

Urban Stormwater Management in Dambi Dollo town: The case of Laga Hida river area.



Dajane Kana Darkushe

A Thesis is submitted to Department of Architecture

School of Civil Engineering and Architecture

Presented in Partial Fulfillment of the Requirement of the Degree of Master of
Science in Urban Planning and Design.

Office of Graduate studies

Adama Science and Technology University

July, 2021

Adama, Ethiopia

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Approval sheet

I, the advisor of the thesis entitled “Urban Stormwater Management in Dambi Dollo town: the case of Laga Hida river area” and developed by Dajane Kana Darkushe, hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

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We, the undersigned, members of the Board of Examiners of the thesis by Dajane Kana Darkushe have read and evaluated the thesis entitled “Urban Stormwater Management in Dambi Dollo town: the case of Laga Hida river area” and examined the candidate during open defense. This is, therefore, to certify that the thesis is accepted for partial fulfillment of the requirement of the degree of Master of Science in Urban Planning and Design.

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Declaration

I, hereby declare that this thesis entitled “Urban Stormwater Management in Dambi Dollo town: the case of Laga Hida river area” submitted for the partial fulfillment of the requirements for the Masters of science in Urban Planning and Design, is original work done by me under the supervision of Fikirte Demissie (Ph.D) and this thesis has not been published or presented for a degree in any other university. Materials or ideas of other authors used in this thesis have been accordingly acknowledged and references are listed at the end of the main document.

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Signature

Date

Recommendation

I, the advisor of this thesis, hereby certify that I have read the revised version of the thesis entitled “Urban Stormwater Management in Dambi Dollo town: the case of Laga Hida river area” prepared under my guidance by Dajane Kana Darkushe submitted in partial fulfillment of the requirements for the degree of Master of Science in Urban Planning and Design. Therefore, I recommend the submission of revised version of the thesis to the department following the applicable procedures.

Advisor

Signature

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ACKNOWLEDGMENT

Ahead of all I would like to thank the almighty GOD for his unspeakable gift, help and protection during my work.

I would like to express my honest thankfulness and appreciation to Dr. Fikirte Demissie whose encouragement, guidance and support me from the initial to the final level of this thesis. I am extremely indebted and thankful to her for support, guidance, constructive criticisms and encouragement, which helped me to complete this research work successfully.

My most gratitude expression also goes to Kellem Wollega Zone Administration and Dambi Dollo Town municipality workers of different sectors their contribution on relevant documents that helped the study.

Finally, I would like to express my great pleasure to my family, friends, and others for their encouragement and supports.

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List of Acronyms

ARFI	Annual Rain Fall Intensity
BMP	Best Management Practice
C	Runoff coefficient
GIS	Geographical Information System
LDP	Local Development Plan
LID	Low Impact Development
NUGIS	National Urban Green Infrastructure Standard
OUPI	Oromia Urban Planning Institute
SPSS	Statistical Package for Social Sciences
SUSWM	Sustainable Urban Stormwater Management
SUDS	Sustainable Urban Drainage Systems
USDD	Urban Stormwater Drainage Design
WSUD	Water Sensitive Urban Design

Abstract

Sustainable urban Stormwater management is to develop the strategy of stormwater management for every spatial unit, from a single lot and building block up to a neighborhood and the whole city. The main aim of this research is to investigate the current effect and challenges of poor urban stormwater management of Dambi Dollo town in the case of the Laga Hida river area. 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 convenience 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 different software. The result of the study revealed that the major effects of stormwater runoff include environmental degradation, economical loss, society health, and physical infrastructure destruction due to poor stormwater management of the study area. Likewise, the major provision challenges of the stormwater management system are land-use change, lack of contemporary urban plan and design implementation, shortage of stormwater management experts in the municipality, and others. Again the result of the study revealed that, the past and present strategies for stormwater management the municipality had taken are not successful its temporary solution not permanent. The major findings of the study indicated that stormwater runoff effects in Laga Hida river area caused due to Dambi Dollo town municipality can institutionally; lack of stormwater-related policy and stakeholder invitation, technically; lack of experts that prepare stormwater management techniques and socially; lack of community awareness on proper stormwater management and solid waste management that can to reduce the quantity and improve quality of stormwater. 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.

Key Words: *Degradation, Drainage, Infrastructure, Stormwater, Sustainable, Strategies*

CHAPTER ONE

1. INTRODUCTION

1.1. Background of the Study

The global urbanization rate is predicted to increase from the current 55% to 68% by 2050, with another 2.5 billion individuals living in urban areas, particularly in Asia and Africa (United Nations, 2013). With expanding urbanization, the urban surface is getting covered by increasingly urban infrastructure, which leads to an increase in compacted soils and impervious surfaces. Many environmental problems have been made because of this quick urbanization, with an increase in urban stormwater runoff which causes flooding and damages to the current infrastructure (Mezgebe, 2009).

Stormwater has long been regarded as a major offender in urban flooding due to its; high impacts on the living style of living and non-living environments. In Worldwide around different cities and town vegetation and topsoil are removed to make way for buildings, roads, other infrastructure, and drainage networks are installed (Saraswat et al. 2016). After that the stormwater over flow sewerage or municipal drainage line which can make urban flooding that could affect different environments (Jha et al., 2011).

Extraordinary rainfall occasions are predicted to increment around the world, with joined changes in the volume and patterns of precipitation (Qiao, 2019). As power and time of rainfall actions are uncertain, it encourages the rise in dangers of stormwater runoff occasions. In several African urban areas, rainstorm power has been expanding for 15 years (Ayoub, 2014). Then the larger quantity of stormwater run-off from the built environment is causing more cases of rainstorm flood that damage environments. Hence, higher stormwater overflows the drainage are damage to roads and spread and deposit the solid waste on roads and other places (Bansal et al., 2015).

Urban stormwater management was 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). Similarly, in different developed countries to achieve runoff and pollution control produced by heavy rain, mostly through decentralized, little scope source control should be created (Zhang et al., 2018). Like, stormwater infiltration facilities and, some countries in Switzerland: infiltration of stormwater is mandatory for new developments, other countries such

as Germany, Sweden and Denmark in Europe as well as Australia and USA are actively encouraging are the use of the source control strategies and other management practices (Marsalek and Chocat, 2002). There is also implemented in many developing countries such as Brazil, Chile and Ghana through stormwater on-site treatment and reuse method (Parkinson, 2003). However, Sustainable Urban Stormwater Management (SUSWM) is improving the planned environment for its users through, reducing the negative impacts of stormwater, preserving ecosystems (Carmon et al. 2009), and stormwater quality improvement and flood control in urban areas (Sharma et al., 2016).

Accordingly, the study had been conducted on the effects of urban stormwater on community and physical environments that have different natural and built environment in Dambi Dollo town. This is due to challenges of high amount of impervious surface like; buildings, streets and different infrastructure in the town, which resulted in use and abandonment of green space or vegetated area that can infiltrate the stormwater runoff or control natural and built environment from destruction. Moreover, the area has long rainy seasons that last from May to October resulting in, different roads of the town are covered by surface water and overflow to surrounding space. This surface water accelerates the deterioration rate of the roads. Liquid waste of the town can have also a contribution for the overflow. In addition, liquid and solid waste are also the biggest challenges in contributing for the over flow by blocking the drainage systems. Hence, this is becoming a big problem for the surrounding environments and existing Borta Lake and different Small River of the town.

1.2. Statement of the problem

To gratify new development and improvement, urban communities are regularly increasing the built environments which involve a huge part of impermeable surfaces on the ground (Tian, 2011). According to Beecham et al. (2010) previous surfaces allow stormwater to be filtered and afterward either collected for reuse or discharged gradually into the fundamental soil. But, these constructed structures are not effective for the area that has less permeable or even impermeable surfaces by its nature. However, after natural vegetation is removed the infiltration of the rainwater in to ground is decreases, these can create large amount of stormwater runoff that pollute Natural River through collecting different wastes and flow into it. Also, street deteriorating by storing different waste on the streets, which may lead to increased erosion which can be, degrades the environments (Demu, 2018).

Accordingly in Dambi Dollo town due to the insufficient state of the drainage system, inadequate flood protection, soil type, poor stormwater management, shortage of green area, rough topography, high covered of an impervious surface, weak stakeholder collaboration for flood protection and other social activities intensified the runoff which is resulting very serious damages as well as the loss of several properties. So these all challenges are intensified and have become critical issues in this town due to overflow of existing drainage and street. This causes a different social and economic problem by blocking existing drainage and degrading different infrastructure. In addition, it has environmental impacts through land degradation and storing different solid and liquid waste in town and flowing into the existing Laga Hida small river. In the town there is also frequent occurrence of road over flooding problems during summer. The rainfall in this season causes erosion, damage of pavement and the constructed road line, negatively impact on the wellbeing, and trouble on day to day activities of the societies those are living in this area.

Therefore, the study tries to identify the overall challenges resulted due to poor stormwater management. Additionally, the research examines the effect of urban stormwater runoff on the human settlement, different nature, and built environments. Finally, the study develop stormwater management system the strategies to enhance sustainable urban stormwater management system for Dambi Dollo town around Laga Hida river area to decrease environmental and physical infrastructure degradation, society health and economic loss of the area.

1.3. Objective of the Research

1.3.1. General Objectives

The main objective of the study was to investigate the effect and challenges of poor urban stormwater management systems with developing sustainable urban stormwater management strategies as the solution for Dambi Dollo town Laga Hida river area.

1.3.2. Specific Objectives

The specific objectives of the study are:-

- To analyses the effects of current stormwater in the Laga Hida river area,
- To identify the challenges of stormwater management system in the study area and
- To develop strategies to enhance sustainable urban stormwater management system in the study area.

1.4. Research Questions

- 1) What are the effects of current stormwater in Laga Hida river area?
- 2) What are the challenges of stormwater management system in the study area?
- 3) How to enhance sustainable urban stormwater management system in the study area?

1.5. 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 effects and challenges of the urban stormwater runoff and management system on the community and the environment of the selected site and to provide strategies for sustainable urban stormwater management. The spatial scope of the study is Dambi Dollo town 05 kebele Laga Hida river area. The selected site has covered an area of 24 hectares based on location, topography, exposure to stormwater runoff, and river pollution.

1.6. Significance of the study

This research was important and has some contribution for the developer, decision makers, community, and planner to understand how on-site urban stormwater management achieved in a sustainable manner. Additionally, the study was proposing strategies how to mitigate stormwater effects and to create aesthetic and ecological value benefits. It helps as design guidelines for urban stormwater and flood treatment used in sustainable urban stormwater management. Finally, the proposed strategies had been applicable in a town that has the same character as the local environmental condition of this study area.

1.7. Limitation of the study

The major limitation of the study was collecting physical observation by camera, due to the current political situation. Also, the Municipality does not have better systems of holding recorded documents regarding stormwater runoff effects and management strategies. However, the researcher overcomes the limitations by repeatedly going to the town municipality and asked continuously for guidance from advisors and friends.

1.8. Operational definition of terms

Stormwater -water falls to the earth in the form of rain or snow. Some of it runs off of the surface of the ground into storm drains or streams, some falls into water bodies, and some soaks directly into the ground (Demu, 2018).

Urban stormwater- is the runoff from a landscape that has been affected in some fashion by

human activities, during and immediately after rain (Tucci, 2006).

Stormwater Runoff - the direct response of a watershed to precipitation and includes the surface and subsurface runoff that enters a ditch, storm drain, stream or other concentrated flow during and following the precipitation.

Stormwater management- the collection, conveyance, storage, treatment and disposal of stormwater runoff in a manner to minimize accelerated channel erosion, increased flood damage, or degradation of water quality and in a manner to enhance and ensure the public health, safety and general welfare, which shall include a system of vegetative or structural measures.

Impervious surface -is land where water cannot infiltrate to the subsurface but is conducted by gravity on the surface as overland flow. Roads, parking lots, sidewalks and rooftops are examples of impervious surfaces in urban areas (Yannopoulos, 2003).

Sustainable stormwater management-is a group of technical solutions. Some examples are stormwater best management practice (BMP), techniques alternatives (TA), stormwater control measures (SCM) and stormwater management (Marsalek and Chacot, 2002).

Stormwater Drainage System: Constructed and natural features function together as a system to collect, conveys, channel, hold, inhibit, retain, detain, infiltrate, divert, treat, or filter stormwater (Megen, 2018).

1.9. 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.

¹ Kebele is the smallest administrative unit in Ethiopia

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 effect of current urban stormwater, causative challenges of urban stormwater management system, and solution proposed to mitigate it.

2.2. Concept of Urban stormwater

Stormwater 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. 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 stormwater (Jared, 2011).

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).

There are also concepts related to urban stormwater these are:

- i. Runoff Factors:-**Runoff is rainfall excess or effective rainfall the amount by which rainfall exceeds the capability of the land to infiltrate or otherwise retain the rainwater. The principal physical catchment area characteristics affecting the relationship between rainfall and runoff are land use, land treatment, soil types, and land slope (Jha et al., 2011).
- ii. Runoff Coefficient:-**The runoff coefficient (C) is the variable of the Rational Method least susceptible to precise determination and requires judgment and understanding on the part of the designer. A typical coefficient represents the integrated effects of many drainage basin parameters such as soil groups, land use, and average land slope. Runoff coefficients are

theoretically restricted to the range of 0 to 1.0. According to USDD manual recommended we can use runoff coefficient as (Table 1) related to land use land cover of area (USDD, 2008).

Table 2.1: Selected runoff coefficient values under different surface conditions

Description		Run off coefficient
Business:- Downtown areas		0.70–0.95
Neighborhood areas		0.30–0.70
Industrial:- Light areas		0.30-0.80
Heavy areas		0.60-0.90
Residential:- Single-family		0.30–0.50
	Multi units, detached	0.40–0.60
	Multi units, attached	0.60–0.75
	Residential Suburban	0.25–0.40
	Apartments	0.50–0.70
Parks, cemeteries		0.10–0.25
Playgrounds		0.20–0.35
Unimproved areas:		
• Sand or sandy loam soil, 0-3%		0.15-0.20
• Black or fine-grained soil, 0-3%		0.18-0.25
• Deep sand area		0.05-0.15
• Steep grassed slopes		0.70
Street:- Asphalt		0.85–0.95
Cobble stone		0.60-0.85
Gravel		0.40-0.80
Concrete		0.90-0.95
Drives and walks		0.75–0.95
Roofs		0.75–0.95
Brick		0.70–0.85

(Source: Urban Stormwater Drainage Design manual, 2008)

• Stormwater Runoff volume per day or year estimation formula

Typical methods include:-

The rational method, for example as used in (Pazwash, 2011) typically expressed as $Q = C \times I \times A$, where:-

Q = peak flow (m^3/s)

C = runoff coefficient

I = rainfall intensity (mm/hr) or annual rainfall for the applicable duration (T_c) and design storm magnitude

A = catchment area (ha) Suitability: recommended for use for catchments under about 50 ha.

2.3. Importance of urban stormwater management

Urban Stormwater management has been contributing to rising sustainability in water management (Nassar et al., 2017). According to Carmon & Shamir (2009) the following

3Ms(minimizes) should be followed for better urban stormwater management for every spatial unit, from a single lot and building block up to a neighborhood and the whole city:

1. Minimize the variance in runoff volume leaving the area after urban development as compared with the volume before it.
2. Minimize the modification in discharge leaving the area after urban development as compared with the discharge before it.
3. Minimize the pollutant load in the runoff leaving the urbanized area.

2.3.1. Urban Environment protection

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

The 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 completely and as quickly as possible. The new alternative sustainable approach comprises basically a combination of the conventional approach (providing a drainage network and modifying existing watercourses) complemented or substituted by different concepts including recycling and reuse of stormwater (Gogate et al., 2017).

2.3.2. Effects of urban stormwater runoff

The impacts of stormwater are hydrological, social, environmental, and physical. Increased sediment production from unprotected surfaces and production of solid waste (refuse). It also, deteriorates in quality of surface and groundwater, owing to street cleaning, transport of solid material and clandestine sewage and stormwater connections. These pollutants cause environmental damage to the receiving water bodies of the urban area, as well as the surrounding ecosystems that depend on adjacent waters (Tucci, 2012).

The impermeable surfaces because of urbanization are liable for more stormwater runoff than another type of land use (Mezgebe, 2009). Because it has been mentioned earlier than that the paved surfaces that replace vegetated areas increase the quantity and frequency of rainfall-runoff.

So this stormwater runoff has its every own effects. See the following categorized effects of stormwater runoff such as physical impacts (Parkinson, 2003), social impacts (Jha et al., 2011), environmental impacts (Tucci, 2007), and economic impacts (Bansal et al. 2015).

2.3.1. Physical Effects

Physical impacts of stormwater runoff are including to property damage, infrastructures and contents of buildings. Flooded waters can cause failure to piping situations and damage water supply system, resulting is loss of drinking water as well as other forms of infrastructure and urban services such as electricity supply and waste disposal systems (Parkinson, 2003).

2.3.2. Social Effects

According to Jha et al., (2011), the most difficult and disastrous heavy rainstorm floods on society is loss of life have tended to occur in developing nations. Social mortality rates, deaths are caused by water born disease, disruption of food supplies, ill-health or shock after the event and are also related to flood and development characteristics. Another problem is shortage of freshness consumption water and spoiled sanitation systems by rainstorm flood affected populations. The occurrence of severe includes, diarrhea, malaria, respiratory infections and skin diseases is high due to on-street stored and polluting into waters of rainstorm.

2.3.3. Economic Effects

The Economic impacts of urban stormwater runoff are often with damaged cause physical impacts. On the whole, the developing nations have insurance coverage, lower than 25% of total losses. To evaluating of the economic impact of rainstorm flooding there are two main effects can be occurred in anywhere: That of economic losses, which attempts to measure the impact on society of the actual damage, city infrastructure deterioration and that of financial, or insured losses, which covers payment of the maintenance of damaged social properties and maintain damaged infrastructure and associated expenditure (Bansal et al. 2015).

2.3.4. Environmental Effects

During urban development, several human settlement which could produce environmental impacts because of increasing stormwater runoff through construction of building, clearing of vegetated land for new housing developments, construction of streets, avenues, highways and installation of other infrastructure leading to seriously degraded areas (Tucci, 2007). In addition, because of the difficulties related to impermeable surfaces, drainage systems, solid waste,

movable assets and the sites of buildings, the predictability of rainstorm flood flows was much lower once the affected urban environment was reached (Parkinson, 2003).

This can influence environment in the way of:-

- i. Solid waste obstructing runoff:** - it's production of several solid materials that also reducing runoff capacity through blockage and obstructs of the urban drainage systems for local control of runoff finally creating very poor environmental condition.
- ii. Obstruction of runoff by buildings and hazard:**-in reality urban growth creates environmental impacts by tending to occupy areas of natural runoff of excess storm water, leaving little space for it, which leads to risks to inhabitants and stormwater quality.

2.4. Challenges for the urban stormwater management

Urban settlements and other natural forces are the sources of inner-city stormwater runoff such as rainfall, snowmelt, sea surge, and failure of drainage and water systems. In urban areas major pathway for urban flooding is intense rainfall overwhelming the drainage holding capacity of a city (Adugna, 2011). Urban environment, it is not only increases in the sources of flood water which increase flood hazard. The conveyance of stormwater towards to urban areas and which decrease the ability to diffuse stormwater factors are there.

So, there are some challenges to urban stormwater management like, land-use change, increased urban expansion, and lack of community awareness, the decrease in the permeability of open spaces, lack of well implemented urban planning, and lack of maintenance of aging infrastructure and lack or overload of drainage systems. There are explained below:-

2.4.1. Land use change

Urban land use change is one cause to the increased threat of storm water by reducing the flexibility of the area to absorb excess water (Schutte & Sculze, 2017). The expansion of urban area change land use to include new infrastructure development would be the direct cause of the increase of impervious surface (Haile & Worku, 2018). Such as transportation networks, which may introduce elevated structures obstructing previous natural flow paths. Other more natural land use changes can additionally destroy the sensitive water and land balance main to decrease storage and increased overland flow.

Vegetation removal is another important parameter that affects the surface runoff (Assefaw, 2016). Open spaces and vacant land are developed for commercial, residential and industrial

uses. This can contribute to a reduction in land cover, and with increasing precipitation there can be increase sediments in rivers and accelerating the rate of rainfall runoff and causing environmental degradation.

2.4.2. Lack of Community Awareness

Stormwater management is a major and growing challenge nationwide, with stormwater pollution, flooding and other impacts imposing serious impacts on water quality, public health and local economies (United state Environmental Protection Agency, 2016). Therefore, one of the local governmental roles is making the beautified cities that make comfortable community wellbeing. The Lack of public awareness and lack of preventive measures at household level and by city officials, leads to failure of stormwater management in the urban areas. The district administration, Municipal Corporation and Disaster Mitigation and management center have a very big role to play after and during the stormwater flows to manage, but it seems in spite of their efforts to aware community how they manage storm from surrounding environment. 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 as it is seen in Figure 2.1 (Bansal et al., 2015).



FIGURE 2.1 THE GARBAGE SPILLED ON THE RIVER BED BY COMMUNITIES

(Source: Bansal et al. 2015)

Managing stormwater can create opportunities for communities to rediscover rainwater as a resource, invest in resilient infrastructure, revitalize urban waterways and introduce green space that makes communities more livable (United state Environmental Protection Agency, 2016).

2.4.3. Lack of well implemented urban planning

The structural plan or Local Development Plan of one urban area when it prepared it includes solving different urban issues. But implementing proposed different open space, green area and

drainage master plan are difficult due to lack of appropriate public or private spaces in already developed areas. The plans that regulate land use and infrastructure often do not reserve urban spaces for this use (Goldenfum et al., 2007).

2.4.4. Permeability of open spaces

The unmade roads and green spaces are providing temporary storage to rainwater by increasing permeability of the ground. The urban green space provides multiple ecological benefits, among which the reduction of rainfall runoffs (Demu, 2018; Mezgebe, 2009). But due to construction of concrete structures and building, green spaces and open spaces in urban areas are hindered. Today increasing densification of towns and cities is normally seen as necessary in order to meet sustainability targets. The densification indicates every space is developed to the maximum use of urban dwellers. So, these can lead urban area to increase in hard surfaces and a decreasing permeability of open space. Also changes the land uses, land cover and natural landscapes (Fulle, 2017).

Carmon & Shamir (2009) state the open spaces play critical roles in city life, as places for leisure activities, as air refreshers and also as receptors of stormwater. But, rapid urbanization occurring today is decreasing the level of permeability of open space and green space. These increase the risk of rain flooding and are major causes for the impacts of stormwater runoff (Figure 2.2).

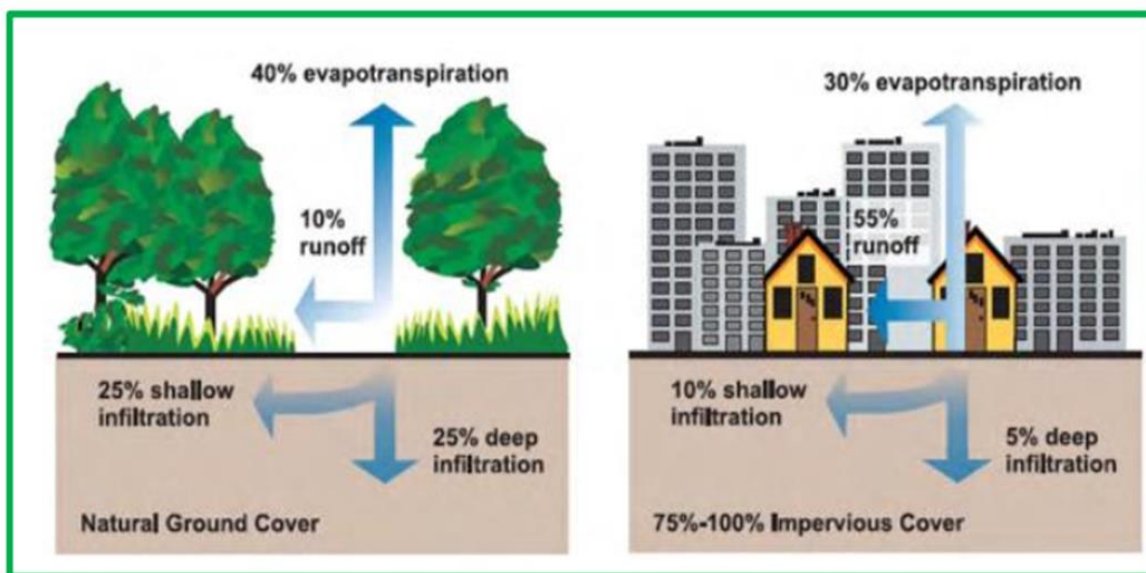


FIGURE 2.2: CHANGE IN URBAN STORMWATER RUNOFF CHARACTERISTICS AFTER URBANIZATION (Source: Jha et al., 2011)

2.4.5. Lack of maintenance of aging infrastructure

Another cause which may increase urban stormwater impacts is lack of repairs of old drainage pipes (Qiao, 2019). This is often the case in both developing and developed countries, and then proper maintenance of these infrastructures needs regular large sums of money which might not be a priority for the local management. According to (Megen, 2018) the absence of drainage maintenances of in Oslo city has directed to 50% of the drainage capacity being lost due to blockages. The importance of maintenance of existing infrastructure which mitigates flood risk is not always recognized. Small actions, taken often can have an actual impact on flood hazard.

2.4.6. Lack or overload of drainage systems

Urban stormwater runoff can be caused by intense rainfall overloading the drainage capacity of existing systems. Today the existing urban drainage system is might be influenced by inadequate water carrying capacity as a result of improper design and connection as well as lack of maintenance (World Meteorological Organization, 2012). It may also be a rainfall occasion which exceeds the criteria for the design of the drainage system. Because, extreme events exceeding the capability of the inner-city drainage structure is a major cause of surface overflowing of stormwater which may make deteriorated drainage systems in short period.

2.5. Sustainable Urban Stormwater Management

The goal of sustainable urban stormwater management is to reduce stormwater runoff by treating the stormwater as close to the source as possible, ideally on-site. “Treat” in this case does not mean to collect and discharge the stormwater to the public sewer system, as it would be treated conventionally, but to reduce runoff by using technologies for stormwater collection (e.g. for utilization or storage) and to increase stormwater penetration and evaporation (Hoyer et al. 2011). For instance, in Australia, one of the greatest sustainable techniques for urban stormwater management is Water Sensitive Urban Design (WSUD). A comparable concept in Europe is Sustainable Urban Drainage Systems (SUDS) and in the United States the equivalent concept is Low Impact Development (LID) (Kazemi et al., 2011).

Therefore, as it is shown in Figure 2.3, a sustainable urban stormwater management on the street has a potential to bring street comfort through shading and reducing peak stormwater runoff volumes. Additionally, Streets that integrate natural, landscape based features in order to infiltrate, reuse, or evapotranspiration stormwater, could bring environmental sustainability (Qiao, 2019).

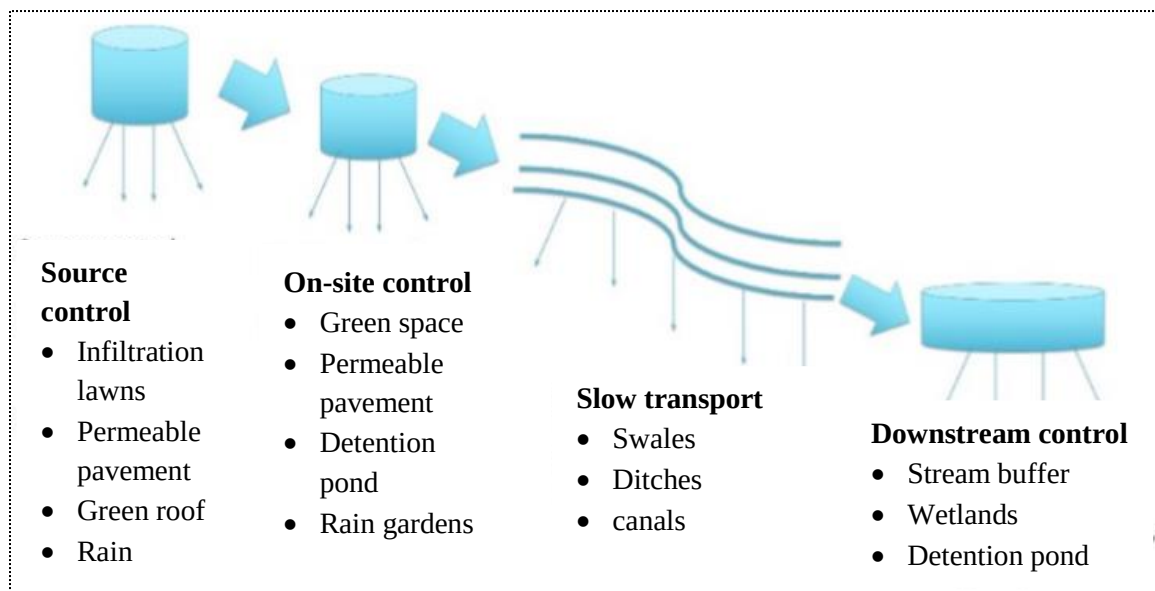


FIGURE 2.3: SUSTAINABLE URBAN STORMWATER MANAGEMENT SYSTEM IN SWEDEN
(Source: Qiao, 2019)

2.5.1. Sustainable Urban Drainage Systems

A sustainable drainage system is designed to decrease the potential effect of unused and existing improvements with regard to surface water waste releases. It is an attempt to manage both water quality and quantity in a sustainable, economically viable way. In addition the implementation of SUDS provides opportunities to provide an urban environment that is beneficial for both natural biodiversity and human populations, through the provision of new green space and the linking of habitats (Jegatheesan et al., 2019).

This can be through rain gardens (shallow landscape depressions with a shrub or herbaceous planting), swales (shallow normally-dry, wide-based ditches), filter drains (gravel-filled trench drain), bio-retention basins (shallow depressions with gravel and/or sand filtration layers beneath the growing medium), and wetland habitats that collect, store, and filter dirty water along with providing a habitat for wildlife (Sharma et al., 2008).

2.5.2. Water Sensitive Urban Design (WSUD)

It is the process of managing, protecting, and preservation of the inner-city water cycles that enhance urban stormwater management in penetrating to natural hydrological and ecological processes by integrating urban planning and design (Noordhoek, 2014 and Wong, 2014). It's a method in stormwater management for purpose cities should be economically, socially, and ecologically (Hoyer et al., 2011). WSUD elements normally have multi-functional objectives, which can include stormwater management, urban flood mitigation, (piped) drinking water

conservation, water quality improvement, and landscape amenity (Sharma et al., 2016 and Donofrio et al., 2009). It has played a vital role in reducing and controlling urban rainfall-runoff, reducing non-point source pollution, and preventing urban infighting (Zhang et al., 2018).

The aims of WSUD from a stormwater management and planning perspective are; improvement of natural water systems inside urban developments, by using retention and infiltration methods, improving the stormwater quality and decreasing stormwater runoff and peak flows through retention and detention using and minimizing impermeable areas.

2.5.3. Sustainable Urban Stormwater Management in terms of Water Sensitive Urban Design

The urban stormwater management through water sensitive urban design approaches are accordingly listed and discussed details (Sharma et al., 2016)

- a) Rainwater harvesting and reuse:-**It can be classified broadly as above ground, called tanks, and below ground called cisterns. They are the systems of harvesting rainwater from the roof and surfaces which manage stormwater runoff effectively. They are not effective in pollutant removal and not aesthetically pleasing (Demu, 2018). Even to this day, there is several traditional rainwater harvesting technologies in Ethiopia (Assefaw, 2016).
- b) Previous pavement:** - Permeable paving is used as another option for outdated impervious durable surfaces, such as streets, car parks, footpaths, and pedestrian areas. Such pavements have many benefits for stormwater management. Porous surfaces allow stormwater released slowly into the primary soil or to be filtered and then either harvested for reuse (Beecham et al., 2011).
- c) Vegetated Swales:-**It is linear vegetated drainage features that convey or store surface water. Swales have an impermeable base and therefore are designed only for water transport and downstream management or permeable for infiltration during transport (Hoyer et al., 2011).
- d) Bio retention:** - This can shallow landscaped depressions, which usually drain from below, and enhanced vegetation and filtration to remove pollution and reduce downstream runoff. This concept manages and treats runoff from frequent rainfall events. Bio retention swales are road-scale WSUD methods that storing stormwater and transmitting it into a storage facility. Then it is used to reuse and discharging it into downstream drainage systems or receiving into waters (Kazemi, 2011) Figure 2.4.

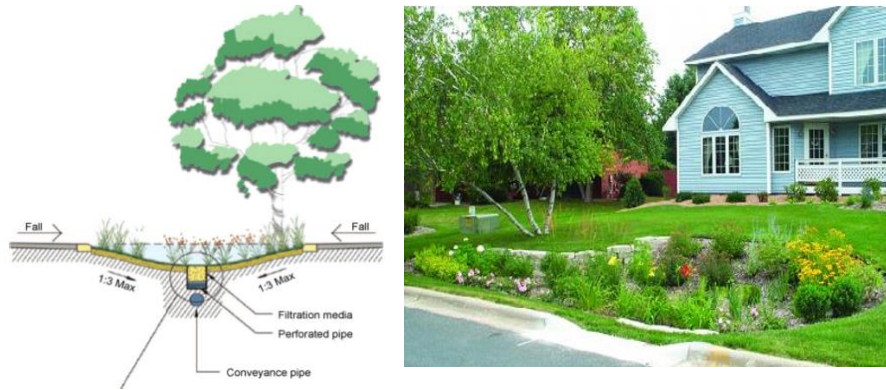


FIGURE 2.4: CROSS SECTION OF BIO RETENTION SWALE WITH GREEN SPACES

(Source, Kazemi et al., 2011)

- e) Green roof:-** Green roof is a multi-layered structure that can be designed according to the size and function of the roof (Megen, 2018). This green roof is divided into two. Extensive green roofs are lighter hardy delicious plants. Also, Intensive green roofs are heavy and thicker medium to support deep-rooted vegetation.
- f) Dry and wet detention pond:-** Detention ponds (dry) and wet can store and hold rainwater. It is surface storage basins that mitigate and hold stormwater runoff. In the wet detention ponds when water is interned into the pond, the particulates settle. Then Stormwater is gradually penetrated or drained into the extra conveyance system or water surface. Similarly, wet detention ponds can be designed to circulate water through filtration devices, such as biotopes, improving water quality as required either for downstream infiltration or in conjunction with other solutions for use in irrigation or appropriate water supply. The main difference from other methods this one constantly embraces water (Hoyer et al., 2011).



FIGURE 2.5: DETENTION POND (DRY) AND (WET) TANNER SPRINGS PARK, USA

(Source Hoyer et al., 2011)

2.5.4. Urban Design implication of the approaches

Urban designers and landscape architects, through close collaboration with it, have been possible to incorporate many water-sensitive urban design approaches into the urban form at a range of spatial scales (Wong, 2016). So, the dry and wet detention ponds can be landscaped and easily incorporated into park planning and design. However, when a pond is dry it can be utilized for recreational use. Also, bio-retention systems can be landscaped and adapted for a variety of urban spaces. It is used for recreation during dry periods and can enjoy visitors (Marsalek and Chocat, 2002).

Similarly, surface filters vegetated swale and infiltration zones can be combined into the urban design as edging along with green spaces or buildings. It is mostly designed around public and private gardens, roadside, pocket parks, driveways, sidewalks, offices, Public Park and median strips (Nassar, 2017). Additionally, green roofs increase evaporation and transpiration, curbing the heat island effect when thoroughly urban designed. When all water-sensitive urban design approaches are wisely designed, it enhances stormwater management and creates an interesting landscape that can even be utilized for recreation (Donofrio et al. 2009).

2.6. Contextual literature review

2.6.1. Urban stormwater management in developed countries

United state

In 2005, the United State city council adopted stormwater guidelines for dense, green development that apply to development projects of 10,000 square feet or more. These guidelines use vegetated stormwater management practices and integrate parking strategies that reduce the parking spaces required in the community by way of shared parking, on-street parking, and pricing strategies (National Academies Press, 2002).

These solutions encourage minimizing total impervious areas and managing stormwater onsite to prevent surface run-off. Tree preservation and planting with structured soils work well within the space constraints of parking lots, sidewalks, and dense development. Green roofs can either be extensive or intensive to manage rainfall through evapotranspiration and bio-filtration. Stormwater reuse is another creative way to manage stormwater in dense urban areas. Additional recreation and open space, as well as helping the city to be more competitive in attracting further housing and business development.

Lesson learned from case study

The United States green project shows how urban design and water management go hand in hand to create a livable sustainable settlement in the dense urban area. This project manages stormwater, adapting to local conditions such as soil permeability and vegetation cover. Swales and drains for decentralized stormwater management used to create an inspiring and attractive area with a real variety in landscaping. The stormwater is reused for irrigation gardens and non-potable water use like for toilet flush.

2.7.2 Urban stormwater management in developing countries

Ghana, Accra

An integrated urban stormwater management strategy developed around Korle Lagoon water Greenfield development planned for 130,000 inhabitants involves the integration of three sources of water supply. Treated stormwater will be reticulated to households for non-potable use, supplemented by harvested roof water for use in bathrooms, laundry, and hot water systems. The estimated reduction in mains drinkable water consumption is more than 80 percent. The strategy also includes the incorporation of swales, bio-retention systems, and constructed wetlands for the treatment of stormwater before its discharge to the receiving waters. The treatment of stormwater using constructed wetlands and subsequent aquifer storage of the treated stormwater is now well-established and has been in operation for over 5 years (Abraham et al, 2011).

Lesson learned from case study

The stormwater must be treated on-site before being released to the stream to protect the stream quality. The target of integrating waste and stormwater management is minimizing and reusing stormwater for other non-potable purposes. Sustainable rainwater harvesting has both environmental and economic advantages to the community. It also improves the water shortage of the city by encouraging the water reuse culture. The urban stormwater management integrated from the scale individual allotments and buildings, to district and regions. Sustainable stormwater management must be considered in the building and landscape design.

In conclusion, the recent fast urbanization creates the expansion of more roads, parking lots, sidewalks, and buildings; in so doing result soil surfaces change from permeable to the impermeable surface which might be created stormwater runoff. So this can have different physical, economic effects, society health effects, and environmental effects. According to the

above literature review were discussed the major causative challenges for stormwater management system in urban areas are; land-use change, decrease in impermeability of open space, lack of well-implemented urban planning, lack of maintenance of aging infrastructure, increased urban expansion, and lack of overload of drainage systems. For solving this issue integrating urban stormwater management with urban design theoretically, some methods are listed such as Green roof, detention pond both (dry and wet), rainwater harvesting, pervious pavement, and infiltration zones are analyzed with applicability in urban design.

CHAPTER THREE

3. MATERIALS AND METHODS

3.1. Introduction

This chapter of the study explains about description of the study area and the methodology that were used in the research to achieve the specified 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.

3.2. Description of the study area

Dambi-Dollo Town is one of the oldest towns in Oromia National Regional Government. The town is located at south western part of the region. It is about 652 km from the national as well as regional capital Finfinne/Addis Ababa. Dambi Dollo town is serving as the capital for both Sayo District and Kellem Wollega zone, presently the town has over 37,339 populations and covers about 4350 ha total land area (OUPI, 2011). The absolute location of the Dambi-Dollo town is roughly lies $8^{\circ} 30' 07''\text{N}$ to $8^{\circ} 46' 24''\text{N}$ latitude and $34^{\circ} 46' 06''\text{E}$ to $34^{\circ} 50' 00''\text{E}$ longitude.

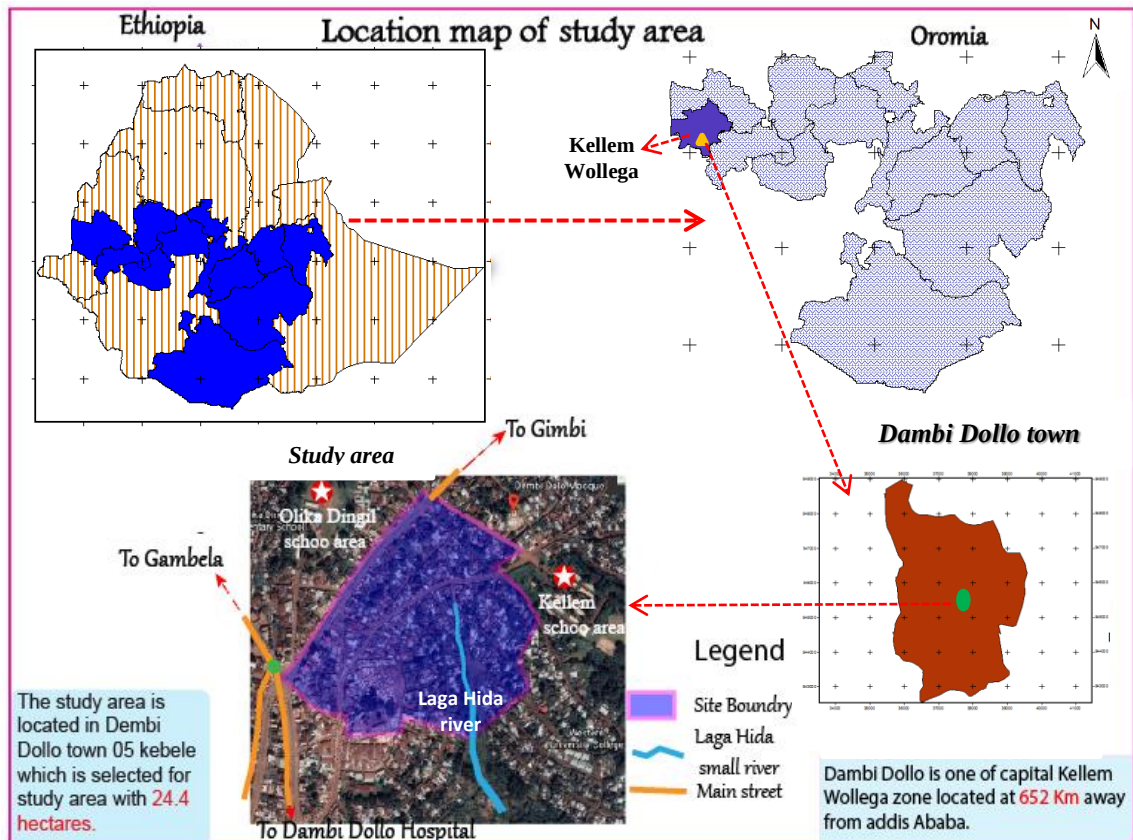


FIGURE 3.1: LOCATION MAP OF STUDY AREA RELATED TO ETHIOPIA AND OROMIA FROM MAP (2021)

Dambi-Dollo is located at south-western highland the region, it acquires rain fall for about 6-7 months. Specifically, the study area or Biftu (05) kebele is located at the northern part of the town from this the selected site is bounded between in west and north direction by main road and by east and south direction Kellem secondary school and Dambi Dollo town general market respectively (Figure:3.1).

Criteria for Selecting the Study Area: - The town gets a high proportion of rainfall per year, which creates high stormwater runoff. Therefore, the study town and specific site are selected intentionally for different reasons: first, researcher know background about the area which would serve the researcher to access to the necessary data. The second reason, there is not research work done on specifically to the study area in relation to urban stormwater management. Concerning the two cases and specifically in the selected site (Laga Hida watershed area) impact of stormwater is mostly occurred in this area through flowing to Laga Hida Small River without any controlling system.

3.3. Research Design

A research design is a plan, organization and policy of investigation so regards as to obtain answers to stated research questions or problems (Kumar, 2011). Depending on stated research problem and objectives it was used exploratory mixed-methods research design, since it is the kind of research wherein a researcher mixed both elements of qualitative and quantitative data collection and analysis in a sequence of phases (Johanson, 2017).

The qualitative research method were used to describe the challenges which can increase the stormwater runoff and effect outcomes from the study area through site observation, damaged infrastructure and properties from municipalities, as well as the others are gathered in this form. Whereas, the quantitative research method type were particularly used to clarify the existing condition by making some required built-up area by percent, drainage size and compare with standards. Also, gathering data through interviews and questionnaires from respondents and selected official experts.

3.4. Research Type

For this study, the researcher used a descriptive type of research method to describe the causes for challenges of stormwater management and its effects socially, economically, and environmentally. Descriptive research is concerned with conditions or relationships that exist, practices that prevail, points of view of attitudes that are held, effects that are being manipulated (Kothari, 1990). In addition, the descriptive research design method is advantageous and relevant

to collected details data from many respondents; it describes the reality of what actually exists within a situation with current practices.

3.5. Sampling

3.5.1. Sample Techniques

Sampling is a method of selecting a subset of individuals from within a population for study (Mcah & Ajah, 2014). The study was employing the Convenience Sampling technique from non-probability sampling to select households of the affected area. The Convenience Sample is taking when the researcher lack of any clear sample strategy depend on the study site selected and used to ease of access data (Phrasisombth, 2009). On the other hand different officials' experts and site of the damaged infrastructure were purposively included.

Before collecting data using questionnaire, preliminary visit of case sites is done by walking through roads, communicating with inhabitants and taking pictures of damaged environments and solid waste dumped in open drainage that has effect on stormwater. As part of the preliminary visit of the study site pilot test was conducted on five households from each case to test the questionnaires. After the pilot test, some corrections were done on research questions and systematic approach towards the interviewee.

3.5.2. Sample size

The study was conducted on one kebele. To make the output of the thesis convincing and reliable, the data source and method of representation had to be appropriate. To obtain reliable and manageable data, the study undertook the sample size from households those found in the study site around Laga Hida river area. However, the different respondents in the site were selected based on Convenience Sampling technique from non-probability sampling. These were conducted on seventy two (72) in number of respondents based on availability who knows the stormwater runoff effect of the area.

Also, for pilot study 5 respondents are selected before collecting the data, totally 77 respondents are interviewed by using questionnaires'.

3.6. Data Types and Sources

In this study both primary and secondary data were used.

- i. Primary Data:-**The primary data were collected from the selected community lives in selected site those affected by problem stormwater runoff study area. In addition, observation and

physical study were conducted using check list and camera to get photo of the physical features.

ii. Secondary Data:-For the study secondary data sources, such as various journals, articles, relevant research papers, Google maps, maps, books and other significant documents were used. Moreover, secondary data like different manuals, photographs and stormwater management related documents were also used for the study.

3.7. Data collection method

Data were collected from both primary and secondary data sources focusing on both qualitative and quantitative data. The data collection mechanisms are conceived and prepared with their proper procedures. The quality of data collected is foundational to the validity of study findings (Tavakol et al. 2006).

3.7.1. Primary Data collection method

Primary data sources contain both qualitative and quantitative data. Primary data comprise interview, site observation and questionnaires, while that of quantitative data sources is survey questionnaires and interview questionnaires. So the following sections explain how the data were gathered from the primary data sources.

a) Site observation

Site observation is the important method in research working to get real information about concerning issues. This method is also important to see the impacts of stormwater runoff on the natural or built environment (streets) and communities. Observation checklist were used, and pictures was also taken in the site to show that some of the physical problems in the site.

b) Questionnaires

It is intended collect primary data from residents of the study area. One of their aims is to evaluate the current stormwater and rain flooding impacts, to identify the major challenges to increasing of stormwater problems and enhance proposed strategies to reduce impacts. On these two type questions, which are closed ended and open-ended questions, were used in the questionnaire that is, closed ended questions include: - sex, frequency of stormwater, damaged amounts, and stormwater effect economically. Open ended questionnaires include:- age, different challenges of stormwater management, effect of stormwater socially, and environmentally.

c) Interview

Interview is designed to obtain the existing problem in-depth knowledge or perspective on a topic. It is useful for investigating an individual's viewpoint, understanding, feelings,

experiences and perspectives of an issue. Also, questions were prepared guide on impacts and challenges to increasing stormwater and rain flooding problems. The key informants of these research interviews are community around issues. These interviews were done to collect specific data which need more clarifications and explanations. The interview sources were arranged for five different organization experts. The following Table 2 shows that detail of interviewee's position in the organization and number.

Table 1.2: Name of the organization (Officials and Experts) with their position

No	Name of organization	Number	Position
1	Dambi Dollo town beautification and greenery office	1	Experts of urban planning or planner
2	Dambi Dollo town disaster risk management offices	1	Manager
3	Dambi Dollo town physical infrastructure office	1	Surveyor
4	Dambi Dollo town health office	1	Environmental Health
5	Dambi Dollo town municipality	1	Planner

(Source: Author, 2021)

3.7.2. Secondary data collection Method

The secondary data such as manuals, different official reports, and photograph were collected from:- Dambi Dollo town beautification and greenery office, Disaster Risk management office, Dambi Dollo town physical infrastructure office, Dambi Dollo town health office.

3.8. Data Analysis Method

The data collected from several sources were analyzed by 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 by using qualitatively and quantitatively.

The data that are collected to investigate the effects of stormwater on natural and built environments were analyzed quantitatively by using SPSS software and data about challenges for stormwater management were analyzed and interpreted by using photographs (plats). And different spatial analysis data, such as land use of the area, topographic analysis, built up areas and others analyses were performed by GIS (Geographical information system), AUTOCAD, ARCHI CAD, adobe illustrator and Photoshop software are analytical tools. Finally, the analyzed data were presentation using bar graph, tables, charts, figures, plans/maps and visual photograph accompanied by textual discussions and interpreted.

CHAPTER FOUR

4. RESULT AND DISCUSSION

This chapter is the main part of the research in which the results of the study along with its interpretation and discussion were presented.

4.1. Demography and Socio-economic characteristics of the Respondents

This part deals with socio-demographic characteristics of the respondents in sex, age, educational level, marital status, and family size. In sex distribution, the below table indicates that about 52.8% of the respondents were male while the remaining 47.2% were female.

Table 4.1: Major characteristics of the respondents

Variables		Frequency	%
Sex	Male	38	52.8
	Female	34	47.2
	Total	72	100
Age	21-24	10	13.9
	25-54	46	63.9
	55-64	11	15.3
	65 and above	5	6.9
	Total	72	100
Marital status	Married	65	87.4
	Single	4	5.6
	Widower	2	2.8
	Divorced	1	1.4
	Separate	2	2.8
	Total	72	100
Education level	Illiterate and 1-8	21	29.1
	9-12	22	30.5
	Diploma	11	15.3
	Tvet	12	16.7
	1 st degree and above	6	8.4
	Total	72	100
Family size	1-5	39	54.1
	6-8	24	33.4
	9-10	9	12.5
	Total	72	100

(Sources: Field survey, 2021)

Also, the age of the respondents was categorized in to (21-24) 13.9%, (25-54) 63.9%, (55-64) 15.3%, those 65 and above years 6.9% (Table:4.1). The proportion of the respondents

significantly was within 25-54 years and 55-64 years that account for 63.9% and 15.3% respectively. The table also shows almost about 6.9% of the respondents 65 and above years old due to that they may be vulnerable to stormwater runoff through there is not active economically and lack of force.

The main implication of the educational level survey, as indicated in Table 4.1, was that the majority of respondents could read and write. This can demonstrate that when the stormwater impact happens, they aid in risk reduction and adaptation measures, as well as when stormwater management measures are implemented, by giving technical support and raising awareness among the area's illiterate residents.

The same Table: 4.1, also indicates that the majority of the respondents were married (87.4%), followed by widowers (2.8%), divorced (1.4%), separated (2.8%), and single (5.6%). Concerning the family size of the households of the study area, over 54.1% of the respondents have between one and five residing in the household, 33.4% of the respondents were had between six and eight and 12.5% of the respondents were having between nine and ten individuals. Each household respondents have a minimum of one and a maximum of ten members with an average family size of 6 per household, this implication is used to know how the large family size is affected highly during stormwater runoff occurs.

As discussed by Jha et al., (2011) the demographics and socio-economic of populations affect the ability to survive after urban stormwater runoff and flooding events. So, the age of people category will measure age vulnerability group, also <25 young groups they protect their settlements from disaster risk (Dewi, 2007). Education level measures perceive of events and lack of awareness on issues coping mechanism, sex ratio measures vulnerable population like a female (Parkinson, 2003), household size that is persons per household and this shall measure their capacity to survive in events, number of dependents per person, number of persons with disability in a given household, expenditure per person (Bansal et al. 2015).

4.2. Factors influencing stormwater in Laga Hida river area

To understand the factor that affects the stormwater occurrences in the Laga Hida river area, the Federal Meteorological services agency of the Dambi Dollo branch were visited. Hence, temperature and rainfall data were collected. It is also used to know the climate variability in general, and temperature and rainfall can have an effect on the occurrence of stormwater that can be described underneath specifically that can affect the amount of evaporation aspect of the area.

a) Temperature:-Temperature can specifically affect the amount of evaporation aspect of the area. In the study areas, according to the data from the Federal Meteorological Services agency of the Dambi Dollo branch (2020), in the Dambi Dollo town, the highest and the lowest mean minimum annual temperature of the town is about 14.69 and 10.75 degree Celsius respectively. The mean minimum temperature is high all the year. This can use to analysis the amount of rain in this area that can influence the stormwater effects. On the other hand, the monthly maximum temperature that has been recorded from 2011-2020 data of ten years shows that the town gets a high amount of temperature all round year. In line with this World Meteorological Organization report, (2012) indicated temperature increasing will lead to an increasingly rainfall patterns changing and storm tracks, which can also increase stormwater runoff risk. Therefore, the highest and the lowest average monthly temperature were seen in March and July within ten years of the area, and it is about 28.68^oc and 22.37^oc respectively (Figure: 4.1).

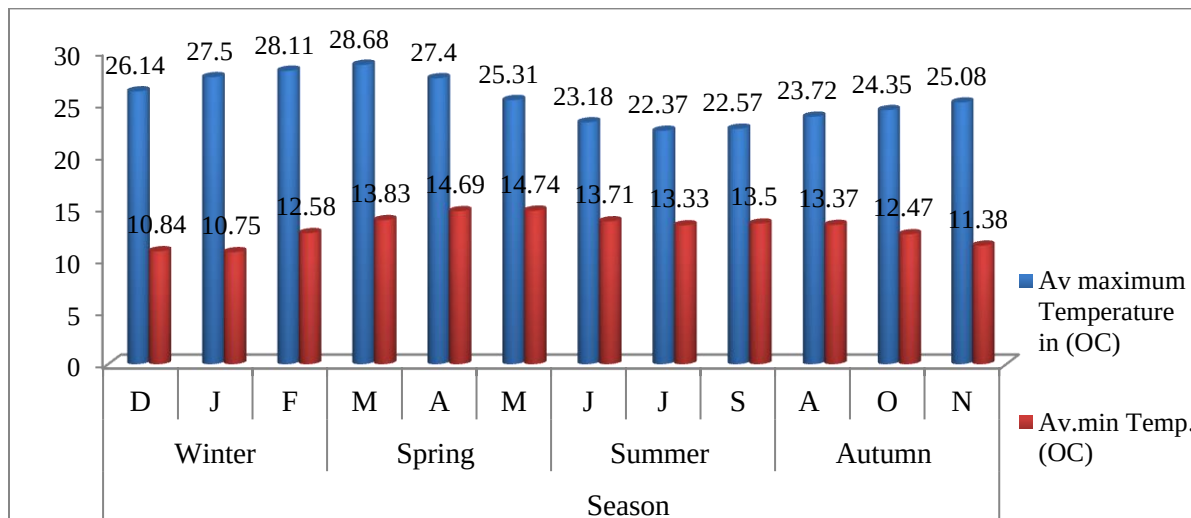


FIGURE 4.1: MEAN MAXIMUM AND MINIMUM TEMPERATURE OF DAMBI DOLLO TOWN (2011-2020) (Source: Federal Meteorological agency Dambi Dollo town branch, 2021)

b) Rain fall:-To calculate the amount of runoff volume generated from each plot per year, month, or daily the rainfall data of the area has great value (Pazwash, 2011). Depending on that, the Dambi Dollo town annual rainfall of the station has taken as input data to understand how stormwater volume has occurred in the study area.

So, the distribution of rainfall in the town was not equal in all years (2011-2020). According to the data obtained from the Federal Meteorological services agency of the Dambi Dollo branch (2021), the annual rainfall of the station for the past ten years was about 1240.38 mm. The highest and the lowest mean monthly rainfall in the station were about 204.8 mm and 9.73 mm

respectively (Figure: 4.2).

According to the national rainfall distribution of the country, these areas have high rainfall throughout the year (OUPI, 2011). As it is indicated on Bansal et al.(2015) study, Dehradun city received high rainfalls in each year but the city is not ready to drain the stormwater. Due to this the increase in surface runoff has been affecting urban environments every year.

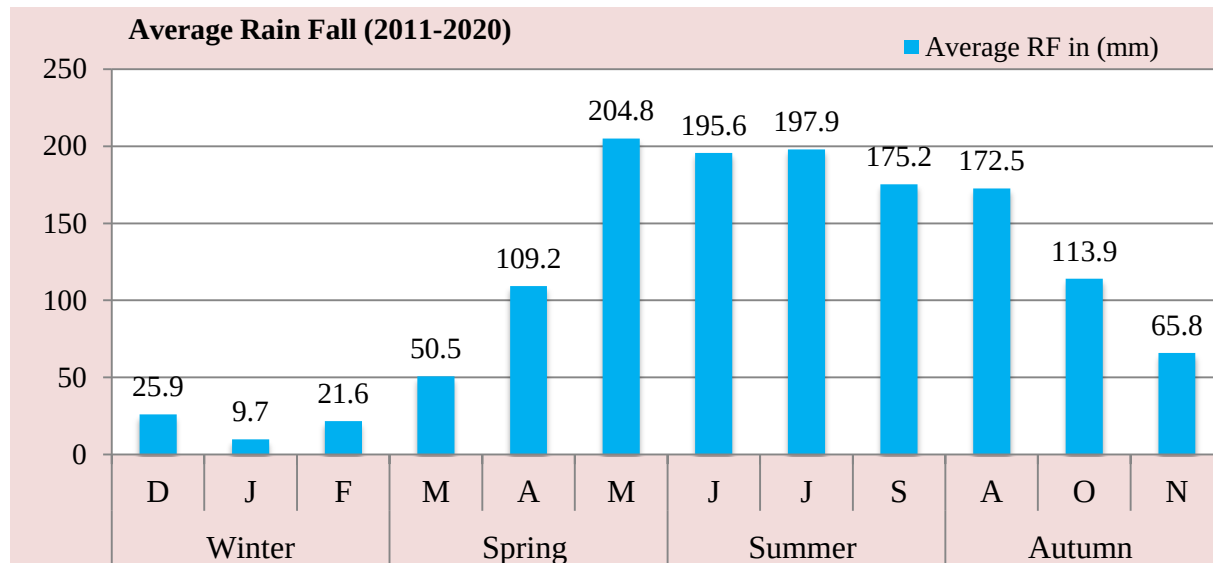


FIGURE 4.2: MONTHLY AVERAGE RAINFALL VARIATIONS OF DAMBI DOLLO TOWN 10 YEARS (Source: Federal Meteorological agency Dambi Dollo town branch, 2021)

Rain Fall Intensity of Dambi Dollo town:- So far rainfall intensity defined as the amount of rain per unit of time in a given time. Annual Rain Fall Intensity (ARFI) is calculated as the total annual rainfall in a year divided by rainy days. In the year between 2011 and 2020, the highest intensity of rainfall in Dambi Dollo town was about 11.2 and it was seen in 2018. The average intensity of annual rainfall that the town got for the last ten years was about 7.8 mm per minute. In general, the possibility of high rainfall intensity in the town may result from high annual rainfall occurred in a short period of time that influence amount of stormwater runoff the area.

4.3. Effect of stormwater Laga Hida river area

4.3.1. Risk of stormwater

The finding related to the effects or risks to stormwater in the Dambi Dollo town Laga Hida river area is measured by effect framework compositions. The compositions of the framework include the general effects of stormwater on society health, physical infrastructure, natural and built environments. This can show effects of stormwater runoff overflow the drainage that can damage the environment.

As indicated in Figure: 4.3, the majority of respondents said that the effect of stormwater runoff is a very serious issue in the study area. Of the total 44.4% of the respondent reported that a stormwater effect is very serious while another 38.9% of respondents are said it is serious, 13.8% of the respondents are said it is serious and a few of them not responded. According to Mezgebe (2009) stormwater runoff can jeopardize private and public infrastructure, damage urban environments and erode stream banks by increased flooding. Therefore, in the study area stormwater runoff have an effect on the community because the responsible body does not provide attention on distressing consequences and its effects on the economy, environment, society health, different infrastructure and people.

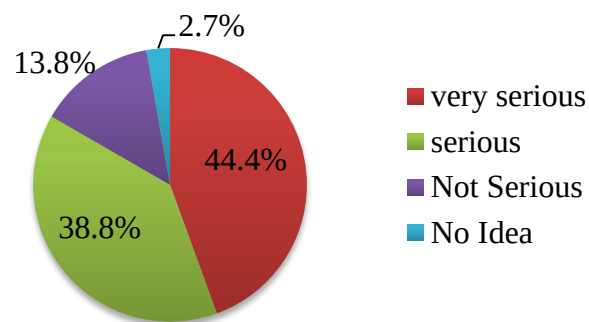


FIGURE 4.3: THE RATE EXTENTS OF STORMWATER EFFECTS (Source: Field survey, 2021)

4.3.2. Effects of stormwater on physical infrastructure

Heavy rains not only affect the environment but severely damage the urban infrastructure like roads, electric poles, and disrupt services such as water supply and drainage lines temporarily. The extent of infrastructure damage that is caused due to the overflow of stormwater is very high in the study area. It confirmed by the physical observation and interview that the effect of stormwater runoff is very high especially in the study area due to the constructed drainage infrastructure is below standard and deteriorated state (Figure: 4.4).



FIGURE 4.4: DETERIORATED AND BELOW STANDARD CONSTRUCTED DRAINAGE (Source: Field survey, 2021)

As shown in Figure: 4.5, 31.9% of the respondent for each reported that the drainage system and road network have been affected by the stormwater and t. It is also reported that 4.2% and 8.3 % of respondents' stormwater affect water supply and electricity respectively. Moreover, 23.6% of the respondent mentioned that all infrastructures are affected by the storm. This implies that stormwater affects different physical infrastructures. Similarly, Jegatheesan et al. (2019) stated stormwater has resulted in physical damage such as erosion and floods of different scales that can adversely affect the urban physical infrastructure such as roads, water lines and drainage systems.

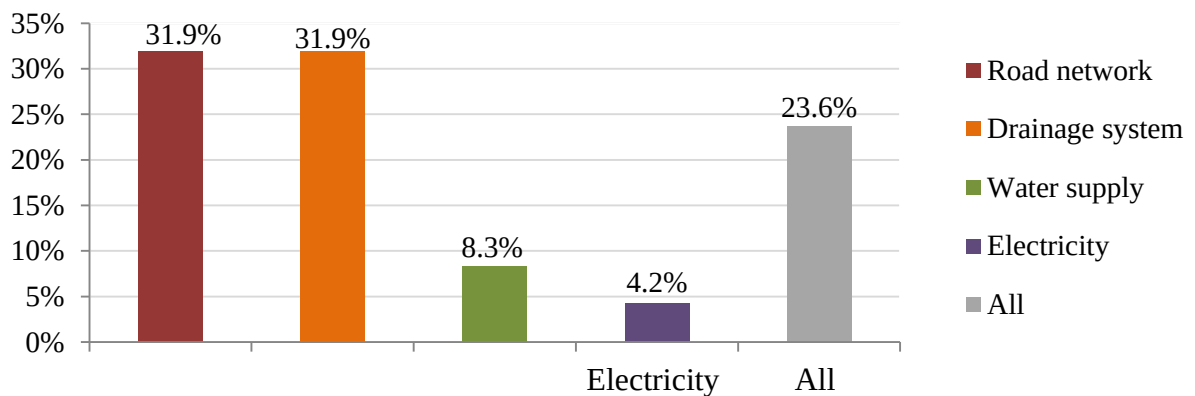


FIGURE 4.5: PHYSICAL INFRASTRUCTURE DAMAGED BY STORMWATER RUNOFF

(Source: Field survey, 2021)

There was also evidence that stormwater damage the physical infrastructure of Dambi Dollo town. An incident of stormwater followed by heavy rains disrupted normal life by damaging electricity wires, disturbing water supply, blocking the roads and drainage system, and damaging properties (Figure:4.6).



FIGURE 4.6: AFFECTED DRAINAGE SYSTEM AND STREET BY STORMWATER EFFECTS

(Source: Field survey, 2021)

4.3.3.Effects of stormwater on urban environments

In the study area, the environments are suffering from the occurrence of stormwater runoff hazards. Solid waste materials and other hazardous substances end up in the existing Laga Hida River and eventually contaminate these water bodies that flood end up in the study area. As explained by Saraswat et al, (2016) the unmanageable stormwater runoff has current ecosystem related problems and a degraded environment in urban areas due to changes in the hydrology of Streams and the quality of runoff.

Table: 4 and Figure: 4.7 show that the major effects of stormwater runoff on the physical environments. Hence, 20.8% and 25.0% of the respondents decided that land degradation due to topography of the area and solid waste pollution that spilled by residents onto street and open drainage, 18.1% of the respondents agreed that existing river pollution through flow into it. These are the major effects of stormwater on the physical environments. These result in drainage deficiencies and impact the proper stormwater management methods. From this result seasonal stormwater runoff can be higher in the study. During rainfall, raindrops transport along higher urban runoff with various solid waste elements and pollutants attached to urban surface that affect quality of environments (Yannopoulos et al., 2013).

Table 4.2: The affected environments due stormwater runoff effect

Affected Environmental type	Frequency	Percent	Cumulative Percent
Land degradation	15	20.8	20.8
Solid waste pollution	18	25.0	45.8
Existing river pollution	13	18.1	63.9
Destroying Vegetation	8	11.1	75.0
All	18	25.0	100.0
Total	72	100.0	

(Source: Field survey, 2021)



FIGURE 4.7: SOLID WASTE SPREADER AND DESTROYED VEGETATION BY STORMWATER RUNOFF (Source: Field survey, 2021)

Similarly, one of the environmental effects of stormwater runoff in the study area is land degradations. It is also reported in Table: 4.2, by 20.8% of the respondent that degradation of land has contribution towards stormwater. When stormwater flooding becomes a hazard and potentially it washes the top covering soil and forms deep gully, gradually soil down the slope of the land cracks during the dry season due to the sunshine whereas it starts to widen immediately at the time of rain season. These combination results in topsoil parts washed away by running water which maximizes the soil erosion of the area. Here the soil type of the study area is Cambisols and Nitosols that are easily erodible by stormwater runoff causing gorges that then leads to land degradation. According to (Haile and Worku, 2018) the occurrences of land degradation are due to geographical location, soil type, topography, and rainfall pattern of the area watershed. Therefore, the study area nearby the Laga Hida river area is triggered by this problem due to the topography and rainfall distribution of the area (Figure: 4.8).



FIGURE 4.8: LAND DEGRADATION AROUND THE LAGA HIDA RIVER THROUGH STORMWATER EVENTS (Source: Field survey, 2021)

4.3.4. Effects stormwater on natural water ways of Laga Hida River

One of the main effects of stormwater is polluting or damaging the existing urban water bodies. As it has been indicated in Table 4.3, the general problems in the Laga Hida natural waterways/rivers in the study area as indicated by 43.1% of the residents are that it is damaged due to all issues like blockage by solid wastes, encroached by residents, the connection of drainage stormwater to the river and have a not regular buffer. Similarly, 19.4% and 18.1% of them agreed it is damaged because of the connection of the stormwater drain to the river and blocked by solid waste. Also, 5.6% and 13.9% replied it is damaged due to encroached by residents and a lack of regular buffers along the river.

Table 4.3: The existing problems in and around Laga Hida River in Laga Hida river area

Existing problems around Laga Hida river	Frequency	Percent	Cumulative Percent
Encroached by residents	4	5.6	5.6
Blocked by solid waste	13	18.1	23.6
Connection of the stormwater drain to the river	14	19.4	43.1
Lack of regular buffer	10	13.9	56.9
All	31	43.1	100.0
Total	72	100.0	

(Source: Field survey, 2021)

The implication of these can realize that the stormwater runoff in this town can transport the different solid waste and polluted material from the entire town into the Laga Hida river through existing connected drainage line into the river which can pollute or affect the existing river quality or environment (Figure:4.9).



FIGURE 4.9: THE DRAINAGE CONNECTED TO THE RIVER AND BLOCKED BY SOLID WASTE

(Source: Field survey, 2021)

4.3.5. Effects of stormwater on economy

The effects of stormwater runoff in terms of the economy are analyzed through to physical damage on the study area. One of the stormwater runoff impacts is the creation of stress on the existing infrastructure (Mezgebe, 2009). The interview with different experts of Dambi Dollo town municipality reported that the stormwater runoff of the study area had different effects on the urban economy, through degrading different infrastructure due to deficiency of storm drainage system and poor stormwater management. Also, they described the annual budget for drainage cleaning and road maintenance as increasing from year to year. And it has come at a

heavy cost to both societies and the local government, in 2020 each year 75,215 ETB for cleaning of the clogged drainage along the main street by various solid and liquid wastes.

Similarly, 2.2 million ETB for the construction of a culvert structure that connects stormwater and flooding into the Laga Hida River, as well as road maintenance. Also, during 2019 around Laga Hida river 11 houses were affected through stormwater. It had entered in their houses and damages their property. This can shows that the town administration and issues related experts should give better attention and find better solution for the future stormwater management of the town.

4.3.6. Effects of stormwater on society health

In this area, the situation with respect to society health issues turns worse during the rains with overflowing drains spreading the high amount onto the roads.

According to household survey for this study area, more than half of the respondents (54.2%) of them respond strongly agree on the effect of stormwater on social health, 19.4% of the respondents had agreed on the effect of stormwater on social health, and the left respondents 15.3%, 5.6% and 5.5% are given neutral, disagree and strongly disagree respectively (Figure 4.10). Those respondents who do not agreed to the health effect of stormwater are the communities those lived around the main street that they get daily cleaning services by municipality. The urban runoff in poorly drained areas with inadequate sanitation increases the risks of different waterborne diseases on the health of residents (Parkinson, 2003).

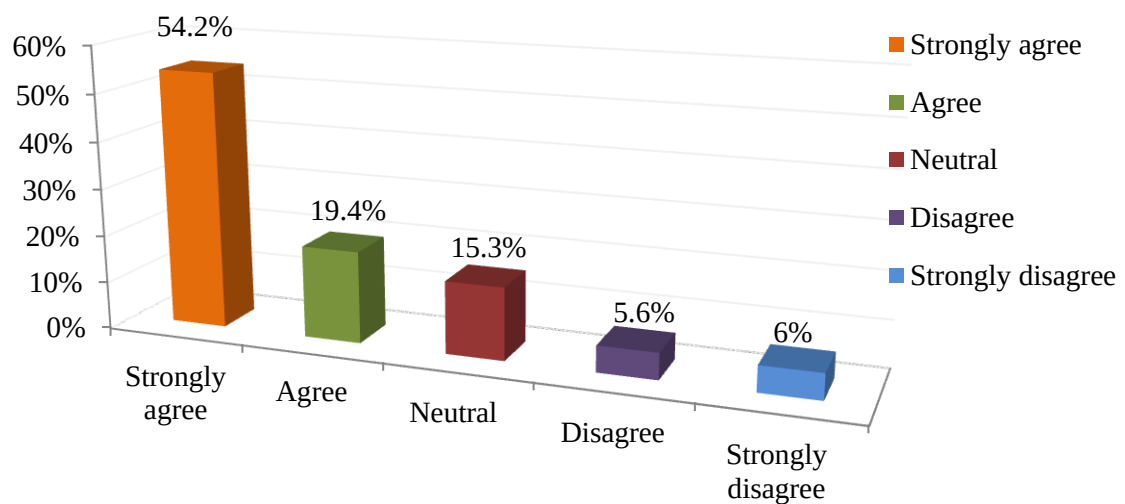


FIGURE 4.10: RESIDENTS OPINION RELATED TO STORMWATER EFFECT ON SOCIAL HEALTH (Source: Field survey, 2021)

The interview from Dambi Dollo town health office shows that communicable disease is one of the cases, which is reported from the area due to the stormwater stored on the street and garbage that spilled from residents. The cases are; Typhoid, Malaria, Helminthiasis, Ambebiasis, Giardia, respiratory tract infections, and skin infections are some of the major. And also different mosquitoes are spreading from the Laga Hida River and snatching the residents of surrounding that area during the night. But still, even a day in these areas can cause a great deal of health damage.

Also, the Environmental health expert in the Health office of the Dambi Dollo town expressed his concern over the fact that garbage generated in that area due to market area, the solid waste per day is very high and the other is through community lack of awareness spilled in the open ditch which into drains ultimately Laga Hida river (Figure: 4.11).



FIGURE 4.11: SOLID WASTE DISPOSED AROUND THE RIVER AND IN OPEN DITCH WHICH AFFECT SOCIAL HEALTH (Source: Field survey, 2021)

Generally, the finding in relation to society health effects of seasonal stormwater runoff in the study area had examined more on effects associated with seasonal disease epidemics occurred after stormwater events like water borne diseases.

4.4. Challenges of stormwater management system in the study area

The major causative challenges of urban stormwater management system problems that result in stormwater runoff effect in the Laga Hida river area have been asked. The respondent reported that in the area about 31.9%, 22.2% and 19.5% of them respectively replied that inadequate urban stormwater management system, rough topography, and lack of stormwater drainage maintenance are the major challenges in the study area. Also, 12.5% of the respondents replied due to the land-use change of the town (urbanization), and 11.1% of the respondents respond high percent of impervious surfaces like roofs, asphalt streets, parking lots, and others (Table:4.4).

Furthermore, from site observation and the respondent's response, urban stormwater management system of the study area is very weak. The topography is also very rough due to that all stormwater runoff in this town and the study area generally flows into Laga Hida River without any mitigation. Similarly, an inadequate urban stormwater management system exists in the area. According to interview from the municipality stated that due to different factors; like institutionally; lack of stormwater-related policy and stakeholder invitation on a stormwater management issue, technically; lack of experts that prepare stormwater management method and socially; lack of community awareness on how they involve and its function of stormwater management is the major. However, the land-use changes (from green land to urbanized area) and impervious area increases of the study area are also the major challenges to the stormwater management system of the area.

Table 4.4: The major challenges which can increase the stormwater effect in Laga Hida river area.

Major challenges	Frequency	Percent
High percent of impervious surface	8	11.1
Land use change/Urbanization	9	12.5
Inadequate urban stormwater management system	24	33.3
Lack of stormwater drainage maintenance	14	19.4
Rough topography	15	20.8
All	2	2.8
Total	72	100.0

(Source:Field survey, 2021)

The residents were also interviewed regarding the major challenges for the provision of urban stormwater management systems in the study area. Accordingly, 43.1%, 26.4% and 16.6% of them respectively responded that urban plan and design implementation problems, shortage of stormwater management experts in the municipality, and with lack of community awareness how to manage stormwater and 13.9% agreed the shortage of budget is the major challenges for the provision of urban stormwater management system in Dambi Dollo town also, Laga Hida river area (Figure: 4.12).

According to the physical observation that was made during fieldwork, there is a lack of proper stormwater management structure provision and maintenance along the study area's various

streets, indicating the existence of stormwater management system challenges. It is caused to the town municipality's mismanagement or a lack of experts and adequate stormwater management. In line with this, the study conducted by (Hoyer et al., 2006) decentralized stormwater management can provide solutions for stormwater runoff management, when planning is done in interdisciplinary collaboration of experts of water management, urban design and landscape planning, and also with community involvement. Similarly, a lack of funding, particularly for stormwater management that is paid for this to municipalities, is a major challenge. According to Qiao et al. (2018), the municipality does not receive any additional subsidies from the federal government. It is usually applied own budgets that gather in the form of various taxes. This is insufficient to overcome all of the town's problems.

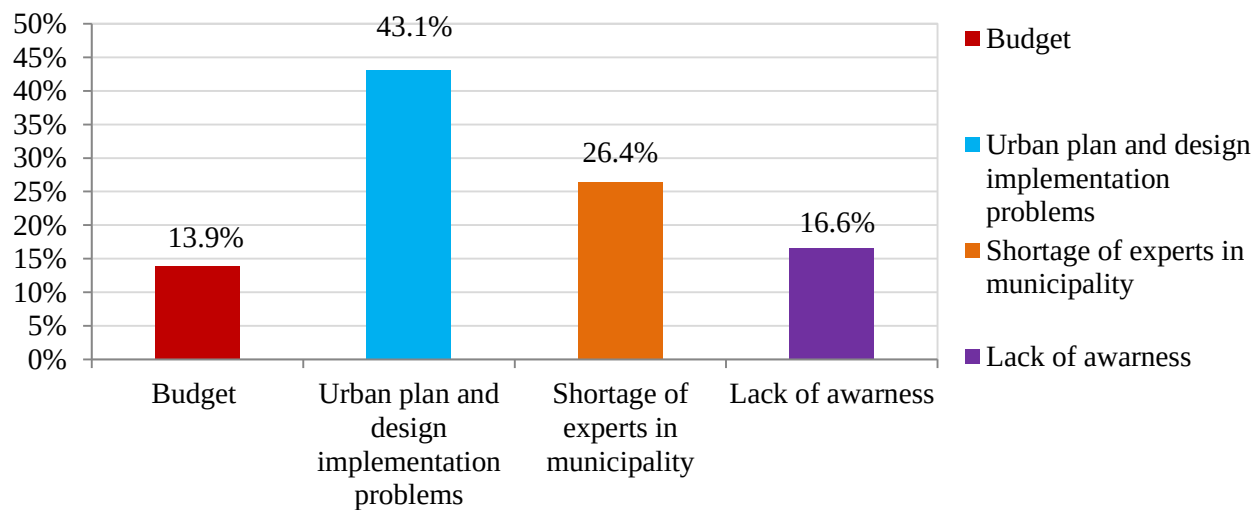


FIGURE 4.12: MAJOR CHALLENGES IN THE PROVISION OF URBAN STORMWATER MANAGEMENT SYSTEM IN LAGA HIDA RIVER AREA. (Source: Field survey, 2021)

Interview was conducted with Dambi Dollo town municipality Greenery and Beautification office experts about the challenges of stormwater management system in this town and the study area. Accordingly, the experts mentioned, there are lack implementation of the urban plan. The main reason is overcrowd of the settlements or lack of space. This resulted in the difficulty to implement green space and different landscape area that used to infiltrate the stormwater directly into ground. Moreover, respondents were also asked on this issue and most of them responded that absence of greenery space in their block are exposing to them different problem like stormwater runoff effects.

As stated on the Figure: 4.13, the households were asked whether the roads have a standardized drainage system or structures to pass stormwater runoff through or not. Accordingly, the

majority of the households (91.7%) of them stated that most streets do not have standardized ditch or drainage at the necessary sites while (8.3%) of them replied there is a standardize ditch or drainage. Standardized urban drainage challenge in urban areas has been frequent occurrences of urban flooding (Fanta, et al., 2020).

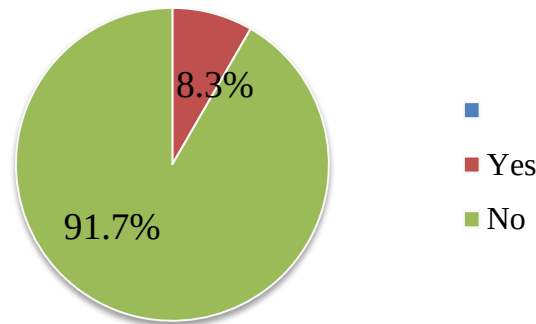


FIGURE 4.13: STANDARDIZED DRAINAGE AVAILABILITY (Source: Field survey, 2021)

Additionally, different experts of Dambi Dollo town municipality were asked and confirmed that most of the study area roads lack of standardized drainage. It is due to lack of careful attention during the design and construction of the roads by the concerned bodies is the major cause for this problem mentioned in the interview. According to Adugna, (2011) in an urban center to defend stormwater runoff damage, standardized drainage infrastructure and utilities that consider different local environments are critical. The design and implementation process will also require the experts, different stakeholders and community involvement.

4.5. Propose strategies for Sustainable urban stormwater management system for the study area

4.5.1. Strategies for stormwater management

In relation to the responsible bodies for managing stormwater risk-related issues in the study area, experts from Dambi Dollo town municipality were interviewed, they respond the design of the study area which is the Laga Hida river area specifically around the Laga Hida river stormwater management is in progress with standardized drainage and culvert structure design and implement the design with the budget allocated through the municipality and other non-governmental bodies.

Respondents were asked about the success of the stormwater management method at present and the past to report into four categories, successful, less successful, not successful, and no idea. Accordingly, 56.9% of the respondent's responses to stormwater runoff management taken were not successful, 29.2% of the respondent's responses less successful and 7% responses successful (Figure: 4.14). The implication of this is the stormwater management taken in the study area is

not successful due to the lack of current sustainable stormwater management methods. As explained by Zhang et al., (2018) contemporary alternative solutions to manage stormwater in a sustainable way, resulting in concepts and technologies, such as; low impact development, water sensitive urban design, and sustainable urban drainage systems.

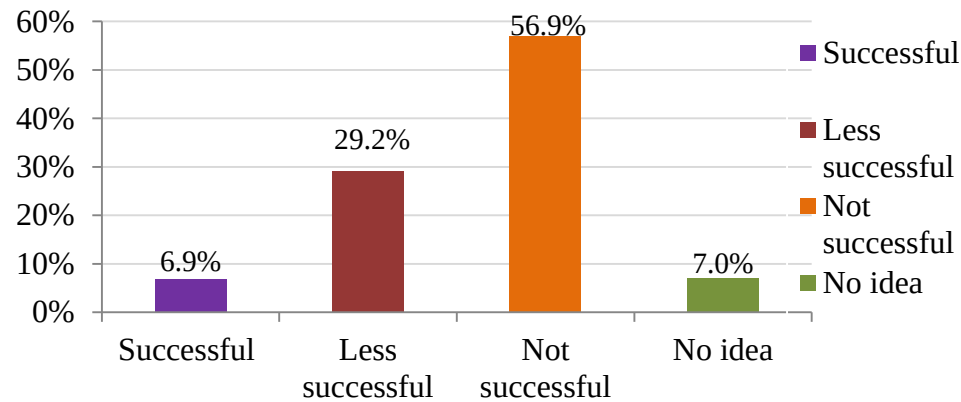


FIGURE 4.14: SUCCESS OF STORMWATER MANAGEMENT (Source: Field survey, 2021)

Regarding temporary solution that was taken to manage stormwater in the study area in the last periods, different of the Dambi Dollo town municipality staffs interviewed informed us that the actions were undertaken to aware the residents to keep drainages clean and not to use them as a refuse dump sites as a temporary solution in the site but most of the societies are not applied. However, few of them also responded that their institution does not have a detailed plan for the next few years to renew or repair aging drainage, roads and others in the Laga Hida river area.

Table: 4.5, shows 30.6%, 27.8%, 18.1%, and 11.1% replied cleaning drainage channels, earth embankments, using gravel covering, and constructing new stormwater drainage facilities respectively have been undertaken as temporary solutions to manage stormwater runoff problem in their neighborhoods and residents in the study area.

Table 4.5: Temporary solutions before taken to Stormwater management in Laga Hida river area.

Temporary solution have been taken	Frequency	Percent	Cumulative Percent
Cleaning drainage channels	22	30.6	30.6
Using gravel covering	13	18.1	48.6
Constructing new urban stormwater drainage facilities	8	11.1	59.7
Earth embankments	20	27.8	87.5
Planting different vegetation	4	5.6	93.1
Not taken	5	6.9	100.0
Total	72	100.0	

(Source: Field survey, 2021)

Figure: 4.15, shows that the most action taken to manage stormwater is drainage cleaning. The closed ditch is opened and cleaned by human force and a dozer. However, the opened drainage on that day is not closed up to now this can affect the visual quality of the town and environments.



FIGURE 4.15: TEMPORARY SOLUTION BEFORE TAKEN CLEANING DRAINAGE CHANNELS
(Source: Dambi Dollo town municipality, 2020)

4.5.2.Type of sustainable urban stormwater management strategies required in the study area

Figure: 4.16, shows that 38.8% of respondents all stormwater management systems, whereas on-site control and downstream control systems have been applied by 20.8% and 15.3% respectively. Source control on private land & slow transport (12.5%) through a ditch or permeable pavement can mitigate urban stormwater runoff in the way along the street and in a different block. These responses on the stormwater management system that is applied by respondents helped to protect themselves from the damage that has happened due to poor stormwater management. In line with this, Qiao (2019) discussed sustainable stormwater management solutions in order to protect the community, the environment, and the infrastructure, these are; i) source control, ii) onsite control (both are small-scale such as green roofs, rain gardens. iii) slow transport using swales and ditches iv) downstream control using large-scale facilities are the major.

This can show the sustainable urban stormwater management method needed for the discussed issue is recommended by most respondents to a very high extent.

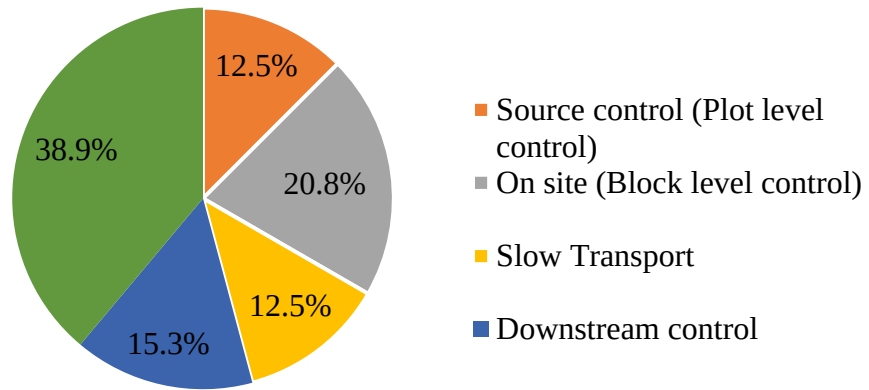


FIGURE: 4.16 SUSTAINABLE URBAN STORMWATER MANAGEMENT SYSTEMS IN LAGA HIDA RIVER AREA. (Source: Field survey, 2021)

4.5.3. Physical Site Analysis

4.5.3.1. Topographic analysis of the study area

i. Elevation map:-The elevation map shows the different levels of the natural landform in different heights above sea level in meters. The study area is located with a minimum elevation of 1806m and a maximum elevation of 1854m above sea level. As explained by Tesema et al. (2017) stormwater always gathered at cells with lower elevation. Therefore, the high elevation area is around Main Street or Sif cafe with 1854m. So, the stormwater directly flows towards the Laga Hida River that area has a small elevation of 1806m (Figure: 4.17).

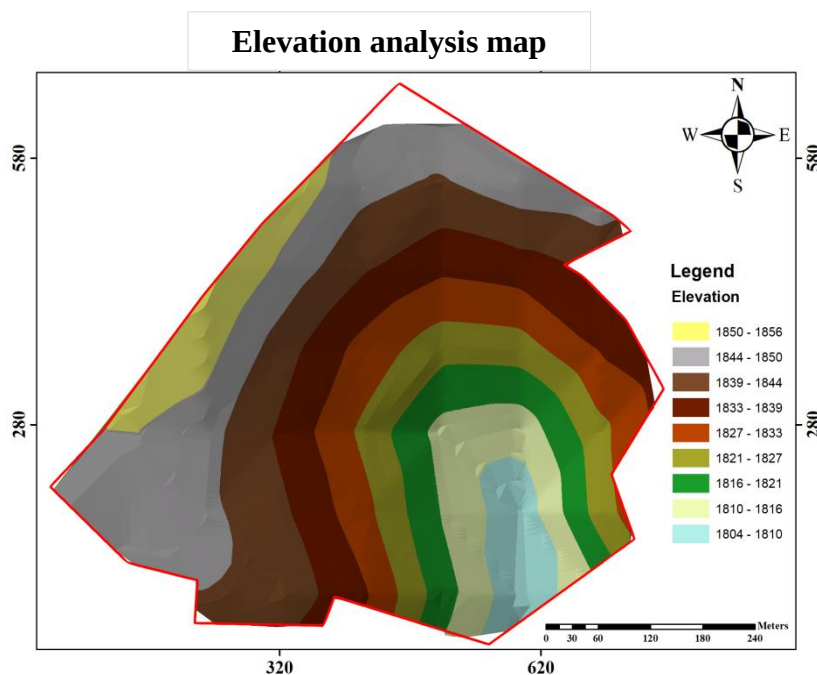


FIGURE 4.17: ELEVATION ANALYSIS MAP OF THE STUDY AREA (Source: Author, 2021)

ii. Slope analysis map

The slope of the land surface varies from place to place because of the landform variety of the area. Slope analysis is useful for knowing in what direction stormwater are flows for stagnation and it make environmental damage. Jin et al., (2015) stated that assessment of slope suitability has great significance to classify land use categories to ensure orderly development to minimize environmental disturbance and destruction.

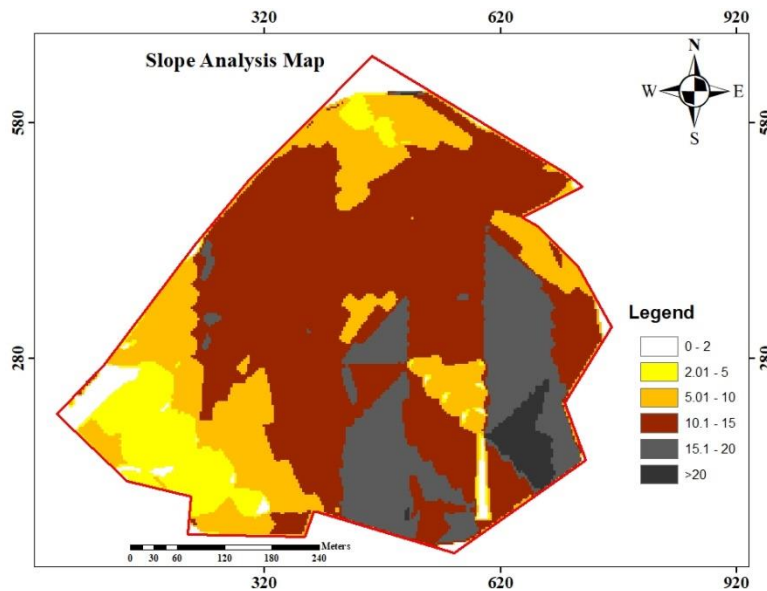


FIGURE 4.18: SLOPE CATEGORY OF THE STUDY AREA (Source: Author, 2021)

As shown in Table 4.6 and Figure 4.17, the slope of the study area is categorized refereeing standard from (Structure Plan Manual report, 2012). The highest slope range of the area is found between 5.01-10 (20.4%) and 10.01-15 (51.1%) respectively. According to the manual, the area (<1%) is flooding and water stagnation area, and (>20%) is excessive slopes for urban development activities.

Table 4.6: Slope analysis of the study area

No	Slope categories	Area in hectare	%
1	0-2	0.38	1.6
2	2.01-5	2.02	8.3
3	5.01-10	4.93	20.4
4	10.1-15	12.34	51.1
5	15.1-20	4.03	16.6
6	>20	0.45	2.0
	Total	24.15	100

(Source: Author, 2021)

This can show the slope of the area is more suitable for proposed sustainable urban stormwater management. In contrast, according to Demu (2018) the site which has a slope of less than 1% and greater than 15% is the lowest suitable area for developing stormwater structures.

4.5.4. Figure ground map

The figure-ground map shows that the relationship between the built-up area and unbuilt-up areas. Also, it displays the configuration of buildings and the solid-void relationship (Hebbert, 2016). In the study area, it shows that the built-up area 17.6 ha (72.5%) and the unbuilt-up area 6.9 ha (28.5%) (Figure: 4.19). The result indicates the study area is mainly covered by different building roofs and does not have enough open spaces that can contribute to runoff infiltration to the ground surface. So, this can require sustainable urban stormwater management that enhancing water permeability on the surface of the earth. As explained by Yannopoulos et al., (2013) built-up areas or impervious areas can increase stormwater runoff with makes the ground surface less pervious. As a result, floods and land degradation around the Laga Hida River have taken place. Even the built-up areas or impervious areas of the site affect decreasing infiltration rate, as they are not covered with vegetation.

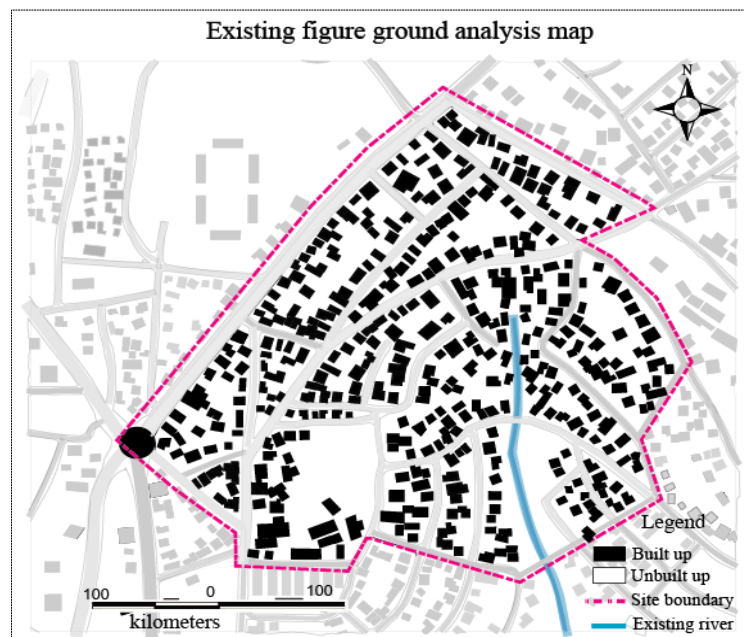


FIGURE 4.19: FIGURE GROUND MAP OF THE STUDY AREA (Source: Author, 2021)

4.5.5. Existing land use

In this area, land uses are categorized into different uses like residential, commercial, social service, mixed-use, open space and roads. Out of this 38.9% is residential (Figure: 4.20 and Table: 9). As the area of land-use is higher, it creates high runoff volumes; in the study area, the

residential land-use produces higher runoff which affects the surrounding environments. The effect of each land use was considered depending on the area coverage and the volume of runoff that was generated during rainfall events (Zare et al. 2016).

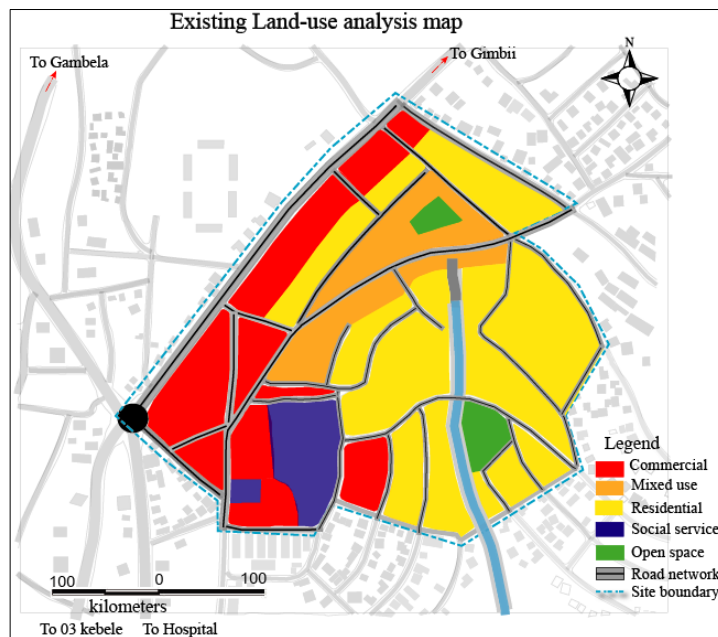


FIGURE 4.20: LAND USE CATEGORIES MAP OF THE STUDY AREA (Source: Author, 2021)

Table 4.7: Land use categories of the study area

No	Land use type	Hectare m ²	Area in %
1	Residences	94,920	38.9
2	Mixed Use	29,280	12
3	Commerce	50,680	20.7
4	Social Services	14,152	5.8
5	Open Spaces	6,100	2.5
6	Road network	48,703	19.9
	Total	244,000	100

(Source: Author, 2021)

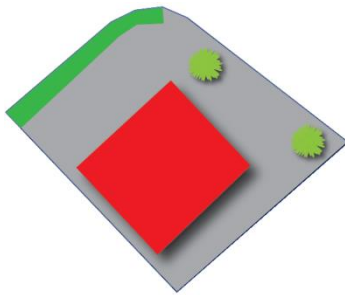
Land use categories are indicated in Figure: 4.20 and Table: 4.7. It is shown that the small percent is green and open space though. The green space has a great role in stormwater management by reducing stormwater runoff through penetration into the ground. On the other hand, impervious surfaces like residences, streets, and commercial areas have covered more spaces than the previous surfaces like green space. From this, it can be considered that the

amount of stormwater runoff is high in the study area. According to Zare et al. (2016) land use affects capture, surface retention, evapotranspiration, and resistance to overland flow of stormwater runoff.

Sample land uses stormwater runoff calculation

The following Figure:4.21 shows sample runoff calculation that is categorized according to land use and used, through considering runoff coefficient for each area from (Table:1). The runoff analysis for a particular area shall be based on the proposed land use for that area (USDD, 2008). This helps the planner to know the amount of stormwater runoff is produced and make an effect on the surrounding environment in each land use and plot per year.

Sif cafe (commercial)



Total Plot Area = 227 m² Roof Area = 67.9 m²

Paved area = 159.1 m²

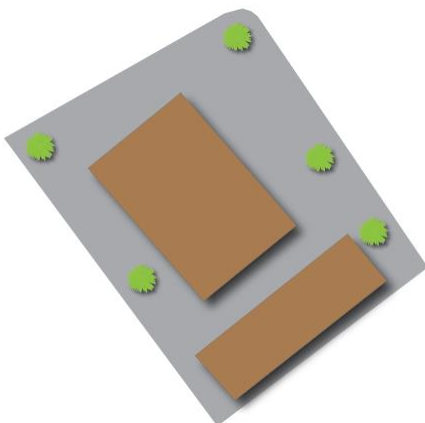
Runoff volume = Runoff Coefficient x Annual rainfall x Roof
/Paved/green area

Roof area = 0.75 * 1240mm * 67.9 m² = 63,147 liters/year

Paved area = 0.9 * 1240mm * 159.1 m² = 177,555.6 liters/year

Therefore total runoff volume of this compound is 240,702.6
liters/year

Residence



Total Plot Area = 951 m² Roof Area = 337.3 m²

Paved area = 613.7 m²

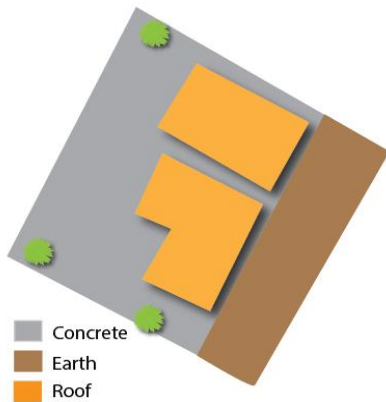
Runoff volume = Runoff Coefficient x Annual rainfall x Roof
/Paved/green area

Roof area = 0.75 * 1240mm * 337.3 m² = 313,689 liters/year

Paved area = 0.9 * 1240mm * 613.7 m² = 684,889.2 liters/year

Therefore total runoff volume of this compound is 998,578.2
Liters/year

Mixed use



Total Plot Area = 960.64 m² Roof Area = 258.34 m²

Paved area = 599.1 m² Earth surface = 103.2 m²

Runoff volume = Run off Coefficient x Annual rainfall x Roof / Paved/green area

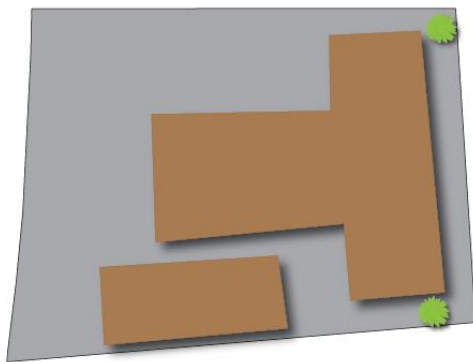
Roof area = 0.75 * 1240mm * 258.34 m² = 240,256.2 liters/year

Paved area = 0.9 * 1240mm * 599.1 m² = 668,595.6 liters/year

Earth surface = 0.25 * 1240mm * 103.2 m² = 31,992 liters/year

Therefore total runoff volume of this compound is 940,843.8 liters/year

Betel church (social service)



Total Plot Area = 2370.4 m² Roof Area = 917.34 m²

Paved area = 1,453.4 m²

Runoff volume = Runoff Coefficient x Annual rainfall x Roof / Paved/green area

Roof area = 0.75 * 1240mm * 917.34 m² = 853,126.2 liters/year

Paved area = 0.9 * 1240mm * 1,453.4 m² = 1,621,994.4 liters/year

Therefore total runoff volume of this compound is 2,475,120.6 liters/year

Open space



Total Plot Area = 3109.34 m²

Runoff volume = Runoff Coefficient x Annual rainfall x Roof / Paved/green area

Open space = 0.25 * 1240mm * 3109.34 m² = 963,895.4 liters/year

Therefore total runoff volume of this open space is 963,895.4 liters/year

FIGURE 4.21: SAMPLE LAND-USE RUNOFF PER YEAR IN EACH PLOT

(Source: Author, 2021)

4.5.5.1. Existing Street hierarchy of the study area

Concerning street hierarchy analysis the existing street is arterial (22m), collector (12-15m), and Local Street (4-8m) Figure: 4.22 and Table 10. As it is discussed in Table: 10 and Figure: 30 when we compare the existing street with street standards, all streets are below standard. According to Street Design Standard for Urban Ethiopia report (2017) the arterial street should be (25-30m), Collector Street (15-20m), and Local Street (6-12m). The implication of this that: the standardized street has its contribution to reducing stormwater runoff. In the study area due to the street are narrower and lack of drainage the stormwater logging to residents and affect the environment.

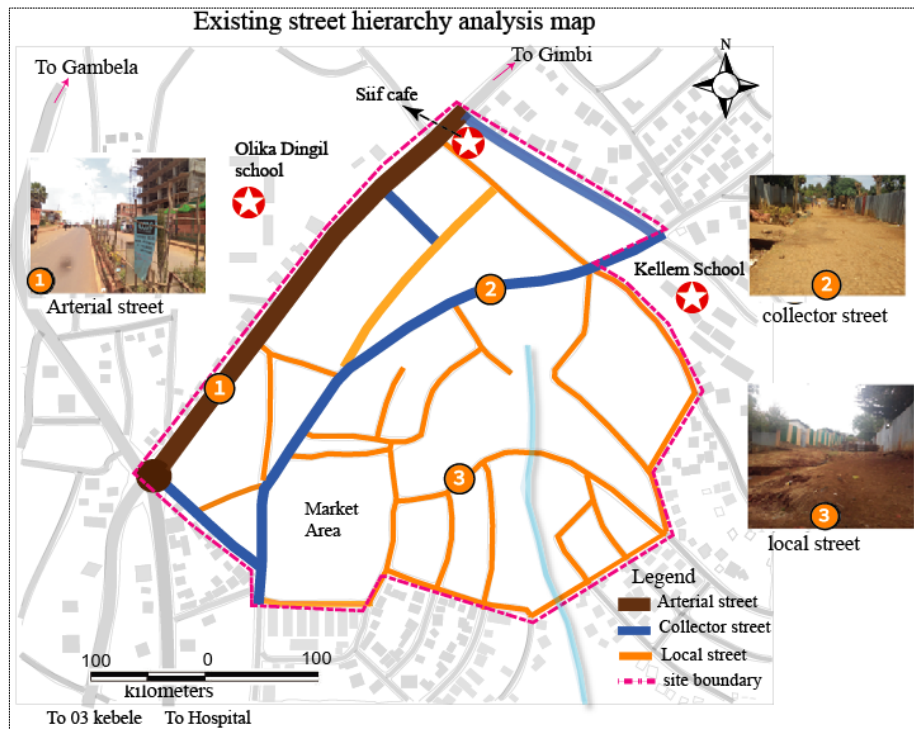


FIGURE 4.22: MAP OF STREET HIERARCHY ANALYSIS OF 2021 (Source: Author, 2021)

Table 2: Street hierarchy and comparing with standards in 2021

No	Street type	Width	Standard	Drainage along street in(m)	Standard
1	Arterial street	22m	25-30m	0.8m	1.2m
2	Collector street	12-15m	12-16m	0.5m	0.7m
3	Local street	4-8m	8-12m	-	0.4-0.7m

(Source: Field survey, 2021 and, Street Design Standard, 2017)

4.5.6. Street surface pavement of the study area

Figure: 4.23, shows existing roads constructed from asphalt (26%), cobblestone (21%), gravel (33%), and soil (30%). The Arterial Street is made up of Asphalt or impervious surface covering is (26%), which is one factor that increases the stormwater runoff of the study area. As explained by Lukes and Kloss (2008) impervious roadways, increased runoff volume, and high runoff peak flows, are damaging to the environment. In contrast, 54% of the roads are paved with cobblestone and gravel surfaces. So, it has its contribution in reducing runoff but, there is no drainage line. This implies cobblestone and gravel-surfaced roads can decrease stormwater runoff than asphalt roads. Furthermore, according to an interview report of Dambi Dollo town municipality experts, proposing more permeable material like, cobblestone and gravel are very essential to manage stormwater runoff.

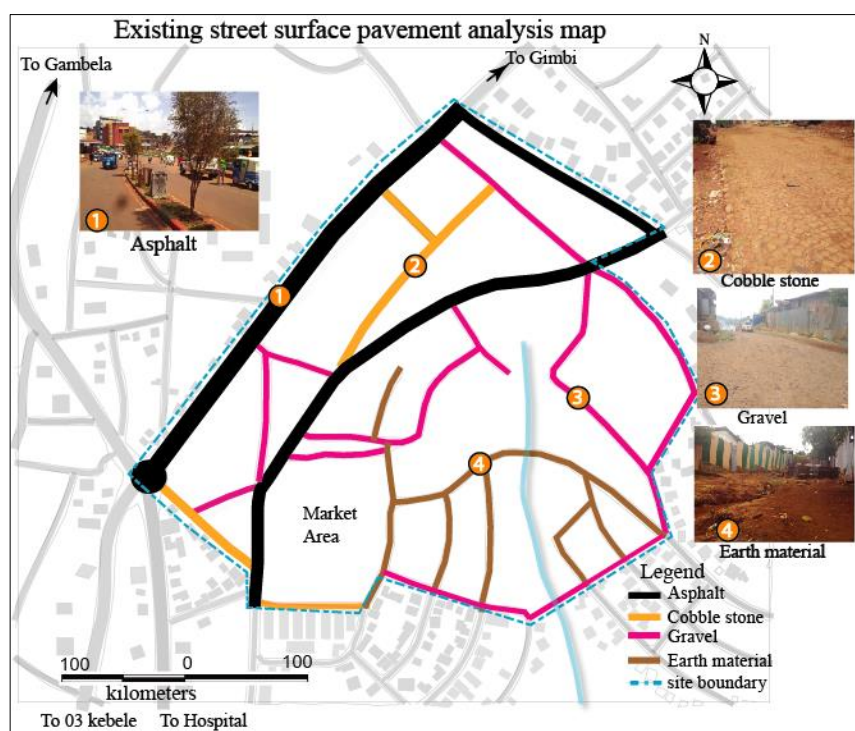


FIGURE 4.23: EXISTING STREET SURFACE PAVEMENT ANALYSIS MAP OF 2021

(Source: Author, 2021)

Table 4.9 shows the entire street's surface pavement area in M^2 and calculated runoff produced from each street per year. When it is comparing all streets, the highest runoff is produced by asphalt paved streets due to having many areas and according to (USDD, 2008), has a high runoff coefficient (0.70–0.95). In line with this, the study by Lukes and Kloss (2008) indicates in

the United States Asphalt pavement covers 95% of the total paved roads due to this it create higher stormwater runoff harmful effects on environments.

Table 4.9: Existing street surface pavement and total runoff volume in Liter/year

No	Surface pavement	Total area in (M ²)	Runoff coefficient	Total Runoff Volume in Liter/ average year
1	Asphalt	20,268 m ²	0.70–0.95	21,362,472
2	Cobble stone	3,391m ²	0.60-0.85	2,943,388
3	Gravel	13,589m ²	0.40-0.80	10,110,216
4	Earth material	10,825 m ²	0.20–0.35	3,355,750
	Total	48,703m ²		37,771,826

(Source: Author, 2021)

4.5.7. Existing Drainage shapes and surface condition

The flow of the stormwater runoff is one of the major problems in the study area as a result of urbanization, land-use change, and impervious pavements related to the blockage of the urban stormwater drainage network that can increase stormwater runoff and its effect. The condition, shape, and coverage of existing urban stormwater drainage infrastructure in the study area are presented in (Figure: 4.24 and Table: 12).

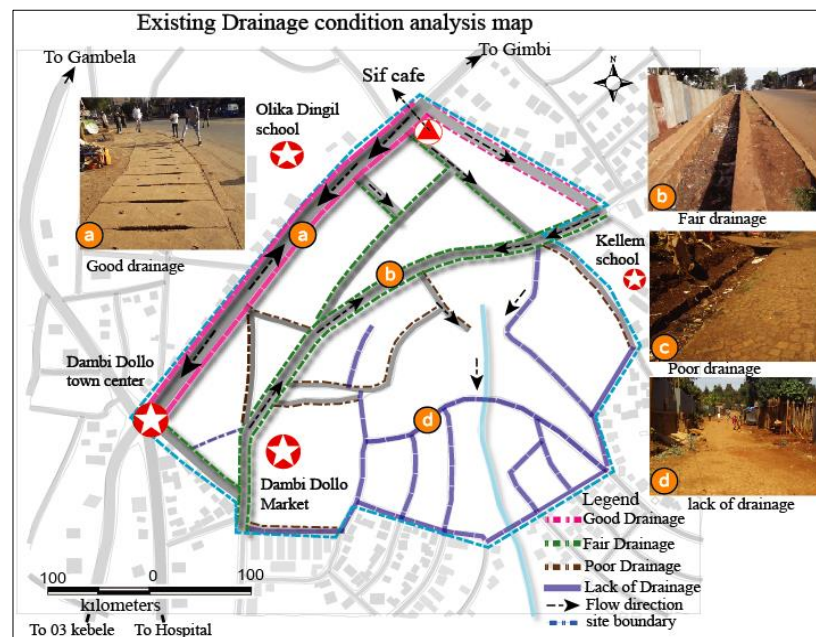


FIGURE 4.24: EXISTING DRAINAGE CONDITION ANALYSIS MAP OF 2021

(Source: Author, 2021)

According to the Street Design Standard Manual for Urban Ethiopia report (2017), the drainage size along the arterial street width should be 1.2m, collector street 0.7m and 0.4-0.7m. But, in the study area according to Figure: 4.24, all existing local streets have not stormwater drainage and

the existing drainage lines are below standards. Along the main street start from the town center to Sif cafe have 0.8m stormwater drainage, the collector street from Sif cafe up to Dambi Dollo town general market has 0.5m drainage. And also, the different local street has no stormwater drainage this can maximize the effect of stormwater runoff in this study area (Figure: 4.24). This implication was shown the study area required a standardized drainage system to manage the stormwater effect on the community and environments. According to Gogate et al. (2017) sustainable urban stormwater drainage systems are recommended to mitigate the adverse effects of impervious areas and restore the water quality. It is also one of the methods that are intended to control stormwater runoff at the source and prevent pollution.

Table 4.10: Existing drainage types and surface condition (in meters)

No	Drainage shapes	Surface condition (in meters)			
		Good	Fair	Poor	Total
1	Trapezoidal	665.2	235.8	546.9	1447.9
2	Rectangular	1132.5	689.0	745.8	2567.3
3	Circular	-	235.1	-	235.1
4	Street Lack of Drainage	2134.5			2134.5

(Source: Author, 2021)

As it has also been shown in the Table: 4.10, most of the existing rectangular and trapezoidal drains are open and are not environment friendly, which may encourage residents to connect their sewerage systems and dump solid wastes into the drainage systems resulting in unpleasant smells which are also unaesthetic to the environment and affect society health.



Rectangular drainage

Trapezoidal drainage

Circular

FIGURE 4.25: TYPES AND SHAPES OF EXISTING DRAINAGE IN LAGA HIDA RIVER AREA

(Source: Field survey, 2021)

The researcher observed that in most of the study area the capacity of stormwater drains are smaller than the rainfall volume generated each year of the town, also in some areas they are broken and not been repaired. However, in some areas, the drainage is not regularly cleaned and

solid waste residues are dumped to it by people. As a result, the rain stormwater overflows from the drainage on the roads and can increase the damage amount of streets and environments.

Therefore, in the study area, the major challenge to manage stormwater is the drainage system. Some road might not have but some road might have but due to damage by various reasons create overflow. According to interviews from residents and Dambi Dollo town municipality, insufficient drainage installation and capacity, the stormwater enters houses in most localities of the residents around the Laga Hida river area and damages their property. This implies, in the study area there is poor or no stormwater management system. As explained by Parkinson (2003) the problems of poor drainage systems have disturbed effect upon damage to homes and local properties that causing families to lack assets for treatment.

4.5.8. Stormwater flow direction of the study area

Figure: 4.26 shows the stormwater flow direction analysis of the study area where the flow is from the steep and hilly slope to flat slope. As explained by Tesema et al (2017) the slope influences the direction and amount of surface runoff or subsurface drainage reaching a site. Steeper slopes are more susceptible to surface runoff, while flat topographies are susceptible to waterlogging.

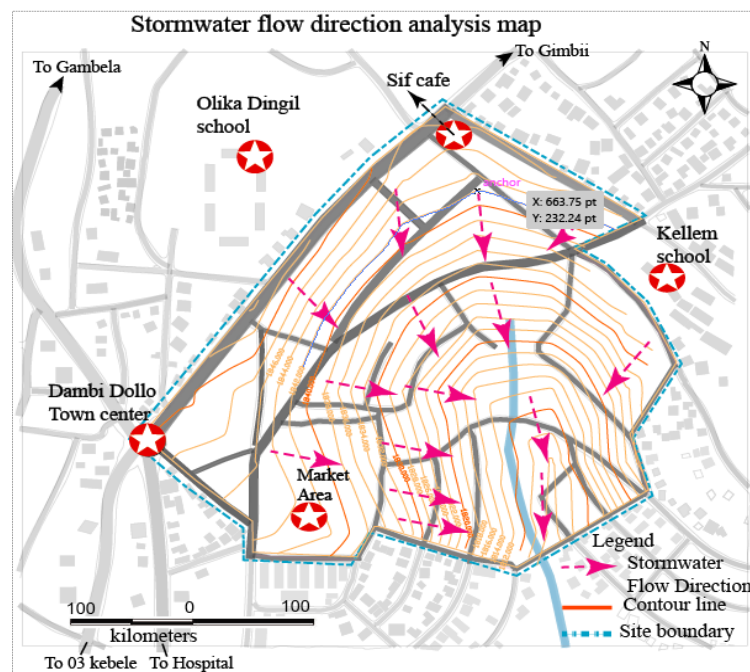


FIGURE 4.26: STORMWATER FLOW DIRECTION OF THE STUDY AREA
(Source: Author, 2021)

From this, the Laga Hida river area lies on an elevated topography that has slope categories of moderate slopes 10.1-15 (51.1%), steep slopes 15.1-20 (16.6%), and hilly slopes >20 (2.0%)

which forms the watershed boundary of Laga Hida small river. Thus, runoffs were borne from Olika Dingil and Laga Hida river area flow into Laga Hida Small River that has a flat or slope 0-2 slope range (Figure: 4.26).

As can be seen in Figure 34 stormwater flow direction, stormwater outlets are distributed from all directions of the site to the existing river, largely run north to south. The stormwater that comes from different directions of the town is distributed into the study area without enough mitigation and it becomes runoff that can affect the community, existing built, and natural environment. This is due to the different street has no enough drainage system, which can take in the stormwater that comes from the different area due to this it can easily overflow the existing drainage and transport different solid waste into the river.

4.5.9. Proposed sustainable urban stormwater management strategies

The increased runoff and flooding will force planners and water experts to improve strategies to deal with the increased volume and velocity of stormwater (Gupta, 2015). The proposed sustainable urban stormwater management strategies were considering stormwater runoff quality improvement and volume reduction. It is including Water Sensitive Urban Design technical approaches that can be used to manage stormwater through integrating into urban planning and design in order to reduce environmental degradation and improve its sustainability and attractiveness (Noordhoek, 2014). The study area has lack of inadequate plan and design of urban stormwater management method and existing drainage systems cannot carry large amounts of stormwater, hence resulting in overflowing. This can show how the area should require a stormwater management method.

Strategies are proposed by considering the stormwater run-off effects of the study area. These provide infiltrating rainwater directly into natural ground and serve stormwater can be passively directed into amenity areas slowly after heavy rainfall events. It contains a set of stormwater management practices, whether structural or non-structural, on or off-site, that fit into the natural environment, it is functional, safe, and aesthetically acceptable (Urban Stormwater Drainage Design Manual, 2008). Hence, it is control facilities, and strategies designed to efficiently and effectively drain surface water of the study area, while reducing pollution to the impact of quality on the existing Laga Hida River.

It is illustrated in Figure 4.27 the conceptual development of the proposed strategies.

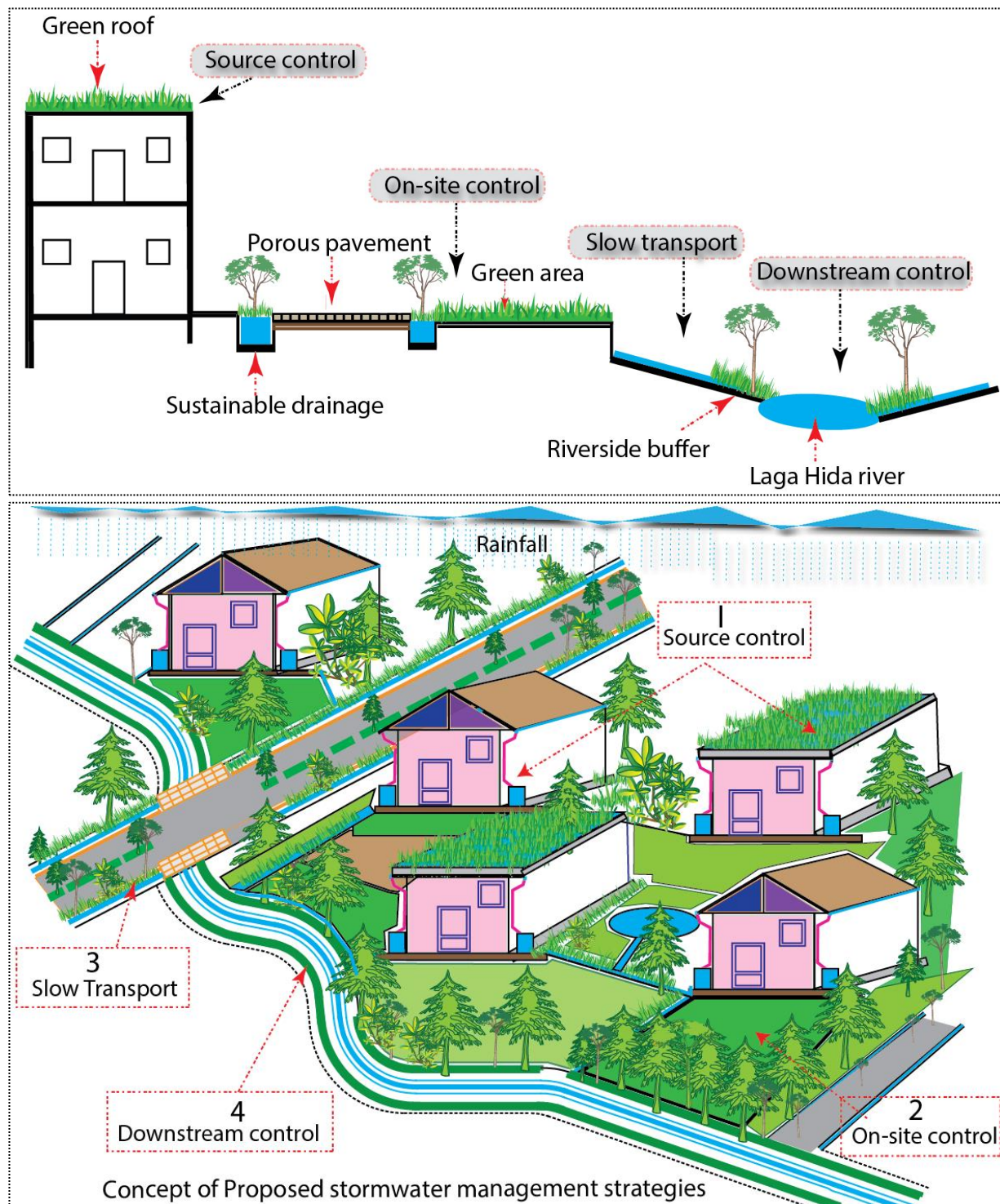


FIGURE 4.27: CONCEPTUAL DEVELOPMENT OF SUSTAINABLE STORMWATER

MANAGEMENT PROPOSED STRATEGIES (Source: Author, 2021)

Similarly, reduce the effects of stormwater runoff results in the reduction of degradation from both natural and built-environment of the study area. Additionally, incorporating the principles

of sustainable urban stormwater management plans by integrating with other planning mechanisms can reduce the degradation of resources. This can be done by source control, on-site control, multi-site, slow transport, and downstream control, all of which should be integrated to achieve the goal of sustainability in urban stormwater management (Qiao, 2019). The scale of application can range from individual houses, streetscapes, blocks, and surroundings whole urbanized catchments (Lloyd et al., 2002). Therefore the proposed strategies are presented underneath:-

4.5.9.1. Source control Strategy (Plot level control)

Stormwater source controls are considered minor measures implemented at the lot level (Marsalek and Chocat, 2002). It is proposed to prevent pollutants from entering stormwater and the accumulation of stormwater at the source that affects the quality of stormwater and pollutes the environment in residential, commercial, and industrial areas (Figure 4.28). The principle of source control is targeted toward low rainfall and expressed as the volume capture ratio of annual rainfall. Through:-

- a) Providing green roofs especially in commercial areas where their aesthetic qualities can come to the frontage, even though their uptake is slow, detain rainfall, allow some evapotranspiration, and 50% reduce stormwater runoff (Marsalek and Schreier, 2015 and NUGIS, 2015).
- b) Rainwater harvesting through building septic tanks in each household to reduce the amount of stormwater runoff and used as a resource.
- c) Developing permeable and porous pavements in each plot that reduce runoff from pavements.
- d) Developing vegetable gardens, green areas, and a minimum of 12% of a plot area should be unsealed (as a green open space so that rainwater can percolate to the ground, decreasing water discharge and reducing runoff).
- e) Planting different indigenous trees in each plot that naturally stormwater infiltrate to the ground and enhance evapotranspiration. Also, every plot of area of up to 150 m² should be provided with at least one tree, and at least one additional tree should be provided for every additional 50 m² of the plot area (NUGIS, 2015).
- f) Redirecting roof leader discharges to ponding areas or reuse for different recreational activities.

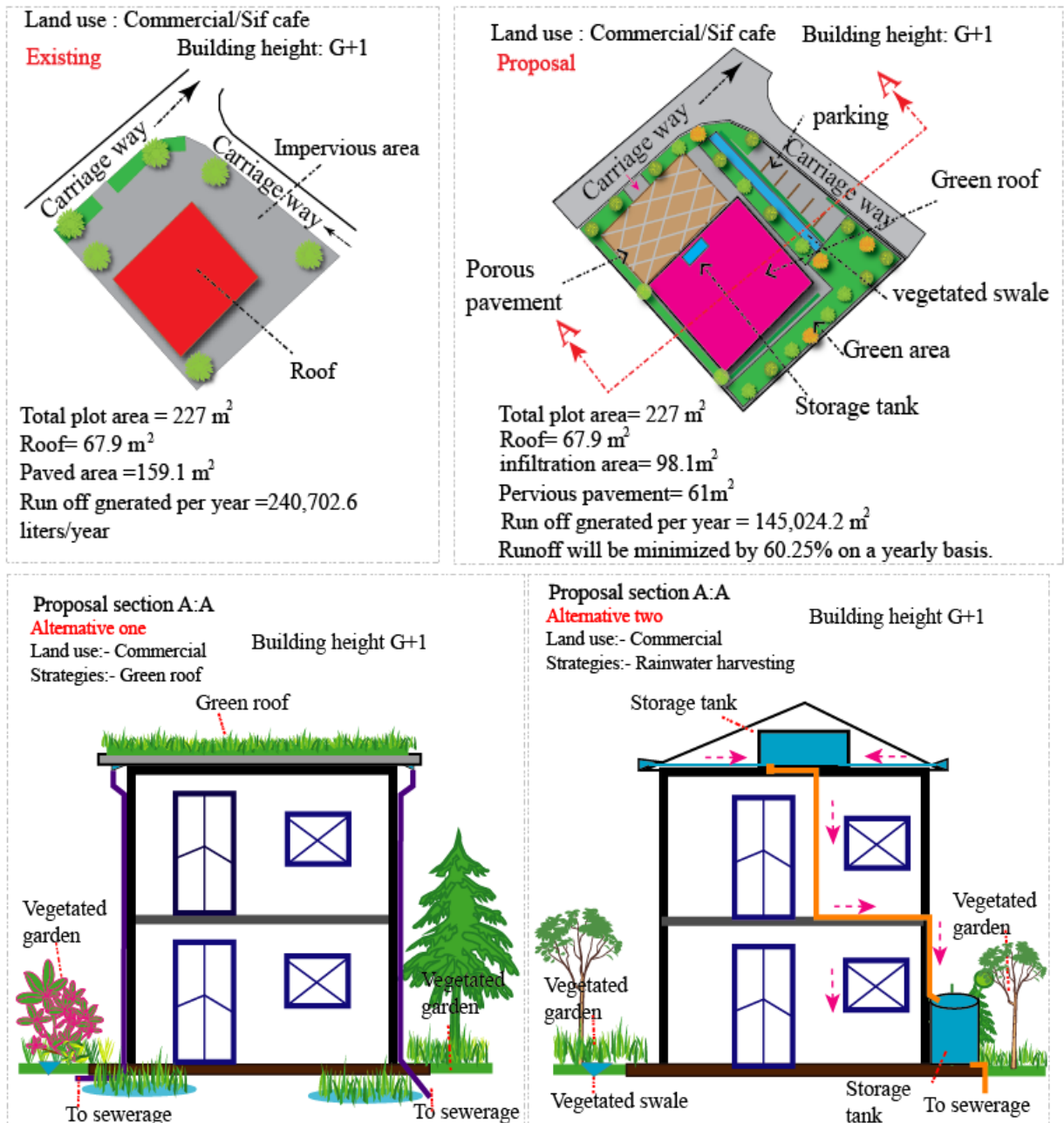


FIGURE 4.28: PROPOSED STORMWATER SOURCE CONTROL (PLOT-LEVEL) STRATEGIES BY PLAN (Source: Author, 2021)

4.5.9.2. On site control Strategy (Block level)

This strategy is applied to manage stormwater in block and road stormwater runoff. It provides re-use opportunities to households for garden and recreational activity. It is applicable to new or re-developed allotments or blocks. On-site stormwater control systems can consequently provide quantity and quality improvements and will also enhance the effectiveness of downstream treatment systems by reducing the hydraulic loading (Figure 4.29). That can be developed by:-

- i. Providing retention and detention pond between blocks that retain and temporarily stores stormwater from the roof or impervious areas of the site.
- ii. Developing smart growth objectives that combining compact, mixed-use development through vertical development that increases green space and reduces stormwater runoff.
- iii. Providing rain gardens and open green areas supported with vegetation on communal space.
- iv. Using permeable pavement along the arterial street and also, paving all in all collector and local streets surface material like (cobblestone, porous asphalt, permeable interlocking concrete pavers) and soft landscape rather than using the standard impervious pavement.
- v. Develop different vegetation along a right of way; at least 30% of trees are fruit trees to support food security and parking space should be covered to a minimum of 50 % by shade trees. (NUGIS, 2015).

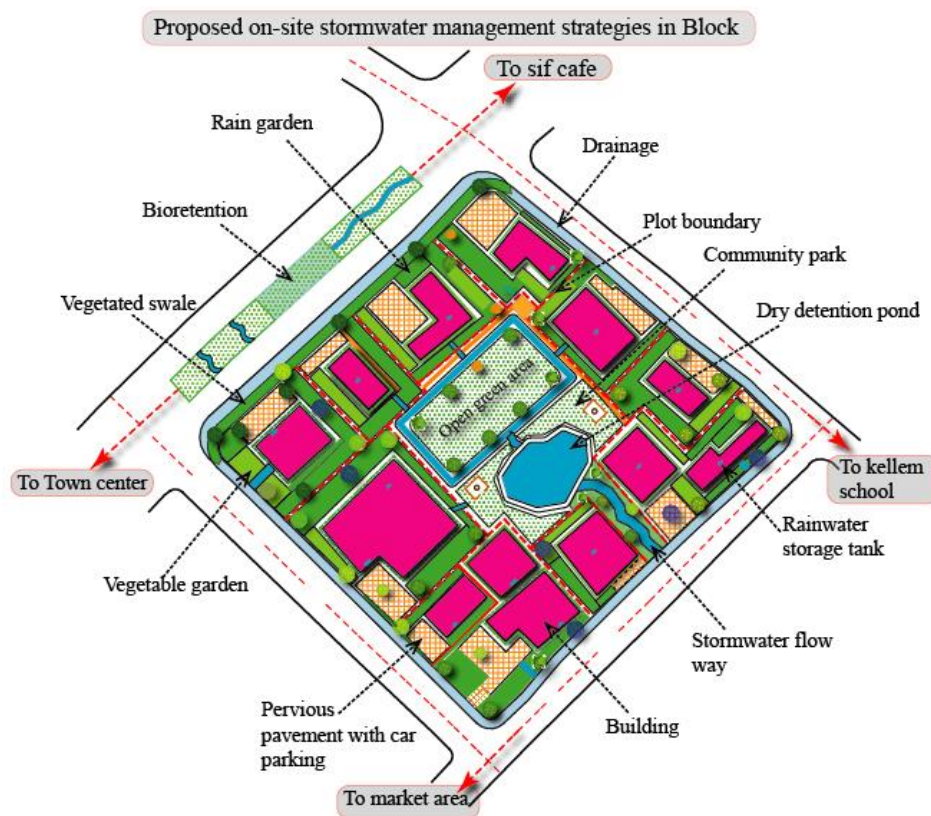


FIGURE 4.29: PROPOSED STORMWATER ON-SITE CONTROL STRATEGIES BY PLAN
(Source: Author, 2021)

4.5.9.3. Stormwater slow Transport strategy

It should depend on considering the frequency of stormwater in that area. Flow control provides the basis for all stormwater management schemes (Lloyd et al., 2002). Figure 4.30 depicts a standardized stormwater drainage system that can be proposed and incorporates purposeful natural features for slow stormwater transport by collecting, retaining, detaining, infiltrating, transporting, and purifying runoff.

- Providing 2m width grassed channel or concrete ditch along the streets, depending on stormwater flow velocity and locations of extensive damage or lack of damage,
- Enhancing vegetation swales and the green area along the streets that promote infiltration and detention of stormwater runoff,
- Connection to the public stormwater system to road curb/channel, pipe, waterways

i. Proposed street hierarchy and drainage:- According to Bansal et al. (2015), a narrow road creates and intensifies the overflowing of streets and roads for hours during rains, causing damage to adjacent environments. As a result, a street hierarchy based on street standards is presented to solve the study area street narrower associated stormwater issues. Accordingly, the Arterial Street is 30m, collector street is 16m, the local street is 8-12m and Green Way along the river buffer zone is 4m are proposed (Street Design Standard Manual report, 2017).

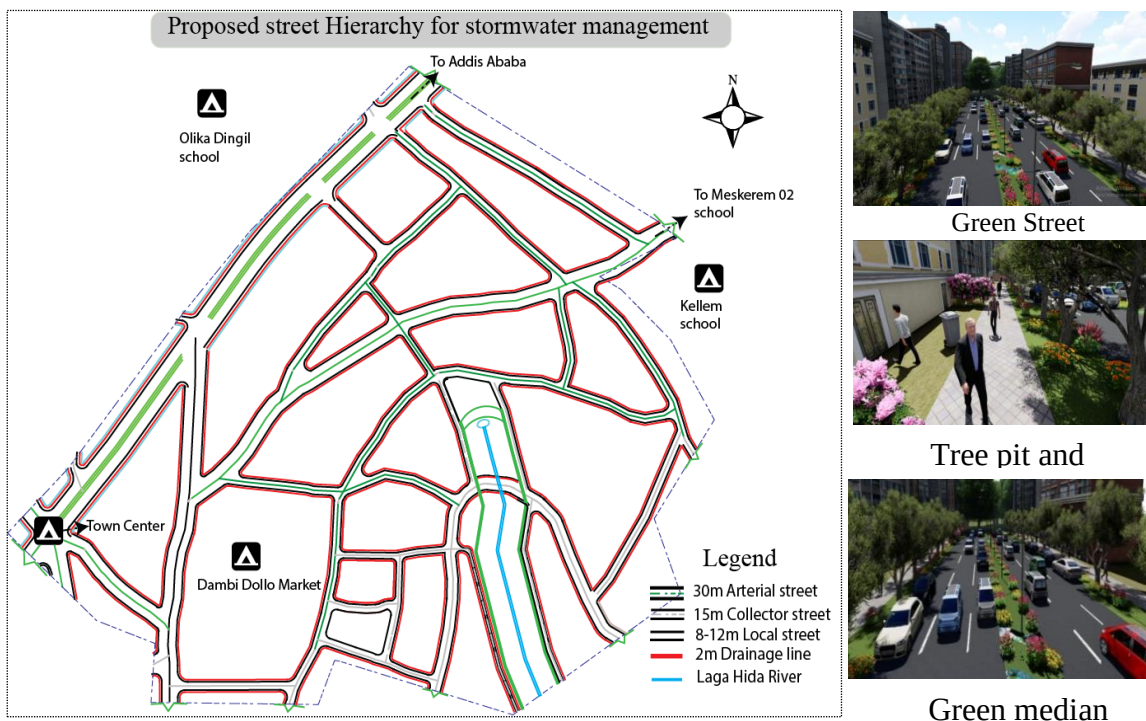


FIGURE 4.30: PROPOSED STREET HIERARCHY FOR STORMWATER MANAGEMENT

(Source: Author, 2021)

Hence, depending on this the proposed naturalized drainage is considering, drainage size standards 1.2m and require 15% to 20% circulation area totally 2m with grassed or vegetated swales is proposed through considering how it conveys stormwater slowly, infiltrate and evapotranspiration on site (Figure 4.30). According to Urban Stormwater Drainage Design Manual report (2008), the grassed channel is protected from erosion by a turf cover. It is used in main road construction for roadside ditches, medians, and for channel changes of small watercourses. A grassed channel has the advantage of being compatible with the natural environment. This type of channel should be selected for use whenever possible.

ii. Proposed street Surface materials: - The proposed street surface material is considering the existing structural plan, the existing condition of the area, and how to manage or decrease the stormwater runoff. Depending on this the arterial street is paved with porous asphalt; the collector and local street is covered cobblestone. And the greenway along the border of the buffer zone is paved for the porous materials to decrease runoff flow and infiltration to the ground (Figure 4.31).

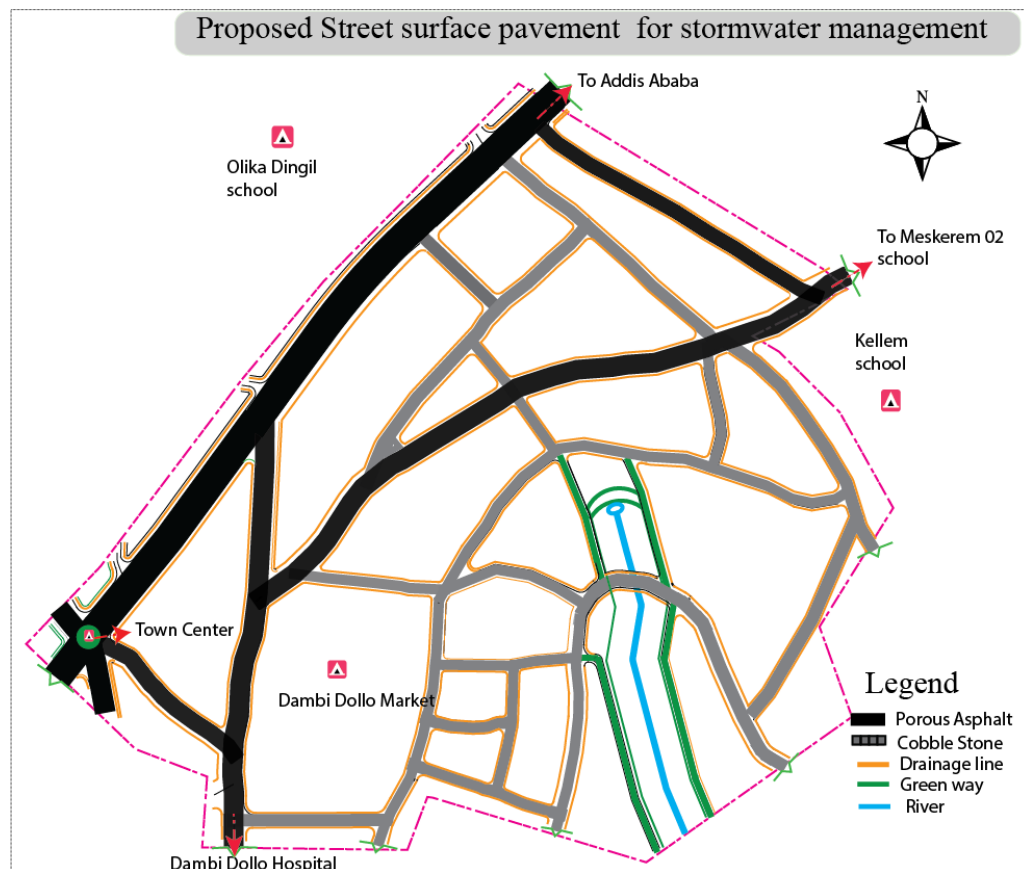


FIGURE 4.31: PROPOSED STREET SURFACE MATERIAL PAVEMENT FOR STORMWATER MANAGEMENT (Source: Author, 2021)

iii. Proposed street cross section for stormwater management

Proposed on-site and slow transport stormwater management of street

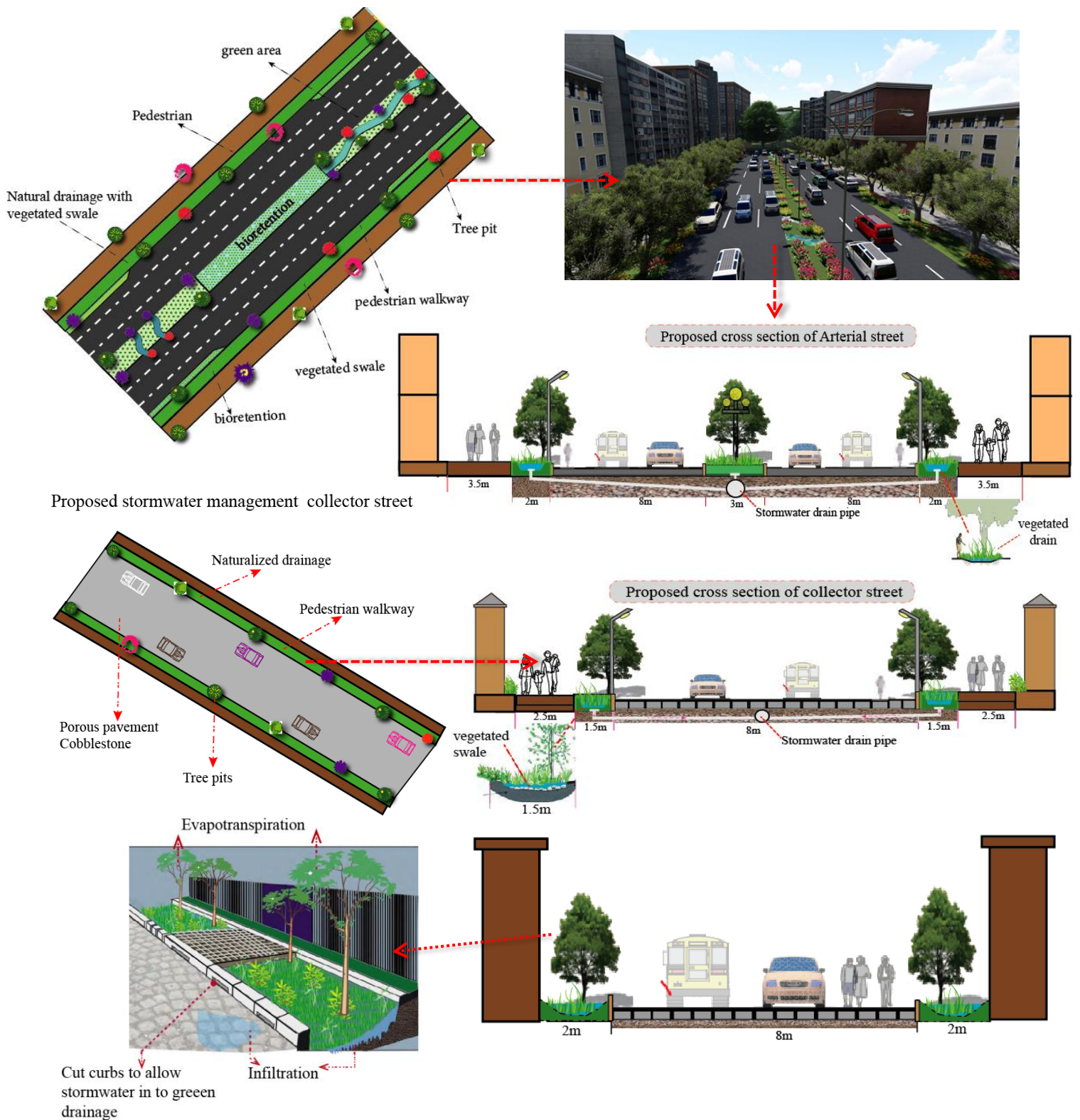


FIGURE 4.32: PROPOSED ARTERIAL, COLLECTOR AND LOCAL STREETS CROSS SECTION
(Source: Author, 2021)

Figure 4.32 can show the proposed slow transport of stormwater green or naturalized drainage that has on the top vegetation underground pipes. It is also proposed surface pavement of each street for Arterial streets porous asphalt and for the collector and local streets cobblestone that can use to encourage slow transport of stormwater through accumulating and infiltrating the stormwater and for the aesthetic beauty of the town. In line with this, the study conducted by (Gupta,2015) minimizing impervious surfaces such as parking lots, roads, and rooftops can reduce stormwater runoff.

Additionally, Figure 4.32 can show the cross-section of the street proposed for slow transport of stormwater through standardized street design. That contains:-

- a) Incorporated natural drainage facilities and water retention landscape features.
- b) Vegetated swale on the side of the pedestrian and the median with green area.
- c) Tree pits the side of all streets used for biofiltration and evapotranspiration of the stormwater.

4.5.9.4. Downstream or watershed scale control Strategy

It is stated by Marsalek and Schreie (2018) in their study, wide riparian buffer zones and constructed wetlands are important to minimize or eliminate all stormwater outfalls discharging directly into streams. So, using a sustainable drainage system in each street and riparian green buffer along the existing river of the Laga Hida River and flood damage is important to mitigate the pollution. This kind of practice helps to eliminate major pollutants before inflowing into the Laga Hida River and decrease runoff speed (NUGIS (2015); Urban Stormwater Drainage Design Manual (2008)). Therefore, to reduce stormwater runoff damage in the case area, the following points are proposed and indicated in (Figure 4.33 and Appendix v):-

- a) There should be proposing different urban agriculture and community parks along the river that at least 50% of trees are fruit trees to support the food security of the dwellers.
- b) Developing greenway for the case area that urban riverside greenway, to protect Laga Hida River and the surrounding area from further damage.
- c) Plants along riversides should have deep roots so that they protect the river bank and its immediate surrounding from erosion (NUGIS, 2015).
- d) To protect the water quality of the river and reduce flood problems, enhancing riverside buffer zone of 30m with categorizing three distinctive zones, riverside zone 6m to protect the physical and ecological integrity of the river ecosystem, middle zone 18m from the

outer zone of the zone one area of native vegetation protects and the outer zone 6m immediately from the outer edge of zone two to protect the water quality of the river and reduce flood problems.

- e) Reforesting edges of the river by selecting appropriate tree species/preferably indigenous species, terracing, provision of retention or detention facilities or storage facilities.

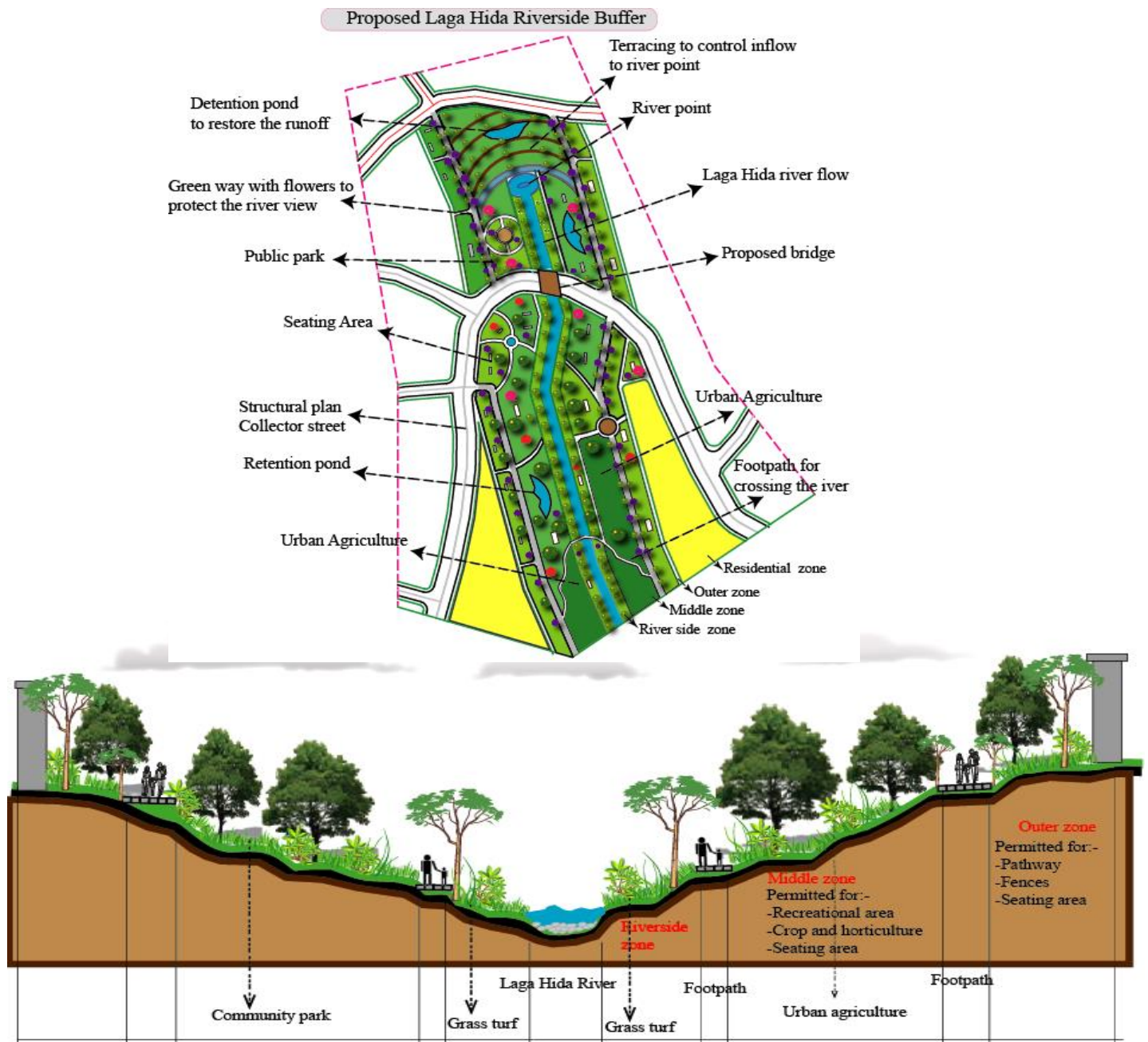


FIGURE 4.33: PROPOSED LAGA HIDA RIVER SIDE BUFFER PLAN AND CROSS SECTION

(Source: Author, 2021)

Similarly, to protect the quality and flood damage of the Laga Hida River the action that has taken are planning integrated riverside riparian vegetation, terracing, urban agriculture, Park and recreational space. According to Urban Green Infrastructure Standard report (2015), appropriately developed riverside or lakeshores provide additional green open space and recreational opportunities, increase environmental awareness, improve stormwater management and enhance the town's attractiveness. However, in the study area, the sustainable stormwater management integrated with the landscape of the park around the Laga Hida River enhances the natural ecosystem of the river. These parks connect the site with other surrounding neighborhoods facilitating the recreational activity. The proposed retention pond in the parks to retain the extra stormwater and used it for recreational activity. Plentiful existing vegetation along with the river bank and plant additional riparian vegetation within buffer strips to manage erosion and the water quality.

Also, urban agriculture irrigation is integrated with parks to support the sustainable food supply of the town. Urban agriculture and horticulture are practiced in areas where sufficient water is available along rivers (NUGIS, 2015). According to Figure 41 and Appendix v, the vegetated swale proposed with irrigated urban agriculture to purify the eroded soil. The sitting space provided within the park on the riverside is increasing the interaction of the people with the natural ecosystem and it is also used as a reading space. The cultural vernacular house is used for the cafeteria and restaurant with a thatch roof. The wet shallow detention pond serves as a swimming pool enclosed by a 2m offset of bio-retention to control runoff and lowering peak water discharges (Recreational Parks Development and Management Manual report, No.13/2016). The buffer zone separated from the middle zone by using greenways that contain used as bikeways, footpath and also, as a borderline of the buffer of the river by using different flowers along the greenway. The space above the point of the river or water shade area is designed for terraces and cultivating different vegetation to reduce the inflow of runoff from the river point (USDD, 2008). Structural solution at the bank of the river applied like gabion and infiltration trenches to avoid degradation of soil and wetlands for the protection of the river.

4.5.10. Applicability and functions of the proposed strategies

The stormwater management of the study area is considering the existing local condition such as topography, rainfall variation, existing environments, and water quality to bring sustainable urban stormwater management. It can be applicable starting from individual plot areas to large

institutions or whole urban areas to achieve a better life with the biodiversity of the natural ecosystem through reducing stormwater runoff. The experts and mayor of the town create awareness on the functionality of the proposed strategies to implement by initiating the dweller and supporting them technically. This in turn leads to appreciation and care, which reduces pollution of water and leads to better environmental practices.

Firstly, the source control strategy is enhanced by a green roof that can use as a shading function and reduces urban heat island (Sheng, 2015). In the collection process, the green roof plays an important role; the large amount of water that falls on the roof could be collected directly by the green roof and goes to conserve the tank by rain pipes. The Green roof is unique and provides a different type of habitat, water storage capacity and economic benefits, including a longer roof life and heating and cooling energy savings (NUGIS, 2015).

Secondly, the on-site control through green space, permeable pavements, and different plant species proposed in each plot and block is ensured rainwater quality. According to NUGIS, (2015) a minimum of 12% of a plot area should be unsealed (as a green open space so that rainwater can percolate to the ground, decreasing water discharge and reducing runoff) this enables the site to reduce the frequency of runoff during heavy rain and clean the stormwater discharged to the Laga Hida river.

Similarly, for slow transport of stormwater, the Green Street with the vegetated swale on both sides of the street enhances the environmental safety and aesthetic beauty of the site (Marsalek and Schreier, 2015). By constructing vegetated swale along streets, planting trees on the roadside and green space increase the public attraction of public space and recreational parks that also, enhance stormwater slow transport. As result, the town becomes green and livable with balanced natural ecosystem biodiversity. For this to be possible the system had to take the naturally existing site feature into account. Moreover, the downstream control is the way to buffering the river by using different indigenous trees; like mango, orange, avocado, and coffee, that are used to protect the quality of the river, habitat fragmentation, for food through irrigation, for recreational activities integrating with parks.

Hence, these strategies aim to bring sustainable urban stormwater management by reducing the amount of stormwater runoff. This increases the groundwater recharge of the area and the quality of the river with a reduction of flood problems. The flexibility of the proposed strategies enables

the town to adopt different measurements of stormwater management considering the local environment of the study area. Generally, the functions of the proposed strategies are: - It regenerates the environment and expanding biodiversity, gives flow protection, and provides characteristic filtration, and advances evapotranspiration.

Generally, the proposed sustainable urban stormwater management strategies show how urban design and water management go hand in hand to create a sustainable settlement. The implementation is flexible, cost-effectively, and creates an attractive and exciting living environment for the dweller. When people walk around, they can experience ever-changing ranging from dense-urban to open rural space. Sustainable stormwater runoff management adapted to the local condition such as rainfall pattern, climate, and topography. Therefore, it can apply to the other parts of this town and others that have similar local characteristics.

5. CONCLUSION AND RECOMMENDATION

5.1. Conclusion

In this section, the conclusion of the study is derived based on the objectives set out at the beginning of the study. The urban stormwater management system in Dambi Dollo town has been weak. But, the town is in a location where a high amount of temperature and rainfall for a longer period in a year results in the highest stormwater runoff. According to the results of this study, the majority of the respondent agrees that the main effect of stormwater in the study area is a very serious issue that can have an impact on both the built environment and the surrounding natural environment due to inadequacy in stormwater runoff management.

The results of the study revealed, most respondents said that it is disrupted their normal life, by damaging electricity wires, disturbing water supply, blocking the roads and drainage system, and damaging properties. This is due to the stormwater runoff that is poorly managed has brought effect on physical infrastructures like road network, drainage system, water supply, and electricity of the study area. Furthermore, stormwater has a significant impact on the physical environment by degrading land, polluting solid waste, polluting existing rivers, and damaging vegetation. Because of the high-velocity flow of stormwater runoff, the inadequacy of storm drains, and the highly erodible soil type, it is carried with various solid waste materials and other harmful chemicals into the existing Laga Hida River due to a lack of recommended buffer, polluting these water bodies and destroying land and vegetation in this area.

Similarly, communicable diseases such as malaria and other waterborne diseases get a serious effect on society's health. They polluted stormwater by spilling waste in an open ditch and on the street due to a lack of community awareness. In the same way, the economy of inhabitants and the government are both affected by these concerns, which include the maintenance of damaged infrastructure and property damage due to inadequate stormwater management.

Moreover, the study results with field observation demonstrate that there is a lack of drainage systems, and even those that exist are unable to convey huge volumes of stormwater due to a lack of maintenance, resulting in overflowing into the surrounding space and environmental degradation. This is due to the challenges of stormwater management system characteristics such as urbanization or land-use change, stormwater-related infrastructure inadequacies, blockages of urban stormwater drainage caused by spilled residents' solid waste, lack of standardized street

with surface pavement and drainage system, lack of green area and impervious coverage is high through built-up areas. These are minimized infiltration and purification of raindrops into groundwater and increasing the surface runoff in this area, in case of the absence of a stormwater management system. Furthermore, on the case study analysis, most respondents said that mismanagement or lack of proper stormwater management by the town municipality. This is due to challenges of the provision of stormwater management system offer increase stormwater runoff and its damage like lack of contemporary urban plan implementation due to overcrowded settlement, inadequate stormwater management system; technically shortage of stormwater management experts, institutionally; lack of policy stormwater-related and socially; lack of community awareness and lack of attention from concerned bodies' are the major.

The present and past stormwater management taken in the study area is not successful because it is a temporary solution like cleaning drainage channels, earth embankments, and gravel covering. This is in line with the lack of a green solution that infiltrates or slow-transport of stormwater runoff. 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), stormwater slow transport (sustainable drainage system, vegetation swales, naturalized street), 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. Recommendation

Depending on the findings of the study and the conclusions derived so far, the following recommendations are forwarded for urban stormwater management of the study area, and the following actions need to be considered.

- Municipalities should promoting public awareness from top to bottom through preparing a strict weekly schedule to clean up existing streets and drainage facilities, control the dumping of pollutants through enforcement with penalties they do not spill on the street and in the opened drainages, which would significantly reduce the damage. And training on how they harvest rainwater and green area development in their compound should enhance stormwater management.

- The municipality should collaborate with different development groups which are interested in improving the town environment. These organizations can be private or non-governmental. It is recommended that these groups apply technical supports and funds for SUSWM projects and they participate in tree planting and greening activities for their town that should lead to increased infiltration of rainwater.
- Dambi Dollo town administration and municipal authority should plan, design, and implement structural measures through preparing a Local Development Plan that encourages smart city growth goals which is compact and mixed-use development for redeveloped or newly developed areas, that give better opportunities for preservation of open space and critical environmental areas for stormwater management.
- The current stormwater management system in the study area is only through closed and open drainage, but these should be changed to sustainable stormwater management strategies that promote green solutions which more environmentally friendly systems, that encourages infiltrations and storage of water in the soil is highly recommended to minimize the stormwater runoff through the facilitation of effective purification of stormwater. Such as infiltration trenches, porous pavements, rainwater harvesting, green roofs into new and existing residential and commercial developments.
- The concerned bodies who plan, design and construct drainage network of the town and study area is mandatory should use of the procedures considered in the 'Urban Stormwater Drainage Design, Urban Green Infrastructure Standard and Urban Street Design Standard' manual will help in achieving standardized street with drainage structure that hold and drain high capacity of stormwater runoff.
- Making Greenway and buffer in 30m along Laga Hida River through community mobilization to cultivate riparian forest actively that have long root-like podocarpus falcatus, pinus strobus, Jacaranda Mimosifoli, and like are the major. From edible fruit orange, avocado, mango is suitable for stormwater filtration, evergreen, and adaptive to the local environment to reduce and control stormwater runoff logging to the river that can pollute the river.

- Successful green solutions have learned from the sample designed, the study area should enact a strategy supporting the implementation of SUSWM principles. It has to integrate these stormwater management practices into a wide range of public and private spaces, at both new and existing development sites. Finally, some proposed strategies of sustainable stormwater management need to be studied in detail. It can be done by the dividing source control, on-site control, slow transport, and downstream control.

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Appendix I

I. QUESTIONS TO BE FILLED BY THE RESPONDENTS

Dear Respondents,

This questionnaire prepared for the partial fulfillment of the requirement of master's degree in Urban Planning and Design from Adama science and Technology University. So, you have been selected to participate in the study designed to collecting information on the title "Urban stormwater management in Dambi Dollo Town: The case of Laga Hida river area". So you are kindly requested to share your opinion and experiences. Your honest responses are treated confidentially and are only used for the research purpose.

Thank you very much in advance!

PART-I General backgrounds of the respondents

1. Name _____

2. Age: A. 21-24 ☐ B. 25-54 ☐ C. 55-64 ☐ D. 65 and above ☐

3. Sex: A. Male ☐ B. Female ☐

4. Educational status of the respondents: A. Grade 1-8 ☐ B. Grade 9-12 ☐

C. Diploma ☐ D. TVET ☐ E. 1st Degree ☐ F. Others ☐

5. Marital status of the respondents

A. Married ☐ B. Single ☐ C. Divorce ☐ D. Widower ☐ E. separated ☐

6. Family size A. 1-5 ☐ B. 6-8 ☐ C. 9-10 ☐

PART-II Questions related to status of stormwater effects

7. Is stormwater a major problem in your residential area? Yes _____ No _____

8. If your answer is 'yes' to the above question, how do you rate the extent of the problem?

1) Very serious 2) Serious 3) Not serious 4. No idea

9. Is there damaged physical infrastructure due to lack of stormwater management in this area?

1) Yes 2) No

10. If your answer is yes to the above question, what kind of infrastructure is damaged?

a) Road network b) Drainage system c) Water supply d) Electricity e) all

f) Other (specify) _____

11. Is there stormwater effects on existing Environments on your area? 1) Yes 2) No
12. If your answer is yes to the above question, in what case it affected environments?
- a) Land degradation b) Solid waste pollution c) Existing river pollution d) destroying vegetation e) all f) Other (specify) _____
13. Does the stormwater flow towards the existing Laga Hida River? a) Yes b) No
14. Existing practices in and around the natural water ways/Laga Hida Rivers:
- a. Encroached by residents b. Blocked by solid wastes
- c. Connection of stormwater drain d. No regular buffer e) all
- f) Other (specify) _____
15. The stored stormwater on street which garbage is spilled in have health risks (water born diseases) on community.
- a. Strongly agree b. Agree c. Neutral d. Disagree f. strongly disagree.

PART-III Questions related to Challenges of stormwater management

16. What do you think are the major challenges which can increase the stormwater effect in Dambi Dollo town Laga Hida river area?
- i. Land use change or urbanization ii. Inadequate urban stormwater management system
- iii. Lack of stormwater drainage maintenance iv. High percent of impervious surface
- v. Rough topography vi. If others, specify _____
17. What are the major challenges in the provision of stormwater management method?
- a. Budget b. Urban Plan and design implementation problems
- c. shortage of experts in municipality d. Lack of awareness e. Others
18. Is there any open space or green areas are existed in your block or Neighborhood which infiltrate run off? 1) Yes 2) No
19. Is there any ditch for the stormwater flow a. Yes b. No

PART-IV Questions related to strategies for stormwater management

19. Have any remedial actions have been undertaken with managing effect of stormwater? It was _____
- 1) Successful 2) less successful 3) not successful 4. No idea
- 19.1. What temporary solutions have ever been taken to stormwater problems?
- a. Cleaning drainage channels b. Gravel covering
- c. Constructing new urban stormwater drainage facilities d. Earth embankments
- e. Planting vegetation f. not taken g. Specify, if any _____

20. At what extent planning and design sustainable stormwater management is needed to mitigate stormwater?

a) Very high extent b) High extent c) Low extent d) Very low extent e) No response

21. What permanent solutions you will suggest managing stormwater problems from sustainable urban stormwater management approaches?

- a) Source control (Plot level control) c) slow Transport
b) On site (Block level control) d) Downstream control e) all

Appendix II

I. Interview for Dambi Dollo town Municipality, Office of beautification and greenery

Department: Planner

Interview Questionnaire

This questionnaire is a research instrument of the study on “Urban stormwater management in Dambi Dollo Town: The case of Laga Hida river area”. This survey is strictly confidential and your answers will only appear as totals combined with those of other respondents for academic purposes only.

Purpose of the interview

1. To analysis the effect of current stormwater in Laga Hida river area.
2. To identify the challenges of stormwater management system in Laga Hida river area.
3. To propose strategies to enhance sustainable urban stormwater management system in Laga Hida river area.

1. Can you tell me about the urban stormwater management problems encountered 05 kebele?

2. What do you think about the main Challenges of stormwater management difficulties?

3. Are you considering the green area and open space implementation from SP of the town when you papered the greenery site plan? A. yes B. No

4. If yes, is there any implemented green area and open space to reduce effect of stormwater? How?

5. How much money do the government body allotted for the maintenance of damaged road networks, drainage cleaning or other environments by stormwater effect within 2 years in 05 kebele? _____

6. Are there any guideline/principles of the town to manage or reduce stormwater effect? Yes
No

If yes what kind of guideline/principles?

7. What do you think is the best approach to solve this problem related to urban planning and design? _____

II. Interview for Dambi Dollo Town Disaster risk management office

Interview Questionnaire

This questionnaire is a research instrument of the study on “Urban stormwater management in Dambi Dollo Town: The case of Laga Hida river area”. This survey is strictly confidential and your answers will only appear as totals combined with those of other respondents for academic purposes only.

Purpose of the interview

1. To analysis the effect of current stormwater in Laga Hida river area.
2. To identify the challenges of stormwater management system in Laga Hida river area.
3. To propose strategies to enhance sustainable urban stormwater management system in Laga Hida river area.
1. What do you think about the stormwater effect encountered 05 kebele around Laga Hida river area?

2. What do you think about the challenges of the stormwater mismanagement?

3. What do you think about the effect of the stormwater mismanagement? Physical environment

4. What kind of strategy is needed to reduce the risk of stormwater through planning and design of environments?

5. What are guidelines of built and natural environment to protect effect of stormwater from them?

III. Interview for Dambi Dollo town Health office: Environmental Health

Interview Questionnaire

This questionnaire is a research instrument of the study on “Urban stormwater management in Dambi Dollo Town: The case of Laga Hida river area”. This survey is strictly confidential and your answers will only appear as totals combined with those of other respondents for academic purposes only.

Purpose of the interview,

1. To analysis the effect of current stormwater in Laga Hida river area.
2. To identify the challenges of stormwater management system in Laga Hida river area.
3. To propose strategies to enhance sustainable urban stormwater management system in Laga Hida river area.

1. What do you think about Stormwater effect on community health around 05 kebele?

2. What kind of impact of stormwater on community through health issues?

A) No impact B) minor impact C) extreme impact

3. What type of water born diseases dominant due to garbage spilled on street and water is contaminated and after stormwater event?

4. What are the major challenges for stormwater management in this area you have seen?

5. What are actions to be taken to reduce the effect of stormwater on community?

Appendix III

I. FIELD SURVEY CHECKLIST

1. Total impervious area of the selected site: _____ ha or _____ km².

Green area _____ ha.

2. The general existing condition of the drainage system in the study area:

a. Existing width of drainage with standard _____

b. Condition: Good _____ fair _____ poor _____

c. Which drainage type is applied? Open drain _____ closed drain _____

d. Which drainage shape is applied?

Rectangular _____ Trapezoidal _____ circular _____

3. Existing Road Types

No	Road type	Road		Drainage facilities of street	
		Condition	Surface material	Concrete	Earth
1	Arterial street				
2	Sub arterial street				
3	Collector street				
4	Local street				

4. Existing Drainage facilities types

No	Drainage type	Width and length	Surface material	
			Concrete lines	Earth lines
1	Trapezoidal			
2	Circular			
3	Rectangular			

5. Visiting the physical and environmental effect of stormwater

✚ Is there degraded land area due to lack of stormwater management?

✚ How did the people tried to manage the stormwater effect in their compound and surround?

✚ Is there different physical infrastructure are damaged by stormwater?

- Electricity

- Water supply
- Sewerage line
- Drainage line and road network

6. Taking Rain fall data of the town from the metrological agency of the town.

Appendix IV: - Interview pictures



Appendix V: Proposed Laga Hida riverside riparian buffer and recreational area



A Panoramic view of the Laga Hida riverside buffer



Grass turf along the river



Detention pond



Different urban agriculture along the river



Watershed area



Reading space and recreational area



Terracing the watershed area



collector Street

The 3D view of proposed stormwater management Laga Hida riverside (Source, Author, 2021)