JIMMA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

JIMMA INSITUT OF TECHNOLOGY

SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

DEPARTMENT OF CIVIL ENGINEERING

HIGHWAY ENGINEERING STREAM

The Effect of Discharge Amount on Drainage Structure Failure

A case Study on Ambo Town

BY

Motuma Dagebassa

A Thesis Submitted to the School of Graduated Studies of Jimma University in Partial Fulfillment of the Requirement for the Degree of Masters of Science in Civil Engineering (Highway Engineering Stream)

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JIMMA, ETHIOPIA

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Main Advisor: Prof. Dr -Ing-Alemayehu Gebissa

Co-Advisor: Eng. Getachew Kebede

DECLARATION

This Thesis is my original work and has not been presented for a degree in any other university

By:

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ABSTRACT

Drainage is one of the most important factors to be considered in the world to road design, construction and maintenance projects. Commonly, Inadequate drainage structure problems become one of the most common sources of problems from the residents and runoff water, flooding problems and this problem becoming worse in every year in Ethiopia. Poor existing drains and their improper operation of drainage mainly cause damage and problems to the road users and vehicles. Due to the development of infrastructures in the town, the surface runoff water greatly increased in Ambo town thus, damaging the drainage structure and road surface.

The main objective of this research is, to investigate the major cause of the failure of drainage structures and to estimate the quantity of runoff for existing drainage structures. In order to attain the objective of the study, the researcher focused to collect Structural plan map of Ambo town, existing drainage structure plan, and rainfall data from Ambo town municipal office and Ethiopian metrological agency and also the dimensions of the side drainages were measured by the researcher on the field by using tap meter. The methods of data to be processed was by QSWAT for peak flow (Qp)to compare with the capacity of existing drainage structures of the areas if Qc>Qp is safe and Leveling instruments was determine the design slope and measured slope of the existing drainage structure at the area of case study.

According to the out puts of slope from the leveling instrument of surveying data's, the slopes of existing drainage and asphalt cross fall was a problem to drain the water from the road and drainage structures properly. And peak flows from QSWAT was determined the capacity of the existing drainage structure of trapezoidal and rectangular shapes. From these existing drainage types of study area, the rectangular type was drain safely from the structure than trapezoidal shape.

The concerned authorities are strongly recommended to control and monitor the structural failure of drainage and Environmental problems by maintain and re-constructing the failure parts, developing the skill of QSWAT and QGIS software and by providing a specific budget annually to increase the service life and was the major recommended counter-measure.

Keywords: *Discharge, Hydraulic capacity, Peak flow and Slope*

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LIST OF ACRONYMS

AACRA	Addis Ababa City Roads Authority
AASHTO	American Association of State Highway
ADOT	Arizona Department of Transportation
ASCE	American Society of Civil Engineers
BMS	Bridge Management System
DDM	Drainage Design Manual
EMA	Ethiopian Mapping Agency
ERA	Ethiopian Roads Authority
FHWA	Federal Highway Administration
GDM	Geometric Design Manual
HDS	Hydraulic Design Series
HEC	Hydraulic Engineering Circular (FHWA)
HEC	Hydrologic Engineering Center (USACE)
IDF	Intensity-Duration-Frequency
LVRs	Low Volume Roads
NBIS	National Bridge Inspection Standards
NMA	National Meteorological Agency
US NRCS	United States Natural Resources Conservation Service
US SCS	United States Soil Conservation Service

CHAPTER ONE

1. INTRODUCTION

1.1 Background

Drainage is one of the most important factors to be considered in the world to road design, construction and maintenance projects. It is generally accepted that road structures work well and last longer to give the desired service; it must need the adequate drainage structures. When a road fails, whether it is concrete, asphalt or gravel, inadequate drainage is often a major factor to be considered (Getachew Kebede Warati and, Tamene Adugna Demissie, 2002).

The design involves providing facilities that collect, transport and remove storm water from the roadway. The design must also consider these facilities during the construction of roads in every where through the countries in the case of vehicle transportation purposes. The one of the reason why to cause the damage on drainage structure and road is due to un-proper design and construction of these facilities.ERA DDM is a guideline for the constructions and designs of road and drainage structure for protect and ensure the safety and service life of the road.

Inadequate drainage problems become one of the most common sources of compliant from the residents and runoff water, flooding problems and this problem becoming worse in every year. Poor existing drains and their improper operation of drainage mainly cause a damages and problems to the road users and vehicles. Due to the development of infrastructures the surface runoff water greatly increased in the town damaging the drainage and roads (Donald Walker, 2000).

The most economical and effective to plan and upgrade drainage as part of road surface improvements is easily minor damage be repaired as part of regular maintenance. If the flow of water is not properly managed, the deterioration of the drainage and road will be more serious and occur more rapidly. This will lead to higher maintenance demands and in the worst cases result in serious damage which may obstruct the traffic flow. The main problem to lead the road damage in current situation is the construction of inadequate drainage structures.

There are two sources of water that the highway engineer is primarily concerned to provide highway drainage facilities. The first source, surface water, is that which occurs as rain or snow. Drainage for runoff water on the surface from this source is referred to as surface drainage. The second source, ground water, is that which flows in underground streams. This may become important in highway cuts or at locations where a high water table exists near the pavement structure. Drainage for seepage water and underground streams is referred to as subsurface drainage.

Adequate drainage is essential during the design of roadways, since it affects the serviceability and usable life of the roadway, including the structural strength of the pavement. Satisfactory cross-drainage facilities will limit the buildup of pond against the upstream side of roadway embankments and avoid overtopping of the roadway. Information of pond on the carriageway occurs; hydroplaning (sliding of vehicles) becomes an important safety concern. Rapid removal of storm water from the pavement minimizes the phenomenon, which can result in the hazardous of hydroplaning. Adequate cross-slope and longitudinal grade on the road enhance such rapid removal of storm water (ERA pavement design, 2002).

Most developing countries like Ethiopia have lost valuable infrastructure worth billions of dollars through the failure of drainage. If they do not conduct condition survey of the damaged drainage and roads and begin immediate maintenance, they may lose billions of Birr or more. To reduce failure, the concerned bodies must keep the design standards of the drainage structures and integration of drainage structure with the other infrastructures like, installation of electric cable, tell cable and water pipe is consider during the construction (GTZ-IS, 2006).

Durable drainage structure can be built by proper choice of construction materials and selection of mix properties with respect to, durability, flexibility as well as thickness of structure layers which has the capability to perform well under adverse conditions without significant loss in stability during the intended service period.

On this research, it is intended to identify critical parameters contributing to drainage structure failure and develop a remedial measure for drainage structure that predicts the damage accumulation and serves the highway community to design drainage for extended period of time.

The purpose of this study was to assess the possible causes of drainage structure failure in the Ambo town (about 139.187km long), and recommend remedies to minimize the failure of the structure. It is known that, the quality of drainage structures studied decrease from time to time due to unexpected damage. Now, it may be very difficult to make safe, and economical along the road side in Ambo town. Hence, the researcher has conducted investigations to come up with some indications for the cause of failure and forward remedial measures for those identified problems based on the results of the study. The output of the research brings some remedial measure on this issue of the failures of drainage. Though, the above researches focused on the general characteristics of failure causes; identifying types of failure during site survey visit and by using method of defects of un proper material will be used so as to develop counter measure in order to reduce the Severity of drainage structural failure. Finally, an appropriate intervention method was proposed to reduce drainage structure failure on Ambo town road.

1.2 Statement of the Problem

Drainage structure failure is a critical issue on the flexible pavement where it involves a very high maintenance cost every year. So it requires proper and timely maintenance. The inadequacy of drainage structures causes obstacles on the traffic movements due to closing the pass of the flood. The causes of the damages are:-poor quality construction, inappropriate site selection and improper alignment of some drainage structures with respect to the road alignment. These shortcomings cause damage to superstructures of drainage structures and affect the environments. At some parts of the road way, due to no construction of the drainage structure, the degree of damage of the road and surrounding residents are high(FHWA,1966).

Infrastructures of land occurred on both sides of the road due to the maintenance of road and causes indigenous of people. This has resulted in increased dampness of soil and its accumulation in the drainage structures. This causes storm water to overflow on the carriageway and clogging of culverts by silts. In addition to silts, the logs and soils are transported to the drainage structures on the upstream side of the culverts. These are the main causes for the clogging of these drainage structures, which causes overtopping of embankment by flood. Runoff, which is in excess of the drainage structures capacity, overtops the road embankment and makes the road to function improperly due to erosion and ponding. During the design period of the road, the one must be considered is the space of walk way (between shoulder and drainage).ERA DDM puts the rules for the design of walkway the same to other road elements. In Ambo town, the walkway does not covered completely by concrete or asphalt during the construction of roads in the town and it contributes to the failure of drainage by increasing soil dampness and siltation from the transported soils to the drainage by erosion.

The study of investigated causes of damages due to poor drainage experienced during the past few years on major roads of Ambo town. On the previous experiences in design and construction of drainage structure, the study provides design guidelines for a proper and efficient drainage system that lead to enhance road performance and increasing the service life of pavement. Regular annual evaluation of drainage systems is an important part of maintaining and managing road. The statement of the problem from the investigation conducted is due to the negative attitude of resident and slope problems.

1.3. Research Questions

1) What are the main causes for the failure of drainage structure in Ambo town?
2) What are the factors affecting the drainage structure
3) What is the major action taken to repair the drainage?
4) How often the runoff water affect the drainage structure in Ambo town?

1.4 Objective of the Study

1.4.1 General objective

- To investigate the major cause of the failure of drainage structure and to estimate the quantity of runoff for existing drainage structures.

1.4.2 Specific objectives

- To identify the major causes of failure of drainage structure.
- To assess the performance of drainage structure

- To determine the effect of run-off on the failure of drainage structure
- To provide the necessary recommendation.

1.5 Significance of the Study

- To minimize the possible damage of drainage structures and increase serviceability.
- To minimize the structural problem which is affecting the drainage structures and Ambo towns concerned body organizations can use it as reference for drainage infrastructure proper design.
- To reduce the environmental problems caused by wastes.
- To increase the integration of the infrastructures for increasing the service time of the drainage. Generally:-

The study, design and construction of road drainage structures require skilled workforce and intensive financial resources. If the drainage structures fail, high investment is required to maintain them in order to avoid traffic interruption. To minimize maintenance expenses proper protection and management of these road assets is important.

Therefore, this study is beneficial to the region for future road drainage structures construction to avoid problems by assessing the performances of the existing drainage structures and proposing mitigation measures to avoid improper functioning.

The study is expected to propose appropriate solutions to the drainage systems whose implementation will contribute to the sustainability of the case study road. The study is beneficial for academicians and researchers who conduct similar researches on other road drainage structures failure.

1.6 Scopes and Limitations of the Study

The research does not include structural design of all types of drainage structures except proposing the type and size of the required drainage structures. The study of this research is to cover the problem of drainage failure and to know its ultimate effect on the human health's because of failure of those drainage structures especially the closure of the drainage structures by debris, silt and domestic solid wastes from the residential and the concerned bodies that do not properly managed the communities.

1.7 Expected Output/Outcome

Based on general and specific objective and methodology, the following results are the outcome from the study. The degree of damage caused on drainage structure is a result of the effect of surface water, low performance workers, dampness of soils and quality of construction materials. This unexpected drainage damage facilitates the structure before giving service as per new construction and causes economical crises to the town. At the completion of this research, the research question was answered and the possible solution for the drainage problem was been indicated. This research serves as a reference material for different government and public organization as well as other researchers.

CHAPTER TWO

2. LITERATURE REVIEW

2.1 General Description of Road Drainage Structure

Drainage is simply defined as the natural or artificial removal of surface and subsurface water from a catchment area. The surface drainage in roads is defined as a process of removing runoff water from road surface and directing it towards a drain to be disposed away from road in a water course or open area (Fleckenstein and Fwa, 1987). This stated that drainage system is an integral component of road pavement and therefore its design cannot be undertaken in isolation from the road geometric design. The road network complements natural drainage network and therefore modifies the path of runoff water flow within the slope and accelerates the water cycle. Thus, surface water flows as a result of adequate sloped road cross section that removes water from surface and then directed to drainage channels in the system. The main functions of a road drainage system are to prevent flooding of the road and pounding on the pavement surface, to protect the bearing capacity of the pavement and the sub grade soils, and to avoid the erosion of side slopes.

Any damage or collapse of the structures can cause the risk of the lives of road users as well as create serious influence to the entire country economic development. Drainage structure failure causes a serious problem of economic developments to the country.

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

The two main types of water flows that can be considered are the flows that usually crossing the area that could be diverted by the presence of the road, and the flows generated by the runoff of the rainwater falling on the carriageway and its surroundings. The basic design techniques in roadway drainage system should be developed for economic design of surface drainage structures including ditches, culverts and bridges (ERA, 2002). A hydraulic investigation and analysis of both the upstream and downstream reaches of the watercourse is necessary to determine the best location, size, and elevation of the proposed crossroad structure, whether a culvert or abridge. The investigation should ensure that any roadway structure or roadway embankment that encroaches on or crosses the flood plain of a watercourse will not cause significant adverse effect to the flood plain and will be capable of withstanding the flood flow with minimal damage. It is significant to provide attention during design of the magnitude, frequency and appropriate water surface elevations for the design flood, the 100-year flood, and the overtopping or 500-year flood for all structures (ADOT, 2007).

2.1.1 Culverts

A culvert is a drainage structure primarily used to convey surface water through embankments that are often constructed in a variety of shapes, sizes, and various materials. Culverts are defined according to their shape, size, material type, and usage. Culverts are distinguished from bridges in that they are usually covered with embankment material and are composed of structural material around the entire perimeter, although some are bottomless. Box, pipe, or arched culverts that have a clear span width of 20 ft or less, as measured parallel to the roadway centerline between the outermost hydraulic ends, are considered to be a culvert by definition(FHWA Hydraulic Design Series No. 5 (HDS 5), Hydraulic Design of Highway Culverts.)

Culverts are closed conduits in which the top of the structure is covered by embankment at a minimum thickness of 30cm (AACRA, 2004). Bridges are mainly provided for large streams and drivers. United States National Bridge Inspection Standards (USNBIS, 1990) and ERA drainage design manuals (ERA DDM, 2002 and 2011) define bridges as those structures that have at least 6 meters of span along the roadway centerline.

Culverts can be classified into two based on their functional types, stream crossing and runoff management. Stream crossing culvert is a drainage structure installed on the stream with recommended skewed angle, 150 - 450 if conditions do not permit to install normal to the stream channel. Installing culverts normal to the stream channel decreases construction cost. Where large skew angles are required, consideration of the most appropriate road alignment is significant (Austroads, 1994).Runoff management culvert strategically placed to manage and route roadway runoff along, under, and away from the roadway. Many times these culverts are used to transport upland runoff, accumulated in road ditches on the upland side of the roadway, to the lower side for disposal. Strategically placed culverts, along with road ditch turnouts, will help to maintain a stable velocity and the proper flow capacity for the road ditches by timely out letting water. This will help to alleviate roadway flooding, reduce erosion, and thus reduce maintenance problems. Culverts preserve the road base by draining water from ditches along the road, and keeping the sub base dry. They are built using a variety of materials, in different shapes and sizes, depending on the preferred design and construction practices. Culverts are required in order to (i) allow natural streams to cross the road, and (ii) discharge surface water from drains and the areas adjacent to the road. Culverts form an essential part of the drainage system on most roads (ERA, 2002).

Scour may occur at culvert inlets if the inlet is choked with debris. Remove the debris to restore water movement. Another possibility is that the inlet capacity is simply inadequate. The makeup of the drainage area may have changed since the culvert's construction. In this case, the culvert will have to be reconstructed to provide a larger opening/capacity. At outlets, scour occurs when a large volume of water is discharged at a high velocity. When scour occurs at outlets, curtain walls may be undermined. Repair the scour by backfilling the eroded area with suitable material, then placing riprap, concrete, or bituminous material to protect the outlet from further damage.

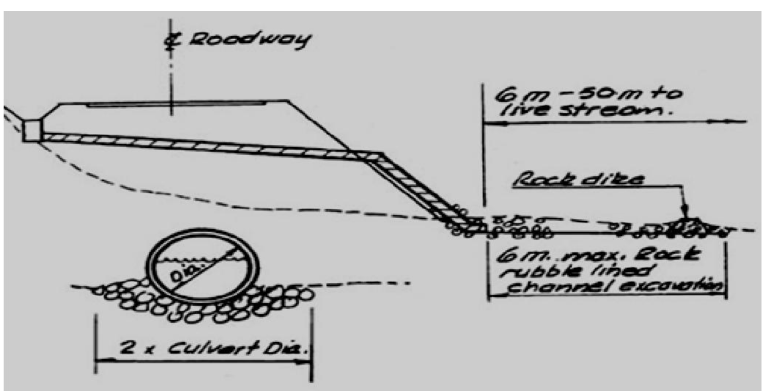

Figure -1. Design standards of culvert

Installing culverts without wing walls and head walls will decrease the hydraulic efficiency of the culvert. As a result, scouring and potential of diversion of water will be created. The minimum grade for a culvert should generally be 0.5 (ACT Government, 1994). Flatter grades may be prone to siltation and are difficult to construct. The maximum grade for a culvert should be chosen to limit the pipe full flow velocity to value less than or equal to 6m/sec to avoid scour (ACT Government)

2.1.2 Bridges

Bridge is usually associated with structures that are required to carry the roadbed over an established waterway; it may also be somewhat loosely applied to grade separation structures and elevated highways in urban and rural areas.

Generally, however, the location of a suitable stream crossing may be the most important single factor influencing the location of the highway in a given section; such is usually the case when long bridge spans are involved. The ideal location for a bridge crossing is, of course, one in which the crossing is made at right angles to the centerline of the stream at the narrowest point, where the alignment of the approach pavement is straight, where the approach grade is slight, and where soil conditions are adequate for the installation of the most economical foundation for the span involved.

In many locations the natural stream channel is somewhat constricted by the bridge structure and roadway approaches. In the interests of economy, the road way is frequently placed on an embankment on either side of the bridge span; the distance between abutments is reduced as much as possible, and piers may be placed in the stream channel. All these things serve in many cases to reduce severely the area through which the water must pass, particularly when the stream is at flood stage. Two results may immediately be noticed: during flood stage the velocity of the water through the bridge opening may be considerably increased, with resultant danger to the bridge structure through scour at abutments and piers, and the elevation of the water on the upstream side may be increased, with the result that the area subjected to flooding above the bridge site is increased and adjacent property is subjected to over flow beyond the limits of the normal floodplain. AASHTO specifies that the roadway width at bridges shall be equal to the full shoulder width of the approach section. Along curbed roadways, the full width of the approach section should similarly be crossed the structure (High way Drainage, 2009).

2.1.3 Inlets

These are parts of a drainage system that receive runoff at grade and permit the water to flow downward into underground storm drains. Inlets shall be selected, sized and located to prevent silt and debris carried in suspension from being deposited on the traveled way where the longitudinal gradient is decreased. Inlet should be capable of passing design floods without Clogging with debris. The entrance to inlets should be protected with a grating set flush with the surface of gutters or medians and to be a hazard to vehicles (DDM).According to these principles the drainage which is constructed on any types of road must consider the rules of DDM to be approve the life of drainage and pavements without damages.

Inlets used for the drainage of highway surfaces can be divided in to curb-opening, grate, combination inlet and slotted drain. Those inlets are classified according to their openings and the capacity to receive runoff and constructed at every 10ms (ERA DDM, 2002).

2.1.4 Outlets

Outlets must be provided at locations and intervals indicated by design considerations. The outlets must be located to ensure that the drainage system will be completely free draining for the entire life of the highway pavement section. Outlets should be provided at the sag of every vertical curve. The spacing of outlets should be determined by hydraulic computation of discharge capacities of the pipe sizes utilized, but the location of outlets may frequently be restricted by the adjacent land elevations and the geometries of the highway. However, for most drainage systems, the outlet pipes should be obtainable by proper engineering analysis to be safe the drainage structures and pavements. According to EDDM, the open end of the outlet pipe should be at least 12 inches above the flow line of the roadside ditch and be protected against damage or the intrusion of foreign matter. The trench for the outlet pipe should be backfilled with material of low permeability or provided with a cutoff wall or diaphragm to prevent piping (ERA DDM, 2002) .

2.1.5 Ditches

Ditches are collect runoff from the road surface. A well-maintained, smooth-flowing ditch will be free of heavy vegetation (tall grass, trees, cattails, etc.) and standing water, with enough grades to ensure self-cleaning and continuous flow. Ditches with flat percent-of-grade allow residue or debris to settle and fill in the ditch. If sediment accumulates, water may erode a new path outside of the ditch (ERA DDM, 2013).

2.2 Surface and Subsurface Drainage

The surface drainage elements include road surface, side drains, gutters and storm sewer systems. These elements work together as a system to prevent water from penetrating the pavement, remove it from the travel lanes to the side drains or gutter, and carry it away from the road **(**ERA pavement design, 2002**)**

When groundwater cannot be effectively removed or intercepted by surface drainage, subsurface drainage techniques are required. If water is not removed from sub grade or pavement structures it may create instability, reduce load bearing capacity, increase the danger of frost action and create a safety hazard by freezing of the traveled surface.

Field investigations carried out during the route reconnaissance and design stages may not always reveal sub drainage problems. These less obvious problems can be effectively dealt with during construction. Field investigations should be carried out during the wet season and may include soil and/or geologic studies, borings or trenches to locate groundwater, inspections of natural and cut slopes in the local area, and measurement of discharge when possible. Sites with potential slope stability problems should be more thoroughly evaluated. When groundwater tables approach the ground surface, such as in low, swampy areas, the grade line should be placed high enough to keep water from being drawn up into the fill by capillary action. Whenever possible, well graded granular materials, such as coarse sand, should be used for fill construction. For a detailed discussion of grading requirements for filter materials the reader is referred to the Earth Manual published by the (U.S. Department of the Interior, 1974).

A major difficulty in selecting a drainage system is the lack of adequate performance data for various drainage methods. A good knowledge of seasonal groundwater fluctuations, variation in lateral and vertical permeability, and the ratio of vertical to lateral permeability are critical. Long term monitoring of drainage performance is important in determining appropriate prescriptions for future installations. For example, perforated drains are commonly prescribed but often will not function properly as a result of clogging of pores with fines or from geochemical reactions leading to the formation of precipitates. Several methods may be used to prevent plugging depending on soil characteristics and material availability. The first is to enclose the perforated pipe with geo textile fabric. Second, surround the pipe with an open graded aggregate material, which in turn is surrounded by a fabric. The use of fabric eliminates the need for an inverted filter consisting of various sized gravel and sand layers. Third, if fabric is not available, surround the pipe with a graded aggregate filter. Although the cost of installing such a drainage system is high, it may effectively reduce final road costs by decreasing the depth of base rock needed, thereby reducing sub grade widths and associated costs for clearing, excavating, and maintenance (FHAO, hydraulic design, 1996).

The design of subsurface drainage should be carried out as an integral part of the complete design of the highway, since inadequate subsurface drainage have detrimental effects on the stability of slopes and pavement performance. The procedure usually adopted for subsurface drainage design is first to determine the geometric and structural requirements of the highway based on standard design practice, and then to subject these to a subsurface drainage analysis to determine the subsurface drainage requirements. It is extremely difficult, if not impossible; to develop standard solutions for solving subsurface drainage problems because of the many different situations that engineer come across in practice (Fabian P.Barry JA, 2003).

2.2.1 Road Surface Drainage

If surface water penetrates into the road body, it reduces the load bearing capacity of the pavement, which may cause further damage of the road. To avoid these problems, it is important to secure adequate drainage of the road surface. According to ERA geometric design manual (ERA, 2011) the normal cross-slope is not less than 3% in order to dispose water from the roadway quickly that avoids infiltration of water into the roadway. If the cross-slope is less, water will get time to infiltrate into the roadway and weakens the pavement that cannot withstand traffic load.

2.2.2 Roadside Drainage

Road side drainage must be designed to satisfy hydraulic specifications of ditches. The two most common types of ditches are flat bottom and V-section ditches. A flat bottom ditch is recommended where design constraints allow its use. Flat or rounded ditches reduce the distance, the distance from a steep grade or drop drivers are comfortable with; they also increase the probability that a driver can safely recover after leaving the road way. Ditches should be designed so that the water in them does not saturate the sub grade (ERA DDM 2001).

Drainage in cut sections or v-section is of particular importance due to the increased likelihood that runs off will accumulate on the roadway surface. By intercepting the runoff, the chance during high intensity precipitation is reduced. Runoff should be intercepted and redirected before that a chance to accumulate on or near the road. This can be accomplished with the use of intercepting channels alongside the roadway (Handbook of Highway Engineering Edited by, T.F.Fwa).

2.2.3 Adequate Road Surface Drainage

It is an essential consideration that adequate provision is made for road drainage to ensure a road pavement performs satisfactorily. Rainwater drainage system should be designed to collect and convey runoff water generated within a catchment area during and after rainfall events, for safe discharge into a receiving watercourse. The magnitude of peak flows that have to be accommodated depends primarily on the intensity of rainfall, topography, soil type, and configuration and land use of the catchment area. Drains are normally located and shaped to minimize the potential traffic hazards and accommodate the anticipated surface water flows. Drainage inlets are often provided to prevent water pounding and limit the spread of water into traffic lanes (Federal urban coordinating Bureau, 2008)**.**

Proper design of the surface drainage system is an essential part of economic road design (ERA, 2000: Drainage manual). The surface drainage system collects and diverts runoff water from the road surface and surrounding areas to avoid flooding. Road ditches decrease the possibility of water infiltrating into pavement layers and thus help retain the road's bearing capability. The road surface and cross-fall conduct water to surface drains, which take care of the runoff water. The majority of ditches normally have a V-shaped cross section. Roadside ditches and culverts carry flow from the area around the road, especially during peak discharge events. This flow can be directed to streams by either ditches or culverts. Suitable drainage dimensioning always contributes to the bearing capacity of the pavement and to road lifetime (Roadway and road side drainage David P.Orr.P.E, 2003).

The effective road geometric factors on drainage are road cross-sectional width, traverse and longitudinal slopes, and slope of shoulders or sidewalks. Drainage is a basic consideration in the establishment of road geometry and in general this means that: (a) cross falls should be a minimum of 3% on carriageways, with increased cross falls of up to 5.0% on hard shoulders draining to filter drains; (b) longitudinal gradients should not be less than 0.5% on kerbed roads; (c) flat areas should be avoided and consideration of surface water drainage is particularly important at rollovers, roundabouts and junctions; (d) outfall levels must be achievable; (e) the spacing of road gullies should be sufficient to remove surface water whilst achieving an acceptable width of channel flow. One gully for every 200 m2 of paved surface is generally found to be satisfactory (ERA DDM, 2013).

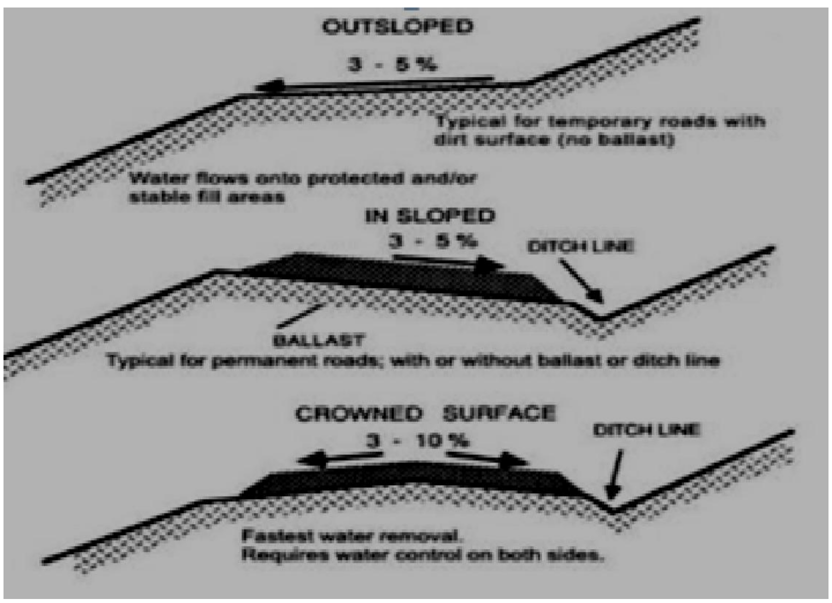

Figure- 2 Typical Road Drainage Systems

2.2.4 Drainage Structure

Drainage structures provide support for grate inlets, and combination inlets, and serve as a point of connection for the storm drains. Provide general guidance regarding the type and size of drainage structure to be specified.

2.2.4.1 Types of Drainage Structures

The pay items in the standard specifications provide a number of alternatives for drainage structures including:

1. Rectangular drainage structure/Trapezoidal:- This is the preferred pay item of the structures which is constructed to low capacity of discharge of waters and no cause of construction problems.
2. Rectangular drainage structure with round option:-This item should only be selected if shape is unimportant in the design and construction of the drainage system. Placement of round structures in lieu of rectangular structures may shift the centerline of the drainage structure as well as the centerline of pipe entries. This may cause construction problems or adversely affect adjacent features.
3. Round precast manhole:-This pay item should be used to provide a structure for connecting pipelines on differing alignments where a drainage structure with a grate inlet is not necessary.
4. Special drainage structure:-Regions which have established special drainage structure details shall include the details in the contract documents. When a top slab is used, the top slab should be as small as possible and yet provide adequate structural stability. Concrete block and mortar structures are not acceptable due to the damage they incur from salt and highway loads (Guo, J.C.Y. 1999).

2.2.4.2 Size of Drainage Structures

Drainage structures should be large enough to accommodate the inlet frame and grate maintenance personnel, and connecting pipes. To avoid excessive head losses, structure should be no larger than necessary. The minimum internal rectangular drainage structure dimensions necessary for the various pipe sizes and pipe entry skew angles (θ).The maximum size round pipe that can be accommodated is by drainage structure types, based on pipe size and skew angle and based on the relationships between skew angel, wall thickness of drainage structure, outside pipe diameter, and the knockout clearance (AASHTO, 1993).

2.2.4.3 Requirements to Construct Drainage Structures

A complete drainage system design includes consideration of both major and minor drainage systems. The minor system, sometimes referred to as the "Convenience" system, consists of the component that historically considered as part of the "storm drainage system". The requirements to construct drainage structures are: - curb gutters, ditches, inlets, access holes, pipes and other conduits, open channels, detention basins, and quality control facilities

(Alderson, 2006). The minor system normally designed to carry runoff from 10-year frequency storm events (FHWA, 2001).Avoiding of improper alignment of drainage structures is significant in order to avoid hazardous problems of traffic and damage foundations, abutments and piers of structures. Crosscurrents of stream and river flows are the causes of foundations, abutments and piers of drainage structures. May those requirements service for all constructions of drainage structure to be constructed in everywhere on the roads. Narrow sections and hard basement are important during construction of drainage structures in order to minimize the cost of construction with the exception of excavation cost. Constructing drainage structures on hard basement avoids scouring problem.

2.3. Function and Description of Road Drainage Structures

2.3.1 Function of Road Drainage Structures

The design of a drainage system should address the needs of the traveling public as well as those of the local community through which it passes. The drainage system for a roadway traversing an urbanized region can be more complex. This can be attributed to areas with a heavy concentration of development and associated conflicts with existing utilities and the drainage system. Drainage facilities consist of curbs, gutters, inlets, storm drains, ditches, and culverts. The placement and hydraulic capacities of storm drainage structures and conveyances should be designed to avoid/minimize damage to adjacent property and secure a low degree of risk of traffic interruption by flooding. Different types of structures are employed in the drainage systems:-

- √ Open channels whether artificial or natural convey the flows of water.
- √ Culverts and bridges convey flows under road cross-section.
- √ Energy dissipaters, used to control the velocities of flows, especially at culvert outlets.
- √ Storm drainage facilities, used to collect the runoff of the carriageway and surrounding areas and direct it to the channels (ERA, 2002).As a principle of these the terms to determine capacity of storm drainage structures and the types of damage is must identified to ensure the durability of drainage structures from the beginning of design and construction times

2.3.2 Description of Road Drainage Structures

Two different types of drainage systems commonly used to direct water from the area surrounding the road and to evacuate extra water from the road structures. These are surface and sub surface systems.

A surface drainage system collects and diverts storm water from the road surface and adjoining areas to avoid flooding.. It decreases the possibility of water infiltration into the road and retains the road bearing capacity. Appropriate design of the surface drainage system is an essential part of roads. Sub-surface drainage systems drain water that has infiltrated through the pavement and the inner slope.

In ERA low volume roads drainage design manual the fall of 3-5% allowed on culverts to ensure that water flows without depositing silt and other debris. In flat terrain, where there is a high risk of silting, a factor of safety of two allowed in the design of the culvert. Moreover, all pipes should have a minimum diameter of 0.60m to ensure that they can be cleaned manually. It is important to install energy dissipating structures and/or at the outlet where scour and erosion are likely to occur. These structures are required where high exit velocity due to steep culvert installation, near proximity to channel banks, and drops at the end of the culvert. Culverts are drainage structures that have the span length of less than or equal to 6-meters otherwise it is major drainage structure (ERA, 2002). However, ERA BMS considers those drainage structures that have span length of 4-meters and above as bridge. In this research, drainage structures are considered bridges that have span length of greater than 6-meters. Bridges are major roadway drainage structures, which are used in runoff drainage systems where stream span is large, for which special designs are made almost in every case greater than 6-meters (USNBIS, 1990).

The sizing of minor drainage structures is of considerable economic importance, as these structures can comprise a significant cost of total road construction costs. The selection of the appropriate design flood and good practice in the design of these structures determines the initial costs, the provision of the desired level of to traffic, and the safety of the road users. With this respect, the most important parameters for the design of major and minor drainage structures are the design flood, hydraulics analysis and selection of construction materials.

2.3.3 Functions of Road Drainage Structures

The function of road drainage structure is used to collect, transport, and dispose of surface/sub-surface water originating on or near the roadway right of way or flowing in streams crossing bordering the right of way. It prevents erosion of the back slope by runoff from the hill above. It intercepts water, not allowing it to enter side drain that may cause greater discharge inside drains.

A road drainage system must satisfy two main criteria if it is to be effective throughout its design life.

- It must allow for a minimum of disturbance of the natural drainage pattern.
- It must drain surface and subsurface water away from the roadway and dissipate it in a way that prevents excessive collection of water in unstable areas and subsequent downstream erosion.

The design of drainage structures is based on the sciences of hydrology and hydraulics of the former deals with the occurrence and form of water in the natural environment (precipitation, stream flow, soil moisture, etc.). The constructions of road drainage structure is depends on the nature of terrain types of the areas (Watershed management field manual).

2.4. Drainage Problems

Drainage is a system includes the pavement and the water handling system. Logically they must be properly designed, built, and maintained. Poor design of drainage structure can direct water back onto the road or keep it from draining away. The failure of drainage can adversely the water handling system includes: road surface, shoulders, drains and culverts; curb, gutter and storm sewer. When a road fails, whether it’s concrete, asphalt or gravel, inadequate drainage often is a major factor affects pavement performance (Earth and Gravel roads (Penny state University, 1997)). The problem of drainage leads to major cause of pavement distresses due to large amount of costly repairs before reaching their design life. Pavement service life can be increased by 50% if water can be drained without delay. Similarly, pavement systems incorporating good drainage can be expected to have a design life of two to three times that of undrained pavement sections. To achieve proper drainage, drains (or ditches) a long side of road are essential to collect water from road surface and surrounding areas and lead it to an exit point where it can be safely discharged. The use of edge drains was also for conventional asphalt pavements with unbound dense-graded aggregate bases, the addition of appeared to reduce fatigue cracking, but not rutting (Local road assessment and improvement drainage manual (Donald Walker (2000) Colorado (Guo, J.C.Y. 1999)).

Water is the biggest enemy of roads and most experts believe that most of pavement distresses and damages are due to poor drainage. According to (Guo, J.C.Y. 1999), 8% of existing road way problems can be traced to the presence of water from poor drainage either in or on the road pavement. Excessive water content in the pavement layers such as base, sub base, and sub grade soils can cause early distresses and lead to structural or functional failure of road and drainage, unless counter measures are undertaken. Back water of drainage structure is due to; depositing sediment and debris in ditches, pipes, catch basins and waterways; creating driving hazards for motorists and damaging the structures (Fabian P.Barry JA, 2003). Floods and high water flows significantly affect the performance of drainage infrastructure. The anticipated pattern of flooding occasions will influence the number of incidents such as landslides, landslips, roads being washed away, submerged and inundated bridge supports, and road closures (AASHTO, 1993). Many culverts, trenches, and other drainage facilities lack the capacity to deal with the current frequency of extreme flows.

The drainage problems can directly cause or contribute to crashes of the vehicles. As an example, drainage features that fail to remove runoff water because they are too small or are clogged and pond water on the roadway can cause hydroplaning or force drivers to leave their lane. Additionally, other drainage features which do not have anything to do with causing a crash can significantly contribute to the severity of the crash, such as an errant vehicle striking a culvert headwall (Fleckenstein and Fwa, 1987; Tart, Jr, 2000). It is important to identify these potentially hazardous situations as soon as possible. Some of these conditions may have been in existence for quite some time, while others may have recently developed as a result of flooding or change in weather conditions.

2.4.1 Backwater Effect on Road Drainage Structures

This type of effects occurred only during the rainy seasons. Due to the geographical natures of the land was not exposed to maximum erosion the extreme back effect to damage the road structure does not consider. But due to the failure of the drainage structure the directions of the flow of water in the drainage blocked during the rainy season and affect the road performances**.**

When a roadway crosses a natural drainage way, the resistance to flow of the structure may increase the water depth upstream of the drainage structure. This backwater effect may cause areas close to the drainage way to become flooded where previously they remained above the floodwaters. When dwellings or other manmade structures are close to the drainage way, a limitation placed on the maximum backwater effect tolerated for drainage structure design. Aggradations increase the backwater effect; affect the pressure on the structure, and passes ability of the bridge (Johnson *et al.,* 2002). Bridges seem to more readily allow sediment transport than culverts and therefore have less accumulation up stream of the crossing (Wellman *et al.,* 2000).

2.4.2 Failures of Road Drainage Structures and Environmental impacts

In this research of “The effect of discharge amount on drainage structure failure” the road drainage was obstructed the general flow of surface water or stream water in any unreasonable manner to cause an unnecessary accumulation either of water flooding or water soaking uplands, or an unreasonable accumulation and discharge of surface water flooding or water soaking lowlands due to the problem of slope and soil types. The failure of road drainage structure was caused for the reason that referred the above.

The main problems which occur on the drainage network’s are, relate to:

- Modification of the existing drainage network;
- Introduction of polluting elements;
- Erosion increment on slopes in landfill or excavation.

The critical situations occur during the construction and on the early operating periods. and causes air pollution by stored waste waters through the drainage from blocked by debris to the area. In past years and in most known situations it was proved that diffused or non punctual sources of pollution, like runoff, constitute significant contamination points of the natural drainage system, for which in certain cases we should take appropriate measures to control it.
In general, the environmental component constitutes today an integral and fundamental parts of road project, which as obliged a greater and stronger interdependency between the several studies and intervention’s in the process. The choice of treatment system to adopt shall answer

to diverse conditions: type of pollutants to treat, the regional climate, the compatibility with the roads' drainage project, the impacts on the landscape without the need of energy, with great reliability and reduced maintenance needs.

2.4.3 Protection Measures of Failure on Drainage Structures

According to ERA drainage design manual 2002, many serious construction problems arise because important drainage and water related factors were over looked or neglected in the planning and location phase of the project. With proper planning, many factors can be avoided or cost effective solutions developed to prevent extended damages such that soil erosion, sediment deposition and drainage and landslides. Serious construction problem and water related factors should rise rather than sedimentation and land slide.

Poorly designed culverts are also more appropriate to become jammed with sediment and debris during medium to large-scale rain events. This can cause the road to fail and drainage, often introducing a large amount of fine sediment that can clog other structures downstream. Providing scour protections are important at both inlet and outlet for all culverts to protect the structure from damage. Providing rock armor is significant protection measure of scour for inlets and outlets of culverts. To prevent the possible piping failure, cement stabilized fill can be used to form the culvert invert bedding for a suitable length. These measures found to perform well in clayey/silty/sandy soils (Sheared *et al.,* 1963).The protection measure of drainage structure is to provide the adequate structure interims of stabilities and ensure the service life of drainage by protect flooding, wastes from external and selection of construction materials. In addition to these the maintenance or repair of the drainage structure extends the serviceability of drainage structures.

2.5 Erosion and Sediment Control

Erosion and sediment control is any temporary or permanent measure taken to reduce erosion, control siltation and sedimentation. There are a number of publications and sources of guidance regarding erosion and sediment control. This section discusses erosion and sediment control guidelines within the context of the Standards and Specifications for Erosion and Sediment Control.

The following is recommended guidance:

1. Preserve the existing vegetative groundcover on the project site as much as possible to protect the soil surface and limit erosion.
2. Sediment control practices/measures, where necessary, should be designed to protect the natural character of rivers, streams, lakes, coastal waters, wetlands, or other water bodies on-site and minimize erosion and sedimentation off-site from the start of land disturbance activities to establishment of permanent stabilization.

The off-site impacts of erosion and sedimentation related to land clearing, grading, and construction activities should not be any greater during and following land disturbance activities than under pre-development conditions (Del DOT, 2008).

2.5.1 Runoff Coefficient(C)

The most common definition of a runoff coefficient is the ratio of the peak rate of direct runoff to the average intensity of rainfall in a storm .The runoff coefficient is a dimensionless ratio intended to indicate the amount of runoff generated by a watershed given an average intensity of precipitation for a storm. While it is implied by the rational method, intensity of runoff is proportional to intensity of rainfall; calibration of the runoff coefficient has usually depended on comparing the total depth of runoff with the total depth of precipitation.

The runoff coefficient is a general representation of the drainage basin characteristics. These include antecedent precipitation, soil moisture, infiltration, detention, evaporation, and ground slope and cover. The coefficient "C" can be determined in one of two ways and based on the overall character of the drainage area. The second method develops a composite coefficient based on the percentages of different surface types in the drainage area (Highway Design Manual Revision 87, 2016).

The runoff coefficient accounts for the effects of infiltration, detention storage, surface retention, evapotranspiration, surface retention, flow routing and interception. The product of runoff coefficient and rainfall intensity is the rainfall excess of runoff per hectare. The runoff coefficient should be weighted to reflect the different conditions that exist within a watershed.

2.5.2 Surface Runoff

Surface runoff is directly determined by the amount of excess precipitation. Excess precipitation is the precipitation that is left once all losses have been accounted. Some of the losses include evaporation during the event, infiltration, and storage in depressions.

Evaporation is the process of transferring water vapor from land and water sources to the atmosphere. Another form of evaporation is transpiration, or the amount of water expelled from vegetation. Evaporation generally accounts for the largest portion of water losses from a storm event. The rate of evaporation for any given area depends on temperature, surface type, relative humidity, and wind. Infiltrated precipitation is the amount of water filtered through the earth's surface. This water returns moisture to the soil and replenishes ground water supplies. Once the precipitation has fallen to the ground, it may be detained in depression storage areas from where the precipitation cannot runoff. Depression areas around the towns accumulate water that may infiltrate the surface because of permeable. However, if the surface is not permeable, the water is left to evaporate. A depression storage area does not add to runoff and must be deducted as a loss. Topographic maps of the town can be helpful in determined the drainage area since they accurately displayed the surrounded terrain. The drainage area was the entire area that was contributed to the runoff at the point where the amount of runoff was calculated (Handbook of Highway Engineering Edited by, T.F.Fwa).

2.5.3 Estimating Runoff

Estimating runoff is depending on the water that reaches the ground in the form of rain, some will percolate in to the soil to be stored until it is taken up by plants or transported through pores as subsurface flow, some will evaporate back in to the atmosphere, and the rest will contribute to over land flow or runoff. Stream flow consists of stored soil moisture which is supplied to the stream at a more or less constant rate throughout the year in the form of subsurface or ground water flow plus water which is contribute to the channel more rapidly as the drainage net expands in to channels to incorporate excess rainfall during a major storm event. The proportion of rainfall that eventually becomes stream flow is dependent on the following factor.

1) The size of the drainage area:- The large the area, the greater the volume of runoff. An estimating of basin area is needed in order to use runoff formulas and charts.
2) Topography:-Runoff volume generally increases with steepness of slope. Average slope, basin elevation, and aspect, although not often called for in most runoff formulas and charts, may provide helpful clues in refining a design.

3) Soil:-Runoff varies with soil characteristics, particularly permeability and infiltration capacity. The infiltration rate of dry soil, by nature of its intrinsic permeability, will steadily decrease with time as it becomes wetted, given a constant rainfall rate. If the rainfall rate is greater than the final infiltration rate of the soil (infiltration capacity), that quantity of water which cannot be absorbed is stored in depressions in the ground or runs off the surface. Any condition which adversely affects the infiltration characteristics of the soil will increase the amount of runoff. Such conditions may include hydrophobicity, compaction and frozen earth (FHAO).

Depending on the above points, there was a number of different methods are available to predicted peak flows. Flood frequency analysis was the most accurate method employed when sufficient hydrological data is available. The means of estimated peak flows on an un gagged stream and intermediate frequency curve of ERA DDM, the recurrence interval associated with a given flow event of both can be identified and used for evaluated the failure of drainage structure in Ambo town.

In addition to considering intensity and duration of a peak rainfall event, the frequency, or how often the design maximum may be expected to occur, is also a consideration and it most often based on the life of the road, traffic and consequence of failure. Primary highway often incorporate frequency period of 50 to 100 years, secondary roads 25 years, and low volume forest roads 10 to 25 years (ERA DDM, 2011). The design life of road is correlated with design life of drainage, both are governed by design procedures, but now a day's especially in Ethiopia the maximum period of life of road and drainage becomes to 5years.

When stream flow records are not available, peak discharge can be estimated by the "rational" method or formula and is recommended for use on channels draining less than 50 hectares (200 acres):

2.6. Maintenance of Drainage Structures

The side drain ditch is full of garbage and sediment at many places which obstruct the normal flow of water in the channel and causes air pollutions to the surrounding areas and disease such as diarrhea, ameba and related problems to the peoples. This critical situation was severely aggravated because the drainage system of the towns not fully operated and the existing drains blocked with huge amount of garbage, solid waste, silt sand accumulation and vegetation.

2.7 Hydrology Analysis

Hydrology for the purpose of this research will deal with estimating flood magnitudes as a result of precipitation. In the design of drainage facilities, which are designed to control volume of runoff, like time of detention facilities, or where flood rooting through culvert is used, the entire discharge hydrograph will be of interest. The analysis of the peak rate of runoff, volume of runoff, and time distribution of flow is fundamental to the design of drainage structures. Errors in the estimates will result in a structure that is either undersized and causes more drainage problems or oversized and costs more than necessary. According to ERA drainage design manual 2002, the hydrologic analysis for a drainage structure, there are many variable factors that affect floods. Some of which need to be recognized and considered on an individual site by site bases include:

- Rainfall amount and storm distribution;
- Catchment area size, shape and orientation;
- Ground cover;
- Type of soil;
- Slopes of terrain and stream(s);
- Antecedent moisture condition;
- Storage potential (overbank, ponds, wetlands, reservoirs, channel, etc.); and
- Catchment area development potential

2.7.1 Rainfall Intensity

The rainfall intensity (I) is the average rainfall rate in mm/hr for duration equal to the time of concentration for a selected return period. Once a particular return period has been selected for design and a time of concentration calculated for the catchment area, the rainfall intensity can be determined from intensity-duration-curve of ERA drainage manual. The relation between storm duration, storm intensity, and storm return interval, is represented by a family of curves called the intensity-duration-frequency curves, or IDF curves. Quantification of rainfall is generally carried out using Return Period maps and intensity-duration-frequency

(IDF) curves (Chow et al., 1988). Various rainfall contour maps developed to provide the design rain depths for various return periods and durations (Hirschfield, 1961). The IDF relationship is a mathematical relationship between the rainfall intensity, the duration, and the return period (the annual frequency of exceedance).

The rain fall intensity (I) is the average rainfall rate in mm/hr for a particular basin or sub basin. A 25year daily maximum rain fall and annual number of rainy days are obtained.
The relationship b/w rainfall duration and intensity is graphically expressed by IDF (intensity duration frequency) curve as shown on the figure 26.

2.7.2 Determining hydraulic capacity of the channels

2.7.2.1 Using Manning's formula

The most widely used formula for determining the hydraulic capacity of the channels for gravity and pressure flows are Manning's formula and it is expressed by the equations of:

$$Q= VA =1/nS^{1/2}R^{2/3}A$$

Where, V= mean velocity of flow, m/s

n= manning's roughness coefficient

R= hydraulic radius

S= slop of energy grade line, m/m

Q= rate of flow, m^3/s

A= cross sectional of area flow, m^3

Discharge is determined for a known opening size of the drainage structure and bottom slope and/or the size of the drainage structure is determined for a known discharge and bottom slope by trial and error method. The Manning's equation can be used for uniform flow in a drainage, and stream channel, but the Manning's roughness coefficient needs to be considered variable, dependent upon the depth of flow. The Manning's equation is used for calculating the cross-sectional area, wetted perimeter, and hydraulic radius for flow of a specified depth in a pipe of known diameter and/or stream channel cross-section. Manning's equation is applicable for constant flow rate of water through a channel with constant slope, size & shape, and roughness.

2.7.2.2 Using Rational Method or Peak Discharge

Rational method is particularly useful if local stream flow data do not exist (Keller and Sherar, 2003). For hydraulic designs on very small watersheds, a complete hydrograph of runoff is not always required (David, 2007). The maximum, or peak, of the hydrograph is sufficient for design of the structure in question. Among a number of methods for estimating a design discharge, the rational formula is an empirical formula relating runoff to rainfall intensity. According to ERA drainage design manual 2002 and AASHTO 1990, the rational formula is most accurate for estimating the design peak discharge for small catchment areas of up to 50 hectares ($0.5km^2$).Actual runoff is far more complicated than the values that are calculated by rational formula.

Rainfall intensity is seldom the same over an area of appreciable size or for any substantial length of time during the same storm. Even if a uniform intensity of rainfall of duration equal to the time of concentration that occurs on all parts of the drainage area, the rate of runoff would vary in different parts of the area because of differences in the characteristics of the land surface and the non-uniformity of antecedent conditions. However, for this thesis, the same characteristics of the land surface and uniform antecedent conditions are considered. Under some conditions, maximum rate of runoff occurs before all of the drainage areas are contributing. Temporary storage of storm water routing toward defined channels and within the channels themselves accounts considerable reduction in the peak rate off low except on very small areas. The error in the runoff estimate increases as the size of the drainage area increases.

Due to these facts, for this thesis the rational method is not used to determine the rate of runoff for large drainage areas. For the design of highway drainage structures, the use of the rational method should be restricted to drainage areas up to 50 hectares in Ethiopia. Hence, for this thesis the maximum value of the catchment area, 50 hectares, is considered and the formula used for the rational method (DDM, 2001) is:-

$$Q=CIA.$$

Where, Q=discharge (m^3/s)

C=runoff coefficient

I=rainfall intensity (mm/hr)

A=catchment area (ha)

Depending on the above formulas, Peak discharge expressed as the quantity (Q) of flow in cubic meters per second (m3/s) is the peak discharge that highway drainage structure is sized to handle. Peak discharge is different for every storm and it is the highway engineer's responsibility to size drainage facilities and structures for the magnitude of the design storm and flood severity. The magnitude of peak discharge varies with the severity of flood events which is based on probability of exceedance.

2.7.3 Catchment Area

Catchment area can be determined from topographic maps and field surveys. For this thesis the catchment area is determined from topographic map of the study area. For large catchment areas, it is necessary to divide the area into sub-catchment areas to account for major land use changes, obtain analysis results at different points within the catchment area, or locate drainage structures and assess their effects on the flood flows. For this thesis, a field inspection of existing or proposed drainage systems has-been made to determine if the natural drainage divides have been altered. These alterations could make significant changes of the size and slope of the sub-catchment areas. However, it is obtained that the alterations do not occur.

CHAPTER THREE

3 . METHODOLOGY

3.1 Study Setting Area

Ambo town is located in the West Shewa Zone of the Oromia Region, west of Addis Ababa, this town is between latitude of 8°49'19" N - 8° 59'44" N and longitude of 37°48'59"E - 37° 55'44" E an elevation of 2101 meters. Relatively Ambo city is located 112kmsfar away west of Addis Ababa, 60kms North West of Weliso and 12kms East of Guder city. The area under administration of the city including the adjacent proposed expansion areas is reckoned to be about 8587.58 ha (85.87km^2). It is one the largest town of oromiya regions and geographically it is flattened and sloppy surface.

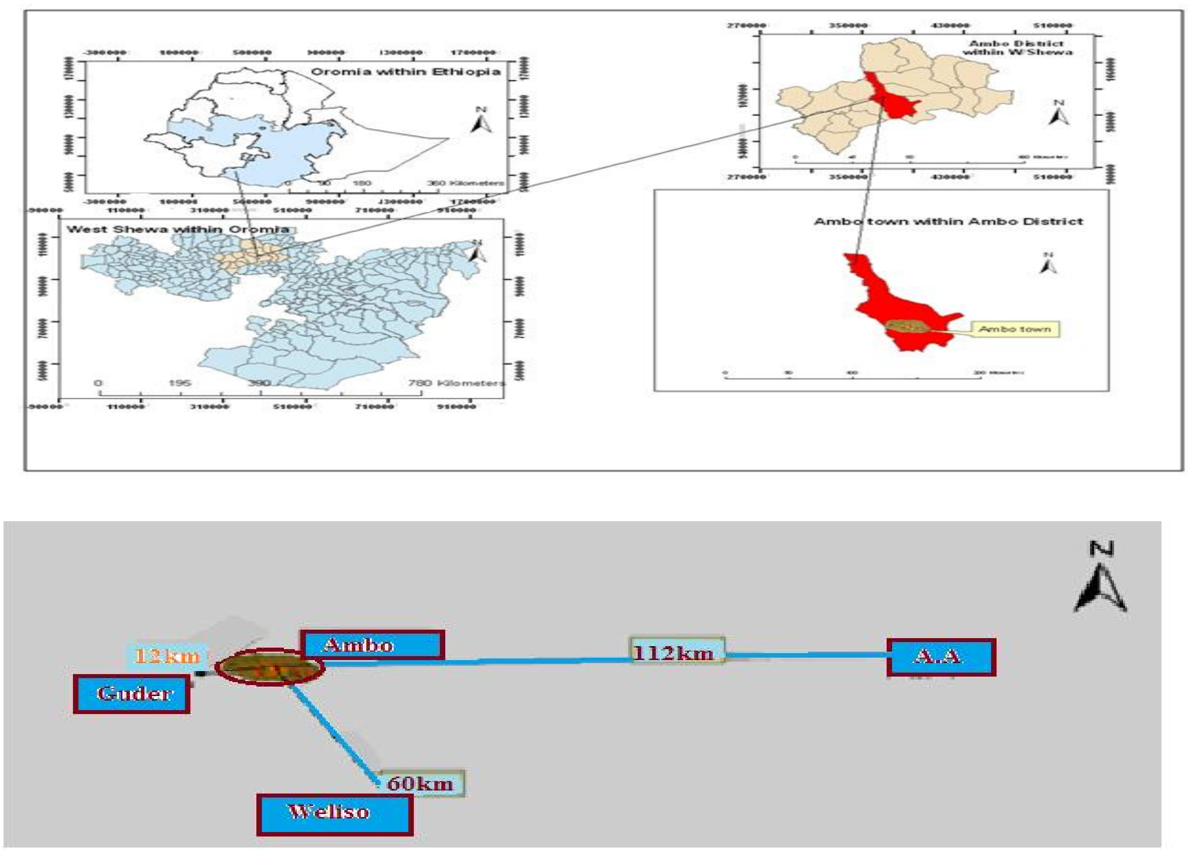

Figure-3 Ambo town Map and Location

Both descriptive and exploratory types of research methods were employed. The descriptive type was used to describe the condition of the drainage failure, surface water and erosion of drainage facilitates. Whereas, the exploratory type was particularly used to explore the existing condition by making some required physical measurements and compare with standards.

3.2 Study Period

The study was conducted from April *to* August 2016G.C for collected data's and analysis. Within the specific period of time, the required research plans preparation of data collection sampling, evaluation, writing up and finally dissemination is executed.

3.3 Study Design /Data Types

Qualitative as well as quantitative data type was employed. The major research data's was collected from primary sources as quantitative with the help of surveying field measurements, and site investigation. To achieve the research an objective, the study was addressed the practical problems/Applied researches. Whereas the minor data's was collected from secondary data sources of qualitative such that, questioner and interview, reference books and related data's.

3.4 Data collection method

Two data collection methods were employed at case study place for the studied are:-.

1. Questioner and interview was employed to collect data's related to flood and wastes from the residents by prepared data sheet for recorded the information's as shown the table on Appendix-3 about types of failure, Magnitude of the problem caused by surface water and erosions, Causes of the failure and Problems related to health's and actions taken by concerned bodies.

For the selections of the problems related to the failure of drainage structure and human health's, the data sheets prepared as below and filled by the peoples near to the areas of case study for sample was expressed the problems related to closed drainage and exposed to diseases and lack of maintenance leads the directions of flows to their residences.

2. The site investigation and field survey measurement was done using surveying equipment such as meter and leveling to determine the slope and capacity of the drainage.

3.5 Sampling Size and Procedure

The sampling procedures are taken:-

- By site inspection of the drainage systems of the town which was poor and affect the drainage system due to lack of flow of water control during rainy season.
- By using the leveling instrument, checked the slope of side drainage of the surface water.
- A sample unit peak discharge and hydraulic capacity calculated as the sample unit velocity multiplied by area. In this research, the sample size or a discharge of sample units (Q) that were inspected in drainage structure was computed using a formula (eq1 and eq2) that provide a statistically adequate estimation of 95% confidence level of the discharge.

Eq1) $Q = CIA$

Where, Q=discharge (m^3/s)

C=runoff coefficient

I=rainfall intensity (mm/hr)

A=catchment area (ha

Eq2), $Q=1/n*S^{1/2}*R^{2/3}*A$

Where, n= Manning Roughness Coefficients,

S= Slopes of the drainage

A= cross sectional area of the drainage

R=Hydraulic mean

- Identify the main cause of damage of drainage at the selected area.
- Check the drain suffered from low capacity, natural siltation, and absence of inlets,
- Indefinite drainage outlets, and lack of proper maintenance and over and above disposal of solid waste into the drain from residential.

3.6 Data quality assurance

The data's which collected the related to the drainage failed of this road is quantitative and qualitative. The collected data and results was analyzed and interpreted to evaluate the major factors affecting the drainage structure related to engineering solutions. The selected study areas in ambo town which is failed before reached the construction period was need further investigation.ERA manual of drainage is also the guidance for quality assurance. The purpose of the study was clearly described to each organization and concerned body.

3.7 Data Collection Process

3.7.1 Selection of drainage section

Selection of drainage sections for the study had to be conducted by an objective process that would allow discrimination among the different drainage failure to be studied. The failure found in the sample unit is used to calculate the hydraulic capacity and peak flow(Q) for the sample unit inspected. The discharge of the sample unit in the section are then used to represent the condition of the entire section of the drainage. This project is a field study of a length of 112km.

3.7.2 Drainage condition survey

Type and severity of failure was assessed by previous studies and literatures on the subject matter, visual inspection of failure of structure and the quantity of each distress was measured. In this study, both data types, quantitative and qualitative data types were collected manually on the field survey from April to August 2016G.C. During the data gathering of the study, the drainage was defined by breaking in to classes and then in to Sections based on functional classification, type, dimensions, and construction history as stated in different literatures. Some drainage inventory data such Open concrete, closed concrete, open masonry and earthen of each section were gathered through field observation.

Table- 1 Drainage types of the town

No	Type of drains	Unit	Quantity
1	Open Concrete	Km	6.61
2	Closed Concrete	Km	3.97
3	Open Masonry	Km	8.00
4	Earthen	Km	92.64
Total			**111.22km**

After drainage inventory data collected and organized for each section of the drainage segment, the lay out plan of the drainage segment was prepared for inspection of failure in the study area.

Figure-4 Surveying data collection

The drainage failure survey was conducted through visual inspection and surveying instrument to identify types of failure and estimate their severity levels and to quantify the identified one through calculations. The measurements for each identified and estimated level of failure carried out by direct measurement method using linear measuring instruments and QSWAT software. The quantities of inspected severity level and failure were recorded. The data was collected by leveling instrument and meter on the flexible pavement of cross fall and drainage to evaluate the existing design data.

3.7.2.1. Topographic feature

The topography of Ambo town is irregular and it is surrounded by a chain of terrain and It has a moderate climate and its dominant soil type is black cotton (vertisoil). From all of the terrains storm water drain (flow) down to the town through different streams and channels. It become highly deforested that makes storm water (flood) generated within them to erode the bank of the river and stream and surface soil forming new water way (gorge).

There are much of natural water ways passing in the town and near adjacent of the town which is used to convey storm water (flood) and discharge to the last outlet Abay River. The perennial river in the town is Huluka. This river is flows to North West of the town conveying storm water from terrain of southern part and there are also many intermittent streams and gorges that receive runoff from inlets and convey the runoff to some point where it is then discharged into these river

As town is located on the Shewa plateau land, most of the existing built up areas of the town is almost gentle slope if properly constructed the drainage structure & undulated while some hill slope and mountain are also seen in the town. But due to the construction and low analysis related to flows the failure was happened on the drainage structures. Concerning the altitude of the town, the town's altitude ranges from 1872 to 2362 above mean sea level. Most of the proposed expansion areas are characterized by flat, gentle slopes and undulated plains towards the directions of eastern, Northern and southern and needs less treatments during constructions of drainage structures. But some of the slopes in the Western direction have higher slopes.

3.7.2.2. Rainfall

Rainfall is the most common factor used to predict design discharge. Unfortunately, due to the many interactive factors involved, the relationship between rainfall and runoff is not all that well defined. Intuitively, engineers know and studies confirm, that runoff increases in proportion to the rainfall on a drainage basin. Highway design engineers are cautioned about assuming that a given frequency storm always produces a flood of the same frequency. There are analytical techniques for un-gaged watersheds that are based on this assumption. A statistical analysis of extensive past rainfall records should be made before such a correlation is accepted. Rainfall event characteristics which are important to highway drainage design are:- Intensity, Duration, Frequency, Time Distribution, Storm Type, Storm Size and Storm Movement. (Highway Design Manual May1, 2001)

Accordingly, the total mean annual rainfall of Ambo town is about 823.13mm. The highest rainfall concentration occurs from June to September. Thus Low infiltration of rain Water, storm water occurrence, and inundation of Low gradient areas and incidence of sheet and gully erosion are some of the problems in the town & surrounding areas.

Table -2 Monthly Rainfall

Year	**Monthly Rainfall(mm)**												**Mean Annual RF**
	J	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	
2004	8.4	0.3	39.5	12.5	69.2	59.8	173.9	129.9	95.9	119.2	1.3	1	59.2417
2005	0	0	9.3	51.5	93.7	121.2	186.4	191.6	135.4	84.1	20.7	14.8	75.725
2006	5.6	12.5	60.5	70.4	186.1	148.5	219.8	243.1	110.5	41.8	5.4	11	92.9333
2007	78.7	16.9	55.6	56.3	51.9	177.6	162.5	130.2	40.3	3	0	17.8	65.9
2008	32.9	99.3	55	179.1	9.4	209.5	134.2	142.7	78.4	9.3	1.2	16.4	80.6167
2009	38.7	16	30.2	108.7	26.8	137.1	203.6	210.7	134.9	19	0	9.6	77.9417
2010	25.2	0	86.9	47.5	67.7	166.3	158	187.2	98.4	19	12.4	0	72.3833
2011	0	16.7	150.7	65.1	157.7	109.9	196.8	298.6	76.5	17.9	18.8	0	92.3917
2012	49.3	36.8	40.2	38.9	130.9	275.2	232	310.1	187.5	11	0	0	109.325
2013	0	0	1	18.7	157.3	161.8	308	260.2	84	64.8	101.8	2.7	96.6917
Mean Monthly Average RF	23.88	19.85	52.89	64.87	95.07	156.69	197.52	210.43	104.18	38.91	16.16	7.33	823.135

The monthly average rain fall and monthly average temperature of the ambo town recorded in meteorological agency is at the month of July and April (Ethiopia Meteorological Agency, Addis Ababa).

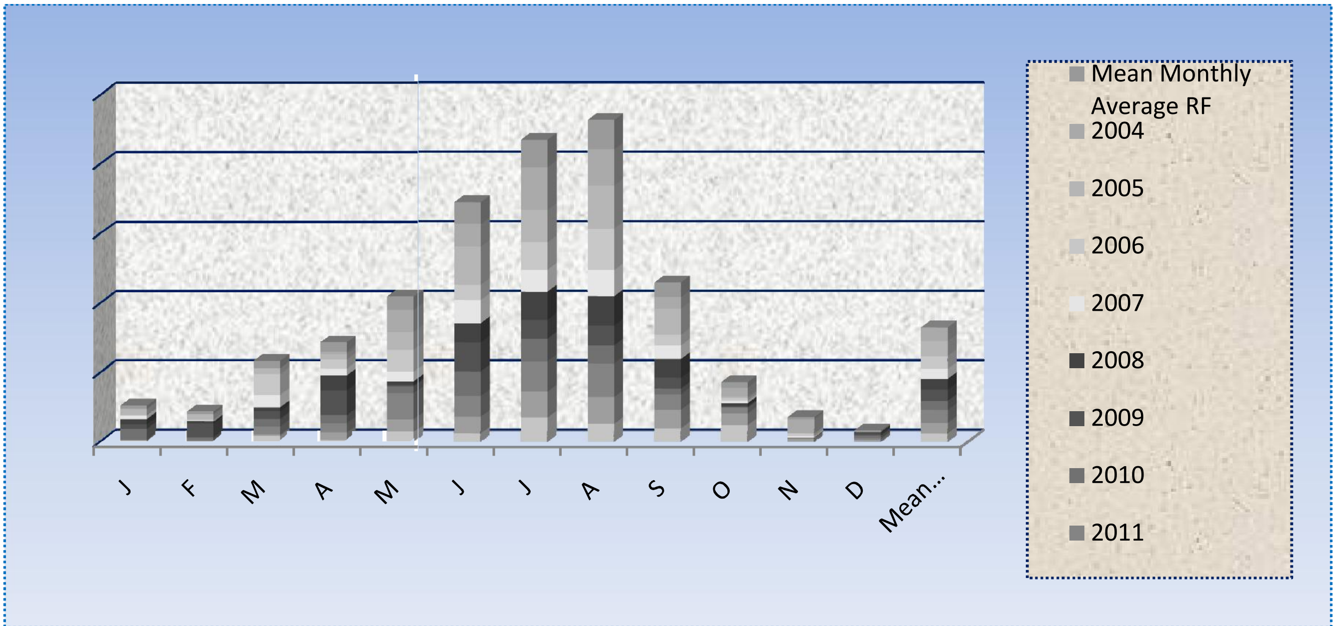

Figure-5 Graphical representation of rainfall

3.7.2.3. Soil Type

The soil types encountered in Ambo town and their surroundings which are identified by geotechnical engineering departments are red clay, black cotton, sandy silts and silty clays. But the dominant type of soil in Ambo town and its surrounding area is black cotton soils. Black cotton Soils which are dark, usually occupying vast areas that are water logged during the rainy season and shrinks & has deep cracks in dry season. The black cotton Soils covers the gently slopes in the southern, eastern and northern part of the town. The impacts are gully erosion, land degradation, road destruction, cracks when dry which can damage building, very sticky and plastic when wet that hinders driving vehicles and walking on the road. The salty clays and sandy silts mainly cover the central parts of the town. They usually occupy topographically flat parts of the town.

3.7.2.4. Water due to infiltration (qi)

This is the amount of surface water that infiltrates into the pavement structure through cracks in the pavement surface. It is extremely difficult to calculate this amount of water exactly, since the rate of infiltration depends on the intensity of the design storm, the frequency and size of the cracks and/or joints in the pavement, the moisture conditions of the atmosphere, and the permeability characteristics of the materials below the pavement surface. The Federal Highway Administration recommends the use of the following empirical relationship to estimate the infiltration rate:

$$q_i = Ic\left(N/W + Wc/WCs\right) + Kp$$

Where, qi = design infiltration rate (ft3/day/ft2 of drainage layer).

Ic = crack infiltration rate (ft3/day/ft of crack); Ic =2.4 ft3/day/ft is recommended for most designs, but with local experience this value may be increased or decreased as necessary.

Nc = number of contributing longitudinal cracks or joints; N + 1 for new pavements.

Where N is the number of traffic lanes.

Wc = length of contributing transverse cracks (ft).

W = width of granular base or sub base subjected to infiltration (ft).

Cs = spacing of the transverse cracks or joints (ft); a value of 40 has been suggested for new bituminous concrete pavements, but local experience should be used.

Kp = rate of infiltration (ft3/day/ft2), coefficient of permeability through the Un cracked Pavement surface.

Depending on the above determinations, the infiltration rates of the town is very low and the amount of surface water and erosion is increase due to low of storm, the frequency and less size of the cracks and/or joints in the pavement, and low permeability characteristics of the materials below the pavement surface.

3.7.2.5.. Existing Roads

Roads are classified mainly according to the road type as asphalt, gravel, red ash, cobblestone and earthen road. The roads have been allocated to one of the four categories described above. The categories are: Asphalt, Gravel, Red-ash, Earth and Cobblestone we made a site measurement at each Kebele of totally 139.19km. The inventory in the central part of the city has good accessibility, alignment and proximity. But their width is not enough to support vehicular circulation. The dominant road width is 3m, however their qualities and condition is poor and the network has suffered from junction and pedestrian walkway problems. And the total drainage structure problems along all categories of road are different. Specially gravel road and earthen road have taken more length than the rest types of roads and causes the problem of erosions due to closed by wastes from roads.

Table - 3. Road inventory of the town

No	Road Category	Unit	Length
1	Asphalt	Km	2.4
2	Gravel Road	Km	104.8
3	Cobblestone	Km	4.628
4	Red Ash road	Km	9.919
5	Earthen Road	Km	17.44
	Total		**139.187km**

- This data includes the asphalt roads within the municipal boundary that are Owned by the Ethiopian Roads Authority (ERA).

3.7.2.6. Drainage issue

Ambo town drainage problem is dominantly due to urbanization that change land surface characteristic without proper coverage of drainage line and construction problems in addition to waste water, sedimentation and debris. Many serious construction problems arise because important drainage and water-related factors were overlooked or neglected in the planning and location phases of the project. With proper planning, many factors can be avoided or cost effective solutions developed to prevent extended damages. Such factors include: Soil erosion, Sediment deposition, Drainage and landslide, Timing of project stages, Protection of irrigation systems and continued use during construction, Protection of streams, lakes, and rivers; and Protection of wetlands.

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

According to the existing drainage design, the bottom width, depth and slopes especially at the areas where the case studies, it doesn't considered the standards of the ERA drainage design manual as practically taken the exact field measurements from the sites. But there is no probability of flood hazard and water stagnation problem from the adjacent recharging catchment area of storm water due to that many stream and channel flow in the town by receiving runoff from inlet and convey to the Huluka River. But storm water runs over roads, rooftops, and compacted land poses a hazard to a habitats property owing to the increase in water velocity and volume for surface runoff water. Failures and severe distresses were observed on the road surface and drainage structure

As drainage design manual procedure, Sidewalks should be provided along both sides of urban collector streets that are used for pedestrian access to schools, parks, shopping areas, and transit stops and along all collectors in commercial areas. In residential areas, sidewalks are desirable on both sides of the street, but should be provided on at least one side of all collector streets. The sidewalk should be situated as far as practical from the traffic lanes, usually close to the right-of-way line.

Clear sidewalk width should be at least 1.2 m in residential areas and range from 1.2 to 2.4m in commercial areas. But on the major road of Ambo town, especially on the selected area of case studies is the residential area and the clear width is 1m and it does not covered by asphalt or concrete during a construction of the road, so this contribute for failure of drainage by increasing soil dampness and siltation coming from upper stream those close the drainage structures. Due to that the drainage is filled by sedimentation of the soils, the water back to the road and contributes to the failure of the road, block traffic flow and peoples.

Other factor that aggravate drainage problem in the town is;

- Flooding and stagnation of water because of low laying area especially in kebele 3
- Flooding caused by negligence to clean ditches and construct flood protection structure
- Disposing of solid waste in open ditch and natural waterway.
- Overflow of ditch and flow channels during high rainy time.
- Land degradation e.g. around 01 kebele
- Deterioration of existing ditch.

3.7.2.7. The total Slope of the land surface of the town

From the slope map below the land surface terrain of the majority part of the surface of the town has slope gradient less than 20 percent. The slope classification of Ambo is largely dominated by terrain with flat to undulating and steep slopes. Eight slope classifications are considered here to identify areas, which are appropriate and which are difficult for built up environments. From different urban experience under normal conditions, urban areas with slopes greater than 20% are not recommended for construction activities. However, this situation doesn't be taken as a rule in the case of Ambo town. In the case of Ambo town to have a wide area for construction purpose slope up to 35% can be taken as a maximum limit of elevation.

Slope with less than 2% is highly dominated in eastern & northeastern parts of the town. These are areas, which are prone to flood inundation and are not recommended for construction purposes. But slopes with 15%-60% are dominantly found in the northern, western and northwestern parts of the town. Slopes with 20%- 60% cover small area in the town where as slopes beyond 2% up to 20% cover the majority areas of the town as shown the figure below.

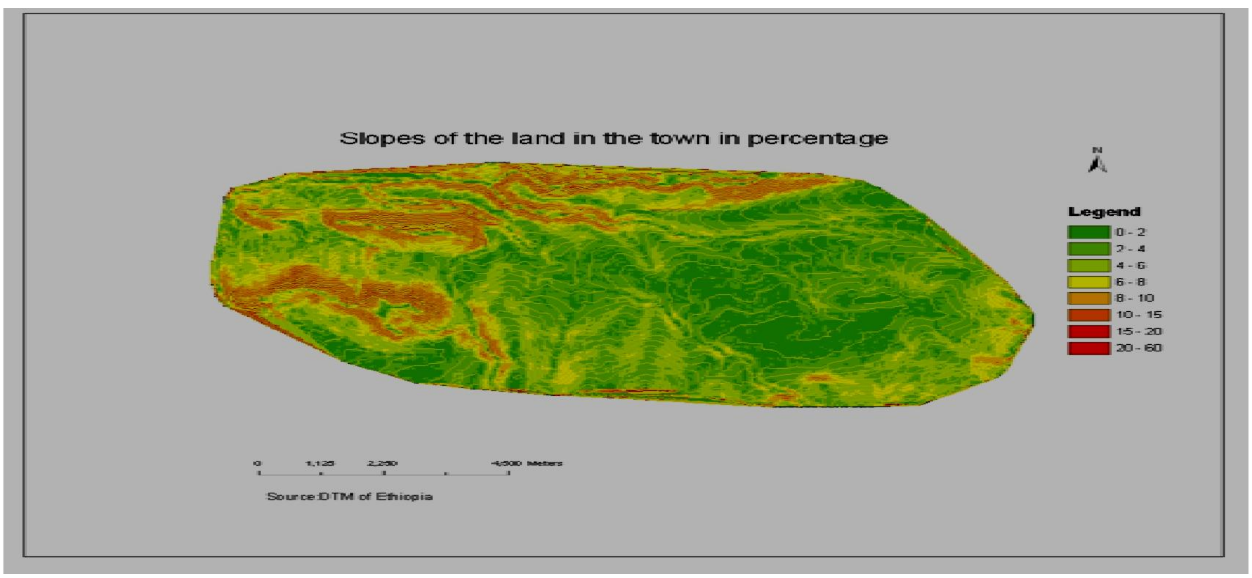

Figure- 6 Map of the Slope of the Land Surface

3.7.2.8. Drainage systems

The town is drained by Perennial and seasonal rivers and streams. The town is found within the Abay drainage basin, and it is particularly drained by major rivers Huluka. A number of intermittent or seasonal streams are found within the catchment area .The rivers and streams drain to the major Huluka river in the surrounding area of Ambo and Huluka river drains Westward to Guder river and finally Guder river drains to Abay river and the drainage system is therefore under the Mediterranean drainage system. The discharges of the streams are relatively small or no during dry seasons, where as the volume of these rivers / streams drastically increases during summer season (June - October) and inundates the low gradient areas close to their banks. Therefore, it is recommended that adequate buffer zone should be reserved along the riverbanks.

Figure-7 Waste waters drain to Huluka River

Urban waste water and storm water management is vital to sustain healthy and safe living environments. The existence and occurrence of waste water and storm water are expected as the natures of urban activities allow them to happen. The lands escape the city established on critically determines the prevalence of storm water runoff and the way the drainage structures are designed.

Ambo city topographically slopes down toward North West. The city is highly susceptible to flood hazards due to the high volume of rain water that originates from the elevated zones. There is no drainage infrastructure and sewer lines for the urban waste water and storm water in the city except very few road side opened stone masonry and earthen ditches constructed by the municipality.

Residents are observed to splash household waste water from domestic use along the nearby road sides the drainage structure development for the city should require an approach to deal with because the situation in Ambo city is beyond thinking road side drainage development.

Drains are only provided adjacent to roads. Those adjacent to asphalt road are mainly covered, and are either pipes or masonry channels. They are found either on one or on both sides of the road, depending on the width of roads.

Drains adjacent to gravel roads are earthen drains or rectangular shape stone masonry. Ambo is currently converting a few numbers of roads to cobble stone road and these have masonry drains on both sides of the road.

3.8 Data Processing

The general flow of data processing systems are described by two methods

1) QSWAT software
2) Leveling instrument

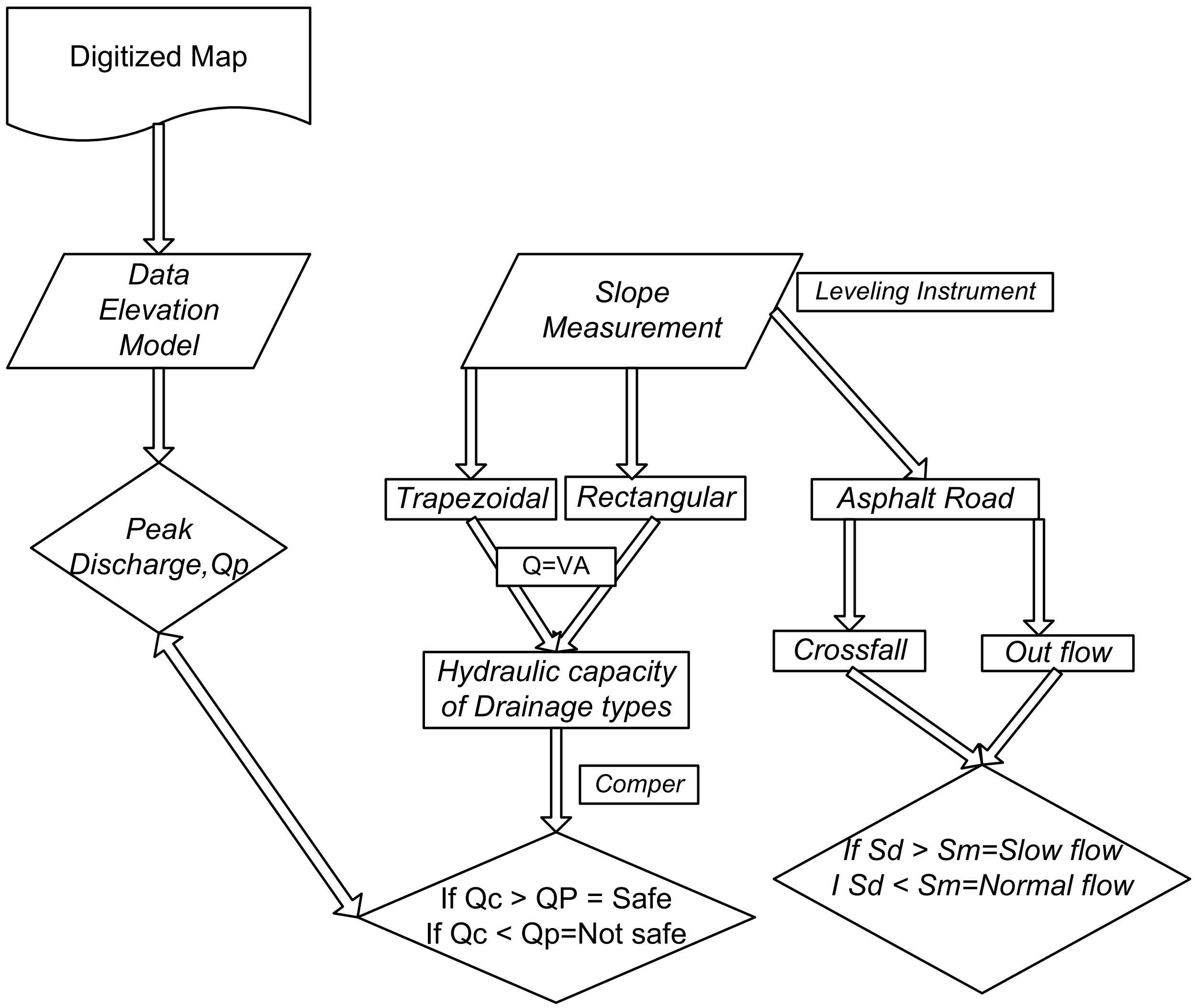

Figure- 8 Flow chart of leveling instrument and QSWAT

3.9 Problem Identifications

The problem of drainage structure failure was identified by three cases of site investigations used to identify the types of failure, by QSWAT software used to determine and camper the actual peak discharge and hydraulic capacity with existing conditions and by leveling instrument and meter is used to determined the slope for flow and the actual measurements

3.10 Data Analysis

- After successful collected, arrange the data according the context of the research and analysis the data using the QSWAT.
- From the result, analyzed all the factors affecting drainage structures.
- Determined and examine the factors according to their magnitude of their effect and according to their urgency.
- The collected data from different sources and results were analyzed and interpreted to charts, graphs, figures and table formats.

3.11 Causes of Drainage Failures

The early detection and repair of defects in the drainage will prevent minor failures from developing in to a drainage failure. The identification of the failure aids the engineer or maintenance professional in identifying what caused the failure and the required approach in repairing it. Crack and other defects start appearing during the rainy season when the soil load is increasing.

For the structure failure inspections, the inspector walk over each sample areas, measure the slope of existing drainage and areas to identify the failure type and severity, and records the data on the drainage structure failure inspection to indicate the level of failure. To understand which repair to choose, it is important to understand the failure that occur in drainage. Assessing the condition of drainage by visual observation and recording the types of the failure on the drainage structure, including the elements to assess the situation visually as: Causes of failure and severity of failure

The followings are the major causes of failures observed in the study area during the field survey.

3.11.1. Drainage Filled with debris and siltation

Figure-9 Drainage side failure

Figure-10 Drainage filled with wastes

Figure-11 Dimension problem

3.11.2 Surface water and erosion problems

Figure-12 Road surface water

Figure-13 Road Side drain

Figure-14 Over flow

3.11.3 Soil dampness and road side failure

Figure-15 Soil over load

Figure-16 pavement edge raviling

Figure- 17 Soil covered area

Figure-18 Cause of erosion

3.11.4. Lack of maintenance

Figure- 19 Poor maintenance

Figure-20 Failure of manhole

Figure-21 Closed culvert

3.11.5 Ponding of water and inlet problems

Figure-22 Ponding of water

Figure-23 Inlet problem

3.12. Environmental pollution

When it was observed that, liquid wastes released to the storm water drainage ditch & streams from some residential buildings which affected the proper functioning of the drainage structures and creating environmental pollution. Some drain ditches are also covered totally with grasses and shrubs and thus not giving the desired function for which it was constructed.

Figure-24 Drainage filled by wastes and covered by plants

CHAPTER FOUR

4. RESULT AND DISCUSSION

4.1 Causes of Failure and Performance of Drainage Structure

The main objective of drainage design is to allow the runoff of any water with limited damages and disturbances to the road and to the surrounding areas (Guo,J.C.Y., 1999).

The major cause of failure of drainage structure in Ambo town discussed in the previous Chapter is: - Wastes from residential, accumulations of silts and debris and poor workman ships. Related to hydrology like surface water, runoff water and erosions is the contributor to the failure of structures. In the case of Ambo town, more of the drainage structures are blocked and directly cause or contribute to crashes and force drivers to leave their lane. During the summer season, the quantity of runoff increases and decrease the infiltration rate of the rain. The strength of the drainage structure is lost their stability to resist the loads. The lower bearing capacity of the soil at foundation of the drainage structures made un- opening or cracked and leads the drainage structure to a failure.

On the previous experiences in design and construction of drainage structure, the study provides design guidelines for a proper and efficient drainage system that lead to enhance drainage performance and increasing the service life of structures. To increase the performance of drainage structure regular annual evaluation of drainage systems is an important part of maintaining and managing drainage structures.

The drainage structure failure mostly happened in the town is due to the problem of different types of drainage structures which is designed and constructed in the town without proper care of the integrations one from the other. All types of drainage structures doesn't functioned properly for the reason why constructed. Due to that the drainage was closed with debris, sediments and wastes from the side of the road and residents and facilitates the drainage to the failure without reaching the design period. The data's which was collected in the form of questioners and interview from the peoples of the town about the cause of drainage failure, environmental impacts, erosion problems and wastes from residential shows that the concerned bodies does not take an actions to maintain and repair the damaged parts of the structure to protect the problems. In addition, the main causes of drainage failures in Ambo town were; high flood pressure from elevated section of the road, lack of drainage infrastructures, and the interruption of waste water from residential and storm water from the city. The field survey by leveling instrument approved the problem of slopes on drainage structure and asphalt road.

One of the defects of transportation is drainage inlet problems. Drainage inlet is provided according to the condition of flows to protect the road from the accumulation of water and easily to drain water from the road surface. In the case of Ambo, there are no the problem inlet provision but there are wastes and debris found on the inlet structures which blocks the drain of waters to the side drainage and the water accumulated back to the road surface to cause obstacles on traffic movement.

4.2. Determinations of flow according to QSWAT software

QSWAT is a basin-scale, continuous-time model that operates on a daily time step and is designed to predict the impact of management on water, sediment, and agricultural chemical yields in ungauged watersheds. The model is physically based, computationally efficient, and capable of continuous simulation over long time periods. Major model components include weather, hydrology, soil temperature and properties, plant growth, nutrients, pesticides, bacteria and pathogens, and land management. In SWAT, a watershed is divided into multiple sub watersheds, which are then further subdivided into hydrologic response units (HRUs) that consist of homogeneous land use, management, and soil characteristics. The HRUs represent percentages of the sub watershed area and are not identified spatially within a SWAT simulation. Alternatively, a watershed can be subdivided into only sub water sheds that are characterized by dominant land use, soil type, and management.

As shown below on Figure 28 and 29, the determinations of flow was analyzed by QSWAT software's from the DEM of the town by using latitude 8^{o}49'19" N - 8^{o} 59'44" N and longitude of "E - 37^{o} 55'44" E of the town. From the map of the areas, QSWAT determines and locates the flow of outlet, the area of water shade, stream flow and point of sources and the output shown in the Figure 26 and 27 below. This system was used to identify the problems of flow after construction and in order to design the road by considering those elements before construction.

4.2.1 Watershed

Watershed is the area of land where all of the water that falls in it and drains off of it goes to a common outlet, or watershed is an area of land that drains all the streams and rainfall to a common outlet such as the outflow of a reservoir, any point along a stream channel. The word watershed is sometimes used interchangeably with drainage basin or catchment. The Ambo town water basin map shows set of watershed boundaries in the town and draining to Huluka River; these are known as 9-digit hydrologic units (watersheds).

Ridges and hills that separate two watersheds are called the drainage divide. The watershed consists of surface water, streams, reservoirs, and wetlands and all the underlying ground water. Larger watersheds contain many smaller watersheds. It all depends on the outflow point; all of the land that drains water to the outflow points as shown in Figure 29 below the watershed for that outflow location.

The Digital Elevation Map (DEM) were obtained from structural map of the town by digitizing the areas and used as input in QSWAT to delineate water shade as shown below for suitable analysis.

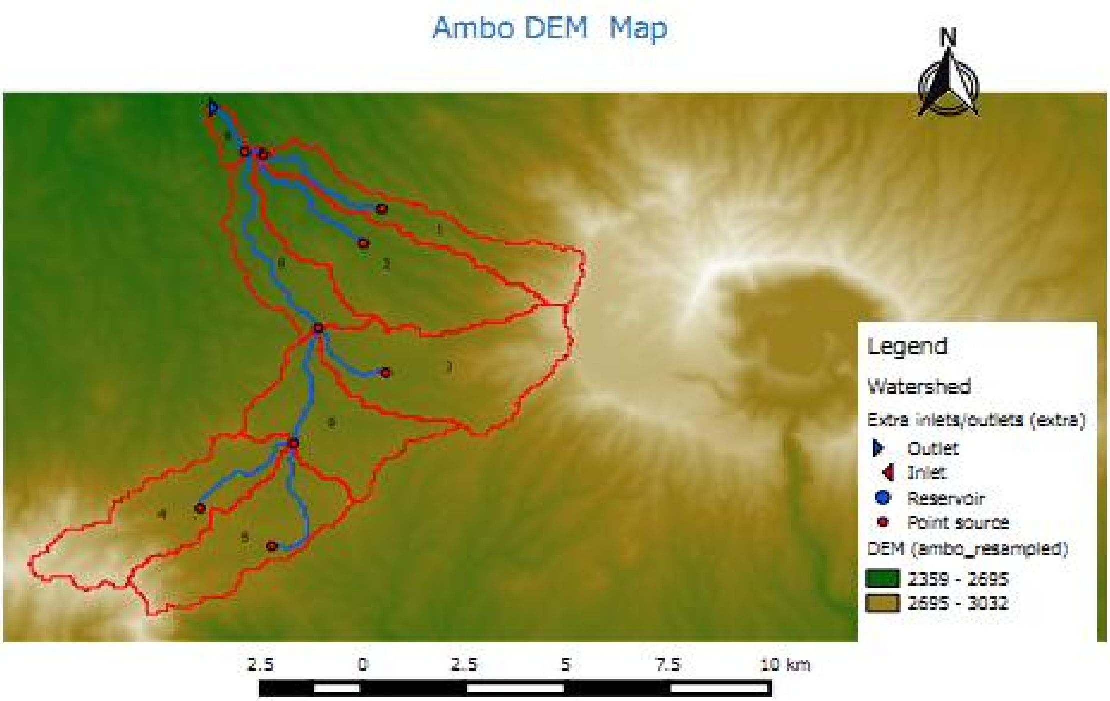

Figure-25 Ambo Digital Elevation Modeling Map

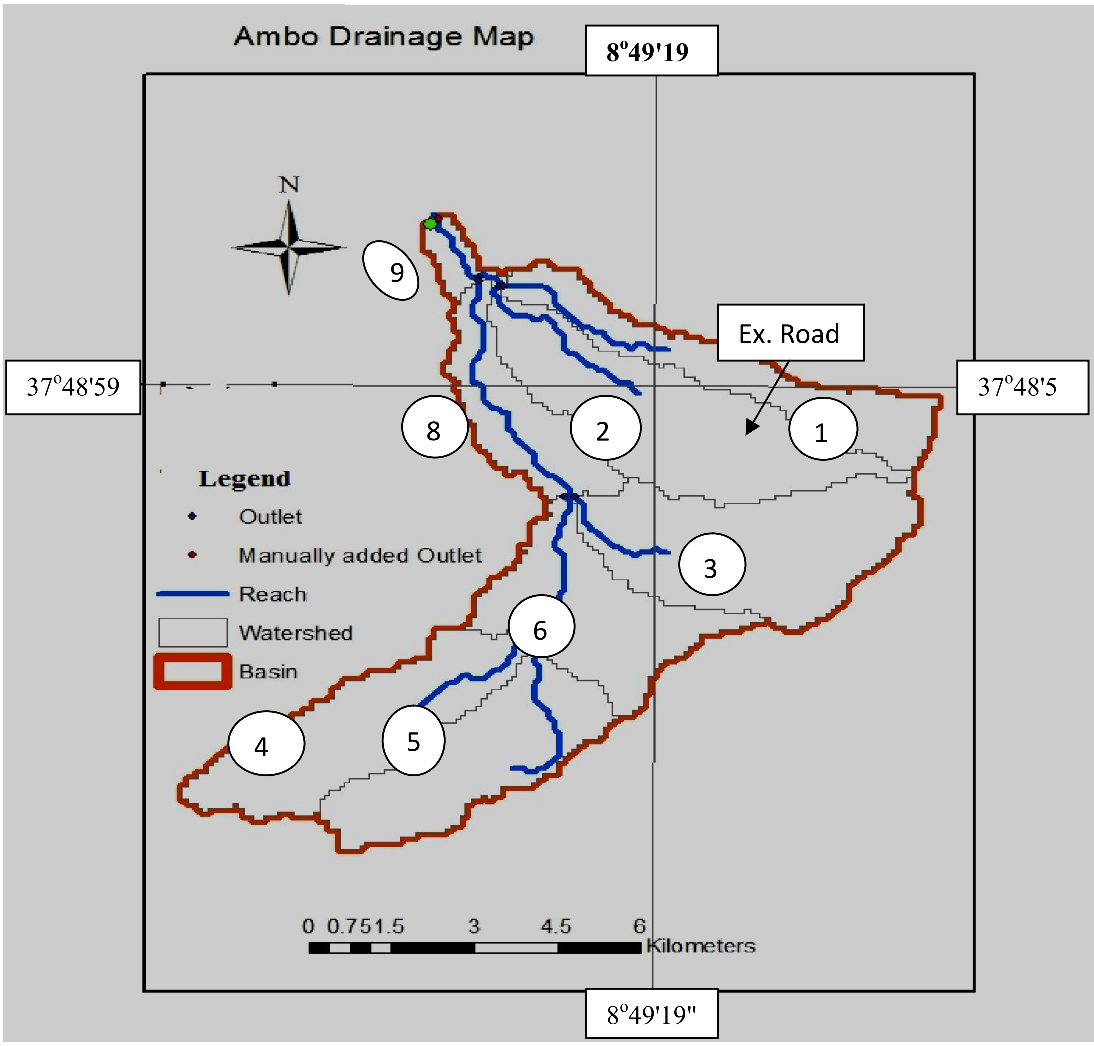

Figure-26 Ambo water basin maps

4.2.1.1 Outlet

An outlet, or pour point, is the point at which water flows out of an area. This is the lowest point along the boundary of the watershed. The cells in the source raster are used as pour points above which the contributing area is determined. By using outlet selection tool in QSWAT, the watershed outlets are defined as shown in Figure 26. The outlets must be located to ensure that the drainage system will be completely free draining for the entire life of the highway pavement section.

Outlets should be provided at the sag of every vertical curve. The spacing of outlets should be determined by hydraulic computation of discharge capacities of the pipe sizes, but the location of outlets may frequently be restricted by the adjacent land elevations and the geometries of the highway

The stream flow, inlet, and outlets were analyzed and compared with the previous existing data's of the town and the locations of the out let was evaluated depending on the number of stream flow of the inlet and area slopes. The existing locations of the drainage outlets were not properly located according to the analysis output of QSWAT guide for drainage outlet.

4.2.1.2. Inlet

These are parts of a drainage system that receive runoff at grade and permit the water to flow downward into underground storm drains. It should be capable of passing design floods without Clogging with debris. The inlets or point of sources from QSWAT analysis result are shown in Figure 27 of stream flow map. In addition to QSWAT software analysis, during the visual inspections of Ambo town highway drainage surface of inlet, the curb-opening type of inlet was constructed to receive runoff from asphalt road and direct drain to the outlet. These inlets are vertical openings in the curb, covered by a top slab and constructed at variable meter lengths. Due to the standard design length of inlet recommended by ERA DDM at every 10ms was not satisfied and blocked by debris, runoff water was back to the road and subject to traffic should be made un safe for the passage of vehicles at summer season.

4.2.1.3. Stream flow

Figure 27 shows Stream flow that receives runoff from point of source and convey the runoff to the river through the outlets. Runoff increases in proportion to the rainfall on a drainage basin.

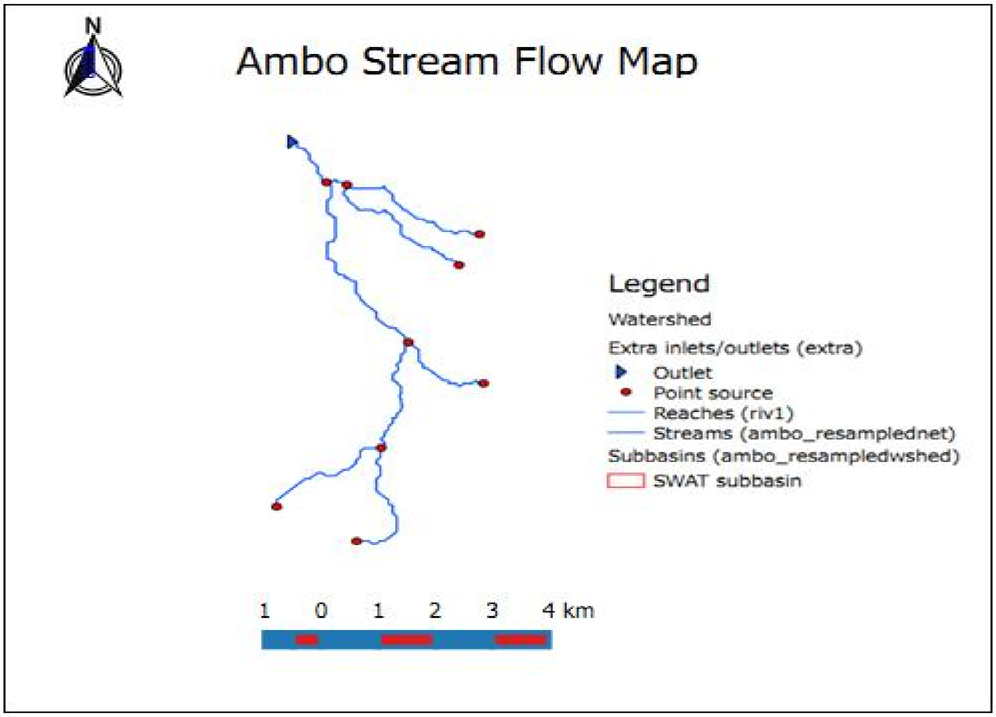

Figure- 27 Stream flow map

In drainage structure design, Water shade and stream flow of the town must have to be considered, which are important factors to drain waters from sub-surface and runoff with adequate and economical provision of structures.The amount of discharge and capacity of drainage were determined from the total area of basins depending on the attribute table.

4.3 Determinations of Discharges

Table-4 Attribute table

Polygon	Sub basin	Area(cm^2)	stream Order	Length	Slope	Width	Max Elevation	Depth
6	7	7090	3	1561	0.035	16.63	2463	0.7148
8	9	4882	2	6096	0.032	13.29	2663	0.6157
0	1	2111	2	597	0.041	8.04	2492	0.4403
1	2	2919	2	3785	0.015	9.76	2722	0.5012
7	8	972	1	3892	0.011	5.05	2763	0.3229
2	3	1038	1	3356	0.014	5.25	2772	0.3315
5	6	1344	1	2612	0.019	6.13	2714	0.3675
3	4	1353	1	4241	0.026	6.15	2603	0.3685
4	5	745	1	3842	0.028	4.30	2601	0.2903
Total Area = 2.2454m²			**Average slope=0.0245**					

- The problems related to discharge and capacity of drainage structures were estimated according to the following procedures:
  1) Analysis of QSWAT software
  2) Existing drainage structure capacity

Runoff coefficient is calculated from the table below

Tabele-5 Types of drainage area and Runoff Coefficient (Source: - US Department of Transportation, 1965)

Type of Drainage Area	**C**
Residential:	
Multi units	0.60-0.75
Sandy soil, flat, < 2%	0.05-0.10
Sandy soil, average, 2 to 7%	0.10-0.15
Sandy soil, steep, > 7%	0.15-0.20
Heavy soil, flat, < 2%	0.13-0.17
Heavy soil, average 2 to 7%	0.18-0.22
Heavy soil, steep, > 7%	0.25-0.35
Streets:	
Asphaltic	0.70-0.95
Concrete	0.80-0.95

According to hydraulic design series of department of transportation, the runoff coefficient is calculated depending on the types of drainage areas as shown the above tables. Accordingly, most of Ambo town coverage areas are residents of multi unit (0.60-0.75), heavy soil steep greater than 7 % (0.25-0.35) and the road type is asphaltic (0.70-0.95) and Coverage of resident in Ambo town is 49%.Thereforethe calculations of runoff coefficient is:-

- ✓ Residential(multiunit)=0.72*1.1*0.49 = 0.388
- ✓ Heavy soil, steep = 0.3*1.1*0.6 = 0.198
- ✓ Asphalt street(the town covered of 10%asphalt) = 0.825*1.1*0.1 = 0.09075

❖ Runoff coefficient weight (Cw) = 0.388+0.198+0.09075 =0.677

- ✓ The Area of the town covers = 8587.58 ha (85.87km^2).
- ✓ The coverage of residential in the town = 49%

4.4. Determination of time of concentration (Tc)

Time of concentrations is the time taken for runoff to travel from the most remote point of the drainage structure.

The empirical equation, which is known by Kirpich equation (1940), was used in this research which considers significant parameters such as the stream and elevation difference through which the surface runoff travels.

$$Tc=\frac{L^{1.15}}{52\,H^{0.38}},$$

Where; Tc = time of concentration

L = Length of stream

H = Level difference in meters between the original stream and the crossing site.

The catchment basin area, A = 2.2454 ha

L = 436.235 m

H = 9.19 m

$$Tc = \frac{L^{1.15}}{52\,H^{0.38}}$$

$$= \frac{436.235^{1.15}}{52*9.19^{0.38}}$$

= 8.987 min

So the rainfall intensity for 25 years return time at 8.987 time of concentration, the rainfall intensity of the channel is 150 mm/hr, , where c = 0.677

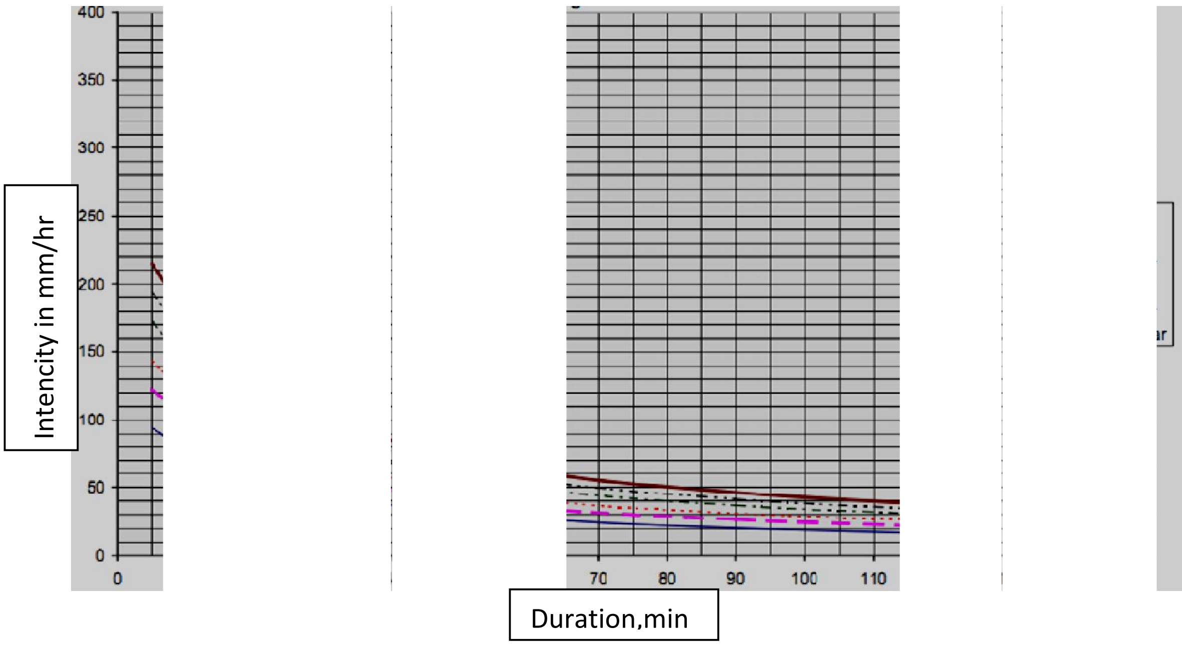

Figure-28 Intensity-duration-frequency curve

1) Analysis of QSWAT software

1.1. QSWAT results for peak discharge

A= 2.2454ha,

I= 150mm/hr = 9m/s (from IDF curve of 25 years return period)

C= 0.677

The determination of discharge by QSWAT was done using rational method (peak discharge) to camper and provides the hydraulic capacity of the drainage structures.

For the design of highway drainage structures, the use of the rational method should be restricted to drainage areas up to 50 hectares in Ethiopia. Hence, for this thesis a maximum of 50 hectares of catchment area was considered. Accordingly, the peak rate of runoff and hydraulic capacities of the channel constructed were computed by the formulae stated and the obtained results.

1.1.1 Rational method (Peak discharge)

Qp = CIA

Qp = 0.677*9m/s*2.2454

= $\underline{13.66 m^3/s}$

4.5 Existing drainage structure capacity

4.5.1. Slopes of existing drainage and Asphalt cross fall

4.5.1.1 Slopes of Existing Drainage

For this thesis, surveying data's were collected by leveling instrument for both trapezoidal and rectangular types of drainage structures at case study of 2km length from asphalt of 2.4km according to road inventory of the town shown above table-3 and the result had confirmed the presence of slope problems of trapezoidal type of structure had shown during the construction period of time. From these measurements, only 800m length of drainage structures have a gentle slope, 500m length of drainage structures drains water slowly due to inappropriate slope and the rest of 700m length of drainage structure have a problem of drain water properly. According to ERA DDM 2001, the bed slopes of drainage structure was determined above 2% to drain the water properly from the drainage structure types but it depends on the topography of the earth. The types of existing drainages in the town are trapezoidal and rectangular which was constructed from concrete and masonry. For the trapezoidal parts of 700m length of the drainage structure which had a problem to drain water properly, slopes were determined by using leveling instrument at each 15m distance to calculate the capacity of the structure. . The result from field survey showed that an average slope of 0.0612 whereas averages slope of 0.0552 was recorded from municipal office of Ambo town.

At the places where the drainage structure failed through the town was mostly happened due to the problem of design and construction. Measurements of the existing drainage structure for trapezoidal shape were done by using meter tape and accordingly the measured depths and widths doesn't considered ERA DDM rule. And also, the trapezoidal structure design collected from municipal office had showed departure from standard.

4.5.1.2. Slopes of asphalt cross fall

The major road in Ambo town had showed the problem of asphalt cross fall slopes while considering cross section property of standard specification. According to ERA Geometric Design Manual (ERA, 2011) the minimum slope of normal cross fall is 3% in order to dispose water from the roadway properly and that avoids infiltration of water into the roadways. During field studies, the measurements had taken the same as for drainage structures (at every 15m for the total of 2km) by using surveying instruments of leveling.

The result had showed that 578m length of pavement have gentle slope which allows the flow of runoff and surface water properly to the side drainage, 1,342m length of the pavement had a problem of cross fall slopes even the water on the road surface flows parallel to the road and 80m of the length of the pavement had out flow slope and drain the water from the road properly. The slopes were measured by leveling instrument from three points of back slope, intermediate slope and foreside slopes for the 2km length used to calculate the slopes from the center of the asphalt to side drainage.

The appropriate design of cross fall of the pavement was used to drain the surface water from the asphalt to the side drainage. ERA 2011 Manual specifies the minimum cross fall slope of 3%. But the existing cross fall slopes had been observed departing from specification of ERA Manual, 2011 which is major factor causing drainage structure damage. The measured data's from field had showed cross fall slope of 2.029% which is less than the standard specification of 3%.

4.5.2 Trapezoidal Shape of Drainage Structure

4.5.2.1. Hydraulic capacity of the existing drainage

- ❖ From Design Chart for open-channel Flow, US Department of Transportation, 1961, specifies Range of Manning Roughness Coefficients in table form and the researcher has used those values.

The types of drainage work grouped under the Dressed stone in mortar and the range between 0.015 to 0.017 and the average of n = 0.016.and

$$Q=1/n*S^{1/2}*R^{2/3}*A$$

Where, n= Manning Roughness Coefficients,

S= Slopes of the drainage

A= cross sectional area of the drainage

R= Hydraulic mean

- ✓ From the actual measurement of the existing drainage of trapezoidal, the measured and calculated values were; A=0.95, P =1.86, R=0.51 and average slope drainage structure =0.0612%.

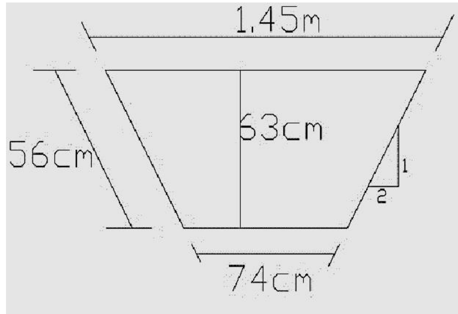

Figure-29 Trapezoidal Drainage types

$$A=y\,(b+2y)$$

$$P=b+2h$$

The hydraulic capacity of the existing drainage structure calculated from the measurements taken by meter:-

$$Q = 1/n * S^{1/2} * R^{2/3} * A$$

$$= 1/0.016 * 0.0612^{1/2} * 0.51^{2/3} * 0.95m^2$$

$$= \underline{\underline{9.359\ m^3/s}}$$

4.5.3. Rectangular shape of drainage structure

The slope of the rectangular types of drainage structure of the town 0.153% is properly drain the water from the surface of the road as the actual measurements were taken from the site as shown below.

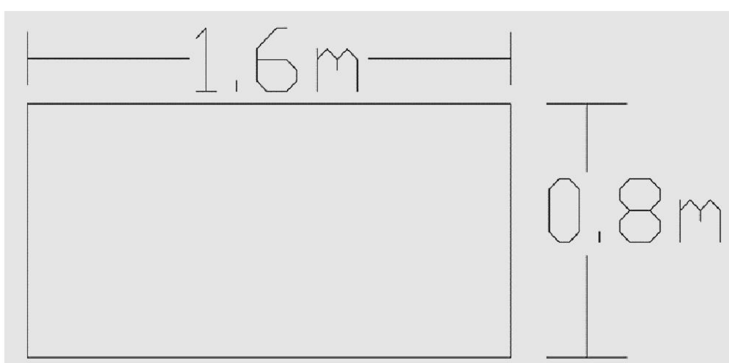

Figure-30 Rectangular drainage type

4.5.3.1. Hydraulic capacity (Manning's formulas) of the drainage

$$Q = 1/n * S^{1/2} * R^{2/3} * A$$

$$= 1/0.016 * 0.153^{1/2} * 0.4^{2/3} * 1.28m^2$$

$$= \underline{\underline{16.89\ m^3/s}}$$

The rectangular type of drainage structure of the town is properly draining the flow of water from the town. According to the calculated values of hydraulic capacity and peak discharge of the drainage structure above (Qc > Qp) which means that the flow of the disposal of water and the capacity of drainage is properly working without causing structural failures. From the constructed side ditches only estimated about 28 % provided with reinforced concrete cover protect the ditches from any garbage.

4.6. Assessment on the adequacy of drainage structure according to determinations of existing structure and QSWAT

Peak discharge and hydraulic capacity of drainage were determined independently for QSWAT estimation and existing drainage structure. In this section both results are checked in correlation in order to assess the capacity of drainage structure whether it drains properly or not.

Depending on the results of QSWAT of Peak discharge (Qp) the design of drainage structure to be constructed to drain the water is approves the safety and service life of structure. In the case of trapezoidal drainage structure, the calculated values of the peak discharge (Qp) by QSWAT is greater than the hydraulic capacity (Qc) of existing drainage structures (**Qp > $\mathbf{Q_c}$**). Depending on these results, it is possible to approve the major causes of drainage structure failure in the town. Accordingly, due to insufficient drainage structure capacity so as to carry the peak discharge, the drainage structure failure caused has been higher. And also, the performance of respective drainage structures was minimized due to greater peak discharge which is beyond the capacity of the drainage structure.

In the case of rectangular drainage structures, the Qc > Qp results had showed that the existing drainage structure is sufficient to carry the peak discharge coming. But, there are problems of visible cracks at the place where the trapezoidal structure joins the rectangular and it needs attention for repair.

CHAPTER FIVE

5. CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The major causes of failure of drainage structure, discussed in this research paper due to site investigated and actual measurements taken from the site by leveling and QSWAT software analysis, the causes for drainage structural failures in Ambo town have seen classified in to four. These are:-

1) Cross section problem
2) Construction problem
3) Water and related load and.
4) Software's analysis problems are the basic ones.

1) **Cross section problems:-**The cross section of the drainage structure problems including depth and width of the drainage structures are not constructed as a rule of ERA manual recommended for the peak and capacity of the structures to carry and properly drain. Slope, Culvert, inlet and outlets and ditches are doesn't properly function during summer seasons due to un proper design and methods of construction loads of the flow of water in the town and the problems of dimensions during the design period.
2) **Construction problems:-**During site assessments of the drainage structure failure in the town, the problems which was identified for the failure of the structures are:-

Locations of inlet/outlet problems, accumulations of wastes from soil excavated and poor workman ships are the causes for the failures and collapse without reached the service life.

3) **Water and related loads: -** waters in the form of erosion, ground water, surface water and runoff water needs a great care for the construction of drainage structures and roads. The failure of the drainage and road can be reduced if the flow of water is controlled properly in the town. The major road in Ambo town caries a heavy load per day due to lack of alternative roads. According to site investigations, the existing width of road in the town is less and also, parking of vehicles at the edge of the drainage structures which contributes a lot to structural failure in addition to soil dampness.
4) **Determinations of software: -** QSWAT analysis of water shade, stream flow and inlet/outlets were important to determine the peak discharge and hydraulic capacity of the

drainage structure of the town. During the constructions of the structures, the concerned bodies and contractors didn't consider the determination of software analysis to relate the discharge of the waters and the capacities of the drainage structures. The results from the QSWAT (Qc>Qp) values were confirmed the presence of problems on the existing drainage structures according to the out puts of peak value and hydraulic capacities.

Generally, the problems caused by drainage structure failed was: environmental impact, back water flow, damaging the land that can be used for other purposes, vehicle congestion and block sidewalks for pedestrian commonly happened throughout the year. Those problems refercе in this research paper and showed all the problems related to the causes of the failure and the solutions with the help of surveying instruments, meters and QSWAT to investigate the major cause of the failure of drainage structure and to for existing drainage structures and conditions of the slope and capacity of the current drainage conditions.

Runoff varies with soil characteristics, particularly permeability and infiltration capacity. If the rainfall rate is greater than the final infiltration rate of the soil (infiltration capacity),that quantity of water which can't be absorbed made runs off the surface. The capacity of the drainage which doesn't considering the estimated quantity of runoff causes the failure of drainage structure.

5.2 Recommendations

To increase the infrastructure facility supply in the city, able to meet the demands of the people in the city including drainage and roads. The primary focus of this paper is on the assessment of the drainage structure failures of the town which is causes the obstacles during the summer season for the people and vehicles and the drainage structures can be applied equally to the social infrastructures (e.g. schools and health centers)..

The concerned authorities are strongly recommended to control and monitor the structural failure of drainage and Environmental problems. On this respect the following measures are recommended.

- Control the construction of materials during construction periods on site.
- Select the quality of contractors during tender time.
- Increase the service life of drainage structure by improving the capacity of structures.

- Collect and put the data's related to the construction like soil types, weather properties like maximum yearly area erosion behaviors and priority for constructions in the town.
- Improvement of surface drainage system layout as per to the master plan of the town and implementing the urban storm water drainage design manual of the country to improve storm drainage systems of the area.
- Developing the skill of QSWAT and QGIS software for planning, analysis and design of storm water runoff and drainage systems in urban areas and monitoring the infrastructures.
- Use of the research study results for further study of other sub catchment of the Ambo town in order to have a standardized and harmonized urban drainage systems.
- Should consider providing a specific budget on an annual basis for both drainage maintenance works, drainage improvement works and for the maintenance/repair of culverts and bridges. They should also aim to employ drainage inspectors who would monitor and report on required drainage maintenance works.
- A program for cleaning out the drainage system is essential and need to clean out open drains and culverts by using manpower or machine. Also existing inlets and outlets of drains need to be cleaned and maintained.

Generally, the drainage structures of Ambo town need maintenance/repair and re-construction to increase the service life of the structure control the surface water from cause's traffic accidents and to safe the human health's. The concerned bodies give the priority rather than other to solve the problems within a short period of time.

REFERENCES

- Fleckenstein and Fwa,1987; Tart, Jr, 2000:Evaluation of the effectiveness of Existing Drainage System
- Wingnall,KendrickAncill and Copson,1999:Highway Engineering hand book 2nd edition
- GetachewKebedeWarati and, TameneAdugna Demissie,2002:Assessment of the Effect of Urban Road Surface Drainage
- vol.1 and 2,2002:ERA pavement design,
- Randolph et al., 1996a; Randolph et al., 1996b;Lindiy and Elsayed, 1995; Kolisoja,et al.,2002; Tandon and Picornell,1998:Determination of Drainage Coefficient of Various Drainage Materials
- Evaluation and analysis of highway pavement drainage ByKamyarC.Mahboub, Ph.D., P.E.
- David P.Orr.P.E, 2003 :Roadway and road side drainage
- Drainage of Highway and Airfield Pavements, Cedergren, harry R, (1974), John Wiley and Sons, Inc.New York.
- DelDOT, 2008 : Road design manual
- Donald Walker,2000 : Local road assessment and improvement drainage manual
- AASHTO, 1993 : Effects of water on the structural support of the pavement system
- Mallela et al., 2000; Richardson and Roberson, 2000 :Considerations in Pavement Drainage System Design and Construction
- ERA, 2000:Drainage manual. Addis Ababa, Ethiopia
- Fabian P.Barry JA,2003 :Urban storm management planning
- Urban drainage design manual (Federal Highway administration, FHWA (1996).
- Federal urban coordinating Bureau, 2008 : Urban storm drainage design manual of Ethiopia
- Guo, J.C.Y. 1999 : Storm water system design.CE58, University of Colorado

- GTZ-IS,2006;and Ababa Belete D.A,2011 : road and urban storm drainage network integration in Addis
- David P.Orr.P.E, 2003 :Road and road side drainage
- DelDOT, 2008 :Highway drainage and storm water management, road design manual
- AASHTO , 1993 :Effect of water on the structural support of the pavement system
- Federal Urban, Coordinating bureau, 2008 :Urban storm drainage design manual of Ethiopia
- Effectiveness Analysis of Subsurface Drainage Features Based on Design Adequacy, Transportation Research Record 1709,TRB, National Research Council, Washington, D.C., 2000, pp69-76.
- http://www.era.gov.et/Publications/ERAsManualsStandards/DesignManuals.aspx
- Yifred Kassa, 2002 : Performance Assessment of Road Drainage Structures and Proposed Mitigation Measures

APPENDIXS

Appendix1. Data collection instrument

- Camera
- Surveying instrument of leveling
- QSWAT software
- Tap Meter

Appendix 2. Average Measured slopes of Existing drainage and Asphalt cross-slope

BS	IS	FS	Remark
2.593	2.023	1.675	Waste Accumulation

BS	IS	FS	Remarks
1.394	1.163	0.946	Side Flow problem

BS	IS	FS	Remarks
32.394	1.163	1.946	Flow problem

Appendix -3 Formats for questioners

Questioners related to flood and waste waters from residents						
No	Types of failure	Magnitude	Causes	Problems related to health's	Actions taken	Recommendations