ASSESSMENT OF URBAN DRAINAGE SYSTEMS:

THE CASE OF ADAMA CITY,DEMBELA SUB-CITY,

MASTER OF SCIENCE THESIS

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HAWASSA UNIVERSITY HAWASSA, ETHIOPIA

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ASSESSMENT OF URBAN DRAINAGE SYSTEMS:
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EXAMINERS' APPROVAL SHEET

We the undersigned, members of the Board of Examiners of the final open defense by **Tesfaye Girma Adugna** have read and evaluated his thesis entitled "**Assessment of Urban Drainage Systems: The Case of Adama City Dembela Sub-City",** and examined the candidate. This is, therefore, to certify that the thesis has been accepted in partial fulfillment of the requirements for the degree of Master's with specialization in Hydraulic Engineering.

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Final approval and acceptance of the thesis is contingent upon the submission of the final copy of the thesis to the School of Graduate Studies (SGS) through the Department/School Graduate Committee (DGC/SGC) of the candidate's department.

Dedication

I dedicate this thesis to my father Mr. Girma Adugna and my mother Ms. Etenesh Ayalew Moreover I dedicate this thesis to my brothers and sisters; Ms.Aster, Dr.Abebe, Mr.Dejene, Ms.Aynalem, Meseret, Daniel and Kidist to all for nursing me with affection and love and for their dedicated partnership in the Success of my life.

STATEMENT OF AUTHOR

I, Tesfaye Girma, declares that this thesis, which I submit to the school of Graduate studies of Hawassa University for the Partial fulfillment of Degree of Masters of Science in Hydraulic Engineering, is my original work and that it has not been presented and will not be presented, as whole or in part, by me to any other university for similar or any other degree award. Additionally, I reasonably ensure that the work is original and to the best of my knowledge and has not been taken from other sources except where such works have been cited and acknowledged within the text.

Name;Tesfaye Girma Signature___________

Place;Hawassa University Institute of Technology

Date of Submission________

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LISTS OF ACRONYMS AND ABBREVATIONS

ACA	Adama City Administration
ACAEPO	Adama City Administrative Environmental Protection
Arc-GIS	Architectural Geographical Information System
ARI	Average Recurrence Interval
ASTU	Adama Science and Technology University
CSA	Central Statistic Authority
DEM	Digital Elevation Model
DL	Drainage Line
EPA	Environmental Protection Agency
ERA	Ethiopian Road Authority
FUPI	Federal Urban Planning Institute
GIS	Geographical Information System
GOF	Goodness of Fit
GPS	Global Position System
IDF	Intensity Duration Frequency
LCLU	Land Use and Land Cover
OF	Outfall
SCS	Soil Conservation Service
SWMM	Storm Water Manage Model
WHO	World Health Organization

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ABSTRACT

This study was conducted to investigate the storm water drainage of Dembela Sub-City. Recently, Dembela Sub-City has become one of the flood prone sub-cities of Adama City. Rapid population pressure and poor urban drainage managements are the major driving problems in the area. Moreover, most of drainage structures are not giving the intended purpose since they refilled up with debris and waste materials. So, the main objective of the study is to assess the existing storm water drainage system of Dembela Sub-City.GPS survey, drainage lines dimensions and metrological data(1978-2011) were collected. The catchments contribute flow were delineated and drainage network in the catchment was generated using DEM (20x20). Frequency analysis of rainfall was computed using Gumbel and log Pearson Type III probability distribution functions and the later found to fit the actual data using the goodness of fit test. IDF curve were developed for different return periods. The Storm water drainage and hydraulic structures had been analyzed and evaluated the performance of drainage lines and catchments with the help of AutoCAD and Arc GIS, EPA SWMM, Flow Master and other statistical tools were employed. SWMM 5.1 was implemented to simulate areas of 27 sub-catchments, the water level in the 73 links and 49 nodes, flow in links and flooding at nodes by considering the current land use condition. The results shows that in Dagaga Zone from135DL 59.26%,in Irrecha Zone from 89DL 82.42% and in Melka Adama Zone from 150 DL 61.33% are in sever condition. Most of drainage lines sever and no capacity to carry the runoff stormwater.Hence, recommendations is referring this document use the appropriate proposed drainage network on specific site which measures should be taken to avoid problems of inadequate urban storm water drainage systems, lack of sustainable urban storm management system and integrated waste management systems.

***Keywords**: Urban,SWMM, Drainage, Flood, Dembela, Adama*

1. INTRODUCTION

1.1 Background

A good and efficient storm water management is badly required at the moment all over the globe especially in developing countries like Ethiopia. The idea of efficient storm water is based on the requirement to protect the health of the public, welfare and safety of the public, conservation of water, need to strive for suitable environment, etc. Currently, urbanization has negative impact on urban drainages system in unplanned cities and towns in Ethiopia. The densely populated town and cities are facing water logging and flooding during heavy rainfalls which are the common issues mostly in the developing nation(Anisha. N.F and Hossain. S. 2014).

Urban storm water management becomes an issue which deals about everything done within a catchment to remedy existing storm water problems and to prevent the occurrence of new problems. This involves the development and implementation of a combination of structural and non-structural measures to reconcile the conveyance and storage function of storm water systems, with space and related needs of expanding urban populations. Naturally, the channel network in the runoff process increases as the watershed area increases so as in urban areas with artificial channels

The problem of blockage and backflow in urban storm water drainage network is also the other challenge in urban areas, because the runoff produced with in a particular urban area could not safely be discharged in to the final receiving system(Belete,2009.).Thus, this could be the source of environmental problems like erosion, pollution, overtopping, barrier to traffic and other related problems.

In Ethiopian context, where watersheds of many urban centers receive significant amount of annual rainfall and where rainfall intensity is produced high, Control of runoff at the source, flood protection, and safe disposal of the excess water/runoff through proper drainage facilities becomes significant(FUPI ,2008). Ethiopian cities and towns at large are troubled with storm water leading into floods especially during the rainy season due to inadequate installation of drainage infrastructure, poor maintenance of existing drains and the problem is more critical in city like Adama.Adama City is one of the cities which is highly affected by flood resulted from unnatural and natural resources situations and events. The runoff from rural areas is the leading source of impairments which affects the city by flooding problems. To ensure sustainable economic development and bring stable society, it is important to implement community based participatory flood risk mitigation and management systems(ACA,2018.).

Inadequate drainage network system has far reaching consequences on the urban residents, commercial buildings and all infrastructures because poor drainage network system cause clogging of water in the channel and over flowed on road surfaces and hence deterioration of unpaved land surface, stream embankment and drainage ditch inlets and outlets are created everywhere in the city.

Most of the years of summer season in Adama City, poor existing drains and their improper operation and management mainly cause severe flooding which creates damages and problems to the resident area, road and road users , especially in Migira, Dagaagaa, Irreechaa and MelkaAdama., the overall problems of blocked drainage channels deteriorates the environment and favorable place for mosquito breeding. This disturbs the natural landscapes everywhere in the Adama City(ACA,2018).

The purpose of this study is to investigate the problem and proposed the appropriate drainage networks systems by delineated the drainage system and estimate the runoff generated from the study area then simulation was implemented. To achieve this primary data such as visual inspection, local enquiry and secondary data which includes hydro-meteorological data and reviewing relevant documents were consulted and AutoCAD and Arc GIS, EPA SWMM, Flow Master tools were employed.

1.2 Statement of the Problem

An urban storm water drainage system is one of the most common problems in many towns of Ethiopia .Adama city is repeatedly affected by drainage problem and causing loss of lives and property damage as well. Dembela sub-city geographic location is the low elevated topography in the floor of the bowl shape of Adama city. There are many drainage networks that are connected to the City from all direction which can carry a very high discharge of runoff during intense rainfall. As the natural drainage runoff across the lower and virtually flat area which is with major land use of residential. Flood risk management of the city is not well organized and established, and hence, every year flood risks occurred and create social crisis.

Because of the major factors affecting the urban drainage system and very high discharge of runoff, there is a big problem of overtopping and blockage of drainage facilities in Dembela Sub-

City in which wastes flow along the drainage system has bad smell, and unwelcoming environment.

1.3 Research Objective

1.3.1 General Objective

The main objective of the study was to assess the existing storm water drainage system of Dembela Sub-City.

1.3.2 Specific Objectives

- ❖ To delineate the drainage system and estimate the runoff generated from the study area
- ❖ To develop Intensity Duration Frequency Curve (IDF) of the Dembela Sub-City for various return period.
- ❖ To evaluate the performance of existing drainage network system of the study area
- ❖ To propose the appropriate drainage networks

1.4 Research Questions

This research was intended to answer the following research questions in line with the topic
How much is the capacity of existing urban storm water drainage system?
Does the existing drainage network system adequate?
What are the appropriate drainage networks to minimize the problem?

1.5 Significance of the Study

Assessing the urban drainage system of Dembela Sub-City will have a significant input for governmental, different non-governmental organizations who have an interests in planning, design and construction activities in Adama City. In addition to this, this study will contribute for those who have the concern with environment and health issues in the study area.

1.6 Scope of the Study

Drainage design and provision needs a great consideration as the scale of damage due to lack of proper drainage facilities provision is high. This study is geographically limited to Dembela Sub-City of Adama City, Ethiopia. The study focused on identification of causes of flooding of the study area.

2. LITERATURE REVIEW

2.1 Historical Development of Urban Drainage system

A research conducted Burian and Edwards (2002): stated that urban drainage in the early parts of the twentieth century was firmly established as a vital public works system. Engineers continued to improve design concepts and methods. During the second half of the twentieth century regulatory elements were promulgated in the United States, Europe, and other locations addressing urban drainage issues. Historically, urban drainage systems have been viewed with various perspectives. During different time periods and in different locations, urban drainage has been considered a vital natural resource, a convenient cleansing mechanism, an efficient waste transport medium, a flooding concern, a nuisance wastewater, and a transmitter of disease. In general, climate, topography, geology, scientific knowledge, engineering and construction capabilities, societal values, religious beliefs, and other factors have influenced the local perspective of urban drainage. For as long as humans have been constructing cities these factors have guided and constrained the development of urban drainage solutions. Historical accounts provide sights of many interesting and unique urban drainage techniques(Burian and Edwards 2002)

Extensive monitoring efforts vastly improved the understanding of urban drainage quantity and quality characteristics. Impervious surfaces associated with urbanization alter the natural amount of water that takes each route as topography of land changes by urbanization. The consequences of this change are a decrease in the volume of water that percolates into the ground, and a resulting increase in volume and decrease in quality of surface water.

According to Raghunath research with natural groundcover, 25% of rain infiltrates into the aquifer and only 10% ends up as runoff (H.M Raghunath ,2008)In highly urbanized areas, over one-half of all rain becomes surface runoff, and deep infiltration is only a fraction of what it was naturally.The increased surface runoff requires more infrastructure to minimize flooding. Natural waterways end up being used as drainage channels, and are frequently lined with rocks or concrete to move water more quickly and prevent erosion. In addition, as deep infiltration decreases, the water table drops, reducing groundwater for wetlands, riparian vegetation, wells, and other uses. Consequently, as the land cover and land use changes during urbanization so does the water cycle.

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

The major system provides overland relief for storm water flows exceeding the capacity of the minor system. This usually occurs during more infrequent storm events, such as the 25,50, and 100 year storms. The major system is composed of pathways that are provided knowingly or unknowingly for the runoff to flow to natural or manmade receiving channels such as streams, creeks, or rivers. The practice of urban drainage in developing countries encounters more serious problems than those of developed countries, because urban development occurs under more difficult socio-economic, technological and climatic conditions. Flood is one of the major natural disasters that have been affecting many countries or regions in the world year after year (Dilley et al,2005.)

2.2 Urban Storm Water Drainage Problems

Developing counties experience accelerated urbanization without adequate investment in infrastructure, and against a background of deficient public services for water treatment, collection and treatment of foul sewage, garbage collection, urban drainage, transport and health. Urban concentrations have environmental consequences in the form of urban flooding and pollution of water courses, soil and air. Settlements are established in inappropriate areas such as those originally set aside for environmental preservation and on steep hillsides and areas liable to flooding (Novatech, Lyon and GRAYE 2001).

The specific factors inhibiting modernization of urban drainage in developing countries, basically by means of infiltration and retention of storm runoff, can be grouped under the following headings: (1) concern for the environment is less familiar than concern for conventional sanitary planning ; (2) there is no effective control over urban development, whether legal or clandestine; (3) runoff from storm rainfall is highly contaminated; (4) runoff transports large quantities of sediment and garbage ; (5) climatic factors can increase risk of epidemics and construction costs; (6) there is a shortage of engineering ‘know-how’ concerning modern approaches to urban drainage; (7) there is a lack of interaction between the population and public administrators seeking solutions to urban drainage problems(Novatech, Lyon and GRAYE 2001).

2.2.1 Increasing of Urban Population Density

The extent of impermeable cover is directly correlated with runoff coefficients and also with population density, so that an indirect method of evaluating the impact of urbanization on drainage is to relate population density with runoff coefficients. There is evidence world-wide that higher urban population density commonly results in greater storm-water generation,(Debo and Reese, 2003)but many urban planners take no account of this important effect and neglect the wider costs of their storm-water control procedures.

Modern urban drainage calls for detention and infiltration areas, contrary to the philosophy of higher population density. Many cities in developing countries have a density index which already causes critical drainage situations. Besides the problems of control in legal settlements, socio-economic problems lead to the invasion of public areas, forming slums with high population density and high rates of impermeable soil surface(Debo and Reese, 2003).

2.2.2 Excess Sediment and Garbage

Tucci(2000) states that urban areas in developing countries have significant proportions of exposed soil liable to erosion and giving rise to large quantities of sediment. Building sites, whether in areas where the city is expanding or within the developed urban area, do not normally have controls for erosion prevention or for retaining sediment so that it does not reach the streets, storm drains and urban rivers. It is no exaggeration to say that 10 to 15% of urbanized area in developing countries contributes extensively to sediment production and transport. The amount of garbage entering the drainage network is reduced corresponding to a production of 0.4 to 0.8% of total garbage produced(Tucci, C. E. M. 2000)..For developing countries, the rate of garbage accumulation in the streets is certainly higher, since in some parts of the cities the storm-drain network is used for garbage disposal.

2.2.3 Lack of Community Participation

Lack of community participation in the search for enduring solutions for urban drainage problems is one of the main obstacles preventing the success of modern storm runoff control measures, whether by structural or non-structural measures(Novatech, Lyon and GRAYE 2001). In most developing countries this has been a problem for sustainable storm water drainage management. Lack of community participation leads to the repetition of earlier errors in solving drainage problems, to the discredit of public action, and lack of concern with environmental questions. It can also bring about low investment in urban facilities.

2.3 Urban Storm Water Drainage Practices in Ethiopia

According to the NUPI report floods in many parts of Ethiopia are seasonal phenomena and watersheds of many urban centers receive significant amount of annual rainfall,the magnitude of the current flooding is unprecedented. The disaster continues to unfold and the impact in terms of lives, infrastructure and livelihoods has not been yet assessed .Rainfall intensity is generally high, control of runoff at the source, flood protection, and safe disposal of the excess water/runoff through proper drainage facilities become essential (NUPI, 2000)

With urbanization, impermeability increases with the increase in impervious surfaces (i.e. residential houses, commercial buildings, paved roads, parking lots, etc.), drainage pattern changes, overland flow gets faster, flooding and environmental problems such as land degradation increases. It is a crucial problem facing the existing and future environmental conditions of urban centers(FUPI, 2008)

Before the establishment of the National Urban planning institute some twenty year ago, there has been no formal working organization in the area of urban storm water drainage system. Even now a day the attention towards urban storm water system is at its immature stage that is why most of the urban storm water drainage structures gets blocked with solid waste of various types after huge amount of money has been invested on them. In some areas they by themselves are sources of environmental problems(FUPI, 2008).Historically, Dire Dawa, the second largest city of Ethiopia, has been vulnerable to flash flooding, in particular of the Dechatu River which passes through the centre of the city. On the night of 5/6 August 2006, the most devastating flood to date swept through Dire Dawa, resulting in over 300 fatalities and significant damage to the flood defenses, public infrastructure, housing and livelihoods

2.4 Urban Storm Water Drainage Practice in Adama

Adama City drainage problems was studied by different scholars in order to establish the fact that drainage problem exists in the city.In 2013 ACAEPO developed a supportive macro-watershed study of environmental concern aimed at analyzing common themes and particular variations in the experience of the 14 watershed sites, with the ultimate goal of eliciting lessons learned on participatory and integrated watershed management. In the study the major problems that maximize flood risks mitigation measures was 14 catchment areas were identified. Possible structural and non-structural mitigation measures mentioned but lack engineering points of view (ACAEPO,2013)

No doubt on the existence of drainage problem in the city. The identified problems in the literature are presented either in the form of malfunctioning of specific component of the urban drainage conveyance structure only around Migira area. Three studies on drainage problems that exist in Adama City around Migira are reviewed in this sub section. The studies are performed by Water Works Construction, with the key conclusion and recommendation of draw of water out of Migira Retention Pond through channel (cutting)as a feasible option. Adama Science and Technology University in collaboration with Adama City Administration, by taking retention and conserving water in Migira Pond as a feasible option. The PACE consulting Architects and Engineers PLC, which state nothing about final storm drainage plan layout with any format and finally selected the tunneling as feasible option for Migira Pond Outlet.

Flooding is a significant natural hazard in the Adama city attributed to its location within the flat lying rift. The main causes of flooding are heavy rain, high water table, and culvert damage or blockage(Getahun,1987).The city is exposed to different problems such as soil and water conservation, which led to severe flooding problems. Urbanization (horizontal expansion) of city, industrialization, road construction and negative human intervention has fueled the flooding hazardous though out the city and the surroundings rural. The threat of the flooding is increasing from season to season.

Generally Extreme flood events in Adama City result in loss of life and cause substantial property damage. In June of 20016, flooding tragically resulted in the loss of property and life and disaster service payments and many unaccounted hardships for Adama city. In an effort to identify potential mitigation measures to this natural disaster, a steering committee and flood mitigation technical task force with nine members has been established. The committee consisted of representatives from ASTU, Adama City Administration and Awash Basin Authority (AWBA)(ASTU, 2016)

2.5 Factors Affecting Urban Drainage

For all hydrologic analyses, the following factors shall be evaluated and included if they have a significant effect on the final results:

Drainage basin characteristics including size, shape, slope, land use, geology, soil type, surface infiltration, and storage. Stream channel characteristics including geometry and configuration, natural and artificial controls, channel modification, aggradations/degradation, and debris;

Flood plain characteristics; and Meteorological characteristics including precipitation amounts and type (rain, hail, or combinations thereof), storm cell size and distribution characteristics, storm direction, and time rate of precipitation(ERA, 2001)

2.6 Different Software Application for Urban Drainage System

Computer modeling tools advanced the methods used to design and analyze urban drainage systems. Regulations, monitoring, computer modeling, and environmental concerns have altered the perspective of urban drainage from a public health and nuisance flooding concern during the first half of the twentieth century into a public health and nuisance flooding with additional concerns for ecosystem protection and urban sustainability (S.K Garg,2005).

pproaches to the development of integrated models of urban water systems, comprising potable and sewer networks, land surface runoff and river waters for water quality control were proposed as early as the late 1970s (Beck 1976); however, such approaches were largely constrained by technological limitations (i.e. computer model capabilities), and it was not until the early 1990s.

2.6.1 Storm Water Management Model (SWMM 5.1)

The EPA Storm Water Management Model (SWMM) is a well-known dynamic rainfall runoff simulation model used for single event or long-term (continuous) simulation of runoff quantity from primarily urban areas(A.Rossman 2004)

Dynamic wave routing can account for channel storage, backwater effect, entrance/exit losses flow reversal and pressurized flow. Because it couples together the solution for both water levels at nodes and flow in conduits it can be applied to any general network layout. Final this method was selected for this study due to the its accuracy results (A.Rossman 2004).

SWMM was development and has undergone several major upgrade since then it continues to be widely used throughout the world for planning, analysis and design relate to storm water runoff ,combined sewers, sanitary sewers and other drainage system in urban areas with many applications in non-urban areas as well .SWMW model is developed to analyze drainage network for the campus of National Institute of Technology, Warangal in the city of Warangal, Telangana, India Since its inception, SWMM has been used in thousands of sewer and stormwater studies throughout the world. Typical applications include:

- Design and sizing of drainage system components for flood control
- Sizing of detention facilities and their appurtenances for flood control and water quality protection
- Flood plain mapping of natural channel systems
- Designing control strategies for minimizing combined sewer overflows
- Evaluating the impact of inflow and infiltration on sanitary sewer overflows (Nanduri 2015)

2.7 Review of Hydraulic to Protect the Flood

2.7.1 Flow Type Assumptions

The design procedures presented here assume that flow within each storm drain segment is steady and uniform. This means that the discharge and flow depth in each segment are assumed to be constant with respect to time and distance. Also, since storm drain conduits are typically prismatic, the average velocity throughout a segment is considered to be constant. In actual storm drainage systems, the flow at each inlet is variable, and flow conditions are not truly steady or uniform

2.7.2 Design Frequency

A design frequency shall be selected commensurate with the facility cost, volume of traffic, potential flood hazard to property, expected level of service, strategic considerations, and budgetary constraints, as well as the magnitude and risk associated with damages from larger flood events. With long highway routes having no practical detour, where many sites are subject to independent flood events, it may be necessary to increase the design frequency at each site to avoid frequent route interruptions from floods. When selecting a design frequency, potential upstream land use which could reasonably occur over the anticipated life of the drainage facility shall be considered(ERA, 2001)

2.7.3 Hydraulic Capacity

The hydraulic capacity of a storm drain is controlled by its size, shape, slope, and friction resistance. Several flow friction formulas have been advanced which define the relationship between flow capacity and these parameters. The most widely used formula for gravity and pressure flow in storm drains is Manning's Equation. The Hydrology/Hydraulic & Structural report stated that the discharge capacities of the existing cross section structures have been estimated using Manning Formula the dimensions of the openings of the existing structures, the water area and wetted perimeter of each cross-drainage structure were determined.

- .The slope of every cross drainage structure was estimated from 1:50,000 scale
- Values of Manning's roughness coefficient were estimated for all existing major

Cross-drainage structures by actual observations in the field and selecting suitable Values from standardtables.

- Permissible flow velocities through various soils and linings of the existing cross drainageStructures were taken from as estimated by actual observations in the Field and of suitable values from standard tables. The discharge capacities of the existing cross drainage structures have been estimated using Manning's Formula

The maximum possible velocities through the openings of the existing structures have Been computed assuming structure nearly full flow using Manning's equation: and

$\mathbf{V} = \frac{1}{n} \times \mathbf{R}^{2/3} \times \mathbf{S}^{1/2}$ where: V – Velocity in meters/second

n – Manning's roughness coefficient

R – Hydraulic radius in meters (Area/Wetted Perimeter)

S – Estimated bed slope of structure from 1:50,000 scale maps(NRCS & ERA 2001)

2.7.4 Hydraulic Design Elements

General principles relating to channels, culverts, bridges, and other storm drainage elements are listed below.

• The design of artificial drainage channels or other facilities should consider the frequency and types of maintenance expected and make allowance for access by maintenance equipment.

• A stable channel is an important aspect for a proper functioning of highway drainage structures.

• The range of design channel discharges shall be selected and based on Geometric Design Standards, consequences of traffic interruptions flood hazard risks, economics, and local site conditions.

• Coordination with Ministry of Water Resources shall have high priority in the planning of highway facilities(NRCS & ERA, 2001).

2.8 The Storm Water Drainage

Storm water drainage is generated by rainfall, and consists of that proportion of rainfall that runs off from urban surfaces. Hence, the properties of storm water, in terms of quantity and quality, aintrinsically linked to the nature and characteristics of both the rainfall and the catchment. (American Society for Testing and Materials (ASTM et al. ,2008)Storm water (surface runoff) is the second major urban flow of concern to the drainage engineer. Safe and efficient drainage of stormwater is particularly important to maintain public health and safety (due to the potential impact of flooding on life and property) and to protect the receiving water environment. Reliable data on the quantity and quality of existing and projected storm water flows is a prerequisite for cost-effective urban drainage design and analysis.

3. MATERIALS AND METHODS

3.1Description of the Study Area

As it is documented, prior to the establishment of Adama city in1909E.C the area was covered by pristine and thick forest with thorn bushes and large canopies and occupied by indigenous pastoralists of Oromo who were moving with their flock and herds in search of water and pasture seasonally(ACA,2018). The stretched railway from Djibouti to Addis Ababa was one of the main attributes for the establishment of the city. Adama was established at a distance of 96 kilometers southeast of Addis Ababa in the Great Rift Valley of East Africa beneath of kechema ridge as rail way depot known by the time by plentiful cactus ("adamii') in 'Afaan Oromo'which means 'a generic milky small plant with thick fleshy stems bearing spines called cactus/euphorbia tree that became the cause for naming the city as Adama. Demographically, Adama is the most rapidly growing city both in terms of population and physical areas in the region starting from the outset of its establishment due to ongoing urban spread out, natural growth of population and high level of rural urban migrations. So according to the third Ethiopian population and housing census which was conducted in 2007 (the most recent year for which data are available), 220,212 people of whom 108,872 males and 111,341 females that distributed over land areas 133.6 km^2 were inhabited in Adama.

3.1.1Location

The city of Adama is situated in Rift valley, within Awash River Watershed in Oromia regional state.at terrain characteristics and surrounded by plateaus, mountainous and ridged topography. Adama city extends from 8° 25' 57" to 8° 38' 41" N Latitude to 39° 09' 15" to 39° 22' 7" E Longitude. The city is located in the flat lying rift. The altitude drops gradually from west and east to the center of the city where the slopes become gentle in the heart of the city and creates floodplains in sub-city like Dembela Sub-City and Migira Sub-City. Adama has at an altitudinal range from 1600 to 1700 meters above mean sea level. The bowl-shaped topographic feature of Adama ranges from plain areas in the center of the city to chain of sloppy ridges. This intensifies the problem of flood on one hand and its physical attractiveness on the other hand. Dembela Sub-City has Dagaga Zone,Irrecha Zone and Melka Adama Zone. Dembela Sub-City has a total of 67743 population and 2743 hectares of areal coverage. This area is selected because of the problem is more serious as compared to the other sub-cities and it is due to one of the two outlets of Adama City .

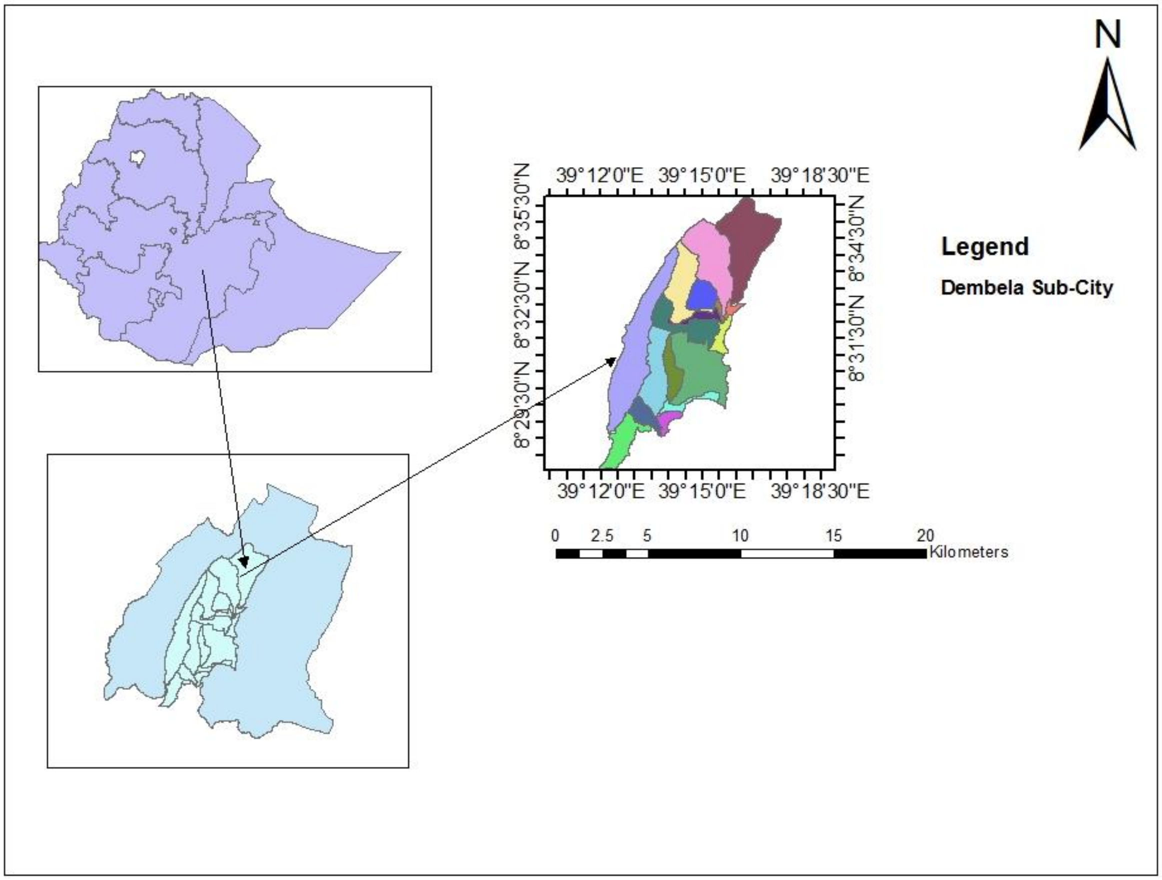


Figure 1:Map of Dembela Sub-city

3.1.2 Climate

Adama enjoys favorable climatic conditions due to its geographical locations surrounded by plateaus that experiences moderate temperature and its immediate surroundings lie on the border between various climate zones. In terms of the traditional classification which is mainly using altitude and temperature information of the town lays under Weina-Dega (sub-tropical) or Qolla (tropical) climate zone classify the area. However, if judged according to the moisture balance and plant growth, the town is classified as semi-arid(ACA,2018). The mean annual temperature of Adama city is 21.7^0c. This amount of temperature reflects the characteristics of tropical region climate. Due to minor variation in elevation or altitude there is slight micro climate variation on surrounding uplands like Kechema that is located in North western part of the city (ACA,2018)

3.1.3 Rain Fall Data

Generally, there are four seasons at Adama; summer (main rainy season),autumn(very small rains) winter (dry season), spring (small rains).Most of the rain occurs between June to September .The wettest months are July and August(ACA,2018). The average amount of rainfall in July and in August is about 45.93 mm. The proportion of the precipitation in these two months is about 55% of the annual total. Data on rainfall intensity for Adama City is not available. The rainfall intensity data recorded at the nearby station of Bishoftu, Kulumsa and Methara is sometimes considered; accordingly, the average maximum rainfall intensity in the three stations for the past 27 years (1975-2002) is about 39.7mm/hr(ASTU, 2016)

3.1.4 Geology and Soils

The formation of great East African Rift Valley in the tertiary period has great relevance to land formation and geological events around the city of Adama and East Shoa Zone where the city is located. Many quarries with different kind of rocks are abundantly found around the city where many people are digging up them for road constructions and buildings. Many different building materials are available around the city that the city naturally endowed with abundance of quality sand and pumice supply which have great economic significance to the development of the city and created conducive environment for housing and road constructions. Besides, numerous hot springs and fumaroles discharge hot water like "sodore, bokko and gergedi" used to cure many illnesses are found around Adama city due to its geological formation.

The types of soils existing in Adama area are predominantly sandy and loam in texture with less moisture contents that prevent the digging of various ponds to harvest water. Adama's soil is identified with permeability and susceptibility to wind sweep and water erosion that prevails on its environment. The upper layer of the soil is very vulnerable to wind and water erosion. Water is the main agent of erosion in the form of sheet and gully erosion in Adama that causes much destruction in risk areas of the city during the rainy season in the city. The thickness of the soil is shallow and at one meter depth, pumice is abundant(ACA,2018)

3.1.5 Land Use Land Cover

Adama city have land use ranges from agricultural to high density commercial areas. Information about changes in land use/cover provides valuable insights while planning future natural resource management strategies. The other type of data required is the land use land cover of the study area. The land use land cover data will be an essential input for the calculation of runoff coefficient in the determination runoff rate using rational method. The runoff coefficient of a surface is dependent on the land use and land cover of the area. For the study area is relatively small, categorization of different land use was done by field survey and with help of Google earth map. The land use land cover for the catchment area grouped in to Mixed Residences, Government compounds, Colleges, Asphalt roads, Cobble stone roads, Commercial Areas, school, Health center and play grounds. As there is no sufficient available data to name an area as commercial or mixed residence, the categorization is judgmental.

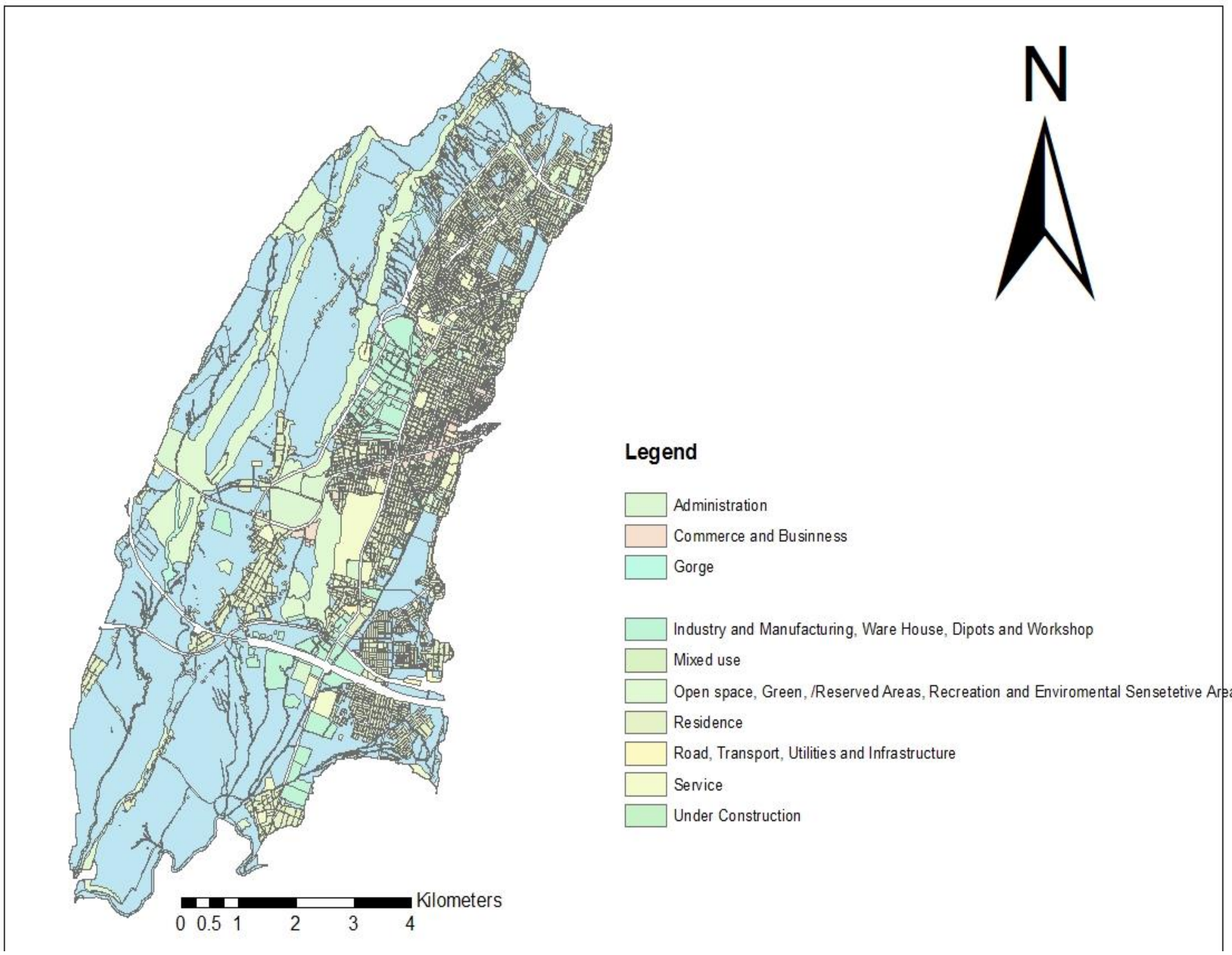


Figure 2:Existing Land use and land cover classification of Dembela sub-city

(Source: computed from *land use of the Adama City*)

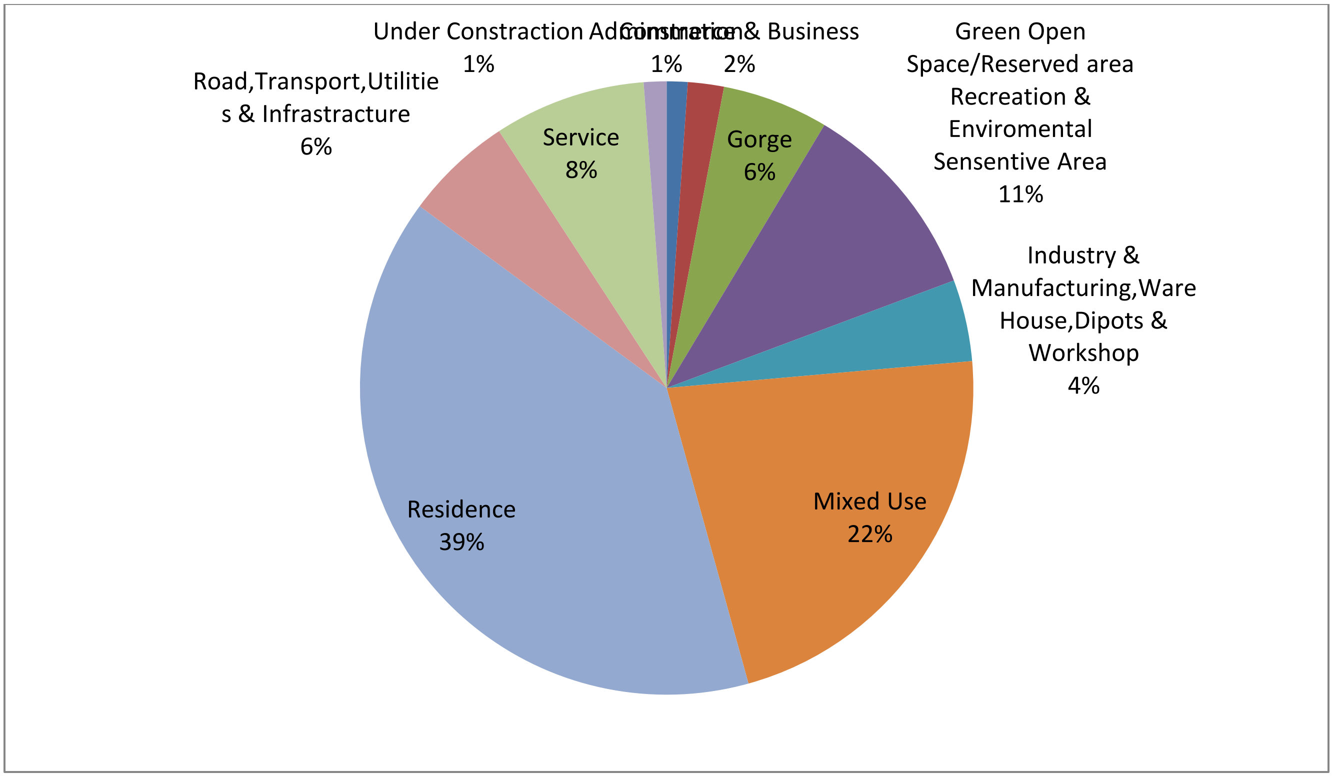


Figure 3:Land use and land cover composition of Dembela Sub-City

(Source: Data SIO. NOAA. U.S Navy. NGA. 2018 Google)

3.2 Methods

The Study is focused on performance assessment of drainage systems on Dembela Sub-City. To deal the object of the study the following methods necessary. Gathered data will be analyzed critically on the responses found from the primary data and secondary data and analyzed will be presented with tabular, diagrammatic and graphical formats.

Two types of methodologies were used to perform this research. The descriptive type was used to describe challenges and major factors which impaired the performance of storm water drainage system and the condition of the Dembela sub-city. Whereas, the exploratory type was particularly used to explore the existing condition and coverage of urban storm water drainage facilities which have been used by the sub-cities and the proposed appropriate drainage line for the existing drainage problem.

3.2.1 Sampling Techniques

Purposive sampling technique was used in this study. Assessing the whole catchment is not necessarily important to come up with solution for storm water drainage problem. Therefore, some representative major flood prone areas, the area where the problem is most encountered have drainage facility to assess are selected. This study conducted on three zones. These three zones are Dagaga,Irrecha and Melka Adama zones are located in Dembela sub-city according to Adama city new master plan. They are selected for this study because of their low rift inner city which have been facing high flooding during the rainy season. The steps (A-E) and the methods (1-17) that are used to address the specific objectives of this study are;

A. **Study current condition of the drainage system**

1. Field survey (GPS, different dimension of channels)
2. For existing drainage lines; calculate the Capacity by Manning Formula & Checked by Flow Master Software=VA=$1/n*R^{2/3}S^{1/2}$ R= hydraulic radius n=Manning roughness, A=Areas of Channel (m^2) ,P=Wetted perimeter (m),S=Channel bed slope(m/m)

B. Estimation runoff

3. Use secondary data (rainfall, contour map, base map, DEM, land use and land cover)
4. Data analysis by Google ,Excel, AutoCAD and ArchGIS(from No.1 and 3)
5. Check the quality of data (arranging data filling missing data, check consistency,)
6. Design rainfall analysis (frequency analysis by using different statically parameters)
7. Estimate Design rainfall for shorter durations
8. Develop IDF curve for 2, 5,10,25,50 ,100 and 200 years return period.
9. Found intensity I
10. Delineate drainage system/ water shed
11. Found area and runoff coefficien
12. Determining the design flood by Rational Method (0.8 km2).Q = 0.278C I A ,

    Q = Maximum rate of runoff, m3/s, C = Runoff coefficient, $=\Sigma AiCi/\Sigma Ai$

    I = Rainfall intensity (mm/hr) ,A = catchment area (km^2), $Tc=(0.87L2/1000Sav)$^0.385

    Tc = time of concentration (min), L = maximum length of flow (km).

    The channel slope = ((terminal – initial) elevation / channel or drain length)*100

C. Evaluating the performance of drainage system

13 Existing drainage capacity and estimated runoff(No.2 &12)

D. Challenges of Stormwater and Condition in drainage system

14. Drainage system by stormwater model management software
15. Identify the problem in Dembela Sub-City

E. Propose the appropriate drainage channel

16. Managements and increase community participation to clean the drainage channels

17. Use the most economical hydraulic section to propose the drainage channel for Melka Adama Zone Dagaga Zone, and Irrecha Zone

3 .3 Data Collection

The study was based on field survey of the actual field conditions. In addition to this, primary data were obtained consisted of in-depth interviews with experienced experts from the city municipality responsible for urban drainage infrastructures and field observations.

Meteorological data was collected from Adama station and spatial data of 20X20 DEM was used to analysis the catchment drainage characteristics moreover tools like Excel, Hydrognomon, Google,AutoCAD, ArcGIS, SWMM(Hydraulic Modeling) were also used accordingly

3.3.1 Rainfall Data

3.3.2 Rainfall Distribution

Adama City, rain fall data was extracted from Adama Meteorological Station for planning purpose. The distribution of rain fall in the city was not equal in all years. Thus within the past thirty six years, the highest amount of rain fall was recorded in May, 2001 (104.8mm) within only 93 rainy days. About 99.8mm rain fall was also recorded in autumn, 2000 within 102 rainy days. Besides, the occurrence of rain fall in the city varies within the days of the months in the distribution.

According to the data from Adama city meteorological station, the highest annual rain fall in the distribution is recorded in 1985, 2003, 2007,2008 and 2012 comparatively(see fig.4). On the contrary minimum annual rain fall within the past thirty eight years was observed in 2009. In the year 1981 – 2018, July and August have the highest amount of mean monthly rain fall distribution and stand first and second in its amount. The minimum mean monthly amount of rain fall is recorded in January and December.

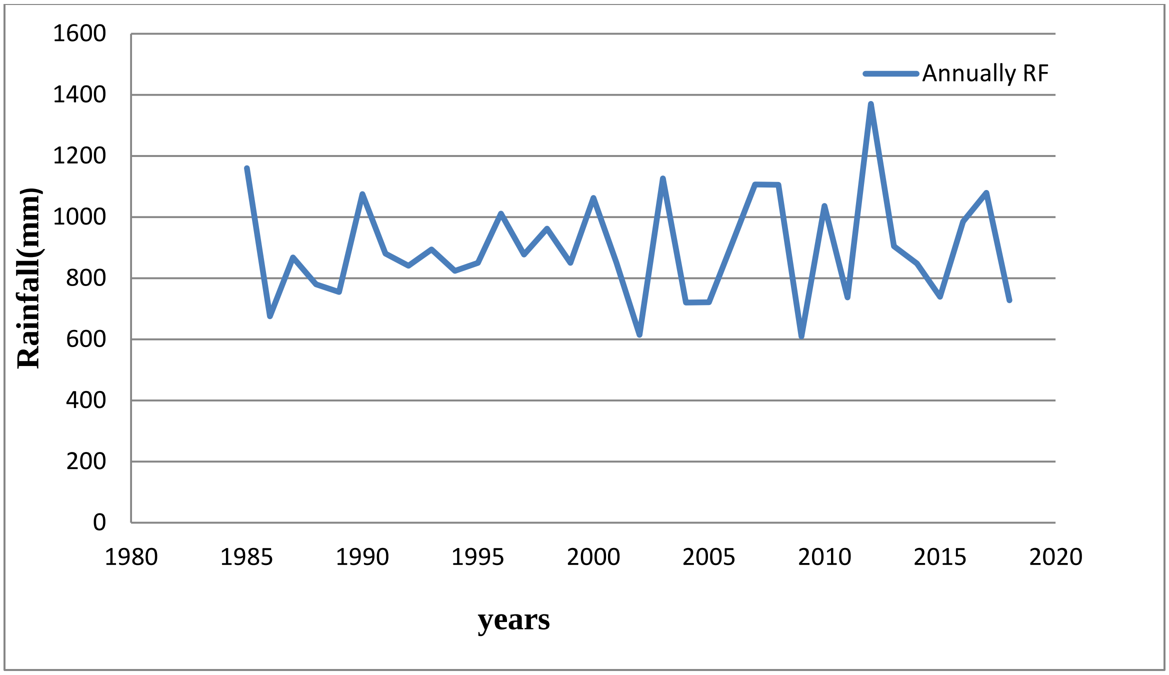


Figure 4:Computed Annual rainfall of Adama during past 33 years

3.3.3 Estimating Missing RF Data

There are different methods estimating the missing values. Simple arithmetic mean of precipitations was mainly used for this purpose. The four meteorological stations of nearby Adama city (Mojo,Koka and Walenchiti) has been taken. This method is used if the average annual daily rainfall at each of the four index stations differ within 10% of the average annual rainfall of Adama station. The data collected from Adama City Meteorology station contained a lot of missing data which was required to be corrected. It was observed that there were many data that were not available and missed.

Generally,as data from Adama meteorology agency for 33 years (1985-2018).The mean annual rainfall of is 898.49 mm. Most of the rain occurs between June to September. The two months that show maximum rainfall is July and August.

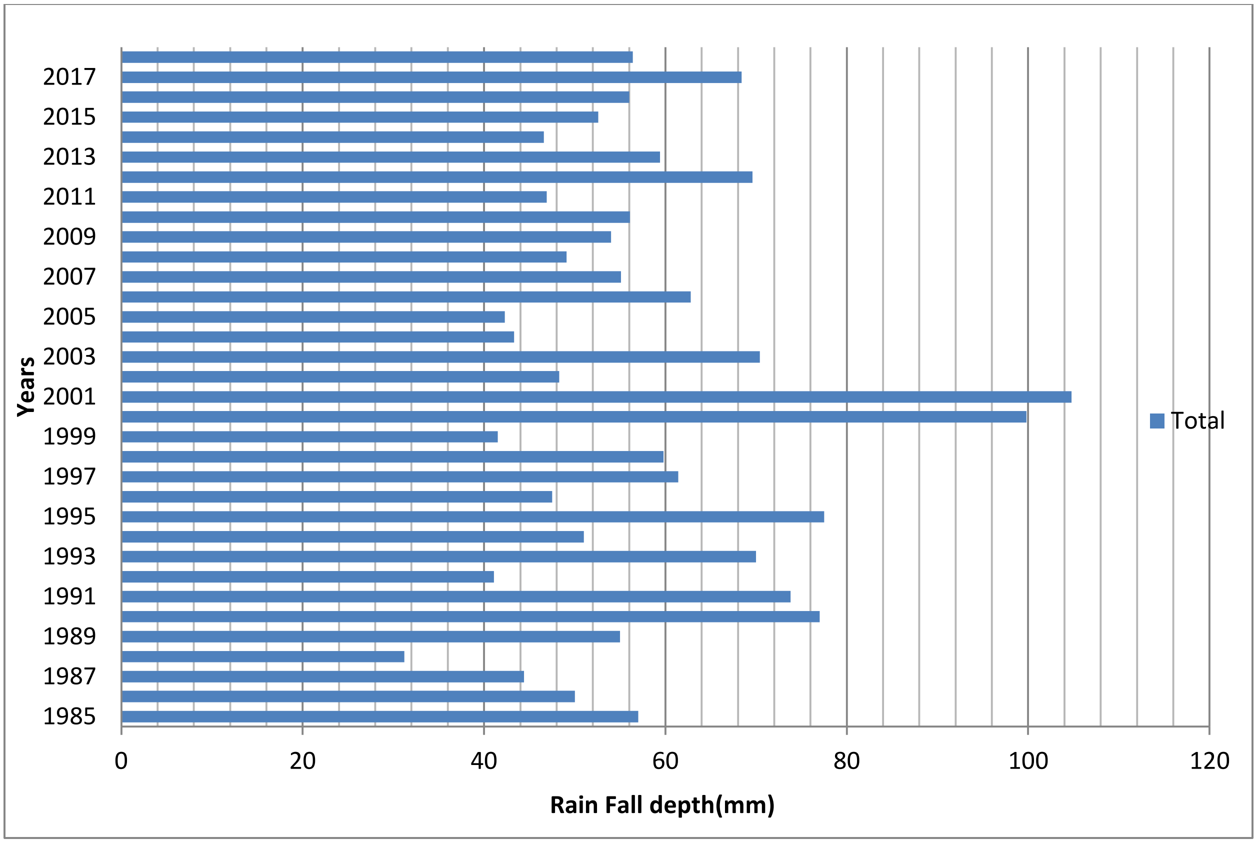


Figure 5:Computed maximum total rainfall of Adama during past (1985-2018) years

3.3.4 Consistency Checking

When a significant change occurs in and around rain gauge station in a particular year which affecting the rain gauge data consistency was detected. The rainfall data values were corrected and adjusted by double mass curve method. The following double formula were used

$C'_x = C_x G'/G$ where C'_X=corrected ppt. at Adama station

C_x=Original recorded ppt. at Adama Station

G' =Corrected slope of the double mass curve.

G =Original Slope of the double mass curve

In this method, Koka,Walenchiti and Mojo rainfall stations were chosen, in the vicinity of the Adama station. The yearly rainfall values, reported from this group of stations are serial led , and their mean yearly values are worked out for each consecutive year of available data record. These mean yearly rainfall values (of the chosen group of stations) are serially arranged in chronological order and against these values, the recorded yearly rainfall values of the Adama station are also serial led for each year. The cumulative values of both the columns were worked. The cumulative precipitation values of the Adama station and the cumulative values of the group averages are then plotted on the following graph

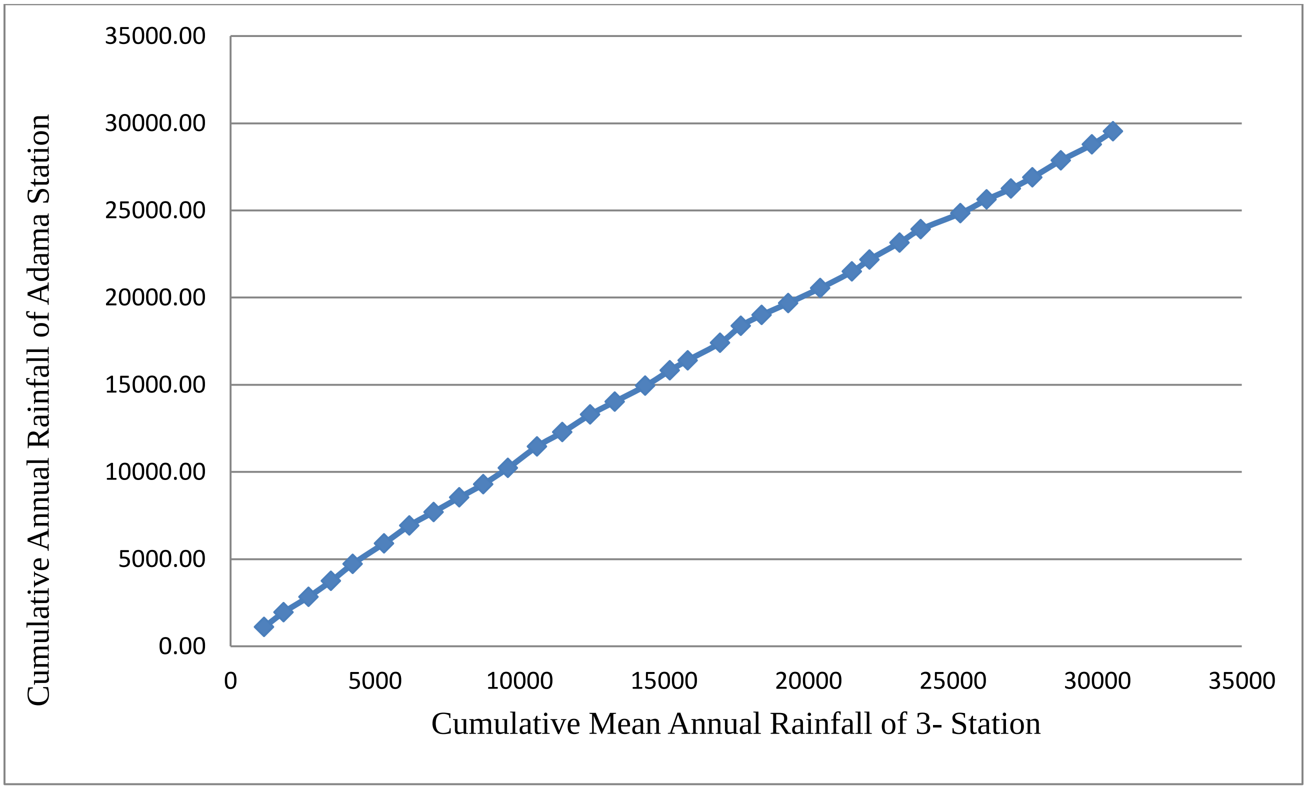


Figure 6: Consistency of Adama Station relative to Koka, Walenchiti and Mojo

$$S_1 = \frac{23159.57 - 1159.5}{23160.33 - 1103.47} = 1.06 \qquad S2 = \frac{30548.67 - 23159.57}{29550.26 - 23160.33} = 1.15$$

$$\nabla S = (1.15 - 1.06)/1.06 = 0.085, \quad = 8.5\% \text{ and the change of slope was } < 10\%$$

From the above simple calculation the double mass curve the slope is constant and the change of slope is less than 10% therefore the record rainfall data were consistent and the reported rainfall data were not corrected and adjusted by double mass curve method.

Additionally the Adama Metrologic station are fairly evenly distributed and the variation of rainfall is uniform which the areal average precipitation is used

3.3.5 Intensity-Duration-Frequency (IDF) Curves

Estimates of precipitation intensity for selected return periods are often required for the design of drainage systems. The results, the so-called IDF (intensity-duration-frequency Rain fall of a place can be completely defined if the intensities, durations and frequencies of the various storms occurring at that place are known. Whenever an intense rain occurs, its magnitude and duration is generally known from meteorological readings. This available data can be used to determine the frequencies of the various rains. Such frequency data for storms of various durations can be represented by Intensity-Duration-Investigation of Flooding Problems in Urban Drainage Systems: the case at Adama city

An IDF curve is a plot of average rainfall intensity (rainfall depth is averaged over the duration

$$\frac{\text{Rainfall depth}}{\text{duration}} = average\ rainfall\ intensity\ in\ that\ duration) \ldots\ldots\ldots\ldots 3.1$$

and the duration in minutes (S. K Garg, 2005)

However, when short time duration rainfall data is not available intensity of a short time rainfall long time rainfall would be calculated using reduction formula.

The rainfall depths obtained from gauging stations were for 24hr duration however design and analysis of drainage structures require rainfall intensity of shorter duration. Since rainfall data of shorter duration is unavailable, appropriate IDF derivation for shorter duration is required. Ethiopian Road Authority (ERA) Drainage Design Manual of 2013 suggests the following equation for calculation of shorter duration rainfall from 24hour duration rainfall.

$$R_{Rt} = \frac{t(b+24)^n}{24(b+t)^n} \ldots\ldots\ldots\ldots 3.2$$

Where: RRt = Rainfall depth ratioRt: $R24$,= Rainfall depth in a given duration t (hours)

$R24$ = 24hr rainfall depth, Coefficients b = 0.3 and n = 0.78 - 1.09

The methods employed to develop IDF curve for the shorter duration events using the above equations are as follows.$R24$ is calculated for 2, 5, 10, 25, 50 and 100 year return period. Rearranging the above equation gives

$$R_{Rt} = \frac{t(b+24)^n}{24(b+t)^n} * R24 \ldots\ldots\ldots\ldots 3.3$$

Intensity (mm/hr.) $It = Rtt$ Substituting in the above equation gives Urban Drainage Systems: the

$$I_t = 24 * \frac{t(b+24)^n}{24(b+t)^n} \ldots\ldots\ldots\ldots 3.4$$

$where I_t\ (mm/hr), t\ (hours), R_{24}(mm)$

Using b = 0.3 and n = 0.92 as suggested by ERA 2013 manual results are tabulated (appendix Table 3) for rainfall durations 10, 20, 30 … 200 minutes.

The resulting table is graphed for each return period. That is IDF curve is developed using reduction formula.

Any probability distribution can be used as a model but the reliability of the distribution is checked by the goodness of fit tests. Gumbel and Log Pearson Type III methods were used as suggested by Ethiopian Drainage Design Manual (ERA, 2013) and their goodness of fit was analyzed below. Secondary data was used to drive the sample and then the sample was used to estimate a population for projection of the magnitude and frequency of rainfall (Chow, et al., 2012). Hence, for reliable estimates for extreme hydrological event, long term data series was required.

a. **Gumbel distribution;** is the most widely used distribution in the field of hydrology. This distribution is suitable for modeling of maxima. This is a single parameter distribution with frequency factor as the only parameter to be determined. In Gumbel distribution, the frequency factor is a function of the return period only

The methods employed in Microsoft Excel are as follows

- Annual extreme values are obtained using =max(∀) function, where ∀ represents all record of 24 hour daily rainfall obtained from Ethiopian Meteorological Agency as mentioned in data section.
- Average of yearly maximum rainfall data is obtained using =average () function
- Standard deviation of the data set is obtained using =stdev () function
- The constant α of the data set is calculated using $\propto=()*\sqrt{6\pi}$
- The constant u of the data set is calculated using u= ( )−0.5772

The following Equation is used to calculate the Gumbel frequency factor.

$K_T = -\frac{\sqrt{6}}{\pi}\left[0.5772 + \ln(\ln\frac{T}{T-1})\right]$ WhereK_T is frequency factor

T is Return period (years)

b. Log Pearson Type-III Distribution: involves the log transformed series of the rainfall data. Using this distribution, the mean, the standard deviation and the skewness coefficient are calculated based on the logarithms of the original data values to the base 10. Frequency factors for all the annual maximum series corresponding to different durations are obtained from the available statistical tables as functions of return periods and skewness coefficients. Antilog of the solution obtained from the general statistical equation provides the estimate for the extreme rainfall for a given duration and return period. If X is the of random hydrologic series, then the series of Z Variante, Where$z = \log x$ are first obtained.For this z series,

$z_T = \mu + K_z S$ WhereK_z -frequency factor, S -standard deviation

μ-mean of the z values

Standard deviation

$S = \sqrt{\frac{\sum(z-\mu)^2}{(N-1)}}$ Where: S -Standard deviation of the z variante sample, z −Variante sample.

μ -is mean of z values- number of years of record

Coefficient of skewness

$C_s = \frac{N\sum_{i=1}^{n}(z-\mu)^3}{(N-1)(N-2)*S^3}$ Where C_s-is coefficient of skewness of variante Zv-Variante Zz −Variante sample,μ -is mean of z value-is number of years of record.

S-is the standard deviation of the series.

The variations of K_z =f(C_s, T) is given in table After finding z_T the corresponding value of x_T is obtained by$z$ −Variate sample. μ -is mean of z value-is number of years of record.

S-is the standard deviation of the series. The variations of K_z =f(C_s, T) is given in table

Coefficient Z to be used in calculating KT is obtained using excels = $Normsin$ (1/T) function where T is the desired return period. Or, the value of Z corresponding to an Exceedence probability of p(p=1/T) can be calculated by finding the value of an intermediate variable w:

W=$\left[Ln\frac{1}{p2}\right]$ ^0.5(0<p≤0.5) ……………………………………………….…………….3.5

Then calculate Z using the approximation

$$,Z = w - \frac{2.5255517+0.802853w+0.10328w^2}{1+1.432788611+0.189269w^2+0.001308w^3} \quad \text{……………………….……3.6}$$

Coefficient KT is calculated as

KT=Z+ (Z^2−1)+0.333(Z^3−6Z)K^2−(Z2−1)K^3+ZK^4+0.333K^5…..……………......……..3.7

YT is calculated using YT=$aver$( )+$KT*stdev$( ) ; That is $YT=\bar{y}+kT*S$ Magnitude of precipitation with a return period of T,XT is obtained by After finding $z_T$the corresponding value of $x_T$is obtained. $X_T=10^{YT}$

Goodness of Fit Test

The goodness of fit (GOF) tests measures the compatibility of a random sample with a theoretical probability distribution function. These tests show how well the selected distribution fits to data. There are three most commonly used GOF tests. These tests are the Anderson-Darling, the Kolmogorov-Smirnov, and the Chi-Squared tests. In all three tests a parameter or statistic unique to each method was calculated for the required distribution types and these distributions are ranked based on their parameter values.

1.Kolmogorov-Smirnov test is used to decide if a sample comes from a hypothesized continuous distribution. It is based on the empirical cumulative distribution function (ECDF). Assume that we have a random sample $X1.........Xn$ from some continuous distribution with CDF F(x). The empirical CDF is denoted by

$$F(X)=\frac{1}{n}[Number of observations \leq X] \quad ....3.8$$

The Kolmogorov-Smirnov statistic (D) is based on the largest vertical difference between F(x) and(x). It is defined as $Dn= X^{sup} |(x)-F(x)|$ When comparing different distribution, lower statistics means better fit.

2. Anderson-Darling Test procedure is a general test to compare the fit of an observed cumulative distribution function to an expected cumulative distribution function. This test gives more weight to the tails than the Kolmogorov-Smirnov test. The Anderson-Darling statistic ($A2$) is defined as

$$A^2=-n-\frac{1}{n}\Sigma(2i-1)1.[\ln F(Xi)+\ln(1-F(X_{n-i+1}))]$$

The hypothesis regarding the distributional form is rejected at the chosen significance level (alpha) if the test statistic,2 is greater than the critical value obtained from a table. When comparing different distribution, lower statistics means better fit.

3.Chi-Squared Test is used to determine if a sample comes from a population with a specific distribution. This test is applied to binned data, so the value of the test statistic depends on how the data is binned. Although there is no optimal choice for the number of bins (k), there are several formulas which can be used to calculate this number based on the sample size (N). For example, Easy Fit employs the following empirical formula: $k=1+\log 2N$The data can be grouped into intervals of equal probability or equal width. The first approach is generally more acceptable since it handles peaked data much better. The Chi-Squared statistic is defined as

,$X^2= \sum_{i=1}^{k}((Oi + Ei)/Ei)$where$Oi$is the observed frequency for bin i, and Ei

$$Ei=(X2)-(X1)$$

Where F is the CDF of the probability distribution being tested, and x1, x2 are the limits for bin i. When comparing different distribution, lower statistics means better fit. Easy Fit Professional software is used for testing goodness of the recommended Log Pearson-III and Gumbel Methods

3.4 Drainage Network

The main cause for flood overtopping, sedimentation, deterioration of roads, flood overtopping, was the lack of detail flood information during rainy season and inadequate hydraulic design. Moreover, the construction of the drainage ditch was carried out without considering statistical assessment of the expected flow; which means that, ignoring hydrological analysis and calculating hydraulic parameters during the design stage. The hydrological analysis was used to know the peak flood generated from the surrounding catchment. In general, drainage crossings must be designed to pass the appropriate storm flows and allowable debris. For sustainable and long term design should pass through appropriate hydrological analysis of the catchment area and estimation of hydraulic parameters should be conducted before the actual drainage construction. If proper hydrological analysis and hydraulic calculation were not practiced, either overdesign or under design would occur that both involve excessive costs on a long-term basis.

A drainage structure designed to carry allowable recurrence interval flood otherwise accidental flood may damage by under estimated (low peak runoff) construction or over topping storm runoff on the surface of drainage facility and road surface almost in every year. Design of the drainage network system in the study area was under estimated to carry out peak runoff and not properly managed by municipality even to reduce pollution and health related problem.

3.4.1 Dembela Sub-City Drainage Network

1. AYU-Rift valley – Dembela drainage Lines

This drainage line is receiving flood run from Elemo Kiltu and Oliyad building' to Dembela. In front of AYU Hotel or at fuel station the size of drainage line is purposefully reduced to double small pipes results the drainage in under capacity and exacerbate the backflow effect. Most of manholes of this line were closed due to private property built upon on different segments of this drainage line. These all are responsible for flooding occurred around bus station. Moreover, Sewerage lines from surrounding centers and markets which connected to this storm drainage lines are polluting the environment at downstream.

2. TIM business center - Dambela drainage line

This line passes under TIM business center. It serves flows from center of kebele 08 and from the end of no. 1 along Addis Ababa main road. The flow from the upstream of the bridge overflow out of the bank of the river and floods the eastern side of the river bank up to German

Hotel. The second route which is from Ayu-River Café as These sites are different from the other routes by its highly accumulated runoff volume that caused very disastrous flood problem in Kebele 09 area last. The problem is characterized by closed culvert crossing the main road, Closed of manhole, Connected sanitary system to storm drainage line and Built property on drainage line. These favor flooding around German Adama

3.Drainage line on the side of KideneMihiret Hotel

This line passes beside KidaneMihret hotel to serve the flow on downstream. It has common problems with the above two drainage lines, which causes flooding on the area.

4.Dembela stream /water way

This stream line is a cumulative flow from all upstream (Awash Hotel, drainage line from ORGAN Hotel and drainage line through Rift Valley University). The main problem of this site is alignments of streams at junction point. It is observed that the larger discharge coming through the stream from Awash Hotel joins the other two streams. This intersection will be responsible for obscuring the flow come from AYU Hotel and ORGAN Hotel. This will increase the backflow effect of the two streams and flooding the surrounding area through breaking of stream banks and outflow. It is observed that illegal settlement around the junction obscured the flow from residential areas. In addition to these, the sedimentation and stream bed slope especially from this junction point to Nursery site located at downstream decreases the velocity of the flow and contributes in backflow effect. At downstream, around cattle market, where the main stream and the stream from 'Tankegna' intersect shares exactly the same problems.

5.Awash Hotel Bridge-Dembela Gorge

This was identified due to its typical characteristics of the potential accumulation of huge volume of runoff from upstream of the bridge (Silasie-Old Kera-Agricultural machinery), from Ayu-River Cafe and the western side of the Awash Hotel. The flow from the upstream of the bridge overflow out of the bank of the river and floods the eastern side of the river bank up to German Hotel. The second route which is from Ayu-River Café as well as from the other sides of the Rift Valley University floods the Southeastern side of the bridge. These sites (the flow line from the Awash Bridge to Dembela) are different from the other routes by its highly accumulated runoff volume that caused very disastrous flood problem in Kebele 09 area. The bed of drainage system is highly scoured with the alluvial soil at upstream with highly affected river banks, whereas, the downstream of this Bridge up to Dembela is characterized by shallow bed in some rocky exposure and there is a distinct change in topography of the river bed surface as it flows downstream that shows deep gorgy nature due to the thick soil exposure

3.5 Storm Water Modeling Software

The EPA Storm Water Management Model (SWMM) provide an integrated environmental for editing study area input data running hydrologic ,hydraulic and water quality simulation and viewing the results in variety of formats. SWMM has been an effective tool for simulating floods in urban areas and a free, code-open simulation engine, so modellers can develop different personal functions with SWMM. In this project, a modified personal SWMM 5.1 version is selected as the modelling environment

3.5.1 Data Collection for Modeling

The modelling data in the project includes

1) Drainage networks data collection is often carried out under local GIS scheme. A drainage network survey plan is conducted, and the bottom depth of the conduits is emphasized. The survey outcome is submitted with CAD image and Excel sheet.

2) Catchment delineation is the crucial necessary step for catchment data collection and the attribute data used in the project are empirical data.

3) Modelling is a rainfall-driven application and rainfall events are collected, but the time scale of the rainfall is large (24hrs) to meet the modelling demand. Hence, rainfall-synthesized method and rainfall-disaggregated method were taken into consideration.

4) Land use and Land cover data of the study area known

5) GPS of drainage lines with their dimension and slope

6) Model calibration data can help to improve the model accuracy.

7) Other data such as data consist of pump station data (dimension of the tank, control rules, etc) and water level of the drainage ditch canal.

4. RESULTS AND DISCUSSIONS

This chapter describes and discusses the result obtained from different analysis and evaluation in this study. Results of the existing condition of the drainage network system, runoff estimation generated from the Dembela sub-city using different tools such as flow master, rational formula and SWWM software's. The performance and capacities of the drainage network evaluation results and discussions are included in this chapter. Finally, the proposed drainage networks are discussed.

4.1 Catchment Delineation and Drainage Network

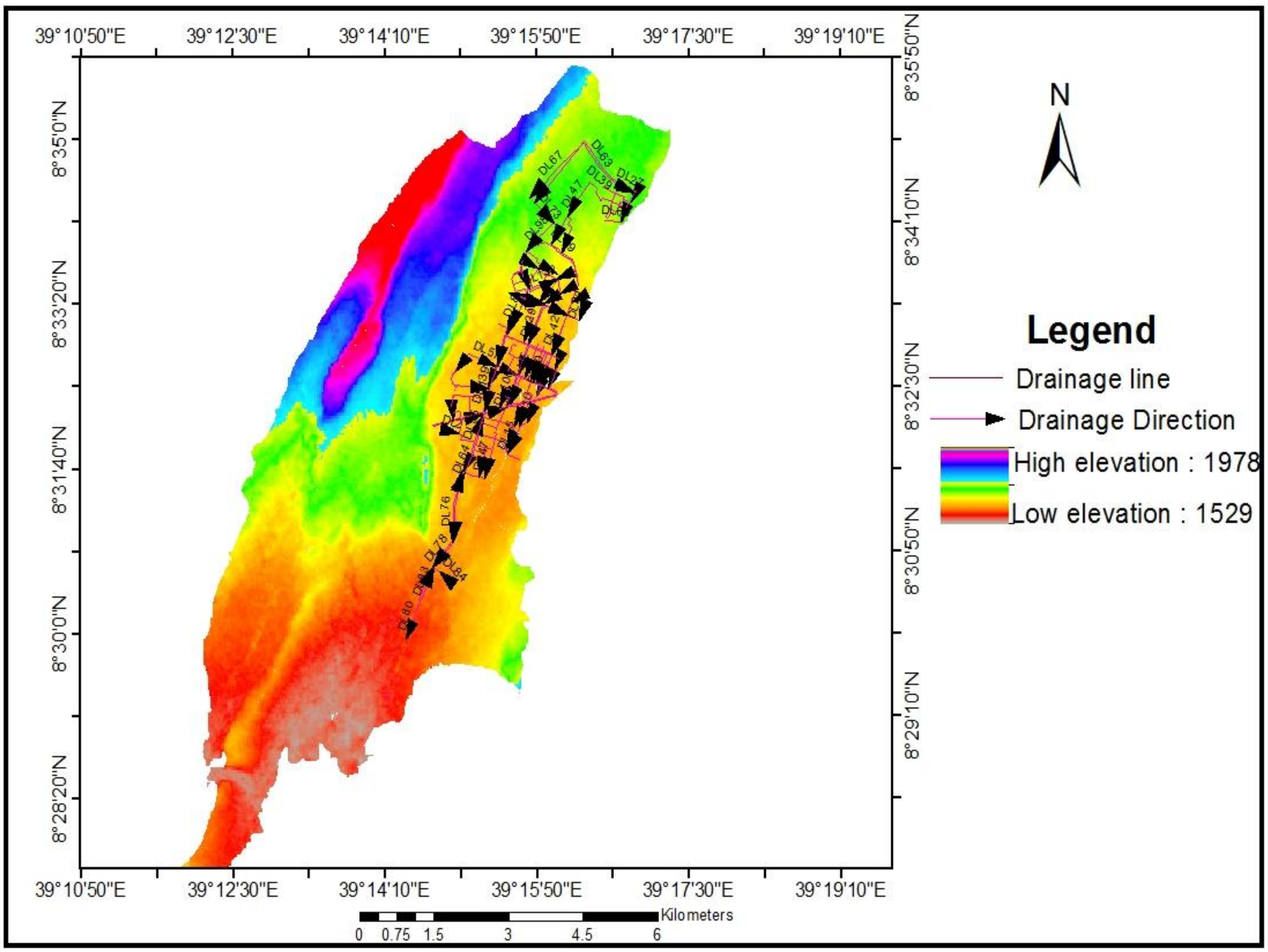


Figure 7:Computed delineate the drainage system and network

The delineated map of the catchment area is shown in the Figures 9 above. From the delinated study area the topography elevated from three zones of Dembela Sub-city, Melka Adama zone Dagaga zone ,Irrecha zone and SW to NE respectively as it is one of two outlets of Adama town The Field survey have been done in order to identify the ridges of the catchment for the resolution on DEM.The catchment properties such as slope, area, flow length and flow directions was worked out by using GPS

4.2 Rainfall and the Consequent Run off

The rainfall frequency analysis is done using both Gumbel and log Pearson type III methods as recommended by ERA manual (2013). The result obtained is tabulated in the following table.

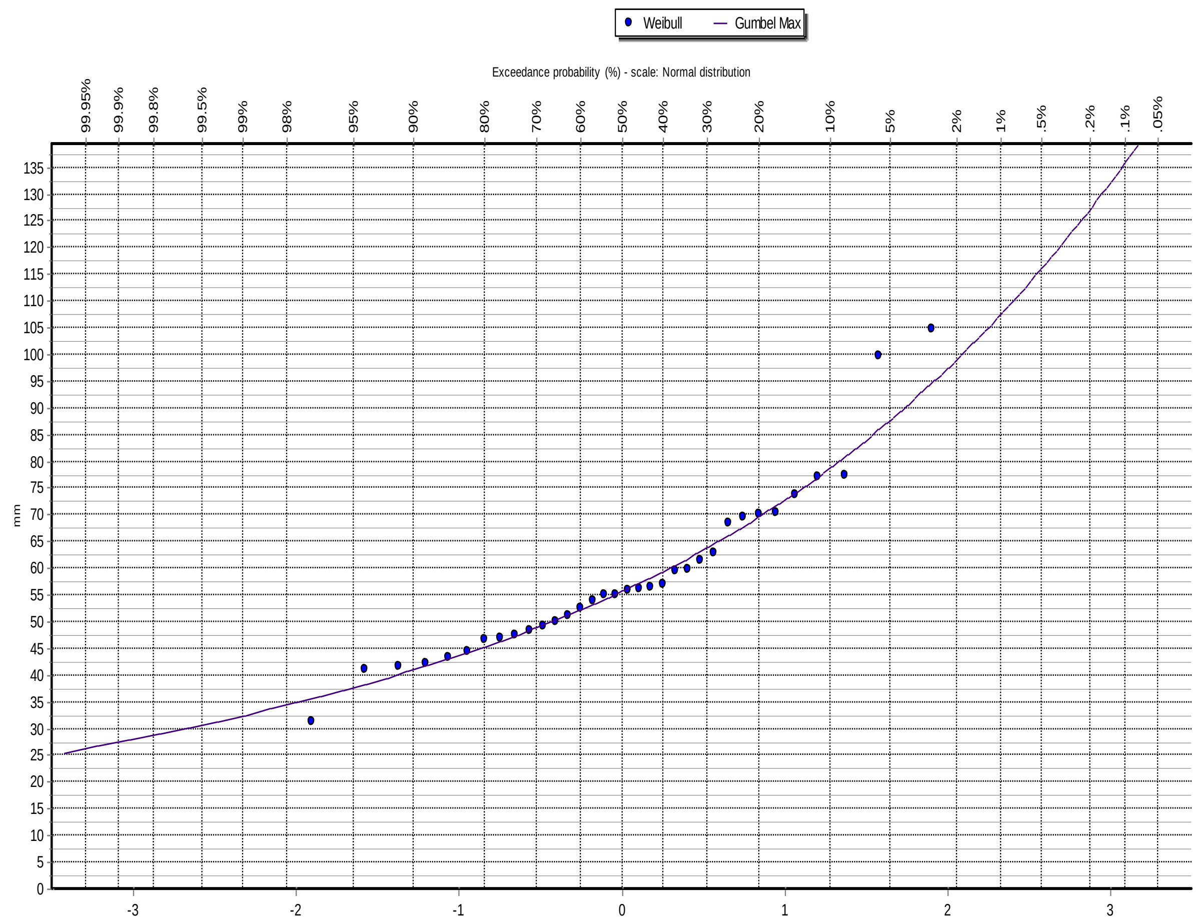


Figure 8:Probability Plotting Position Log Person III Distribution

Log Person III fits for the distribution with $R2$=0.9993.Therefore, both methods show that the log Pearson type III distribution fits with the rainfall data used for this study. Accordingly, the Log-Pearson III was chosen for further analysis.

4.2.1 Intensity – Duration Frequency Curves (IDF)

The IDF curve was developed from a 24-hour rainfall data of 33 years duration i.e. from 1978 to 2019, obtained from Adama Meteorological Agency - gauge located around Adama Science and Technology University. Consequently, the following two different IDF curve has been produced and compared. The one with 24 hour rainfall of A3 region and other which are appropriate to this research by develop 24 hour rainfall .The data obtained for production of IDF curve is the result of calculations using reduction formula and it is tabulated below. Then, using the data in the table the IDF curve has been produced which shown below.

Table 1: Duration of Rainfall against their corresponding average Intensities

Duration (minutes)	2 years return period	5 years return period	10 years return period	25 years return period	50 years return period	100 years return period	200 years return period
10	73	87	103	112	120	135	153
20	55	66	77	85	90	102	116
30	45	53	62	68	73	82	93
40	37	44	52	57	61	69	79
50	32	38	45	50	53	60	68
60	28	34	40	44	47	53	60
70	25	30	36	39	42	47	54
80	23	27	32	35	38	43	48
90	21	25	30	32	35	39	44
100	19	23	27	30	32	36	41
110	18	21	25	28	30	33	38
120	17	20	24	26	28	31	35
130	16	19	22	24	26	29	33
140	15	18	21	23	24	28	31
150	14	17	20	22	23	26	30
160	13	16	19	20	22	25	28
170	13	15	18	19	21	23	27
180	12	14	17	19	20	22	25
190	12	14	16	18	19	21	24
200	11	13	16	17	18	20	23

The (ERA) Drainage Design Manual of 2013 equations and reduction formula as described in the methodology section has been applied to developed IDF curve for region A3 and Dembela sub-city for comparison of the results obtained from both. There was rainfall for 24hrs in different return period/years and duration time were used to developed IDF for A3 and the rainfall data(1987-2011)years were used forR24generated to developed IDF of Dembela sub-city or Adama city

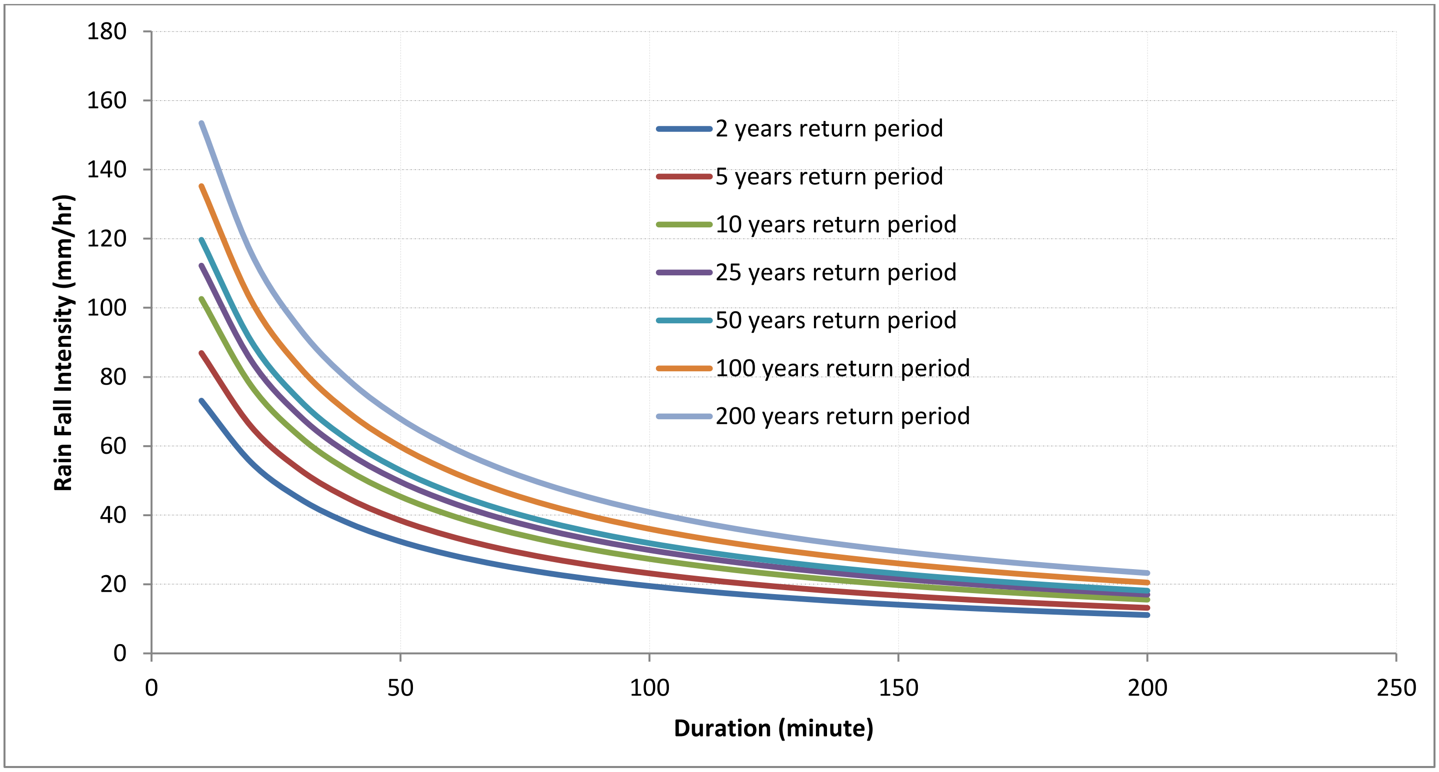


Figure 9:The developed IDF Curve for Dembela sub-city(1978-2011)

The comparison results showed disparity mainly because the rainfall data used for developing IDF curve for Adama city is from 1978 to 2011 and that of the ERA was collected in the past years. In addition to this, ERA developed IDF curve based on combining intensities from different stations together which were not applicable for the specific area since the intensity values were too much different for each stations.

Table 2: Comparison of IDF curve results

RPY/DM	10		30		60		90		150		200	
	DS.IDF	A3.IDF	DS.IDF	A3.IDF	DS.IDF	A3.IDF	DS.IDF	A3.IDF	DS.IDF	A3.IDF	DS.IDF	A3.IDF
2	73	75	45	45	28	29	21	22	14	14	11	12
5	87	94	53	57	34	37	25	27	17	18	13	14

10	103	107	62	65	40	42	30	31	20	21	16	16
25	112	123	68	75	44	48	32	36	22	23	17	19
50	120	135	73	82	47	52	35	39	23	25	18	20
100	135	148	82	90	53	57	39	43	26	28	20	22
200	153	160	93	97	60	62	44	46	30	31	23	24

DS :Dembela sub-city IDF :intensity duration frequency

RPY: return period in years DM: duration in minute

It can be seen from the two IDF curves developed (the one which used a 33 year daily rain fall data (1985-2018) in this study and the one which developed from 24 hour rainfall of A3 region.. Notice that each value IDF of Dembela sub-city in the Table 4 above are smaller than that of the correspondent values of ERA for Dembela sub-city IDF. It would be said that the use of ERA IDF curve is uneconomical, average IDF from different Meteorological station which not represent the Dembela sub-city IDF however it could be disturb the correct design of hydraulic structures

4.3 Existing Situation of Study Area

4.3.1 Capacities of the Existing Drainage System

The existing conditions of drainage system were investigated in detail, and photos were taken to show the existing conditions of the drain.With referring crew field observation and survey data, it was claimed that the existing condition of the drainage network system performance and capacity is poor and unable to perform their intended purpose, and most the interviewed peoples around the Dagaga Zone said that the drainage infrastructures of the Dembela Sub-City are directed drains from the upper of Malka Adama to Dagaga collect around German Adama Hotel, whereas some of households were responded that the drainage system from the stream gorge to drainage canals due to inadequate capacity of downstream gorge to carry the whole discharge from the city to Awash river through Irrechaa. General, the existing drainage capacity and Networks and the capacity of the combined stream(from Ganda Hara, Galma Abba Gadaa through Dagaagaa in the city are not efficient, well planned and the people living in the area suffering by different problems like bad smell, transmitting of water born disease during summer season.

Existing drainage system network facilities were generally classified into closed and open drainage lines. Closed drainage lines are found in some areas especially along roads, from post office to Wonji circle road and from Sar-tara to the old bus station. Open drainage channels, constructed by masonry and some with RCC are found along mains, sub-mains and local roads. In many areas, cobble stone ditches and access roads serve as wide open channels with severe erosion and causes surface flooding problems. There are three types of storm drainage facilities in the Adama city; unlined open drainage channels (gravel. earth surfaces and stone paved surfaces), concrete pipe conduits and stone lined open ditches. The dimensions of existing drainage facilities, masonry (concrete) open channels vary depending on the need and design of each channel with mostly trapezoidal (some Rectangular exist) shape and concrete pipes vary from 0.60m up to 0.90m in diameter. Except in some areas, most of the topography of Dembela Sub-City was generally not suitable for both natural and artificial drainage facilities and system network.

The existing dimension of drainage canals were measured as observed in the following table and was computed by Manning formula then checked by flow master software .The other tables were computed (appendix 5,6 and 7)

Table 3: Computation of the capacity of the existing drainage system

Sr.No	Flow Direction		Drainage Types											
	From	To	Trapezoidal			Rectangular		Circular						
			B(m)	Y(m)	T(m)	B(m)	Y(m)	D(m)	n	A(m^2)	p(m)	S(%)	Q(m^3/s)	V(m/s)
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	DL1	DL2						0.8	0.020	0.5	2.51	2.6	1.367	2.73
2	DL2	DL3						0.8	0.020	0.5	2.51	2.1	1.227	2.45
3	DL3	DL4						0.8	0.020	0.5	2.51	3.3	1.546	3.09
4	DL4	DL5						0.8	0.020	0.5	2.51	1.4	0.996	1.99
5	DL5	DL6						0.8	0.020	0.5	2.51	1.1	0.862	1.72
6	DL6	DL7						0.8	0.020	0.5	2.51	1.2	0.930	1.86
7	DL7	outlet						0.8	0.020	0.5	2.51	0.4	0.527	1.05
8	DL8	DL9						0.8	0.020	0.5	2.51	2.3	1.300	2.60
9	DL9	DL10						0.8	0.020	0.5	2.51	3.7	1.640	3.28
10	DL10	DL12						0.8	0.020	0.5	2.51	2.2	1.270	2.54

11	DL11	DL12						0.8	0.020	0.5	2.51	0.9	0.838	1.68
12	DL12	DL13						0.8	0.020	0.5	2.51	3.7	1.640	3.28
13	DL13	outlet						0.8	0.020	0.5	2.51	1.9	1.160	2.32
14	DL14	DL15						0.8	0.020	0.5	2.51	4.4	1.791	3.58
15	DL15	DL16						0.8	0.020	0.5	2.51	2.8	1.429	2.86
16	DL16	outlet						0.8	0.020	0.5	2.51	1.9	1.160	2.32
17	DL17	DL18	0.9	0.8	1.2				0.045	0.84	1.63	3.6	2.302	2.74
18	DL18	DL19	0.9	0.8	1.2				0.045	0.84	1.63	2.3	1.829	2.18
19	DL19	Outlet	0.9	0.8	1.2				0.045	0.84	1.63	5.4	2.789	3.32
20	DL20	DL21				0.7	0.5		0.045	0.35	1.7	2.2	0.407	1.16
21	DL21	DL22				0.7	0.5		0.045	0.35	1.7	2.7	0.446	1.27
22	DL22	DL27				0.7	0.5		0.045	0.35	1.7	1.1	0.281	0.80
23	DL23	DL24				0.6	0.8		0.045	0.48	2.2	1.6	0.497	1.04
24	DL24	DL27				0.6	0.8		0.045	0.48	2.2	0.5	0.283	0.59

4.4 Estimated Runoff for the Study Area

In order to evaluate the capacities of the drainage system the current runoff has to be estimated. Therefore this part is prepared to brief the hydrologic investigation and evaluation of major and minor storm water drainages of Dembela sub-city which includes Malka Adama Degaga, irrecha, and other minor drainage lines for minor roads.

Estimation of current runoff for the study area was done for each drainage line by considering the plot basin area, length of drainage line (DL),runoff coefficient (C)of land use, slope DL from Google earth and ,arcGIS. The runoff estimated by design flood formula and for other tables(refer appendences 8,9,and10)

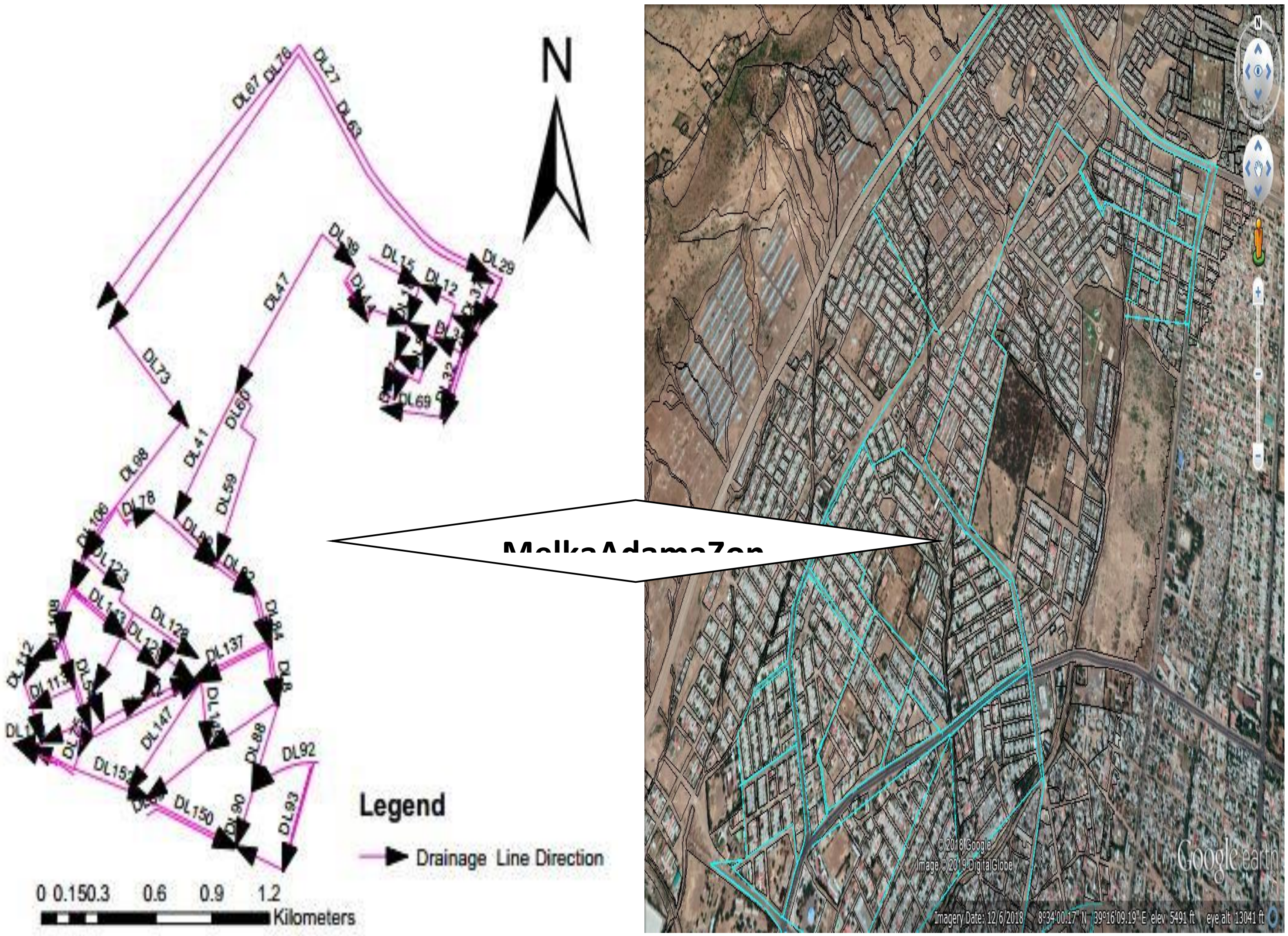


Figure 10:Drainage network system of Melka Adama Zone from Arc GIS and Google Earth

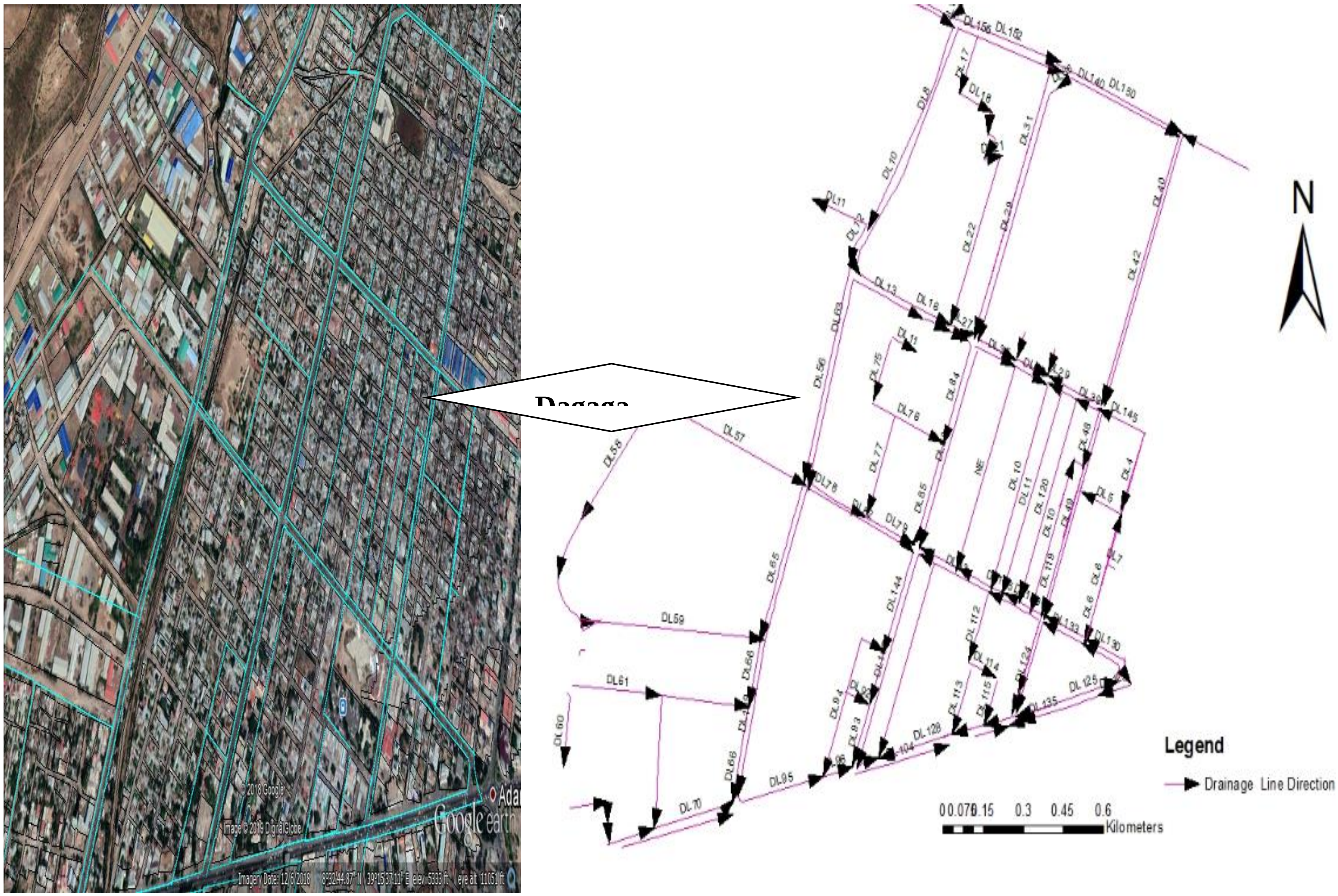


Figure 11:Drainage network system of Dagaga Zone from Arc GIS and Google Eearth

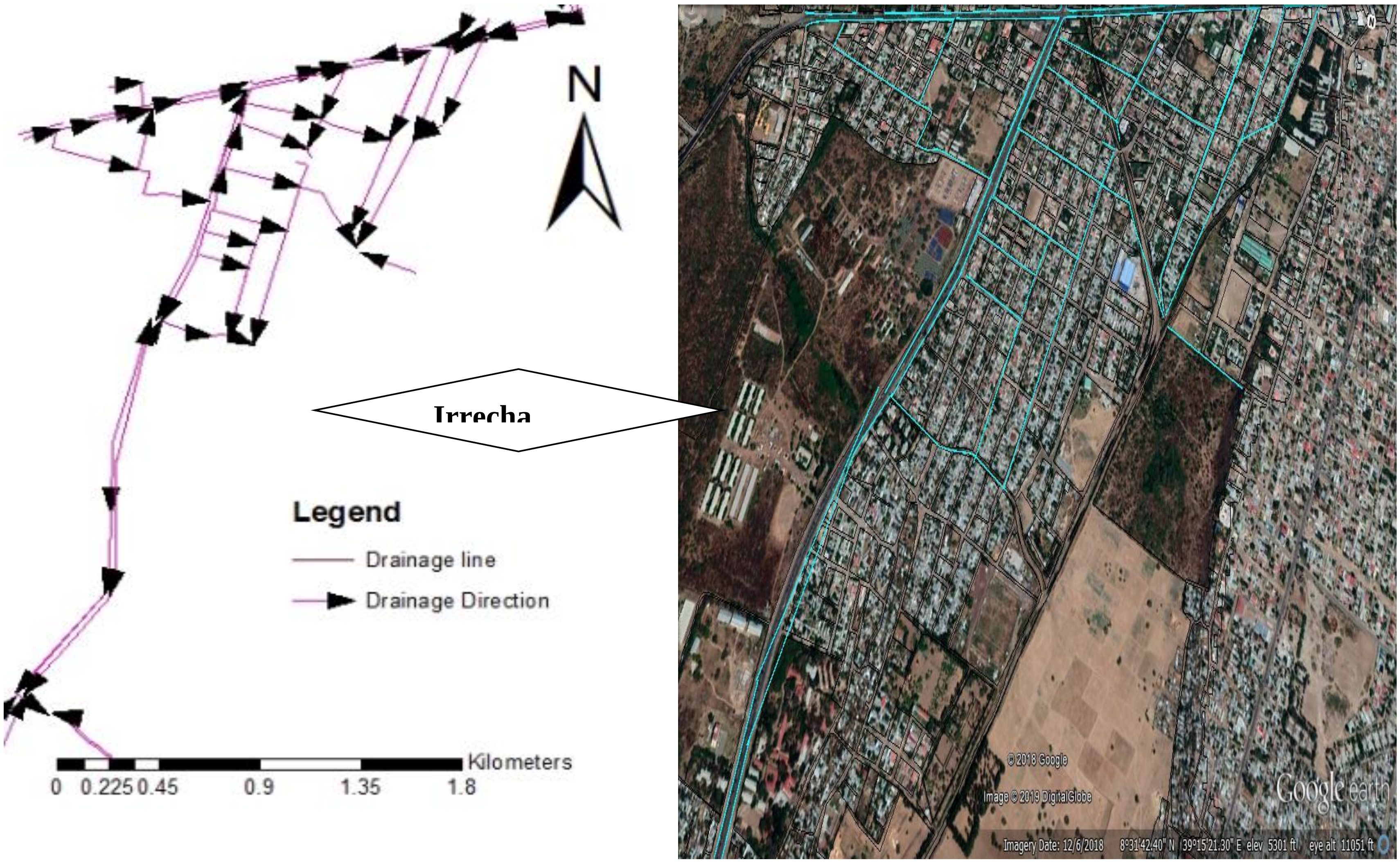


Figure 12:Drainage network system of Dagaga zone from Arc GIS and Google Earth

Table 4: Estimated current runoff for the study area

Plot No.	Flow Direction		Desciption of sub catchment	Sub basin area As(ha)	Runoff coffient ©	Total basin area A(ha)	Length of basin L(m)	Lowest elevation of the basin H1(m)	Highest elevation of the basin H2(m)	Average slope of the basin S	Time concentration of the basin Tc(hr)	Rainfall intensity I(mm/hr)		Total Runoff for plot of basin Qs(m^3/sec)
	From	To										5 years	10 years	
1	DL1	DL2	Asphalt Road Area	4.27	0.85	4.27	311	1659	1667	0.026	0.110		118	1.19
2	DL2	DL3	Asphalt Road Area	0.12	0.85	4.120	193	1655	1659	0.021	0.083		133	0.04
3	DL3	DL4	Asphalt Road Area	0.31	0.85	4.700	486	1639	1655	0.033	0.142		113	0.08
4	DL4	DL5	Asphalt Road Area	0.28	0.85	4.980	439	1633	1639	0.014	0.184		100	0.07
5	DL5	DL6	Asphalt Road Area	0.25	0.85	5.230	391	1629	1633	0.010	0.188		100	0.06
6	DL6	DL7	Asphalt Road Area	0.22	0.85	5.450	336	1625	1629	0.012	0.158		108	0.05
7	DL7	Outlet	Asphalt Road Area	1.17	0.85	6.620	262	1624	1625	0.004	0.202		97	0.27
8	DL8	DL9	Asphalt & School Arae	7.73	0.84	7.728	215	1657	1662	0.023	0.086		128	2.31
9	DL9	DL10	Asphalt & Residence Area	3.37	0.71	11.100	243	1648	1657	0.037	0.079		133	0.89
10	DL10	DL12	Asphalt & Residence Area	2.05	0.74	13.500	180	1644	1648	0.022	0.077		133	0.56

4.5 Performance of the Drainage System in the Dembela Sub-city

One of the most important factors in proposing sustainable stormwater drainage systems channel is the physical storage volume that needs to be provided to achieve flood control and minimize the pollution impact of urban stormwater runoff. This section on stormwater drainage begins by examining the performance of current drainage systems.

As presented in fig.13 out of 150 DL of the total storm water drainage existed in Malka Adama zone only 58 DL(38.67%) of the drainages are capable of conveying safely the runoff in to the water ways. In Dagaga (see Fig.14) out of 135 DL of the total drains 55 DL(40.74%) of the drains have the capacity to convey the run off in to the stream. And also in Irrecha Zone (see fig.15) out of 91 DL the total drains only 16DL (17.58 %) of the total drainage system have the capacity to convey the runoff generated under current condition. This shows that most of the drainage lines have lower capacity and the flood generated within these zones cannot safely be discharged in to the nearby river. On the other hand this will stagnate on open surfaces, overflow or inundate over road surfaces and also causes flood hazards in these zones.

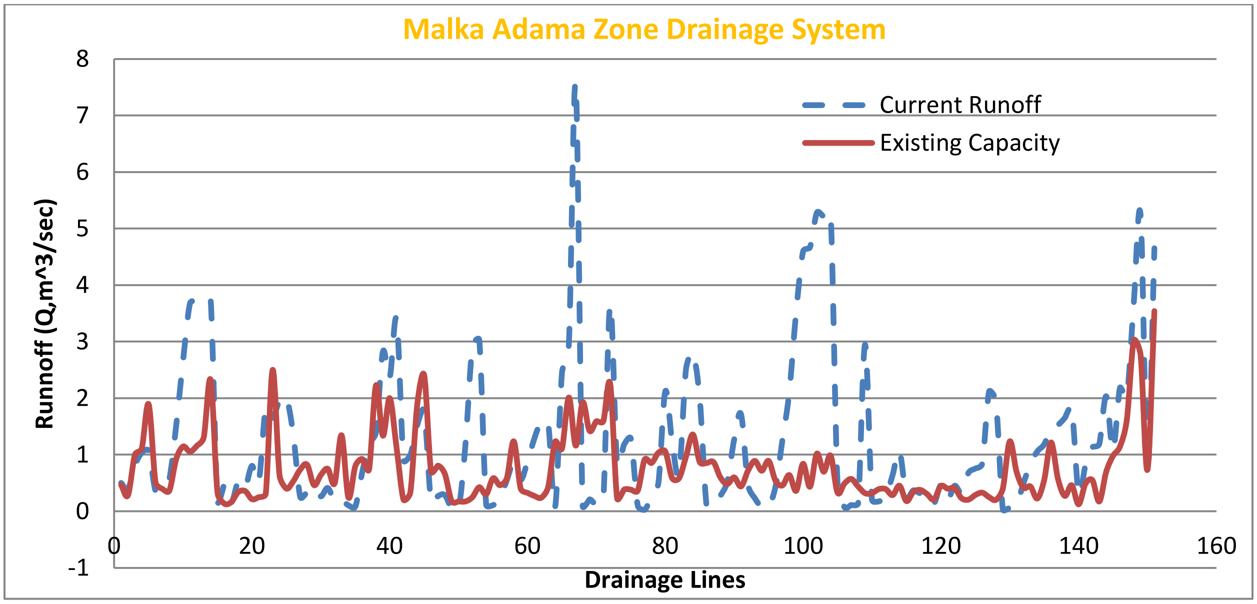


Figure 13:Comparison of the capacity and the current runoff for MalkaAdama Zone

Analysis, calculating the existing capacity by measuring dimensions of the drainages and compare it with the current runoff

There are different reasons why the capacities of these drainage systems are poor. Of all the reasons this is mostly due to the fact that most of the drainage systems in these zones have been installed long time ago and failing to consider and forecast the correct land cover changes while designing the drainages' capacities. Since then the land use cover has been changed resulting much more runoff than the capacities of the drainage system could handle.

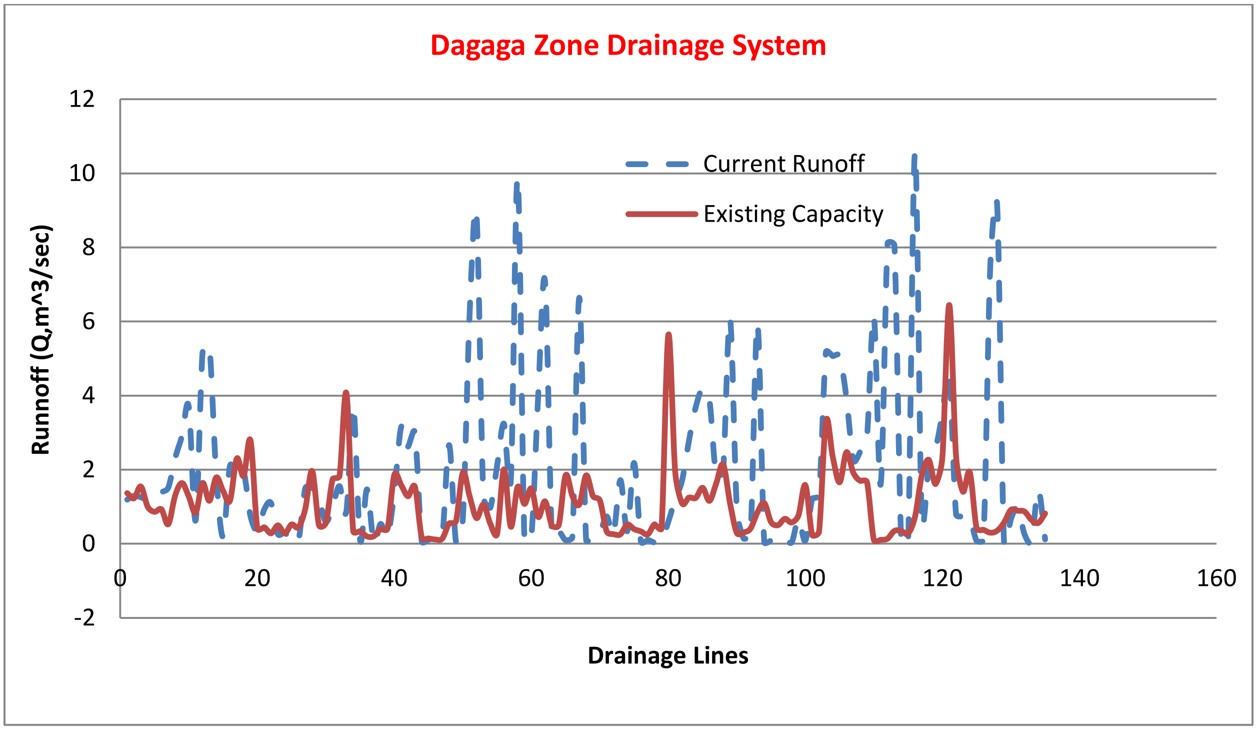


Figure 14:Comparison of the capacity and the current runoff for Dagaga zone

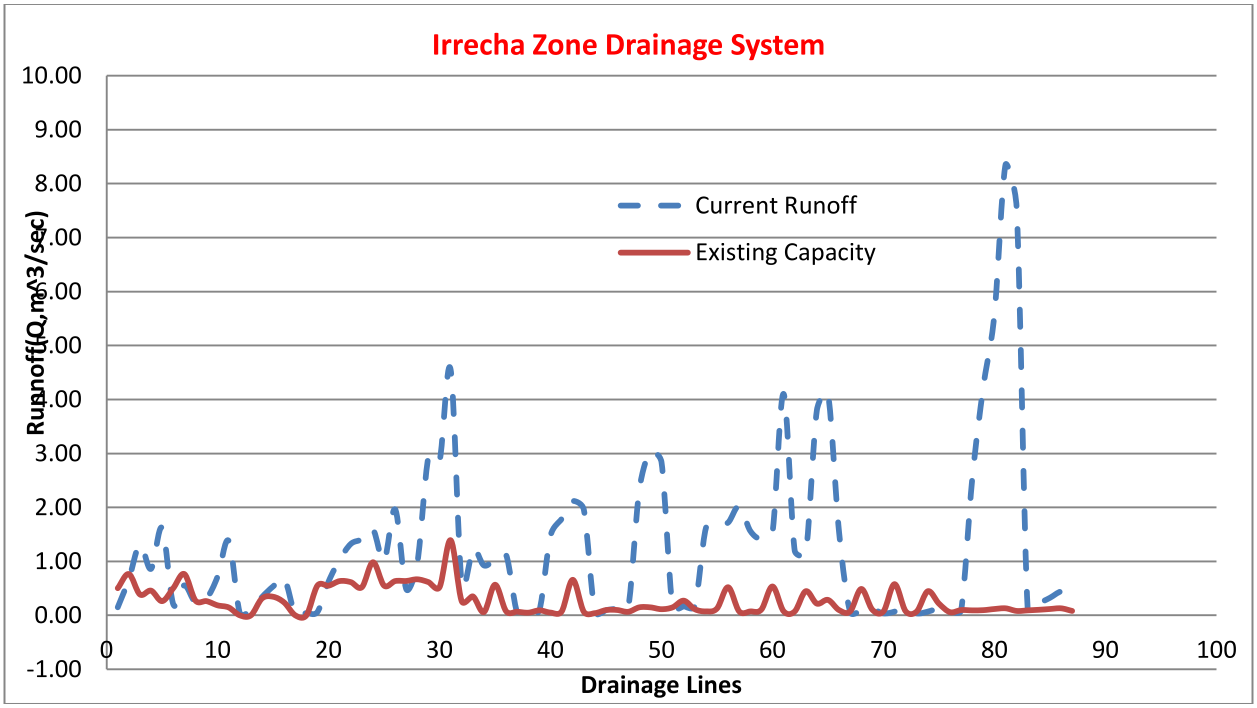


Figure 15:Comparison of the capacity and the current runoff for Irrecha Zone

4.6 The Storm Water Management Model Simulation

Urban drainage networks modelling projects were initiated in recent years in our country. However, modelling information were not enough for most cities. Hence, in Dembela sub-city case using SWMM for drainage network modelling was presented to illustrate the modelling methodology under data scarcity. The practical methodology includes data collection and inputting, sub-catchment delineation, initial optimization for model parameters, sensitivity analysis, the macro-level calibration and simulation scenario analysis.

The simulation of this research results were based on 27 subcatchments,1rainguage,73 conduits with their own slope and length,49 junctions with their own depth, and four outfalls. All parameters have with their coordination(X, Y) and 3.33hrs Rainfall intensity are used. After the successful run of the Storm water management model (SWMM), both report file and output file results are obtained.

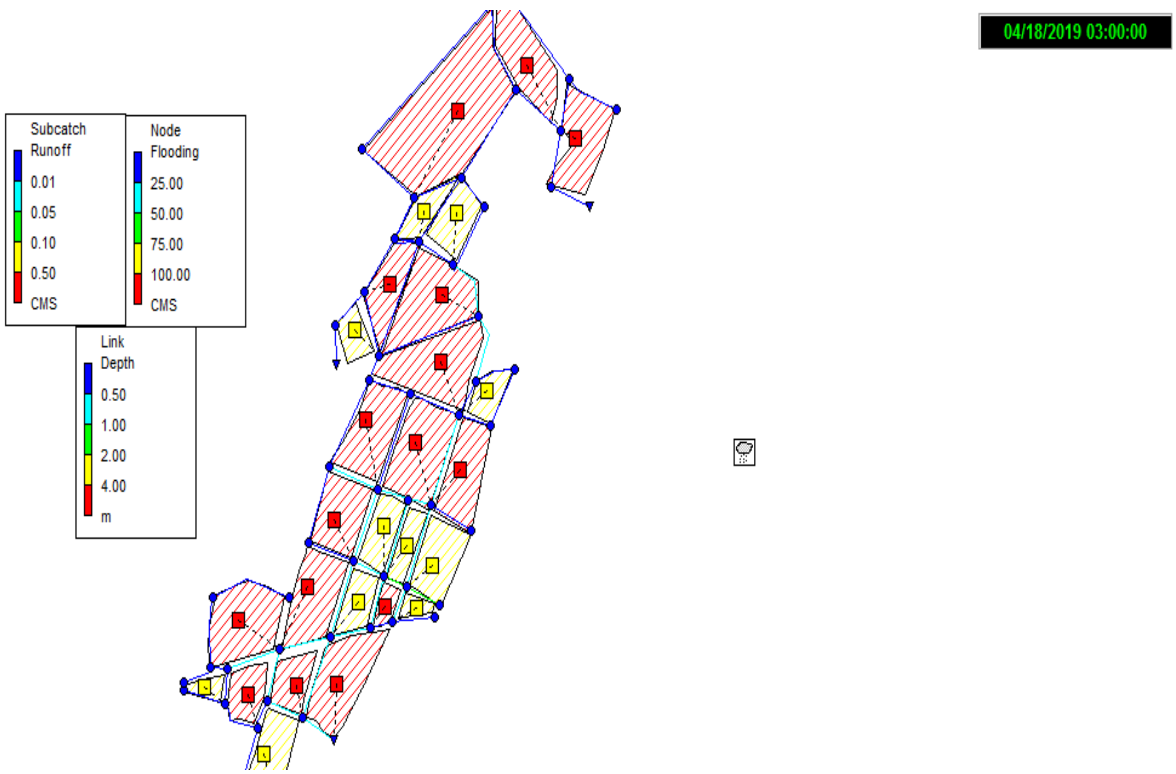


Figure 16:Simulation of Dembela Sub-City drainage networks

The report summary of SWMM software provided the following results after simulation run with the data incorporated. The 27 sub-catchments peak runoff and runoff coefficient is elaborated in table 8 above, the others junctions and drainage conduits are selected as it suitable to analysis the results to met the objective of this research below:

Table 5:Report summary of junctions and drainage conduits parameters

Junctions	MaX. HGL(m)	Max. depth(m)	Hours flooded	Max .rate(CMS)	conduits	Max/full depth	Max/full flow	Max. V(m^3/s)	Max/ flow(CMS)
J1	1678.0	1.00	1.80	0.53	C14	0.82	0.94	5.43	1.43
J4	1685.0	1.00	1.75	5.25	C17	1.00	1.00	4.53	0.10
J8	1680.2	1.00	1.49	4.45	C18	0.57	0.59	6.76	3.10
J16	1613.8	0.45	4.46	1.50	C19	0.44	0.41	4.21	1.37
J18	1617.0	1.00	4.34	10.11	C20	0.62	0.49	5.78	1.61
J23	1629.6	1.30	1.00	2.95	C22	1.00	1.06	3.33	2.58
J25	1637.4	1.00	2.51	3.20	C23	1.00	1.15	2.80	2.76
J28	1622.2	1.00	3.27	0.16	C25	0.62	0.74	1.01	0.51
J29	1624.3	1.30	0.90	2.68	C26	0.67	2.41	1.91	1.00
J32	1614.6	1.30	3.55	11.26	C28	1.00	1.28	1.91	1.50

From The report summary of simulation of SWMM maximum rate of junction and the flooded hours was obtained. In the drainage canal above shown compare the maximum full depth is less than the maximum full flow there is flooding because they have no capacity to carry the runoff (see table 5.above C14,C18,C22,C23,C25,C26 & C28) and the maximum full depth is greater than the maximum full flow there is no flooding (see tableC19 & C20) and C17 is equal which has the capacity to carry the coming flood. Hence the maximum flow in CMS occurs is computed.

4.6.1 Scenarios

The Flooding and other flow characteristics are high or causes flooding problems at the mentioned junctions and links for long duration of rainfall intensity 3:20hr both upstream and downstream part of the system. But, for the short duration rainfall intensity of rate of flood occurrence (time to peak) is very fast at the upstream of the junction and its release (falls) with fast rate. This is true for all the simulated junctions. Also, the graphs are self-explanatory for each junction presented here which are simulated for 3:20hr and rainfall intensity for the same junction and links.

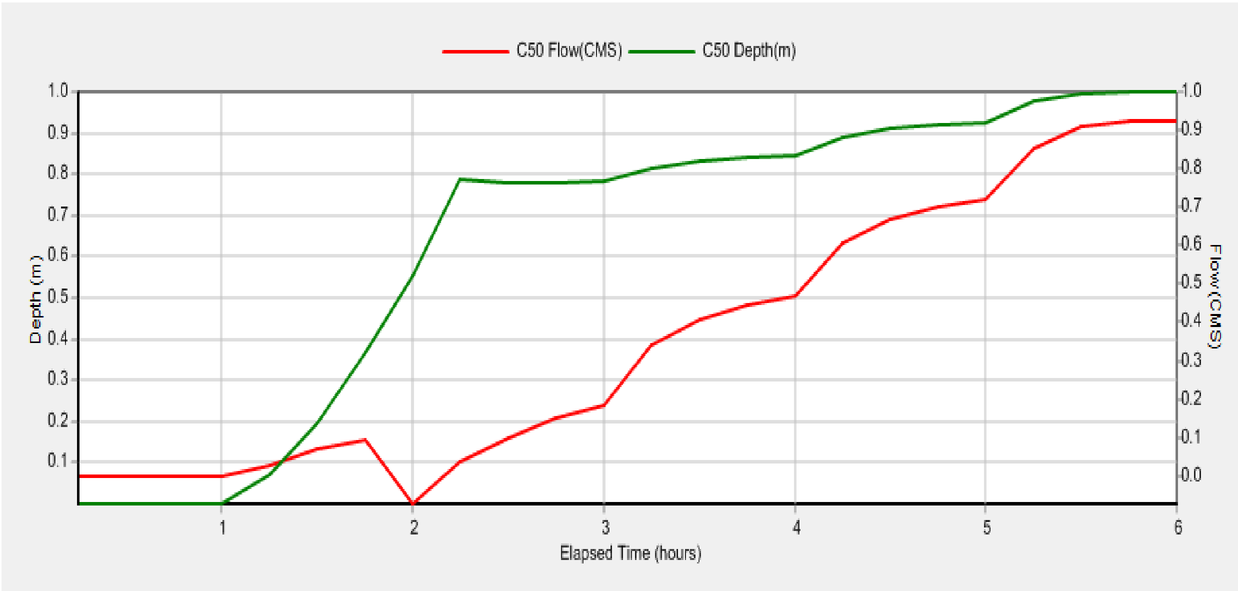


Figure 17:Water elevation profile and Water depth in channel 50

The depth and the flow of conduit 50 was 1m and 0.9 CMS respectively as see from figure 17 above.

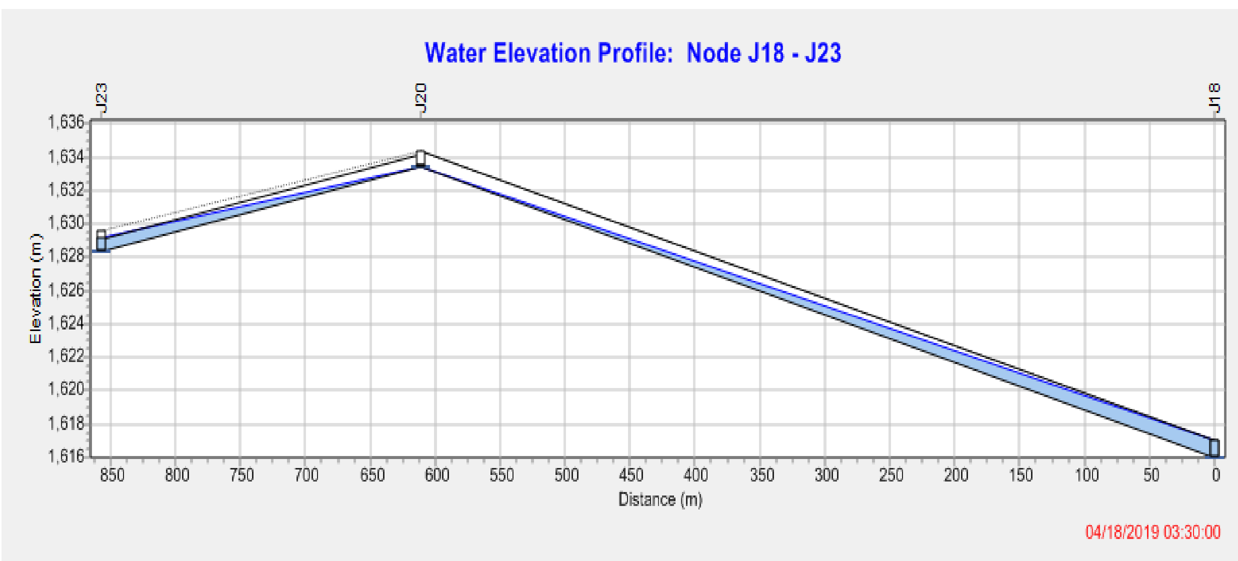
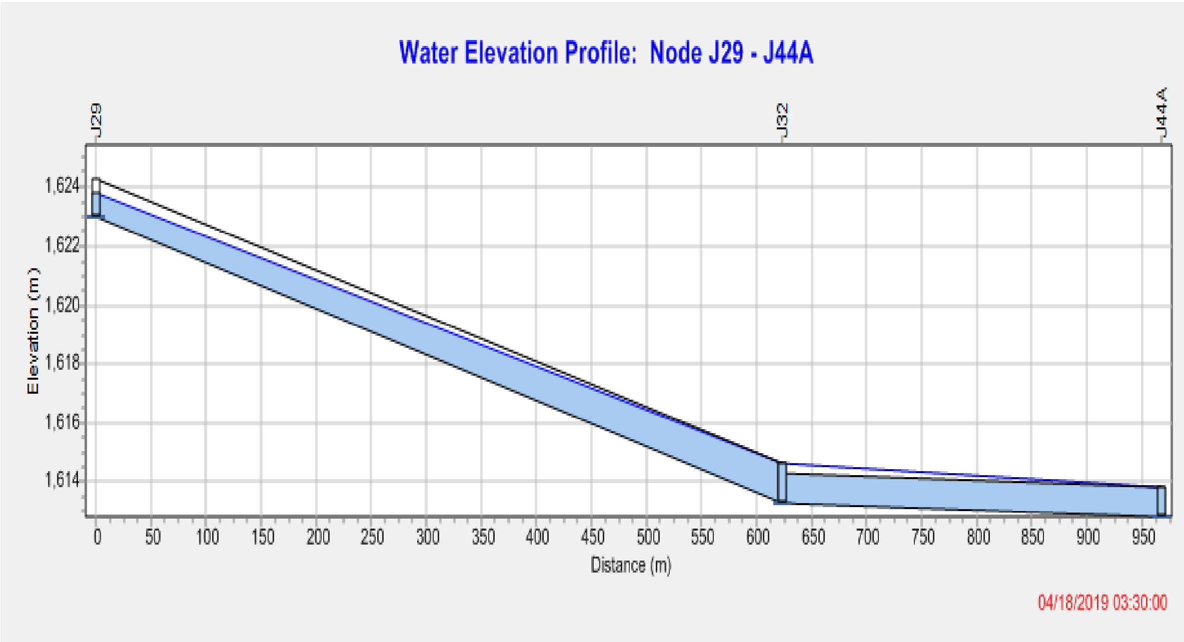


Figure 18:Evaluation of Junction and drainage line with the intensity of RF in MalkaAdama zone

The flow Path (from J29 to J44A) water elevation profile J32 and J44A are flooding in intensity rain fall 3:30 and J 29 is no flooding. The water level profile also indicates that flow path is from J29 and J44A both to J32 around Elemo Kiltu building as shown below in figure 19. The right side represents the depth in meters and left side represents amounts of flood in CMS and flow.

DL40 and J32 have maximum depth 1.3m. Hence the maximum flow of DL40 is 10.9CMS and maximum flood in J29 is 2.5CMS.



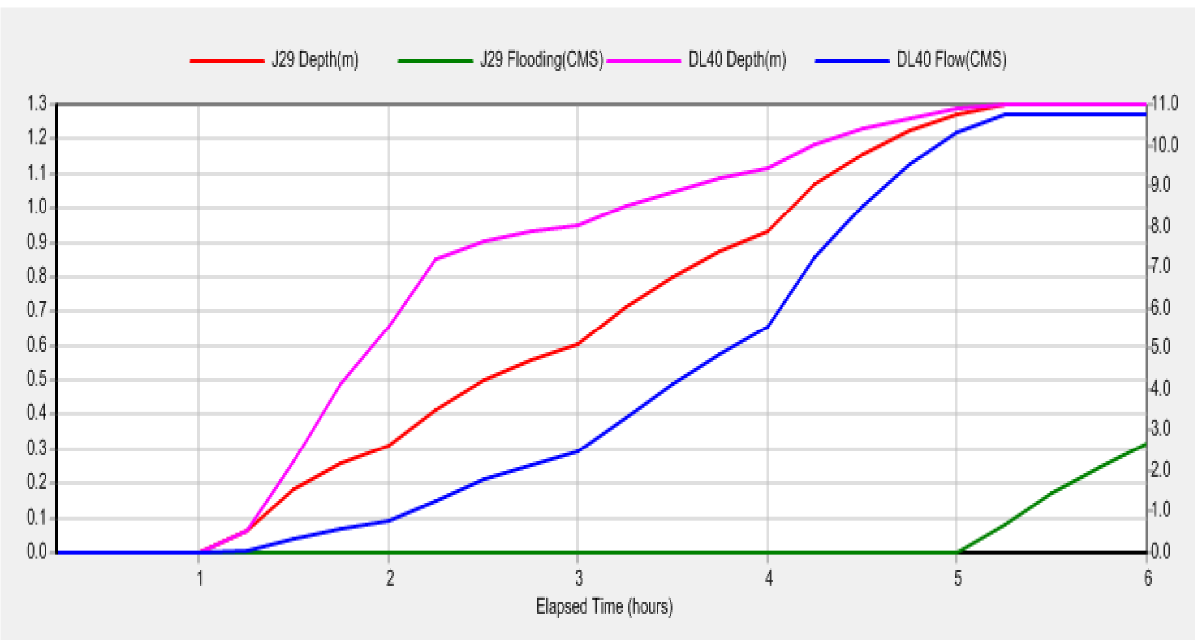


Figure 19:Evaluation of J and DL with the intensity of RF in Dagaga zone around ElemoKiltu

The figure 20 shown below The flow Path from J40 to the Outfall GMA1 has drainage line DL65,DL69 and DL63. They have maximum water elevation 1.612m and 1.61m respectively in the rain fall intensity 3:30hrs. J 41 and J44 is flooding and J40 and Outfall GMA1 is no flooding

.Hence DL69 and DL62 have the the maximum to convey the runoff 0.65CMS and 1CMS respectively. The maximum depth and flooding of J44m is 1m and 3CMS respectively.

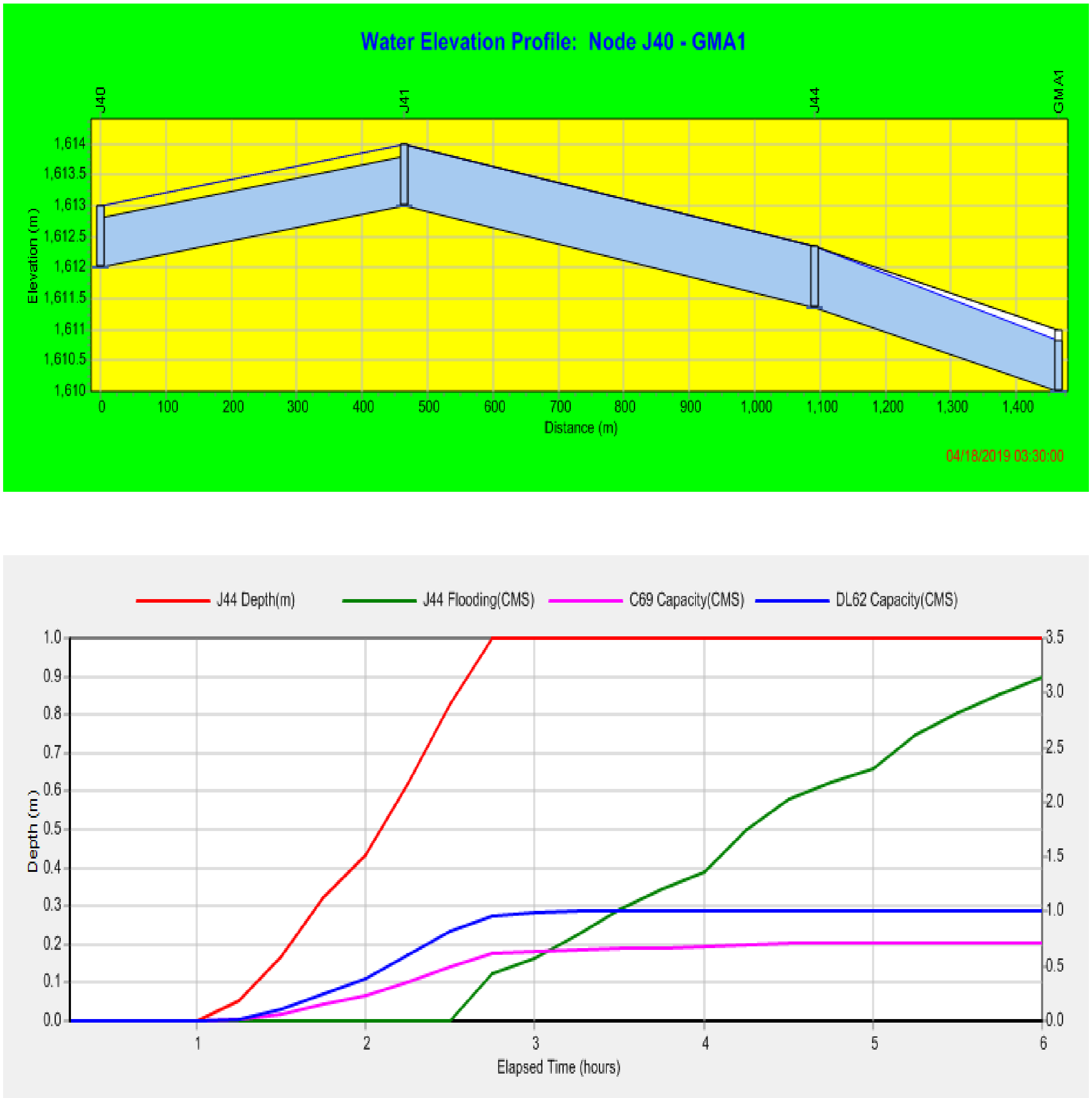


Figure 20:Evaluation of Junction and drainage line with the intensity of RF in Irrecha zone

4.6.2 Model Calibration Limitation

Model Pre-calibration scheme is presented aiming to improving the initial value for model parameters. For hydrologic model (rainfall runoff model) parameter calibration, the comprehensive runoff coefficient is used as the calibration data. That is to say, the hydrologic model simulation output should comply with the comprehensive runoff coefficient. If not, the hydrologic model parameter should be adjusted. For hydraulic model (drain flow model) parameter calibration, the water logging event records are used as the calibration data. In applications, it can be monitored by video recorders scattered at the road crossing. According to the location and extent of the water logging nodes, the drain parameters can be initially calibrated. The importance of the model parameter pre-calibration is it can improve the efficiency and accuracy for the later calibration and optimization arithmetic.

The calibration process is an iteration and update evolvement. The calibration process will stop until the difference between the simulation output and the field investigation can meet the modelling standard. Therefore because of lack of sufficient data to calibrate the study limited. So, the model results are simulations without calibrations. The water level in the junctions and outfall in Dembela Sub-City is no measured.

4.7 Dembela Sub-City Storm Water Drainage Problems

Apart from significant flood regime change, field survey reveals, the interview of 62 peoples and analysis show above there are different major factors affecting the urban drainage system that makes the process of disposing runoff in to water ways made difficult in this area. The results are discussed below:

a .Dumping of solid wastes in to storm water drainages and streams

Dumping solid waste materials in to drainages and streams was the other challenge of storm water drainage system. Urban litter (alternatively called trash, debris, junk, floatables, gross pollutants, rubbish or solid waste) has become a major problem in Malka Adama, Dagaga and Irrecha zone it typically consists of manufactured materials such as bottles, cans, plastic and paper wrappings, newspapers, shopping bags, cigarette packets and remains of chat. As a result of damping these solid wastes in to drains the drainage system has been clogged and causes flooding over streets and walk ways.

b. Release of liquid wastes in to storm water drainages and streams

The water that is running directly into the streams is often picking up pollutants along the way. These pollutants can include motor oils and gasoline that leak from vehicles, waste from sewer lines and anything else that will float or dissolve in water..

c. Lack of Community Awareness to Environmental Management

Community awareness is one of the best proactive measures for the sustainable urban drainage management. Unfortunately, from the interview it was studied about 47% (29 out of 62 people) of the residents thought that damping wastes in to the natural water ways and storm water drainage system is the right thing so as to keep their homes clean and they don't even know what is wrong with the idea of dumping waste outside their home as long as their residence is clean. The other 53% of the residents knew that damping liquid wastes in to existing drainage system and water ways is wrong however, they have been enforced to damp the wastes in to the water ways irrespective of the effects that could cause to their environment. They have implied that there is no proper sewage system to collect wastes extracted from each household.

d. Damaged Drain Lines Due to Construction

From the field observation it was recognized that some of the drainage lines failed because of poor construction and majority of infrastructure development in the sub cities have less attention to the drainage system. For example, housing construction, water supply lines and telephone line installation and expansion have been damaging drainage lines. Most of the time after the construction they didn't care enough to maintains and they have not been maintained regularly.

e. Land use Land cover change

Adama is one of the fastest growing cities in Ethiopia. The cities' land use has been changed from rural area in to urban area that Agricultural lands changed to urban areas.Generally the land use change is due to expansion of residential area, industrialization and paved road. Because of this reason most of the drainage lines designed for the earlier land use have lower capacity to handle the amount of runoff currently produced over the changed land use. Especially Irrecha zone have been extensively changed from undeveloped area in to commercial area.

f. Manholes (Catch pit) Problems

Some of the manholes or catch pits in Dagaga zone and irrecha zone have been clogged with waste and blocked due to lack of clearance. As a result the runoff that is generated in that sub basin over flows with higher velocity which erodes the ditches as well as the road and walk ways.

g. Lack of Frequent Clearance of Drainage system

Due to lack of frequent clearance of drainage lines they have become out of services. Sediment load, solid wastes blocked most of the drainage system. So without scheduled clearance the service life of those ditches could be out of their life span.

4.8 Propose Drainage Networks

In all analysis and results done above the existing canal have no the capacity to carry the rainfall intensity. Therefore proposed drainage facility with proper estimation of hydrological and hydraulic analysis was carried out as appropriate measure. Design the appropriate canals with the most economic and most efficient hydraulics section such that rectangular canals to MalkaAdama and Irrecha and trapezoidal to Dagaga zone (table 6,7 & 8) below;

Table 6:The appropriate Proposed drainage channels for MalkaAdama zone

		Malka Adama Drainage Channel Capacity					
Subcatchment	Description	Existing	Proposed Rectangular Type of Drainage Channel				
			Design 10yrs	For 25yrs	For 50yrs	For 100	For 200yrs
	Discharge(m3/S)	28.80	29.55	31.69	33.57	37.18	39.86
	n	0.045	0.045	0.045	0.045	0.045	0.045
	s	0.036	0.036	0.036	0.036	0.036	0.036
1	**Depth D(m)**	**1.88**	**1.90**	**1.95**	**2.00**	**2.07**	**2.13**
	Width B(m)	**0.94**	**0.95**	**0.98**	**1.00**	**1.04**	**1.06**
	Discharge(m3/S)	9.40	11.26	11.98	12.62	13.82	15.02
	n	0.045	0.045	0.045	0.045	0.045	0.045
	s	0.037	0.037	0.037	0.037	0.037	0.037
2	**Depth D(m)**	**1.23**	**1.32**	**1.35**	**1.38**	**1.42**	**1.47**
	Width B(m)	**0.62**	**0.66**	**0.67**	**0.69**	**0.71**	**0.73**
	Discharge(m3/S)	16.21	28.24	30.03	31.62	29.24	35.16
	n	0.045	0.045	0.045	0.045	0.045	0.045
	s	0.027	0.027	0.027	0.027	0.027	0.027
3	**Depth D(m)**	**1.60**	**1.97**	**2.02**	**2.06**	**2.00**	**2.14**
	Width B(m)	**0.80**	**0.99**	**1.01**	**1.03**	**1.00**	**1.07**
	Discharge(m3/S)	15.12	17.90	18.76	20.15	22.15	19.44
	n	0.045	0.045	0.045	0.045	0.045	0.045
	s	0.027	0.027	0.027	0.027	0.027	0.027
4	**Depth D(m)**	**1.56**	**1.66**	**1.69**	**1.74**	**1.80**	**1.72**
	Width B(m)	**0.78**	**0.83**	**0.85**	**0.87**	**0.90**	**0.86**
	Discharge(m3/S)	10.98	9.06	9.67	10.22	11.24	11.53
	n	0.045	0.045	0.045	0.045	0.045	0.045
	s	0.029	0.029	0.029	0.029	0.029	0.029
5	**Depth D(m)**	**1.37**	**1.27**	**1.30**	**1.33**	**1.38**	**1.39**
	Width B(m)	**0.68**	**0.64**	**0.65**	**0.67**	**0.69**	**0.70**
	Discharge(m3/S)	8.85	10.62	11.32	11.95	13.13	14.30
	n	0.045	0.045	0.045	0.045	0.045	0.045
	s	0.023	0.023	0.023	0.023	0.023	0.023

6	**Depth D(m)**	**1.32**	**1.41**	**1.44**	**1.47**	**1.53**	**1.58**
	Width B(m)	**0.66**	**0.71**	**0.72**	**0.74**	**0.76**	**0.79**
	Discharge(m3/S)	39.48	47.25	50.53	53.45	58.93	60.11
	n	0.045	0.045	0.045	0.045	0.045	0.045
	s	0.02	0.02	0.02	0.02	0.02	0.02
7	**Depth D(m)**	**2.37**	**2.53**	**2.60**	**2.65**	**2.75**	**2.77**
	Width B(m)	**1.18**	**1.27**	**1.30**	**1.33**	**1.38**	**1.39**
	Discharge(m3/S)	27.54	30.28	32.21	34.06	37.53	39.30
	n	0.045	0.045	0.045	0.045	0.045	0.045
	s	0.027	0.027	0.027	0.027	0.027	0.027
8	**Depth D(m)**	**1.96**	**2.03**	**2.07**	**2.12**	**2.20**	**2.24**
	Width B(m)	**0.98**	**1.01**	**1.04**	**1.06**	**1.10**	**1.12**
	Discharge(m3/S)	10.65	9.19	13.43	10.38	11.43	12.25
	n	0.045	0.045	0.045	0.045	0.045	0.045
	s	0.015	0.015	0.015	0.015	0.015	0.015
26	**Depth D(m)**	**1.53**	**1.45**	**1.67**	**1.51**	**1.57**	**1.61**
	Width B(m)	**0.76**	**0.72**	**0.83**	**0.76**	**0.79**	**0.81**
	Discharge(m3/S)	7.71	7.58	8.14	8.63	10.21	10.56
	n	0.045	0.045	0.045	0.045	0.045	0.045
	s	0.031	0.031	0.031	0.031	0.031	0.031
27	**Depth D(m)**	**1.18**	**1.18**	**1.21**	**1.23**	**1.31**	**1.33**
	Width B(m)	**0.59**	**0.59**	**0.60**	**0.62**	**0.66**	**0.67**

Malka Adama drainage lines is proposed from estimated runoff (appendix 8) and others variable in above table were obtained from(appendix 5).The proposed dimension of canals were have increased which have the capacity to carry the runoff in the surroundings rather than the existing drainage canals.

Table 7:The appropriate proposed drainage channels for Dagaga zone

Dagaga Drainage Channel Capacity							
Subcatchment	Description	Existing	Proposed Trapezoidal of Drainage Channel				
			Design 10yrs	For 25yrs	For 50yrs	For 100	For 200yrs
	Discharge(m3/S)	4.62	19.79	21.13	22.33	24.56	23.00
	n	0.045	0.045	0.045	0.045	0.045	0.045
	s	0.043	0.043	0.043	0.043	0.043	0.043
	m	1.73	1.73	1.73	1.73	1.73	1.73
9	**Depth D(m)**	**0.84**	**1.44**	**1.48**	**1.51**	**1.57**	**1.53**
	Bottom Width b(m)	**0.73**	**1.25**	**1.28**	**1.31**	**1.36**	**1.32**
	Top Width B(m)	**3.62**	**6.25**	**6.41**	**6.54**	**6.78**	**6.61**
	Discharge(m3/S)	4.64	7.48	9.95	10.50	11.54	10.98

	n	0.045	0.045	0.045	0.045	0.045	0.045
	s	0.022	0.022	0.022	0.022	0.022	0.022
	m	1.73	1.73	1.73	1.73	1.73	1.73
10	**Depth D(m)**	**0.95**	**1.14**	**1.27**	**1.29**	**1.34**	**1.31**
	Bottom Width b(m)	**0.82**	**0.98**	**1.10**	**1.12**	**1.16**	**1.14**
	Top Width B(m)	**2.74**	**2.90**	**2.02**	**2.04**	**2.08**	**2.06**
	Discharge(m3/S)	1.76	9.12	9.76	10.43	11.69	13.08
	n	0.045	0.045	0.045	0.045	0.045	0.045
	s	0.02	0.02	0.02	0.02	0.02	0.02
	m	1.73	1.73	1.73	1.73	1.73	1.73
11	**Depth D(m)**	**0.67**	**1.25**	**1.28**	**1.31**	**1.37**	**1.43**
	Bottom Width b(m)	**0.58**	**1.08**	**1.11**	**1.14**	**1.19**	**1.24**
	Top Width B(m)	**2.91**	**5.40**	**5.54**	**5.67**	**5.92**	**6.18**
	Discharge(m3/S)	11.31	12.67	13.52	14.34	15.90	16.81
	n	0.045	0.045	0.045	0.045	0.045	0.045
	s	0.019	0.019	0.019	0.019	0.019	0.019
	m	1.73	1.73	1.73	1.73	1.73	1.73
12	**Depth D(m)**	**1.37**	**1.42**	**1.46**	**1.49**	**1.55**	**1.58**
	Bottom Width b(m)	**1.18**	**1.23**	**1.26**	**1.29**	**1.34**	**1.37**
	Top Width B(m)	**5.91**	**6.16**	**6.31**	**6.46**	**6.71**	**6.85**
	Discharge(m3/S)	20.16	23.19	24.82	26.46	29.53	32.33
	n	0.045	0.045	0.045	0.045	0.045	0.045
	s	0.012	0.012	0.012	0.012	0.012	0.012
	m	1.73	1.73	1.73	1.73	1.73	1.73
13	**Depth D(m)**	**1.85**	**1.95**	**2.00**	**2.05**	**2.13**	**2.21**
	Bottom Width b(m)	**1.60**	**1.69**	**1.73**	**1.77**	**1.85**	**1.91**
	Top Width B(m)	**4.12**	**4.43**	**4.64**	**4.85**	**5.23**	**5.54**
	Discharge(m3/S)	45.61	45.01	49.22	52.81	59.33	65.41
	n	0.045	0.045	0.045	0.045	0.045	0.045
	s	0.01	0.01	0.01	0.01	0.01	0.01
	m	1.73	1.73	1.73	1.73	1.73	1.73
14	**Depth D(m)**	**2.60**	**2.58**	**2.67**	**2.74**	**2.87**	**2.97**
	Bottom Width b(m)	**2.25**	**2.24**	**2.31**	**2.38**	**2.48**	**2.58**
	Top Width B(m)	**3.24**	**3.18**	**3.56**	**3.87**	**3.40**	**3.86**
	Discharge(m3/S)	7.46	8.79	9.36	9.89	10.88	8.98
	n	0.045	0.045	0.045	0.045	0.045	0.045
	s	0.01	0.01	0.01	0.01	0.01	0.01
	m	1.73	1.73	1.73	1.73	1.73	1.73

15	**Depth D(m)**	**1.32**	**1.40**	**1.43**	**1.46**	**1.52**	**1.41**
	Bottom Width b(m)	**1.14**	**1.21**	**1.24**	**1.27**	**1.31**	**1.22**
	Top Width B(m)	**5.70**	**6.06**	**6.21**	**6.33**	**6.57**	**6.11**
	Discharge(m3/S)	0.56	1.44	1.54	1.64	1.82	1.90
	n	0.045	0.045	0.045	0.045	0.045	0.045
	s	0.005	0.005	0.005	0.005	0.005	0.005
	m	1.73	1.73	1.73	1.73	1.73	1.73
16	**Depth D(m)**	**0.57**	**0.81**	**0.83**	**0.85**	**0.88**	**0.90**
	Bottom Width b(m)	**0.49**	**0.70**	**0.72**	**0.74**	**0.77**	**0.78**
	Top Width B(m)	**2.46**	**3.50**	**3.59**	**3.68**	**3.83**	**3.89**
	Discharge(m3/S)	40.66	46.41	49.76	52.75	58.37	63.47
	n	0.045	0.045	0.045	0.045	0.045	0.045
	s	0.013	0.013	0.013	0.013	0.013	0.013
	m	1.73	1.73	1.73	1.73	1.73	1.73
17	**Depth D(m)**	**2.37**	**2.49**	**2.55**	**2.61**	**2.71**	**2.80**
	Bottom Width b(m)	**2.05**	**2.16**	**2.21**	**2.26**	**2.35**	**2.42**
	Top Width B(m)	**6.15**	**6.37**	**6.50**	**6.60**	**6.79**	**6.95**
	Discharge(m3/S)	1.22	1.23	1.31	1.39	1.55	1.71
	n	0.045	0.045	0.045	0.045	0.045	0.045
	s	0.004	0.004	0.004	0.004	0.004	0.004
	m	1.73	1.73	1.73	1.73	1.73	1.73
18	**Depth D(m)**	**0.79**	**0.79**	**0.81**	**0.83**	**0.87**	**0.90**
	Bottom Width b(m)	**0.69**	**0.69**	**0.71**	**0.72**	**0.75**	**0.78**
	Top Width B(m)	**3.44**	**3.44**	**3.52**	**3.61**	**3.75**	**3.90**
	Discharge(m3/S)	56.00	62.06	66.77	71.00	78.94	87.67
	n	0.045	0.045	0.045	0.045	0.045	0.045
	s	0.005	0.005	0.005	0.005	0.005	0.005
	m	1.73	1.73	1.73	1.73	1.73	1.73
19	**Depth D(m)**	**3.19**	**3.32**	**3.41**	**3.49**	**3.63**	**3.78**
	Bottom Width b(m)	**2.77**	**2.88**	**2.96**	**3.02**	**3.15**	**3.27**
	Top Width B(m)	**3.29**	**3.62**	**3.86**	**4.07**	**4.43**	**4.81**
	Discharge(m3/S)	3.54	55.06	58.68	62.49	69.64	72.69
	n	0.045	0.045	0.045	0.045	0.045	0.045
	s	0.027	0.027	0.027	0.027	0.027	0.027
	m	1.73	1.73	1.73	1.73	1.73	1.73
20	**Depth D(m)**	**0.83**	**2.31**	**2.37**	**2.43**	**2.53**	**2.57**
	Bottom Width b(m)	**0.72**	**2.00**	**2.05**	**2.10**	**2.19**	**2.22**

Top Width B(m)	**3.58**	**10.01**	**10.25**	**10.50**	**10.93**	**11.11**

The drainage proposed from the variable in appendances 9 and 6.The depth and width of trapezoidal have been high because the runoff were accumulated from different direction .

Table 8:The appropriate Proposed drainage channels for Irrecha zone

		Irrecha Drainage Channel Capacity					
Subcatchment	Description	Existing	Proposed Rectangular Type of Drainage Channel				
			Design 10yrs	For 25yrs	For 50yrs	For 100	For 200yrs
	Discharge(m3/S)	8.03	9.38	10.03	10.71	11.98	13.15
	n	0.045	0.045	0.045	0.045	0.045	0.045
	s	0.028	0.028	0.028	0.028	0.028	0.028
21	**Depth D(m)**	**1.12**	**1.19**	**1.22**	**1.25**	**1.30**	**1.35**
	Width B(m)	**0.56**	**0.59**	**0.61**	**0.62**	**0.65**	**0.67**
	Discharge(m3/S)	1.82	2.68	2.87	3.06	3.42	3.81
	n	0.045	0.045	0.045	0.045	0.045	0.045
	s	0.01	0.01	0.01	0.01	0.01	0.01
22	**Depth D(m)**	**0.85**	**0.98**	**1.01**	**1.03**	**1.08**	**1.12**
	Width B(m)	**0.43**	**0.49**	**0.50**	**0.52**	**0.54**	**0.56**
	Discharge(m3/S)	5.98	20.77	22.16	23.59	26.27	28.67
	n	0.045	0.045	0.045	0.045	0.045	0.045
	s	0.006	0.006	0.006	0.006	0.006	0.006
23	**Depth D(m)**	**1.46**	**2.33**	**2.39**	**2.45**	**2.55**	**2.63**
	Width B(m)	**0.73**	**1.17**	**1.20**	**1.22**	**1.27**	**1.32**
	Discharge(m3/S)	58.16	55.49	59.31	63.18	70.45	75.95
	n	0.045	0.045	0.045	0.045	0.045	0.045
	s	0.0055	0.0055	0.0055	0.0055	0.0055	0.0055
24	**Depth D(m)**	**3.49**	**3.43**	**3.51**	**3.60**	**3.75**	**3.86**
	Width B(m)	**1.74**	**1.71**	**1.76**	**1.80**	**1.87**	**1.93**
	Discharge(m3/S)	30.70	28.74	31.00	33.01	36.79	37.87
	n	0.045	0.045	0.045	0.045	0.045	0.045
	s	0.0078	0.0078	0.0078	0.0078	0.0078	0.0078
25	**Depth D(m)**	**2.57**	**2.51**	**2.58**	**2.64**	**2.75**	**2.78**
	Width B(m)	**1.29**	**1.25**	**1.29**	**1.32**	**1.38**	**1.39**

Refering appendices 10 and 7 for variable in above table depth and width of rectangular canals to propose the The dimension of the drainage canal not similar for plot from start to end for all the flood problem more series

5. CONCLUSIONS & RECOMMENDATIONS

5.1Conclusions

Dembela sub-city is found in the low elevated topography in the floor of the bowl shape of Adama city. The city faced frequent flooding problems. There are many drainage networks that are connected to the city from all direction which can carry a very high discharge of runoff during intense rainfall but the drainage system was not properly functioning. So, to address this problem, estimation of runoff generated from the study area was computed; performance of the existing drainage system was assessed and the most economic and efficient hydraulics section of drainage networks was proposed.

After analyzing the results, the following conclusions were drawn:

- ❖ The new intensity duration frequency curve (IDF) is developed and can be the input for Dembela Sub-city and shall consulted during the construction of asphalts, cobble stones, culverts and other hydraulic structures and drainage canals area planned to be designed and constructed.
- ❖ Sometimes the estimated of runoff generated from Dembela sub-city is high and above the capacity of existing drainage canals
- ❖ The existing drainage system network is filled by sediment and other rubbish materials. The performances of the existing drainage system were inadequate to convey the peak discharge and did not consider hydrology analysis.
- ❖ The constructed drainage system is now operating under high level of urbanization and majority of infrastructure development in the sub cities have less concern to the drainage system and made the function of the drainage system difficult.
- ❖ The drainages channels were poorly constructed have the same dimension and their performances were not satisfactory.
- ❖ General, the existing drainage capacity, the back flow of runoff from the drainage canals due to inadequate capacity of downstream and the runoff generate from combined stream(from Malka Adama Ganda Hara, Galma Abbaa Gadaa through Dagaagaa and through Irreechaa whole discharge from the city to Awash river.
- ❖ The most efficient hydraulics section of drainage canals which had the capacity to perform the estimated of runoff generated was proposed appropriately

5.2 Recommendations

The Dembela Sub-City drainage lines were collects and carries all the flow of the run of with high volume from the inner city, is affected by the flooding of the water in the surrounding residence areas. In order to alleviate the problems that have been hindering the drainage systems. The following recommendations were made for sustainable urban storm water drainage system;

- Based on the study, before design construction of any drainage network, it is seriously recommended use recent developed intensity duration frequency curve (IDF) and the proposed drainage dimensions for Dembela sub-city. Mainly reality and impotency of the drainage line on specific site.
- Cleaning of all the existing drainage systems should be frequently done to solve the existing problems and it needs regular supervision of drainage networks.
- Create awareness within the community to use the drainage systems in a way that the drainage systems should be handled so as to serve up to the designed life span.
- Increased the width and depth of the downstream channels in order to accommodate of flow coming from upper stream and to prevent overflow of flood at the downstream
- Managed the existing drainage network properly and careful design of storm water drainage system network master plan is crucial

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APPENDICES

Appendix1: TableYearly Extreme series frequency analysis Calculations

year	Annual Maximum 24hr RF	y=logx	year	Annual Maximum 24hr RF	y=logx
1985	57	1.755875	2002	48.3	1.683947
1986	50	1.69897	2003	70.4	1.847573
1987	44.4	1.647383	2004	43.3	1.636488
1988	31.2	1.494155	2005	42.3	1.62634
1989	55	1.740363	2006	62.8	1.79796
1990	77	1.886491	2007	55.1	1.741152
1991	73.8	1.868056	2008	49.1	1.691081
1992	41.1	1.613842	2009	54	1.732394
1993	70	1.845098	2010	56.1	1.748963
1994	51	1.70757	2011	46.9	1.671173
1995	77.5	1.889302	2012	69.6	1.842609
1996	47.5	1.676694	2013	59.4	1.773786
1997	61.4	1.788168	2014	46.6	1.668386
1998	59.8	1.776701	2015	52.6	1.720986
1999	41.5	1.618048	2016	56	1.748188
2000	99.8	1.999131	2017	68.4	1.835056
2001	104.8	2.020361	2018	56.4	1.751279

Gumbelmethos			**calculation**	
	R eturn period(T)	Y-T	X-T	
	2	0.3665		55.657
x=58.238	5	1.4999		69.555

Sx=15.719	10	2.25	78.7525
a=12.262	25	3.1985	90.383
u=51.163	50	3.9019	99.008
	100	4.6001	107.569
	200	5.2958	116.1

Log pearson Type-III Methods					**calculation**			
		Return period(T)	1/T	w	z	K-T	Y-T	X-T(mm)
		2	0.5	1.386294	0.245098	-0.06543	1.665	46.2381
cs=	0.4	5	0.2	3.218876	2.40882	0.8324	1.74	54.95409
k=	0.066	10	0.1	4.60517	3.889398	1.3112	1.812	64.86344
y	1.751	25	0.04	6.437752	5.788112	1.8567	1.851	70.95778
sdev.=	0.1099	50	0.02	7.824046	7.204978	2.2374	1.879	75.68329
		100	0.01	9.21034	8.613319	2.5624	1.932	85.50667
		200	0.005	10.59663	10.01651	2.7231	1.987	97.051

Appendix 2:Table Calculation of RF of shorter duration using results from Log Pearson Type I

Duration (mints)	Return period in years (T)						
	2	5	10	25	50	100	200
	Annual Maximum 24-hr rain fall in mm(X) R-24						
	47.54	59.61	67.66	77.92	85.62	93.34	101.13
10	75	94	107	123	135	148	160
20	56	71	81	93	102	111	121
30	45	57	65	75	82	90	97
40	38	48	55	63	69	76	82
50	33	42	47	54	60	65	71
60	29	37	42	48	52	57	62
70	26	33	37	43	46	51	56
80	24	30	34	39	42	46	51
90	22	27	31	36	39	43	46
100	20	25	28	33	35	39	43

110	19	23	26	33	33	36	40
120	17	22	25	28	31	33	39
130	16	20	22	26	29	31	36
140	15	19	22	24	27	30	33
150	14	18	21	23	25	28	31
160	14	17	20	22	24	26	29
170	13	16	19	21	23	25	28
180	12	16	18	20	22	24	26
190	12	15	17	19	21	23	25
200	12	14	16	18	20	22	24

Appendix 3:Table Coefficient of runoff (c)

Type of Drainage Area	C
Business:	
Commercial area	0.70-0.95
Neighborhood areas	0.50-0.70
Residential:	
Single-family areas	0.30-0.50
Multi-units, detached	0.40-0.60
Multi-units, attached	0.60-0.75
Suburban	0.25-0.40
Apartment dwelling areas	0.50-0.70
Industrial:	
Light areas	0.50-0.80
Heavy areas	0.60-0.90
Parks, cemeteries	0.10-0.25
Playgrounds	0.20-0.40
Railroad yard areas	0.20-0.40
Unimproved areas	0.10-0.30
Streets:	
Asphaltic	0.70-0.95
Concrete	0.80-0.95
Brick	0.70-0.85
Drives and walks	0.75-0.85
Roofs	

Appendix 4:Table Manning's Roughness Coefficient (n)

Various open channel surfaces	
Concrete	0.02-0.03
Natural stream channel	0.03-0.1
Flood Plains	0.035-0.1

Appendix 5:Table Capacity of the Existing Storm Water Drainage System of Malka Adama

Sr.No	Flow Direction		Drainage Types											
	From	To	Trapizoidal			Rectangular		Circular						
			B(m)	Y(m)	T(m)	B(m)	Y(m)	D(m)	n	A(m^2)	p(m)	S(%)	Q(m^3/s)	V(m/s)
1	2	3	4	5	6	7	8	9	10	11	12	13		15
1	DL1	DL2				0.5	0.65		0.045	0.325	1.8	4.1	0.46	1.43
2	DL11	DL2				0.6	0.46		0.045	0.276	1.52	2.1	0.28	1.03
3	DL2	DL3				1	0.8		0.045	0.8	2.6	1.5	1.00	1.25
4	DL3	DL4				1	0.8		0.045	0.8	2.6	1.9	1.11	1.39
5	DL4	DL5				1	0.8		0.045	0.8	2.6	5.5	1.89	2.36
6	DL34	DL35				0.7	0.5		0.045	0.35	1.7	3.6	0.51	1.46
7	DL35	DL36				0.7	0.5		0.045	0.35	1.7	2.1	0.40	1.13
8	DL36	DL5				0.7	0.5		0.045	0.35	1.7	1.8	0.36	1.03
9	DL5	DL6				1	0.8		0.045	0.8	2.6	1.3	0.92	1.15
10	DL6	DL7				1	0.8		0.045	0.8	2.6	2.0	1.15	1.43
11	DL7	DL8				1	0.8		0.045	0.8	2.6	1.7	1.05	1.32
12	DL8	DL9				1	0.8		0.045	0.8	2.6	2.0	1.16	1.45
13	DL9	DL10				1.2	0.75		0.045	0.9	2.7	1.9	1.31	1.45
14	DL10	outlet				1.2	1.2		0.045	1.44	3.6	1.8	2.32	1.61
15	DL12	DL13				0.4	0.65		0.045	0.26	1.7	3.8	0.32	1.25
16	DL13	DL18				0.4	0.65		0.045	0.26	1.7	0.7	0.13	0.51
17	DL14	DL18				0.4	0.65		0.045	0.26	1.7	1.0	0.16	0.63
18	DL150	DL16				0.4	0.65		0.045	0.26	1.7	4.2	0.34	1.30
19	DL16	DL17				0.4	0.65		0.045	0.26	1.7	4.7	0.36	1.38
20	DL17	DL18				0.4	0.65		0.045	0.26	1.7	1.6	0.21	0.82
21	DL62	DL18				0.4	0.65		0.045	0.26	1.7	2.3	0.25	0.96
22	DL18	DL19				2.3	1.9		0.045	4.37	6.1	4.1	15.71	3.59
23	DL19	DL23				2.3	1.9		0.045	4.37	6.1	0.8	7.10	1.62

24	DL23	DL24				0.5	0.8		0.045	0.4	2.1	4.7	0.64	1.59
25	DL24	outlet				0.5	0.8		0.045	0.4	2.1	1.9	0.40	1.00
26	DL20	DL21				0.6	0.8		0.045	0.48	2.2	1.9	0.53	1.11
27	DL21	DL22				0.6	0.8		0.045	0.48	2.2	3.6	0.74	1.54
28	DL22	DL23				0.6	0.8		0.045	0.48	2.2	4.5	0.82	1.72
29	DL25	DL27				0.6	0.8		0.045	0.48	2.2	1.4	0.46	0.96
30	DL26	DL27				0.6	0.8		0.045	0.48	2.2	2.8	0.64	1.34
31	DL27	outlet				0.6	0.8		0.045	0.48	2.2	3.8	0.75	1.56
32	DL28	outlet				0.5	0.8		0.045	0.4	2.1	2.8	0.49	1.24
33	DL63	outlet						0.9	0.020	0.64	2.83	1.3	1.34	2.10
34	DL29	outlet				0.5	0.8		0.045	0.4	2.1	0.7	0.24	0.61
35	DL64	outlet						0.8	0.020	0.64	2.83	0.5	0.80	1.25
36	DL30	DL31						0.8	0.020	0.5	2.51	1.2	0.92	1.85
37	DL31	DL32						0.8	0.020	0.5	2.51	0.8	0.74	1.48
38	DL32	DL33						0.8	0.020	0.5	2.51	6.8	2.23	4.45
39	DL33	outlet						0.8	0.020	0.5	2.51	2.5	1.34	2.67
40	DL37	DL38						0.8	0.020	0.5	2.51	3.3	8.23	16.46
41	DL38	outlet						0.8	0.020	0.5	2.51	1.7	1.11	2.22
42	DL39	DL40	0.4	0.4	0.5				0.045	0.18	1.2	3.2	0.20	1.13
43	DL40	DL41	0.5	0.35	0.6				0.045	0.19	1.21	7.7	0.34	1.79
44	DL41	DL42				1	1.5		0.045	1.5	4	1.2	1.90	1.27
45	DL42	outlet				1	1.5		0.045	1.5	4	1.9	2.40	1.60
46	DL43	DL44				0.58	0.84		0.045	0.487	2.26	3.2	0.70	1.44
47	DL44	DL65				0.58	0.84		0.045	0.487	2.26	4.3	0.81	1.66
48	DL65	outlet				0.58	0.84		0.045	0.487	2.26	2.9	0.66	1.35
49	DL45	outlet				0.58	0.84		0.045	0.487	2.26	0.2	0.17	0.35
50	DL46	outlet				0.58	0.84		0.045	0.487	2.26	0.2	0.17	0.35
51	DL47	DL48				0.58	0.84		0.045	0.487	2.26	0.2	0.17	0.36

52	DL48	DL49				0.58	0.84		0.045	0.487	2.26	0.4	0.25	0.51
53	DL49	outlet				0.58	0.84		0.045	0.487	2.26	1.2	0.42	0.87
54	DL50	DL51				0.58	0.84		0.045	0.487	2.26	0.6	0.30	0.62
55	DL51	outlet				0.58	0.84		0.045	0.487	2.26	2.3	0.58	1.20
56	DL54	DL55	0.4	0.45	0.6				0.045	0.23	0.75	3.9	0.46	2.00
57	DL55	outlet	0.4	0.45	0.6				0.045	0.23	0.75	6.4	0.59	2.55
58	DL52	outlet	0.4	0.45	0.6				0.045	0.23	0.75	2.8	1.24	5.38
59	DL56	DL57	0.4	0.45	0.6				0.045	0.23	0.75	3.0	0.40	1.76
60	DL57	DL58	0.4	0.45	0.6				0.045	0.23	0.75	2.0	0.33	1.41
61	DL58	DL59	0.4	0.45	0.6				0.045	0.23	0.75	1.4	0.27	1.18
62	DL59	DL60	0.4	0.45	0.6				0.045	0.23	0.75	1.1	0.24	1.04
63	DL60	outlet	0.4	0.45	0.6				0.045	0.23	0.75	3.5	0.43	1.88
64	DL61	DL62						0.8	0.020	0.5	2.51	2.1	1.23	2.46
65	DL62	outlet						0.8	0.020	0.5	2.51	1.7	1.11	2.21
66	DL66	DL67				1.1	0.83		0.045	0.913	2.76	4.3	2.01	2.20
67	DL67	DL28				1.1	0.83		0.045	0.913	2.76	1.4	1.16	1.27
68	DL68	DL69				1.1	0.83		0.045	0.913	2.76	3.9	1.93	2.11
69	DL70	DL71						0.9	0.020	0.64	2.83	1.4	1.42	2.22
70	DL69	outlet						0.9	0.020	0.64	2.83	1.8	1.59	2.49
71	DL71	outlet						0.9	0.020	0.64	2.83	1.8	1.59	2.49
72	DL72	DL73						0.9	0.020	0.64	2.83	3.6	2.25	3.52
73	DL73	DL74				0.5	0.6		0.045	0.3	1.7	1.2	0.23	0.77
74	DL74	DL75				0.5	0.6		0.045	0.3	1.7	3.3	0.38	1.27
75	DL75	outlet				0.5	0.6		0.045	0.3	1.7	3.3	0.38	1.28
76	DL76	outlet				0.5	0.6		0.045	0.3	1.7	3.0	0.36	1.21
77	DL77	outlet				0.7	0.84		0.045	0.588	2.38	3.2	0.91	1.55
78	DL78	outlet				0.7	0.84		0.045	0.588	2.38	2.8	0.85	1.45
79	DL79	DL81				0.7	0.84		0.045	0.588	2.38	4.1	1.04	1.76

80	DL80	DL82				0.7	0.84		0.045	0.588	2.38	4.2	1.06	1.80
81	DL81	DL83				0.7	0.84		0.045	0.588	2.38	1.3	0.58	0.99
82	DL82	DL86				0.7	0.84		0.045	0.588	2.38	1.3	0.58	0.99
83	DL83	DL84				0.7	0.84		0.045	0.588	2.38	3.5	0.96	1.64
84	DL84	DL85				0.7	0.84		0.045	0.588	2.38	7.0	1.36	2.31
85	DL85	outlet				0.7	0.84		0.045	0.588	2.38	2.9	0.87	1.48
86	DL86	DL87				0.7	0.84		0.045	0.588	2.38	2.8	0.85	1.45
87	DL87	outlet				0.7	0.84		0.045	0.588	2.38	2.9	0.87	1.48
88	DL88	DL69	0.5	0.6	0.8				0.045	0.39	1.24	2.2	0.60	1.53
89	DL89	DL90	0.5	0.6	0.8				0.045	0.39	1.24	1.4	0.48	1.24
90	DL90	DL91	0.5	0.6	0.8				0.045	0.39	1.24	2.2	0.60	1.54
91	DL91	DL44	0.5	0.6	0.8				0.045	0.39	1.24	1.2	0.44	1.13
93	DL92	DL91	0.5	0.6	0.8				0.045	0.39	1.24	3.2	0.72	1.84
92	DL93	outlet	0.5	0.6	0.8				0.045	0.39	1.24	4.9	0.89	2.28
93	DL94	D91	0.5	0.6	0.8				0.045	0.39	1.24	3.2	0.72	1.84
94	DL95	DL44	0.5	0.6	0.8				0.045	0.39	1.24	4.9	0.89	2.28
95	DL96	DL97	0.5	0.6	0.8				0.045	0.39	1.24	1.8	0.54	1.38
96	DL97	DL40	0.5	0.6	0.8				0.045	0.39	1.24	1.3	0.46	1.17
97	DL98	DL99				0.6	1		0.045	0.6	2.6	1.6	0.64	1.07
98	DL99	DL100				0.6	1		0.045	0.6	2.6	0.5	0.36	0.60
99	DL100	DL101				0.6	1		0.045	0.6	2.6	2.8	0.84	1.40
100	DL101	DL102				0.6	1		0.045	0.6	2.6	0.7	0.43	0.72
101	DL102	DL103				0.6	1		0.045	0.6	2.6	4.1	1.02	1.70
102	DL103	DL104				0.6	1		0.045	0.6	2.6	1.9	0.70	1.16
103	DL104	DL109				0.6	1		0.045	0.6	2.6	3.8	0.98	1.64
104	DL105	DL106				0.54	0.7		0.045	0.378	1.94	1.4	0.33	0.87
105	DL106	DL107				0.54	0.7		0.045	0.378	1.94	3.0	0.49	1.29
106	DL107	DL108				0.54	0.7		0.045	0.378	1.94	4.1	0.57	1.51

107	DL108	DL110				0.54	0.7		0.045	0.378	1.94	2.4	0.44	1.15
108	DL109	outlet				0.54	0.7		0.045	0.378	1.94	1.3	0.32	0.85
109	DL110	outlet				0.54	0.7		0.045	0.378	1.94	1.3	0.32	0.85
110	DL11	DL109				0.54	0.7		0.045	0.378	1.94	1.9	0.39	1.04
111	DL112	DL113				0.54	0.7		0.045	0.378	1.94	1.9	0.39	1.04
112	DL113	DL114				0.54	0.7		0.045	0.378	1.94	1.0	0.29	0.75
113	DL114	outlet				0.45	0.6		0.045	0.27	1.65	6.4	0.45	1.68
114	DL115	DL116				0.45	0.6		0.045	0.27	1.65	2.3	0.18	0.66
115	DL116	outlet				0.45	0.6		0.045	0.27	1.65	3.6	0.34	1.26
116	DL117	DL118				0.45	0.6		0.045	0.27	1.65	4.4	0.38	1.40
117	DL118	outlet				0.45	0.6		0.045	0.27	1.65	2.9	0.30	1.13
118	DL119	DL120				0.47	0.7		0.045	0.329	1.87	0.8	0.21	0.63
119	DL120	outlet				0.47	0.7		0.045	0.329	1.87	3.8	0.45	1.36
120	DL121	DL122				0.47	0.7		0.045	0.329	1.87	3.0	0.40	1.21
121	DL122	outlet				0.47	0.7		0.045	0.329	1.87	3.2	0.41	1.24
122	DL123	DL124				0.6	0.46		0.045	0.276	1.52	1.4	0.23	0.83
123	DL124	DL125				0.6	0.46		0.045	0.276	1.52	1.1	0.20	0.74
124	DL125	DL126				0.6	0.46		0.045	0.276	1.52	2.1	0.29	1.04
125	DL126	DL127				0.6	0.46		0.045	0.276	1.52	3.8	0.33	1.19
126	DL127	DL128				0.6	0.46		0.045	0.276	1.52	1.6	0.25	0.91
127	DL128	outlet				0.6	0.46		0.045	0.276	1.52	1.0	0.20	0.73
128	DL145	DL146	0.5	0.8	1.2				0.045	0.68	2.25	0.3	0.40	0.59
129	DL146	DL129	0.5	0.8	1.2				0.045	0.68	2.25	3.3	1.24	1.82
130	DL129	outlet				0.6	0.5		0.045	0.3	1.6	10.1	0.69	2.31
131	DL130	DL131				0.6	0.5		0.045	0.3	1.6	3.6	0.42	1.39
132	DL131	DL132				0.6	0.5		0.045	0.3	1.6	4.1	0.44	1.46
133	DL132	DL133				0.6	0.5		0.045	0.3	1.6	1.1	0.23	0.75
134	DL133	DL134				0.6	0.5		0.045	0.3	1.6	2.3	0.55	1.84

135	DL134	DL135				0.6	0.5		0.045	0.3	1.6	3.1	1.22	4.06
136	DL135	DL136				0.6	0.5		0.045	0.3	1.6	1.6	0.58	1.92
137	DL136	DL140				0.6	0.5		0.045	0.3	1.6	1.5	0.27	0.90
138	DL140	DL147				0.6	0.5		0.045	0.3	1.6	4.4	0.46	1.53
139	DL143	DL144				0.6	0.5		0.045	0.3	1.6	0.3	0.12	0.41
140	DL144	DL145				0.6	0.5		0.045	0.3	1.6	3.5	0.49	1.63
141	DL145	DL146				0.6	0.5		0.045	0.3	1.6	6.3	0.55	1.83
142	DL146	outlet				0.6	0.5		0.045	0.3	1.6	0.6	0.17	0.57
143	DL137	outlet						0.9	0.020	0.64	2.83	0.3	0.69	1.08
144	DL141	outlet						0.9	0.020	0.64	2.83	0.7	0.98	1.53
145	DL138	outlet						0.9	0.020	0.64	2.83	0.9	1.14	1.79
146	DL142	outlet						0.9	0.020	0.64	2.83	1.9	1.62	2.52
147	DL147	DL150						0.9	0.020	0.64	2.83	4.0	3.02	4.72
148	DL148	outlet						0.9	0.020	0.64	2.83	2.3	2.76	4.31
149	DL149	DL150						0.9	0.020	0.64	2.83	0.4	0.73	1.15
150	DL150	outlet						0.9	0.020	0.64	2.83	2.5	5.97	9.32

Appendix 6:Table Capacity of the Existing Storm Water Drainage System of Dagaga Zone

Sr.No	Flow Direction		Drainage Types											
	From	To	Trapizoidal			Rectangular		Circular						
			B(m)	Y(m)	T(m)	B(m)	Y(m)	D(m)	n	A(m^2)	p(m)	S(%)	Q(m^3/s)	V(m/s)
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	DL1	DL2						0.8	0.020	0.5	2.51	2.6	1.367	2.73
2	DL2	DL3						0.8	0.020	0.5	2.51	2.1	1.227	2.45
3	DL3	DL4						0.8	0.020	0.5	2.51	3.3	1.546	3.09
4	DL4	DL5						0.8	0.020	0.5	2.51	1.4	0.996	1.99
5	DL5	DL6						0.8	0.020	0.5	2.51	1.1	0.862	1.72
6	DL6	DL7						0.8	0.020	0.5	2.51	1.2	0.930	1.86
7	DL7	Outlet						0.8	0.020	0.5	2.51	0.4	0.527	1.05

8	DL8	DL9						0.8	0.020	0.5	2.51	2.3	1.300	2.60
9	DL9	DL10						0.8	0.020	0.5	2.51	3.7	1.640	3.28
10	DL10	DL12						0.8	0.020	0.5	2.51	2.2	1.270	2.54
11	DL11	DL12						0.8	0.020	0.5	2.51	0.9	0.838	1.68
12	DL12	DL13						0.8	0.020	0.5	2.51	3.7	1.640	3.28
13	DL13	Outlet						0.8	0.020	0.5	2.51	1.9	1.160	2.32
14	DL14	DL15						0.8	0.020	0.5	2.51	4.4	1.791	3.58
15	DL15	DL16						0.8	0.020	0.5	2.51	2.8	1.429	2.86
16	DL16	Outlet						0.8	0.020	0.5	2.51	1.9	1.160	2.32
17	DL17	DL18	0.9	0.8	1.2				0.045	0.84	1.63	3.6	2.302	2.74
18	DL18	DL19	0.9	0.8	1.2				0.045	0.84	1.63	2.3	1.829	2.18
19	DL19	Outlet	0.9	0.8	1.2				0.045	0.84	1.63	5.4	2.789	3.32
20	DL20	DL21				0.7	0.5		0.045	0.35	1.7	2.2	0.407	1.16
21	DL21	DL22				0.7	0.5		0.045	0.35	1.7	2.7	0.446	1.27
22	DL22	DL27				0.7	0.5		0.045	0.35	1.7	1.1	0.281	0.80
23	DL23	DL24				0.6	0.8		0.045	0.48	2.2	1.6	0.497	1.04
24	DL24	DL27				0.6	0.8		0.045	0.48	2.2	0.5	0.283	0.59
25	DL25	DL26						0.6	0.020	0.28	1.88	1.7	0.522	1.86
26	DL26	DL35						0.6	0.020	0.28	1.88	1.3	0.448	1.60
27	DL27	DL34				0.6	0.8		0.020	0.48	2.2	1.2	0.943	1.96
28	DL28	DL29						0.8	0.020	0.5	2.51	5.3	1.966	3.93
29	DL29	DL30						0.8	0.020	0.5	2.51	0.3	0.500	1.00
30	DL30	DL34						0.8	0.020	0.5	2.51	0.4	0.560	1.12
31	DL31	DL32				1	1.4		0.045	1.4	3.8	1.2	1.746	1.25
32	DL32	DL33				1	1.4		0.045	1.4	3.8	1.3	1.833	1.31
33	DL33	DL34				1	1.4		0.045	1.4	3.8	6.4	4.067	2.91
34	DL34	DL50				0.6	0.8		0.045	0.48	2.2	0.7	0.336	0.70
35	DL35	DL50						0.6	0.020	0.28	1.88	0.7	0.342	1.22

36	DL36	DL51				0.6	0.8		0.045	0.48	2.2	0.3	0.199	0.41
37	DL37	DL51						0.6	0.020	0.28	1.88	0.3	0.202	0.72
38	DL38	DL48				0.6	0.8		0.045	0.48	2.2	1.1	0.399	0.83
39	DL39	DL48						0.6	0.020	0.28	1.88	1.1	0.405	1.45
40	DL40	DL41	0.9	0.8	1.2				0.045	0.84	1.63	2.4	1.866	2.22
41	DL41	DL42	0.9	0.8	1.2				0.045	0.84	1.63	1.7	1.584	1.89
42	DL42	DL43	0.9	0.8	1.2				0.045	0.84	1.63	1.1	1.282	1.53
43	DL43	DL48	0.9	0.8	1.2				0.045	0.84	1.63	1.6	1.540	1.83
44	DL44	DL45	0.65	0.7	0.85				0.045	0.22	2.1	2.4	0.169	0.77
45	DL45	DL46	0.9	0.8	1.2				0.045	0.22	2.1	1.7	0.143	0.65
46	DL46	DL47	0.9	0.8	1.2				0.045	0.22	2.1	1.1	0.116	0.53
47	DL47	DL49	0.9	0.8	1.2				0.045	0.22	2.1	1.6	0.139	0.63
48	DL52	DL49				0.8	1		0.045	0.8	2.8	0.5	0.550	0.69
49	DL53	DL49						0.8	0.020	0.5	2.51	0.5	0.608	1.22
50	DL54	Outlet						0.8	0.020	0.5	2.51	5.1	1.919	3.84
51	DL55	DL56						0.8	0.020	0.5	2.51	2.2	1.275	2.55
52	DL56	Outlet						0.8	0.020	0.5	2.51	0.6	0.691	1.38
53	DL57	DL65				0.8	1		0.045	0.8	2.8	1.9	1.061	1.33
54	DL58	DL59				0.8	1		0.045	0.8	2.8	0.5	0.544	0.68
55	DL59	DL66				0.8	1		0.045	0.8	2.8	0.1	0.261	0.33
56	DL60	DL61	0.9	0.8	1.2				0.045	0.84	1.63	0.3	2.008	2.39
57	DL61	DL62	0.9	0.8	1.2				0.045	0.84	1.63	0.1	0.459	0.55
58	DL62	DL71						0.8	0.020	0.5	2.51	3.2	1.536	3.07
59	DL63	DL64						0.8	0.020	0.5	2.51	1.6	1.075	2.15
60	DL64	DL67						0.8	0.020	0.5	2.51	3.1	1.494	2.99
61	DL65	DL66						0.8	0.020	0.5	2.51	0.7	0.721	1.44
62	DL66	Outlet						0.8	0.020	0.5	2.51	1.9	1.146	2.29
63	DL67	DL68						0.8	0.020	0.5	2.51	0.3	0.491	0.98

64	DL68	DL71						0.8	0.020	0.5	2.51	0.3	0.502	1.00
65	DL69	DL70						0.8	0.020	0.5	2.51	4.6	1.847	3.69
66	DL70	DL71						0.8	0.020	0.5	2.51	2.3	1.284	2.57
67	DL71	Outlet				0.8	1		0.045	0.8	2.8	1.9	1.059	1.32
68	DL72	DL73						0.8	0.020	0.5	2.51	4.6	1.847	3.69
69	DL73	DL74						0.8	0.020	0.5	2.51	2.3	1.284	2.57
70	DL74	Outlet						0.8	0.020	0.5	2.51	1.9	1.171	2.34
71	DL75	DL77				0.5	0.7		0.045	0.35	1.9	1.8	0.333	0.95
72	DL76	DL77				0.5	0.7		0.045	0.35	1.9	1.1	0.260	0.74
73	DL77	DL79				0.5	0.7		0.045	0.35	1.9	1.0	0.254	0.73
74	DL78	DL79				0.6	0.8		0.045	0.48	2.2	1.8	0.518	1.08
75	DL79	DL87				0.6	0.8		0.045	0.48	2.2	1.1	0.396	0.83
76	DL80	DL81				0.5	0.7		0.045	0.35	1.9	1.8	0.333	0.95
77	DL81	DL79				0.5	0.7		0.045	0.35	1.9	1.0	0.254	0.73
78	DL82	DL83						0.6	0.020	0.28	1.88	1.8	0.527	1.88
79	DL83	DL87						0.6	0.020	0.28	1.88	1.1	0.414	1.48
80	DL84	DL85				0.65	1.4		0.045	0.91	3.45	1.4	5.640	6.20
81	DL85	DL86				1	1.4		0.045	1.4	3.8	1.5	1.945	1.39
82	DL86	DL87				1	1.4		0.045	1.4	3.8	0.5	1.090	0.78
83	DL87	DL88				1	1.3		0.045	1.3	3.6	0.7	1.247	0.96
84	DL88	DL90				1	1.3		0.045	1.3	3.6	0.7	1.238	0.95
85	DL89	DL90				1	1.3		0.045	1.3	3.6	1.1	1.510	1.16
86	DL90	DL93				1	1.3		0.045	1.3	3.6	0.6	1.158	0.89
87	DL91	DL92				1	1.3		0.045	1.3	3.6	1.3	1.637	1.26
88	DL92	DL93				1	1.3		0.045	1.3	3.6	2.1	2.136	1.64
89	DL93	DL97				1	1.3		0.045	1.3	3.6	0.6	1.098	0.84
90	DL94	DL96				0.8	0.65		0.045	0.52	2.1	0.4	0.289	0.56
91	DL95	DL96				0.8	0.65		0.045	0.52	2.1	0.5	0.306	0.59

93	DL96	DL97				0.8	0.65		0.045	0.52	2.1	0.8	0.411	0.79
92	DL97	Outlet				0.8	0.65		0.045	0.52	2.1	3.4	0.846	1.63
93	DL98	DL99						0.8	0.020	0.5	2.51	1.7	1.099	2.20
94	DL99	DL100						0.8	0.020	0.5	2.51	0.5	0.581	1.16
95	DL100	DL101						0.8	0.020	0.5	2.51	0.3	0.501	1.00
96	DL101	DL97						0.8	0.020	0.5	2.51	0.6	0.674	1.35
97	DL102	DL103						0.8	0.020	0.5	2.51	0.5	0.573	1.15
98	DL103	DL104						0.8	0.020	0.5	2.51	0.8	0.768	1.54
99	DL104	Outlet						0.8	0.020	0.5	2.51	3.4	1.583	3.17
100	DL105	DL112				0.6	0.8		0.045	0.48	2.2	0.4	0.232	0.48
101	DL106	DL112				0.6	0.8		0.045	0.48	2.2	0.7	0.328	0.68
102	DL50	DL107				1.3	1.45		0.045	1.885	4.2	1.8	3.310	1.76
103	DL107	DL108				1.3	1.45		0.045	1.885	4.2	0.9	2.346	1.24
104	DL108	DL112				1.3	1.45		0.045	1.885	4.2	0.5	1.659	0.88
105	DL109	DL112				1	1		0.045	1	3	5.4	2.472	2.47
106	DL51	DL110				1.3	1.45		0.045	1.885	4.2	0.6	1.917	1.02
107	DL110	DL111				1.3	1.45		0.045	1.885	4.2	0.5	1.698	0.90
108	DL111	DL112				1.3	1.45		0.045	1.885	4.2	0.5	1.663	0.88
	DL112	DL114				0.5	0.45		0.045	0.225	1.4	0.5	0.103	0.46
110	DL113	DL128				0.5	0.45		0.045	0.225	1.4	0.5	0.106	0.47
111	DL114	DL115				0.5	0.45		0.045	0.225	1.4	0.9	0.138	0.61
112	DL115	DL127				0.6	0.8		0.045	0.48	2.2	0.8	0.347	0.72
113	DL116	DL127				0.6	0.8		0.045	0.48	2.2	0.8	0.347	0.72
114	DL117	DL128				0.6	0.8		0.045	0.48	2.2	0.5	0.277	0.58
115	DL118	DL116				0.6	0.8		0.045	0.48	2.2	3.5	0.724	1.51
116	DL48	DL119	0.5	1.4	2				0.045	1.75	3.68	0.6	1.844	1.05
117	DL119	DL120	0.5	1.4	2				0.045	1.75	3.68	0.9	2.269	1.30
118	DL120	DL121	0.5	1.4	2				0.045	1.75	3.68	0.5	1.612	0.92

119	DL121	DL122	0.5	1.4	2				0.045	1.75	3.68	1.0	2.328	1.33
120	DL122	DL127	0.5	1.4	2				0.045	1.75	3.68	7.4	6.447	3.68
121	DL49	DL123	0.5	1.4	2				0.045	1.75	3.68	1.0	2.357	1.35
122	DL123	DL124	0.5	1.4	2				0.045	1.75	3.68	0.4	1.406	0.80
123	DL124	DL127	0.5	1.4	2				0.045	1.75	3.68	0.7	1.928	1.10
124	DL125	DL126				0.8	0.65		0.045	0.52	2.1	0.8	0.418	0.80
125	DL126	DL127				0.8	0.65		0.045	0.52	2.1	0.7	0.377	0.72
126	DL127	DL128				0.8	0.65		0.045	0.52	2.1	0.4	0.299	0.58
127	DL128	Outlet				0.8	0.65		0.045	0.52	2.1	0.6	0.351	0.68
128	DL129	DL135						0.8	0.020	0.5	2.51	0.5	0.573	1.15
129	DL130	DL131				1	0.8		0.045	0.8	2.6	1.3	0.914	1.14
130	DL131	DL124				1	0.8		0.045	0.8	2.6	1.2	0.892	1.11
131	DL132	DL112				1	0.8		0.045	0.8	2.6	1.1	0.868	1.09
132	DL133	DL124				1	0.8		0.045	0.8	2.6	0.6	0.645	0.81
133	DL134	DL112				1	0.8		0.045	0.8	2.6	0.5	0.562	0.70
134	DL135	Outlet						0.8	0.020	0.5	2.51	0.9	0.818	1.64

Appendix 7:Table Capacity of the Existing Storm Water Drainage System of Irrecha Zone

Sr no	Flow Direction		Drainage Types											
	From	To	Trapizoidal			Rectangular		Circular						
			B(m)	Y(m)	T(m)	B(m)	Y(m)	D(m)	n	A(m^2)	p(m)	S(%)	Q(m^3/s)	V(m/s)
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	DL1	DL2				0.8	0.65		0.045	0.52	2.1	1.2	0.50	0.97
2	DL2	DL3				0.8	0.65		0.045	0.52	2.1	2.8	0.76	1.47
3	DL3	Outlet				0.8	0.65		0.045	0.52	2.1	0.7	0.39	0.74
4	DL4	DL5				0.8	0.65		0.045	0.52	2.1	1.0	0.46	0.88
5	DL5	DL56				0.8	0.65		0.045	0.52	2.1	0.3	0.26	0.51

6	DL6	DL7				0.8	0.65		0.045	0.52	2.1	1.2	0.50	0.97
7	DL7	Outlet				0.8	0.65		0.045	0.52	2.1	2.8	0.76	1.47
8	DL8	DL9				0.8	0.65		0.045	0.52	2.1	0.4	0.27	0.53
9	DL9	DL56				0.8	0.65		0.045	0.52	2.1	0.3	0.26	0.51
10	DL10	DL11				0.45	0.55		0.045	0.19	1.45	2.9	0.19	0.98
11	DL11	Outlet				0.45	0.55		0.045	0.19	1.45	1.8	0.15	0.77
12	DL12	DL13										1.9	0.00	0.00
13	DL13	Outlet										1.8	0.00	0.00
14	DL14	DL15	0.5	0.7	0.75				0.045	0.44	1.92	0.7	0.31	0.71
15	DL15	DL16	0.5	0.7	0.75				0.045	0.44	1.92	0.9	0.34	0.78
16	DL16	Outlet	0.5	0.7	0.75				0.045	0.44	1.92	0.4	0.24	0.54
17	DL17	DL18										0.7	0.00	0.00
18	DL18	DL19										0.9	0.00	0.00
19	DL19	Outlet						0.8	0.020	0.5	2.51	0.4	0.55	1.10
20	DL20	DL21						0.8	0.020	0.5	2.51	0.4	0.55	1.10
21	DL21	DL22						0.8	0.020	0.5	2.51	0.6	0.64	1.27
22	DL22	DL23						0.8	0.020	0.5	2.51	0.5	0.62	1.23
23	DL23	DL24						0.8	0.020	0.5	2.51	0.4	0.52	1.04
24	DL24	Outlet						0.8	0.020	0.5	2.51	1.3	0.98	1.97
25	DL25	DL26						0.8	0.020	0.5	2.51	0.4	0.55	1.10
26	DL26	DL27						0.8	0.020	0.5	2.51	0.6	0.64	1.27
27	DL27	DL28						0.8	0.020	0.5	2.51	0.6	0.64	1.27
28	DL28	DL29						0.8	0.020	0.5	2.51	0.6	0.67	1.34
29	DL29	DL30						0.8	0.020	0.5	2.51	0.5	0.62	1.23
30	DL30	DL31						0.8	0.020	0.5	2.51	0.4	0.52	1.05
31	DL31	Outlet						0.8	0.020	0.5	2.51	2.7	1.39	2.78
32	DL86	DL87	0.6	0.7	0.85				0.045	0.5	2.13	0.4	0.26	0.52
33	DL87	Outlet	0.6	0.85	0.85				0.045	0.5	2.13	0.7	0.35	0.70

34	DL32	DL33				0.35	0.4		0.045	0.14	1.15	0.6	0.06	0.44
35	DL33	DL34						0.6	0.020	0.28	1.88	2.1	0.57	2.03
36	DL34	DL35				0.3	0.4		0.045	0.12	1.15	1.6	0.08	0.63
37	DL35	DL36				0.3	0.4		0.045	0.12	1.15	1.3	0.07	0.56
38	DL36	DL37				0.3	0.4		0.045	0.12	1.15	0.7	0.05	0.41
39	DL37	DL38				0.3	0.4		0.045	0.12	1.15	2.4	0.09	0.77
40	DL38	DL39				0.35	0.4		0.045	0.14	1.21	0.5	0.05	0.36
41	DL39	DL40				0.3	0.4		0.045	0.12	1.15	1.4	0.07	0.59
42	DL40	DL41						0.6	0.020	0.28	1.88	2.8	0.66	2.35
43	DL41	DL46				0.3	0.4		0.045	0.12	1.15	1.2	0.07	0.55
44	DL42	DL43				0.3	0.4		0.045	0.12	1.15	0.5	0.04	0.34
45	DL43	DL44				0.3	0.4		0.045	0.12	1.15	2.7	0.10	0.81
46	DL44	DL45				0.3	0.4		0.045	0.12	1.15	2.8	0.10	0.82
47	DL45	DL49				0.3	0.4		0.045	0.12	1.15	1.2	0.07	0.55
48	DL46	DL47	0.4	0.6	0.7				0.045	0.3	1.65	0.5	0.15	0.49
49	DL47	DL48	0.4	0.6	0.7				0.045	0.3	1.65	0.5	0.15	0.49
50	DL48	Outlet	0.4	0.6	0.7				0.045	0.3	1.65	0.3	0.11	0.38
51	DL49	DL50	0.4	0.6	0.7				0.045	0.3	1.65	0.5	0.15	0.49
52	DL50	DL51						0.6	0.020	0.28	1.88	0.5	0.27	0.97
53	DL51	Outlet	0.4	0.6	0.7				0.045	0.3	1.65	0.3	0.11	0.38
54	DL52	DL53				0.35	0.4		0.045	0.14	1.15	0.9	0.07	0.52
55	DL53	DL54				0.35	0.4		0.045	0.14	1.15	2.8	0.13	0.91
56	DL54	DL55						0.6	0.020	0.28	1.88	1.8	0.52	1.86
57	DL55	DL59				0.35	0.4		0.045	0.14	1.15	0.9	0.07	0.52
58	DL56	DL57				0.35	0.4		0.045	0.14	1.15	0.9	0.07	0.52
59	DL57	DL58				0.35	0.4		0.045	0.14	1.15	2.0	0.11	0.77
60	DL58	DL59						0.6	0.020	0.28	1.88	1.9	0.53	1.91
61	DL59	DL62				0.35	0.4		0.045	0.14	1.15	1.0	0.08	0.54

62	DL60	DL61				0.35	0.4		0.045	0.14	1.15	0.9	0.07	0.51
63	DL61	DL62						0.6	0.020	0.28	1.88	1.3	0.45	1.60
64	DL62	Outlet						0.6	0.020	0.28	1.88	0.3	0.22	0.77
65	DL63	DL64						0.6	0.020	0.28	1.88	0.5	0.29	1.02
66	DL64	Outlet				0.35	0.4		0.045	0.14	1.15	1.6	0.10	0.70
67	DL65	DL66				0.35	0.4		0.045	0.14	1.15	0.9	0.07	0.52
68	DL66	DL70						0.6	0.020	0.28	1.88	1.5	0.49	1.74
69	DL67	DL68				0.35	0.4		0.045	0.14	1.15	1.8	0.10	0.74
70	DL68	DL69				0.35	0.4		0.045	0.14	1.15	0.9	0.07	0.52
71	DL69	DL59						0.6	0.020	0.28	1.88	2.2	0.58	2.07
72	DL70	DL73				0.35	0.4		0.045	0.14	1.15	1.0	0.08	0.54
73	DL71	DL72				0.35	0.4		0.045	0.14	1.15	0.9	0.07	0.51
74	DL72	DL62						0.6	0.020	0.28	1.88	1.3	0.45	1.60
75	DL73	Outlet						0.6	0.020	0.28	1.88	0.3	0.22	0.77
76	DL74	DL75				0.35	0.4		0.045	0.14	1.15		0.06	0.42
77	DL75	Outlet				0.35	0.4		0.045	0.14	1.15		0.10	0.70
78	DL76	DL77				0.35	0.4		0.045	0.14	1.15	1.5	0.09	0.66
79	DL77	DL78				0.35	0.4		0.045	0.14	1.15	1.6	0.10	0.68
80	DL78	DL79				0.35	0.4		0.045	0.14	1.15	2.4	0.12	0.84
81	DL79	DL80				0.35	0.4		0.045	0.14	1.15	2.9	0.13	0.93
82	DL80	Outlet				0.35	0.4		0.045	0.14	1.15	1.1	0.08	0.58
83	DL81	DL82				0.35	0.4		0.045	0.14	1.15	1.5	0.09	0.66
84	DL82	DL83				0.35	0.4		0.045	0.14	1.15	1.8	0.10	0.73
85	DL83	DL84				0.35	0.4		0.045	0.14	1.15	2.4	0.12	0.84
86	DL84	DL85				0.35	0.4		0.045	0.14	1.15	2.9	0.13	0.93
87	DL85	Outlet				0.35	0.4		0.045	0.14	1.15	1.1	0.08	0.58

Appendix 8:Table Runoff Estimation for MalkaAdama zone

Plot NO.	Flow Direction		Desciption of sub catchment	Sub basin area As(ha)	Runoff coffient ©	Total basin area A(ha)	Length of basin L(m)	Lowest elevation of the basin H1(m)	Highest elevation of the basin H2(m)	Average slope of the basin S	Time concentration of the basin Tc(hr)	Rainfall intensity I(mm/hr)		Total Runoff for plot of basin Qs(m^3/sec)
	From	To										5 years	10 years	
1	DL1	DL2	Asphalt & Residence area	1.83	0.83	1.83	123	1687	1692	0.041	0.045	115		0.49
2	DL11	DL2	School areas	1.43	0.80	1.430	48	1687	1688	0.021	0.028	119		0.38
3	DL2	DL3	Residence areas	0.24	0.70	3.500	66	1686	1687	0.015	0.041	115		0.78
4	DL3	DL4	Asphalt & Residence area	0.41	0.75	3.910	53	1685	1686	0.019	0.032	123		1.00
5	DL4	DL5	Residence areas	0.41	0.70	4.320	55	1689	1692	0.055	0.022	123		1.03
6	DL34	DL35	Residence areas	1.50	0.70	1.500	56	1687	1689	0.036	0.026	119		0.35
7	DL35	DL36	Residence areas	0.24	0.70	1.740	47	1685	1686	0.021	0.028	119		0.40
8	DL36	DL5	Residence areas	0.64	0.70	2.380	56	1685	1686	0.018	0.034	119		0.55
9	DL5	DL6	Residence areas	4.20	0.70	6.580	77	1684	1685	0.013	0.049	115		1.47
10	DL6	DL7	Residence areas	4.60	0.70	11.180	50	1683	1684	0.020	0.030	119		2.59

11	DL7	DL8	Residence areas	4.20	0.70	15.380	59	1682	1683	0.017	0.036	119		3.56
12	DL8	DL9	Residence areas	0.18	0.70	15.560	49	1681	1682	0.020	0.029	119		3.60
13	DL9	DL10	Residence areas	0.29	0.70	15.850	54	1680	1681	0.019	0.033	119		3.67
14	DL10	outlet	Residence areas	0.37	0.70	16.220	112	1678	1680	0.018	0.058	115		3.63
15	DL12	DL13	Office	0.61	0.85	0.607	52	1686	1688	0.038	0.024	123		0.18
16	DL13	DL18	Residence areas	1.75	0.70	2.354	153	1685	1686	0.007	0.108	103		0.47
17	DL14	DL18	Gravel Road	0.21	0.80	0.205	205	1686	1688	0.010	0.116	99		0.05
18	DL150	DL16	Residence areas	1.02	0.70	1.016	24	1690	1691	0.042	0.013	123		0.24
19	DL16	DL17	C0bblestone & Residence	0.75	0.70	1.767	64	1687	1690	0.047	0.026	119		0.41
20	DL17	DL18	C0bblestone & Residence	1.59	0.70	3.359	12	1685	1687	0.167	0.040	119		0.78
21	DL62	DL18	C0bblestone & Residence	0.22	0.70	0.218	218	1685	1690	0.023	0.088		128	0.05
22	DL18	DL19	Gravel Road & Residence	1.12	0.72	7.242	49	1685	1687	0.041	0.022	123		1.78
23	DL19	DL23	Gravel Road & Residence	0.23	0.72	7.472	120	1684	1685	0.008	0.082	107		1.60
24	DL23	DL24	Gravel Road	0.23	0.72	7.703	54	1680	1684	0.074	0.019	123		1.90

			&Residence											
25	DL24	outlet	Gravel Road & Residence	0.46	0.72	8.158	54	1679	1680	0.019	0.033	119		1.94
26	DL20	DL21	Gravel Road & Residence	0.47	0.72	0.469	52	1684	1685	0.019	0.650	51		0.05
27	DL21	DL22	School areas	0.46	0.80	0.927	55	1683	1685	0.036	0.025	119		0.25
28	DL22	DL23	Residence areas	0.46	0.70	1.386	44	1681	1683	0.045	0.020	123		0.33
29	DL25	DL27	Residence areas	0.86	0.70	1.972	140	1679	1681	0.014	0.075	107		0.41
30	DL26	DL27	Residence areas	1.18	0.70	1.180	145	1679	1683	0.028	0.060	111		0.25
31	DL27	outlet	Asphalt & Residence area	0.24	0.82	1.423	53	1677	1679	0.038	0.024	123		0.40
32	DL28	outlet	Asphalt & Green area	1.27	0.57	1.271	601	1694	1711	0.028	0.177	85		0.17
33	DL63	outlet	Asphalt Road	1.33	0.85	1.326	###	1696	1713	0.013	0.441	60		0.19
34	DL29	outlet	Green & Residence	0.81	0.69	0.811	725	1693	1698	0.007	0.352	65		0.10
35	DL64	outlet	Asphalt Road	0.49	0.85	0.491	664	1693	1696	0.005	0.387		71	0.08
36	DL30	DL31	Asphalt & Residence area	3.39	0.71	3.390	340	1694	1698	0.012	0.160		103	0.69
37	DL31	DL32	Asphalt & Residence area	0.95	0.81	4.341	132	1690	1691	0.008	0.091		123	1.20
38	DL32	DL33	Asphalt & Residence area	0.31	0.73	4.654	44	1688	1691	0.068	0.017		148	1.40

39	DL33	outlet	Asphalt & Residence area	5.15	0.75	9.804	122	1688	1691	0.025	0.055		138	2.82
40	DL37	DL38	Asphalt & Residence area	7.65	0.78	7.65	326	1692	1996	0.933	0.029		143	2.37
41	DL38	outlet	Asphalt Road	5.04	0.85	12.690	354	1686	1692	0.017	0.143		113	3.39
42	DL39	DL40	Residence areas	4.03	0.70	4.033	154	1690	1695	0.032	0.059	111		0.87
43	DL40	DL41	Residence areas	4.03	0.70	4.033	65	1685	1690	0.077	0.022	123		0.97
44	DL41	DL42	Residence areas	2.15	0.70	6.183	41	1684	1689	0.122	0.013	123		1.48
45	DL42	outlet	Residence areas	1.23	0.70	7.413	52	1683	1684	0.019	0.031	119		1.72
46	DL43	DL44	Gravel Road	0.66	0.80	0.662	154	1690	1695	0.032	0.059	111		0.16
47	DL44	DL65	Gravel Road	0.29	0.80	0.948	65	1685	1690	0.077	0.022	123		0.26
48	DL65	outlet	Gravel Road	0.17	0.80	1.122	174	1684	1689	0.029	0.068	111		0.28
49	DL45	outlet	Gravel Road	0.33	0.80	0.326	506	1694	1695	0.002	0.432	61		0.04
50	DL46	outlet	Gravel Road	0.33	0.80	0.326	506	1693	1694	0.002	0.432	61		0.04
51	DL47	DL48	Green & Residence	12.00	0.57	12.000	504	1694	1695	0.002	0.430	61		1.16
52	DL48	DL49	0ffice	2.15	0.85	14.149	244	1693	1694	0.004	0.186	85		2.84
53	DL49	outlet	Residence areas	0.49	0.70	14.637	168	1690	1692	0.012	0.092	103		2.93
54	DL50	DL51	Gravel Road	0.17	0.80	0.495	168	1693	1694	0.006	0.121	99		0.11

55	DL51	outlet	Residence area	0.49	0.70	0.488	133	1687	1690	0.023	0.060	111		0.11
56	DL54	DL55	Residence area	0.43	0.70	0.913	51	1683	1685	0.039	0.023	123		0.22
57	DL55	outlet	Residence area	1.31	0.70	2.234	47	1680	1683	0.064	0.018	123		0.53
58	DL52	outlet	Gravel Road	0.83	0.80	3.066	60	1677	1694	0.283	0.012	123		0.84
59	DL56	DL57	Residence area	2.39	0.70	2.388	132	1673	1677	0.030	0.054	115		0.53
60	DL57	DL58	Residence area	1.56	0.70	3.948	153	1670	1673	0.020	0.071	111		0.85
61	DL58	DL59	Residence area	2.05	0.70	5.998	147	1668	1670	0.014	0.079	107		1.25
62	DL59	DL60	Residence area	1.14	0.70	7.139	94	1667	1668	0.011	0.062	111		1.54
63	DL60	outlet	Residence area	0.68	0.70	7.823	376	1667	1680	0.035	0.114	99		1.51
64	DL61	DL62	Gravel Road	0.29	0.80	0.289	289	1673	1679	0.021	0.113		118	0.08
65	DL62	outlet	Gravel Road	0.24	0.80	0.526	237	1669	1673	0.017	0.105		123	0.14
66	DL66	DL67	Green & Residence	17.83	0.54	17.829	302	1703	1716	0.043	0.089	107		2.86
67	DL67	DL28	Green & Residence	23.69	0.55	41.532	237	1668	1703	0.148	0.046	115		7.30
68	DL68	DL69	Asphalt Road	0.41	0.85	0.412	557	1694	1716	0.039	0.147	91		0.09
69	DL70	DL71	Asphalt Road	0.41	0.85	0.948	557	1708	1716	0.014	0.217		94	0.21
70	DL69	outlet	Asphalt Road	0.54	0.85	0.536	724	1702	1715	0.018	0.243		88	0.11
71	DL71	outlet	Asphalt Road	0.54	0.85	0.948	724	1702	1715	0.018	0.243		88	0.20
72	DL72	DL73	Residence area	1.88	0.70	2.886	139	1701	1706	0.036	0.052		138	0.78
73	DL73	DL74	Residence area	0.98	0.70	3.669	83	1700	1701	0.012	0.053	115		0.82

74	DL74	DL75	Residence area	1.22	0.70	5.089	121	1696	1700	0.033	0.048	115		1.14
75	DL75	outlet	Residence area	0.28	0.70	5.367	90	1693	1696	0.033	0.038	119		1.24
76	DL76	outlet	Asphalt Road	0.43	0.85	0.433	433	1693	1706	0.030	0.134	95		0.10
77	DL77	outlet	Gravel Road	0.10	0.80	0.095	95	1682	1685	0.032	0.041	119		0.03
78	DL78	outlet	Residence area	1.12	0.70	1.119	109	1682	1685	0.028	0.048	115		0.25
79	DL79	DL81	Mixed Residence area	1.12	0.65	2.257	74	1680	1683	0.041	0.031	119		0.49
80	DL80	DL82	Cobble Stone	0.28	0.70	0.284	284	1668	1680	0.042	0.085	107		0.06
81	DL81	DL83	Green Area	10.52	0.41	10.520	232	1665	1668	0.013	0.115	99		1.19
82	DL82	DL86	Cobble Stone	0.23	0.65	0.232	232	1665	1668	0.013	0.115	99		0.04
83	DL83	DL84	Residence area	0.73	0.70	11.249	171	1659	1665	0.035	0.062	111		2.43
84	DL84	DL85	Residence area	0.12	0.70	11.372	43	1656	1659	0.070	0.016	123		2.72
85	DL85	outlet	Governmentcinstitution	1.13	0.50	12.503	175	1651	1656	0.029	0.068	111		1.93
86	DL86	DL87	Cobble Stone	0.22	0.65	0.450	218	1659	1665	0.028	0.082	107		0.09
87	DL87	outlet	Cobble Stone	0.18	0.65	0.625	175	1651	1656	0.029	0.068	111		0.13
88	DL88	DL69	Residence area	1.28	0.70	1.282	180	1647	1651	0.022	0.077	107		0.27
89	DL89	DL90	Commercial & Residence area	1.12	0.74	2.405	207	1644	1647	0.014	0.101	103		0.51

90	DL90	DL91	Mixed Residence area	1.10	0.65	6.126	134	1641	1644	0.022	0.061	111		1.23
91	DL91	DL44	Residence area	0.81	0.70	6.932	95	1644	1656	0.126	0.024	123		1.66
93	DL92	DL91	Commercial & Residence area	2.24	0.74	2.242	376	1644	1656	0.032	0.118	99		0.46
92	DL93	outlet	school &Residence area	1.02	0.76	1.024	344	1639	1656	0.049	0.093	103		0.22
93	DL94	D91	Cobble stone & Residence area	0.38	0.68	0.376	376	1644	1656	0.032	0.118	99		0.07
94	DL95	DL44	Asphalt Road	0.34	0.85	0.344	344	1639	1656	0.049	0.093	103		0.08
95	DL96	DL97	Cobblestone & Mixed Residence	2.54	0.66	2.535	387	1644	1651	0.018	0.150	91		0.42
96	DL97	DL40	Cobblestone & Mixed Residence	4.83	0.60	7.361	232	1641	1644	0.013	0.115	99		1.22
97	DL98	DL99	Green & Residence	13.27	0.56	13.271	245	1686	1690	0.016	0.109	99		2.05
98	DL99	DL100	Commercial	4.29	0.77	17.561	193	1685	1686	0.005	0.142	91		3.42
99	DL100	DL101	Residence area	3.14	0.70	20.598	178	1680	1685	0.028	0.069	111		4.45
100	DL101	DL102	school &Residence area	0.92	0.73	21.630	134	1679	1680	0.007	0.093	103		4.52
101	DL102	DL103	Residence area	0.45	0.70	22.083	97	1675	1679	0.041	0.038	119		5.11

102	DL103	DL104	Residence area	0.49	0.70	22.573	103	1673	1675	0.019	0.053	115		5.05
103	DL104	DL109	Residence area	0.24	0.70	22.840	130	1685	1690	0.038	0.048	115		5.11
104	DL105	DL106	Cobblestone Road	0.28	0.70	0.283	438	1679	1685	0.014	0.183	85		0.05
105	DL106	DL107	Cobblestone Road	0.16	0.70	0.444	256	1678	1679	0.004	0.196	83		0.07
106	DL107	DL108	Cobblestone Road	0.09	0.70	0.534	141	1677	1678	0.007	0.099	103		0.11
107	DL108	DL110	Cobblestone Road	0.13	0.70	0.668	209	1672	1677	0.024	0.084	107		0.14
108	DL109	outlet	Residence area	0.40	0.40	23.992	156	1664	1666	0.013	0.085	107		2.85
####	DL110	outlet	Gravel Road	0.16	0.80	0.824	156	1664	1666	0.013	0.085	107		0.20
110	DL11	DL109	Residence area	0.76	0.70	0.757	104	1672	1674	0.019	0.053	115		0.17
111	DL112	DL113	Residence area	0.34	0.70	1.097	104	1672	1674	0.019	0.053	115		0.25
112	DL113	DL114	Residence area	1.79	0.70	2.880	98	1671	1672	0.010	0.065	111		0.62
113	DL114	outlet	Residence area	1.54	0.70	4.430	110	1664	1671	0.064	0.035	119		1.03
114	DL11	DL116	Cobblestone Road	1.28	0.70	1.280	200	1672	1674	0.010	0.113	99		0.25

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115	DL116	outlet	Gravel Road	0.22	0.80	1.504	224	1664	1672	0.036	0.076	107		0.36
116	DL117	DL118	Cobblestone Road	0.01	0.70	1.381	158	1664	1671	0.044	0.053	115		0.31
117	DL118	outlet	Cobblestone Road	0.09	0.70	1.469	139	1667	1671	0.029	0.057	115		0.33
118	DL119	DL120	Residence area	0.66	0.70	0.659	122	1669	1670	0.008	0.083	107		0.14
119	DL120	outlet	Residence area	1.26	0.70	1.922	132	1664	1669	0.038	0.049	119		0.45
120	DL121	DL122	Residence area	0.90	0.70	0.897	99	1672	1675	0.030	0.043	115		0.20
121	DL122	outlet	Residence area	0.99	0.70	1.886	95	1669	1672	0.032	0.041	119		0.44
122	DL123	DL124	Residence area	1.55	0.70	1.554	146	1678	1680	0.014	0.079	107		0.32
123	DL124	DL125	Residence area	1.38	0.70	2.929	92	1677	1678	0.011	0.060	115		0.66
124	DL125	DL126	Residence area	0.23	0.70	3.159	47	1676	1677	0.021	0.028	119		0.73
125	DL126	DL127	Residence area	0.25	0.70	3.404	71	1670	1676	0.085	0.022	123		0.81
126	DL12	DL128	school &Residence	6.40	0.73	9.805	247	1666	1670	0.016	0.111	103		2.05

	7		area											
127	DL128	outlet	Residence area	0.79	0.70	10.599	286	1662	1665	0.010	0.146	91		1.88
128	DL145	DL146	Gravel Road	0.19	0.80	0.186	286	1676	1677	0.003	0.223	81		0.03
129	DL146	DL129	Gravel Road	0.06	0.80	0.243	57	1657	1676	0.333	0.011	123		0.07
130	DL129	outlet	Gravel Road	0.17	0.80	0.408	89	1648	1657	0.101	0.025	123		0.11
131	DL130	DL131	Residence area	2.23	0.70	2.228	165	1670	1676	0.036	0.059	111		0.48
132	DL131	DL132	Residence area	1.39	0.70	3.614	148	1670	1676	0.041	0.052	115		0.81
133	DL132	DL133	Residence area	0.96	0.70	4.577	94	1675	1676	0.011	0.062	115		1.02
134	DL133	DL134	Residence area	1.14	0.70	5.721	150	1674	1675	0.007	0.106	103		1.15
135	DL134	DL135	Residence area	0.20	0.70	5.925	45	1660	1674	0.311	0.010	123		1.42
136	DL135	DL136	Residence area	0.46	0.70	6.384	115	1660	1668	0.070	0.035	119		1.48
137	DL136	DL140	Residence area	0.52	0.70	6.903	65	1667	1668	0.015	0.040	119		1.60
138	DL14	DL147	Residence area	0.99	0.70	7.890	180	1660	1668	0.044	0.059	115		1.77

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139	DL143	DL144	Cobblestone Road	2.03	0.70	2.028	317	1675	1676	0.003	0.251	77		0.30
140	DL144	DL145	Cobblestone Road	1.78	0.70	3.807	278	1660	1674	0.050	0.078	107		0.79
141	DL145	DL146	Cobblestone Road	0.93	0.70	4.735	126	1660	1668	0.063	0.039	119		1.10
142	DL146	outlet	Asphalt Road	0.19	0.85	4.926	161	1675	1676	0.006	0.115	99		1.15
143	DL137	outlet	school &Residence area	2.61	0.73	11.014	293	1656	1657	0.003	0.230		91	2.03
144	DL141	outlet	Cobblestone Road	1.87	0.70	1.942	293	1657	1659	0.007	0.176		100	0.38
145	DL138	outlet	school &Residence area	8.41	0.73	8.406	108	1656	1657	0.009	0.072		128	2.18
146	DL142	outlet	Cobblestone Road	0.07	0.70	0.069	108	1657	1659	0.019	0.056		133	0.02
147	DL147	DL150	Services area	4.08	0.80	11.970	170	1651	1662	0.065	0.049		138	3.67
148	DL148	outlet	Residence area	2.12	0.70	2.12	111	1651	1657	0.054	0.038		143	0.59
149	DL149	DL150	Residence area	3.87	0.70	3.873	261	1650	1651	0.004	0.201		97	0.73
150	DL15	outlet	Residence area	0.31	0.70	16.15	95	1651	1675	0.253	0.018		148	4.65

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Appendix 9:Table Runoff Estimation for Dagaga Zone

plot NO.	Flow Direction		Desciption of sub catchment	Sub basin area As(ha)	Runoff coffient ©	Total basin area A(ha)	Length of basin L(m)	Lowest elevation of the basin H1(m)	Highest elevation of the basin H2(m)	Average slope of the basin S	Time concentration of the basin Tc(hr)	Rainfall intensity I(mm/hr)		Total Runoff for plot of basin Qs(m^3/sec)
	From	To										5 years	10 years	
1	DL1	DL2	Asphalt Road Area	4.27	0.85	4.27	311	1659	1667	0.026	0.110		118	1.19
2	DL2	DL3	Asphalt Road Area	0.12	0.85	4.120	193	1655	1659	0.021	0.083		133	0.04
3	DL3	DL4	Asphalt Road Area	0.31	0.85	4.700	486	1639	1655	0.033	0.142		113	0.08
4	DL4	DL5	Asphalt Road Area	0.28	0.85	4.980	439	1633	1639	0.014	0.184		100	0.07
5	DL5	DL6	Asphalt Road Area	0.25	0.85	5.230	391	1629	1633	0.010	0.188		100	0.06
6	DL6	DL7	Asphalt Road Area	0.22	0.85	5.450	336	1625	1629	0.012	0.158		108	0.05
7	DL7	Outlet	Asphalt Road Area	1.17	0.85	6.620	262	1624	1625	0.004	0.202		97	0.27

8	DL8	DL9	Asphalt & School Arae	7.73	0.84	7.728	215	1657	1662	0.023	0.086		128	2.31
9	DL9	DL10	Asphalt & Residence Area	3.37	0.71	11.100	243	1648	1657	0.037	0.079		133	0.89
10	DL10	DL12	Asphalt & Residence Area	2.05	0.74	13.500	180	1644	1648	0.022	0.077		133	0.56
11	DL11	DL12	Commercia Area	2.51	0.77	2.513	207	1644	1646	0.010	0.118		118	0.63
12	DL12	DL13	Asphalt Road Area	0.14	0.85	15.798	135	1639	1644	0.037	0.050		138	0.04
13	DL13	Outlet	Office Area	0.57	0.85	16.364	108	1637	1639	0.019	0.056		138	0.18
14	DL14	DL15	Asphalt Road Area	0.32	0.85	6.120	317	1648	1662	0.044	0.091		128	0.10
15	DL15	DL16	Asphalt Road Area	0.32	0.85	0.637	320	1639	1648	0.028	0.109		123	0.09
16	DL16	Outlet	Asphalt Road Area	0.11	0.85	6.440	108	1637	1639	0.019	0.056		138	0.04
17	DL17	DL18	Cobblestone & Residence Area	1.12	0.75	7.230	163	1652	1658	0.037	0.059	115		1.73

18	DL18	DL19	Cobblestone & Residence Area	1.45	0.70	8.680	129	1649	1652	0.023	0.058	115		1.94
19	DL19	Outlet	Cobblestone & Residence Area	0.54	0.70	3.105	74	1645	1649	0.054	0.027	123		0.74
20	DL20	DL21	Residence Area	1.62	0.70	1.620	222	1637	1642	0.023	0.090	107		0.34
21	DL21	DL22	Government Comp & Residence	2.62	0.68	4.237	148	1633	1637	0.027	0.061	115		0.92
22	DL22	DL27	Residence Area	0.68	0.70	4.915	93	1632	1633	0.011	0.061	115		1.10
23	DL23	DL24	Residence Area	1.24	0.70	1.243	181	1633	1636	0.017	0.086	107		0.26
24	DL24	DL27	Residence Area	0.39	0.70	1.633	187	1632	1633	0.005	0.137	95		0.30
25	DL25	DL26	Asphalt Road Area	0.18	0.85	0.182	284	1632	1637	0.018	0.119		118	0.05
26	DL26	DL35	Asphalt Road Area	0.05	0.85	0.231	77	1631	1632	0.013	0.049		143	0.08
27	DL27	DL34	Residence Area	0.16	0.70	6.708	85	1631	1632	0.012	0.055	115		1.50

28	DL28	DL29	Asphalt Road Area	0.28	0.85	4.830	282	1632	1647	0.053	0.077		133	1.52
29	DL29	DL30	Asphalt Road Area	0.29	0.85	5.430	290	1631	1632	0.003	0.227		94	1.21
30	DL30	DL34	Asphalt Road Area	0.23	0.85	2.430	232	1630	1631	0.004	0.175		103	0.59
31	DL31	DL32	Residence Area	1.56	0.70	6.130	419	1637	1642	0.012	0.187	85		1.01
32	DL32	DL33	Residence Area	1.20	0.70	7.210	152	1635	1637	0.013	0.082	111		1.56
33	DL33	Outlet	Residence Area	1.20	0.70	3.786	139	1626	1635	0.065	0.042	119		0.88
34	DL34	DL50	Residence Area	10.52	0.70	21.017	264	1628	1630	0.008	0.156	91		3.72
35	DL35	DL50	Asphalt Road Area	0.22	0.85	0.399	264	1628	1630	0.008	0.156		108	0.10
36	DL36	DL51	Residence Area	9.56	0.70	9.556	377	1627	1628	0.003	0.307		79	1.47
37	DL37	DL51	Asphalt Road Area	0.24	0.85	0.241	377	1627	1628	0.003	0.307		79	0.04
38	DL38	DL48	Residence Area	2.38	0.70	2.399	94	1626	1627	0.011	0.062	115		0.54
39	DL39	DL48	Asphalt Road Area	0.60	0.85	0.601	94	1626	1627	0.011	0.062		138	0.20

40	DL40	DL41	Commercia Area	9.39	0.50	9.390	248	1634	1640	0.024	0.095	107		1.40
41	DL41	DL42	Commercia Area	5.20	0.70	14.585	172	1631	1634	0.017	0.081	111		3.15
42	DL42	DL43	Commercia Area	3.07	0.50	17.656	175	1629	1631	0.011	0.097	107		2.63
43	DL43	DL48	Commercia Area	2.54	0.50	20.199	182	1626	1629	0.016	0.087	107		3.00
44	DL44	DL45	Asphalt Road Area	0.25	0.85	0.248	248	1634	1640	0.024	0.095	107		0.06
45	DL45	DL46	Asphalt Road Area	0.17	0.85	0.420	172	1631	1634	0.017	0.081	111		0.11
46	DL46	DL47	Asphalt Road Area	0.18	0.85	0.595	175	1629	1631	0.011	0.097	107		0.15
47	DL47	DL49	Asphalt Road Area	0.18	0.85	0.777	182	1626	1629	0.016	0.087	107		0.20
48	DL52	DL49	Commercial Area	24.25	0.50	24.253	393	1627	1629	0.005	0.247	79		2.66
49	DL53	DL49	Asphalt Road Area	0.25	0.85	0.252	393	1627	1629	0.005	0.247		91	0.05
50	DL54	Outlet	Asphalt & Industry Area	2.25	0.76	2.245	138	1633	1640	0.051	0.045		143	0.68
51	DL55	DL56	Asphalt & Industry	22.58	0.81	22.581	268	1627	1633	0.022	0.104		123	6.25

			Area											
52	DL56	Outlet	Asphalt & Industry Area	10.66	0.78	33.205	152	1626	1627	0.007	0.108		123	8.86
53	DL57	DL65	Cobblestone &Industry Area	7.52	0.72	7.518	581	1626	1637	0.019	0.201	83		1.25
54	DL58	DL59	Cobblestone &Industry Area	7.35	0.72	7.346	603	1634	1637	0.005	0.346	66		0.97
55	DL59	DL66	Gravel Road &Residence Area	14.14	0.75	21.465	872	1635	1636	0.001	0.809	47		2.10
56	DL60	DL61	Cobblestone &Industry Area	16.82	0.73	16.824	464	1622	1635	0.028	0.145	95		3.24
57	DL61	DL62	Gravel Road &Residence Area	0.68	0.70	17.507	683	1622	1623	0.001	0.610	50		1.70
58	DL62	DL71	Gravel Road &Residenc	22.15	0.70	39.653	277	1631	1640	0.032	0.092		128	9.88

			e Area											
59	DL63	DL64	Asphalt Road Area	0.31	0.85	0.314	314	1626	1631	0.016	0.134		113	0.08
60	DL64	DL67	Asphalt Road Area	0.29	0.85	0.607	293	1626	1635	0.031	0.099		128	0.18
61	DL65	DL66	Gravel Road &Residenc e Area	21.57	0.71	21.57 4	419	1632	1635	0.007	0.227		94	4.00
62	DL66	Outle t	Industry Area	13.65	0.65	29.45 0	166	1626	1629	0.018	0.078		133	7.08
63	DL67	DL68	Asphalt Road Area	0.60	0.85	1.210	603	1633	1635	0.003	0.405		70	0.20
64	DL68	DL71	Asphalt Road Area	0.29	0.85	1.498	288	1622	1623	0.003	0.225		94	0.33
65	DL69	DL70	Asphalt Road Area	0.33	0.85	0.331	447	1637	1658	0.047	0.116		123	0.10
66	DL70	DL71	Asphalt Road Area	0.46	0.85	0.787	617	1623	1637	0.023	0.196		100	0.19
67	DL71	Outle t	Asphalt Road Area	0.08	0.85	24.44 5	106	1621	1623	0.019	0.054	115		6.64
68	DL72	DL73	Asphalt Road Area	0.33	0.85	0.331	447	1637	1658	0.047	0.116		123	0.10
69	DL73	DL74	Asphalt Road Area	0.46	0.85	0.787	617	1623	1637	0.023	0.196		100	0.19

70	DL74	Outlet	Asphalt Road Area	0.08	0.85	0.865	106	1621	1623	0.019	0.054		138	0.28
71	DL75	DL77	Residence Area	3.83	0.70	3.830	285	1620	1625	0.018	0.120	99		0.74
72	DL76	DL77	Residence Area	1.37	0.70	1.374	188	1620	1622	0.011	0.105	103		0.28
73	DL77	DL79	School Area	3.85	0.75	9.057	295	1617	1620	0.010	0.152	91		1.72
74	DL78	DL79	School Area	1.46	0.75	1.463	167	1617	1620	0.018	0.079	111		0.34
75	DL79	DL87	Residence Area	1.25	0.70	10.886	190	1615	1617	0.011	0.107	103		2.18
76	DL80	DL81	Cobble stone Area	0.29	0.70	0.285	285	1620	1625	0.018	0.120	99		0.05
77	DL81	DL79	Cobble stone Area	0.30	0.70	0.580	295	1617	1620	0.010	0.152	91		0.10
78	DL82	DL83	Asphalt Road Area	0.11	0.85	0.107	167	1617	1620	0.018	0.079		133	0.03
79	DL83	DL87	Asphalt & Residence Area	0.19	0.76	0.297	90	1616	1617	0.011	0.059		138	0.09
80	DL84	DL85	Asphalt & Residence Area	1.96	0.74	1.961	226	1618	1722	0.460	0.028		148	0.60
81	DL85	DL86	Asphalt	3.05	0.78	5.015	135	1616	1618	0.015	0.072	111		1.21

			&Residence Area											
82	DL86	DL87	Asphalt & Residence Area	3.31	0.81	8.322	215	1615	1616	0.005	0.161	91		1.71
83	DL87	DL88	Asphalt & Residence Area	1.66	0.74	12.596	138	1614	1615	0.007	0.096	107		2.77
84	DL88	DL90	Asphalt & Residence Area	3.96	0.75	16.555	140	1613	1614	0.007	0.098	107		3.69
85	DL89	DL90	Asphalt & Residence Area	1.38	0.73	17.934	94	1613	1614	0.011	0.062	115		4.19
86	DL90	DL93	Cobblestone & Residence Area	1.22	0.70	19.310	160	1612	1613	0.006	0.114	103		3.87
87	DL91	DL92	Cobblestone & Residence Area	8.55	0.70	8.547	160	1612	1614	0.013	0.087	107		1.78
88	DL92	DL93	Cobblestone & Residence Area	0.09	0.70	8.638	94	1612	1614	0.021	0.047	119		2.00

89	DL93	DL97	Asphalt & Commercial Area	1.22	0.79	27.948	178	1612	1613	0.006	0.129	99		6.08
90	DL94	DL96	Cobblestone & Residence Area	5.66	0.70	5.655	249	1613	1614	0.004	0.190	85		0.94
91	DL95	DL96	Asphalt & Residence Area	0.74	0.74	0.735	221	1613	1614	0.005	0.166	91		0.14
93	DL96	DL97	Asphalt & Commercial Area	0.25	0.80	0.987	123	1613	1614	0.008	0.084	107		0.23
92	DL97	Outlet	Asphalt & Commercial Area	2.16	0.81	21.432	29	1612	1613	0.034	0.016	123		5.94
93	DL98	DL99	Asphalt & Residence Area	0.23	0.74	0.231	361	1616	1622	0.017	0.147	95		0.05
94	DL99	DL100	Asphalt Road Area	0.14	0.85	0.368	215	1615	1616	0.005	0.161		108	0.09
95	DL100	DL101	Asphalt Road Area	0.19	0.85	0.553	289	1614	1615	0.003	0.226		94	0.12
96	DL101	DL97	Asphalt Road Area	0.03	0.85	0.759	320	1612	1614	0.006	0.195		100	0.18
97	DL10	DL10	Asphalt	0.14	0.85	0.141	221	1613	1614	0.005	0.166		108	0.04

	2	3	Road Area											
98	DL103	DL104	Asphalt Road Area	0.08	0.85	2.194	123	1613	1614	0.008	0.084		128	0.66
99	DL104	Outlet	Asphalt Road Area	0.92	0.85	0.237	29	1612	1613	0.034	0.016		148	0.08
100	DL105	DL112	Asphalt & Commercial Area	5.95	0.76	5.951	277	1617	1618	0.004	0.215		97	1.22
101	DL106	DL112	Asphalt Road Area	0.18	0.85	6.128	277	1615	1617	0.007	0.165	91		1.32
102	DL50	DL107	Residence Area	2.04	0.70	23.952	165	1617	1620	0.018	0.077	111		5.17
103	DL107	DL108	Residence Area	2.84	0.70	26.296	219	1615	1617	0.009	0.126	99		5.07
104	DL108	DL112	Residence Area	2.38	0.70	28.671	219	1614	1615	0.005	0.164	91		5.08
105	DL109	DL112	Cobble stone Area	0.60	0.70	16.978	112	1614	1620	0.054	0.038	119		3.93
106	DL51	DL110	Cobble stone Area	1.90	0.70	11.694	164	1613	1614	0.006	0.117	99		2.25
107	DL110	DL111	Residence Area	2.34	0.70	14.030	209	1613	1614	0.005	0.155	91		2.48
108	DL111	DL112	Residence Area	2.36	0.70	16.390	218	1614	1615	0.005	0.163	91		2.90

###	DL112	DL114	Commercial Area	2.31	0.77	31.506	205	1613	1614	0.005	0.152	91		6.14
110	DL113	DL128	Commercial Area	7.89	0.77	7.894	195	1613	1614	0.005	0.143	95		1.61
111	DL114	DL115	Commercial Area	2.62	0.77	34.124	114	1613	1614	0.009	0.077	111		8.11
112	DL115	DL127	Commercial Area	1.04	0.77	35.167	124	1613	1614	0.008	0.085	107		8.05
113	DL116	DL127	Cobble stone Area	0.12	0.70	0.238	124	1613	1614	0.008	0.085	107		0.05
114	DL117	DL128	Cobble stone Area	0.20	0.70	0.195	195	1613	1614	0.005	0.143	95		0.04
115	DL118	DL116	Cobble stone Area	0.11	0.70	45.632	114	1616	1620	0.035	0.045	119		10.57
116	DL48	DL119	Asphalt & Residence Area	3.02	0.74	3.020	165	1617	1618	0.006	0.118	99		0.62
117	DL119	DL120	Asphalt & Commercial Area	6.44	0.81	9.456	218	1615	1617	0.009	0.125	99		2.11
118	DL120	DL121	Asphalt & Commercial Area	2.88	0.82	12.336	216	1613	1614	0.005	0.161	91		2.56
119	DL121	DL122	Asphalt & Commerci	3.18	0.82	15.515	207	1612	1614	0.010	0.118	99		3.50

			al Area											
120	DL122	DL127	Asphalt & Commercial Area	0.91	0.81	16.420	54	1618	1622	0.074	0.019	123		4.55
121	DL49	DL123	Asphalt Road Area	0.19	0.85	3.700	303	1617	1620	0.010	0.156	91		0.80
122	DL123	DL124	Asphalt Road Area	0.18	0.85	3.880	284	1615	1616	0.004	0.221	81		0.74
123	DL124	DL127	Asphalt &Green AREA	0.19	0.63	4.592	302	1616	1618	0.007	0.182	87		0.70
124	DL125	DL126	Asphalt & Green Area	0.50	0.57	0.500	237	1614	1616	0.008	0.138	95		0.08
125	DL126	DL127	Asphalt & Green Area	0.95	0.61	0.595	146	1616	1617	0.007	0.103	103		0.10
126	DL127	DL128	Asphalt & Commercial Area	0.76	0.81	38.450	232	1614	1615	0.004	0.175	87		7.53
127	DL128	Outlet	Asphalt & Commercial Area	6.73	0.80	49.459	336	1612	1614	0.006	0.206	83		9.13
128	DL129	DL135	Asphalt & Commercial Area	0.28	0.79	0.283	442	1616	1618	0.005	0.283	75	85	0.05

129	DL130	DL131	Asphalt & Commercial Area	2.69	0.83	2.693	157	1614	1616	0.013	0.086	107		0.66
130	DL131	DL124	Asphalt & Commercial Area	1.33	0.81	4.023	165	1614	1616	0.012	0.091	107		0.97
131	DL132	DL112	Asphalt & Commercial Area	0.98	0.81	0.975	87	1614	1615	0.011	0.056	115		0.25
132	DL133	DL124	Asphalt Road Area	0.20	0.85	0.202	315	1614	1616	0.006	0.191	85		0.04
133	DL134	DL112	Asphalt Road Area	6.73	0.85	6.73	208	1613	1614	0.005	0.155	91		1.45
134	DL135	Outlet	Asphalt Road Area	0.14	0.85	0.422	217	1612	1614	0.009	0.124		118	0.12

Appendix 10:Table Runoff Estimation for irrecha Zone

plot NO.	Flow Direction		Desciption of sub catchment	Sub basin area As(ha)	Runoff coffient ©	Total basin area A(ha)	Length of basin L(m)	Lowest elevation of the basin H1(m)	Highest elevation of the basin H2(m)	Average slope of the basin S	Time concentration of the basin Tc(hr)	Rainfall intensity I(mm/hr)		Total Runoff for plot of basin Qs(m^3/sec)
	From	To										5 years	10 years	
1	DL1	DL2	Residence	0.67	0.70	0.667	82	1637	1638	0.012	0.053	115		0.15

			Area											
2	DL2	DL3	Governme nt Comp. Area	2.61	0.74	3.274	390	1626	1637	0.028	0.127	99		0.67
3	DL3	Outle t	Commercia l & Residence	6.84	0.76	6.835	277	1626	1628	0.007	0.165	91		1.31
4	DL4	DL5	Governme nt cmp& Residence	3.80	0.69	3.905	99	1626	1627	0.010	0.066	115		0.86
5	DL5	DL56	Governme nt Comp. Area	0.85	0.50	14.75 0	300	1626	1627	0.003	0.236	79		1.62
6	DL6	DL7	Gravel Road Area	0.82	0.80	0.811	82	1637	1638	0.012	0.053	115		0.21
7	DL7	Outle t	Gravel Road & Residence	0.85	1.67	1.209	390	1626	1637	0.028	0.127	99		0.56
8	DL8	DL9	Cobble stone Area	0.28	0.70	1.486	277	1626	1627	0.004	0.215	83		0.24
9	DL9	DL56	Gravel Road Area	0.30	0.80	1.786	300	1626	1627	0.003	0.236	79		0.31
10	DL1 0	DL11	Commercia l &School	2.94	0.79	2.951	207	1612	1618	0.029	0.077	111		0.72
11	DL1	Outle	School	3.23	0.75	6.180	223	1612	1616	0.018	0.098	107		1.38

	1	t	Area											
12	DL12	DL13	Cobble stone Area	0.21	0.70	0.207	207	1612	1616	0.019	0.090	107		0.04
13	DL13	Outlet	Cobble stone Area	0.22	0.70	0.430	223	1612	1616	0.018	0.098	107		0.09
14	DL14	DL15	Commercial & Mixed Residence	1.50	0.76	1.497	137	1612	1613	0.007	0.095	107		0.34
15	DL15	DL16	Commercial & Mixed Residence	6.85	0.74	2.344	113	1611	1612	0.009	0.076	111		0.54
16	DL16	Outlet	Mixed Residence	2.01	0.65	4.350	238	1611	1612	0.004	0.181	87		0.68
17	DL17	DL18	Asphalt Road Area	0.09	0.85	0.087	137	1611	1612	0.007	0.095	107		0.02
18	DL18	DL19	Asphalt Road Area	0.07	0.85	0.159	113	1611	1612	0.009	0.076	111		0.04
19	DL19	Outlet	Asphalt Road Area	0.15	0.85	0.311	238	1611	1612	0.004	0.181	87		0.06
20	DL20	DL21	Asphalt & Commercial Area	2.67	0.82	2.669	240	1612	1613	0.004	0.182		103	0.63
21	DL21	DL22	Asphalt & Commercial Area	1.47	0.75	4.190	180	1611	1612	0.006	0.131		118	1.03

22	DL22	DL23	Asphalt & Commercial Area	1.63	0.73	5.770	192	1611	1612	0.005	0.141		113	1.32
23	DL23	DL24	Asphalt & Residence Area	1.31	0.67	7.810	267	1610	1611	0.004	0.206		97	1.41
24	DL24	Outlet	Asphalt & Commercial Area	0.20	0.55	7.277	75	1609	1610	0.013	0.048		143	1.59
25	DL25	DL26	Asphalt & Commercial Area	4.33	0.81	4.350	240	1612	1613	0.004	0.182		103	1.01
26	DL26	DL27	Asphalt & Commercial Area	2.88	0.83	7.209	180	1611	1612	0.006	0.131		118	1.96
27	DL27	DL28	Asphalt & Green Area	2.34	0.63	2.345	179	1611	1612	0.006	0.130		118	0.48
28	DL28	DL29	Asphalt & Commercial Area	1.08	0.84	3.418	163	1611	1612	0.006	0.117		123	0.98
29	DL29	DL30	Asphalt & Residence Area	1.37	0.78	11.994	192	1610	1611	0.005	0.141		113	2.94
30	DL30	DL31	Residence Area	3.20	0.70	15.149	266	1609	1610	0.004	0.205		97	2.86
31	DL3	Outle	Asphalt	0.06	0.75	15.25	75	1616	1618	0.027	0.036		143	4.55

	1	t	&Mixed Residence			9								
32	DL8 6	DL87	Commercia l & Mixed Residence	3.54	0.71	3.540	265	1611	1612	0.004	0.204	83		0.58
33	DL8 7	Outle t	Commercia l & Mixed Residence	2.08	0.77	5.617	145	1610	1611	0.007	0.102	103		1.24
34	DL3 2	DL33	Asphalt & Mixed Residence	4.42	0.73	4.423	156	1615	1616	0.006	0.111	103		0.92
35	DL3 3	DL34	Residence Area	0.41	0.70	4.641	144	1612	1615	0.021	0.066	115		1.04
36	DL3 4	DL35	Residence Area	558.0 0	0.70	4.991	123	1616	1618	0.016	0.065	115		1.12
37	DL3 5	DL36	Asphalt Road Area	0.16	0.85	0.156	156	1616	1618	0.013	0.085		128	0.05
38	DL3 6	DL37	Cobble stone Area	0.14	0.70	0.300	144	1615	1616	0.007	0.101	103		0.06
39	DL3 7	DL38	Cobble stone Area	0.12	0.70	0.423	123	1612	1615	0.024	0.055	115		0.09
40	DL3 8	DL39	Asphalt & Mixed Residence	7.49	0.78	7.489	212	1618	1619	0.005	0.158	91		1.48
41	DL3	DL40	Residence	1.42	0.70	8.916	210	1615	1618	0.014	0.102	103		1.79

	9		Area											
42	DL40	DL41	Residence Area	0.23	0.70	9.146	107	1612	1615	0.028	0.047	119		2.12
43	DL41	DL46	Residence Area	0.24	0.70	9.404	161	1610	1612	0.012	0.088	107		1.96
44	DL42	DL43	Asphalt Road Area	0.21	0.85	0.212	212	1618	1619	0.005	0.158		108	0.05
45	DL43	DL44	Cobble stone Area	0.21	0.70	0.422	110	1615	1618	0.027	0.049	119		0.10
46	DL44	DL45	Cobble stone Area	0.11	0.70	0.532	107	1612	1615	0.028	0.047	119		0.12
47	DL45	DL49	Cobble stone Area	1.61	0.70	0.693	161	1610	1612	0.012	0.088	107		0.14
48	DL46	DL47	Asphalt & Green Area	5.25	0.62	14.823	208	1610	1611	0.005	0.155	91		2.32
49	DL47	DL48	Cobblestone & Residence Area	2.39	0.70	17.218	209	1609	1610	0.005	0.155	91		3.05
50	DL48	Outlet	Cobblestone & Residence Area	2.76	0.70	19.974	353	1609	1610	0.003	0.285	73		2.84
51	DL49	DL50	Cobblestone & Residence	0.13	0.70	0.826	208	1610	1611	0.005	0.155	91		0.15

			Area											
52	DL5 0	DL51	Cobbleston e & Residence Area	0.13	0.70	0.959	209	1609	1610	0.005	0.155	91		0.17
53	DL5 1	Outle t	Cobbleston e & Residence Area	0.27	0.70	1.185	353	1609	1610	0.003	0.285	73		0.17
54	DL5 2	DL53	Asphalt & Governme nt comp	7.25	0.68	7.250	217	1618	1620	0.009	0.124		118	1.62
55	DL5 3	DL54	Residence Area	0.29	0.70	7.537	145	1614	1618	0.028	0.060	115		1.69
56	DL5 4	DL55	Residence Area	0.15	0.70	7.682	114	1612	1614	0.018	0.059	115		1.72
57	DL5 5	DL59	Residence Area	1.86	0.70	9.356	109	1611	1612	0.009	0.073	111		2.02
58	DL5 6	DL57	Asphalt & Governme nt comp	6.32	0.67	6.315	111	1616	1617	0.009	0.075		133	1.56
59	DL5 7	DL58	Residence Area	0.23	0.70	6.540	152	1613	1616	0.020	0.070	111		1.41
60	DL5 8	DL59	Residence Area	0.34	0.70	6.881	108	1611	1613	0.019	0.056	115		1.54

61	DL59	DL62	Residence Area	2.21	0.70	18.997	101	1610	1611	0.010	0.067	111		4.10
62	DL60	DL61	Asphalt & Government comp	4.92	0.66	4.923	113	1616	1617	0.009	0.076		133	1.20
63	DL61	DL62	Cobble stone Area	0.82	0.70	5.744	232	1613	1616	0.013	0.115	103		1.15
64	DL62	Outlet	Residence Area	9.62	0.70	25.364	329	1610	1611	0.003	0.262	77		3.80
65	DL63	DL64	Asphalt & Government comp	8.86	0.67	24.240	377	1616	1618	0.005	0.235		91	4.11
66	DL64	Outlet	Asphalt & Government comp	7.99	0.65	7.913	369	1616	1622	0.016	0.150		108	1.54
67	DL65	DL66	Asphalt Road Area	0.22	0.85	0.217	217	1618	1620	0.009	0.124		118	0.06
68	DL66	DL70	Cobble stone Area	0.26	0.70	0.476	259	1614	1618	0.015	0.117	99		0.09
69	DL67	DL68	Cobble stone Area	0.11	0.70	0.515	109	1612	1614	0.018	0.056	115		0.12
70	DL68	DL69	Asphalt Road Area	0.11	0.85	0.111	111	1616	1617	0.009	0.075		133	0.03
71	DL69	DL59	Cobble stone Area	0.24	0.70	0.332	231	1611	1616	0.022	0.094	107		0.07

72	DL70	DL73	Cobble stone Area	0.10	0.70	0.686	101	1610	1611	0.010	0.067	111		0.15
73	DL71	DL72	Asphalt Road Area	0.11	0.85	0.113	113	1616	1617	0.009	0.076		133	0.04
74	DL72	DL62	Cobble stone Area	0.23	0.70	0.345	232	1613	1616	0.013	0.115	103		0.07
75	DL73	Outlet	Asphalt Road Area	0.24	0.85	0.686	329	1610	1611	0.003	0.262	77		0.12
76	DL74	DL75	Asphalt Road Area	0.34	0.85	0.337	337	1616	1618	0.006	0.207		97	0.08
77	DL75	Outlet	Asphalt Road Area	0.37	0.85	0.369	369	1616	1622	0.016	0.150		108	0.09
78	DL76	DL77	Asphalt & Government comp	9.21	0.69	9.21	412	1616	1622	0.015	0.171		143	2.53
79	DL77	DL78	Residence Area	7.80	0.70	17.010	381	1610	1616	0.016	0.156		128	4.24
80	DL78	DL79	Industry Area	5.20	0.80	22.210	424	1600	1610	0.024	0.145		113	5.58
81	DL79	DL80	Asphalt & Industry Area	4.02	0.83	26.230	138	1596	1600	0.029	0.056		138	8.35
82	DL80	Outlet	Asphalt & Industry Area	3.03	0.86	29.260	350	1592	1596	0.011	0.165		108	7.56

83	DL8 1	DL82	Asphalt Road Area	0.41	0.85	0.412	412	1616	1622	0.015	0.171		103	0.10
84	DL8 2	DL83	Asphalt Road Area	0.35	0.85	0.793	331	1610	1616	0.018	0.133		118	0.22
85	DL8 3	DL84	Asphalt Road Area	0.42	0.85	1.214	424	1600	1610	0.024	0.145		113	0.32
86	DL8 4	DL85	Asphalt Road Area	0.14	0.85	1.358	138	1596	1600	0.029	0.056		138	0.44
87	DL8 5	Outle t	Asphalt Road Area	0.35	0.85	1.705	350	1592	1596	0.011	0.165		108	0.44