JIMMA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

JIMMA INSTITUTE OF TECHNOLOGY

FACULTY OF CIVIL AND ENVIRONMENTAL ENGINEERING

HIGHWAY ENGINEERING STREAM

Evaluation on the Integration of Road Network and Drainage System for the Occurrence of Flood: A Case of Bishoftu City

Thesis submitted to school of postgraduate studies of Jimma University Institute of Technology in partial fulfillment of the requirements for the degree of Master of Science in Civil Engineering (Highway Engineering)

By

By: Belay Demissie Bekele

DECEMBER, 2021

JIMMA, ETHIOPIA

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Advisor: Dr. Habtamu Melese (PhD, PE)

Co-Advisor: Mr. Basha Fayisa (MSc)

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DECLARATION

I declare that the research entitled "Evaluation on the integration of road network and drainage system for the occurrence of flood" is my own original work, and has not been presented as a requirement for the award of any degree in any University.

Belay Demmissie		November 26, 2021
Student	Signature	Date

As Masters research advisors, we here by certify that we have read and evaluated this MSc research prepared under guidance, by Belay Demissie entitled "Evaluation on the integration of road network and drainage system for the occurrence of flood." We recommend that it can be submitted as fulfilling the MSc thesis requirements.

Habtamu Melese (PhD, PE)		November 26, 2021
Advisor	Signature	Date
Basha Fayissa (MSc)		November 29, 2021
Co-advisor	Signature	Date

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ABSTRACT

The road networks are system of interconnected carriageways which are designed for transportation where their performances are influenced by proper provision of drainage system. This study has evaluated the integration of road network and urban storm water drainage system with the help of topographic map. The study particularly focused on flood prone areas with specific to main road and its feeding roads in Bishoftu City. The objective of this study was to evaluate the integration of road network and drainage system for the occurrence of flooding. Exploratory and descriptive types of research design with qualitative data type were used to describe and investigate the existing condition, coverage and level of integration of road and drainage system. Data collected using observation and interview for primary data source and document review for secondary data source were used to collect information and have been analyzed qualitatively. Interpretations have been done based on the common points and conceptualizing and explaining issues interrelated to one another in the themes. The analysis was mainly descriptive and the information collected from both primary and secondary sources were processed with the help of Microsoft excel, AutoCAD and ArcGIS software's and the analyzed data were presented using tables, figures, chart, percentage, and graphs. The study was conducted from July to October, 2021 and strongly evaluated the integration of road and drainage infrastructure those feeding to main road for their causes to flooding and found that there is poor integration. Road surface drainage of the study area was found to be inadequate due insufficient road profile ranging from no cross fall to maximum of 1.5%, insufficient drainage structures provision, improper maintenance and lack of proper interconnection between the road and drainage infrastructures. The study recommended that there should be enough space for storm runoff to travel to its destination and conveyance channels as well as culverts should be adequately designed and properly reconstructed as well as regular maintenance of both road and drainage lines are found to be appropriate to mitigate the problem. City wide structural plan and urban flood drainage database management system has to be prepared in all sections of the road and drainage integration to solve the harmful impacts of flooding in city.

Key Words: Road, Storm Water Drainage, Flooding, Infrastructure, Pavement, Integration.

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ACRONYMS

AASHTO	American Association of State Highway and Transportation Officials
AMP	Infrastructure Asset Management Plan
BC	Box Culvert
BVC	Beginning of Vertical Curve
CAD	Computer Aided Design
CC	Circular Culvert
cm	Centimeter
CSA	Central Statistics Agency
ERA	Ethiopian Road Authority
EVC	End of Vertical Curve
FGD	Focus Group Discussion
GIS	Geographic Information System
Ha	Hectares
KII	Key Informants Interview
km	Kilo meter
LTPP	Long Term Pavement Performance
mm	millimeter
NRCS	Natural Resources Conservation Service
ORA	Oromia Road Authority
PVI	Point of Vertical Intersection
RWH	Rain Water Harvesting
SCS	Soil Conservation Service
SC	Slab Culvert

CHAPTER ONE

INTRODUCTION

1.1. Background of the Study

Infrastructure is critical to the country's continuing development. While infrastructure provision can be costly, it has the potential to boost urban growth and the economy, impact settlement patterns and land use, and improve quality of life. Inappropriate land-use decisions, on the other hand, can have a negative impact on the efficient and effective functioning of infrastructure, reducing the advantages provided by infrastructure investment decisions (Afolayan et.al, 2017).

As the population grows, so does the demand for infrastructure, such as roads and urban storm water drainage systems. Ethiopia's growing urbanization, exacerbated by global climate change consequences, is posing huge issues for the country's largest cities, with increased storm runoff and flooding. Runoff coefficients in cities are higher than in rural locations, where vegetation and agricultural lands absorb or infiltrate rainfall to lessen storm runoff. However, paved surfaces and built-up regions in metropolitan areas will increase storm runoff, lowering infiltration rates. Sediment, feces, nutrients, organic debris, and heavy metals are all sources of pollutants in storm water from urban runoff. Because of the increase in impervious surfaces associated with urbanization, impermeability rises. As a result, the drainage pattern is altered, and overland flow increases, resulting in flooding and other environmental issues. This has a significant impact on spatial structures such as roads. This is because floods and its associated environmental issues, such as sheet and gulley erosion, as well as surface inundation, have a negative impact on road services and lifespan (Dagnachew Adugna Belete, 2011).

The high rate of urbanization in Ethiopia is posing considerable issues for large cities in terms of providing new infrastructure to their growing populations. As a result, demand for various infrastructure development continues to climb, despite the fact that most cities' financial and technical capability is restricted, leading in increased competition for limited resources as well as environmental deterioration. In most parts of the country, properly designed and constructed storm water drainage is at an all-time low (Ministry of Urban Development and Construction report, 2020). As rapid rate of urbanization and growing urban economic development has been on the rise in most of the urban centres of Ethiopia, Bishoftu city currently started giving importance to development of the required urban infrastructure that include road and storm water drainage facilities. Street flooding, over topping and other environmental related problems are common in Bishoftu city highway. This is particularly severe in areas where road infrastructure appears to be

without adequate storm water drainage infrastructure and week in integration of road and drainage network.
Bishoftu city is highly exposed to flood every year following the summer season, this occurrence shall be deeply studied, and this paper has also concentrated on one of the major reasons for this challenge of the residents. Deep evaluation has been conducted on road network, drainage system and their integration on the area feeding to the main road for its occurrence of flooding. According to the infrastructure asset inventory result from the city administration asset inventory document; there is a total length of about 543.38 km of road in Bishoftu city urban boundary. The total area according the structure plan boundary of the city had an area of 205.7 km^2; of which the total area reserved for road network from the structural plan was 24.6 km^2 with a total of 11.96 %.

The Infrastructure Asset Inventory of Bishoftu City shows road coverage of; Red ash road is 150.24 km, followed by Cobblestone, Asphalt, Earth Road and Gravel Road with lengths of 145.39 km, 111.95 km, 96.98 km and 29.67 km respectively. While the remaining's are earth pressed road and large block stones which accounts total of 9.15 km of the total road coverage in the city. Road Structures that include Bridge and Culvert are inventoried in Bishoftu City Infrastructure Asset Inventory and Management Plan. The road crossing (Slab) structures which are found at the junction of roads and which has a short span with no defined structural components are also inventoried. A total of 585 road structures including ERA and ORA owned are found within the city boundary. The city administration has a total of 585 road structures of which 20 are bridge structure, 61 are culverts and the remaining 504 are concrete slab crossing. The asset inventory results also revealed that there is a total 158.20 km of drainage line in Bishoftu City; of which about 62.89 km of the drainage line is open masonry; followed by Earth drain and Closed Masonry Drain with a total length of 47.94 km and 18.97 km respectively. On the other hand; Open Concrete Line Drain, Piped Concrete Drain and Cobble Stone Lined Drain have a total length of 13.75 km, 9.66 km and 3.70 km respectively. Besides both Closed Concrete Lined Drain and Semi piped Concrete Lined Drain will accounts 1.29 km of the total coverage (Infrastructure Bishoftu Asset Management Plan, 2013).

Even if these all-infrastructure components are built by the city there remains a challenge of high flood that runs over and around the highway of Bishoftu city, this flood affects the people leaving along the main road both in infrastructure damage and health. Due to flood, the life span of the infrastructure including the road, highway and drainage canals/channels is highly affected and exposed to damage.

The magnitude of the problem is very high, as it became a common challenge for the community every year. People are complaining for the occurrences to the municipality plus looking at this big challenge, the city administration have conducted the study that concentrate on drainage system, but the issue goes around the integration of both the road network and drainage system in separate as well as its effect in combined manner. Hence it is recorded as magnified issue both at community and municipality level. The problem manifests mainly on the main road and on the roads, those feed to this main road and majorly concentrated on the diverged part which is around Bus Station where it seems the out let of the flood that flows towards the area is without proper outlet. Here this paper essence is to evaluate the basic causes of the aforementioned problem.

Evaluating the existing road and drainage network those feeding to the main road is very crucial in analyzing the cause of flood over the main road of Bishoftu City, as floods are generated from the catchments and conveyed via drainage aside of road. Hence evaluating the integration of both road network and drainage systems is important to know the causes of flooding.

1.2. Statement of the Problem

Exposure to flood and runoff water is prevalent due to the city's flat terrain, which is flanked by hills and slopes. Due to insufficient geographic location, road profile, drainage structure provision, improper maintenance, and lack of proper integration between the road and drainage infrastructures, the road surface drainage was found to be inadequate, resulting in damage to the road surface material and flooding in the area (Getachew Kebede Warati et.al, 2015). The land on which the city is established is a flat land that is part of the natural flood way through which the rainfall from the surrounding mountains and the upstream peasant areas drains into the creator lakes found inside the city such as Cheleleka. Every year during the rainy season flood overflows the drainage structures and causes extensive destruction to public facilities and individual property in many parts of the City. According to the infrastructure department report, 01 Kebele, and 02 Kebele are the most affected parts of the city. The combined effect of the city flatness of the topography and being surrounded by the hills and slopes results in higher rain drop intensity and consequently accelerated and concentrated runoff toward the main road.

As per the reports from Bishoftu city infrastructure department, floods are frequent phenomenon in Bishoftu causing damage to property and death to human beings and livestock; there are also reports about widespread destruction of access roads and drainage canals affecting inter-town mobility of people and goods.

Closed slab culvert condition Surface flooding

Figure 1. 1: Existing flood condition (Picture taken by Author on 23rd of August 2021).

Due to inadequate integration of road network and urban storm water drainage system infrastructure provision, main road in the city is exposed to flooding hazards/risks. This has resulted in negative impacts on road infrastructure and urban storm water drainage performance. The runoff and drainages of Bishoftu City are most converging towards one outlet and these convergence shape of the city leads the runoff to certain area where high flood accumulation is occurred to result in overflow on the main road. Therefore, this paper evaluates the extent of integration of road network, drainage system and associated problems.

1.3. Research Questions

The basic research questions are:

- What are the characteristics and performance of elements of the existing road networks on the main road to erode runoff?
- What are the performances of elements of the existing drainage networks feeding to main road?
- What are the performances of the properties of the integration of road and drainage network feeding to the main road for the causes of flooding?

1.4. Objective of the Study

1.4.1. General Objective

The main objective of the study is to evaluate integration of road network and urban storm water drainage system for the causes of highway flooding in Bishoftu city.

1.4.2. Specific Objectives

The specific objectives of the study are:

- To evaluate the performance and characteristics of the elements the existing road network of the city to erode runoff.
- To evaluate the performance of elements of existing drainage network of the city.
- To evaluate the performance of the properties of the integration of road and drainage network of the city for the causes of flooding.

1.5. Scope of the Study

The scope of the study is limited to evaluation of existing road network and drainage system feeding to the main road. The evaluation of existing road network includes geometric characteristics, existing road surface condition (paved, unpaved, damaged), existing gradient condition, existing crown slope condition, pavement type and pavement distresses. While the drainage system includes drainage structures, inlet and outlet capacity of existing drainage (for curve stone), presence of curve stone, capacity of existing drainage structure, location of cross drainage structure, existing discharge, terrain and soil type, provision of side drainage structure, existing slope of drainage structure. In addition, the study evaluates integration of road network and urban storm water drainage system feeding to main road and extent of integration of urban storm water drainage infrastructures in road provision, existing condition of road network and urban storm water drainage system. In this study, detailed engineering design aspects of road network and drainage system were not incorporated except for some drainage and drainage structure which are used for evaluation purpose only.

1.6. Significance of the Study

This study will significantly be used as a reference by the city administration while preparing annual plans in relation to spatial and financial plans for roads and urban storm water drainage infrastructure. Additionally, the study has a special relevance to be used as a reference for infrastructure asset inventory, so that the new added and upgraded infrastructure will easily be upgraded to a recent data report through appropriate software. Policy makers and any organization working in the area of roads and urban storm water drainage infrastructure can use it as a further reference to fill the existing gap between road and urban storm water drainage demand and supply. The study has shown sensitive areas of flood in the city and areas where drainage structures are under functioning and this will help Ethiopian road authority for the purpose of correcting defects on the road and uses it as an input for maintenance activities. Finally, the study helps in reduction of traffic accident by showing the gaps where the structures are under functioning and helps the community by reducing number of deaths.

1.7. Limitations

The study is limited to Bishoftu city main road and roads feeding to this main road and drainages feeding to same. Precisely the study has also narrowed to the area where high flood was occurring, and affecting the community and infrastructure. As this is study focused on communities' challenges, the underlying issues was examined in depth and in details, the research framework and directions were tried to be prepared so that data collected from human subjects becomes powerful and compelling.

However, there are a number of limitations that have expected throughout the study.

- The way how the societies respond for the interviews to get accurate respond, as a case of this study, due to the current situation happening in the country, the respondents were not willing to get audio recorded during focus group discussion for latter clearance for the researcher, as they fear that things will get political view if they are heard that there is poor infrastructure integration and there is design as well as construction quality problem. But, should have been understood that the finding of this study represents only respondents' perceptions.
- The study did not cover large geographic areas and new location which affect generalization of the finding information.
- In some of the drainage structures under this study, the true construction depth was impossible to measure as solid wastes and sediments were deposited for years in the area without maintenance clearings so that the true capacity will be determined and evaluated against the true discharge value as per the city-wide structural plan.

CHAPTER TWO

LITERATURE REVIEWS

2.1. Road Network

Road and drainage networks integration play an important role in urban growth. A good design will work as a catalyst, but a bad design will halt city life. The urban road network must be adequately integrated to improve the coherence between urban and road design. Integrating road design (horizontal, vertical, intersections, interchanges, roundabouts, camber, cross slopes, pavement distresses, material, and drainages) is essential to avoid failures caused by improper integration. Transportation is disrupted, and the drainage system is clogged as a result of poor integration (Dagnachew Adugna Belete, 2011).

Integration of road shall be accommodated by the geometric designs of road. Geometric design deals with the dimensioning of the elements of highways, such as vertical and horizontal curves, cross sections, truck climbing lanes, bicycle paths, and parking facilities. Geometric roadway design can be broken into three main parts: alignment, profile, and cross-section. Combined, they provide a three-dimensional layout for a roadway (ERA Geometric Design Manual, 2013).

2.1.1. Horizontal Alignment

There are different consistency evaluation criteria in the design of horizontal alignment which consists of straight line and circular curves, during the design of this curve, a proper relation should be established between the design speed and curvature and their joint relations with super elevation and side friction and drainage.

The first measure available in the literature to assess design consistency is to use speed of operation. This is often determined as the 85th percentile speed (V85) of the vehicle sample. The second consistency criterion is based on the dynamics of the vehicle, or more precisely the stability of the vehicle on horizontal curves, "which can be caused by incorrect design elements and sequence choices in the horizontal and vertical directions. To reduce certain dynamic safety risks. “A third and easier approach to assessing design consistency is to reduce targeting to a size that is easy to calculate and understand. Such an approach uses a route index that quantitatively measures the general characteristics of routes in road sections. Examples of directional indexes include average radius (AR), maximum radius to minimum radius ratio (RR), and average velocity of vertical curvature (AVC). An additional parameter, called CRR, which is defined as the ratio of the radius of a single horizontal curve to the average radius of the entire section, is that the radius of a particular horizontal curve is the average radius along the highway section. Can disagree with the driver's expectations, create geometric discrepancies, and lead to high accident rates. The fourth approach to assessing design consistency is the driver's mental workload, which can be classified as a "user-side" consistency measurement compared to previous consistency measurements that can be classified as "designer-side" (Yasser Hassan, 2004).

For simple circular curves horizontal alignment will be designed based on the following simple geometric calculations.

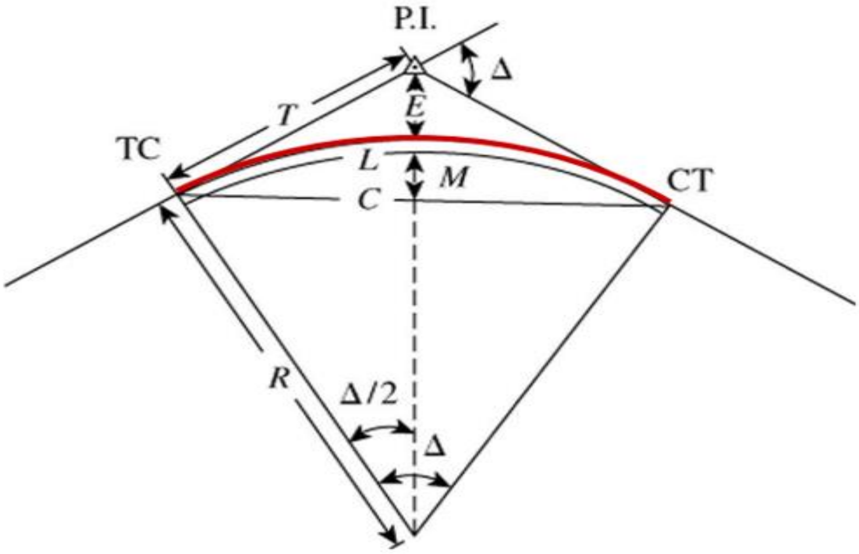

Figure 2. 1: Typical horizontal curve alignment

Where; T = Rtan(Δ/2),

C = 2Rsin(Δ/2),

L = RΔ,

E = R[sec(Δ/2)-1],

M = R[1-cos(Δ/2)]

Maximum degree of curvature by limiting value of a given design speed is,

$$\mathbf{R} = \frac{V^2}{127(e+f_s)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad \mathbf{(2.1)}$$

Where; e = super elevation and

f_s = coefficient of side friction.

Extra width of pavement may be necessary on curves. As a vehicle turns, the rear wheels follow the front wheels on a shorter radius, and this has the effect of increasing the width of the vehicle in relation to the lane width of the roadway. Studies of drivers traversing curves have shown that there is a tendency to drive a curved path longer than the actual curve, shifting the vehicle laterally to the right on right-turning curves and to the left on left-turning curves. Thus, on right-turning curves the vehicle shifts toward the inside edge of the pavement, creating a need for additional

pavement width. The amount of widening needed varies with the width of the pavement on tangent, the design speed, and the curve radius or degree of curvature.
The widening required can be calculated from;

$$\mathbf{W_e = n * \frac{B^2}{2R} + \frac{V}{10\sqrt{R}}} \text{ ………………………………………………… } \mathbf{(2.2)}$$

Where: We = total widening

B = wheel base

R = radius of curve

V = design speed (Km/h)

n = number of lanes

Based on the above stated formulas the existing road under this study is going to be checked for its proper integration and we need not consider transition curve and super elevations as the case we are considering is flat and urban area.

2.1.2. Vertical Alignment

In connecting roadway grades with an appropriate vertical curve, a mathematical parabolic function will be used as it provides a constant rate of change of slope and implies equal curve tangents.

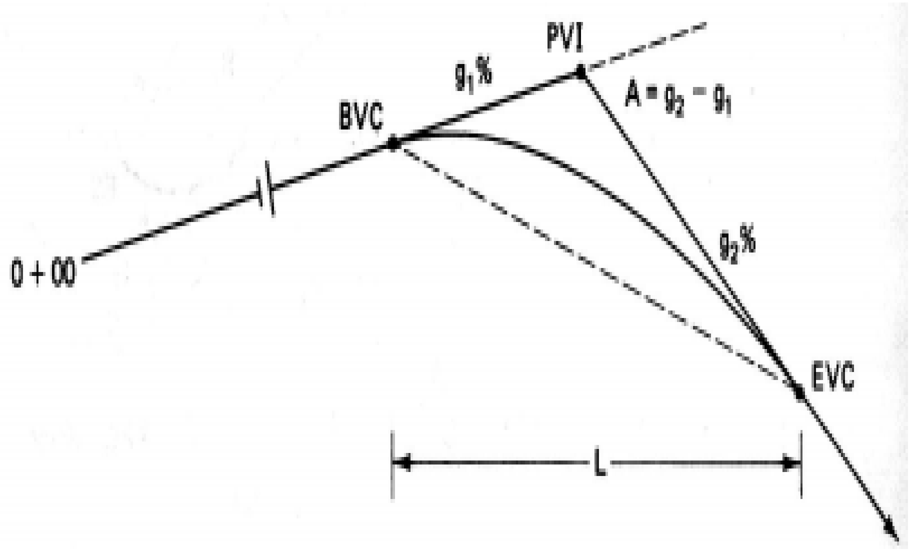

Figure 2. 2: Typical vertical curve (Source: ERA, 2013)

The general form of the parabolic equation, as applied to vertical curves, is

$$y = ax^2+bx+c \text{ ………………………………………… } (2.3)$$

Where; y = roadway elevation at distance x from the beginning of the vertical curve (the BVC) in stations or m,

x = distance from the beginning of the vertical curve in stations or m,

a, b = coefficients, $a = \frac{g_2 - g_1}{2L}$, $b = g_1$

L = length of the curve in stations or m measured in a constant-elevation horizontal plane.

c = elevation of the BVC (because x = 0 corresponds to the BVC) in m.

2.1.3. Cross Sectional Designs

The cross-sectional elements in a highway design pertain to those features that deal with its width. The cross-sectional aspects to be considered in the study are; right-of-way, roadway width, central reservations (medians), shoulders, camber, cross falls, side-slope, drainage, curbs, gutter, clear zones, and so on.

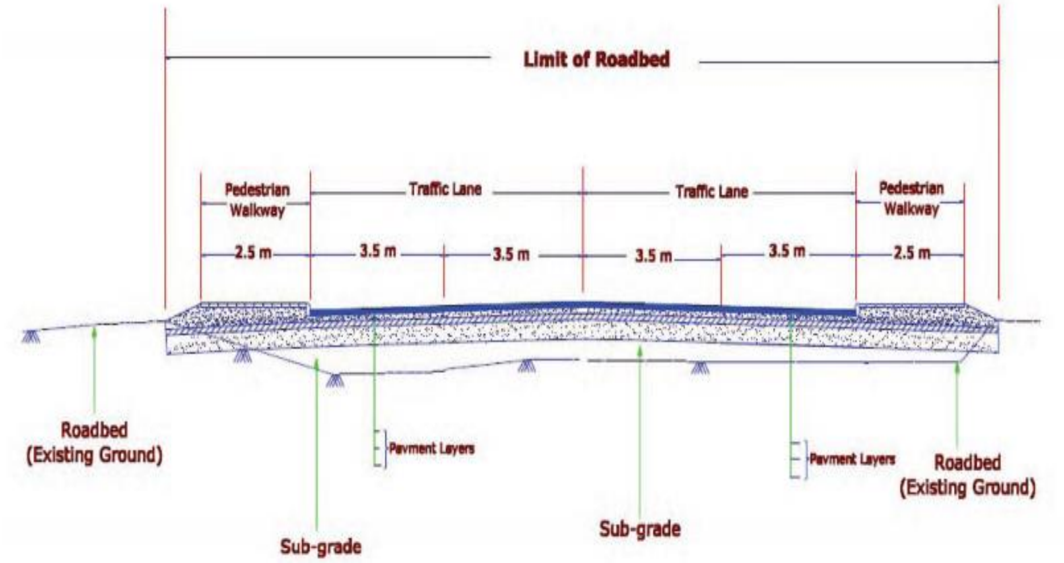

Figure 2. 3: Divided two lane typical town section (Source: ERA, 2013).

- **Right- Of –Way**

The right-of-way width is the width of land secured and preserved to the public for road purposes. The right-of-way should be adequate to accommodate all the elements that make up the cross-section of the highway and may reasonably provide for future development.

- **Road Width**

Road width should be minimized so as to reduce the costs of construction and maintenance, whilst being sufficient to carry the traffic loading efficiently and safely.

The following factors need to be taken into account when selecting the width of a road:

Classification of the road: A road is normally classified according to its function in the road network. The higher the class of road, the higher the level of service expected and the wider the road will need to be.

Traffic: Heavy traffic volumes on a road mean that passing of oncoming vehicles and overtaking of slower vehicles are more frequent and therefore that paths of vehicles will be further from the center-line of the road and the traffic lanes should be wider.

Vehicle dimensions: Normal steering deviations and tracking errors, particularly of heavy vehicles, reduce clearances between passing vehicles. Higher truck percentages require wider traffic lanes.

Vehicle speed: As speeds increase, drivers have less control of the lateral position of vehicles, reducing clearances, and so wider traffic lanes are needed.

The cross-section of the road is usually maintained across culverts, but special cross-sections need to be designed for bridges, taking into account traffic such as pedestrians, cyclists, and so on, as well as motor traffic. Reduction in the carriageway width may be accepted, for instance, when an existing narrow bridge has to be retained because it is not economically feasible to replace or widen it. It may also sometimes be economic to construct a superstructure of reduced width initially with provision for it to be widened later when traffic warrants it. In such cases a proper application of traffic signs, rumble strips or speed bumps is required to warn motorists of the discontinuity in the road.

- **Shoulders**

Shoulders directing water flow to the side drains or ditches and should slope more than the carriageway to keep water moving to the side drains. If shoulders slope less, water will build up during heavy rain at the join between shoulder and carriageway, flooding traffic lanes. For asphalt roads, the shoulders slope is normally 3 to 5 % while for gravel and earth surfaces is 8 to 10 %. When the surface runoff water penetrates shoulders a filter column just below the shoulders can be constructed by making a shallow excavation, then filling it with crushed rock, gravel or sand. At the trench bottom perforated pipes are placed to drain the filtered water into ditches or streams. Shoulders provide for the accommodation of stopped vehicles. Properly designed shoulders also provide an emergency outlet for motorists finding themselves on a collision course and they also serve to provide lateral support to the carriageway. Further, shoulders improve sight distances and induce a sense of ‘openness’ that improves capacity and encourages uniformity of speed.

In developing countries shoulders are used extensively by non-motorized traffic (pedestrians, bicycles and animals) and a significant proportion of the goods may be transported by such non-motorized means.

- **Cross-Fall**

Two-lane roads should be provided with a camber consisting of a straight-line cross-fall from the center-line to the carriageway edges, while straight cross-fall from edge to edge of the carriageway is used for single-lane roads and for each carriageway of divided roads.

The cross-fall should be sufficient to provide adequate surface drainage whilst not being so great as to be hazardous by making steering difficult. The ability of a surface to shed water varies with its smoothness and integrity. On unpaved roads, the minimum acceptable value of cross-fall should be related to the need to carry surface water away from the pavement structure effectively, with a maximum value above which erosion of a material starts to become a problem.

Due to the action of traffic and weather the cross-fall of unpaved roads will gradually be reduced and rutting may develop. To avoid the rutting developing into potholes a cross-fall of 5–6% should be reestablished during the routine and periodic maintenance works.

Shoulders having the same surface as the carriageway should have the same cross-slope. Unpaved shoulders on a paved road should be about 2% steeper than the cross-fall of the carriageway.

- **Side Slopes**

The slopes of fills (embankments) and cuts must be adapted to the soil properties, topography and importance of the road. Earth fills of common soil types and usual height may stand safely on slopes of 1 on 1.5 and slopes of cuts through undisturbed earth with cementing properties remain in place with slopes of about 1 on 1. Rock cuts are usually stable at slopes of 4 on 1 or even steeper depending on the homogeneity of the rock formation and direction of possible dips and strikes.

Using these relatively steep slopes will result in minimization of earthworks, but steep slopes are, on the other hand, more liable to erosion than flatter slopes as plant and grass growth is hampered and surface water velocity will be higher. Thus, the savings in original excavation and embankment costs may be more than offset by increased maintenance through the years.

- **Median**

Median is always provided on divided multilane highways to provide a separation of opposing traffic lanes.

Uses of median; Provides space for left-turning vehicle

- To collect some of the surface water
- Adding future lanes
- Provide space for pedestrian on crossing streets
- Where there is snow, it can be used for storing snow
- Reducing the effect of headlight glare
- Provide temporary lanes and cross-over during maintenance

- **Roadside Ditches**

Minimum depth of ditches should be 0.6m in mountainous and escarpment terrain, and 1.0m elsewhere, using a "v-ditch" configuration. The side slope and back slope of ditches should generally be no less than 1:2. Side drains should be avoided in areas with expansive clay soils such as black cotton soils. Where this is not possible, they shall be kept at a minimum distance of 4-6m from the toe of the embankment, dependent on functional classification (6m for trunk roads), as shown in Fig. The ditch in this instance should have a trapezoidal, flat-bottom configuration.

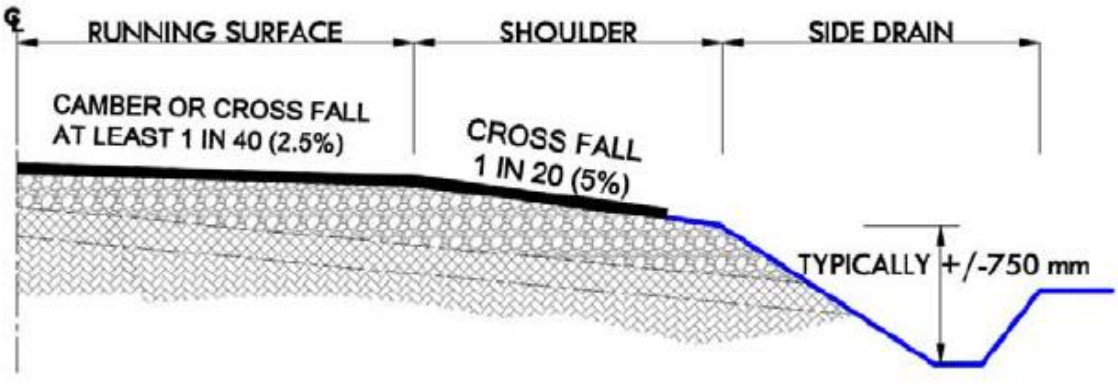

Figure 2. 4: Side drain ditch location in expansive soils (Source: ERA, 2013)

- **Curbs**

These are raised structure made of either PCC or bituminous concrete that are used mainly of urban highways to separate the pavement edges and pedestrian walkway.

Applications of curbs include; control drainage, improve aesthetics and reduce travelled way.

- **Gutter**

Mostly called drainage ditches, usually located on the pavement side of a curb to provide the principal drainage facility for the highway.

It can be designed as V-type section or as broad, flat, rounded section with 1 to 6ft wide and 5 to 8% cross slope,

- **Clear Zone**

Lateral clearances between roadside objects and obstructions and the edge of the carriageway should normally be not less than 1.5 meters. At existing pipe culverts, box culverts and bridges, the clearance cannot be less than the carriageway width; if this clearance is not met, the structure must be widened. New pipe and box culvert installations, and extensions to same, must be designed with a 1.5-meter clearance from the edge of the shoulder.

Horizontal clearance to road signs, marker posts, etc. shall be a minimum of 1.0m from the edge of the carriageway.

Integration of road infrastructure is a must in all correspondences like horizontal alignment, vertical alignment Design and pavement materials design which otherwise will cause blockage of transportation system and flood. Both interruption of Transportation system and blockage of storm water will have great economical factor for the growth of the nation. In addition to the economic factor highway floods will damage the infrastructure and even to the extent of interruption of the day to day activities of community and losses of life to the community.

2.1.4. Pavement Distress

One of the basic parameters to be considered in road integration study is pavement distress and level of these distresses. Type of pavement will also be one of the basic parameters in the design for the integration with drainage to affect the design process of the road, pavement type will be influenced by priorities of road as cobbles and gravels are rarely built on trunk roads, and surface flow is dependent of pavement type and paved road have less infiltration rate than un paved. As the level of distress increases the traffic flow as well as drainage flow arrangement will be affected. The following are types of pavement distresses for pavements with asphalt surfaces as per distress identification manual for the LTPP program (Distress Identification Manual for the Long Term Pavement Performance Program, 2014).

Cracking

Fatigue Cracking

Block cracking

Edge cracking

Wheel path cracking

Non Wheel path cracking

Reflection cracking

Transverse cracking

Patching and Potholes

Patching

Pothole

Surface Deformation

Rutting

Shoving

Surface Defects

Bleeding

Polished aggrigate

Raveling

Miscellaneous slineous Distresses

Land to shoulder drop-off

Water bleeding and pumping

Figure 2. 5: Types of distress (Source: distress identification manual, LTPP Program, 2014)

2.2. Drainage Systems

The basic function of drainage is to serve as removal of excess water from an area by surface or subsurface means. During design of urban road drainage, the parameters to be considered include; rain fall amount and storm distribution, catchment area size, ground cover, type of soil, slopes of terrain and steam, antecedent moisture condition and storage potential, shape, width and depth of the drainage channel. Highway location and geometric design are influenced by the availability of adequate drainage. Any highway or street should have adequate drainage systems to allow water to move away from the pavement's surface into properly planned channels. Inadequate drainages have resulted in serious damage to the pavement structure (Robi Diriba, 2017).

Storm drainage facilities consist of curbs, gutters, storm drains, channels and culverts. The placement and hydraulic capacities of storm drainage structures and conveyances shall be designed to take into consideration damage to adjacent property and to secure as low a degree of risk of traffic interruption by flooding as is consistent with the importance of the road. Drainage inlets are sized and located to limit the spread on traffic lanes to tolerable widths for the design storm. Inlets shall be placed upstream of locations where the pavement cross slope reverses, such as on the high side of super elevated horizontal curves, to avoid concentrated flows crossing the carriageway. A storm drain is that portion of the storm drainage system that receives runoff from inlets and conveys the runoff to some point where it is then discharged into a channel. Drainage becomes a problem when a ditch is not functioning properly to direct and carry the runoff away due to improper physical condition, capacity and maintenance. The effect of water puddles on the road is a weakening of the soil load carrying capacity followed by the acceleration of the pavement cracking process (ERA Drainage Design Manual, 2013).

2.2.1. Surface Channels

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

2.2.2. Drainage Inlets

Drainage inlets are sized and located to limit the spread on traffic lanes to tolerable widths for the design storm.

Inlets shall be placed upstream of locations where the pavement cross slope reverses, such as on the high side of super elevated horizontal curves, to avoid concentrated flows crossing the carriageway.

2.2.3. Storm Drains

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

- **Design Frequency of Drains**

Storm systems, culverts (Minor Drainage Systems)	-	5 Year
Channels with outfalls (Major Drainage Systems)	-	10 Year
Large Culverts	-	25 Year

- **Velocity**

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

- **Runoff Coefficients**

The general guideline of runoff coefficients for different land uses in storm water drainage design is given in Table 2.1 as adopted from United States Federal Highway Administration HEC 19.

Table 2. 1: Recommended runoff coefficient “C” for various selected land uses

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

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

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

2.3. Road and Drainage Integrations

Drainage is an integral part of the road infrastructure, so drainage planning and construction cannot be carried out separately from the geometric design of the road. The effects of poor drainage on roads are very detrimental. It causes road failures in a variety of ways. Road-friendly drainage systems extend the life of roads, but improper drainage systems lead to road breakdown (D.Y. Patil Prathisthan’s et.al, 2011).

Due to insufficient road profile, insufficient drainage structures provision, improper maintenance, and lack of proper interconnection between the road and drainage infrastructures, the study area's road surface drainage was found to be inadequate which resulted in damages to road surfacing material and flooding problems in the area (Getachew Kebede Warati et.al, 2015)

Drainage is a critical factor in determining a road pavement's ability to survive the effects of traffic and the environment. Poor road pavement drainage has negative consequences and can lead to failure in a variety of ways. Road pavements with proper and well-kept drainage systems have a longer life span, but road pavements with faulty and poorly maintained drainage systems fail at an early age, severely limiting their service lifespan (Agbonkhese Onoyan-usina et.al, 2013)

When the major causes of highway flooding are due to a lack of integration between road and drainage infrastructure, early design and construction attention must be given to avoid further damage by evaluating road and drainage integration performance. The performance of road infrastructure might be hampered when road and urban storm water drainage systems are not effectively provided or integrated in a specific metropolitan region. Flooding and erosion, for example, can limit the life expectancy of road infrastructure and other urban services if they are persistent (Dagnachew Adugna Belete, 2011)

2.4. Flooding

When the capacity of the urban drainage system cannot handle the storm water from excessive rainfall, an urban flood occurs, inundating houses and dry land in densely built-up areas. Despite the fact that there are numerous hydrological and metrological factors that contribute to urban flooding, inadequacies or design issues with drainage systems are the primary causes of urban flooding. The huge impervious surfaces of metropolitan areas, as well as the pavement of streets and highways, reduce infiltration and speeds up the flow, making the flood more dangerous. Because it rises slowly and has a low level, an urban flood causes significant disruption to the urban environment with significant economic losses but few casualties (Manaye Teshome Sewnet, 2020).

The key difficulties for floods include blockages, deficiencies, and the lack of urban storm water drainage facilities. The provision of integrated road and urban storm water drainage infrastructure was hampered by a lack of awareness, design issues, and issues with professional ethics (Tadele Fullee, May 2017)

There are different types of rain fall runoff modeling and of which rational and Natural Resources Conservation Service Methods are the most widely used once.

2.4.1. Rational Method

The rational formula is used for estimating peak discharges for small watersheds. The main assumption in the formula is that the maximum rate of flow results from a uniform rainfall intensity over the entire watershed area where the rainfall has duration equal to the time of concentration. The commonly known formula is used to quantify the peak storm run-off from a specified catchment area with its own catchment characteristics.

$$\mathbf{Q_p = 0.00278C*I*A} \quad \text{……………………………………………} \quad \mathbf{(2.4)}$$

Where; Q_p = Peak discharge in m^3/s

I = rainfall intensity in mm/hr

A = Catchment's area in km^2

C = run off coefficient

- **Drainage Area (A)**

The area which contributes flow to an open channel segment is obtained by delineating on digitized topographic maps (scanned maps), or Digital Elevation Model (DEM). For Rational method estimates of peak runoff rates for small urban and rural watersheds of less than 50 hectares (0.5 km2) and in which natural or man-made storage is small.

- **Run - off Coefficient (C)**

Run-off Coefficient indicates run-off generating capacity of a given watershed. Since Bishoftu is composed of different types of surfaces, in most cases cobblestone roads, unpaved surfaces with sandy soils, and roofs a composite runoff coefficient of 0.6 is adopted urban catchments and 0.5 for larger catchments mostly from unbuilt areas. In general, the mean run-off coefficients, which are relevant to urban and semi-urban areas, are given in Table 2.1 above under drainage system.

- **Rainfall Intensity**

Rainfall intensity (I) is the intensity of rainfall in millimetres per hour for duration equal to the time of concentration. Rainfall Intensity for the required return period and storm duration can be derived from the IDF Curve.

- **Time of Concentration (Tc)**

The time of concentration, Tc, is an index of lag frequently used to define a catchment's response time. Time of concentration is the time taken for runoff to travel from the hydraulically most remote point of the catchment to the point of outlet. For small watersheds used in the Rational Formula, one of the most used empirical equation to calculate time of concentration is the Kirpich equation (1940), given by:

$$Tc = 0.0195*[\frac{L}{S^{0.5}}]^{0.77} \quad \textbf{.. (2.5)}$$

Where; T_c = Time of concentration (min)

L = the length of the catchment along the longest river channel (m)

S = the overall catchment slope in m/m = ΔH/L

ΔH = the difference in elevation between the most remote point on the catchment and the outlet

The basic assumption of the formula is that the time of travel of the rain or the time of concentration is equal to the duration of the rain.

2.4.2. SCS (NRCS) Method

It is developed by the Natural Resources Conservation Service (formerly Soil Conservation Service) to provide estimation of peak discharges and runoff hydrographs from complex watersheds.

The SCS method is usually used for larger catchments which are out of the scope of the rational method. The procedure allows the designer to estimate the effect of urbanization, channel storage, flood control storage, and multiple tributaries. It can be applied to the design of culverts, bridges, detention ponds, channel modification, and analysis of flood control reservoirs. A relationship between accumulated rainfall and accumulated runoff was derived by SCS. The SCS runoff equation is the method for estimating direct runoff from 24-hour or 1-day storm rainfall.

$$Q = \frac{(P - I_a)^2}{(P - I_a) + S} \quad \textbf{.. (2.6)}$$

Where; Q = accumulated direct runoff, mm, P = accumulated rainfall (potential maximum runoff), mm,

I_a = initial abstraction including surface storage, inception, and infiltration prior to runoff, mm,

S = potential maximum retention, mm

The relationship between I_a and S was developed from experimental catchment area data. It removes the necessity of estimating I_a for common usage. The empirical relationship used in the SCS runoff equation is:

$$I_a = 0.2xS \quad \textbf{(2.7)}$$

Substituting 0.2xS for I_a, the SCS rainfall-runoff equation becomes:

$$Q = \frac{(P - 0.2S)^2}{(P + 0.8S)} \quad \textbf{(2.8)}$$

S is related to soil and cover conditions of the catchment area through CN. CN has a range of 0 to 100, and S is related to CN by:

$$S = \left(\frac{25400}{CN}\right) - 254 \quad \textbf{(2.9)}$$

The curve number (CN) is an index expressing a catchment's storm flow response to a rainfall event. The catchment's characteristics considered in determining its CN are:

- Hydrological soil properties
- Land cover properties (including land use, its treatment and hydrological condition) and
- The soils in the catchment relative wetness or dryness just prior to the rainfall event.

The land use land cover of the project area is a combination of forest and cultivated area. A CN value of 75 is estimated for Hydrologic Soil Group Type B is adopted for the peak discharge computation as given in the ERA Design Manual.

SCS Peak Discharge Equation

The calculation of peak discharge by SCS techniques is based on the triangular unit Hydrograph (UH) concept.

$$q_p = \frac{0.2083AQ}{\frac{D}{2} + 0.6T_c} \quad \textbf{(2.10)}$$

Where; q_p = Peak discharge (m3/s)

A = catchment Area (km2)

Q = storm flow depth (mm)

Tc = time of concentration (hrs)

D = storm duration (hrs)

2.4.3. Discrete Convolution

Once the unit hydrograph is determined by the above procedures the direct hydrograph will be determined by convolution of a series of unit hydrographs as a result of the proportionality and superposition principle of unit hydrographs. This will be given by a series of equation:

$$Q_1 = P_1U_1$$

$$Q_2 = P_1U_2 + P_2U_1$$

$$Q_3 = P_1U_3 + P_2U_2 + P_3U_1, \text{ and so on}$$

The general equation is expressed as:

$$\mathbf{Q_n = \sum_{i=1}^{n\leq m}(P_i U_{n-i+1})} \quad \text{.. (2.11)}$$

Where; Q_1 = the hydrograph for D hours' duration.

D = approximated by the equation $0.133T_c$.

Q_2, Q_3, etc. are the incremental hydrographs and

Q_n = the total hydrograph for rainfall duration of about the time of concentration.

2.4.4. Hydraulic Design

The rainfall excess (runoff) is transported to the design point through various flow processes. The flow in most elements of urban watershed has a free surface at atmospheric pressure and is generally classified as open-channel flow. Along a typical flow path, the rainfall excess will generally take the form of sheet flow over the roofs, lawns, driveways, and street pavements. This special type of open channel flow has a very small depth and is called overland flow. The rainfall excess will then reach a channel like street gutter, ditch, and drainage channel flowing partly full under the effect of gravitational forces and continue to move in the form of channel flow towards the watershed outlet. Storm water drainage systems represent a significant portion of urban infrastructure. They are made up of many structures that require proper design, installation and maintenance. These drainage structures include street gutters, drainage inlets, manholes, culverts, drop structures energy dissipaters and surface drainage channels.

- **Surface Channels**

Open channels are often used to collect storm water runoff from urban areas and convey it to an outfall channel or to a storm water drainage inlet. Road side ditches, median channels, and storm water channels are example of surface drainage systems. Open channels are preferred for use, especially in the major drainage system, and can have advantages in terms of cost, capacity, multiple use and flow routing storage. However, open channels have the disadvantages right-of-way needs and maintenance requirements. Most open drainage channels are trapezoidal in cross section. Designing an open channel involves the selection of the longitudinal slope and the cross-sectional dimensions, namely the bottom width, side slope and the section depth. The longitudinal bottom slope is usually governed by topography, and the in-situ soil type dictates the side slopes (based on slope stability analysis).

Given the longitudinal slope and cross-section side slopes, the bottom width and the depth of the section can be determined so that the design discharge can be conveyed without exceeding the permissible shear stress on the channel bed. Under design-storm conditions, the flow in surface drainage channel is neither steady nor uniform. However, in practice, the channels are designed for normal flow conditions assuming the flow is steady at the peak discharge. To account for deviation from normal flow conditions, a freeboard is added to the design flow depth in the channel section. The principles of open channel hydraulics are applicable to all drainage facilities including culverts.

The topography of the project area generally controls the channel alignment and bottom slope. The other factors that affect design of storm drainage channel includes width of right-of-way; location of existing channel; and adjacent existing structures, such as buildings, transportation facilities, utility structures, outlet for local drainage and tributaries. The bottom slope may be controlled by elevations of existing structures as well as by general topography, elevations at end of improvements, and hydraulic features (flow velocity, etc.). The proper channel cross section for a given reach is the one that has adequate hydraulic capacity for a minimum cost of construction and maintenance. The economics must include the costs of right-of-way and structures such as culverts and bridges. In rural areas a trapezoidal cross section may be least costly, whereas in urban areas a rectangular cross section is often the least costly (ERA Drainage Design Manual, 2013)

- **Design of Open channels**

The hydraulic principle of drainage for a given storm entails the determination of the minimum cross-sectional area of the ditch that will accommodate the flow due to the storm and prevent water from overflowing the side of the ditch. The most commonly used formula for open channel design which assumes uniform steady flow and mean velocity is the Manning's formula.

$$\mathbf{Q = \frac{1}{n} A R^{2/3} S^{1/2}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad \mathbf{(2.12)}$$

Where: Q = Discharge of flow (m^3/s),

V = Velocity of flow (m/s),

S = slope of energy grade line in m/m,

n = Manning's roughness coefficient

R = hydraulic radius in (m) = a/P

a = channel cross sectional area

P = wetted perimeter

- **Flow Velocities**

The permissible velocity and shear for a non-erodible channel should be somewhat less than the critical velocity or shear that will erode the channel. The adoption of maximum permissible velocities that are used in the design of channels has been widely accepted. Departures from suggested permissible velocity values should be based on reliable field experience or laboratory tests. Channels whose velocities exceed permissible values will require paving, lining or bank revetment. The permissible values of velocity should be determined so that damage exceeding normal maintenance will not result from any flood that could be reasonably expected to occur during the service life of the channel. The channel slope shall be such that the velocity in the channel is high enough to prevent siltation but low enough to prevent erosion. Velocities less than 0.5m/s should be avoided because siltation will take place and ultimately reduce the channel cross-section. The allowable maximum velocity should not be more than 3m/s where otherwise; there will be possibility of erosion of particles from bed and bank of channels.

Manning's formula is used to determine the flow velocities in drainage conduits (open as well as closed systems)

$$V = \frac{1}{n} R^{\frac{2}{3}} S^{\frac{1}{2}} \quad \textbf{(2.13)}$$

Where; V = Velocity of flow (m/s)

R = hydraulic radius in (m)

S = slope of energy grade line in m/m

n = Manning's roughness coefficient

The velocity of flow in drains depends on hydraulic radius (R), the invert slope of the conduit and roughness coefficient. The minimum flow velocity in a storm drain will be based on non-silting characteristics i.e. it should not allow free deposition of particles. When channel slopes are very mild less than 0.2% the flow becomes sluggish and result in sediment deposition. Maximum velocity limits and maximum excavation depths are taken as boundary conditions when designing the proposed drainage conduits. Drop structures will be provided when there is excessive slope resulting in higher velocities

- **Roughness coefficient (n)**

The hydraulic friction coefficient is determined by roughness of the conduit wall or open channel material (Table 2.2). Selected roughness coefficients are also required to have allowances for turbulence loses at junctions and drops structures.

Table 2. 2: Roughness coefficients, Manning's "n", for various materials

Material	**Manning's "n"**
Concrete	0.013
Asbestos-cement	0.011
Ductile Cast iron	0.012
PVC	0.01
Stone Masonry	0.023
Riprap	0.033
Earth Channel Clean and straight	0.03

Source: ERA, Drainage design manual, 2013

- **Discharge Capacity of Drains**

The carrying capacity of drains is determined using the continuity equation as given below. The velocity in this equation is obtained from Manning's formula.

$$Q = VA \qquad (2.14)$$

- **Design of Drainage Ditch Sections**

After evaluation of trapezoidal and rectangular channel geometries rectangular section will be selected where the roads are narrow and trapezoidal section will be adopted for flows through interceptor drains.

In order to reduce the initial cost for constructing the drainage system an economic section of rectangular and trapezoidal shape will be used. The economic rectangular section will have width which equals twice the depth and for trapezoidal section, the side slope of channel section will be adopted to be 60 degrees. This reduces the perimeter of the section for the same area or flow. These in turn reduces the material to be used. Since the storm outflow discharge in Bishoftu is to the Lakes instead of Rivers and the topography around the lake is very flat stilling or sediment basin instead of outfalls might be needed to collect solid wastes and sediment not to discharge into the natural lakes.

The selections of the above sections are based on some of aspects considered including:

- Accessibility of the channel for cleansing,
- Handling of minimum flow situations,
- Construction material availability,
- Minimum width requirement so as to minimize the construction of drainage structures and social impacts.

- **Culvert**

A culvert is a structure that is designed hydraulically to take advantage of submergence to increase hydraulic capacity. It is also a structure used to convey surface runoff through embankments. A culvert can be a structure, as distinguished from bridges, that is usually covered with an embankment and is composed of structural material around the entire perimeter. The primary purpose of a culvert is to convey surface water across or from the roadway right-of-way. In addition to the hydraulic function, a culvert must also support the embankment and roadway for traffic conveyance, and protect the traveling public and adjacent property owners from flood hazards to the extent practicable. The design of a culvert is influenced by cost, hydraulic efficiency, purpose, and the topography at the proposed culvert site. In this thesis paper culverts are considered as a continuation of channels with reinforced concrete slab covers are provided for passing and carrying vehicles load.

The hydraulic capacity of culverts in this thesis were evaluated by the following equation for rectangular culverts with H/D <= 1.2.

Where; H is the head water depth, and

D = Depth or height of culvert opening, the equation is given by:

$$Q = \frac{2}{3} C_B BH \sqrt{\frac{2}{3} gH} \quad \textbf{.......................................} \quad \textbf{(2.15)}$$

Where; Q = Design Discharge

C_B = Contraction coefficient 0.9 for square edged entrance

B = width of the culvert, and

g = Acceleration due to gravity

- **Drop Structure**

Drop structures are commonly used for flow control and energy dissipation. Changing the channel slope from steep to mild, by placing drop structures at intervals along the channel reach, changes a continuous steep slope into a series of gentle slopes and vertical drops. Instead of slowing down and transferring high erosion producing velocities into low non-erosive velocities, drop structures control the slope of the channel in such a way that the high, erosive velocities never develop. The kinetic energy or velocity gained by the water as it drops over the crest of each structure is dissipated by a specially designed apron or stilling basin.

- **Slab Culverts at the Main Road and Rail Crossings**

The slab culverts at the main road and rail crossings were checked for their adequacy by the methodology outlined below. Excessive head upstream of the culvert barrels at these locations are not allowed as overflow could affect the neighbourhood built up areas.

The hydraulic design of the culverts comprises the determination of an adequate structure that will pass the design flow with a maximum head water elevation that provides a reasonable free board against flooding of the road. A second hydraulic consideration is the prevention of scour at the culvert outlet. The total head loss h_L is the sum of an entrance loss, h_e, friction loss in the barrel, h_f, and the velocity head, h_v in the barrel.

$$h_l = h_e + h_f + h_v \quad \textbf{... (2.16)}$$

Where; h_l = total head loss;

h_e = entrance loss;

h_f = friction loss;

h_v = velocity head in the barrel.

Entrance loss is a function of the velocity head in the culvert. Friction loss may be computed with the Manning formula.

$$h_L = k_e \frac{v^2}{2g} + \frac{n^2 v^2 L}{R^{4/3}} + \frac{v^2}{2g} \quad \textbf{... (2.17)}$$

The expression can be reduced to

$$\mathbf{h_l = (K_e + 1 + 2gn^2L/R^{4/3})v^2/2g} \quad \textbf{.................................... (2.18)}$$

The entrance coefficient k_e is about 0.5 for a square-edged entrance and about 0.05 if the entrance is well rounded. If the outlet is submerged, the head loss may be reduced somewhat by flaring the culvert outlet so that the outlet velocity is reduced and some of the velocity head recovered. Tests show that the flare angle should not exceed about 6 percent for maximum effectiveness. In this paper all the sated cross-sectional as well as flow capacities of drainage channels were checked and evaluated for their adequacy on the selected section of the road segment.

CHAPTER THREE

RESEARCH DESIGN METHODOLOGY

This chapter states methodology detailing includes defining study area, population, materials used for the study, study design and variables, sources of data, way of data collection, types of data collected and methods used for data analysis and evaluation with required resources.

3.1. Study Area

The Study area is located in Oromia National Regional State, East Shewa Zone at a distance of 47 km southeast of Addis Ababa and is astronomical location is 8º 43’- 8º 46’ North Latitude & 38º 56’- 39º 01’ East Longitude on an average elevation of 1,920 m. The town was founded in 1917 GC. Bishoftu is one of the reform towns in Oromia region and has a city administration, municipality and nine kebelles. The town has a structure plan which was prepared in 2010 GC.

Documented data show that the Bishoftu city covers nearly 205.74 km^2 of land based on the 2010 Revised Structure Plan of the City prepared by Oromia Urban Planning institute. There are varying figures concerning the population size of the city. According to the 2013 Population projection of Central Statistics Agency (CSA), Bishoftu city has a total population of 128,408 but as per Ethiopian urban studies of 2015; the population of the city is 140,039 and sources from the city administration show that total population of the city is 200,064 in 2016.

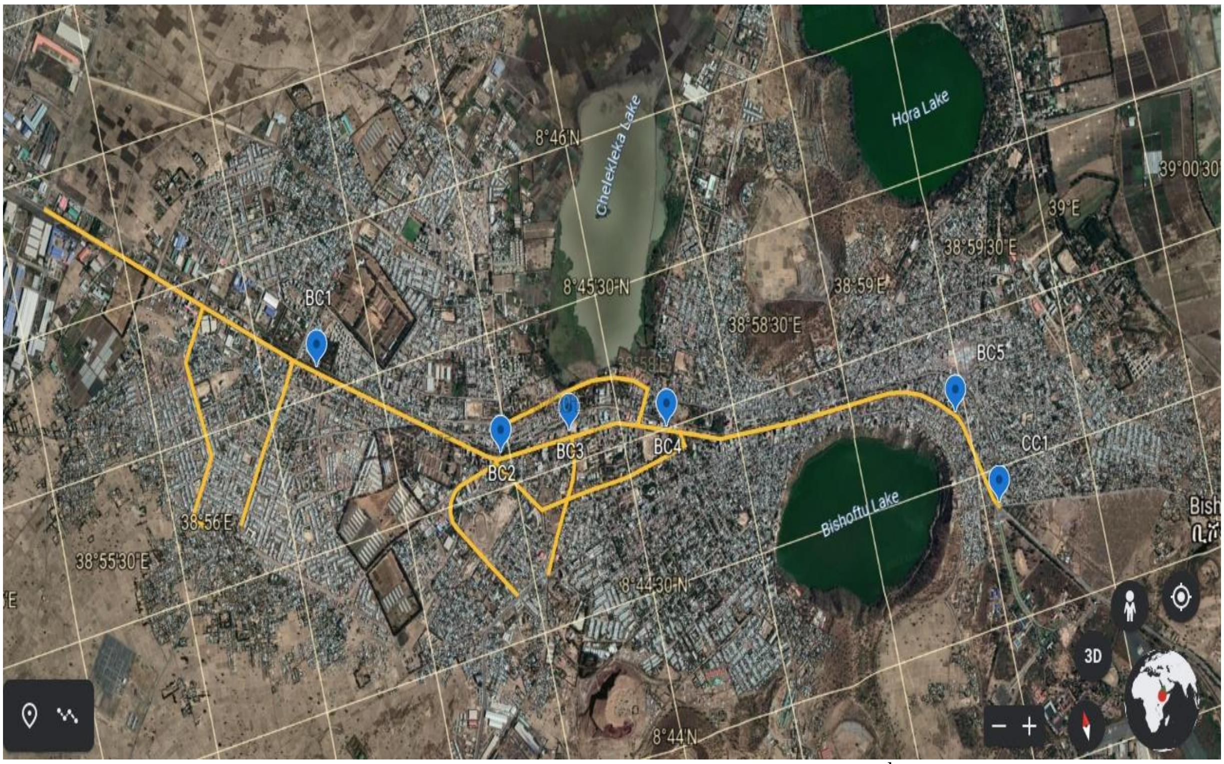

Figure 3. 1: Geo-referenced study area (Source: Google Earth, on 24th of August 2021).

3.2. Study Design

The study adapts descriptive and exploratory research designs which involving qualitative data so as to describe and examine the findings to come up with conclusions and recommendations for implementation. The descriptive type was used to describe the existing condition and coverage of roads and urban storm water drainage facilities and its integration. Whereas, the exploratory type was particularly used to explore the existing condition by making some required physical measurements, and compare with standards and coverage of road network and urban storm water drainage facilities which were not found in the base-map, and were collected from the Bishoftu-city Infrastructure Asset Management Plan.

The study followed the following steps in the study design:
Statement of the Objectives: as this is the first step in this survey, the researcher formulated a list of objectives to be obtained from the questionnaires. This step determines what is to be included in the survey and what is to be excluded.
Determination of the Sampling Design: as aforementioned, this research used purposive sampling for data collection from a group of the community (Both FGD and KII). The non-probability sampling method was used to sample the community as the research matter needs some technical background and selected based on experience from those technical. In order to make inferences about the population, the study assumed that the sample is representative of the entire population with their technical skills and exposures to explain about the situation.

Instrument Design: a sequence of semi structured KII, focused group discussion questions and observation checklists were designed to obtain information about critical challenges of integration of road network, drainage systems and highway flooding.

Data Collection: this is the process of gathering the required information for each selected unit in the survey. In depth interviews with FGD and field observations with actual measurements were used as the main technique for collecting data. KII and FGD discussion points have open ended questions conducted to the participants who were purposively selected from residents, contractors, construction office and stakeholders of Bishoftu city infrastructure department. The study data collection was conducted during summer season and helped to properly identify and evaluate flood prone areas by eye witnesses and helped to validate KII and FGD points during field survey with the help of field survey equipment's.

Data Analysis: after data is collected and captured, and coded, analyses of these data were conducted and triangulations were made to see how the integration of road and drainage system caused flooding in the main road.

3.3. Sampling Size and Techniques

From the measurements taken from the google earth map and confirmed from evidences obtained from Infrastructure asset management report of the city as well as direct measurements, the overall road network of the city showed 96.6 km of primary road. The main road passing through Bishoftu city is 8.5 km with an equivalent 15 m width, while 31.58 km of the primary road and drainage of 11.084 km feeding to this main road was purposely selected for the study.

Flood prone areas are identified by city disaster risk management plan through drainage map by delineating hodological map using ArcGIS and same was confirmed during using discussions with KII and FGD as well as field survey and detail evaluation was conducted on road and drainage networks.

Prior to field investigation, different data relevant to the drainage situation was collected. This includes, DEM (Digital Elevation Model), Satellite Imagery and drainage design repots. Accordingly, major drainage basins and outfalls in the city prone to the flood are identified based on the main road passing through the city as a base point of discussion while roads and drainages feeding to this road are considered for integration evaluation.

The study used purposive sampling technique as the areas prone to the flooding as well as the effect of poor integration of road and drainage infrastructure are reflected on the main road passing through the city. The study was conducted on 15.788 km (31.58 km equivalent 7 m width) of road including the main road and road feeding to this main road and 11.084 km of drainage line integrated with these roads.

The study participants are persons with technical know-how with exposure to design and construction supervision of road and drainage structures in the city, which are deliberately selected as the research focuses on technical terms. Infrastructure department intervenient are selected based on experience they possess in the areas of integration of road and drainage networks with a total of four key informants for KII from infrastructure department and community as well as eight persons involved in FGD from community, contractors and construction department where the persons used for KII and FGD are different.

3.4. Source of Data

The study uses both primary and secondary data sources. Majority of the primary research data were collected through observation, questionnaires and key informant interview with focus group discussion. The secondary data was collected from available reports, documents and published articles, journals, books, magazines, and broachers. Report available in the construction departments, study design drawing and reports, manuals, guidelines and other relevant sources like historical metrological data were also used to determine rainfall intensity to check for design as secondary data sources.

3.5. Data Collection Method

Formulations of interview by semi-structure interview, questions for FGD, observation checklist, guided by the literature review and the objectives of the study were employed to collect pertinent descriptive information. Primary data were collected through open-ended questionnaire which are used to get essential information from respondents, through structured and semi-structured interview. Observation was also conducted by the researcher himself to collect the data using materials used for this study. Secondary data were gathered and reviewed from different sources that are related to the study such as; books, published articles, journals, magazines, broachers, guidelines, manuals and others sources like city reports, infrastructure asset management document, drainage study documents, infrastructure design documents and city disaster risk management plan document.

Questionnaires were prepared for Bishoftu city infrastructure professionals in order to identify: how roads and drainages are to be designed, constructed and integrated, major causes of flooding, techniques of urban storm water drainage contract and budget allocation to road and urban storm water drainage infrastructure. Interview was employed to collect data related on integration of road and drainage network. A focus group discussions were focused majorly on community level relevant to the technical know-how. Field survey was used to observe the field condition and what exactly the integration of the roads and drainage network mainly feeding to main road looks like and some measurements were also taken. The measurement was done using surveying equipment such as tape, GPS, leveling, pavement markers and camera was used to back up the observation. Secondary data were collected in the form of topographical maps, reports, design documents from city construction department, metrological data and so on. The collected data were checked and analyzed using software like Auto CAD and GIS besides the common Microsoft office software.

3.5.1. Key information interviews:

According to (Leedy and Ormrod, 2005:146) interview can yield a great deal of useful information. Key information interview is particularly important to identify problems which are living with the communities. The qualitative information was gathered using pre designed checklists and interview guides. Key informants were, thus interviewed using both open ended questions. Hence, the targeted key informants of two community representatives with technical know-how on the subject area and two infrastructure department engineers total of four KII were conducted.

3.5.2. Focus group discussion:

According to (Solomon, 2005) focus group discussions are used to obtain opinion or attitude at another level and help the researcher as a source of validation. The data that would be collected from the key informant would be enriched by additional information that will be gathered through focus group discussion. The local four community members, one construction engineer, one infrastructure department representatives and two contractor representatives total of eight persons were invited to FGD and conducted the discussion.

3.5.3. Observations:

It was carried out within pre identified area of challenges related to integration of road and drainage through transect walk in order to cross check the data gathering by interview and to support their validity through eye witnessing. It is very important as it enables the study to relate the actual type of community problems and validated the existing information and better understanding the prevailing situation of target communities.

3.5.4. Data Validity and Reliability

Validity is the most critical criterion and indicates the degree to which an instrument measures what it is supposed to measure. The validity of the instrument as well as the data were checked for its validness based on content validity concept, criterion-related validity and construct validity while preparing observation check list and interview questionnaires. It is concerned with the integrity of the conclusions that are generated from a piece of research. In qualitative data, validity can be addressed through the honesty, depth, richness and scope of the data achieved, the participants approached, the extent of triangulation and the disinterestedness or objectivity of the researcher. The finding clearly shows that there are clear indications of the validity of the instruments as the results much and are consistent with the findings as well as conclusions at which the researcher arrived and this is the content validity measure of degree of representativeness of the sample.

Reliability of the instruments was also checked before the instruments were taken for measurements of the data, based on the international standards and guidelines of the subject area.

3.6. Data Presentation and Analysis

As such, good research makes a perfect plan of processing and analysis data. The following procedures and activities were taken during data analysis process. Secondary reference documents stated above were used as a source document to help the researcher understand the status of the city in regard to infrastructure performance against standards. Information collected through observations, interviews, open ended questionnaire and other secondary data were analyzed qualitatively. Interpretations were done based on the common points and conceptualizing and explaining issues interrelated to one another in the themes. Data collected for integration of road network and drainage systems were triangulated for the correspondence of its effect towards flooding of highway. The analysis is mainly descriptive and the information collected from both primary and secondary sources were processed with the help of Microsoft excel, AutoCAD and ArcGIS software's and the analyzed data were presented using tables, figures, chart and graphs. In addition to these analyzing tools, figures and field survey photos were also incorporated.

3.7. Research Ethics

To reach an agreement with all participants including in the study informed consent form were orally read for FGD and written consent form was given to KII before the interview started. The informed consent has incorporated information such as the voluntary nature of the research, purpose of the research, extent and procedure of confidentiality and anonymity. The informants' consent was also confirmed before doing the data collection, and they were informed on how it was planned to handle it. The informed consent has clearly showed that there is no incentive to be given to any research participant in return for the information they provide. It also clearly stated in the informed consent that the participants are sincerely acknowledged for participating and contributing for the purpose of the research work only.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1. Identification of Flood Prone areas

Main road Asphalt with constant lane width of 15 m have been assessed and identified that segments from Entry to Innova and Innova to Getshet as well as Getshet to Ziquala are highly affected by flood and the areas pavement have been distressed.

As shown in the assessment Table 4.1 the road segment from Entry to Innova is 76.71 % highly damaged, while 100 % and 41.89 % of Innova to Getshet and Getshet to Ziquala segments are with higher severity damage respectively, there are no side drains constructed for these areas. On the other hand, Segments from Ziquala to Bus station and Circle to Airforce are moderately damaged for the whole section. Segments of Bus station to circle and Ziquala joint asphalt were constructed with both side drainage which are functioning properly and exhibits low severity damage. In addition, from KII and field surveys it was observed that areas around Bus station are also highly affected by flood even if the damage on the road infrastructure is seen moderate.

Table 4. 1: Identification of flood prone areas.

S/N	Name of Segment	Observed Problem	Extent of Damage (m)		
			High	Moderate	Low
1	Entry to Innova, 1.4 km	Potholes, deformation, absence of side drains and surface flow.	1,074	326	-
2	Innova to Getshet, 0.8 km	Potholes, deformation, absence of side drains and surface flow.	800	-	-
3	Getshet to Ziquala, 1.8 km	Potholes, surface deformation and overflow.	754	1,046	-
4	Ziquala to Bus Station, 1.4 km	Flooding, surface deformation, overflow & backflow.	-	1,400	-
5	Bus Station to Circle, 1.6 km	-	-	-	1,600
6	Circle to Air Force, 1.5 km	Fatigue cracking, surface flow.	-	1,500	-
7	Ziquala Joint Asphalt, 1.3km	-	-	-	1,300
Total (9.8 km of Asphalt)			2,628	4,272	2,900

Figure 4.1 represents the extent of damage of flood prone area of Asphalt road. It clearly shows that road from Entry to Ziquala are highly damaged where as the road from Bus station to circle and Asphalt road at ziquala junction and segment from Bus station to Circle are with lower damage. From the assements made 26.82 % of the segment were highly damaged and 43.59 % were moderatly damaged while the remaining 29.59 % are with low severity.

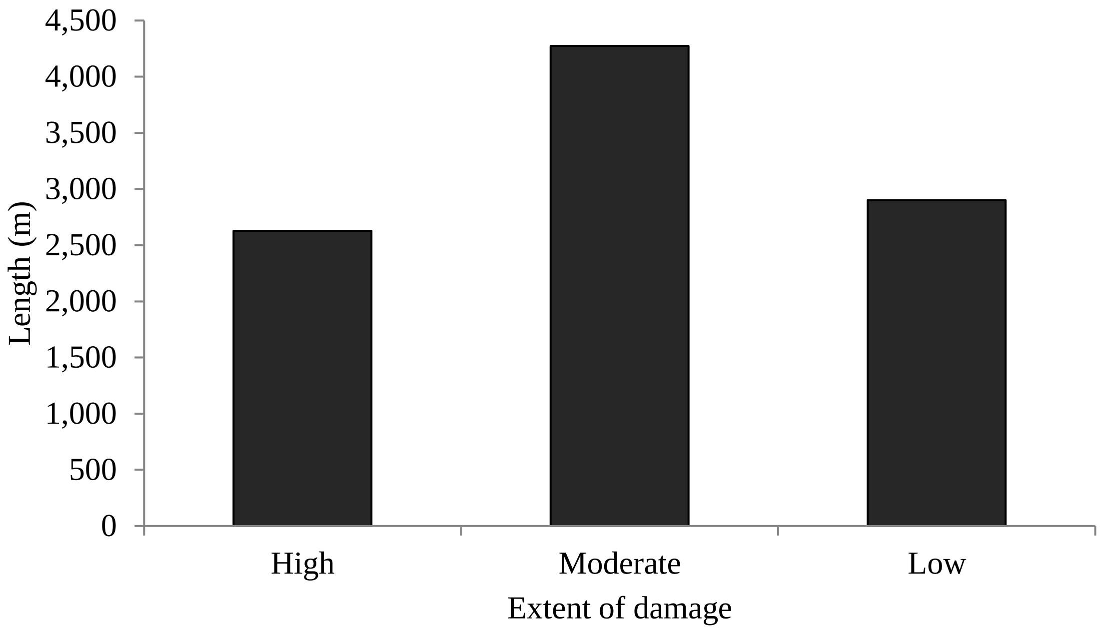

Figure 4. 1: Asphalt Road severity level of damage for flood prone areas

4.2. Evaluation of Road Networks

The main asphalt road passing through the city divides the city from Northwest to Southeast, the asphalt road cross drainage structures are also the outlets for upstream drainage basins of the city. The main road covers 8.5 km with six cross drainage structures provided and these structures are also the only outlets to siphon the upstream drainage.

4.2.1. Geometric Design

The road geometric futures which are important to flow off the road surface runoff to side drains includes carriageway cross section slope and longitudinal gradient and shoulders were assessed in the study.

- **Cross-sectional Slope and Longitudinal Profile**

Drainage of the road pavement is supplied with the aid of shaping the street carriageway with a camber or cross slope. The camber is the slope from either aspect of the center line toward the avenue shoulders. For roads with asphalt surface, the camber is generally 2 to 3 %, because water will easily float off a hard, water-resistant surface. On cobble and gravel roads, the camber wants to be steeper because the water will glide more slowly and the floor is frequently uneven. Gravel and earth surfaces also soak up some of the floor water unless it is shortly drained away from the road, thus, it is endorsed that the camber is 5 to 7 %. On sharp curves, the camber is frequently substituted with a super elevation which leads the water to the interior of the curve (Magdi M. E. Zumrawi, 2014).

From ERA Geometric design manual, it is clearly standardized that, normal cross-fall for trunk road is 2.5 % with shoulder cross-fall of 4 %, while for cobblestone road normal cross-fall is 3 % with shoulder cross-fall of 6 % and for unpaved gravel road normal cross-fall shall be 6 %.

Study results of Table 4.2 shows the maximum cross slope of the area is for section from Bus station to Circle which is 1.5 % and is even too much below the standard and hence the probability of the surface flow not to flow with expected speed to side drainage channels will increase and as the time it took to flow from the surface will increase it leads to surface flooding.

Table 4. 2: Existing property of cross-sectional elements of segments.

S/N	Name of segment	Road width(m)	Crown (%)	Grade (%)	Shoulder (%)	Curb stone(m)	Standard camber (%)
1	Asphalt Road						
1.1	Entry – Innova	15	1.0	1.5	-	0	2.5
1.2	Innova – Getshet	15	0.5	0.9		0	2.5
1.3	Getishet – Ziquala	15	1.1	1.2		1,046	2.5
1.4	Ziquala - Bus Station	15	0.2	0.5		1,400	2.5
1.5	Bus Station - Circle	15	1.5	1.5		1,600	2.5
1.6	Circle to Air Force	15	0.5	2.0		1,500	2.5
1.7	Ziquala Joint	14	0.5	1.7		1,300	2.5
2	Cobblestone						
2.1	Innova (1.488km)	12	0	2.0	-	0	3.0
2.2	Getshet (1.1km)	14	0	1.8		0	3.0
2.3	Eyasu Meda (0.85Km)	10	0	1.3		0	3.0
2.4	Bust Station (1.3km)	10	0	1.2		0	3.0

S/N	Name of segment	Road width(m)	Crown (%)	Grade (%)	Shoulder (%)	Curb stone(m)	Standard camber (%)
3	Gravel (1.25km)	20	0	0.8	-	0	6.0

For cobble stone and gravel road even if the standards set are above the asphalt road which is 3% and 6% respectively to let surface runoff to flow to side drains, there are no provided cross-fall in the existing site condition and the flood will not flow to the side drains and there observed detention of flood on the road infrastructure. As per KII and FGD held with participants the designs provided to cobblestone road lacks cross sectional slopes and has been confirmed by secondary design documents reviewed, even in areas like Innova cobblestone as show in Figure 4.5 the cross-drainage slopes are inverted to the center of the road and flood remains in the road for longer durations.

- **Existing Road Profile of the Main Road**

In flat or slightly undulating terrain and level gradient one would aim to achieve a longitudinal gradient of minimum 0.5 %, if the cross slope and carriageway elevation above the surrounding ground is adequate to drain the surface laterally. Longitudinal gradients should be provided to facilitate surface runoff in cases of curbed highways. For drainage structures which are to be constructed in line with road infrastructure, for bed slope less than 2 percent will be subjected to silting and for steeper than 5 percent the ditches will easily erode. (ERA, 2013)

Profile of the main road clearly shows that the elevation difference of the minimum and maximum road section is 28 m. There are ups and downs in between this section as maximum elevation is between Getshet and Ziquala of 1918 m with minimum elevation at the gate of the Air Force 1890 m. Figure 4.2 shows longitudinal profile of the main road, the road needs crossing structures at six points as it was already provided on the existing road. It is remarkable that the longitudinal and cross-sectional slope of the road was not built in a uniform manner which will retard surface runoff to flow to the side drains. The longitudinal gradient of the main road is less deficient to move the surface runoff when compared to the mild cross-sectional slope of maximum 1.5 % and minimum 0.2 % which are below the standards of 2-3 %.

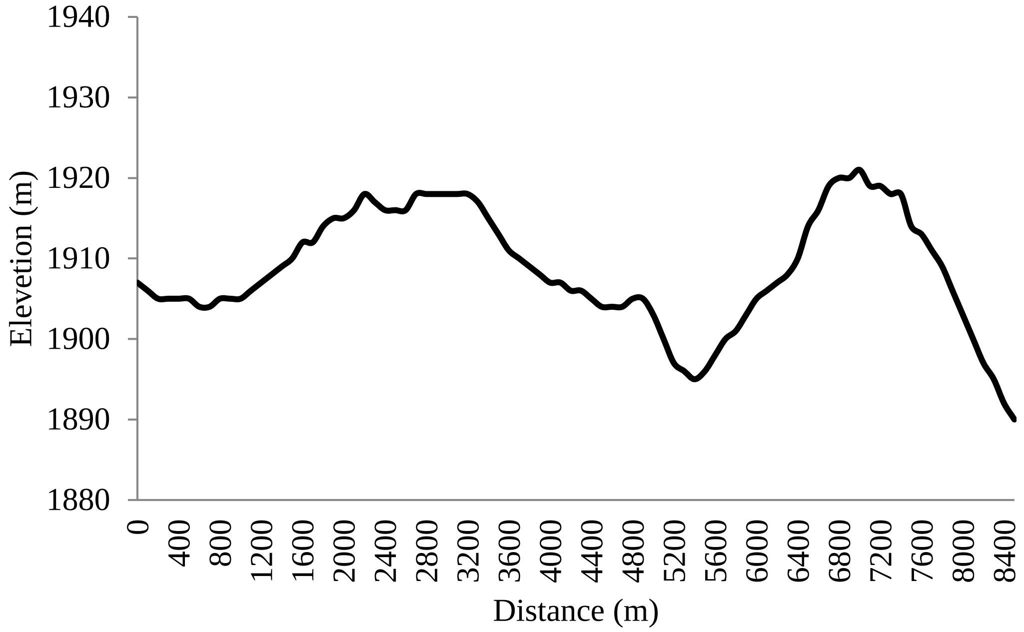

Figure 4. 2: Main Road profile.

- **Existing Road Profile of Ziquala Joint Asphalt**

Asphalt road profile at joint of Ziquala shows Maximum elevation of 1931 m and minimum elevation of 1907 m. The road is inclined to main road with variable slope varying from 1-5 % from station 0+00 to 1+000 for 1 km. On the other hand, the remaining 300 m of the road is inclined to back ward with slope of (-3 %) and the side drain is also flowing to the other side of the road. There is no significant problem on this road and side ditches, even if the cross-sectional slope of this section is also mild (0.5 %) which is much less than the standard 2.5 %, the inlets and chamfers of the side ditches are properly provided and the longitudinal gradient helped to move surface flood to side drains.

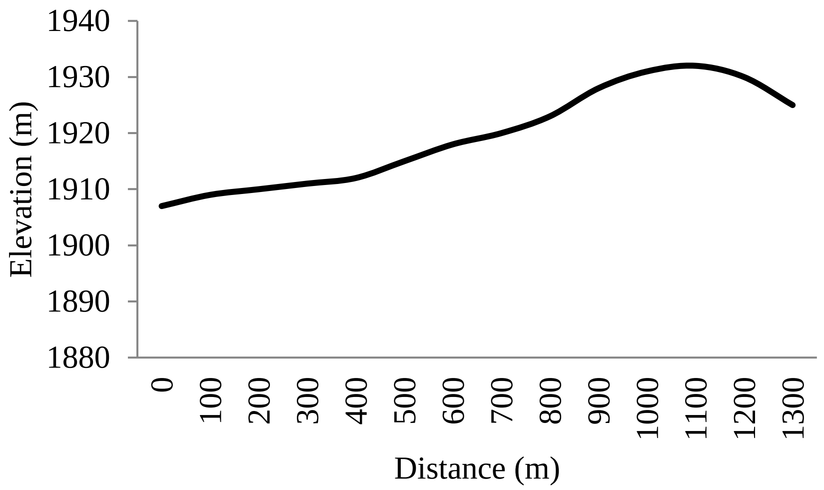

Figure 4. 3: Asphalt Road profile at Ziquala joint.

- **Existing Road Profile of Innova Cobble Stone**

Cobble stone road profile at Innova shows Maximum elevation of 1939 m and minimum elevation of 1909 m. The road is inclined to main road with an average slope of 2.0 % varying from 1-3 % slope every 100 m. for this section as it was clearly seen during field survey, there is no cross-sectional slope provided to this section and the water was flowing over the whole section of the road and finally the road is subjected to distress with water detained over the distress areas.

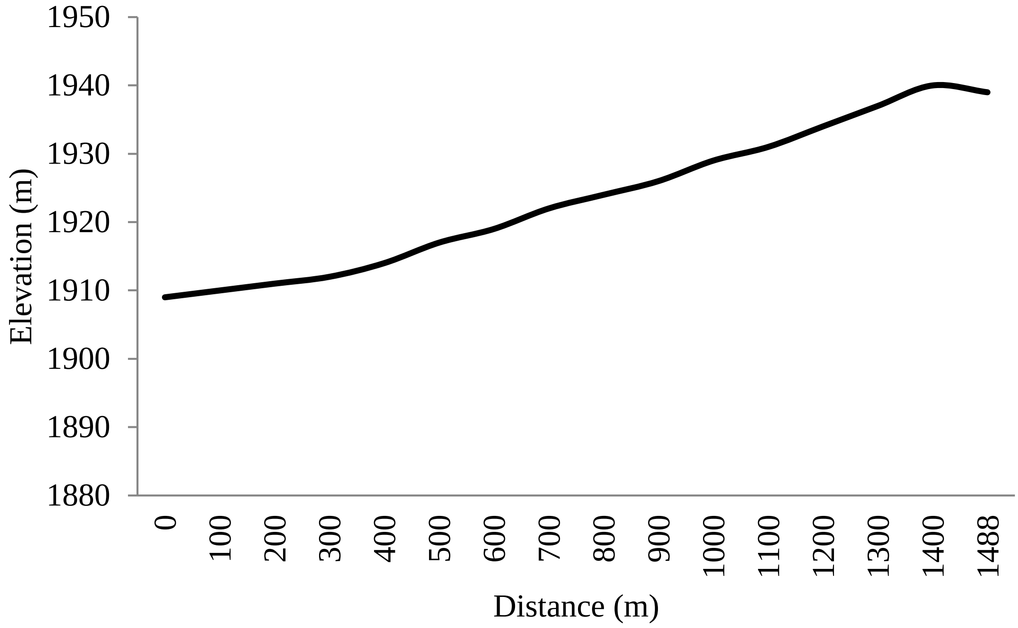

Figure 4. 4: Cobblestone Road profile at Innova.

As shown in the Figure 4.5 cobblestone at Innova was deformed and the water is detained on the surface, even if there are side drains in both side, insufficient road profile and drainage structure provision results in damage to road surface pavements and flooding problem in the area of Innova and Getshet.

Road Profile condition during no rain | Road profile condition during rain

Figure 4. 5: Cobblestone Road with no cross-fall.

- **Existing Road Profile of Getshet Cobble Stone**

Cobble stone road profile at Getshet shows Maximum elevation of 1938 m and minimum elevation of 1918 m. The road is inclined to main road with almost constant slope of 1.8 % varying from 1-3 % slope every 100 m.

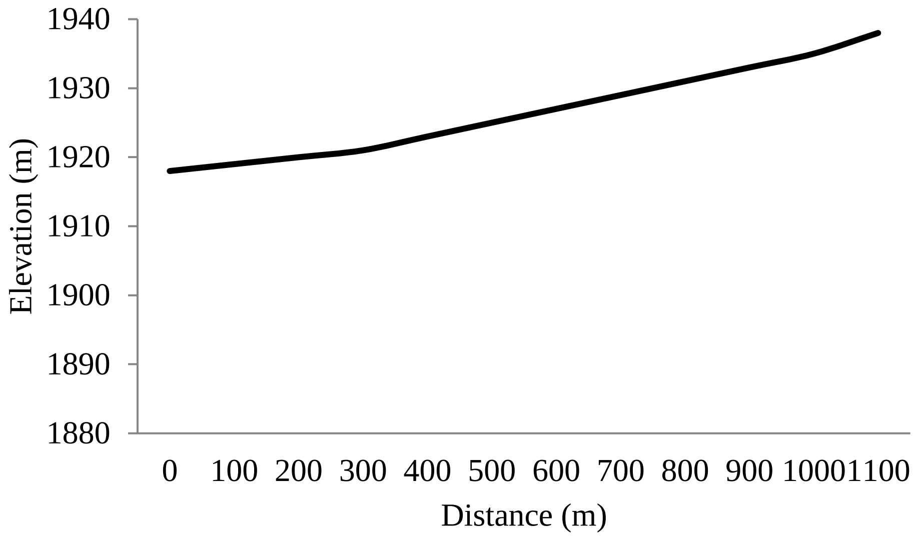

Figure 4. 6: Cobblestone Road profile at Getshet.

- **Existing Road Profile of Eyasu Meda Cobble Stone**

Cobble stone road profile at Eyasu Meda shows Maximum elevation of 1916 m and minimum elevation of 1905 m. The road is inclined to main road with variable slope varying from (-1.0 %) for 100 m (b/n station 0+500 and 0+600) to maximum slope of 3 % for 200 m at the joint on the main road, while the average slope is 1.3 % inclined to the main road.

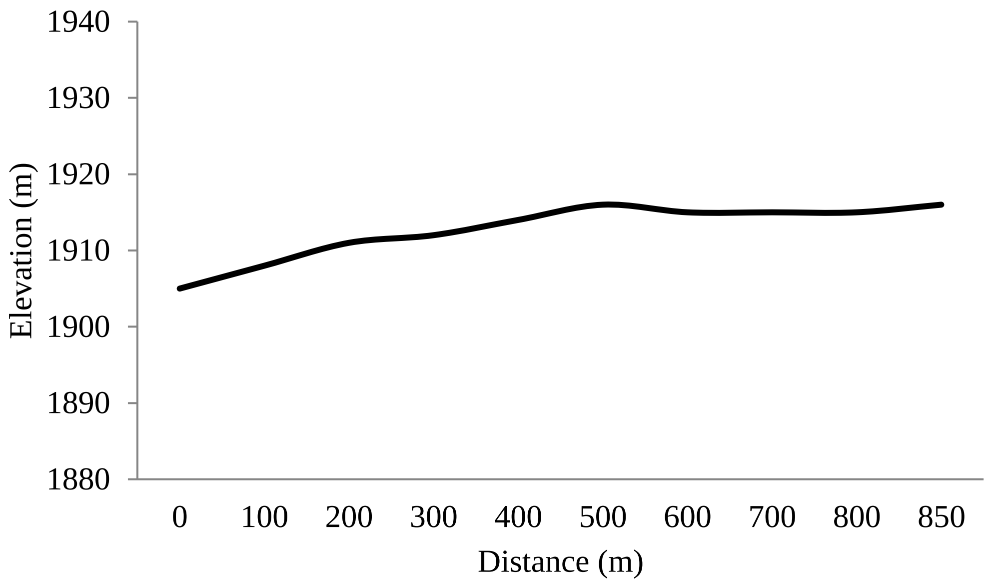

Figure 4. 7: Cobblestone Road profile at Eyasu Meda.

- **Existing Road Profile of back of Bus station Cobble Stone**

Cobble stone road profile at back of Bus station shows Maximum and minimum of 1920 m and 1894 m respectively. The road is inclined to main road with variable slope varying from (-4.0 %) for 100 m (b/n station 0+100 and 0+200) to maximum slope of 10% for 100 m (b/n 0+800 and 0+900), while the average slope is 2 % inclined to the main road. The area is highly affected by flood, and there is drainage line constructed from station 0+700 to 1+300 but there is no road side drainage for the remaining section from 0+00 to 0+700, and this area is always flooded by runoff.

Providing the vertical alignment of the road with a gentle longitudinal gradient improves the road surface drainage. This slope facilitates the discharge of water from sections of the road surface with limited cross-slope. Steep road slope causes surface water to move rapidly and makes surface drainage difficult to control. This problem starts when the longitudinal gradient exceeds 8 % as it is seen for section b/n 0+800 and 0+900 which has slope of 10% for 100 m. Due to the steep grade; it becomes more difficult to evacuate water from the carriageway. This will result in accelerated wear of the road surface. If the steep slopes cannot be avoided by realigning the road, an alternative is to provide an erosion resistant surface to this section, such as stone pavement, asphalt or concrete. Equally, the side drains need to be protected in a similar way and here again after this steep slope of road profile there is a completely flat slope where there is no gradient and the surface runoff from upstream easily detained on the flat areas of section from 0+200 to 0+700. In addition to flatness of the area there are no side drains as well as no cross slopes in this area which will exaggerates the effects of flooding.

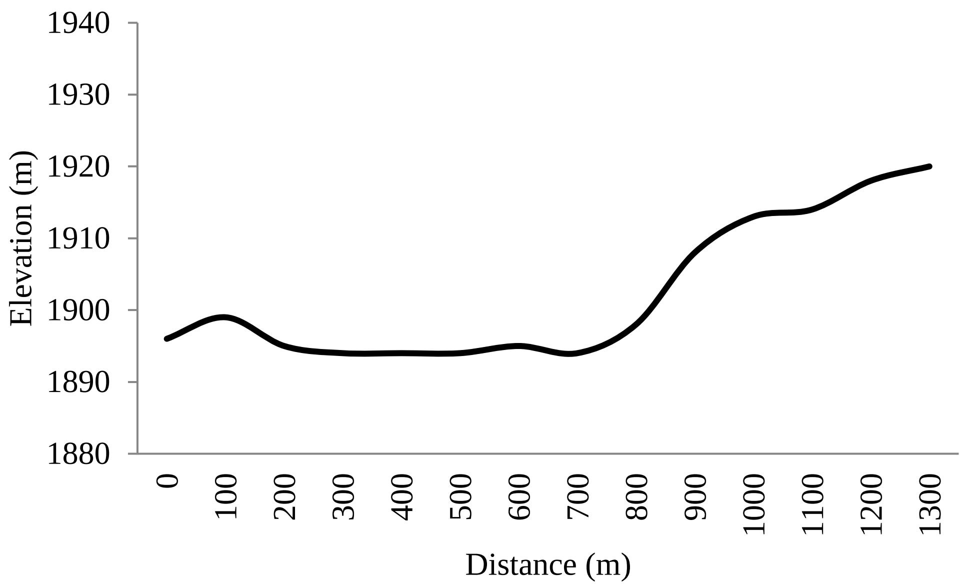

Figure 4. 8: Cobblestone Road profile at back of Bus station.

- **Existing Road Profile of Gravel Road**

Gravel road profile shows maximum elevation of 1905 m and minimum elevation of 1891 m. The road is inclined to mid-way, between the road section of 0+400 up to 0+700 where there is constant elevation, with variable slope varying from (-2 %) for 200m (b/n station 0+200 and 0+400) to maximum slope of 3 % and 4 % for 100 m b/n 0+900 and 1+000 and 1+000 and 1+100 respectively, while the average slope is 2 % inclined to the mid-way between the roads. The area is highly affected by flood, and there are no side drains constructed for the whole section of the road, this section is just aside of the creator Cheleleka lake with no cross-fall slope.

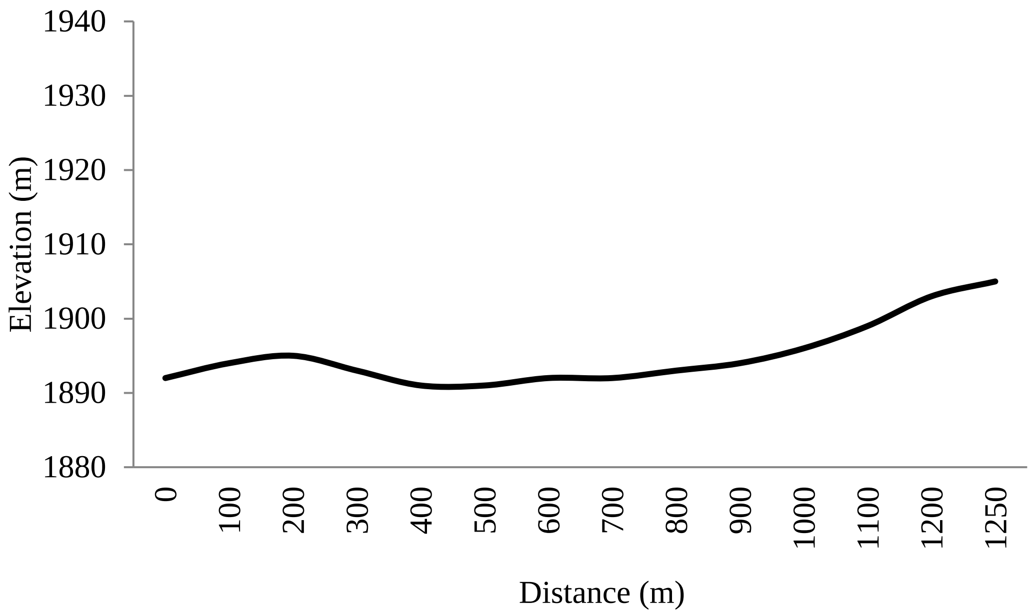

Figure 4. 9: Gravel Road profile.

As a result of no cross falls in cobblestone and gravel road, points raised by KII and FGD as well as confirmed during field survey include;

- A road is assumed to be completely closed when its crown is covered by water, regardless of depth.
- The roads are damaged by the surface water runoff and experiencing detention of water on distress areas for prolonged time.
- Traffic on open roads continues to flow smoothly, perhaps at a slightly reduced maximum speed and formed traffic congestion.
- Increase traffic accident as the distressed places are not visible during flooding of the whole section of the road.
- Diversion routes, and changes (or not) to driver behaviour as a result of the flood and affects economic movement of the area.

In addition to cross-fall the longitudinal slopes are tried to be assessed and evaluated, but no major problems were seen with longitudinal slopes except for cobblestone site behind Bus station where the road is 0 % slope for about 700 m (from 0+000 to 0+700) and experiences detention of water on the road surface and 10 % b/n 0+800 and 0+900 where the road is experiencing accelerated wear of road surface.

- **Shoulders**

Importance of road network and at grade junction as per ERA Geometric Design Manual 2013 clearly states that, in town section there should be an area left for parking on the road with 3.5m for DC8. In addition, it is recommendable to use shoulder slope of 3-5 % for paved roads and 8-10 % for gravel road to let the water flow easily to the side drains. However, in case of Bishoftu main road there is neither free shoulder nor parking space width provided on the road geometry for both side of the carriageway, and this has also contribution to flooding of the surface of the road.

4.2.2. Road Distresses

Based on the evaluations conducted to the road networks of the flood prone areas of the main road during flood prone area identification and shown in Table 4.1 as well as evidenced in site pictures taken during field survey and shown in Figure 4.11, for places where there are no drainage structures (Entry to Innova and Innova to Getshet) are with major road distresses whereas in places where both side drainages are constructed (Bus station to Circle and Ziquala Joint Asphalt) there are minor defects on the road. It was found out that, areas with less integration of road network and drainage system including the less capacity of the drainage channels exhibited too much distress. It was also remarkable from cross sectional slopes study above those areas with less cross-sectional slope and longitudinal gradient are highly exposed for surface runoff and this is where the critical distresses are witnessed. As shown on Table 4.3 areas most prone to surface runoff with minimum integration of road and drainage infrastructure shows remarkable damages.

Table 4. 3: Extent of identified distresses and problems.

S/N	Name of Segment	Level/Extent of Damage (m)				
		High	Moderate	Low	Total	Identified Problem
1	Asphalt Road	2,628	4,272	2,900	9,800	Total 9.8 km
1.1	Entry to Innova	1,074	326	-	1,400	Pothole, Fatigue, deformations.

S/N	Name of Segment	Level/Extent of Damage (m)				
		High	Moderate	Low	Total	Identified Problem
1.2	Innova to Getshet	800	-	-	800	Pothole, Fatigue & Deformations.
1.3	Getshet to Ziquala	754	1,046	-	1,800	Potholes, Fatigue and Deformations.
1.4	Ziqual to Bus Station	-	1,400	-	1,400	Fatigue, Sag Point.
1.5	Bus Station to Circle	-	-	1,600	1,600	-
1.6	Circle to Air Force	-	1,500		1,500	Potholes & Fatigue Cracking
1.7	Ziquala Joint	-	-	1,300	1,300	-
2	Cobblestone	1,488	3,250	-	4,738	Total 4.738Km
2.1	Innova (12m)	1,488	-	-	1,488	Surface deformations, water detention.
2.2	Getshet (14m)	-	1,100	-	1,100	Poor joint, surface flow
2.3	Eyasu Meda (10m)	-	850	-	850	Less capacity, Surface flow
2.4	Bust Station (10m)	-	1,300	-	1,300	No side drainage, Detention of water
3	Gravel (20m)	-	1,250	-	1,250	-
	Total	4,116	8,772	2,900	15,788	

From Table 4.3 shows that for segment from Entry to Getshet, there is no side drains and the road is with major damage with high rate of potholes and block cracking, surface runoffs are detained over the surfaces of the road and actually minimum cross-sectional slopes are also the factors exaggerating surface flooding to this section. Evaluations of the survey indicates 26.07 % of the assessment area is highly damaged while 55.56 % of the area is with Moderate damage. But inspections of every route indicate 100 % of Innova to Getshet main road and Innova Cobble and 76.71 % of Entry to Innova main road are highly damaged.

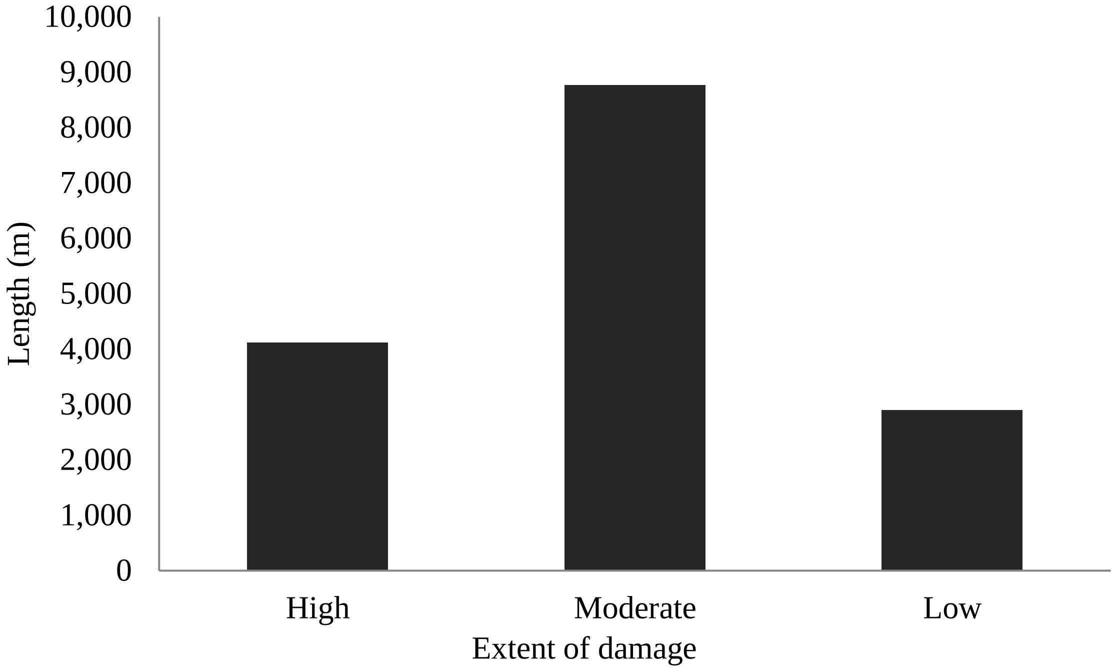

Figure 4. 10: Total level of damage.

Figure 4.11 shows the road without side drains are highly affected by the flood and the area needs fundamental maintenance as the Potholes are with high severity damage. At this particular place the depth of pothole surpasses the pavement and base coarse thickness. Fatigue and Block cracking's are also changed to potholes as they didn't get maintained in timely manner, after some time of prolonged services without maintenance of the area, the pavement is totally demolished and changed to almost gravel road.

Water ponding Block cracking Potholes.

Figure 4. 11: Types of road failure

Asphalt road from Lemlem to Bus station and Circle to Air Force, the road is with one side drainage and reflects moderate damage on road infrastructure here as the one side drains are not adequate to discharge the surface runoff and are filled with sediments, there are also surface runoff in these sections of the road. The road in these sections exhibits distresses of Block Cracking, Fatigue Cracking and Potholes. From Bus station to Circle there is no damage on road surface as there is both sided drainage along the road and this section has no surface flooding's as well as no sediment in the drainage channels and the flood on the surface will easily flow to the side drains to the outlet.

4.3. Evaluation of Drainage Systems

The function of the drainage channel is to collect water from the road and the surrounding surface areas and to lead it to an exit point the place it can be safely discharged. The side drains need to have sufficient capacity to collect all rainwater from the road surface and dispose it quickly and in a controlled manner to minimize damage (Magdi M. E. Zumrawi, 2014).

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

4.3.1. Existing Storm Drainage Facilities

As urbanization grows the paved area increase which results in increased runoff than infiltration. Usually, sufficient space is not allowed to drain storm runoff hence runoff/flood interferes with development areas by inundating roads, houses and villages and occupying open spaces. In addition, sediment transported from upper watersheds is clogging channels and culverts which reduce their flow transporting capacity. Random solid waste disposal which is a major problem in city is also concern which blocks channels and culverts and contributes for design depth reduction of drainage structures and water quality deterioration of the receiving lakes like Cheleleka.

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

Most open drainage ditches are not adequately designed and slopes are not adequately provided in flatter areas and drops at highly steep areas where excessive velocity is observed to cause damage on the channel. Most of the drainage ditches are filled with solid waste and sewerage resulting in formation of sewage ponds in the channel as well as on the road.

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

As presented in the introduction of this thesis, the physical facilities have been increased and installed in areas prioritized by the municipalities. To date, different drainage facilities have reached over 158.20 km in length of which only 62.89 km (39.75 %) are stone masonry drainage constructed following the road infrastructure where the remaining are earthen and cobblestone lined drains which were done without considering the actual flood capacity of the area. However, from field survey conducted it is evident that the management, operation and maintenance of the drainage facilities didn’t match the formidable efforts put towards increasing the physical facilities.

Due to the coincidence of the study and the rainy season it was possible to observe that the investment in rehabilitation and expansion project is playing a key role in channelling the generated runoff and significantly reducing the problems related to flooding in some parts of the city. However, field observation by the study also showed that the performance of some of the newly constructed drainage system is compromised by indiscriminate dumping of solid waste in the drainage system, siltation and/or sedimentation, connection of some household sewer system to drainage.

The combined of effect of the increase in the quantity of storm water requiring management due to substantial ongoing and future intended expansion as well as the unsanitary conditions requires continued efforts and investment to protect the public and environment from the ill effect of storm drainage problem. Uncontrolled storm water runoff has markedly damaged roads, drainage system, private and public property and different infrastructure developments, which has been established with a huge investment cost. Equally, the pollutant discharged with storm water considerably affects public health particularly those of poor people. The problem is highly aggravated in overcrowded urban settlements of 02 Kebele.

4.3.2. Major Outlet and Culverts

Catchment delineation clearly indicates that major outlets and culverts are those that are located in BC_2, BC_3 and BC_4. Most of the drainage of the city upstream the road surface crosses to downstream via these outlets. If we divide the city along the Bishoftu-Hora Lake in to east and west zones, the entire western zone drains to Cheleleka Lake. The western part of the city is drained by two major watersheds that crosses the road at Ziquala Junction and in front of Bus Station, and accordingly named Ziquala outlet and Meneharia outlet for this assessment. The corresponding watersheds are also named as Ziquala Watershed and Meneharia Watershed. The third intermediate crossing is in front of Adea Flour Factory; but this is a sub-catchment of Ziquala basin.

- **Meneharia Catchment**

The catchment is the single biggest watershed that drains through Meneharia outlet in to Cheleleka Lake. The total air distance of the catchment is about 6 km and covers a total area of 12.66 km^2.

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

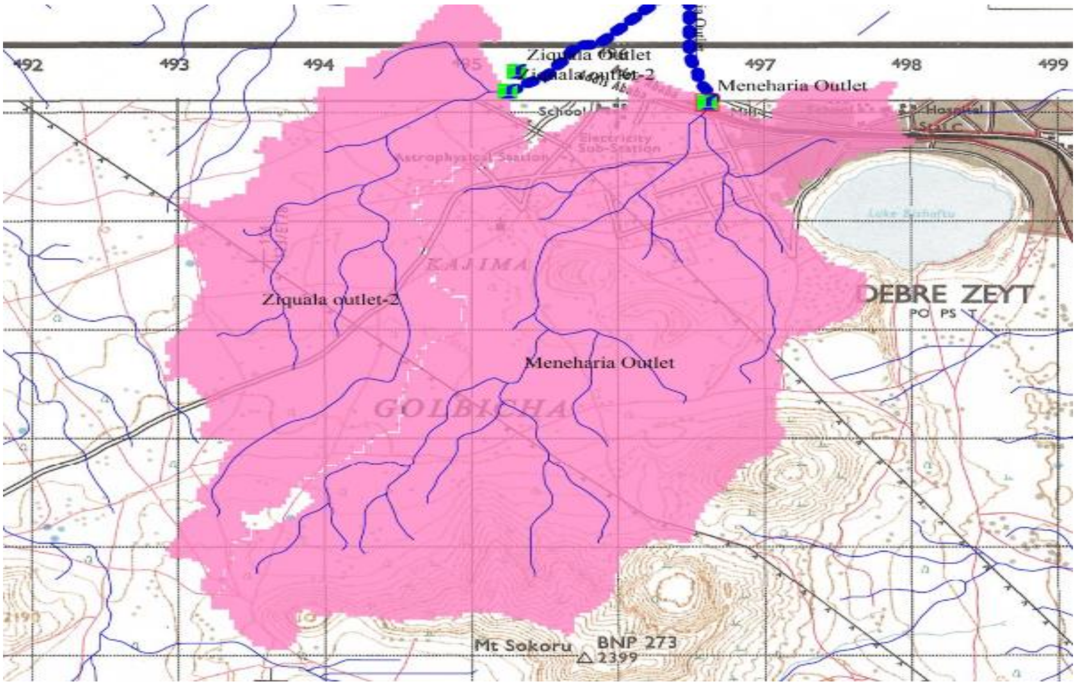

Figure 4. 12: Ziquala and Meneharia catchment delineations.

- **Ziquala Catchment Outlets**

This catchment is about half the Meneharia catchment. The total area of the watershed is about 6.33 km^2. The major portion of the basin is drained via box culvert at Ziquala junction towards the low lying Chelelek Lake. There is another outlet that drains sub-catchment of the basin in front of Adea Flour factory, and the two then join before passing through old railway culvert just in front of Adea Flour Factory.

Location of structures Drainage filled with solid waste Drainage with L turn

Figure 4. 13: Zikuala catchment drainage structures condition.

The storm flow immediately changes direction after final culvert outlet, figure 4.13 b, and this is not recommendable as it leads to siltation and accumulation of waste that prevent smooth and unobstructed flow. Bridges and culverts shall be constructed perpendicular to the road as much as possible to avoid siltation and pressures to be created by the water.

- **Wedecha Catchment**

This catchment covers the eastern part of the city between Bishoftu & Hora Lake, the basin is moderately sloped in the upland catchments before reaching small to flat slopes of the outlet wetlands of Wedecha. The drainage area is significant but, the contributing area from the city is referred as Rufael Sub-Catchment, and the area is about 4.77 km^2.

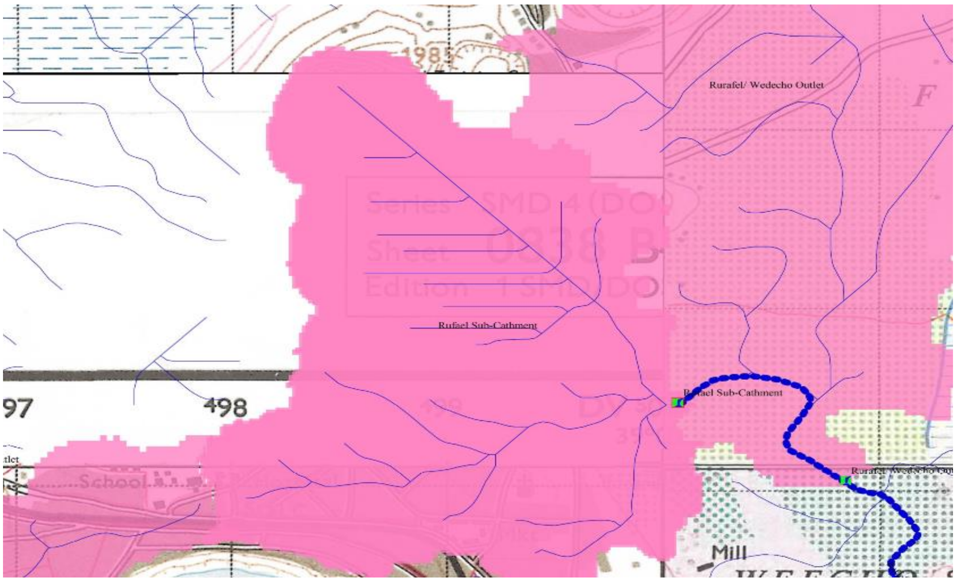

Figure 4. 14: Critical outlets condition of Wedecha catchment at downstream.

4.3.3. Drainage Geometry

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

In flat or slightly undulating terrain, a longitudinal slope to be used between 2 % and 5 % in the drains. With gradients less than 2 %, silting occurs easily while with gradients steeper than 5 % the ditches will easily erode (Magdi M. E. Zumrawi, 2014). In cases of roads under consideration it all forms silting with less than 2 % longitudinal bed slope except for Eyasu Meda cobblestone side drainage channel which is 3.5 %, where in this case as drainage bed is weak, some areas along the line are subjected to erosion.

Some of the defects pointed out were; when compared to the huge volume of flood, the existing drainage structures are under sized in some kebeles. Mostly the drainage lines are shallow in depth and narrow in diameters resulting in flood overflowing to the unwanted directions instead of its intended destination. The workmanship is also questionable as some drainages crumble in less than two years. It was reported that the size of the receptor lines is smaller than the size of the collector pipes in many places creating overflow into roads and houses. In some areas, the drainages are short in length with no connection to any receiving line downwards, and simply release storm water on the low-lying infrastructure and communities often causing severe flooding. Drainage canals found in flat parts of the city lack adequate slope required to convey to downstream areas. As a result, stagnant water stays in the canals for more than a week pausing health and environmental risks to the population of the localities.

From field assessment made Longitudinal drainage structures geometry and extent of damage are identified.

Table 4. 4: Drainage geometry and degree of damage.

S/N	Drainage Shape	Drainage Geometry			Level/Extent of Damage (m)			
		Width	Depth	Bed Slope	High	Moderate	Low	Total
1	Asphalt Road							
1.1	Entry - Innova	-	-	-	-	-	-	0
1.2	Innova - Getshet	-	-	-	-	-	-	0
1.3	Getishet - Zikuala	0.5	0.8	1.7	1,046	-	-	1,046
1.4	Zikuala - Bus Station	0.5	0.8	1.16	1,400	-	-	1,400

S/N	Drainage Shape	Drainage Geometry			Level/Extent of Damage (m)			
		Width	Depth	Bed Slope	High	Moderate	Low	Total
1.5	Bus Station - Circle	0.5	0.8	1.6	-	-	1,600	1,600
1.6	Circle to Air Force	1.3	0.7	1.8	-	1,500		1,500
1.7	Zikuala Joint	1.0	0.8	1.5	-	-	1,300	1,300
2	Cobble Road							
2.1	Innova	0.7	0.8	2.8	1,488	-	-	1,488
2..2	Getshet	0.9	0.7	1.8	1,100	-	-	1,100
2.3	Eyasu Meda	1.1	1.6	3.5	-	850	-	850
2.4	Bus Station	1.0	0.7	Var	-	800	-	800
3	Gravel Road	-	-	-	-	-	-	-
Total					5,034	3,150	2,900	11,084

There is no drainage on Asphalt Road passing Innova and Getshet but on cobbles feeding to this area and it is confirmed that the drainage on this arterial road releases flood on the main road as there is no drainage line receiving these drains.

As shown in the Figure 4.15 the drainage lines which are highly damaged constitutes about 45.42 % of the totally assessed area, while 28.42 % are moderately damaged and only 26.16 % have low damage. This indicates that most of the drainages are functioning under design capacity as most are damaged and filled with solid wastes.

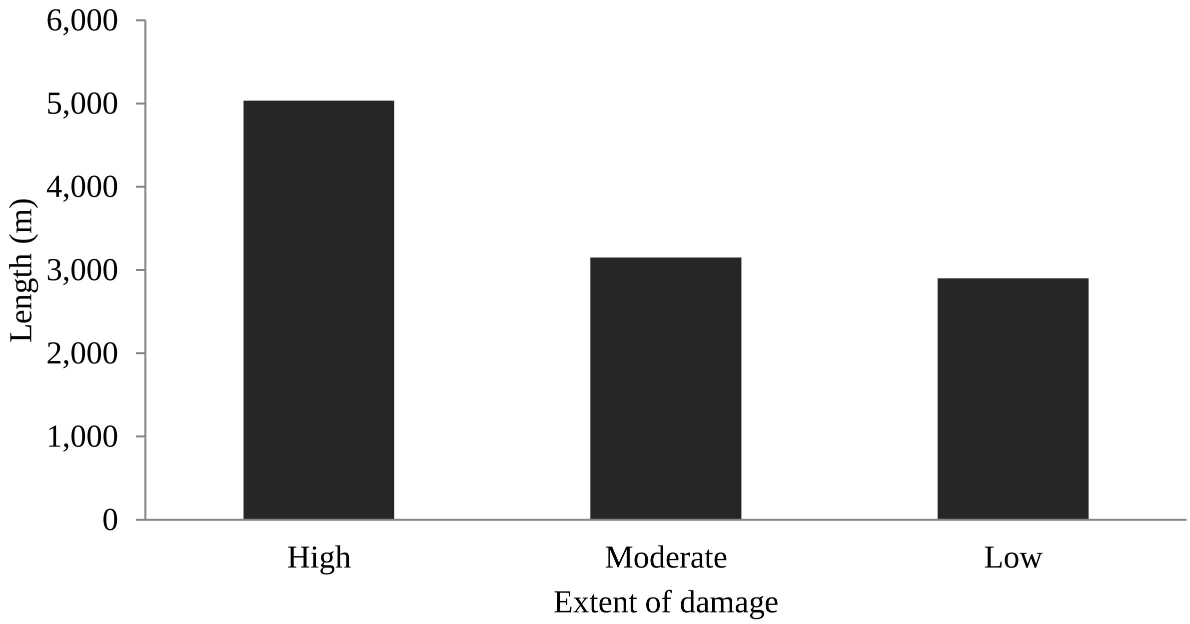

Figure 4. 15: Total level of damage for ditch.

4.3.4. Evaluation of Drainage Capacity on the Main Road

Hydrological result of the peak discharge was computed by SCS method “using equation 2.6 to 2.14” and after which drainage section capacity is evaluated based on the city master plan for different sections. Detailed hydraulic analysis and hydraulic capacity design computations are calculated and annexed in this study on annex 8 & 9.

Getshet to Ziquala; the peak discharge passing this area “by using equation 2.10” was estimated to be 4.1 m^3/sec, and the area needed for this discharge is to be 1.7 m^2, whereas the existing drainage channel dimension of 0.5x0.8 m is inadequate. Therefore, it is recommended to upgrade to a width of 1.7 m and a depth of 1.2 m including freeboard “by using equation 2.14”.

Ziquala to Bus Station; the peak discharge passing this area “by using equation 2.10” was estimated to be 1.2 m^3/s, and the area needed for this discharge is 0.84 m^2, whereas the existing drainage channel dimension of 0.5x0.8 m is inadequate. Therefore, it is recommended to upgrade to a width of 1.2 m and a depth of 0.9 m including freeboard “by using equation 2.14”.

Bus Station to Circle; the peak discharge passing this area “by using equation 2.10” was estimated to be 1.5 m^3/sec, and the area needed for this discharge is 0.72 m^2, whereas the existing drainage channel dimension of 0.5x0.8 m is inadequate. Therefore, it is recommended to upgrade to a width of 1.2 m and a depth of 0.8 m including freeboard “by using equation 2.14”. But as this section have both side drainage it can accommodate the peak discharge indicated and no modification for this section.

Based on the capacity design checked above, it can be concluded that the expected flood and main road side drains capacity are not compatible and needs improvement for above sections except for drainage line from Bust station to circle with both side drainage.

4.3.5. Drainage Maintenance

The participants of the FGD were encouraged to express their opinions regarding the performance of the Municipality regarding flood control and drainage management activities. The overall evaluation of the discussants as well as the affected households was not very favourable. Deep grievances and accusations of ineffectual interventions were raised that characterized the hitherto municipal efforts as inadequate and not commensurate with the magnitude of the flooding problem in the city.

Accumulated plastic waste concealed by slab cover Damaged ditch

Figure 4. 16: Conditions of drainage structures.

As indicated in Figure 4.16 the solid waste including plastic bag accumulation in a storm channel in front of Bus station between highway and railway culverts, the plastic bags are concealed from sight by application of the slab cover.

It is also evident that some of the drainage constructions are damaged and the city didn’t manage to maintain them for years; this is also a cause for the occurrence of flooding on road surface as drainage channels were closed by the demolished structures.

Evidences from figure 4.16 shows the drainage lines at the critical part of the flow are not functioning at their full capacity and filled with solid wastes, (b) side masonries are broken into the flow lines and yet decreasing design capacity, finally creating flood to the area.

The major shortcomings identified from KII and FGD interviews were:

- Slow reaction to complaints, recommendations and hazard warnings coming from residents in flood prone areas.
- Poor design of drainage lines: in many areas the existing drainage lines are severely undersized, lacking in slope and easily filled with silt.
- Low quality of workmanship: instances of ditch collapse and cobblestones washed by flood are common. Some residents blamed the increasing trend of beginning construction activities in winter as one of the reasons for poor quality of the structures.
- Little community participation in planning and execution of drainage canals.

- Unsatisfactory drainage clearing and maintenance: Canals and culverts filled or blocked by different types of solid materials like silt, stone, cobblestone and other objects are not cleaned on time, while some drainages if not totally forgotten they are used to be cleaned after rainy season. Moreover, maintenance of roads and drainage structures is not receiving adequate attention.

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

4.3.6. Drainage Structures

The field investigation also confirmed the desk study and feedbacks from KII and FGD that major drainage outlets of the city catchment cross the main highway at six points and the road construction provided cross drainage outlets in these six points, and the physical location of these outlets totally overlaps with drainage lines generated from DEM.

Table 4. 5: Identification of cross drainage type, location and number.

S/N	Cross-drainage type	Sloppy area	Sag point	Flat	Junction point	Total
1	Bridge	-	-	-	-	-
2	Box culvert	-	1	3	1	5
3	Pipe culvert	-	-	1	-	1
4	Curb Stones	-	-	-	-	-
5	Other	-	-	-	-	-
	Total	-	1	4	1	6

Except one Bus Station area Box Culvert (BC_4) which is found in sag point and Ziquala Box Culvert (BC_2) which is found in junction point the remaining four culvers (BC_1, BC_3, BC_5 and CC_1) are located in flat areas and also proper areas as per the road profile and drainage catchment study.

Table 4. 6: Existing inlet and outlet drainage structure extent of damage.

S/N	Cross-drainage type	Geometry			Level/Extent of damage (m)			
		Width (m)	Depth (m)	Slope (%)	High	Moderate	Low	Total
1	Box culvert (Hagemaf)	2.0	1.0	0.50			20	20
2	Box Culverts[1] (Ziquala)	1.60	0.60	2.30			30	30
3	Box Culverts (Adea)	1.50	2.00	4.50		25		25
4	Box culvert (B/station)	1.50	1.30	0.2			25	25
5	Box Culverts			3.50			25	25
6	Twin circular culvert	0.6(r)	0.6 (r)	4.0			25	25
	Total					25	125	150

Evidences from KII and FGD as well as field survey showed that Bus station and Ziquala culverts which are undersized are the most critical. The hydraulic capacities of the three major culverts at the main road crossing are evaluated based on the peak discharge determined as:

- Road crossing of Menaheria (Bus Station) catchment (BC_4)
- Road crossing of Ziquala catchment (BC_2)
- Culvert in front of Adea Floor Factory catchment (BC_3)
    - **Road crossing of Bus Station catchment (BC_4)**

BC_4: is the location of cross drainage structure in front of bus station, the box culvert is located on main highway. The pictures taken during field investigation are used to reflect the actual reality about width and flow depth of the culverts. BC_4 is the outlet point for significant catchment size smaller opening and flat slope. The major and critical drainage problem in the city currently is attributed to the drainage condition along the downstream of this culvert. The section is characterized by several existing culverts. Some of them are inadequate to accommodate the flow volume and some of them are fixed at an invert that disturbed the section hydraulics. The drainage basin with outlet at BC_4 is characterized by upland catchment of gentle to steep slope and low-lying downstream areas with very minimum slope.

The 1 in 10-year peak discharge passing the section was estimated by SCS method as 22.6 m^3/s. A minimum of about 8.4 m^2 opening area is required to safely pass this discharge, whereas the existing culvert with a dimension of 1.5 m by 1.3 m is inadequate. Therefore, this culvert is recommended to upgrade to width of 4m and height of 2.5 m including freeboard and allowance for debris passage or equivalent ERA standard double (2 cell) box culvert of 3 m width by 2 m height.

Location of drainage structures Blocked to prevent backflow

Drainage line in front of bus station seriously blocked with silt-up of mud and waste

Outlet point of highway culvert Inlet point to culvert Wall in front of outlet

Figure 4. 17: Bus station culvert inlet and outlet configuration, BC_4.

As shown in the Figure 4.17 Section (A) indicates that the inlet configuration to highway culvert leads to siltation and flow obstruction. The slab cover exacerbated the problem and difficulty in cleaning as a result there is a tendency of water backflow. Section (B) shows the outlet configuration is also similar; moreover, the minimum slope leading to railway culvert and absence of cleaning the segment leads to stagnation and flow obstruction all the way to point-A-in front of the mosque. If point B was not closed the flood in the Channel A will flow to Channel B and will make detention of water on the road, as there is no outlet for drainage channel B on the other side. The outlet and inlet at section C is totally mal-functioned due to accumulation of solid waste. The situation is very critical due to the inadequate size of the opening coupled with minimal slope and significant flow volume amongst all the outlet points. Section D is the problem ring for the drainage problem the city is experiencing especially in some parts of 02 kebele. As the slopes of the drainage line are on flat structure with less than 0.5 % and with inadequate culvert size and blockage of the solid waste and the wall in front of the outlet, the flow is experiencing back flow to the channel which results in flooding over the road and the residents around. There is also critical L turn to the flow which exaggerates the rate of commutations of wastes and the filling of the outlets of the culvert.

- **Road crossing of Ziquala catchment (BC_2)**

BC_2: is the second major outlet for all the upstream drainages for the north-western and western basins of the town. The junction is an intersection point for roads from five directions. In general, the inlet and outlet conditions of all the roads at this junction are deteriorated, and some of the inlets and outlets are nearly closed by dumping of all sort of solid wastes.

The 1 in 10-year peak discharge passing the section was estimated by SCS method as 13 m^3/s. The clear span opening of the existing culvert width and depth (depth reduced by sedimentation) are 1.6 and 0.6 m respectively; where as to safely pass a discharge of 13 m^3/s need a minimum opening area of about 5 m^2. Therefore, this culvert needs shall be replaced by ERA standard of width and height 3 and 2 m respectively.

Location of drainage structures Inlet of pipe culvert blocked with solid waste.

Culvert filled with solid waste and grasses

Figure 4. 18: Ziquala culvert inlet and outlet configuration, BC_2.

As shown in the Figure 4.18 the main cross drainage inlet at A and outlet at B are full of silt and debris that nearly the effective flow depth is consumed and the freeboard is the flow depth. The Outlet at C is nearly clogged with debris, vegetation and grass, additionally the Channel geometry is not smooth. On top of that the channel between 1 & 2 of Section C were filled with grass and debris of solid waste including mud and siltation. The section also contains water supply line as shown in channel 3 of section C and, this is not only compromising the quality of the water but also placed in such a way to obstruct the flow of drainage due to eating up of flow depth via clogging of waste and silting up of mud.

- **Culvert in front of Adea Floor Factory catchment (BC_3)**

BC_3: this Junction has the largest cross drainage structure on the asphalt road. This serves as an outlet for a very small sub basin in the upland of the road. As shown in the Figure 4.19 all the dry and wet scenarios are displayed and tried to be compared where the problem was. The surface and other drainage coming from the high school area flows over road surface before entering the inlet as under sized inlets not accommodating the flows from the tributary drainage channels. In addition to this culvert, the bed of the culvert is scored to a minimum of 30 cm at the outlets of section B, which have led to failure of the structure because of high speed of water flow in this culvert.

The culvert at in front of Adea Floor Factory which has a much better capacity of 1.5 m width and 2 m depth can be retained, but needs clearing of the debris in the culvert. This culvert additionally needs modification of inlets as the inlet has less capacity to accommodate the upstream catchment runoff. This area is usually affected by flood rushing from the upper catchment area. Due to the sloping nature of the catchment and insufficient drainage approach inlet structure constructed along the road as a result the asphalt roadway is usually flooded. Proper priority approach inlet structure channel will be recommended to safely manage and transfer the flood to appropriate culvert.

Location of drainage structures

Inlet during rain

Inlet during dry Outlet during rain Outlet during dry

Figure 4. 19: Ziquala culvert inlet and outlet configuration, BC_2.

4.4. Evaluation of Road and Drainage Integrations

Integration of road network and drainage system is mandatory so that the road and drainage infrastructures functions monolithically as to dispose flood. Drainage is an integral component of road infrastructure and therefore drainage design and construction should not be undertaken in isolation from the geometric design of the road. In the design of the road-watercourse crossing, it is important to consider the skew angle between the road alignment and drainage structure. Keeping the skew angle as small as possible (or eliminating it altogether) reduces costs and construction difficulty and is therefore the most desirable option. (ERA Drainage Design Manual, 2013)

As per KII and FGD integration of road and drainage is one of the basic parameters in affecting the road flooding in addition to the capacities of the drainage structures. The city drainage and flooding problem can be solved with proper storm water drainage design which is integrated to the existing and planned roads and other built-up structures such as commercial and residential houses.

Table 4. 7: Existing coverage and integration of road and drainage.

S/N	Road type	Length (km)				Total (km)	Coverage (km)
		One side ditch	Both side ditch	No ditch	Curb stone		
1	**Asphalt Road**	**6.592**	**1.8**	**2.954**	**6.846**	**9.8**	**67.27%**
1.1	Entry - Innova	0		1.4		1.4	0.00%
1.2	Innova - Getshet	0		0.8		0.8	0.00%
1.3	Getishet - Zikuala	1.046		0.754	1.046	1.8	58.11%

S/N	Road type	Length (km)				Total (km)	Coverage (km)
		One side ditch	Both side ditch	No ditch	Curb stone		
1.4	Zikuala - Bus Station	1.146			1.146	1.4	81.86%
1.5	Bus Station - Circle	1.6	1.6		1.6	1.6	100.00%
1.6	Circle to Air Force	1.5			1.5	1.5	100.00%
1.7	Zikuala Joint	1.3	1.3		1.3	1.3	100.00%
2	**Cobblestone**	**4.238**	**3.438**	**0.5**		**4.738**	**89.45%**
2.1	Innova	1.488	1.488			1.488	100.00%
2.2	Getshet	1.1	1.1			1.1	100.00%
2.3	Eyasu Meda	0.85	0.85			0.85	100.00%
2.4	Bust Station	0.8		0.5		1.3	61.54%
3	**Gravel**	**0**		**1.25**		**1.25**	**0.00%**
	Total	**11.084**	**6.338**	**4.704**	**6.846**	**15.788**	**70.21%**

From table 4.7 it can be clearly seen that integration of asphalt road and drainage is found to be only 67.27 %, where it is 89.45 % for cobble stone road, and for section of the main road from Entry to Innova and Innova to Getshet as well as for the gravel road, there is no side drains provided which exhibits no integration. While the integration configuration is seen to be only 58.11 % for Getshet to Zikuala Asphalt and 61.54 % for Bus station cobblestone. In areas with absence of side drainages and poor integration of road and drainage infrastructure there is surface flooding as well as surface failure.

The following pictures taken in recent trip (24th August 2021) to the city are clear manifestation of the storm drainage problem along the main asphalt road.

Location of Joints Water detention at joint Water film spread along profile

Figure 4. 20: Main Road with absence of side drains around Hulegeb and Getshet

Figure (a): Water detention on joint of arterial and main road as there is no side drains provided on the main road to accommodate surface runoff from arterial road.

Figure (b): Water film spreads along the longitudinal profile of the road as there is no proper crow slopes and no side drainages provided.

4.4.1. Slab Cover

The city Administration has constructed or covered major open masonry ditches with pre cast and cast in-situ concrete slab covers. The construction of these structures had resulted in improvements to public safety and urban aesthetics. However, there are clear and evident signs of lack of planning and due consideration for post construction management.
The major issues that were raised by the community and confirmed during field survey are;

- Slab covers are placed without clear flow depth and freeboard in some areas.
- Slab covers prevented storm entry to existing channels.
- Cleaning of the masonry channels becoming difficult.
- The sizing of the slab cover does not allow for easy operation.
- It prevented visual inspection of accumulation of waste in channels.

SC_1: is located in area north of Elfora around Military Camp, Section a: The side drain along the asphalt road is blocked with debris and the surface drain flows and stagnation is visible on the pre-cast slabs at junction to arterial road. Section b: The side drain along the asphalt road is blocked with debris, vegetation & grass. And the storm water flow overland. Section c: The overland flow on the pedestrian re-joins the road surface drain downstream again, but further blocked and the overland flow continues downstream next junction pictures which is around 500 m far.

Location of structures

The size of tributary drain is higher than the surface drain

Blocked Side Drain at road junction with arterial roads

overland flow

Figure 4. 21: Main Road slab culvert condition at Military camp.

SC_2: is located South of Elfora around Pyramid Hotel and the road side drain upstream flows along the pedestrian and blocked side drain flows to the road surface at inlet of slab culvert at junction (SC_2). Both the slab culvert connecting to the junction road and outlet of slab culvert is blocked. Effort by the community to confine the storm water from over flowing road by placing stone barricade was not successful, as curb stone will protect water from entry to the drainage channels.

Location of the drains

The upstream side drain and connecting road at junction flowing across the road.

Figure 4. 22: Main Road slab culvert and curb stone condition at Elfora.

4.4.2. Curb Stone

Road and drainage interconnection problems (Roads are built considering only one straight line and didn't take any additional effort in connecting to the road networks built to join the road, no Ramp is considered)

Even if there are curb stone for 6.566 km (67%) of the main road, 74.5% the curb stones are either damaged or the spacing provided for inlets are filled by dusts to the extent of growing grasses as shown in the Figure 4.23 (a) and will not let in the surface runoff to side drainage channels.

In some parts of the road the curb stones are totally damaged and is not giving proper service it was constructed for, except the newly built Ziquala Joint Road of 1.3 km.

Poor condition of curb stone Slab cover not receiving surface runoff

Figure 4. 23: Drainage and slab cover don't receive surface runoff.

Figure 4.23 (b) also clearly indicates the covered drainage channel is already full of solid waste and even if there were no blockage of surface flow, there is no place for the runoff to flow in the drainages, here it will let the flow to flooding of the surface as well as the surrounding area.

 **Drainage Chamfer not receiving Surface drains and ditch filled with sediment**	 **Flood flowing on the main road (no side drains)**	 **Road started eroding by surface runoff**
 **Improper connection of both drainage and road**	 **Defromed Cobblestone road by Flood detention of the surface**	 **Flood prone area with no side drainage**

Table 4. 8: Distress and flooding effects due to poor integration of road and drainage network.

CHAPTER FIVE

CONCLUSIONS AND RECOMENDATIONS

After a thorough analysis and evaluation of KII and FGD with the existing situational field survey in line with design reviews, the following conclusion and recommendations are drawn:

5.1. Conclusions

Road surface drainage of the study area was inadequate due insufficient provision of; road cross sectional slope, drainage structures, proper maintenance and lack of proper integration of road and drainage networks which resulted damages to road pavement and created flooding problems in the area. Moreover, through field survey, the locations visited have maintenance problems, indicating that in its current state, the road and drainage structures are not properly working according to its original design and has a high level of exposure to flooding.

There areas like in front of Adea floor factory and Behind Bus station which are prone to flooding problem due to absence of proper interceptor channel. The existing drainage structure constructed on the other side of the road will only collect storm water flowing from the upstream side for culvert in front of Adea Floor Factory.

There are areas usually affected by flood rushing from the upper catchment area. Due to the sloping nature of the catchment and insufficient drainage channels constructed along the road as a result the asphalt roadway is usually flooded. Proper priority channel will be recommended to safely manage and transfer the flood to appropriate location.

- Most of the sections of the road have no proper cross sectional and longitudinal slopes as per the standard and are below the minimum requirements with maximum and minimum of 1.5 % and 0.2 % cross falls respectively for the main asphalt.
- The design of the drainage system is based on the available funding, so efforts has been paid to make the system safe and economic with the provision of rectangular channels and culverts where needed. Existing main road drainage channels (Getshet to Ziquala, Ziquala to Bus station and Bus station to Circle) and structures (BC_2, BC_4 and CC_1) are inadequately designed. The existing culvert located along the main Asphalt Road in front of the Air Force (CC1) is a twin 60 mm concrete pipes. The size of the culvert is inadequate and is blocked

with sediment. As a result of this the asphalt road in front of the Air Force is flooded with runoff from the upland area below Bishoftu Lake.

- Existing drainage channels and structures are highly misused and mismanaged mainly due to dumping of solid waste by residents, necessary cleaning will keep the structures efficient. Problems due to scouring effects cause failure of structures; the provision of protection measure has to be made so that the effect will be controlled for culverts like in front of Adea Floor Factory. Outfall structure at the culvert outlet of main road crossings has to be considered.
- Poor integration of road network and drainage systems is the basic for the occurrence of the city flooding especially to areas of Innova, Getshet, Bus station, Military camp and Elfora which are highly prone to flood.
- Lacking a well-conceived drainage master plan which was integrated with city development and road network was a major shortcoming. It is well observed that the existing drainage design and construction are under optimum because of in adequate size of culvert and channels, slope, and in some cases in appropriate locations of slab covers.

The question of whose responsibility the mitigation of flood hazard was assessed to determine the readiness of the community to involve in construction, rehabilitation, protection and management of the drainage lines. The results of the assessment show that majority of the residents strongly believe that communities should play a wider role in the management of the drainage canals. Many people don't expect the flooding problem of the city to be solved by governments' efforts only and think that contribution of residents can be crucial for sustainable improvement. Stopping the use of drainage canals for garbage disposal, take responsibility for clearing drainage ditches found in their vicinities as well as participating in the planning and design of the city's drainage system were among the core areas of community participation as indicated by the KII and FGD. Many people also believe that the Kebele Administrations have the responsibility to mobilize the residents to do community work.

5.2. Recommendations

There is no option except providing enough space for storm runoff to travel to its destination and conveyance channels and culverts should be adequately designed and properly constructed. Diverting storm from one place to another will not be a solution unless integrated from upstream to downstream up to disposal site.

- Construction of road networks shall be done as per the design standards keeping the entire cross-sectional elements, shoulder, cross sectional and longitudinal slopes in to consideration.
- Proper routine maintenance of road infrastructure is mandatory to avoid traffic jam and reduction of accidents specially during flooding.
- Drainage channels and structures which are under functioning shall be replaced by proper and sufficient drainage structures. The implementation of the construction of the drainage channels and structures designed as per the city structural plan has to be considered as soon as possible and reconstruction of defective existing main road and drainage channels like (Getshet to Ziquala, Ziquala to Bus station and Bus station to Circle) and drainage structures like (BC_2, BC_4 and CC_1) are mandatory.
- The size of Meneharia, Ziqula and Air Force culverts on the main asphalt road is found inadequate to deliver the incoming flow from the upper catchment area. These culverts shall be resized to accommodate the flow.
- Dumping of solid waste and debris in the drainage ditch must be avoided by the community; there should be public awareness campaign. Using the corresponding return period, the channels require major maintenance such as providing adequate slope in flatter areas drop structures at the steep sections and each channel should be maintained and cleaned before rainy season begins and should be supervised at least twice during the duration of the rainy seasons.
- Integration of the road network and drainage systems shall be kept in to consideration as per the structural plan of the city to avoid flooding in the flood prone areas. Areas with poor integration of road and drainage infrastructure; Innova, Getshet, Military camp, Elfora and Bust station shall be redesigned and rebuilt to make proper integration so that the surface flows will easily drain to side drainages.

Based on analysis of the existing socioeconomic impacts of flooding in the city as well as by analysing the opinions and expectations of the KII and FGD, this study recommends the implementation of the city-wide structural plan as well as urban flood drainage management database system has to be developed and implemented in all sections of the road and drainage. It is also advisable to properly implement road network and drainage system integration recommended by this thesis paper to solve the harmful impacts of flooding in city.

5.3. Future Study

The recommendations for future study include the limitations of this study, larger geographic areas shall be covered in addition to the flood prone areas as the effects of flooding are interrelated to one another. It is advisable to conduct city wide water delineation study so that the capacity requirements of each section of the road side drainage will be determined for the flood capacity requirements.

It is also good to have study related to assessment of road distress type and condition because of flooding in the city. The study will also finally recommend the study related to impacts of flooding on road infrastructure because of poor integration of road and drainage networks for the whole section of the city.

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APPENDIXES

Annex 1: Table of Main Road Profile reading

It No	Distance (m)	Elevation (m)	It No	Distance (m)	Elevation (m)	It No	Distance (m)	Elevation (m)
1	0	1907	31	3000	1918	61	6000	1905
2	100	1906	32	3100	1918	62	6100	1906
3	200	1905	33	3200	1918	63	6200	1907
4	300	1905	34	3300	1917	64	6300	1908
5	400	1905	35	3400	1915	65	6400	1910
6	500	1905	36	3500	1913	66	6500	1914
7	600	1904	37	3600	1911	68	6600	1916
8	700	1904	38	3700	1910	68	6700	1919
9	800	1905	39	3800	1909	69	6800	1920
10	900	1905	40	3900	1908	70	6900	1920
11	1000	1905	41	4000	1907	71	7000	1921
12	1100	1906	42	4100	1907	72	7100	1919
13	1200	1907	43	4200	1906	73	7200	1919
14	1300	1908	44	4300	1906	74	7300	1918
15	1400	1909	45	4400	1905	75	7400	1918
16	1500	1910	46	4500	1904	76	7500	1914
17	1600	1912	47	4600	1904	77	7600	1913
18	1700	1912	48	4700	1904	78	7700	1911
19	1800	1914	49	4800	1905	79	7800	1909
20	1900	1915	50	4900	1905	80	7900	1906
21	2000	1915	51	5000	1903	81	8000	1903
22	2100	1916	52	5100	1900	82	8100	1900
23	2200	1918	53	5200	1897	83	8200	1897
24	2300	1917	54	5300	1896	84	8300	1895
25	2400	1916	55	5400	1895	85	8400	1892
26	2500	1916	56	5500	1896	86	8500	1890

It No	Distance (m)	Elevation (m)	It No	Distance (m)	Elevation (m)	It No	Distance (m)	Elevation (m)
27	2600	1916	57	5600	1898			
28	2700	1918	58	5700	1900			
29	2800	1918	59	5800	1901			
30	2900	1918	60	5900	1903			

Annex 2: Table of Ziquala Asphalt Road Profile reading

It No	Distance (m)	Elevation (m)	It No	Distance (m)	Elevation (m)
1	0	1907	8	700	1920
2	100	1909	9	800	1923
3	200	1910	10	900	1928
4	300	1911	11	1000	1931
5	400	1912	12	1100	1932
6	500	1915	13	1200	1930
7	600	1918	14	1300	1925

Annex 3: Table of Innova Cobblestone Road Profile reading

It No	Distance (m)	Elevation (m)	It No	Distance (m)	Elevation (m)
1	0	1909	9	800	1924
2	100	1910	10	900	1926
3	200	1911	11	1000	1929
4	300	1912	12	1100	1931
5	400	1914	13	1200	1934
6	500	1917	14	1300	1937
7	600	1919	15	1400	1940
8	700	1922	16	1488	1939

Annex 4: Table of Getshet Cobblestone Road Profile reading

It No	Distance (m)	Elevation (m)	It No	Distance (m)	Elevation (m)
1	0	1918	7	600	1927
2	100	1919	8	700	1929

3	200	1920	9	800	1931
4	300	1921	10	900	1933
5	400	1923	11	1000	1935
6	500	1925	12	1100	1938

Annex 5: Table of Eyasu Meda Cobblestone Road Profile reading

It No	Distance (m)	Elevation (m)	It No	Distance (m)	Elevation (m)
1	0	1905	6	500	1916
2	100	1908	7	600	1915
3	200	1911	8	700	1915
4	300	1912	9	800	1915
5	400	1914	10	850	1916

Annex 6: Table of Bus Station Cobblestone Road Profile reading

It No	Distance (m)	Elevation (m)	It No	Distance (m)	Elevation (m)
1	0	1896	8	700	1894
2	100	1899	9	800	1898
3	200	1895	10	900	1908
4	300	1894	11	1000	1913
5	400	1894	12	1100	1914
6	500	1894	13	1200	1918
7	600	1895	14	1300	1920

Annex 7: Table of Gravel Road Profile reading

It No	Distance (m)	Elevation (m)	It No	Distance (m)	Elevation (m)
1	0	1892	8	700	1892
2	100	1894	9	800	1893
3	200	1895	10	900	1894
4	300	1893	11	1000	1896
5	400	1891	12	1100	1899
6	500	1891	13	1200	1903
7	600	1892	14	1250	1905

Annex 8: Maximum Daily (24-hr) Rainfall

Year	I: X		No. of years: log X	Annual Maximum Daily Rainfall	
2001	34.6		1.53908		
2002	32.4		1.51055		
2003	62		1.79239		
2004	57		1.75587		
2005	70		1.8451		
2006	78		1.89209		
2007	47		1.6721		
2008	39.8		1.59988		
2009	44.7		1.65031		
2010	45.6		1.65896		
2011	46.2		1.66464		
2012	37		1.5682		
2013	74.4		1.87157		
2014	38.1		1.58092		
2015	45.9		1.66181		
2016	31.5		1.49831		
2017	44.6		1.64933		
2018	61		1.78533		
2019	40.3		1.60531		
2020	51		1.70757		
Avg	49.1		1.67547		
Std	13.28		0.11643		
Skew			0.39218		
	2 Years	5 years	10 years	25 years	50 years
log-Pearson III		58.9	67.4	78.4	86.8
Gumbel	46.9	58.6	66.3	76.2	83.4

Extreme value type I or Gumbel and Log Pearson type III distributions are used for rainfall frequency analysis. The distribution which fits better to the data series is finally used to determine the magnitudes of rainfall at various recurrence intervals.

Extreme Value Type I or Gumbel distribution is a frequency analysis procedure usually used in flood analysis; the equation is given by:

$$X_T = X_{avg} + KS$$

In this case, X_T = The T year return period rainfall

X_{avg} = Average annual maximum rainfall

K = Frequency factor

S = Standard deviation

$K = 0.7797y - 0.45$

where, y is a reduced variate and is given by:

$$y = -\ln(-\ln(1 - 1/T)$$

Where, T is the return period

Log-Pearson Type III distribution is a statistical method usually used for flood frequency analysis. It has a form of:

$$LogQ = Q_L + KS_L$$

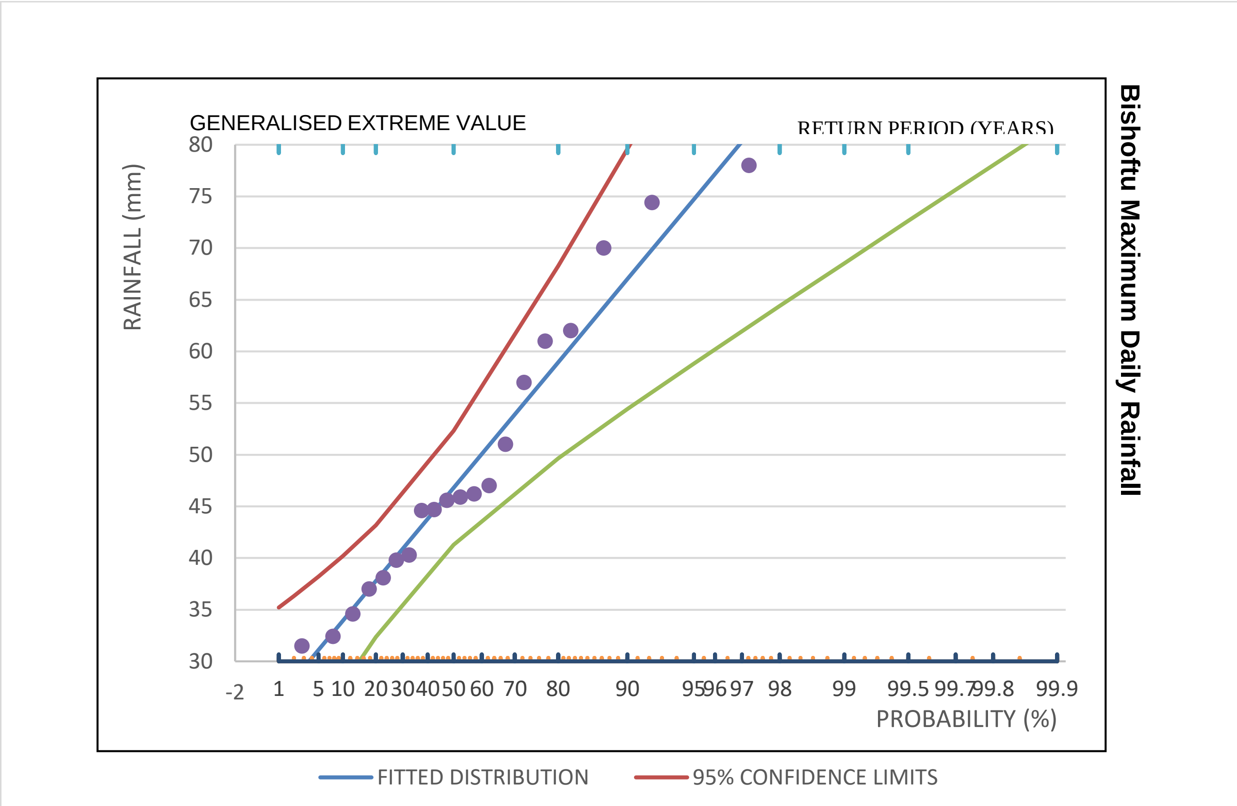
where, $LogQ$ = The logarithm of the peak rainfall for a particular return period.

Q_L = The mean of the logarithms of peak annual rainfall.

K = Frequency factor for particular return period and coefficient of skewness, it is available in table form in publications.

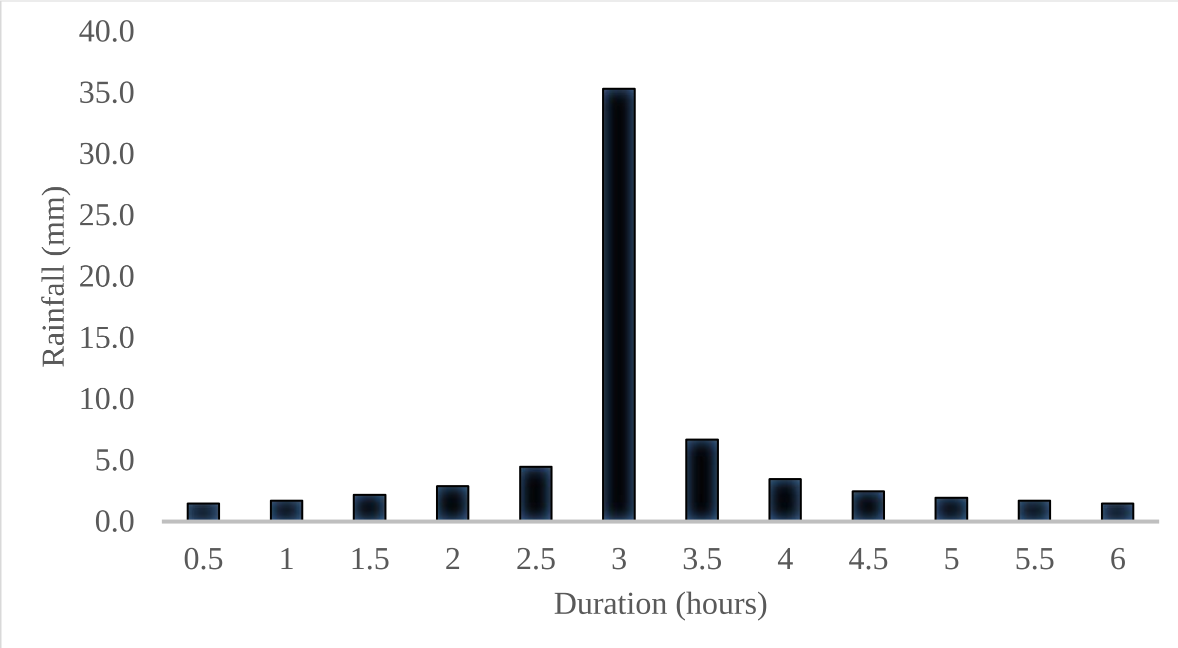
S_L = Standard deviation of the logarithms of the peak annual rainfalls.

Annex 9: Maximum Daily Rainfall fitted to General Extreme Value Distribution



Annex 10: 1 in 10 years' maximum daily rainfall distributed in 6-hrs duration

The recorded daily maximum (24-hr) rainfall is distributed according to SCS-II storm profile in a maximum duration of 6 hours divided in 30 minutes. This type of profile produces maximum storm at the center; nature is not as uniformly distributed but for design purpose it suits the requirement by producing maximum rainfall and the resulting storm for rainfall runoff modelling.



Annex 11: IDF Curve derived for Bishoftu City

The 1-hr storm duration as obtained from SCS-II storm profile is further sub divided into small durations of 5,10,15 minutes, etc. to derive the IDF curve which will be used to determine peak discharges where channels and culverts are need to be designed. The 1-hr data will be fitted to the following equation:

$$I = \frac{a}{(b+T)}n$$

where I = rainfall intensity (mm/hr)

T = duration (hour)

a, b and n are locality constants

A b-value of 1/3, and n value of 0.9 widely used in East Africa and neighboring regions was adopted.

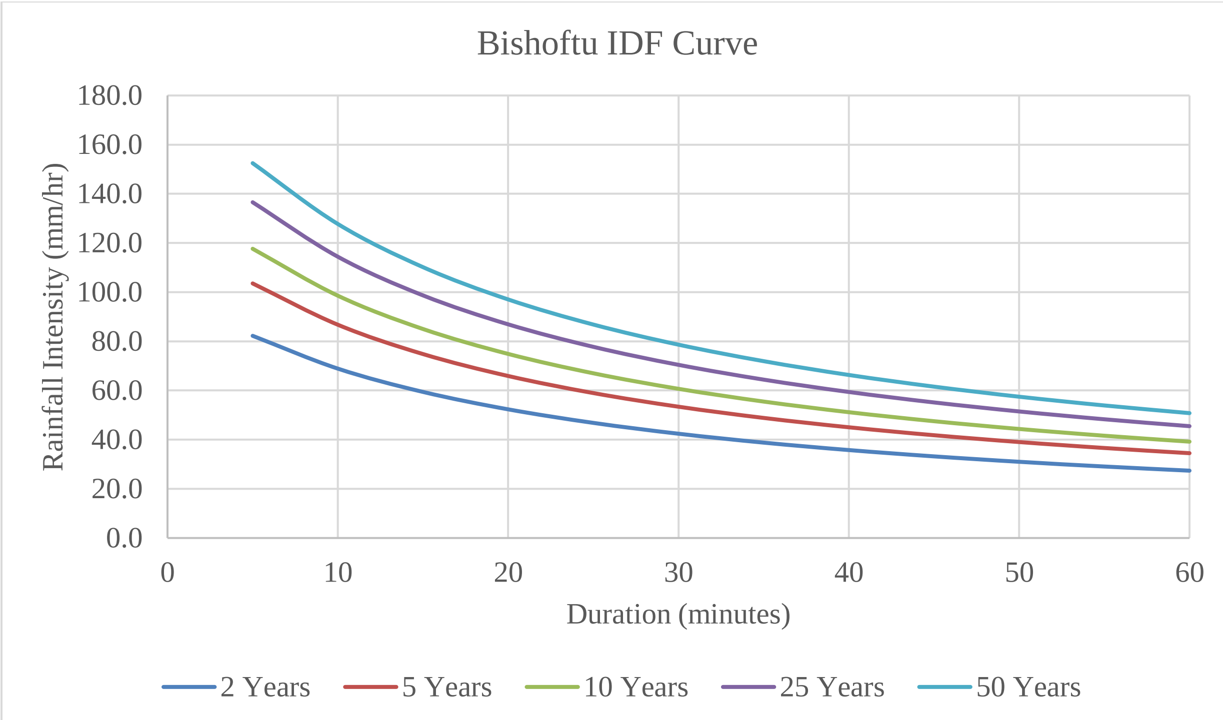


Table of Hydraulic Computation

Drainage Line Name	CA (km^2)	Max_ E (m)	Min_ E (m)	L (m)	Slope	Tc (min)	C	I_{10} (mm/hr)	Q10 (m3/sec)
Getshet - Ziquala	1910	1910	1898	1922	0.38	1573	0.02	28	4.1
Ziquala – Bus Station	1889	1889	1884	1956	1.82	872	0.08	9	1.2
Bus Station - Circle	1902	1902	1882	1902	0.118	1247	0.02	23	1.4

Annex 10: Table of Hydraulic Capacity Design

Drainage Line Name	Max E(m)	Min E(m)	L-(m)	S	S_{des}	b (m)	d (m)	A (m^2)	P (m)	R (m)	V (m^2/s)	Q (m^3/s)	Q_{10} (m3/s)	B (m)	D (m)
Getshet - Ziquala	1910	1898	1184	0.01	0.01	1.7	1	1.7	3.7	0.46	2.4	4.1	4	1.7	1.2
Ziquala – Bus Station	1889	1884	872	0.01	0.006	1.2	0.7	0.84	2.6	0.32	1.43	1.2	1.2	1.2	0.9
Bus Station - Circle	1902	1882	1456	0.01	0.014	1.2	0.6	0.72	2.4	0.3	2.1	1.5	1.4	1.2	0.8

Annex 10: Questionnaires related to the Integration of Road network and Drainage system (KII)

Part I: Questionnaire for professionals

A. Respondents' background information

1. Sex: ■ Male □ Female
2. Age (year): □ ≤ 20 □ 21 – 30 ■ 31 -40 □ 41-50 □ ≥ 50
3. Educational background: □ Diploma □ BA/BSc ■ MA/MSC □ PhD
4. Work experience in construction sector (year): □ ≤ 5 □ 6-10 ■ 11-15 □ 16-20 □ ≥ 20
5. What is your profession? ■ Civil Engineer □ Hydraulic Engineer □ Architect Engineer □ other
6. Did you experience in road and drainage construction projects? ■ Yes □ No

   If yes, what were your occupations? ■ Project manager ■ Site Engineer ■ Office Engineer □ Designer □ other

   If other specify ______________________________

B. Technical questions for professionals

i. Discussion points related to Road Network

1. Do you think the roads in Bishoftu City built following the master plan of the city?

☐Yes ☐No,

If No, why?

- Because most of the road not built as master plan in terms of the recommended surface type, width of road and standards of road.

2. Do you think the Horizontal and vertical alignment construction is proper?

☐ Yes ☐ No,

If No, how?

- Not at all but at some segment horizontal and vertical alignment is not considered.

3. Do you think the cross-sectional alignment is properly provided to the main road?

☐Yes ☐No,

If No, how?

- Not considered especially cross-sectional slopes, utility line, pedestrian lane not proper.

4. Do you think of the existing crown slope of the main road (Condition, Construction slopes) is sufficiently provided?

☐Yes ☐No,

If No, what do you recommend is the solution?

- The crown slope is not enough to convey the water way and is insufficient to take away the surface runoff. Reconstruction of the segment as it is already distressed.

5. Do you think that the pavement condition of the main road is good?

☐Yes ☐No,

If No, what do you think is the proposed solution to solve the distresses in the road?

- Need regular maintenance and axel load should be controlled for vehicles especially for trucks and freight.

6. Do you think that there are proper maintenance activities conducted to the main road?

☐Yes ☐No,

If No, what do you think is the solution?

Based on the characteristics and type of road failure of road structure the following mechanism must be applied: -

- Preventive maintenance, Corrective or breakdown maintenance, scheduled maintenance, predictive (Condition-based) maintenance

7. How do you rate the existing main road condition?

☐Good ☐Moderate ☐Poor

If you rate below Moderate, what do you think is the solution to improve the condition?

- Maintain regularly, add width, drainage line, control of over loading

There are also some other types of maintenance including: Operational maintenance, reliability centered maintenance, improvement maintenance (IM)

ii. Discussion Points related to Drainage System

1. Do you think that the Drainage construction in the city is in line with Master Plan of the City? ☐Yes ☐No,

If No, why?

Depth, width, Alignment, drainage structures, shape, material type is not as per Master plan

2. How do you rate the existing condition of Drainage on the main road?

☐Good ☐Moderate ☐Poor

If you rate below Moderate, what do you think is the solution to improve the condition?

- Same as road solution i.e., Preventive maintenance, Corrective or Breakdown maintenance, Scheduled maintenance, Predictive (Condition-based) maintenance

There are also some other types of maintenance; i.e.

- Operational Maintenance, Reliability Centered Maintenance, Improvement Maintenance (IM)

3. Do you think the drainage structure capacity is capable for accommodating existing flooding in the city? Specify your feedback using tick in front of respective structure.

S/N	X-drainage type	Capacity of structure	
		Sufficient	Insufficient
1	Bridge		√
2	Box culvert		√
3	Pipe culvert		√
4	Ditch		√
5	Inlets		√
6	Outlets		√
	Total		√

What do you think is the solution for structures which are insufficient?

- Need detail study about the catchments, volume of storm and properly design all the structures.

4. Do you think that the locations of Cross Drainage structures (Bridges and Culverts) are properly provided?

   ☐Yes ☐No,

   If No, why?

   ____.

5. Do you think that inlet is properly spaced and have proper capacity to take flows to the drainage channels?

   ☐Yes ☐No,

   If No, what do you think is the solution?

- Redesign properly applies.

6. Do you think that the geometry of drainages built in the city are proper and sufficient to carry the discharges?

   ☐Yes ☐No,

   If No, why?

- Not properly designed as per volume of storm water.

7. Do you think that there are proper side drainage structures built on the main road?

☐Yes ☒No,

If No, how?

- <u>Size is not compatible with volume of storm produced most of the time overflow occurs</u>

8. Do you think that the slope of side drainage is sufficiently built, neither too sloppy not to erode nor very mild to avoid sediment deposition?

   ☐Yes ☒No,

   If No, how?

- <u>Because some of the drainage lines are even backflowing when cheleleka river was filled by the sediments.</u>

9. Do you think that there is proper curve stone provided between the road and drainage?

   ☐Yes ☒No,

   If No, what do you recommend is the solution?

- <u>Even if it was provided for some areas it was filled by wastes to extent of growing grasses and in some areas are broken and not functioning well as demanded</u>.

10. Do you think that the Road network and drainage system of the main road was built integrally?

    ☒Yes ☐No,

    If No, why?

- <u>It is integrated but not compatible with standard.</u>

11. Are there areas highly affected by flooding in the city? ☒Yes ☐No,

    If yes, specify them

- <u>Around 02 kebele back of Bus station, Michael Kajima, Lemlem area, Innova and Getshet.</u>

12. Do you think drainage facility (Bridge, Culverts, Ditches, inlets…) are sufficient to convey storm water in the city?

    ☐Yes ☒No,

    If No, How?

- Depth, width, alignment, shape, material type is not as per standard.

13. Do you think that proper attention was given to Drainage design and construction in the city?

☐Yes ■No,

If No, what do you think is the solution?

- Need to be following up seriously on cleaning, maintaining, redesigning and building

14. Do you think that the flood in the city is caused by poor integration of Road network and Drainage system?

■Yes ☐No,

If yes, how?

- Not meet required standard.

15. Do you think that there are proper Maintenance activities conducted to the Drainage channels on the main road?

☐Yes ■No,

If No, why?

- Ownership issue by municipality and ERA, Budget, less attention.

16. The following might be some of the parameters related for the cause of flooding. Thus, indicate the extent of your agreement by putting "√" mark in one of the boxes provided against each parameter.

S/N	Cause	High	Medium	Low
1	Pavement distress			√
2	Absence of urban storm water drainage infrastructure			√
3	Inadequate urban storm water drainage infrastructure		√	
4	Blockage of urban storm water drainage structures by solid wastes	√		
5	Inadequate road infrastructure networks	√		
6	Rugged topography			
7	If others, specify			

Specify those are described as other ____.

Annex 11: Discussion Points raised during FGD with selected Groups

IDENTIFICATION:

- No of Female participants' 1 No of Male participants' 7
- Time of Discussion; Started: 10:45 Ended 12:45 Time taken 02:00 hrs.

1. Do you think that there is proper design before implementation and quality construction works of road and drainage in the city? □Yes ■No

   If No, why?

- Poor attention given by city administration, Lack of technical skill in both data collection and design, Giving priority to self than community, Lack of proper engineering test

2. Do you think the drainage and road master plan of the city are well integrated?

   □Yes ■No

   If No, how?

- There are overflows of flood to road infrastructure as Construction of road and drainage are not performed at the same time and there are no proper data collected during drainage Design/construction.
- Geometry of drainage channels both the capacity and alignment are not sufficient for accumulation of storm water.
- Drainages are not designed properly, forecasting the storm capacity that will happen in the future and drainage outlets are not sufficient to convey flood in the city.

3. Do you think that the geometric design of both road (Horizontal, Vertical, Cross sectional) and drainage (Capacity to convey storm water) infrastructures are done properly? □Yes ■No

   If No, why?

- Drainage catchment areas are not properly determined and delineated during the design of drainage channels.
- Main road infrastructures are owned by ERA while Drainage structures are owned by City Administration, here they will not integrate the infrastructures together and they are used to construct independently.
- There is no proper original ground level data collected for specific site as per their topography, the city uses the same typological design for drainage infrastructure

4. Do you think flooding is a major problem in the city and have you experienced any flooding events in the city? ■Yes □No

   If yes, how do you rate or describe the extent of the problem? What was the frequency?

- Sanction of Transport (make community to the extent of not accessing to let in/out of the Transport), Traffic Jam, and Traffic accident, economic, social, and even to the extent of losses of life of the community.
- Pavement distress on road infrastructure.
- There is flood in the city every year following the rainy season.

5. Do you think the capacity of inlets; outlets and other drainage structures (ditches, Culverts, Bridge) are convenient to carry floods in the city? □Yes ■No

   If No, what do you recommend so as to improve the drainage capacities?

- There is no sufficient capacity of inlets and outlets.
- To improve the capacities of these drainage structures the City has to re-design the structures like reduction of spacing of inlet, width of inlets, preparation of sediment trap.
- Designing the drainage structure by properly considering proper forecast mechanism for future rainfall.

6. Where do you think highway flooding are typical problem in the city and how it affects the life of the community in the city?

- Flood is prone around bus station, Lemlem, Innova, Hulegeb and Kebele 02 in the city

  Its effects are;

- As Electric poles are damaged by the flood; the light will be off for a week and there are accidents created because of the damage of the electric poles,
- Loss of life because of the flood, accumulation of different solid wastes on the street which will affect the community health, disruptions of different social and economic movements.

7. Do you think that the community is aware in disposing solid wastes in appropriate places provided for solid waste? □Yes ■No

   If No, where do you think that the community dispose the solid waste, what is the side effect and what do you think is the solution?

   The community disposes the solid wastes;

- In side ditches, on road, in front of their residence, free spaces like sport field and greenery of the city, in places where there is no street light.

The side effects are;

- The community will be affected by communicable diseases,
- Drainage channels will be filled by solid waste which then decrease the capacity of the channels, creates pollution of the area, Creates conflict between the community.
- The Solutions are;
- Awareness creation to the community, Preparation of solid waste disposal temporary stations, Preparation of proper regulations and follow up mechanisms for solid waste management system, and penalizing those which dispose the solid waste in appropriate places.

8. What do you think are the major challenges in providing integrated road and urban storm water drainage infrastructure?

- Topography of the area, Inappropriate design, poor attention given by the city higher officials and technical staff, lack budget to re-construct or make proper maintenance, Lack of routine maintenance in cleaning of the drainage channels.

9. Do you think that there is proper maintenance to road and drainage infrastructure in the city? □Yes ■No

   If No, what do you recommend to improve the maintenance activities?

- Re design of the road and Drainage infrastructure with poor maintenance activities by updating the design period, Reconstruction of the main road and the drainage infrastructure on these main roads, properly updating the inventory of the infrastructure asset, Allocating proper maintenance for the maintenance activities as per the infrastructure asset inventory demand.

10. Do you think that the problem of flooding remaining challenge over the years?

    ■Yes □No

    If yes, what do you recommend to overcome the problem?

- Flood forecast, and proper delineation of hydrological studies as well as detail integration management and design of road and drainage infrastructure.