ADOPTING LANDSCAPE INFRASTRUCTURE TO INTEGRATED URBAN STORMWATER AND WASTEWATER MANAGEMENT SYSTEM (CASE STUDY OF KEBENA WATERSHED)

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Adopting Landscape Infrastructure to Integrated Urban Stormwater And Wastewater Management System

(Case study of Kebena Watershed)

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School of Civil and Environmental Engineering

This is to certify that the thesis prepared by Feyisa Nibo, Entitled: Evaluation of the Integration of Urban Drainage (Stormwater) and Wastewater Management System in Kebena Watershed and submitted in partial fulfillment of the requirements for the degree of master sciences (Civil and Environmental Engineering) complies with the regulation of university and Meet the accepted standards with respect to originality and quality

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CERTIFICATION

The undersigned certify that he has read the Thesis entitled **Adopting Landscape Infrastructure to Integrated Urban Stormwater and Wastewater Management System** in Kebena Watershed and hereby recommend for acceptance by the Addis Ababa University in partial fulfillment of the requirements for the degree of Master of Science (Engineering).

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June, 2017

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I, Feyisa Nibo Gnafaro, declare that this thesis is my own original work and that it has not been presented and will not be presented by me to any other University for similar or any other degree award.

Declaration

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Abstract

The main goal of this study is to evaluate the existing urban wastewater and storm drainage management system and made recommendation on best selected alternative option of integrated urban wastewater and storm drainage management system. Any technical wastewater and stormwater management system adopted in urban drainage based on prior quantitate design discharge estimation. This study contributes a lot to understanding of the integrated urban water management system key technique to minimize the diffuse pollution load into natural stream, to reduce point source/wastewater discharges and to preserve the hydrologic regime of natural drainage systems.

Wastewater and stormwater flow discharge are analyzed based on the three-part methodology. The rainfall of 100, 50, 25, 10, 5 and 2 year annual exceedance probability meteorological method was simulated SCS unit hydrograph rainfall-runoff using HEC-HMS. The calibration result indicates basin parameters were used in HEC-HMS model is improved. Different scenarios for landcover change were evaluated for all rainfall frequency models. The frequency storm of 25 year return period produced the maximum peak discharge at the outlet found 209m^3/s in 1995, 238.1m^3/s, in 2002 and 262.6m^3/s in 2009. The hydrological response indicated that with urban area increase by 24.95%, an increase in peak flow. This study shows that peak discharge increase in 13.87% in period 2002, 25.64% in 2009 compared to period of 1995 as reference. The storm drainage management infrastructures are not updated – not sufficient to the peak discharge. Flooding impact on streets, and public property damage were reported in every year.

The wastewater generation from domestic, industrial, public and intuitional have direct relation water supplied and 80% of water used is changed to wastewater. Monthly billed volume of consumed water from 2011 to 2016 was evaluated to determine domestic per capita demand. The average per capita demand is found 26.74l/cap/day. Per capita demand by mode of service were found 89.2L/cap/day for High Consumption, 41.48 L/cap/day medium consumption , 21.06 L/cap/day low consumption, and 9.88 L/cap/day very low consumption. From these demand estimation the total wastewater flow rate are found 2898.9m^3/day (0.0334m^3/s). Only 255m^3/day (4%) of sewer facilities is existed for wastewater management system. These infrastructures are limited to only to onsite sewer line connected to the flash toilet, off-site pitlitrine discharged to treatment plant. GIS specific landscape Suitability assessed where specific practice to place, i.e.

integrated urban water management system like stormwater best management practice and Wastewater Generation Reduction. The evaluated stormwater best management practices selected is Sediment Basins, Sand Filters Pervious landscape Pavements, Bio Basins, Infiltration, Ponds and Lakes, Swales & Buffer Strips, Bio Swales, Constructed Wetlands. For wastewater reduction the selected are Stormwater Harvesting/Reuse, Rainwater Tanks, Changing Landscape Form and Water Use Education Programs.

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List of Abbreviation

AAU	Addis Ababa University
AAWSA	Addis Ababa Water supply and Sewerage Authority
CN	Curve Number
ETM+	Enhanced Thematic Mapper
CORR	Correlation Coefficient
CAD	Computer Aided Design
FAO	Food and Agricultural Organization
HEC-HMS	Hydrological Engineering Center hydrological Modeling system
HMS	Hydrological Modeling System
GIS	Geographic Information System
AA Obs	Addis Ababa Observatory
PEPF	Percentage Error in Peak Flow
PEV	Percentage Error in Volume
RBAIS	Residual Bias
TM	Thematic Mapper
PWRMSE	Peak weighted Root Mean Square
UTM	Universal Traverse Mercator
DEM	Digital elevation model
IUWM	Integrated Urban Water Management
USACE	United States Army Corps of Engineers

Introduction

1.1. Study Background

Assessing, evaluating the quantity of wastewater and stormwater in city urban drainage is a complex task by its nature. Quantity Estimation of urban water and evaluation of existing integrated urban stormwater and wastewater management technical option needs much data, sophisticated data processing material and method, and detailed field investigation sometimes sophisticated equipment and objective oriented software. It goes much beyond providing water and sanitation services and overseeing related infrastructure. It also includes mitigating the risk of floods, landslides and other water-mediated disasters, as well as managing solid waste and storm water drainage (Bahri,A. 2012).

Urban developments to support a growing community have consequential impacts on the land and water environments. Potable water from pure sources is rare, other sources of water must be treated at high cost, and the volume of wastewater is growing. Integrated urban water management (IUWM) premises better approach than conventional system, in which sanitation, stormwater and wastewater are managed by isolated entities. This study contributes a lot to understanding of the integrated urban water management system key technique to minimize the diffuse pollution load into natural stream, to reduce point source/wastewater discharges and to preserve the hydrologic regime of natural drainage systems based on IUWM principle.

Water is a critical natural resource for the world‟s growing urban areas. Commercial, residential, and industrial users already place considerable demands on this resource, which often requires treatment, may be located at great distance from the city, and is usually in demand by multiple sectors (Bahri, A., et al., 2012). According to World Development Report (2006), water infrastructure development in Africa is abysmal, lagging behind the rest of the world in terms of quality, quantity, and access. The situation is worse in poor countries like Ethiopia, where a myriad of problems have made the supply of physical infrastructure and services to continually lag behind the urban population growth rate.

According to (URAdapt, 2013) Strategic agenda for adaptation to urban water on Addis Ababa, urban water management systems become subject to a range of pressures on problem of wastewater and storm water management. Lack of integrated urban developments within watersheds may pollute surface waters and complicate water source protection. Land clearance, deforestation and the expansion of impermeable surfaces like road, asphalt and housing increase the risk of flooding, and slow the rate of infiltration and waste aquifer recharge (Palaniappan et al., 2010). Beside lack of IUWM infrastructure and low rate of conventional urban water management, the stream pollution, urban channel overflow, high contaminant concentration in drainage and risk of flooding is the main of problem in developing country urban area.

Principle of water resource management of the existing period “integrated urban water management (here in after IUWM)” sticks on the necessity of managing water resource in integrated manner specifically on storm water and wastewater management system. The primary aim of this principle is to enable multi functionality of urban water services like low impact development infrastructure. The dimensions of this multi functionality includes affordability, amenity, including recreation(open space land and water), ecosystem protection, greenhouse, gas emissions, equity, groundwater management, maintenance of biodiversity, pollution prevention and control, public health protection and sanitation (Butler, D., and Maksimovic, 1999).

Limited institution and stockholder participation and capacity are also one of the problem that hinder cities of developing countries for urban water management infrastructure. Impacts of land use landcover change on flood and wastewater discharge on urban natural stream environment are less recognized. Evaluation of the existing quantitative urban drainage (stormwater) and wastewater management system within catchment is important to improve management system and also urban reduces the impact. Quantitative Wastewater discharge and urban drainage (stormwater) flow discharge are assessed based on the three-part methodology. Stormwater surface runoff was modeled using the HEC-HMS based Soil Conservation Service (SCS)-based storm runoff model. In this regard, it is imperative to integrate the various quantification methods with the spatial data handling capabilities of Geographic Information Systems (GIS) to process data for hydrological modeling. Also GIS based specific site suitability assessment was used where to place selected integrated urban water management option. Wastewater generation flow was evaluating using water consumption demand by mode of service to population served in area.

1.2. Statement of the Problem

As many research reveals of Kebena river watershed and its tributaries have so many problems related to IUWM. These include the following: impairment of aquatic habitat and modifications to natural ecosystems due to reduced environmental flows; increased wastewater disposal, resulting in negative consequences for native flora and fauna and stream flow quality of river basins and coastal waters; inadequate handling of contaminants and nutrients; significant energy and chemical usage from household and institute. There is no rehabilitation and replacement of aging water infrastructure in Kebena watershed. The panel of the Research into Strategic Action Platform (Re-SAP, 2013) meetings has recommended "the need to work on further studies and Designing and integrating locally appropriate flood management and adaptation measures into the overall city management plan" which is mainly recommended for stream in Addis Ababa.

Relying on the recommendations and findings of the different research journal, as part of the problem, on other hand urbanization development cause the increasing of wastewater generation, affluence, and climate change that cause over flooding. This paper proposes to study the possible best available option evaluation of IUWM options within the framework of integrated urban water management and adaptation of landscape as solution. If expected demand is met, wastewater generation to river watershed in the City of Addis Ababa will triple by 2030. There is no wastewater management policy plan and the existing wastewater treatment plants in the city have no mandate to sell or recycle treated wastewater (as a possible adaptation option). (Ministry of Energy and water resource, 2013)

Unplanned Urban growth close to river and in a watershed consumed the natural and scenic beauty of the landscape and; and altered the attractiveness of the City. (P. Z. Mpofu, 2013). Generally, Conventional urban water management has been found wanting in its ability to address key challenges for growing cities such as increasing competition for water, sanitation and stormwater management, and water resources protection (Bahri, A., 2012).

The city urban water managements, which includes demand management, sanitation and stormwater has not occurred in integrated and sufficient framework; instead, each has been planned and delivered as an isolated service – thus interconnections among problems and potential solutions are missed.

1.3. Objective of the Study

1.3.1. General Objective

The general objective of the research is to evaluate integration of urban drainage (Stormwater) and Wastewater management system in Kebena river watershed and make recommendation on appropriate IUWM system.

1.3.2. Specific Objectives

The specific objectives of the research are listed as follows

- To evaluate the existing quantitative wastewater management system;
- To evaluate the urban drainage (Stormwater) management system;
- To make recommendation on appropriate IUWM systems and urban wastewater and drainage water; integration, and management system

1.4. Research Question

Specific objective	**Research Question**
To evaluate the existing quantitative wastewater management system	➢ How much water is consumed by domestic and non-domestic ➢ What is per capita demand of water consumption ➢ How much consumed water as wastewater discharged to drainage ➢ Is there enough Sanitation service to populations per house unit
To Evaluate existing the urban drainage (stormwater) management system;	➢ Is there landuse landcover Change in Kebena Catchment? ➢ Is there Rainfall-runoff changes due to urbanization in past two decade? ➢ Does the LULC change affect urban Kebena drainage hydrology? ➢ Is there flood risk due urban drainage design performance?
To make recommendation on appropriate IUWM systems	➢ What are topographic and landcover criterion to identify specific site suitability for IUWM system options? ➢ What is Evaluation methodology to identify and suggest of IUWM system

1.5. Scope of the Study

This study is geographically limited Kebena river watershed; a subbassin of big Akaki catchment and till it joins Bulbula River at outlet Urael school stage flow gauge. The general study of river is to evaluate the integration of urban drainage (storm) and wastewater management system. Also GIS based Methodology assesses the suitability of landcover and topography to make suggestion to integrate urban water management system. The suggested methodology that was apply to solve the existing problem of the river is multi- functionality, but this study is only limited technical evaluation wastewater and stormwater management system.

2. Literature Review

2.1. Introduction

The major problem facing cities are increasing and one of the major problems is management of urban water to its balanced natural form. Lack of IUWM within watersheds may pollute surface waters and complicate water source protection. In many parts of sub-Saharan Africa, rapid urbanization outpaces the ability of city manage to adjust basic service provision, including water supply, sanitation and flood protection (Mafuta et al. 2011). Land clearance, deforestation and the expansion of impermeable surfaces increase the risk of flooding, and slow the rate of infiltration and aquifer recharge. As storm and surface water runoff flow through built-up areas, their pollution loads increase, particularly where the necessary solid waste management practices are lacking (Palaniappan et al. 2010).

Integrated urban water management, seeks to change the impact of urban development on the natural water cycle, by managing the urban water cycle as a whole (Semu et al 2012). The importance of Adopting integrated water management in urban area and evaluating technical management with time has been widely recognized in the scientific community. Integrated urban water management, promises a better approach than the current system, in which water supply, sanitation, stormwater and wastewater are managed by isolated entities, and all four are separated from land-use planning and economic development. IUWM calls for the alignment of urban development and basin management to achieve sustainable economic, social, and environmental goals (Bahri A. 2012)

2.2. Adopting Integrated Urban Water Management

The definition of IUWM came relative to the term like integrated water cycle, integrated water resource‟s management, which is commonly used in planning at river level. The processes and systems to which these names apply have much in common with IUWM. IUWM can be viewed as a subset of IWRM that is concerned with the management of water supply, wastewater and stormwater in urban areas within the boundary conditions set as part of the IWRM process. Close interaction and communication between IWRM and IUWM planning processes is critical if each is to be successfully implemented (Maheepala S., 2010).

The goals of urban water management are to ensure access to water and sanitation infrastructure and services; manage rainwater, wastewater, stormwater drainage, and runoff pollution; control waterborne diseases and epidemics; and reduce the risk of water-related hazards, including floods, droughts, and landslides. All the while, water management practices must prevent resource degradation (Bahri A., 2012).

Depending on the goals IUWM we classify urban water as waste water, stormwater and potable water demand. The three parts of the water are interdisciplinary, which one is depends on each other as source urban water. The integrated management of the urban water streams addresses the three key management objectives of mains potable water conservation, minimization of wastewater discharge and stormwater quantity and quality management (Wong T., 2007).

Rainwater or stormwater harvesting has benefits in achieving water conservation and stormwater management. Efforts to reduce the import of water and the export of wastewater and stormwater pollutants will increase the overall sustainability of an urban area. To this end, water reuse and water treatment are essential elements. Within the context of stormwater, the harvesting of stormwater as an alternative water resource is clearly an initiative that would address both the potable water conservation and stormwater quality objectives. Some adopting IUWM option are classified according two broad scales in urban planning and design and urban Stream scale

Integrating Water Management with Urban Planning and Design: Integrating urban water management with urban planning and design has many dimensions including:

- Integrated management of the three urban water streams of potable water, wastewater and stormwater
- Integration of the scale of urban water management from individual allotments and buildings, to precinct and regions

Integrated Management of the Urban Water Streams: The integrated management of the urban water streams addresses the three key management objectives of mains potable water conservation, minimization of wastewater discharge and stormwater quantity and quality management.

2.3. Conventional Versus Integrated Urban Water Management

Conveyance approach is arranging channels & pipes in an artificial flow network system, to convey exceeding water away. Initially, this solution was able to deal with floods in a certain area, transferring water downstream with no major consequences; as urbanization grows and more areas of the watershed turn impervious, upstream development stresses the system as a whole and the conveyance approach fails. Networks of pipes that collect both sewage and stormwater must convey the combined flows to wastewater treatment plants for treatment before being discharged to the stream. Urban water management seeks to ensure access to water and sanitation infrastructure and services. It must also manage rainwater, wastewater, stormwater drainage, and runoff pollution, while controlling waterborne diseases and epidemics, mitigating floods, droughts, and landslides, and preventing resource degradation (Bahri A. 2012)..

The description by (Bahri, 2012) how IUWM is address the entire urban water system and IUWM different from conventional urban water management is as follows.

- It encompasses the different water sources that are present within an urban catchment.
- It considers the quality of different water sources
- It looks at the processes for water storage, distribution, treatment, recycling and disposal as part of one cycle
- It plans for the protection, conservation and exploitation of water resources at their source,
- It takes into account the range of other users and landscapes that depend on the same water bodies as the city.
- It accounts for the range of formal (organizations, legislation and policies) and informal (norms and conventions) institutions that govern water in and for cities.
- It seeks to balance economic efficiency, social equity and environmental sustainability.
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- It seeks to balance economic efficiency, social equity and environmental sustainability.

2.4. Water Sensitive Urban Development

The first definition in its broadest context, WSUD encompasses all aspects of integrated urban water cycle management, including the harvesting and/or treatment of stormwater and wastewater to supplement non-potable water supplies. To date, individual WSUD demonstration projects partially address planning and design issues associated with fully integrating the urban water cycle. Collectively, the projects highlight the full potential for WSUD (Lloyd S. 2001).

The Joint Steering Committee for Water Sensitive Cities (JSCWSC, 2009), defines Water Sensitive Urban Development (WSUD) is the integrated design of the urban water cycle, incorporating water supply, wastewater, stormwater and groundwater management, urban design and environmental protection. It represents a fundamental shift in the way water and related environmental resources and water infrastructure are considered in the planning and design of cities and towns, at all scales and densities, i.e. it aims to see all streams of water being managed as a resource, as they have quantitative and qualitative impacts on land, water and biodiversity, and the community‟s aesthetic and recreational enjoyment of waterways. This applies at all levels of urban water governance, i.e. community, institutional and government (JSCWSC, 2009).

WSUD embraces a range of measures that are designed to avoid, or at least minimize, the environmental impacts of urbanization. WSUD recognizes all water streams in the urban water cycle as a resource. Rainwater (collected from the roof), stormwater (collected from all impervious surfaces), potable mains water (drinking water), grey water (water from the bathroom taps, shower, and laundry) and black water (toilet and kitchen) possess an inherent value (Water initiative committee of Melbourne city, 2010).

2.5. Integrated Management of the Urban Water Cycle

As the (Wong T., 2007, and Water initiative committee of Melbourne city, 2010) stated The integrated management of the urban water streams addresses the three key management objectives of mains potable water conservation, minimization of wastewater discharge and stormwater quantity and quality management. The design of integrated water management systems is evolving towards a practical balance between WSUD approaches (Lloyd. S. 2001) This is represented in Figure 1 which shows alternative sources of water with their uses guided by a „fi-for-purpose" approach to the use of different water sources and associated quality.

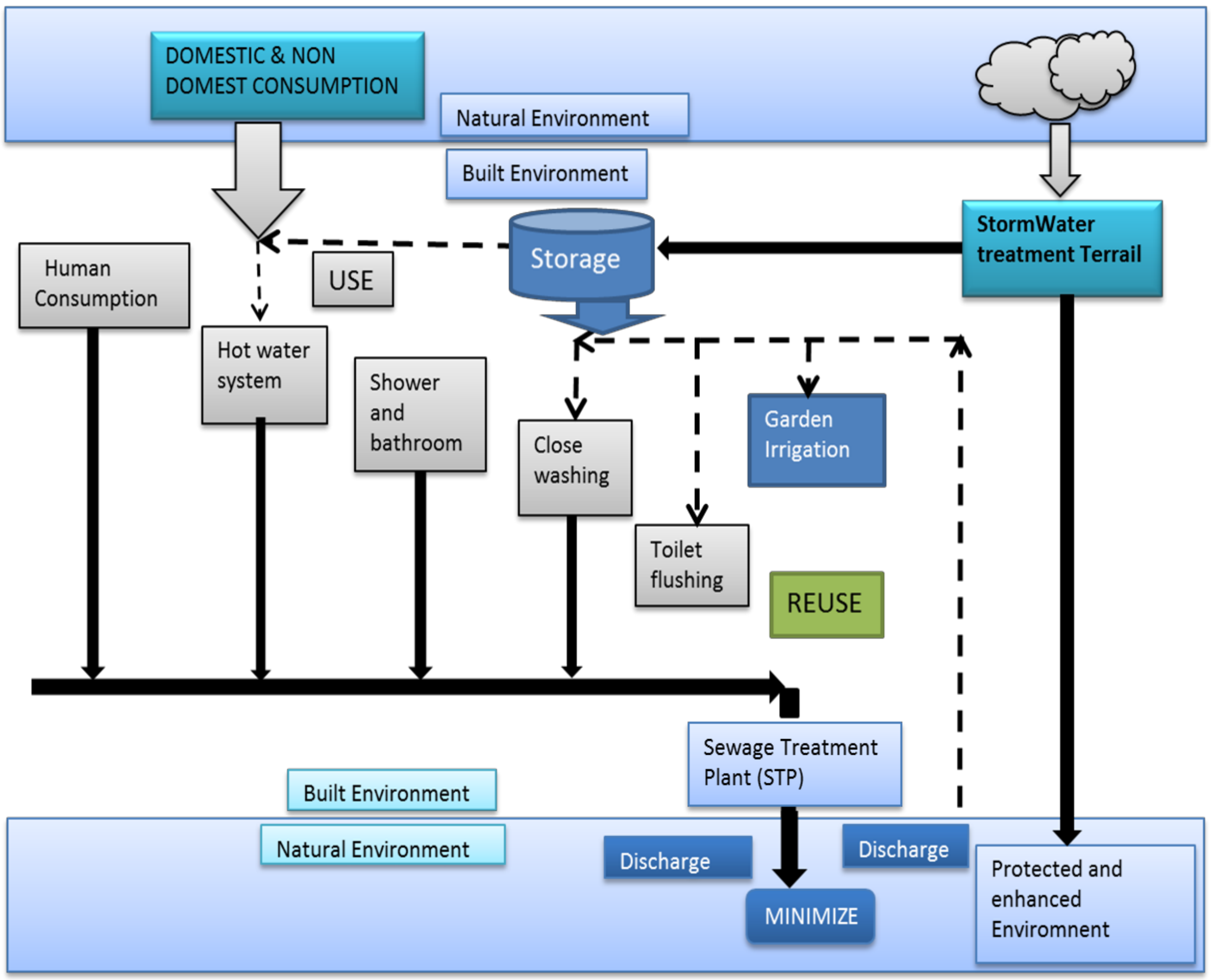


Fig.1.1: Schematic Illustration of Alternative Sources of IUWM

(Adopted: An Initiative of the Inner Melbourne Action Plan, 2010)

2.5.1. Options for Achieving Water Sensitive Urban Development

2.5.1.1. Potable Water Conservation

There are a number of natural synergies in achieving individual urban water management objectives. For example, the installation of water efficient appliances has the benefit of reducing mains potable water usage but also reduces the generation of wastewater. Rainwater or stormwater harvesting has benefits in achieving water conservation (demand management) and stormwater management. Efforts to reduce the import of water and the export of wastewater and stormwater pollutants will increase the overall sustainability of an urban area (Wong T., 2007).

2.5.1.2. Demand management

Demand management is a relatively easy way to reduce water consumption. Water demand can be reduced through changing, Behavior, Regulation, Technology and Design. Water efficient fittings, appliances (dishwashers and washing machines) and water efficient garden design are the water demand appliances for urban water (JSCWSC, 2009).

2.5.1.3. Rainwater/ stormwater harvesting and Reuse

Rainwater harvesting is a valuable means of alternative non-potable water supply for a variety of domestic and industrial usages. The significance of rainwater harvesting, as a primary source of water for non-potable use, is often understated (Wong T., 2007). Rainwater covers water that is captured on roofs. It is an alternative water source for use within the City, Rainwater can be used for; Toilet flushing, Garden irrigation, Washing machines, Hot water systems. Rainwater harvesting can help address water scarcity at the household level and may be easy and cost-effective to implement. Flow- or roof-water harvesting provides a direct water supply and can recharge groundwater, while reducing flooding. Such measures may be an immediate solution to accompany long-term infrastructure improvements in water supply and drainage (Bahri A., 2012).

Rainwater Tanks: Rainwater tanks are particularly suited to detached housing, multi dwelling developments and high density residential apartment buildings and mixed use buildings where a greater proportion of the site (roofing area) contributes to rainwater tanks and minimizes adverse effects associated with Stormwater runoff. Stormwater harvesting includes the collection, storage, treatment, distribution, and use for beneficial purposes.

Stormwater harvesting can occur over a wide range of scales, from small-scale rainwater harvesting projects, where water are collected from rooftops to large-scale diversion and use of stormwater from streams and reservoirs (JSCWSC, 2009).

Stormwater harvesting is sometime called— ""Stormwater reuse."" However, the word —""reuse"" is also used to describe the use of treated wastewater effluent. The collection and reuse of Stormwater for potable water substitution purposes can be under taken on individual lots, or at the cluster or suburb scale.

2.5.1.4. Grey water/ Black water Treatment and Reuse

Grey water is source of wastewater from shower, bathroom and laundry sinks, and washing machine wastewater, which contain high concentration of phosphorus, nitrogen and sulphate. Grey water reuse can save significant quantities of potable water. Its effective use requires separation of grey water from other wastewater streams and additional infrastructure. Grey water reuse after treatment needs to be applied in a manner which does not cause environmental contamination or present a public health hazard (NSW Health, 2000).Grey water treatment and reuse systems can range from a simple grey water diversion system, which directs grey water to a subsurface irrigation system, to a complex treatment system including collection, treatment, storage and possibly disinfection (EPA, 2001).

The wastewater (blackwater) Blackwater extraction from sewers is highly contaminated and of variable water quality**.** Domestic wastewater typically contains: High total suspended solids (120-370 mg/L)

- High biochemical oxygen demand (BOD) (120-380 mg/L)
- High levels of micro-organisms (fecal coliform bacteria 10^5-10^7)
- High nutrients - total nitrogen (20-705 mg/L) and phosphorous (4 -12 mg/L) (Metcalf and Eddy, 2003).

Blackwater can be extracted from the sewerage system, treated and reused appropriately for irrigation purposes or for toilet flushing. Blackwater reuse (or „water mining") requires a higher level of treatment than grey water. The treatment train must include disinfection to reduce high pathogen levels. Treatment can be energy intensive. When selecting a blackwater project, the broader ecologically sustainable development objectives must be considered, particularly the greenhouse gas emissions and a land capability assessment (LCA) (Crites and Tchobanoglous, 1998). An LCA assesses the capability of the site to sustainably manage wastewater and looks at parameters such as the site drainage, rainfall and soil characteristics (EPA Victoria, 2003).

2.5.1.5. Changing Landscape Form

Sewage treatment can remove physical, chemical and biological contaminants from wastewater. The treated effluent and sewage sludge can then be safely discharged or even reused – for urban landscaping, Efforts such as retaining native vegetation, converting landscape plantings in gardens and public spaces to more water efficient planting varieties, or using gardens with xeriscaping forms, will reduce demands on the potable water system (EPA Victoria, 2003).

2.5.1.6. Water Use Education Programs

Community education programs have been demonstrated to contribute to reductions in potable water consumption.

2.6. Urban Water Demand and Wastewater Relation

Water and sanitation are important indicators of development. Access to water correlates strongly with the nature of water balance in the city. Connection to improved water supply, sewage and solid waste disposal system, among other services, is a critical process of ensuring business productivity in cities (UN-Habitat., 2003). Absence of proper environmental management practices paralleling economic. There are numerous sources of pollutants that could deteriorate the quality of water resources. In developing countries sources of pollution from domestic, agricultural, industrial, activities are unregulated (Ethiopian team, 2002).

Rate of water supply may be fully available in the form of sewage, but reduction can occur due to consumption, evaporation, gardens and lawn, fire-fighting private sources and infiltration increases sewage. Hence, careful analysis should be made while determining the relation between rate of water supply and sewage quantity usually reduction and increase are assumed to cancel out each other and Rate of sewage is assumed to be 70 to 80 % rate of water supply (Geremew S., 2012). In general, municipal wastewater is made up of domestic wastewater, industrial wastewater, stormwater, and by groundwater seepage entering the municipal sewage network.

Domestic wastewater consists of effluent discharges from households, institutions, and commercial buildings. Industrial wastewater is the effluent discharged by manufacturing units and food processing plants. Multiple sources of waste water are from, residential, industrial, public institutions/health/educational, facilities/office, hotels and other commercial buildings, and overall it is estimated that 80% of water used is, changed to wastewater (Geremew S., 2012).

2.6.1. Urban Water Demand and coverage

A fundamental prerequisite to begin the design of water supply facilities is a determination of the design capacity. This, in turn, is a function of water demand. The determination of water demand consists of four parts: (1) selection of a design period, (2) estimation of the population, commercial, and industrial growth, (3) estimation of the unit water use, and (4) estimation of the variability of the demand. The percentages of population with or without piped water connection are a relevant indicator to compare the coverage of water supply in urban areas. According to the Global Water Supply and Sanitation Assessment 2000 Report, the African largest cities are having 43% house connection or yard tap, 21 % served by public tap while 31% of the population are un-served (WHO, 2000). Minimum quantity of 25litres of potable water per person per day provided at a minimum flow rate of not less than 10litres per minute with the source being available within 200 meters from a household and the supply not interrupted for more than seven days per year (i.e. water should be available 98% of the time) is considered as a basic service for southern African cities‟ domestic water supply (Wallingford HR., 2003)..

As studies of (UN-Habitat 2003) shows around world, almost all the households (98.8%) obtain their water within one hour, a substantial proportion of them (90.5%) collect their water within 15 minutes. A very small proportion of the households (1.2%) require more than 60 minutes collecting the water. The study showed that 28.6% of the households experienced disruptions in water supply at given time Water disruptions affect mainly households that relied on public tap (34.1%), followed by water piped into yard or plot (31.6%) and water piped into dwelling (24.8%). Water disruptions impact negatively on the time spent accessing water and the quality of water acquired for use by households.

2.6.2. Urban Water Demand (Per capita) Management

The amount of water used per person per day ((Per capita) for daily life and activity is known as per capita water demand. It is often considered equal to water consumption, although conceptually the two terms do not have the same meaning (Wallingford HR., 2003). In most developing countries, the theoretical water demand considerably exceeds the actual consumptive water use. Water demand management is the adaptation and implementation of a strategy by a water institution to influence the water demand and usage in order to meet any of the following objectives (Rother and Macy ,2000); the objective of water Demand management are, economic efficiency, social development, social equity (Mwendera et al., 2003).

Water is used in three main areas in the home. Approximately one third of the water is used for WC flushing, one third for personal washing via the wash basin, bath and shower, and the final third for other uses such as washing-up, laundry and food/drink preparation household occupancy (Mitchell et al., 2000). When the proposed project is in a community with an existing community supply, the community‟s historic records provide the best estimate of water use. Conversion of total urban demand management in term per capita demand (liters per capita per day (l/cap/day) allows for the separation of population growth from the growth in unit consumption. If the proposed project is to improve the water quality, consideration should be given to the likelihood that unit demand will increase because of the improved water quality. A household is considered to have access to improved drinking water if it has sufficient amount of water (20l/cap/day) for family use, at an affordable price (less than 10% of the total household income), available to household members without being subject to extreme effort (less than one hour) a day for the minimum sufficient quantity, especially to (women and children) (UN-Habitat, 2003).

In the absence of existing data for the client community, nearby communities with similar demographics are good alternative sources. When the demographics differ in some particular aspect such as a higher or lower density of commercial facilities or a major industrial component, adjustment in the total demand will be appropriate (Mackenzie L., 2010). The estimated water use by state and the U. S. Bureau of Census (Census, 2006) maintains a population database by state. A detail demand study in Africa found that average water carried was about 22 l/cap/day per capital over a long distance rising to about 30 l/day per capital where water was obtained from the consumer own stand pipe. Of course distance is not a big problem in urban areas rather than rural areas (ADB, 1993).

2.6.3. Wastewater Quantity

Residential district: When the proposed project is in a community with an existing wastewater collection system, the community"s historic records provide the best estimate of wastewater production. Conversion of total wastewater flow to a per capita basis allows for the separation of population growth from the growth in unit production of wastewater (Mackenzie L., 2010). Wastewater production is strongly linked to the widespread ownership and use of a wide range of domestic appliances like , WC (8.8 l/use), bath (74 l/use), shower (36 l/use), wash basin (3.7 l/use), kitchen sink (6.5l/use), and washing machine (116 l/use) (Butler D. et al., 2004). All the water withdrawn for use does not end up in the sewer. A rough estimate of 60 to 90 percent of the domestic water-withdrawal rate may be used to estimate the production of residential wastewater (Mackenzie L., 2010). In our country its trend that the average of 80 percentage of domestic water consumed is used to estimate residential wastewater.

Commercial: This category includes businesses such as shops, offices and light industrial units, and commercial establishments such as restaurants, laundries, public houses and hotels. Demand is generated by drinking, washing and sanitary facilities, but patterns of use are inevitably different to those generated by domestic usage.

Industrial: The component of wastewater generated by industrial processes can be important in specific situations, but is more difficult to characterize in general. Depending on the relative magnitude of the flows, industrial discharges can completely alter the normal diurnal patterns of flow. There may also be significant seasonal changes in demand, for example due to agro-industrial practices responding to the needs of food production. Other important factors include the size of organization, the availability and cost of water, and the extent of process water recycling (Butler D. et al., 2004). But the Recommended Standards for Water Works (GLUMRB, 2003) stipulates that the design basis for the wastewater source and treatment facilities shall be for the maximum day demand at the design year.

2.7. Stormwater quantity and quality Management Techniques

The urbanization of the city has resulted in extensive areas of sealed surfaces, including roofs, pavements and roads. Rain that falls on lawns and gardens (pervious areas) soaks into the soils. Rain that falls on hard impervious sealed surfaces cannot soak to the ground and is directed to the piped network and eventually the river (During heavy rain the piped network can be overwhelmed. When this happens, localized flooding can occur, damaging property and blocking streets. In traditional stormwater management, collection, storage, and treatment facilities are relatively independent and each serve separate functions. However, in stormwater harvesting systems that are based on low impact development (LID) principles, many of the collection and storage facilities also provide significant treatment (Alan Plummer et al., 2010).

Collection: Collection facilities may consist of traditional gutter/pipe/channel systems or LID conveyance systems such as grass buffer strips, swales, porous pavements, and bio filters. LID conveyance systems are projected to lose minimal amounts of water through evapotranspiration (ET) and larger amounts due to infiltration of water into the soil, depending on the soil type (Mitchell et al, 2006b).

Storage: Potential storage types include open storage, aboveground tanks, underground tanks, and aquifers.

Storage Sizing: Sizing of storage for stormwater harvesting depends on the temporal pattern and volume of stormwater runoff, the temporal pattern and size of the water demand, and the required degree of supply reliability (Wanielista, M. et al. 2006). Stormwater harvesting projects are generally designed to capture runoff from low average recurrence interval (ARI) storm events (e.g., a 3-month average recurrence interval)

2.7.1. Stormwater Quantity Management/ Peak Flow Reduction

If flood control is a project objective, then stormwater storage should be designed based on the projected stormwater runoff from a design storm event (rather than from monthly flows). Stormwater hydrographs can be estimated using the Rational Method or the Natural Resources Conservation Service Curve Number Method (USACE, 2010b). Because the focus of this analysis is flood control, the curve number was adjusted from typical antecedent moisture conditions (AMC II) to saturated antecedent moisture conditions (AMC III); this will generate the maximum amount of stormwater runoff. The direct runoff volume was estimated using the curve number method, and the time of concentration was estimated from a nomograph of watercourse slope, land cover type, and flow velocity (USACE, 1998). Finally, the direct runoff volume was multiplied by interpolated Natural Resources Conservation Service unit hydrographs for Type III storms to obtain projected storm hydrographs (USACE, 1998).

The potential impact of urbanization was represented by changing the curve number from 68.5 to 75 to reflect a change in land cover type from grassland to a residential subdivision with quarter acre lots. This change resulted in a 19.8 percent increase in the projected peak flow, a 13.9

percent increase in projected runoff volume, and a decrease in the projected time-to-peak of 24 minutes (Plummer, A., et al., 2010). The above mentioned method reveals the assessment of stormwater at site specific to evaluate the management systems.

2.7.2. Stormwater quality management System

Stormwater discharge permits require a stormwater management plan (SWMP) that is designed to control pollution through structural and nonstructural best management practices, rather than treating the stormwater prior to discharge. The focus of stormwater treatment is evolving from protection of receiving water quality to new technologies aimed specifically at providing stormwater for various uses. The necessary level of water treatment depends on the stormwater end uses and the potential for human contact Potential levels of treatment include pretreatment technologies, stormwater treatment technologies, advanced water treatment technologies, and disinfection.

(Melbourne WSUD, 2010) describes best management practice of urban stormwater aims to meet multiple objectives including:

- Providing flood conveyance to reduce flow volumes and velocities (safe transport of floodwaters downstream that reduces risk to humans, riverine habitat and infrastructure)
- Removing contaminants to protect downstream aquatic ecosystems
- Providing for infiltration to groundwater and base flow
- Promoting WSUD elements as part of the urban form

Typical urbanization produces many contaminants that can be blown or washed into waterways and affect the health of streams and waterways. Best practice stormwater management makes sure that runoff is treated to remove water borne contaminants and protect or enhance the environmental, social and economic values of receiving waterways.

Pretreatment Technologies: Pretreatment technologies may include the use of gross pollutant traps, such as racks, screens, baskets, booms, pits, grinders, grit chambers, oil/water separators, etc., to remove large debris, coarse sediment, floating matter, and oil and grease (Plummer, A., et al, 2010).

2.7.3. Stormwater Treatment Best Management Practice

Stormwater treatment technologies may be classified as vegetative practices, detention facilities, infiltration facilities, and filtration practices.

Table 2.1: Site Conditions and Benefits of Stormwater Treatments (Adopted from Melbourne WSUD, 2010)

Treatment Measure	**Potential benefits**	**Suitable site conditions**	**Unsuitable conditions**
Gross pollutant traps *(Fact Sheet 9)*	Reduces litter and debris Can reduce sediment Pretreatment for other measure	Conventional drainage ha systems	Sites larger than 100 Natural channels
Sediment basins	Coarse sediment capture Temporary installation Pretreatment for other measure	Need available land area	Proximity to airports because bird presence of
Rainwater tanks*(Fact Sheets 2, 3, 8)*	Storage for reuse Sediment removal in tank	Proximity to roof Suitable site for gravity feed Incorporate to urban design	Non-roof runoff treatment
Vegetated swales*(Fact Sheet 12)*	Medium and fine particulate removal Streetscape amenity Passive irrigation	Mild slopes (<4%)	Steep slopes
Buffer strips*(Fact Sheet 12)*	Pretreatment of runoff for sediment removal Streetscape amenity	Flat terrain	Steep terrain
Raingarden	Fine and soluble pollutants removal Streetscape amenity	Flat terrain	Steep terrain High groundwater table
Ponds *(Fact Sheet 11)*	Storage for reuse Fine sediment settling	Steep terrain with confined	Proximity to airports, landfill
Wetlands *(Fact Sheet 15)*	Community asset Medium to fie particulate and some soluble pollutant removal Storage for reuse Wildlife habitat	Flat terrain	Steep terrain High groundwater table Acid sulphate soils Proximity to
Retarding basins	Flood retardation Community asset	Available space	Limited available space

2.8. Hydrology of Urban watershed and Stream

The hydrologic cycle is the central focus of hydrology. The cycle has no beginning or end, and its many processes occur continuously. water vapor is transported and lifted in the atmosphere until it condenses and precipitates on the land or the oceans; precipitated water may be intercepted by vegetation, become overland flow over the ground surface infiltrated (Horton, 1933); in to the ground, flow through the soil as subsurface flow, and discharge into streams as surface runoff. Much of the intercepted water and surface runoff returns to the atmosphere through evaporation. The infiltrated water may percolate deeper and eventually recharge to ground water, later emerging in spring so seeping into streams to form surface runoff, and finally flowing out to the sea or evaporating into the atmosphere as the hydrologic cycle continues (Chow et al., 1988).

Storm magnitudes and their frequency of occurrence are of greater importance than annual rainfall totals in urban hydrology. The changes made to a rural area by the construction of a concentration of building have a direct effect on its surface hydrology. The covering of the land surface by a large proportion of impervious materials means that a much larger proportion of any rainfall forms immediate runoff. In addition to extensive ground coverage by building in a city, the paved streets and car parks contribute large areas to the impervious surface (USACE, 1998). Any slope of the land also greatly enhances the runoff response of a paved area. In a defined catchment area, the effect on the stream discharge is dependent on the extent on the remaining pervious surfaces, where normal infiltration in to the soil and percolation in to the underlying strata can take place.

2.9. Application of GIS and HEC-HMS on Urban Hydrology

The GIS technology has the ability to capture, store, manipulate, analyze, and visualize the georeferenced data. On the other hand, hydrological features are inherently temporally and spatially distributed, thus producing large data requirements for hydrologic modeling. Therefore, the integration of hydrological model and GIS is quite natural.

Hydrological modeling is a powerful technique in the planning and development of integrated approach for management of water resources. GIS can assist in design, calibration, modification and comparison of models. The spatial nature of these variables like physical chemical and biological associated with water resources and hydrological modeling is the single most significant factor that contributes to the complexity of data management (William, 1994). However, with GIS‟s ability to combine a variety of data into an easily understood format, GIS software can drastically change the way engineers handle water resources modeling. Hydrologic elements are used to break the sub-basin into manageable pieces. They are connected together in a dendritic (branched extension or shape of a tree branch) network to form a representation of the stream system. The physical parameter analysis is done using HEC-GeoHMS pro HEC-HMS.

2.9.1. HMS-Model Development Using GeoHMS

HEC-GeoHMS has been developed as a geospatial hydrology tool kit for engineers and hydrologist. The program is an extension of ArcView and allows users to visualize spatial information, document watershed characteristics, perform spatial analysis, delineate sub-basins and streams, construct inputs to hydrologic models, and assist with report preparation (USACE, 2010). HEC-GeoHMS provides the connection for translating GIS spatial information into hydrologic models. The end result of the GIS processing is a spatial hydrology database that consists of the digital elevation model (DEM), soil types, land use information, rainfall, etc.

HEC-GeoHMS transforms the drainage paths and watershed boundaries into a hydrologic data structure that represents the watershed response to precipitation. In addition to the hydrologic data structure, capabilities include the development of grid-based data for linear quasi-distributed runoff transformation (Mod Clark), HEC-HMS basin model, physical watershed and stream characteristics, and background map file (Maidment and Djokic, 2000). To this end, HEC-GeoHMS generates tables that are populated with physical characteristics of streams and watersheds. In general the user can visualize spatial information, edit watershed characteristics, perform spatial analysis, delineate subbasins and streams, develop inputs for hydrologic models and extract necessary hydrological information for the catchment (USACE, 2010a).

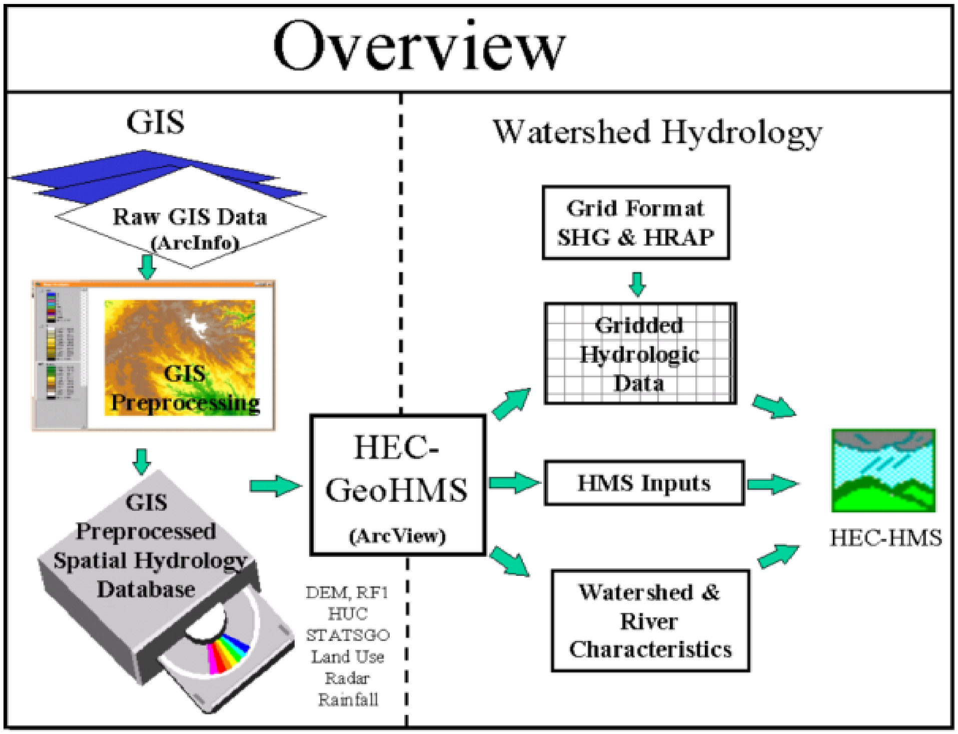


Fig.2.1. The Relationship Between GIS, HEC-GeoHMS and HEC-HMS

The physical watershed is represented using HMS elements used as an input including subbasins, reaches, junctions, reservoirs, diversions, sources, and/or sinks. This model offers the option to import a geographical file with the study area, its subbasins and their properties that is created in GIS environment (USACE, 2010a).

2.9.2. HEC-HMS (Hydrological Modeling System)

Increasing urbanization brings changes in the types of land cover, and these in turn cause several changes within the natural world. One way in which urbanization affects the natural world is the hydrology of the urbanizing area. Increases in urbanization have been found to increase the quantity of water flowing over land and decrease the amount of time to reach peak flow for the over land water(Howard D., 2005). Hydrologic models are helpful to predict how changes in land cover translate into changes in the flow regime of an area.

The software that is used for the hydrologic simulation is HEC-HMS and (USACE, 2010b). HEC-HMS is a computational modeling system developed by the Hydrologic Engineering Center (HEC) of the U.S. Army Corps of Engineers (USACE, 2010) in Davis, California. HEC-HMS is designed to simulate the precipitation-runoff process of watershed systems. Computer program HEC-HMS can provide much of that information including estimates of runoff volume, of peak flow rates, and of timing of flows. The program provides this information by simulating the behavior of watershed, its channels, and water-control facilities in the hydrologic system. The HEC-HMS program Applications are to studies, urban flood, flood frequency, flood-loss reduction, flood-warning system planning, reservoir design, and environmental USACE, 2008).

Several types of models are available to simulate the rainfall-runoff process. One of the first choices to make is between models that are public domain and those that are proprietary. There are also differences in how models simulate the rainfall-runoff process over the area of concern. Lumped hydrologic models take an average over the entire watershed area for parameters, such as Curve Number (CN), precipitation, and initial abstraction. Distributed hydrologic models typically use parameters values at the same resolution as the data input, and are generally more complicated and computationally intensive (Beven, 2001).

The two lumped hydrologic models, the Soil Conservation Service (SCS), Unit Hydrograph (UH) and Clark UH, used by the Hydrologic Engineering Center, Hydrologic Modeling System (HEC-HMS) translated changes in land cover to changes in the quantity of runoff. The SCS CN model was selected for the loss method to accompany the SCS UH transform model. The SCS CN loss model converted the precipitation depth into runoff, with some amount infiltrating into the soil. The amount of infiltration, or abstraction, was based upon the average CN, Initial Abstraction, and Percent Impervious Cover parameter values (USACE, 2001).

Each of these sub-areas is assigned individual lag time, instead of one value for the whole watershed, as in the case of SCS UH. The precipitation excess at each sub-area is transported to the watershed outlet using the corresponding lag time. The Lag method simply held water within the channel, or reach, until the amount of time specified had passed. This resulted in the incoming hydrographs ordinates being translated a specified amount of time. Therefore, the shape of the incoming hydrograph remained unchanged (Feldman 2000). The channels, or reaches, within HEC-HMS were used primarily to link the output of the upstream watershed to that of the downstream watershed.

HEC-HMS Features: Data entry can be performed for individual basin elements such as subbasins and stream reaches or simultaneously for entire classes of similar elements. Tables and forms for entering necessary data are accessed from a visual schematic of the basin. Each HEC-

HMS project requires three data components: a Basin Model, a Meteorological Model, and Control Specifications.

2.10. Landscape Suitability Analysis for Integrated Urban water Management

Land suitability analysis is a process of determining the fitness of a given tract of land for a given defined use (Hopkins, et al. 1977). In other definition, suitability, analysis is the process to determine whether the land resource is suitable for some specific use and to determine its suitability level. It is important analytical method for urban water management planning and management. The process of site suitability requires the identification of the appropriate locations for a particular land use activity by considering physical resources. The physical character of land are elevation, slope, aspect, climate, and the natural type are soils, geology, hydrology, groundwater, rainfall, sociology etc. land suitability will have no meaning unless it is relevant to some specific use, and it is very important for good use of land and promoting the

2.10.1. GIS Application in Suitability Analysis and Data Prepossessing

GIS is a set of tools, for inputs, storage, Retrievals and manipulation and analysis as well as output of spatial data (Malczewski, 1999). ArcGIS is acknowledged to be a powerful tool in solving spatial problem. The decision criteria for site selection are examined for assigning relative ranks and individual feature weights based on the land use type for which suitability is being examined with GIS tool. GIS (Geographic Information System) is a computerized system that facilitates the phases of data entry, data analysis, and data presentation when we are dealing with georeferenced data. There are six Arc Map tools: data source selection, data prepossessing, data management, data analysts, data displaying and mapping. The process of clipping, overlay, combination, raster grid analysis, statistic measurement and overlay are core process of analysis.

2.10.2. GIS Based Suitability Analysis Model

Land suitability analysis is very important for the land planning and management. With the rapid development of GIS, land suitability analysis more applied in the urban planning (Yang, M. 2003). One of the most important spatial analysis functions in GIS overlay, primarily designed for the multiple factors evaluation (e.g. land suitability analysis)

3. Research Methodology

3.1. The Research Process

Based on the research objectives and questions stated on chapter one, the methodology how research was carried out is discussed the following research process diagram. A method of data collection, data preparation and data source are also discussed the following flow chart diagram. The research methodology carried out are divided in to three major parts, to simulate the rainfall-runoff, the hydrology of a watershed process, analysis of potable water demand-wastewater flow rates and landscape site suitability analysis..

Hydrological components simulated in landuse landcover are loss, transform, surface runoff, channel lag and LULC classification. Surface runoff or overland flow in urban is a flow that occurs along a sloping surface and it occurs whenever the rate of water application to the ground surface exceeds the rate of infiltration. It is the major component of the hydrologic cycle. Hydrologic Modeling System (HEC-HMS) translated changes in land cover to changes in the quantity of runoff and the quantity of runoff would increase as land cover changed from a natural state to a developed state. The second part of analysis is wastewater. The monthly water production and consumption, data was used to analysis per capita demand and quantify wastewater quantity. After potable water and wastewater analyzed, the integrated water management, low impact development options evaluated for quantity and quality. The best options selected that have low impact on receiving Environments.

The water supply coverage evaluated based on the average per capita consumption, level of connection, nondomestic consumption. The average per capita consumption has been derived from the yearly consumption of each kebeles for individual water meter. Statistical analysis used to evaluate per capita demand to relate with the wastewater flow rates for study area. The research methodology is shown in the process diagram of fig. 3.1 below.

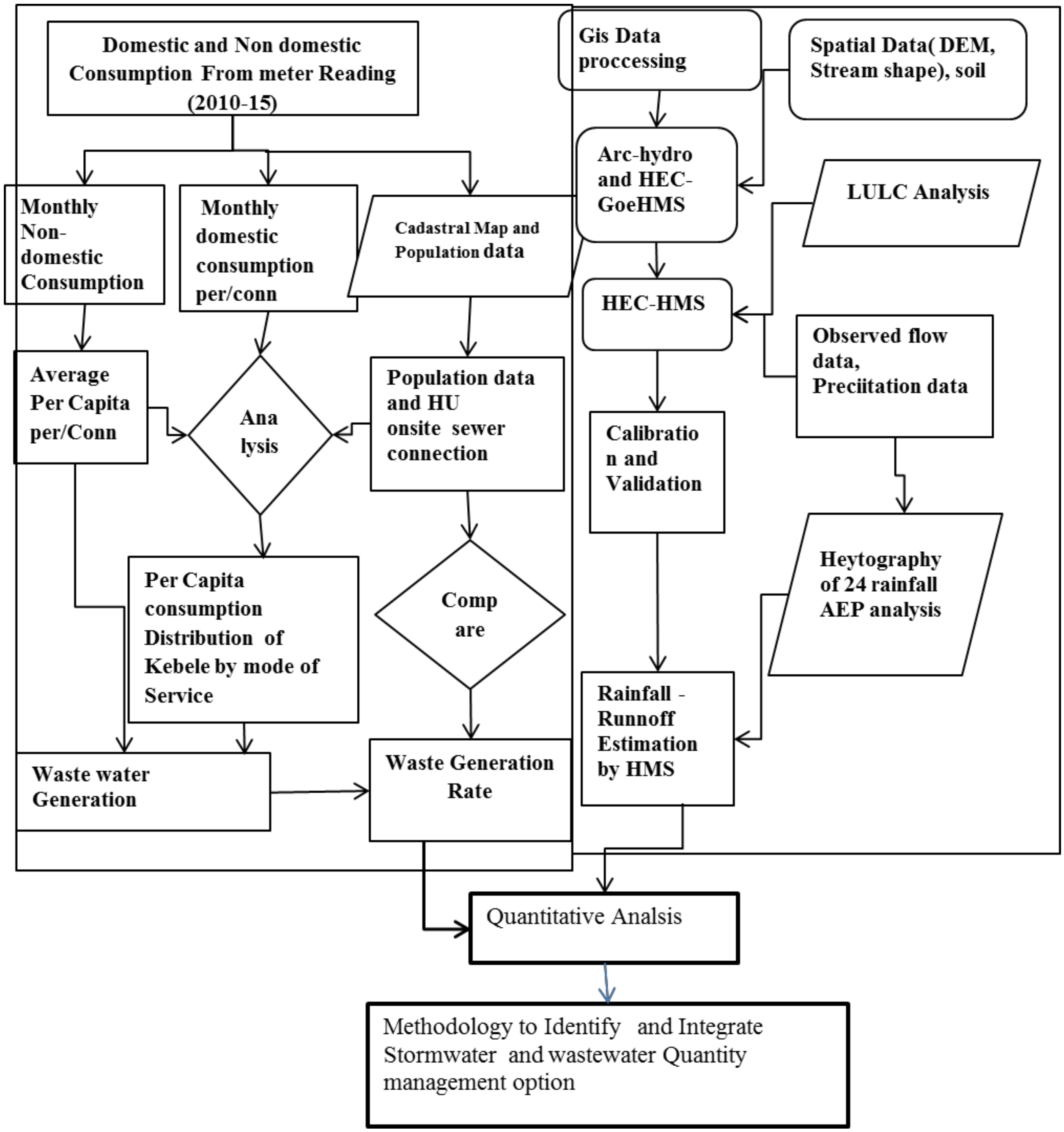


Fig. 3.1: Research Methodologies (Process Diagram)

3.2. Study Area

3.2.1. Location

Addis Ababa lies in the center of the country on the western escarpment of the main Ethiopian rift valley. The altitude of the city varies from 2100 m a.s.l. to 2700 m a.s.l. and latitude of Location at 9^o 4‟51.16"N 38^o 46‟32.82"E. From its lowest point at outlet, around Urael church, at 2,334 meters above sea level in the southern periphery, the city rises to over 3,190 meters in the Entoto Mountains to the north. The outlet of Kebena river watershed delineated where the flow leaves the Kebena and Buntiketu rivers watershed to Bulbula River at coordinate of 38.779°, 9.0049°. The location of study is shown on fig 3.2 below.

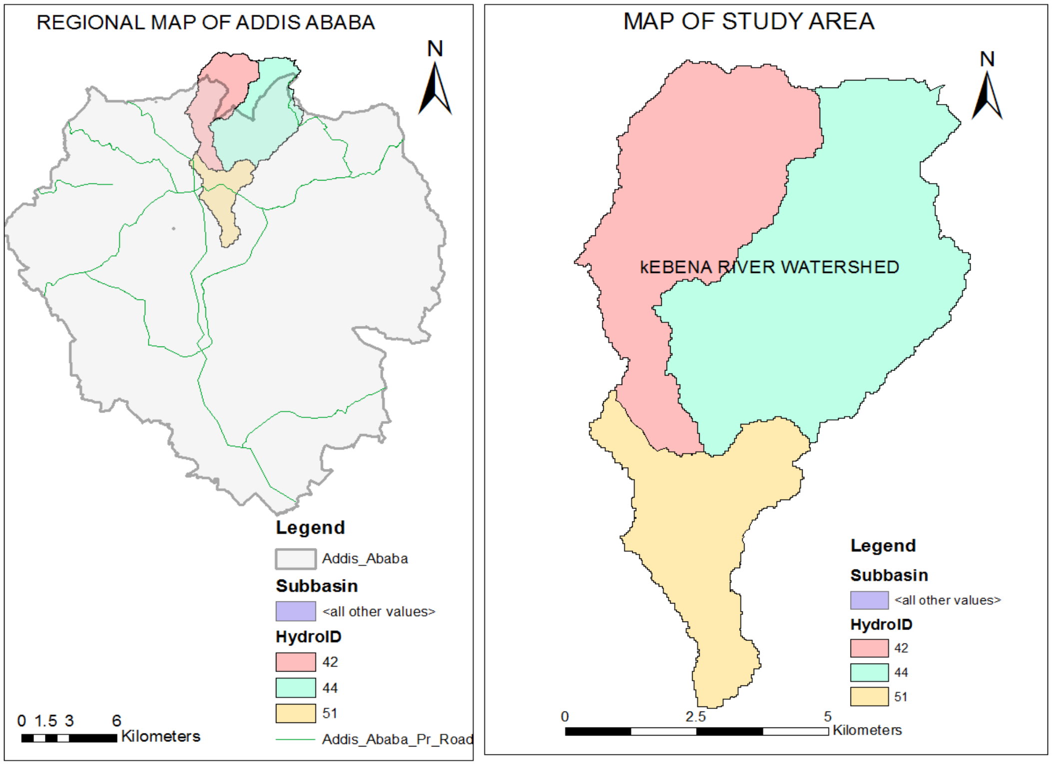


Fig. 3.2: Map of Study Area

3.2.2. Topography, slope and hill shade

The Kebena watershed covers 51.82 square kilometer and measures approximately 7.507 from east to west and 12.95km from north to south. The Watershed is divided into 3 principal drainage systems. The slopes of the main river systems crossing the watershed is range from 0.0286 to 0.0437 in along the stream flow. Kebena river watershed topography is highly diverse, ranging from steep hills at upper subbasin to lowland flats lower subbasin of urban area (Dagnachew, L., 2003). Slopes affect the velocity and amount of surface water flows, and the rate and amount of infiltration. When water flows quickly there are potential erosion hazards. High velocities also carry sediments and pollutants which, in concentration, affect the quality of water downstream. Infiltration reduces surface water problems (Wraigh, et al., 2013).

3.2.3. Geology

The largest part of Addis Ababa is covered with volcanic material. The hill chain (Entoto) in the northern part of Addis Ababa is composed of basalts, called Entoto Cilcic and it is covered with volcanic topsoil materials of about one to two meters thick. The urban area is composed of youngest basalts called "Addis Ababa basalts" which are also covered with volcanic topsoil materials. Olivine porphyritic basalts outcrop in the central part of the town that includes Mercato, Teklehymanot and Sidist Kilo. It outcrops in an area, which includes Sidist Kilo, General Winget School and French Embassy (Morton, 1974). The thickness of the former varies from 1m or less in the foothills of Entoto, Lideta Airfield and Filwoha to greater than 130 meters at Ketchene stream (Varnier et al., 1985).

3.2.4. Soil

To have the ArcGIS model inputs concerning catchment„s soil physical and chemical properties, first the shape file format of soil type distribution through the catchment was collected from Ethiopian Ministry of water Resources GIS department and FAO online data base. Using this shape file, soil texture, available water content, hydraulic conductivity, and organic carbon content for different layers (up to 4 layers) of each soil type were extracted from major Soils of the world database FAO (1995). Major soil types in the catchment are chromic luvisols, eutric vertisols, vertic cambisol, humic nitisols and lithic leptosols.

3.2.5. Land use and land cover

The land use land cover data of urban area are extracted from satellite image which is categorized as forest, cropland, urban (residential, commercial and industrial), road and water body. Flat, low-lying areas have the most dense development and attract diverse uses including industry, commercial and residential uses, all serviced by paved road networks which altogether create a high site coverage. These land uses generate contaminants, and the high site coverage reduces infiltration. Less-dense housing, often occurs on higher slopes, generally has less site coverage and lower levels of contaminant generation. It is important that any increase in density or site coverage maintains the current levels of infiltration and contamination dispersal. Large parklands like the town Belts, on higher slopes, assist in water infiltration and where the velocity of runoff, retaining sediments on site vegetated slowly. The classification of urban landuse land cover have been done using model ArcGIS, ILWIS, and ERDAS softer as supervised and unsupervised method, which discussed in methodology parts of landuse/land cover classification.

3.2.6. Cadastral Information

The cadastral information with sewer line connections map of was collected from the planning commission of the Addis Ababa municipality and from AWWSA sewerage department respectively. The data includes information on buildings, parcels and blocks for in Arada, Yeka and Gulale sub city of each Kebeles are included, which are located in 12, 15, 16 and 17 former Wereda.. The cadastral data are composed of water supply pipe network, Parcel of blocks, house number, and wastewater infrastructure and all boundaries of kebeles. The cadastral information data used as main input to the specific land suitability analysis for urban water management with the existing infrastructure.

3.2.7. Population and Census Documents Data

Beside to a census document of the country, number of population by each Kebele projected from base population of the year 2007. The census data of 2007 includes the house units numbers, population density of sub city, number of public toilets, are included. The population of Addis Ababa increases annually by about 6%. The natural population growth is 2.2 to 2.5 as census of 2007 report.

3.3. Methodology

3.3.1. Land Use Change Detection

A common approach in integrated RS-GIS-Modeling for event-based watershed runoff predictions usually involves; i) the derivation of land-cover related parameters of the models from remotely-sensed images, (ii) the use of GIS to prepare the model and to extract additional parameters, (iii) calibration and validation of the model using field measured data to test its efficiency, and then (iv) using the model to simulate runoff and use the simulated information to characterize the conditions of the watershed (O‟Connell et.al,2007 Vafeidis,et.al,2007).

3.3.2. HEC-HMS Model

HEC-HMS which is a comprehensive hydrologic model, developed by Hydrologic Engineering Centre (HEC) of United States Army Corps of Engineers (USACE), was used in this study. HEC-HMS is designed to simulate the precipitation-runoff processes of dendritic watershed systems. As part of the water resource planning mission, the HEC office has created and released several modeling software packages to assist resource managers in evaluating the impact of decisions i.e. HEC-HMS and HEC-GeoHMS. In HEC-GeoHMS the HMS project setup menu is responsible for extracting data that will be used to develop the necessary information to create an HEC-HMS project (USACE, 2010). The approach for extraction involves specifying a control point at the downstream outlet. This location represents the downstream boundary for the HEC-HMS project and basin model and background map are created used to simulate hydrology. The main reasons for the selection of HEC-HMS hydrological model is that the model is physically based, spatially distributed and it belongs to public domain.

By performing hydrologic simulations with watersheds near the size limitation for HE-HMS and comparing those results to calculation over the same area with much smaller watersheds more insight was gained into the role of the spatial distribution of the physical characteristics and rainfall intensities. It includes different methods to simulate infiltration losses, transforming excess precipitation, base flow estimation and channel routing

3.3.3. GIS based Site Stormwater Treatment Suitability Assessment Model

Specific site suitability analysis is to determine the suitability for some specific landuse by scoring the land. In other expression, the sites with the suitable criteria have higher score and the land with the moderate or unsuitable criteria given moderate and low score. Terrain and topography can be critical to the selection of stormwater treatment devices as such influences can totally preclude some best management planning options for consideration. According to (Yang, M. 2003) the steps to analyze model the suitability Analysis by GIS tools is as follows. GIS suitability method divided into three classes: direct overlay, weighted score, and environmental factor Combination. This method is used in this study for assessment of stormwater treatment option selection.

3.4. Data Source and Analysis

The secondary data used as input for models are meteorological, hydrological runoff, Landsat, DEM, monthly total water consumption, and sewer line connection. The data sources are Addis Ababa city municipality, AAWSA, meteorological agency and MEoWE.

3.4.1. Meteorological Data

Meteorological data are collected form the meteorology station at different site of watershed, has used for hydrological simulation of watershed. The data of daily precipitation time series of different time from 1965 to 2005, at different spatial distribution. The data includes are precipitation, sunshine, wind speed, sunshine hours, gauge coordinates and daily flow data.

3.4.1.1.Precipitations Depth and Mean Areal Annual Rainfall analysis

The range of mean annual rainfall for the stations in the period 1997- 2004 lies between 900 to 1250 mm. The mean monthly rainfall of all station, between June and September is above 100mm, with monthly maximum rainfall record 303mm in August. While November and December show the lowest, mean monthly rainfall. Mean annual rainfall is higher and 1010 for bole and 1244 for Entoto observation.

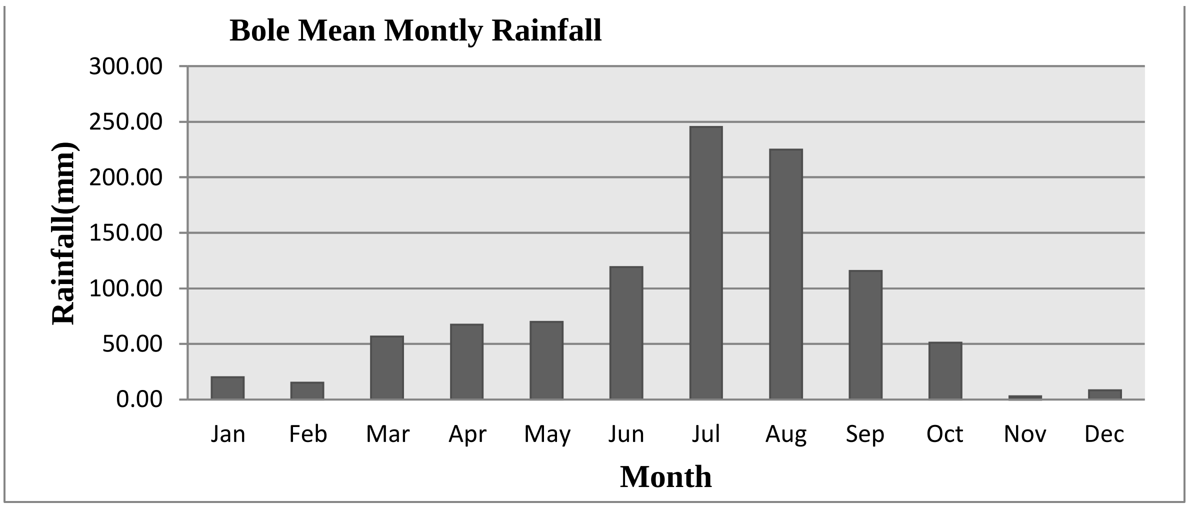


Fig.3.3: Monthly Rainfall of Meteorological Model

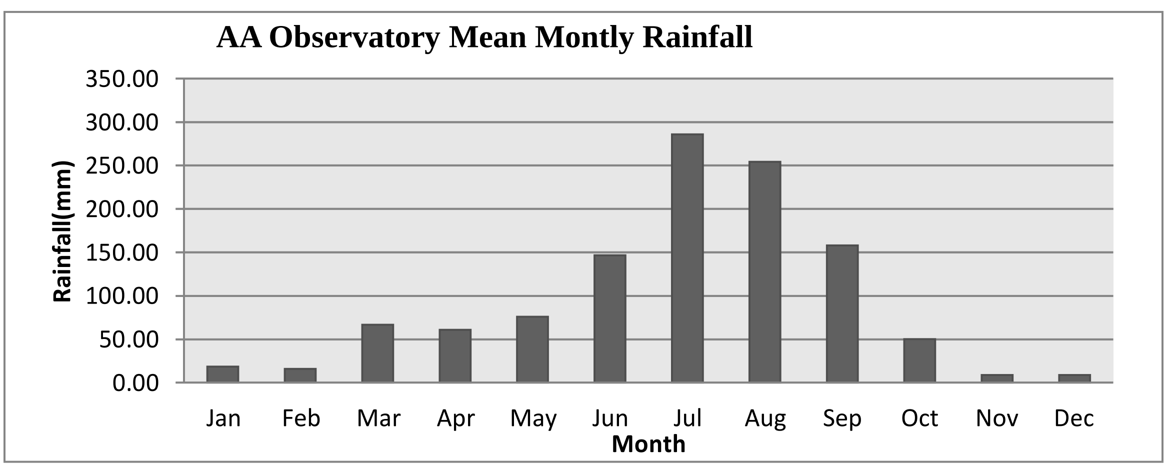


Fig.3.3: Monthly Rainfall of Meteorological Model

3.4.1.2.Checking the Consistency of Precipitation Data

The most common method of checking for inconsistency of record is Double Mass Curve analysis (DMC). The curve is a plot on arithmetic graph paper, of cumulative rainfall collected at a gauge where measurement condition may have changed significantly against the average of the cumulative rainfall for the same period of record collected at several gauges in the same region. Double mass curve plot made for all five stations shows fig.3.2 only for Addis Ababa Teklehymanot Observatory.

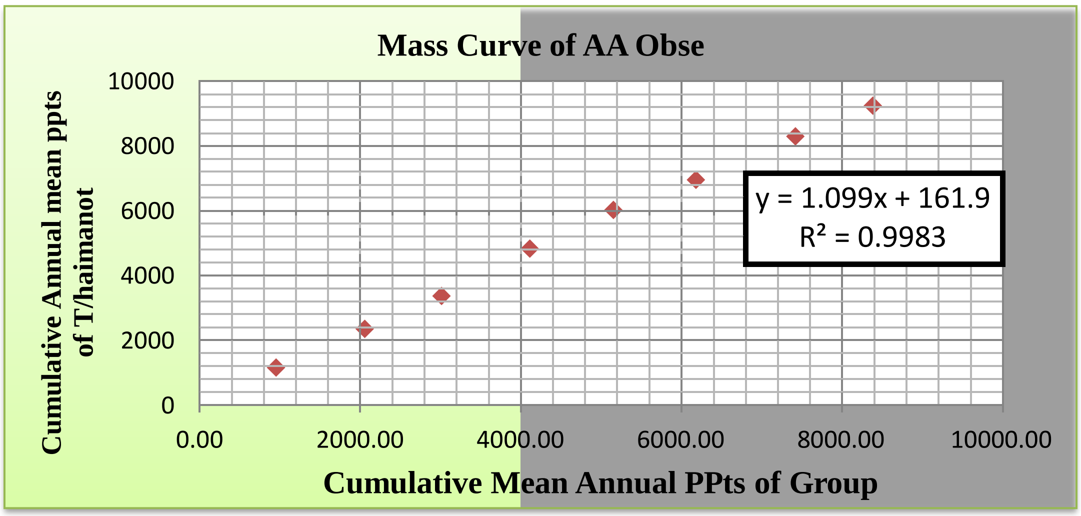


Fig. 3.4: Mass Curve of Precipitation Model

3.4.1.3.Precipitation Hyetography

Defines design storm of 25 year recurrence interval of 24 hour duration, used in hydrologic models. The 25 years return period daily maximum rainfall, i.e. 79.25mm, is changed to 24hrs incremental rainfall, using equation of $\sqrt{}$ Thus, for T=24, is given hourly fraction of rainfall of 16.17mm, so that $\frac{}{\sqrt{}}$ Accordingly, the 24hrs incremental rainfalls for A.A Teklehymanot station, using 25 years return period hyetograph of point rainfall is shown on figure 3.5 below.

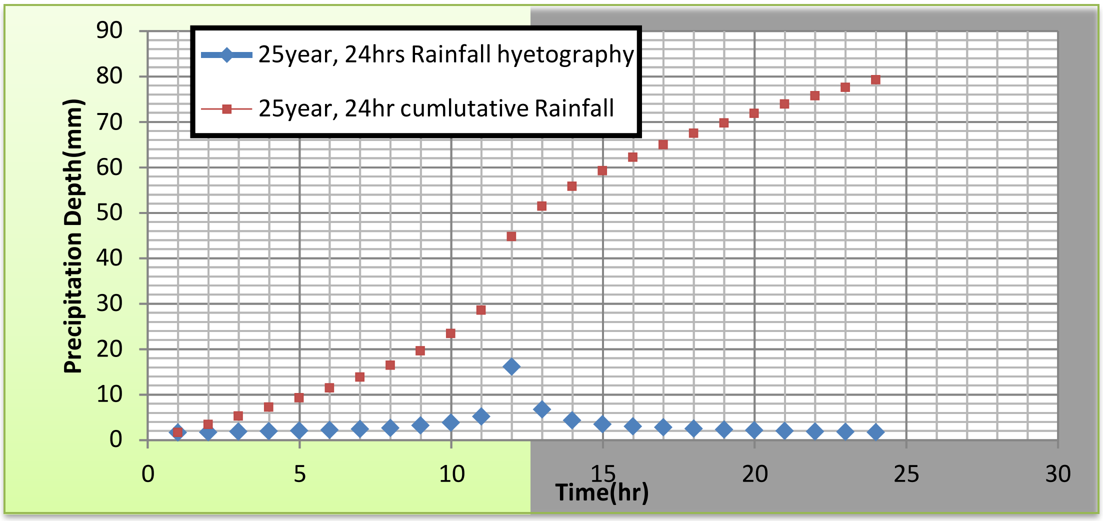


Fig.3.5: 25 Years Returns Yeriod of 24hrs Maximum Cumulative Rainfall and Hyetography

3.4.2. Digital Elevation Model (DEM) Data Analysis

Topography is defined by a Digital Elevation Model (DEM) of Kebena water, which describes the elevation of any point in a given area at a specific spatial resolution as a digital file. Digital elevation model is one of the essential inputs required by HEC-GeoHMS to delineate the watershed in to a number of sub watershed or sub basins. Study area map of Digital elevation model shown fig.3.6 above.

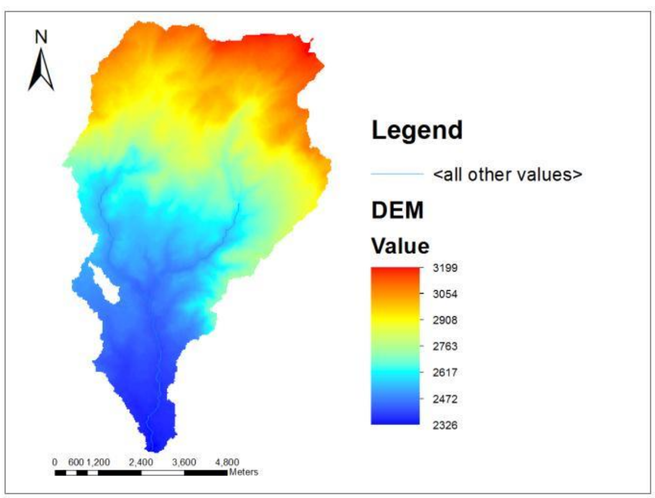


Fig. 3.6 Digital Elevation Model of Kebena Watershed

DEM is used to analyze the drainage pattern of the watershed, slope, stream length, width of channel within the watershed. The row data is gained from ministry of water recourses and energy at high resolution of 30mx30m representation of pixel size.

3.4.3. Monthly billed Customer Water Consumption Data

The data collected for more than 31000 customers with in the city was a large file; this data has been collected from Megenagna and Gulale AWWSA branch. The data water pipe network and per month consumption has been collected in AutoCAD and Excel format by exporting to each of Kebeles. The One of the difficulties faced in this data was that the house number of the customers was not recorded in a similar way as of the cadastral information. The excel format of each kebele consumption are calculated to get per capita demand as well as connection per families. This analysis accurately determines the water demand of specific area. The consumption by mode of service id depend on percentage of population used high, low, medium and yard connection standard of city. The assumptions made by CSA 2007 and steps followed to determine the per capita consumptions Modes of services for domestic billed water volume users is proportioned as house connection (HC), 20% House Connection Shared (HCS), 5%; Individual Yard Connection (YC), 40% ,Yard Connection Shared (YCS) 35% (CSA 2007).

3.5. Waste Water Connection Data

The existing sewerage line connected to housing unit for wastewater management system is not available and not sufficient to the wastewater hydraulic load. According to THAL consultancy and CSA 2007, the information regarding the existing sewer system can be summarized. The secondary and tertiary sewer network covers only a limited part of the Kaliti sewer district. The connection of house unit to the sewer line of give block of resident analyzed to give the wastewater load. Cadastral information of area have identified the sewer line and percentage of sub city sewer connection to house hold are 0.6, 32.0, 49.6, 6.1 and 6.3 for house number in Yeka, Arada, bole, Gulale and Kirkos respectively.

3.6. HEC-HMS Model Development and Rainfall –Runoff Analysis

3.6.1. Watershed Delineation (Arc Hydro)

The flow accumulation grid was then used to define cells as being in a stream or not based on either the size of the drainage area, or number of cells accumulated. The next step was to use the stream definition grid to develop a stream segmentation grid. The stream segmentation processed defined cells as head segment, or part of a segment between two junctions. All of the cells in a segment were given the same unique value. Once the stream network was defined and individual stream segments were separated, grid based catchments were delineated.

3.6.2. Watershed Delineation by HEC-GeoHMS

The basin model is responsible for describing the physical properties of the watershed and the topology of the stream network. This portion describes how watershed information is entered into the program using HEC-GeoHMS to HEC-HMS 3.5.0 basin model. The initial input required from HEC-GeoHMS is the Digital Elevation Model (DEM). An updated version of the DEM of the area was finalized and was used for this study. The coordinate system finally adopted is WGS 1984 UTM Zone37. The study area map used the DEM was clip to the boundaries of this mask. After clip and mask tool was performed done, finally the exact boundaries of the catchment were produced. The standard procedure for the application of HEC-GeoHMS for the development of the basin model delineation and physical file includes the running of modules in ArcGIS.

Terrain Preprocessing: Terrain processing involves using the DEM to create a stream network and catchments. The Processing menu in HEC-GeoHMS is used for terrain processing. Terrain Preprocessing is the geomorphological analysis of DEM is accomplished through terrain Preprocessing. A terrain model is used as an input to derive a final stream and subbasin delineation. The physical characteristics analysis is done using HEC-GeoHMS.

3.6.3. Stream Physical Description of Subbasin by HEC-GeoHMS

Hydrologic elements a physical symbol to break the sub-basin into manageable pieces. They are chained together in a dendritic (branched extension or shape of a tree branch) network to form a segment of the stream system. The physical parameter analysis processed using HEC- GeoHMS. While a sub-basin element conceptually represents infiltration, surface runoff, and subsurface processes interacting together, the actual infiltration calculations evaluated by a loss method. CN loss method were used for computation, because the available data of SCS Curve Number. The selected the method, three parameters of basin shown in table 3.1 below.

Table 3.1: Subbasin Physical Parameter of HEC-HMS

Name of	Area (m^2)	Basin slope	Shape length	Area (Km^2)

Subbasin		(Percent Rise)	(m)	
W40	16939187	17.6	31071.8	16.9
W50	25181547	18.2	33155.5	25.2
W60	9581344.8	11.2	24820.6	9.6

Table 3.2: HEC-GeoHMS River parameter Output Used in HEC-HMS

Reach Name	River Length (m)	U/S Elv(m)	D/S Elv(m)	Slope (%)
R10	4229.9	2544	2423	0.02
R20	4458.2	2618	2423	0.04
R30	4916.7	2423	2423	0

Then using the methodology described above the following delineated watershed is shown on fig.3.7 below.

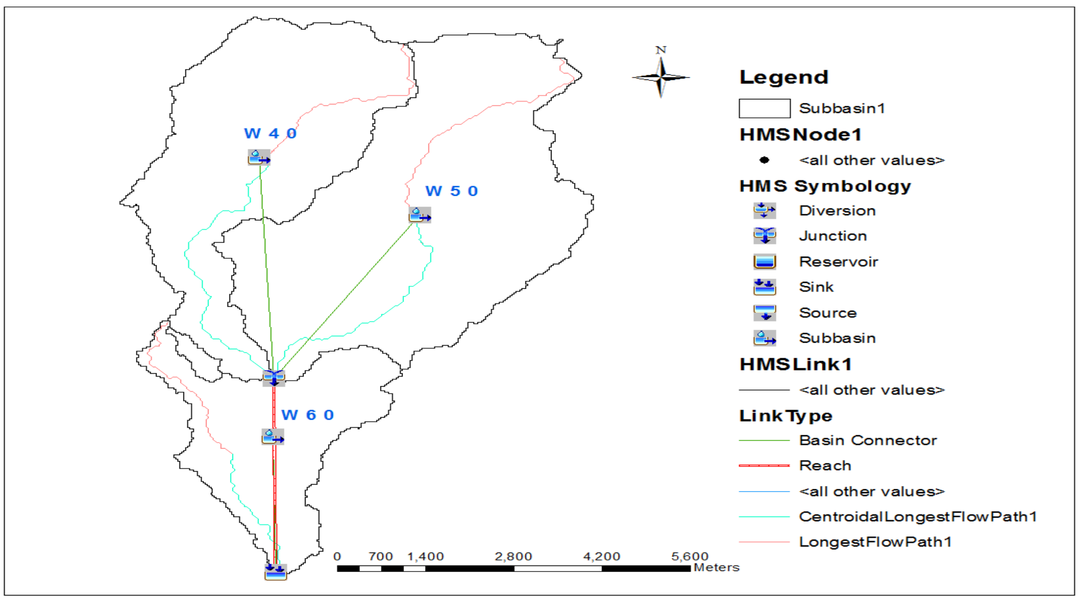


Fig. 3.7: Basin Model of HEC-GeoHMS Delineated Subbasin

3.6.4. Curve Number Parameter

The curve number, commonly abbreviated as CN, is a composite curve number that represents the entire different soil group and land use combinations in the sub-basin. The composite curve number does not include impervious area that shown separately as the percentage of impervious area in the program. CN values range from 100 (for water bodies) to about 30 for permeable soils with high infiltration rates. To compute the curve number, land use and soil types are spatial intersected the catchment. To standardize these curves, a dimensionless curve number CN is defined such that zero < CN < 100. For impervious and water surfaces CN = 100; for natural surfaces CN < 100. Curve numbers have been tabulated by the American Soil Conservation Service on the basis of soil type and land use. Four soil groups are defined:

- **Group A:** Deep sand, deep loess, aggregated silts (very high permeability),
- **Group B**: Shallow loess, sandy loam (high permeability),
- **Group C:** Clay loams, shallow sandy loam, soils low in organic content, and soils usually high in clay(moderate permeability),
- **Group D:** Soils that swell significantly when wet, heavy plastic clays, and certain saline soil (low permeability)

Land use and building density are key factors influencing: Decreased infiltration (the greater the surface cover, the less infiltration occurs) for a watershed that consists of more than one soil types and land uses, formula of composite CN is showed as follow.

$$\frac{\sum}{\sum}$$

In which, $CN_{composite}$ = the composite CN used for runoff volume computation for each an index (i) of watersheds subdivisions of uniform land use and soil type; CN_i is the CN for subdivision i; and A_i of the drainage area of subdivision. Using spatial tool overlay, the spatial join of soil group with landuse land cover combined to give abstraction. GIS application Flow chart diagram is shown in fig. 3.8 below.

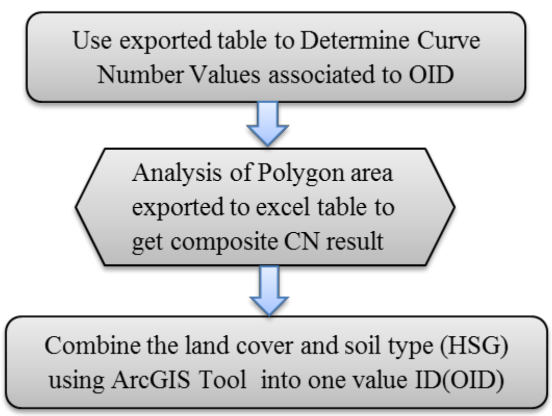


Fig.3.8: Flow Chart of Spatial Tool to Overlay of LULC and Soil Type

Initial Abstraction (I_a): From analysis of results from many small experimental watersheds, the SCS developed an empirical relationship of I_a and S: $I_a = 0.2S$, the maximum retention, S, and watershed characteristics are related through an intermediate parameter, the curve number (CN) as: the formula of S the maximum retention is showed as follow.

Initial Abstraction is

The initial Land use type and calculate polygon area represents to the Kebena catchment are extracted from the map agency and top map at given time. Using GIS intersection of watershed map, Land use land cover corresponds to Soil type (HSG) coverage areas calculated for given sub watershed.

Table 3.4a: Maximum retention (S) and Initial abstraction (Ia)

Subbasin name	Hydrologic Soil Type	HSG	Land use	∑Ai (Km)	CN_{comp} & %Imperv	(S)	I_a) =0.2S
W60	Low permeability	D	Forest land				
			Urban settlement				
			Forest &Urban open space				
			Urban settlement				
	Moderate permeability	C	Urban settlement	**8.02**	**82.69%**		
			Forest &Urban open space				
			Urban settlement				
	Very High Perm	A	Urban settlement	**1.67**	**79.93**	**63.77**	**12.75**

Table 3.4b: Maximum retention (S) and Initial abstraction (Ia)

Sub. name	Hydrologic Soil Type	HSG	Land use	∑Ai (Km)	CN_{comp} & %Imperv.	(S)	(I_a)=0.2 S
W40	Low permeability	D	Forest land				
			Urban settlement				
	Moderate permeability	C	Urban settlement	**2.51**	**14.79%**		
			Forest land				
			Open space				
	High Permeability	B	Forest land	**14.21**	**86.67**	**39.06**	**7.82**

W50	Low permeability	D	Agricultural Land				
			Forest land				
			Urban settlement	**3.81 4**	**15.18%**		
	High Permeability	A	Forest land				
	Moderate permeability	C	Agricultural land				
			Forest land				
			Forest &Urban open space				
			Opens pace				
			Urban settlement	**21.3 1**	**79.1**	**67.09**	**13.41**

3.6.5. Basin Model Parameters

Within the HMS component for Basin Models there were several options available to select for performing the simulations. For all of the simulations, the Loss Model used was the Soil Conservation Service (SCS) Curve Number (CN) method, the Channel Routing model used was the Lag method and the watershed Transform models evaluated were the SCS UH and Clark UH methods selected to these particular studies. The HEC-HMS basin and river model is shown on figure 3.9 below.

Fig.3.9: Basic HEC-HMS Model Components

3.6.6. Soil Conservation Service Curve Number Loss Method

The purpose of the loss method within HEC-HMS was to determine how much of the rainfall would eventually become runoff. The SCS CN method relied on the relationship between hydrologic soil type and land cover to determine how much of the rainfall would become runoff. While a sub-basin element conceptually represents infiltration, surface runoff, and subsurface processes interacting together, the actual infiltration calculations are performed by a loss method. After selecting the method, three parameters of basin model are to compute the loss. These are curve number, initial abstraction, and impervious (%). HEC-HMS simulated the SCS CN runoff generation process using the equation below.

In which I_a= represent initial abstraction, S represent maximum retention or ponding, P = total rainfall flow, Pe = rainfall excess, after saturation of soil. By study of results from many small experimental watersheds, an empirical relation was developed of I_a = 0.2S which led to the equation.

CN values ranged from a maximum of 100 for water bodies, to a minimum of 30 for permeable soils with high infiltration rates (Feldman 2000). The CN for a watershed can be estimated as a function of land use, soil type, as discussed in previous topic.

3.6.7. Channel Flow Lag Method

The lag method for channelized flow was selected for its simplicity and ease of use. The outflow hydrograph is simply the inflow hydrograph, but with all ordinates translated (lagged in time) by a specified duration. The flows are not attenuated, so the shape is not changed (Feldman 2000).

Where O_t = outflow hydrograph ordinate at time t; I_t = inflow hydrograph ordinate at time t; and lag = time by which the inflow ordinates are to be lagged. The lag time could have been determined by comparing flow data from two gages, however there was only one gage within the watersheds of interest and therefore the lag times were manipulated to adjust the hydrograph at the USGS gage to reflect the observed data (Feldman 2000).

3.6.8. Soil Conservation Service Unit Hydrograph Model

The unit hydrograph is a well-known, commonly-used empirical model of the relationship of direct runoff to excess precipitation. As originally proposed by Sherman in 1932, it is "…the basin outflow resulting from one unit of direct runoff generated uniformly over the drainage area at a uniform rainfall rate during a specified period of rainfall duration" (Feldman, 2000). The runoff process is linear, so the runoff from greater or less than one unit is simply a multiple of the unit runoff hydrograph (Feldman D., 2000). In HEC-HMS, the UH model solved using the following equation.

$$Q_n = \sum_{m=1}^{n \leq M} P_m U_{n-m+1}$$

Where Q_n is storm hydrograph ordinate at time t; P_m = rainfall excess depth in time interval and U_{n-m+1} = UH ordinate at time (n-m+1) Δt. According to USACE (2010), the following assumptions of hydrology model basic to simulate rainfall runoff model.

1. "The excess precipitation is distributed uniformly spatially and is of constant intensity throughout a time interval Δt."""
2. "The ordinates of a direct-runoff hydrograph corresponding to excess precipitation of a given duration are directly proportional to the volume of excess. Thus, twice the excess produces a doubling of runoff hydrograph ordinates and half the excess produces a halving. This is the so-called assumption of linearity.
3. "The direct runoff hydrograph resulting from a given increment of excess is independent of the time of occurrence of the excess and of the antecedent precipitation. This is the assumption of time-invariance.
4. "Precipitation excesses of equal duration are assumed to produce hydrographs with equivalent time bases regardless of the intensity of the precipitation"""" (Feldman 2000).

The SCS UH method was one method used to simulate the transformation process of precipitation excess to runoff. The Soil Conservation Service (SCS) proposed a parametric UH model; this model is included in the HEC-HMS program and adopted for the transformation process. Research by the SCS suggests that the UH peak and time of UH peak are related by;

In which A = watershed area; and C = conversion constant (2.08 in SI system). The time of peak (also known as the time of rise) is related to the duration of the unit of excess precipitation as:

In which Δt = the excess precipitation duration (which is also the computational interval in the run); and t_{lag} = the basin lag, defined as the time difference between the center of mass of rainfall excess and the peak of the UH. When the lag time is specified, the HEC-HMS program solves the above equations to find the time of UH peak and Up. With Up and T_p known, the UH can be found from the dimensionless form, which is built into the program, by multiplication (Feldman, 2000).

3.6.9. Time of Concentration

For ungagged watersheds, the SCS suggests that the UH lag time may be related to time of concentration.

Time of concentration can be estimated as:

$$\mathbf{t_c = t_{sheet} + t_{shallow} + t_{channel}}$$

Where, t_{sheet} is sum of travel time in sheet flow segments over the watershed land surface; $t_{shallow}$ is sum of travel time in shallow flow segments, down streets, in gutters, or in shallow rills and rivulets; and $t_{channel}$ is sum of travel time in channel segments. Sheet flow is flow over the watershed plane surface, before water reaches a channel. Distances are short and overland flow length is 10-100 meters (. For sheet flow of less than 100 meters, use Manning‟s kinematic solution (Overton and Meadows, 1976) to compute Sheet flow t_{sheet}:-

Where: tsheet = travel time, hr; N = an overland-flow roughness coefficient; L = flow length, m; P2 = 2-year, 24-hour rainfall depth, mm; and S = slope of hydraulic grade line, which may be approximated by the land slope.

The topography of our catchment is mountainous. Hence, the sheet flow is negligible since rills and rivulets are the dominant ones in mountainous topography; which are considered in the next section (shallow flow).

Shallow Flow: Sheet flow usually turns into shallow concentrated flow after 100 meters. The average velocity m/sec for shallow concentrated flow can be estimated as:

$$\{ \quad \frac{\sqrt{\ }}{\sqrt{\ }} \quad \}$$

Where V = average velocity; 16.1345 = coefficient for unpaved surfaces; and S = slope of hydraulic grade line. The coefficient for paved surfaces was 20.3282, but was not used because the majority of the watersheds were primarily rural and had few expansive paved surfaces (Feldman 2000). Once velocity is thus estimated, channel travel time is computed as: $\mathbf{t_{channel} = L/V}$ Where L is channel length; and V is average velocity throughout the river channel. The time of concentration of watershed along stream segment calculated is 2.7 hours. The time of lag is 60 percentage of time of concentration. The initial physical parameter time of concentration and the lag time of basin model shown in table 3.5 below.

Table 3.5: SCS model time of concentration and lag time (initial)

Subbassin Name	Time of concentration T_c (hr)	Lag Time (min)
W40	1.505	54.02
W50	2.01	72.36
W60	2.71	97.52

3.7. Landsat Image Data Acquisition Classification

The original land cover dataset was a raster downloaded from the Landsat 7 satellite via the USGS Global Visualization server (Glovi‟s) at different time. To determine if the lumped hydrologic models respond to land cover change differently at different spatial scales, it was necessary to manipulate this dataset to imitate land cover changes from an undeveloped state to a developed state. Landsat satellite imageries were used to identify changes in LU/LC classified distribution in the Kebena catchment over a years from 1995-2010. Landsat, TM and ETM+ data were selected to represent the land cover conditions in the years 1995, 2002 and 2009.

Table 3.6: The data sources and type for the analysis of land cover change

Path/Row	sensor	Acquisition date	Resolution (m)	Provider
168/54	ETM+	1/14/1995	30x30	USGS/Glovis
168/54	ETM+	1/10/2000	30x30	USGS/Glovis
168/55	TM	1/28/2002	30x30	USGS/Glovis
168/55	TM	12/3/2009	30x30	USGS/Glovis

3.7.1. Image Classification

Basically, satellite data consists of several bands from visible to infrared wave band. For instance, LANDSAT ETM+ data has eight (8) bands as follows;

Table 3.7: LANDSAT ETM+ data has eight (8) bands

Wave Band (Micro Meter)	Band 1	1 0.45-0.56	VB
	Band 2	0.52-0.66	VG
	Band 3	0.63-0.69	VR
	Band 4	0.76-0.9	NIR
	Band 5	1.55-1.75	SWI
	Band 6	10.4-12.5	TIR
	Band 7	2.08-2.35	SWI
	Band 8	0.52 - 0.90	VG – NI

Band 1 to Band 3 are visible band, Band 4 is near infrared, Band 5 and Band 7 are short wave infrared, Band 6 is thermal infrared and Band 8 is panchromatic mode and using visible bands and near infrared band, some color composite imageries can be produced. True and false color

Combination of Different Band Spectrum value produced color shown on fig.3.11 below.

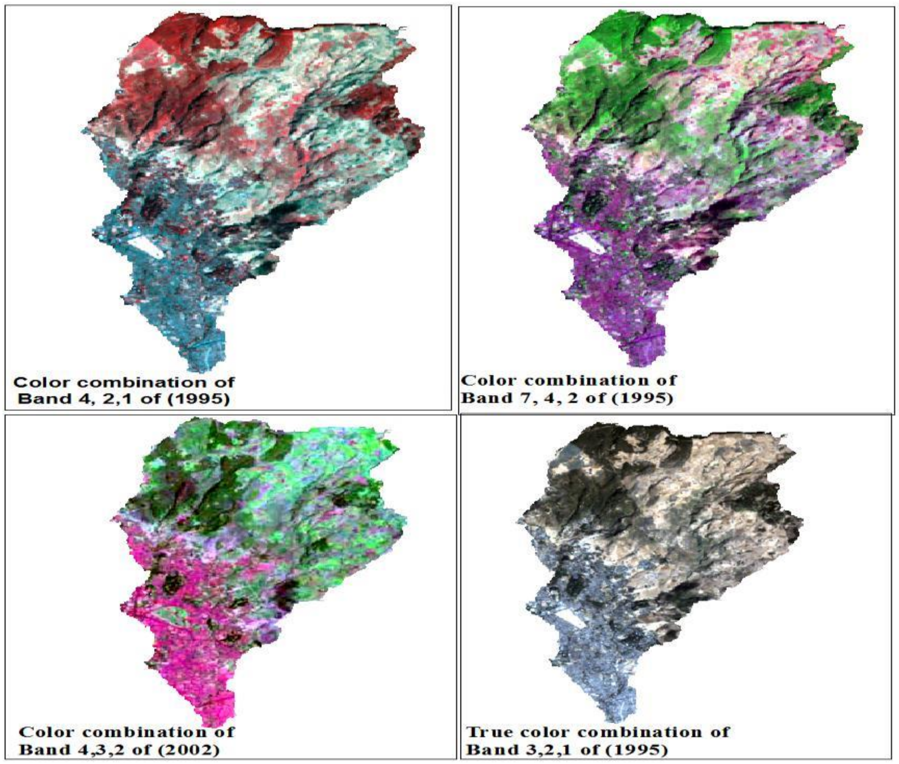


Fig.3.10: True and False color Combination of Different Band Spectrum Value

In Remote Sensing, there are three (3) kinds of color composite imagery: “False Color Composite Imagery”, “Natural Color Composite Imagery” and “True Color Composite Imagery” (JICA, 2014). False color composite imagery band combination often applied for the landcover classification analysis because this composite imagery contains the near infrared band. In addition, the near infrared is very useful to identify the vegetation area. Therefore, the false color composite imagery is widely used for the land use classification (JICA, 2014).

3.7.2. Definitions Used in Classification of Land Cover.

- **Grass Land:-**This class includes any geographic area dominated by natural herbaceous plants (grasslands, prairies, steppes and savannahs) with a cover of 10% or more, irrespective of different human and/or animal activities, such as: grazing, selective fire management etc. Woody plants (trees and/or shrubs) can be present assuming their cover is less than 10%.
- **Forest Land:-**area with high density of trees which include eucalyptus and coniferous trees, dense woodland. III.
- **Agricultural Land: -** areas used for crop cultivation, and the scattered rural settlements.

- **Water body: -** area which ponds water throughout the year, and rivers.
- **Urban Settlement: -** area which remains building, residential area, Roads, industrial and impervious throughout the years.

3.7.3. Landsat Image Classification Method

Supervised classification used in this study was also supported by unsupervised classification. Therefore, both supervised and unsupervised image classification was done during image classification.

3.7.4. Supervised Classification

A supervised classification is the most popular classification method in Remote Sensing. Basically, in the supervised classification method, the satellite image data can be classified based on the statistical data of the training sample data.

Table 3.7: Land-cover classes images of ETM+ and TM of the study area with number of samples pixel

Land cover Class	1995 Landsat Number Pixel	2002 Landsat Number of Pixel	2009 Landsat Number of Pixel
Forest land	34094	22730	17078
Grass land	9000	15865	11934
Crop land	6485	7576	14384
Urban built up area	8256	11633	14423

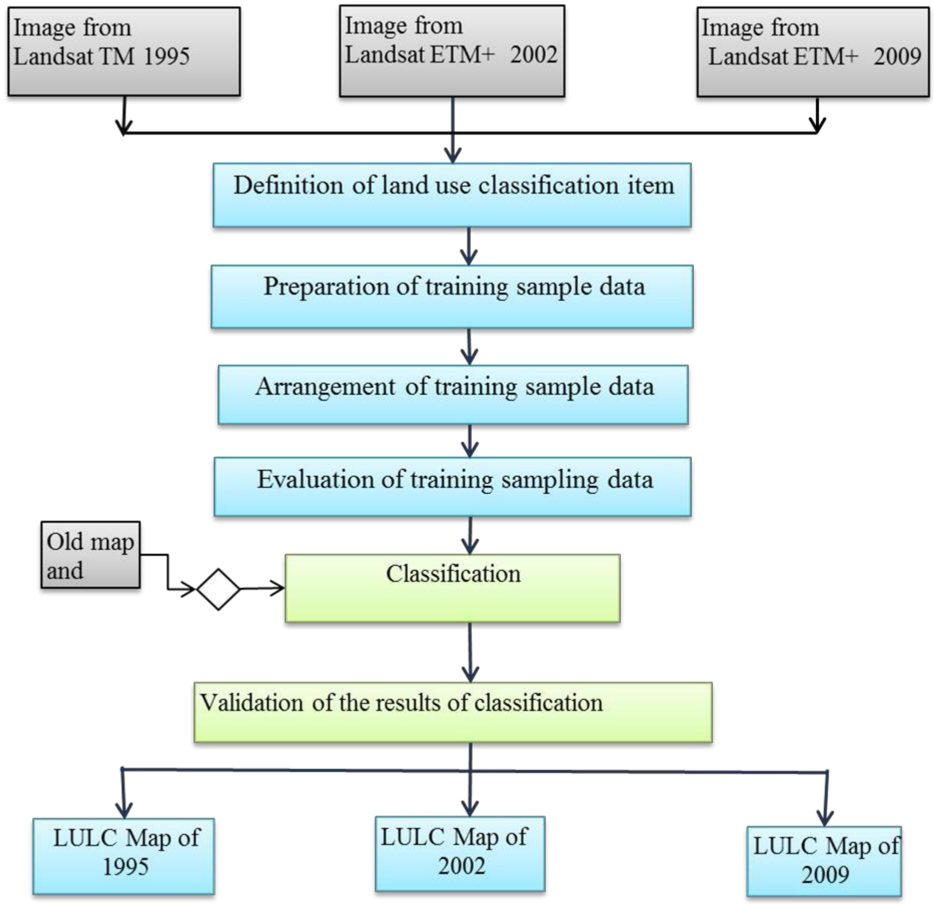


Fig.3.11: Manual on Land Use Classification Analysis Using Remote Sensing

3.7.5. Unsupervised Classification of GIS and Arc Map tools

This tool combines the functionalities of the Iso Cluster and Maximum Likelihood Classification tools. It outputs a classified raster. It optionally outputs a signature file. The resulting signature file from this tool can be used as the input for another classification tool, such as Maximum Likelihood Classification, for greater control over the classification parameters. The minimum valid value for the number of classes is two. There is no maximum number of clusters. In general, more clusters require more iteration. This study evaluated land cover change detection for three intensities to attempt to track the progress of development study area.

- The first level of intensity was developed to simulate an amount of change that would be feasible to occur within a seven year 1995 to 2002 from the original state.
- The second level of intensity was to simulate a higher degree of development change of landuse landcover, of 7 to 15 years from the original state.

- The third level of intensity was designed to simulate a dramatic but realistic, change in the land cover throughout the watershed from 15-20 years after the original state of development i. e from 1995 to 2015. This change was designed to exhibit an effect on the CN value at all three level of development

3.7.6. Accuracy Assessment

For 1995 and 2002 image classification, accuracy assessment was done using topographic map of the study area prepared in 1976. About 30 random points were created for 1995 image classification of Kebena watershed and 35 points for 1986 image classification. Error matrix table was completed by comparing values of random points on classified image and topographic map as shown in Table 3.8.

	Forest land	Grass land	Crop land	Urban built up area	Total
Forest land(1)	5	3	0	0	8
Grass land(3)	0	10	0	0	10
Crop land a(5)	0	0	0	0	0
Urban built up area(1)	0	0	0	6	6
Total column	5	13	0	6	21

Using the error matrix overall accuracy was calculated. Overall accuracy is the percentage of random points that are the same in both images (year 1973 classified image and topographic map). In error matrix of 1995, (Table 3.8) there are 21 points (5 forests, 6 Grassland, 0 Crop land and 10 urban settlements). There are 28 random points created. So, overall accuracy was estimated by dividing number of point in error matrix by total random points i.e.21/28, which is 75%.

3.8. HEC-HMS Model Calibration, Validation and Sensitive Evaluation

The value of each parameter must be specified to use the model for estimating runoff or routing hydrographs. In HEC-HMS, the systematic search for the best (optimal) parameter values .For rainfall-runoff models; the required data are rainfall and flow time series (Feldman, 2000).. The available hydro-climatic records of meteorological stations and one stream flow gage stations were analyzed for selection of calibration and verification data for the HEC-HMS model.

3.8.1. HEC-HMS Calibration and Validation Procedure

Model calibration is a systematic process of adjusting model parameter values until model results match acceptably the observed data. The objective function is the quantitative measure of observed and simulated match. In the precipitation-runoff models, this function measures the degree of variation between computed and observed hydrographs. The calibration process finds the optimal parameter values that minimize the objective function. Further, the calibration estimates some model parameters that are difficult estimated by observation or measurement, or have no direct physical meaning.

Calibration can be either manual or automated (optimization). Manual calibration relies on user‟s knowledge of basin physical properties and expertise in hydrologic modeling. In automated model calibration, parameters area iteratively adjusted until objective function minimized. The latest version of the HEC-HMS model includes optimization manager that allows automated model calibration. There are five objective functions available in the optimization manager as given Complete technical description of these search methods is provided in (USACE, 2000b).

- **Peak-weighted root mean square error (PWRMSE):** Using a weighting factor, the PWRMSE measure gives greater overall weight to error near the peak discharge (USACE, 1998). It compares all ordinates, squaring differences, and it weights the squared differences.

$$Z = \left\{ \frac{1}{NQ} \left[\sum_{i=1}^{NQ} \left(q_O(i) - q_S(i) \right)^2 \left(\frac{q_O(i) + q_O(mean)}{2 q_O(mean)} \right) \right] \right\}^{1/2}$$

Where, Z = objective function; NQ = number of computed hydrograph ordinates; $q_o(t)$ = observed flows; $q_s(t)$ = calculated flows, computed with a selected set of model parameters; $q_o(peak)$ = observed peak; $q_o(mean)$ = mean of observed flows; and $q_s(peak)$ = calculated peak. The symbol works for the rest of following objective function formula.

- **Sum of Absolute Error:** This objective function compares each ordinate of the computed hydrograph with the observed, weighting each equally.

$$Z = \sum_{i=1}^{NQ} \left| q_O(i) - q_S(i) \right|$$

- **Sum of Squared Residuals:** This is a commonly used objective function for model calibration. It too compares all ordinates, but uses the squared differences as the measure of fit (Disking and Simon, 1977).

$$Z = \sum_{i=1}^{NQ} \left[q_O(i) - q_S(i) \right]^2$$

- **Percent error in peak**: This measures only the goodness-of-fit of the computed-hydrograph peak to the observed peak. It quantifies the fit as the absolute value of the difference, expressed as a percentage, thus treating overestimates and underestimates as equally undesirable.
- **Percent error in volume (PEV)**: The PEV function only considers the computed volume and does not account for the magnitude or timing of the peak flow:

$$PEV = 100 \left| \frac{V_O - V_M}{V_O} \right|$$

Where V_o (V_m) is the volume of the observed (modeled) hydrograph. Two search methods are available in the HEC-HMS model for minimizing the objective functions defined above (USACE, 2001):

- **The univariate gradient method (UG):** The UG method evaluates and adjusts one Parameter at a time while holding other parameters constant.
- **The Nelder and Mead method (NM):** The NM method uses a downhill Simplex to evaluate all parameters simultaneously and determine which parameter to adjust.

3.8.2. Verification Procedure

Model verification is a process of testing model ability to simulate observed data other than those used for the calibration, with acceptable accuracy. During this process, calibrated model parameters are not subject to change, their values are kept constant. The quantitative measure of the match is again the degree of variation between computed and observed hydrographs.

3.8.3. Sensitivity Analysis

Search method estimate optimal parameter values but do not indicate which parameters have the greatest impact on the solution. At the conclusion of the optimization, the sensitivity of each parameter with respect to the objective function is estimated. A value of the objective function was computed for parameter values 0.995 and 1.005 times the optimal values using the following equation.

$$S = \frac{(0.995X - 1.005X}{(X)}$$

Where S is the sensitivity measure and X is the final parameter value at the end of optimization. The sensitivity measure is the percent change in the value of the objective function resulting from a 1% increase in the value of the parameter (USACE, 2001).

3.9. Urban Water Demand and Wastewater Generation

Problem in provision of potable water demand management to the rapidly growing urban population are increasing dramatically. Potable Water demands including, domestic, industrial and commercial sector of developing urban areas increases through time that as a result demand for additional water sources and infrastructure. The water demand of a particular urban center have proportionally related with the population to be served, their standard of living and activities, the cost of water supplied, the availability or the potential for wastewater service and the purpose of demand. In addition to these, demand allowances need to be included for leakage, wastage, and operational requirements. The key issues to consider in the context of areal scale assessments of the urban water management elements, Low Impact Design (LID) essentially relate to the suite of techniques, which have been applied, and whether these techniques are suitable to the particular area under investigation. Domestic, Non-Domestic Per capita Demand and Wastewater Flow rate relation (Process Diagram) is shown on fig. 3.12 below.

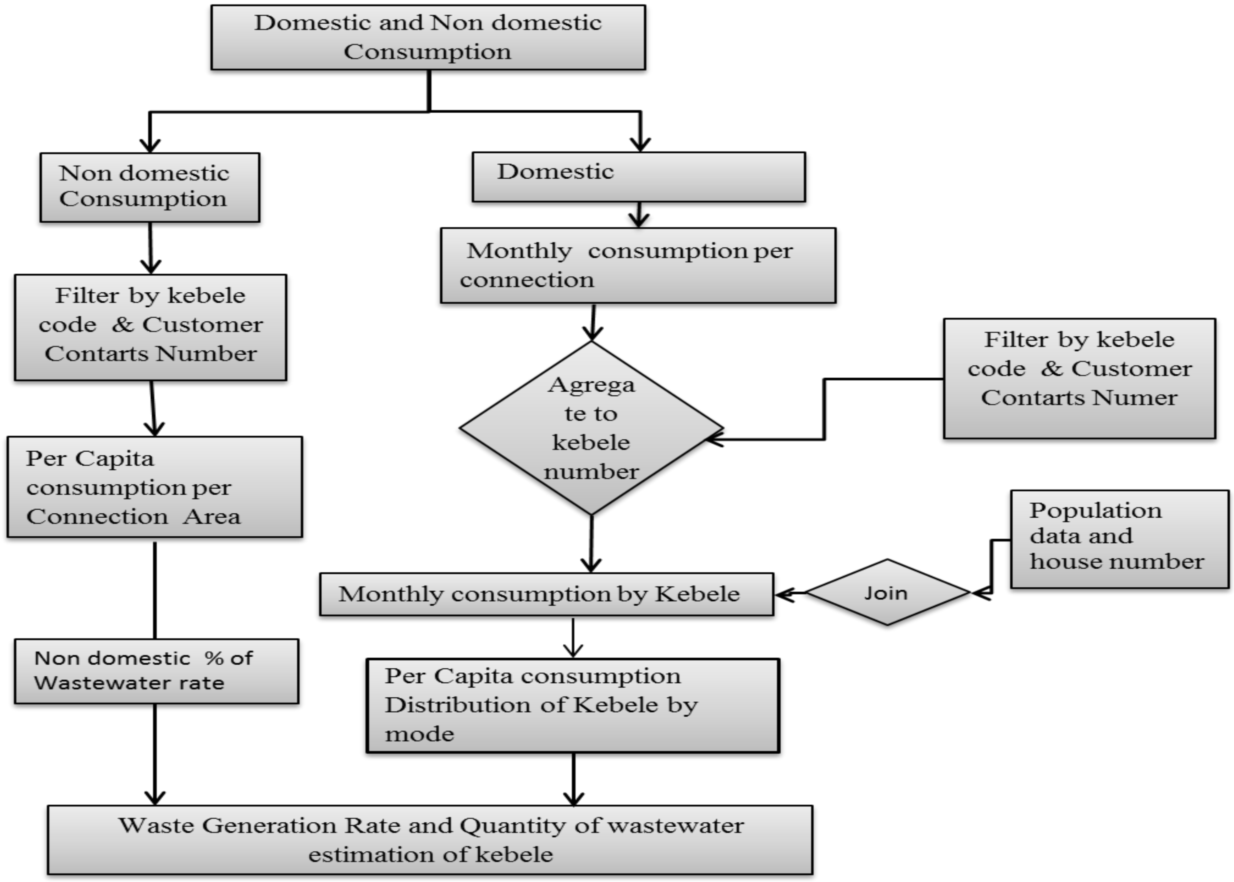


Fig.3.12: Per capita Demand Analysis and Wastewater Flow Rate Relation (Process Diagram)

3.9.1. Urban Water Supply and Consumption

Water supply coverage is usually evaluated based on the quantity, quality, paying capacity of the people, distance, etc., but the intention of this context is to evaluate related to the quantity of supply and level of per capita consumption that are related to the wastewater generation. In this part of the analysis, the number of domestic connections per family and the average daily per capita consumption is used to analyze the domestic water supply coverage for the entire study Area. A fundamental prerequisite to begin the design of potable water supply facilities is a determination of the design capacity. This, in turn, is a function of water demand. The determination of water demand consists of four parts: (1) selection of a design period, (2) estimation of the population, commercial, and industrial growth, (3) estimation of the unit water use, and (4) estimation of the variability of the demand.

3.9.2. Domestic Water Supply Coverage

Access to water supply may be evaluated using the amount of water consumed and the level of connection. For evaluating the amount of water consumption, the annual water consumption is converted to average daily per capita consumption using the population data of each Kebele. The number of domestic connections per family has been also used for analyzing the level of connection as elaborated below.

3.9.3. Average Daily Per Capita Consumption Analysis

The water consumed per kebeles of domestic user is filtered form billed data of each house hold in a month for period of six years. The 72 months of 6 years consumption data were converted to the annual volume of consumption per population of each kebele. Data were Statistical analysis was used to evaluate the distribution of the supply coverage in 10, 2 and 2 kebeles of the yeka sub city, bole and 2 Gulale sub city respectively. The annual consumption data has been converted to average daily per capita consumption using the number of population and population density of each kebele.

Per capita (l/cap/day) $\overline{\hspace{10em}}$

3.9.4. Consumption per Connection (Domestic and Non Domestic)

Level of water consumption per connection is an important element on the one hand for evaluating the demand management that will be the focus of this section and on the other hand it has a direct impact on the potable water supply delivery and quantity of wastewater generation relationships in watershed that have detail discussed separately in next section. The calculated, volume of water consumed in period divided by no connection for nondomestic domestic and public fountain. The total no of connection is 8412 is filtered for domestic connection and 1440 for non- domestic connection are collected for total volume of water billed per house unit.

( )

Quantitative Analysis of billed data of consumed water showed that, average domestic consumption per connection is 10.87m3/month in 2015 for the whole kebeles. The higher and lower of data statics value is excluded and consumed water per connection of domestic users have different from month to month and year to year for whole kebeles but the variability is very low as shown on table 3.8 below.

Table 3.8 Average Monthly Domestic Consumption Per Connection (2010-2015)

Year	**2014/15**	**2013/14**	**2012/13**	**2011/12**	**2010/11**
Monthly Average (m3/conn)	10.87	10.65	10.77	10.54	10.45

When the overall developments since 2010 are considered the average domestic consumption per connection the billing data from 2010 to 2015 show increase for kebele 9-12 and decrease for kebele 1, 2, 4 and 5of the average consumption per domestic connection, which has been falling down at same annual rate over the period.

3.9.5. Non Domestic Consumption

The average non domestic consumption per connection is calculate by filtering „NONDOM" billed data of each month for period of five year from year 2010-15. The result showed that per capita consumption per connection has variation among year; generally, the consumption per connection is decrease from 2012 to 2015, as shown in table 3.7 below.

Table 3.9: Per capita consumption of Non Domestic Users

Year	Total Consumption		No of NONDOM Connection	Per Capita Consumption
	m3/yr	l/yr	Number	(l/con/day)
2012	1581278.00	1581278452.00	1385.82	3126.14
2013	1269619.00	1269619000.00	1316.90	2641.35
2014	914142.00	914142000.00	1242.60	2015.54
2015	1076275.00	1076275000.00	1440.03	2047.66

The main reason for the decline of average consumption per connection is that the increase of connections was not supported with proportional increase in supply. Another reason is that the consumption of non-domestic users was not affected significantly and as a result the domestic users had to take the higher share of burden on the supply constraint. This is evident when one analyses the growth on the connection number in proportion to the growth to consumption.

3.9.6. Determining Per capita Consumption by Mode of Service

The socio-economic conditions of the residents of Addis Ababa are improving with time and high quality housing units are being constructed by the government and private developers; their water consumption is different depending house unit sharing connection and number person in house unit on the mode of service**.** It common that settlements having more people consume more water than the settlements with low number of population as far as all the areas are having similar chance of getting water. Conventional population (Population residing in conventional HU) is taken as 98.1% of the total population and annual population growth rate is taken to be 2.10%. Person residing in that housing unit is 4.40 in 2005, 4.27 in 2007 and to 4.1 in 2015 As CSA report of Addis Ababa city. This Assumption is direct report of CSA and AWWSA business report of 2007.

3.9.7. House unit Level of Water Connection

The cadastral information that has been prepared in 2011 by the Addis Ababa municipality fully covers all the12 Kebeles of the city. The cadastral information is stored for each Kebele in coverage of Yeka, Arada, Cherkos and Gulale sub city are extracted from AutoCAD format to the ArcGIS spatial point and line format to Count number of house unit each kebele .

Evaluating the domestic water supply coverage using volume of consumption may not allow realizing the distribution comparison among the kebeles. For this reason, the annual consumption billed data of residing populations are converted to average daily per capita consumption of each kebeles was derived using the following expressions.

Per Capita Consumption (l/cap/day) = ______________________________

The house units consumption per connection is filtered to the different modes of billed volume of water as monthly amount [$2m^3$-$3m^3$] as low1 consumption, [$3.8m^3$ - $5m^3$] as low2 consumption, [$17.8m^3$-$22.4m^3$] as medium consumption and [$15.2m^3$ – $19.2m^3$] high consumption per connation. The calculated per capita consumption of domestic and non-domestic area accurately determined to use in wastewater flow rate according to existing and projected number of population.

3.10. Determining Wastewater Quantity and Quality Parameter

3.10.1. Residential House unit spatial distribution:

The cadastral information that has been prepared in 2011 by the Addis Ababa municipality fully covers all the sub city of Arada, Bole, Gulale Kirkos, and Yeka Wereda extracted to count the residential Industrial and public institution. Cadastral information is stored for each Kebele in coverage area were extracted from AutoCAD format to the ArcGIS spatial point and line format to Count number of house unit each kebele the percentage of house unit connected to the sewer line. Using this integrated software the percentage of house units with the sanitation system is calculated.

3.10.2. Non Domestic Insustrial and public Insitution spatial distibution

Industrial Sewarage wastewate coming from manufacturing units and commercial, like tannery, soft drinks, alcohol industry, textile etc. The area disribution quantity of existing waste water flow from industrial, and Public institution in Kebena catchment, area map as shown on Fig. 3.13 below.

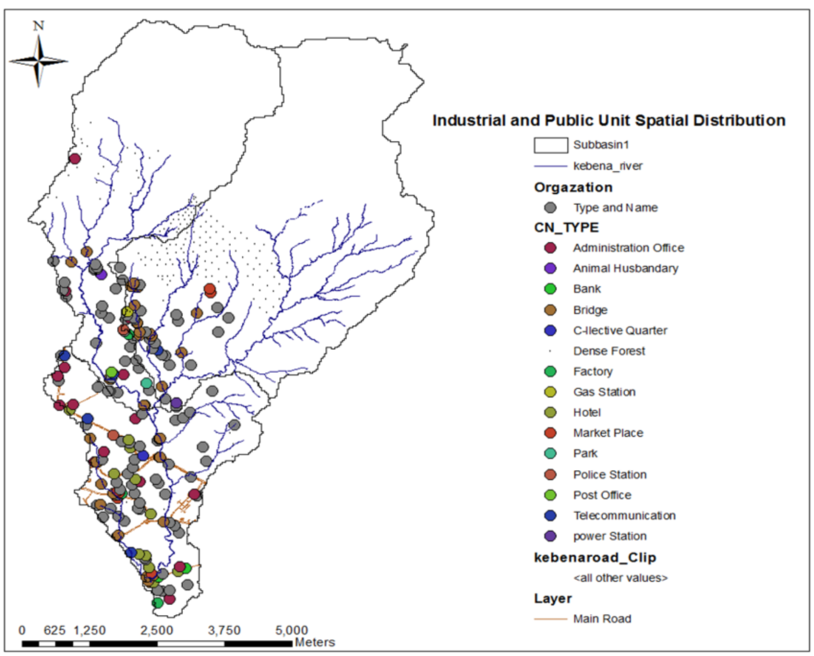


Fig.3.13: Industral and Public Organisation Spatial Distribution of Place in watershed

The factory found are, oil factory, food and beverage factory and many public institution are found on there. The small scale factory like garage, washing machine, car washing parks and loundry sparcely found in area. these small scale industry are significant source of wastewater. .

3.11. GIS based Suitability Analysis method

This methodology helps to outlines environmental suitability analysis assessment (topography, hydrology, geology and climatology) for land development and cultivation. GIS based methodology for locating appropriate sites for each land use activity. The activity criteria guided by the intent to minimize the possible adverse effects of development on the environment and on existing communities, and to emphasize the positive impacts of such development, by locating them in a most suitable location (UN Guideline, 1999). GIS suitability method divided into three classes: direct overlay, weighted score, and environmental factors combination.

3.11.1. Direct Overlay Sum

The Weighted Sum tool provides the ability to weight and combine multiple inputs to create an integrated suitable analysis. It is similar to the Weighted Overlay tool in that multiple raster inputs, representing multiple factors, can be easily combined incorporating weights or relative importance (ESRI ArcGIS, 1995-2011. There are two major differences between these tools: The Weighted Sum tool does not rescale the reclassified values back to an evaluation scale. The Weighted Sum tool allows floating-point and integer values, whereas the Weighted Overlay tool only accepts integer roasters as inputs.

3.11.2. Weighted Overlay Score

Weighted Overlays several land map using a common measurement scale and weights each according to its importance. All input raster must be integer. A floating-point raster data first reclassified to an integer raster before it used in Weighted Overlay. Each value class in an input land raster assigned a new value based on an evaluation scale. These new values are reclassifications of the original input raster values. A restricted value like no data and without criteria grids area exclude from the analysis. Each input raster is weighted according to its importance or its percent influence. The weight is a relative percentage, and the sum of the percent influence weights must equal 100.

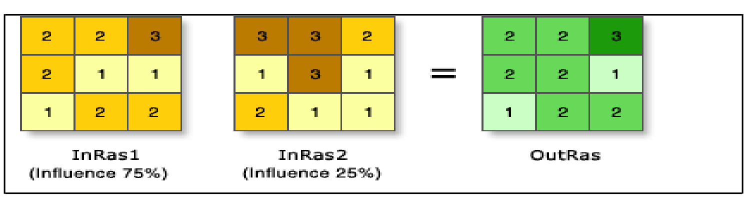


Fig. 3.14: The Diagram of Grid Value Weighted Overlay Sum

Based on scoring each single factor class, it will carry out the weighted summation for the evaluation result of each single factor. Finally, we will get the total scores of the corresponding parcels or grids of the specific land use. Generally, a higher score represents the more suitability. The formula of weighted overlay score is showed as follow. Where, W_k is the weight of the k^{th} factor for the j^{th} land use. B_{kij} represents the suitability evaluation of k^{th} ecological factor in the i^{th} parcel of the j^{th} landuse.

$$\Sigma$$

(1) Selecting suitability factor: These factors represent by the grid cell thematic map in GIS.

(2) Single factor analysis: According to the single-factor evaluation standard, score is given to the map unit of each factor and then the single factor suitability map is generated. The score is normally grouped into „1‟, „2‟, „3‟ (ratio value) these three classes, which respectively represent „no suitability‟, „moderate suitability‟ and „high suitability‟.

(3) Multiple factors overlay: first weights assigned to the suitability factors according to their relative importance and then combine to the weights together. The multiple overlay tools of reclassified data set model shown on Fig. 3.15 below

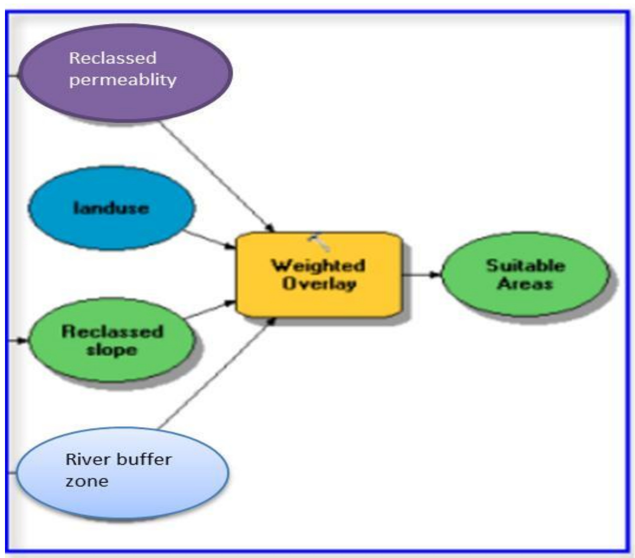


Fig.3.15: Multiple Overlay Tools Model of Specific Site Suitability Analysis

Topography and slope overlay: Catchment Zones and contours are overlay: this identifies the assessment criteria like high steep slope, characterized Typically Steep terrain and vegetated, Low site coverage Issue-High water velocities Slip Hazard.

- **Foothills moderate slope:** Characteristics by medium site coverage some areas of fill. Issue: • High water velocities, • Convergence of tributaries• flooding.
- **Lowland Characteristics:** Typically flat, Low water velocities cause flooding area Extensive areas of fill High site coverage Issue, Flooding, Tidal influence, Limited open space.
- **Soil, Geology and permeability:** These landcover has relatively high influence over decision-making process for treatment terrain location, yet, soils with less porosity and permeability is preferred to prevent ground water contamination from waste.

Table 3.12: Site Suitability Assessment for Potential Water Management Options (Adopted from Melbourne city WSUD Manual, 2010)

Factor of weightage	**Assessment Constraints (Site Specific Suitability Criteria)**		
	low	moderate(2)	High
Imperviousness (%).	1 = 0-10%	2 = 10-50%	3 = 50-100%
Average Slope	1 = 2-5%	2 = 0-1%	3 = >5%
Developed Area	1= <1ha	2 = 1-10ha	3 = >10ha
Mean Annual	1 = <600mm/yr.	2 = 600-1200mm/yr.	3 = >1200mm/yr.
Soil permeability	1 = 3.6-3600mm/hr.	2 = >3600mm/hr.	3 =<3.6mm/hr.
Groundwater	1= >2m below surface	2= 1-2m below surface	3 = <1m below surface
Salinity or Acid Sulfate Hazard	1 = Not in defined hazard area	2 = low to moderate hazard area	3 = high hazard area
Existing land use	Important land use	vacant area and Government reserved Areas	existing green space
River drainage buffer zone	buffer zone >250m	buffer zone 100 to250m	buffer zone 20m to 150m
Surface water quality	channel with low no pollutant zone	channel with low pollutant zone and human activity	channel with high pollutant zone and human activity
waste water	no wastewater load	medium wastewater load	high wastewater load

Land use and land cover (forest cropland urban residential industrial, commercial, road): Land use, density and site coverage in Addis Ababa has been influenced heavily by topography and proximity to infrastructure. Flat, low-lying areas have the most dense development and attract diverse uses including industry, commercial and residential uses, all serviced by paved road networks which altogether create a high site coverage. These land uses generate contaminants, and the high site coverage reduces infiltration. Sparsely distributed house, often occurs on higher slopes, generally has less site coverage and lower levels of contaminant generation. Parklands, permeability and low slopes assist infiltration of water; slow the velocity of runoff and retaining sediments on site vegetation.

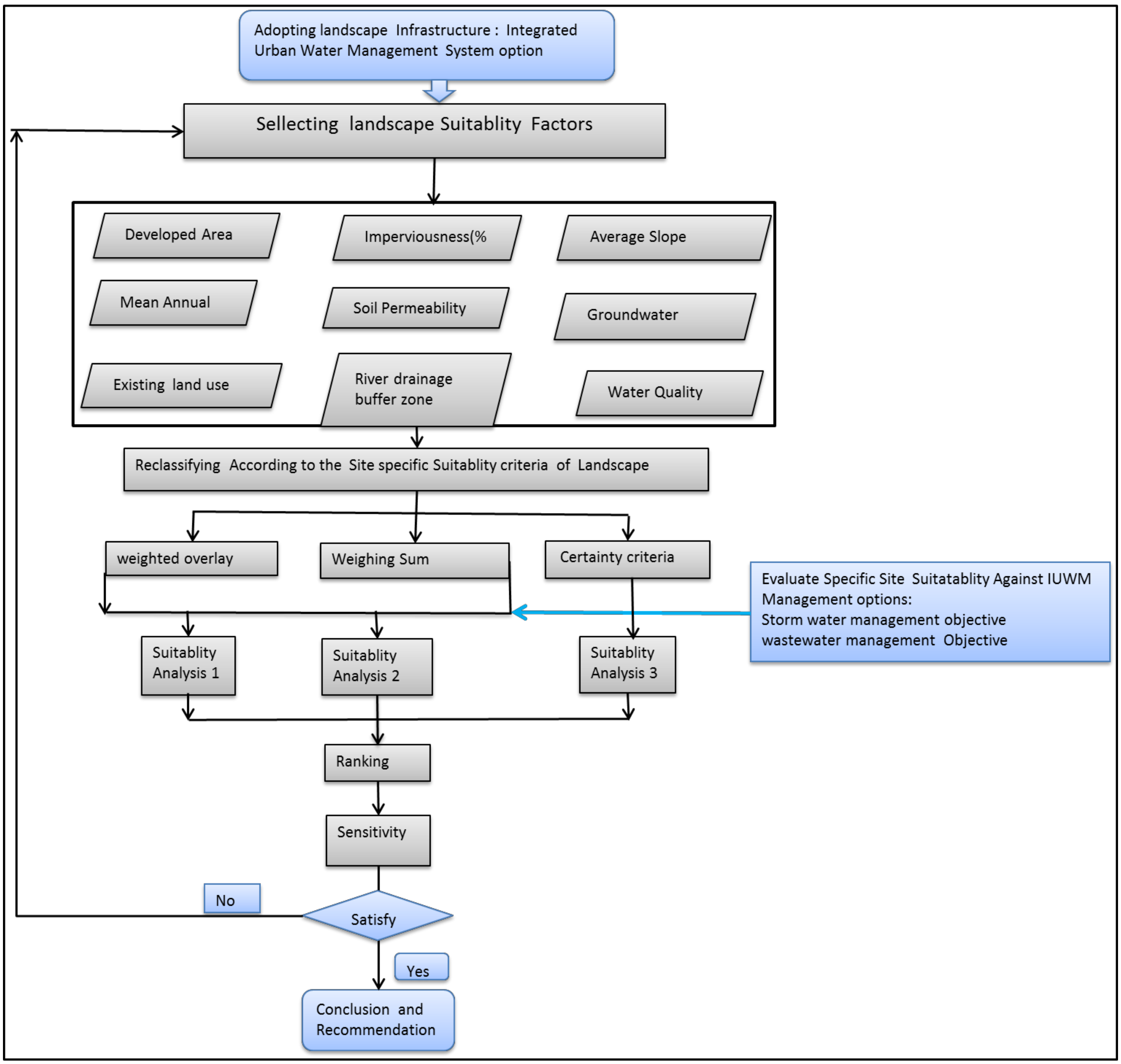


Fig.3.16: Land Suitability Methodology Flow Chart

4. Result and Discussion

4.1. Landsat Image Classification and Accuracy Assessment

The land cover map of the study area for year 1995, 2002, 2005 and 2009 derived from classified Landsat images are shown in Figure 4.1, 4.2, 4.3 The 1995 land-cover map has an overall classification accuracy of 75% and kappa statistic of 0.603 while the 1986 land-cover map obtained 74.28% accuracy and kappa statistic of 0.5565. This figure is interpreted as that the classification of 1973 image is 60.3% better than would have occurred strictly by chance and 1986 image is 55.65% better than would have occurred strictly by chance. Monserud (1990) suggested a kappa value of <40 % as poor, 40–55 % fair, 55–70 % good,70–85 % very good and >85 % as excellent.. GIS Spatial analysis tool applied to classify land use land cover to their percentage of classification. This were evaluated after image classification of the three land use land cover maps (1995, 2002 and 2009) whose results for each analysis can be expressed as forest,, grassland/open green space, cultivated land and urban built area.

4.1.1. Land Use Land Cover Map Of 1995

The land cover map of 1995 and the percentage coverage of each land cover class was conducted using ArcGIS to see the change between the periods. LULC cover classification percentage of 1995 show that the catchment covered by 58.92% forest, 15.56% grass, and 11.21% cultivated land, 14.27% Settlement as shown on figure 4.1 below.

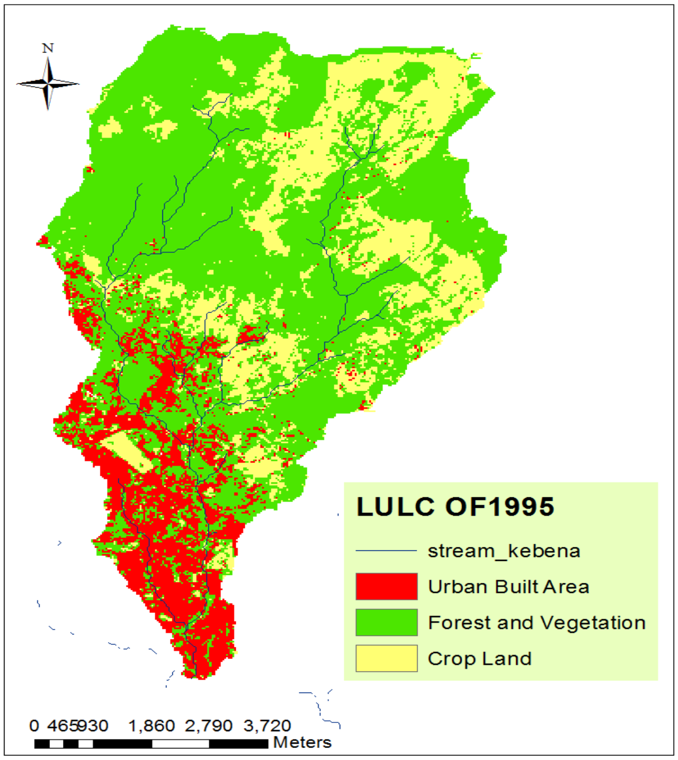


Fig.4.1: Land Use land Cover Map of 1995 Kebena Watershed

The data revealed upstream area of watershed is covered with forest, cultivated and grassland whereas downstream area is more covered with urban built. Left sides of upstream divide area covered with forest and grass. The downstream near outlet is heavily urbanized and there is green parking area covered with Grass in few places.

4.1.2. Land use land Cover Map of 2002

The data revealed that the landcover in two different times showed significant changes. Urban built land coverage drastically changed from 14.27% in 1995 to 20.22% in 2002. Urban center grew 7% in 7 years and it was around 7% per year. According to the classified result data, percentage coverage forest covered some 39.35% while Grassland, cropland (green area) and

Urban built area covered 27.43, 13.1%, and 20.11% respectively as shown on fig. 4.2 below.

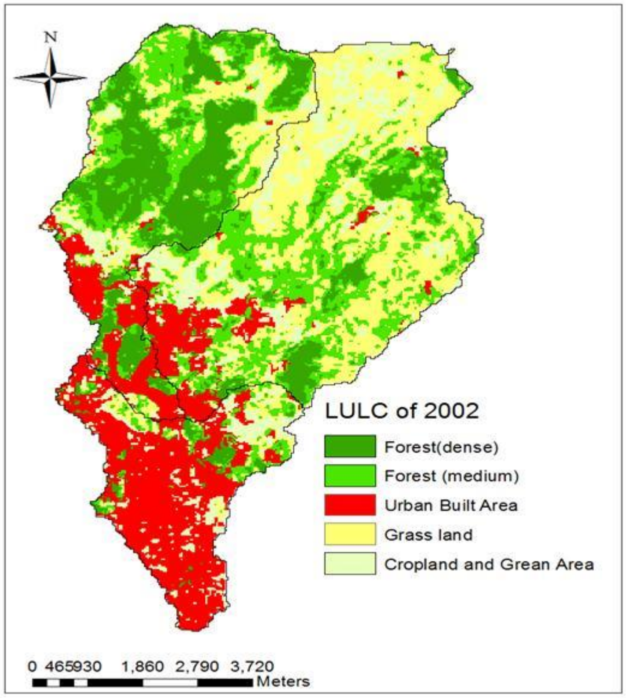


Fig.4.2. Land Use land cover Map of 2002 Kebena Watershed

The urban expansion is increased by 6% from 1995 to 2002. This means the rate of change of impervious area increased by 1% every year. The change of urbanization

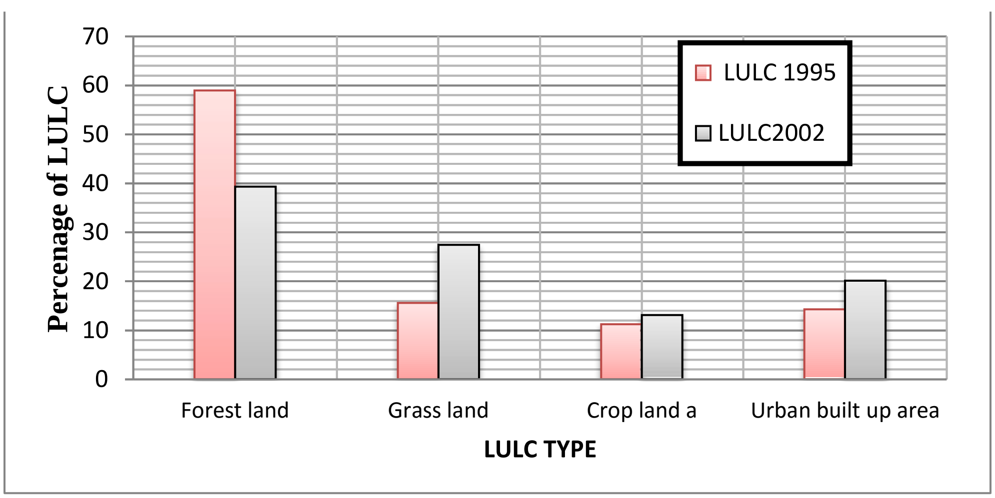


Fig.4.3. Percentage of LULC of 1995 and 2002 Chart

4.1.3. Land use Land Cover Map of 2009

The satellite image data of 2009 classification had carried out to give land cover type. According to the classified result, percentage coverage of each class indicates that forest covered 29.54%

while Grassland (open green area), cropland and Urban built area covered 20.64, 24.88%, and 25.0% respectively. The urban built was increased by 5% from 2002 to 2009. This means the rate of change of impervious area increased by 1% every year. The percentages of landcover type map as shown on fig. 4.4 below.

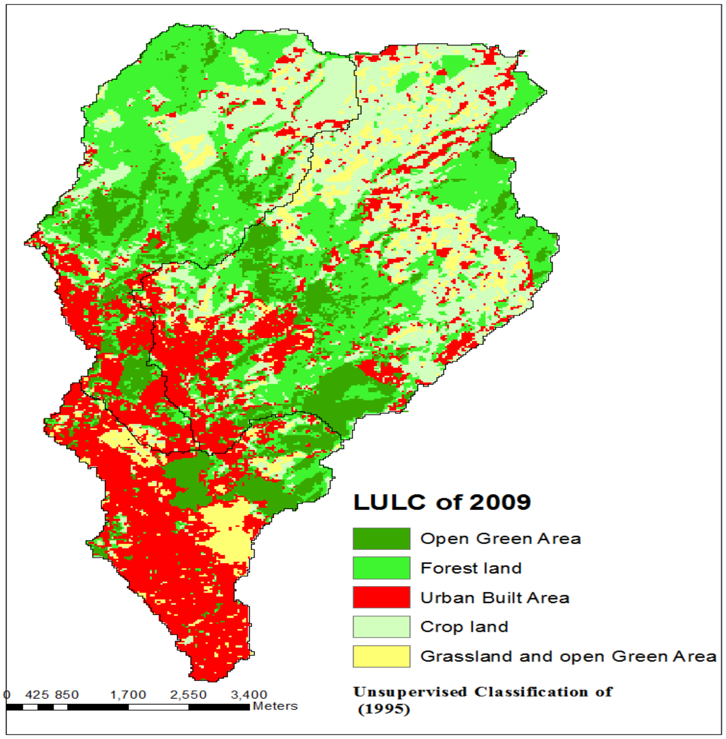


Fig.4.4. Land Use Land Cover Map of 2009 Kebena Watershed

The changes of land cover from pervious to impervious area have great impact on rainfall runoff change. One of the purposes for the land cover change evaluation this context was to explore the relationship between changes in land cover, CN and storm flow. It was suggested that as percentage impervious area increased the peak flow is also increased.The change of land cover were evaluated between 1995 and 2009 to see difference in lancover type and urban expansion to impervoues areas that have impact on rainfall runoff. The comparison of landcover type and urban built area chart is as shown in fig. 4.5 below.

Table 4.1: Land Use Land Cover Changen in Between 1995, 2002 and 2009

	Landuse Landcover						LULC Change Between			
	LULC 1995		LULC 2002		LULC 2009		1995 -2002		2002-2009	
LULC Type	Area (km2)	Area (%)	Area (km2)	Area (%)	Area (km2)	Area (%)	Change (km2)	Change (%)	Change (km2)	Change (%)
Forest land	30.68	58.95	20.46	39.30	13.18	29.54	-10.23	-33.33	7.28	35.60
Grass land/open space	8.10	15.56	14.28	27.43	12.44	20.64	6.18	76.28	1.84	12.88
Crop land a	5.84	11.21	6.82	13.10	12.68	24.88	0.98	16.82	-5.86	-85.98
Urban bult up area	7.43	14.28	10.47	20.11	13.74	24.95	3.04	40.90	-3.27	-31.26
Urban built up	**7.43**	**14.28**	**10.47**	**20.11**	**13.74**	**24.95**	**3.04**	**40.90**	**-3.27**	**-23.81**
Non- built up	**44.62**	**85.73**	**41.55**	**79.83**	**38.30**	**75.07**	**-3.07**	**59.77**	**3.26**	**-37.50**

With this study frame, large area of land changed from forest land and grass open space to urban activities at the periphery of the city. The large portion of area of land change detected forest land to cropland and urban activitie. It is seen that 3.02km^2 and 3.04km^2 of area changed from non built green area to built up urban area between 1995-1995 and 2002- 2009. The percentage of imperviusness is doubled on 2009 from the initial.

4.1.4. Land Cover Change Evaluation and Response

One of the purposes for the land cover change evaluation of this study was to explore the relationship between changes in land cover, CN and storm flow. To understand the flow processes during different seasons under different land cover conditions, the average peak flow of rainfall response were plotted for the different land cover condition of different season are simulated. The response of land cover change to rainfall – runoff hydrograph have found to be as table 4.4 shown below

Table 4.2: Landuse Land Cover Change Response of Runoff

Land use land cover change			Peak Flow and volume % Change			
Scenario	% Impervious					
SCS UH	% Impervious	Change	Peak Flow m3/s	% Change	Volume	Change
1995	14.28	0	264.3	0	40.57	0
2002	20.11	5.83	294.5	30.2	45.12	4.55
2005	22.96	2.85	305	10.5	46.54	1.42
2009	24.95	1.99	320.2	15.2	48.57	2.03

The average peak flow shows differences between simulations of different season of 25yrs annual rainfall exceedance probability. For the 1995 and 2002 land cover average peak flow was 264.3 m^3/s, while that of 2002 land cover data was between 294.5m^3/s. There found that the change between peak flow in period is 30.2 m^3/s. For the 2005 and 2009 land cover average peak flow was 305.3 m^3/s, while that of 2009 peak was found 320.3m^3/s. there found that the change between peak flow in period 15.2 m^3/s.

4.2. HEC-HMS Hydrological Basin Model Parameter

HEC-HMS worked by creating with project. The HEC-HMS project contain different basin model, meteorological model, control specification. The basin model created by HEC-GeoHMS is imported to the basin model manager and initial parameters filled to start simulations. Meteorological data model created in the HEC-HMS model to simulate the hydro meteorological conditions of individual subbasin to different time serial precipitation gages. The Gage created and then populated with data using the time window of the corresponding Control Specification. The Control Specification component contained information about the start and end time, and time-step interval for the simulation. Once setup of these three components was complete, the run Configuration tool identify which Basin Model, Meteorological Model and Control Specification. Then simulation trail prepared for simulation as shown on fig. 4.6 below.

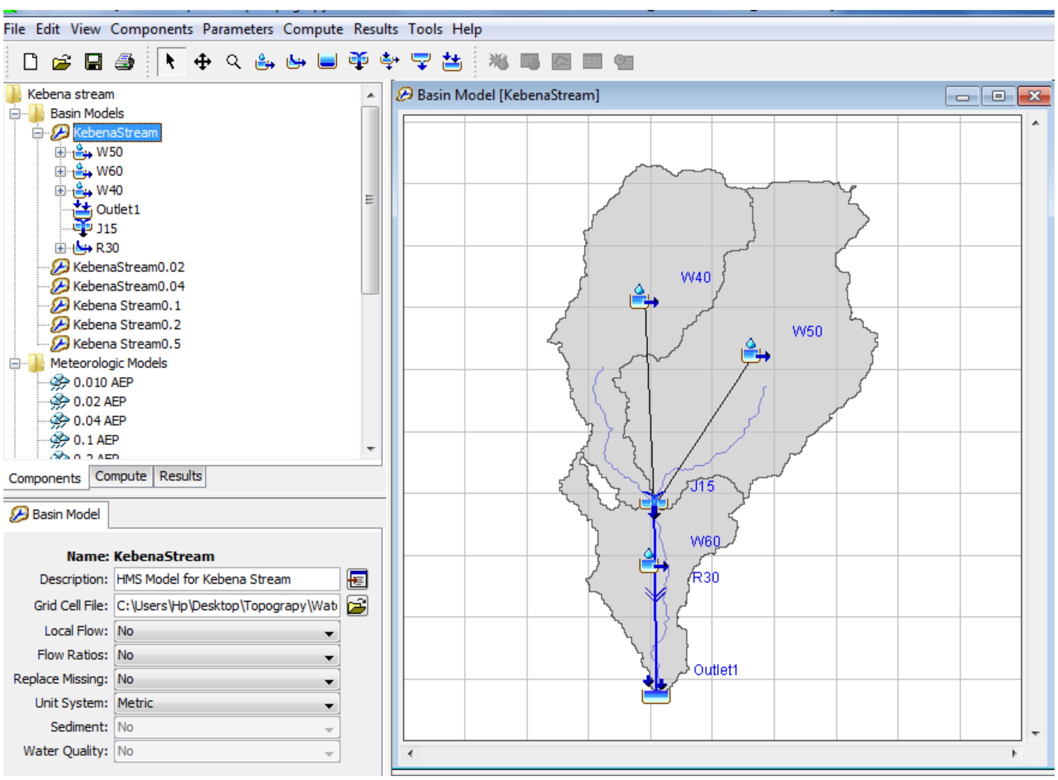


Fig.4.6: Hydrological Model of Kebena Catchment with Three subbasin

The hydrologic simulation parameters were prepared for initial model condition. The initial hydrologic parameter CN loss model, initial abstraction, Curve Number CN,SCS transform lag time, Impervious area and recession Constant. The initial parameters value estimated shown in table 4.1 below.

Table 4.3: Hydrologic Parameter Initial and Optimized Condition of Kebena Subbasin

Hydrologic Elements	Parameter	Unit	Initial value	Optimized value	Constraints	
					Minimum	**Maximum**
Subbasin-1 (W40)	Initial Abstraction	Mm	7.8	7.82	0	39.06
	Curve Number CN	%	86.67	80.14	0	100
	SCS Transform lag time	Min	54.02	60.68	0.001	10000
	Impervious area	%	14.79	15.08	0.001	100000
	Recession Constant		1		0.00001	1
	Base flow Threshold		0	0	0.0001	1
Subbasin-2 (W50)	Initial Abstraction	Mm	13.41	13.41	0	67.09
	Curve Number CN	%	79.1	81.50	0	100
	SCS Transform lag time	Min	72.36	78.12		
	Impervious area	%	15.18	17.95	0.001	100000
	Recession Constant				0.00001	1
	Base flow Threshold Ratio		0	0	0.0001	1
Subbasin-3 (W60)	Initial Abstraction	Mm	12.75	12.75	0	63.77
	Curve Number CN	%	79.93	86.70	0	100
	SCS Transform lag time	Min	97.52	82.77		
	Impervious area	%	82.69	86.69	0.001	100000
	Recession Constant		1	1	0.00001	1
	Base flow Threshold Ratio		0.0	0.0	0.0001	1

For HEC-HMS the initial parameter of subbassin are estimated before simulation of HEC-HMS. The initial value of curve number estimated are 79.93 for downstream of watershed W60 which have found 82.69 percentage impervious areas covered and 86.67% CN of upstream of watershed W40 which have 14.79% of impervious area. The initial abstraction of watershed was calculated based on SCS formula. After simulation and validation the optimized value of HEC-HMS software iterate to gate the optimized and validated value.

4.2.1. Simulation and Calibration of HEC-HMS Subbasin Model

Big Akaki Hydro meteorological station data used for the calibration due to the hydrological similarity of the Kebena watershed that is located upstream drainage area of big Akaki catchment. Calibrated physical and hydrologic parameters of big Akaki catchment were used Kebena subbassin. The Flow calibration and validation was performed a period of six years from

January 1997 to December 31, 2002 and also flow validation was performed from January, 2003 to December, 2005 for monthly stream flow using the sensitive parameters identified above. The initial and optimal parameters used for calibration and validation analysis are shown in table 4.2 below.

Table 4.4: Big Akaki Average Optimal Model Calibration Parameters

Hydrologic Elements	Parameter	Unit	Initial value	Optimized value	Constraints	
					Minimum	**Maximum**
Big Akaki catchment	Initial Abstraction	Mm	14.73	14.32	14.73	73.65
	Curve Number CN	%	82	78	0	100
	SCS Transform lag time	Min	95	79.64	75.68	1000
	Impervious area	%	22.00	24.50	0	100
	Recession Constant		1	1	0.00001	1
	Base flow Threshold Ratio		0.016	0.0167	0.0001	1

After big Akaki outlet gaged station basin was calibrated upstream contributing subbasins to outlet station followed. At this stage, the parameters of ungagged contributing subbasins also estimated. In the final stage, individually calibrated subbasins linked into one model and the calibration finalized. Rainfall-runoff events (Summer 1997, 1998 and 1999) met model used for the calibration of hydrologic model parameter of subbasin. The events are exceptionally suitable for rainfall-runoff calibration in terms of its magnitude and spatial extent. The compares of observed and simulated hydrography were present from result of HEC-HMS and changed to mean monthly flow. There was peak flow observed and produced on August 1999. The basin was able to produce model fits the observed hydrograph very well. Simulated peaks hydrograph fairly well match to observed peak hydrograph but there are different of time to peak earlier than the observed peak flow. The HEC-HMS flow comparison graph shows monthly mean of the modeled and observed hydrographs at the optimization outlet location. The graph comparison observed and modeled a shown in Fig. 4.7 below.

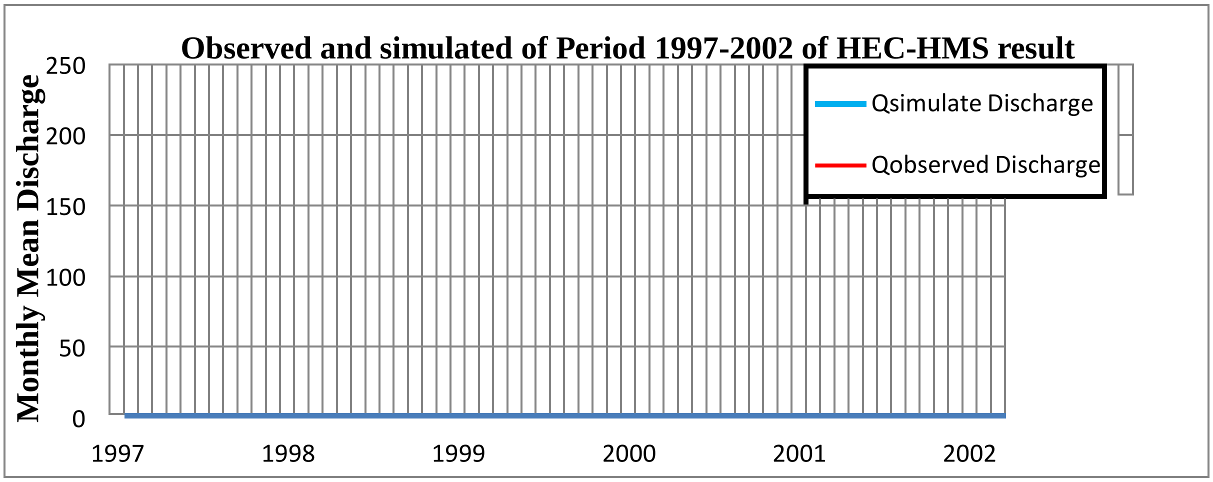


Fig.4.7: HEC-HMS Observed and Modeled Hydrographs of 1997-2002 at Akaki Bridge

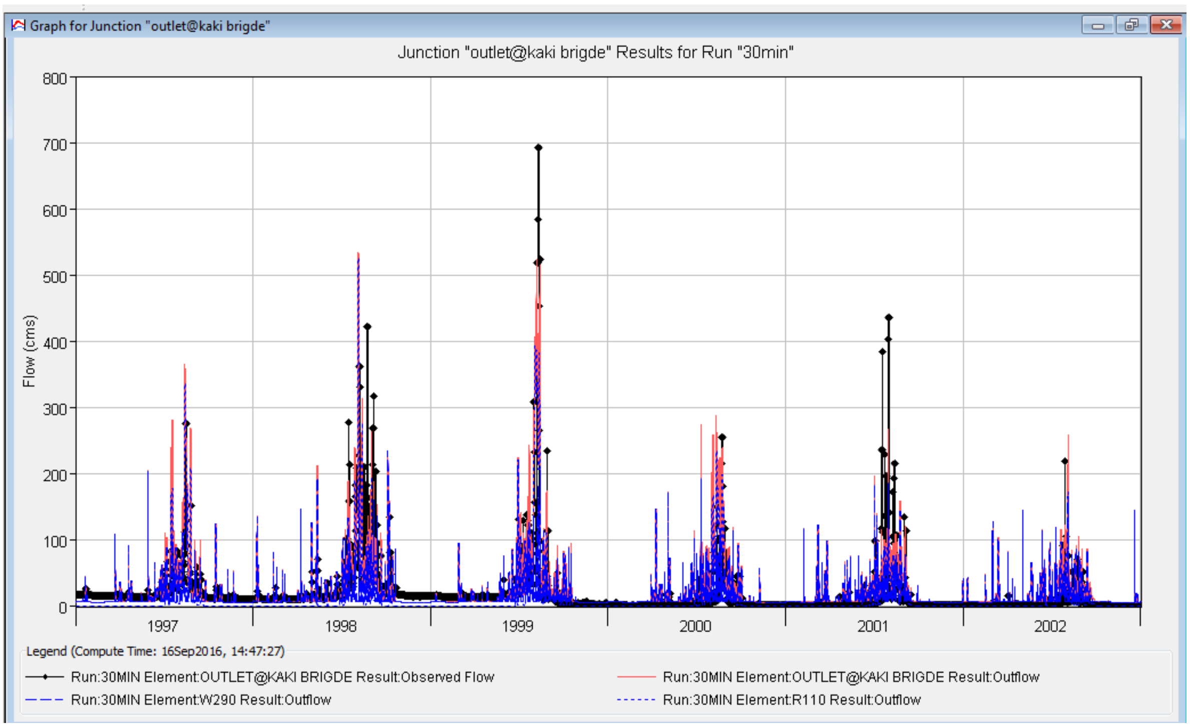


Fig4.8: HEC-HMS observed and modeled hydrographs of 1997-2002 at Akaki Bridge

Correlation coefficient of observed and simulated comparison observed and simulated monthly hydrograph as shown on fig 4.9 below

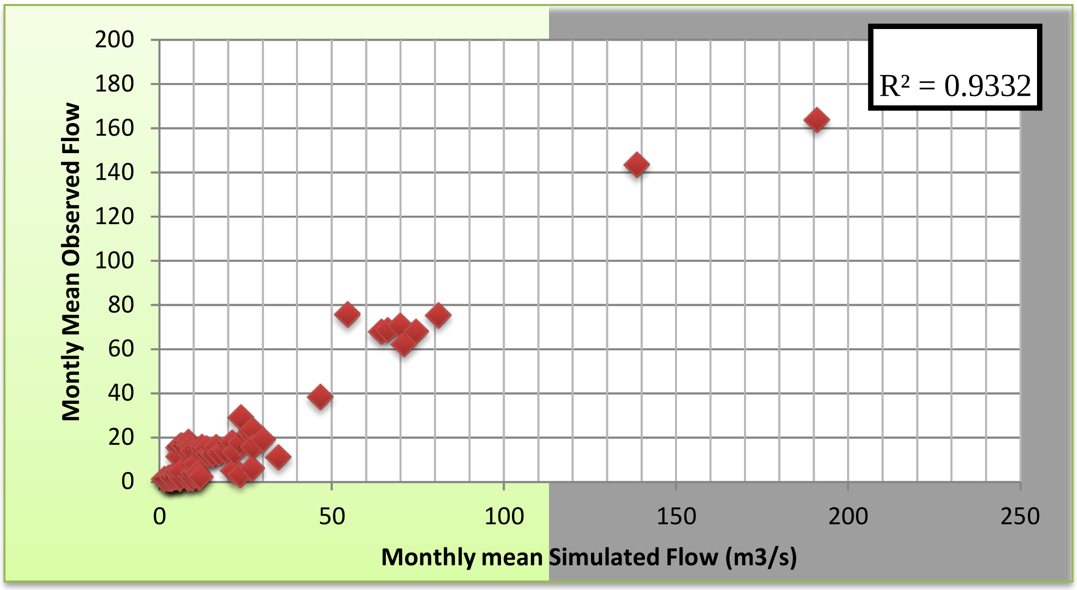


Fig. 4.9: Correlation Scatter Graph of Observed and Modeled Monthly Mean Flow

The output from manual calibration performance evaluation by hydrographic flow comparison, correlation and statistical performance goodness-of- fit defined in methodology parts. The daily and monthly flow comparison of time event from 1997 to 2002 of observed and modeled at outlet big Akaki basin compared by graph as seen on fig 4.7. The statistical performance evaluation measures obtain for hydrometric station. The percentage error in peak flow, PEPF, is very low and 14.3%. The second measure, the percentage peak in volume, PEV, is high a (37.36%) and Scatter graph cross-correlation coefficient is 0.93, and above figure 4.9 suggests a very good correspondence between the modeled and observed hydrograph ordinates. Table 4.3 compares the statistical measures obtained for each event at outlet location. The correlation efficient *CO*RR and percent error in peak flow, *PEPF*, in period showed a good result.

Table 4.5: Statistical Performance Measures of Calibration and Validation (1997 - 2005)

	Statistical Performance Measure: Model Evaluation				
Event	***PEPF[%]***	***PEV[%]***	***CORR[-]***	***RBAIS [%]***	***RPWRMSE [%]***
Simulation (1997-2002)	14.13	37.36	0.93	73.79	0.86
calibration and validation (2003-	0.24	29.27	0.941	35	0.88

2005)					

4.2.2. Verification of Result

Model verification is a process of testing model ability to simulate observed data other than those used for the calibration, with acceptable accuracy and the Parameters are kept constant without any change. The quantitative measure of the match is again the degree of variation between computed and observed hydrographs (Juraj M., et al., 2004). The summer from 2003 - 2004 and 1999 rainfall-runoff events were chosen for the verification of the single-event hydrologic model to determine peak discharge. The result is on figure below shown in the summary of result. The peak mean square root, average residual of statically tool is expressed HEC-HMS result window configuration. The measured and observed peak flow during calibration and validation of model compared for rainfall event of 2003 to 2004 and event of August 2004 are in table 4.4 shown below.

Table 4.6: Simulation Result of HEC - HMS during Validation (2003-2004)

Measure	Simulated	Observed	Difference	Percent Difference
Volume(mm)	1130.25	874.3	255.95	29.27
Peak Flow(m^3/s)	419.6	420	-0.4	-0.095

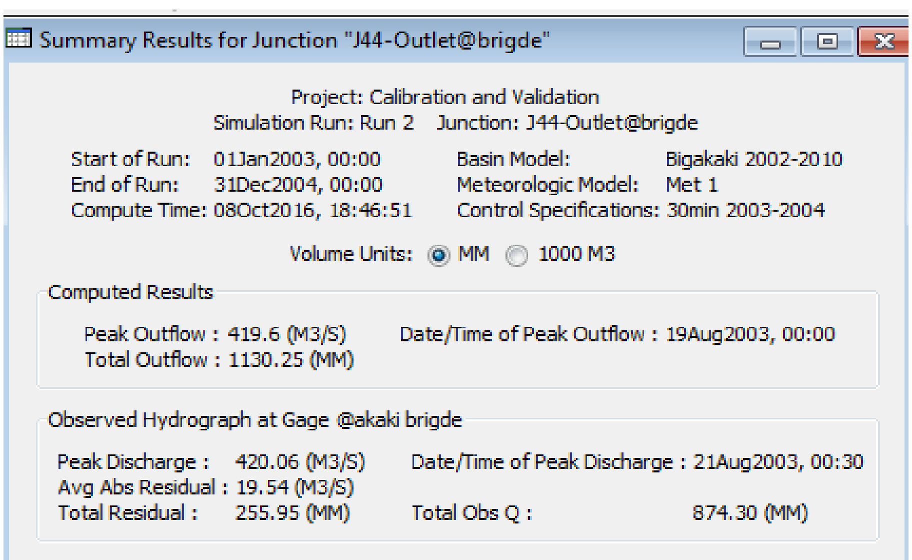


Fig. 4.10 Summary Result of HEC-HMS during Calibration and Validation Event

Table 4.7: The statistical Tool of Model Performance Evaluation Result

	Statistical Performance Measure: Evaluation Of Model				
Event	***PEPF*** ***[%]***	***PEV*** ***[%]***	***CORR*** ***[-]***	***RBAIS [%]***	***RPWRMSE*** ***[%]***
Calibration And Validation (2003-2004)	**0.10**	**29.27**	**0.941**	**35**	**0.88**

4.2.3. Sensitivity Analysis Result

Using rainfall- runoff data of summer event of 2003, 2004 and 2005, the sensitivity analysis applied to the subbasin of kebena parameter. These seven parameter of the event model subjected to the sensitivity analyses are SCS CN loss model and SCS tranform model parameters. SCS CN loss model parameter ara composite curve number CN, which accounts for event landuse land cover change , initial bstraction and percent impervous of land cover. The SCC trasform model sensitivity of parameter change in lag time was done to see the baseline hydrograph and generated hydrography shows difference. The model parameters change

increased/ decreased by 5%, 10%, 15% and 20% , then percent error peak flow and percent error volume were analysed. The percent error in peak flow is high when comparing to the baseline peak flow sensitive to the CN and percent impervious area of kebena watershed. The impervious area lag time sensitivity is moderate to peak flow change thus 5% impervious area change is in16m^3/s increase in peak flow. The change of CN of 5% and 10% were observed the change of 11.42% and 19.62% increase in peak volume respectively. Curve number parameter is more sensitive to basin rainfall to runoff change from baseline hydrograph. The lag time is lag the peak flow earlier than observed hydrography peak flow and have influence on flow volume by 32%. The calibration and verification result is similar according to the correlation coefficient result of 0.93 and 0.94 respecively. The sensitivity result of watershed of kebena for rainfall event AEP of 2. 5, 10, 25, 50, 100 years return period are done by adjusting on met model to one basin model of hec-hms and total of 5 basin model and 5 met model are created.

4.2.4. Hydrographic Result for Annual Exceedance Probability Hyetograph

Result Kebena Watershed_1:- Using the annual maximum daily rainfall as 24 hours duration storm of AEP 0.01, produced peak flow. Though registered rainfalls are over 24 hours, the actual duration of the storm will normally be much less than 24 hours and will include all or nearly the entire recorded 24-hour rainfall amount. For this reason, three options considered for meteorological modeling daily maximum cumulative precipitations. The rainfall of 100, 50, 25, 10, 5 and 2 AEP simulated to produce peak flow. The calibrated and validated basin parameters were used model simulations with respect to percentage change impervious area of a watershed. The peak flow produced of 0.02 AEP are 294.3m^3/s, 305m^3/s and 320.2m^3/s for land cover change of 1995, 2002, and 2009 respectively. The result graph summarized below. The maximum rainfall event of annual maximum 0.02 AEP exceedance values analyzed percentage change of landcover-produced hydrography shown in fig. 4.11 below.

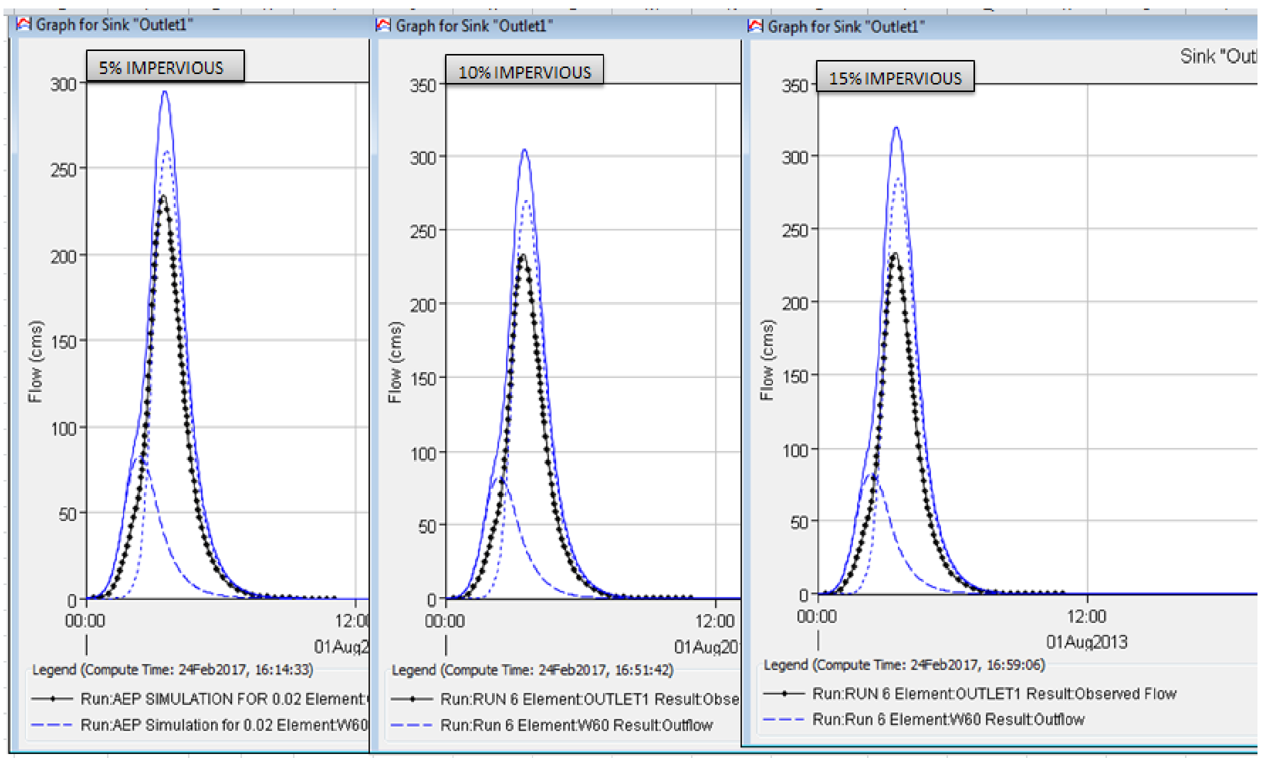


Fig.4.11: Time Series Hydrograph of 0.02 Exceedance Annual Maximum Daily Rainfall (AEP)

As shown on graph the of 50 years return period peak flood increases 3.44% (294.3 m^3/s to 305 m^3/s) in the first phase change of imperviousness (increase of urbanization at upstream, 7.43km^2 to 10.47km^2). The second phase 50 year return period of peak flood increased by 4.91% (from 305 m^3/s to 320.2m^3/s because of increase of urbanization by 3.37km^2. This peak discharge will occurred once in 50 years of return period. Comparing with the existing stormwater management infrastructure capacities, it is not sufficient capacity to manage the quantity and quality of stormwater. The only Flood management system in the study area is stormwater drainage line in which all collect rainwater and drain to stream. Because of under designed conveyance system, flood impacts observed in flood prone areas every year. As research revealed (URadapt, 2012), existing drainage infrastructures may not cope with the situation and flooding may affect already vulnerable communities. As research on drainage and infrastructure found that the return periods of peak floods have changed, so the design guidelines for drainage infrastructure have to be revised, ten year return period of flood in the 1990s of is equal to two year return period flood in the 2030s (Semu. A, et al. 2013). The found of because of main impact of climate change flood and as the same time increase of runoff coefficient.

Result Kebena Watershed_2:-Peak hydrography and global summary result of 50 year AEP of 0.02 annual exceedence value rainfall shown in figure 4.7 below. As we can see from the result, the maximum flood discharge at the outlet is 294.5.2m^3/s observed for 10% change of impervious area from base. The 50 year AEP precipitation model Peak flow discharge as shown on fig. 3.12 below.

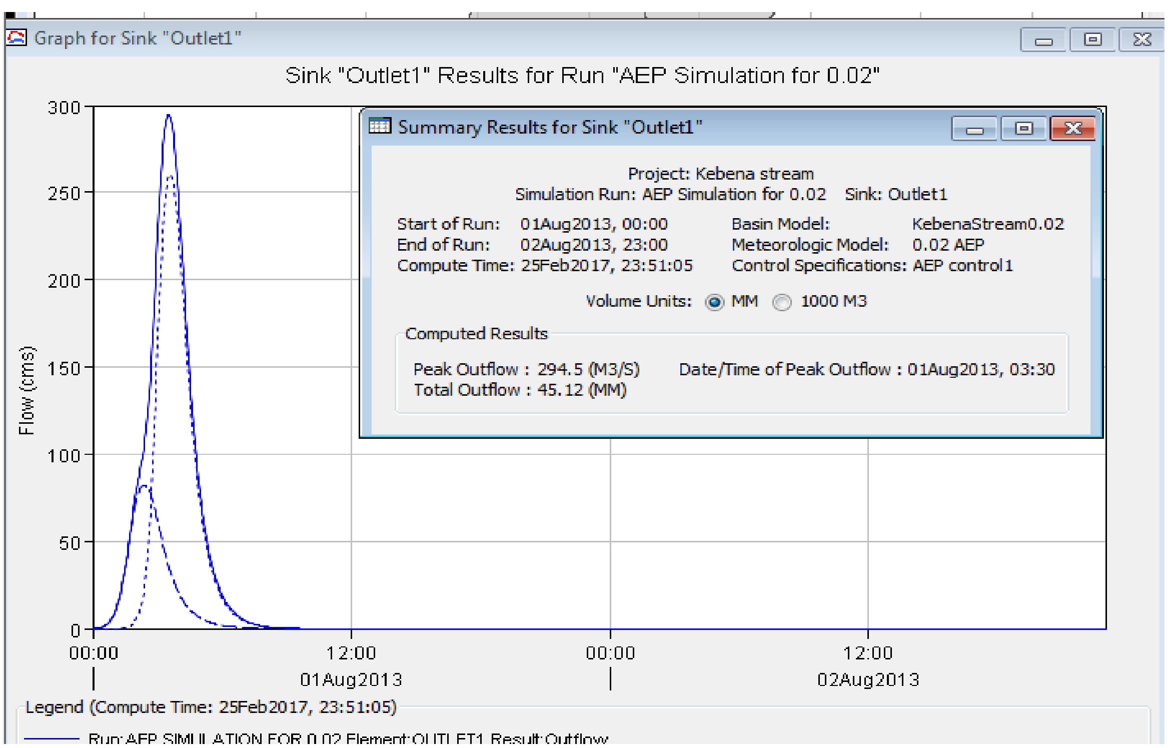


Fig.4.12: Hydrograph of 0.02 Exceedance Value Annual Maximum Daily Rainfall

Result Kebena Watershed_3:-Hydrologic Elements‟ Summary of sink outlet result for 25(0.04) year return period of time series table and hydrograph. The AEP of frequency storm of 25 year return period produced the maximum peak discharge at the outlet is, 209m^3/s in 1995, 238.1m3/s, in 2002 and 262.6m^3/s in 2009. The AEP rainfalls created storm of 0.01, 0.02, 0.04, 0.10, 0.2, and 0.5 meteorological model were included into to five copy of basin model created for individual storm frequency event. The global parameter editor was used to change the percentage of impervious area every 5% in basin model parameter of loss. The simulation run created to see the percentage change of peak flow corresponds to percentage imperviousness of land use. After simulation of run the peak flow to each meteorological model evaluated and shown the graph in the sensitivity analysis.

4.2.5. Sensitivity Analysis of Model parameter

The flood prone areas were delineated using GIS spatial analyst tool. The purpose of identifying such flood prone areas was to synthesis in identification and reduction of the flooding problems. The proposed alternative is future low impact development in which mitigates flooding, wastewater quantity and quality management from the HEC-HMS result the summary of peak discharge for percentage impervious change from base at outlet of catchment is shown on the fig. 4.13 below.

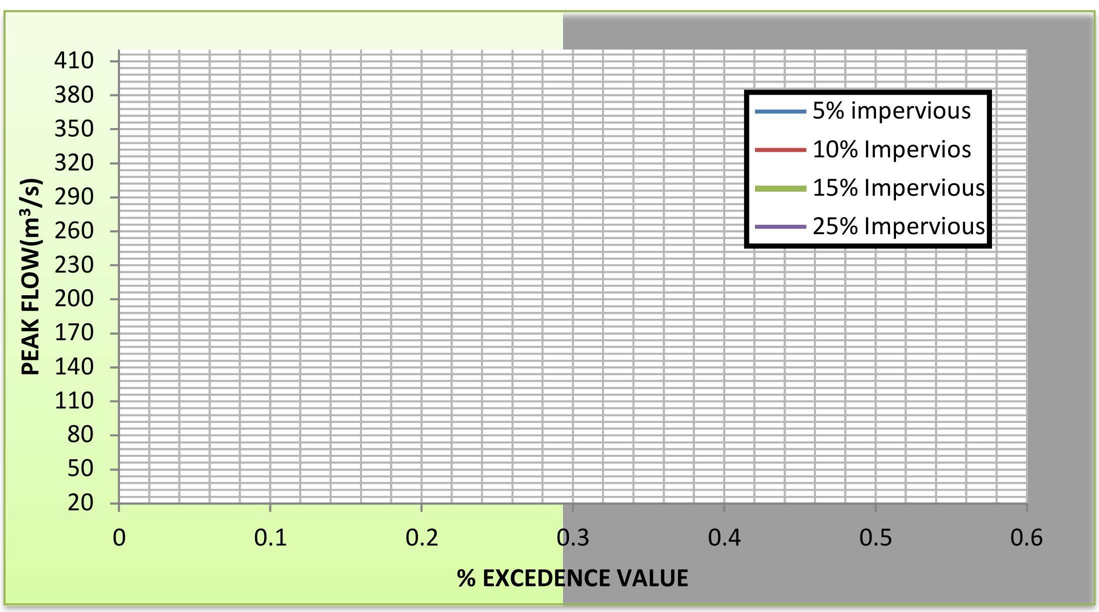
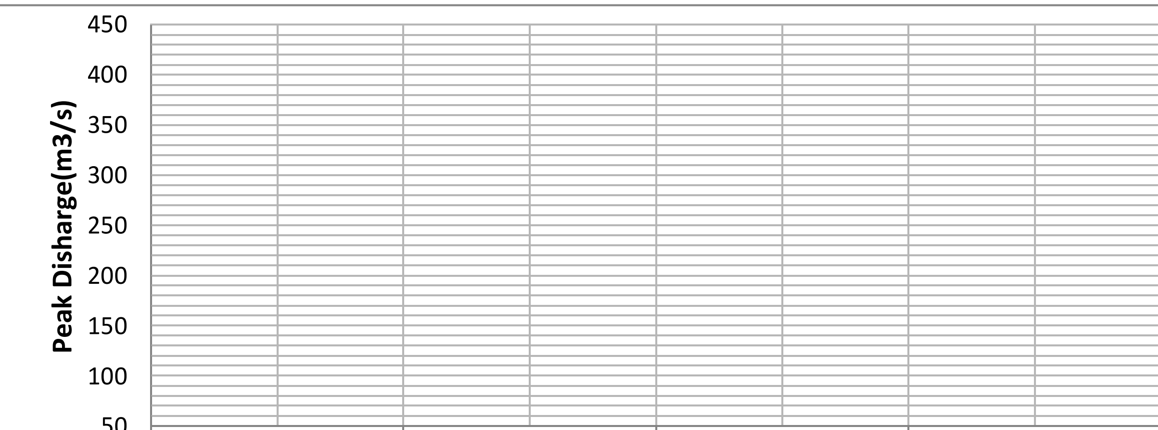


Fig 4.13: Peak Discharge of Extreme Rainfall Response of Percentage Impervious Area

The buffer zones of drainage infiltration system, treatment terrain and WSUD have ability of flood reduction. The suggested measures for adaptation to flood impacts (URadapt, 2002) develop best management plans that focus more on flood absorbing than flood removing (IUFM) – through distributed beneficial ponds, infiltration galleries, green areas, water harvesting etc. the suggested measures have ability of flood removing. The ability test modeled through HEC-HMS software. The green area, infiltration system, landscape form, water harvesting, vegetated swales are permeable land cover. The applications of best management practices in river buffer zone are reduce the flood, convey stormwater, treat stormwater, and reduce wastewater/demand reduction. It also removes pollutant concentration as the same time environmental amenity. Model response to land use land cover (percentage impervious) of extreme rainfall as shown on the figure 4.14 below.



% Imervious	2	5	10	25
100	347.5	358.6	384.9	416.5
50	264.3	273.2	294.5	320.2
25	209	220	238.1	262.6
10	156.8	164.7	184	206.8
5	104	111.2	128.5	148.9
2	70	76.8	93.1	112.5

Fig.4.14: Peak Discharge to Model Response of Land Use Land Cover at Different Urbanization

Most but not all precipitation falling over impervious surfaces becomes direct runoff. The land cover change from original state to urban impervious percent change of 5, 10, 15 and 25 given different peak and volume of runoff. Change imperviousness from zero to 25% increases the peak runoff rate by 20%, 60.7% for rainfall of 0.01 and 0.50-percentage exceedance probability. The existing peak of stormwater shown in the graph is useful to apply on the integrated stormwater management technical option. The existing Drainage infrastructure is only conventional Drainage and natural stream channel may not cope with the situation and cause over flooding.

5. Urban Water Demand and Wastewater Generation

5.1. Level of Domestic Water Connection Coverage

For the purpose of evaluating of water consumption by mode of service, Kebele house unit, 12 kebeles were selected that their blocks were merged and dissolved using ArcGIS in order to create Kebele boundary and count number of house point in kebele.

Table 5.1: Water supply Coverage and Connection per House Unit in Kebele (2014/15)

kebele	1	2	3	4	5	6	7	8	9	10	11	12
No. of House	1321	1169	998	1889	859	1712	1972	1658	1215	1001	1961	1258
No. of connection	481	713	1835	640	506	599	683	626	555	657	618	336
Number Conn/HU	0.36	0.61	1.00	0.34	0.59	0.35	0.35	0.38	0.46	0.66	0.32	0.27

The domestic connection per house unit is calculated 0.34 lower to 0.66 higher. The connection distribution percentage is covered more than three house units per one connection and the more or less connection could influence the water demand in kebele. This means a minimum of 3*5.1=15.3 number of person sharing single water line connection. In order to get a realistic average daily per capital consumption of the in Kebena catchment kebele it was necessary to exclude both higher and lower extreme values both for per capital consumption and connection per family residing in house unit. For accurate result the analysis is take for 5 consecutive year data is analysis on each month billed water for coverage of 12 kebele.

5.1.1. Average Daily Per Capita Consumption Result

The 72 months of 6 years billed monthly consumption data has been converted monthly volume for respective kebele. The average daily per capita consumption calculated using the number of population in kebele. The annual volume of consumption of each kebele also calculated. For sake of accurate qualitative data analysis, the monthly-billed consumption volume collected for period of five years and analyzed. The monthly billed volume of water of each kebele were divided to the population of kebele to give average daily per capita and result is shown in the following descriptive statistics graph in figure 5.1 below, which compare the results. The average per capita consumption is 26.7l/cap/day.

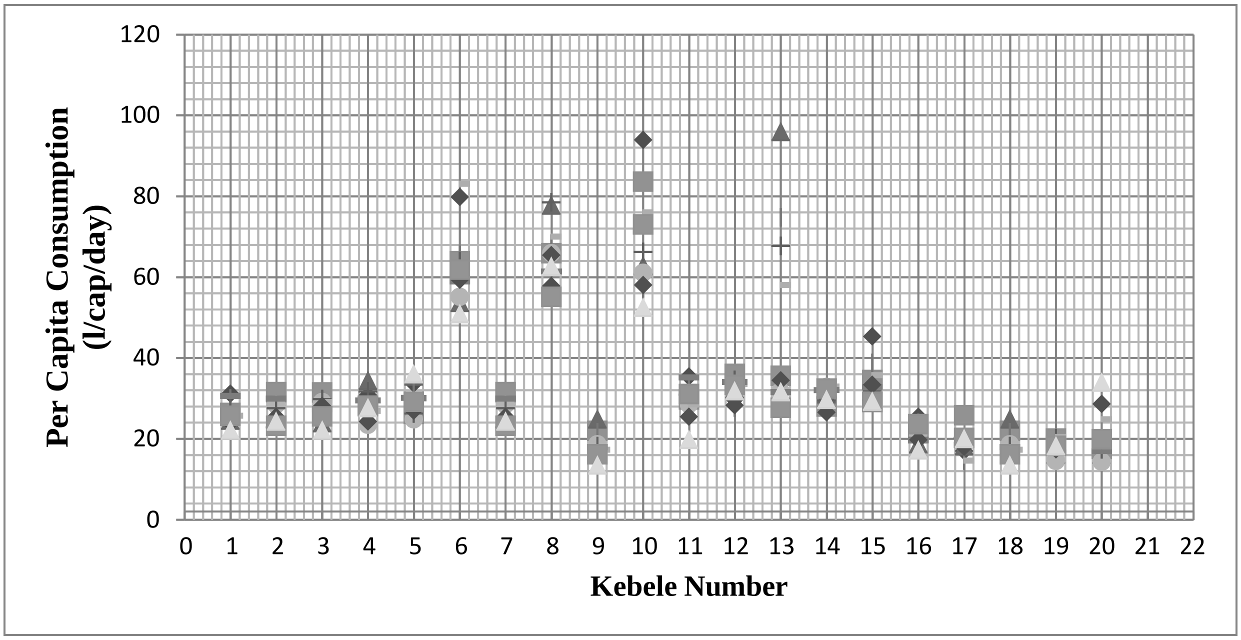


Fig 5.1: Average Daily Per Capita Consumption by Kebeles (Symbol, i.e. x-April)

The distribution of the water consumption varies among, kebeles as well as among season of the year. The variation of consumption is dependents on availability of waters supply delivered to each kebeles of sample study area as. The variation of consumption are shown for kebele 6, 8, and 10 area shown outlines and for rest of kebele are the same per capita consumption. Excluding outliner and the average consumption of kebele, taking the mean annual consumption as shown on graph 5.2 below, the average domestic water coverage of the study area is found to be 26.74 l/cap/day.

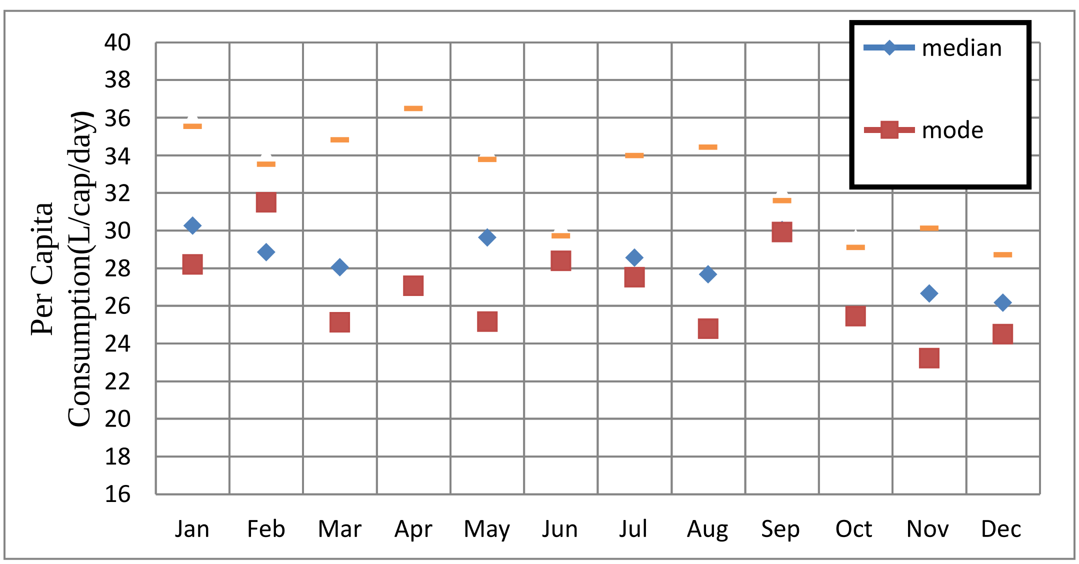


Figure 5.2: Average per capita Consumption of Kebeles on Different Season

More or less the variations is observed in all kebeles but particularly in kebele 6, 8, and 10, per capita is higher and varies among season of the year. On the one hands these kebeles are having better average consumption while compared to the others and per capita variation on month of season in kebeles. For variation of consumption on months of season is may help to understand the availability rate of water supply, climate condition effect and living standard of each population residing in kebeles. Average daily per capita consumption of the area is low while compared to per capita by mode of services. Accuracy of results is compared to reviewed paper of the AWWSA business plan report of study shown that the per capita consumption of consecutive year of 2005, 2006, 2007, 2007, 2008, 2009 and 2010 are 24, 25, 25, 26, 28, and 29 L/cap/day respectively. The growth rate is 4% of annually and the result above have similar to this context. Within the monthly consumption volume trends per capita demand consumption of kebele, exponential formula developed as shown below.

LPCD= 0.572M + 36.87 L/cap/day, where M is month in the year for Jan =1, Feb =2.

5.1.2. Determining Per Capita Consumption by Mode of Service

The per capita domestic demand by mode of service determined using percentage of house unit connected to low, medium, high volume consumed in month. The excel filter categorized the volume, block type consume water volume. The house units consumption per connection is filtered to the different modes of billed volume of water as monthly amount [2m3-3m3] as low1 consumption, [3.8m3 - 5m3] as low2 consumption, [17.8m3-22.4m3] as medium consumption and [15.2m3 – 19.2m3] high consumption per connation. The domestic per capita demand by mode of service bar diagram as shown on fig. 5.3.

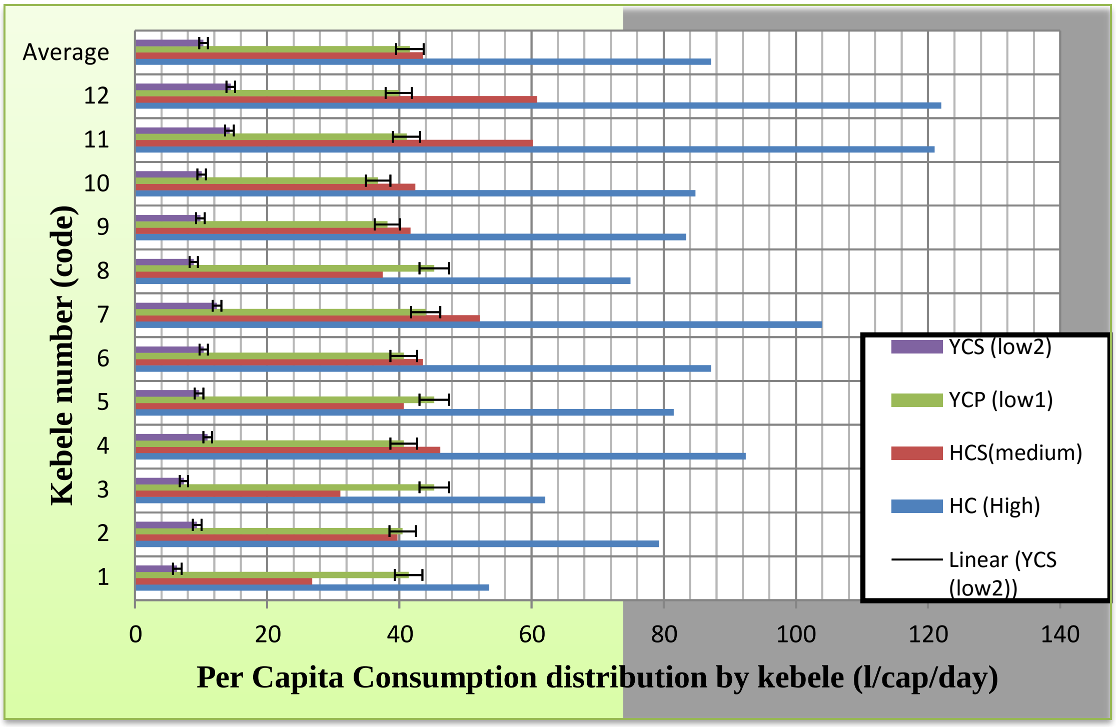


Fig.5.3: Daily Domestic Per Capita Consumptions by Mode of Service 2014/5

The result shown above is the daily water consumption aspect evaluated was mode per capit consumption at kebele house unit. Consumption of house unit is defferrent from one kebele to another. Excluding extreme values of result the of each month consumption, the monthly result analysis is converted to the year and the five year period of consuption mode is evaluated. The average percapita consumption by mode of service that of study area were found to be 82.9l/cap/day (high), 41.48 l/cap/day medium, 21.06 l/cap/day low and 9.88 l/cap/day. The average of five year per capita consumption by mode of service is shown table 5.1 below.

Table 5.2: The Average of Five Year Per Capita Consumption by Mode of Service

Consumer Category	High (HC)	Medium (HCS)	Low 1 (YCP)	(YCP) Low 2
Per Capita Consumption (l/c/day)	**82.97**	**41.48**	**21.06**	**9.88**

5.2. Existing Wastewater Quantity Analysis and Infrastructure Evaluation

The existing sanitary sewerage canal and stormwater drainage canals are separated system. It is very difficult to differentiate the storm drainage designed to collect rainstorm runoff from that of sewer lines collects wastewater flow. The position of wastewater sewer line of municipality is hidden unknown and difficult to get sewer network data map. With help of AAWSA sewer line connection team the extracted data and house unit connection to sewer line is analyzed. The data from AAWSA is help to get number of sewerage line connection in area. To know wastewater load per day the sewer connection in residential area is necessary. According to Bill data of Addis Ababa water Supply and sewage authority the percentage of household in block connected sewer line were shown in the table 5.2 below.

Table 5.3: Percentage of Households connection toilet flush to sewer line

Sub city in Watershed	Total House hold units (HU)	Percentage of HU using flush toilet sewer line
Yeka	57110	0.6%
Kirkos	2448	6.3%
Arada	14729	32%
Bole	4105	49.6%
Gulale	11528	6.1%

The sewage conveyance in watershed is old and outdated system of disposal and mostly used in villages / undeveloped urban areas. Dirty water, storm water, sewage flows in open drains and join natural stream.

5.2.1. Evaluation of Existing Wastewater Quantity Daily Flow Rate

The house unit connected to sewer line, which is shared to the parcel of building, are counted from the cadastral information of municipality. The count of house unit percentage connected to sewer line in Yeka, Kirkos, Arada, bole and Gulale sub city used to calculate wastewater generation. The household connection percentage of flush toilet to sewer line are, 0.6, 6.3%, 32.0%, 49.6%, and 6.1%, house unit connected to sewer at Yeka, Kirkos, Arada, bole and Gulale Sub city respectively. The streams also directly received untreated sewage from toilets, petrol stations, garages, industries, high concentration of nitrogen (8.9-531) mg/l, phosphorus, heavy metal pollution, total coliform and pathogen pollution. Sanitation services in the in study area are divided according to the disposal system, on-site and off-site wastewater disposal system. The existing sewerage line connected to housing unit for wastewater management system is not sufficient to the wastewater hydraulic load.

Table 5.4: The Percentage of Wastewater Infrastructure at Sub City in Drainage Area

Sub city	Total HU	Percentage of HU using flush toilet sewer	Public HU connection (No.)	NON domestic connection	Institution/public	Industrial
Yeka	57110	1.0	342.66	13.71	7.26	6.44
Kirkos	2448	8.0	154.22	6.17	3.27	2.90
Arada	14729	32.0	4713.28	188.53	99.92	88.61
Bole	4105	49.6	2036.08	81.44	43.16	38.28
Gulale	11528	6.4	703.21	28.13	14.91	13.22

Type of landuse land cover (residential, commercial and public) affects quantity of sewage flow because of this quantity of sewage in industrial, commercial and residential area cannot be the same. From table 5.2 the sewer line connection in bole is higher comparing to other, so that the wastewater load is higher. Arada has 32.0% coverage of sewer line connection because the area has high number of public institution comparing to the Yeka and Kirkos. The wastewater generation load of Arada is higher than other sub city.

Quantity of sewage can be expressed liter per person per day and multiplied by population to get the total sewage quantity. The waste water rate was high for Arada, and bole than Yeka Gulale and Kirkos sub city. House unit flow rate and total sewer line connection unit as shown in table 5.3 shown below.

Table 5.5: Existing Wastewater Flow Rate to Sewerage Line in Kebena Drainage

	Total Wastewater Flow (Domestic and Nondomestic)(m3/day) of sub city						
Sub city	2007	2010	2011	2012	2013	2014	2015
Yeka	124.96	133.08	135.90	150.99	141.70	144.74	147.82
Kirkos	56.24	59.90	61.17	67.96	63.78	65.15	66.53
Arada	1718.79	1830.56	1869.36	2076.86	1949.11	1990.96	2033.23
Bole	742.50	790.78	807.54	897.18	841.99	860.07	878.33
Gulale	256.44	273.11	278.90	309.86	290.80	297.05	303.35
Total wastewater (m^3/day)	2898.93	3087.44	3152.87	3502.84	3287.38	3357.97	3429.26
Total house Connection to sewer line	7783.95	8290.11	8465.82	8647.96	8827.00	9016.53	9207.94

The wastewater discharged to offsite sewer line like urban drainage and storm drainage were observed high for Yeka and Gulale and Kirkos. From 2010 to 2015 there was seen 18.28% – 20.0% percentage increase of domestic sewage and the existing capacity of infrastructure is only 20 percent of waste water flow rate load. Rate of increase in water demand and subsequently sewage increase with rise in population and city population increases since peoples are attracted by economic development in the urban areas. From water demand analysis, per capita demand has shown no significant percentage of improvement. So the wastewater generation increased direct of population growth. The urban development increased by 1% per year to building human settlement. If there is economic development, consumption of water per capita increase hence sewage. The wastewater generation rate per day from different sub city in the study area is spatially located and shown as on fig 5.5 below.

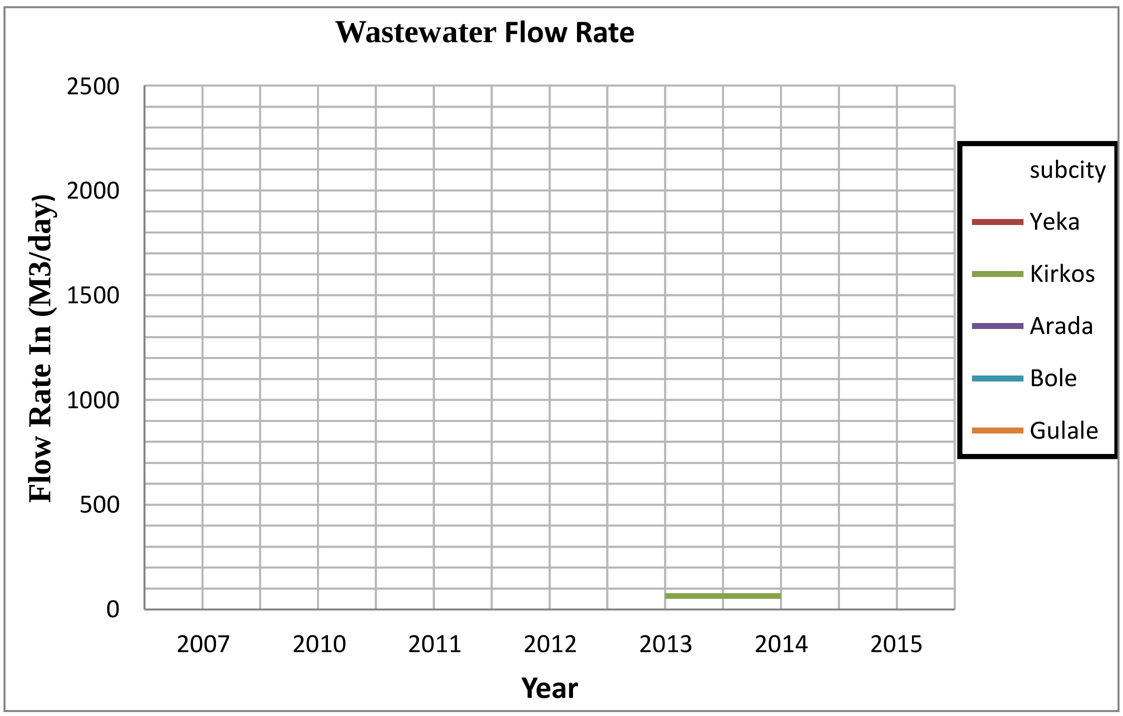


Fig. 5.4: Spatial distribution of Wastewater Flow Rate of Sub City in Drainage Area

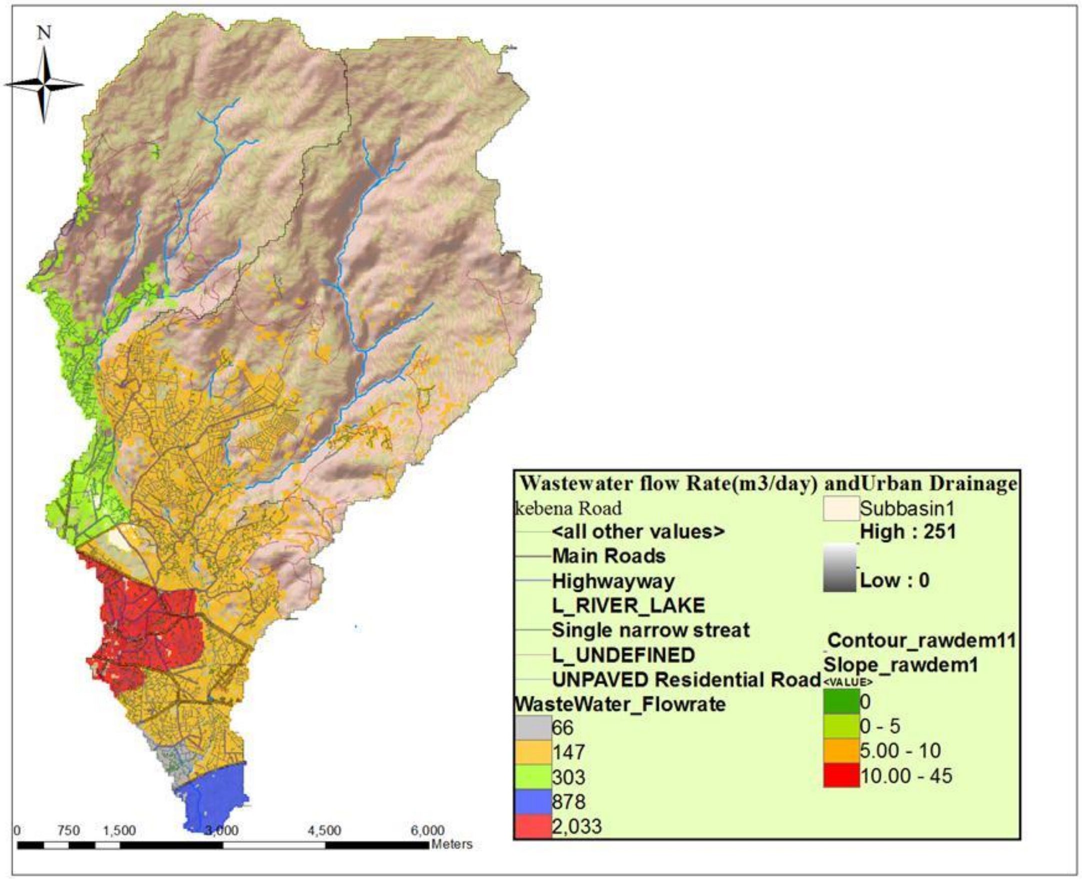


Fig. 5.5: Wastewater Flow Rate Evaluation and Integrated Site Suitability Criteria map

5.2.2. Analysis of Wastewater Flow Generation of Demand Projection

With increase in number of population will increase in wastewater demand generation and subsequently sewage increases. City population increases since people are attracted by economic development in urban areas and if there is economic development consumption of water per capita increase, hence sewage production that the percentage increase 18-20 % percentage but the facility capacity of sewer line is still at 10% of Rate of flow. This cause natural stream pollutant flow, very nuisance and groundwater pollution contamination. The flow rate and infrastructure capacity evaluated is shown on fig 5.6 below.

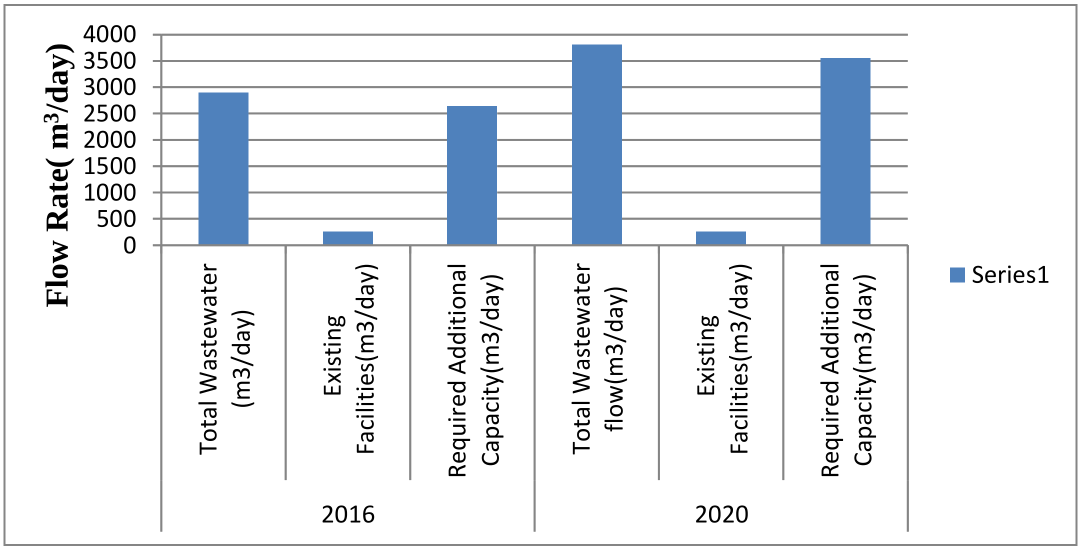


Fig.5.6: Waste Water Generation Rate and Infrastructure Capacity

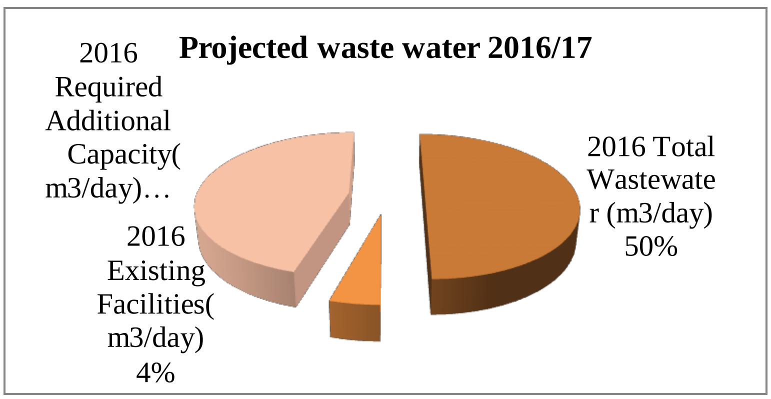


Fig.5.7a. Percentage of infrastructure capacity existing and required

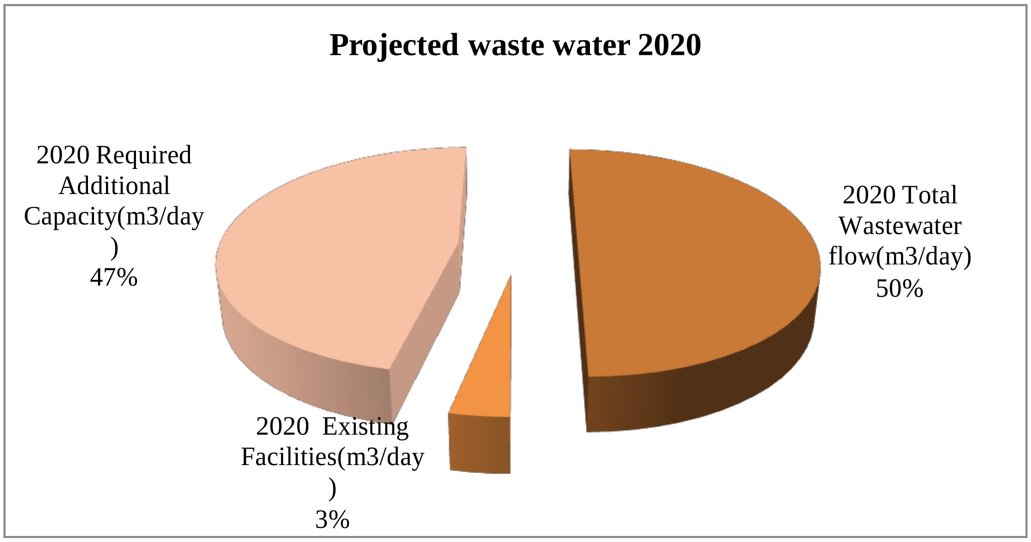


Fig.5.7b: Percentage of Infrastructure Capacity Existing and Required of 2020

As this research paper revealed the capacity of existing waste water collection facility is not sufficient to collect existing wastewater quantity projected. The capacity of existing wastewater infrastructures were less than 20% of wastewater volume produced per day facility required. The wastewater is simple released to the urban natural drainage so that dry flow of stream is only the sewage and pollutant contaminant. To overcome such problem low impact development option is the best management of urban drainage rather than conveying to the separated sewer line and urban open channels in the residential area. Because of this in opened trapezoidal channel sewer line in the resident is cause overflow during blockage of line by solid waste in many residential areas.

- Existing storm Drainage and sewerage line infrastructures may not cope with the existing quantity and quality of stormwater and wastewater respectively.
- Flooding may affect already vulnerable communities in the flood prone areas of watershed specifically at around kilo and amist kilo.
- There may need integrated urban wastewater and stormwater management option like treatment terrain, buffer zone of stream, and regulation on management option.

5.3. Land Suitability Analysis of Integrated Stormwater Wastewater management

Land Suitability of for Low impact development, such WSUD and best management practices were analyzed. Land suitability methodology used were environmentally suitable land, topography, hydrology, geology, soil type, landuse land cover and meteorology are constraints as input to evaluate assess IUWM system. The analytical map of Kebena landuse land cove, permeability of soil, percent impermeable area, elevation, slope, aspect, ground water table, and infrastructure (main road, unpaved district road, cobblestone, secondary road paved road line, sewer lines) are extracted from primary and secondary data and weighted overlay to give suitable land infrastructure.

5.3.1. Landscape Scores of Suitability Factors

Without a proper understanding of a site, it is unlikely that any application of WSUD will be successful. This understanding of a site is best conducted by field spatial assessments – there is simply no substitute for „kicking the dirt" if the opportunities and constraints of a site are to be properly understood. Suitable class scoring system is to determine the potential risk of WSUD implementation. Scoring factors used in suitability analysis can be measured using interval or ratio values (scores) or ordinal values (score classes). The choice of either scores or score classes can markedly influence the efficiency of scoring factors Ordinal values, as the name suggests, implies an order or ranking among factors. The order may be either ascending or descending according to the application. In addition, a ranking implies on an ordering among factors but nothing more. Ordinal value is a kind of qualitative measurement scales that are often used, especially in environmental decision problems.

5.3.1.1.Specific Suitability of Slope, Soil Permeability and Topography

Data of digital elevation model of 30mx30m were extracted from the Aster Dem and analyzed the physical constrain elevation, slope, hill shade and aspect. These physical data of Kebena watershed were used as input and evaluated the areas used integrated management of storm water treatment terrain and low impact development of post project. The criteria explained in the table 4.5 below shows that the flat slope is Vern arable to flooding, and the slope greater than 10% is best to option of treatment terrain like wetland vegetated swales, pervious pavement, infiltration trench, basin wet pond, and ground water storage. The slope between 5 % and 10% is best criteria to choose the vegetated swale and buffer strips at core area of stream and road side of highway. The river buffer at the specific position of stormwater treatment and management were analyzed and shown on figure 5.8 as shown below.

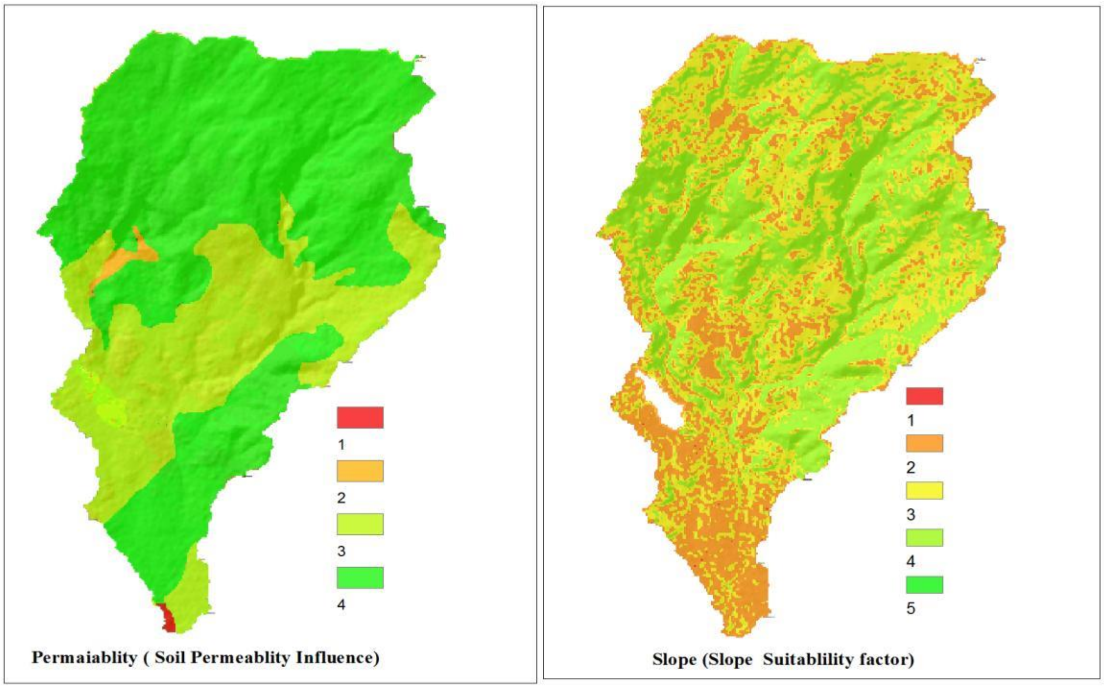


Fig. 5.8.Topographic Influence of Average slope, Permeability of Soil

5.3.1.2. Specific Suitability of Landuse and ground water vulnerability

The spatial characteristics watershed like Soil layer, geology and soil permeability and ground water table have identified. The influence over decision making process for integrated urban water management system, soils with less porosity and permeability is preferred to prevent ground water contamination from waste. But in longitudinal and latitudinal of Kebena stream drainage groundwater table is greater or equal to 3m below surface level, the permeability of soil is has no impact on ground water contamination. The map of permeability of soil is extracted from data and classified as very high, moderate, low and very low. The topographic analytical map of slope, aspect, elevation and stream buffer location were identified. The weighted spatial overlay model of soil permeability, slope contour, aspect of flood prone area analyzed to evaluate site specific land suitability of integrated urban water management system.

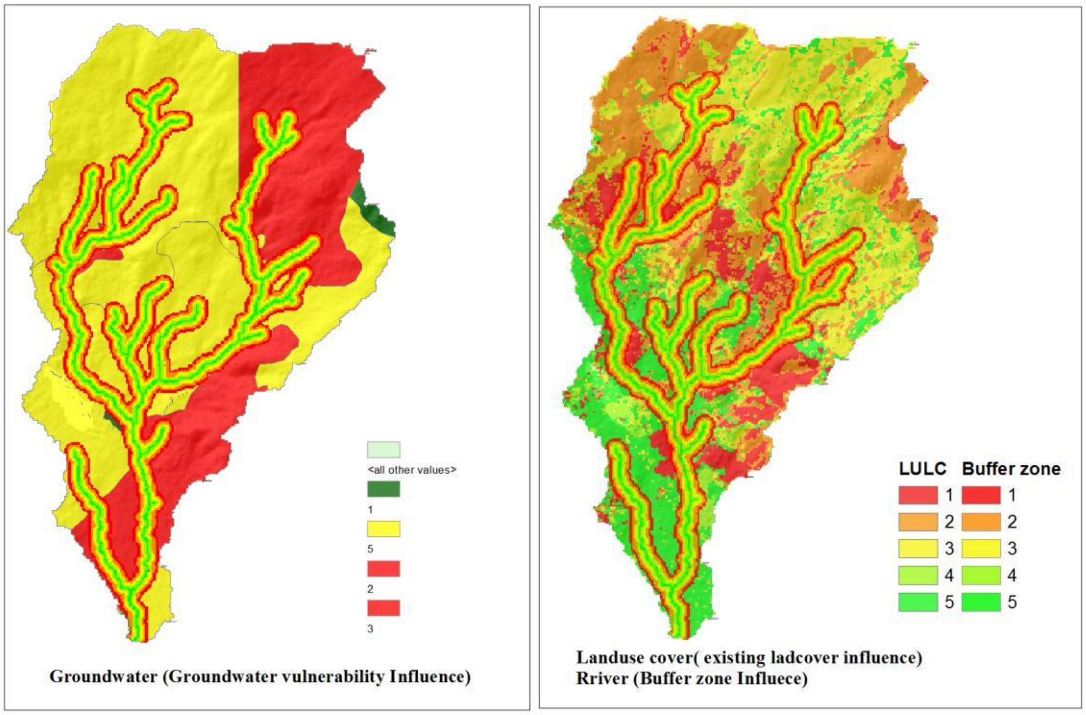


Fig 5.9 Landuse land cover, groundwater and buffer zone score influence

5.3.1.3. Buffer zones and Drainage line infrastructure Influence

The buffer zones are area legally established and long term protection to landscapes, ecosystem and species it contain. This area was analyzed by multiple ring buffer tools along stream cross section at distance of 20m, 40m, and 60m, 100,150m is buffer distance to landscape treatment terrain. The suitable treatment terrain of buffer area along stream cross section is vegetated swales, bioretention swales and buffer strips. The area in the figure below analytical map of flood plain, landcover and buffer zones at distance of 10, 20, 30, 40, 60, 100, 150 and 200m are analyzed to evaluate rainfall runoff change, pollutant load reduction when the treatment terrain explained were applied. The suitable landscape treatment terrain reduce pollutant load like total nitrogen removal, total suspended solids and total phosphorus and runoff reduction by percentage change of impervious area. From calibrated HEC-HMS result, as percentage of impervious area increased/decreased the runoff peak and volume were increased/decreased by 11.2%.

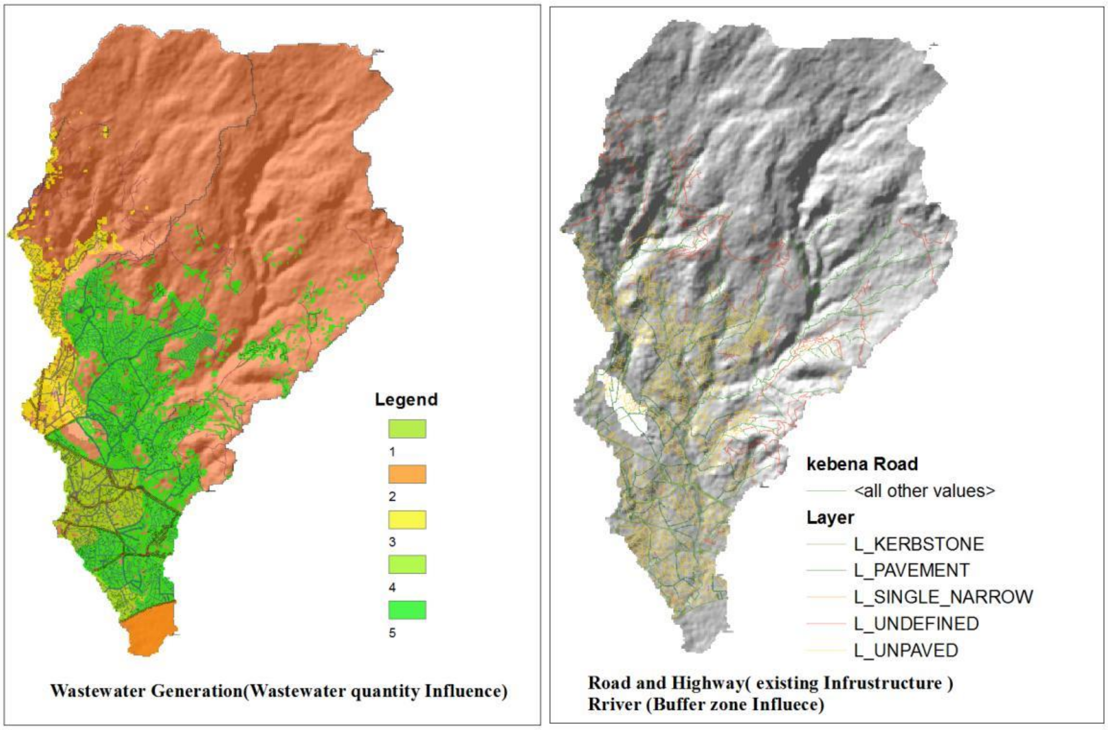


Fig. 5.10: Existing Wastewater and Infrastructure Influence

Table 5.5: Landscape Site suitability assessment criteria

Characteristic	Assessment Constraints of site suitable			At buffer zone specifi Area
	low	moderate(2)	High	
Imperviousness (%).	1 = 0-10%	2 = 10-50%	3 = 50-100%	Moderate (10- 50%)
Average Slope	1 = 2-5%	2 = 0-1%	3 = >5%	High (> 5%)
Developed Area	1 = <1ha	2 = 1-10ha	3 = >10ha	Moderate
Mean Annual	1 = <600mm/yr.	2 = 600-1200mm/yr.	3 = >1200mm/yr.	high (>1200mm)
Soil permeability	1 = 3.6-3600mm/hr.	2 = >3600mm/hr.	3 =<3.6mm/hr.	Low (area around buffer zone is built slum homes at down stream
Groundwater	1= >2m below surface	2 = 1-2m below surface	3 = <1m below surface	moderate from place to place
Salinity or Acid Sulfate Hazard	1 = Not in defined hazard area	2 = low to moderate hazard area	3 = high hazard area	highly hazard flow in buffer Zone

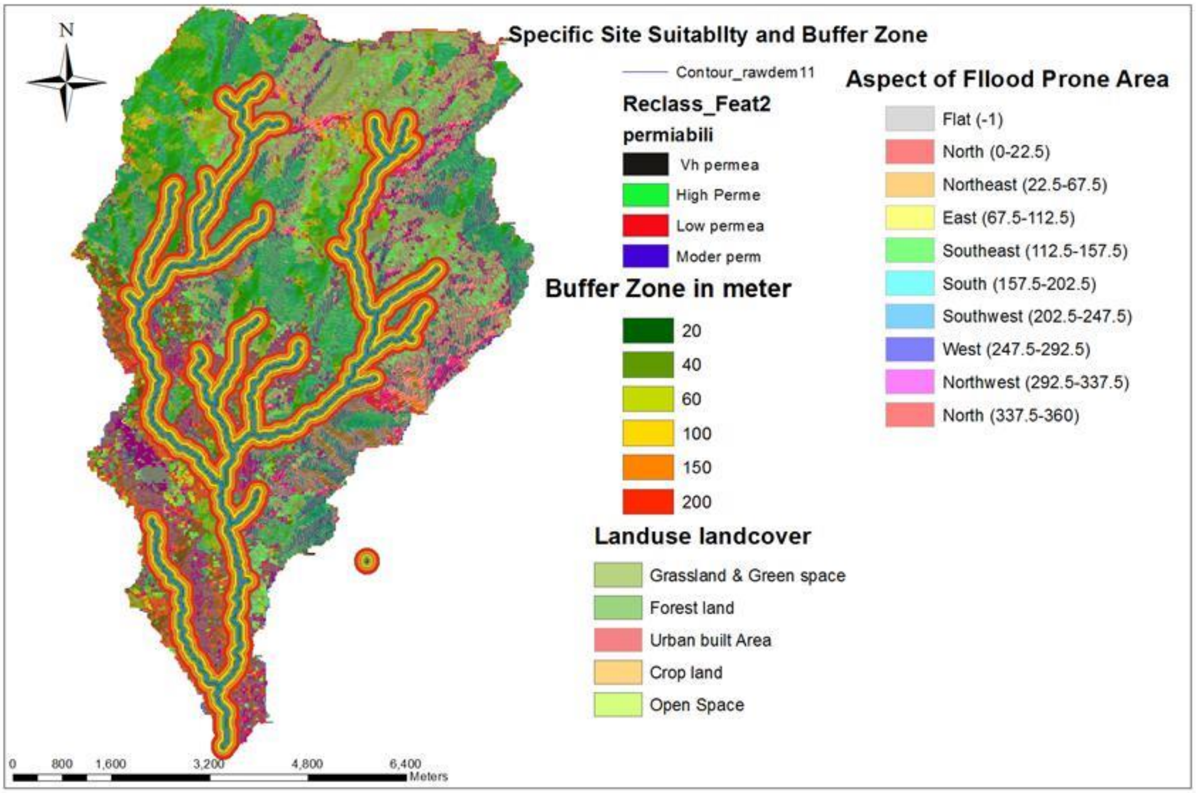


Fig 5.11: Landscape specific site suitability assessment polygons and weighted overlay map

5.3.2. Results of Suitable Integrated Urban Water management option Evaluation

As the suitable area is identified the following management option were selected against pollutant load were treated and specific site suitability criteria. The sediment basin and sand filter and pond and lakes have more suitability meet the integrated basin management at urban level as shown on figure 5.9 below.

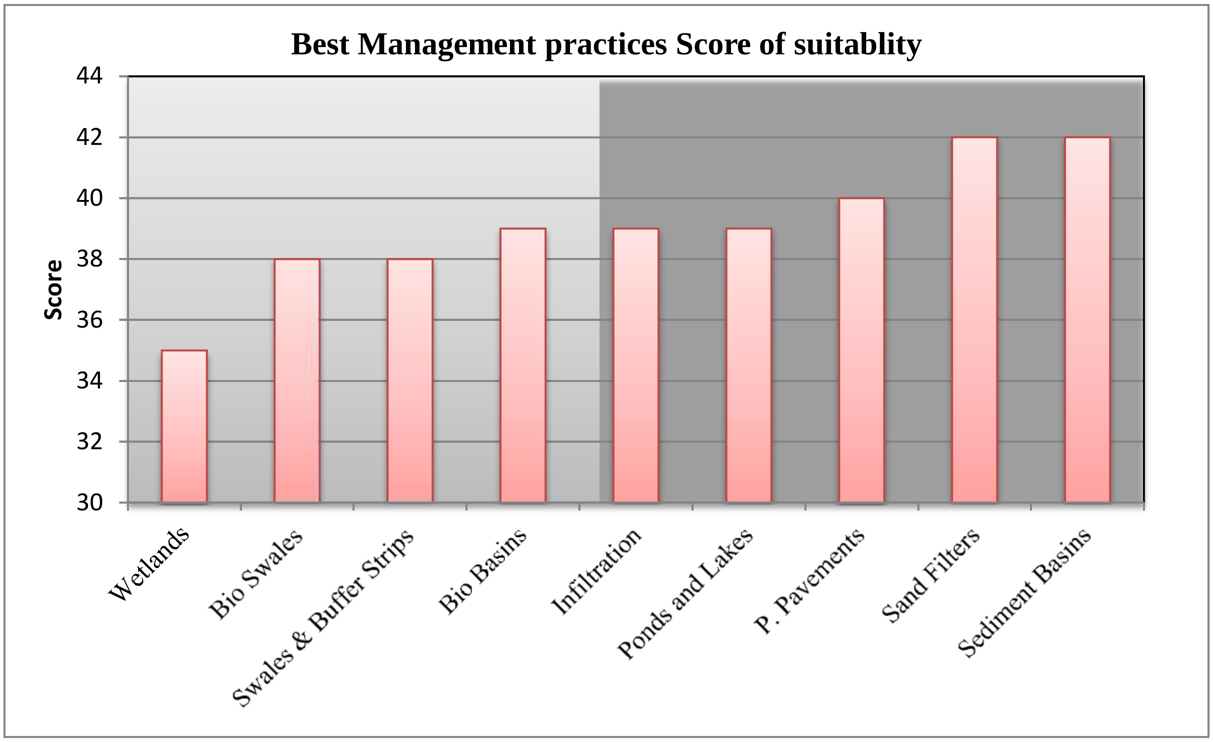


Fig 5.12: LID Best Management practice Score of Suitablity

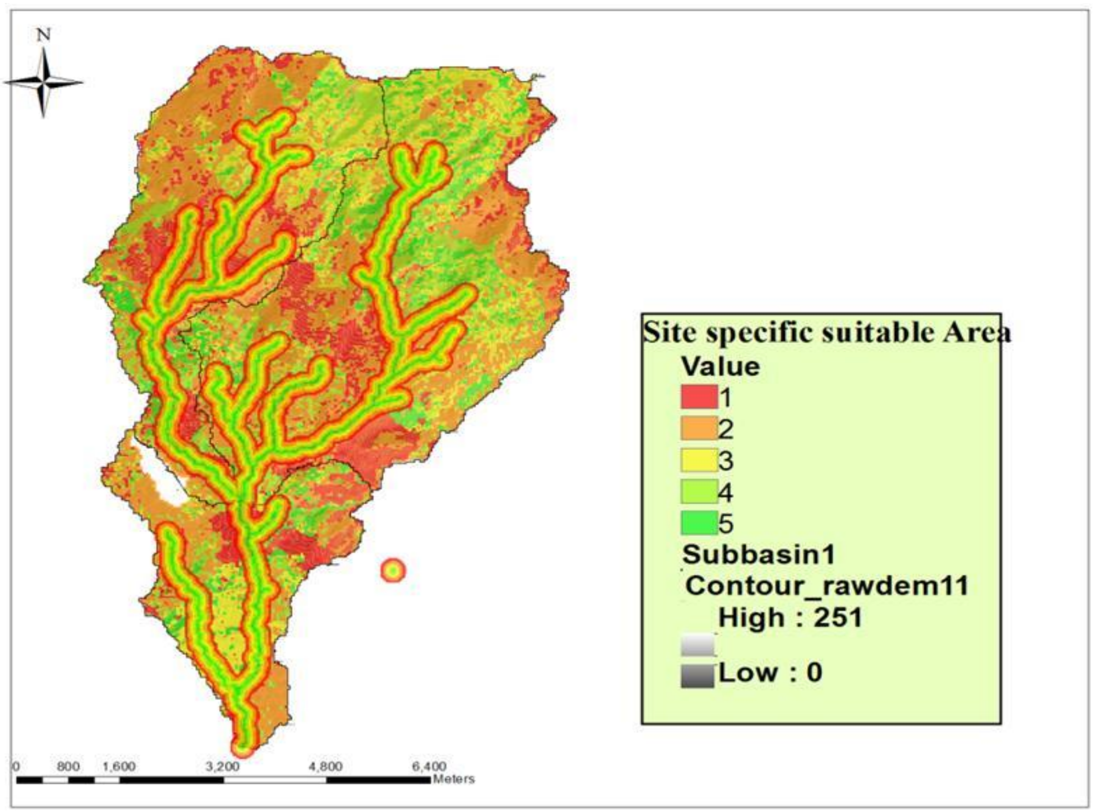


Fig. 5.13: The Specific Suitable Area for IUWM and River Buffer Zone Map

(Green zone are highly suitable and red is not suitable)

To assess whether a WSUD system is appropriate requires an understanding of the requirements of WSUD outcome, and the suitability of particular measures to assist in achieving those outcomes. The compliance of low impact development such mentioned below are assessed and evaluated with respect to water quality, water quantity, wastewater reduction, and amenity and functionality objective achieved. High score is given for all objective function is achieved. The short lists of objective function are given in table 5.6 below.

Table 5.6: Objective of Wastewater and Stormwater Evaluation Check List

Objective	**Suitability criteria to the objective**	**Objective**	**Suitability criteria to the Multi use objective**
Water Quality objective	Primary Treatment	**Amenity objective**	Multiple uses
	Secondary Treatment		Form is integrated into landscape
	Tertiary Treatment		Existing natural features retained
	Reduce Pollutant Loads		Public safety addressed
Water Quantity objective	Disconnect Impervious areas		Linkages (pedestrian, bicycle, vehicular)
	Provide flood detention hydrologic regimes	**Functionality objective**	Maintenance elements
	Stormwater Harvesting		Maintenance plans provided
Wastewater	Provide alternative water source		Service corridors allowed for
	Reduce Wastewater discharge		

The selected best management practice that meets objective function is given score of 0 to 3. The best management practice have high score 3 and the one cannot fulfill suitable criteria given 1 and total of 54 score were evaluated. The best of evaluated and selected to area is as shown in table 5.7 below.

Table 5.7: Evaluated Best Management Practices against The Objective Set

Urban water management						
Best Management Practices Selection/LID	Water Quality	Water Quantity	Waste water	Amenity Functionality	Score	percentage total
Sediment Basins	9	9	4	20	42	77.78
Sand Filters	9	8	3	22	42	77.78
Pervious landscape Pavements	11	6	1	22	40	74.07
Bio Basins	9	7	3	20	39	72.22
Infiltration	9	9	3	18	39	72.22
Ponds and Lakes	9	7	3	20	39	72.22

Swales & Buffer Strips	9	6	1	22	38	70.37
Bio Swales	8	9	3	18	38	70.37
Constructed Wetlands	9	5	3	18	35	64.81
Potable Water Demand/Wastewater Generation Reduction	Water Quality	Water Quantity	Waste water	Amenity Functionality	Score	percentage total
Stormwater Harvesting/Reuse	8	8	4	14	34	62.96
Rainwater Tanks	8	8	6	11	33	61.11
Changing Landscape Form	6	5	1	19	31	57.41
Water Use Education Programs	8	3	4	14	29	53.7
Reticulated/ Recycled Water	4	3	6	13	26	48.15
Greywater, Treatment/Reuse	4	3	6	13	26	48.15

The integrated urban water management options are evaluated against suitability criteria. The selected WSUD are pervious landscape pavements, swales & buffer strips, bio basins, wetlands infiltration, bio swales, ponds and lakes, sediment basins, and sand filters. The landscape suitability score and urban water objective are evaluation criteria confirm the management of water in the future.

5.3.3. Function of WSUD Measures at Suitable Site Location

In proposed plan, the water sensitive urban development is planned primarily allowing for IUWM and environmental factors (stream water quality, flood control and wastewater flow reduction/ demand management) while conventional water management is only focused traditional discharge removal. The following diagrams show how the various measures described in the next section can be put together to form a suite of elements that provide stormwater and wastewater quality and quantity improvements. They can be described as follows.

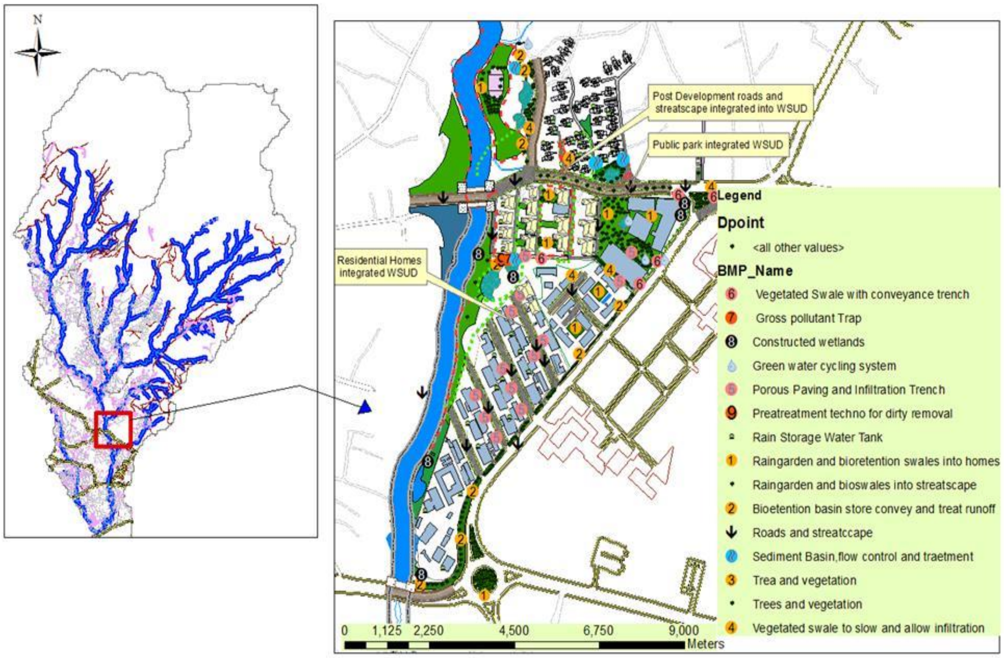


Fig.5.14a: Typical site layout Veiw Of River buffer zone, Streatcape and Residental Area into I

Fig.5.14b: Urban Stream Buffer Zone(Left) And Streatcape And Residental House Hold(Right)

Fig.5.15: Typical Proposed Roads/ Streets(left) and Public Park (right) Into IUWM

5.3.4. Sedimentation Basins:

As previously discussed, Sedimentation basins are designed to retain coarse sediments from run-off and are generally the first element in a treatment train. As shown on map, also protects downstream stormwater treatment measures such as wetland from becoming overloaded with sedimentation. The main objective of sediment basin is Peak flow control, collection and water quality treatment by removing course sediment.

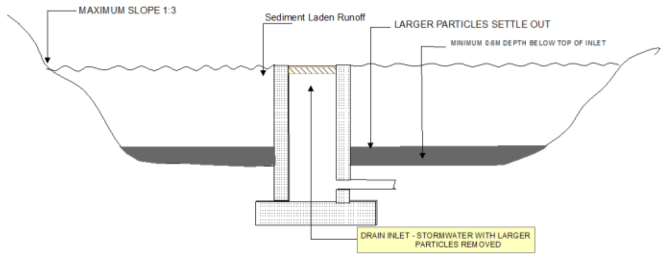


Fig. 5.16: Typical Sedimentation Basin (left) and Cross Section of Sedimentation Basin (right)

5.3.5. Bioretention Swales:

The main Objective bio swales are originally designed for providing an element of water quality control, bioretention cells can achieve *quantity* control as well.

- Stormwater connection - protect against erosion from fast flowing discharge. Surface runoff collected from the homes and street is first filtered through the surface vegetation removing coarse to medium sediments.
- As shown on map the sedimentation basin with the grassed swale **(@6 on map)** near streetscape and residential area can maintain quality and quantity by removing pollutants and flow reduction.

Fig. 5. 17: Grassed Swales (left) and Vegetated Swale (Right) (Source: Water Sensitive Urban Design of the Sydney Region)

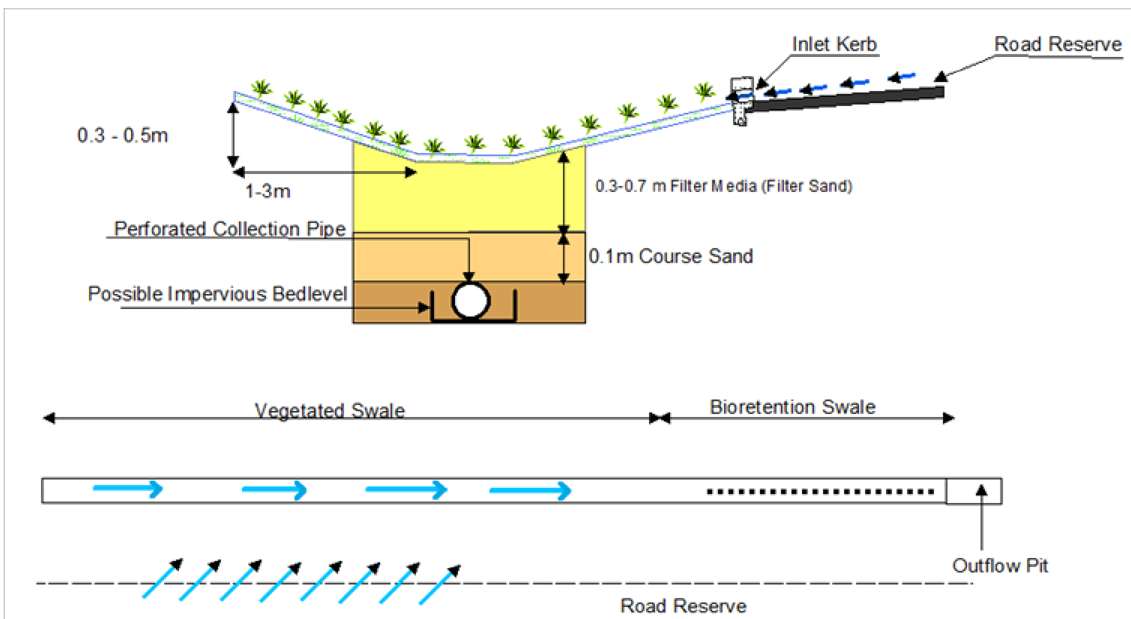


Fig 5.18: Typical Cross Section of Vegetated and Bioretention Swale

5.3.6. Porous Pavements:

The Objectives are the integration of collection, detention, treatment and infiltration of stormwater within road reserves, private ways and car parks, prior to discharge into the conventional stormwater network or receiving environment. It provide conveyance and treatment of pollutant off at site and minimize the export of sediments and pollutants off the site;

Fig.5.19a: Grassed Infiltration area (left) and Porous Paving (Right) (Source: Water Sensitive Urban Design of the Sydney Region)

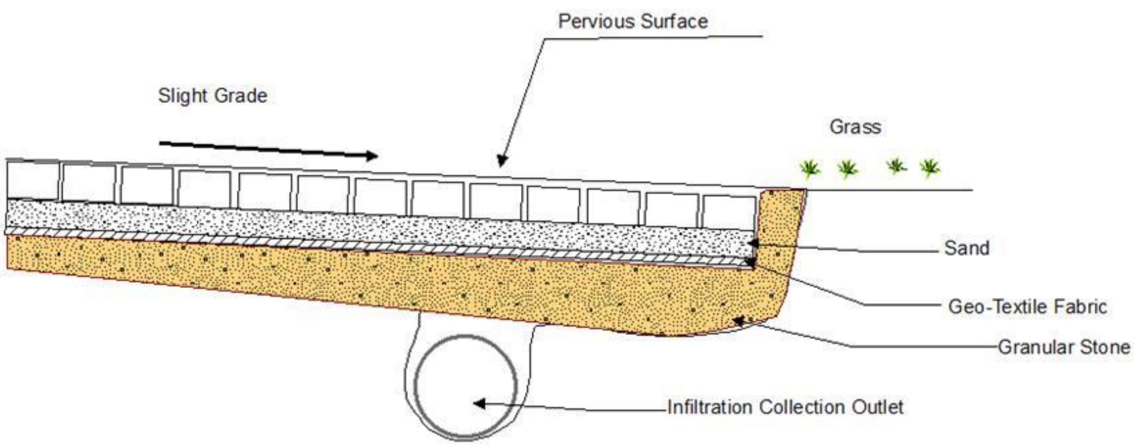


Fig.5.19b: Typical Cross Section of Porous Paving cross Section Constructed Wetland

5.3.7. Constructed Wetlands

Constructed wetlands (also known as Stormwater wetlands, wetland basins, extended detention wetlands, and shallow marshes (**See at 8** on map) are similar to retention basins but have more than half of their surface area covered by emergent wetland vegetation.

Fig.5.20a Constructed Wetland (Left) Within Retention Basin
(Adopted from EPA WSUD Engineering Guideline)

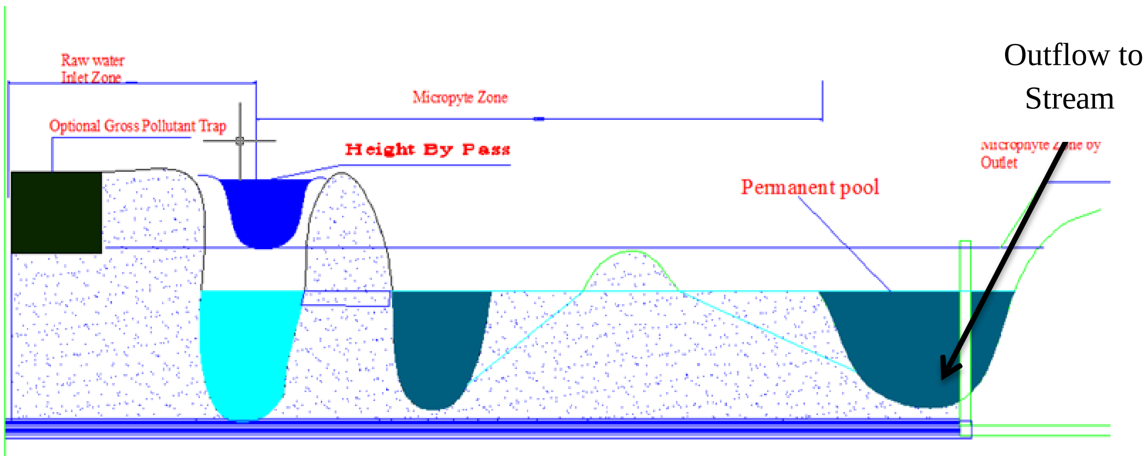


Fig.5.20b: Constructed Wetland (Left) Within Retention Basin
(Adopted from EPA WSUD Engineering Guideline)

5.3.8. Ponds and lakes

Ponds and lakes are artificial bodies of open water usually formed by a simple dam wall with a weir outlet structure, or created by excavating below the natural surface level. Ponds and lakes can provide water storage for stormwater reuse schemes and often form part of a flood detention system. They also serve to remove pollutants by promoting sedimentation, adsorption of nutrients and ultraviolet disinfection

Fig.5.21a: Typical Ponds And Lakes at Stream Buffer Zone (Adopted from Melbourne City WSUD)

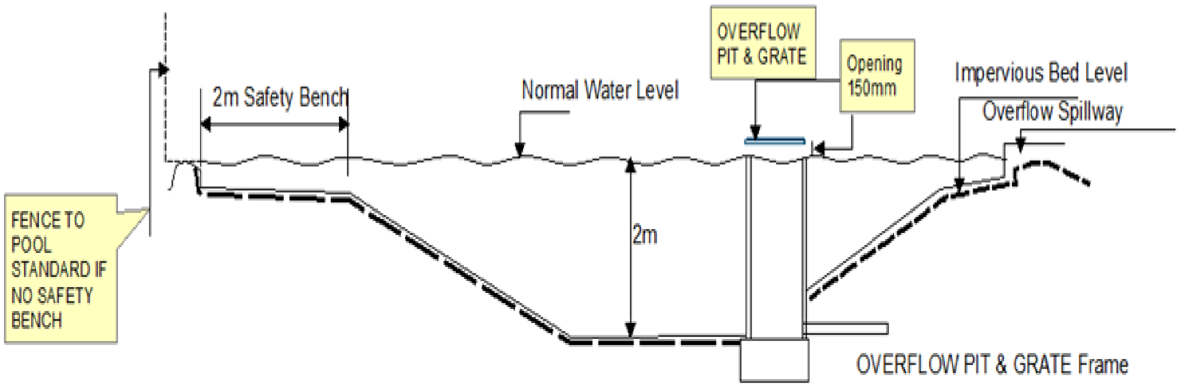


Fig.5.21b: Typical Cross section of Ponds and Lakes at Stream Buffer Zone

(Adopted from WSUD Engineering Guide Line)

6. Conclusion and Recommendation

6.1. Conclusion

The primary objective of this study was to evaluate existing urban storm water and wastewater management system and explore integrated management of urban water into adopting landscape infrastructure suitable practice in study area drainage. Adopting landscape infrastructures suitability into integrated urban stormwater and wastewater management are useful for evaluating stream flow impact of development and stormwater management practices. To accomplish these objectives, the analysis was divided into three methodological parts. The first parts of analysis were simulation of hydrologic model of different scenario, useful for evaluation stream peak flow impact of urban development and stormwater management practices. The second parts of methodological analysis were water supply distribution and consumption among kebeles in watershed are useful in determining and evaluation of proportion of wastewater generation flow rate and to evaluate its existing management practices. The third methodological part was landscape infrastructure suitability analysis is useful to assess and evaluate low impact development option into integrated urban water management plan and practices.

- The hydrologic model selected were SCS UH transform, SCS loss model and lag time routing model to simulate the rainfall-runoff transform, loss, and routing of stream hydrograph. Calibrated and validated rainfall runoff parameter of basin was used to evaluate land use cover change response to stream flow. The percentage change of impervious area from 1995 to 2009 was 15% of total area. The upstream of watershed forest land were converted to the urban built area. Because increase of impervious area to 25.0% area the percentage of peak increase 9.7% to 37.5% at which means the increase of 42m3/s of peak flow.
- The increase of urbanization has increased the flooding impact in drainage for all rainfall events. By analyzing percentage in peak flow, as more urban development occurred in time more peak flow produced at for all rainfall events. The low to medium rainfall magnitude produced more peak than the low return period of rainfall at the same development scenario. The volume of runoff produced is analyzed to see the percentage change but is very rare insight was observed for different rainfall events at different development from 1995 to 2009.
- The wastewater generation from domestic, industrial, public and intuitional have direct relation and 80% water supplied for domestic users and for non-domestic users are

convert wastewater. Water supply consumption of billed water volume give is converted to per capita demand analysis. The existing water demand of kebele and warada were estimated and correlated with population residing in area. The average per capita demand of whole area found is 26.74l/cap/day. The wastewater flow rates were calculated depending on projected per capita demand calculated by mode of services. The wastewater flow discharge is greater than the capacity of existing infrastructure capacity. The only wastewater management in area was sewer line which only conveys less than 10% percentage of wastewater generated. The rest of wastewater discharged to the urban drainage and open channel near the residential area and the stream flow is pollutant the only management available is the irrigation practice at Bentiketu and Kebena river junction near EU delegation office. The Existing integrated best management practice existing Infrastructure at the city level has found near the St. Stephen Church that is the one of exemplary landscape infrastructure used as integrated urban wastewater and stormwater management practice.

- The landscape suitability analysis has done to assess and evaluate urban water management practice. The permeability, slope, hydrology, geology, mean annual rainfall, ground water table, and river buffer zone are the site suitability constraints for integrated urban water management practice options implementation. The objective of this thesis was used as evaluation parameters against the defined and selected management practices and demonstrated implementation. The wastewater generation reduction and potable demand management are objectives set against selected management practices. The stormwater peak flow reduction and stormwater quality treatment measure are objectives set against selected management practices. Best management practice evaluated and selected area sand filters, sediment basins, p. pavements, bio basins, infiltration, ponds and lakes, bio swales vegetated swales & buffer strips, wetlands.

6.2. Recommendation

The existing management practices of stormwater and wastewater sanitation system are evaluated and very small in scale, environmental impact are higher than we observed. The existing drainage system and wastewater sewer line capacity are not capable of managing the stormwater peak flow and wastewater, so that the attention have to be given. The only available integrated urban water management practice infrastructure, seen near St. Stephen church in bentiketu river buffer zone perfectly exemplifies in practical modern system, environmentally naturalistic style. The practice can demonstrate how relevance to adopt infrastructure, for the stakeholder the rest of drainage area and for future proper management technique. The evaluation of implementation and cost related comparison between the existing conventional and integrated urban water management practice in the Kebena Catchment need further studies.

There was a difficult of wastewater flow data, spatial sewage line connection to the household units are limited, so that the municipality have to identify and put in map to be used scholars studying this context. The cadastral information and AAWSA billing of study only shown the proposed house unit, main roads, highway, water supply, network, drainage and other non- water related lines, missing the sewage line connection. Therefore, the better spatial map of existing and proposed sewage line connection to the house, better evaluation of wastewater quantity and quality need further study

This study integrated many spatial, quantities and qualitative data and a lot of methodology models output where each possess certain level of uncertainty. The result this study taken with care and considered indicative of further exploration of existing problem solving method and management rather than the accurate prediction. The qualitative data like stormwater quality, pollutant concentration, of this study likely used usual scholar‟s checklist methods, developed algorism to test applicability at specific suitable landscape, and not considered further field investigation of stormwater pollutant specification, wastewater contaminant concentration test.

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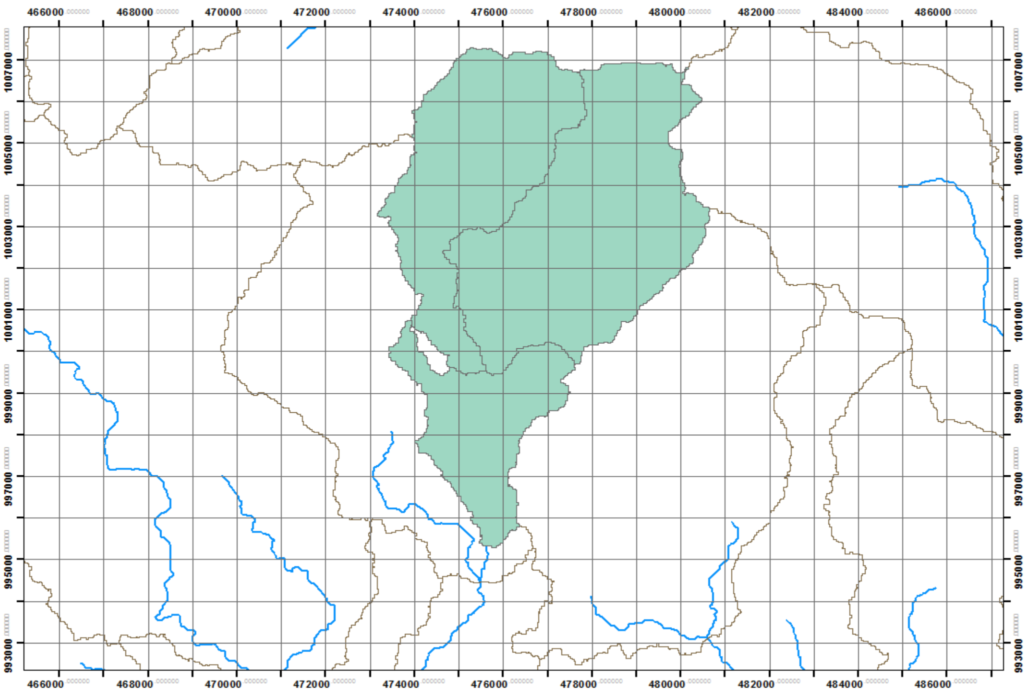
Appedix A: HEC-GeoHMS Delineated Sub-basin

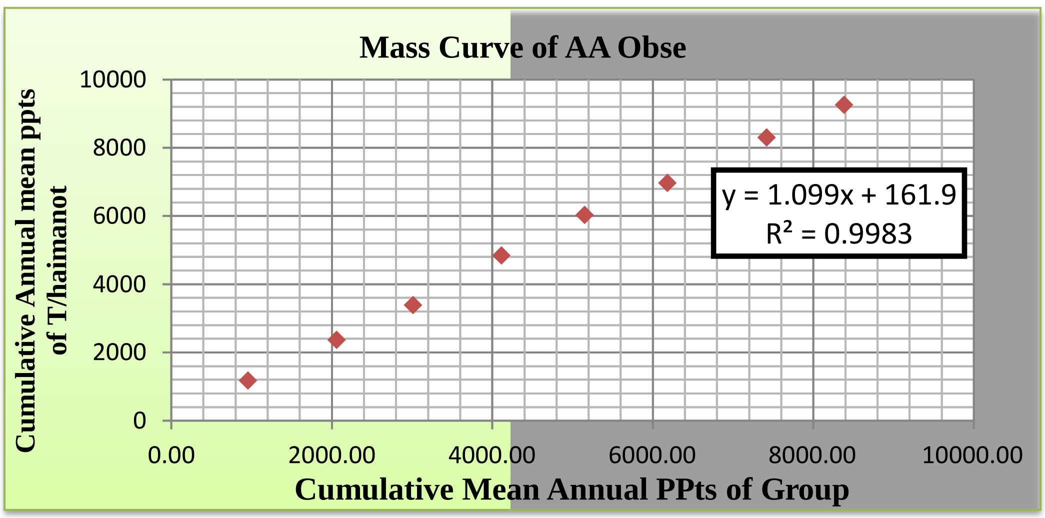


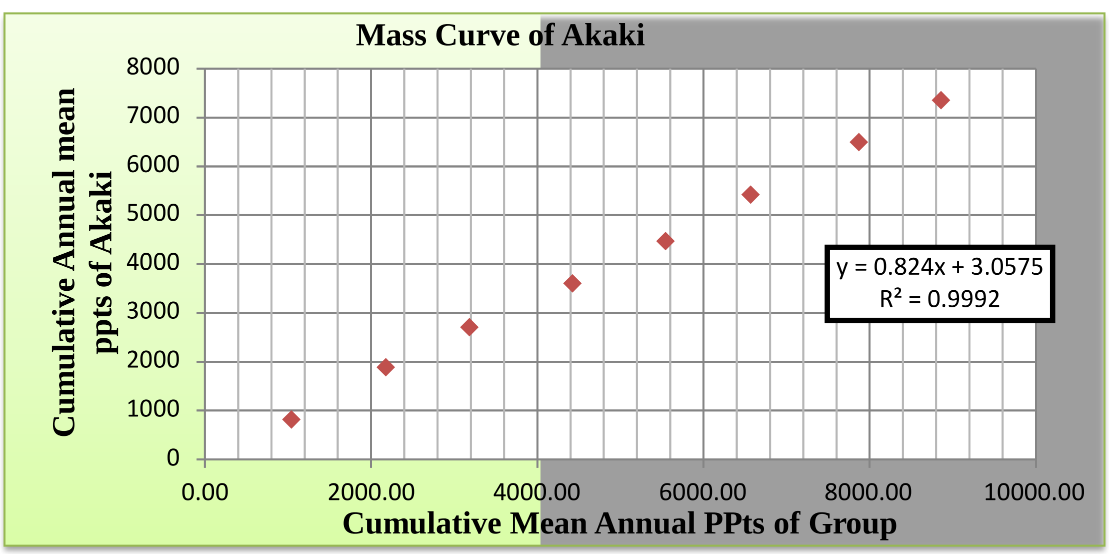
Appendix B: Monthly Precipitation Data

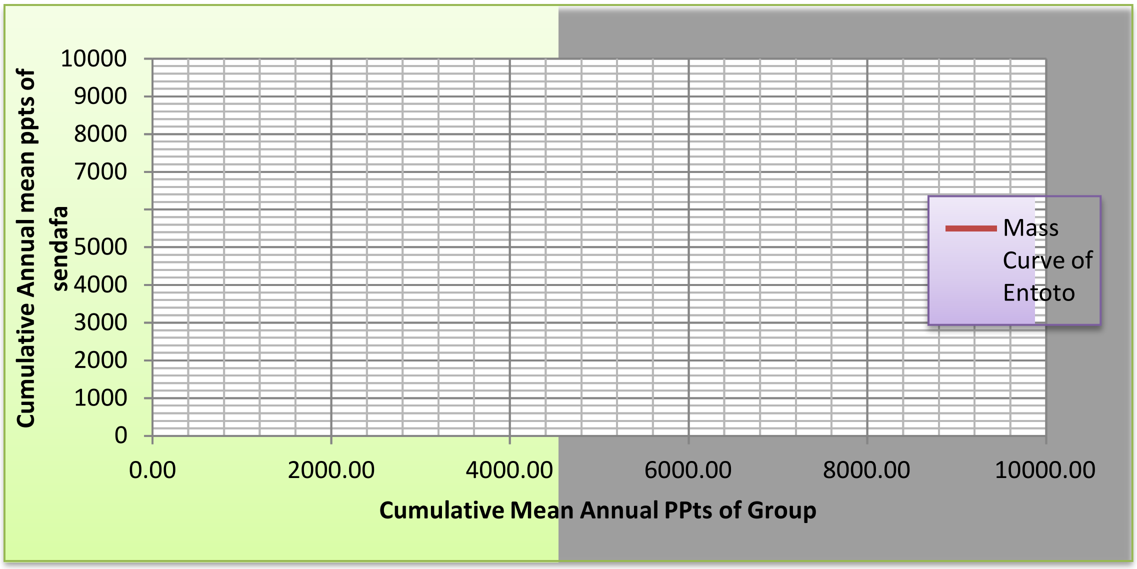
		AA Obser Precipitation Data											
1991	0	74.5	106.6	34.7	55.3	248.9	191.1	262.6	126.4	3.4	0	50	1153.5
1992	20.2	33.7	20.2	41	52	109.1	248.5	294.7	209.4	69.7	0		1098.5
1993	10.8	67.2	16.1	157.9	97.2	208.3	274	426.5	243.3	62.1	0	4.5	1567.9
1994	0	0	82.4	82.3	63.3	123.4	308.9	225	142	0.5	14.7	0	1042.5
1995	0	69	41.5	174.4	68.2	102.9	190.2	314.9	136.1	0	0	48.4	1145.6
1996	28.1	5.2	106.8	128.2	122	258.5	266.4	338.7	294.2	0.2	0.2	0	1548.5
1997	39.2	0	24.5	51.3	38.5	104	272.6	194.3	113.8	62.4	50.3	1.5	952.4
1998	55.2	20.5	49	48.5	154	124.4	285.4	260	213.6	126.9	0	0	1337.7
1999	2.9	0.3	28.8	16.3	23.8	119.6	268.6	305.3	88.4	75.4	0	0	929.4
2000	0	0	17.6	49.9	110	144.5	244.8	306.2	250.6	46.4	21.1	0	1191.1
2001	0	12.2	210.8	25	168	216.2	428	246.4	131.7	13.7	0	0	1452
2002	14.7	21	90.2	56.3	63.1	172.5	256.9	215.9	108.8	0.2	0	16.5	1016.1
2003	10.5	53.3	62.6	99.3	20.2	151.8	291.8	233.3	193.3	0.8	1.5	54.9	1173.3
2004	24.8	20.3	49.5	139.9	30.1	141.9	238.5	272.6	0	0	164	76.9	1158.5
Mean	14.7	26.9	64.8	78.9	76.1	159.0	269.0	278.3	160.8	33.0	18.0	19.4	1197.6
Max	55.2	74.5	210.8	174.4	168	258.5	428	426.5	294.2	126.9	164	76.9	1567.9
Min	0	0	16.1	16.3	20.2	102.9	190.2	194.3	0	0	0	0	929.4
StDev	17.1	27.9	52.9	52.0	47.3	53.4	56.9	59.6	77.4	40.7	44.3	27.6	205.7
C.V.	116%	103%	82%	66%	62%	34%	21%	21%	48%	123%	247%	142%	17%
No. year	14	14	14	14	14	14	14	14	14	14	14	13	14

		Bole meteorolical station, Mean monthly Precipitation.											
yr	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Annual
1997	29.1	0	22.1	66.8	44.8	128	257	160.7	94.7	58.6	15.3	0	877.1
1998	66.6	40	43.8	99.8	197.7	111.6	270.7	236.8	173.4	139.4	0	0	1379.8
1999	4.4	0	35	17.8	30.5	104.6	294	270.5	62.8	127.1	0	0	946.7
2000	0	0	17.6	87.8	95.2	102.1	192.9	221.9	157.5	19.6	7.5	0	902.1
2001	0	10.3	174.3	14.8	116.7	166	289.4	207.3	113.3	10.6	0	0	1102.7
2002	30.6	25.9	79.4	36.6	49.6	115.5	213.9	233.6	72.6	0.5	0	32.8	891
2003	4.8	34.1	48.9	111.5	18	111	204.3	238.4	130.2	4.6	0	33.3	939.1
2004	26.1	11.7	32.4	104.2	7	114.5	240.6	230.1	122.1	50	0.6	0	939.3
Mean	20.2	15.3	56.7	67.4	69.9	119.2	245.4	224.9	115.8	51.3	2.9	8.3	997.2
Max	66.60	40.00	174.30	111.50	197.70	166.00	294.00	270.50	173.40	139.40	15.30	33.30	1379.80
Min	0.00	0.00	17.60	14.80	7.00	102.10	192.90	160.70	62.80	0.50	0.00	0.00	877.10
StDev	22.92	16.11	51.21	39.53	63.70	20.47	38.79	31.50	38.60	54.75	5.63	15.30	169.68
C.V.	290.5%	248.3%	340.3%	282.0%	310.3%	810.8%	757.9%	858.7%	449.2%	254.6%	271.5%	217.7%	813.2%
No. year	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00

Appendix C: Double Mass curve of Precipitation







10000
9000
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7000
5000
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2000
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0
0.00
2000.00
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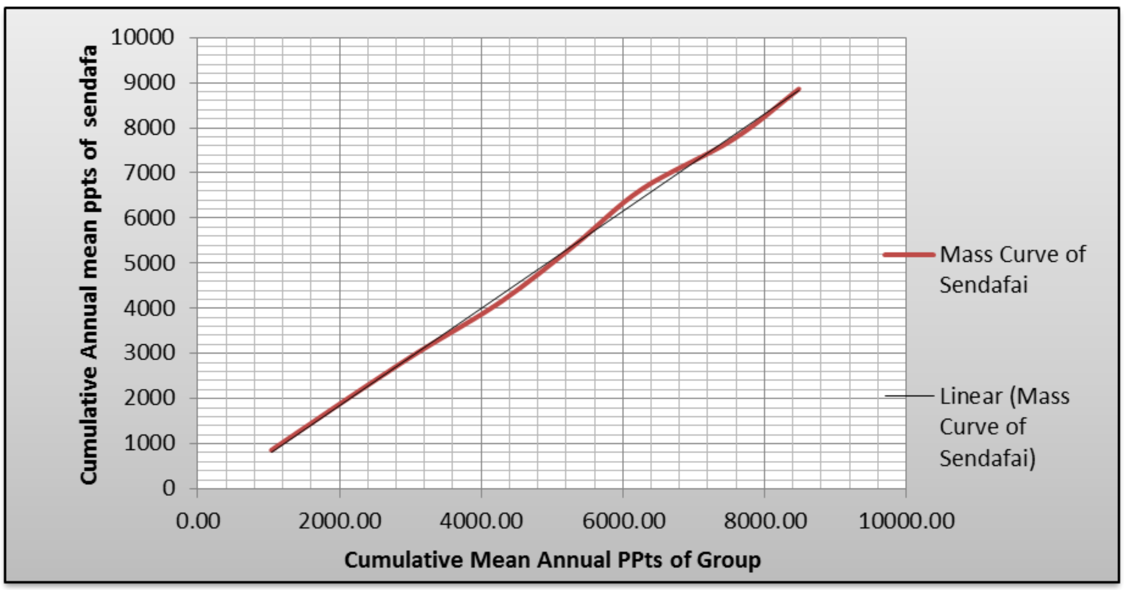
8000.00
10000.00
Cumulative Annual mean ppts of sendafa
Cumulative Mean Annual PPts of Group
Mass Curve of Entoto



10000
9000
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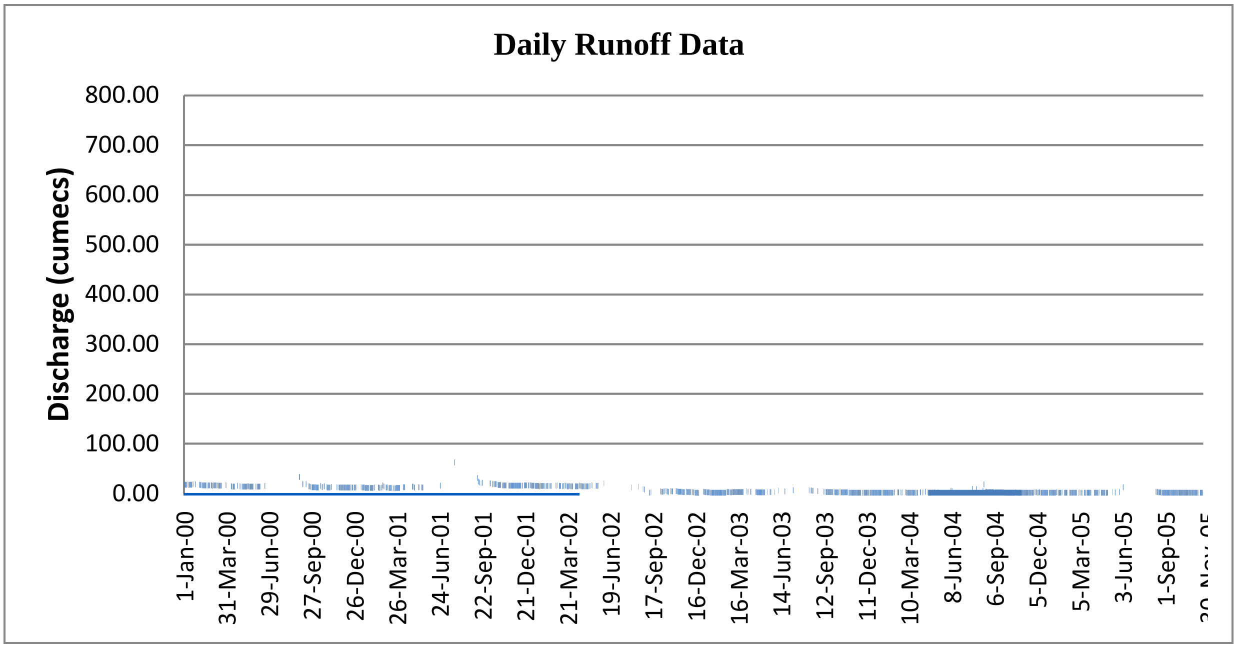
8000.00
10000.00
Cumulative Annual mean ppts of sendafa
Cumulative Mean Annual PPts of Group
Mass Curve of Sendafai
Linear (Mass Curve of Sendafai)

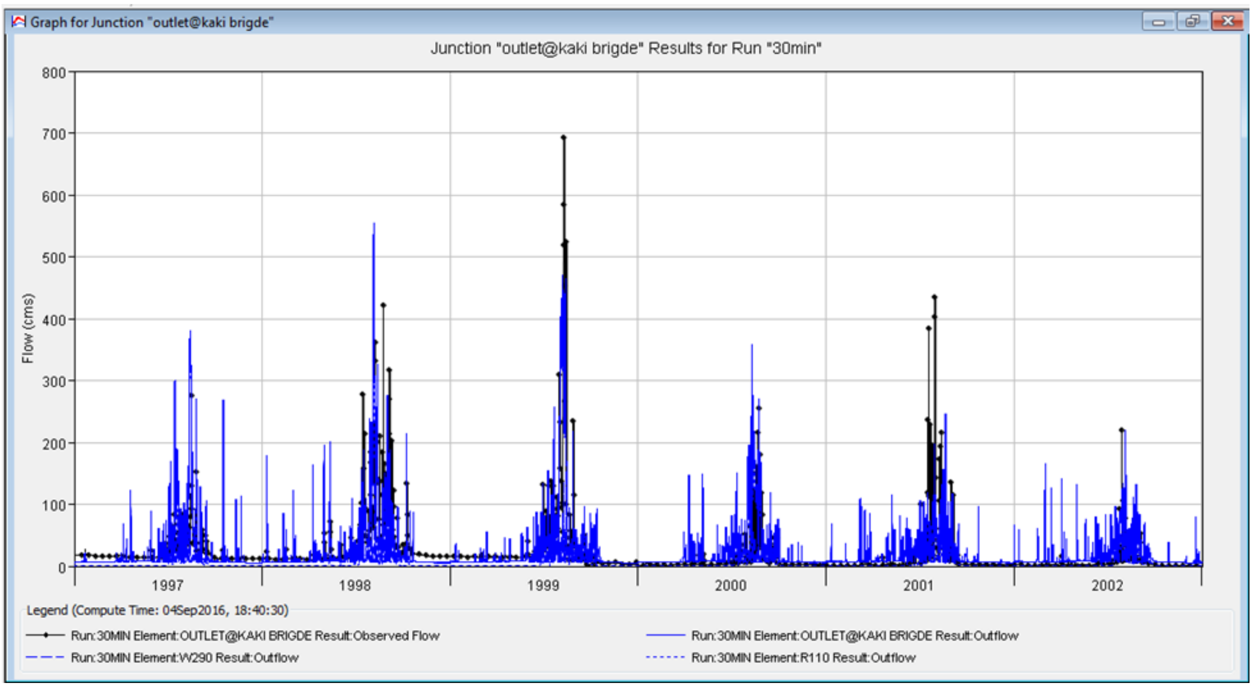
Appendix D: Observed Runoff Hydrographic Data (Observed @ Akaki bridge)



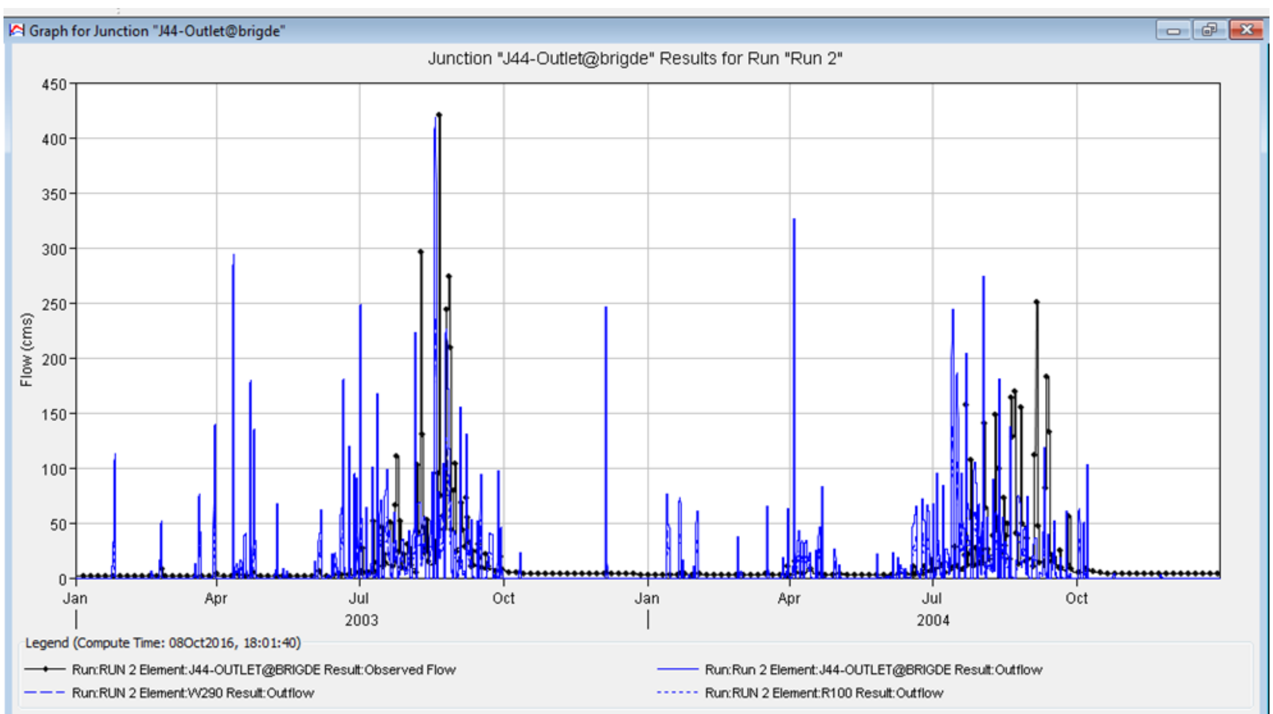
Appendix F: Observed Mean Monthly Flow of Big Akaki River

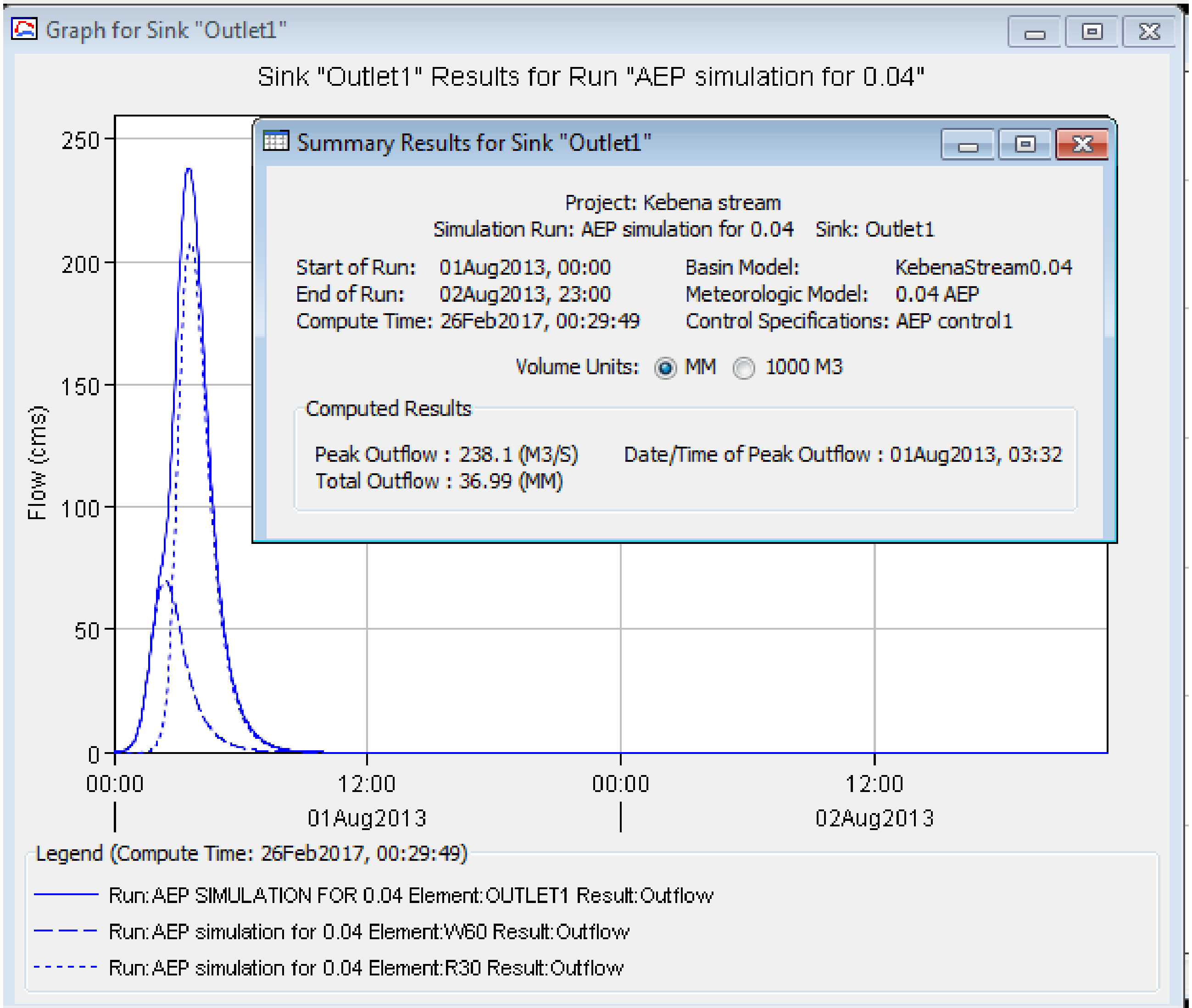
Mean Monthly Flow of Big Akaki Flow (m3/s)												
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1997	18.294	16.517	16.421	15.835	14.378	17.44	38.523	62.614	24.099	14.111	12.797	11.593
1998	12.505	12.415	12.054	12.498	19.136	17.706	63.415	145.684	78.454	29.366	16.802	15.847
1999	16.019	14.995	15.893	15.019	15.202	20.828	67.668	164.468	12.268	5.277	4.838	3.294
2000	2.647	1.766	2.212	4.216	4.074	3.948	13.039	71.084	13.236	3.849	2.351	1.832
2001	1.716	1.641	2.909	2.217	3.35	6.297	62.878	80.522	16.137	2.315	1.869	1.796
2002	1.939	1.705	2.104	2.534	1.823	3.395	17.648	21.736	8.522	1.636	1.434	1.587
2003	1.437	1.646	1.473	2.377	1.548	2.675	21.416	79.886	24.395	4.575	3.529	3.626
2004	3.361	3.123	3.302	4.776	3.06	4.373	19.398	58.25	38.373	5.091	3.594	3.656
mean	**7.23975**	**6.726**	**7.046**	**7.434**	**7.821375**	**9.58275**	**37.99813**	**85.5305**	**26.9355**	**8.2775**	**5.90175**	**5.403875**

Appendix F: Rainfall runoff Data of observed and simulate Hydrograph

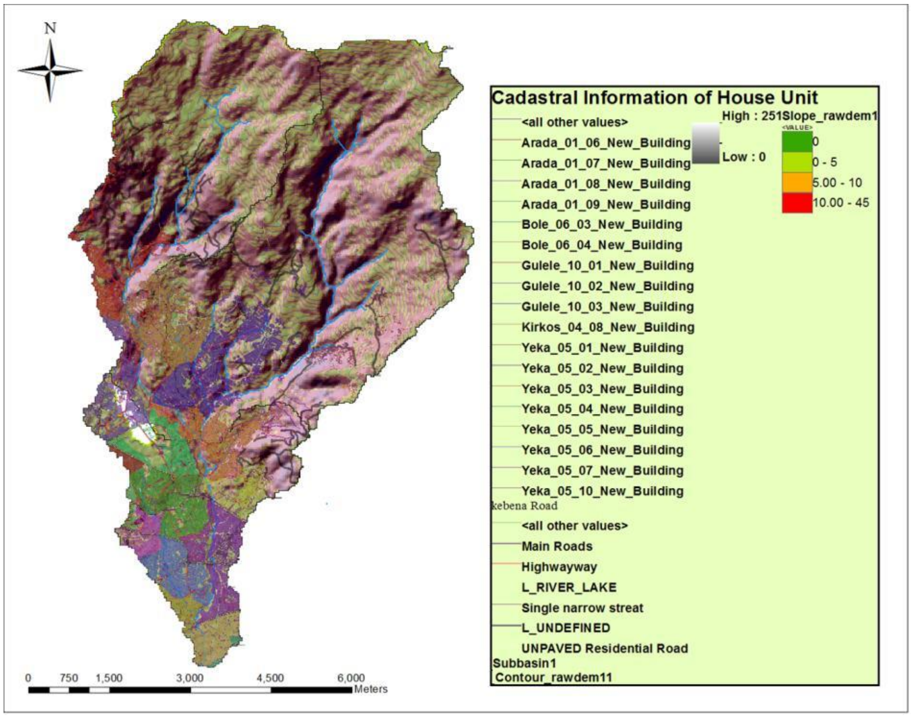


Hydrograph of simulated and observed of Calibration (2002-2004)

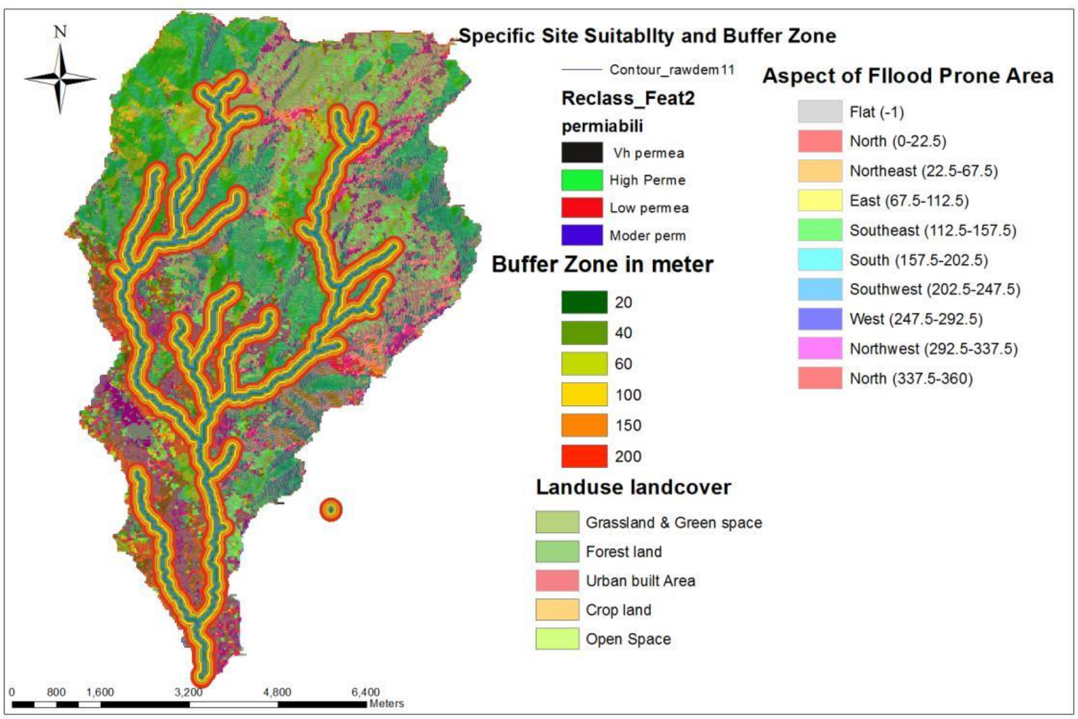


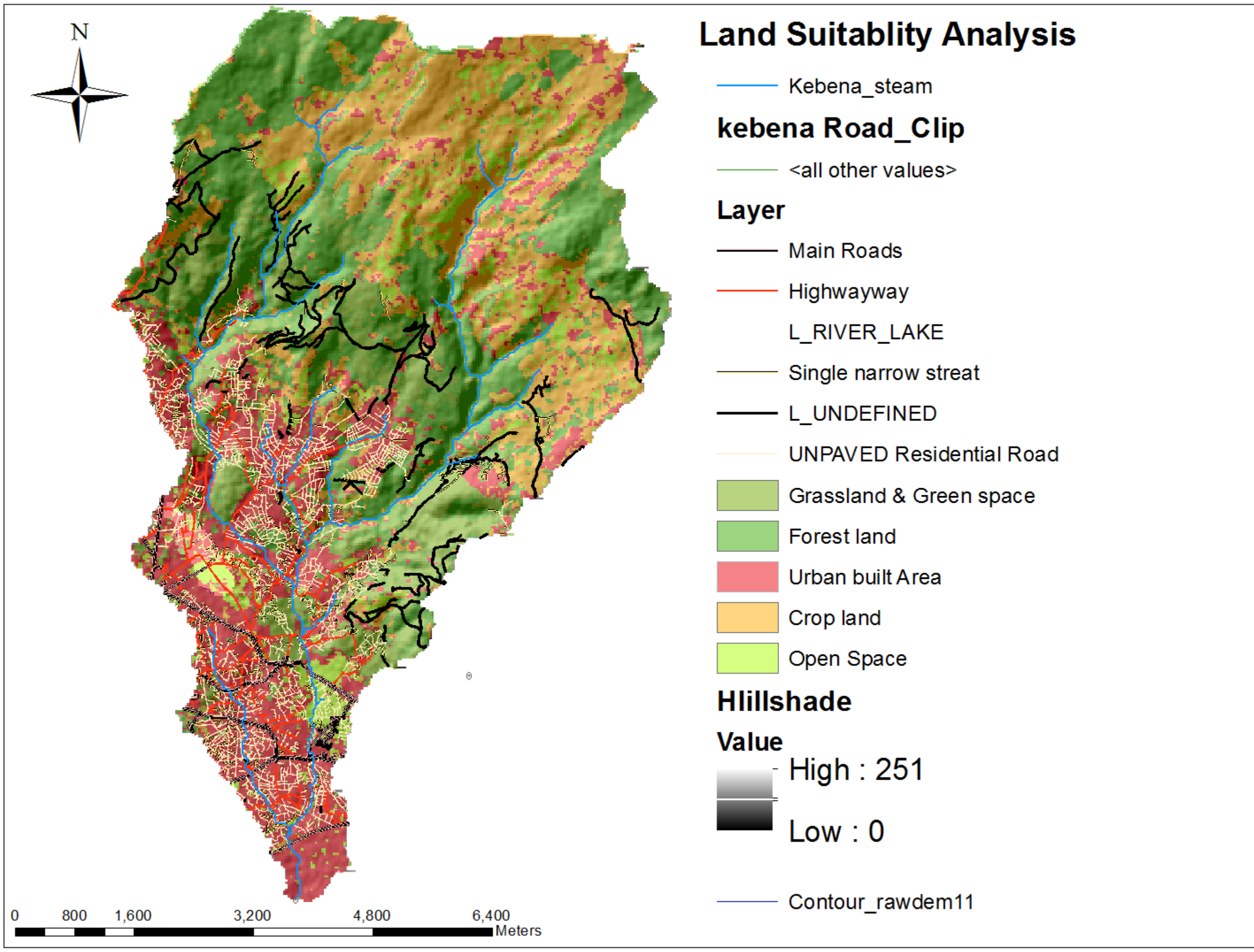

Graph for Sink "Outlet1"
Sink "Outlet1" Results for Run "AEP simulation for 0.04"
Summary Results for Sink "Outlet1"
Project: Kebena stream
Simulation Run: AEP simulation for 0.04 Sink: Outlet1
Start of Run: 01Aug2013, 00:00
End of Run: 02Aug2013, 23:00
Compute Time: 26Feb2017, 00:29:49
Basin Model: KebenaStream0.04
Meteorologic Model: 0.04 AEP
Control Specifications: AEP control1
Volume Units: MM 1000 M3
Computed Results
Peak Outflow : 238.1 (M3/S)
Date/Time of Peak Outflow : 01Aug2013, 03:32
Total Outflow : 36.99 (MM)
Flow (cms)
250
200
150
100
50
0
00:00
12:00
00:00
12:00
01Aug2013
02Aug2013
Legend (Compute Time: 26Feb2017, 00:29:49)
Run:AEP SIMULATION FOR 0.04 Element:OUTLET1 Result:Outflow
Run:AEP simulation for 0.04 Element:W60 Result:Outflow
Run:AEP simulation for 0.04 Element:R30 Result:Outflow

Appendix G: Cadastral information of house units



Appendix G: Site Suitability map





		Stormwater Management Techniques										Potable Water Demand/Wastewater Generation Reduction						
Management Practices	**Stormwater Managem**	Sediment Basins	Swales and Buffer Strips	Bioretention Swales	Bioretention Basins	Sand Filters	Constructed Wetlands	Ponds and Lakes	Infiltration Systems	Aquifer Storage and Recovery	Porous Pavements	Rainwater Tanks	Reticulated Recycled Water	Greywater Treatment/Reu	Storm water Harvesting/	Changing Landscape Form	Water Use Education	Stream and Riparian Vegetatio
Water Quality	Primary Treatment	3	3	0	0	0	0	0	0	0	0	2	1	1	2	2	2	3
	Secondary Treatment	2	3	3	3	3	3	3	3	3	3	2	1	1	2	1	2	3
	Tertiary Treatment	0	2	3	3	3	3	2	3	3	3	2	1	1	2	1	2	3
	Reduce Pollutant Loads	3	3	3	3	3	3	3	3	3	3	2	1	1	2	2	2	3
Water Quantity	Disconnect Impervious areas	2	3	3	3	2	3	3	3	3	3	3	1	1	2	2	1	3
	Provide flood detention hyd	3	2	2	3	2	3	3	2	3	3	3	1	1	3	1	1	3
	Stormwater Harvesting	2	1	1	1	1	3	3	2	3	2	2	1	1	3	2	1	3
Waste water	Provide alternative water so	2	0	0	2	2	2	2	2	3	2	3	3	3	3	0	1	3
	Reduce Wastewater discharg	1	1	1	1	1	1	1	1	1	1	3	3	3	1	1	3	3
	Treatwastewater	3	1	1	3	3	3		3	4	3	6	6	6	4	1	4	
		18	18	16	19	17	21	20	19	22	20	22	13	13	20	12	15	
Amenity	Multiple uses	3	3	3	3	2	3	3	3	3	3	1	1	1	2	2	1	3
	Form is integrated into lands	3	3	3	3	2	3	3	3	3	3	2	2	2	2	2	3	3
	Existing natural features reta	2	3	3	2	2	2	2	2	2	2	1	1	1		2	1	3
	Public safety addressed	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	3	3
	Linkages (pedestrian, bicycle	2	2	2	2	2	2	2	2	2	3	1	1	1	1	3	1	3
Functionality	Maintenance elements	3	3	3	3	3	3	3	3	3	3	1	1	1	2	2	1	3
	Maintenance plans provided	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
	Service corridors allowed for	0	3	3	2	2	0	0	2	2	3	0	2	2	2	2	1	3
		18	22	22	20	18	18	18	20	20	22	11	13	13	14	19	14	24