JIMMA UNIVERSITY

JIMMA INSTITUTE OF TECHNOLOGY

FACULTY OF CIVIL AND ENVIRONMENTAL ENGINEERING

DEPARTMENT OF CIVIL ENGINEERING

HIGHWAY ENGINEERING STREAM

EVALUATION ON THE EXISTING DRAINAGE CONDITION OF JIMMA TOWN

By: Sisay Abadir

An independent project Submitted to Jimma University, Jimma Institute of Technology, Faculty of Civil and Environmental Engineering, in Partial Fulfillment of the Requirements for the Degree of Master of engineering in highway engineering

May, 2020

Jimma, Ethiopia

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May, 2020

Jimma, Ethiopia

DECLARATION

Sisay Abadir, declare that this independent Project is my own original work that has not been presented and will not be presented by me to any other University for similar or any other degree award.

____

Signature

This independent project has been submitted for examination with my approval as university supervisors.

Approved by

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Firstly, I would like to thank the almighty GOD for his priceless help and protection during whole activity of my work. It is also important and right to acknowledge the support and help of various people who had contributed for successful completion of this project. First and for most, I would like to express my genuine gratitude and appreciation to my Advisors -Ing. Biruk Yigezu. And Ing. Oluma Gudina whose encouragement, guidance and support from the start to the end enabled me to develop an understanding of the subject matter very well. This project would have not been possible within such relatively short time without kind support from them.

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Abstract

Drainage is one of the most important factors to be considered in the road design, construction and maintenance projects. It is generally accepted that road structures work well and last longer to give the desired service. When a road fails, whether it is concrete, asphalt or gravel, inadequate drainage is often a major factor to be considered. Jimma town is well accessed throughout the year by an asphalted road and it is among the old cities of Ethiopia having vibrant economic activity based on cash crop namely coffee. Currently, the town is experiencing development of infrastructures (mainly roads) and the preparation of modern drainage design should be seen in line with the overall development endeavor of the municipal administration. Objective of the project is to evaluate the performances of the existing drainage structures and propose mitigation measures. The project was conducted based on both primary and secondary data. The primary data were collected through field assessment using different approaches. Secondary data were obtained through review of reports and graphic documents produced by the municipal administration as well as relevant stakeholders. The drainage issue, associated with urban wastes (both liquid and solid), have become among the most critical agenda of the town causing both physical and sanitation problems. The physical problem is associated with inundation and eventual destruction of personal and public properties; whereas the sanitation problem, resulted from absence of proper management of urban wastes (household and commercial), is posing serious health threat like malaria and other water-borne diseases on citizens of the town. Due to large volume of water from the highland catchment areas of the town, the natural water ways couldn't carry the incoming runoff, particularly during rainy seasons, and as a result causing inundation in some parts of the town especially in the Merkato (market area), high ground water table condition around genu to ajip and other low laying areas causing severe damage to property. In order to minimize these negative impacts improvement in the integration of road and water drainage infrastructure and integrated solid waste management to prevent over flowing of flood as a result of blockage of drains.

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Key words: *Drainage structure, urban waste, sanitation problem, runoff, solid waste*

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Acronyms

ADO: Arizona Department of Transportation

AMP: Asset Management Plan

DDM: Drainage Design Manual

DS: Design Standard

EMA: Ethiopian Meteorology Agency

ERA: Ethiopian road authority

HVS: Heavy Vehicle Simulator

JCDMP: Jimma City Drainage Master Plan

MUDH: Ministry of Urban Development and Housing

ULGDP: Urban Local Government Development Project

USA: United States of America

CHAPTER ONE

1. INTRODUCTION

1.1 Back ground.

Infrastructure is one of the indispensable elements in the process of urbanization and emergence and continuity of an urban growth. It is considered as motor/engine for economic development (World Bank, 2006). Infrastructure is important in eradicating poverty through various job creation opportunities and by so doing, it enables to speed up economic development and ultimately ensures improved quality of life. According to World Development Report (2006), infrastructure development in Africa is abysmal, lagging behind the rest of the world in terms of quality, quantity, and access. World Development Report (2006).

Ethiopia is a low income country where waste management is at its lowest stage of development; only small drainage and natural earth drainage system are evident in urban centers, particularly in big towns. The Government of the Federal Democratic Republic of Ethiopia (FDRE) is addressing this problem as a vital component of its effort to change the backward economic and social status of the country and provide basic urban infrastructure for cities. It is undertaking projects for the development of urban infrastructure in selected urban centers of the country with the assistance of donors and international financial institutions. One such project is Jimma City Drainage Master Plan Project under the "Urban Local Government Development Project (ULGDP)" program. The project has been given high priority by the City Administration due to the entire city drainage master plan and management of drainage system which are major causes of flood hazard in the city.

Jimma city experiences a warm and humid tropical climate with relatively long wet season. This general climatic condition categorizes the city under a Woina Dega climate of warm and humid class. The climate of the city from the point of view of temperature, annual rainfall, humidity and prevailing wind direction are discussed below.

Average monthly temperature is between 17.9 and 20.5 degree Celsius, the annual average being 19.5 degree Celsius. Temperature variations are observed between seasons, the lowest temperature was observed from September to November period. Jimma's average Monthly temperature shows seasonal variation; the hottest months being February, March, April and the coldest July, August and September. Mornings are relatively colder and at noon the temperature becomes high or hot and also calm.

Jimma enjoys moderately heavy rainfall throughout the year, with annual precipitation ranging from 1450 to 1800 mm (GTZ IS, 2005). The annual average rainfall was 1470 mm (Ethiopian Meteorological Agency cited on Jimma City Administration, 2007). Relative humidity was 56.8 % and the highest average humidity was observed during the main rainy season. According to the data presented in the executive summary report of the 1997 Jimma Development Plan that was prepared by NUPI, the city received an annual average of 1300 mm of rainfall, which varies between 1373 mm and 2382.2 mm. The rainfall however, shows seasonal variation with average monthly rainfall ranging between 37.8 mm in January and 229.1 mm in August. The daily maximum rainfall and number of rainy days from 1995 to 2012.

Water is the most important compound ensuring life in this planet. But on roads the presence of water means mainly trouble. A main cause of road damage, and problems with the serviceability of road networks, is excess water filling the pores of road materials in the road and in the subgrade soils. It is generally known that road structures operate well in dry conditions and because of this roads historically have been built on dry terrain. On those occasions where roads have had to be built on wet terrain, drainage structures have usually been designed to keep the road structures dry. The first roads in Europe were built about 3500 years ago. Already at that time engineers designed the road structures to take into account the importance of drainage. They paid attention to cross-fall (to help water to flow to the lateral ditches), grade line (the road surface should be above of the groundwater table and the surrounding ground) and lateral ditches (to convey water away from the road structure and prevent water table rise) (Dawson, 2002).

Drainage is a must component in the road construction. In lay world language we know that tarmac and water are never "best friends." For this reason in most designs of the road, the first thing to be put in place is drainage system. The presence of water in the pavement layer will tend to reduce the bearing capacity of the road and thereby its lifetime. It is required that the surface water from carriage ways and the shoulders should be efficiently drained off without allowing it to the subgrade of the road (Victory K. Rono, 2014).

Drainage system is a process of removing and controlling excess surface water with in right of way. Drainage is an important feature in determining the ability of given pavement to withstand the effects of traffic and environment. (Adequate drainage is very essential in the design of highways since it affects the highway's serviceability and usable life. If ponding on the traveled way occurs, hydroplaning becomes an important safety concern. Drainage design involves providing facilities that collect, transport and removes storm water from the highway (O‟Flaherty, et al., 2000).

The objective of drainage system is to prevent onsite water standing on the surface and convey the offsite storm runoff from one side of the roadway to the other. To carry out the offsite drainage. Culverts are closed conduits in which the top of the structure is covered by embankment (ERA Drainage Design Manual, 2013). As the water can cause a serious impact on both the road access and its strength, an efficient drainage system is the most important part of road construction and maintenance works.

Good drainage needs to be taken into consideration at the early design stages in order to secure a long life for the road. With a well-designed drainage system, future rehabilitation and maintenance works can be considerably reduced and thus limit the costs of keeping the road in a good condition.

Ensuring good drainage begins when selecting the road alignment. A Centre line that avoids poorly drained areas, large runoffs and unnecessary stream crossings will greatly reduce the drainage problems. Provision of sufficient drainage is an important factor in the location and geometric design of highways. Drainage facilities on any highway or street should adequately provide for the flow of water away from the surface of the pavement to properly designed channels. In addition, traffic may be slowed by accumulated water on the pavement, and accidents may occur as a result of hydroplaning and loss of visibility from squish and sprig. The importance of enough drainage is recognized in the amount of highway construction dollars allocated to drainage facilities. About 25 percent of highway construction dollars are spent for erosion control and drainage structures, such as culverts, bridges, channels, and ditches (Wyatt, 2000).

Surface drainage encompasses all means by which surface water is removed from the pavement and right of way of the highway or street. A properly designed highway surface drainage system should effectively intercept all surface and watershed runoff and direct this water into adequately designed channels and gutters for eventual discharge into the natural waterways. Water seeping through cracks in the highway riding surface and shoulder areas into underlying layers of the pavement may result in serious damage to the highway pavement. The major source of water for this type of intrusion is surface runoff. An adequately designed surface drainage system will therefore minimize this type of damage. The surface drainage system for rural highways should include sufficient transverse and longitudinal slopes on both the pavement and shoulder to ensure positive runoff and longitudinal channels (ditches), culverts to provide for the discharge of the surface water to the natural waterways. Storm drains and inlets are also provided on the median of divided highways in rural areas. In urban areas, the surface drainage system also includes enough longitudinal and transverse slopes, but the longitudinal drains are usually underground pipe drains designed to carry both surface runoff and ground water. Curbs and gutters also may be used in urban and rural areas to control street runoff, although they are more frequently used in urban areas (Wyatt, 2000).

The ancient Romans who started building the 50,000 mile Imperial Roman road network in 312 B.C knew of the damaging effects of water and tried to keep their roads above the level of the surroundings terrain. In addition to constructing these roads with thick section, they often provided a sand layer on top of the sub-grade. The durability of those highways is provided by the fact that many of them still exist (Muhammad, 2014).

Drainage facilities are required to protect the road against damage from surface and sub-surface water. Traffic safety is also important as poor drainage can result in dangerous conditions like hydroplaning. Poor drainage can also compromise the structural integrity and life of a pavement. Drainage systems combine various natural and a man-made facility e.g. ditches, pipes, culverts, curbs to convey this water safely (US Forest Service, 1979).

Jimma town is well accessed throughout the year by an asphalted road and it is among the old cities of Ethiopia having vibrant economic activity based on cash crop namely coffee. Currently, the town is experiencing development of infrastructures (mainly roads) and the preparation of modern drainage design should be seen in line with the overall development endeavor of the municipal administration.

Currently the town is experiencing development of infrastructures (mainly roads) and the preparation of this modern drainage design should be seen in line with the overall development efforts of the municipal administration.

1.2. Statement of the Problem

Out of the total road network coverage of the town, the proportion of roads which have drainage facilities of any type (open or closed, piped or earthed) is negligible. In addition to absence of proper drainage lines and flood protection structures, sedimentation, disposal of construction leftovers, decomposable as well as non-decomposable wastes that retard the velocity of the runoff and thereby aggravate the flood problem of the town. During rainy season it is a usual phenomenon to see overflow of water and hence inundation of some parts of the town. The limited drainage facility coupled with highly intensive rainfall of the region has exposed the town to severe flooding problems. Runoff, which is in excess of the drainage structures capacity, overtops the road embankment and makes the road to function improperly due to erosion and ponding. Major sources of upper catchments that cause flood hazard on the town are: Jiren, Genjo-Gudru, Hermata merkato/mentina, and mendera kochi/awetu which drain to Kito and Aweytu rivers, Aweytu being the major river into which most part of the run off drain and eventually enters into the swampy area of the town and thereby to the Gibe River. To alleviate this problem, side ditch and culvert drainage structures performance will be evaluated and mitigation measures shall be propose for sustainable and proper functioning based on ERA drainage design manuals.

1.3. Research questions

The fundamental questions that are addressed and investigated are:

- What are the major causes of existing drainage infrastructure?
- How to evaluate the existing drainage condition of the town?
- What are remedial measures to be taken for respective cause effect?

1.3 Objective of the project

1.3.1. General objective

- To evaluate the performances of the existing drainage condition and propose mitigation measures

1.3.2. Specific Objectives

- To evaluate the conditions of the existing drainage infrastructure

- To evaluate the Existing drainage condition of the Town.
- To recommended remedial measures to be taken for the respective cause and effect.

1.4. Significance of the project

- Jimma City Road Administration will benefit from the project as a source of information and foundation to gate possible causes to tackle of the distress.
- This project is conducted Owners, contractors and consultants will benefit from the project as a source of information to maintain and rehabilitate the road stretch.
- This project will use the findings as a reference for further research project on the specified stretch.

1.5 Scope of study

This study is geographically limited to Jimma City road. Generally, it was addressed issues related to drainage structures and its integration with road provision. Even though drainage problem exist all over the country it is difficult to have a look at each road of whole country. Therefore Jimma City roads are taken and analysis was done on different drainage structures like culvert, bridge, road side ditch and curbs to convey water safely.

CHAPTER TWO

2. LITERATURE REVIEW

2.1. History of Drainage Development

Natural hydrological processes would have prevailed; there might have been floods in extreme conditions, but these would not have been made worse by human alteration of the surface of the ground. Artificial drainage systems were developed as soon as humans attempted to control their environment. Archaeological evidence reveals that drainage was provided to the buildings of many ancient civilizations such as the Mesopotamians, the Minoans (Crete) and the Greeks (Athens). Historical accounts show that the objectives of the drainage systems were to collect rainwater, prevent flooding, and convey wastes. At the time, planning and design were limited, people used to able to find the systems that met their objectives after trial-and-error modifications. Despite the lack of optimization and the use of trial-and-error construction methods, numerous ancient urban drainage systems can be rated very successful.

Urban drainage was firmly established as a vital public works system in the early parts of the twentieth century. Engineers continued to improve design concepts and methods. During the second half of the twentieth century regulatory elements were spread in the United States, Europe, and other locations addressing urban drainage issues. Computer modeling tools advanced the methods used to design and analyze urban drainage systems. Regulations, monitoring, computer modeling, and environmental concerns have altered the perspective of urban drainage from a public health and nuisance flooding concern during the first half of the twentieth century into a public health and nuisance flooding with additional concerns for ecosystem protection and urban sustainability (S.K. Garg, 2005).

Congested traffic due to flooding of roads after small depth of rainfall, erosion of pavements resulting in reduction of service life of road infrastructure and impact of road flooding on nearby community are consequences of poor drainage system in the area.

These problems would be solved if good design, construction and maintenance of drainage infrastructures were practiced. In addition, smaller inlet spacing, higher inlet efficiency and frequent maintenance would alleviate the flood problem totally (Dessalegn, 2011) the pattern of urbanization and modernization in Ethiopia has meant increase densification along with urban infrastructure development. The combined effect of this results in higher rain drop intensity and consequently accelerated and concentrated runoff. Inadequate integration between road and urban storm water drainage infrastructure provision and poor management, significant proportion of the study area is exposed to flooding hazards/risks. This has resulted in negative impacts on urban storm water drainage provision and management. The major causes of flooding was found to be the blockage of urban storm water drainage lines along with inadequate/poor integration between road and urban storm water drainage infrastructures. The paper recommended improvement in the integration of road and urban storm water drainage infrastructure and integrated solid waste management to prevent over flowing of flood as a result of blockage of drains (Dagnachew, 2011).

Communities worldwide are yet searching for innovative techniques to capture, detain, and use rainwater within the watershed instead of constructing massive drainage structures. Many communities are developing watershed-wide storm water quality management plans to meet the dual objectives of flood prevention and water quality control. Urban drainage has indeed expanded significantly during the past few decades beyond a technical challenge to drain the urban area rapidly to include the consideration of social, economic, political, environmental, and regulatory factors (David Butler and John W. Davies, 2004).

Drainage systems are needed in developed urban areas because of the interaction between human activity and the natural water cycle. This interaction has two main forms: the abstraction of water from the natural cycle to provide a water supply for human life, and the covering of land with impermeable surfaces that divert rainwater away from the local natural system of drainage. These two types of interaction give rise to two types of water that require drainage. The first type, wastewater, is water that has been supplied to support life, maintain a standard of living satisfy and the needs of industry. The second type of water requiring drainage, storm water, is rainwater (or water resulting from any form of precipitation) that has fallen on a built-up area. (David Butler and John W. Davies, 2004).

Drainage is one of the most important factors to be considered in the road design, construction and maintenance. When a road fails, whether it is concrete, asphalt or gravel, inadequate drainage is often a major factor to be considered. Poor drainage is often the main cause of road damages and problems with long term road serviceability. Though provision of proper road surface drainage systems have such a great importance for the urban road to give the intended use and thereby contribute to the overall development of a nation, in particular in road sector, the practice of the construction of proper integrated drainage structures did not get due attention in our country. Therefore the problems and achievements on the design, construction and maintenance of surface road drainage systems need to be assessed to provide remedial measures for the better performance of the road infrastructure. Insufficient urban storm water drainage facility represent one of the most common sources of compliant from the citizens in many towns of Ethiopia and this problem is getting worse and worse with the ongoing high rate of urbanization in different parts of the country, especially in Addis Ababa. (Getachew K. W, et al 2011) Storm drainage design is an integral component in the design of highway and transportation networks. Drainage design for highway facilities must strive to maintain compatibility and minimize interference with existing drainage patterns, control flooding of the roadway surface for design flood events, and minimize potential environmental impacts from highway related storm water runoff. (Dabara I. D., O. et al, 2012). Storm water collection systems must be designed to provide adequate surface drainage. Traffic safety is intimately related to surface drainage. Surface drainage is a function of transverse and longitudinal pavement slope, pavement roughness, inlet spacing, and inlet capacity (Dabara I. D. O, et al, 2012)

Service life of infrastructure can be highly reduced by improper drainage system. It can be seen from rainy season which lasts from July to September where the highways are covered by surface water. This water accelerates the deterioration rate of the roads and results in economic loss. The flooding of the highways is the result of improper drainage system of the roads and poor integration of road and urban storm water drainage network (Ewnetu, 2013).

2.2. General Description of Road Drainage Structures

Road drainage structures that cross the rivers and valleys are vital components of the road network that contributes greatly to the national development and public daily life. Any damage or collapse of these structures can cause the risk of the lives of road users as well as create serious influence to the entire country economic development.

Furthermore, the reconstruction of these road drainage structures needs considerable amount of skilled work force, money and time. Road drainage structures are essential components during the design development of road infrastructures. Drainage structures intended to allow the runoff of any flow of water with limited damages and disturbances to the road and to the surrounding areas.

The two main types of water flows that can be considered are the flows that usually crossing the area that could be diverted by the presence of the road, and the flows generated by the runoff of the rainwater falling on the carriageway and its surroundings. The basic design techniques in roadway drainage system should be developed for economic design of surface drainage structures including ditches, culverts and bridges (ERA, 2013).

2.2.1 Surface drainage systems (ditches)

A surface drainage system collects and diverts storm water from the road surface and surrounding areas to avoid flooding. It also prevents damage to sub-surface drains, water supplies (wells) and other sensitive areas adjacent to roads. It decreases the possibility of water infiltration into the road and retains the road bearing capability (Faísca et al., 2009). Appropriate design of the surface drainage system is an essential part of commercial road design (O'Flaherty, C.A., 2002).

There are different types of trenches with different functions, but the majority of ditches are normally provided with V-shaped cross-sections. Depending on the location of the ditch relative to the road construction, it is called a cutting ditch, shallow ditch or covered ditch (Linde et al., 2010).

When rain falls on a sloped pavement surface, it forms a thin film of water that increases in thickness as it flows to the edge of the pavement. Factors which influence the depth of water on the pavement are the length of flow path, surface texture, surface slope, and rainfall intensity. As the depth of water on the pavement increases, the potential for vehicular hydroplaning increases (ERA, 2013).

2.2.2 Subsurface drainage systems (culverts)

Subsurface drainage systems drain water that has infiltrated through the pavement and the inner slope but also groundwater.

Subsurface drainage systems are directly linked to surface drainage systems (Faísca et al, 2009).

According to the SRA handbook, culverts are road constructions with a theoretical span of ≤2.0 m. Culverts have an open inlet and outlet and conduct water underneath a road. Particular care in both design and maintenance is required to prevent obstruction of water flow by obstacles (Vägverket, 2008).

Diversion of water from the central reservation of major roads is achieved with a pipe running either along or across the road to the subsurface drains on the excavation slope (ATB Väg, 2004)

2.3. Road Crossing drainage structures

A hydraulic investigation and analysis of both the upstream and downstream reaches of the watercourse is necessary to determine the best location, size, and elevation of the proposed crossroad structure, whether a culvert or a bridge. The investigation should ensure that any roadway structure or roadway embankment that encroaches on or crosses the flood plain of a watercourse will not cause significant adverse effect to the flood plain and will be capable of withstanding the flood flow with minimal damage. It is significant to provide attention during design of the magnitude, frequency and appropriate water surface elevations for the design flood, the 100-year flood, and the overtopping or 500-year flood for all structures (ADOT, 2007) .

Stream crossing culvert is a drainage structure installed on the stream with recommended skewed angle, 150- 450 if conditions do not permit to install normal to the stream channel. Installing culverts normal to the stream channel decreases construction cost. Where large skew angles are required, consideration of the most appropriate road alignment is significant (Austroads , 1994). Runoff management culvert strategically placed to manage and route roadway runoff along, under, and away from the roadway. Many times these culverts are used to transport upland runoff, accumulated in road ditches on the upland side of the roadway, to the lower side for disposal. Highway drainage is the process of removing and controlling excess surface and sub-surface water within the right way. This includes interception and diversion of water from the road surface and subgrade. The installation of suitable surface and sub-surface drainage system is an essential part of highway design and construction. Highway drainage is used to clear surface water from the highway (Austroads, 1994).

Good highway drainage is important for road safety. Roads need to be well drained to stop flooding; even surface water can cause problems with ice in the winter. Water left standing on roads can also cause maintenance problems, as it can soften the ground under a road making the road surface break up and as well lead to an accident from the road users (Amit, 2016).

(Muhammad, 2014) studied highway drainage system and started that highway is importance for removing water from the road surface, preventing ingress of water into the pavement, passing water across the road, either under or over and preventing scour and/ or washout of the pavement, shoulder, batter slopes, water courses and drainage structures. He identified types of drainage on the highway to include kerb and gullies, surface water channel, combined filter drain (French drain), over-the-edge drainage, drainage channel locks, combined kerb and drainage units, linear drainage channels, fin and narrow filter drain (sub-surface drainage) and edge drainage for porous asphalt.

According to civil engineering dictionary (Engineering Dictionary, 2004), highway drainage includes collecting, transporting, and disposing of surface/subsurface water originating on or near the highway right of way or flowing in streams crossing bordering that right of way. This is important because of water damage highway structure in many ways. The water which are dangerous for highways are: Rainwater: Cause erosion on surface or may seep downward and damage pavement (surface drains), Groundwater: May rise by capillary action and damage pavement (sub-surface damage) and water body: May cross a road (river/stream) and may damage road (cross drainage words).

In a research on drainage on roads by (Singh et al., 2014), a well-designed and well maintained road drainage is important in order to minimize the environmental impact of road runoff on the receiving water environment, ensure the speedy removal of surface water to enhance safety and minimize disruption to road users and to maximize the longevity of the road surface and associated infrastructures. Water in the pavement system can lead to moisture damage, modulus reduction and loss of strength. In order to prevent such damages to the pavement, it is essential to provide proper drainage to the roads. They maintained that the presence of water in a highway layer reduces the bearing capacity of the road, and in doing so it also reduces the structure's lifetime. Highway drainage is used to clear surface water from the highway. Roads need to be well drained to stop flooding; even surface water can cause problems with ice in the winter. Water left standing on roads can also cause maintenance problems, as it can soften the ground under a road making the road surface break up (Singh et al., 2014).

The “maintenance related” category covers all of those drainage problems that can be avoided by good maintenance policies and practices.

Poor drainage maintenance can have a major effect on the lifetime of a pavement and annual paving costs. It can also affect traffic safety. For this reason accurate definitions and requirements for each drainage maintenance task should be included in the contract documents, and followed up on site to ensure that the contractor fulfills its duties (Bentsen and Saarenketo, 2006).

2.4. Components of a Drainage System

A complete storm drainage system design includes consideration of both major and minor drainage systems. The minor system consists of curbs, gutters, ditches, inlets, access holes, pipes and other conduits, open channels, pumps, detention basins, water quality control facilities, etc. The minor system is normally designed to carry runoff from 10 year frequency storm events.

The major system provides overland relief for storm water flows exceeding the capacity of the minor system. This usually occurs during more infrequent storm events, such as the 25-, 50-, and 100-year storms. The major system is composed of pathways that are provided – knowingly or unknowingly -for the runoff to flow to natural or manmade receiving channels such as streams, creeks, or rivers.

Usually, storm drainage design efforts have focused on components of the minor system with little attention being paid to the major system. Although the more significant design effort is still focused on the minor system, lack of attention to the supplementary functioning of the major storm drainage system is no longer acceptable (urban Drainage Design Manual, 2001)

2.4.1. Storm Water Collection

Storm water collection is a function of the minor storm drainage system which is accommodated through the use of roadside and median ditches, gutters, and drainage inlets. Roadside and median ditches are used to intercept runoff and carry it to an adequate storm drain. These ditches should have adequate capacity for the design runoff and should be located and shaped in a manner that does not present a traffic hazard. If necessary, channel linings should be provided to control erosion in ditches. Where design velocities will permit, vegetative linings should be used (Thomas N, 2003).Gutters are used to intercept pavement runoff and carry it along the roadway shoulder to an adequate storm drain inlet. Curbs are typically installed in combination with gutters where runoff from the pavement surface would erode fill slopes and/or where right-of-way requirements or topographic conditions will not permit the development of roadside ditches. Pavement sections are typically curbed in urban settings. Parabolic gutters without curbs are used in some areas.

Inlets are the receptors for surface water collected in ditches and gutters, and serve as the mechanism whereby surface water enters storm drains. When located along the shoulder of the roadway, storm drain inlets are sized and located to limit the spread of surface water on to travel lanes. Drainage inlet locations are often established by the roadway geometries as well as by the intent to reduce the spread of water onto the roadway surface. Generally, inlets are placed at low points in the gutter grade, intersections, crosswalks, cross-slope reversals, and on side streets to prevent the water from flowing onto the main road (Ahern, 1995).

Storm drain inlets are used to collect runoff and discharge it to an underground storm drainage system. Inlets are typically located in gutter sections, paved medians, and roadside and median ditches (ERA, 2013).

2.4.2. Storm Water Conveyance

Storm drains are that portion of the storm drainage system that receive runoff from inlets and conveys the runoff to some point where it is discharged into a channel, water body, or other piped system. Storm drains can be closed conduit or open channel. They may consist of one or more pipes or conveyance channels connecting two or more inlets. Access holes, junction boxes and inlets serve as access structures and alignment control points in storm drainage systems. Critical design parameters related to these structures include access structure spacing and storm drain deflection. Spacing limits are often dictated by maintenance activities. In addition, these structures should be located at the intersections of two or more storm drains, when there is a change in the pipe size, and at changes in alignment (horizontal or vertical). In areas where gravity drainage is impossible or not economically justifiable, storm water pump stations are often required to drain depressed sections of roadways. Detention/ retention facilities are used to control the quantity of runoff discharged to receiving waters. A reduction in runoff quantity can be achieved by the storage of runoff in detention/retention basins, storm drainage pipes, swales and channels, or other storage facilities.

Outlet controls on these facilities are used to reduce the rate of storm water discharge (David Butler and John W. Davies, 2004).This concept should be considered for use in highway drainage design where existing downstream receiving channels are inadequate to handle peak flow rates from the highway project, where highway development would contribute to increased peak flow rates and aggravate downstream flooding problems, or as a technique to reduce the size and associated cost of outfalls from highway storm drainage facilities.

2.4.3 Storm water Discharge Controls

Storm water discharge controls are often required to off-set potential runoff quantity and/or quality impacts. Water quantity controls include detention/retention facilities. Water quality controls include extended detention facilities as well as other water quality management practices.

Detention/retention facilities are used to control the quantity of runoff discharged to receiving waters. A reduction in runoff quantity can be achieved by the storage of runoff in detention/retention basins, storm drainage pipes, swales and channels, or other storage facilities. Outlet controls on these facilities are used to reduce the rate of storm water discharge. This concept should be considered for use in highway drainage design where existing downstream receiving channels are inadequate to handle peak flow rates from the highway project, where highway development would contribute to increased peak flow rates and aggravate downstream flooding problems, or as a technique to reduce the size and associated cost of outfalls from highway storm drainage facilities (ODOT, 2014).

Water quality controls are used to control the quality of storm water discharges from highway storm drainage systems. Water quality controls include extended detention ponds, wet ponds, infiltration trenches, infiltration basins, porous pavements, sand filters, water quality inlets, vegetative practices, erosion control practices, and wetlands. Classes of pollutants typically associated with highway runoff include suspended solids, heavy metals, nutrients, and organics. Water quality controls should be considered for use as mitigation measures where predictions indicate that highway runoff may significantly impact the water quality of receiving waters (USA Department of Transportation, 2013).

The objective of road storm drainage design is to provide for safe passage of vehicles during the design storm event. The design of a drainage system for a curbed road pavement section is to collect runoff in the gutter and convey it to pavement inlets in a manner that provides reasonable safety for traffic and pedestrians at a reasonable cost. As spread from the curb increases, the risks of traffic accidents and delays, and the nuisance and possible hazard to pedestrian traffic increase (ERA, 2013).

2.5. Construction and maintenance of drainage systems

The planned drainage systems for a project can only be finalized during the work's execution, when the local geotechnical conditions are fully understood. Thus, it is important that an adequate specification is produced for the anticipated type of drainage system and for suitable materials, so that the implementation teams are able to deliver the best solutions (Andrew Dawson, October 2008).

The many phases which constitute the construction of a road are sometimes delayed, and this can be drainage related, due to:

- Alteration in design flows;
- Obstruction of the surface and underground water flow path, due to earth moving and material placement;
- Possible surface and underground water contamination, due to earth moving, machine cleaning and associated incidents;
- Increase in the soil's compaction in the areas where there is flow to or from an aquifer; and
- Alteration in the hydrological regime, as a consequence of the disturbed soil caused by the construction of the road structure. (Andrew Dawson, October 2008).

2.5.1 Maintenance of drainage system:

It is of great importance that the draining system is working properly, hence regular checks and maintenance are required. Every drainage system should be designed to ensure that inspection and maintenance operations are possible and accessible. Usually, the cleaning of the drainage system should be done at the end of the summer, but inspections could be intensified in periods of high precipitation. However, at least every 5 years it is fundamental that there is a proper inspection of every part of the drainage system.

The problems that practitioners encounter are manifold. In the questionnaire survey (see the following issues were mentioned:

- The drainage system becomes clogged with fine materials,
- Crushed pipes,
- Poor outlet conditions, i.e. outlets have negative slopes,
- Root penetration, Generation of ferrous hydroxide and calcium carbonate,
- Insufficient capacity,
- Inadequate water velocity,
- The (plastic) cover of the inspection well at the slope may be damaged (sometimes due to snow clearance of the road).

2.6. The impacts of drainage underperformance

Poor road pavement can result in costly repairs or pavement replacement long before the road pavements reach their expected design life.

Additionally, excessive water/moisture content in the pavement base, sub base and subgrade can cause early distresses, i.e., rutting, fatigue cracking, raveling alligator cracking, potholes, base failures, settlement, swelling…etc. That can lead to structural and functional failures. The following are some water-related effects: Reduce base, sub base, and subgrade strength; Differential swelling in expansive cohesive clay soils; Stripping of binder/bitumen from aggregate;

Movement of "fines" into base or sub base course material causing reduction of hydraulic conductivity; Reduce pavement load bearing capacity; Washout of road segments or structures; and Reduced engineering properties of soils, i.e. cohesiveness, friction……etc.

Consequently, water combined with traffic loading can have a negative effect on both material properties and the overall performance of the road system, i.e., premature road failure. Water entering the road pavement can accelerate pavement deterioration that results in

1) Increase operation and maintenance cost;

2) Shorten road lifecycle,

3) Poor ride quality,

4) Increase accidents,

5) Increase road users' delay,

6) Accelerated pavement replacement and increased cost and increased vehicle users operating cost (Prithvi S, 2002).

Roads will affect the natural surface and subsurface drainage pattern of a watershed or individual hill slope. Road drainage design has as its basic objective the reduction and/or elimination of energy generated by flowing water. Therefore, water must not be allowed to develop sufficient volume or velocity so as to cause excessive wear along ditches, below culverts, or along exposed running surfaces, cuts, or fills. Provision for adequate drainage is of paramount importance in road design and cannot be overemphasized. The presence of excess water or moisture within the roadway will adversely affect the engineering properties of the materials with which it was constructed. Cut or fill failures, road surface erosion, and weakened subgrades followed by a mass failure are all products of inadequate or poorly designed drainage. As has been stated previously, many drainage problems can be avoided in the location and design of the road: Drainage design is most appropriately included in alignment and gradient planning (Larson, et al., 1949).

2.6.1 Effects of Poor Drainage system on Roads

An appropriate understanding of the dynamics of water flow in roads is important for many reasons. It is well known that the rate of road deterioration increases if the water content of the granular material increases. Presents no less than six adverse effects related to excess water: reduction of shear strength of unbound materials, differential swelling on expansive sub grade soils, movement of unbound fines in flexible pavement base and sub base layers, pumping of fines and durability cracking in rigid pavements, frost-heave and thaw weakening, and stripping of asphalt in flexible pavements. In a recently performed accelerated load test, used a Heavy Vehicle Simulator (HVS) to show that the rate of rutting increased in all layers of a flexible construction when the ground water table was raised. On the positive side, ensuring proper (optimal) water content greatly improves packing of the road during construction, and may also increase its resilience when trafficked, even though this effect is often neglected. In conclusion, initially maintaining adequate water contents in asphalt road materials is bene ficial but if the water content increases with time, negative effects will most likely emerge. It is generally desired to keep the road as close to or less than optimum water content as possible over time (Diriba, 2016).

However, to realize road benefits, roads must be properly designed, constructed, operated and maintained. A key factor in effective road performance is proper drainage (Edgar Leonard , 2004).Prithvi Singh Kandhal, associate director of the National Center for Asphalt Technology at Auburn University and internationally-recognized for work in asphalt road construction technology, noted, “It is a fundamental tenet of practicing pavement engineering that three things are vital for pavement performance: Drainage, Drainage, and Drainage.”

2.6.2 Causes of flooding

A flood is an excess of water (or mud) on land that's normally dry and is a situation wherein the inundation is caused by high flow, or overflow of water in an established watercourse, such as a river, stream, or drainage ditch; or ponding of water at or near the point where the rain falls. Flooding is a duration type event. A flood can strike anywhere without warning, occurs when a large volume of rain falls within a short time. In general flooding are categorized in to two: according to duration (as Slow-onset, Rapid-onset and flash flooding) and according to location (Coastal Flooding, Arroyos Flooding, River Flooding and Urban Flooding). The urban area is paved with roads, houses etc. and the discharge of heavy rain can’t absorbed into the ground due to drainage constraints leads to flooding of streets, underpasses, low lying areas and storm drains .Causes of urban flooding are either natural or human. The natural causes are heavy rainfall or flash floods, lack of lakes and silting. On the other hand, human causes are: Population pressure: Because of large amount of people, more materials are needed, like wood, land, food, etc. This aggravates overgrazing, over cultivation and soil erosion which increases the risk of flooding. Deforestation: Large areas of forests near the rivers/catchment of cities are used to make rooms for settlements, roads and farmlands and is being cleared due to which soil is quickly lost to drains. This raises the drain bed causing overflow and in turn urban flooding. Urbanization: leads to paving of surfaces which decreases ground absorption and increases the speed and amount of surface flow. The water rushes down suddenly into the streams from their catchment areas leading to a sudden rise in water level and flash floods. Unplanned urbanization is the key cause of urban flooding. Various kinds of depression and low lying areas near or around the cities which were act as cushions and flood absorbers are gradually filled up and built upon due to urbanization pressure. This results in inadequate channel capacity causing urban flooding. Poor Water and Sewerage Management: Old drainage and sewerage system has not been repaired nor it is adequate now (Er. Pareva, 2005)

Urban flooding is specific in the fact that the cause is a lack of drainage in an urban area. A lot of the sewerage and drainage network would be old and its condition may be unknown. They cannot cope with the volume of water or are blocked by rubbish and by non-biodegradable plastic bags. Sewers overflow because of illegal connections and the sewer system cannot cope with the increased volumes. As new developments cover previously permeable ground, the amount of rainwater running off the surface into drains and sewers increases dramatically. Developments encroach floodplains, obstructing floodways and causing loss of natural flood storage. Continued development and redevelopment to higher density land uses by high land costs. The proportion of impermeable ground in existing developments is increasing as people build patios and pave over front gardens. Increased impervious areas such as roads, roofs and paving, due to increasing development densities means more run-offs. Some of the major hydrological effects of urbanization are:

(1) Increased water demand, often exceeding the available natural resources;

(2) Increased wastewater, burdening rivers and lakes and endangering the ecology;

(3) Increased peak flow;

(4) Reduced infiltration and

(5) Reduced groundwater recharge, increased use of groundwater, and diminishing base flow of streams. According to natural hydrological phenomena, due to increased impervious area precipitation responds quickly reducing the time to peak and producing higher peak flows in the drainage channels (Debu Mukherja. July 2016).

CHAPTER THREE

3. PROJECT METHODOLOGY

3.1. Description of the city

Jimma City is situated at a distance of 345 km from Addis Ababa in Jimma Zone of Oromia National Regional State in South Western part of Ethiopia in the heart of Coffee belt. The city was established more than hundred years ago by king ***Aba Jifar*** and is playing significant role in the development course of Ethiopia. According to the currently prepared Structure plan, Jimma has a total area of about 102 Km^2 of which the built area is estimated to be 76 $Km.^2$ All in all Jimma town administration comprises of 17 kebeles (districts) of which 3 of them are rural. The geographical location of the city is 7041' N Latitude and 360 50' E Longitude. It is positioned on the western part of the country and drained by river Gibe and its tributaries.

The town is characterized by moderately slope topography with mild or flat surfaces in the inner part of the town, particularly the market area. The western and southern peripheries of the town are flat and swampy whereby the entire runoff flows into this part of the town and thereby ends into river Gibe.

Jimma town is well accessed throughout the year by an asphalted road and it is among the old cities of Ethiopia having vibrant economic activity based on cash crop namely coffee. Currently, the town is experiencing development of infrastructures (mainly roads) and the preparation of modern drainage design should be seen in line with the overall development endeavor of the municipal administration.

Currently the town is experiencing development of infrastructures (mainly roads) and the preparation of this modern drainage design should be seen in line with the overall development efforts of the municipal administration. During discussions made with officials as well as the local community, poor drainage facility has remained to be the critical problem of the town since long time ago. Due to the absence of well-organized and integrated drainage facilities, residents of the town are suffering from flood and associated problems.

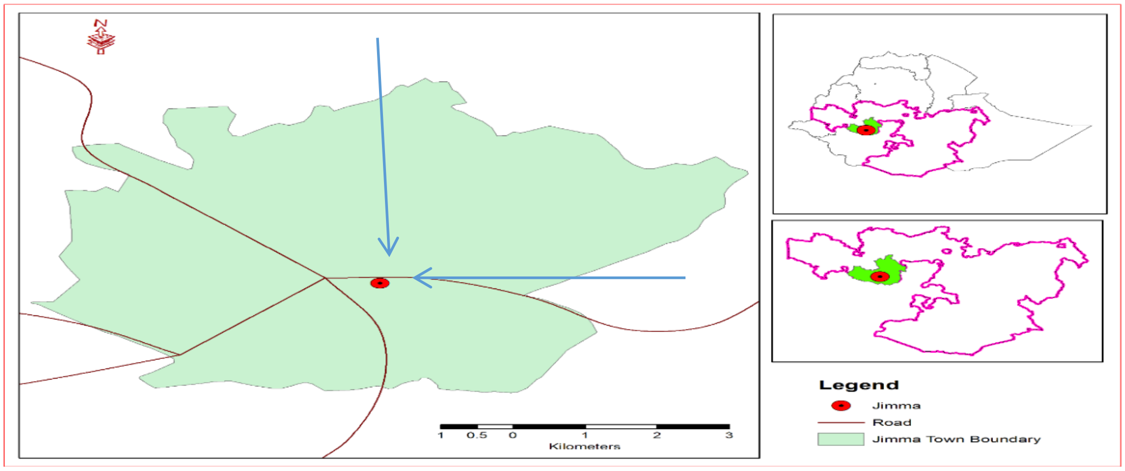

Figure 1. Location Map of Jimma City

Source: Jimma AMP (asset management plan), 2010

Jimma City is situated at the junction point of three important regional roads, i.e. the road to Addis Ababa, road to Bonga and Mizan Aman, and road to Mettu and Gambella, and other rural roads of the surrounding Woredas. This makes the city an important nodal point in the south-western part of the country as it is accessible from different regions and also connecting a number of zones in Oromia Region.

The city is located in a strategic location connecting the south-west part of the country with the *Kaffa* and *Bench Maji* zones in Southern Nations Nationalities and Peoples region and with Ilu Ababora Zone of Oromia Region. The city is also situated at about 50 kilo meters distance from the artificial Lake of Gilgel Gibe hydro-electric power dam and in a wide plain of coffee growing region. In addition, Jimma is among the strategic cities selected for industrial park development in the country.

The population size of the city varies from source to source. According to the 2015 National Urban System Project, the population of the city was 179,556 while the city administration claims over 200,000. This makes the city among the 10 top most populous cities in the country.

Jimma is located in the south-west, where the rainfall amounts to 1,500 mm (60 in) per year, including more than 100 mm (4 in) per month from April to September. Here is the average precipitation.

Jimma city experiences a warm and humid tropical climate with relatively long wet season. This general climatic condition categorizes the city under a Woina Dega climate of warm and humid class. The climate of the city from the point of view of temperature, annual rainfall, humidity and prevailing wind direction are discussed below.

Average monthly temperature is between 17.9 and 20.5 degree Celsius, the annual average being 19.5 degree Celsius. Temperature variations are observed between seasons, the lowest temperature was observed from September to November period. Jimma's average Monthly temperature shows seasonal variation; the hottest months being February, March, April and the coldest July, August and September. Mornings are relatively colder and at noon the temperature becomes high or hot and also calm.

Jimma enjoys moderately heavy rainfall throughout the year, with annual precipitation ranging from 1450 to 1800 mm (GTZ IS, 2005). The annual average rainfall was 1470 mm (Ethiopian Meteorological Agency cited on Jimma City Administration, 2007). Relative humidity was 56.8 % and the highest average humidity was observed during the main rainy season. According to the data presented in the executive summary report of the 1997 Jimma Development Plan that was prepared by NUPI, the city received an annual average of 1300 mm of rainfall, which varies between 1373 mm and 2382.2 mm. The rainfall however, shows seasonal variation with average monthly rainfall ranging between 37.8 mm in January and 229.1 mm in August. The daily maximum rainfall and number of rainy days from 1995 to 2012.

Table 1: Daily Maximum Rainfall (mm) and Number of Rainy Days in Jimma City (1995-2012)

n G.C	**Daily maximum rainfall in mm**	**Number of Rainy days**
1995	47.8	147
1996	48.8	166
1997	69	164
1998	62.5	165

1999	49.9	143
2000	50.5	148
2001	56.2	158
2002	42.5	150
2003	42.6	130
2004	46.2	140
2005	60.9	139
2006	44.5	176
2007	44.6	137
2008	62.3	153
2009	69.7	156
2010	42.2	149
2011	65.7	148
2012	54.9	121

Source: Ethiopian Meteorological Agency (2013)

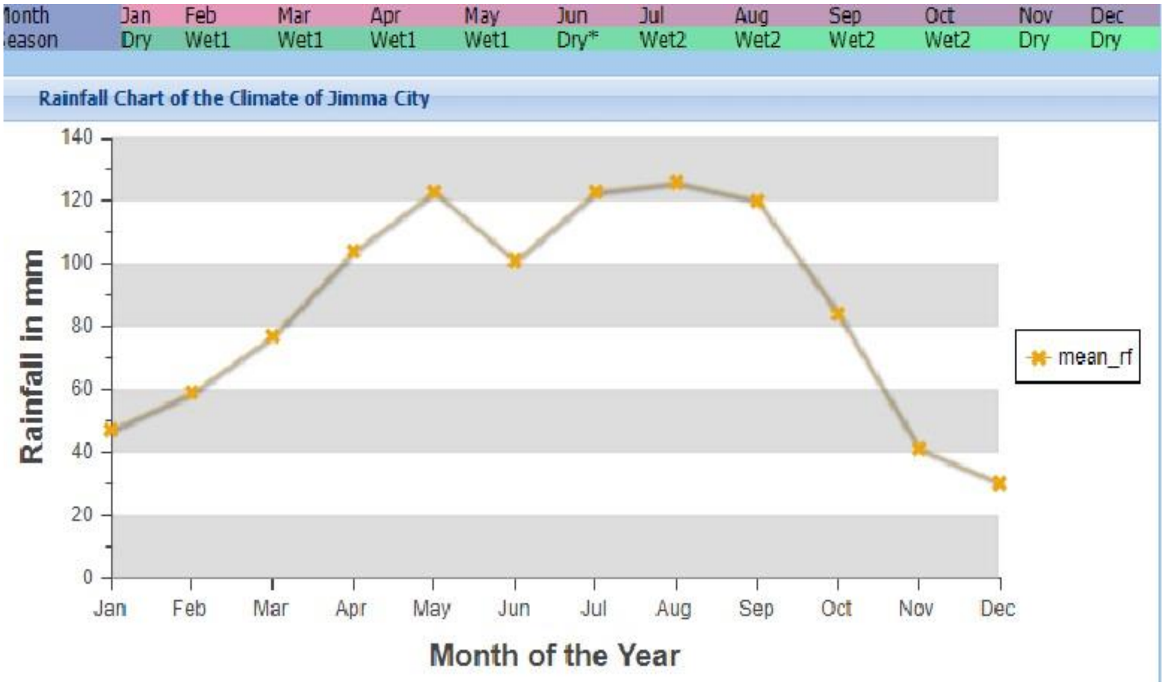

Figure 2: Average monthly climograph of Jimma City (source: National Meteorology Agency (NMA)**)**

This project area covers the assessment of the existing Drainage condition of the town. From Awetu Mendera ,Mendera kochi Herimata mentina/merkato ,Bosa Addis ketema ,Becho Bore ,Gunjo Gudiro , Bosa kito and Jiren. Which drain to Kito and Aweytu rivers (Jimma city Development Plan, 2006 and Jimma AMP, 2010)

Jimma has a humid and warm weather in most periods of the year. The air of Jimma is wet and has a suffocating feeling in some periods (JCA, 2007). This is mainly due to the existence of forests in the city. The average evapo-transpiration experienced in the city is about 3.4mm.

3.1.1. Drainage Basin of the city

Jimma area is found within the Gilgel- Gibe River basin which is tributary of the Gibe River, which in turn drains to Lake Turkana. Gilgel- Gibe, which is found at about 1.5 km from the existing boundary of Jimma originates from the highlands of north and west of Jimma and drains an area of about 4750 sq.km. Its head stream tributaries mainly start from the highlands found in the North, North - West and North- East of the city.

The local drainage of the city is basically from the north and north east and drains to the south through the two most important perennial rivers Aweytu, and Kito that form Boye. Boye is a very large swampy area of artificial water body bounding the city at the south which is said to be created by an Italian who formed the dyke for fishery development. The drainage in the upper parts of the city has many branches of waterways forming a tree branch structure following the rolling topography of the area. There are a number of streams that cross the city in the north-south direction within the built-up and expansion areas including: Furdissa, Abey, Faki, Mole, and Denge Dewi. All these streams have very small discharge and they also have shallow depths and some of them will not have water during the dry season. In addition to these, there are gullies and waterways crossing the city in the same direction. All these drain eventually into Gilgel Gibe which is located south of the city.

The ongoing construction activities compounded with the inappropriate and indiscriminate waste disposal practices in the city were found to have aggravated surface water runoff. The lack of appropriate storm water drainage system resulted in uncontrolled surface flow of water creates serious flooding problems in different parts of the city. Parts of the city which are located near or along the streams are swampy and face seasonal flooding. The flood hazard due to overflow of Aweytu has increased in recent years and nowadays it poses serious health hazards to the residents of the city. Problem of flooding is among the highest priority concerns of residents in Jimma. Unless serious measures are taken this has and will have negative environmental impacts on people living within the city and the surrounding areas.

Kito and Aweytu rivers constitute the major natural drainage system of the city. They collect storm water from the built-up and undeveloped mountainous areas which are found at the north of the city and drain it to the south. Aweytu River, in particular bisects the built-up parts of the city along the north –south direction.

Aweytu and Kito rivers join and form Boye which joins Gilgel Ghibe. A small embankment was constructed across Boye. This embankment made the water to stagnate and also occasionally flow back. This stagnation effect has been felt hundreds of meters upstream. As specifically stated in the 1997 Jimma Development Plan such poundage, however, is not advisable for areas like Jimma where (a) there is prevailing risk of malaria; and (b) Aweytu River crosses the densely built up areas washing all sorts of wastes.

Because of very gentle slope and availability of large flood plain area, all rivers didn't cut enough section capable of conveying high flows. During heavy storms, the rivers overflow and inundating the flood plains. The vegetation cover both in the flood plain areas and main sections highly retards water flow thereby creating soapiness which is a favorable condition for mosquito breeding.

The central district of the city is partly provided with storm sewer lines, both open ditches and concert pipes. In addition to their initial inadequacy, their capacity is further reduced by accumulation of wastes. According to NUPI, 1997 submergence of a number of houses and complete inundation of roads at some localities by the twenty five minutes storm on 09/01/88 (EC) has given an impression about the seriousness of the problem which implies revision of the capacity of the existing network and designing new lines for non-existent ones. (JCDMP, 2014)

3.2. Approach and Methodology

The project was conducted based on both primary and secondary data. The primary data were collected through field assessment using different approaches. Secondary data were obtained through review of reports and graphic documents produced by the municipal administration as well as relevant stakeholders.

I have already been undertaken the project which includes field visit, data collection and preliminary project assessment on the existing drainage network of the town. During the field visit made to the town observations were made through rapid appraisal method. In addition to this, various stakeholders including the municipal administration as well as dwellers of the town were approached and their perception has been documented as an input to the project.

Topography field visiting of the study area is carried out to determine existing performance condition of drainage structures. Observing flood marks, measuring the size of the existing drainage structures, measuring the elevation difference between rivers or stream bed and flood mark as well as gathering information is carried out about the overall performance of drainage structures during the rainy season.

3.3. Project Design

Observations, available documents and public discussion during which quite a number of problems have been identified. The drainage issue, associated with urban wastes (both liquid and solid.

Project Design

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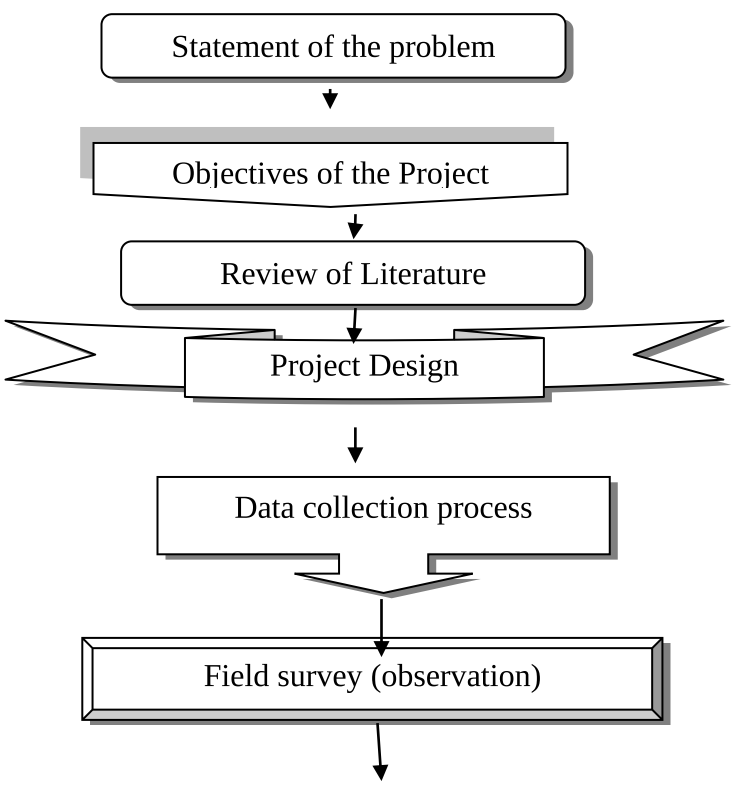

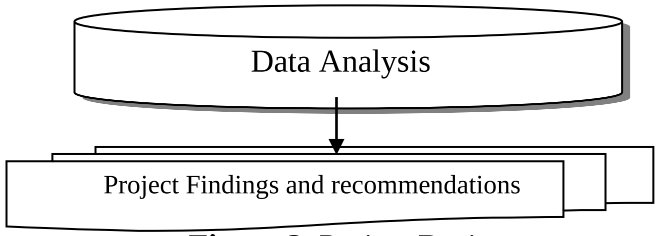

Figure 3. Project Design

3.4. Methods of Data Collection

The project were conducted based on both primary and secondary data. The primary data was collected through field assessment using different approaches. The secondary data were obtained through review of reports and graphic documents produced by the municipal administration as well as relevant stakeholders. Generally, the project was heavily relay on primary data.

A) Primary data Method 1: Direct Observation (Rapid appraisal method)

- **Type of Data:** This method is employed mainly to collect qualitative data on the physical condition of the following infrastructures:
  - Roads with and without drainage lines / ditches /channels;
  - Type of drainage lines / ditches /channels(closed and open);
  - Construction material of drainage lines (masonry, concrete, earth);
  - Slope, flow direction, outlet type and protection;
  - apparent blockades against smooth flow of runoff (vegetation, debris/ sedimentation, solid wastes, etc) ;
  - Physical condition of drainage lines;
  - Areas affected by flood;
  - Water logging areas, etc.
- **Tools:** Direct observation, taking Photographs,
- **Source:** Existing reality on the ground.

Method 2: Other Rapid appraisal methods: The other rapid appraisal methods that include key informant interviewing, focus group discussion with the community, municipal officials and experts.

- **Type of Data:** – The data were collected through rapid assessment method include the following:

- Areas affected by flood;
- Areas where drainage line facilities are absent;
- Priority areas(risk prone areas);
- Reasons behind absence of the facilities;
- Adverse effects on the community;
- Proposed Solutions;

➢ **Tools:** Interviewing, discussion and checklist preparation.

➢ **Source/Participants:** Key informants, the municipality and representatives of the local community.

3.5. Summary on Road Asset

According to the infrastructure asset inventory result; there was a total length of about **469.7.** Kilometers of road in Jimma city urban boundary of which 428.4 kilo meter belongs to the city administration and 41.3 kilo meter belongs to the Ethiopian Road Authority. The inventory result further revealed that from the total road surface covered with Earth Pressed with a total length of **183.21 Kilometer (43%**) followed by Earth Road **83.31** Kilo Meter (19.48%) and Gravel Road covers a total length of **79.47** Kilo Meter (18.58%).The remaining road surface are briefly explained in table 1 below. Moreover culvert and bridge were also inventoried with a total count of 158 and 8 respectively. Besides, Traffic Signals and Street Light were also mapped with a total count of 117 and 1361 respectively. The roundabouts in the city have higher variation in size: from larger and standard size with respective roads to small and not important for traffic management. At last there were four round about in Jimma city.

Table 2. Summary Information Required for the Road Asset Category

S.No	Surface Material	Length(KMs)	Percent
1	Asphalt (ERA)	41.3	
2	Asphalt (Jimma city)	11.71	6.22
3	Cobble	44.95	10.51
4	Earth Pressed	183.21	42.84
5	Earth	83.31	19.48
6	Gravel	79.47	18.58
7	Under Construction	10.14	2.37
		468.71	100.00

Source: Jimma AMP (asset management plan), 2010

3.6. Summary on Drainage

The asset inventory result revealed that there is **101.23 kilometers** of drainage line and of which about **90.88** Kilo Meter of the total drainage line belongs to the city`s administration. From the total (90.88 Km) of the town administration drainage line; about **41.55** kilo meter (45.72%) is Masonry drain followed by Earth drain **29.81** kilo meter with a percentage of 32.8%.

Table 3. Drainage Asset Category Inventory Result

S.No	Drainage Category Type	Length(KM)	Percent
1	Piped Concrete Drain	5.37	5.91
2	Closed Masonry Drain	7.23	7.96
3	Open Masonry Drain	34.32	37.76
4	Closed Concrete Lined Drain	4.15	4.57
5	Open Concrete Lined Drain	8.09	8.90
6	Earth Drain	29.81	32.80
7	Cobble Lined Drain	1.91	2.10
	Total	**90.88**	**100.00**

Source: Jimma AMP (asset management plan), 2010

3.7. Assessement of the asset condition

Table 4: Condition Indicator Table for All Roads (Asphalt, Cobble, Red Ash and Gravel Surface)

Level	Description	Detailed Description	Type of Deterioration	Indicative RUL
1	Very Good	✓Sound Structure or New ✓Road on the original status of construction	None	71-100%
2	Good	✓Serves but minor deterioration (<5%). ✓Minor maintenance required.	None	46-70%
3	Moderate	✓Marginal, clearly evident deterioration (6-20%). ✓Significant maintenance required.	If there is minor Crack ,Peeling and/or Siltation(Alluvial Formation)	26-45%
4	Poor	✓Significant deterioration of structure, and/or appearance; ✓Significant impairment of functionality (21-50%); ✓Retain of Water on the Surface due to potholing or cracking Intensive maintenance required.	If there is Crack, Peeling, Pot Hole, Siltation(Alluvial Formation) and Channeling of 20-49% of area of the road segment	11-25%
5	Severe	✓Unsound and failed ✓Disintegrated Surface or Total Collapse of the Road Structure (>50% of the road segment that needs total Rehabilitation)	If there is Crack, Peeling, Pot Hole, Channeling and Wash away of 50% or more area of the road segment	0-10%

Source: Jimma AMP (asset management plan), 2010

Table 5: Condition Indicator Table for Bridges, Culverts and Overpasses

Level	Rating Scale	Condition Indicator	Type of Deterioration	
1	Very Good	No defects; as new	None	
2	Good	Structurally sound and no serious cracking or scour requiring attention	None	
3	Moderate	Minor maintenance required	If there is minor crack in joint and support If there is deposition of Sediments or Alluvials in the Culvert	
4	Poor	Scour, erosion of abutments and piers or Structural defects; some rehabilitation work required	If there is erosion of Abutments and or Piers; If there are structural defects which needs some rehabilitation work is needed	
5	Severe	Serious structural damage that is a safety hazard	Serious Structural damage which needs complete rehabilitation	

Source: Jimma AMP (asset management plan), 2010

Table 6: Condition Indicator Table for Drainage Channels and Pipes

Level	Rating Scale	Condition Indicator	Deterioration
1	Very Good	Shape of drain still in original design condition	None
2	Good	Less than 5% of the channel length suffers deterioration, either on the walls or the floor	None
3	Moderate	Drainage effective but slightly impaired • : Between 6% and 20% of the channel length suffers deterioration, either on the walls or the floor	Minor Joint Damage, Minor Siltation Problem
4	Poor	Design function impeded due to siltation, vegetation or scour • Between 21% and 50% of the channel length suffers deterioration, either on the walls or the floor	Major Joint Damage, Major Siltation Problem
5	Severe	Drainage not functional • Greater than 50% of the channel length suffers deterioration, either on the walls or the floor	Masnory Collapse, Fully filled with silt

Source: Jimma AMP (asset management plan), 2010

3.8. Condition Assessment for Drainage

Condition Assessment had been done using the revised Asset Management Operational manual of the Ministry of Urban Development and Housing (MUDH) five level condition indicators which is showed in table 23 above. Accordingly, the inventory result revealed that from the total (41.55 kilo metre) Masnory drain; about 22.81 kilo metre were in good condition followed by 5.08 were in very good condition. On the other hand from the total 29.8 kilo metre earth drain, about 10.56 kilo metre in moderate condition followed by 9.4 kilo metre in good condition. The details of each are clearly presented in table 27 below.

Table 7: Surface Drainage Condition Assessment

Type of Drainage	Total Length(Km)	Condition				
		Very Good(Km)	Good(Km)	Moderate(Km)	Poor(KM)	Very Poor(KM)
Masnory	41.55	5.08	22.81	2.77	0.6	1.02
Piped Concrete	5.4	1.84	2.44	0.74		
Concrete Lined	12.2	7.5	2.05	2.7		
Cobble	1.9		1.38		0.53	
Earth	29.8	1.73	9.4	10.56	7.6	0.53
Total	90.85					

Source: Jimma AMP (asset management plan), 2010

CHAPTER FOUR

4. RESULT AND DISCUSSION

Results from Focal Group, Stakeholders Discussion and Interview analysis were well-arranged on the existing drainage condition of the town. Of the Interview and discussion comprised on issues that are related to the project. No of responders from the stakeholders which is around 12person and from the community focal groups of the projected area which is around 45persons were participate in the interview and discussion.

The evaluation on existing drainage condition by using the primary and secondary data (discussion and interview) to ensure performance level such as excellent, very good, good, average, and poor. Considering on discussion with community and stakeholder's data, maximum of the community (approximately 72.02%) had responded for poor condition of drainage and about 10 percent of the community for average category in the areas of flood, over tapping and stagnation of water occurred during rainy season in the city. Only 5.6 percent of community were responded for excellent category, 7 percent of community for very good category, and 5.38 percent for the good category.

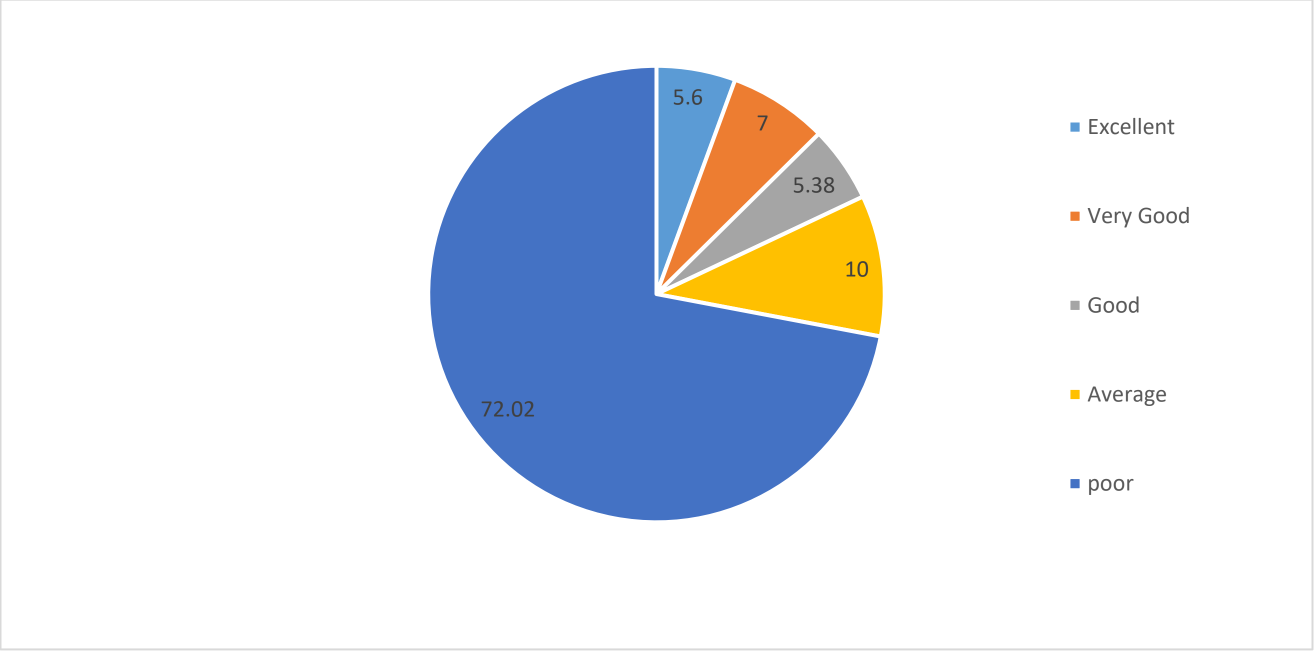

Fig. 4: Status of the Drainage condition as per the respondent

The assessments based on observations, available documents, public discussion and interview during which quite a number of problems have been identified. The drainage issue, associated with urban wastes (both liquid and solid), have become among the most critical agenda of the town causing both physical and sanitation problems. The physical problem is associated with inundation and eventual destruction of personal and public properties; whereas the sanitation problem, resulted from absence of proper management of urban wastes (household and commercial), is posing serious health threat like malaria and other water-borne diseases on citizens of the town.

Table 8. Drainage Problems, Causes and Effects identified during community discussion and interview

S.N	Problem	Location	Cause	Effect/ Consequence
1	Inadequate storm water drainage facility;	- In almost all parts of the town with the exception of the limited areas in the central part	- Lack of attention to drainage facility; - Financial problem; - Absence of integration between utility rendering institutions - Absence of periodic maintenance service	- Flooding; - Over tapping - Sedimentation - Stagnation or water - Formation of gullies - Traffic jamming
2	Sedimentation	- In Mendera qochi along “Cross Land” road - In Becho along Kingnom constr.main road. - Ginjo gudru kebele from w/c the road constructed by cross land (jimma university new hall up betekenet) - Hermata mentina / merkato kebele. - Bosa addis ketema Infront of JIT.	- Absence of silt trap structures; - Inadequate slope; - Disposal of solid waste in to drainage line; - Failure to regularly clear drainage channels;	- Reduction in carrying capacity of channels - Retardation in the velocity of runoff; -
3	Flooding	- Hermata Mentina/Hermat merkato - Around “Ferensay Arada” - From “Kotebe” to “Arat	- Inadequate drainage facility - Small drainage str. that could not	- Formation of gullies - traffic congestion - deterioration of roads - loss of properties and

		Anbessa" and from " - Around "Beshishe" in Hermata Merkato - "Mendera qochi kebele JU Staff Apartment condiminum - Around "Kuas Meda" in Kito	convey the big discharges - Design problem - Decline in vegetation cover - Absence of natural streams or big artificial canals in to which runoff from the catchment drains	life - creation of unsanitary conditions - formation of mud - Malaria breeding - Sheet and rill erosion - Blockage of access - Formation of ponds
4	Over tapping	- From "Firdbet" to "Kuteba" in Aweitu Mendera. - Becho bore from fedi round up shene gibe hospital - Hermata merkato from photo park up awetu	- Design problem - Urbanization,; - Size of drainage facilities.	- inundation of the surrounding areas - deterioration of bridges and roads - formation of mud - Sheet and rill erosion - Blockage of access - Formation of ponds
5	Disposal of waste in to drainage channels	- Drainage line from "jimma police station up yordanos hotel.(Hermata mentina) - Drainage line at the back of bus station (abegaze wolde hotel) - Drainage line hermata merkato (khat tera ,stadium and besheshe) - Hawetu qochi around tenatabiya	- Lack of awareness among community - Carelessness -there is no supervision and follow up	- Reduced velocity of storm water - Over tapping
6	Stagnation of water	- Hawetu mendera and hawetu qochi kebele around urael line and tenatabiya - Around "Kuas Meda" in Kito - Hermata merkato around in front of stadium - Ginjo Guderu at the back of ceneral hotel infront of ahemed higher clinic	- Flooding - Over tapping - flat topography - Inadequate storm water drainage facility	- Creation of favor condition for malaria breeding and other water born disease

Figure 5. Absence of storm water drainage facility

Figure 6. Over topping due to drainage line blockage

The result of the study shows that though the drainage problem is common in the area, the hazard of the over tapping problem, As shown on the picture due to the construction of tell building project on going and they start huge excavation work without construction protection work (shoring).due to this case the drainage facility line failed.

4.1 Conditions of the existing drainage infrastructure

4.2.1 Observed damage on minor structure

Site information was recorded for all of the existing structures on Jimma City road upgrading project. The major comprises details of structure type, construction material, clearances, height of substructure etc. the entire common defect encounter.

Generally the following defects are observed on culverts

- There is vegetation around inlet and outlet
- Blocking of inlet due to boulder
- High deposition of silt
- Deterioration of concrete
- Formation of water pond due to absence of sufficient slope
- Cracking of wing wall
- There is scouring problem
- And total blocked inlet and outlet condition due to silt up problem.

Figure 7. Channels which do not have silt trapping structures

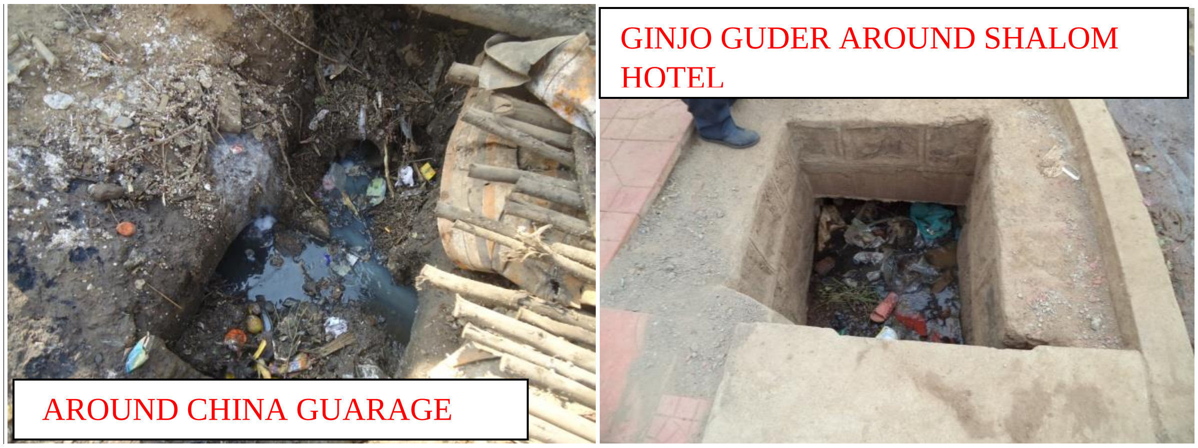

Figure 8. Disposal of solid waste into the storm water drainage channels and manholes

Figure 9. Areas which are frequently affected by flood

Figure 10. Liquid wastes are connected with storm water drainage lines

Generally linear type of storm water drainage U-ditch constructed in the study area of town section. But it was observed that liquid wastes released to the storm water drainage ditch and streams from some residential buildings which affected the proper functioning of the drainage structures.

Figure 11. Poor solid and liquid waste management

The result of the study shows that though the drainage problem is common in the area, the hazard of the flooding problem is dominant for some areas and this flooded prone area is located at both upstream and downstream reach of the Jimma town sub -catchment along the road.

Figure 12. Sedimentation occurred due non accumulation of drainage and slope problem

Figure 13. Stagnation of water due to absence of proper drainage

Generally due to absence of storm water drainage system it was observed that stagnation of water and filled by rubbish materials which is the cause for malaria and water born disease.

CHAPTER FIVE

5. CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

Based on the existing drainage condition survey the following conclusions are drawn:

- Due to large volume of water from the highland catchment areas of the town, the natural water ways couldn't carry the incoming runoff, particularly during rainy seasons, and as a result causing inundation in some parts of the town especially in the *Merkato* (*market* area) ,high ground water table condition around genu to ajip and other low laying areas causing severe damage to property;
- Due to lack of proper drainage channels, roads are severally damaged and water ponds area created on the road sides, in the urban centers and crossing structures;
- The existing natural courses of the drainage channels are blocked by urban wastes such as plastics bags, water container plastics, wastes from *khat* (c*hat)* and other wastes generated from the urban dwellers;
- Some drainage channels have very mild slope with limited drainage capacity of accommodating the incoming runoff and hence causing flooding in some parts of the town;
- Currently the major roads are under construction and this situation has created mobility constraint, added with the existing drainage problem.
- Inadequate integration between road and urban storm water drainage lines followed by blockage of drains by solid wastes and silt accumulation are the major causes of flooding in the study area.
- The sides of the embankment also eroded at different section along the road by the high driving force of the surface runoff water contributed from the surrounding upstream
- The flow of storm water run-off is one of the major problems in the project area as a result of urbanization and pavements of surfaces associated with blockage of urban storm water drainage network management.

5.2. RECOMMENDATION

In Jimma town road drainage structures analysis structures underperformance have had serious negative impact on road, dwellers along the road and road user. In order to minimize these negative impacts, the following appropriate mitigation measures are recommended.

- Proactive measures should be taken to reduce and manage flooding hazards (like clearing of drains before rain season begins).
- Improvement on the integration of road and water drainage infrastructure.
- Integrated solid waste management should be developed.
- Water drainage infrastructure should be contracted with road infrastructure.
- Encourage site infiltration through: Permeable pavements like porous concrete, coble stone, vegetated structures or grassing on road sides and vacant spaces/ gardens.
- Teaching the community to aware released liquid wastes to the storm water drainage ditch and streams from residential buildings is cause for flooding and pollution of the environmental and air

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Annexes

Annex1: QUESTIONNAIRES

Questionnaire – PART ONE - Guide questions for the FOCUS GROUP DISCUSSION OF STAFFS

1. Is flooding a major problem in your town or have you experienced any flooding events in the town? How do you rate or describe the extent of the problem? What was the frequency?

2. Are there any awareness campaigns undertaken to keep drainages clean and not use them as a refuse dump sites? If yes, when and how? If No, why?

3. What do you think is the major causes of flooding in the town?

4. Is inspection of pits/holes or drainage systems undertaken in the sub-city? If yes, what was the nature of these problems (blockages, breaks…)? What were the likely causes of these problems? How have you addressed the problems? What has succeeded, what has failed?

5. What are the major challenges in providing/handling integrated road and water drainage infrastructure??

6. What were the major risks (economic damages of infrastructures, inconveniences and threats to the road users, residents or others) arisen from failure of storm-water drainage network systems in the sub-city? What were the biggest risks associated with the storm water network?

7. Do you have any preventive, maintenance or contingency plans [or major assets - bridges, pits, roads, etc... renewals plan] for drainage systems? If yes, ask for its implementation. If No, why?

8. What temporary and/or permanent solutions have ever been taken to flooding problems?

9. What do you suggest to manage the problems of flooding in the sub-city?

10. Is there any integration among various stakeholders (Urban development office, volunteers, individuals, community, Idirs, etc…) to prevent risks arising from flooding in risky areas? If yes, who has done it and when? If not available, why?

Questionnaire – PART TWO - Guide questions for the FOCUS GROUP DISCUSSION OF STUDY PARTICIPANTS (RESIDENTS)

1. Is flooding a major problem in your residential area or have you experienced any flooding events in this area? How do you rate or describe the extent of the problem? What was the frequency?

2. Are there any awareness campaigns undertaken to keep drainages clean and not use them as a refuse dump sites? If yes, when and how?

3. What do you think is the major causes of flooding in this area?

4. Is inspection of pits/holes or drainage systems undertaken in this area? If yes, who has inspected? What were the problems (blockages, breaks…) identified? What were the likely causes of these problems? Have the problems been addressed? What has succeeded, what has failed?

5. What were the major risks (economic damages of infrastructures, inconveniences and threats to the road users, residents or others) arisen from failure of storm-water drainage network systems in this area? What were the biggest risks associated with the stormwater network?

6. Do the concerned bodies do preventive maintenance of major assets like bridges, pits, roads, etc... renewals for the drainage systems? If yes, when it was done?

7. What temporary and/or permanent solutions have ever been taken to flooding problems?

8. What do you suggest to manage the problems of flooding in this area?

9. Is there any integration among various stakeholders (Environmental protection office, volunteers, individuals, community, Idirs, etc…) to prevent risks arising from flooding in risky areas? If yes, who was organizing it and when it was undertaken?