This thesis is submitted to the Ethiopia Institute of Architecture, Building Construction and City Development (EIABC) and to the School of Graduate studies of Addis Ababa University in partial fulfillment of all requirements for Degree of Masters in Urban Design and Development

Title of Thesis "*Water Sensitive Urban Design* (*WSU*D) *intervention for the alleviation of water scarcity in the government schools of Yeka sub-city*"

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Declaration

I hereby declare that this thesis entitled Water Sensitive Urban Design (WSUD) intervention for alleviating the water scarcity in the government schools of Yeka sub- city has been done by me under the continuous advice of Alazar Assefa in the year 2016. I also declare that this work is my original work and that it has not been submitted partially; or in full, by any other person for an award of a degree in any other university/institution.

Kagnew Assefaw

Signature ___________

Date: October 2016

Addis Ababa, Ethiopia

Confirmation

This thesis has been submitted for examination with my approval as an institute's advisor

Advisor

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Abbreviations

Abbreviations	Meaning
WSUD	Water Sensitive Urban Design.
AAU	Addis Ababa University
NRW	Non- Revenue Water.
AAWSA	Addis Ababa Water and Sewerage Authority.
GIS	Geographic Information System.
UNICEF	United Nations Children's Fund.
HA	Hectare
AAMA	Addis Ababa Metropolitan Area.
CGWA	Central Ground Water Authority.
BASIX	Building and Sustainability Index.
NGOs	Non-Governmental Organizations.
CSA	Central Statistical Agency.
BMPs	Best Management Practices.
lpcd	Liter per Capita per day
UNDP	United Nations Development Programmed.
UNEP	United Nations Environment Programme
WWAP	World Water Assessment programmed.
RWH	Rain Water Harvesting.
PMWS	Piped Municipal Water Supply
ERHA	Ethiopian Rainwater Harvesting Association
KM	Knowledge Multiple

Table of Contents

List of Figures

List of Tables

List of Charts

List of Maps

List of Images

List of Photos

Abstract

The provision of improved water supply in primary schools is vital service for the well-being of students in urban areas of the country. In order to ensure water supply of schools in Addis Ababa, we need to consider the proper use of the resources and other sustainable source of water. The main objective of this paper is to scrutinize the scarcity of water in schools of the city and alleviate shortage by improved water supply.

In order to achieve this objective, the combinations of qualitative and quantitative research approach were employed. The research method applied in this research is applied research by observation the challenge in water shortage in Kara-Alo primary school. Furthermore, identification of key challenges and potential of case sites to come up with appropriate design solution and compare the result of design interventions with the pre-development situation.

The key finding of the research identifies. The main factors that cause the water scarcity in the schools as well as in the sub city were; water demand for the growing population, rainfall fluctuation, poor water management practices, poor water infrastructure, climate change and economic challenges.

Therefore, the study recommends the possible solutions to minimize the problem of water scarcity by reducing flooding, at the same time application of water harvesting design for the rooftops and ground surface within the school compound are proposed as the primary strategy of the research. The secondary strategy is to educate people so as to not waste water, to identify more water sources and also to protect the flow of water over the ground surface without use.

Keywords: Rainwater harvesting, water scarcity, and institutional development.

CHAPTER ONE

1 Introduction

1.1 Background

The main challenges of water demand against supply are the accelerated demand for water from increasing growth of population, lack of proper infrastructure, economic barriers and fast expansion of the metropolitan area. The growing number of industries at unprecedented level and the water wastage has aggravated the water supply shortfall (The public relations of Addis Ababa water and sewerage Authority, July2001).

More than one in every six people in the world is water stressed, meaning that they do not have access to potable water. Those that are water stressed make up 1.1 billion people in the world and are living in developing countries. According to the Falkenmark Water Stress Indicator, a country or region is said to experience "water stress" when annual water supplies drop below 1,700 cubic meters per person per year. At levels between 1,700 and 1,000 cubic meters per person per year, periodic or limited water shortages can be expected. When a country is below 1,000 cubic meters per person per year, the country then faces water scarcity. In 2006, about 700 million people in 43 countries were living below the 1,700 cubic meters per person threshold ("Water stress", Retrived 20 October 2013).

- Around 700 million people in 43 countries suffer today from water scarcity.
- By 2025, **1.8 billion** people will be living in countries or regions with absolute water scarcity, and two-thirds of the world's population could be living under water stressed conditions.
- With the existing climate change scenario, almost **half the world's population** will be living in areas of high water stress by 2030, including between 75 million and 250 million people in Africa. In addition, water scarcity in some arid and semi-arid places will displace between 24 million and 700 million people(Challenges of the twenty-first century, 2007).
- **Sub-Saharan Africa** has the largest number of water-stressed countries of any region (ibid).
- As Ethiopia’s population grows at a rapid rate, the available fresh water for drinking will also shrink. “Based on the current trend of population growth, by the year 2025, Ethiopia will have nearly 120 million people and the per capita water availability will drop to about 947 m3/person per year.” (Source: AAWSA).

In the majority of cities, rainstorm water logging normally occurs within a very short period after heavy rain falls, but rainstorms are not the only cause of water logging problems. As a result of the urbanization process, the topology, terrains, and water convergence conditions in urban areas are altered, leading to the decimation of vegetation coverage and river and pond areas. Large proportions of land have been changed into impervious areas, resulting in reduced ground water holding capacity, shortened water stagnation periods and low permeability, and fast surface runoff. On the other hand, the underground water discharge pipe network facilities are typically not upgraded concurrently with city development, so there is a lack of sufficient capacity for discharging large volumes of water. These two factors together are responsible for causing urban rainstorm water logging disasters (Theo.M, 2004).

Throughout the history of Ethiopia, the seat of the government has never been static. It has constantly moved from place to place following the whims of conquest and the pressure of unavailability of life sustaining resources or dwinding supply of basic necessities like water, fuel wood or food reserves which are necessary for urban life.

Menilik's rational to move the capital from Ankober to Entoto, particularly his prefernce of the site to Addis Alem is said to emanate from not only its proxy to the historical capitals of his forefathers, but more so owing to the abundance of fuel wood and water resources avaliable in the environs particulary the prevalence of the hot springs around Filowha.

1.2 Modern Water Supply System in Addis Ababa

Emperor Menelik must have been advised by his technical advisor, the Swiss engineer Alfred Ilg, of the need and importance of clean water to keep healthy and the possibility of conveying water from a distance. The idea was according his blessing and was put into effect by his technical advisor engineer and his subordinates. Masonary ducts were constructed and laid along the sources of Kebena river at the top of Entoto where water was collected in a small dam from where the water was carried down to the described destination in the city.

An earth dam was built at the site following the track that leads to what is now Hamere Noah Kidane Mihret Church. The line carrying water stretched down to the residence of Leul Ras Mekonne, the present campus of Addis Ababa University (AAU). The trench was made to follow the right track along the river, serving as conveying line, and was draining at the reservior constructed infront of the residence of Luel Ras Mekonnen.

There were three dry masonry water storage, which were constructed with the intention of enabling physical purification like sedimentation, water filtration and temporary storage respectively. A perforated iron gate was fixed to the third constructed near the cement duct where 5.13cm diameter metallic pipes were fitted through which the purfied water was conveyed. These pipes were laid to distribute water to different points including the residence of the patriarch,the grand Palace, to the site where the existing parliament is located, to the residence of Fitawrari W/Gebriel and the community nearby (Water for life ,July2001).

1.3 Pre-Fascist Invasion Period

A major turn – took place when in 1924 Rastafarian, the regent to the throne, considering the shortage of water pipes as possible while on the throne, considering the shortage of water the capital had faced previously, imported as many water pipes as possible while on his tour to Europe and entrusted Ras Desta Damtew in 1926 to undertake a revised water supply project Accordingly, the water from the springs near Menbere Kibre was collected in one reservoir and distributed by means of 7.69cm pipes to:-

A) Genete Luel palace and the surrounding area
B) The residence of the patriarch
C) Menelik II Hospital
D) Empress Zewditu Memorial Hospital

1.4 Post -War Water Supply System Development

After the end of the fascist occupation in 1941, his imperial majesty Haile-Selassie I launched reconstruction and rehabilitation programs in every sphere of development activities. Consequently, Addis Ababa Municipality was reorganized in 1942 and water supply service section was in corporate within the structure of the municipality under the name of the water supply service. It remained operational until 1970.

Generally rainfall in the area of Addis Ababa, including all of the catchment areas is characterized by a bimodal distribution exhibited during the March – April small rains and the July – September Main rainy season therefore, plenty excess run off during main rainy season has to be retained and can be used throughout the dry period of the year is the best solution to meet the long term demand.

On the other hand, in biography written in 1887 E.C entitled "Tarik Zemen ze dagmawi Menelik or Historical Epoch of Menelik II describes how Emperor gave order to his engineer who brought the water from the high altitude of Entoto down to the low field near the grand palace by means of constructed ditches" the water was stored in a big pond dug and constructed with stone walls stuffed with charcoal and lime stone for filtration purpose. imported pipes were fitted to drive the water uphill through connected pump to the palace where it was drunk by countries who were subjected to the scorching heat of the sun while queuing before entering the grand place dining hall or those who wanted to cool themselves from the heating effects of the beverage offered at the luncheons most of the guests were amazed more by the water supply system rather than by the recipe of the feast Gradually, construction of small dams on rivers was expanded and tap water was being supplied to quite a number of the residents of the different areas of the capital (Water for life , July 2001).

1.5 Problem Statement

Water scarcity is among the main problems faced by many societies throughout the world in the 21Stcentury. Water use has been growing at more than twice the rate of population increase in the last century, and, although there is no global water scarcity as such, an increasing number of regions are chronically short of water.

Lack of clean water has serious effects on students' academic performance and attendance rates. The lack of safe water can cause even the best students to lose momentum as they deal with stomach pains and diarrhea from disease and hunger. Schools cannot run programs, if they cannot provide water to students, faculty and their families.

Legedadi and Gefersa providing 162,000m3/day and 23,000m3/day respectively. As far as the Ground Water is concerned 54,000m3/day is obtained from Akaki well field and other scatter wells Thus, altogether 239,000m3/day is obtained from the existing water source which is far behind the demand, 479,000m3/day. On the top of this, AAWSA has estimated 30-35% of Non-Revenue Water (NRW), which includes both the commercial and physical losses (2016 first quarter AAWSA project office report).

Water supply: Schools that have water supply is 96.79% (1,778). Thirty schools in Bole, fifteen Schools from Akaki-Kality, eight schools from Yeka, five Schools from Nifas Silk Lafeto and one school from Gullele Sub cities do not have water supply. The existence of water supply system alone may not ensure that water is consistently available in schools. 82.65% schools do not have water and sanitation (Educational Statistics Annual Abstract, 2015).

The water tap to student ratio: all sub cities do not meet the standard (1 tap for 20 students) set by Addis Ababa Educational Bureau. The water tap – student ratio is 1:70 goes two or three fold against the standard. This needs special attention of the school management (Ibid).

1.6 Objectives

1.6.1 General Objective

The main objective of the research is to develop strategies that can alleviate the water scarcity in the institutional plots of Addis Ababa through Water Sensitive Urban Design intervention, particular emphasis on government owned primary schools in Yeka sub-city.

1.6.2 Specific Objectives

1. To identify and map schools of Addis Ababa that encountered serious water shortage.
2. To figure out challenges and potentials for water harvesting within the schools compound by taking case schools within particular administrative unit.
3. To design landscape based sustainable options and test their water harvesting performance within the case school / schools compound.
4. To test the upscale effects of each design solution into other schools with water shortage within the same administrative unit with the case school.

1.7 Research Questions

To achieve the stated objectives the following questions shall be addressed

Major question

How to solve water scarcity in the schools of Addis Ababa through water sensitive urban design interventions?

Sub-questions

1. Where are the water-starved schools in Addis Ababa?
2. What is the water demand of schools in Addis Ababa?
3. What are the sources of water in educational plots of Addis Ababa?
4. How to harvest extra water from rain to fill the gap and augmenting water in the school?

1.8 Significance

In addition to its academic purpose, this study is important to contribute by improving rainwater harvesting management and conservation in institutional plots of the city through assessing the general circumstance of the problems. For researchers, that can be further used as a spring board for future developments of studies regarding the topic of solving the water scarcity in the government schools of Addis Ababa through water sensitive urban design intervention as it is important to harvest rainwater for different uses of the schools water demand. Large number of students will be beneficiary from rain water harvesting and be able to solve water scarcity in schools. Furthermore, the same study can be used as a reference and source of knowledge to water sensitive urban design intervention to solve water scarcity for similar study in this area.

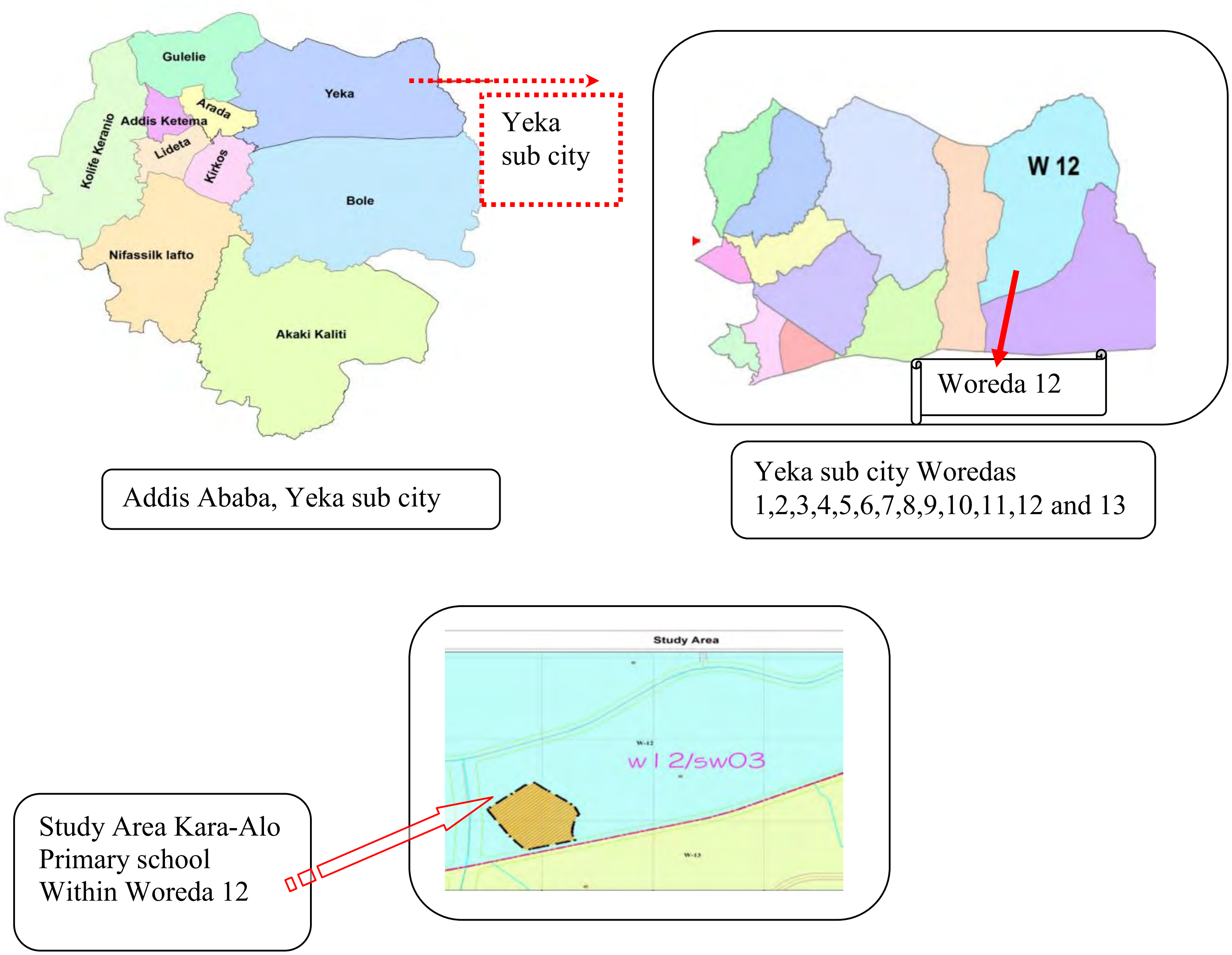
1.9 Scope

Since it is not possible to cover the whole aspects of the study area, it is better to limit its size and the scope of the problem to a manageable degree. Hence, the study focuses on the representative sites that are concerned with water scarcity and storm water management challenges in government owned educational plots.

Geographically, Addis Ababa has 814 elementary schools in the jurisdiction area. According to Yeka sub-city educational bureau report, Yeka sub-city has 117 elementary schools from these 27 has governmental and 90 private schools. Since, It is difficult to manage those all schools in the given time period hence select Kara-Alo primary school from woreda12 sub Woreda 03 governmental primary schools in Yeka sub-city in Addis Ababa emphasis on rainwater harvesting and storm water management in educational plots.

The thematic scope of the study is limited to solving the water scarcity and storm water management challenges in government-owned educational plots in Addis Ababa through water sensitive urban design and increasing the level of participation all stakeholders in rainwater harvesting system within each compound. In this regards, the study limited on the issue of:

- ✓ Hydrology and soil
- ✓ Open green spaces
- ✓ Natural landscape and
- ✓ Land use and land cover characteristics of the study area.



1.10 Organization of the Paper

The paper has been organized into six chapters. Chapter one is the introductory section. The research methodology was presented in chapter two, while chapter three deals with review of related literatures. Chapter four is about discussions and findings; the Water Sensitive Urban Design (WSUD) proposal plan presented in chapter five whereas the last chapter is concerned with conclusions and recommendations.

1.11 Limitation of the Study

The time taken by the research to acquire the relevant data particularly from the primary sources was more as per the proposed schedule due to the resistance of respondents and busyness of higher officials by meeting at working hours' time. The research needs properly collected and quality survey data; however, the students lacked of awareness about the thesis and had difficulty to respond the given questionnaires and also not have of similar studies about water sensitive urban design in a sustainable approach are delimitation within our country. The most intricate thing that I faced is that I lost both my lovely mother and brother during the thesis time hence it is difficult to back the normal work environment. Lack of properly organized water related data in the AAWSA.

CHAPTER Two

2 Methodology

2.1 Introduction

This chapter outlines the methods that the researcher employed to achieve the aims and the objectives of the study as outlined in the first chapter of the thesis.

To describe the water sensitive urban design intervention to solve water scarcity and storm water management in governmental schools of Addis Ababa, qualitative and quantitative data were employed in order to make close investigation of water scarcity and stormwater management.

The main data for this study were obtained from primary and secondary sources. The primary data was gathered from the actual study area through fieldwork, maps, photographing, structured and unstructured interview of students, teachers and higher officials, and the secondary data was obtained from books, reviewing different literatures, reports, journals, magazines and by studying documents relating to the subject as well as from the internet and maps.

2.2 Selection Criteria for Cases

The selection of the study area was based upon different criteria such as: the area coverage or plot areas, large number of students, teachers as well as staff members, topographic feature of the area and existence of water scarcity in schools.

Table 2.1 Selection Criteria of the Study Area

Name of school	Case selection criteria	Remark
Kara Alo junior Secondary School	**<u>The existence of water scarcity</u>:-**for this particular case was originally high rate of shortage. ✓ The demand and supply of water could not be proportional. ✓ One functional water tap for all students as well as administration workers.	

	The area coverage or plot size: - Large area coverage is decisive for designing storm water management. ✓ The catchment area is significant to collect enough water for available students.	
	Large number of students: - The demand and supply of water according to the number of students could not be proportional. ✓ The age of students also another factor for the demand and supply of water. The wastage of water related with the age that means the children waste more water than elders.	
	The topographic feature of the **site: -** the topographic feature is very pivotal to collect rainwater and storm water according to the characteristics of the land. The slope ranges between 0 up to 5 is suitable for bio-retention system; however, the slope above five percent is in appropriate to the intended objectives. The slope suitable for stormwater and rainwater management that the slope increased from North to South ranges from 0 – 15 degrees.	

2.3 Methods of Data Collection

Primary and secondary data were collected in this research. The instruments and tools for primary data collection were direct observation, questionnaires and interviews. The field works chosen in this research to depict the water supply system and storm water management of the school. In addition to this, it was used to identify and understand the general physical setting and characteristics of the study area. A questionnaire was chosen to collect quantitative and qualitative data from selected.

The data gathering methods are shown in the following table:

Table 2.2 Data Gathering Methods

No	Data Type	Source Type	Methods
1.	Primary	Field works	Surveying (Questionnaires& Interviews)
			Observation
		Maps	By GIS analysis
		AutoCAD data	By GIS analysis
2.	Secondary	Reports	search and read
		Books	
		Journals	
		Magazines	

2.4 Data Collection Procedures

Detailed data on storm water management and water scarcity including statistical data on the socio-economic and physical conditions of the educational plots were collected from relevant institutions, residents and used to analyze and identify the major problems of the topic. To collect data, questionnaires were administered personally to respondents of the study and interviews were held with the head departments and relevant experts to substantiate and compare the information obtained. The collection of completed questionnaires was started a week after distribution. In addition to this field reconnaissance was held using printout images and different photos were taken to express the spatial locations of the study area.

2.5 Type and Sources of Used Data

Both primary and secondary data were used as input for conducting this research. Primary data source were collect directly from the respondents and a field survey were carried out while the secondary data relayed on published and unpublished materials.

2.5.1 Primary Data Sources

Primary data were collected through the subsequent instruments and tools: direct observation, a questionnaire, and interviews. The primary data that was collected through direct observation the physical setup of the existing space such as vegetation type, topographic feature, soil type and land use (greenery, permeable and impermeable surfaces). The primary data that was collected through the questionnaire and interviews was being the number of students, water consumptions, the causes of water scarcity, demand and supply of water to identify the gap and the impacts of water scarcity in institutional plots.

2.5.2 Secondary Data Sources

The secondary data were supposed to provide details about the scarcity of water in institutional plots in residential areas were collected from possible sources like rainfall data at least of ten(10) years from Meteorology of Addis Ababa, water consumption of schools from Addis Ababa Water and Sewerage Authority (AAWSA), number of government schools and its distribution from Addis Ababa Education Bureau, Addis Ababa and Oromya integrated master plan, Addis Ababa city Environmental Protection as well as from different published and unpublished documents, websites and international precedents related to the topic.

2.6 Sampling Techniques

Yeka sub city has 117 elementary schools with different water scarcity problems and physical settings. In this study Kara – Alo primary school was selected as a study area based on its current water scarcity problem and convenient physical setting for rainwater harvesting development.

Probability (each element has a known probability of being included in the sample)and stratified sampling (divides the population into strata on the basis of some characteristics) were used to acquire the representative sample of the population of interest that are students, from grade 5 up to 8 since it closely matches the characteristics of the population. To acquire the representative of the population of interest the sampling techniques involved was the concept of first using stratified sampling was applied by dividing the target population into important sub categories of students according to grade levels (grade 5, 6, 7 and 8) and then arranged in alphabetical order. Based on their alphabetical order and grade level the first sample units was selected on a list of a population through systematic sampling and then preceding every Nth at fixed intervals (population/sample size=1,959/132=14.84~15) through systematic sampling to eliminate bias to select the sample. In addition, purposive sampling was used for interviews for teachers, administrators and higher officials. So the combinations of stratified, systematic and purposive sampling techniques were chosen for this research to ensure a representative sample of the population.

Purposive sampling is use in order to access knowledgeable people, that is who have in depth knowledge about particular issues.

2.7 Population or Universe

The students from grade 5 up to 8, teachers, administrators and higher officials constitute the population under this study from which the sample was drawn. The population under study which the sample was drawn from 141 people in total from those 132 and 9 be students and teachers respectively. In addition to this school administrators and higher officials were also considered in the population. This population was also supposed to be the most substantial units and data was collected from them through questionnaires and interviews.

2.8 Sampling Frame

The sampling frame consisted of all categories of sampling units or units of analysis. Sampling frame was the list from which sample was selected or it was the list of study population. The sampling units that the data was collected through questionnaire were grade 5, 6, 7 and 8. In addition to these teachers, school administrators and higher officials were also considered in the sampling frame to collect data from them through interview.

2.9 Sample

An important goal of many research studies is to apply the results, based on a sample of individuals, to the larger population from which the individuals are drawn. The total sample unit taken was 150 in order to achieve the objective of the research.

Table 2.3.Total Sampling Units.

No	Data collection tools	Data collected from	Quantity	Remark
1.	Questionnaire	Students from grade5,6,7 and 8	132	Stratified sampling and then using Systematic sampling
2.	Interview	Teachers and School administrators	12	Purposive sampling
4.	Interview	Higher officials	6	Purposive sampling
Total sample units			150	

2.9.1 Sample Size Determination

The formula below was used to calculate the sample size as:

$$n = \frac{z^2pqN}{e^2(N-1) + z^2pq}$$ **(Kothari, 2004)**

Where: n: is the sample size for a finite population

N: size of population which is the number of students, Teachers and staffs

p: population reliability (or frequency estimated for a sample of size n), where p is 0.5 which is taken for all developing countries population and p + q= 1

e: margin of error considered is 10% for this study.

$Z\ \alpha\ /2$: normal reduced variable at 0.05 level of significance z is 1.96

N=1342, P=0.5, q=0.5, e=0.1 and z=1.96

$$n = \frac{z^2pqN}{e^2(N-1) + z^2pq}$$

$$n = \frac{(1.96)^2 \times 0.5 \times 0.5 \times 1342}{(0.1)^2(1342-1) + (1.96)^2 \times 0.5 \times 0.5}$$

$$n = \frac{(3.84) \times 0.5 \times 0.5 \times 1342}{(0.01)(1341) + (3.84) \times 0.5 \times 0.5}$$

$$n = \frac{1288.32}{14.37} = 89.65 \approx \mathbf{90}$$

Number of students=1959

Teachers and staffs=183

Number of Higher officials=84

$$\mathbf{n = \frac{N\ (Sector) \times n\ (all\ sector)}{N\ (all\ sectors)}}$$

$$n\ (\text{Grade 5 Students}) = \frac{389 \times 90}{1342} = 26.09 \approx \mathbf{26}$$

$$n\ (\text{Grade 6 Students}) = \frac{427 \times 90}{1342} = 28.64 \approx \mathbf{29}$$

$$n\ (\text{Grade 7 Students}) = \frac{554 \times 90}{1342} = 37.15 \approx \mathbf{37}$$

$$n\ (\text{Grade 8 Students}) = \frac{589 \times 90}{1342} = 39.50 \approx \mathbf{40}$$

$$n\ (\text{Teachers and staffs}) = \frac{183 \times 90}{1342} = 12.27 \approx \mathbf{12}$$

$$n\ (\text{Higher Officials}) = \frac{84 \times 90}{1342} = 5.63 \approx \mathbf{6}$$

2.10 Data Analysis

Both primary and secondary data were analyzed through qualitative and quantitative methods. The qualitative and quantitative data collected by the questionnaire, interview discussion and published and unpublished documents were analyzed through text, tables and graphs. The type of soft wares used to analyze the data were SPSS, GIS, Graphic Design (AutoCAD, Arch CAD and Sketch up).

Generally, the data will be analyzed using appropriate soft wares in maps, graphs and tables

Table 2.4.Data Analysis Tools and Its Deliverables.

No	Soft ware Type	Input	Deliverable
1.	SPSS	Figures	Tables
			Graphs
2.	GIS	CAD Files, Maps and Shape files	Maps
			Tables
			Graphs
3.	Excel	Figures	Tables
			Graphs

2.11 Data Presentation

Data presentation is one of the important tools in the research writing process. The collected primary and secondary data analyzed and the results were presented in text, tabular form and figures (graphs, maps, and photographs).

CHAPTER THREE

3 Literature Review

3.1 Definition of Key Terminologies

- **Water Sensitive Urban Design (WSUD)** is a holistic approach to the planning and design of urban development that aims to minimize negative impacts on the natural water cycle and protect the health of aquatic systems. It is the interdisciplinary cooperation of water management, urban design, and landscape planning. It considers all parts of the urban water cycle and combines the functionality of water management with principles of urban design (STEPS, 2004).
- **Water scarcity** is the absence of (lack of) water, or inadequate safe water in any geographic area for human, animal and environmental use. In many places, there may be water not far away, but there are simple very little resources (money and ability) to bring it to the needed location, and makes it very expensive. “Lack of sufficient available water resources to meet the demands of water usage within a region” (World Water Assessment Programme (WWAP), March 2012.).
    - **Physical water scarcity** is a result of inadequate natural water resources to supply a region's demand
    - **Economic water scarcity** is a result of poor management of the sufficient available water resources.
- **Scaling up:** Scaling up is defined as “expanding, replicating, adapting and sustaining successful policies, programs or projects in geographic space and over time to reach a greater number of people (Larry Cooley and Johannes F.Linn,September 2014).
- **Water harvesting** is “The collection and management of floodwater or rainwater runoff to increase water availability for domestic and agricultural use as well as ecosystem sustenance". Water harvesting includes all methods of concentrating, diverting, collecting, storing and utilizing and managing runoff for productive use (Worn, J., & Hattun, V., 2006).

3.2 Water Use and Shortage in Primary Schools in Urban Areas

3.2.1 Introduction

Water is a critically needed resource for both drinking and sanitary uses anywhere, but especially in schools and without adequate and reliable water supply; it is difficult to sustain a healthy learning environment for children. Each student requires about five liters per day for meeting the metabolic, sanitary and hygiene requirements, to keep the toilets and urinals clean as well as for hand washing after using toilets and urinals. The designed school latrine and urinal cannot function without water. Water supply projects for schools must clearly address these water requirements.

The provision of clean and safe water in plentiful quantities, adequate sanitary and hygienic facilities is a significant factor in the improvement of the health status of school children particularly in prevention of the diseases that prevail in most schools. Hence a school without water supply and sanitary facilities could be a potential spot for the spread of diseases. A survey made by the ministry of health in collaboration with UNICEF in 2007 showed that about half of the ailments found among school children are related to urinary infections and it is by lack of personal hygiene caused by inadequate provision of water. In the absence of water supply, sanitation and hygiene services in schools, water born disease can easily breakout and rapidly transmitted by any route which permits unclean material to pass into the mouth, and there is a vital linkage and intimate relationship between health and personal hygiene, which depend largely on the availability of sufficient water and sanitary facilities. It is for this reason that access to adequate and safe water supply for sanitation services is vital in schools. The services are needed to promote the use of sanitary facilities and hand washing practices as an important life skill for school children (Source: Field visit to primary schools in Ethiopia Report, 2010).

3.2.2 Major Water Use

Majority of the schools in the world use water for different purposes. The major uses are:

- Flushing toilets
- Washing hands
- Watering the garden
- Water fountains
- Drinking water from bubblers, and
- Preparing food in the canteen and kitchens

Table 3.1 Water Use for Primary Schools in Sydney (Source: Sydney water).

Water use (liters a student a day)	Rating
less than 3	Very low water use
3 - 9	Normal water use
10 - 18	Medium water use
19 - 49	High water use
more than 50	Extremely high water use

Water Usage Breakdown for Typical Schools

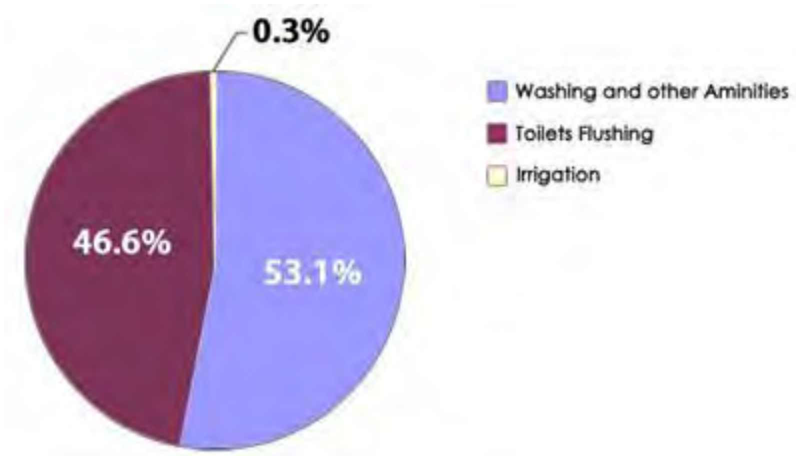


Chart 3.1 Water Usage Breakdown for Schools (Source: Sydney water).

In most schools, the majority of water used is for toilet flushing and washing purposes.

3.3 Water Supply for Schools

According to the field visit to primary schools in Ethiopia Report (2010) broadly there are two water supply systems that effectively be used in schools in Ethiopia, and these are:

(i) Rainwater catchment system,

(ii) Groundwater supply system,

- Spring catchment
- Hand-dug well
- Bored or drilled well (shallow and deep wells)

(iii) Municipal water supply system

Apart from the above two major water sources, there are convention water supply sources where water may be taken directly from a river or lake or reservoir and subjects it to treatment before domestic use. The water treatment requires higher investment and high level management that demands the use of a complex set of equipment, and these water supply systems has limited application for use in schools. If there is exceptional need that require the development of small scale water treatment systems, references are available in several books and web sites. (Source: WASH Ethiopian field visit to primary schools in Ethiopia Report, 2010).

The water situation in Ngumbulu and the surrounding areas is a complex and severe matter. The landscape shows signs of semi-aridity, which according to locals have developed during the post-colonial times. Most of the vegetation was removed, thus a slow deforestation process started. The aftereffect of this, in cooperation with climate change, is what the current generations in the area now desperately try to battle (Source: Andersen, M. k., June 2014).

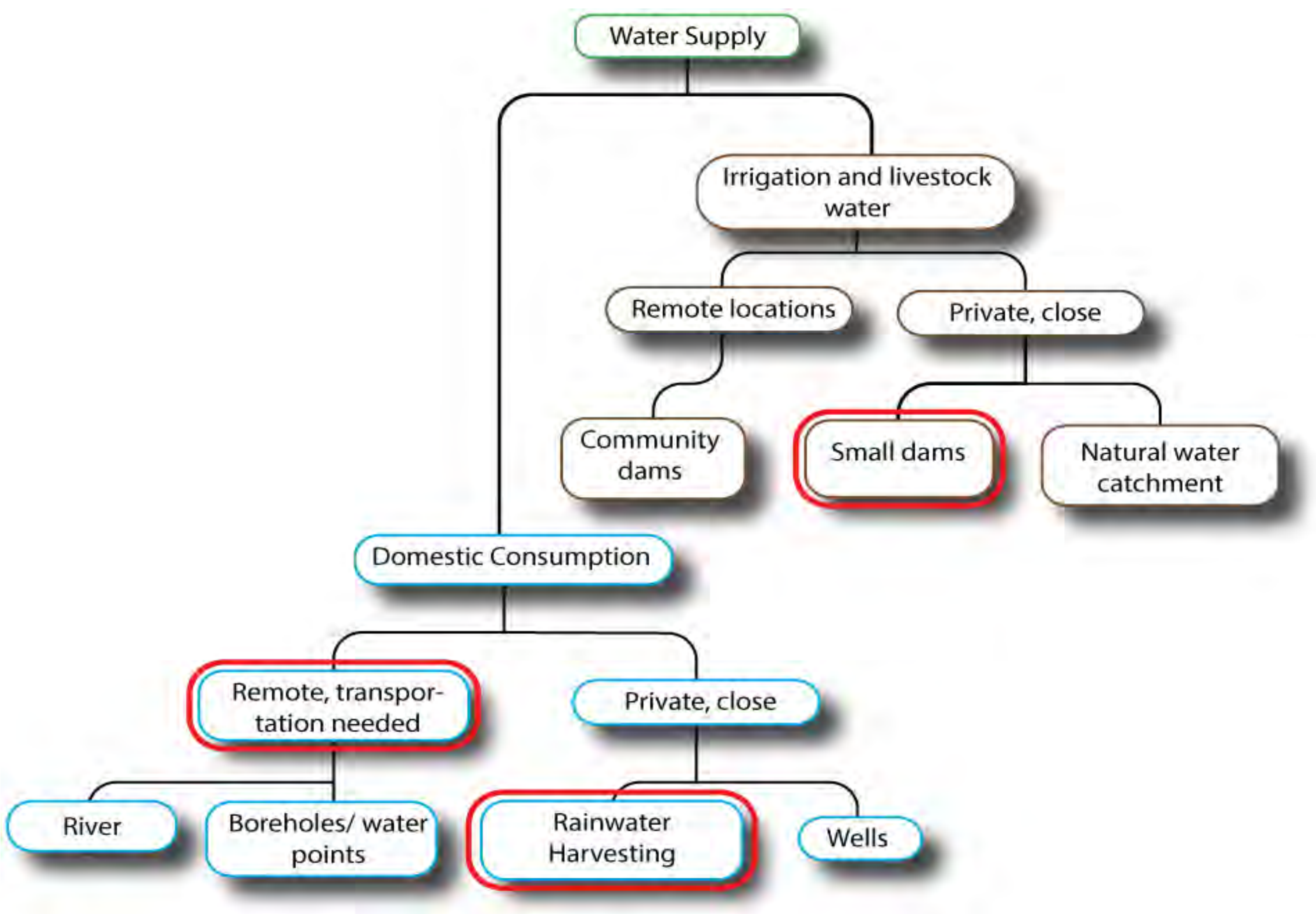


Chart 3.2 Water Supply System in Ngumbulu (Source: Andersen, M. k., June 2014).

3.4 Water Demand

Estimated water demand per day for a school with average school population at peak hour water demand is given in the box below.

Water Demand in Schools
The fundamental question: How much water is needed? For a typical school of a given population, with a flushing type toilet, urinals, we estimate that 1 liter is needed for drinking, 0.5 liters for hygiene (hand washing with soap) and 0.5 liters for cleaning both the toilet and urinal per student per day. There are also needs for water for cleaning class rooms, offices, and for greening schools. For a 4 stand toilet block and urinal (catering for 400 students), this equates to 200 liters for hand washing and 200 liters for cleaning. Inevitably, some water is wasted, and additional water may be needed for menstrual hygiene, so on average of 2 liters per student per day ONLY FOR HYGIENE AND TOILET CLEANING is appropriate. An additional 1 to 2 liters per student per day is needed for DRINKING. Even providing a total of 3 to 4 liters per student and teacher can be a great challenge for some schools. An additional one to two meters cube of water is required for other uses in schools including irrigating green areas. Much more water is required for residential schools, for staff living on campus, and to operate flush toilets. The greater the water demand, the greater the amount of waste water and grey water that will need to be disposed of (WASH Ethiopian. 2010).

3.5 Water Scarcity

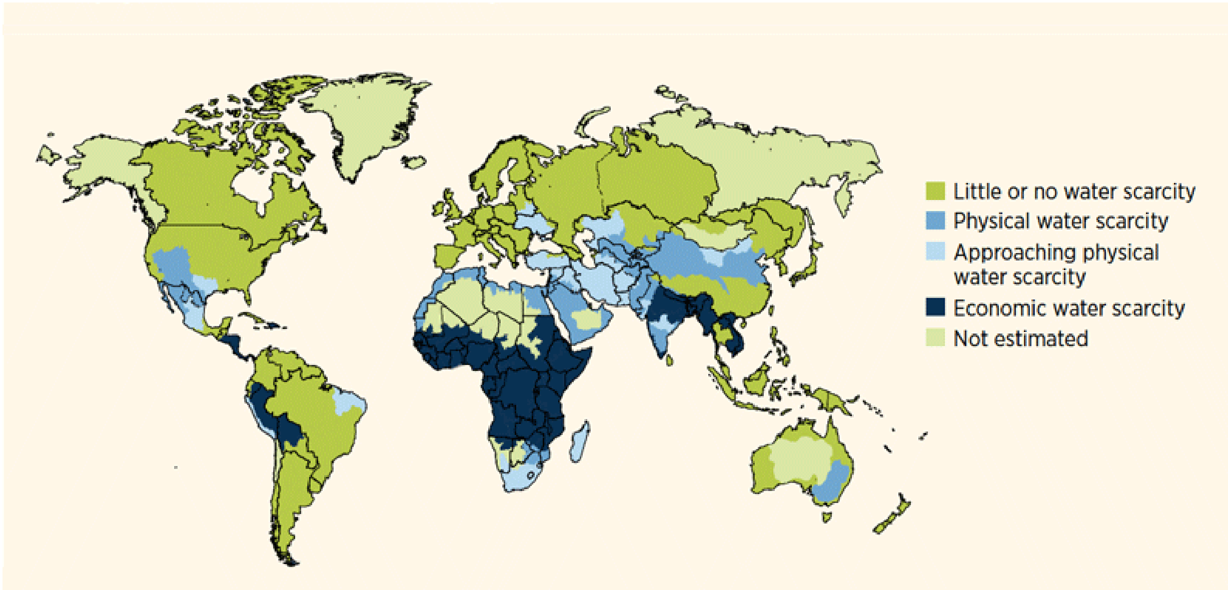
Water scarcity is the lack of sufficient available water resources to meet the demands of water usage within a region. It already affects every continent and around 2.8 billion people around the world at least one month out of every year. More than 1.2 billion people lack access to clean drinking water ("Water scarcity /international decade for action 'Water for life' 2005-2015", Retrieved 20 October 2013).

Water scarcity involves water stress, water shortage or deficits, and water crisis. While the concept of water stress is relatively new, it is the difficulty of obtaining sources of fresh water for use during a period of time and may result in further depletion and deterioration of available water resources. Water shortages may be caused by climate change, such as altered weather patterns including droughts or floods, increased pollution, and increased human demand and overuse of water. A water crisis is a situation where the available potable, unpolluted water within a region is less than that region's demand. Water scarcity is being driven by two converging phenomena: growing freshwater use and depletion of usable freshwater resources.

Water scarcity can be a result of two mechanisms: physical (absolute) water scarcity and economic water scarcity, where physical water scarcity is a result of inadequate natural water resources to supply a region's demand, and economic water scarcity is a result of poor management of the sufficient available water resources. According to the United Nations Development Programmed (UNDP), the latter is found more often to be the cause of countries or regions experiencing water scarcity, as most countries or regions have enough water to meet household, industrial, agricultural, and environmental needs, but lack the means to provide it in an accessible manner.

Economic water scarcity is caused by a lack of investment in infrastructure or technology to draw water from rivers, aquifers or other water sources, or insufficient human capacity to satisfy the demand for water. One quarter of the world's population is affected by economic water scarcity. Symptoms of economic water scarcity include a lack of infrastructure, causing the people without reliable access to water to have to travel long distances in or fetch water that is often contaminated from rivers for domestic and agricultural uses. Large parts of Africa suffer from economic water scarcity; developing water infrastructure in those areas could therefore help to reduce poverty. Critical conditions often arise for economically poor and politically weak communities living in already dry environment.

Around one fifth of the world's population currently live in regions affected by physical water scarcity; where there are inadequate water resources to meet a country's or regional demand, including the water needed to fulfill the demand of ecosystems to function effectively. Arid regions frequently suffer from physical water scarcity. It also occurs where water seems abundant but where resources are over-committed, such as when there is over development of hydraulic infrastructure for irrigation. Symptoms of physical water scarcity include environmental degradation and declining groundwater as well as other forms of exploitation or overuse.



Map 3.1. Global Physical and Economic Water Scarcity (Source: World Water Development Report 4. World Water Assessment Programme (WWAP), March 2012).

3.6 Water Resource, Demand and Supply in Addis Ababa

3.6.1 Introduction

When the city was first established, the principal sources of water were the numerous springs located at foot of the Entoto mountain range together with a series of hand dug wells within the city itself. In 1938, the Entoto treatment plant was commissioned which provided filtration, sedimentation and chlorination. Increased demand for water led to the construction of the original Gafarse dam in 1942/43 and in 1960 the Gafarsa dam was raised, in order to increase its capacity to 30,000m^3/d, while the springs were taken out service, It is of interesting to note that at this stage the whole of Addis Ababa was served by sources to the North and West of the city.

3.6.2 Potential Water Resources

Addis Ababa water supply sources are mainly from Legadadi & Gefarsa reservoirs besides Akaki well fields. In 1984 additional five potential water resources were investigated. Four of these are reservoirs, namely Gafarse IV, Akaki A, Gerbi&Sibilu, and the fifth one is the use of ground water with different well depths was also recommended. This indicates both surface and ground water sources are feasible for further development (A biannual magazine prepared by AAWSA, June 2008).

3.6.3 Ground Water Resources

Seureca Consulting Engineers (1984) conducted a water resource reconnaissance study of Addis Ababa and recommended that one of the possible water supply sources for Addis Ababa is ground water. The detailed feasibility study conducted by Seureca (1991) and subsequent test drilling showed that three areas could readily be developed. These include: Sebeta area, Koy (South west of Addis Ababa) &Akaki area and a minimum of 65,000m^3 / day is expected.

Moreover, the study recommended an integrated water resource development program considering both ground water and surface water resources in order to overcome supply shortfalls.

Low yield areas are also identified by the study including areas like Yeka Bole, Yeka Dale, Legedadi, Keranyo and Gefersa (A biannual magazine prepared by AAWSA, June 2008).

3.6.4 Surface Water Resources

The city receives an annual average rainfall of about 1,250mm (data obtained from Addis Abba Observatory) the perennial streams within the city include little Akaki, Bantyktu, Kurtume, Kebena, Ginfle and Great Akaki are also other intermittent streams; however, almost all the these rivers are polluted by industrial effluents and house hold waster. This situation necessitates the need to go for other surface water sources within or out the city. Thus, this includes the development of the Sibyl and Gerbi river.

The project encompasses areas beyond the boundaries of the city government of Addis Ababa which are situated within the National Regional State of Oromiya, the source of water and certain installations will be located within are within the city boundaries (A biannual magazine prepared by AAWSA, June 2016).

3.6.5 Existing Situations and Development Plan Addis Ababa Water Supply

The water supply to Addis Ababa Metropolitan Area (AAMA) is presently supplied from various sources as described below.

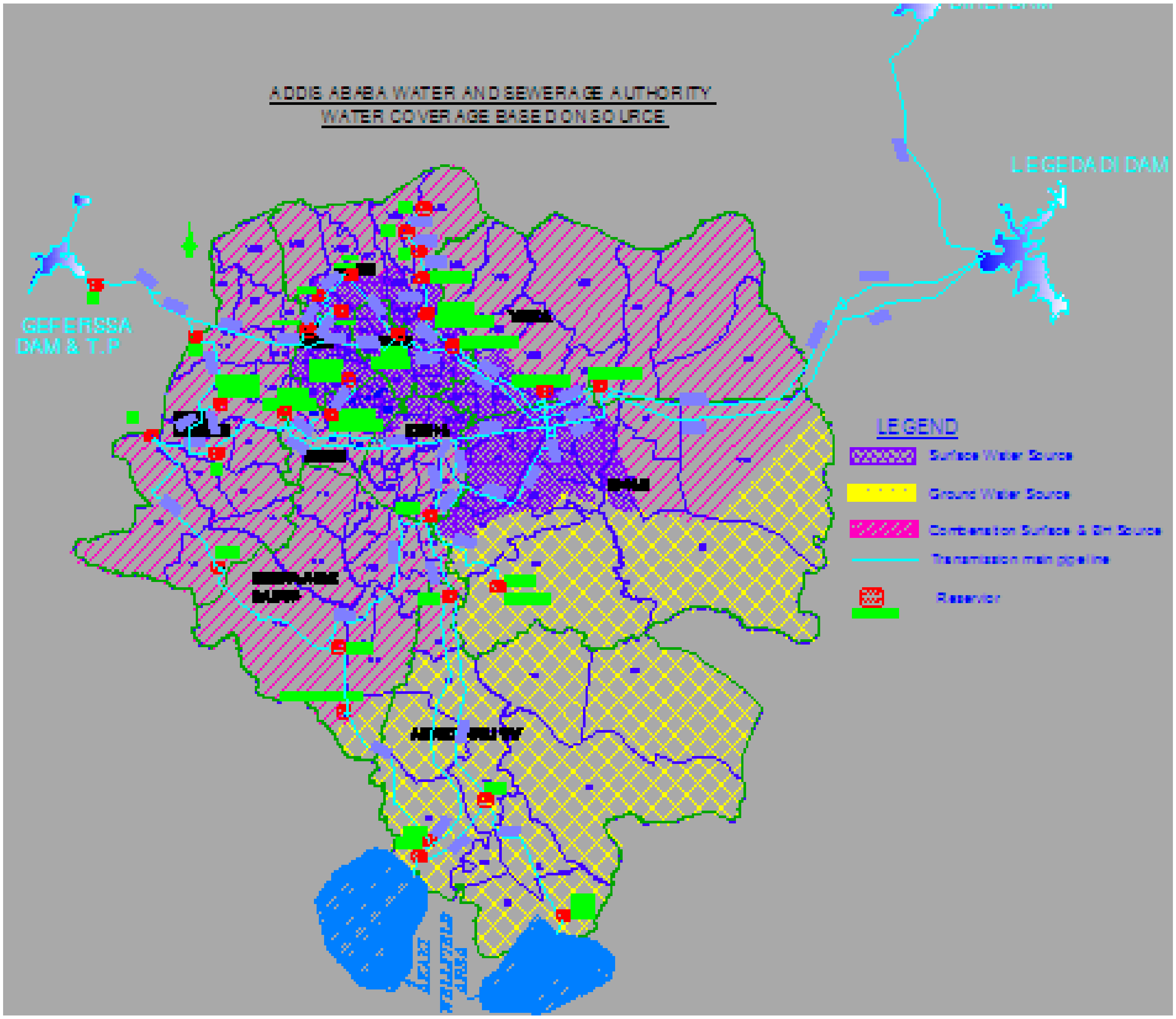
1. Surface water supplies
   - The oldest source of water supply to the city is from Geferssa dam supplying 30.000m^3/day
   - Two additional dams, at Legadadi and Dire, in the North-East of the city, supply an aggregated quality of 165, 000m^3/day.

2. Ground water supplies
   - Ground water from Akaki well field (field number-1) supply 41,000m^3/day
   - Ground water form Akaki well field (field number -2) supply 83,000m^3/day

Therefore the total production of water from various sources now is 381,000m^3/day; however, the currently expanded treatment plant at Legedadi and the completed construction work of the Akaki well field are expected to boost the coverage by adding 100,000m^3/day water to the entire system (i.e. 30,000m^3/day from the Legedadi treatment plant expansion and 70,000m^3/day from the Akaki well field).

Water supply development works through assistance from different development partners are also underway. World Bank funded the development of 70,000m^3/day from Akaki well filed is under progress and likely to be completed by 2015. Additional water extraction from Legedadi wells shall give another 45,000m^3/day (as per AAWSA business plan expected utilization). Ground water extraction from Ayate wells is also under consideration for 80,000m^3/day (as per AAWSA business plan expected utilization). Sebeta Tefki and Melkakunture well fields have potential but it is not being considered due to social reasons.

Total planning for production of additional water from various sources is 215,000m^3/day. Total water available from sources i.e. ground and surface shall be 596,000m^3/day, which means that there will be short fall of 653,122-596,000=57,122m^3/day to achieve the objective of supplying 110 lPcd for domestic purposes to the projected population of 2020 (2016 First quarter AAWSA project office report).



Map 3.2 Water Coverage of Addis Ababa Based on Source (Source: AAWSA).

Summary

Water scarcity can be a result of two mechanisms:-

- **physical (absolute) water scarcity** and
- **Economic water scarcity**

According to world water development report 4

One quarter of the world's population is affected by economic water scarcity.

Large parts of Africa suffer from economic water scarcity Ethiopia also included within it this shows that as most African countries have enough water to meet household, industrial, agricultural, and environmental needs, but lack the means to provide it in an accessible manner.

It has been seen in this study that there are different use the water for different purposes. The major one is used for things like:-

- Flushing toilets,
- Washing hands,
- Watering the garden,
- Drinking water from bubblers and
- Preparing food in the canteen and kitchens.

Considering the water supply system broadly there are two water supply systems that can effectively be used in schools in Ethiopia, and these are:

(i) Rainwater catchment system,

(ii) Groundwater supply system,

- ❖ Spring catchment
- ❖ Hand-dug well
- ❖ Bored or drilled well (shallow and deep wells)

(iii) Municipal water supply system

Legedadi, Gefersa and Ground water sources altogether 239,000m^3/day is obtained from the existing water source which is far behind the demand, i.e. 479,000m3/day.

The water supply to Addis Ababa metropolitan area is presently supplied from:-

1. Surface water supplies
   - Legadadi
   - Gefarsa, and
   - Dire dam
2. Ground water supplies
   - Akaki well field number-1
   - Akaki well field number-2

3.7 Challenges and Potential of Water Harvesting in Institutional Plots

Among the several challenges that influence the rainwater harvesting of a site, the factors that are considered to be the most important, are the following:

1. **Rainfall:** knowledge of rainfall characteristics (*intensity and distribution*) for a given area is one of the pre-requisites for designing a water harvesting system. The availability of rainfall data series in space and time and rainfall distribution is important for rainfall-runoff process and also for determination of available soil moisture. A threshold rainfall event (*e.g. of 5 mm/event*) is used in many rainfall runoff models as a start value for runoff to occur. The intensity of rainfall is a good indicator of which rainfall is likely to produce runoff. Useful rainfall factors for the design of a rain- or floodwater harvesting system include:
    a) Number of days in which the rain exceeds the threshold rainfall of the catchment, on a weekly or monthly basis.
    b) Probability and occurrence (in years) for the mean monthly rainfall.
    c) Probability and reoccurrence for the minimum and maximum monthly rainfall.
    d) Frequency distribution of storms of different specific intensities.

Rainfall Condition

A. **Rainfall Quantity:** Rainfall is the largest unpredictable variable in the calculation and hence, it is difficult or reliable rainfall data to determine the potential rainwater supply for a given catchment, reliable rainfall data are required, preferably for a period of at least10 years. Also, it would be far better to use rainfall data from the nearest station with comparable conditions.

B. **Pattern:** The number of annual rainy days is also another challenge for influences the need and design for rainwater harvesting. The fewer the annual rainy days or longer the dry period, the more the need for rainwater collection in a region. However, if the dry period is too long, big storage tanks would be needed to store rainwater. Hence inEthiopia, distribution of rain over the season nowadays it is more difficult to understand the annual rain fall pattern because of world climate change problems.

C. **Unpredictable Rainfall:** Rainfall is hard to predict and sometimes little or no rainfall can limit the supply of rainwater. It is not advisable to depend on rainwater alone for all your water needs in areas where there is limited rainfall. Rainwater harvesting is suitable in those areas that receive plenty of rainfall.

2. **Land use or vegetation cover:** Vegetation is another important parameter that affects the surface runoff. From studies in West Africa (Prinz, D.& Singh A. K. 2000) proved that an increase in the vegetation density results in a corresponding increase in interception losses, retention and infiltration rates which consequently decrease the volume of runoff. Vegetation density can be characterized by the size of the area covered under vegetation (ibid).
3. **Large catchment area runoff** depends upon the area and type of the catchment over which it falls as well as surface features. All calculations relating to the performance of rainwater catchment systems involve the use of runoff 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). Urban area and institutional plots have potential for large rooftop to collect rainwater harvesting (Prinz, D. & Singh A. K. 2000).
4. **Topography and terrain profile:** Land forms along with slope gradient and relief intensity are other parameters to determine the type of water harvesting. The terrain analysis can be used for determination of the length of slope, a parameter regarded of very high importance for the suitability of an area for macro-catchment water harvesting. With a given inclination, the runoff volume increases with the length of slope. The slope length can be used to determine the suitability for macro or micro- or mixed water harvesting systems decision making (Prinz, D. & Singh A. K. 2000).
5. **Soil type & soil depth:** The suitability of a certain area either as catchment or as cropping area in water harvesting depend strongly on its soils characteristics.
   i. surface structure; which influence the rainfall-runoff process,
   ii. the infiltration and percolation rate; which determine water movement into the soil and within the soil matrix, and
   iii. The soil depth including. Soil texture; which determines the quantity of water which can be stored in the soil.
6. **Hydrology and water resources:** The hydrological processes relevant to water harvesting practices are those involved in the production, flow and storage of runoff from rainfall within a particular project area. The rain falling on a particular catchment area can be effective (*as direct runoff*) or

ineffective (*as evaporation, deep percolation*). The quantity of rainfall which produces runoff is a good indicator of the suitability of the area for water harvesting.

7. **Socio-economic and infrastructure conditions:** The socio-economic conditions of a region being considered for any water harvesting scheme are very important for planning, designing and implementation. The chances for success are much greater if resource users and community groups are involved from early planning stage onwards. Lack of awareness is another challenge that the practice is also declining due to a lack of awareness, knowledge and skills to set up systems.
8. **Environmental and ecological impacts:** Dry area ecosystems are generally fragile and have a limited capacity to adjust to change (Oweis et al. 1999). If the use of natural resources (land and water), is suddenly changed by water harvesting, the environmental consequences are often far greater than foreseen. Consideration should be given to the possible effect on natural wetlands as on other water users, both in terms of water quality and quantity. New water harvesting systems may intercept runoff at the upstream part of the catchment, thus depriving potential downstream users of their share of the resources. Water harvesting technology should be seen as one component of a regional water management improvement project. Components of such integrated plans should be the improvement of agronomic practices, including the use of good plant material, plant protection measures and soil fertility management (Ibid).

3.8 Rainwater Harvesting Policies in Different Countries

As battles over water rights rage and profligate water usage continues in many places, policy makers will have to find tools to lead communities towards more responsible water management. One such policy tool is an ordinance to encourage or even require rainwater harvesting. The best rainwater harvesting policies protect water as a human right, protect public health and promote sustainability. Through a combination of incentives, taxes and penalties, meaningful water conservation can be achieved. Restrictive policies can create barriers to implementation and add unnecessary costs, but well-designed policies will encourage rainwater harvesting and help to maximize the benefits of implementing these systems. When developing a rainwater catchment policy or ordinance, consider the following criteria. One policy or ordinance should be (Meinzen, S. Jully14,2009):

- Economically viable and ecologically sustainable
- Achievable and measurable

- Easy for the public to understand and simple to implement with streamlined processes
- Reviewed by actual rainwater harvesting professionals
- Include education and technical training for the public, staff and elected officials
- Include financial support such as subsidies or grants for low-income communities

Hundreds of thousands of rainwater harvesting systems exist throughout the world. While in many places in the U.S. rainwater harvesting is actually banned because of "first come, first serve" laws dating back a century, a few American cities actually require that new buildings use cisterns to store roof runoff. Some examples are:

Legislation around the U.S.:

Tucson, Arizona: In October of 2008, the city of Tucson, Arizona became the first municipality in the country to require developers of commercial properties to harvest rainwater for landscaping. The new measure approved by a unanimous vote by the City Council requires that new developments meet 50% of their landscaping water requirements by capturing rainwater. The new rule went into effect June 1, 2010 (Meinzen, S. July14,2009).

Santa Fe County, New Mexico: Residences with 2,500 square feet or more area must install an active rainwater catchment system comprised of cisterns. All commercial developments are required to collect all roof drainage into cisterns to be reused for landscape irrigation (Ibid).

Legislation around the world:

Mumbai, India: The state government has made rainwater harvesting mandatory for all buildings that are being constructed on plots that are more than 1,000 sq. m in size.

New Delhi, India: Since June 2001, the Ministry of Urban Affairs and Poverty Alleviation has made rainwater harvesting mandatory in all new buildings with a roof area of more than 100 sq. m and in all plots with an area of more than 1,000 sq. m that are being developed. Furthermore, the Central Ground Water Authority (CGWA) has made rainwater harvesting mandatory in all institutions and residential colonies in notified areas (Kloss, C. December 2008).

Himachal Pradesh, India: All commercial and institutional buildings, tourist and industrial complexes, hotels etc., existing or coming up and having a plinth area of more than 1,000 square meters will have rain water storage facilities commensurate with the size of roof area. No objection certificates, required under different statutes, will not be issued to the owners of the buildings-unless they produce satisfactory proof of compliance of the new law. Toilet flush systems will have to be connected with the rainwater storage tank. It has been recommended that the buildings will have rain water storage facility commensurate with the size of roof in the open and set back area of the plot at the rate of 0.24 cft. Per sq. m of the roof area (Ibid).

Victoria, Australia: Since July 2005, new houses and apartments in Victoria must be built to meet the energy efficiency and water management requirements of the 5 Star standards, which require either a rainwater tank for toilet flushing, or a solar hot water system.

Sydney, New South Wales, and Australia: The BASIX (Building and Sustainability Index) building regulations call for a 40% reduction in mains water usage. In order to meet the BASIX target for water conservation, a typical single dwelling design must include a rainwater tank or alternative water supply for outdoor water use and toilet flushing and/or laundry, among other water conservation devices (Kloss, C. December 2008).

Germany: Rain taxes in Germany are a great example of internalizing externalities for a more fair system. Fees are collected for the amount of impervious surface cover on a property that generates runoff directed to the local storm sewer. That means that the more the rainwater is caught and conserved, the less rainwater runs off and is added to the storm drains. Less runoff allows for smaller storm sewers, which, in turn, saves construction and maintenance costs at the site. Thus there is a large incentive to convert impervious pavement/roof into a porous surface.

Rainwater catchment policy has implications not only for addressing water shortages, but also for reductions in energy use and related carbon emissions, as treating water consumes a lot of energy (in California, municipal water supply and wastewater treatment systems account for about 35% of energy used by municipalities.). As local governments begin to face mandatory emissions reductions, saving water may become a cost-effective way to shave off carbon emissions that requires little capital investment compared with other strategies (Kloss, C. December 2008).

3.9 Water Harvesting in Ethiopia

In Ethiopia, there are evidences that ancient churches, monasteries and castles used to collect rainwater from rooftops. According to the same source, history of rainwater harvesting in Ethiopia dates back as early as 560 BC by the Axumite Kingdom. During this period rainwater was harvested and stored in ponds for agriculture and water supply purposes. This is evidenced with documented literatures and visual observations on the remains of ponds that were once used for irrigation during that period. Furthermore, a roof water harvesting set up still exists in the remains of one of the oldest palaces in Axum; the palace of the legendary Queen of Sheba. Other evidences include the remains of one of the old castles in Gondar, constructed in the 15 - 16th century which has a pond built for rainwater harvesting for drinking and religious rituals by the kings. Also by king Lalibela (over 800 years ago), ponds and underground water storage tanks were used both for drinking and religious rituals within the system of rock hewn churches that have existed up to now. The excess water management (drainage) of the rock hewn churches is also impressive. Even to this day, there is several traditional rainwater harvesting technologies in Ethiopia, which have been used by communities in areas of water shortage since long ago. For many traditional communities in rural areas where natural sources of water are lacking, collection of rainwater from pits on rock outcrops and excavated ponds are common practices. In south of the country, the Konso people have had a long and well established tradition of building level terraces to harvest rain water to produce sorghum successfully under extremely harsh environment; low, erratic and unreliable rainfall conditions (Habtamu 1999).

Figure 3.1 Water Harvesting Using Dams in Tigray.

Figure 3.2 Ferro Cement Reservoir in Chele Primary School

3.10 Design Option for Water Harvesting for Institutional Plots/in Schools

3.10.1 Introduction

The design of rainwater harvesting system for specific area requires detailed analysis. Information will be needed on rainfall, existing water sources, and availability of materials and harvesting surface or area. Professional personnel should not design the technical aspect of rainwater harvesting without reference to local views. One might make a precise technical calculation of the optimum size of storage tank or area to make construction easier or to cut costs. If users draw water from the tank at different quantities or at different intervals from those assumed the constructed tank would not give service as expected.

It is not possible to design an appropriate rainwater harvesting system by simple process of data collection to come up with optimum design. System design should be based on information and opinion, which come from users and designers (Mekelle, The experience of water harvesting in the dry lands of Ethiopia, December, 2001).

Key planning and design objectives are to:

- Protect and enhance natural water systems in urban developments.
- Integrate storm water treatments into the landscape by incorporating multiple use corridors that maximize the visual and recreational amenity of the development.
- Protect water quality draining from urban development Reduce runoff and
- Peak flows from urban development by employing local detention measures and minimizing impervious areas.

3.10.2 Principles and Techniques

Measures that have been developed to control, store, and/or treat stormwater runoff from developed areas for the purpose of reducing flooding or removing pollutants while maintaining or enhancing environmental quality are referred to as best management practices (BMPs),BMPs commonly used include, but are not limited to, wet ponds, wetlands, grass buffer strips, sedimentation basins, rain gardens, infiltration trenches, ponds or lakes and vegetated or grass swales, as well as bio-retention systems. Typical design characteristics and capabilities for each of these are briefly described (Steven, 2009).

- **Grass buffer strips** are commonly used as a source control measure, particularly for management of road runoff, and are effective in the removal of course to medium-size sediments.

Figure 3.3 Grass Buffer Strips

- **Vegetated or grass swales** are open channel systems that utilize vegetation to aid in the removal of sediment and suspended solids. Their removal efficiency is dependent on the density and height of the vegetation in the channel.

Figure 3.4 Vegetated or Grass Swales

- **Wetlands** are an effective stormwater treatment measure for the removal of fine suspended solids and associated contaminants, as well as soluble contaminants. In some cases stormwater stored in wetlands can be employed for re-use opportunities (New Jersey Department of Environmental Protection, 2004).

Figure 3.5 Wetlands

- **Bio-retention systems** promote the removal of particulate and soluble contaminates by passing stormwater through a filter medium. The type of filter medium determines the effectiveness of the pollutant removal (Lloyd, S., 2002).

Figure 3.6 Bio-retention System

- **Ponds or lakes** use the temporary detention of stormwater to facilitate settling of suspended solids and include open water bodies (without significant shallow vegetated areas in the predominant flow paths) and ornamental ponds. Again in some cases stormwater collected can be employed for re-use opportunities(ibid).

Figure 3.7 Ponds or Lakes

- **Sedimentation basins** are open water bodies primarily for removing coarse and medium particles. This is achieved almost entirely by the temporary detention of stormwater to facilitate settling of suspended solids” (ibid).

Figure 3.8 Sedimentation Basin

- **Wet Ponds**

"Retention (or wet) ponds are basins that contain a permanent pool of water. This control measure, through careful planning and design, can serve multiple purposes including storm water management, pollutant removal, habitat improvement, and aesthetic enhancement. The following features, should be considered when designing a wet pond" (Brown, R., & Clarke, J.,2007).

1. Maximize flow length between inlet and outlet. This extends the flow path before the water exits, thus increasing the time for sediment and pollutant settlement. A suggested minimum length-to-width ratio is 3:1. If this ratio cannot be achieved, baffles (a device used to restrain the flow of a fluid) can be used to break up flow and lengthen the flow path between inlet and outlet.

2. The pond should expand gradually in the direction of flow. Water entering the pond spreads out and uniformly displaces the existing water, thus preventing the creation of "dead zones."Generally, an irregular shoreline is preferred when a more natural appearance is desired.

3. Pool depth should be between 1.2-2.4 m. Depths of less than 1.2m can result in elevated water temperatures and re suspension of sediment due to surface disturbance. A level safety bench at least 3.0 m wide by 0.3 m deep should be provided around the perimeter of the pond to reduce potential safety problems. Where groundwater quality is a concern, the pond should be lined and the basin depth should be above the seasonal high water table to prevent mixing of groundwater and runoff. Obviously, under these circumstances, wet ponds cannot be used to recharge groundwater.

4. The use of a complex and organic geometry for the shape of and the topography within the pond can improve both the feature's treatment of storm water and its habitat value. Rigid rectilinear geometries can lead to zones in the composition that do not perform a treatment function.

➢ **Infiltration basins**

An infiltration basin is a surface impoundment created by damming or excavating. The purpose of the basin is to store runoff for a selected design storm or specific volume temporarily so that the water will enter the soil over a given time period. These basins, in terms of performance and appearance, are very similar to detention basins, and, in fact, basins are often designed to combine infiltration and detention functions. There are two types of infiltration basins:

1. Surface Infiltration Basins
2. Subsurface Infiltration Basins

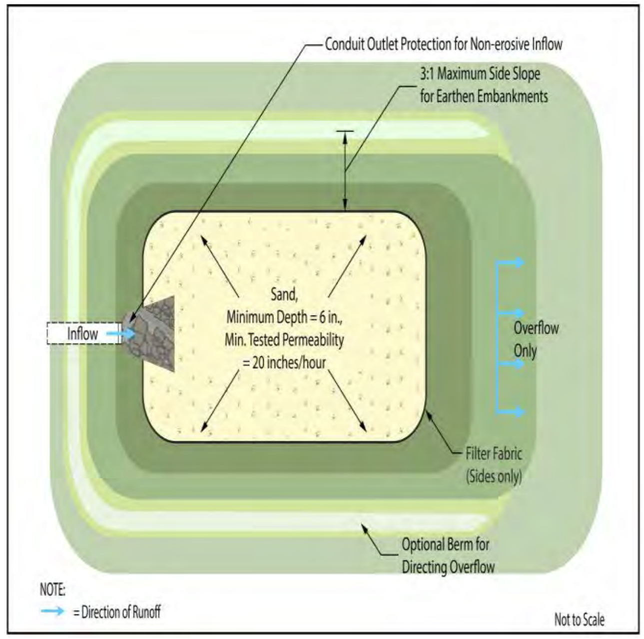


Figure 3.9 Surface Infiltration Basin –Plan View

Infiltration basins are designed so that storm water eventually soaks into the ground, imitating natural conditions and recharging groundwater supplies. In addition to recharging groundwater, infiltration basins also trap pollutants, making them a highly valued storm water management tool. Site conditions must be right in order for infiltration basins to work properly. For example, a high water table or soils with high clay content will prevent runoff from sufficiently infiltrating through the soil. It is a requirement that Infiltration basins be dry within 48 hours after a storm (Infiltration basins design guidance, dated February 2011).

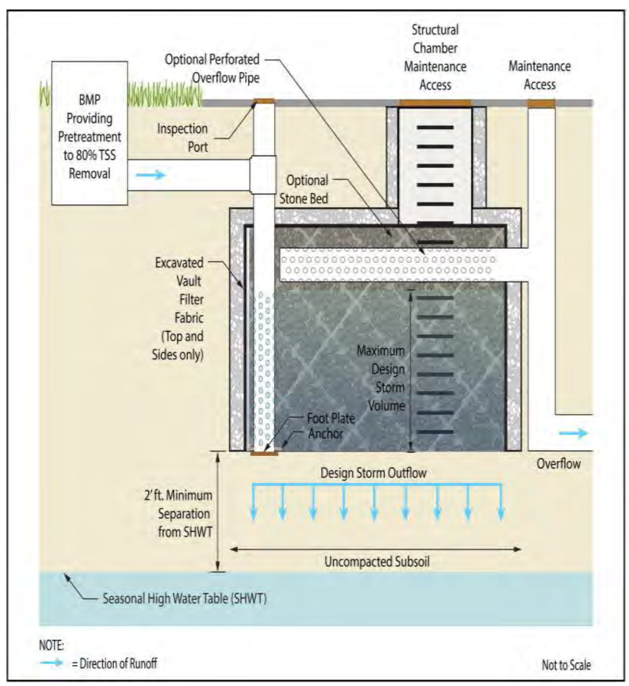


Figure 3.10 Subsurface Infiltration Basins

- **Infiltration trenches**

An infiltration trench is an excavation backfilled with coarse aggregate stone. The voids between the aggregate materials provide the volume for temporary storage of storm runoff. Runoff stored in the trench gradually infiltrates the surrounding soil. The surface of the trench may be covered with grass having a surface inlet, or with porous material, such as sand, gravel, or stone. Infiltration trenches are appropriate for relatively small drainage areas (New Jersey Department of Environmental Protection and Department of Agriculture. December 1994).

Figure 3.11 Infiltration Trenches

- **Rain gardens**

A rain garden is a more informal and organic appearing infiltration basin. Rather than relying on a basin requiring embankment structures, as above, rain gardens are meant to be installed in areas that already show good soil drainage, though the soil can be manipulated to improve its drainage characteristics. Ideally, they are located in already low-lying areas and away from building foundations and septic systems that receive full to partial sun to maximize evaporation and minimize the potential for damage to other site elements.

Figure 3.12 Rain Garden

3.10.3 Designing Rooftop Rainwater Harvesting

Rainwater can be collected from most forms of roofs. pitched roofs or roofs sheeted with corrugated mild steel etc are preferable, since they are the easiest to use and give the cleanest water.

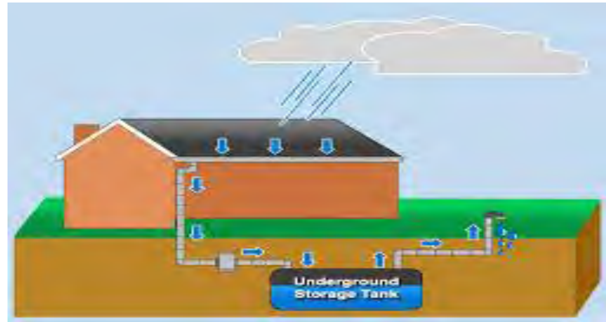


Figure 3.13 Underground Storage Tank

The water project completes rainwater catchment projects at schools, where on-site, safe water keeps children in school. Water is collected from specific areas of a roof, enters a custom guttering system (which filters out debris) and leads to a storage tank. Tanks can vary in sizes and are determined by the population of the school and average rainfall patterns.

F

Figure 3.14 On the Ground Storage Tank

Water can be stored for months, is easily treated in a tank and is accessible through taps on the tank.

The main consideration in designing a rainwater harvesting system is to size the volume of the storage tank correctly. The tank should give adequate storage capacity at minimum construction cost (Joe M. et al. 2009).

3.10.4 Five Steps to be followed in designing a RWH System:

Step1 Determine the total amount of required and available rainwater.

Step2 Design your catchment area.

Step3 Design your delivery system.

Step4 Determine the necessary size of your storage reservoir.

Figure 3.15AClean Storage Tank on a Painted White on the Outside Platform

Step5 Select suitable design of storage reservoir (Source: Gould, John, and Erik Nissen-peterson. Rainwater catchment system.UK: intermediate Technology publication, 1999).

3.11 Case Study

3.11.1 Construction of Household Rainwater Harvesting Jars in Uganda

Water aid has been working to improve household water supplies in a Ugandan village where 3,000 people lack access to safe water. The terrain is hilly, often with very steep gradients, making it difficult for old or infirm people to access safe water sources.

Figure 3.16 Anna Maria Nanvubya and Husband Zevilo Constructing a Rainwater Harvesting Jar at their Home in Kitayita Village.

Local masons were trained in the construction of rainwater harvesting "jars". These jars are made from locally available materials and have a capacity of 1,500 liters which is equivalent to 75 "jerry cans" of water. The objective has been to help the community construct on-site water supplies, close to home, removing the need for old or infirm people to travel long distances across difficult terrain to collect water.

Figure 3.17 A Rainwater Harvesting Tank at a School Guirhora kello.

The jars have a long life and once constructed can provide a stable water source for many years. There are two dry seasons and two wet seasons in this part of Uganda and the jars augment supply over the dry Uganda seasons, although the water inside may not last for the duration of a whole dry season.

Table 3.2 Construction of Household Rainwater Harvesting Jars in Uganda

Materials required for construction		**Construction methodology**
• Locally made bricks for base (50)		50 bricks are used to assemble a stable platform upon which the jar is constructed.
		A one meter long copper pipe is shaped and laid in the brick base. This will channel water from the jar to the tap fitting.
• Three bags of sieved sand		A reusable wooden mould is assembled from 12 component pieces on top of the brick base.
		The outside of the mould is smeared with mud for approximately three hours.
• One bag of normal cement		s left to stand for three days after which it is plastered with normal cement.
• One kilograms of waterproof cement		The jar is left to dry for four days, giving time for the cement to set.
		After four days the mould is removed by extracting individual pieces from the mouth of the jar. The layer of mud inside the jar is also removed.
• One meter copper pipe		
• A wooden mould that can be reused to make a number of jars		The inside of the jar is then sealed using waterproof cement.
		Community members provide guttering for their roofs and a plastic basin which is perforated to act as a filter at the top of the jar.
• One brass tap		Some jars have lockable tap chambers attached to their base to prevent theft of water.
		All jars are made in situ as they are fragile to transport. One jar costs around £35 to make. This cost can be shared between five households.

3.11.2 Rainwater Utilization Facility at the Community Level in Tokyo, Japan

In Tokyo, rainwater harvesting and utilization is promoted to mitigate water shortages, control floods, and secure water for emergencies. The Ryogoku Kokugikan Sumo-wrestling Arena, built in 1985 in Sumida City, is a well-known facility that utilizes rainwater on a large scale. The 8,400 m^2 rooftop of this arena is the catchment surface of the rainwater utilization system. Collected rainwater is drained into a 1,000 m^3 underground storage tank and used for toilet flushing and air conditioning. Sumida City Hall uses a similar system. Following the example of Kokugikan, many new public facilities have begun to introduce rainwater utilization systems in Tokyo.

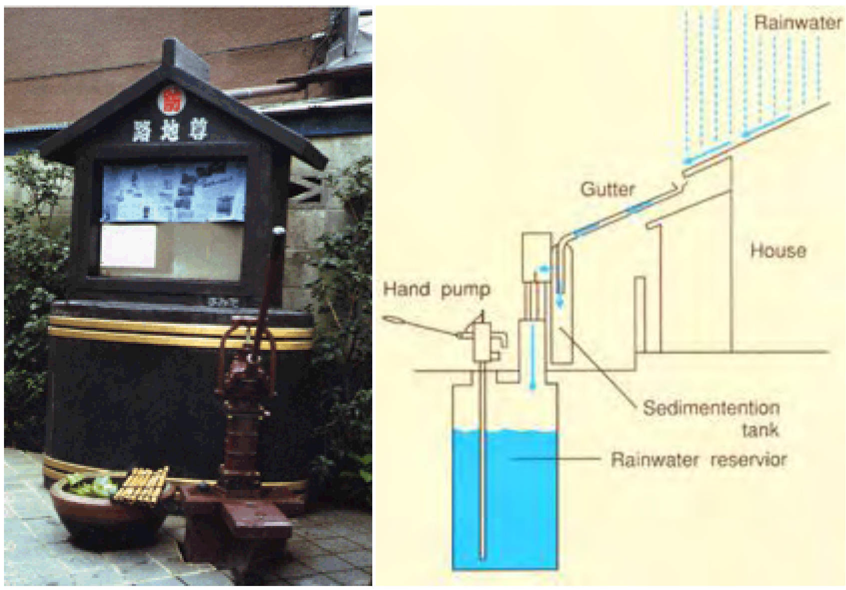


Chart 3.3 "Rojison", A Simple and Unique Rainwater Utilization Facility at the Community Level in Tokyo, Japan (Source: UNEP, 2009).

At the community level, a simple and unique rainwater utilization facility, "Rojison", has been set up by local residents in the Mukojima district of Tokyo to utilize rainwater collected from the roofs of private houses for garden watering, fire-fighting and drinking water in emergencies.

To date, about 750 private and public buildings in Tokyo have introduced rainwater collection and utilization systems. Rainwater utilization is now flourishing at both the public and private levels.

Summary

Rainwater harvesting can be constructed either above ground or below ground. The advantage of reservoirs above ground and underground can be if there are small cracks in the joints they should be sealed with cement immediately, the tank should also be completely water tight.

Measures that have been developed to control, store, and/or treat storm water runoff from school compound areas for the purpose of reducing flooding and use the water for other purposes like irrigation, water for plants within the compound while maintaining or enhancing environmental quality, increase water table, will also prevent runoff, pollutant removal and storm water soaks in to the soil are referred to as best management practices. It commonly used include, but are not limited to, wetlands, rain gardens, and infiltration trenches, as well as infiltration basins, grass buffer strips, sedimentation basins etc.

In our context for primary schools it is better to use above ground or underground tank constructed and, or a combination of these practices for rooftop water harvesting purpose.

3.12 How to Upscale into Different Schools in the Sub-city

3.12.1 Definition of Scaling up

Scaling up is defined as expanding, replicating, adapting and sustaining successful policies, programs or projects in geographic space and over time to reach a greater number of people.

3.12.2 The Innovation-Learning-Scaling up Process

Scaling up is presented as part of a broader process of innovation, learning and scaling up. A new idea, model or approach is typically embodied in a pilot project with limited impact. By learning from this experience with monitoring and evaluation, organization-internal knowledge is created and organization-external knowledge is disseminated. Internal and external knowledge in turn can be used to scale up the model through expansion, replication and adaptation with multiple impacts. The experience from scaling up feeds back into new ideas and learning. Outside knowledge can also feed scaling-up efforts, if an organization picks up on the pilot experience and learning of another organization.

3.12.3 Pathways for Scaling up

A pathway is the sequence of steps that need to be taken in the innovation-learning-scaling up cycle. The pathway starts with an innovation, pilot, or practice and requires a vision of the ultimate scale judged to be appropriate, if the intervention is successful. The pathway also requires a strategy for reaching that scale through intermediate steps, which may or may not involve individual projects, and help ensure progress towards the ultimate scale goal. Normally, there are many possible pathways for scaling up a successful intervention. The challenge is to find the pathway that is most effective in a given country and sectoral context.

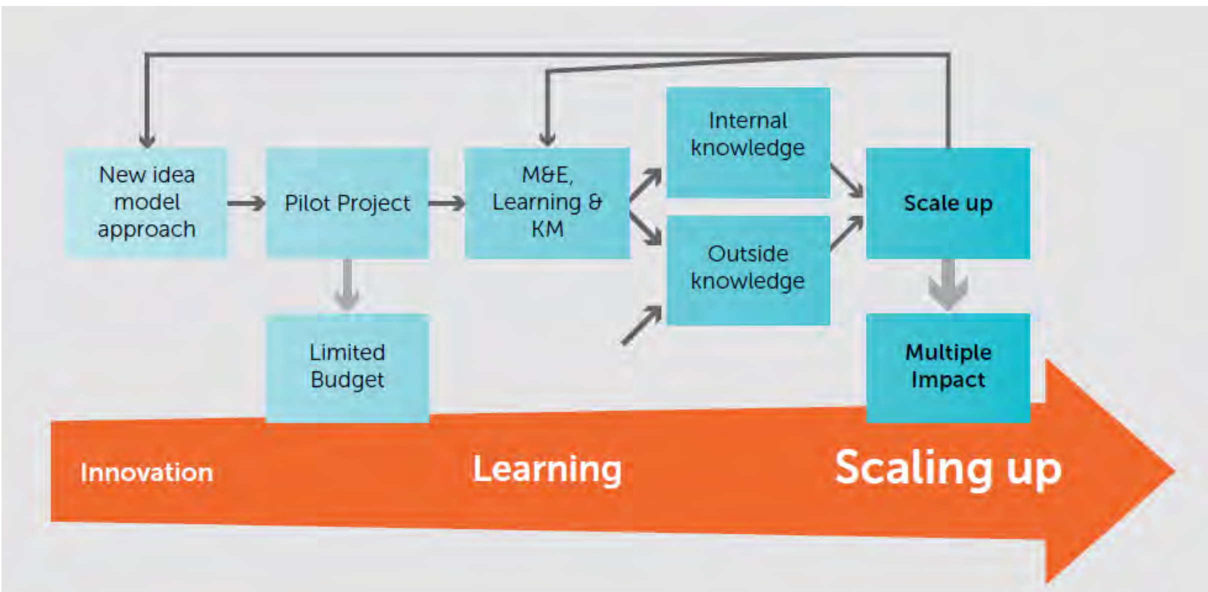


Chart 3.4 the links of innovation, learning and scaling up (Source: “Taking innovation to scale”).

3.12.3.1 Drivers

Forces, or drivers, are needed to push the scaling up process forward along a pathway. They are four common drivers:

- **Ideas and models:** There has to be an idea or model that works at a small scale. These may emerge from research or practice. The attraction of the idea or model may drive diffusion. Spontaneous diffusion happens, but more often other drivers are needed to assure scaling up.
- **Vision and leadership:** A vision is needed to recognize that scaling up of an idea is necessary, desirable, and feasible. Visionary leaders or champions often drive the scaling up process forward.

- **External catalysts:** Political and economic crises or pressure from outside actors (donors, NGOs, market or community demand, etc.) may drive the scaling up process forward.
- **Incentives and accountability:** Incentives are key to driving the behavior of actors and institutions in order for sustained scaling up to be possible. These incentives include rewards, competition, and pressure through the political process, peer reviews, and evaluations. Monitoring and evaluation against goals, benchmarks and performance metrics are essential ingredients to establish incentives and accountability.

3.12.3.2 Spaces

For successful scaling up, potential obstacles need to be removed and enabling conditions, otherwise known as spaces, have to be created for interventions to grow. Hartmann and Linn identify eight spaces that most commonly have to open up when pursuing a scaling up pathway:

- **Fiscal/financial space:** Fiscal and financial resources need to be mobilized to support the scaled up intervention, and/or the costs of the intervention need to be adapted to fit into the available fiscal/financial space.
- **Natural resource/environmental space:** The impact of the intervention on natural resources and the environment must be considered. Harmful effects of scaling up on natural resources and the environment must be mitigated, and the benefits of scaling up for natural resources and the environment should be promoted.
- **Policy space:** The policy (and legal) framework has to allow for, or be adapted to support, scaling up.
- **Institutional/organizational/staff capacity space:** The capacity for institutional and organizational resources has to be created in order to carry the scaling-up process forward.
- **Political space:** Important stakeholders, both those in support and those against the intervention, need to be attended to through outreach and suitable safeguards to ensure political support for a scaled up intervention.
- **Cultural space:** Possible cultural obstacles or support mechanisms need to be identified, and the intervention needs to be suitably adapted in order to permit scaling up in a culturally diverse environment.

- **Partnership space:** Partners need to be mobilized to join in the effort of scaling up

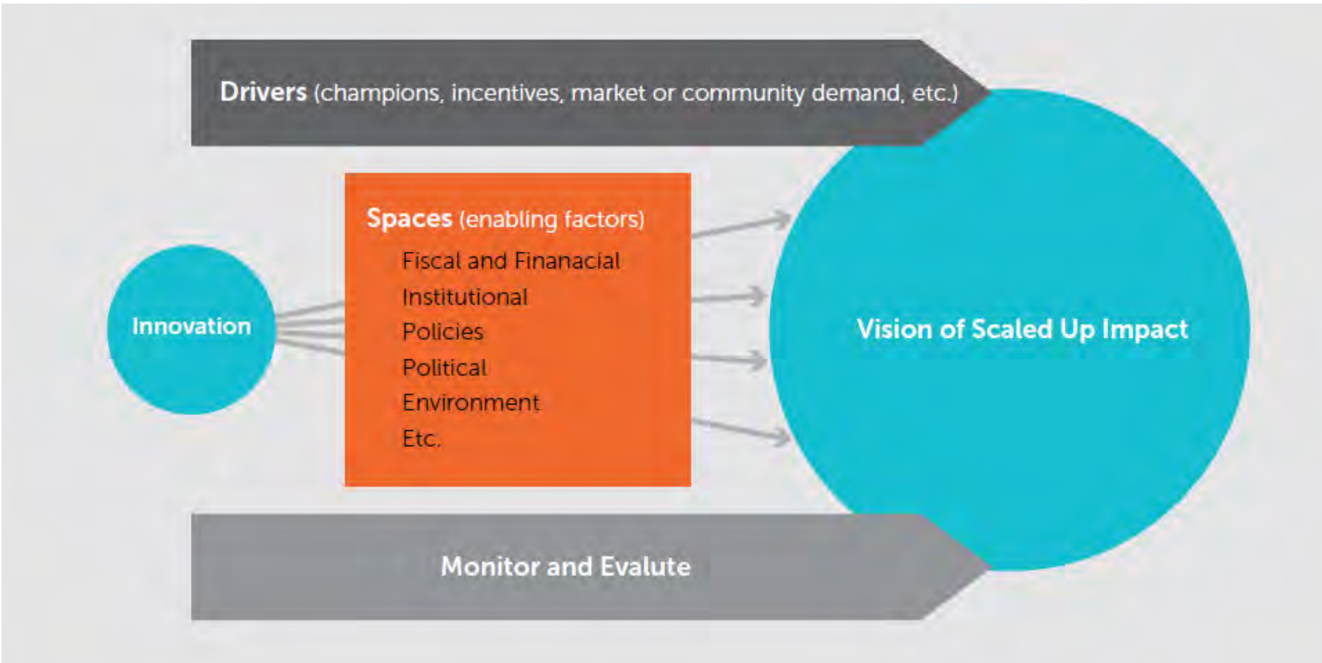


Chart 3.5 Key Components of a Systematic Scaling up Pathway (Source: "Taking innovation to scale").

Table 3.3 Scaling up Approaches and Methods (Source: "Taking innovation to scale").

Scaling Up Approaches and Methods of Scaling Up	
Type	**Method**
Expansion	• Growth • Restructuring • Franchising • Spin-off
Replication	• Policy Adoption • Grafting • Diffusion • Commercialization
Collaboration	• Formal Partnerships and Strategic Alliances • Networks and Coalitions

Summary

Scaling up is presented as part of a broader process of

- Innovation
- Learning, and
- Scaling up.

A new idea, model or approach is typically embodied in a pilot project with limited impact. By learning from this experience with monitoring and evaluation, organization-internal knowledge is created and organization-external knowledge is disseminated. Internal and external knowledge in turn can be used to scale up the model through expansion, replication and adaptation with multiple impacts. The experience from scaling up feeds back into new ideas and learning. Outside knowledge can also feed scaling-up efforts, if an organization picks up on the pilot experience and learning of another organization.

The above process of scaling up practice related to our project is that first the proposed project applied by pilot project by using limited budget to know the effectiveness of the project and then from the pilot project will learn by measurement and evaluation that keep the strong side and improve the weak side of the project. Finally, incorporated internal as well as external knowledge to scale up the project into other schools in Addis Ababa in particular and Ethiopia in general.

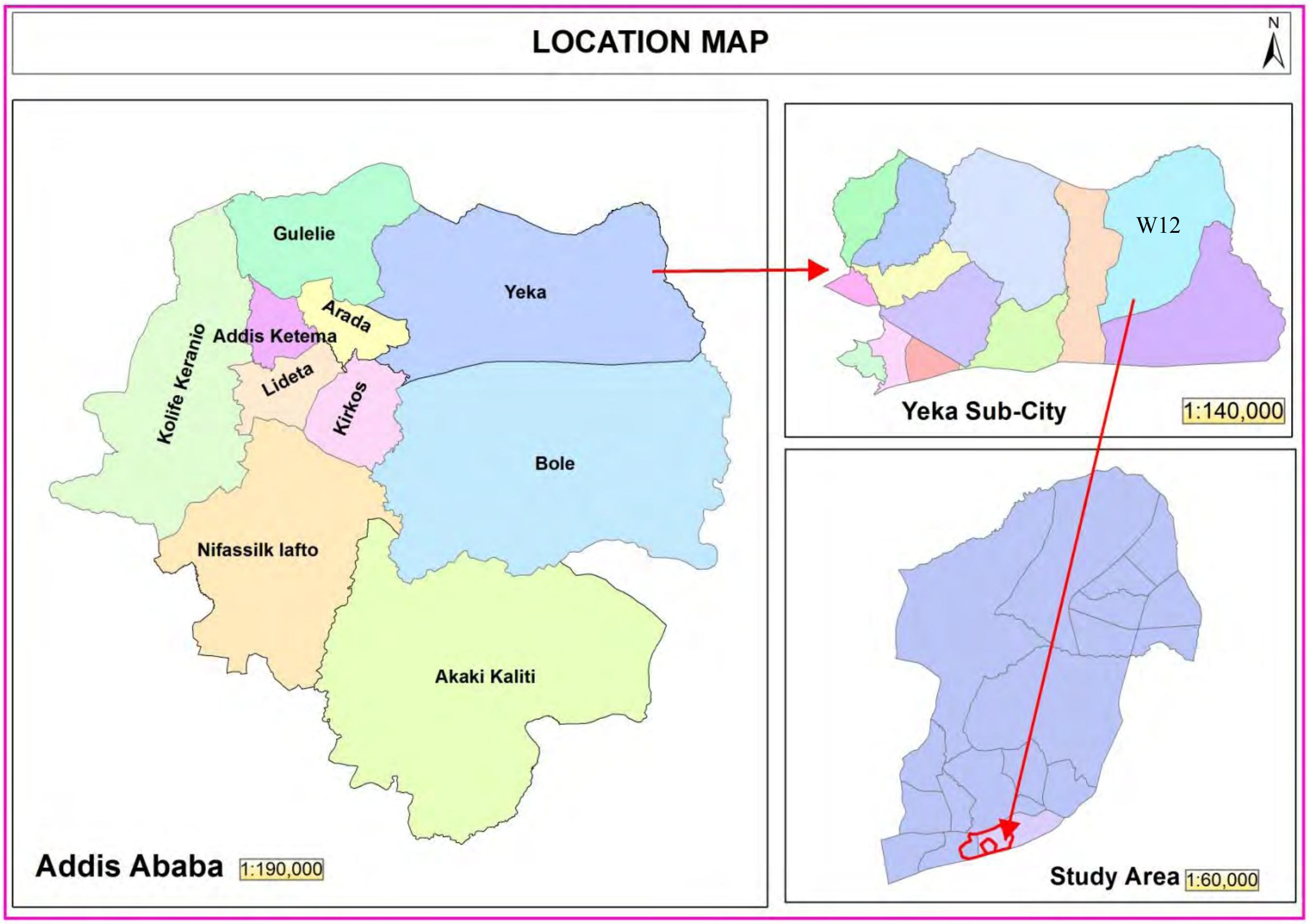
Forces, or drivers, are needed to push the scaling up process forward along a pathway. They are four common drivers:

- Incentives and accountability
- Vision and leadership
- External catalysts
- Ideas and models

CHAPTER FOUR

4 Data Presentation, Interpretation and Analysis

4.1 Location Map



Map 4.1 Location Map (Source: Personal GIS Analysis,2016).

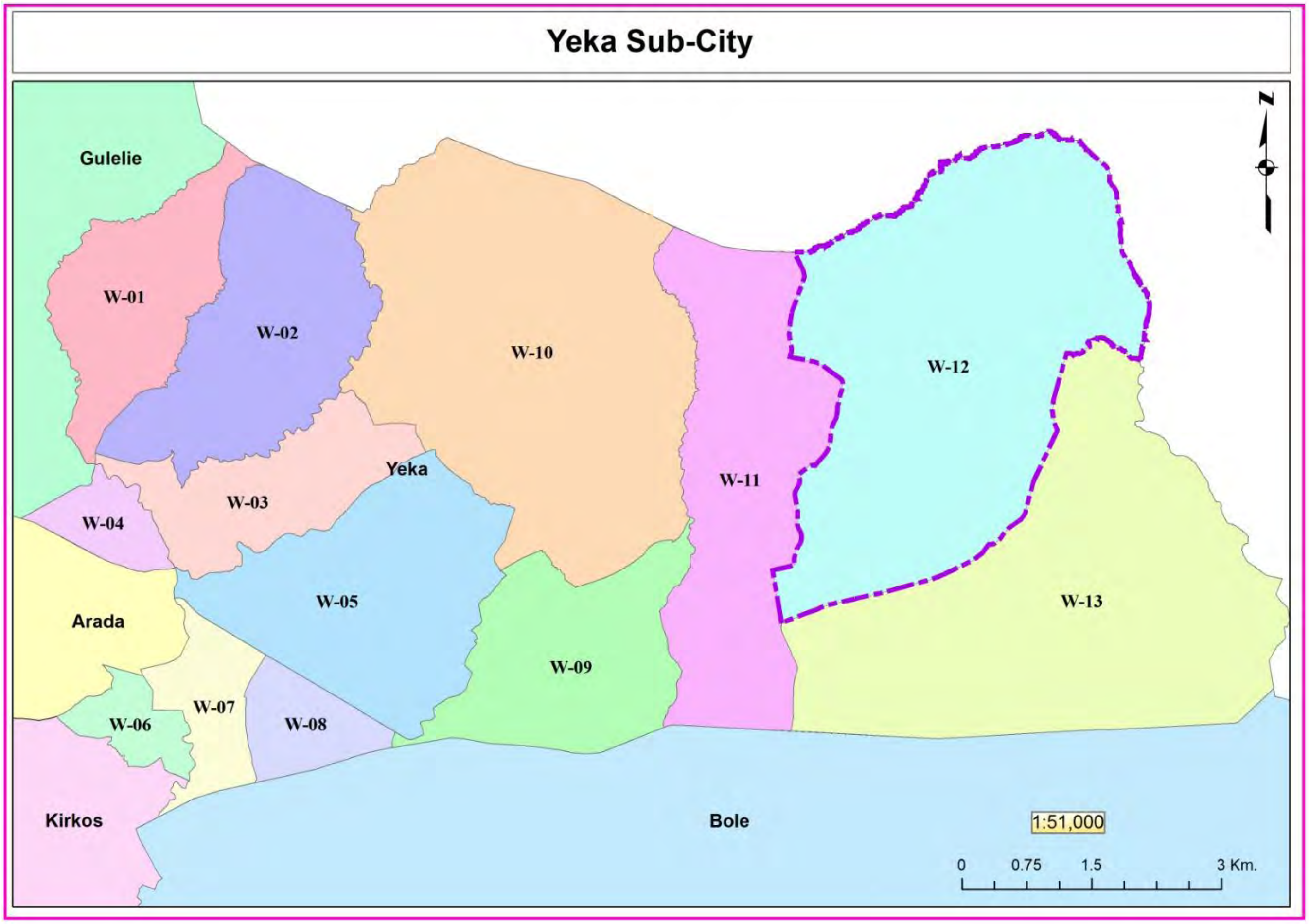
Image 4.1 Description of the Study Area by Main Roads (Source: Google Earth).

4.2 Description of the Study Area

Addis Ababa is the capital city of Ethiopia as well as a diplomatic city of Africa, located about the center of Ethiopia with a geographical range of $38^0$38” 50.7’- $38^0$54” 22.1’E and 8050” 16.7’- 9049” 3.7’N. Administratively the city divided in to 10 sub cities.

The study area is located Yeka sub city and described by 38051” 17’ E and 9002” 14’N.The highway from Addis Ababa to Mekele passes through Kotebe University road. The administrative center of the woredas, Yeka sub-city, is situated in Megenagana and the study area is 6km from Megenagan in Easter direction.

The soils of the study area are mostly the result of Luvisols depositions and mainly occupied by chromic Luvisols soil association type. This type of soil in the study area mainly clay texture and colors are less red-dish in Luvisols in cool regions than in warmer climates. In wet environments, the surface soil may become depleted of clay.



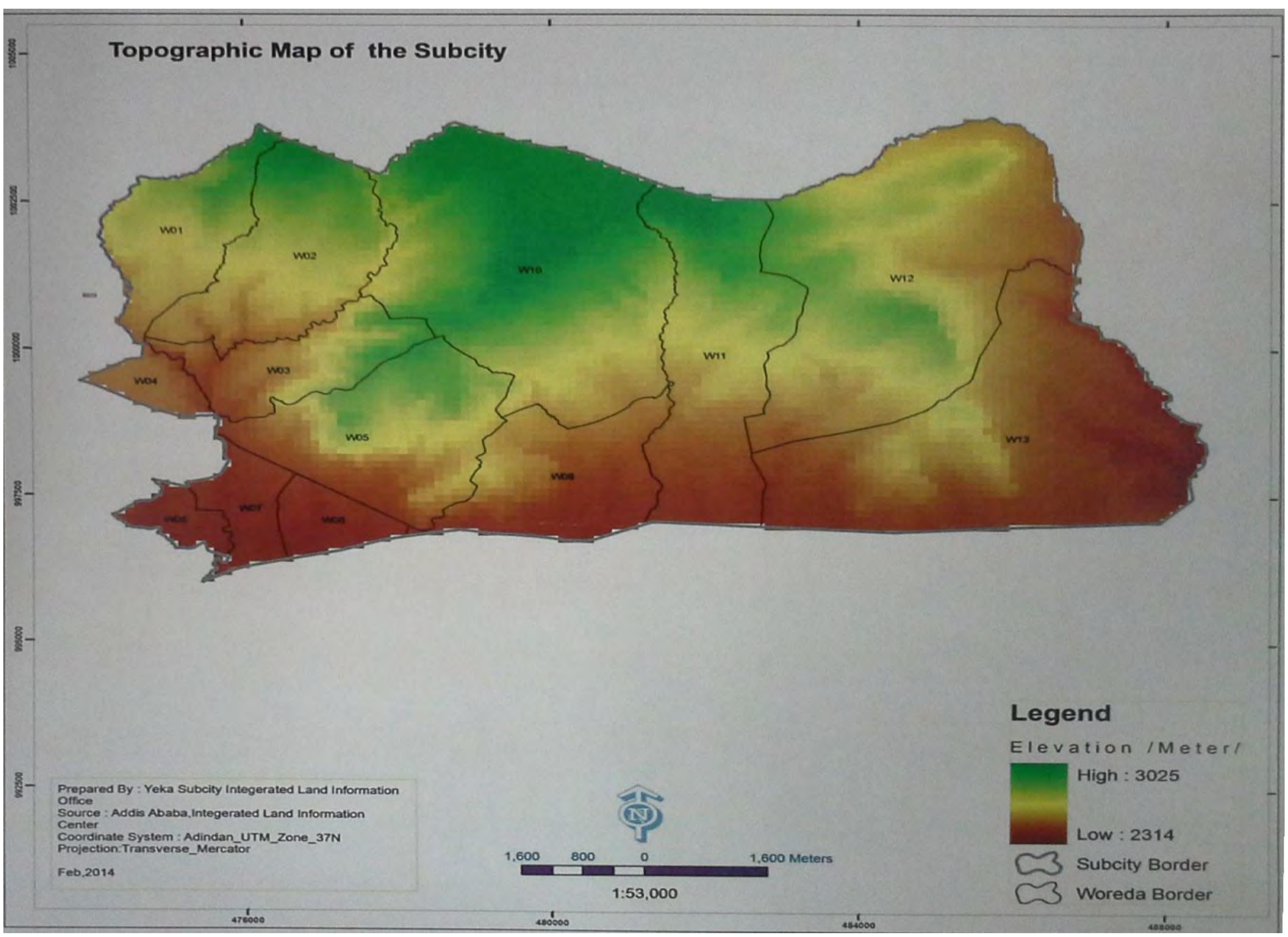
Map 4.2 Woredas of Yeka Sub – city (Source: Personal GIS Analysis,2016).

Yeka is one of the ten sub-cities in Addis Ababa city administration. It is situated in the Northern part of Addis Ababa, bounded from South by bole, from West by Arada and Gulelle sub cities and from North and East by Oromia region. At present, the sub-city is divided in to 13 Woredas, 124 sub Woredas, 394 sefers, and 1,344 blocks.

Yeka sub-city is characterized by a vigorous type of topography with noticeable elevation difference and steep landscape especially in the Northern part .Generally speaking in the sub-city, the altitude ranges from 3,025 to 2,314 meters above sea level which has a range of 711 meters in between.

Table 4.1.Elevation Range in Yeka Sub city

Elevation Range(m)	Area (Hectare)	Percent covered
2315 - 2550	661.30	21.21
2550 -2635	763.75	24.5
2635 - 2720	549.18	17.61
2720 - 2800	492.07	15.78
2800 - 2900	387.06	12.41
2900 - 3025	264.45	8.48
Total	3117.81	100.00



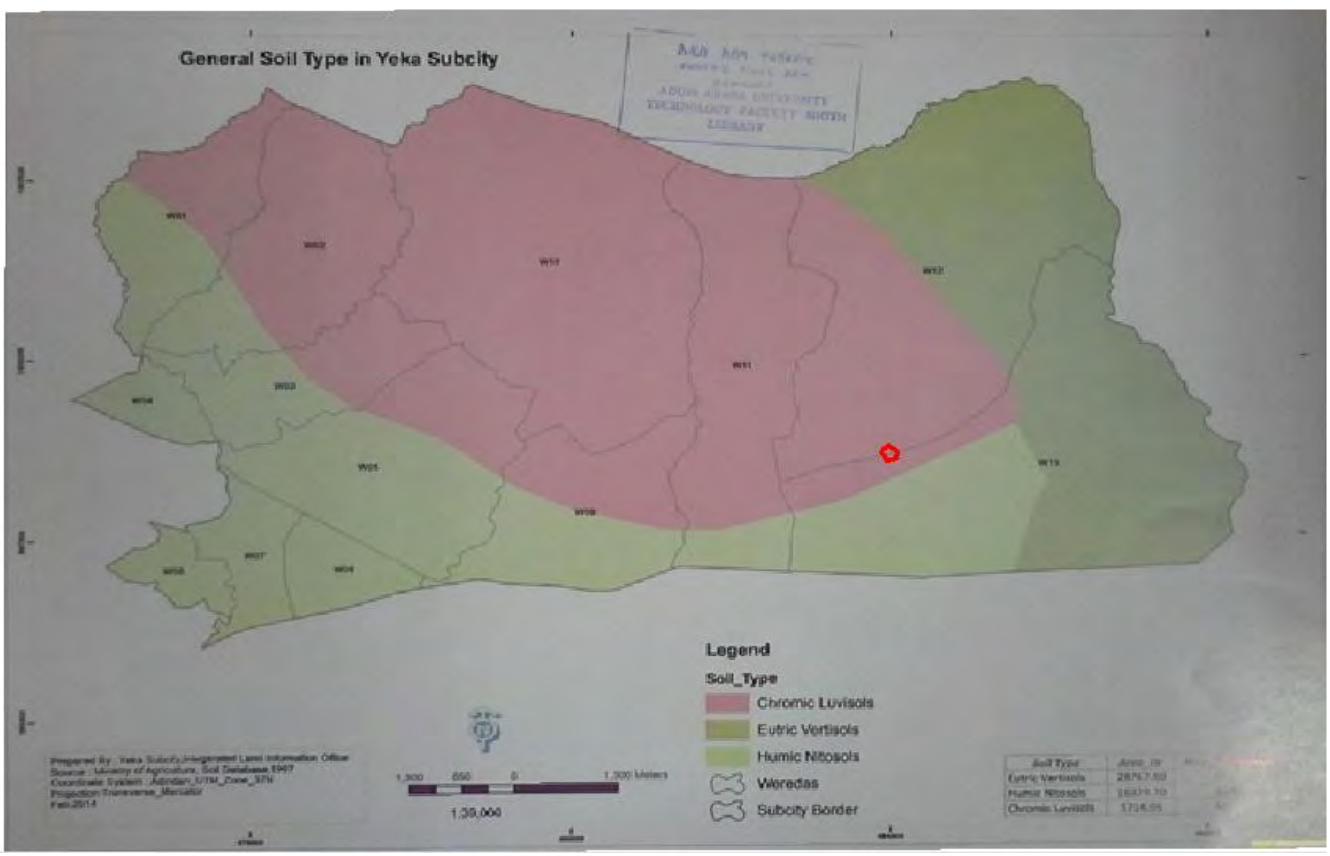
Map 4.3 Elevation Range (Source: Yeka sub - city Atlas map).

Table4.2 General Soil Type in Yeka Sub-city

Soil Type	Area (Hectare)	Area - Percentage
Eutric vertisols	28,767.80	55.37
Humic Nitosols	16,329.70	31.43
Chromic Luvisols	5,714.56	11.00

Luvisols have favorable physical properties; they have granular or crumb surface soils that are porous and well aerated. The 'available' moisture storage capacity is highest. The argic horizon has a stable blocky structure but surface soils with high silt content may be sensitive to slaking and erosion most Luvisols are well drained but shallow groundwater may occur in Luvisols in depression areas.

Stagnic properties are found where a dense illuviation horizon obstructs downward percolation and the surface soil becomes saturated with water for extended periods of time.



Map 4.4 General Soil Type (Source: Yeka sub - city Atlas map).

The land area covered by Yeka Sub-city is 8,213.11 hectares and this constitutes 15.8% of the total land area of the city which makes Yeka sub –city 3rd in land area covered from the ten sub-cities. Among the thirteen Woredas, the large area is covered by Woreda 12 with 1,470.68 hectares that is 17.91% of the sub-city land area and Woreda 06 covers the smallest land area of 101.44 hectares which is 1.24% of the sub-city land area.

According to the 2007 census, the total population with in this sub-city is 346,484 which are 12.65% of the entire population of the city. From the total population 161,480 are male while 185,004 are female. Lots of people live in Woreda 12 with population number of 32,544 which is 9.39% of the sub-city population. And relatively few people live in Woreda 04 with population number of 13,693 which is 3.95% of the sub-city population.

4.3 Population Projection

Components &methods of population projection

Knowledge of future sizes and compositions of population has been vital for appropriate planning of physical and social infrastructures.

That has, basically, been why population analysts, work hard to provide planners, decision makers and all other development workers with the adequate population data. It was from this background that population projections are made based on current realities of a given data of population at hand. Therefore, when it comes to methods there are, mainly, two major categories of population projections. These are:-

1) Cohort component method which projects the population considering mortality, fertility, and migration by age and sex components.
2) Mathematical methods.

The cohort component method is usually applicable for longer period projections under different variants, with sufficient data on such variables as fertility, mortality and migration.
In this study, however, the mathematical growth or as sometimes called the exponential growth method ($P_t = P_0e^{rt}$) is employed.
Where, P_t= population required at a given future period.

P_o = base year population

r = population growth rate between two periods (censuses)

t = number of years between the two population figures (e.g., two censuses, or survey populations, etc.)

The population projection has been undertaken by exponential method ($P_t = P_0e^{rn}$) using estimated average growth rates for urban areas of Ethiopia Region in general and Addis Ababa City in particular.

Table 4.3 Population Projection (Source: Personal, 2016).

Year	Population Projection of Addis Ababa	Water demand projection (m3/day)
2015	3,430,000	430,000
2016	3,560,000	494,000
2017	3,690,000	528,000
2018	3,830,000	565,000
2019	3,908,000	605,000
2030	4,130,000	646,000
2031	4,290,000	691,000
2032	4,450,000	739,000
2033	4,620,000	790,000
2034	4,800,000	846,000
2035	4,980,000	903,000
2036	5,170,000	967,000
2037	5,370.000	1,034,000
2038	5,570,000	1,105,000
2039	5,890,000	1,148,000

Table 4.4. Land Area Covered by Yeka Sub-city (Source: Yeka sub - city Atlas map)

No	Woreda	Area(Ha)	Total population	%of the total sub-city popn.	popn. Density (popn./hectare)
1	W01	394.19	27150	7.84	68.87
2	W02	615.37	32331	9.33	52.54
3	W03	349.59	18841	5.44	53.9
4	W04	107.92	13693	3.95	126.88
5	W05	681.32	30413	8.78	44.64
6	W06	101.44	27019	7.8	266.35
7	W07	172.22	21286	6.14	123.6

8	W08	148.09	23838	6.88	160.97
9	W09	504.02	27493	7.94	54.55
10	W10	1442.05	27495	7.94	19.07
11	W11	789.26	31837	9.19	40.44
12	W12	1470.68	32544	9.39	22.13
13	W13	1438.95	32544	9.39	22.62
Total		**8,213.10**	**346,484.00**	**100.01**	**1,056.56**

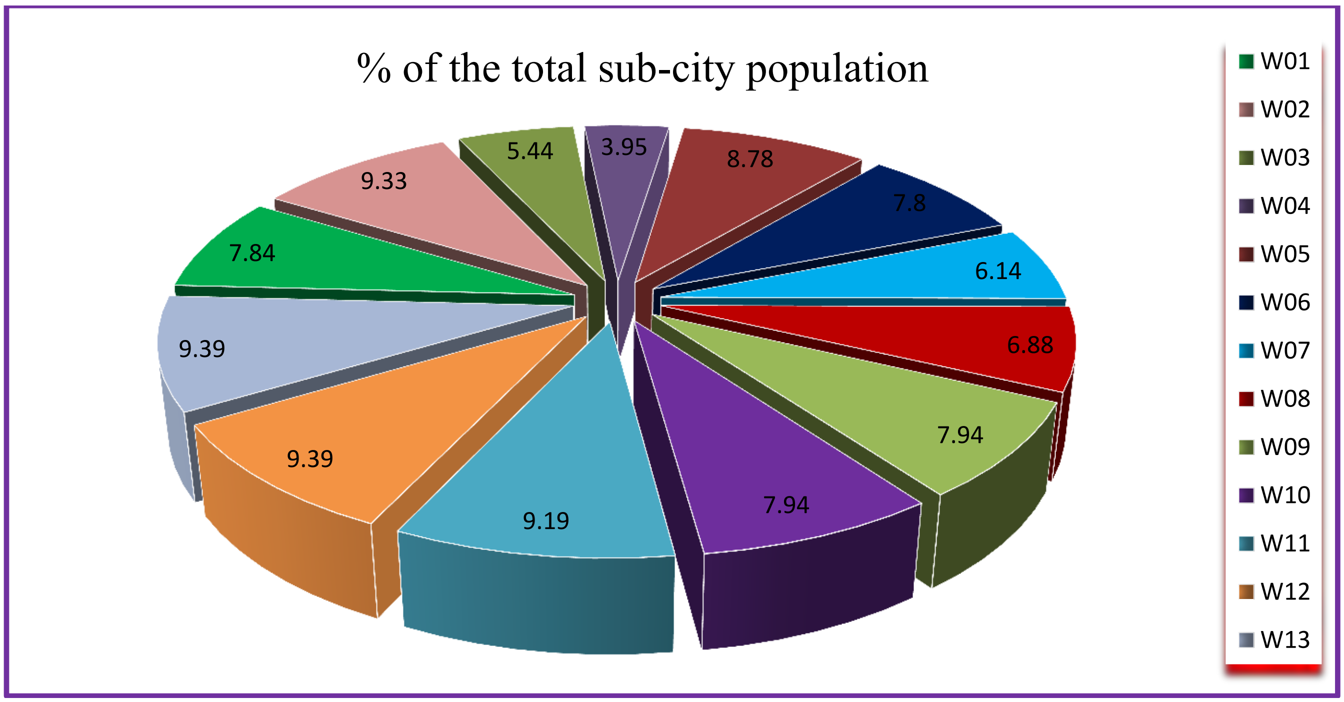


Chart 4.1 Percentage Distribution of the Sub-city Population by Woreda (Source: Personal summarizes GIS Analysis).

Table 4.5.Population Density of the Sub-city (Source: Yeka sub - city Atlas map).

Woreda	Area(Ha)	Area (%)	# Sub-Woreda	#Sefer	#Blocks
1	394.19	4.8	7	25	94
2	615.37	7.49	11	36	115
3	349.59	4.26		23	80
4	107.92	1.31	9	5	18
5	681.32	8.3	10	27	96
6	101.44	1.24	3	11	40

7	172.22	2.1	5	15	54
8	148.09	1.8	4	14	53
9	504.02	6.14	11	37	112
10	1,442.05	17.56	11	36	161
11	787.26	9.59	10	33	110
12	1,470.68	17.91	19	63	196
13	1,438.95	17.52	24	69	215
Total	**8,213.11**	**100**	**124**	**394**	**1344**

4.4 Population Density

Population density is population per unit of land area for example: persons per square kilometer of land. According to CSA 2007 data of population density of all sub cities of Addis Ababa is 5,271 person per square kilometer. Density decreases from inner to peripheral areas. Peripheral Woredas are sparsely occupied with value ranging from 1 to 15 persons per hectare. In general population densities are decreasing from central to peripheral areas.

The densely populated woreda in the sub city is Woreda 06 with population density of 266.35 people/hectare and the least dense Woreda is Woreda 10 with population density of 1,907 people/hectare. Average of 42.18 people live in each hectare area of the sub city which makes Yeka the 7th densely populated sub city in Addis Ababa.

4.5 Schools of Addis Ababa that Encountered Serious Water Shortage

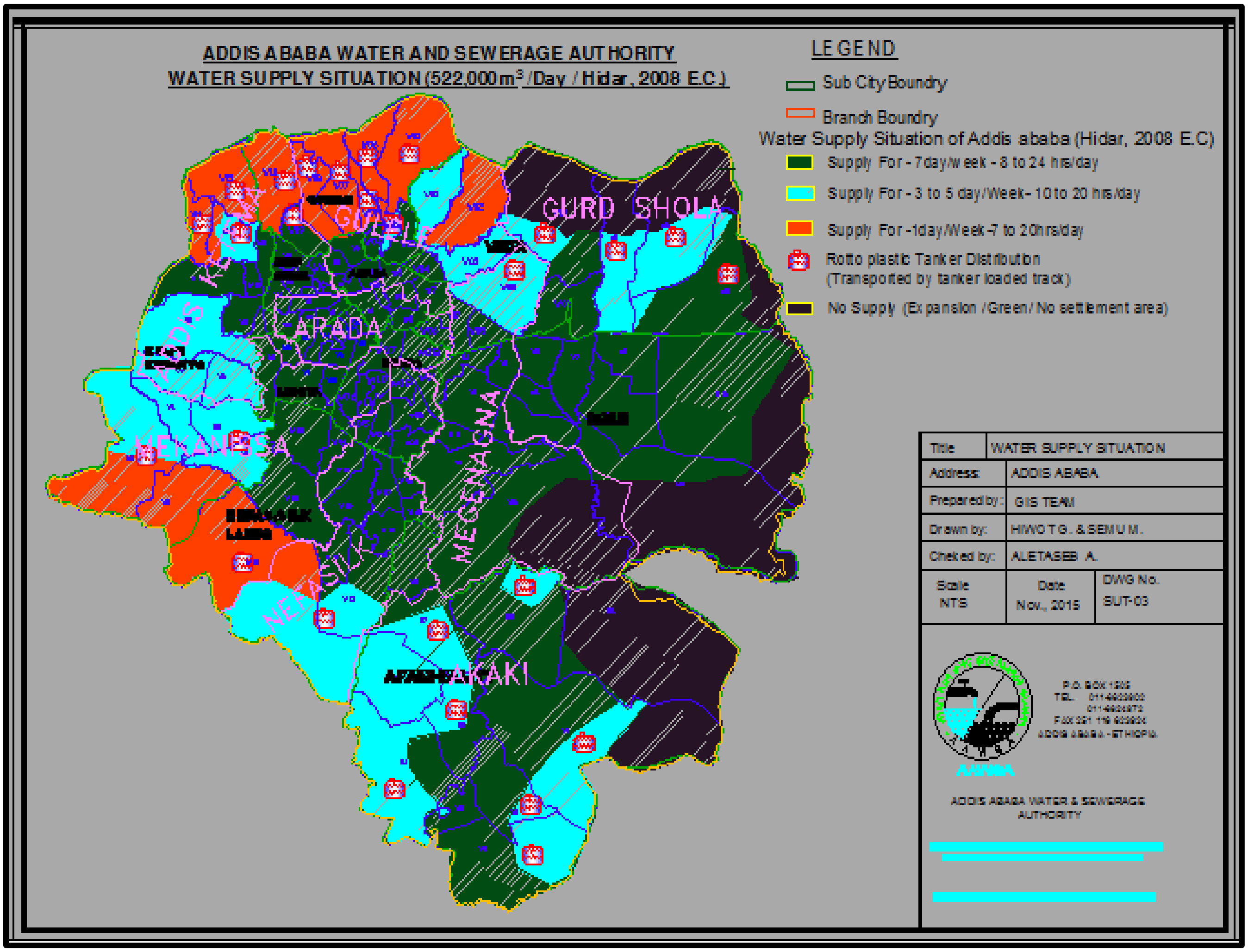
Schools' existing status in the provision of water, sanitation and latrine services against students and the staff (Teachers and Supporting staff) are shown as follows.

Table 4.6. School Water Sanitation and Hygiene (Source: Yeka sub - city Atlas map).

Sub city	**Number of schools**	**School with water supply**	**Ratio per water tap**			**Number of School toilet**
			Student	**Teachers and admin.stff**	**Total**	
Addis ketema	91	91	1:48	1:35	1:36	91
Akaki-kality	185	170	1:66	1:53	1:43	183

Arada	100	100	1:72	1:32	1:42	100
Bole	251	221	1:60	1:26	1:34	247
Gullele	127	126	1:65	1:38	1:39	124
Kirkos	107	107	1:53	1:29	1:44	107
Kolfe	299	299	1:72	1:25	1:51	296
Lideta	74	74	1:81	1:45	1:43	74
Nifasilk	314	309	1:60	1:26	1:39	308
Yeka	289	281	1:64	1:27	1:37	289
Total	**1,837**	**1,778**	**1:64**	**1:34**	**1:43**	**1,819**

- Water supply: Schools that have water supply is 96.79% (1,778). Thirty schools in Bole, fifteen Schools from Akaki-Kality, eight schools from Yeka, five Schools from Nifas Silk Lafeto and one school from Gullele sub cities do not have water supply. The existence of water supply system alone may not ensure that water is consistently available in schools.
- The water tap – student ratio: all sub cities do not meet the standard (1 tap for 20 students) set by the Bureau. The water tap – student ratio is 1:70 goes two or three fold against the standard. This needs special attention of the school management. All sub cities have better water tap – teacher ratio in relative terms.
- Toilet: The number of schools that have toilet is 98.9 % (1,819). The rest (1.1%) schools do not have a toilet. This problem is observed in Akaki-kality 2 schools, Nifas silk Lafeto 6 schools, Gullele 2 schools, Bole 4 schools and Kolfe 3 School.



Map 4.5. Water Supply Situations in Addis Ababa (Source: AAWSA).

4.6 Response Rate

To conduct the research on Water Sensitive Urban Design (WSUD) intervention for the alleviation of water scarcity in the government schools of Addis Ababa in Yeka sub city; the primary data was collected from the sample using different data collection tools. The respondent's profile is significant to realize the reliability of the collected data. Hence, before reporting findings from data analysis the response rate is explained in the following table.

Table 4.7. Response Rate (Source: Personal field survey, 2016).

No	Primary data collection tools	Response Rate			Personal Profile				Remark
					Sex		Education		
		Planned	Attained	%	M	F	Diploma and below	Degree and above	
1.	Questionnaire for students	132	132	100	58	74	---	---	All are students
2.	Interview for teachers and school administrators	12	12	100	5	7	10	2	
3.	Interview for higher officials	6	6	100	5	1	---	6	
	Total	**150**	**150**	**100**	**68**	**82**	**10**	**8**	

In the table 4.7, the respondent rates on questionnaire were 132 among which 58 of them were male and 74 of them are female students. In the same way the respondent rate on interview were 12 in which 7 of them were female and 5 of them are male teachers as well as school administrators and higher officials are 6 out of this 5 are males and 1 is female. From the total respondent rate 54.67% and 45.33% were female and male respectively. Regarding education level 44.45% were first degree and above.

Table 4.8.Primary Water Sources of the School (Source: Personal field survey, 2016).

No	Water sources	Frequency				%				Average %	Remark
		Grade level									
		5	6	7	8	5	6	7	8		
1.	Piped municipal water supply	24	28	34	36	92.3	96.5	91.9	90	92.0	
2.	Rainwater harvesting	1	N/A	1	N/A	3.85	--	2.7	--	3.28	
3.	Pump										
4.	River or lake										
5.	Bore well										
6.	Spring										
7.	Others	1	1	2	4	3.85	3.5	5.4	10	5.50	
	Total	**26**	**29**	**37**	**40**	**100**	**100**	**100**	**100**	**100**	

Photo 4.1 Only One Functional Tap Piped Municipal Water Supply
(Source: Personal field survey, 2016)

The results presented in the table 4.8 above show that 122 out of 132 (92.0%) respond that the main source of water are piped municipal source water, only 2 out of 132 (3.28%) are the source of water from rainwater harvesting system. This result implies that the source of water in the school compound is almost all piped municipal water supply system. This piped municipal water supply is served as for drinking purpose, washing, gardening, and cleaning rooms.

As mentioned above the school compound use only one functional tap.

The diameter of the water tap is 1.28cm.

To find the charge of water by the only functional tap could be calculated as

1 inch = 25.4mm

1cm = 0.39 inches = 0.013m

Area of the 1.28cm pipe

$A= \pi r^2 = \pi (d/2)^2 = \pi (0.013/2)^2 = 0.000133m^2$

$\mathbf{A = 0.000133m^2}$

Charged of Water through the pipe

$Q = A * V = 0.000133m^2 * 1m/s$

$\mathbf{Q = 0.000133m^3/s}$

$1m^3 = 1000$liters

Q = 0.133 liters/sec

Q = 119.7 liters/sec ≈ **120 liters of water per 15 min.**

From the above argument the water supplied by municipal water pipe of the school compound within 15 minutes of time was 120 liters only for 2,142 users such as students, teachers and administration staff for drinking, cleaning rooms, gardening and washing purposes; however, the demand of water for drinking purpose only within 15 minutes was 11,440 liters for 2,142 users of the school compound. This shows that there is a big gap between the demand and supply of water in the school compound.

Table 4.9.The Main Purposes of Water in School (Source: Personal field survey, 2016).

No	Main uses of water	Frequency Grade level				%				Total %	Remark
		5	6	7	8	5	6	7	8		
1.	For flushing toilets	N/A	1	2	N/A	---	3.45	4.40	---	3.40	
2.	For washing hands	6	4	11	8	23.01	13.80	29.73	20	21.60	
3.	For drinking	18	22	19	30	69.23	74.86	51.35	75	66.86	
4.	Gardening purpose	2	1	4	2	7.69	3.45	9.81	5	5.40	
5.	Others	N/A	1	1	N/A	---	3.45	2.70	---	3.10	
Total		**26**	**29**	**37**	**40**	**100**	**100**	**100**	**100**	**100**	

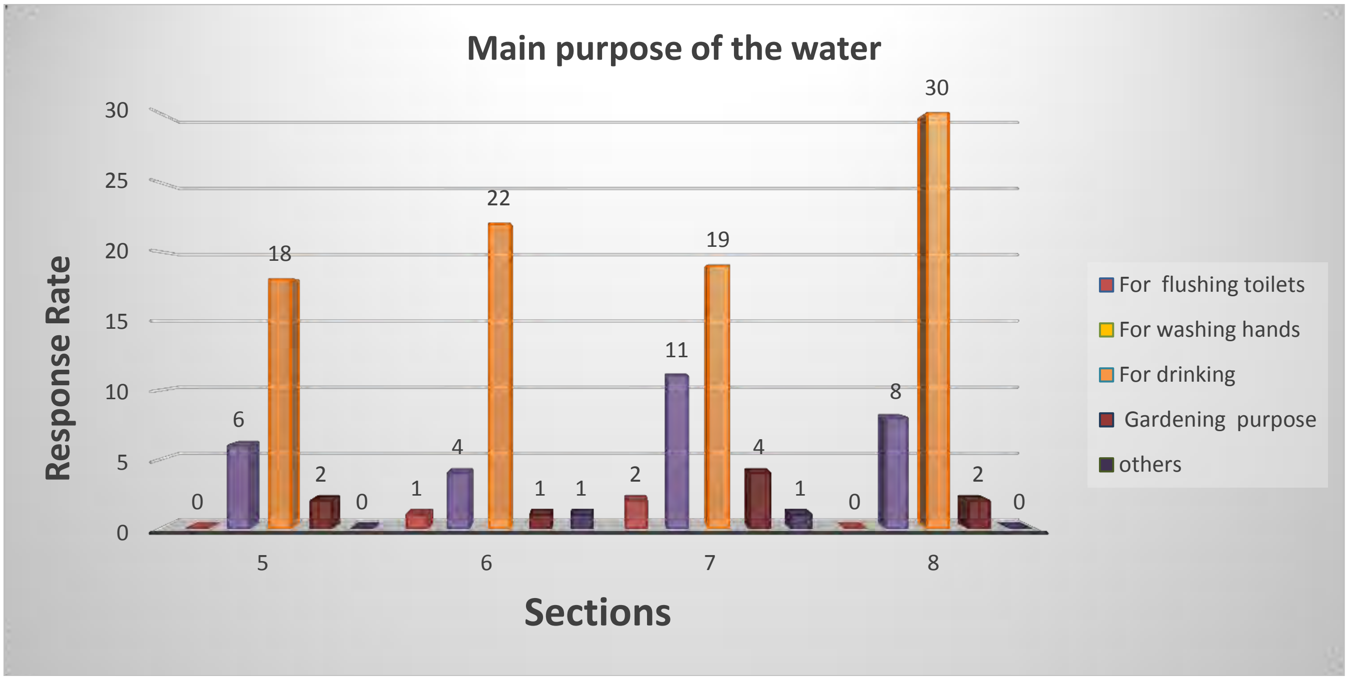


Chart 4.2 The Main Purposes of Water in School (Source: Personal Field survey, 2016).

Photo 4.2 Water for Gardening Purpose (Source: - personal Field survey, 2016).

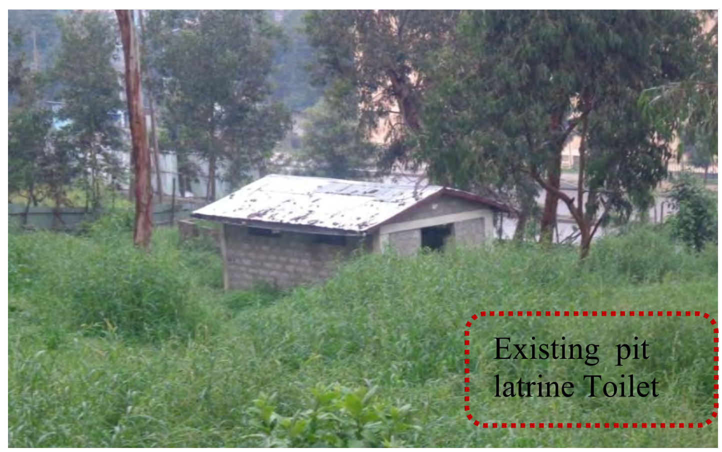


Photo 4.3 Water for Cleaning and Washing the Toilet after use (Source: personal Field survey, 2016).

Table 4.9 reveals that 29 out of 132 (21.60%) responds that the main purpose of the water for washing hands, 79 out of 132 (66.86%) is for drinking purpose, 9 out of 132 (5.4%) and 2 out of 132 (3.10%) is for gardening purpose and other activities respectively. This reveals that the greater part of the delivered water in the school compound is used for drinking purpose and washing hands.

Table 4.10.Key Climate and Environment Challenges (Source: Personal Field survey, 2016).

No	Key climate and environment challenges	Frequency Grade level				%				Total %	Remark
		5	6	7	8	5	6	7	8		
1.	Drought	2	5	4	1	7.69	17.24	10.8	5	10.2	
2.	Flooding	7	8	11	21	25.92	27.58	29.73	50	32.5	
3.	Pollution	17	14	20	16	64.38	48.28	54	40	51	
4.	Sewage facilities	N/A	N/A	1	1	---	----	2.70	2.5	2.6	
5.	Others	N/A	2	1	1	---	6.90	2.70	2.5	4	
Total		**26**	**29**	**37**	**40**	**100**	**100**	**100**	**100**	**100**	

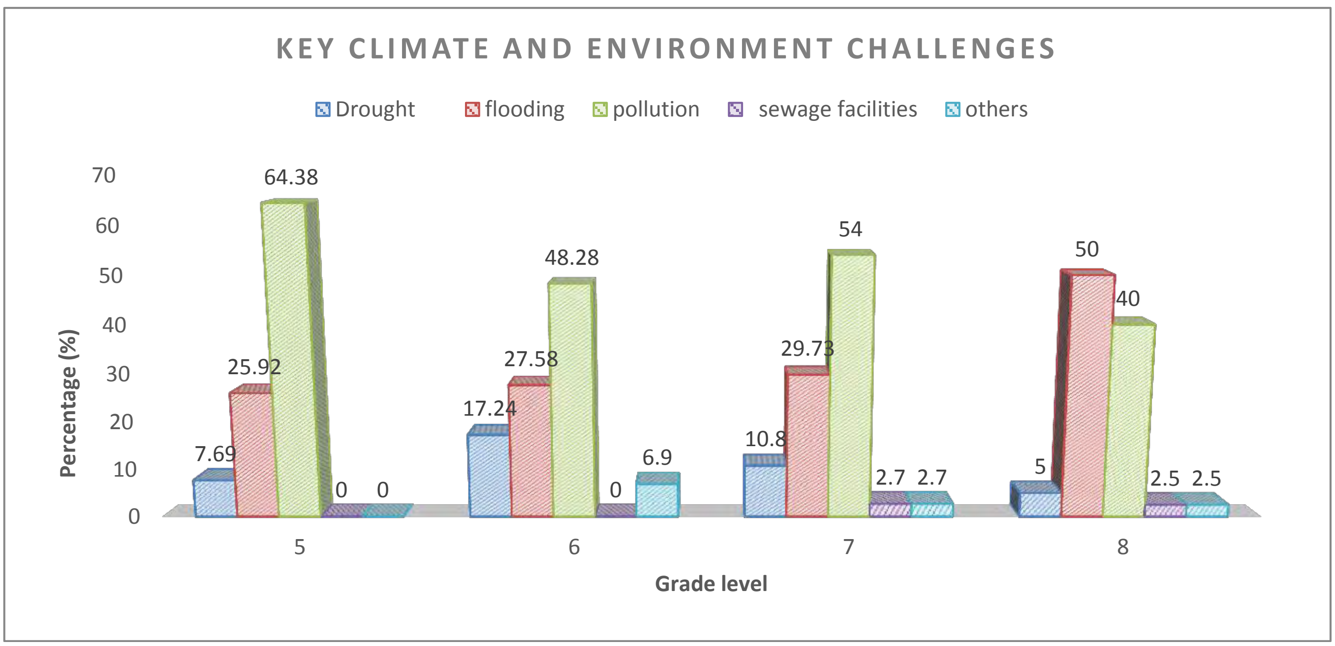
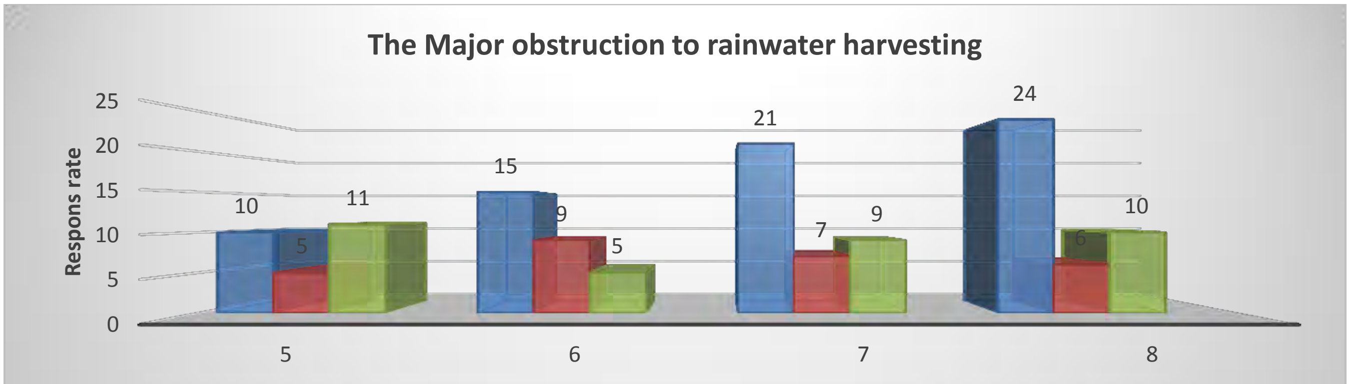


Chart 4.3 The Major Obstruction to Rainwater Harvesting (Source: Personal field survey, 2016).

According to the result from table 4.10 most of the respondents opinion that accounts 32.5% suggested, the key climatic challenges of the school area is flooding this is due to topography and its catchment area. It is also contributed the runoff to the study area and poor stormwater management system within the school jurisdiction. 10.2% and 51% were accounts by drought and pollution respectively. It is one of the characteristics of Addis Ababa due to poor solid and liquid waste management system. The pollution is the result of negligence to the environment and to minimize the cost of waste water treatment. Some of the waste water is from kitchen and septic tanks wastes. In addition, storm water is one of the main sources of waste water that washed different wastes and conveying them in to the area. It contributed significant roles in contaminating the surface as well as underground water hence the major key climatic and environmental challenges are pollution and flooding.

Table 4.11. The Major Obstruction to Rainwater Harvesting in the School Compound (Source: Personal Field survey, 2016).

No	Major obstruction to rainwater harvesting	Frequency Grade level				%				Total %	Remark
		5	6	7	8	5	6	7	8		
1.	Lack of knowledge	10	15	21	24	38.5	51.7	56.8	60	51.75	
2.	Lack of attention	5	9	7	6	19.3	31	19	15	21	
3.	Lack of responsibilities	11	5	9	10	42.31	17.3	24	25	27.15	
4.	Others	N/A	N/A	N/A	N/A	--	--	--	--	--	
Total		**26**	**29**	**37**	**40**	**100**	**100**	**100**	**100**	**100**	



	5	6	7	8
Lack of knowledge	10	15	21	24
lack of attention	5	9	7	6
lack of responsibilities	11	5	9	10
others				

Chart 4.4 The Major Obstruction to Rainwater Harvesting (Source: Personal Field survey, 2016).

According to the above table 4.10, about 51.75% of the respondent's responded that the major impediment to harvesting rainwater with in the school compound is lack of knowledge how to harvest rainwater and lack of awareness for the importance of rainwater. In addition, 21% and 27.15% of the respondents reported that the main impediment of harvesting rainwater is lack of attention and lack of responsibilities respectively.

4.7 Time of Water Shortage at School (Season) and its Impact

The numbers of available fresh potable water sources for drinking purpose is still low in this area and especially during dry seasons, availability of fresh water becomes a serious problem.

From September to February is the long dry season known as the bega; this is followed by a short rainy season, the belg, in March and April. May is a hot and dry month proceeding the long rainy season (kremt) in June, July, and August. The coldest temperatures generally occur in December or January (bega) and the hottest in March, April, or May (belg). However, in many localities July has the coldest temperatures because of the moderating influence of rainfall.

In all the four seasons of the year water is not accessible. More than ever in the winter and spring season the severity of water scarcity is very high. In the absence of water supply, sanitation and hygiene services in schools, water born disease can easily breakout and rapidly transmitted by any route which permits faucal material to pass into the mouth, and there is a vital linkage and intimate relationship between health and personal hygiene, which depend largely on the availability of sufficient water and sanitary facilities.

4.8 Characteristics of Respondents

A total of 12 sample teachers and staff members were interviewed in the survey. From the total sample respondents, 9 (75%) are teachers, of which 3 are male and 6 are female. The rest 4 (25%) of the respondents are staff members. Out of these, 1 is male and 3 are female. 6 samples are higher officials, of which 5are males and 1 is female. The education levels of the respondents range from a minimum of diploma holder to a maximum of completed first degree level. From the total respondents 10 (55.6%) are diploma holders and the rest 8 (44.5%) have completed higher education.

4.9 The Main Source of Water Supply in Addis Ababa

Considering the water supply system in Addis Ababa are Legedadi, Gefersa, Dire dam and Ground water supplies. These sources are classified into surface and Ground water supplies:-

Surface water supplies

- Legadadi
- Gefarsa, and
- Dire dam

Ground water supplies

- Akaki well field number-1
- Akaki Well field number-2

4.11 Existing Water Supply

4.11.1 The Uses of Water in the School Compound

Water is a fixed resource. At any time in history, the planet contains about 332 million cubic miles. Most is salty. Only 2 percent is fresh water and two-thirds of that is unavailable for human use, locked in snow, ice, and permafrost. We are using the same water that the dinosaurs drank, and this same water has to make ice creams in Pasadena and the morning frost in Paris. It is limited, and it is being wasted. . . . But usage is only part of the problem. We are wasting our water mostly by putting waste into it. (Rose George, 2008)

All the respondents use the existing water supply for drinking and washing purposes. In addition to using for these purposes, 34.43% of the total respondents use water supply for gardening. The percentage of use for drinking purpose is 45% and washing purpose is 65%. Hence this implies that according to the quantitative research report through questionnaire the only water sources of the school is piped municipal supply. All those activities such as drinking, washing and gardening are used from this source.

Table 4.12. Water Risk for Flooding or Drought and Water Guidelines, Clear Goals in Schools (Source: Personal field survey, 2016).

No	**Interviewed Questions**	**Interviewed Response Rate**		**Total**	**Remark**
		Yes	**No**		
1.	Is your organization exposed to water risk for Flooding or drought?	13	5	18	Both teachers, administrators and higher officials
2.	Does your organization have a water guidelines and clear goals for action?	1	17	18	

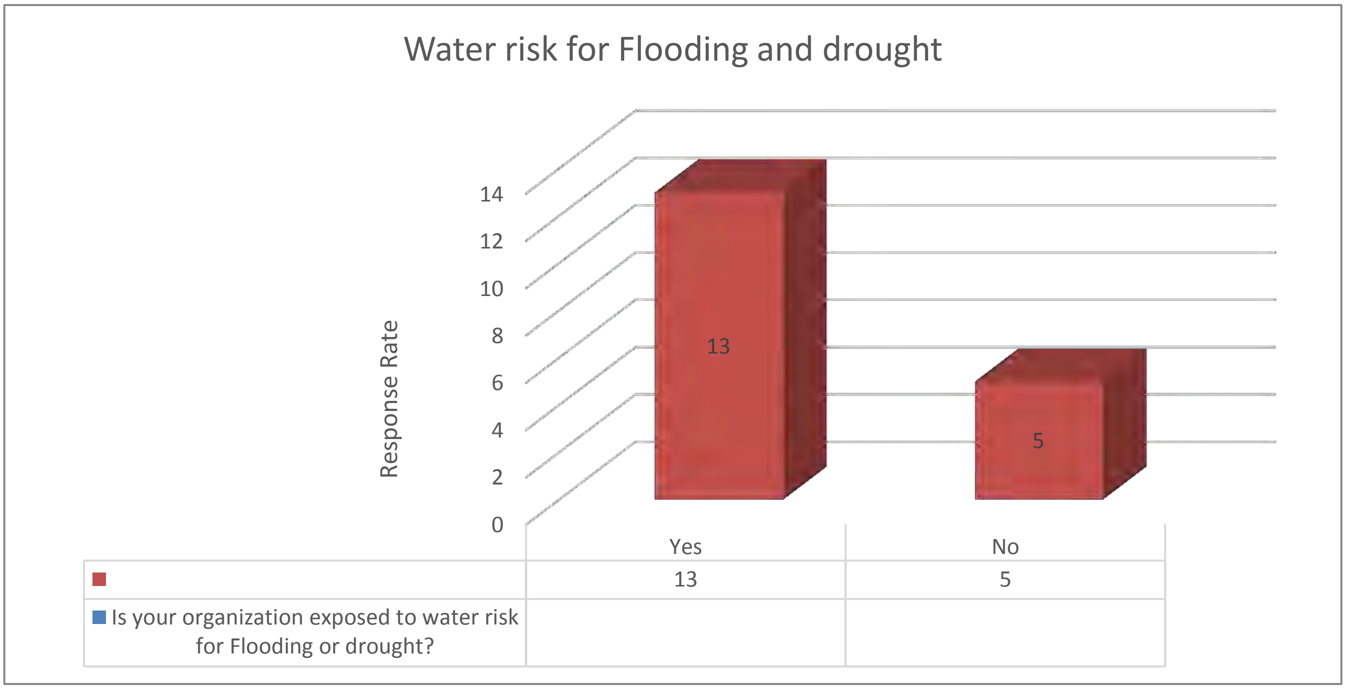


Chart 4.5 Organization Exposed to Water Risk for Flooding and Drought (Source: Personal Field Survey, 2016)

The sources of water which produce floods include: saturated groundwater (water flowing on the ground in an unsaturated state). Surface water, artificial water (burst water mains, canals or reservoirs) rivers, streams or watercourses, sewers and drains for each of the sources of water, different hydraulic intensities occur. Floods can occur because of a combination of sources of flooding, such as high groundwater and an inadequate surface water drainage system.

The school suffers from a severe water crisis due to droughts and floods. Another main reason for why droughts have prolonged is due to deforestation. The problem with deforestation is that it almost always leads to increased runoff, which has negative implications in both the rainy as well as the subsequent dry season. The number and severity of droughts and floods is due to the ongoing climate change likely to increase in the foreseeable future. Global warming is another critical factor that has prolonged the droughts and floods.

From the total sample of 18, only 5 (27.77%) are not exposed to water risk for flooding or drought and 13 (72.22%) of the responses are exposed to water risk for flooding or drought and all the responses 95% of the responses have not a water guidelines or clear goals. The reasons why they are not water guidelines in the school is lack of awareness about the importance of water.

4.11.2 Potentials for Water in the School Compound other than the Existing Municipal Sources and the Strategies to utilize them.

As is known from the previous questionnaire responses, the only water source is from the piped municipal water supply. This source of water is not functioning properly, because of the water shortage problem which means the time of water availability is unpredictable. The water resources or potentials in school compound are characterized by the existence of rivers, streams, and ground water sources. The most important water resource is however rainfall. It is the best potential from the other resources because we use the existing roof area that offers excellent catchment avenue for rainwater harvesting.

4.11.3 The Main Factors that Cause Water Scarcity in the School as well as in the Sub city

We need water to live. When there is a water shortage, there is a serious problem. This problem is now facing many schools in our country. The main reason for water shortage is the growing population, particularly in the sub city and in general in Addis, climate change, chronic water waste (poor water management). This means there are more demands on the water supply. Due to migration from rural to urban areas, there has been increased pressure on the urban water supply.

An additional problem is water pollution and improper solid as well as liquid waste management system contributes its own key contribution. Another reason for water shortage is that as countries become life style of people changed use more and more water in their homes. For instance, people like to bath or shower every day.

Generally, the interview identified population growth, poor infrastructure and economic challenges as the major challenges affecting efficient water delivery in the school as well as in the sub city; however, the study carried out that lack of adequate sanitation and pollution were among major factors contributing to water scarcity in school. Moreover, these results indicate that climate change is a long-term threat to efficient water provision for the present and future generations which was in line with the findings of the study. The changing climate is exacerbating water management problems in schools as well as in city through its impact on variable rainfall and extreme events like drought.

4.11.4 The Possible Solutions to Minimize the Problem of Water Scarcity and Flooding

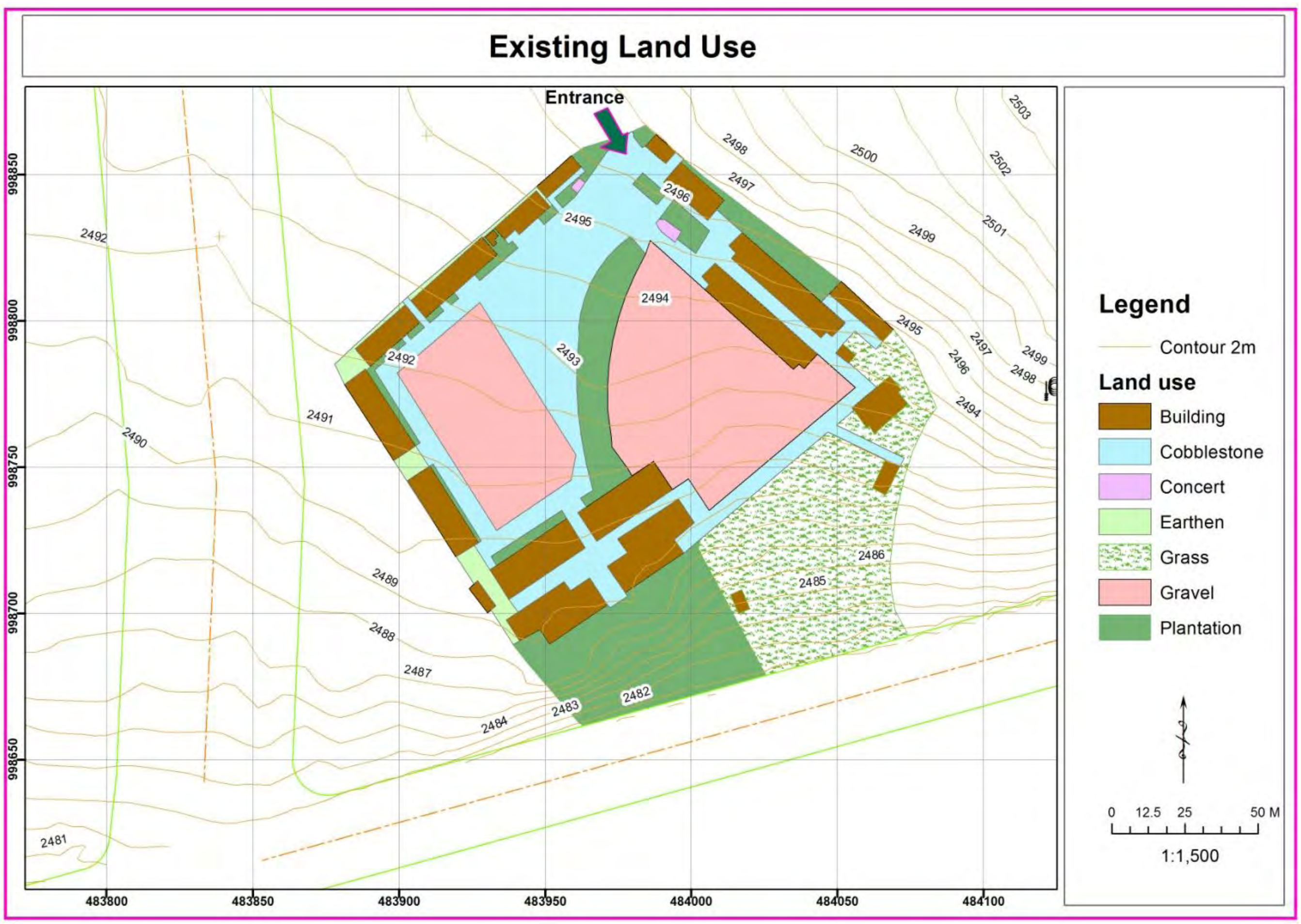
Assess potential water sources to undertake the scarcity of water to sustain the future provision of water. Some of the main potential sources are rainwater harvesting, increase the level of ground water and also conserve excess flow water by Best Management Practices (BMPs) such as rain garden, bio-retention system, sedimentation, swales and ponds.

Another possibility is to educate people so they do not waste water. Another solution is to protect existing water supplies like underground supplies and take steps to prevent them becoming polluted. Also, recycled water could be used for other purposes.

The school with the help of the government should aim to identify and develop more water sources potentials.

4.12 Existing Situation of the Case School Compound

4.12.1 Existing Land use



Map 4.6 Existing Land use (Source: Personal GIS analysis, 2016).

Table 4.13. Land use Coverage with Area in Square Meter of School Compound (Source: Personal summarized from GIS analysis, 2016).

S/N	Land use	coefficient	Permeability	Area in Sq.m	%
1	Building	0.75-0.95	impervious	4378.14	16.49
2	Gravel	0.2-0.35	Semi-impervious	6473.87	24.39
3	Vegetation	0.1-0.25	pervious	4860.37	18.31
4	Grass land	0.1-0.25	pervious	4487.01	16.90
5	Cobble Stone	0.5-0.6	Semi-impervious	5849.39	22.03
6	Concrete	0.8-0.95	impervious	46.56	0.18
7	Earthen	0.1-0.3	pervious	453.18	1.71
Total				26548.52	100.00

An advantage here is the low percentage of impervious surfaces.

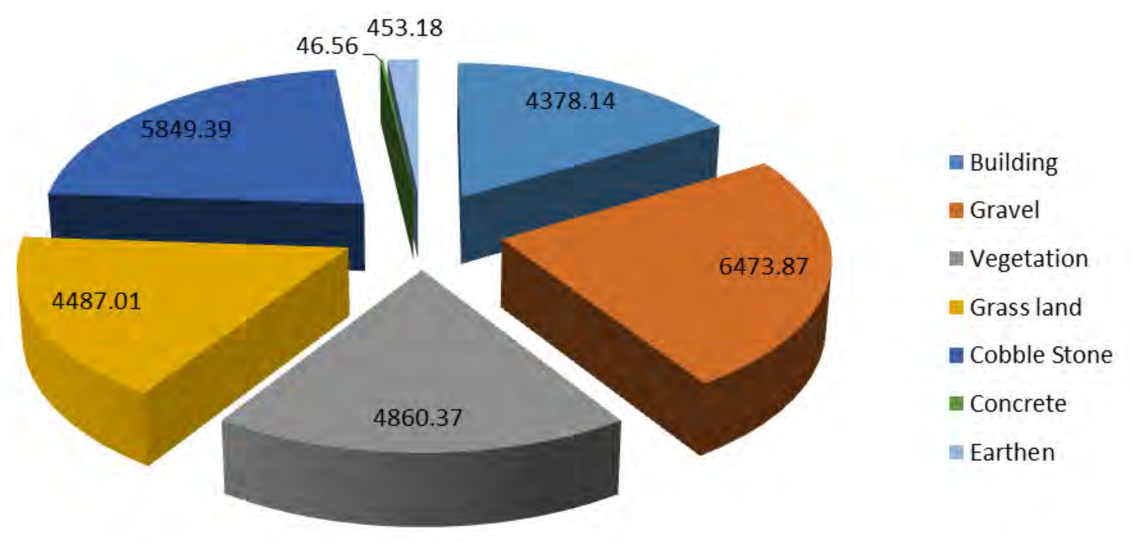
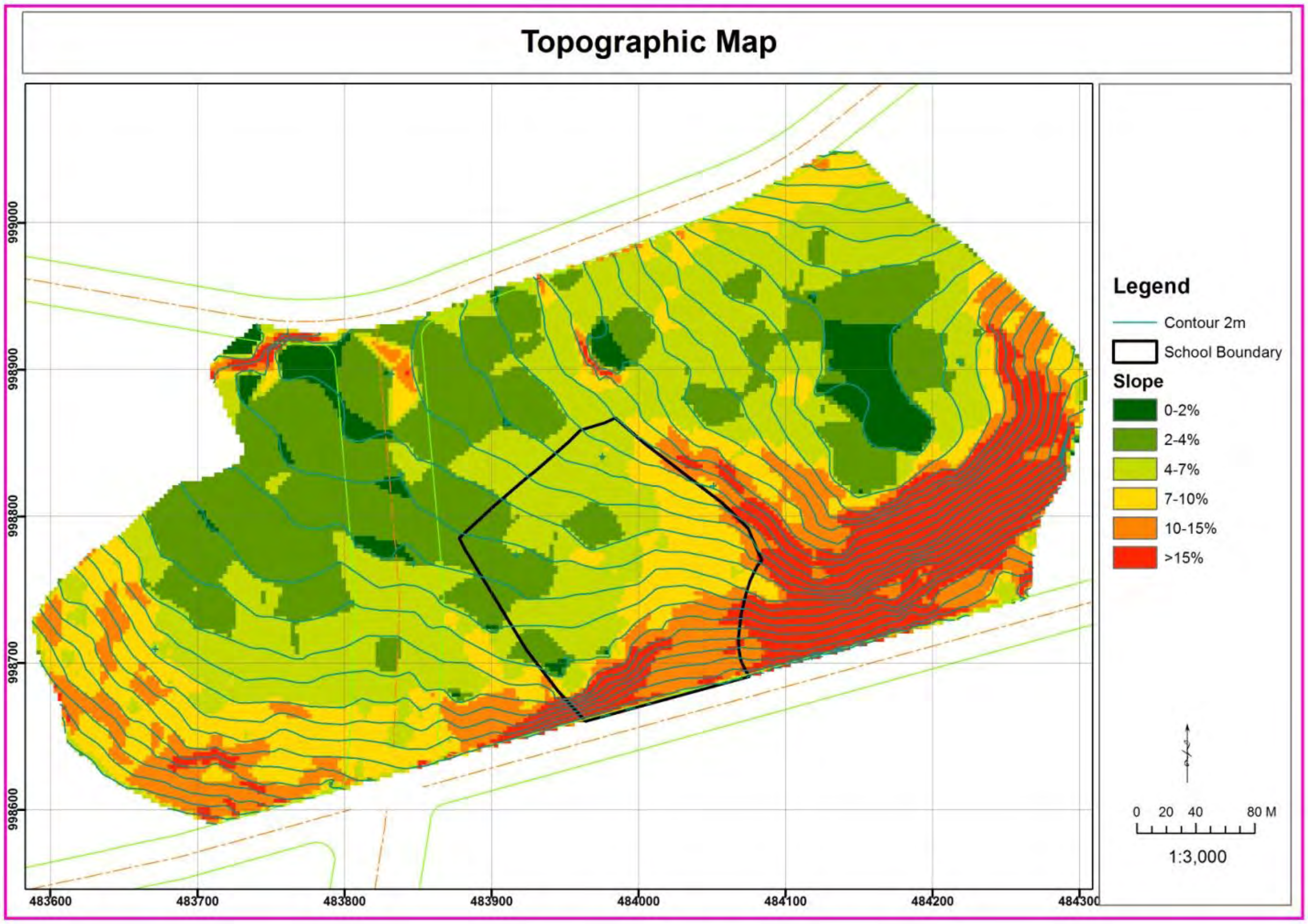


Chart 4.6 Area Coverage of the School Compound (Source: Personal summarized from GIS analysis, 2016).

According to the table 4.13 and Pie chart 4.6, it is revealed that about 4,378.14m^2 of the area covers different buildings, 6,473.87m^2 covers gravel, 453.18m^2 is earthen, concrete coverage is 46.56m^2, cobblestone 5,849.39m^2, grass land and vegetation covers are 4,487.01m^2 and 4,860.37m^2,respectively. Semi-impervious area covers about 12,323.26 square meters, impervious area covers 4,424.70 Square meters and pervious area also covers 9,800.56 square meters. This shows that the area suitable for storm water management and rainwater harvesting system which reduces or eliminates the negative impacts of storm water runoff, controlling flooding, reducing erosion and improving water quality. This can be accomplished by implementing what are known as Best Management Practices (BMPs) like bio-swales, rain garden and bio-retentions. BMPs are structural, vegetative or managerial practices used to treat, prevent or reduce water pollution.

4.12.2 Existing Situation Topography

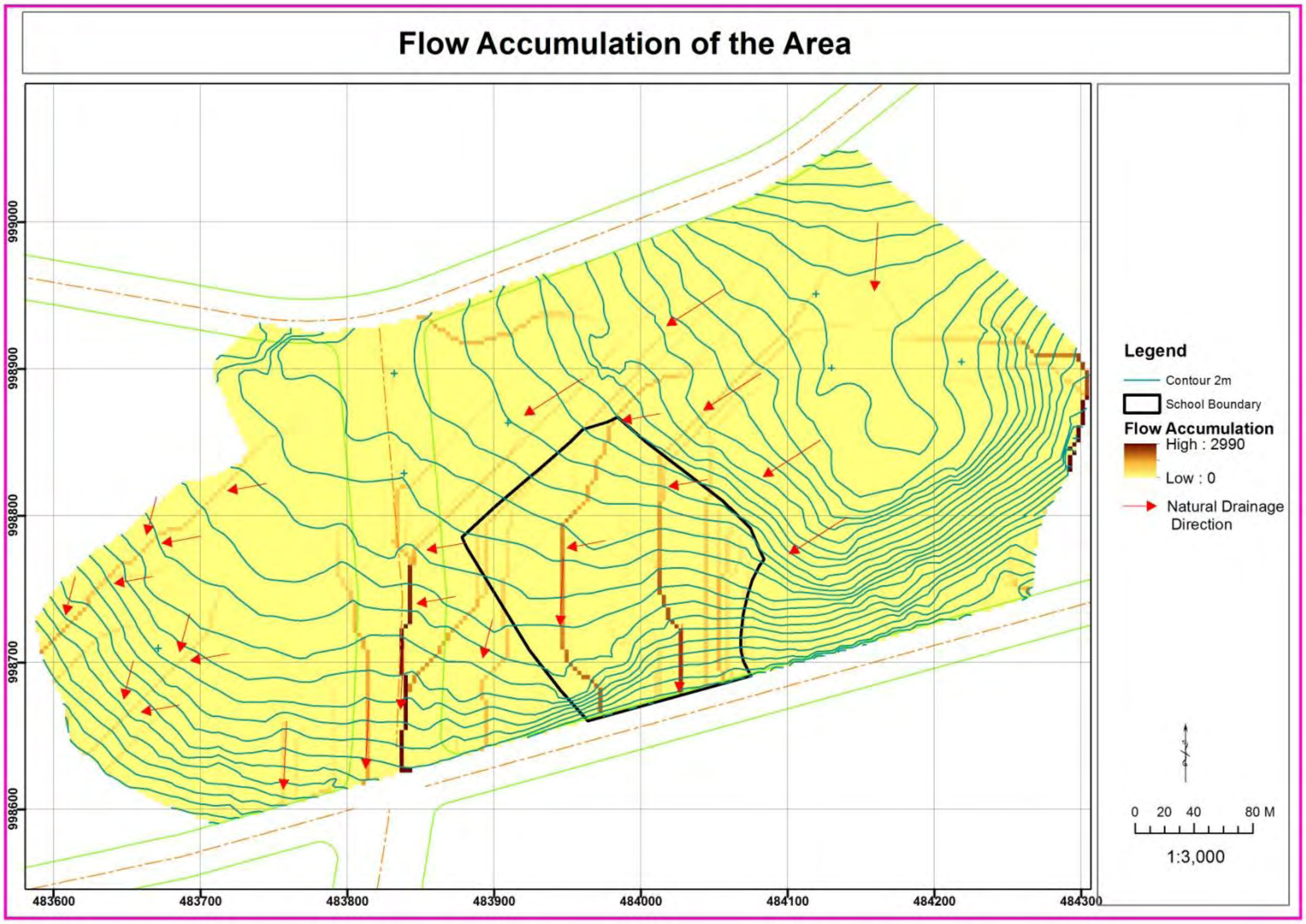


Map 4.7 Topography Map of Study Area (Source: Personal GIS analysis, 2016).

- Majority of the slope coverage is 0 – 10%; however, in the southern part the slope coverage is > 10% this increases storm water runoff from Northern to Southern part. hence this affects the project area.

- Due to the site topography, significant elevation difference is found within the school compound hence the elevation difference may play a role in the magnitude of very high rate of flooding.

4.12.3 Existing Situation of Flow Accumulation

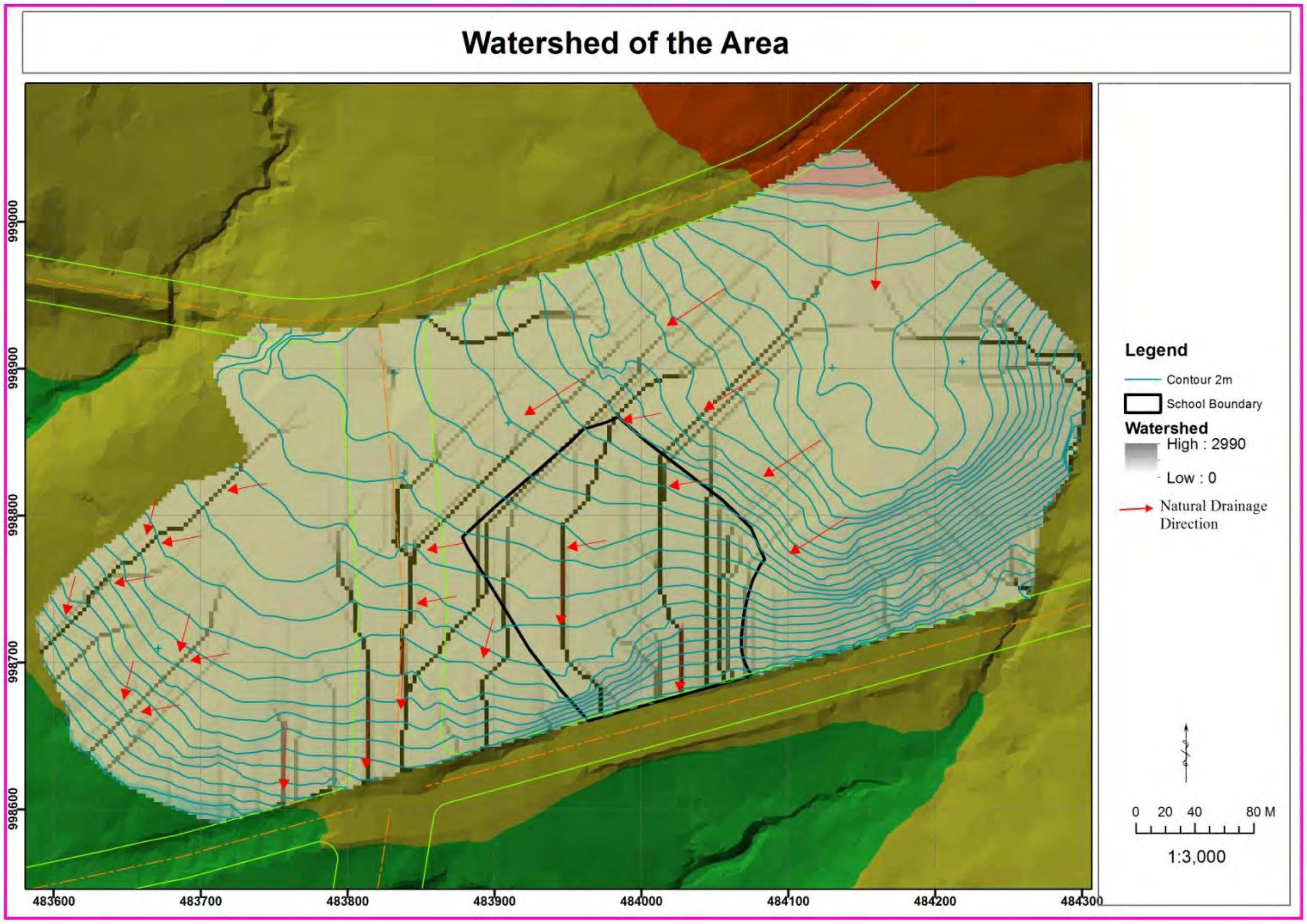


Map 4.8 Flow Accumulation Map of the Study Area (Source: Personal GIS analysis, 2016).

Flow accumulation: is the most important parameter in defining flood hazard. The accumulated flow sums the water flowing down-slope into the cells of the output raster. The high values of the accumulated flow indicate the areas of concentrated flow and consequently, the higher flood hazard.

- Flow accumulation is one factor for the water sensitive urban design
- It indicates the intervention areas of the Water Sensitive Urban Design (WSUD).
- As can be seen in the diagram above, stormwater is not accumulated in this project area due to its steep slope. There for it needs Water Sensitive Urban Design intervention within the area of the school.

4.12.4 Existing Situation of Watershed Area



Map 4.10 Watershed Map of the Study Area (Source: Personal GIS analysis, 2016).

A watershed is defined as any surface area from which runoff resulting from rainfall is collected and drained through a common confluence point. The term is synonymous with a drainage basin or catchment area.

The above figure shows that rainwater collected and drained through within the study area hence it needs watershed management to reduced run off, and increased vegetation cover, increased recharge of groundwater table. These imply that watershed management contributes for increasing the availability of water in school.

4.13 Runoff Calculation Based on Existing Land use

Map 4.9 Existing Land use (Source: Personal GIS analysis, 2016).

Runoff Calculation in the case Kara- Alo primary school compound

Impervious Surfaces

Runoff Volume for Roofs = Total area of the roof *annual rainfall* runoff Coefficient

= 4378.14 * 931 * 0.85

= **3,464,641.10 Liters/average year**

Runoff Volume for Concrete = Total area of the Concrete *annual rainfall* runoff Coefficient

= 46.56 * 931 * 0.85

= **36,845.26 Liters/average year**

Photo 4.4 G+4 School Building

Photo 4.5 G+1 Administration Office

Pervious Surfaces

Runoff Volume for grass = Total area of the grass *annual rainfall * runoff Coefficient

= 4487.01 * 931 * 0.175

= **731,046.11 Liters/average year**

Runoff Volume for Vegetation= Total area of the Vegetation *annual rainfall* runoff Coefficient

= 4860.37 * 931 * 0.25

= **1,131,251.12 Liters/average year**

Photo 4.6 School Compound Vegetation

Photo4.7 School Compound Grass

Semi-impervious Surfaces

Runoff Volume for gravel = Total area of the gravel *annual rainfall * runoff Coefficient

= 6473.87 * 931 * 0.25

= **1,506,793.25 Liters/average year**

Runoff Volume for Earth = Total area of the Earthen *annual rainfall* runoff Coefficient

= 453.18 * 931 * 0.30

= **126,573.18 Liters/average year**

Runoff Volume for Cobblestone = Total area of the Cobblestone *annual rainfall* runoff Coefficient

= 5849.39 * 931 * 0.60

= **3,267,469.26 Liters/average year**

Photo 4.8 Gravel Surface

Photo 4.9 Cobblestone Surface

Total runoff of the school compound =Impervious + pervious+ Semi-impervious Surfaces

= 3,501,486.36 L/av. yr +1,862,297.23 L/av. yr +4,900,835.69 L/av. yr

= 10,264,619.28 Liters/average year

Table 4.14 Runoff Calculation in Different Month of the Year (Source: Personal calculated, 2016).

Months	Runoff calculation in different months of the year							
	Roofs	**Concrete**	**Grass**	**Vegetation**	**Gravel**	**Earth**	**Cobblestones**	**Average**
September	35,353	376	7,459	11,543	15,375	1,291	33,341	**104,738**
October	141,414	1,504	29,838	46,173	61,502	5,166	133,366	**418,963**
November	219,563	2,335	46,328	71,691	95,489	8,021	207,068	**650,495**
December	331,206	3,522	69,885	108,143	144,043	12,100	312,357	**981,256**
January	264,220	2,810	55,751	86,271	114,911	9,652	249,184	**782,799**
February	401,913	4,274	84,804	131,230	174,794	14,683	379,040	**1,190,738**
March	721,955	7,678	152,334	235,728	313,982	26,375	680,869	**2,138,921**
April	807,522	8,588	170,394	263,655	351,207	27,490	661,539	**2,290,395**
May	323,763	3,274	84,804	105,713	140,806	11,828	379,015	**1,049,203**
June	145,135	1,544	3,324	47,389	63,120	5,302	136,876	**402,690**
July	50,239	534	10,600	16,404	21,849	1,835	47,380	**148,841**
August	44,657	475	9,423	14,581	19,422	1,632	42,116	**132,306**
Total	**3,486,940**	**36,914**	**724,944**	**1,138,521**	**1,516,500**	**125,375**	**3,262,151**	**10,291,345**
	10,291,345							

<u>Implication</u>

The existing school compound is covered with cobblestone, gravel, grass and bare ground. The School compound approximately 66% covered by previous and impervious surfaces, which is more than half percent, is covered with those surfaces. Therefore, it has its own contribution in reducing runoff.

CHAPTER FIVE

5 Water Harvesting and Utilization Proposal for Kar-Alo Primary School

This chapter looks in to the proposed design of the Kara - Alo Primary school and its proposed water sensitive urban design using bio-retention system. A bio-retention basin is a landscaped depression or shallow basins used to slow and treat- on site storm water runoff. Stormwater and rainwater and are directed to the basin and then percolates through the system where it is treated by a number of physical as well as biological processes. The slowed, filtered water is directed to the receiving water tank.

Table 5.1 Peak Water Demand for An Average School Population (Source: Revision and upgrading of the 2010 school WASH manual).

Type of water use	Peak water demand (m3/day) for an average school population of							
	600	800	1000	1500	2000	2500	3000	Remark
Drinking	0.6	0.80	1.00	1.50	2.00	2.50	3.00	
Hand washing	0.3	0.40	0.50	0.75	1.00	1.50	2.00	
Cleaning and washing sanitary facilities	0.3	0.40	0.50	0.75	1.00	1.50	2.00	
Cleaning class rooms and administration offices	0.10	0.10	0.10	0.10	0.10	0.10	0.10	
Gardening	1.50	1.50	2.00	2.50	3.00	3.50	4.00	
Greening the school compound	1.00	1.00	1.50	1.50	2.00	2.00	2.50	
Total volume of water required	**4.00**	**4.20**	**5.60**	**6.10**	**8.10**	**11.10**	**13.60**	

The total amount of water i.e. received in the form of rainfall over an area is called the rainwater endowment of that area. Out of this the amount that can be effectively harvested is called the rainwater harvesting potential.

Rainwater harvesting potential = Rainfall (mm) x collection efficiency

Rainwater endowment of the area = Area plot x height of rainfall

Water harvesting potential = Rainfall (m) x Area of catchment (m^2) x Runoff coefficient

Design for Storage Tanks

The quantity of water stored in a water harvesting system depends on size of the catchment area and the size of the storage tanks. The storage tanks have to be designed according to the water requirements, rain fall and catchment availability.

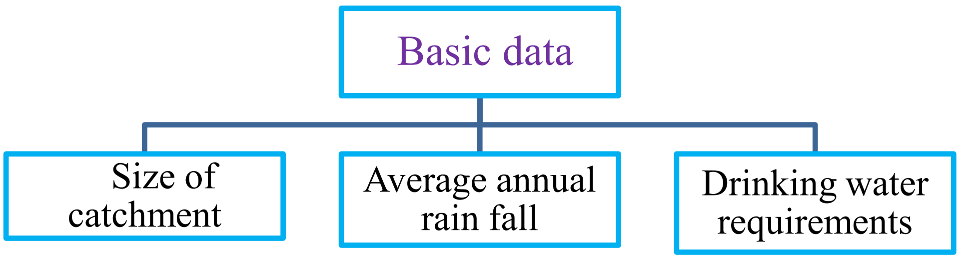


Chart 5.1 Requirements of Basic Data Design for Storage Tank (Lloyd, S., 2002).

Demand Calculation

Amount of Rainfall in Kotebe site = 931mm (0.93 liters)

Total Number of students = 2142 (Calculated by 2500)

Hand Washing

$1.5m^3$/day

Monthly Rainwater demand=1.5 m^3 x 30

= 45 m^3

Yearly Demand = 45 m^3 x 12

= 540 m^3

Cleaning and washing sanitary facilities

$1.5m^3$/day

Monthly Rainwater demand=1.5 m^3 x 30

= 45 m^3

Yearly Demand = 45 m^3 x 12

= 540 m^3

Cleaning class rooms and Administration offices

$0.1m^3$/day

Monthly Rainwater demand=0.1 m^3 x 30

=$3m^3$

Yearly Demand = 3 m^3 x 12

= 36 m^3

Gardening
$3.5m^3$/day
Monthly Rainwater demand=$3.5\ m^3$ x 30
=$105m^3$
Yearly Demand = $105\ m^3$ x 12
= $1,260\ m^3$

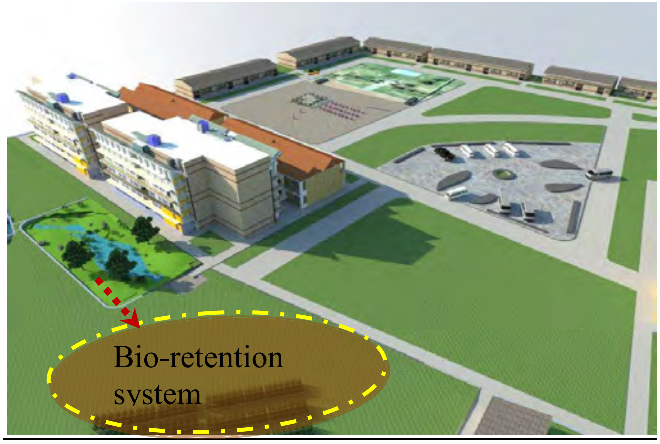
Greening the school compound
$2m^3$/day
Monthly Rainwater demand= $2\ m^3$ x 30
=$60m^3$
Yearly Demand = $60\ m^3$ x 12
= $720\ m^3$

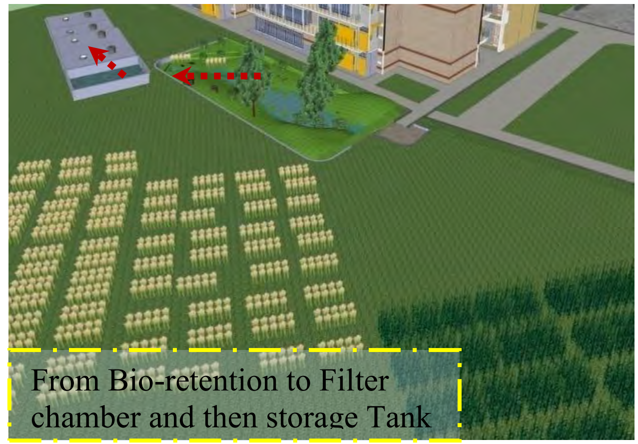
Therefore Total demand of water = $540\ m^3 + 540\ m^3 + 36\ m^3 + 1,260m^3 + 720\ m^3$
= $3,096\ m^3$

Table 5.3 Demand and Supply Calculation

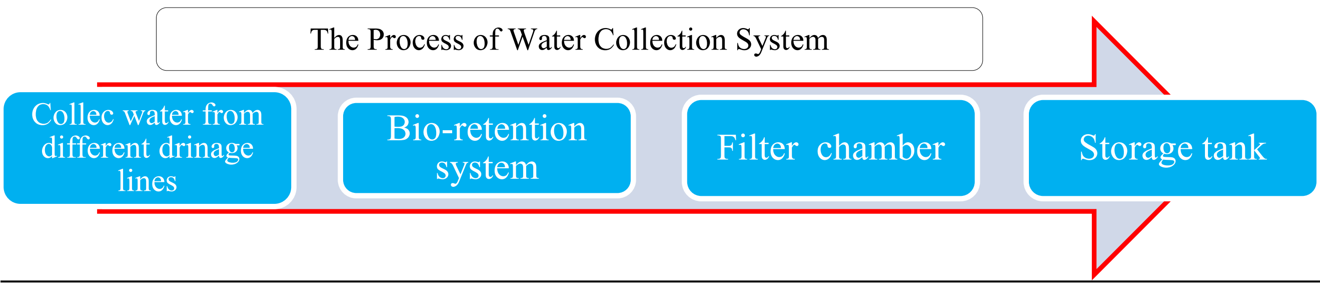
Demand (m^3/year)		Supply (m^3/year)		Surplus Water (m^3/year)	Percentage of Roof and cobblestone supply expressed against its demand
Services	Annual (m^3/year)	Source	Annual (m^3/year)		
✓Hand Washing ✓Cleaning and washing sanitary facilities ✓Cleaning class rooms and administration offices ✓Gardening ✓Greening the school compound	3,096	Rain water harvesting	4040	944	1.3%

From the above table we can see that the Annual rainwater harvesting from impervious as well as semi-impervious surface could be $4,040m^3$/year or 4,040,000liters/year and the price of 1meter cube water those consuming more than 500 meter cube is 11.60 birr (See the price from Annex 4) hence calculated the amount of money saved from this amount of rainwater harvesting system is 46,864 Ethiopian birr per year.

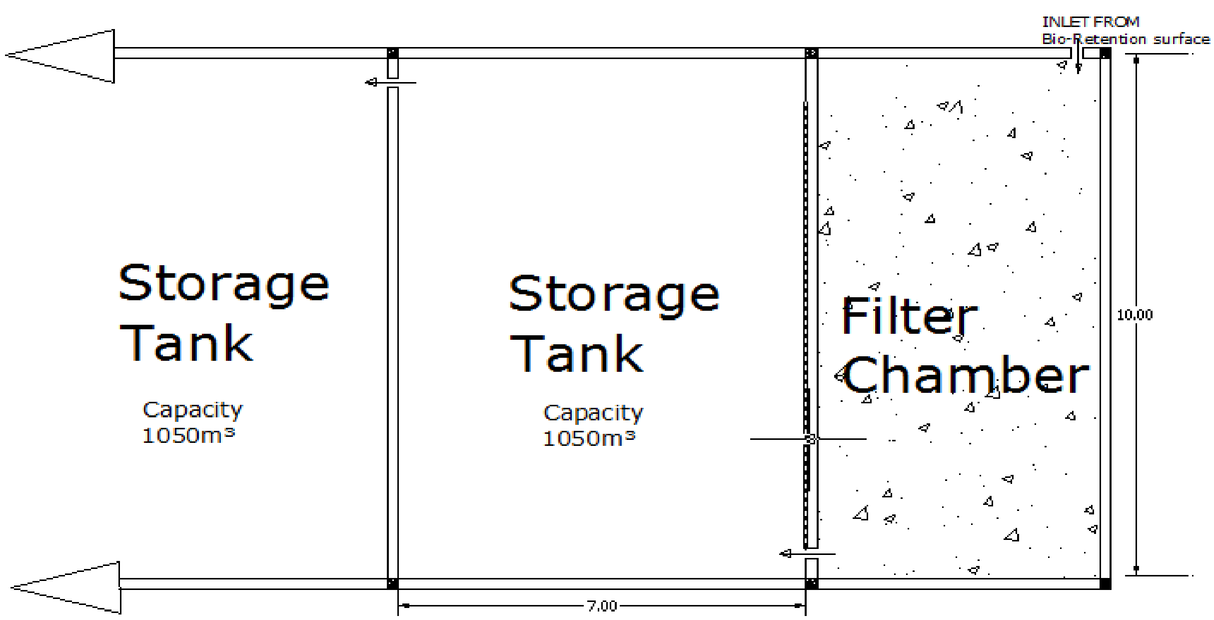




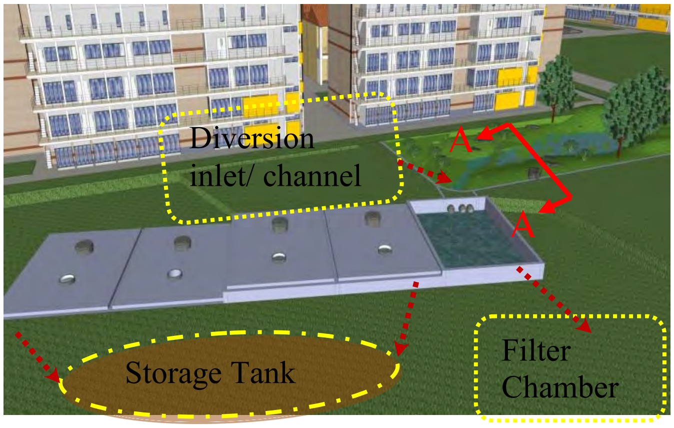
Map 5.1 Collecting and Purifying Water Using Bio-retention System (Source: Personal Sketch up model, 2016).

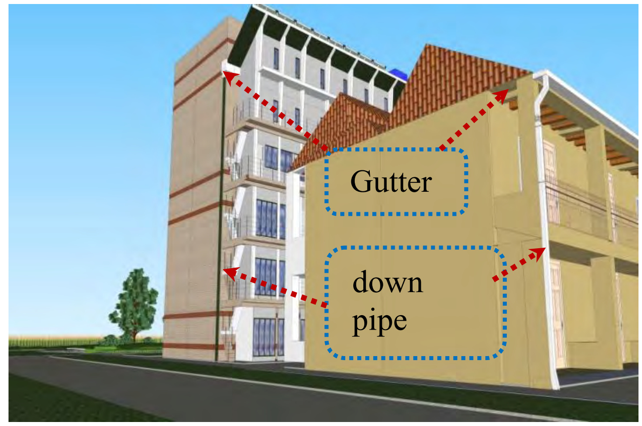


Storage Tank Capacity

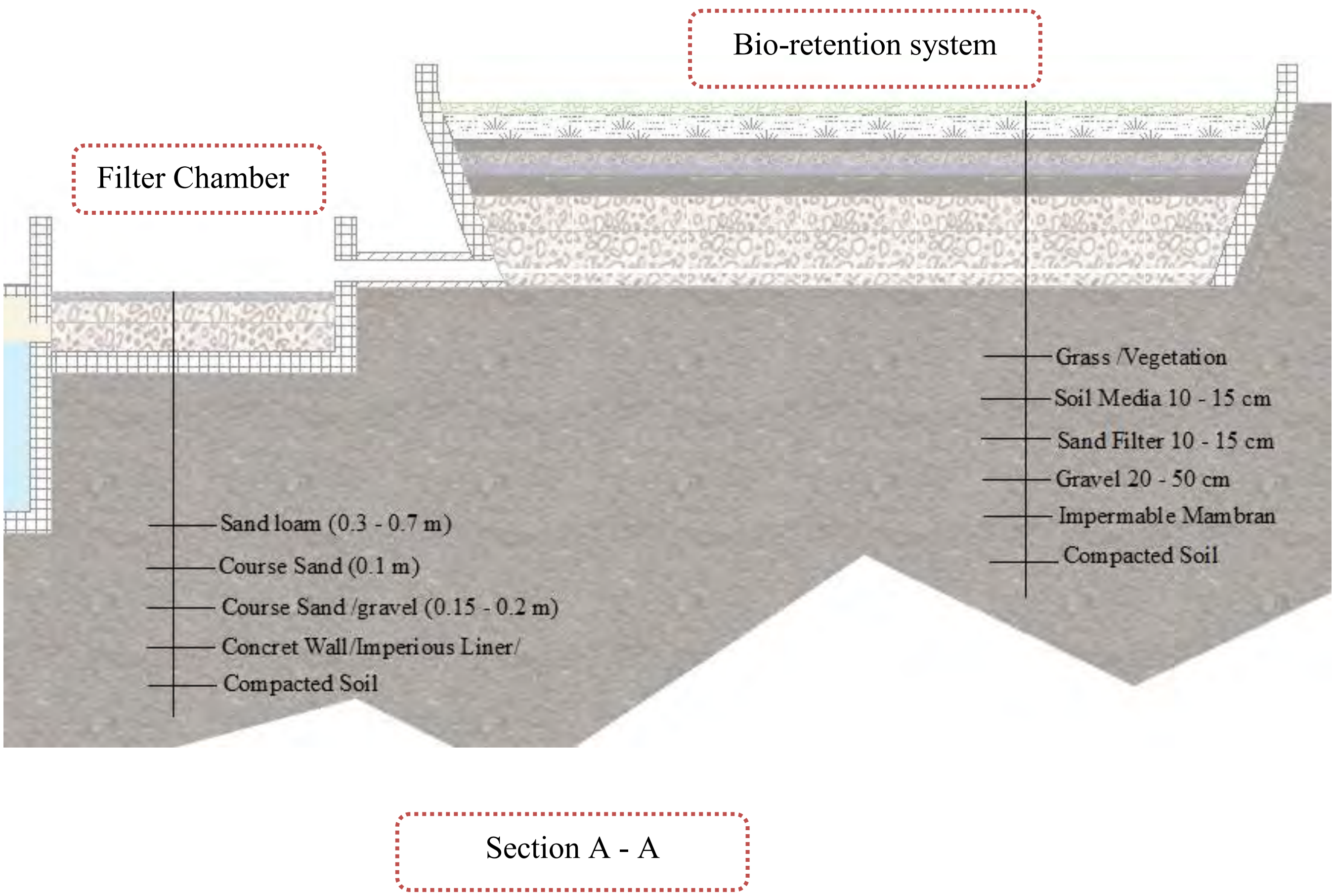


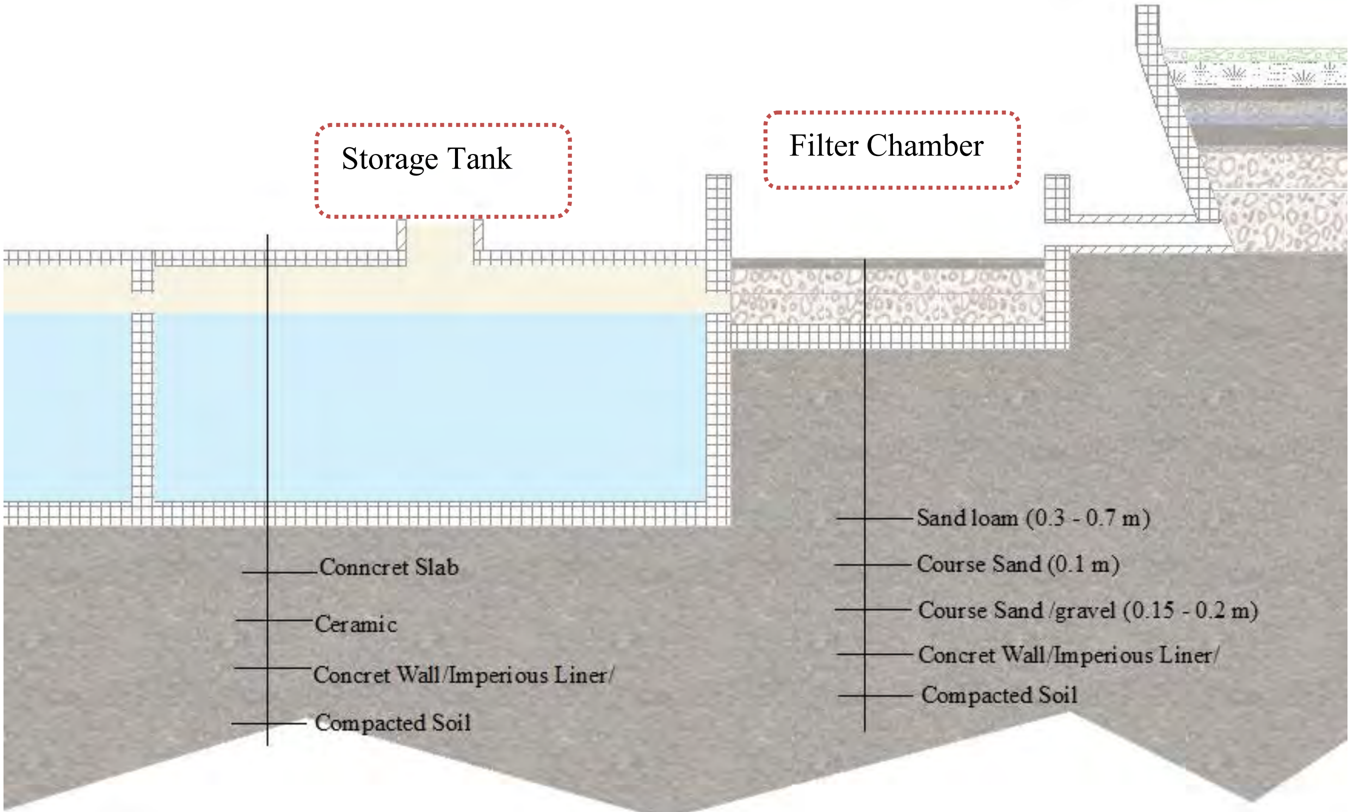
Paln view of horizontzl Filter and Storage Tank



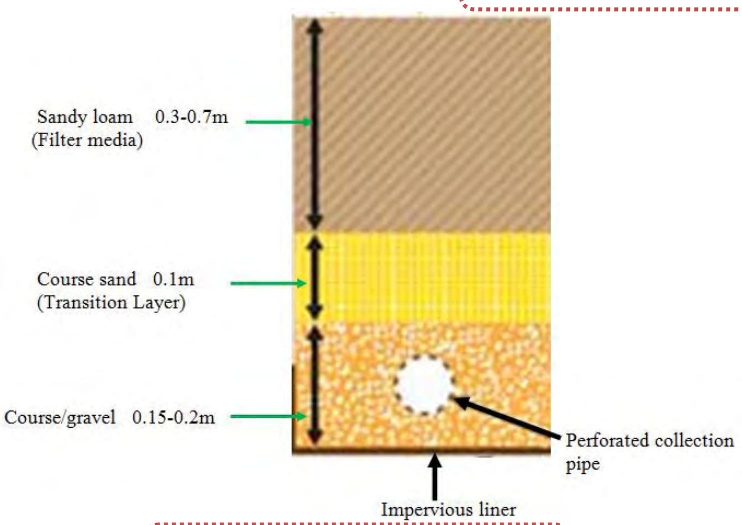


Map 5.2 Filter Chamber and Storage Tank (Source: Personal Sketch up model, 2016).



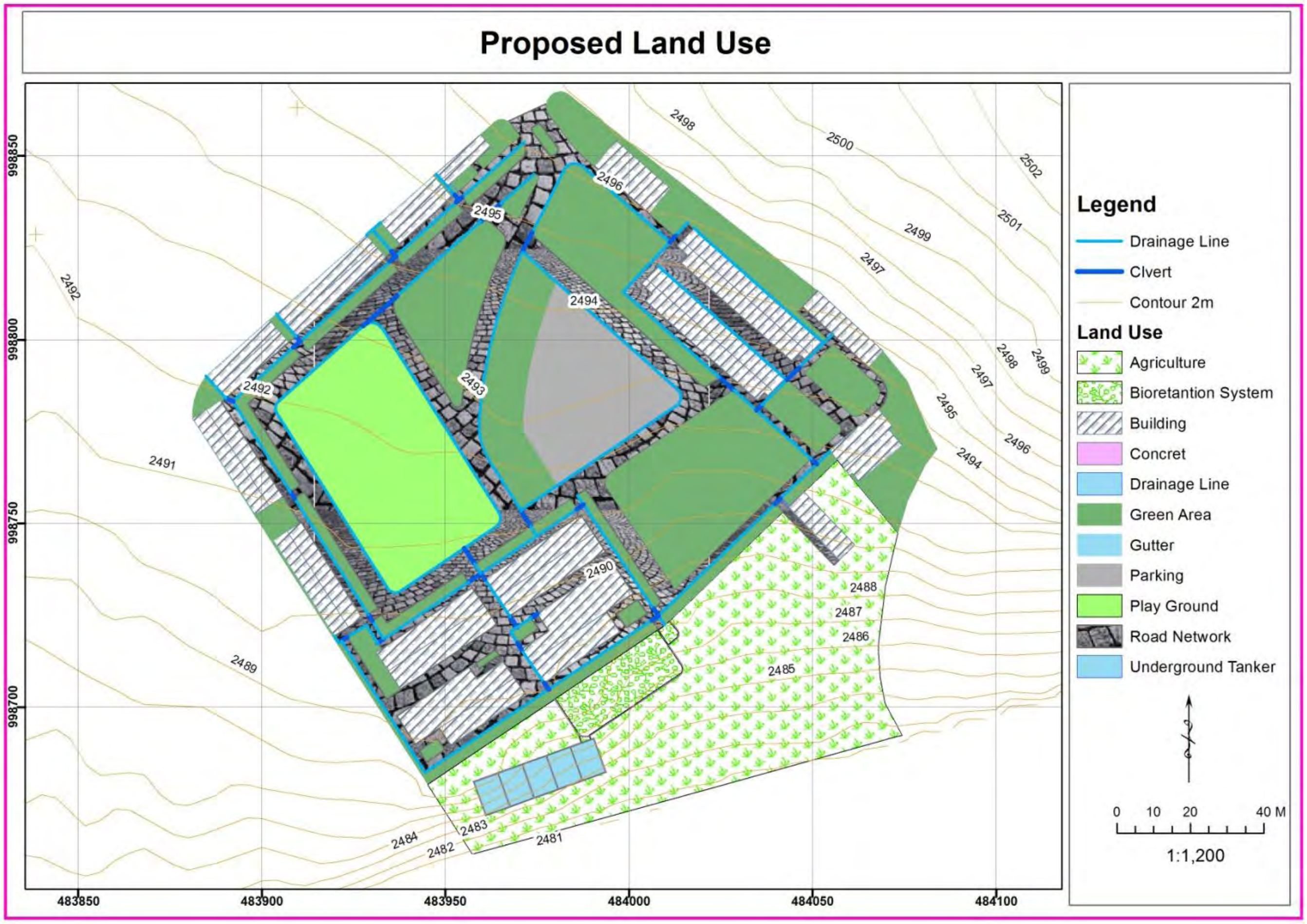


Section A - A

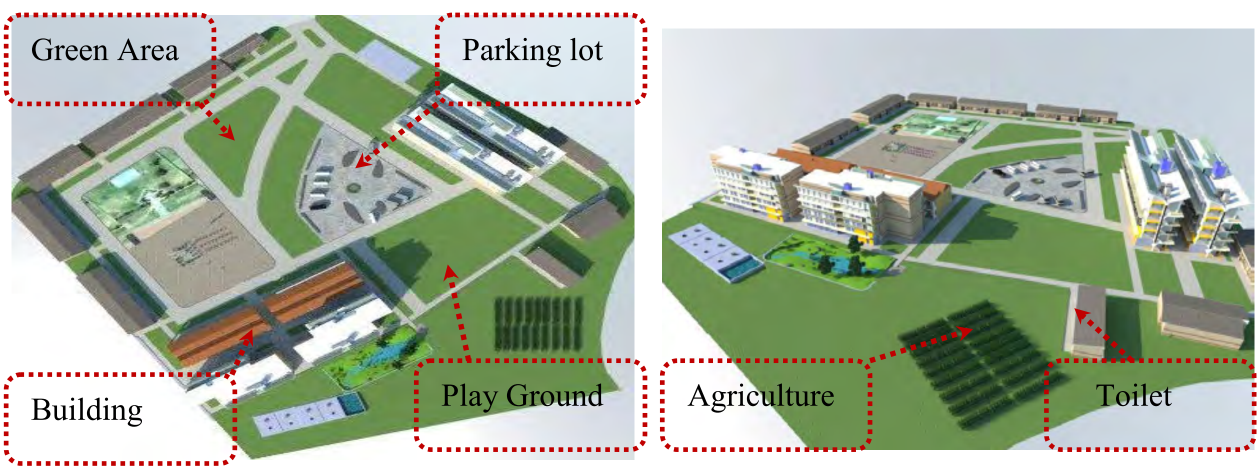


Section for Filter Chamber

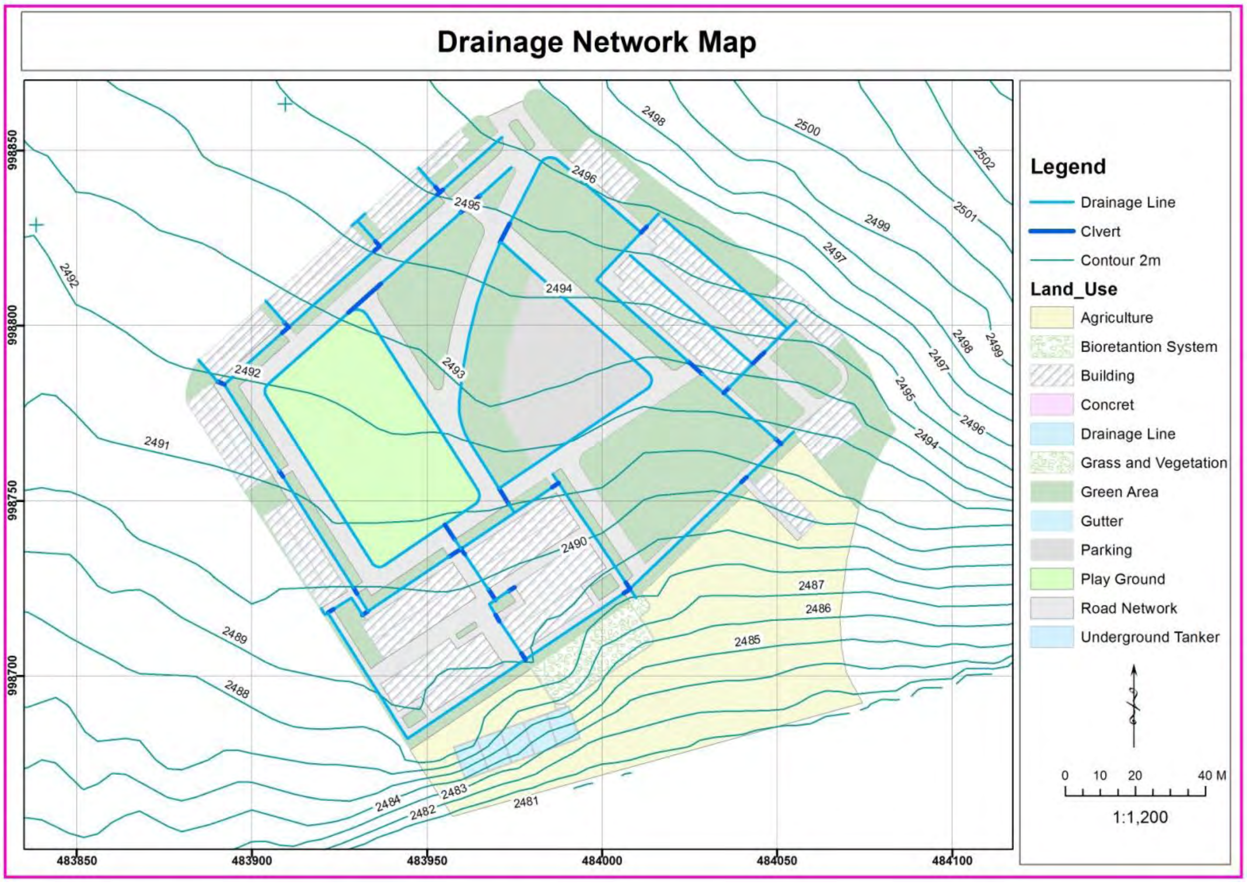
Geotextile Fabric



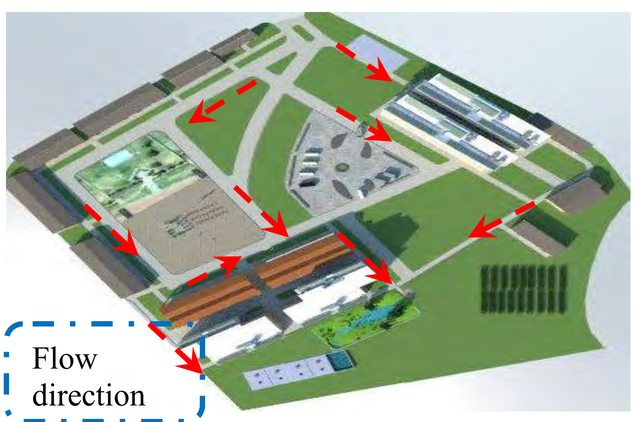
Map 5.3 Proposed Land Use Map (Source: Personal GIS Analysis, 2016).

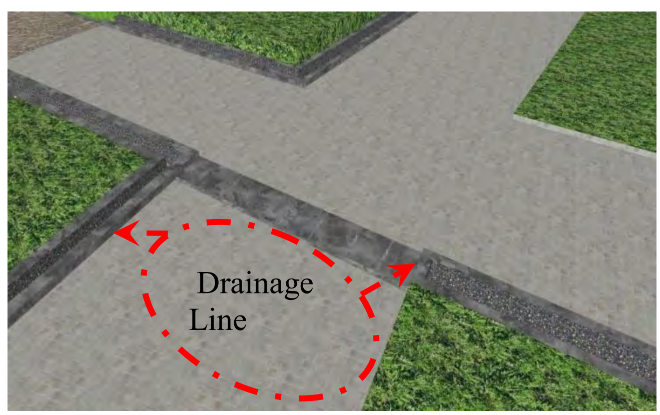


Map 5.4 3D Land use Model (Source: Personal Sketch up model, 2016).



Map 5.5 Proposed Drainage Map (Source: Personal GIS Analysis, 2016).





Map 5.6 Water Flow Direction Direct in to Bio-retention System (Source: Personal Sketch up model, 2016).

CHAPTER SIX

6 Conclusion and Recommendations

6.1 Introduction

The findings, analysis and discussion on the Kara Alo primary School has been made on chapter four and the water sensitive urban design has been proposed in chapter five to reduce the water scarcity problems. In this last chapter the conclusion of all research questions have been presented accordingly. Based on findings and conclusion made the researcher recommends actions to be taken for solving water scarcity of Kara Alo primary school to enhance sustainable water supply system.

6.2 Conclusion

Kara Alo Primary school suffers from a severe water crisis due to multiple causes, including droughts, forest degradation, floods, lack of water supply management, contamination of water, while problems like poor water management and the contamination of water are potentially solvable, the number and severity of droughts and floods is due to the ongoing climate change likely to increase in the foreseeable future.

Similarly, Addis Ababa's population is projected to grow more for the next few decades. Given these realities, Addis Ababa will also need to tackle some of the effects of the water crisis. The result of the study comprehends the following findings:

Water supply in schools of Addis Ababa of which thirty schools in Bole, fifteen Schools from Akaki-Kality, eight schools from Yeka, five Schools from Nifas Silk Lafeto and one school from Gullele sub cities do not have proper water supply. The existence of water supply system alone may not ensure that water is consistently available in schools.

The per capita water consumption has a negative relationship with number of students, teachers and administration staffs. Besides that the standards set by the Addis Ababa Educational Bureau water tap to student ratio is one tap for 20 Students; however, the existing functional tap was one but the number of students, teachers and administration staffs is 2,142.Hence there was a big gap between supply and demand, when the school children and staff have less accessible to the water. If access to water is restricted to break times, then peak demand could be high, particularly if all the classes have breaks at the same time.

The water supplied by the municipal water pipe of the school compound within 15 minutes of time was 120 liters only for 2,142 users such as students, teachers and administration staff for different purposes; however, the demand of water for drinking purpose only within 15 minutes was 2,500 liters for 2,142 users of the school compound. This shows that there is a big gap between the demand and supply of water in the case school compound.

It was impossible to isolate the sanitation and hygiene practices from the water supply. Out of the total respondents, about 92% of which stated that, the main sources of water supply were piped municipal sources that connected with residential lines. From the result of survey conducted, only 8% of those rain water harvesting and other sources utilized in the area.

To fill the gap of water shortage in the school, collecting extra rainwater from the school compound according to the following procedures. First, collect extra rainwater from previous and semi- previous surfaces such as roofs and cobblestone pavement by the above proposed designed drainage system using bio-retention system to filter debris as well as other unnecessary pollutants and then to collect those filtered water in to the prepared storage tank. The total amount of water can be harvested from previous and a semi- previous surface was 3,501,486.36 liters/average year and 4,900,835.69 liters/average year respectively, hence the total runoff within the school compound was 8,402,322 liters/average year.

Out of the total respondents on the main purposes of the water revealed that for washing hands was 21%, 66.86% was for drinking and the remaining percent were used for gardening, cleaning rooms and other purposes. In general, 88.5% response reveals that the greater parts of the delivered water in the school compound were used for drinking and washing hand purposes.

6.3 Recommendations

- ✓ In addition to specific projects and the tacking (approach) of some effects, it will be important to raise awareness among the city population about the dangers of contaminated water hence every individuals keep rivers, streams and rainwater with solid as well as liquid waste because to maintain groundwater, surface and rainwater to clean.
- ✓ Rainwater consciousness Programme for schoolchildren plus teachers. There are activities specially designed to expose schoolchildren with RWH practice. Other than that, visits to rainwater experiences from other places & rain concerning audio as well as audio –visual library are arranged on RWH and other interesting activities for the children. Encourage children to comply with procedures for use and care of water, sanitation and hygiene enabling facilities at school.
- ✓ Addis Ababa Educational Bureau should include the rainwater harvesting system and Best Management Practices (BMPs) within the curriculums at different Grade levels.
- ✓ Community Involvements Programmes for RWH such as meeting and conference etc. especially in our city are conducted with involvement of local community. This would lead to increasing awareness on RWH practice among the community members. Besides, water harvesting at the household level is a relatively simple and cheap option to reduce the scarcity of water in community as well as in the schools. It has created the culture of rainwater harvesting and it will become the symbol of the community. Change of the community shall also change the students because every student learns before schools first learn from the community. Developing a strategy and action plan for public awareness campaign both in water demand management and in related environmental issues.
- ✓ Access to potential water sources will motivate funding agencies to participate for development endeavors.
- ✓ In the school, students have been gained knowledge about the importance of water harvesting system as well as Best Management Practices (BMPs) and so the knowledge gained be able to disseminate in to the community.
- ✓ To enhance sustainable rainwater harvesting development and ensure balanced natural resources utilization between the current and future generation the city administration should properly

prepare and implement a rainwater development plan by setting basic rainwater harvesting regulations and guidelines.

- ✓ Reduction in run-off and peak flows: that is to reduce peak flows from urban development by local detention measures and minimizing impervious areas. This is lined to the availability of space to hold storm water.
- ✓ As water is one of the basic necessities of life, it will be good to remember this fact and make an economic use of it. Using it uneconomically, the water that is brought to the house with so much effort and expense does not only harm the client, but also becomes the cause for so much wastage of water that would otherwise be of use somewhere else. Therefore, utmost care must be taken by each client in order to avoid wastages of water.
- ✓ Integration of storm water treatment into the landscape: that is using storm water in the landscape by incorporating multiple use corridors that maximize the visual and recreational amenity of developments
- ✓ Scale up the project within Addis Ababa primary school as well as throughout the city to minimize the water scarcity of non-potable water.
- ✓ The other important thing of the system is operation and maintenance. During the survey, it is observed that nearly all the taps are out of use only one tap is functional. This indicates that proper operation and maintenances are ignored. Therefore, the study recommends that school administration hire professionals to operate and maintain the scheme regularly to manage resources from the piped municipal water sources.
- ✓ Before pumping or discharging of water from the centralized system (Storage tank), it should add chlorine to the centralized water supply system to control infectious diseases through clean water and improve sanitation so as to important users health achievement.
- ✓ Efficient management of water resources especially rainwater and storm water are the main sources of the water development. Indeed this type of management is substantial. There for an integrated rainwater and storm water management design should properly implement.

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Annexes

Annex 1: Interview Questions for Teachers and Higher Officials

Interview questions for teachers and higher officials

Research topic: Water Sensitive Urban Design (WSUD) intervention alleviating the water scarcity in the government schools of Addis Ababa.

Dear Respondent: I would like to forward my gratitude in advance to your cooperation to respond for my question by sacrifice your time.

Respondent personal profile

School Name----------------------------------

Sex M ☐ F ☐

Education background---------------

Position---------------------------

Date------------------------

1. What are the main water sources in your organizations?

----

2. For what purpose use the water in your organization?

----

3. Is your organization exposed to water risk for Flooding or drought?

Yes ☐ No ☐

If yes, what are the main reasons?

----

4. What is the total water consumption? Is the demand and supply of water proportional?

----

5. What are the main challenges for providing water in your organization?

----

6. Please describe other potentials for water in your organization other than the existing sources and your strategies to utilize them?

----

7. Is there any flood risk in your school compound?

   Yes ☐ No ☐

8. If yes, what are the measures taken by the responsible officers?

----

9. Is a stormwater management practice in case area to control flood?

----

10. If the aforementioned stormwater management practice is not used by the school compound, what are the main reasons?

----

11. Does your organization have a water guidelines and clear goals for action?

   Yes ☐ No ☐

If yes, please explain?

----

12. What actions have been introduced in the school or neighbor communities to aware the active use of rainwater?

----

13. How the Government working on water issue in your area?

----

14. Have you evaluated how water quality and quantity affects the success of your students?

Yes ☐ No ☐

15. If yes, Please explain the effects

----

16. If no, what is the reason?

----

17. What is the perception of staffs and students about rainwater harvesting systems?

----

18. What are the possible solutions to minimize the problem of water scarcity and flooding?

Thank you for your participation

Questionnaire for students

Research topic: Water Sensitive Urban Design (WSUD) intervention alleviating the water scarcity in the government schools of Addis Ababa.

Dear Respondent: I would like to forward my gratitude in advance to your cooperation to respond for my question by sacrifice your time.

Respondent personal profile

School Name----------------------------------

Sex M ☐ F ☐

Education background--------------

Position---------------------------

Date------------------------

1. What are your primary water sources?

   Piped Municipal Water Supply ☐ Rainwater Harvesting ☐ Pump ☐

   River or lake ☐ Bore Well ☐ Spring ☐

   Other (Please State)

   ....

   ....

2. What are the main purposes of the water in your school?

   For flushing toilets ☐ for washing hands ☐

   For drinking ☐ Irrigation purpose ☐

   Other (Please State)...

   ....

   ....

3. What treatment is given to your school's water before drinking?

   Filtered & Boiled ☐ Boiled ☐

   Unfiltered &Unboiled ☐ Filtered ☐

4. What are the key climate and environment challenges facing your area?

   Drought ☐ flooding ☐ pollution ☐ sewage facilities ☐

   Other (Please State)

   ....

   ....

5. How would you rate your school's water related provision or facilities in terms of?

   A. Safety to drink and use? Excellent ☐ well ☐ Adequate ☐ Poor ☐ Terrible ☐

   B. Reliability of water source? Excellent ☐ well ☐ Adequate ☐ Poor ☐ Terrible ☐

   C. supply of water? Excellent ☐ well ☐ Adequate ☐ Poor ☐ Terrible ☐

   If you have not marked well or Excellent in one of more of the categories, what improvements could be made, and what are the obstacles?

   ....

   ....

   ....

6. How would you rate your school's sanitation facilities in terms of?

   A. Safety? Excellent ☐ well ☐ Adequate ☐ Poor ☐ Terrible ☐

   B. Cleanliness? Excellent ☐ well ☐ Adequate ☐ Poor ☐ Terrible ☐

   C. supply of water? Excellent ☐ well ☐ Adequate ☐ Poor ☐ Terrible ☐

   If you have not marked well or Excellent in one of more of the categories, what improvements could be made, and what are the obstacles?

   ....

   ....

   ....

7. What are the major obstructions to rainwater harvesting in your school?

   Lack of knowledge ☐ lack of attention ☐ lack of responsibilities ☐

   Others please specify...

   ....

8. Is it included topic of Water as part of the school curriculum?

   Yes ☐ No ☐

   If yes, what are the importance issues raised by the topics?

   ……………………………………………………………………………………………

   ……………………………………………………………………………………………

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If not, what is your opinion?

…………………………………………………………………………………………………
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9. Is there an experience for rainwater harvesting in your school?

   Yes ☐ No ☐

   If no, what are the main reasons?

……
……
…………………………………………………………

10. When did you experience a water shortage at school (Season), what was the reason and what was the impact?

……
……
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Thank you for your participation

Annex 2: Checklist

Checklist for Rainwater Harvesting

Here are 20-points

No	Item	Checked/considered		Comments /Remarks
	Step1: Detail site Analysis	**Y**	**N**	
1.	Existing and planned infrastructure identified. • Existing future analysis • Rooftops • Paved areas • Unpaved areas			
2.	Soil, Terrain and Geology analysis under taken Slope analysis Topographic analysis (suitability analysis)			
3.	-Hydrologic pattern and feature identified. -Water table analysis -Water shade calculation			
4.	Information on natural features obtained (Vegetation cover and type of vegetation ,Open space, flood lines)			
5.	Opportunities and constraints summarized.			
Step 2: Rainfall data from metrology office				
6.	Collect climatic data like rainfall data from nearest rain measuring station, preferable monthly data, for 10 years.			
7	Calculate rainfall endowment and rainfall harvestable for all 3 catchments i.e. rooftops, paved areas and unpaved areas			
Step 3: Water demand and supply data from AAWSA				
8.	All branch boundary			

9.	Water supply situation of Addis Ababa			
10.	Main water supply source of Addis Ababa.			
11.	Demand and supply gap			
Step 4: Number of schools, students, Teachers and employees(From AA Education Bureau)				
12.	Number of Elementary schools in the sub-city			
13.	Number of students, teachers and Employees within the schools.			
Step 5: Calculate catchment area, demand and Supply				
14.	Identify water consumption for various demands.			
15	Calculate the capacity of rooftop to capture the rainwater.			
16	Calculate the maximum harvesting capacity and it demands by the school users.			
17.	If landscape water requirement is your top demand can appropriate planting strategies be adopted to reduce water consumption?			
Step 6. Conceptual site design and sizing the storage				
18.	Design storage and recharge systems based on maximum or optimum intensity of rainfall.			
19.	Calculate the storage size according to the rainfall data			
20.	Examine whether separate storage and line for potable water and non-potable water makes economic sense. Build it into future designs.			

Annex 3: Methodological Matrix

Methodological Matrix						
Objectives	**Descriptions**	**Literature/ Summery**	**Data Type**		**Analytic Tool**	**Result**
			Type	**Source**		
Objective One	Water use and shortage in institutional plots	Water scarcity can be a result of two mechanisms:- - **physical water scarcity** and - **Economic water scarcity** There are different uses the water for different purposes like:- • Flushing toilets • Washing hands • Watering the garden • Drinking water from bubblers and • Preparing food in the canteen and kitchens. Generally, most schools, the majority of water used is for toilet flushing and washing purposes. Broadly there are two water supply systems that	-primary & Secondary data	-Maps -Reports -Books -AAWSA office -Public institutions (Elementary Schools)		Map Graphs Figures

		can effectively be used in schools in Ethiopia, and these are: (I) Rainwater catchment system, (ii) Groundwater supply system, ❖ Spring catchment ❖ Hand-dug well ❖ Bored or drilled well (shallow and deep wells) The Water supply to Addis Ababa metropolitan area is presently supplied from:- 5. Surface water supplies • Legadadi • Gefarsa, and • Dire dam 6. Ground water supplies • Akaki well field number-1 • Akaki well field number-2				
		Among the several challenges that influence		-Maps -CAD data		

Objective Two	Challenges and potential for water harvesting in public sector	the rainwater harvesting a site, those factors are considered to be the most important. • Topography and terrain profile • Land use or vegetation cover • Rainfall • Soil type & soil depth • Hydrology and water resources • Environmental and ecological impacts • Socio-economic and infrastructure conditions	primary & Secondary data	-Field work -metrology office -Public institutions such as elementary schools	-GIS	-Tables -Graphs -Figures
Objective Three	Design option for water harvesting in public institutions	Landscape based Rainwater harvesting can be constructed either • Above ground or • Below ground. **Principles and techniques** • Grass Buffer Strips • Vegetated or Grass Swales • Wetlands • Bio-retention Systems • Ponds or Lakes	-primary & Secondary data	Maps from challenge and potentials like soil map, Topography map, land use and hydrology map etc	-GIS -AUTOCAD -ARCICAD	Designs

		• Sedimentation Basins • Wet Ponds • Infiltration Basins • Infiltration Trenches • Rain Gardens **Designing rooftop rainwater harvesting** Rainwater can be collected from most forms of roof. Tiled roofs, or roofs sheeted with corrugated mild steel etc. are preferable **Five steps to be followed in designing a RWH system:** **Step1** Determine the total amount of required and available rainwater. **Step2** Design your catchment area. **Step3** Design your delivery system. **Step4** Determine the necessary size of your storage reservoir. **Step5** Select suitable design of storage				

		reservoir.				
Objective Four	Up Scaling and strategy For water harvesting System.	Scaling up is presented as part of a broader process of • Innovation • Learning, and • Scaling up. Forces, or drivers, are needed to push the scaling up process forward along a pathway. They are four common drivers: • Incentives and accountability • Vision and leadership • External catalysts • Ideas and models	Secondary data			Plan Strategy

Annex 4: The City Administration of Addis Ababa Water Consumption Price per Liter

Water Price per Meter Cube

No	Meter cube/ m^3/	Price in birr
1.	1 -7	1.75
2.	8 - 20	3.80
3.	21 - 40	4.75
4.	41 - 100	5.95
5.	101 - 300	7.45
6.	301 - 500	9.30
7.	> 500	11.60

Source: AAWSA, 2016

Annex 5: Design Principles for Active Water Harvesting Systems

- **Use gravity to your advantage**

Place your tank at a location where you can utilize the elevation of the collection surface, the location of the tank, and the free power of gravity to collect rainwater and distribute it around your site. To fully use gravity power, place your tank at a high point in the yard and use full port valves that do not constrict flow. For aboveground tanks, you can always add pumps to increase distribution pressure, but avoid becoming completely dependent on them

- **Maintain access to the inside and outside of your tank**

You need access to the inside and outside of your tank to check water levels, inspect for leaks, maintain equipment, clean out the tank, and make repairs. Position aboveground tanks so there is enough space to walk completely around them, especially if the tanks are close to a building.

- **Design and install a “closed” tank system**

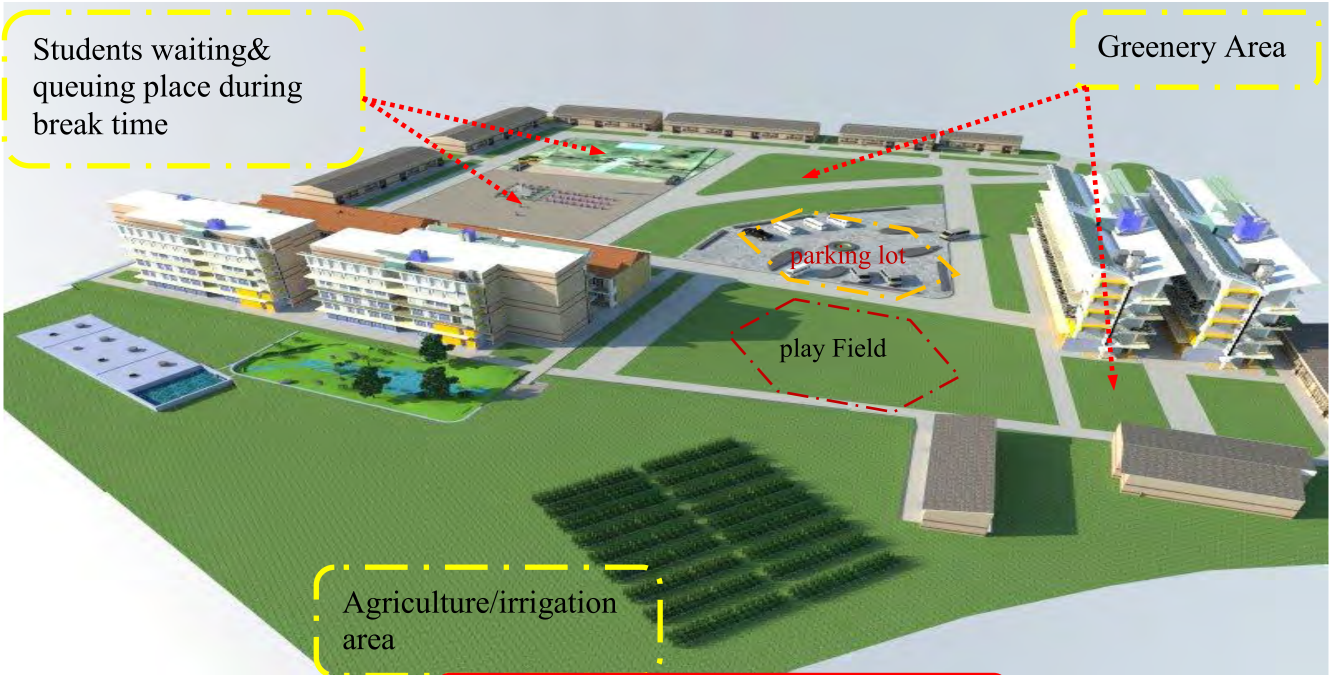
Closed tanks are designed to keep out insects, animals, sunlight, and unauthorized people. Tank inlets and outlets are screened to prevent entry of insects and animals, which prevents mosquitoes from breeding and animals from drowning. To prevent the growth of sunlight-dependent algae and bacteria from contaminating harvested rainwater, tanks can be made of opaque materials, painted to make them opaque, or buried. Opaque tank covers keep out insects, animals, and sunlight, and can be locked to keep out children. Covers also reduce water loss to evaporation

- **Ensure adequate overflow capacity**

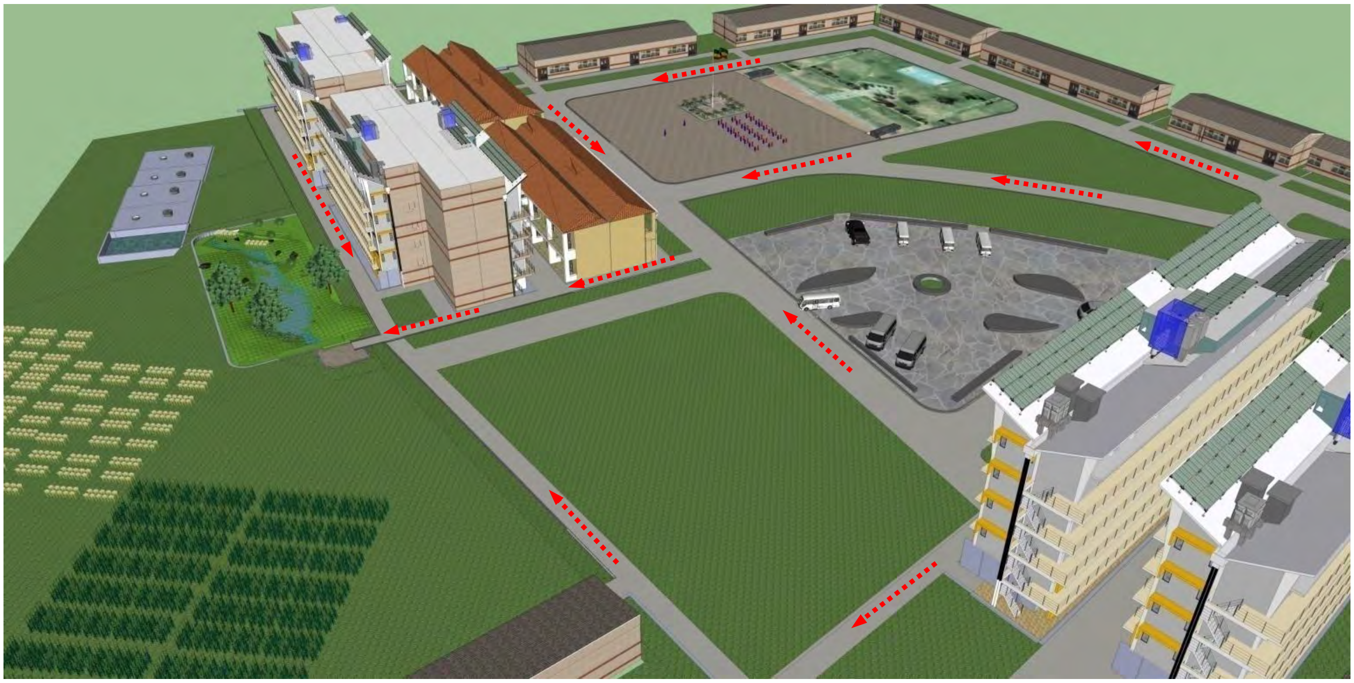
Using gravity flow, always utilize overflow water as a resource. The diameter of the tank overflow pipe must be equal to or larger than the diameter of the inflow pipe so excess inflow water does not back up in the tank. Direct overflow water to another tank or to mulched and vegetated infiltration basins. Belowground tanks must be designed so surplus water overflows using the force of gravity alone.

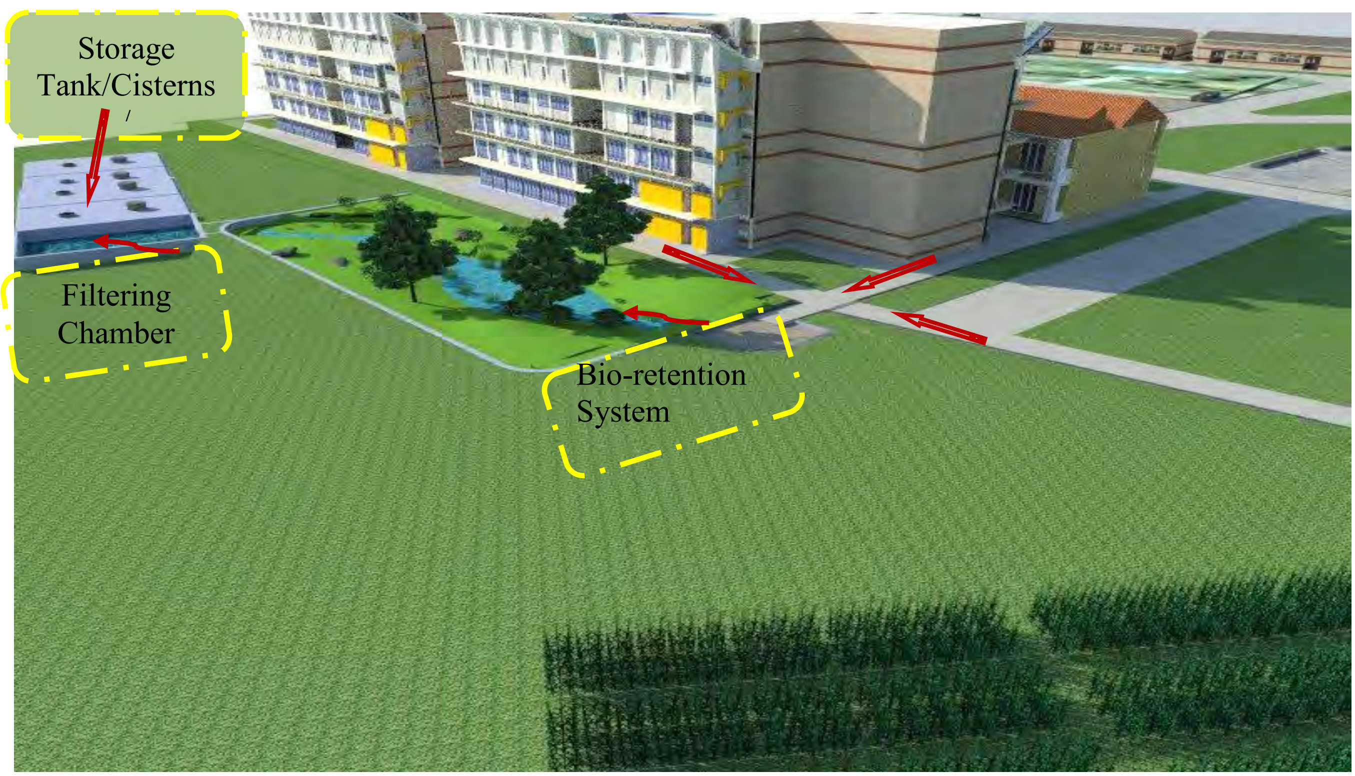
Annex 6: 3-D model of Kara-Alo Primary School

Plan view of the case study area



Proposed Land use of the school


Flow direction of the drainage line



Bio-retention System

Storage Tank

- The storage tank is an RCC structure.
- It is constructed adjoining the bio-retention system to avoid problems conveyance.
- The partition wall supports the RCC slab cover as the span is large.
- All the inner walls of the storage tank are lined with ceramic tiles for easy cleaning and maintenance.
- An over flow pipe is provided at the opposite end at the top.
- The top of the tank is raised 6cm above the ground level to avoid soil depositing on the cover slab.