{10} (m3/s ec)
DA18	A	1902	1884	0.17	1918	188 4	1386	0.0 2	21	0.6
DA19	A	1910	1886	0.18	1910	188 6	1366	0.0 2	24	0.6
DA20	A	1887	1885	0.01	1888	188 5	237	0.0 1	7	0.6
DA21	A	1887	1885	0.022	1888	188 5	331	0.0 1	10	0.6
DA22	A	1893	1889	0.014	1893	188 9	247	0.0 2	7	0.6
DA23	A	1890	1889	0.037	1895	188 9	365	0.0 2	9	0.6
DA24	A	1889	1886	0.117	1894	188 6	746	0.0 1	18	0.6
DA25	A	1986	1984	0.36	1988	198 4	465	0.0 1	14	0.6
DA26	A	1922	1886	0.244	1946	188 6	1749	0.0 3	22	0.6
DA27	A	1895	1890	0.018	1895	189 0	247	0.0 2	6	0.6
DA28	A	1906	1885	0.5	1944	188 5	3000	0.0 2	42	0.6

Drain_ID	Block_ID	MaxE (m)	MinEl (m)	Length (m)	S	S_{des}	b (m)	d (m)	A (m2)	P (m)	R (m)	V (m/sec)	Qc (m3/sec)	Q_{10} (m3/sec)	b (Width, m)	D (Total Depth, m)
DA1	A	1922	1908	271	0.01	0.012	2	1	2	4	0.5	2.80	5.6	6.0	**2**	**1.2**
DA2	A	1986	1972	314	0.01	0.004	4.5	2.5	11.3	9.5	1.18	2.76	31.1	32.6	**4.5**	**2.7**
DA3	A	1970	1955	244	0.03	0.004	4.5	2.5	11.3	9.5	1.18	2.71	30.5	29.4	**4.5**	**2.7**
DA4	A	1968	1958	212	0.01	0.01	1.5	1	1.5	3.5	0.43	2.27	3.4	3.5	**1.5**	**1.2**
DA5	A	1972	1962	266	0.02	0.009	2.5	1.2	3	4.9	0.61	2.74	8.2	7.4	**2.5**	**1.4**
DA6	A	1954	1888	243	0.043	0.005	4.5	2.5	11.3	9.5	1.18	3.02	34	31.3	**4.5**	**2.7**
DA7	A	1988	1984	260	0.01	0.01	1.5	1	1.5	3.5	0.43	2.27	3.4	3.0	**1.5**	**1.2**
DA8	A	1922	1888	289	0.04	0.015	1.5	1	1.5	3.5	0.43	2.74	4.1	3.2	**1.5**	**1.2**
DA9	A	1919	1898	289	0.027	0.027	0.8	0.4	0.32	1.6	0.2	2.23	0.7	0.5	**0.8**	**0.6**
DA10	A	1886	1885	233	0.004	0.004	1	0.6	0.6	2.2	0.27	1.06	0.6	0.6	**1**	**0.8**
DA11	A	1885	1884	224	0.001	0.001	4.5	0.4	1.8	5.3	0.34	0.58	1.1	1.2	**4.5**	**0.6**
DA12	A	1956	1904	269	0.039	0.035	1	0.6	0.6	2.2	0.27	3.15	1.9	1.2	**1**	**0.8**
DA13	A	1916	1912	288	0.01	0.01	0.8	0.6	0.48	2	0.24	1.54	0.7	0.6	**0.8**	**0.8**
DA14	A	1912	1887	306	0.04	0.013	1.5	0.8	1.2	3.1	0.39	2.43	2.9	2.9	**1.5**	**1**
DA15	A	1910	1894	375	0.04	0.029	0.8	0.6	0.48	2	0.24	2.64	1.3	0.6	**0.8**	**0.8**
DA16	A	1988	1986	305	0.007	0.004	4.5	2.5	11.3	9.5	1.18	2.92	32.9	32.1	**4.5**	**2.7**
DA17	A	1985.7	1984	112	0.003	0.003	4.5	2.8	12.6	10.1	1.25	2.55	32.2	31.7	**4.5**	**3**
DA18	A	1902	1884	234	0.02	0.016	1.2	0.8	0.96	2.8	0.34	2.51	2.4	2.1	**1.2**	**1**

Drain_ID	Block_ID	MaxE (m)	MinEl (m)	Length (m)	S	S_{des}	b (m)	d (m)	A (m2)	P (m)	R (m)	V (m/sec)	Qc (m3/sec)	Q_{10} (m3/sec)	b (Width, m)	D (Total Depth, m)
DA19	A	1910	1886	114	0.02	0.021	1.2	0.8	0.96	2.8	0.34	2.83	2.7	2.1	**1.2**	**1**
DA20	A	1887	1885	218	0.02	0.017	0.8	0.6	0.48	2	0.24	2.01	1.0	0.2	**0.8**	**0.8**
DA21	A	1887	1885	124	0.02	0.016	0.8	0.4	0.32	1.6	0.2	1.74	0.6	0.4	**0.8**	**0.6**
DA22	A	1893	1889	235	0.02	0.017	0.8	0.4	0.32	1.6	0.2	1.78	0.6	0.3	**0.8**	**0.6**
DA23	A	1890	1889	190	0.01	0.005	1	0.6	0.6	2.2	0.27	1.22	0.7	0.6	**1**	**0.8**
DA24	A	1889	1886	204	0.01	0.01	1.2	0.8	0.96	2.8	0.34	1.95	1.9	1.5	**1.2**	**1**
DA25	A	1986	1984	237	0.01	0.008	2	1.2	2.4	4.4	0.55	2.45	5.9	5.3	**2**	**1.4**
DA26	A	1922	1886	214	0.03	0.014	1.5	0.8	1.2	3.1	0.39	2.50	3.0	2.9	**1.5**	**1**
DA27	A	1895	1890	236	0.02	0.02	0.8	0.4	0.32	1.6	0.2	1.95	0.6	0.3	**0.8**	**0.6**
DA28	A	1906	1885	124	0.02	0.011	1.7	1	1.7	3.7	0.46	2.53	4.3	4.1	**1.7**	**1.2**

APPENDIX C: QUESTIONNAIRE

Instructions: tick or give reliable answers for the questions presented here with.

Address: Sex: male------female-------Age------Profession-------degree--------diploma----------

Are you expert/engineer-----------------or Administrative staff ---------------------------?

1. Total land area of in kebele01/02 city----------ha. Green area in kebele 01/02 city-------ha

2. Does flooding a major problem in your kebele ? yes----------------No -----------------

3. If your answer is yes, how do you rate the extent: very serious-------serious---------not Serious---.

4. Which specific sites are most prone to flooding and why: use the table below:

Name of local site	kebele	rank	Reason of flooding (why?)

5. What do you think is the major causes of flood problem in Bishoftu 01/02 kebele ?

i. Absence of urban storm water drainage infrastructure -----------------------

ii. Inadequate urban storm water drainage infrastructure------------------------

iii. Blockage of urban storm water drainage structures---------------------------

iv. Deforestation of around Mountain-------------rugged topography--------------

v. If others specify--

6. What temporary solutions have ever been taken to flood problems?

a. Cleaning drainage channels-------------d. Earth embankments--------------

b. Sand bags ------------------------------ e. Afforestation --------------------------.

c. Constructing new urban storm water drainage facilities-----------------------.

f. Specify, if any--.

7. What permanent solutions have ever been taken to flood problems?

i. Cleaning drainage channels--------------- ii. Earth embankments-----------.

iii. Sand bags --.

iv. Constructing new urban storm water drainage facilities----------------------.

v. Specify, if any--.

8. What are the major challenges in the provision of integrated road and urban storm?

Water drainage infrastructure: finance-----------plan--------------profession-----------lack of awareness----------------.

9. Do you plan to provide urban storm water drainage infrastructure in kebele 01/02 sub-city?

yes------no------If so, for what purpose:---.

10. What major impacts the drainage system has on rivers in 01/02 sub-city? ---------------

What impacts do rivers have on 01/02 sub-city? ---

11. What solutions you suggest to handle such problems on existing rivers -----------------

12. What do you suggest to manage the problem of flooding in 01/02 sub-city? -------------

13. Who is the responsible body or organization in urban storm water drainage provision?

In 01/02 sub-city? --

14. What are the major challenges in handling urban storm water drainage system in

01/02 sub-city? --.

15. Is the flood from around mountain a major problem to the sub-city? Yes------- no-----if

Yes how could it be reduced/solved? --.

16. General comments/suggestions in handling the impact of the urban drainage system

On 01/02 sub-city? ---.

Thank you.

APPENDIX D: CHECK LISTS

1. Total built up area of the sub-city-------ha or-----------km2 Green area------------ha.

2. Road coverage in the study area--km

3. USWD lines in the built up area---km

4. The general existing condition of natural water ways in the study area:

4.1 Average width--------------- 4.3 Condition: Good-------light---------severe---------

4.2 Average depth-------------- 4.4 Average length in the study area-------------------

5 General problems in the natural water ways/rivers:

5.1 Encroached by residents-------------5.2 Blocked by solid wastes-------------------

5.2 Connection of Sewerages--------5.4 No recommended buffer------&------meter

6 Road and USWD lines deterioration scales/indicators.

Indicators classification	Surface condition
Very good	Shapes of roads/USWD lines as still in original design condition
good	No significant depressions, undulations and deformation
Light	Shape of the road/USWD lines deteriorate, but still sheds water
Severe	Total collapse of the road/USWD lines structure & barely passable

Source: GTZ, 2006.

7 The road and USWD pavement condition and type.

	Road						Urban storm water drains			
	Asphalt, km		Red ash(km		Earth(km)		Masonry		Earth	
Good										
Fair										
Poor										
Total										

8. Road classification

I. High way _________ km III. Collector ___________ km

II. Arterial __________ km IV. Local_____________ km

6. Urban storm water drainage facilities:

No.	Type of drains	Length (km)	Shape of drains (km)		
			Trapezoidal	circular	rectangular

9. The technique of road and USWD provision/contracting: separately-------------

Together------------and reasons---

10. Integration between road and USWD lines

No.	Road surface type	Total length of road(km)	Drain length(km)					
			Trapezoidal		Rectangular		Circular	
			M	E	M	E	M	E

Note: M= masonry drain, E= earth drain, It is by default known that a circular drain is closed type.

11. Dimensions of existing USWD

No.	No construction material						
		Trapezoidal			rectangular		circular
		L	H	B	B	H	R

Where: L= length, B= base, H= height, R= radius

12. Most flood prone sites/area in the study area.

Specific sites	Causes of flooding	Ranks from observation