JIMMA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

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FACULTY OF CIVIL AND ENVIRONMENTAL ENGINEERING

HYDROLOGY AND HYDRAULIC ENGINEERING CHAIR

MASTERS PROGRAM IN HYDRAULIC ENGINEERING

Assessing Rainwater Harvesting as an Alternative Source of Non-Domestic Water Supply: The Case of Gurgade Condominium, Hosanna

By: Esayas Berhanu

A Thesis Submitted to the School of Postgraduate Studies Jimma University in Partial Fulfillment of the Requirements for the Degree of Master of Science in Hydraulic Engineering

May, 2020

Jimma, Ethiopia

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Main Advisor: - Dr. Ing. Fekadu Fufa (PhD)

Co-Advisor: - Mohammed Hussen (MSc)

DECLARATION

I under signed, declare that this thesis entitled "Assessing Rainwater Harvesting as an Alternative Source of Non-Domestic Water Supply: The Case of Gurgade Condominium, Hosanna" is my original work, and has not been presented by any others person for an award of a degree in Jimma University or other University.

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ACKNOWLEDGEMENT

First of all, I would like to thank ‘Almighty God’ in the name of Jesus Christ who gave me His Mercy and Grace till to finish this work successfully.

I would like to convey my special thanks to Ethiopia Road Authority for providing such chance to continue my study at Jimma University Institute of technology and for their cooperative work that made this research possible through financing.

I am grateful to Dr. Ing. Fekadu Fufa (PhD), and Mohammed Hussen (MSc) for their supervising me in the research and cooperation which gave me enough strength to carry out the present study.

Finally, special thanks to my Family and friends who are always encouraging and rendering me the necessary services and are taking care of some of my responsibilities.

ABSTRACT

Rainwater harvesting and utilization systems have been in place for centuries. Rainwater harvesting refers to the practice of collecting rainwater from rooftops, land surfaces, or rock catchments and storing it for human use. Hosanna Water and Sewerage Enterprise is the only organization responsible for the distribution of water for the town. Gurgade condominium site residents are facing a big challenge due to the water shortage problem. Therefore, the objective of this study is to assess rainwater harvesting as an alternative source for non-domestic purposes in Hosanna Town Gurgade condominium site. The data used for this study was secondary. Data required, such as previous water consumption, area of the roofs, rainfall data, population and runoff coefficient was collected from Hosanna Water and Sewerage Enterprise, National Metrological Service Agency, Hosanna Land Information Center, Hosanna Town Municipality and Central Statistics Agency. Precipitation data for Gurgade condominium was used to determine the amount of water that can be collected. Calculations of the harvesting areas (areas of the rooftop of the blocks) were made by using AutoCAD software from the cadastral map of Hosanna Town. And also the data was collected by personal observations. The built up area of the study was $1536\ \mathrm{m}^2$ *that can be convenient for rainwater collection. The buildings was composed of 4 blocks (the total area of 1 block was 280* m^2*) and 2 communal blocks with each a total area of 208* m^2*. From the area of rainwater harvesting* $1069.95\ m^3$ *of water will be collected in a year but this will satisfy only 45.6 % of the total non-domestic water demand. Accordingly, from the result providing a collecting ground storage reservoir of 67.74* m^3 *near the buildings was needed. It was also tried to design the rainwater harvesting components based on design criteria. Based on the design and analyses performed, it becomes clear that rainwater harvesting is not the only solution that will solve all water scarcity issues in Gurgade. Rainwater harvesting can be an alternative solution to support the increasing water demand and reduce the surface runoff as a best management practice which helps to satisfy environmental sustainability which is one of the millennium development goals.*

Keywords: *Daily per capita demand, Gurgade condominium, Harvesting area, Non-domestic demand, Rainwater harvesting.*

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ACRONYMS

CIS	Corrugated Iron Sheet
CSA	Central Statistics Agency
G.C	Gregorian calendar
GPS	Global Position System
HLIC	Hosanna Land Information Center
HTFEDO	Hosanna Town Finance and Economic Development Office
HWSE	Hosanna Water and Sewerage Enterprise
HTM	Hosanna Town Municipality
ITCZ	Inter Tropical Convergence Zone
JIT	Jimma Institute of Technology
Km^2	Square Kilometer
Lpcd	Liter (s) Per Capita per Day
Mpa	Mega Pascal
M.a.s.l	Meter above sea level
NMSA	National Meteorological Service Agency
NTU	Nephelometric Turbidity Units
PPT	Precipitation
PVC	Polyvinyl Chloride
RWH	Rainwater Harvesting
SNNPR	South Nations, Nationalities, and People Region
UfW	Unaccounted for Water
UNEP	United Nations Environmental Proclamation
WHO	World Health Organization

1. INTRODUCTION

1.1 Background

Water is a very important renewable natural resource and it is available in many areas of the world. Rainwater harvesting and utilization systems have been in place for centuries. Rainwater harvesting refers to the practice of collecting rainwater from rooftops, land surfaces, or rock catchments and storing it for human use. But Freshwater is scarce because of unplanned withdrawal of water from rivers and underground aquifers causing severe environmental problems like arsenic contamination. In many countries, the amount of water being consumed has exceeded the annual amount of renewal creating a non-sustainable situation *(Choudhury & Vasudevan, 2003).*

The importance of water is not only attached to the drinking but also cooking, bathing, washing and other activities. Anything that disturbs the provision and supply of water therefore, tends to disturb the very survival of humanity. Where provisions for water and sanitation are inadequate, the diseases that arise from contaminated water, food and hands are among the world's leading causes of premature death and serious illness. *(Ochocho, 2018)*. There are serious constraints to meeting the challenge to provide adequate water for all urban dwellers. The water supply shortage is one of the problems which require greater attention and action. Various strategies are always being developed to make water accessible to all inhabitants. However, due to insufficient infrastructures coupled with rapid population growth and urbanization, the gap between demand and supply of water continues to widen.

Water sustains life and life support processes. The amount of water available for each person will continue to decrease as the world's population expands. Unfortunately our present and future water supplies in many parts of the world are being degraded by pollution from domestic waste water, solid waste, industrial effluent and agricultural drainage to mention a few. As natural waters become more polluted, less water is available to fulfill the demands and the needs of the natural environment.

Every year, approximately 25 million people die either by drinking polluted water or because they do not have enough water to meet their daily needs. A single person needs at least half a liter per day to meet basic survival needs and two liters per day to avoid the thirst. Some 27 to 110 liters are needed per person per day for drinking, sanitation, bathing and cooking *(UNEP, 2009).* Household water needs vary depending on the type of dwelling, number of residents and type of plumbing fixtures. Traditional sources of water to meet our needs typically include surface waters (rivers and lakes), groundwater (water stored below-ground in aquifers) and rainwater.

Direct capture, storage and use of rainwater, called Rainwater harvesting (RWH) is the oldest method of securing water, having been practiced by ancient civilizations for more than 4,000 years. This technique continues to be an important means of supplying water in many communities, especially those located far away from municipal potable water supplies and in areas the number of population and the availability of water is not proportion. RWH continues to be among the most simple and low-cost means of water supply, employing technologies that are generally easy to install and maintain. RWH has been a traditional practice in some cultures for centuries and as such many technologies are the result of a long evolutionary process. Even the current resurgence of interest in RWH as sources of water supply has been in existence for over thirty-one years and more in some countries like Australia *(Warwick University, 2005).*

Therefore, this study aims to assess an alternative solution for the shortage of water in the Gurgade condominium site and to evaluate how much percentage of non-domestic water demand can meet from RWH system. Gurgade condominium is found in Hosanna Town, capital of Hadiya Zone in SNNPR of Ethiopia.

1.2 Statement of the Problem

The availability of water sources throughout the world is becoming depleted by the rate at which populations are increasing, especially in developing countries. This has brought into focus the urgent need for planned action to manage water resources effectively for sustainable development *(Vairavamoorthy, 2018)*. According to *(Brocklehurst, 2004),* in the last 50 years, the world's urban population has increased fourfold, and now around 50% of the world's population lives in urban centers.

The rainfall of Ethiopia is unpredictable, although the majority of Ethiopian citizens do not have access to reliable and clean water resources, the utilization of rainwater harvesting will be able to preserve and take advantage of each drop of rain and it is essential that action is taken to improve the water conditions of the country. The objectives that are displayed in growth and transformation plan and plan for accelerated and sustained development to end poverty (PASDEP) have established to be insufficient and a new plan must be implemented in order to boost the access to clean water with shorter period of time in Ethiopia. Governmental programs have thus far failed to produce remarkable improvements in countryside water resources, and the implementation of rainwater harvesting could prove to have positive lasting effects. (Matthew, 2013)

In Hosanna Town water sources for public and domestic use varies from place to place. Hosanna Water and Sewerage Enterprise is the only organization responsible for the distribution of water for the town. Construction of existing water supply was completed at the end of 1974 GC. It had two phases. Phase one was designed for 10 years from 1975 –1985 G.C and phase two for 10 years from 1985-1995 G. C. The existing water supply system comprised 6 boreholes, two springs, a dam with a capacity of 460,000m^3 and reservoirs with two 150m^3 capacity each, 500 m^3 and 2000 m^3.The dam was designed to yield 627 l/second. However, as a result of encroaching settlement and erosion, the catchments area of the dam and runoff to the dam is decreasing thereby decreasing the capacity of the dam.

Gurgade site is one of the condominium sites with a serious water problem. Residents of the condominium site are facing a big challenge due to the water shortage problems to run their life. Therefore, looking for an alternative way of supporting, this study was held to assess an alternative solution for the shortage of water in the Gurgade condominium site and to evaluate how much percentage of non-domestic water demand can meet from RWH system.

1.3 Objectives of the Study

1.3.1 General Objective

The general objective of the study is to assess RWH as an alternative source of non-domestic water supply for Gurgade condominium site.

1.3.2 Specific Objectives

The specific objectives of the study have focused on:

1. To estimate the percentage of non-domestic water demand that can be met from RWH;
2. To identify the main challenges of the promotion of RWH system;
3. To propose design standard and criteria for the various components of RWH technology.

1.4 Research Questions

To meet the objective, this study may answer the following questions:

1. How much percentage of non-domestic water demand can met from RWH system?
2. What are the limitations of rainwater harvesting?
3. How could propose design standard and criteria for the various components of RWH technology?

1.5 Scope of the Study

This study was covered only one condominium site, conclusion and recommendations based on the findings might be difficult to generalize for the larger context. Quantity of water used for non-domestic purposes i.e. liters per capita per day (lpcd) taken in to account to analyze water supply service level of households based on data. This study didn't make comparisons between rainwater harvesting and other alternatives such as river flowing across the town and in the proximity of the town's boundary and abandoned groundwater wells. This study did not consider cost-benefit analysis.

1.6 Significance of the Study

The findings of this study serve as the basis for further improvement of RWH systems in Hosanna Town condominium sites in general and the study area in particular. Therefore, the outcomes of the study can serve as a guide to any person or organization involved in planning and designing water-related studies in which rainwater harvesting is under consideration.

1.7 Organization of the Research

This study contains five chapters. Chapter one deals with an introduction that covers the general background of the study area, statements of the problem, the research questions, objectives of research, the significance of the study, the scope of the study, justification of the study. Chapter two incorporates a literature review part. Chapter three comprises the methodology part that includes: background of the study area, data collection, and the research process. Chapter four discuss results and discussions in which precipitation results, water demand, design of storage tanks, sizing of gutters and downpipes were analyzed and chapter five deals with a conclusion and recommendation.

2. LITERATURE REVIEW

2.1 General

Water professionals are becoming increasingly worried about water scarcity. The UN world water development Report of 2003 states that population growth, and climate change are likely to be combined to produce a drastic decline in the water supply *(UN, 2003).* Rainwater harvesting technology is gaining popularity in a new way. Rainwater harvesting is enjoying a renaissance of sorts in the world, but it traces its history to biblical times. An extensive rainwater harvesting apparatus existed 4000 years ago in the Palestine and Greece. In ancient Rome, residents were built with individual cisterns and paved courtyards to capture rainwater to augment water from the city's aqueducts *(Panchayats, 2007).*

In Australia, the use of domestic rainwater tanks has been a long-standing and relatively common practice. In 1994 a survey by the Australian Bureau of Statistics showed that about 13 percent of all Australian households use rainwater tanks as sources of drinking water. A similar survey conducted in the southern Australia in 1996 showed that 82 percent of the rural population use rainwater as primary sources of water for drinking *(David, 1998).*

The history of rainwater harvesting in Ethiopia dated back as early as the pre Axumite period (560 BC). It was a time when rainwater was harvested and stored in ponds for agricultural and water supply purposes. Anthropologist has documented evidences of the remains of ponds that were once used for irrigation during this period *(Fattovich , 1990).* Other evidences include the remains of one of the old castles in Gonder (Fasiludus), constructed in the 15-16th century, which used to have water harvesting set up and pool that was used for religious rituals by the king *(Getachew, 2013).*

Rainwater harvesting is a common practice in the countries and areas where the annual precipitation is high and pure drinking and usable water is scarce. All over the world, economical condition has prompted the low-income groups to harvest the rainwater for household and essential uses. Several countries of the world in different regions have showed the popularity of this method. Originated almost 5000 years ago in Iraq, rainwater harvesting is practiced throughout the Middle East, the Indian subcontinent, in Mexico, Africa as well as in Australia and United States.

As the population of the world increased, irrigation, the most water consuming human activity, as well as domestic water usage increased, leading to a consequence of crisis of water supply in different regions. Among other available alternative sources for water supply, rainwater harvesting has become the most economical solution for the water crisis. Rainwater harvesting measures in Sumida city were first initiated in 1982 when the utilization of rainwater was proposed to the Japan Sumo Association in the Kokugikan (Sumo stadium) in Tokyo *(Dr. Makoto Murase, 2013).*

RWH systems can be categorized in to two groups based on type of catchment surface and uses. According to catchment type, RWH could be roof catchments, rock catchments, ground catchment and according to use check and sand dams. Roof and rock catchment systems could be directly used for domestic purposes with little effort exerted on improving water quality while ground and check or sand dams could be used for livestock watering, nurseries and small-scale irrigation and some domestic purposes. RWH system provides an innovation solution to meet local water needs. In recent years, the system has become cheaper and more predictable in the performance. RWH systems deliver good quality water directly or at every shorter distance to the targeted community.

2.2 Description of RWH

Water harvesting in its broadest sense can be defined as the "collection of runoff for its productive use”. Runoff may be harvested from roofs and ground surfaces as well as from intermittent or ephemeral watercourses. Water harvesting techniques, which harvest runoff from roofs or ground surfaces fall under the term ‘Rainwater Harvesting’ while all systems which collect discharges from watercourses are grouped under the term ‘Floodwater Harvesting’ *(African development bank , 2007)*. Rainwater harvesting is the capture, diversion and storage of rainwater for a number of different purposes including landscape irrigation, drinking and domestic use, aquifer recharge, and storm water abatement *(AUSTIN, 1997).* RWH is an art of harvesting; storing, utilizing and managing rainwater system.

RWH is broadly defined as the collection and concentration of runoff for productive use (crop, fodder, pasture or threes production, livestock and domestic water supply) it includes all method of concentrating, diverting, collecting, storing and utilizing and managing runoff for productive use. The term DRWH has two elements Domestic and RWH. So it may be useful to define both of the terms to clearly understand the meaning and scope of DRWH.

WHO defines domestic water supply as being 'Water used for all usual domestic purposes including consumption, bathing and food preparation' *(WHO, 1996)*.

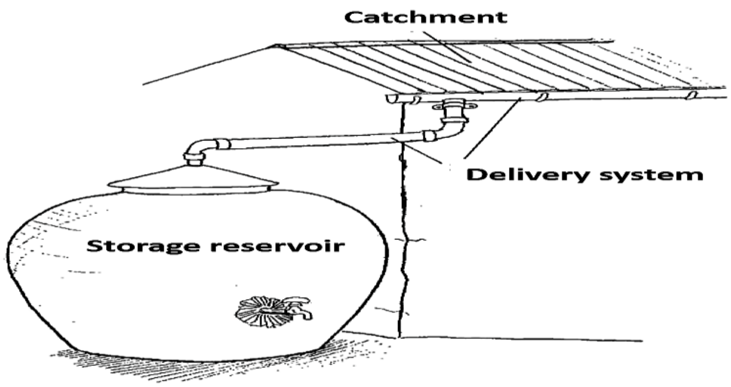

Figure 2.1: A Simple but widely used RWH system in developing countries

(Hatum & Worm, 2006)

2.3 Conceptual Frame Work

The basic source of all water on the earth is rainfall/precipitation, snow. about 70 percent of the precipitation that reach on the land area is evaporated or transpired directly back to the atmosphere; 10 percent socks in and becomes groundwater, and 20 percent runs off in to lake streams and rivers *(Punmia, J.Ashok,J.Arun, 1995).* Thus using RWH system we can use the rainwater/rainfall before any of the losses mentioned and avoid the difficult to regain it back by investing huge amount of money for pumping, construction of dams or reservoirs, construction of purifications or treatment plants and convey the stored water from head works to each house through various pipes size and length. Figure 2.2 shows the main forms of rural water supply *(Thomas, 2003)*

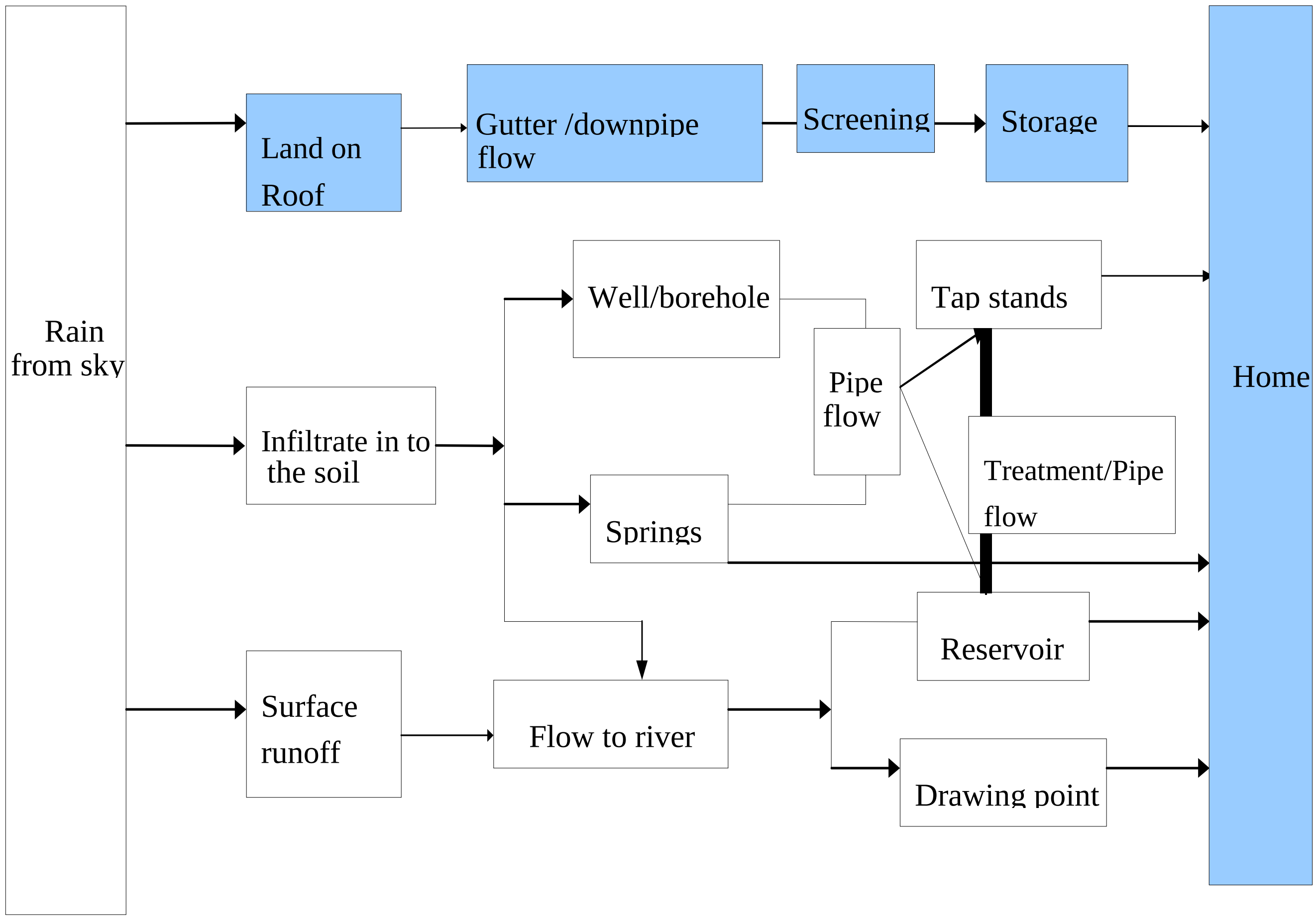

Figure 2.2: Model rainwater harvesting system *(Thomas, 2003)*

2.4 Rainwater Quality and Health

There are different issues when looking at the quality and health aspects of RWH. There is the issue of bacteriological water quality. Rainwater can become contaminated by faces entering the tank from the catchment area. It is advised that the catchment surface to be always kept clean. Rainwater tanks should be designed to protect the water from contamination by leaves, dust, insects, vermin, and other industrial or agricultural pollutants *(Maldives, 2009).*

Tanks should be located away from trees, with good fitting lids and kept in good condition. Incoming water should be filtered or screened, or allowed to settle to take out foreign matter. Water which is relatively clean on entry to the tank will usually improve in quality if allowed to settle for some time inside the tank. Algae will grow inside a tank if sufficient sunlight is available for photosynthesis. Keeping a tank dark and located in a shady spot will prevent algal growth and also keep the water cool *(Maldives, 2009).*

There is also a number of ways of diverting the dirty water ‘first flush’ away from the storage tank. The area surrounding a RWH should be kept in good sanitary condition, fenced off to prevent animals fouling the area or children playing around the tank. Any pools of water gathering around the tank should be drained and filled *(Maldives, 2009).*

Quantitative services indictors established by World Health Organization (WHO) and Ethiopian water quality standard has been used in this study *(WHO, 1996)*.

Table 2.1: WHO Standard for Water Quality

Parameter	Recommended Level
Faecal coli forms	0 per 100ml
Turbidity	< 5 NTU
Disinfectants chlorine residual	0.2 – 0.5 mg/l
PH	6.5 – 8.5

[Source: **(**http://www.lenntech.com)]

2.5 Advantages and Disadvantages of Rainwater Harvesting

2.5.1 Advantages

Relatively construction materials for RWH system are available in local markets or shops. Construction methods are relatively simple, low maintenance costs and requirements. Collected rainwater can be consumed without treatment, if a clean collecting surface has been used. The quality of rainwater is high, especially in developing country (where the level of industrialization is very low and the occurrence of acidic rain is minimal) and no energy costs are needed to run the system. (MAHANYELE, 2005)

2.5.2 Disadvantages

Some of the disadvantages or limitation of RWH system are: Supplies can be contaminated by bird/animal droppings on catchment surfaces and guttering structures unless they are cleaned/flushed before use. The amount of water harvested is limited by rainfall amount and available roof area or size. Supplementary water sources may be needed for long dry seasons, the required storage volume may be too high/ expensive. Mineral free water has a flat taste while people may prefer the test of mineral-rich water and mineral-free water may cause nutrition deficiencies in people who already on mineral deficient diet. (MAHANYELE, 2005)

2.6 Challenges of RWH System

Some of the limitations of the RWH system are:

RWH technology is the limited supply and uncertainty of rainfall. Rainwater is not a reliable water source in times of dry periods or prolonged drought. The first rain drains the dust, bird droppings, leaves, etc. which is found on the roof surface and it may contaminate harvested rainwater result in health risks. Mineral-free water has a flat taste while people may prefer the test of mineral-rich water and mineral-free water may cause nutritional deficiencies in people who already on a mineral-deficient diet. Supplies can be contaminated by bird/animal droppings on harvesting surfaces and guttering structures unless they are cleaned/flushed before use (Agarwall & Narain, 1997).

Therefore, the systems need to be carefully designed to optimize the coverage that a system can provide each year for a given level of investment. System reliability depends on the statistical analysis of rainfall data. Data quality is therefore very important. Harvested water quality is a concern. It is advised that the harvesting surface be always kept clean. Rainwater tanks should be designed to protect the water from contamination by leaves, dust, insects, vermin, and other industrial or agricultural pollutants and also be located away from trees, with well-fitting lids and kept in good condition. The area surrounding a RWH should be kept in good sanitary conditions, fenced off to prevent animals from fouling the area or children playing around the tank (Agarwall & Narain, 1997).

2.7 Requirements for Rainwater Harvesting

For rainwater harvesting to be viable there are a number of environmental requirements: - Rainfall should be over 50mm/month for at least half of the year (unless other sources are extremely scarce) *(Maldives, 2009)*. Local roofs should be made from impermeable materials such as iron sheets or tiles. There should be an area of at least 1 m^2 near each house upon which a tank can be constructed. There should be some other water source, either groundwater or (for secondary uses) surface water that can be used when the stored rainwater runs out.

2.8 Factors Determining the Feasibility of Rainwater Harvesting

Feasibility is defined as something that is practicable or achievable. A series of interlinked factors determine the feasibility of rainwater harvesting. Rainwater harvesting becomes viable when the following factors become acceptable together and also separately:

Water availability: - The initial consideration of the feasibility of RWH concentrates on availability or depth of rainfall as compared to its use or demand. The yield or supply of water depends on how much depth of rainfall the area received under normal and worst condition or the dependable average annual rainfall of the area. As per the NMSA of Ethiopia the country is divided in to four (4) regions based on rainfall types. They are (i) Region B: mono modal type-1 (ii) Region D: Mono modal type-2 (iii) Region A: - Bimodal type-1; and (iv) Region C: Bimodal type-2 *(NMSA, 1996).* When the rainfall occurs in one continuous period of time in a year, this is termed as mono modal and when this occurs in two discontinuous periods in a year, this is termed as bimodal. Again, each of these are divided in to type1 or 2 based on the time of occurrence of the continuous period/s or by the prominence of rainy period. Mono modal type-1: Dominates by a single maxima rainfall pattern, Mono modal type-2 /Diffused pattern/: Irregular rainfall pattern (does not have well defined rainfall pattern Bimodal type-1: Characterized by quasi-double maximum peak in August and Bimodal type- 2: Dominates by double maxima rainfall pattern with peak during April and October.

In a more comprehensive manner the Ethiopia climate seasons could be classified in three seasons. These are given as Bega; which is generally the dry season that covers the period from October to January, Belg: Refer to a small rain season that covers the period from mid-February to mid-May and Kiremt: Refer to the main rainy season that cover the period from June to September. About 50 to 90 Percent of the main annual rainfall occurs in Kiremet season over the principal cropping Zone. In Bega season, the rainfall varies between 10 to 400 mm; this is about 25 to 600 mm in Belg season and about 10 to 1200 mm in Kiremt season *(NMSA, 1996).* The mean annual rainfall of the study area, Gurgade Condominium site is 1156.8 mm and that the annual rainfall of Hosanna metrological station ranges between 744.8-1623.8 mm The monthly rainfall distribution as measured at Hosanna station is a sort of uni-modal where the main rainy season extends over the period of mid -March to mid- October with its peak from April to September. *(NMSA, 1996)*

Acceptability: - Rainwater harvesting is an accepted freshwater augmentation technology in many parts of the world. While the bacteriological quality of rainwater collected from ground catchments is poor, rainwater from properly maintained rooftop catchment systems, which are equipped with tight storage tanks and taps, is generally suitable for drinking and often meets the WHO drinking water standards. This water is generally of higher quality than most traditional water sources found in the developing world. Rooftop catchment of rainwater can provide a good quality water which is clean enough for drinking, as long as the rooftop is clean, impervious and made from non-toxic materials and located away from over-hanging trees. Use of rainwater harvesting for drinking and other purposes has to be culturally accepted by the users. The positive impacts, i.e. the benefits, that the rainwater harvesting system brings to the community influences the level of acceptability towards the RWH system. The users are able to give expression to how valuable rainwater harvesting is to them. An analysis of the benefits that rainwater harvesting offers to the users will help to determine whether the amount of water collected makes a difference. (MAHANYELE, 2005)

Cost of the system: - The cost of installing a rainwater harvesting system should not be substantially higher than other water supply options suitable at the area of study.

Water quality: - Quality of rainwater should be safe for human consumption. Operation and maintenance needs to be done properly to ensure good quality water.

2.9 Parts of Rainwater Harvesting System

Basic Components: -

Regardless of the complexity of the system, the domestic rainwater harvesting system comprises six basic components:-

1. Harvesting area/roof: - the surface upon which the rain drops;
2. Gutters and downpipes:- the transport channels from harvesting surface to storage;
3. Leaf screens: - first-flush diverters and roof washers, the systems that remove contaminants and debris from the captured rainwater before it goes to the tank
4. Cisterns or storage tanks: - where collected rainwater is stored;
5. Delivery system:- gravity-fed or pumped to the end use and;
6. Water treatment filters and equipment: - additives to settle, filter, and disinfect.

2.9.1 Harvesting Area/Roof

Roofs can be made from a variety of materials. The typical roofing materials include the following: Corrugated Iron Sheet (CIS) or plastic sheets, or tiles. Thatched roofs made from palm leaves (coconut and palms with tight thatching are better).Other thatching materials and mud discolor and contaminate the rainwater. Unpainted and uncoated surface areas are best. If paint is used it must be non-toxic (no lead based paints). Asbestos-cement roofing does not pose health risks - no evidence is found in any research. However, the airborne asbestos fibers from cutting do pose a serious health risk if inhaled.

The efficiency of rainwater collection depends on the materials used, the construction, maintenance and the total rainfall. A commonly used overall efficiency figure is 0.8. If cement tiles are used as roofing material, the year-round roof runoff coefficient is some 75 %, while clay tiles collect usually less than 50 % depending on the production method.

Plastic and metal sheets do best with an efficiency of 80-90 %. In the case of this research the runoff coefficient 0.8 used based on the criteria of corrugated metal sheets because of good quality water from glazed tiles, unglazed tile can harbor mold and contamination can exist in tile joints *(Maldives, 2009).*

Table 2.2: Runoff coefficients for various catchment types

Type of roof catchment	Runoff coefficients
A. Roof catchments	
Tiles	0.8 - 0.9
Corrugated metal sheets	0.7 - 0.9
B. Ground surface coverings	
Concrete	0.6- 0.8
Brick pavement	0.5-0.6
C. Untreated ground catchments	
Soil on slopes less than 10 percent	0.1-0.3
Rocky natural catchments	0.2-0.5

[Source: - Alphonsus Daniel, pers.com]

2.9.2 Gutters

Gutters are channels fixed to the edges of roof all around to collect and transport rainwater from the roof to the storage tank. The purpose of the Gutter is to convey the rainwater from the Roof to the storage tank directly or to the down pipes and then finally to the tank. These must be properly sized, sloped and installed to maximize efficiency and minimize water loss. Gutters come in a wide variety of shapes and forms, ranging from the factory made PVC type to home-made gutters using bamboo or folded metal sheet.

The usual Gutter material in developing countries is galvanized sheet metal with triangular (V-shape), rectangular or semi-circle in shape. There are variety of types of gutter in the world such as prefabricated plastic, Aluminum, Steel, Wood and Bamboo, half pipes, Flexible guttering. The selection of the type of the Gutter mainly depends on the cost, difficulty in mounting as well to some extent water quality *(Peter, 1998)*.

Plastic gutter are less available in developing countries but in countries where industrial bases are good like Mexico, India and Sir Lanka, it is readily available at reasonable cost. Aluminum Gutters are non-corrosive but too expensive. Steel Gutter is relatively noncorrosive and very common in Africa. Steel Gutter produced in workshops are usually square in shape and the cost of theses Gutters is 2 to 3 times a similar Gutter produced on-site *(Warwick University, 2005).* On site, Gutters are usual V-shaped. The shape is quite efficient but practices indicate that it has a tendency to block with debris; mounting V-shape Gutter is difficult as it is fixed just under the Roof edge. Rectangular Gutters can be easily fixed on fascia board, which is fixed on the rafter, but the problem is that fascia board might be missed and the distance from the roof edge is random *(Gould & Nissen-Petersen, 1999).* The flow performance of a gutter varies along its length resulting in a spatially varying flow; however for a long gutter it can be approximated by the usual manning formula. Using this formula an idea of the actual size of gutter need can be developed for any gutter profile *(Warwick University, 2005).*

2.9.3 Down pipes

Down pipes are produced from different material; steel pipe or rolled sheet metal and PVC are the most common types. Down pipe cross-sections are sometimes smaller than those of the gutter as it is assumed that since they are normally vertical, water will pass through them faster than through gutters.

In roof catchment systems, however down pipes should have similar dimensions to gutters. This is because the down pipes are often not vertical and act as channel to convey water from the end of the gutter in to tanks. Suggested sizes of down pipes are given against the roof area feeding the down pipe. These sizes are big enough for a pipe whose length is not more than six times its drop (where drop is the change in height from the pipe entry to the water level in tank). For down pipes laid very flat, whose length is more than six times their drop, the next larger size is recommended. If tanks inlet filter is provided, then the drop should be measured to the top of the filter, not the water surface in the tank. In any case it is wise to provide a screen above the pipe entry to prevent twigs and leaves from entering it *(Thomas, 2003).*

Table 2.3: Recommended size of down pipe

Roof Area (m^2)	Gutter Width, mm	Down Pipe, mm
17	60	40
25	70	50
34	80	50
46	90	63
66	100	63
128	125	75
208	150	90

[Source: - Thomas, 2003]

2.9.4 Leaf Screens

To remove debris that gathers on the catchment surface, and ensure high quality water for either potable use or to work well without clogging emitters, a series of filters are necessary. Essentially, mesh screens remove debris both before and after the storage tank. The defense in keeping debris out of a rainwater harvesting system is some type of leaf screen along the gutter or in the downpipes.

Depending upon the amount and type of tree litter and dust accumulation, the homeowner may have to experiment to find the method that works best. Leaf screens must be regularly cleaned to be effective. If not maintained, leaf screens can become clogged and prevent Rainwater from flowing into a tank. Built-up debris can also harbor bacteria and the products of leaf decay.

2.9.5 Storage Tank

A storage tank is a receptacle built to catch and store rainwater. They range in capacity from a few liters to thousands of cubic meters. For rainwater catchment systems, the storage tank is usually the most expensive part, so the design and construction needs due attention. As well as having the appropriate volume with respect to the catchment area, rainfall conditions and demand, it should have a functional, durable and cost effective design. Nevertheless, there are a number of key requirements common to all effective tank designs *(Gould & Nissen-Petersen, 1999).*

Usually, the main calculation in designing a RWH system will be to size the water tank correctly to give adequate storage capacity. The storage requirement will be determined by a number of interrelated factors. These include: Local rainfall data and weather patterns, roof (or other) collection area / more technically catchments; runoff coefficient, and user's number and consumption rates.

2.9.6 First-flushing

First flush or the rain diverter is provided to flush off the first rain before it enters the storage tank. The first flush water will be most contaminated by particulate matter, bird droppings, and other material laying on the roof (debris, dirt and dust). When the first rains arrive, it is essential to prevent this unwanted material to go into the storage tank. This can cause contamination of water collected in the storage tank. After screening gutters a first flush device is incorporated in the roof top rainwater harvesting systems to dispose of the 'first flush' water so that it does not enter the tank.

This device will improve the quality of water lengthen the life of system components and reduce overall maintenance. There are two such simple systems. One is based on a simple manually operated arrangement, whereby, the down pipe is moved away from the tank inlet and replaced again once the first flush water has been disposed. In another simple and semi-automatic system, a separate vertical pipe is fixed to the gutter with a valve provided below the "T" junction. After the first rain is washed out through first flush pipe, the valve is closed to allow the water to enter the down pipe and reach the storage tank. *(Maldives, 2009).*

2.9.7 Filter

The quality of stored water can be much improved if leaves and other debris are kept out of the system by the use of a coarse filter or screen on the inlet of the tank. Without screens, leaves and other material may enter tanks and provide food and nutrients for micro-organisms to multiply. In the absence of such nutrients, bacteria eventually (within 2-20 days) die off from starvation. A filter or screen should be durable, easy to clean and replace, and should not block. It is essential that there are no gaps in the storage tank inlets where mosquitoes can enter or exit. Coarse filtration screens (made of stainless steel or synthetic mesh) are the simplest, most inexpensive and widely used technology.

Typically these are mounted across the top inlet of the storage tank with the downpipe above the screen. Alternatively, the downpipe from the roof could enter the tank through an appropriately sized hole at the top of the tank with the filtration screen at the entrance to the downpipe from the gutter. Finer filter devices have been used to remove small sized sediment which would otherwise either be suspended in the water or settle to the bottom of the tank leaving sludge *(SOPAC, 2004).*

2.10 Volume of Rainwater

The volume of water that can be harvested, thus tank size required, can be estimated by the product of roof area and precipitation:

V=A*P*R…………………………………………………………..........2.1 (*Rough, 2006).*

Where: - A is the area of the rooftops, P is the depth of precipitation in the area being considered for the technology to be applied, R is Runoff coefficient and V is the volume of water that can be captured from precipitation on rooftops, which will be available for use.

Flow (Q) can be multiplied by 0.80, assuming an efficiency of 80 % if we consider 20 % of the water can be lost due to evaporation and runoff (Efficiency will depend on roof material).

2.11 Mean Areal Depth of Precipitation

Point rainfall is the rainfall at a single station. For small areas less than 50 km^2, point rainfall may be taken as the average depth over the area. In large areas, there will be a network of rain-gauge stations. As the rainfall over a large area is not uniform, the average depth of rainfall over the area is determined by one of the following three methods *(Raghunath, 2006).*

2.11.1 Arithmetic Average Method

It is obtained by simply averaging arithmetically the amounts of rainfall at the individual rain-gauge stations in the area.

$$\text{Pavg} = \sum \frac{p1}{n}$$ ....2.2 *(Raghunath, 2006).*

Where: - Pavg = average depth of rainfall over the area ΣP1 = sum of rainfall amounts at individual rain-gauge stations and n = number of rain-gauge stations in the area.

2.11.2 Thiessen Polygon Method

This method attempts to allow for non-uniform distribution of gauges by providing a weighting factor for each gauge. The stations are plotted on a base map and are connected by straight lines. Perpendicular bisectors are drawn to the straight lines, joining adjacent stations to form polygons, known as Thiessen polygons *(Raghunath, 2006).*

Each polygon area is assumed to be influenced by the rain gauge station inside it, i.e., if P1, P2, P3 ...are the rainfalls at the individual stations, and A1, A2, A3 ... are the areas of the polygons surrounding these stations, (influence areas) respectively, the average depth of rainfall for the entire basin is given by:

$$\text{Pavg} = \sum \frac{A1P1}{\sum A1}$$ ………………..…………………………………...……2.3 *(Raghunath, 2006).*

2.11.3 The Isohyet Method

In this method, the point rainfalls are plotted on a suitable base map and the lines of equal rainfall (isohyets) are drawn giving consideration to orographic effects and storm morphology.

The average rainfall between the successive isohyets taken as the average of the two isohyet values are weighted with the area between the isohyets, added up and divided by the total area which gives the average depth of rainfall over the entire basin *(Raghunath, 2006).*

$$\mathbf{Pavg} = \frac{\sum A1 - 2P1 - 2}{\sum A1 - 2}$$ ……………………………………..2.4 *(Raghunath, 2006).*

Where: A_{1-2} = area between the two successive isohyets P_1 and P_2 $P_{1-2} = \frac{P1+P2}{2}$ $\sum A_{1-2}$ = A is the total area of the catchment P_1P_2 = A is the total area of the basin.

2.12 RWH for Non-Domestic Applications

2.12.1 Municipal Applications

Rainwater harvesting can be used in a variety of municipal applications. Direct roof capture off city buildings or capture of excess runoff from paved surfaces can be used to fill cisterns and other storage facilities that can be used for irrigation of green spaces and recreational facilities, washing, and cleaning of streets and facilities, or firefighting. Such bulk water storage can be used to augment emergency water supplies following natural disasters when the potable supply may be out of operation. In this case, filtration and treatment will need to be applied before distribution.

2.12.2 Agricultural Applications

Crop irrigation and livestock watering have heavy water demands. Under rain fed production, crop yields will drop significantly during the dry season unless supplemental irrigation is applied. Livestock production is similarly impacted where water is in short supply. RWH from farm building catchments and constructed surfaces can greatly contribute to meeting water demands during the drier months for sustained production.

2.12.3 Commercial and Industrial Applications

Rainwater harvested off roofs and surface catchments such as roads and parking lots can be stored and used as required to offset the need for use of the potable supply for non-drinking purposes. Typical applications will include washing and cleaning, cooling, firefighting, bathing pool recharge and irrigation. Where water may be required for food preparation and other manufacturing processes, treatment will need to be applied.

3. MATERIALS AND METHODS

3.1 Description of the Study Area

3.1.1 Location and Topography

Hosanna Town, capital of Hadiya Zone is found in Southern Nations and Nationalities Regional Government Administration Region of Ethiopia. Urbanization in this geographic area starts before hundred years (*HTM, 2010)*. Hosanna town was formerly called Sech Duna by the local people. Later the name was given by Ras Abate in 1904, who was the governor of Lemo and Kembata Awraja in that time and since 1904 the town was a capital for Kembata and Hadiya province during the time of the Imperial regimes *(Alebachewu and Samuel, 2009).* In 1949, for the first time the town established a municipality administration *(HTM, 2010)*. Hosanna town is located between 7º53’00’’N and 7º55’00’’N latitudes and 37º30’00’’E and 37º40’00’’E longitudes in UTM coordinates. The town is located in between 2140 m and 2380 m elevated lands above mean sea level and 230 km away from the Country's Capital city Addis Ababa to the southern direction via Alemgena and Butajira Road and 168 km from the Regional town Hawassa via Alaba-Angacha Road. The existing water supply for Hosanna town is obtained from six boreholes located at the periphery of the town (though one borehole is abandoned due to low yield and the other BH-6 is still not functional due to relay system not installed) and two springs located around Mugo ,Siltie Zone, 45 km away from the Hosanna town. The annual water production from the water supply service is collected on the monthly base and then converted to yearly base for the evaluation purpose. The production of the water for distribution purpose is from the boreholes and the newly constructed spring sources.

As there is shortage of water supply provision in the Hosanna town and also a complaint regarding service provision from condominium dwellers was what motivates me to do this research. This study was conducted in Hosanna Town particularly in Gurgade Condominium site that found in the southwestern part of Hosanna Town in Sechi Duna Sub-City, Betel Kebele.

The site has about 4 blocks and 2 communal holding 72 houses those serve about 700 populations *(HLIC, 2008)* with Ground plus (G+2) buildings and 9.3 m height from the ground in the total area of 1536 m^2 . The site is chosen due to the water shortage problem is high and flood problems are evident from the resident's reflection during the rainy session. Additionally, the data is relatively available.

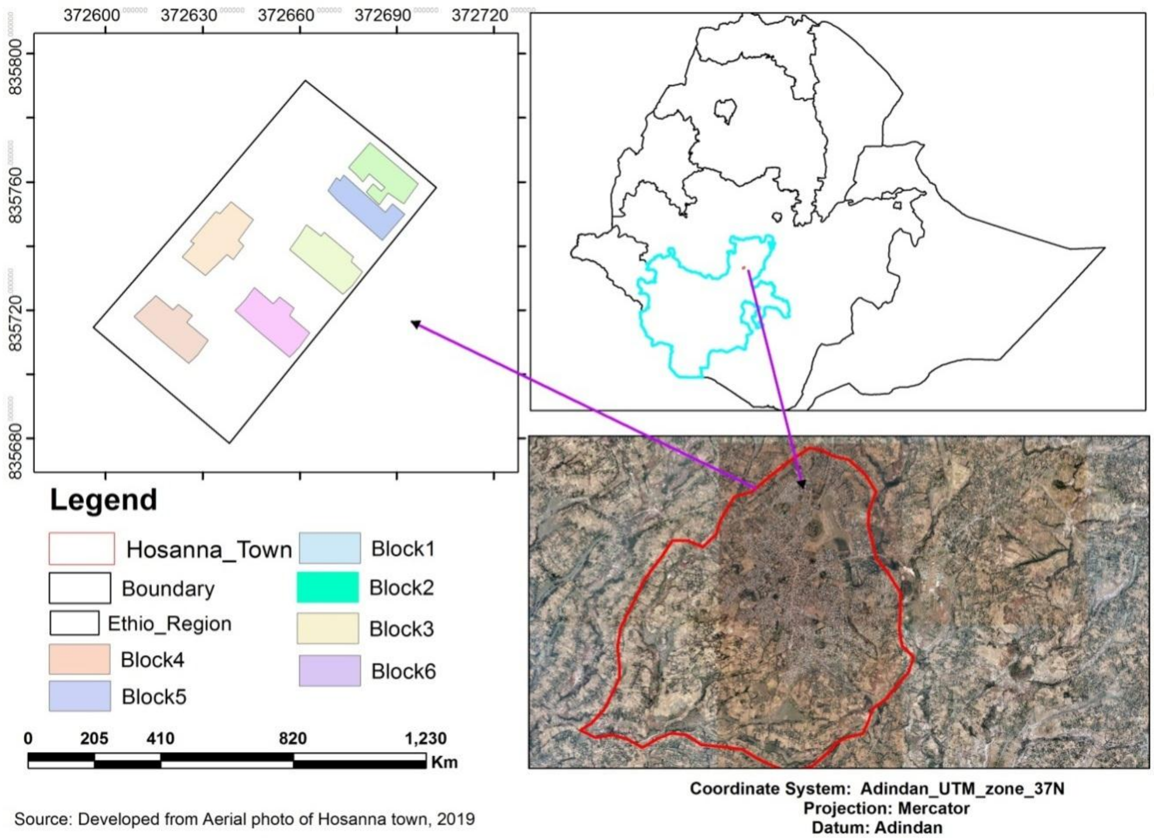

Figure 3.1: Map of the study area

3.1.2 Climate

The study area is mainly characterized by highland ('dega') climatic conditions. There is one rain gauge station in Hosanna with its name Hossana meteorological station, at a specific location of 37º 49'00''E and 83º 28'00''N projected value coordinates.

3.1.3 Rainfall

The mean annual rainfall of the study area is 1156.8 mm and that the annual rainfall of Hosanna metrological station ranges between 744.8-1623.8 mm (NMSA).The monthly rainfall distribution as measured at Hosanna station is a sort of uni-modal where the main rainy season extends over the period of mid -March to mid- October with its peak from April to September. Seasonal distribution of rainfall and the intra month variability is shown in the Figure 3.2 and 3.3 respectively.

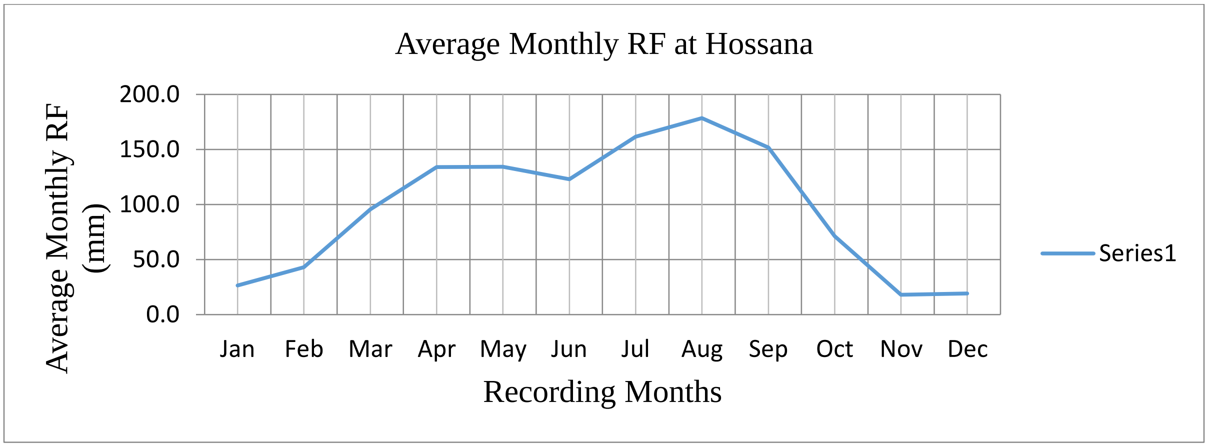

Figure 3.2: Seasonal distribution of rainfall

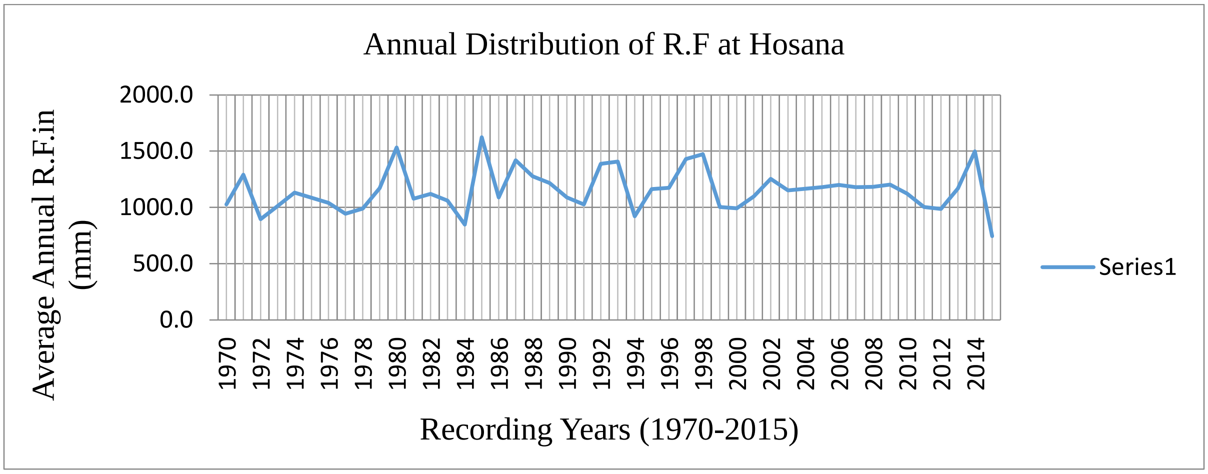

Figure 3.3: Seasonal distribution of rainfall at hosanna metrological station

Table 3.1: Summary of average monthly precipitation (mm/month)

Month	Average monthly precipitation (mm)
January	26.4
February	43.0
March	95.6
April	134.0
May	134.3
June	123.0
July	161.6
August	178.4
September	151.8
October	71.3
November	18.1
December	19.3
TOTAL	1156.8

[Source: - NMSA, 1970 -2015]

3.1.4 Temperature

The study area is found in wet Woyna Dega agro-climatic zone with minimum and maximum temperatures of 7.7 ^{0}c and 25.8 ^{0}c in December and March respectively. The area receives a Uni-Modal type of rainfall that starting in March and ending in October with the maximum rainfalls occurring in April to May and July to September. And also the mean annual temperature is about 16.9 ^{o}C. Table 3.2 shows the mean monthly temperature.

Table 3.2: Shows the mean monthly temperature

variable	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	annual
T max	24.9	25.5	25.8	24.7	23.7	21.9	20.5	20.1	21.4	23.3	23.6	24.2	23.3
T Min	8.9	10.4	11.8	12.0	11.5	9.8	11.4	11.2	11.0	10.9	9.1	7.7	10.5
T av.	16.9	18.0	18.8	18.3	17.6	15.9	15.9	15.7	16.2	17.1	16.3	15.9	16.9

[Source: - NMSA]

3.1.5 Population

According to the CSA population of May 2007, the total number of Hosanna town population was 69, 959 for the year 2007/8. Since the preliminary population count result is not more disaggregated, population distribution by sub-cities and the number of households as well as housing units in the town could not be shown. *(CSA, 2007).*

The Municipality source shows very consistent estimate to that of CSA count and well disaggregated by sub-cities. According to this data source the total population of Hosanna Town as of 2008 is estimated to 70,470 and as per the population projection done by the Hywas Engineering Consultants the total population of the town for the year 2014 and 2015 is estimated to 91,341 and 95,269 and the distribution by localities and gender as of 2008 is summarized below. Hosanna town comprises of three sub-cities and eight kebeles. It is one of the economically and socio-politically dynamic towns in the region and supposed to have adequate supply and availability of all development infrastructures including safe water supply. Gurgade condominium site is located at Sech Duna sub-city, Betel Kebele. Therefore, this study was held on Gurgade condominium site dwellers. As shown in the Table 4 of Appendix A.

3.2 Study Variables

3.2.1 Independent Variable

It is that factor which is measured, manipulated, or selected by the experimenter to determine its relationship to an observed phenomenon. Hence, for this specific study the following variables were considered as independent variables: Rainfall, temperature, harvesting area, and number of users.

3.2.2 Dependent Variable

It is response variable or output. The dependent variable is that factor which is observed and measured to determine the effect of the independent variables. Therefore, RWH, size of storage/tank, runoff coefficient and consumption rates are the dependent variables for this study.

3.3 Materials

For this particular study, different materials and tools were used as listed in table 3.3.

Table 3.3: Software and models were used

Software and model	Purposes
AutoCAD	To design the RWH components
Arc GIS 10.3	For delineating the area to be harvested
Microsoft office excel	For data tabulation and graphical calculations

3.4 Types and Sources of Data

Data for this study was collected from secondary sources. The majority of secondary data was collected from HWSE documents, rainfall data from the office of NMSA, population census reports from CSA and HLIC and areas of the roof and the study site was measured from cadastral map of Hosanna.

3.5 Data collection

Data required for studies such as previous water consumption, area of the roofs, rainfall data, population and runoff coefficient were collected from different sources (NMSA, HWSE documents, CSA, cadastral map of Hosanna). Calculations of the harvesting areas (areas of the rooftops of the blocks) are made by using AutoCAD Software from the cadastral map of Hosanna town.

3.6 Methodology

Existing available data describing the system has been gathered to generate the system. From the system map of the network, monthly customers bill data and different documents the information was collected from HWSE. Forty six (46) years of rainfall data of the station was collected from national meteorological agency. The distribution of conventional households has been collected from CSA of Ethiopia. In the census, the household is defined as a group of persons living together in the same housing unit. Previous year's average monthly consumption of water per-house level data will be collected from the HWSE office. The methodology of this study includes the secondary sources, data analysis for appropriate system and formulating findings. The whole methodology of the study as described figure 3.4.

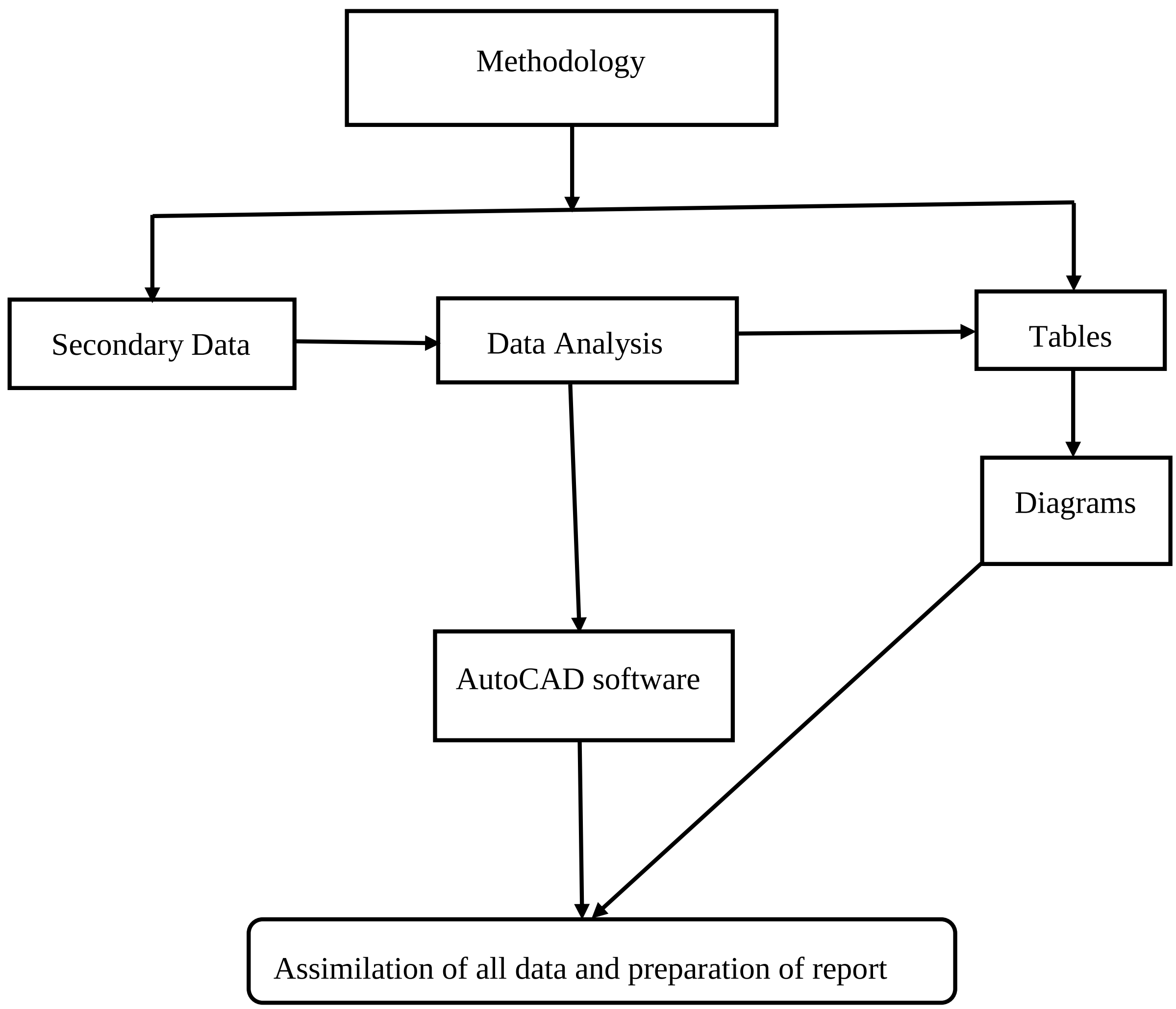

Figure 3.4: Diagrammatic presentation of the study

3.7 Water Consumption and Water Supply Coverage

3.7.1. Water Consumption

The annual water consumption from the water supply service is collected on the monthly base and then converted to yearly base for the evaluation purpose. The consumption of water is combined consumption of private, commercial, Government and public and industry consumption. The average daily per capita consumption calculated as: Capita consumption (l/person/day) = (Annual consumption in m^3*1000 liter/m^3) / (Population number * 365).

Table 3.4: Average monthly water consumption in (m^3) per month per household

S/No.	Year	2011	2012	2013	2014
1	January	25627.34	38116.51	54989.00	61386.00
2	February	21244.90	30566.00	57235.00	58944.00
3	March	31515.97	32612.16	55721.00	74589.00
4	April	30593.42	30443.38	55621.00	64533.00
5	May	28436.21	28739.11	51274.00	62097.00
6	June	27444.61	30800.60	56413.00	55083.00
7	July	25020.75	26007.00	40361.00	63270.01
8	August	26842.89	24585.00	44966.00	63270.01
9	September	28425.89	27331.00	54388.12	63270.01
10	October	26371.00	27464.00	50874.00	63270.01
11	November	30078.00	39880.00	65841.72	63270.01
12	December	27418.16	46181.00	63827.50	63270.01
	Total	329019.14	382725.76	651511.34	756252.06

[Source: - HWSE monthly bill data 2011-2014]

3.7.2 Water Supply Coverage

Water supply coverage can be defined as the percentage of people in access of water supply service in the town. To address the need of highly rising water supply needs in the urban population, the water supply service utilities has to manage the existing water supply systems in a manner to efficiently address the need.

It is observed that the financial constraint, poor management of the water supply system and the low capacity of human resource has a great impact in the low coverage of water supply provision. The water supply coverage of the town has been evaluated based on the average per capital consumption and level of connection per family. Number of population as forecasted to the year 2014 has been used to evaluate the average per capital consumption and also of the water coverage. As presented the water supply coverage of Hosanna town for the years 2011-2014 in tabular form and also refer table 6 in the Appendix A.

3.8 Research Process

In order to determine whether rainwater harvesting is an option worth considering for the water scarcity issue in Hosanna, particularly Gurgade condominium site, water quality, water availability, economic benefit and overall advantages had to be considered. When analyzing the feasibility of rainwater harvesting research, the RWH becomes viable when the following factors become acceptable together and also separately: three factors must be considered:-

1. Technical aspects: - which in this case include water availability, precipitation, demand and water quality;
2. Economics :- including a comparison of the costs of implementing this system with the costs of obtaining water through other means;
3. Social factors: - which includes the community's response to the research, their involvement and interest.

But this study, was aimed to analyze only the technical aspects, to determine the viability of implementing the RWH system in Gurgade condominium site. For designing rainwater harvesting system rainfall data is required. Hence, for this research average monthly rainfall data of 46 years is available and used. The more reliable and specific the data is for the location, the design will be better.

3.9 Data Interpretation and Presentation

The analyzed data were interpreted by the following the relevant correlation to the general aim of the study. The analyzed data be presented in graphs, descriptive statistics, percentages, charts, and tables.

3.10 Data Analysis

The data analysis includes the storage capacity of 67.74 m^3 reservoir for Gurgade condominium site, and the analysis also includes 125 mm gutters width with 75 mm down pipes and 75 mm gutter width with 50 mm down pipes respectively.

3.10.1 Homogeneity Test

Homogeneity is an important issue to detect the variability of the data. In general, when the data is homogeneous, it means that the measurements of the data are taken at a time with the same instruments and environments.

There are many methods proposed and applied for testing homogeneity of meteorological series. The methods for testing the homogeneity of the series may be classified into two groups as absolute method and relative method *(Karabork et al., 2007).*In the first method, the test is applied for each station individually. Alternatively in the second method, neighboring (reference) stations are also used for the testing process *(Wijngaard et al., 2003).*

In this test two samples of size p and q are compared. Set of data combined to size N= p+q is ranked into ascending order. The *(Mann and Whitney, 1947)*; (M-W) test considered the quantities V and W in equation 3.1 and 3.2;

V= N$-\frac{(p(p-1))}{2}$…………………………………...................3.1 *(Mann and Whitney, 1947).*

W= pq-V…………………………………………………..…...3.2 *(Mann and Whitney, 1947).*

N is the sum of the ranks of the elements of the first sample size p in the combined series size N. and V and W are calculated from N, p, and q. V represents the number of times an item in sample one follows an item in sample two in the ranking. Similarly, W can be computed for sample two following sample one. The M-W statistic u is defined by the smaller of v and w. when N>20 and p, q>3 and under the null hypothesis that the two samples came from the same population is approximately normally distributed with mean.

Umean= $\frac{p+q}{2}$…………………………………………...…3.3 *(Mann and Whitney, 1947).*

Var (U) =($\frac{pq}{N(N-1)}$) ($\frac{N^3-N}{12} - \sum T$)………………………………..3.4 *(Mann and Whitney, 1947).*

And T= $J^3 - \frac{J}{12}$…………………………………………….…….3.5 *(Mann and Whitney, 1947).*

Where J is the number of observations tied in a given rank. T is summed overall groups of tied observation in both samples of size p and q.

Ustat $= \frac{(U-Umean)}{(var(u))^{1/2}}$…………………………………………3.6 *(Mann and Whitney, 1947).*

Equation (3.6) is used to test the hypothesis of homogeneity at significance level α by comparing it with the standard normal variant for that significance level.

For no trend in the data series this value should be within the limit of ± 1.96 at the significance level of 5%. The test by mann-Kendal showed that no significant trend in the annual maximum rain fall values exists at station. Hence the annual maximum rainfall series for the station are treated as homogenous for estimation of subsequent parameters.

This study adopted the method of Mann Whitney test *(Wijngaard et al., 2003)* to access the homogeneity series in Hosanna meteorological station's rainfall series, and the testing variables were observation number, annual mean and annual maximum. Table (3.5) shows the homogeneity test of M-W test result for Hosanna.

Table 3.5: Mann-Whitney test to homogeneity of Hossana station

Mann-Whitney rank statistics test result (Mann and Whitney, 1947)		
station name	Hosanna	Remark
sample size	46	
sample 1 (p)	24	
sample 2 (q)	22	
number of observations tied (J)	1	
sum of the tied (T)	0.917	
Var (U)	2067.766	from equation (3.6)
standard test result for 5% significant level (U) or stat U	0.506	0.506<1.96 (Homogenous)

As the result shown at table (3.5) the standard test for Hosanna station with significance level of 5% was found to be less than the critical value of ± 1.96. Therefore, there was no significance trend in the annual maximum observed values. Hence, the annual maximum rainfall for the station is treated as homogenous for later calculation.

3.10.2 Volume of Rainwater

To calculate the amount of rain that can be captured off a roof surface per year, a procedure known as the Rational Method can be applied. All we need to know is the average annual rainfall for the location, the size or area of the roof and the type of roof surface. The average annual rainfall should be available from NMSA.

Supply (litters per year) = rainfall (mm/year) x area (m^2)*runoff coefficient

Roof surface area of a residential building (m^2) = roof length (m) x roof width (m)

= 28 m*10 m = 280 m^2

Roof surface area of a communal building (m^2) = roof length (m) x roof width (m)

= 26 m*8 m = 208 m^2

The potential volume of water that can be harvested from the residential building roof:

Volume captured (liters) = rainfall (mm)*roof area (m^2)*run-off coefficient

Volume captured in January (m^3) = 0.0264 m*280 m^2*0.8 (Corrugated metal sheets)

= 5.91 m^3 (residential building)

And also for communal building (m^2) = 0.0264 m* 208 m^2*0.8 (Corrugated metal sheets)

= 4.39 m^3 (communal building)

Hence, the total volume of water be calculated on similar manner for all months of the year.

There are a total of four condominium (residential) blocks and two communal (residential and commercial) blocks at the site, so total volume of water = (259.03 m^3per year/block*4 blocks) + (195.2 m^3per year/block* 2 blocks) = 1426.6 m^3 per year.

Monthly demand = total population*estimated per capita water requirement

For January:-

Monthly demand (m^3) = (4 blocks*60 persons/blocks*30 l/c/d*30 days) = 216 m^3

Percentage of monthly demand satisfied = (volume of water that can be harvested/volume of monthly demand)*100

For January: **-** Percentage of monthly demand satisfied = (Total volume of water available for a residential building* number of blocks)/ volume of monthly demand)*100

$$= (6.65\ m^3*4/216\ m^3)*100 = 12.31\%$$

Monthly precipitation depths were multiplied by rooftop area to calculate the volume of water available to supply the monthly demand of a building. The success of a rainwater harvesting system depends on many factors. Water demand in the area, cost feasibility, and precipitation are some of the most important issues to be considered when analyzing the viability of implementing such systems. Precipitation data is needed to determine the volume of water that can be captured, with rain depth and roof area, and then use that information to compare with the average monthly demand in an average urban household.

The monthly rainfall data as obtained from (NMSA) cover rainfall records from the 46 yrs. This Data from 1970 to 2015 appears good and reliable hence considered representative in this study. The total average monthly precipitation (mm/month), the year 1970 to 2015 is 1156.8 mm. As shown in the table 1 of Appendix A. From the rainfall data of the station high rainy seasons are observed in July and August. The minimum rainfall is recorded in November and December. During this period the maximum monthly average was 178.4mm of August and the minimum was 18.1 mm for November. *(NMSA, 1996)*

3.10.3 Water Losses

All calculations relating to the performance of rainwater catchment systems involve the use of run off coefficient to account for losses due to spillage, leakage, infiltration, catchment surface wetting and evaporation, which will all, contribute to reducing the amount of runoff. (Runoff coefficient for any catchment is the ratio of the volume of water that runs off a surface to the volume of rainfall that falls on the surface).

Water harvesting potential = Rainfall (mm) x Area of catchment x Runoff coefficient or

Water harvesting potential = Rainfall (mm) x Collection efficiency

The collection efficiency accounts for the fact that all the rainwater falling over an area cannot be effectively harvested, because of evaporation, spillage etc. Factors like runoff coefficient (see Table 2.2: Runoff coefficients for various catchment surfaces) and the first-flush wastage (refer section on Roof Washers/First-Flush device.) are taken into account when estimating the collection efficiency.

Runoff coefficient is the factor which accounts for the fact that all the rainfall falling on a catchment cannot be collected. Some rainfall will be lost from the catchment by evaporation and retention on the surface itself. (Refer Table 2.2 for runoff coefficient). Rainwater yield varies with the size and texture of the catchment area. A smoother, cleaner, and more impervious roofing material contributes to better water quality and greater quantity. While loss is negligible for pitched metal roofs, concrete or asphalt roofs average less than 10 per cent loss, and built up tar and gravel roofs average a maximum of 15 per cent loss. Losses can also occur in the gutters and in storage. Regardless of roofing material, many designers assume loss on annual rainfall up to 25 per cent. These losses are due to several factors: the roofing material texture which slows down the flow; evaporation; and inefficiencies in the collection process. (MAHANYELE, 2005)

Therefore, the amount of water losses are taken into account when estimating the collection efficiency. Regardless of roofing material, many designers assume loss on annual rainfall up to 25 per cent.

Water Losses = the total volume of water expected to be collect per year (m^3)* water losses (25%)

= 1426.6 m^3 per year * 25%

= 356.65 m^3 per year

Hence, the effective volume of Rainwater harvesting could be calculated with the total volume of water expected to be collect per year (m^3) minus water losses:

= (1426.6 - 356.65) m^3 per year

= 1069.95 m^3 per year

3.10.4 Volume of Diverted Water by the First Flush

To calculate the volume of water diverted by the first flush system, it is generally assumed that a depth of rainfall on the roof equivalent to 0.5 mm is required to wash off the accumulated contaminants. First we need to determine the area of the roof and simply multiply by 0.5 mm (*Flo True International Corp, 2004)*.

Volume of diverted water (liters) = house length (m) x house width (m) x 0.5 (mm)

= 28 m*10 m*0.5 mm

= 0.14 m^3 of water being diverted

3.10.5 Sizing of Gutters and Downpipes

The size (width) of the gutters should be chosen based on the roof section area. The South Pacific Applied Geosciences Commission (SOPAC). Handbook rainwater harvesting provides guidance to sizing of the gutters and the downpipes appropriate to handle rainstorms in tropical regions.

The harvesting area for the residential blocks has 4 sides, two of the sides are the same (114 m^2 each) and the other two sides are the same (26 m^2 each). And for the communal blocks two of the sides are 80 m^2 areas each and the other two sides are 24 m^2 each.

For the residential blocks: Using the table 2.3 of gutter width and downpipe size the providing 125 mm gutters width with 75 mm downpipes and 75 mm gutter width with 50 mm downpipes respectively, refer figure 2 of Appendix B.

For communal: Using the table 2.3 of gutter width and down pipe size in the providing 125 mm gutters width with 75 mm down pipes and 75 mm gutter width with 50 mm down pipes respectively, figure 3 of Appendix B.

3.10.6 Estimating Storage Requirements

Unlike other domestic storage reservoirs, RWH reservoirs don't permit an over flow. Because if an excess amount of water comes it will damage infrastructures and other flood problems will happen. So, the storage reservoir capacity must be designed well. But, due to an expected rains and other problems if an over flow happens the over flow water will goes to the nearby river.

From last 46 years of daily rainfall data it is assumes that the maximum daily precipitation for the area is equal to average monthly precipitation/30days.

$$= 1156.8 \text{ mm/days/30 days} = 38.56 \text{ mm}$$

Therefore, for a single block the storage requirement will be: Rainfall*Area* Runoff coefficient*Peak factor   = 0.03856 m*280 m^2 *0.8*1.5 (peak factor) = 12.96 m^3

And for the communal building the storage requirement will be:-

$$= 0.03856 \text{ m}*208 \text{ m}^2*0.8*1.5 \text{ (peak factor)} = 9.62 \text{ m}^3$$

So, an average 11.29 m^3reservoir is required for a single building. Therefore, for 4 residential buildings and 2 communal buildings

$$= (4+2)* 11.29 \text{ m}^3 = 67.74 \text{ m}^3 \text{reservoir is required.}$$

Peak factors:

The actual choice of the peak factor requires considerable thought from the designer, and depends on several factors that must be taken into account. Recent studies have indicated that the peak factors currently in use are conservative; however, a comprehensive review is still outstanding. The following are some of the factors that may significantly influence the choice of a specific peak factor:

Employment trends and practices in the community; gardening activities; number of persons per tap; agricultural activities; number of dwellings (where supply to less than 200 dwellings is being considered, consideration should be given to a higher peak factor); economic status; and extent of unauthorized connections.

Table 3.6: Peak factors for developing areas

Peak factors for developing areas				
Peak Factors: Developing Areas – Unrestricted Flow Systems #				
Type of Domestic Supply	Summer Peak Factor	Daily Peak Factor	Instantaneous Peak#	
			Low density**	High density**
House connection	1.5	2.4	3.6 – 4.0	4.0 minimum
Yard connection	1.35	2.6	3.5 – 4.0	4.0 minimum
Street tap / standpipe	1.2	3.0	3 – 3.6	4.0 minimum
Yard tanks	-	-	see note	see note

Unrestricted systems are those systems where no specific arrangements restrict the flow at all. The instantaneous peak factor for restricted flow systems (yard tanks) is 1.5 at all times.

** Low-density areas are typically found in rural localities. High-density areas are those areas typically found in urban localities.

* Increases with diminishing number of consumers.

(Source: - Guidelines of human settlement planning and Design)

Therefore, providing a collecting ground storage reservoir of 67.74 m^3 near the buildings is needed.

3.10.7 Rainwater Harvesting System Design

The following design criteria and data were employed during the analysis exercises of the RWH system.

Design Criteria: Mean annual rainfall is 1156.8 mm; Runoff coefficient is considered 0.8; since the roof was corrugated iron sheet; Average daily per capita water demand 30 l/p/d for non-domestic demand (Toilet flushing, Cloth washing, Floor washing, Car washing, Pit animals cleaning, Green areas and Other uses). Available roof area and users: Total harvesting roof area of the condominium blocks is 1536 m^2, and total numbers of designed users are 700 inhabitants.

4. RESULTS AND DISCUSSIONS

4.1 Water Demand

HWSE standardized that the per capita daily demand is 50 l/c/day considering population equivalents to include non-domestic water demands. The WHO reports that daily water requirements for drinking cooking, and personal hygiene are about 20 liters to 30 liters per person. Therefore, for rainwater harvesting for a single building with 60 persons 30 l/c/day to be used for non-domestic purposes, by considering toilet flushing, clothes' washing, floor cleaning, car washing, cleaning of pit animals, watering the green areas and for other uses. Household water demand estimation requires care, as demand varies over time and across seasons. So, the average homes accommodate to be 4 persons and also calculated that a single condominium block, has an area of 280m^2, this is the size used in the study as a basis for calculation. Based on these numbers, the average daily non-domestic water demand in a single house is 120 liters/day as shown in the table 8 of Appendix A.

4.2 Volume of Rainwater

Volume captured in January (m^3) = 0.0264 m*280 m^2*0.8 (Corrugated metal sheets)

= 5.91 m^3 (residential building)

And also for communal building (m^2) = 0.0264 m* 208 m^2*0.8 (Corrugated metal sheets)

= 4.39 m^3 (communal building)

Hence, the total volume of water be calculated on similar manner for all months of the year.

There are a total of four condominium (residential) blocks and two communal (residential and commercial) blocks at the site, so total volume of water = (259.03 m^3per year/block*4 blocks) + (195.2 m^3per year/block* 2 blocks) = 1426.6 m^3 per year.

The potential volume of water that can be harvested from the residential building roof: Volume captured per month **(**m^3**)** as shown in table 4.1.

Table 4.1: Volume of water that can be harvested from a single block (m^3)

Month	Average monthly precipitation (mm)	Volume captured per month **(**m^3**)**
January	26.4	5.91
February	43.0	9.63
March	95.6	21.41
April	134.0	30.02
May	134.3	30.01
June	123.0	27.55
July	161.6	36.2
August	178.4	39.96
September	151.8	34
October	71.3	15.97
November	18.1	4.05
December	19.3	4.32
TOTAL	1156.8	259.03

Table 4.2: Volume of water that can be harvested from a communal building (m^3)

Month	Average monthly precipitation (mm)	Volume captured per month (m^3)
January	26.4	4.39
February	43.0	7.15
March	95.6	15.91
April	134.0	22.30
May	134.3	22.35
June	123.0	20.47
July	161.6	26.89
August	178.4	29.70
September	151.8	25.26
October	71.3	11.86
November	18.1	3.01
December	19.3	3.21
TOTAL	1156.8	195.2

4.3 Monthly Demand

Water demand is usually based on historical consumption. Where water consumption records are not available, present consumption per capita can be estimated by consulting the residents. Monthly demand (m^3) = (4 blocks*60 persons/blocks*30 l/c/d*30 days) = 216 m^3

Table 4.3: Monthly water demand from RWH (m^3)

Month	Monthly demand from RWH (m^3)
January	216
February	216
March	216
April	216
May	216
June	216
July	216
August	216
September	216
October	216
November	216
December	216
TOTAL	2592

Percentage of monthly demand satisfied = (volume of water that can be harvested/volume of monthly demand)*100

For January: **-** Percentage of monthly demand satisfied = (Total volume of water available for a residential building* number of blocks)/ volume of monthly demand)*100

$$= (6.65\ m^3 * 4/216\ m^3)*100 = 12.31\%$$

Hence, the total percentage of monthly demand satisfied by rainwater harvesting be 45.6%, refer table 4.3. It also presented in graph of figure 4.1.

Table 4.4: Percentage of monthly demand satisfied by RWH for a single building

Month	Average monthly PPT (mm)	Volume of water that can be harvested from single building (m^3)	Volume of water that can be harvested from Communal building (m^3)	Total Volume of water available for a single building (m^3)	Monthly non-domestic water demand from one building (m^3)	% of monthly demand satisfied by RWH for a single building
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Jan	26.4	5.91	4.39	6.65	54	12.31
Feb	43.0	9.63	7.15	10.84	54	20.07
Mar	95.6	21.41	15.91	24.09	54	44.61
Apr	134.0	30.02	22.30	33.77	54	62.54
May	134.3	30.01	22.35	33.84	54	62.67
Jun	123.0	27.55	20.47	31	54	57.41
Jul	161.6	36.2	26.89	40.7	54	82.78
Aug	178.4	39.96	29.70	44.96	54	83.26
Sep	151.8	34	25.26	38.25	54	70.83
Oct	71.3	15.97	11.86	17.97	54	33.27
Nov	18.1	4.05	3.01	4.56	54	8.44
Dec	19.3	4.32	3.21	4.86	54	9.00
Total	1156.8	259.03	192.5	291.49	648	45.6

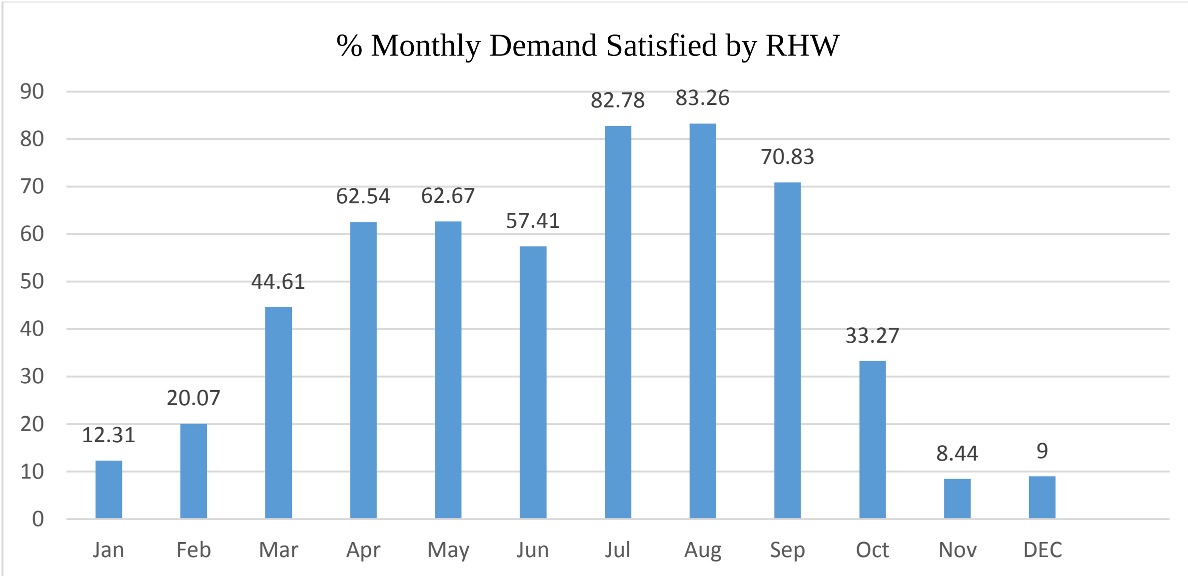

Figure 4.1: Percentage of monthly demand that can be satisfied by RWH

Therefore, the total volume of water expected to be collect could be 1426.6 m^3 per year, refer in the figure 4.2.

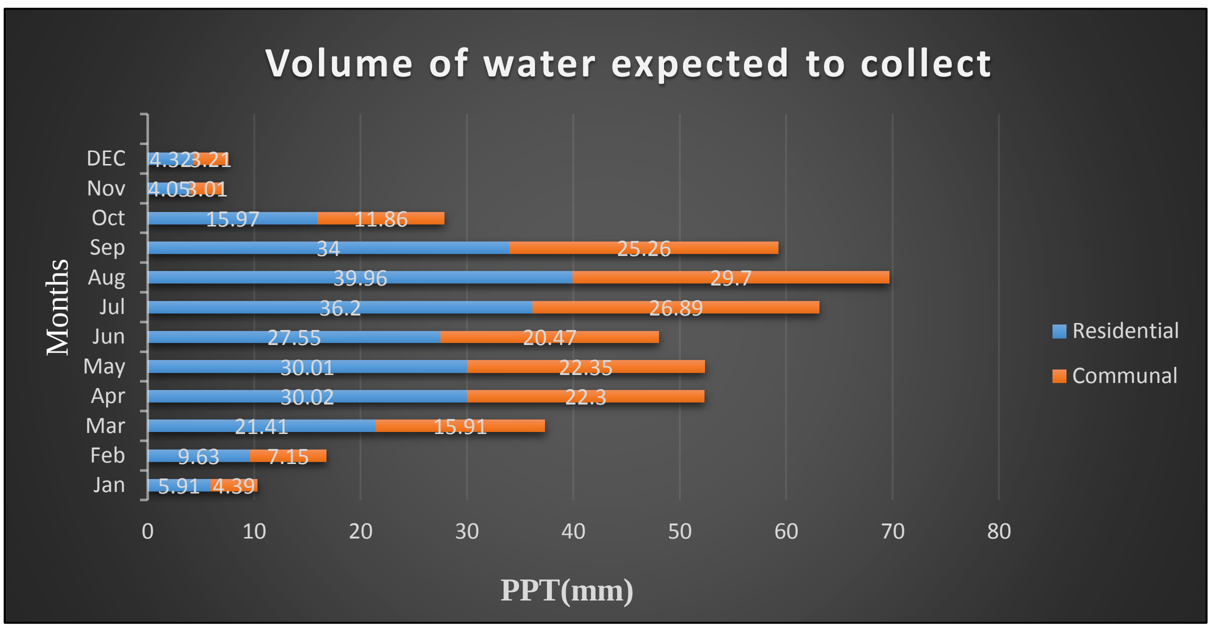

Figure 4.2: Volume of water expected to be collect

4.4 Water Losses

These losses are due to several factors: the roofing material texture which slows down the flow; evaporation; and inefficiencies in the collection process. Therefore, the amount of water losses are taken into account when estimating the collection efficiency. Regardless of roofing material, many designers assume loss on annual rainfall up to 25 per cent.

Water Losses = the total volume of water expected to be collect per year (m^3)* water losses (25%)

= 1426.6 m^3 per year * 25%

= 356.65 m^3 per year

Hence, the effective volume of Rainwater harvesting could be calculated with the total volume of water expected to be collect per year (m^3) minus water losses:

= (1426.6 - 356.65) m^3 per year

= 1069.95 m^3 per year

4.5 Estimating Storage Requirements

From last 46 years of daily rainfall data it is assumes that the maximum daily precipitation for the area is equal to average monthly precipitation/30days = 38.56 mm. Therefore, for a single block, the storage requirement will be: - Storage (volume) = 12.96 m^3 and for the communal buildings the storage requirement will be: - Storage (volume) = 9.62m^3. So, an averagely 11.29 m^3 reservoir is required for a single building. Therefore, for 4 residential buildings and two communal buildings = 67.74 m^3reservoir is required.

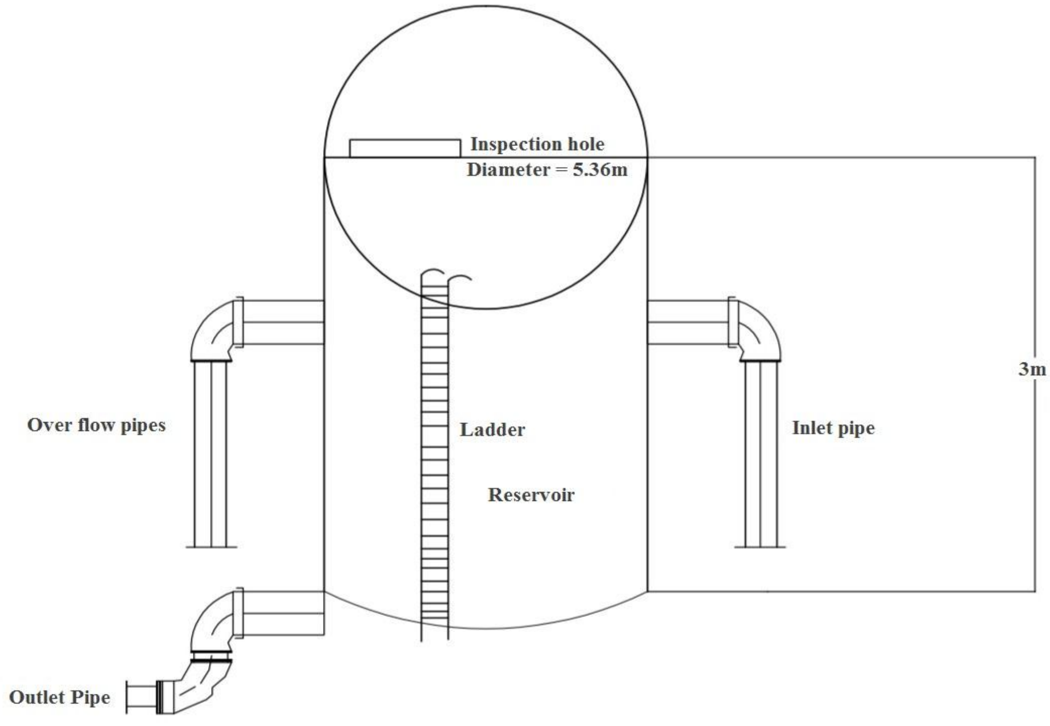

Figure 4.3: Typical layout of recommended 67.74 m^3 Reservoir

4.6 Residual Pressure

The pressure that available at the end of pipe run for a 67.74 m^3 flow rate be 0.167 Mpa which is enough to reach the water to 2^{nd} floor houses with its 10.64 m and 16.64 m friction head loss of pipe and total head loss respectively, as shown in the procedure of Appendix C.

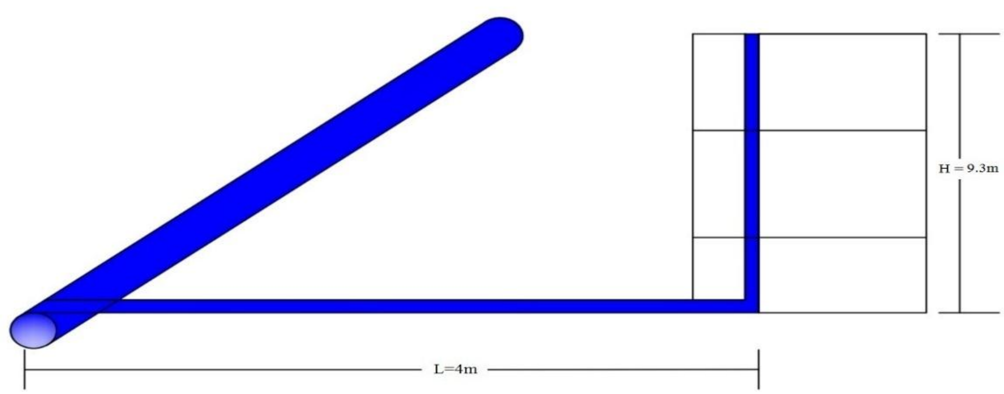

Figure 4.4: Non-domestic water supply pipeline

5. CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

Rainwater harvesting is the capture, diversion and storage of rainwater for a number of different purposes including landscape irrigation, drinking and domestic use, aquifer recharge, and storm water abatement.

The HSWE has been aimed for the improvement of connection systems by connecting additional water from water wells. However, nothing is being done, users receive water for a few hours only some each week in the best cases and the resident who lives on the floors did not get the water regularly. RWH has great potential in freshwater-starved urban areas to be environmentally, socially and economically sustainable.

The availability of water sources in Gurgade condominium site is so severe in part because of the growing population around the site and construction of educational institutions. Due to these problems, the main source of water for the area that founds near the site did not satisfy the water demand of the residents.

Estimation of the percentage of non-domestic water demand that can be met from RWH, propose design standard and criteria for the various components of technology and identify the main challenges of the promotion of RWH system was alternative solution for the shortage of water in the Gurgade condominium site. The estimated design of the per capita water demand for non-domestic purposes be 30 l/c/d. The RWH from rooftops at Gurgade condominium site can reduce the non-domestic water demands by approximately 45.6%.

Accordingly, from the result providing a collecting ground storage reservoir of 67.74 m^3 near the buildings was needed. Therefore, according *(SOPAC, 2004)* and Handbook rainwater harvesting provides guidance to sizing of the gutters and the downpipes 125 mm gutters width with 75 mm downpipes and 75 mm gutter width with 50 mm downpipes was provided for conveying harvested rainwater from the roof area to the storage/reservoir.

The promotion of RWH in general is not a cheap option but in areas where both surface and subsurface water resources potential is poor in terms of quantity and it will be a best option. RWH could be made a cheapest option if promoter has used innovative knowledge to cut down cost of construction of the various components of the system.

RWH can be an alternative solution to support the increasing water demand and reduce the surface runoff as a best management practice which helps to satisfy environmental sustainability which is one of the millennium development goals.

Finally, HWSE can use this research as a guideline to calculate the possible amount of supply water conserved by the RWH as well as the decrease in load on the groundwater.

5.2 RECOMMENDATION

Rooftops can have particles and pathogens that might contaminate water that falls through them. There are basic treatment methods that users can implement at household levels like boiling water and post chlorination on the reservoir that will be low-cost solutions. It is important for users to maintain clean storage tanks, clean filters, gutters, drains and rooftops and it is recommended to let water from the first strong rainfall of the season wash out the roof without collecting it because it could be more contaminated.

For designing rainwater harvesting system rainfall data is required. Preferably data for this research average monthly rainfall data of 46 years is available and used. The more reliable and specific data for the location, and considering growth rate of the population around the site, made the design could be better.

For this study, the daily per capita water requirement is done by estimation and for the best results, it is better to be done by physical measurements and assessing the need of the community.

Some of the design approach and criteria exercised for this study needs to be reconsidered. For instance tank sizes, which are the most important and expensive facility in the promotion of RWH system are determined based on an average annual rainfall that does not consider the rainfall pattern. Storage tanks need to be much larger, precipitation has to be more abundant, and roofs need to have a bigger area and tanks need to be cheaper for it to be the major source of water supply in the area. The method is used only for preliminary works and gives a size that does not fit with the demand. So the research recommends using other methods or software.

Awareness creation for water professionals, policy makers, international financers and donors through workshops, meetings, publications such as brochures and the like are very important works to be under taken to improve the promotion of RWH in the effort made to improve the low level safe water supply of the country.

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APPENDIXES

Appendix A

Table 1: Hosanna Metrological Station Rainfall Data

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1970	26	25.2	40.6	199	82.6	123.9	189.4	127.2	115.9	4.8	17.1	75.5	1027.2
1971	10.8	34.3	142	183	115	168.3	162.6	172.2	169	84.7	0	49.6	1291.7
1972	26	8.5	16.4	84.9	23.7	118.8	208.3	170.2	130.7	88.8	0	18.1	894.4
1973	1	0	72.1	276	58.5	33.3	253.5	184.3	74.5	59	0	0	1012
1974	0	18	115	113	148	110	150	131.7	176	81.5	69.5	18.1	1130.3
1975	0	81.4	65.6	165	71.4	159.7	196.7	172.7	148.7	5.6	0	18.1	1084.8
1976	25.5	4.6	0	40.7	155	120.7	152.1	241.5	215.4	64.3	0	19.7	1039.8
1977	16.1	24.2	137	22.4	147	100.8	135.5	204.2	128.8	28.8	0	0	944.4
1978	0	34.3	90.2	125	0	152.5	170.2	178.2	216.1	21.5	0	0.5	988.9
1979	4	4	93.3	235	161	143.9	114.2	136.9	182.8	27.7	56.2	11.8	1170.3
1980	112	58.1	101	129	142	127.8	216.4	163.7	227.8	196	43.9	14.4	1531.8
1981	4.1	58.5	17.5	54	114	175	190.2	254.8	89.5	38.3	6.7	72.8	1075.8
1982	66.1	68.4	99.1	70.7	145	115.2	179	173.6	121.4	62.5	0	19.9	1120.9
1983	56.7	24.2	81.8	163	91.9	146.7	136.9	178.5	91	87.2	1.4	0	1059.1
1984	0	13.4	204	74.9	39	62.1	91.1	131.9	171.9	15.8	30.7	11.4	846.3
1985	94.6	69.7	62	104	103	171.9	175.1	222.3	202.3	280	117	21.2	1623.8
1986	0	0.4	40.6	215	142	92.5	29.1	290.6	177.9	95.3	0	5.2	1087.8
1987	1.5	178	125	198	282	135.8	196.8	101.2	133.5	35.7	0.9	29.1	1417.9
1988	5.9	81.8	188	112	320	90	105.6	170.4	154.7	47.3	0	0	1276
1989	20.5	79.2	35.5	93.1	69.5	121.2	194.6	299.1	191.4	112	0	0	1216.2
1990	0	145	153	95.6	115	107.2	133.8	156.6	135.3	40.5	6.8	1	1089.6
1991	7.3	45.7	94	31.6	129	138.6	210.5	182.9	110.2	9.7	0	66.3	1025.5
1992	59.2	88.1	120	175	106	171.7	121.4	280.1	104.3	106	52.9	3.7	1387.9
1993	78.1	107	20.6	255	286	75.6	116.8	199	92.7	177	0	0.1	1408.1

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1994	0	0	147	83.9	129	80.9	149.3	128.7	192.8	0	8.8	0	920
1995	0.5	61.7	70	220	109	82.4	201	156.5	160.6	3.2	0	98.9	1163.7
1996	90.7	17.8	152	170	163	115.1	186.7	129.3	125.6	6.6	16.3	0	1173.2
1997	22.1	0	84.3	178	130	171.7	113.1	186.4	140.2	319	85.3	0	1429.5
1998	73.8	63.2	108	204	143	160.2	205.3	187.9	169	159	0	0	1472.2
1999	1	0	56.5	77	123	143.5	181.7	107.8	127.7	186	0	0	1003.6
2000	0	0	15.4	206	105	145.5	86.4	124.6	177.9	64.9	21	45.5	992.2
2001	4.8	70.1	184	110	173	92.3	153.7	135.6	102.3	62	4.7	5.5	1097.3
2002	83.4	47.2	151	112	136	90.2	103.9	244.8	154.8	2.8	0.5	126.4	1252.6
2003	36.1	59	119	195	79.1	108.9	136.7	207.7	183.3	11.7	13.6	0	1149.7
2004	97.3	19.4	90.8	176	82.5	123.4	134.2	152.5	182.3	75.1	17.3	14.2	1165.4
2005	31.9	18.8	178	162	198	65	160.7	95.5	163	38.1	67.7	0	1178.5
2006	28.9	54	132	160	75.8	169.8	183.9	222.4	88.3	50.3	6	27.3	1198.4
2007	31.8	50.7	119	152	121	163.3	180.1	132.9	210.2	19.2	0	0	1180.7
2008	0	1.3	43	71.4	239	144.7	193.1	136	138.6	126	69.5	18.1	1181.4
2009	43.1	4.8	73.4	85.5	120	123.5	188.5	181.3	175	169	5.1	33.7	1203.1
2010	11.8	110	140	111	183	94.39	116	145	139	18.9	19.3	33.7	1121.6
2011	15.5	11.2	102	116	233	0	163.8	193.5	119	0	49.2	0	1002.9
2012	0	0	67.4	138	68.3	150.3	233.1	155.9	164	1.4	0	7.1	985.3
2013	1	17.4	129	67.9	132	182.2	200.8	211	173	46.4	0.4	7.1	1167.5
2014	25	118	76.6	135	252	76.2	188.3	270.9	193	148	14.2	2.2	1499.1
2015	0	3	45.1	19.2	137	213	142.6	0.0	142	0	31.3	11.5	744.8
AV	26.4	43	95.6	134	134	123	161.6	178.4	151.8	71.3	18.1	19.3	1156.8

Table 2: Monthly water consumption (m^3) for the years (2011-2014)

S/No.	Year	2011	2012	2013	2014
1	January	25627.34	38116.51	54989.00	61386.00
2	February	21244.90	30566.00	57235.00	58944.00
3	March	31515.97	32612.16	55721.00	74589.00
4	April	30593.42	30443.38	55621.00	64533.00
5	May	28436.21	28739.11	51274.00	62097.00
6	June	27444.61	30800.60	56413.00	55083.00
7	July	25020.75	26007.00	40361.00	63270.01
8	August	26842.89	24585.00	44966.00	63270.01
9	September	28425.89	27331.00	54388.12	63270.01
10	October	26371.00	27464.00	50874.00	63270.01
11	November	30078.00	39880.00	65841.72	63270.01
12	December	27418.16	46181.00	63827.50	63270.01
	Total	329019.14	382725.76	651511.34	756252.06

Table 3: Monthly water production (m^3) for the years (2011-2014)

S/N	Year	2011	2012	2013	2014
1	January	39,720.00	38,235.00	91,600.00	110,420.00
2	February	38,585.00	40,820.00	133,890.00	100,970.00
3	March	50,345.00	40,484.00	86,840.00	118,973.00
4	April	48,770.00	39,210.00	113,170.00	105,100.00
5	May	48,148.00	33,819.00	123,150.00	122,800.00
6	June	45,348.00	36,680.00	148,700.00	92,335.00
7	July	42,219.00	38,300.00	118,410.00	160,490.00
8	August	49,939.00	37,335.00	115,306.00	124,505.00
9	September	46,848.00	37,414.00	159,535.00	132,300.00
10	October	48,469.00	39,620.00	118,220.00	139,340.00
11	November	38,308.00	89,474.00	120,120.00	156,710.00
12	December	35,095.00	105,975.00	133,270.00	165,470.00
	Total	531,794.00	577,366.00	1,462,211.00	1,529,413.00

Table 4. Population distribution by sub-cities (HTFEDO, 2008)

Sub-City	Head of households			Family members			Total population		
	M	F	T	M	F	T	M	F	T
Sech Duna	2090	2101	4191	11391	13330	24721	13481	15431	28912
Gurgade Condominium	72	68	140	288	272	560	360	340	700
Addis Ketema	941	725	1666	7244	8624	15868	8185	9349	17534
Gofer Meda	5322	728	6050	6102	11172	17274	11424	11900	23324
Total	8425	3622	12047	25025	33398	18423	33450	37020	70470

Table 5: Summarized water production and consumption for the years (2011-2014)

Year	Total production (m3)	Total Billed data ,Consumption(m3)	Total population	Water Production l/person/day	Water Consumption l/person/day
2011	531,794.00	329,019.14	80,503	18.10	11.20
2012	577,366.00	382,725.76	83,965	18.84	12.49
2013	1,462,211.00	651,511.34	87,575	45.74	20.38
2014	1,529,413.00	756,252.06	91,341	45.87	22.68

Table 6: Water supply coverage of hosanna town for the years (2011-2014)

Year	Annual Water Consumption (m3/yr.)	Total Population (No)	Annual Production (m3/yr.)	Consumption l/person/day	Total Annual Demand (m3/yr.) *	%of coverage **
2011	329,019.14	80503	531,794.00	11.20	1,936,690.00	27.46
2012	382,725.76	83965	577,366.00	12.49	2,321,035.00	24.87
2013	651,511.34	87575	1,462,211.00	20.38	2,,878,756.00	50.79
2014	756,252.06	91341	1,529,413.00	22.68	2,960,880	51.65

Percentage of Water Supply Coverage is computed as: (Annual Production/Annual Demand)*100

Table 7: Estimated per capita water requirement

Uses	Amount (Liters per person per day)
Toilet flushing	8-10
Cloth washing	7-9
Floor washing	6-8
Car washing	2-4
Pit animals cleaning	1-3
Green areas	1-3
Other uses	8-10
Total	30

Table 8: Daily water demand

Water demand	
Daily non-domestic water demand	30 l/c/d
Basic roof area(residential building)	280 m^2
Average no of people/building	60 persons
Daily non-domestic water demand per building	1800 l /d

Table 9: Monthly water demand from RWH (m^3)

Month	Monthly demand from RWH (m^3)
January	216
February	216
March	216
April	216
May	216
June	216
July	216
August	216
September	216
October	216
November	216
December	216
TOTAL	2592

Appendix B

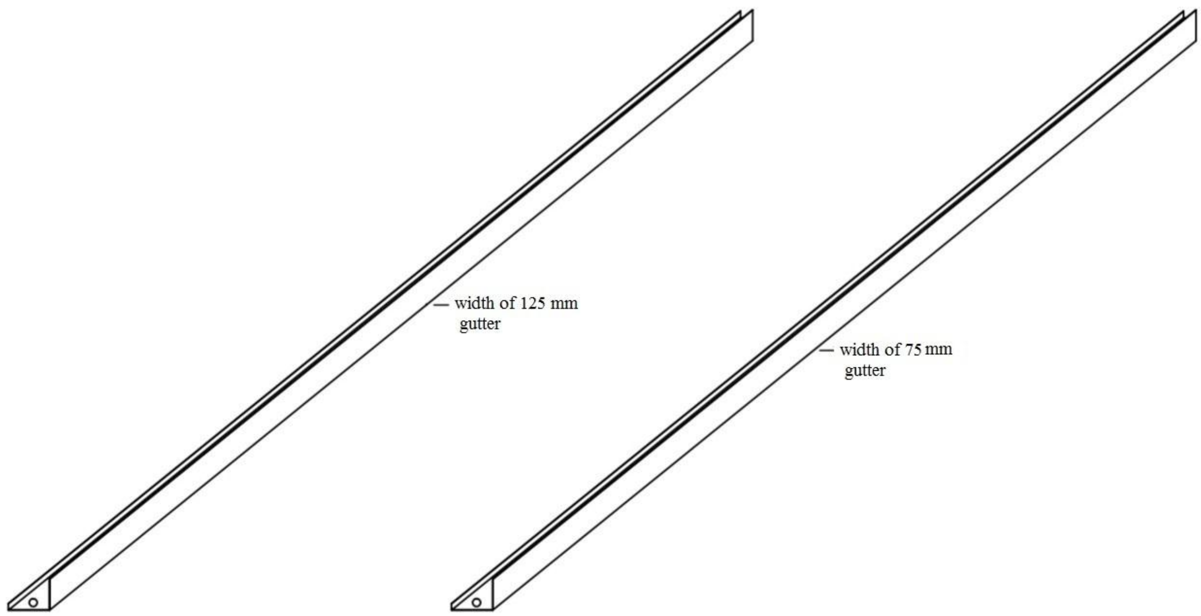

Figure 1: Typical design of 125 and 75 mm gutters

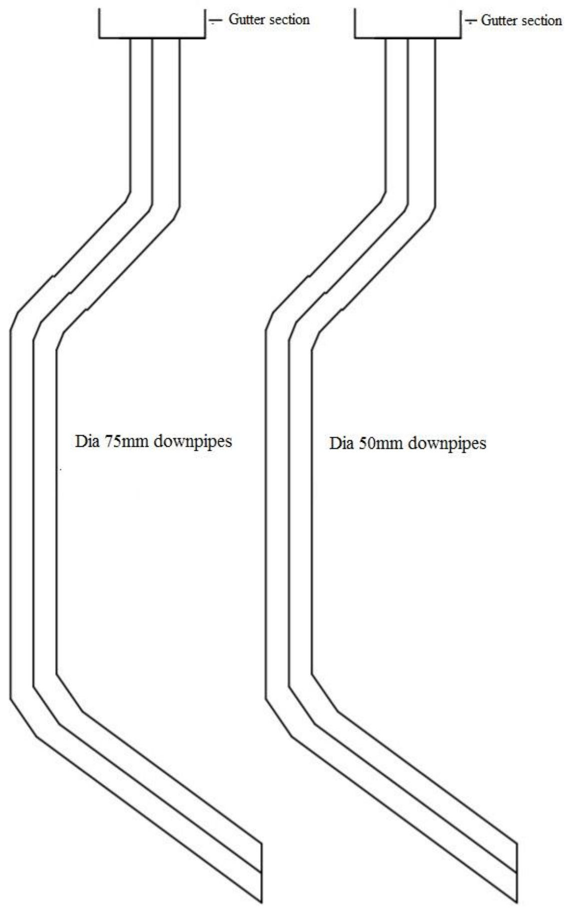

Figure 2: Typical design of 75 and 50 mm diameter downpipes

Appendix C

Procedures

Estimating Storage Requirements

From last 46 years of daily rainfall data it is assumes that the maximum daily precipitation for the area is equal to average monthly precipitation/30days.

= 1156.8 mm/days/30 days =38.56 mm

Therefore, for a single block the storage requirement will be: Rainfall*Area* Runoff coefficient*Peak factor = 0.03856 m*280 m^2 *0.8*1.5 (peak factor) = 12.96 m^3

And for the communal building the storage requirement will be:-

= 0.03856 m*208 m^2*0.8*1.5 (peak factor) = 9.62 m^3

So, an average 11.29 m^3reservoir is required for a single building. Therefore, for 4 residential buildings and 2 communal buildings:

= (4+2)*11.29 m^3= 67.74 m^3reservoir is required.

Therefore, providing a collecting ground storage reservoir of 67.74 m^3 near the communal buildings is recommended.

Residual Pressure

- Riser height = 9.3 m
- Length of 25 mm pipeline= 4 m
- Friction head loss of pipe (Assume I = 800)

  H = I ・ L/1000 = 800*13.3/1000 = 10.64 m
- Head loss of valve, meter Corporation Stop (Staffa) and different fittings assumed to be 6 m

  Total head loss =10.64 m+6 m =16.64 m

  P = ρ* g * Total head loss

  P = 1000 *9.81*17 Mpa
- P = 0.167 Mpa (17 m) is enough to reach the water to 2^{nd} floor house.