

**THE CONTRIBUTION OF RAINWATER HARVESTING FROM ROOF  
CATCHMENTS IN INCREASING WATER RESOURCES FOR NAIROBI  
CITY COUNTY RESIDENTS**

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**DECLARATION**

This thesis is my original work and has not been presented for the award of a degree in any other university or any other award

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## **DEDICATION**

To my parents, siblings, guardians, mentors and friends for their continued support throughout my academic endeavors

## **ACKNOWLEDGEMENT**

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## **LIST OF ABBREVIATIONS AND ACRONYMS**

CDF:	Constituency Development Funds
EPA:	United States Environmental Protection Agency
GPS:	Global Positioning System
IPCC:	Intergovernmental panel on climate change
IRD:	International Relief and Development
JKIA:	Jomo Kenyatta International Airport
KIRDI:	Kenya Industrial Research and Development Institute
KMD:	Kenya Meteorological Department
KNBS:	Kenya National Bureau of Statistics
KRA:	Kenya Rainwater Association
Lpcd:	Litres of water per day per capita
NACOSTI:	National Council of Science and Technology
NCWSC:	Nairobi City Water and Sewerage Company
ND:	Not Detected
NTU:	Nephelometric Turbidity Units
RHW:	Rainwater Harvesting
TDS:	Total Dissolved solid
TSS:	Total Suspended solids
TS:	Total solids
UNEP:	United Nations Environmental Programme
WHO:	World Health Organization

## ABSTRACT

Nairobi City County is faced with acute water scarcity. The daily deficit is currently 170,000 m<sup>3</sup>/day which accounts for about 23%. This deficit will escalate as population increases. However, streets are often flooded during heavy rains and water harvesting has been neglected. The County relies mainly on surface water sources from Athi River basin, Tana River basin and over 3000 boreholes. The objectives of this study were to assess volumes of rainwater that can be harvested from roof catchments, sizes of storage capacity required, water quality and adoption of rainwater harvesting from roof catchments. Five rainfall Thiessen polygons that covered the entire County were created using ArcGIS version 9.2. Samples of 10 maisonettes and multi-story buildings were obtained from each Polygon. More samples of 25 industries and 25 institutions were collected making a total of 150 samples. Data used included rainfall depths, roof surface area, size of tanks, physical, bacteriological and chemical properties of rainwater from roof catchments. Microsoft Excel, SPSS, descriptive analysis, regression and correlation analysis were appropriately used in the study. The result indicated that Kabete receives highest annual rainfall followed by Dagoretti, Eastleigh Moi Airbase, Wilson and J.K.I.A. Over 90% of buildings would have rainwater supplements of above 23% thus filling the current deficit. The size of storage tanks for maisonettes ranged from 5, 126 to 60, 840 litres while multi story buildings it ranged from 32, 400 to 344, 250 litres. A regression model for storage capacities and their cost were generated. The quality of rainwater from different roofing materials was not suitable for potable purposes but, it would be used for non-potable purposes. Majority (93%) of residents depended on city council piped water, private boreholes (7%) and only 16% harvested rainwater as supplement to City council or private borehole sources. Institutions are leading in roof catchment rainwater harvesting (44%), followed by maisonettes( 20%), Multi-story buildings 6% and industries have least adopted rainwater harvesting(4%). The result indicates that if roof top rainwater catchment is done, water deficit that has been estimated in Nairobi County will be definitely offset. Industries and institutions will benefit more from roof catchment rainwater harvesting followed by maisonettes and multi-story residential buildings. Residents should be encouraged to adopt roof catchment rainwater harvesting by enforcing policies and by laws for roof catchment rainwater harvesting in Nairobi City County.

## CHAPTER ONE

### 1.0 INTRODUCTION

#### 1.1 Background information

Water scarcity is recognized as an increasing severe problem with global implications. The distribution of water reserves is not homogeneous both geographically and sequentially. Consequently, many regions face water scarcity problems affecting those in which demand exceeds water supply (Sear Net Briefs., 2003). Urban areas are the most susceptible systems. They largely depend on water from distant sources that are transported by means of large consignments. Centralized water supply and drainage systems are ineffective as they do not take full advantage of urban storm water resources (Jeremy *et al.*, 2012). Urban areas have more impervious surfaces and centralized storm water drainage systems. This turns rainwater from a valuable resource into a societal cost in form of flooding, stream erosion, aquatic habitat destruction and toxic loading on receiving environment (Jeremy *et al.*, 2012). Adoption of rainwater harvesting can increase water resources (Rohitashw *et al.*, 2011).

Kenya is classified as a water scarce country with an annual renewable freshwater per capita of 647 m<sup>3</sup>. The United Nations' recommends a minimum of 1,000 m<sup>3</sup> (NCWSC, 2012). Nairobi County has an estimated population of 3.6 million (KNBS, 2009). According to clause 43 b & d of the constitution of Kenya, water is a basic human right. In September 2012, the Ministry of Water, the World Bank and the French Development Agency launched a master plan to develop

additional supply capacity for Nairobi County. Phase one of the plan is groundwater development, followed by a second phase that would involve inter-basin transfer. At a cost of KSh 25 billions, these projects will increase supply to a partly 654,048 cubic meters per day by 2017, against a projected water demand of 1 million cubic meters per day ( Athi water Services Board annual Report, 2012). According to Olaoye., *et al* (2013), rainwater harvesting is a common form of reducing dependence on ground and surface water sources even in cities.

Rainwater harvesting is defined as the practice of collecting water from surfaces on which rain falls and storage of this water for later use (Chanan.A *et al.*, 2007). Roof- catchment rainwater harvesting system basically consists of the roof – top as the catchment area, gutters for collecting water and storage tanks. The size of the tank depends on the available roof–top area, precipitation and user’s water consumption (Colorado Water Conservation Board, 2010; International Relief Development, 2013). The volume of rainwater from roof tops might meet water demand of occupants of that building, but most buildings do not harvest rainwater from their roof catchments. Some City residents consume less than 40 Litres person per day (lpcd). World health organization suggests that 40 lpcd is fit for a simple life, but that is beyond reach of many consumers in Nairobi. (Ledant.M *et al.*, Moraa. H. *et al*).

## **1.2 Statement of the problem**

Cities require large amounts of water to sustain themselves owing to density of population and housing. The most typical methods of meeting urban water

demand have been to build large dams or withdraw water from groundwater sources and pipe it to residents. In most cases, water demand cannot be met, leaving urban areas under water stress. Additionally, groundwater levels may decline due to increased pumping and extensive impermeable surfaces without natural infiltration. Concentrated storm flows alter flow patterns that affects flora and fauna and possible flood damage downstream (UNEP, 2009). Nairobi's population has recently increased and this has caused a serious threat to the management of her water resources as the gap between demand and supply is continuously widening. Water supply deficit for Nairobi City is currently 170,000 m<sup>3</sup>/day or 23% of the current demand. This deficit will rise to 280,000 m<sup>3</sup>/day and 970,000 m<sup>3</sup>/day by 2017 and 2035 respectively if water supply alternatives are not implemented (Athi Water Services Board Report, 2012).

The water master plan of 2012 considered Ground water and inter-basin transfer developments. These developments are unlikely to satisfy the projected demand of 2.5 million cubic meters per day by 2030 (Awiti, 2013). The contribution of decentralized systems such as roof catchment rainwater harvesting was not included in the master plan. The County is dangerously flood during rainy seasons and this water would be useful if captured before forming ground surface runoffs. Thus, this study analyzed the contribution of roof catchments rainwater harvesting at household levels in augmenting water supplies in Nairobi County.

### **1.3 Justification of the study**

Nairobi County is faced with water scarcity and streets are often flooded during heavy rains. Water harvesting has been neglected worsening the county's water scenario. One of the solution to this crisis would be rainwater harvesting. There are several advantages to urban rainwater harvesting that include; augmenting water supply from surface or underground, preventing runoff from going into sewers or storm drains that reduces load on treatment plants, reduce urban flooding and recharging water into aquifers (Jackson. 2001). In a tropical country like Malaysia it is easy to collect 2 m<sup>3</sup> in a single storm while 10 m<sup>3</sup> has been collected annually in Zambia from a roof of almost the same size (Thamer *et al.*, 2010).

Decentralized water supply systems such as urban rainwater harvesting will greatly conserve agricultural land in the outskirts of Nairobi and increase urban agriculture. Efficient water management is seen as an important signal for attracting investment in cities that are vulnerable to water scarcity. Industries that are water-intensive, such as beverage or agriculture, will not favorably locate investments in counties with poorly managed or declining water supply.

Therefore, this information will guide into formulation of policies and by laws that encourages buildings in Nairobi County to have rainwater harvesting structures. This will build flexible water supply systems, owing to drought or extreme rainfall (Awiti, 2013), which will reduce floods, erosion and increase water supply.

## **1.4 Overall objective**

The overall objective was to assess the contribution of rainwater harvesting from roof catchments in increasing water resources for Nairobi City County Residents

### **1.4.1 Specific objectives**

The specific objectives of the study were:

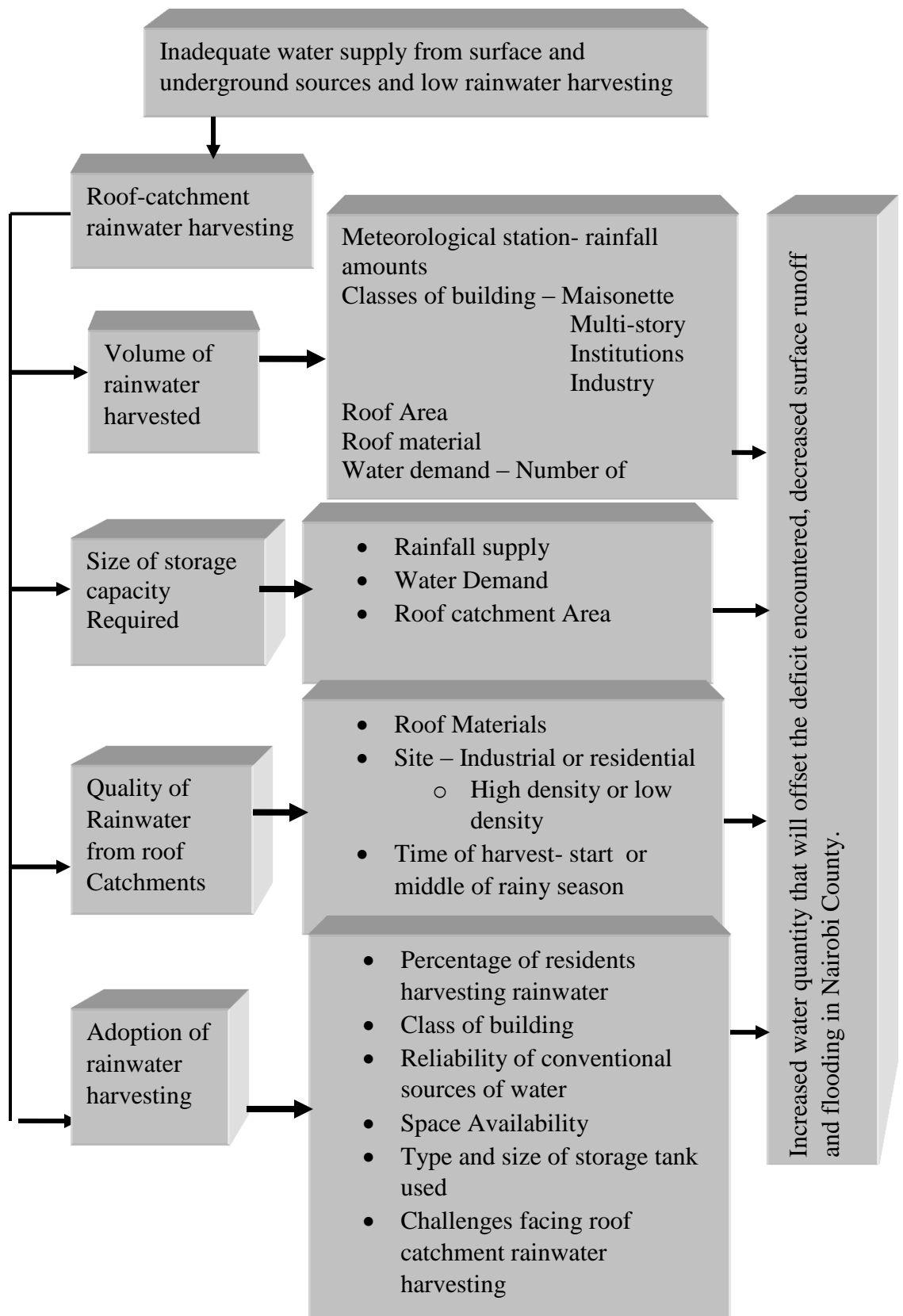
- i. To determine volume of rainwater that could be harvested from roof catchments in meeting water demand of the occupants of that building.
- ii. To determine storage capacity required for different roof catchments.
- iii. To characterize and analyze rainwater quality from residential and industrial roof catchments.
- iv. To assess adoption rate of rainwater harvesting from roof catchments in Nairobi City County.

## **1.5 Hypothesis**

- i. The volume of rainwater harvested from roof catchments, definitely meets water demand of the occupants of that building.
- ii. The size of storage capacity required for collection of rainwater from different roof catchments is the same.
- iii. The quality of rainwater from industrial and residential roof catchments does not differ and can definitely be used for all purposes.
- iv. All Nairobi City County residents harvest rainwater from their roof catchments.

## **1.6 Conceptual Framework**

The typical methods of meeting water demand for Nairobi City County has been to build large dams in the outskirts of the city or withdraw water from groundwater sources, and pipe it as needed. However, in most cases water demand cannot be satisfactorily met by these two sources alone. By harvesting rainwater at domestic or industrial level, it is expected to increase water quantity and meet the demand per capita. In addition, decrease runoff that causes erosion and flooding downstream. Figure 1 indicates the problem, intervention required, independent variables, dependent variables and outputs.



**Figure 1: Conceptual Framework**

## **CHAPTER TWO**

### **2.0 LITERATURE REVIEW**

#### **2.1 Overview of Rainwater Harvesting**

Rainwater harvesting is defined as the practice of collecting water from surfaces on which rain falls and storage of this water for later use (Chanan *et al.*, 2007). The concentrated urban population demands adequate water for consumption and sanitation needs, which requires stable and large supplies of water often through the use of surface water/dams or groundwater. The extractions threatens other landscape habitats and functions, reducing the ecosystem's capacity to supply things such as water downstream, habitat for biodiversity and livelihood support (UNEP, 2009). The amount of rainwater that can be harvested depends on the precipitation in the area and total catchment area (Brad, 2006; Ziyadatal, 2015).

#### **2.2 Rainwater Harvesting from Roof Catchments**

Roof- catchment rainwater harvesting (RHW) system basically consists of the roof – top that provides the catchment area, gutters that collect the water and storage tank. The design of each of the components depends on the available roof – top area, precipitation in the area where the building is located and user's water consumption (International Relief Development, 2013). The decision of which RWH technology to implement depends on the potential volume requirements, quality requirements, availability of funds, materials and skills available locally, space availability and rainfall patterns (Colorado water conservation board, 2010;

International Relief Development, 2013). In India and Sri Lanka, for example, RWH has explicitly been included in water policy as a non – conventional resource of water besides surface and ground water sources.

### **2.3: Rainwater harvesting in urban areas**

According to Vishwanath (2012), Bangalore in South India developed a master plan for rainwater harvesting for its entire comprehensive development plan area of 1279 square kilometers. This supplied 25% of the city's water requirements by 2011. Also, rainwater harvesting was made compulsory for all old and new buildings and 98% of the buildings complied in Chennai, South India. Rainwater from roof catchments may meet about 80% of domestic water requirements (Julius *et al* .,2013).

In China and Brazil, roof catchment rainwater harvesting is being practiced for providing drinking water, domestic water, water for livestock, water for small irrigation and a way to replenish ground water levels. Gansu province in China and semi-arid north east Brazil have the largest roof catchment rainwater harvesting projects ongoing (Zhu Qiang, 1998). In Bermuda, the law requires all new construction to include rainwater harvesting adequate for the residents (UNEP, 2011).

According to UNEP (2011), Kenya is leading in African as far as rainwater harvesting is concerned and many projects have been implemented. Nairobi County has not embraced rainwater harvesting majorly due to lack of policies that govern rainwater harvesting (Kenya Rainwater Association, 2011)

## 2.4 Rainfall Patterns for Nairobi County

There are four distinct seasons: Warm dry Season which begins in January to late March. It has light rainfall; averaging 80 mm per month; long rainy season begins in late March to early June. During this season, rainfall amounts are high and the weather is frequently warm and sunny. The average rainfall peaks are at 211 mm in April although more than that can be recorded. The cool dry season begins in mid – June to early October and is characterized with low-level moisture and a lot of clouds. Short rainy season is from mid-October to mid-December. In November a rainfall of about 167 mm can be recorded, and there is an abrupt change to warm sunny weather (Opijah *et al.*, 2007; Munene *et al.*, 2012).

## 2.5 Quality control for rainfall data

Errors in rainfall records may be due to either non – observation or incorrect recording and is corrected using appropriate spatial interpolation (Technical assistance hydrology project, 1999). In order to use rainfall records at a station for any analysis, the data has to be checked for continuity and consistence.

### 2.5.1 Estimation of missing rainfall data

In case, the normal precipitations at different stations are within 10% of the normal annual precipitation at station **x**, then average arithmetic method is used: as shown in equation i.

$$p_x = \frac{p_1 + p_2 + p_3 + \dots + p_m}{m} \dots\dots\dots(i)$$

Where  $P_x$  is rainfall station  $x$  to be determined,  $P_1, P_2, P_3 \dots P_m$  are monthly rainfall values at neighboring rain gauges and  $m$  is the stations. However, if the normal rainfall at any of the stations varies by more than 10% from the normal annual rainfall at the station, then it is estimated by normal ration method as shown in the equation ii below.

$$p_x = \frac{N_x}{m} \left( \frac{p_1}{N_1} + \frac{p_2}{N_2} + \frac{p_3}{N_3} + \dots + \frac{p_m}{N_m} \right) \dots \dots \dots (ii)$$

Where  $N_1, N_2, N_3 \dots N_m$  are normal monthly rainfall and  $N_x$  is normal monthly rainfall at station  $x$  (Technical assistance hydrology project, 1999).

**2.5.2 Tests for consistency of rainfall records**

Inconsistency would arise in rainfall data at a rain gauge station if conditions relevant to recording of rainfall at the station undergo significant change during the period of record. Check for inconsistency of record is done by double mass analysis. According to James Searcy *et al.*, (1960), the theory of double – mass curve is based on the fact that a graph of cumulating of one quantity against the accumulation of another quantity during the same period will plot as a straight line so long as the data are proportional. The slope of the line will represent constant of proportionality between quantities. A break in the slope of double –mass curve means that a change in constant of proportionality between two variables has occurred or perhaps that the proportionality is not a constant at all rates of accumulation.

## **2.6 Reservoir Sizing**

Correct sizing of storage reservoir is critical in order to ensure that households or institutions have enough water stored to carry them through the dry season (International relief Development, 2013; Gathenya *et al.*, 2012). There are two parameters to consider in determination of size of the reservoir. The demand side approach is a basic calculation using consumption rates and number of users to estimate the largest storage size required. The second approach is the supply; this is a calculation of roof area, annual rainfall, run – off coefficient and percentage losses to know the likely supply that a tank will accommodate (African Development Bank, 2008; Ana, 2012; International relief development, 2013; Ziyadatal, 2015).

Rainwater tanks are available in concrete, plastic, fiberglass and galvanized steel. All are suitable, if material used are of food-grade standard (Commonwealth of Australia, 2010). According to commonwealth of Australia (2010), two common reasons for installing rainwater tanks are that they are a necessity in areas that are not served by main water, where supply is unreliable and to provide a source of water that can be used as an alternative.

## **2.7 Rainwater quality from roof catchments**

According to World Health Organization, rainwater is relatively free from impurities except those picked up by rain from the atmosphere, but the quality of rainwater decline during harvesting, storage and household use. Microbial contamination of collected rainwater indicated by E- coli is quite common,

particularly in samples collected shortly after rainfall. However, the occurrence of pathogens is generally lower in rainwater than in unprotected surface water (Hamer, 1961; [www.who.int/water-sanitation-health](http://www.who.int/water-sanitation-health), 2007). Higher microbial concentration is generally found in the first flush of rainwater and level of contamination reduces as rain continues (Carolina *et al.*, 2011). Table 1 shows WHO standards for drinking water.

**Table 1: World Health Organization Standards for Drinking Water**

Contaminant	Secondary standard
Chloride	250 MG/L
Copper	1.0 MG/L
Lead	0
Fluoride	2.0 MG/L
Iron	0.3 MG/L
Manganese	0.05 MG/L
PH	6.5-8.5
Sulphates	250 MG/L
Total dissolved solids	500 MG/L
Nitrates	50
Turbidity	01.0mg/l
E.coli	0
Coliforms	0
Zinc	5 MG/L

*(Source: United States Environmental Protection Agency/World health Organization, 2008)*

According to Olaoye *et al.*, (2012), who conducted research on rainwater quality, they found that all chemical properties conformed to recommended WHO standards. Coliform was absent from all samples collected from aluminum roofs. Asbestos, concrete and corrugated plastic roofs indicated presence of bacterial contamination. Gakungu (2013), did analysis of rainwater from roof catchments of corrugated Iron sheets, clay tiles and concrete tiles in Embakasi estates, Nairobi

County and concluded that E coli and coliform bacteria were not detected in any of the samples. The pH was within the recommended range of 6.5 – 8.5 (WHO, 2008). However, turbidity was above 1 Nephelometric Turbidity Units (NTU) but below 5 NTU which indicated that rainwater from those roofs cannot be used for potable purposes without treatment but it can be used for non- potable purposes such as washing and irrigation. According to Taha (2014), who conducted research in capital city of Sana'a, Turkey found out that all physical and chemical parameters were below the maximum values of WHO standards. However, turbidity results were close to maximum of WHO standards

### **2.7.1 Effects of chemical and physical properties on water uses**

The pH of a solution is a negative common logarithm of hydrogen ion activity:  $\text{pH} = -\log(\text{H}^+)$ . pH determines corrosiveness of water, the lower the pH the higher the level of corrosion. pH values greater than 11 or below 4 results in irritation of eyes, skin mucous membranes and gastrointestinal irritation. The pH should preferably be less than 8 for effective disinfection with chlorine (World Health Organization, 2012; American Public Health Association, 1989; United states protection Agency, 2007). Low pH causes corrosion in boiler systems.

Turbidity is a measure of water clarity where materials suspended in water decreases passage of light through water. Suspended materials include soil particles (clay, silt, and sand), algae, plankton, microbes, and other substances. These materials are typically in size range of 0.004 mm (clay) to 1.0 mm (sand). Turbidity can affect the color of water. Higher turbidity increases water

temperatures. This reduces the concentration of dissolved oxygen because warm water holds less dissolved oxygen than cold (EPA, 2007). Turbidity can provide food and shelter for pathogens. If not removed, turbidity can promote growth of pathogens in distribution systems, leading to waterborne disease outbreaks (United States Protection Agency, 2007).

Total coliform and E coli are not health threat in themselves but are used to indicate whether other potentially harmful bacteria may be present (World Health Organization, 2012). High level of chloride can cause eye/nose irritation or/and stomach discomfort while short term exposure to copper in water will cause gastrointestinal distress and long term will cause Liver or Kidney damages. Lead has an effect on infants and children's physical, mental development and kidney problems, high blood pressure, shortness of breath and blue – baby syndrome in adults (WHO, 2012).

## **2.8 Water bills and consumption in Nairobi County**

Nairobi City Water and Sewerage Company (NCWSC) deliver water through an increasing block tariff. The lowest charge is at a rate of Ksh 18.71 for per 10 first m<sup>3</sup>. The charges reach a maximum price of Ksh 53.80 per m<sup>3</sup>. In contrast, water kiosk charges for around Ksh 400 per m<sup>3</sup>, handcarts around Ksh 1000 per m<sup>3</sup> while tankers and private boreholes are more costly (Ledant *et al.*, 2010). Residents of well- off estates tend to consume 200 to 300 litres of water per day per capita (lpcd), while a slum dweller will typically use 15 lpcd. A middle class customer consumes a quantity of 130 (lpcd), the rest of city dwellers

consume less than 40 lpcd. WHO suggests that 40 lpcd is a decent amount to live a very simple life but even that is beyond the reach of some consumers in Nairobi (Ledant *et al.*, 2010; Moraa *et al.*, 2012). Nairobi Utility relies almost exclusively on surface water from Athi River basin, Tana River basin and over 3000 boreholes.

**Table 2: Surface Water Sources for Nairobi County**

Distance to Nairobi	Dam	Location	Year Completed	Yield m <sup>3</sup> /day
<b>60 Km</b>	Sasuma	Nyandarua	1968	52,800
<b>25 Km</b>	Ruiru	Githunguri	1950	22,000
<b>80 Km</b>	Ndakaini	Thika	1994	70,000
<b>10 Km</b>	Kikuyu	Kikuyu	1913	4,000
<b>36 Km</b>	Spring Thika	Gatundu North	1984	379,000

(Source: [www.nairobimetro.go.ke](http://www.nairobimetro.go.ke), 2012)

## 2.9 Cost-benefit Analysis of Rainwater harvesting systems

Cost implication of rainwater harvesting system involves initial capital and operation costs. The benefit that accrues are water saving that is same to City council water charges, surface water protection equal to developers obligation to the county's watershed management and flood risk reduction equal to the cost of sizing an onsite detention/ drainage system. Decentralized systems such as rainwater harvesting can greatly conserve public water supply if implemented on a large scale (Caitlin Grady *et al.*, 2008). According to Chanan *et al.*, (2007), Sustainable water management of the future is expected to be significantly different from traditional water management that focused on centralized systems to

meet water demand for urban areas and disposing storm water. Urban rainwater harvesting can enable tremendous urban growth (Julius J. R *et al.*, 2013).

### **2.10: Rainwater harvesting policies and laws**

Rainwater harvesting laws allows the capture of rainwater from roof catchments and ground before entering a natural system. After it has entered a natural system, a permit from regulatory body is required. Rainwater harvesting systems needs standardized designs, routine maintenance and regulatory classification in terms of rainwater uses and treatments (Russell *et al.* , 2014). The Kenya National Water Policy (2012) strives to enhance storm water management, rainwater harvesting and storage. It indicates inadequate strategies for rainwater harvesting and storage as a hindrance to adoption of rainwater harvesting in various locations. There are no policies for roof catchment rainwater harvesting for Nairobi City County despite acute water scarcity, heavy down pour and floods that cause damages.

### **2.11 Research Gaps**

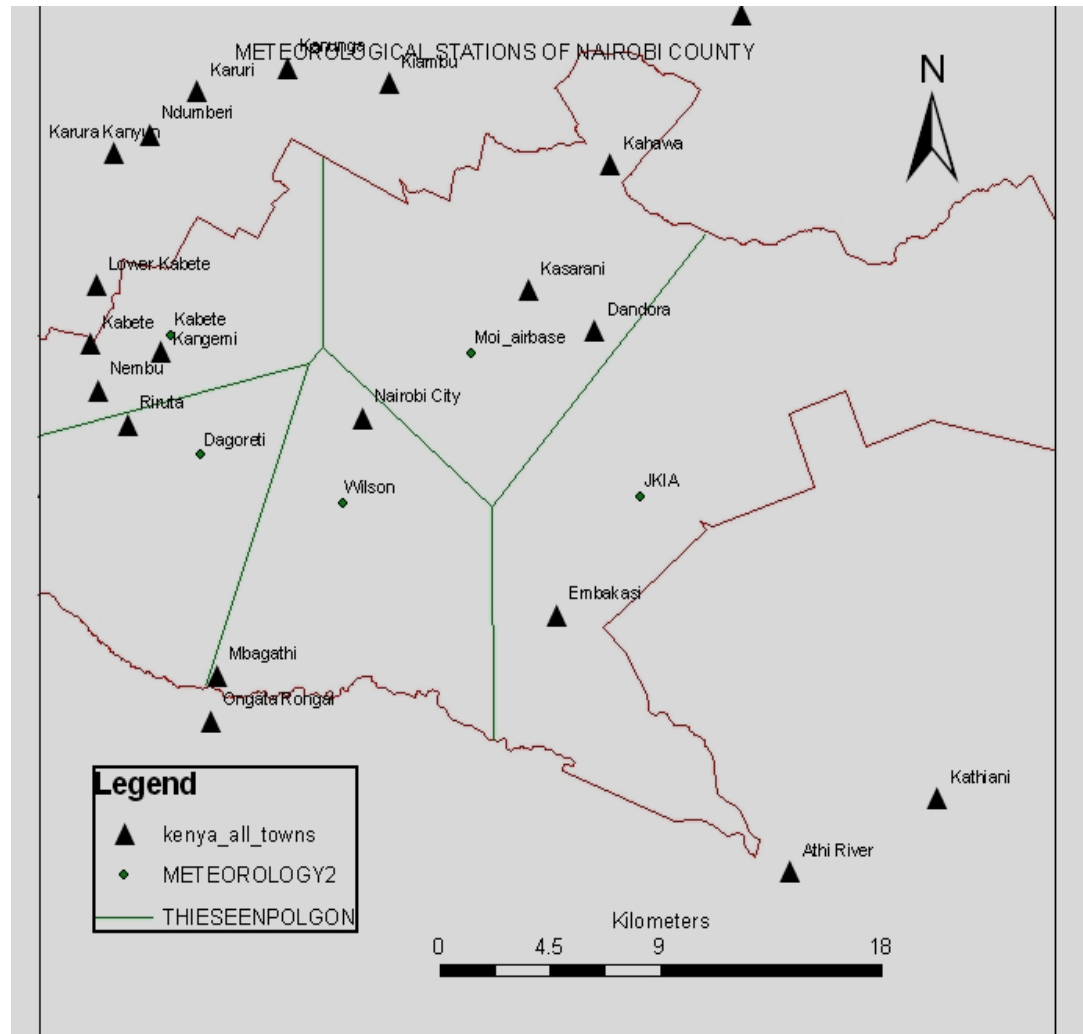
Nairobi City County is often flooded during heavy rains. Rainwater harvesting has been ignored. There are no published work on the amount of water, rainwater harvesting from roof catchments can contribute to conventional surface and ground water supply. This is why this study was conducted in order to generate information on amount of water that can be contributed from roof catchment rainwater harvesting at household levels, storage capacity required and possible uses.

## **CHAPTER THREE**

### **3.0 MATERIALS AND METHODS**

#### **3.1 Study area**

The study was conducted in Nairobi County which has an area of 684 km<sup>2</sup>. It is the capital city of Kenya with an altitude of 1798 m and average annual rainfall of about 900 mm, but the actual amount in any one year may vary from less than 500 mm to more than 1500 mm. There are two rainy seasons, from mid-March to the end of May (Long Rains), and from mid-October to mid-December (Short Rains). The dates on which these rainy seasons start and end are very variable; in fact the beginning and end of a wet season are seldom, if ever, well defined. This can be even more indefinite due to climate change which has affected the onset and lengths of rainfall worldwide (Wiley interdisciplinary Reviews, 2010; IPCC, 2007). The county has five meteorological weather stations that is, Kabete, JKIA, Moi Airbase, Wilson and Dagoreti as shown in figure 3.



**Figure 2: Thiessen Polygons of Five Meteorological Stations of Nairobi City County**

### 3.2 Rainwater harvesting from roof catchments

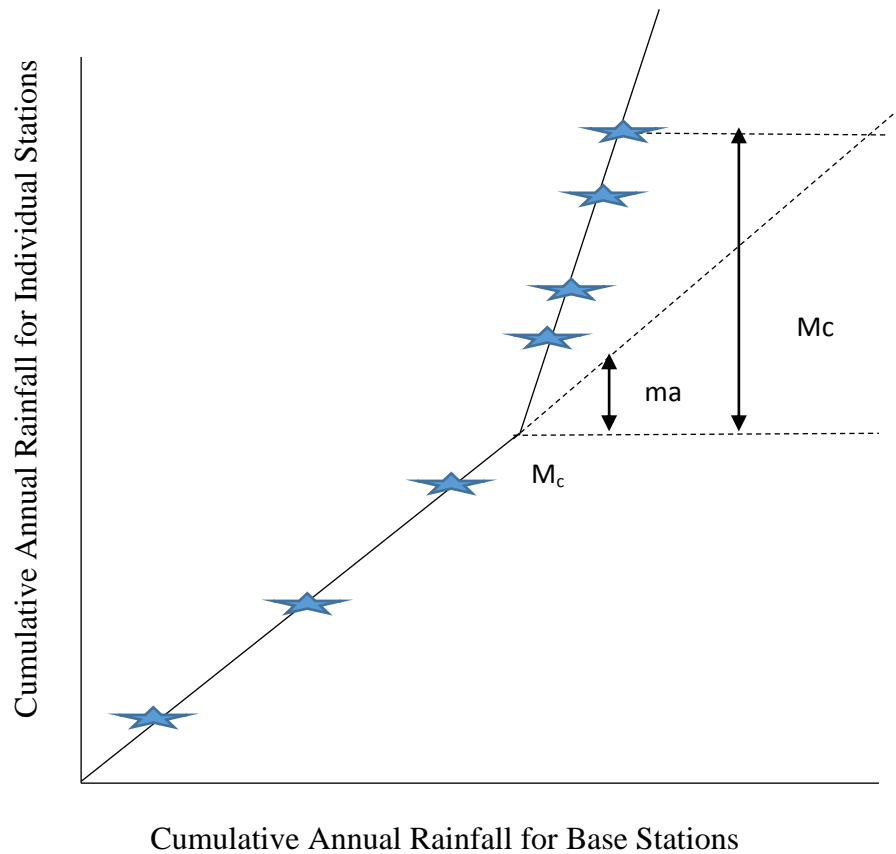
Using five meteorological rainfall stations within Nairobi County, five rainfall Thiessen polygons were constructed using ArcGIS version 9.2. A classification into Multi-story residential building, Bungalows/Maisonettes residential buildings, institutions and industries was done; this is because roof area and water demand varies in these types of buildings. Then, a convenience

sampling method was used to select 10 samples of maisonettes and multi-story buildings in each polygon, five institutions in each polygon and twenty five industries from industrial area which predominately fall in J.K.I.A meteorological polygon. A total of one hundred and fifty samples were obtained. A Germin GPS was used for locating sample positions.

Daily and monthly rainfall data for the stations were obtained from Kenya meteorological Department (KMD) for the last 31( 1981- 2012) years. The data was checked for consistence using double mass analysis curves before using it to calculate volume of water available for storage.

### **3.3 The check of consistence of rainfall data using Double Mass Curves**

Let  $x$  be the station where inconsistency in rainfall records is observed. Select a group of about 5 to 10 base station in the neighborhood of station  $x$ . Data of annual or monthly mean rainfall of station  $x$  as well as the average rainfall of the group of base stations over long time period is arranged in reverse chronological order i.e the latest record is the first entry and the oldest record is the last entry in the list. Accumulated precipitation at station  $x$  ( $\sum P_x$ ) and the accumulated values of the average precipitation of the group of base stations ( $\sum P_{cv}$ ) are computed from the latest records. A plot of ( $\sum P_x$ ) Vs ( $\sum P_{cv}$ ) for various consecutive time period is plotted.



**Figure 3: Consistence check using double mass curve**

A break in the slope of this plot indicates a change in the precipitation regime of station. Precipitation values at x beyond the period of change of regime are corrected as shown in question iii.

$$pcv = px \frac{mc}{ma} \dots\dots\dots(iii)$$

Where: **Pcv** is corrected precipitation at any time period at station **x**,

**Px** is original recorded rainfall for the time period at **x**

**Mc** is corrected slope of the double mass curve

**Ma** is original slope of the mass curve

### 3.4 Volume of Rainwater Available for Storage

$$Q = PxAc \dots\dots\dots (iv)$$

Where Q is Volume of water available for storage in litres per year

P is Annual rainfall in mm

A is Roof area in square meters and

C is coefficient of roofing materials (Jothiprakash et al 2009; Utsau R. Patel *et al.*, 2014 )

According to Brad (2006), the roofs were projected to horizontal surfaces to correctly estimate amount of rain that falls on the surface. Angled roof area was calculated by equation v.

$$A = l \times b \times \sin \theta \dots\dots\dots (v)$$

Other roof sections were calculated using the following formulas:

$$\text{parallelogram} = bh \dots\dots\dots (vi)$$

$$\text{trapezoidal} = \frac{b1 + b2}{2} h \dots\dots\dots (vii)$$

$$\text{Triangle} = \frac{1}{2} bh \dots\dots\dots (viii)$$

Where l is the length, b is the width and h is the height of the roof.

The run- off coefficients of roofing materials used are in Table 3.

**Table 3: Run- off Coefficient of roofing materials**

Type of roof surface	Run- off coefficient
Tiles	0.8-0.9
Corrugated metal sheets	0.7-0.9
Concrete	0.6-0.8

Source: Brad 2006

In this work; the average of 0.85, 0.8 and 0.7 were used for tiles, corrugated metal sheets and concrete roofs respectively.

### 3.5. Methods for determining Annual volume demanded per building

#### 3.5.1. Residential buildings

$$D = Nx80 \frac{l}{p} x365days \dots\dots\dots(ix)$$

(Otti *et al.*, 2013)

#### 3.4.2 Institutions

##### a) Churches

$$D = Nx20 \frac{l}{p} x104days \dots\dots\dots(x)$$

The 20 litres allocated to every member of the church is assumed to take care of cleaning the church, toilet flushing, irrigating flowers and any other functions. Two days were used to give highest possible volumes as most churches hold functions such as weddings and meetings in different days from main worship day.

##### b) Schools

$$D = Nx20 \frac{l}{p} x280days \dots\dots\dots(xi)$$

Assuming school days of 40 weeks /year. 20 litres per person (l/p) was used for day schools and 40 l/p for boarding schools.

##### c) Industries

$$D = \left( N x 20x \frac{l}{p} 365 days \right) + v \dots\dots\dots(xii)$$

Where N is Number of occupants in the building

D is Annual water demand

l/p is litres per person

v is volume used in industrial processes per year

### 3.6 Reservoir sizing

The size of storage tank required is a function of roof area, rainfall amounts in the region and household demand. In determining the size of storage tank required, both rainfall supply and household demand were considered (International Relief Development, 2013). According to rainfall patterns tableted in table 5, April and May received highest amount of rainfall as compared to other months. If percentage annual demand satisfied from rainwater harvesting is less than 100%, the size of reservoir has to harvest 90% of rainfall (Assuming a rainfall efficiency of 90% or 10% first flush allowance) during April and May so as to store water for later use in dry seasons (Ana, 2012; Sear Net Briefs, 2003; UNEP, 2011; United States Environmental Protection Agency, 2007; International Relief Development, 2013).

$$\text{Size of Reservoir} = \{0.9(\text{April} + \text{May Rainfall}) \times A \times C\} - Z \dots\dots\dots(xiii)$$

Where Z is a demand for one month

### 3.7 Cost Analysis

In this study only above ground Polyethylene (Plastic) reservoirs were considered because they are manufactured in Kenya in different sizes (International Relief Development, 2013). Prices were calculated assuming there was no storage tank already working and gutters and pipes were installed.

### **3.8 Water Samples Collection and Analysis**

Rainwater samples were collected from roof tops of corrugated iron sheets, clay tiles and concrete tile; from industrial and residential areas. The samples were collected during the month of October, November, April and May (short and long rainy seasons). They were kept in plastic containers that were thoroughly washed. Analysis was for physical, chemical and bacteriological content using standard methods for water analysis at KIRDI water laboratories. The pH, turbidity, Cl, F, Total suspended solids, and total dissolved solids, total hardness, SO<sub>4</sub>, Cu, Fe, Pb, Zn, Mg, E coli and coliform contents were analyzed. In addition, secondary data from published work was used to highlight in detail the quality of water from different roofing materials. The results were compared for compliance standards such as WHO for different usage.

#### **3.8.1 Testing Procedure for total hardness**

1 ml buffer solution and a dye indicator were added into 25 ml sample and titrated with 0.01 m EDTA until the colour changed from red to blue. Total hardness was calculated as shown on equation xiv

$$\text{Total Hardness} = \text{ml of EDTA} \times 1000 / \text{volume of sample used} \dots\dots\dots (\text{xiv})$$

#### **3.8.2 Determination of Total Solids (TS)**

A well-mixed sample of 50 ml was pipetted into a dish of known weight and evaporated to dryness in a drying oven. The evaporated sample was dried for at least one hour in an oven at 103 to 105<sup>0</sup>c, cooled in a desiccator to room

temperature and weighed. Cycles of drying, cooling and weighing were repeated until constant weight was obtained. Equation (xv) was used to determine total solids.

$$TS/l = (A - B) \times \frac{1000}{\text{sample volume}} \dots\dots\dots (xv)$$

Where A is total weight of the dish and dried sample, B is the weight of the dish and TS is total solids per litre.

**3.8.3 Determination of Total Dissolved Solids (TDS)**

A sample of 50 ml was filtered into a dry dish of known weighed. The filtrate was evaporated to dryness and dried for one hour in an oven at 180<sup>0</sup> c. It was cooled in a desiccators to room temperature and weighted. Cycles of drying, cooling, desiccating and weighing were repeated until a constant weight was obtained. Total solids were determined as shown in equation xvi.

$$TDS = (A - B) \times 1000 / \text{sample volume ml} \dots\dots\dots (xvi)$$

**3.8.4 Determination of Total Suspended Solids (TSS)**

Equation xvii was used to determine total suspended solids.

$$TSS = TS - TDS \dots\dots\dots (xvii)$$

**3.8.5 pH determination**

The water sample was stirred vigorously using clean glass stirring rod then let to stand for one hour to allow temperature to stabilize. The pH meter was standardized with buffer solution of pH 4 and 7. The electrode of pH meter was immersed into the water sample and allowed to stabilize. The value was recorded.

The electrode was then rinsed with distilled water and the procedure was repeated for other samples.

### 3.8.6 Determination of fluorides

A sample of 50 ml was filtered into a flask, 0.1 ml sodium arsenite and 1.0 ml zirconium acid were added into the sample. The solution was left for 20 minutes and the concentration was determined by comparison of reading with standard curve using a spectrophotometer at 420 nm, providing a light of 2.5 to 10 cm.

### 3.8.7 Test method for E coli and coliform

A 25 ml sample was pipetted into a vial with two nutrient – indicator. The samples were incubated in a Millipore single chamber field incubator, 240 V for 24 hours at 35 degrees Celsius. Yellow color change indicated total coliform contamination of greater or equal to 10 CFC /100 ml and yellow with blue fluorescence under a UV lamp indicates E . Coli contamination of greater or equal to 10 CFC/100 ml. E. coli can be compared to determine risk level as indicated in the table 4.

**Table 4: E. coli and Coliform detection in water**

<b>Risk</b>	<b>E. coli in sample CFC /100ml</b>	<b>E coli result</b>
<b>Confirm</b>	< 1	Negative below detection)
<b>Low</b>	1 to 10	Negative below detection)
<b>Intermediate</b>	1 to 100	Positive blue fluorescence)
<b>High</b>	100 to 1000	Positive blue Fluorescence)
<b>Very High</b>	>1000	Positive blue fluorescence)

(Source: WHO 1997)

### **3.8.8 Determination of Lead**

A Varian atomic absorption spectrometer equipped with a deuterium background correcting system was used for determination of lead concentration. It involved a Varian standard premixed – air – acetylene burner and a Varian hollow cathode lamp (Perkin, 1996). A 50 ml of water sample was transferred into a beaker and the pH adjusted with hydrochloric acid. The mixture was digested in a sand bath for about 1 hour, cooled to room temperature. The digested sample was filtered into 250 ml volumetric flask and filled to mark. Then, allowed to stand for 12 hours, lead level read by atomic absorption spectrometer and result compared against standard curves for lead.

### **3.9 Interview Schedule**

Interview schedules were conducted to institutions, industries and residential buildings. It gathered information on type of roofing materials, sources of water, adoption of rainwater harvesting, storage capacities in use and challenges facing rainwater harvesting. The responses to questions were: 1 – strongly disagree, 2 – Disagree, 3 – Neutral, 4 - agree and 5 – Strongly agree.

### **3.10 Data Analysis**

The data was analyzed using Excel 2007 and SPSS version 22 Programs. Annual and monthly averages for 31 (1981- 2012) years were done. Descriptive analysis such as maximum, minimum, means, standard deviations and percentages of volume of rainwater available for storage in different classes of buildings and meteorological stations were computed. Models for determining storage tanks and

their cost per meteorological station were generated using correlation and regression analysis. The suitability of rainwater qualities from roof catchments were compared with World Health Organization Standards for potable water. A detailed description of type of roofing materials, sources of water, adoption of rainwater harvesting, storage capacities in use and challenges facing rainwater harvesting per class of building was analyzed.

## **CHAPTER FOUR**

### **4.0 RESULTS AND DISCUSSIONS**

#### **4.1 Overview of Results and Discussions Presentations**

The results and discussions of this study are presented as follows: Rainfall validation and volume of water harvested in section 4.2; size of storage capacities and cost in section 4.3; rain water quality in section 4.4 and results from interview schedules in section 4.5, sources of water and contribution of rainwater harvesting in section 4.6.

#### **4.2 Rainfall Data Validation**

A consistence check was done using double mass analysis curves, the data was found to be consistent for Kabete, Dagoretti, Eastleigh Moi Airbase and Wilson as shown in appendix II. However, a break in the plot for more than five years was indicated for J.K.I.A station and it was corrected using equation iii, page 21, which increased average annual rainfall from 755 mm to 818 mm.

##### **4.2.1 Rainfall Amounts**

The monthly average for 31 years (1981-2012) was computed for all stations and tabulated in Table 5. The average was used to predict monthly and annual volume of rainwater available for harvesting from different meteorological stations in Nairobi City County. It was found that Kabete is the most wetted area with an annual average of 1085 mm of rainfall, followed by Dagoretti 1031 mm, Eastleigh Moi Airbase 926 mm, Wilson 912 mm and J.K.I.A station is the driest area with an annual average of 818 mm. April receives the highest amount of rainfall in all

meteorological stations followed by May and November, respectively as shown in Table 5. Similar findings were observed by other studies (Munene et al., 2012; Opijah *et al.*, 2007).

**Table 5: Monthly average rainfall in mm for 31 years for Meteorological Stations in Nairobi County**

<b>Month</b>	<b>J.K.I.A</b>	<b>Wilson</b>	<b>Moi Airbase</b>	<b>Dagoretti</b>	<b>Kabete</b>	<b>Monthly Averages</b>
J	55	69	<b>63</b>	66	63	<b>63.2</b>
F	38	37	41	51	50	<b>43.4</b>
M	72	93	89	91	97	<b>88.4</b>
A	129	180	186	213	238	<b>189.2</b>
M	123	142	148	175	179	<b>153.4</b>
J	23	37	35	38	38	<b>34.2</b>
J	10	21	16	16	18	<b>16.2</b>
A	13	18	38	23	24	<b>23.2</b>
S	15	19	19	24	29	<b>21.2</b>
O	55	66	62	78	83	<b>68.8</b>
N	140	136	136	154	162	<b>145.6</b>
D	82	94	93	102	104	<b>95</b>
Maximum	140	180	186	213	238	<b>189.2</b>
Minimum	10	18	16	16	18	<b>16.5</b>
<b>Annual Average</b>	<b>818</b>	<b>912</b>	<b>926</b>	<b>1031</b>	<b>1085</b>	<b>941.8</b>

#### **4.2.2: Percentage water demand satisfied per building from roof catchment rainwater harvesting**

The results shown in Table 6 are measurements of water demand satisfied by harvesting rainwater from different buildings in different meteorological stations. A 10% of rain was deducted from annual rainfall. This was assumed to be the first flush that is recommended for cleaning roofing and piping surfaces. Pollutants such as dust, bird droppings, leaves and dead insect accumulate on roof surfaces

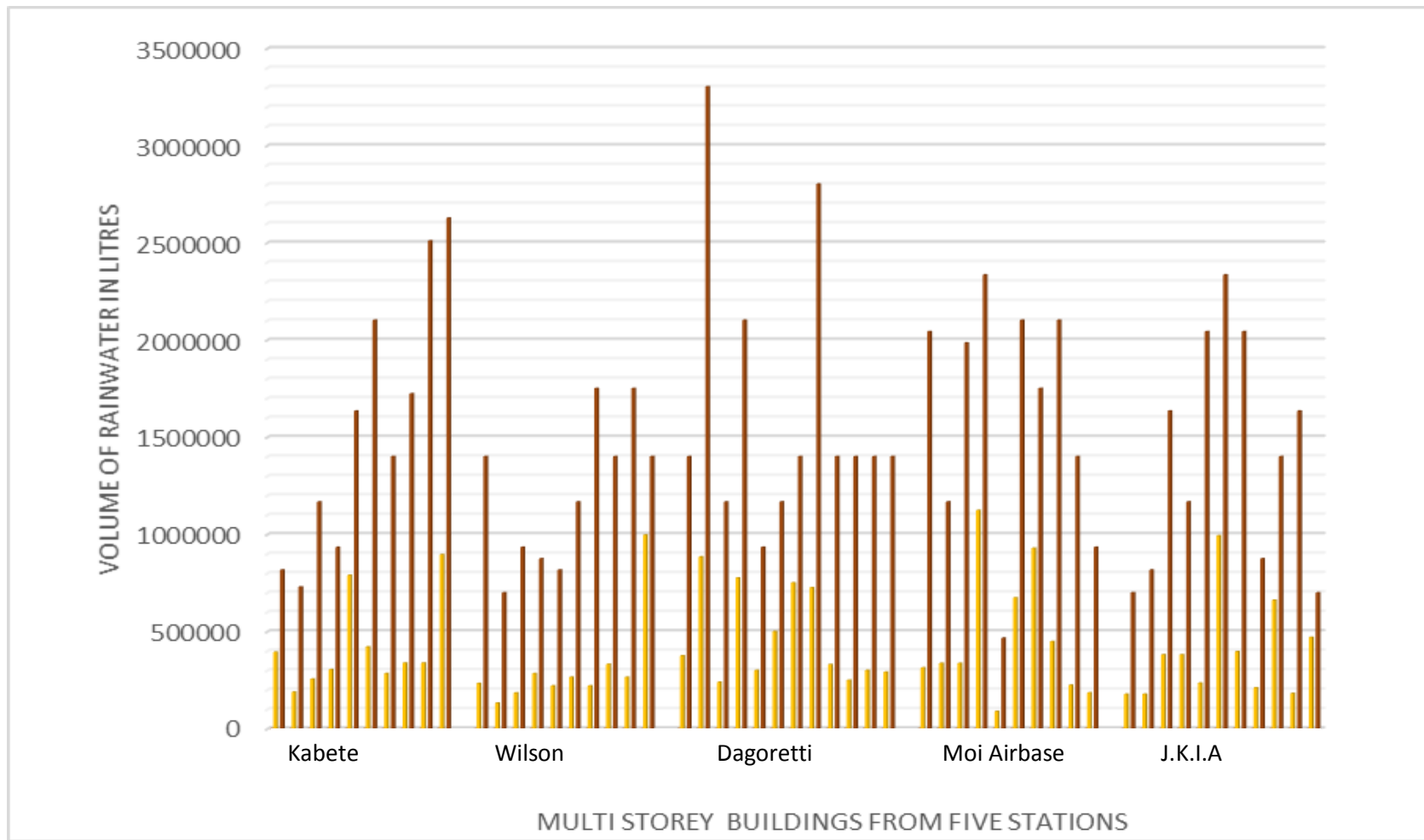
during dry weather. These pollutants can be carried to the tank reducing water quality (Kelly Doyle, 2006; Justin Keith, 2009). Then, 90% of average volume of rainwater available for harvesting from different stations was used to calculate rainwater to be harvested. The results shows total samples per type of building, number of samples that are above 23% of water supply deficit encountered in Nairobi County (Athi Water Services Board, 2012), recorded as maximum, minimum, mean and standard deviation in percentages.

**Table 6: Percentage Water Demand Satisfied from rainwater harvesting from different roof catchments of buildings.**

PERCENTAGES							
Meteorological Station	Building	f	No above 23%	Max	Min	Mean	Std dev
<b>Kabete</b>	Maisonettes	10	10	132	84	130	67.4
	Multi-story	10	6	48	13	28	12.4
<b>Wilson</b>	Maisonettes	10	10	126	61	86.3	22.2
	Multi-story	10	5	71	12	25.9	16.9
<b>Dagoretti</b>	Maisonettes	10	10	155	69	114.5	52.4
	Multi-story	10	8	54	18	29	10.7
<b>Eastleigh</b>	Maisonettes	10	12	135	61	78.8	19.2
<b>Moi Airbase</b>	Multi-story	10	5	53	18	27	12.9
<b>J.K.I.A</b>	Maisonettes	10	11	85	51	60.3	11.7
	Multi-story	10	7	37	11	30.5	16.6
	Industries	25	25	842	30	215.5	186.7
	Institutions	25	25	327	30	122.5	75.9

(*F: Frequency*)

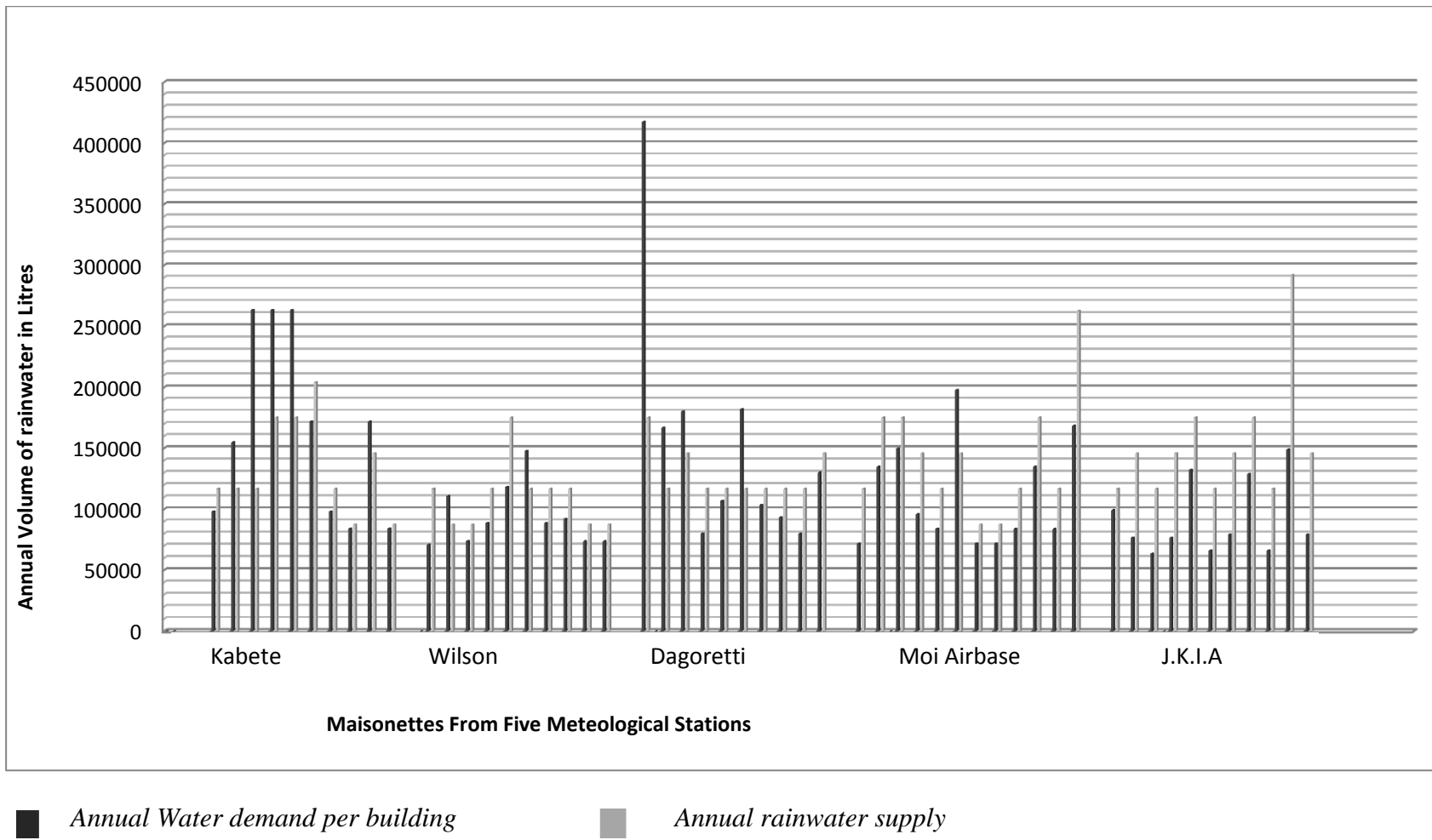
Majority of residents (90%), will offset the daily deficit of 23% as shown in the difference between column three and four above. This is the daily deficit for Nairobi County that had been estimated by Athi River services board, Annual report of 2012.



*Annual Rainwater Supply per Building*
 *Annual water Demand*

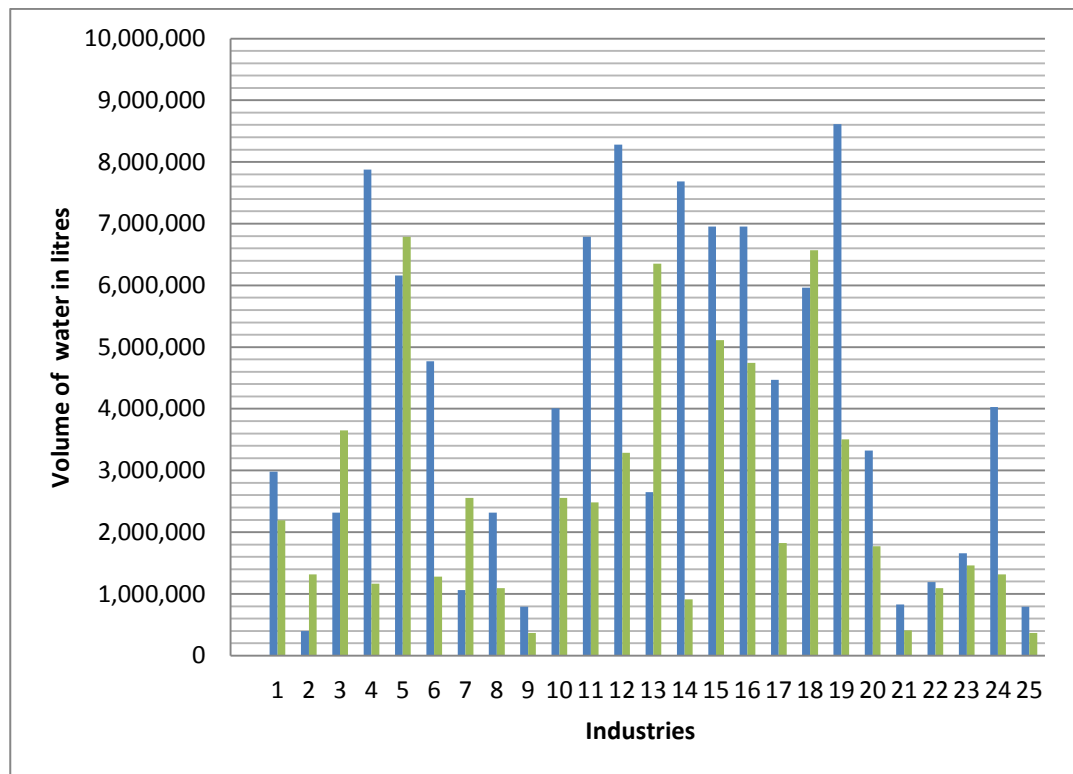
**Figure 4: Rainwater supply and annual water demand per multi-story Building**

Rainwater supply for Multi story buildings was mostly below 50% of water demand. The buildings that are above 50% of rainwater supply are only 7.5%, while 11.3 % lies between 40% - 50%, 15.1% between 30% – 39%, 37.7 % between 20% - 29% and the remaining 28.3% between 10% -19%. Water demand that would be satisfied by rainwater harvesting in multi-story buildings is less compared to Maisonettes, Institutions and Industries. This is due to large sizes of occupants (water demand) and small size of roof catchments. However, roof catchment rainwater harvesting can save on water supply if implemented on large scale (African development Bank, 2008; Chanan et al., 2007).



**Figure 5: Rainwater supply and annual water demand for Maisonettes**

Rainwater supply above the occupants’ demand for maisonette buildings would be 23%. While 30.7% lies between 80% – 99% and all maisonettes within Kabete Meteorological station were above 84% in demand met by roof catchment rainwater supply. The other, 18.8% lies between 70% - 79%, 11.5% between 60% - 69% and 15.4% which are all within J.K.I.A meteorological station lies between 50% – 59% in total demand met by roof catchment rainwater supply.

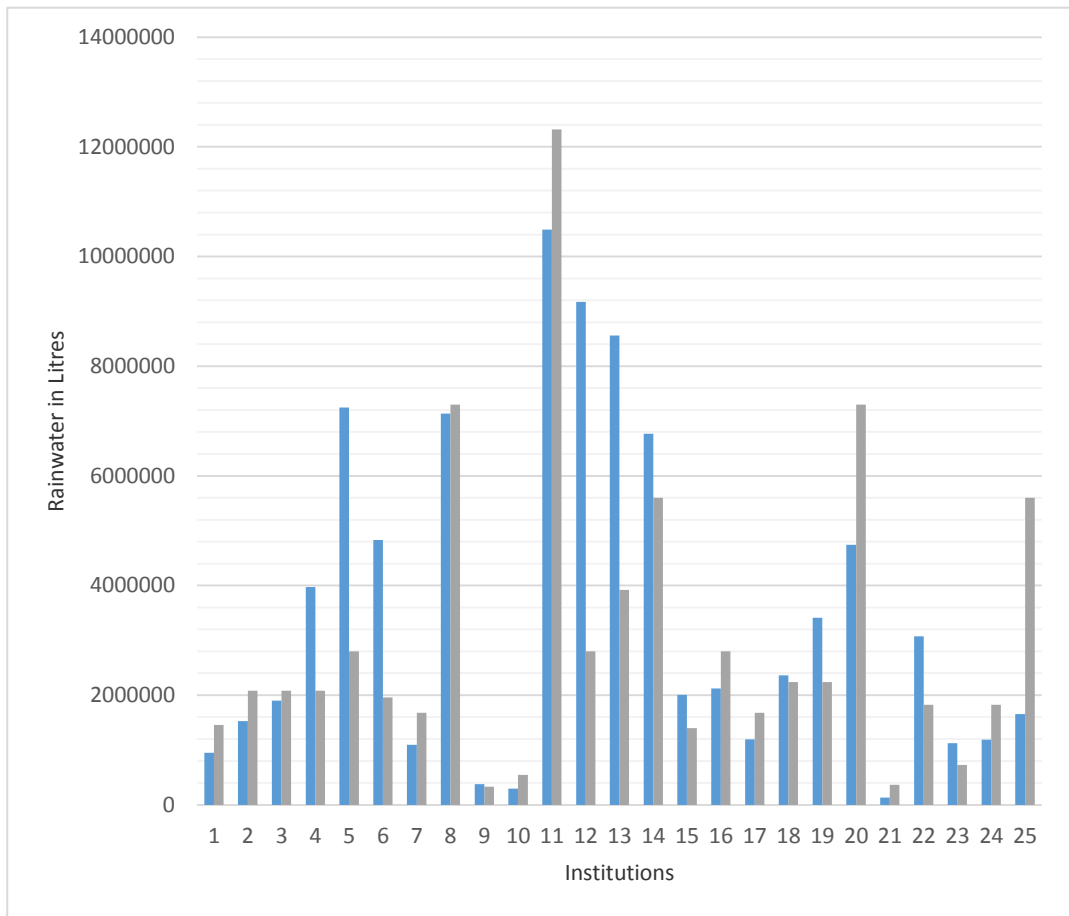


■ *Rainwater Supply*      ■ *Industry Water Demand*

**Figure 6: Rainwater supply and annual water demand per Industry**

Majority of industries, (76%) would meet their water demand from roof catchment rainwater harvesting. These industries have large sizes of roofs that

would capture more water than their demand. The other, 8% has between 90% - 99% which is impressive. A small percentage (16%) lies below 90% of water demand that would be satisfied by roof catchment rainwater harvesting.



■ Annual rainwater supply per Institution ■ water demand per Institution.

**Figure 7: Rainwater supply and annual water demand per Institution**

Rainwater supply above institution’s water demand was 48%. On the other hand, 24% of these institutions had a rainwater supply lying between 70% - 100%; a 20% between 50% - 69% and the other 8% between 30% - 49%.

#### **4.2.3 Volume of Water Contributed from Roof Catchments**

Maisonettes residential buildings within Kabete and Dagoretti meteorological stations indicated a mean of 130% and 114%, respectively of rain water available for storage. This means residents can solely depend on rainwater harvesting from rooftops as source of water. Maisonettes from Wilson, Eastleigh Moi Airbase and J.K.I.A indicated a mean of between 60% – 86%. This means that they will require a small percentage of water supplements from other sources. However, Multi-story buildings had a mean of between 25% - 30% which were above 23% and therefore, one can say the deficit encountered of 23% from surface and borehole supplies can be offset by roof top rainwater harvesting rainwater (Athi water services Board, 2012). A similar study by Otti et al., (2013) indicated that wide adoption of rainwater can reduce water shortage, which agrees with the findings of this study.

Industries and Institutions had means of 215% and 122%, respectively which were above the demand of many industries and Institutions. Industries and institutions can harvest rainwater from roof catchments and meet their demand wholly. A similar study by Arun Kumar *et al.*, (2013) indicates that rainwater harvesting provides enough water for an Educational complex. Also, a study by Sample et al., (2013), suggests that industries and institutions can benefit more from rainwater harvesting than residential areas which is also indicated in this study. Additionally, roof catchment rainwater harvesting reduces stress on critical water supplies such as underground and surface water sources (Colorado Water

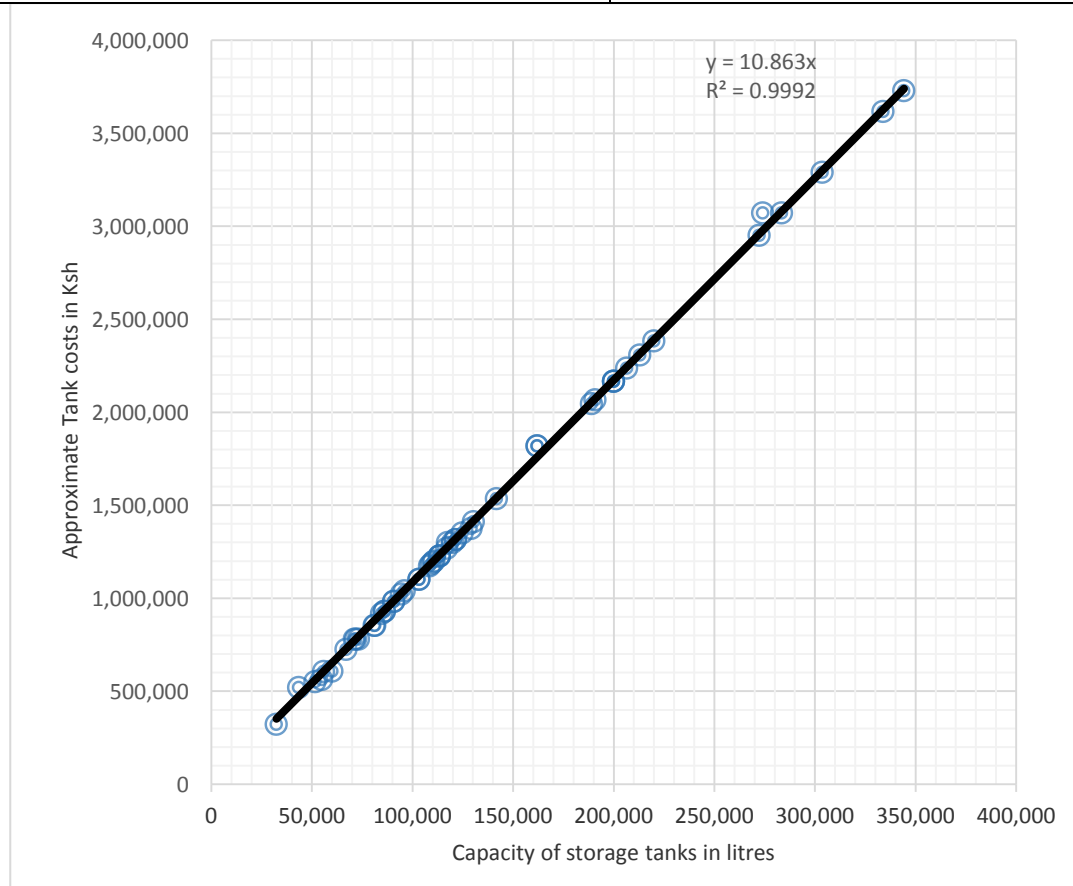
conservation board, 2010; IRD, 2013; Noah *et al.*, 2011). The results for Nairobi County indicate that roof catchment rainwater harvesting will increase supply to future projected demands. This would relieve land that can be used for food production instead of centralized dams at the outskirts of the city that occupies land that would otherwise be used for agriculture. Large scale rainwater harvesting can also decrease seasonal flooding in urban areas. (Chanan *et al*, 2007; Farzan .S, 2007; Noah. G *et al*, 2011; UNEP, 2011).

#### **4.3 Size and cost of Reservoirs**

The size storage tank required for maisonettes ranged from 5,126 - 60,840 litres while multi story buildings, it ranged from 32,400 – 344,250 litres as tabulated in Appendices 4. The results of Appendices 4 were used to compute Pearson product moment of correlation coefficient and regression equations for five meteorological stations, where y is storage tank in litres and x is roof area in square metres. Storage tank has a positive relationship with roof area. The models are shown in Table 7 below.

**Table 7: Pearson product moment of correlation coefficient and regression equations for storage reservoirs**

Stations	r	Regression Equations	
		Maisonettes	Multi-story Buildings
Kabete	0.97	$y = 293x - 5081$	0.98 $y = 349.7x - 14.41$
Wilson	0.97	$y = 253.5x - 4870$	0.99 $y = 180.6x + 33779$
Dagoretti	0.99	$y = 326x - 10835$	0.96 $y = 278.2x + 13329$
Moi Airbase	0.97	$y = 224.8x - 5428$	0.91 $y = 122.6x + 53918$
J.K.I.A	0.97	$y = 211x - 12644$	0.96 $y = 144.6x + 20726$



**Figure 8: Approximate costs of plastic tanks**

The graph above indicates capacity and approximate cost of plastic tanks for water storage. Using regression equations in Table 7, capacity of storage tanks is determined after establishing roof area of the building. The size of storage tank is  $x$  in Fig 8, solving the equation  $y = 10.863x$  will determine approximate cost of above ground plastic tanks in Kenya Shillings. Discounted tables will give past, present or future values.

The capacity of above ground storage tanks manufactured in Kenya ranged from as little as 500 litres to a maximum of 24,000 litres per unit. Their diameters were from 86 cm to 356 cm and a height of 103 cm to 280 cm respectively as indicated in Appendix IV. The maisonettes buildings had an estimated cost of the reservoir ranging from Ksh 35,000 – Ksh 595,000 while multi-story buildings it ranged from Ksh 87,750 – Ksh 3,729,375 as shown in Appendix V.

The purpose of size and cost of storage tank models is to assist engineers, designers, plumbers, builders, government, donors and users in determination of size and cost of tanks for a particular building.

#### **4.3.1 Challenges facing rainwater storage facilities in Nairobi County**

Gabe *et al.*, (2012), did a research in the largest City of New Zealand on perception of rainwater harvesting tank size. He found out that residents who installed above-ground rainwater tanks described the system as inefficient use of land. It would be good if the size of the tank would be reduced. According to an interview schedule conducted in this study, most residents were not harvesting

rainwater due to lack of storage reservoirs. The ones who harvested, their reservoir capacities were far below rainwater supply and/or household water demand.

Constructing or buying a rainwater storage reservoir is a costly venture in rainwater harvesting system (International Relief Development, 2013). This is a major cause why, many residents in Nairobi are not harvesting rainwater from their rooftops. These findings are similar to a study conducted by Jothiprakash et al., (2009) for an industrial area which estimated the cost of the tank as prohibitive. The benefit that accrues are water saving that is equal to city council water rates, surface water protection equal to developers obligation to county's watershed management and flood risk reduction equal to cost of sizing an onsite detention/drainage system(Caitlin. G *et al.*, 2008). The cost of tanks for maisonettes and some multi-story buildings might be affordable to most residents in Nairobi.

#### **4.4 The Quality of Rainwater from Roof Catchments**

Water samples were analyzed for physical, chemical and bacteriological content. E coli and coliform bacteria were not detected in any of the samples. The pH levels of water harvested from corrugated Iron sheets and clay tiles, sampled in high density residential areas were 5.8 and 6.1, respectively which were below World Health Organization (WHO) standards for drinking water. The slightly acidic behavior of this water could be probably because of carbon dioxide generated from these high density populated areas, which reacts with rain water to form carbonic acid that is a weak acid. However, the pH levels of water sampled from industrial areas and low density residential areas were 7.30 and 7.10,

respectively, a slightly alkaline behavior. This pH levels lies within tolerable WHO standards for potable water.

Turbidity was close to 1 NTU in samples from industrial area roofs but within WHO standards for samples from residential area roofs. Unfortunately, lead was detected in rainwater from industrial areas and nearby residential buildings. This might have originated from emissions from industries or corrosion of rainwater piping (EPA, 2011). Nevertheless, all other water samples parameters were within tolerable WHO standards for potable water. Due to detection of lead, high turbidity and low pH in some samples, rainwater from roof catchments can only be suitable for non- potable purposes such as laundry, toilet flushing, general cleaning, industrial cooling and irrigation. Table 8 and 9 shows chemical, physical, bacteriological analysis and WHO standards, respectively.

**Table 8: Chemical Analysis of Rainwater**

PARAMETER	RESULTS					WHO Guidelines
	Units	Industrial Area Sheets	High density residential areas Iron Sheets	Low density residential area, Concrete tiles	High density residential areas clay tiles	
Chloride Cl <sup>-</sup>	mg/l	ND	ND	ND	6.99	250
Fluorides	mg/l	0.6	0.4	0.45	0.45	1.5
Total Hardness	mg/l	6	14	16	32	
Sulphates	mg/l	2.3	0.55	2.15	5.45	250
Copper	mg/l	ND	ND	ND	0.14	2.0
Iron Fe	mg/l	0.53	2.65	0.61	0.18	0.3
Lead Pb	mg/l	0.27	ND	0.57	ND	0.01
Zinc Zn	mg/l	0.25	0.89	0.65	ND	5.0
Magnesium	mg/l	11.94	1.80	15.75	2.54	0.4
Nitrates No <sup>3+</sup>	mg/l	1.7	2.45	1.1	0.15	50
pH	mg/l	7.30@ 22 <sup>0</sup> c	5.8 24 <sup>0</sup> c	@ 22 <sup>0</sup> c	7.10@ 25 <sup>0</sup> c	6.01@ 25 <sup>0</sup> c

(ND: Not Detected) (@: at)

**Table 9: Physical and Bacteriological Analysis of Rainwater**

Parameter	Results Units					WHO Guideline for drinking water
		Industrial Area Corrugated Iron Sheets	High density residential areas Corrugated Iron Sheets	Low density residential areas, Concrete tiles	High density residential areas clay tiles	
Turbidity	NTU	0.98	0.43	0.72	0.32	1.0
Total Suspended solids	mg/l	176.25	66	27.5	35	
Total Dissolved solid	mg/l	153.75	40	20	210	500
E. coli	MPN/100ml	ND	ND	ND	ND	0
Coliforms	MPN/100ml	ND	ND	ND	ND	0

(ND: Not detected) (NTU: Nephelometric Turbidity Unit)

According to Gabe *et al.*, (2012), poor rainwater quality deterred its use by most residents in New Zealand city, they considered rainwater from roof tops of buildings as dirty. This belief is also with Nairobi residents as the ones who harvested rainwater from roof catchments (16%), used it for non – potable purposes. Rainwater quality analysis by several researchers (Carolina *et al.*, 2010; Gakungu, 2013; Olaoye *et al.*, 2012; Thamer M *et al.*, 2010) from different cities has proved that it cannot be used for potable purposes without treatment. The findings of this research on rainwater quality conquered with the findings of above researchers. According to Noah *et al.*, (2011), total non -potable indoor and outdoor water uses is typically 78.3 % for domestic and 86% for office buildings. This is a good indication for harvesting rainwater because the uses would be very high.

#### **4.5 Interview Schedule Analysis**

Interview schedules were conducted to institutions, industries and residential buildings, below are the findings.

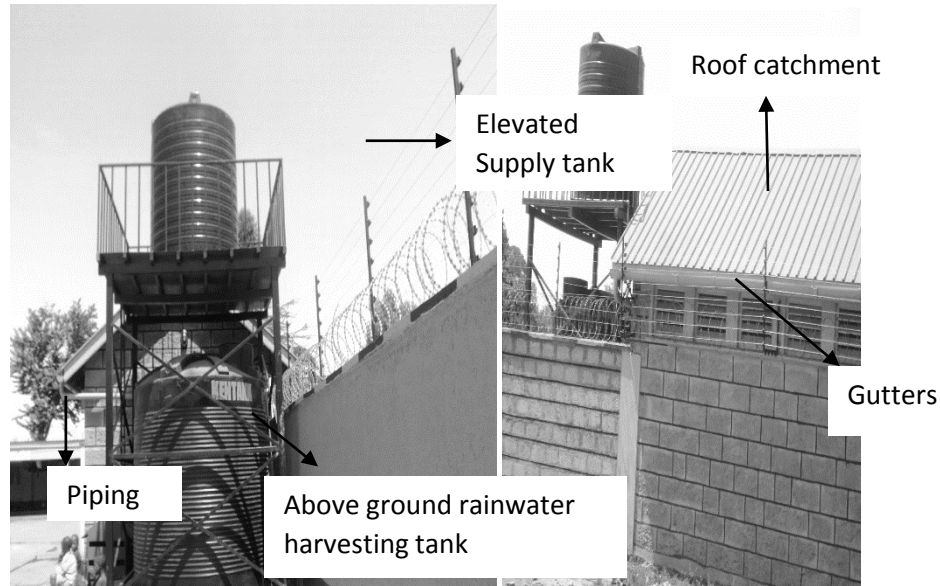
##### **4.5.1 Institutions**

These were mainly schools and churches. Roofing materials were corrugated iron sheets that were 72%, followed by clay tiles 24% and others were 4%. The source of water varied as indicated in table 10. About 48% of the institution relied on city council piped water and only 44% had roof catchment rainwater harvesting.

The uses of water for institutions was mostly for non-portable purposes such as cleaning floors, flushing toilets, watering plants and recharging swimming pools; rarely was it used for food preparation or drinking. Majority of institution considered the source of water as reliable. In case of shortages they used stored water from their reservoirs, skipped regular chores that used water such as cleaning, bought water from nearby boreholes, tankers or handcarts.

The ones that harvested rainwater from roof catchments, 82% used above ground plastic tanks for storage while, 18% used underground concrete tanks. The sizes of these storage tanks were in the range of 20000, 24000, 30000, 40000, 48000 and 100000 litres. In all of the samples, the tanks would serve the users for one week, one month or two months. The uses of rainwater from roof catchments was mainly for cleaning floors, flushing toilets, watering plants, washing cloths and bathing. A 66% of these institutions were satisfied with their rainwater harvesting system, 34% were not satisfied. Majority of institutions used their own money to finance rainwater harvesting systems, the others used donations. There were no reported diseases associated with water usage in any of the institutions.

When asked the need for roof catchment rainwater harvesting, the respondents recommended rainwater to be harvested in Nairobi County. In order to supplement borehole and surface water supplies, reduce the cost of operations, reduce flooding, mitigate water theft along the pipelines and reduce competition for water resources.



**Plate 1: Above ground rainwater reservoirs in a public swimming pool/school in Nairobi County.**



**Plate 2: Improved mechanism for rainwater harvesting by a church in Embakasi; from left is the piping system followed by an underground concrete storage reservoir.**

Plate 3 indicates satisfying water harvesting structure with a harvesting tank and elevated supply tank for a toilet facility in a public school while plate 4 indicates unsatisfying system. The two plates give a preview of technology needs for roof top rainwater harvesting. According to Utsau *et al.*, (2014) who did

research in a SPSU campus in India, rainwater harvesting from roof catchments met water demand for students in the campus. This agrees with this study because the mean volumes analyzed are above the demand for most institutional buildings. This requires institutions to increase the adoption of roof catchment rainwater harvesting than relying on surface and ground water sources.

#### **4.5.2. Industries.**

Industries analyzed were metal products manufacturing, Agro chemical and food processing, warehouses/dispatch and transport. The type of roofing materials were corrugated iron sheets (84%), clay tiles (12%) and others (4%). Major sources of water were city council piped water 76%, and only 4% did roof catchment rainwater harvesting as indicated in table 10.

About 88% of these industries indicated that the sources of water were reliable while 12%, their source was unreliable. The major uses of water was for boiler operation, cleaning floors and equipment, chemical and food processing, cooling and irrigating flowers. All industries had a reservoir for storing water for use in times of water cut off from main supplies.

#### **4.5.3 Maisonettes**

The type of roofing materials for this type of building was majorly clay tile (72%), corrugated iron sheets (12%), concrete tiles (12%) and others were 6%. The source of water differed with city council piped water leading (56%) and only 20% harvested rainwater. Table 10 indicates sources of water for maisonettes

About 72% indicated that water sources were reliable, while 28 % said that they were not reliable at all. In times of shortages, 55% of the residents bought water from vendors such as water tankers or handcarts while 36% used water from their own reservoirs that had been stored for water shortage sessions. The others either recycled or minimized usage. A number of residents, (30%) used water for irrigating kitchen gardens, green houses or flowers.

The ones who harvested rainwater (20%) from roof catchments, 44% used above ground plastic storage tanks while 56% used underground concrete tanks. The capacities were; 1000, 1200, 5000, 10,000, 20,000 and 24,000 litres. The tank would serve the occupants for a period of one week, one month or two months. The uses of rainwater from roof catchments was mainly for laundry, flushing toilets, irrigating plants (non-potable uses) and some used it for all domestic chores. A 77%, were satisfied with their rainwater harvesting system, the other 23% were not satisfied. Majority of them (88%), used their own money, 12% used money from loans to finance storage reservoirs. There were no diseases associated with water usage in any of the maisonettes buildings.

#### **4.5.4. Multi-story buildings**

The type of roofing materials in this type of buildings was corrugated iron sheets (50%), clay tiles (36%), Aluminum sheets (6%), concrete tiles (2%) and others 6%. The sources of water used were from different sources with city council piped water leading (50%) and only 6% harvesting rainwater. Table 10 shows sources of water for multi-story buildings.

Most buildings in this category indicated that water sources were not reliable at all (46%), a higher rate than any type of building highlighted. A 54% had a reliable water source throughout the year. Majority of those who experienced water shortages bought water from water tankers or handcart vendors (60%), while others used water from their reservoirs. Rainwater harvesting from rooftops were very low (6%). The kind of storage reservoir used was underground concrete tank of capacities 1000, 1,500 and 5000 litres, having been financed by builders own money. Water from these reservoirs would serve residents within a week. The harvesting systems were satisfactory and there were no diseases associated with rainwater usage although, some used it for all domestic chores.

**Table 10: Sources of water for Institutions, Industries, Maisonettes and multi-story buildings**

	Source of water	Institutions		Industry		Maisonettes		Multi-story	
		f	%	f	%	f	%	f	%
1	City council	12	<b>48</b>	19	<b>76</b>	28	<b>56</b>	25	<b>50</b>
2	Private borehole, city council, and roof top rain catchment	3	<b>12</b>	0	<b>0</b>	1	<b>2</b>	0	<b>0</b>
3	City council and Roof top rain catchment	8	<b>32</b>	1	<b>4</b>	8	<b>16</b>	3	<b>6</b>
4	Private borehole and city council	2	<b>8</b>	5	<b>20</b>	9	<b>18</b>	15	<b>30</b>
5	Private borehole and roof top rain catchment	0	<b>0</b>	0	<b>0</b>	1	<b>2</b>	0	<b>0</b>
6	Private borehole only	0	<b>0</b>	0	<b>0</b>	3	<b>6</b>	7	<b>14</b>
	<b>Total</b>	25	<b>100</b>	25	<b>100</b>	50	<b>100</b>	50	<b>100</b>

(f: frequency ) (%: Percentage)

#### 4.5.5 Challenges facing roof catchment rainwater harvesting.

Assessment of perception, and challenges of roof –catchment rainwater harvesting in Nairobi County was conducted where responses to the questions were: 1 – strongly disagree 2 – Disagree 3 – Neutral 4 - agree and 5 – Strongly agree. The results are as shown in table 14 in terms of frequency (F), Maximum, Minimum, Mean and Standard deviation.

**Table 10: Perception and challenges of roof catchment rainwater harvesting**

	F	Max	Min	Mean	Std dev
<b>i</b> No storage tank	122	5	1	3.24	1.28
<b>ii</b> Pipe water is reliable	124	4	1	1.94	0.877
<b>iii</b> There is no space to install a tank	121	4	1	1.83	0.69
<b>iv</b> It is costly to install a rainwater harvesting system	123	5	1	1.97	0.71
<b>v</b> The city council does not allow rainwater harvesting	121	5	1	2.21	0.92
<b>vi</b> Rainwater harvesting system was not included in the initial planning or architectural design	120	5	1	3.97	1.04
<b>The following might be causes of flooding in Nairobi City</b>					
<b>i</b> No drainage system	92	5	1	3.1	1.11
<b>ii</b> The drainage system is there but it blocks during heavy rains	128	5	1	4.0	0.95
<b>Perception of Roof top Rainwater Harvesting in Nairobi</b>					
<b>i</b> Rainwater harvesting in Nairobi will increase water quantity and sanitation	142	5	1	4.23	0.76
<b>ii</b> Rainwater harvesting in urban areas will reduce flooding and the associated damages	140	5	1	4.13	0.77
<b>iii</b> Rain water quality is suitable for industrial and domestic consumption	138	5	1	4.17	0.78
<b>iv</b> Rain water harvesting will reduce the cost of pumping water from NWSC, constructing and maintaining drainage system	142	5	1	4.15	0.79

**Table 11: Check list on water structures**

<b>Check list on water structures</b>	<b>Yes</b>	<b>No</b>
1. Building is completely guttered	77%	12.4%
Partially guttered	10.6%	
2. Collection pipes are installed	86.6%	
3. Water pump already installed	97%	
4. Space availability ( Approximate size 4 m <sup>2</sup> or more)	98%	
5. Supply tank already installed	98%	

Most residents (79.4%) felt that they were not harvesting rainwater because rainwater harvesting system was not included in the initial planning or architectural design of the building. However, 84.6% felt that rainwater harvesting in Nairobi would increase water quantity and sanitation. It would also reduce flooding and associated damages 82.6% and that rainwater quality is suitable for some domestic and industrial uses (83.4%). Large scale rainwater harvesting can decrease seasonal flooding in urban areas (Chanan *et al*, 2007; Farzan, 2007; Noah *et al*, 2011; UNEP, 2011). Most buildings (77%) were completely guttered with collection pipes

#### **4.6 Sources of water and Contribution of rainwater harvesting in Nairobi**

Major water sources for four classes of buildings was city council piped water. Industries largely (78%) depended on city council piped water and only 4% harvested rainwater, despite having a potential of meeting their water demand (mean of 215%) from roof catchment rainwater harvesting. Non potable indoor and outdoor water uses would be 86% and above for industries (Noah *et al.*, 2011)

and rainwater quality from roof catchments is suitable for these purposes; unfortunately, this resource is disposed as storm water.

The industries in addition, largely depended on their private borehole (20%) followed by Multi-story buildings (14%) and masionettes (6%). It would be prudent if industries harvest rain water in order to allow some percentage of city council piped water (potable water) to residential (domestic) buildings because according to Noah *at el.*, (2011), their need of potable water is higher than for industries ( 21.7% and 14%, respectively).

In the four classes of buildings assessed, Institutions are leading in roof catchment rainwater harvesting (44%) followed by Maisonettes. These intuitions are either public schools or churches and the source of money for acquiring tanks is from donations and/or CDF. Managing a rainwater catchment system in multi-story buildings might be cumbersome as security of the system is not guaranteed and how the water will be used among the residents without conflict. These might have deterred landlords from installing rainwater harvesting systems in multi-story buildings as compared to maisonettes.

## CHAPTER FIVE

### 5.0 CONCLUSIONS AND RECOMMENDATIONS

#### 5.1 Conclusions

The aims of this study were to assess the volume of rainwater that would be harvested from roof catchments of different buildings in meeting water demand of the occupants of those buildings. The storage capacity required, quality of rainwater from roof catchments and adoption rate of roof catchments rainwater harvesting in Nairobi County. The results of the study lead to the following conclusions:

1. The volume of rainwater harvested from roof catchments will not meet water demand of the occupants for most building but act as a supplement to surface and groundwater sources. If roof catchment rainwater harvesting is done, it will offset the deficit encountered from surface and ground water sources. Nevertheless, water harvested from some maisonettes(23%), institutions (48%) and industrial (76%) buildings could fully meet water demands of the occupants.
2. The size of storage tanks required for rainwater storage differed widely with Maisonette buildings requiring 5,126 to 60,840 litres while Multi Story buildings requires an approximate of 32,400 to 344,250 litres.
3. The quality of water from roof catchments in most cases does not meet the required standards (WHO) for potable water use but it would be used for non-potable purposes.

4. Only 16% of residents harvest rainwater from roof tops and institutions are leading followed by Maisonettes buildings, Multi-story residential buildings and industries have least adopted roof catchment rainwater harvesting.
5. Most residents are not harvesting rainwater from roof catchments because they do not have storage facilities. Moreover, rainwater harvesting facilities are not included in the initial designs and construction of the buildings.
6. Those harvesting rainwater from roof catchments, use that water for non-potable purposes and they have not experienced diseases associated with rainwater usage.

The potential of rainwater harvesting from roof catchments in augmenting water supply in Nairobi County exists. The volume available for harvesting at individual roofs can offset the deficit that has been estimated. The space for installing reservoirs is available for most buildings. The need for non-potable uses of water such as landscaping/irrigation, laundry and many more, is approximately 78% and above.

## **5.2 Recommendations**

Nairobi County should stop depending solely on transporting water from outskirts of Nairobi County and encourage rainwater harvesting from roof catchments at domestic or industrial level. This will greatly increase water quantity and decrease flooding. Rainwater harvesting systems should be included in the initial building designs in order to encourage rainwater harvesting.

The other way of encouraging residents to start harvesting rainwater from their roof catchments lies on provision of storage reservoirs at affordable prices. This ought to be done through Government interventions which may be through subsidies.

A further research on best rainwater harvesting technologies for urban areas, minimizing space requirements and maximizes water quality. Modern plumbing designs allowing different inlets for potable and non-potable water into the building and safety.

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## APPENDIXES

### Appendix 1: Interview Schedule

Nairobi County is faced with acute water scarcity and streets are often flooded during heavy rains. Rainwater harvesting has been neglected worsening the city's water scenario. One of the solution to this crisis would be rainwater harvesting. This questionnaire seeks to assess the potential of rainwater harvesting from roof tops of buildings in augmenting water supply in Nairobi County. The survey results will be reported in general terms and will not identify individuals. Your support in completing this questionnaire will be greatly appreciated. Please fill your response as appropriate.

#### Section One: General Questions

1. Name of Station.....
2. Type of building
  - Bungalow/Masionette Resident ( )
  - Multi- storley Resident ( )
  - Institution, Specify type of institution.....
  - Industry, Specify type of industry.....
3. Details of respondent
  - Owner of the building ( )
  - Tenant ( )
  - Manager ( )
  - Others Specify.....
4. Total roof area in m<sup>2</sup>.....
5. Type of roofing material.....
6. Number of occupants in the building.....
7. Approximate Monthly cost of water Ksh.....
8. Number of bedrooms, if applicable.....
9. Quantity of water used in industries in case of water intensive industry.....

#### Section 2: Water sources

What sources of water do you have? Borehole ( ) City Council water ( )  
Roof catchment rainwater ( )  
Other specify.....

How reliable is the source of water supply? Not reliable at all ( )

Reliable ( ) Very reliable ( )

How do you cope during periods of water shortage .....

#### SECTION 3: Rainwater Harvesting

a) Do you harvest rainwater for your activities Yes ( ) if No turn to section 4

If yes, why did you decide to harvest rainwater.....

b) What type of storage tank do you use to harvest rainwater? Metal tank ( )

Plastic tank ( ) Concrete tank ( )

others specify .....

- c) What is the capacity of your storage tank? (in litres).....
  - d) Have your tank ever been completely full? Yes ( ) No ( )
  - e) For how long would the tank serve you with water? .....
  - f) What do you use the rainwater collected for .....
  - g) Is your rainwater harvesting system working in a satisfying way? Yes ( ) No ( )
- How did you finance your rainwater harvesting system?  
 Own money ( ) loan ( ) Donations ( ) others specify.....
- k) Are there any diseases associated with water usage in the building? Yes ( ) No ( )
  - l) Your general comments about rainwater harvesting in Nairobi county?.....
- .....
- .....

## SECTION 4

The following table assesses knowledge/ perception, challenges and possibilities of roof –top water harvesting in Nairobi County. Please tick in the appropriate box with.

1- Strongly disagree 2- Disagree 3- Neutral 4- Agree 5- Strongly Agree

		Strongly Disagree	Disagree	Neutral	Agree	Strongly agree
<b>Why are you not harvesting Rainwater?</b>						
i	No storage tank					
ii	Pipe water is reliable					
iii	There is no space to install a tank					
iv	It is costly to install a rainwater harvesting system					
v	The city council does not allow rainwater harvesting					
vi	Rainwater harvesting system was not included in the initial planning or architectural design					
<b>The following might be the cause of flooding in Nairobi City</b>						
i	No drainage system					
ii	The drainage system is there but it blocks during heavy rains					
<b>Perception of Roof top Rainwater Harvesting in Nairobi</b>						
i	Rainwater harvesting in Nairobi will increase water quantity and sanitation					
ii	Rainwater harvesting in urban areas will reduce flooding and the associated damages					

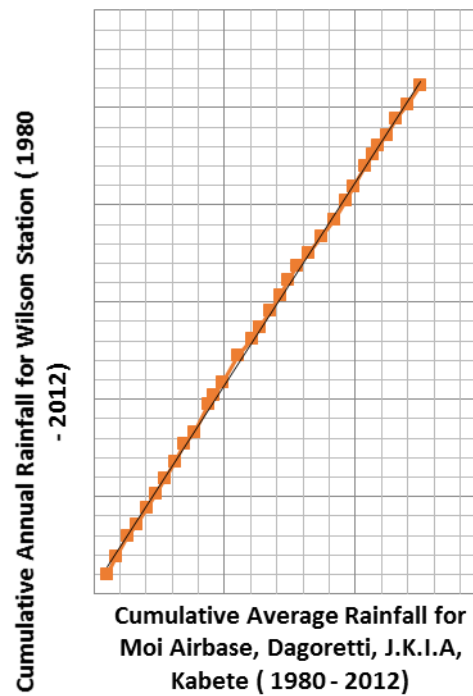
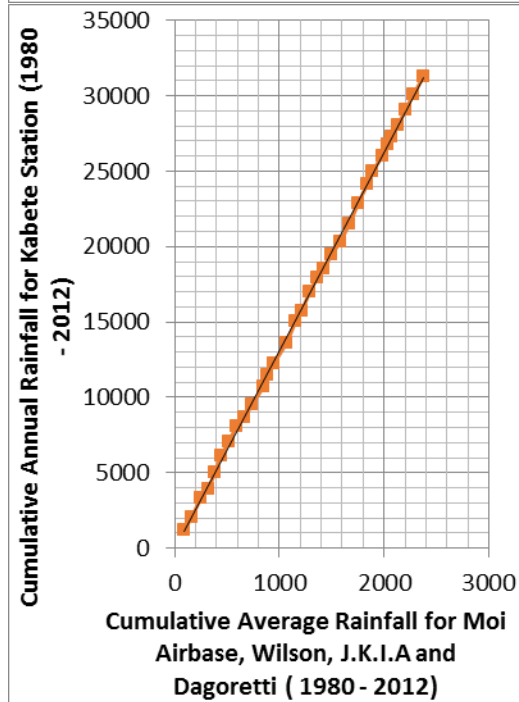
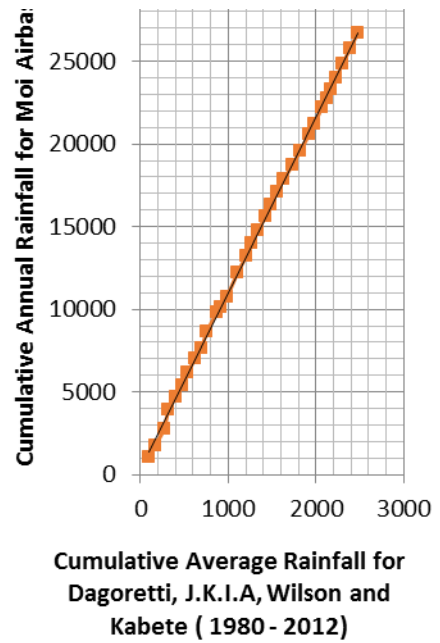
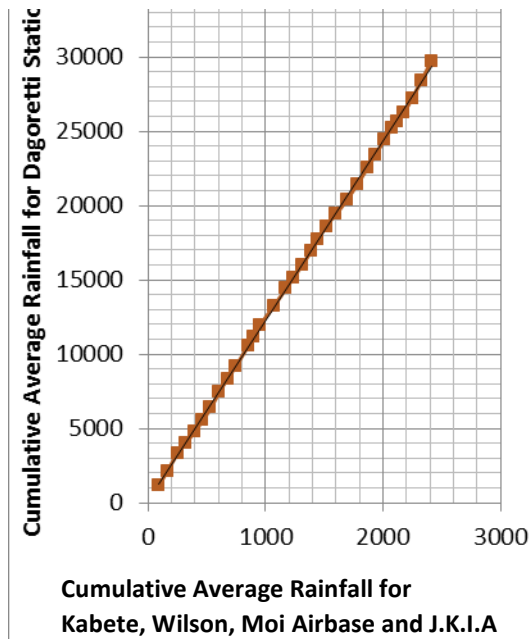
iii	Rain water quality is suitable for industrial and domestic consumption					
iv	Rain water harvesting will reduce the cost of pumping water from NWC, constructing and maintaining drainage systems					

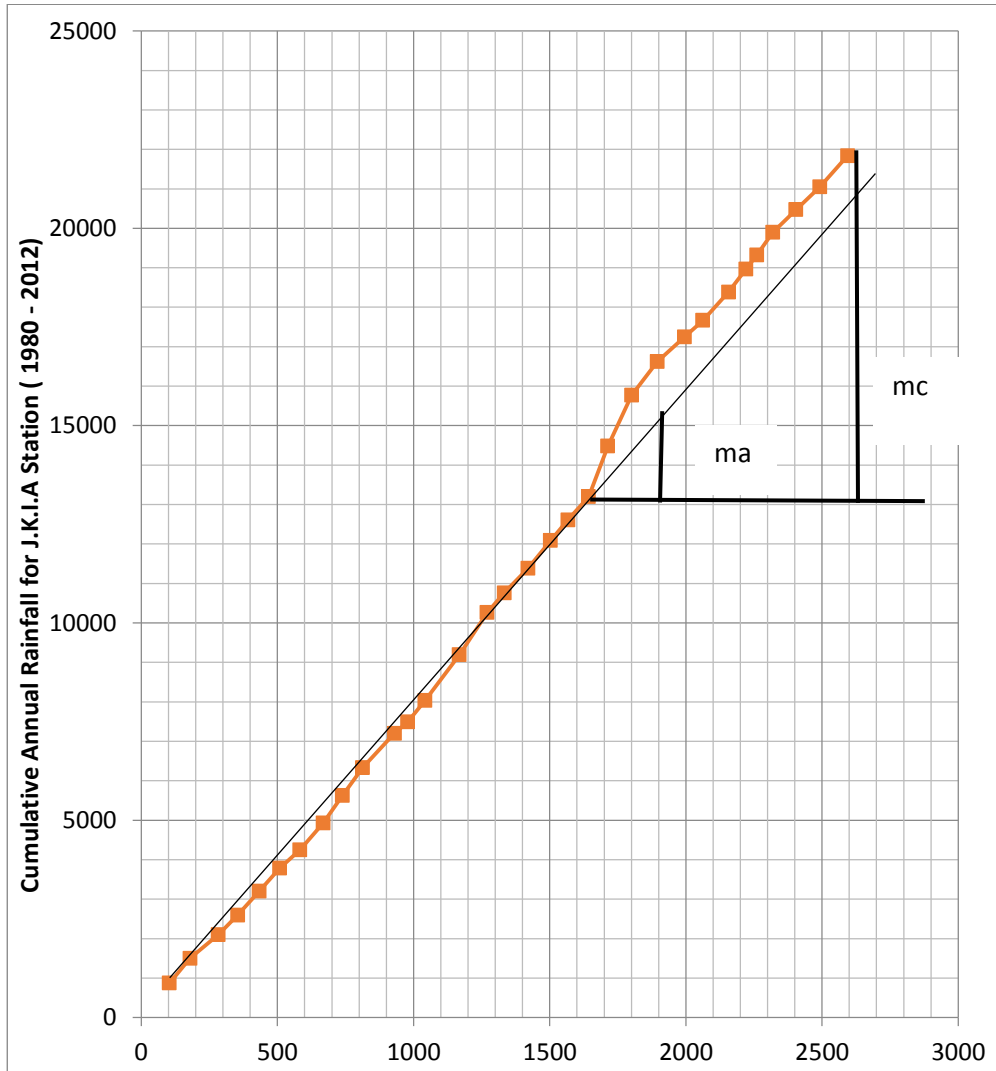
Your general comments on rainwater harvesting in Nairobi Cou'nty.....

**Check List on water structures**

	<b>Parameter</b>	<b>Yes</b>	<b>No</b>
1.	Building is completely guttered		
	Partially guttered		
2.	Collection pipes are installed		
3.	Water pump already installed		
4.	Space availability ( Approximate size 2 m <sup>2</sup> or more)		
5.	Supply tank already installed		

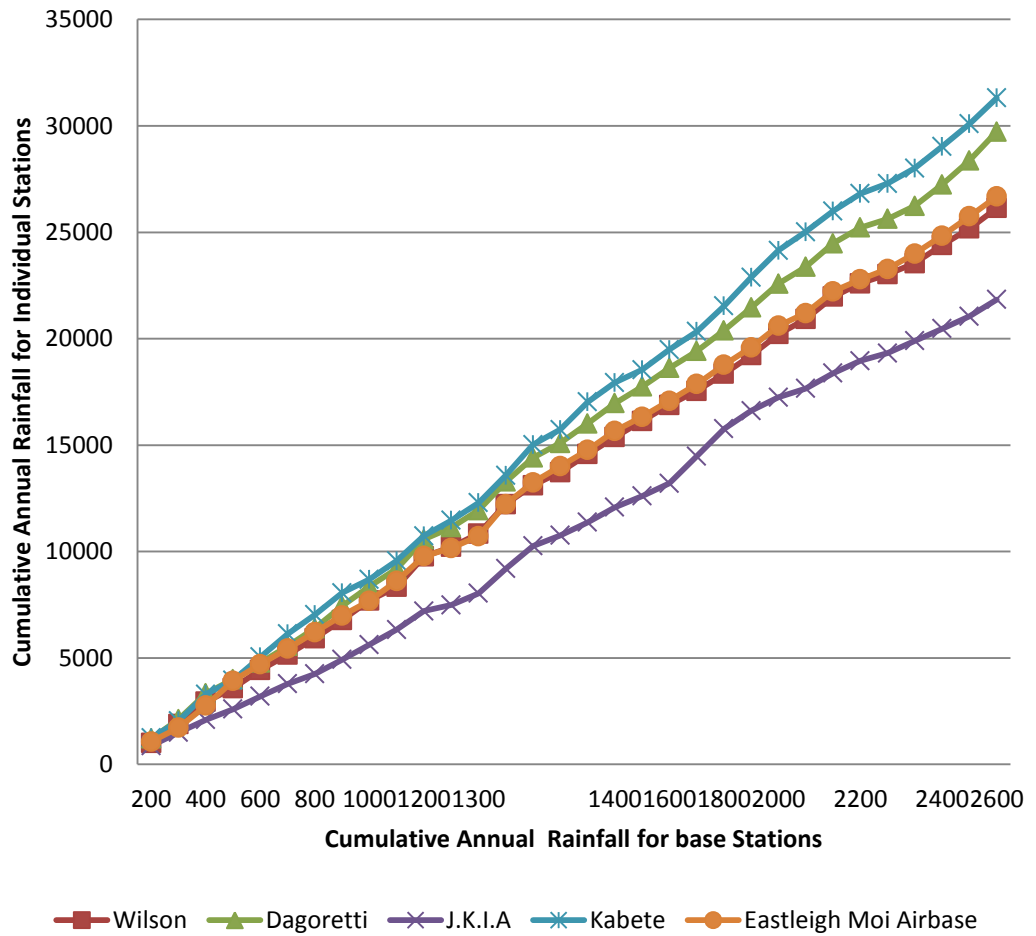
## Appendix 2: Double Mass Analysis Curves





Cumulative Averages for Kabete, Dagoretti, Moi Airbase and Wilson

## Double Mass Curves



### Appendix 3: Rainfall Data from KMD for Nairobi County

NB: This is not the original data from Kenya meteorological Department. Continuity and consistence check has been done to fill missing monthly rainfall data and cumulative. Computations has been done using hydrological continuity and consistence formulas

METEOROLOGICAL STATIONS	Year		J	F	M	A	M	J	J	A	S	O	N	D	Annual Cumulative
EASTLEIGH MOI	Precipitation; monthly total	1980	96	8.6	51.4	100.1	339.2	53.9	0.6	15.4	3.4	28.6	238.9	16.3	952
EASTLEIGH MOI	Precipitation; monthly total	1981	5.8	2.4	115.1	277.9	299.3	2	7.7	23.45	75.5	58.1	38.4	69.9	976
EASTLEIGH MOI	Precipitation; monthly total	1982	3.5	15	33	173.6	162.4	54.9	8.8	3.5	13.7	178.2	201.6	145.5	994
EASTLEIGH MOI	Precipitation monthly total	1983	0.3	150.2	68.3	239.1	33.6	53.6	38.3	42.3	1.9	67.9	23.5	245.6	965
EASTLEIGH MOI	Precipitation monthly	1984	17.8	2.9	6.8	45.5	0	1.8	10.5	16.5	18.6	154.7	210.2	95.9	581
EASTLEIGH MOI	Precipitation; monthly total	1985	0.3	77	77.3	180.5	53.9	12.8	43.4	1.7	29.1	32.1	57.6	106.9	673
EASTLEIGH MOI	Precipitation; monthly total	1986	20.4	0	69.8	348.3	334.8	22.5	1.8	0.5	13.9	34.9	174.3	125.3	1147
EASTLEIGH MOI	Precipitation; monthly total	1987	38	16.6	17.1	219.1	92.6	41	39.8	22.6	8.2	0	98.8	26.5	620
EASTLEIGH MOI	Precipitation; monthly total	1988	91.5	9.8	166.7	391.3	104.2	71.5	5.7	9.7	42.8	24.8	98.1	128.5	1145
EASTLEIGH MOI	Precipitation; monthly total	1989	114.1	22.6	103.5	164.1	145.5	7.4	40.2	35	29.5	52.7	108	206.6	1029
EASTLEIGH MOI	Precipitation; monthly total	1990	44.4	33.1	216.9	199.8	104.2	20.2	5	44.1	20.3	62.2	148.4	120.2	1019
EASTLEIGH MOI	Precipitation;	1991	34.9	5.7	176	119.3	151.6	29.6	7.6	38	3.4	73.1	152.8	75.2	867

<b>MOI</b>																
<b>EASTLEIGH MOI</b>	Precipitation; monthly total	1992	4.5	42.3	16.3	361.7	61.7	23.5	27.2	22.8	6	80.2	103.5	87	<b>837</b>	
<b>EASTLEIGH MOI</b>	Precipitation; monthly total	1993	239.1	77.8	15.8	27.4	79.5	52.9	1.6	22.7	0	46.2	97.9	84.7	<b>746</b>	
<b>EASTLEIGH MOI</b>	Precipitation; monthly total	1994	9.3	81.4	44.5	212.9	65.1	44.4	15.2	26.4	0	111.1	281	67.1	<b>958</b>	
<b>EASTLEIGH MOI</b>	Precipitation; monthly total	1995	52.6	62.4	162.5	110	61.8	58.1	7.2	108.8	7.6	55.1	84.6	55.8	<b>827</b>	
<b>EASTLEIGH MOI</b>	Precipitation; monthly total	1996	5.8	62.7	139.8	160.4	67.4	64.8	21.2	35.2	16.2	0	185.2	2.7	<b>761</b>	
<b>EASTLEIGH MOI</b>	Precipitation; monthly total	1997	0	0	20.8	380.7	128.9	45.5	32.8	33.2	0	69.1	308.6	134.9	<b>1155</b>	
<b>EASTLEIGH MOI</b>	Precipitation; monthly total	1998	375.1	225.5	59.8	110.2	472.8	107.5	13.7	16.9	50.7	16.6	57.1	6.4	<b>1512</b>	
<b>EASTLEIGH MOI</b>	Precipitation; monthly total	1999	1.6	2.4	128.8	126.4	4.5	3.4	10.2	21.8	30.7	24.2	204.1	130.3	<b>688</b>	
<b>EASTLEIGH MOI</b>	Precipitation; monthly total	2000	1.1	0	28.4	71.1	49.7	36.7	1.1	2.3	15.7	36	140.4	82.2	<b>465</b>	
<b>EASTLEIGH MOI</b>	Precipitation; monthly total	2001	403.4	5.2	215	104.7	97.2	31.4	19.9	20.1	7	36.5	220.9	8.6	<b>1170</b>	
<b>EASTLEIGH MOI</b>	Precipitation; monthly total	2002	55.5	43.6	91.5	220	293.9	0.1	4.2	8.4	29.3	89.5	97.5	210	<b>1144</b>	
<b>EASTLEIGH MOI</b>	Precipitation; monthly total	2003	22	8.9	20.4	116.2	294.6	3.2	3.1	29.8	7.3	82.7	104.5	23.9	<b>717</b>	
<b>EASTLEIGH MOI</b>	Precipitation; monthly total	2004	42	64.4	94.2	209.8	199.6	3.8	0	2	11.2	68.6	88.3	77.4	<b>861</b>	
<b>EASTLEIGH MOI</b>	Precipitation; monthly total	2005	66.37	32.8	82	193.5	239.7	0.5	8.1	16.5	17.4	26.4	87.1	1.5	<b>772</b>	
<b>EASTLEIGH MOI</b>	Precipitation; monthly total	2007	40.7	64.4	20.1	194.1	87.7	85.2	46.4	35.5	25.7	35.4	98.7	85.1	<b>819</b>	
<b>EASTLEIGH MOI</b>	Precipitation; monthly total	2008	58.8	28.3	201.5	113.8	7.3	2.4	62.4	6.9	15.6	170.4	115	0.2	<b>783</b>	
<b>EASTLEIGH MOI</b>	Precipitation; monthly total	2009	63.8	21.2	19.3	262.7	144.3	33.4	8.7	496.3	7.6	60.7	41.1	142.5	<b>1302</b>	

<b>EASTLEIGH MOI</b>	Precipitation; monthly total	2010	105.8	80.8	297.4	105.7	157.5	63.3	0.5	10.4	24.1	76.4	118.7	76.2	<b>1117</b>
<b>EASTLEIGH MOI</b>	Precipitation; monthly total	2011	15	46.3	80.2	32.5	91.6	0	9.2	16.1	47	90.4	227.6	75.7	<b>732</b>
<b>EASTLEIGH MOI</b>	Precipitation; monthly total	2012	0	16.4	6.1	379.9	311.6	101	3.9	35.2	36	44.7	131	246.8	<b>1313</b>
												<b>Average</b>			<b>926</b>
<b>WILSON AIRPORT</b>	Precipitation; monthly total	1980	90.5	8.6	51.7	105.3	454.1	19.1	1.7	8.8	5.9	18.2	197.2	27.8	<b>989</b>
<b>WILSON AIRPORT</b>	Precipitation; monthly total	1981	3.7	2	106.3	323.4	144.9	30.7	9.6	30.4	43.9	41.7	40.2	59.9	<b>837</b>
<b>WILSON AIRPORT</b>	Precipitation; monthly total	1982	2.4	14.1	31.2	192.9	164.4	8.4	13.5	3.1	15.9	186.4	220.1	188.9	<b>1041</b>
<b>WILSON AIRPORT</b>	Precipitation; monthly total	1983	1.8	128	43.4	137.1	38	31	22.5	29.8	3.6	63.6	22.4	225.7	<b>747</b>
<b>WILSON AIRPORT</b>	Precipitation; monthly total	1984	7.6	1.6	5.3	87.3	1.6	5	12.8	22.4	13.9	144.8	123.9	85.6	<b>512</b>
<b>WILSON AIRPORT</b>	Precipitation; monthly total	1985	0	91.2	88	188.8	59.7	32.4	50.2	3.1	22.5	20.6	67.5	105	<b>729</b>
<b>WILSON AIRPORT</b>	Precipitation; monthly total	1986	17.1	0	65.2	284.5	300.1	3.7	0.5	1.6	1	228	157.3	143.5	<b>1203</b>
<b>WILSON AIRPORT</b>	Precipitation; monthly total	1987	40.6	13.6	23.9	278.7	109	71.2	15.7	8.4	15.2	1.9	125.3	25.8	<b>729</b>
<b>WILSON AIRPORT</b>	Precipitation; monthly total	1988	78.5	28.4	181.2	322.7	151.1	103.6	7.3	13.1	30.2	9	66.7	123.5	<b>1115</b>
<b>WILSON AIRPORT N</b>	Precipitation; monthly total	1989	95.7	25.1	65.1	277.4	168.3	2.8	59.2	19.5	11.1	45.8	103.5	201.4	<b>1075</b>
<b>WILSON AIRPORT</b>	Precipitation; monthly total	1990	46.2	28.8	271	171.9	107.6	17	6.6	11.1	6.2	34.7	102.6	69.5	<b>873</b>
<b>WILSON AIRPORT</b>	Precipitation; monthly total	1991	28.9	2.4	151.9	114.2	144.2	30.6	2.6	1	4	28.5	149.6	65.2	<b>723</b>
<b>WILSON AIRPORT</b>	Precipitation; monthly total	1992	1.5	15.1	27.4	414.6	56.8	22.6	88.1	8.7	4.9	37.5	80.1	96.2	<b>854</b>

<b>WILSON AIRPORT</b>	Precipitation; monthly total	1993	270.4	104	9.2	9.6	122.9	49.4	0	12.8	0	50.2	128.8	78.2	<b>836</b>
<b>WILSON AIRPORT</b>	Precipitation; monthly total	1994	12		54.5	172.3	133.3	73.6	10.2	40	2.3	69.4	230.9	50.3	<b>849</b>
<b>WILSON AIRPORT</b>	Precipitation; monthly total	1995	46.6	65.4	136.5	80.2	122.3	85.1	18.1	22.1	22.2	117.2	127.3	39.8	<b>883</b>
<b>WILSON AIRPORT</b>	Precipitation; monthly total	1996	6.9	40.2	135.5	95.3	60.1	77	13.2	24	3.8	5.3	161.5	0	<b>623</b>
<b>WILSON AIRPORT</b>	Precipitation; monthly total	1997	0	0	15.8	318.1	130.7	6.9	7.4	27.2	0	102.1	275.3	99.8	<b>983</b>
<b>WILSON AIRPORT</b>	Precipitation; monthly total	1998	434.4	112.2	75	84.8	464.6	63.4	62.9	13.2	11	0	60	28.7	<b>1410</b>
<b>WILSON AIRPORT</b>	Precipitation; monthly total	1999	3	0	126.6	156.3	10.6	1.5	4.2	31.9	17.8	33.2	242.3	125.7	<b>753</b>
<b>WILSON AIRPORT</b>	Precipitation; monthly total	2000	9.8	0	32.7	85.4	52.7	54.9	3	4.2	23.5	43.9	140.3	78.9	<b>529</b>
<b>WILSON AIRPORT</b>	Precipitation; monthly total	2001	480.7	6.3	339.2	104.7	87.4	66.1	35	16.7	15.9	66.9	212.4	10.1	<b>1441</b>
<b>WILSON AIRPORT</b>	Precipitation; monthly total	2002	63.2	13.1	82.2	141.1	117.6	0	6	3.3	25.6	75.5	109.3	315.4	<b>952</b>
<b>WILSON AIRPORT</b>	Precipitation; monthly total	2003	31.5	4.2	26.6	195.5	368.3	8.5	0.6	60.3	60.3	52.1	106.9	21.2	<b>936</b>
<b>WILSON AIRPORT</b>	Precipitation; monthly total	2004	123.8	71.8	88.2	295.3	79.8	6	0	0	11.1	58	121.6	74.1	<b>930</b>
<b>WILSON AIRPORT</b>	Precipitation; monthly total	2005	49.2	14.5	126.5	157.1	285.2	6.6	14.9	5.8	15.8	27.5	73.6	4.7	<b>781</b>
<b>WILSON AIRPORT</b>	Precipitation; monthly total	2007	53.3	104.9	21.6	176.1	60.3	75.4	19	21.7	63.5	29.7	86.8	51	<b>763</b>
<b>WILSON AIRPORT</b>	Precipitation; monthly total	2008	51.6	24.7	172.6	95.1	19.1	1.4	38.3	6.9	64.7	133.3	248.3	1	<b>857</b>
<b>WILSON AIRPORT</b>	Precipitation; monthly total	2009	59.4	15.3	19.4	83.1	111.5	52	114	0.1	6.9	84.6	91.3	175.9	<b>814</b>
<b>WILSON AIRPORT</b>	Precipitation; monthly total	2010	73.5	116.6	256.7	106.6	186.9	48.3	1	23.9	34.8	117.6	79	50.6	<b>1096</b>
<b>WILSON AIRPORT</b>	Precipitation; monthly total	2011	10.4	77.8	144.6	46.8	45.5	102.2	10.7	71	33.4	145	202.3	139	<b>1029</b>

<b>WILSON AIRPORT</b>	Precipitation; monthly total	2012	0	8.6	1.3	444.2	182.1	33.1	30	44.6	9.7	53.4	201.9	234.2	<b>1243</b>
<b><u>Average</u></b>														<b><u>910</u></b>	
<b>DAGORETTI CORNER</b>	Precipitation; monthly total	1980	91.9	13	37.9	105.9	531.5	27.2	2.1	17.3	25.2	250.6	250.6	33.5	<b>1387</b>
<b>DAGORETTI CORNER</b>	Precipitation; monthly total	1981	14.6	6	139.4	568.6	245.2	11.5	10.5	39.1	38.7	44.7	15.4	38	<b>1172</b>
<b>DAGORETTI CORNER</b>	Precipitation; monthly total	1982	0	19.4	61.7	214.3	218.1	35.9	27	8.5	34.1	151.8	235.1	163.7	<b>1170</b>
<b>DAGORETTI CORNER</b>	Precipitation; monthly total	1983	5.6	182.1	67.6	172.9	39.2	13.1	16.1	29.2	2.8	52.9	24.9	317.9	<b>924</b>
<b>DAGORETTI CORNER</b>	Precipitation; monthly total	1984	4.4	1	6.3	78.5	3.1	6.3	7.8	7.6	30.6	123.2	140.3	73.6	<b>483</b>
<b>DAGORETTI CORNER</b>	Precipitation; monthly total	1985	0.1	92.7	131.9	232	72.7	21.6	27.6	5.9	16.1	33.6	111.7	78.5	<b>824</b>
<b>DAGORETTI CORNER</b>	Precipitation; monthly total	1986	12.5	0	80.1	239.1	259.1	26.2	1.1	3.7	0.2	285	192.5	120.8	<b>1220</b>
<b>DAGORETTI CORNER</b>	Precipitation; monthly total	1987	44.5	11.8	50.7	327.5	94.3	75.7	1	10	15.1	1.5	157.4	32.1	<b>822</b>
<b>DAGORETTI CORNER</b>	Precipitation; monthly total	1988	76	25.3	132.3	388.5	241.8	90.6	13.6	30	14.8	25.5	82.9	145.8	<b>1267</b>
<b>DAGORETTI CORNER N</b>	Precipitation; monthly total	1989	110.2	47.4	80.2	264.7	257.8	28.3	37.9	23.6	52.4	60.4	114.9	204.6	<b>1282</b>
<b>DAGORETTI CORNER M</b>	Precipitation; monthly total	1990	52.7	27.6	215.8	247.5	163.3	9.7	15.7	8.6	24.8	63.5	140	92.9	<b>1062</b>
<b>DAGORETTI CORNER</b>	Precipitation; monthly total	1991	12.3	0	94	148.4	253	23.2	2.8	40.2	3.9	31.6	182.7	125.8	<b>918</b>
<b>DAGORETTI CORNER</b>	Precipitation; monthly total	1992	8	73.6	30.2	403	94.4	28.3	40.1	5.3	5.6	51.2	134.9	96.4	<b>971</b>
<b>DAGORETTI CORNER</b>	Precipitation; monthly total	1993	275.1	151.8	29.1	25.1	95.2	46.6	1.4	11.9	0	45.4	101.2	108.2	<b>891</b>
<b>DAGORETTI CORNER M</b>	Precipitation; monthly total	1994	9.9	92.8	59.1	247	114.2	19.8	19.3	53.6	3.4	87.8	245.5	67.7	<b>1020</b>
<b>DAGORETTI CORNER</b>	Precipitation; monthly total	1995	15.1	116.8	168.2	109.7	210.3	31.3	11.8	15.8	29.2	116.5	95.2	33.2	<b>953</b>

<b>DAGORETTI CORNER</b>	Precipitation; monthly total	1996	18.2	45.5	121.4	112.8	89.4	58.3	19.5	28.4	21.9	1.5	167.7	0	<b>685</b>
<b>DAGORETTI CORNER M</b>	Precipitation; monthly total	1997	1.3	0	0	427.8	132.8	4.9	5	15.3	0.5	155.7	383.8	196.1	<b>1323</b>
<b>DAGORETTI CORNER</b>	Precipitation; monthly total	1998	361.1	144.2	73.9	111.8	412.7	86.4	41	25.3	26	7.9	56.2	68.9	<b>1415</b>
<b>DAGORETTI CORNER</b>	Precipitation; monthly total	1999	17.6	0.5	185	174.1	25.8	4.4	4.9	61.2	15.9	22.4	286.7	183.7	<b>982</b>
<b>DAGORETTI CORNER</b>	Precipitation; monthly total	2000	2.7	0	39.5	107.7	120.3	43.9	4.6	9.2	38.6	25.7	174.7	98	<b>665</b>
<b>DAGORETTI CORNER</b>	Precipitation; monthly total	2001	430	31.7	292.6	145	108.9	106.9	25.4	17.6	27.6	35.5	158.7	13.3	<b>1393</b>
<b>DAGORETTI CORNER</b>	Precipitation; monthly total	2002	43	55.4	89.9	205.2	142.9	0.6	22.5	6.4	26.2	75.2	161.5	262.8	<b>1092</b>
<b>DAGORETTI CORNER N</b>	Precipitation; monthly total	2003	52	15.7	28.6	232.9	247.5	37	2.2	12.3	44.2	70.9	167.4	17.2	<b>928</b>
<b>DAGORETTI CORNER</b>	Precipitation; monthly total	2004	133.9	31.7	85.8	310.9	199.2	9.4	0.4	10.1	23	85.7	167.9	62	<b>1120</b>
<b>DAGORETTI CORNER</b>	Precipitation; monthly total	2005	102.8	39.2	62.9	162.8	243.2	16.5	16.6	12.1	21	45.7	114.4	0.2	<b>837</b>
<b>DAGORETTI CORNER</b>	Precipitation; monthly total	2007	28.3	107.3	31.2	199.6	110	47.7	61.6	36.7	51.5	38.4	68.9	39.2	<b>820</b>
<b>DAGORETTI CORNER</b>	Precipitation; monthly total	2008	45	22.8	132.5	99.8	32.6	2.4	55.1	9	89.4	113.8	172.2	0.5	<b>775</b>
<b>DAGORETTI CORNER</b>	Precipitation; monthly total	2009	64.5	20.1	37.9	79.3	158.1	101.5	13.2	3.6	9.1	97.6	79.4	121.1	<b>785</b>
<b>DAGORETTI CORNER</b>	Precipitation; monthly total	2010	76.1	107.3	212	157.3	354.7	37.7	2.5	35.3	28.9	99.2	109.9	65.1	<b>1286</b>
<b>DAGORETTI CORNER</b>	Precipitation; monthly total	2011	14.2	125.8	128.5	49.4	79.1	125.8	8.7	41.8	31.8	132.6	162.3	129.2	<b>1029</b>
<b>DAGORETTI CORNER</b>	Precipitation; monthly total	2012	0	9	5.5	469.1	255.3	25.6	8.6	88.1	11.5	62.8	278.3	261.7	<b>1476</b>
<b>Averages</b>															<b>1031</b>

<b>J.K.I.A. N</b>	Precipitation; monthly total	1980	56.7	10.6	78	93.9	307	16.5	0	14.4	0.3	25	189.3	6.4	<b>798</b>
<b>J.K.I.A. N</b>	Precipitation; monthly total	1981	2	0.8	80.5	196.7	185.2	0	3.5	3.4	21.1	30.7	32.8	51.6	<b>608</b>
<b>J.K.I.A.</b>	Precipitation; monthly total	1982	1.8	4.6	11.6	120.5	91.4	8.1	8.1	13.3	17.9	147.8	149.4	113.6	<b>688</b>
<b>J.K.I.A.</b>	Precipitation; monthly total	1983	1	160.3	38.7	208.3	29.2	68.8	6.9		0.9	29.2	31.8	195.9	<b>771</b>
<b>J.K.I.A.</b>	Precipitation; monthly total	1984	7.8	0	17.6	64.7	3.4	0.7	1.3	6.4	5.5	117.6	134.1	104.5	<b>464</b>
<b>J.K.I.A. ON</b>	Precipitation; monthly total	1985	12.3	141.2	59.3	189.5	54.3	16.7	8.2	1.3	17	35.1	46.1	118.9	<b>700</b>
<b>J.K.I.A.</b>	Precipitation; monthly total	1986	34.7	0	112.1	245.2	167.8	11.1	0.1	2.2	1.5	3	140.4	90.1	<b>808</b>
<b>J.K.I.A.</b>	Precipitation; monthly total	1987	21.5	8.5	7	120	92.8	78.6	0.6	16.5	9	0	63.6	21.6	<b>440</b>
<b>J.K.I.A.</b>	Precipitation; monthly total	1988	46.4	1.6	146.7	223.6	52.5	23	5	4.4	20.5	46.2	57.4	87.5	<b>715</b>
<b>J.K.I.A.</b>	Precipitation; monthly total	1989	108.3	30.2	70.8	217.7	192.3	0.8	34.3	17.7	16.3	59.3	105.4	165	<b>1018</b>
<b>J.K.I.A.</b>	Precipitation; monthly total	1990	27.1	40.9	179.1	167	556	3.2	5.3	56	17.6	60.6	172.8	94.9	<b>1381</b>
<b>J.K.I.A.</b>	Precipitation; monthly total	1991	9.6	6	98.5	54.7	209.3	15.6	1.8	6.9	2.4	35.2	841	95.9	<b>1377</b>
<b>J.K.I.A.</b>	Precipitation; monthly total	1992	3.4	10.2	9.1	228.3	155	12.7	35.7	9.7	0.4	37.7	86.4	132.6	<b>721</b>
<b>J.K.I.A.</b>	Precipitation; monthly total	1993	210.9	51.7	17	8.3	51.4	43.2	0	4.1	0	69.7	68.6	83.2	<b>608</b>
<b>J.K.I.A.</b>	Precipitation; monthly total	1994	0.6	97.2	48.6	163	58	35.7	3.1	23.7	0	73.1	203	28.1	<b>734</b>
<b>J.K.I.A.</b>	Precipitation; monthly total	1995	59.1	79.4	133.3	70.7	86.5	46.9	18.1	17.5	32.3	45.6	29.5	32.4	<b>651</b>
<b>J.K.I.A.</b>	Precipitation; monthly total	1996	36.9	69.4	55.8	61.2	55.8	58.5	16.3	12.1	2	0	129	10.6	<b>508</b>
<b>J.K.I.A.</b>	Precipitation; monthly total	1997	0	0	35.2	235.6	163.2	6.6	14.7	0	0	307.7	307.7	124.9	<b>1196</b>

	monthly total															
<b>J.K.I.A.</b>	Precipitation;	1998	322	125.4	74.2	110.1	322.5	69.9	31.9	6.2	18.9	0	74.2	6.4	<b>1162</b>	
<b>J.K.I.A.</b>	Precipitation;	1999	0	1.3	123.5	91.6	3	1.9	3.9	32.9	0	37.9	251.1	95.9	<b>643</b>	
<b>J.K.I.A.</b>	monthly total															
<b>J.K.I.A.</b>	Precipitation;	2000	13.4	0	18.5	74.8	18.7	26.9	1	1.4	8	11.6	113.4	37.4	<b>325</b>	
<b>J.K.I.A.</b>	monthly total															
<b>J.K.I.A.</b>	Precipitation;	2001	306.	10.7	161.3	67.2	38.3	13.7	19.9	14.3	3.7	33.6	198.6	15.9	<b>884</b>	
<b>J.K.I.A.</b>	monthly total		5													
<b>J.K.I.A.</b>	Precipitation;	2002	57.6	15.1	99.1	151.9	158.9	0.8	0.2	3.9	54.5	48.7	115.1	331.2	<b>1037</b>	
<b>J.K.I.A.</b>	monthly total															
<b>J.K.I.A.</b>	Precipitation;	2003	16.9	9.5	22.1	154.6	229.8	6.8	1.6	47.8	40.8	52.3	119.8	25.2	<b>727</b>	
<b>J.K.I.A.</b>	monthly total															
<b>J.K.I.A.</b>	Precipitation;	2004	95.3	76.2	93.3	137	57.2	2.9	0	0.6	26.5	64.3	124.8	67.9	<b>746</b>	
<b>J.K.I.A.</b>	monthly total															
<b>J.K.I.A.</b>	Precipitation;	2005	36.7	31.7	36.3	115.7	89.5	3.6	11.7	0.3	20.4	26.4	91	122	<b>585</b>	
<b>J.K.I.A.</b>	monthly total															
<b>J.K.I.A.</b>	Precipitation;	2007	83.4	12.4	35.8	194.9	52.6	27.2	27.6	12	19.6	23.7	95	48.2	<b>632</b>	
<b>J.K.I.A.</b>	monthly total															
<b>J.K.I.A.</b>	Precipitation;	2008	51.3	24.1	193.2	81	4.7	1.5	27.2	3.2	35.4	101	82.6	0	<b>605</b>	
<b>J.K.I.A.</b>	monthly total															
<b>J.K.I.A.</b>	Precipitation;	2009	52.4	34.1	27.1	84.5	140	36.6	5	0.6	2.3	65.6	48.6	112.7	<b>610</b>	
<b>J.K.I.A.</b>	monthly total															
<b>J.K.I.A.</b>	Precipitation;	2010	68.9	96.7	132.1	54	81.1	26.6	1.3	6.6	13.9	49.9	67.5	55.7	<b>654</b>	
<b>J.K.I.A.</b>	monthly total															
<b>J.K.I.A.</b>	Precipitation;	2011	1.8	74.8	92.7	17.8	42.4	29.6	2.9	42.2	27.8	47.3	249.6	29.1	<b>658</b>	
<b>J.K.I.A.</b>	monthly total															
<b>J.K.I.A.</b>	Precipitation;	2012	0	0.4	5.2	450	199.6	32.2	13.4	3.8	36.3	63.7	65	98	<b>968</b>	
<b>J.K.I.A.</b>	monthly total															

<b>KABETE</b>	Precipitation; monthly total	1980	159.1	63.5	61.2	154.2	423.4	24.9	3.4	18.8	28.9	25.9	255.2	73.7	<b>1292</b>
<b>KABETE</b>	Precipitation;	1981	2.7	6.7	123.8	506	213.7	10.5	18	20.9	65.2	68.7	26	58.1	<b>1120</b>
<b>KABETE</b>	Precipitation;	1982	0.5	13.4	49.9	241.8	243.2	14.9	29.7	11	41.5	140	233.6	112.6	<b>1132</b>
<b>KABETE</b>	Precipitation;	1983	3.4	180.7	54.5	230.8	45.8	52.5	17.7	41.1	9.9	52.7	34.2	320.7	<b>1044</b>
<b>KABETE</b>	Precipitation;	1984	3.7	0.7	17	54.8	9.7	6.1	23.4	15.3	24.3	185.6	132.6	64.7	<b>538</b>
<b>KABETE</b>	Precipitation;	1985	0	94.1	171.4	200.1	80.4	16.2	30.1	8.7	37.3	42.1	137.9	72.8	<b>891</b>
<b>KABETE</b>	Precipitation;	1986	6.4	0.2	62.8	237.7	315.4	29.5	5.2	2.3	4.3	40.4	274.3	81.5	<b>1060</b>
<b>KABETE</b>	Precipitation;	1987	79.5	95.5	15.4	221.2	145	95.1	10.8	13.4	17.2	4.4	175.9	15.3	<b>889</b>
<b>KABETE</b>	Precipitation;	1988	96.2	20.5	172	466.6	245.9	50.9	18.7	46.9	27.1	16.7	103.9	135.6	<b>1401</b>
<b>KABETE</b>	Precipitation;	1989	134.	45.1	94.1	209.9	496.8	27.5	34.2	25.2	91.1	84.3	102.9	186	<b>1532</b>
<b>KABETE</b>	Precipitation;	1990	51.6	47.8	219.7	284.2	309.7	6.5	13.6	21	32.8	90	126	76.1	<b>1279</b>
<b>KABETE</b>	Precipitation	1991	33.9	0.4	79.7	158.3	282.5	12.5	13.3	40.3	2.8	21.6	199.1	50.7	<b>895</b>
<b>KABETE</b>	Precipitation;	1992	5	70.2	3.9	400.9	216.5	20.6	29.4	3.8	14.9	70.5	112.6	87	<b>1035</b>
<b>KABETE</b>	Precipitation;	1993	200	53.1	61.4	45.9	41.4	61.1	3.5	3.9	0	19.3	108.8	179.8	<b>778</b>
<b>KABETE</b>	Precipitation;	1994	4.9	35.5	56.3	237.2	92.2	44.4	19.5	33.9	1	87.8	301.4	64.7	<b>979</b>
<b>KABETE</b>	Precipitation;	1995	8.6	87.4	165.6	259.3	244.4	124.3	19.2	30.8	51.4	155.7	149.7	67.5	<b>1364</b>
<b>KABETE</b>	Precipitation;	1996	12.9	36.4	110.1	91.1	89.2	51.5	35.6	36.6	37	1.3	209.7	2.6	<b>714</b>
<b>KABETE</b>	Precipitation;	1997	2.7	0	29.2	541.2	106.1	23.1	21.5	85.4	0	322.9	308.8	219.8	<b>1661</b>
<b>KABETE</b>	Precipitation;	1998	315	137.1	101.3	151.8	326.7	63.1	22.6	21.3	33.4	54.8	62.1	11.3	<b>1301</b>
<b>KABETE</b>	Precipitation;	1999	16	0.9	180	150.6	31.2	2.7	11.9	29.6	26.1	21.4	352.9	228	<b>1051</b>
<b>KABETE</b>	Precipitation;	2000	5.4	0	41.7	254.4	100.1	57.9	4.1	6.1	53.5	18.4	187.7	111.3	<b>841</b>
<b>KABETE</b>	Precipitation;	2001	371	3.2	180.3	106.5	85.7	79.4	16.2	23.4	19.5	95.3	189.5	13.3	<b>1184</b>
<b>KABETE</b>	Precipitation;	2002	52	69.1	90.2	278.7	134.3	1.6	6.6	6.4	22.3	59	157.4	230.9	<b>1109</b>
<b>KABETE</b>	Precipitation;	2003	28.4	12	51.6	219.2	28.4	30.2	3.1	54.3	27.8	54.7	117.1	14.1	<b>641</b>
<b>KABETE</b>	Precipitation;l	2004	60.1	45.3	89	411.6	191.3	10.4	6.2	0.2	16.1	82	118.4	58.1	<b>1089</b>

<b>KABETE</b>	Precipitation;	2005	76.8	45.7	104.7	210.4	253.9	27.2	26.5	8.5	28.2	32.3	88.7	0.5	<b>903</b>
<b>KABETE</b>	Precipitation;	2007	51.4	98.6	52.9	349.3	184.2	83	25.4	52.6	89.1	25	69.1	42.4	<b>1123</b>
<b>KABETE</b>	Precipitation;	2008	42.8	151.9	199.3	173.7	19	5.7	64.3	9.1	47.4	165.1	209.6	5.3	<b>1093</b>
<b>KABETE</b>	Precipitation;	2009	42.8	18.1	76.6	75.7	141.4	43.3	6.8	2.3	6.3	141.8	110.2	185.7	<b>851</b>
<b>KABETE</b>	Precipitation;	2010	143	73.8	250.3	252.8	273.8	51.9	2	29.9	19.9	64.3	93.3	74.5	<b>1330</b>
<b>KABETE</b>	Precipitation;	2011	4.2	66.3	147.7	80.7	93.9		14.3	26.9	32.5	154.3	175.7	245.5	<b>1042</b>
<b>KABETE</b>	Precipitation;	2012	0	16	5	352.6	262	39.9	23.4	42.4	8.9	241.7	249.2	244.6	<b>1486</b>
														<b>Averages</b>	<b>1083</b>

Table 15 1

**Appendix 4: Tank sizes and cost for maisonettes and Multi- story buildings**

	Roof Area	C	April & May Rainfall	Rainwater Harvestable	April Demand	Tank Sizes Litres	Tank cost Ksh.	space Required m <sup>2</sup>	Annual Harvestable	Volume %	Annual Demand
<b>Kabete</b>	112	0.9	375	37,800	9,600	28,200	292,000	16	98,380	<b>84</b>	116,800
	176	0.9	375	59,400	9,600	49,800	520,000	24	154,984	<b>132</b>	116,800
	118	0.9	375	39,825	9,600	30,225	304,000	16	103,651	<b>88</b>	116,800
	118	0.9	375	39,825	14,400	25,425	269,980	16	103,651	<b>59</b>	175,200
	118	0.9	375	39,825	14,400	25,425	269,980	16	103,651	<b>59</b>	175,200
	196	0.9	375	66,150	16,800	49,350	529,070	24	172,166	<b>84</b>	204,400
	112	0.9	375	37,800	9,600	28,200	292,200	16	98,380	<b>84</b>	116,800
	96	0.9	375	32,400	7,200	25,200	268,600	16	84,326	<b>96</b>	87,600
	196	0.9	375	66,150	12,000	54,150	564,000	24	172,166	<b>118</b>	146,000
	96	0.9	375	32,400	7,200	25,200	268,600	14	84,326	<b>96</b>	87,600
<b>Wilson</b>	96	0.9	319	27,562	9,600	17,962	161,000	10	70,934	<b>61</b>	116,800
	150	0.9	319	43,065	7,200	35,865	346,000	20	110,835	<b>126</b>	87,600
	100	0.9	319	28,710	7,200	21,510	260,000	12	73,890	<b>84</b>	87,600
	120	0.9	319	34,452	9,600	24,852	260,000	12	88,668	<b>76</b>	116,800
	160	0.9	319	45,936	14,400	31,536	323,000	16	118,224	<b>67</b>	175,200
	200	0.9	319	57,420	9,600	47,000	520,000	24	147,780	<b>126</b>	116,800
	120	0.9	319	34,452	9,600	24,852	260,000	12	88,668	<b>76</b>	116,800
	125	0.9	319	35,887	9,600	26,287	275,500	15	92,362	<b>79</b>	116,800
	100	0.9	319	28,718	7,200	21,510	260,000	12	73,890	<b>84</b>	87,600
	120	0.9	319	34,452	7,200	27,252	281,100	14	73,890	<b>84</b>	87,600
<b>Dagoretti</b>	200	0.9	350	63,000	9,600	53,400	520,000	24	167,000	<b>95</b>	175,200
	200	0.9	350	63,000	7,200	55,800	555,000	24	167,040	<b>143</b>	116,800
	216	0.9	350	68,040	7,200	60,840	595,000	24	180,403	<b>123</b>	146,000

	96	0.9	350	30,240	9,600	20,640	260,000	12	80,179	<b>69</b>	116,800
	128	0.9	350	40,320	14,400	25,920	260,000	12	106,905	<b>91</b>	116,800
	218	0.9	350	68,670	9,600	59,070	550,000	24	182,073	<b>155</b>	116,800
	124	0.9	350	39,060	9,600	29,460	295,000	16	103,564	<b>88</b>	116,800
	112	0.9	350	35,280	9,600	25,680	260,000	12	93,542	<b>80</b>	116,800
	96	0.9	350	30,240	7,200	23,040	260,000	12	80,179	<b>69</b>	116,800
	156	0.9	350	49,140	7,200	41,940	410,000	20	130,291	<b>89</b>	146,000
<b>Moi Airbase</b>	96	0.9	300	25,920	14,400	11,520	84,070	6	71,971	<b>61</b>	116,800
	180	0.9	300	48,600	14,400	34,200	335,000	16	134,946	<b>77</b>	175,200
	200	0.9	300	54,000	14,400	39,600	410,000	20	149,940	<b>86</b>	175,200
	128	0.9	300	34,560	12,000	22,560	260,000	12	95,961	<b>66</b>	146,000
	112	0.9	300	30,240	9,600	20,640	182,000	12	83,966	<b>72</b>	116,800
	264	0.9	300	71,280	12,000	59,280	335,000	16	197,920	<b>135</b>	146,000
	96	0.9	300	25,920	7,200	18,720	166,800	10	71,971	<b>82</b>	87,600
	96	0.9	300	25,920	7,200	18,720	166,800	10	71,971	<b>82</b>	87,600
	112	0.9	300	30,240	9,600	20,640	184,000	10	83,966	<b>72</b>	116,800
	180	0.9	300	48,600	14,400	34,200	335,000	16	134,946	<b>77</b>	175,200
	112	0.9	300	30,240	9,600	20,640	184,000	10	83,966	<b>72</b>	116,800
	225	0.9	300	60,750	21,600	39,150	335,000	16	168,682	<b>64</b>	262,800
<b>J.K.I.A</b>	150	0.9	226	30,510	14,400	16,110	150,000	10	99,360	<b>85</b>	116,800
	116	0.9	226	23,594	14,400	9,194	75,000	6	76,838	<b>52</b>	146,000
	96	0.9	226	19,526	14,400	5,126	35,000	4	63,590	<b>54</b>	116,800
	116	0.9	226	23,594	12,000	11,594	84,070	6	76,838	<b>52</b>	146,000
	200	0.9	226	40,680	9,600	31,080	304,000	16	132,480	<b>75</b>	175,200
	100	0.9	226	20,340	12,000	8,340	63,000	5	66,240	<b>57</b>	116,800
	120	0.8	226	21,696	7,200	14,496	107,200	9	79,488	<b>54</b>	146,000
	195	0.9	226	39,663	7,200	32,463	323,000	16	129,168	<b>73</b>	175,200
	100	0.9	226	20,340	9,600	10,740	75,000	6	66,240	<b>56</b>	116,800

225	0.9	226	45,765	14,400	31,365	304,000	16	149,040	<b>51</b>	292,000
120	0.9	226	24,408	9,600	14,808	107,200	9	79,488	<b>54</b>	146,000

### Multi story buildings

Statio	Roof Area	C	April & May April Rainfall	Rainwater Harvestable	April Demand	Tank Sizes Litres	Tank Costs Ksh.	Annual Volume harvestable	% met	Annual Demand
<b>Kabete</b>	450	0.9	375	151,875	67,200	84,675	855,000	395,280	48	817,600
	216	0.9	375	72,900	60,000	60,000	608,800	189,734	26	730,000
	292	0.9	375	98,550	96,000	96,000	1,040,000	256,492	22	1,168,000
	348	0.9	375	117,450	76,800	117,450	1,300,000	305,683	33	934,400
	900	0.9	375	303,750	134,400	303,750	3,290,625	790,560	48	1,635,200
	480	0.9	375	162,000	172,800	162,000	1,820,000	421,632	20	2,102,400
	324	0.9	375	109,350	115,200	109,350	1,040,000	284,601	17	1,401,600
	612	0.9	375	206,550	144,000	206,550	2,237,625	339,062	19	1,725,000
	386	0.9	375	130,275	206,400	130,275	1,411,312	339,062	13	2,511,200
	1020	0.9	375	344,250	216,000	344,250	3,729,375	895,968	34	2,628,000
<b>Wilson</b>	316	0.9	319	90,724	115,200	90,724	98,284	233,924	17	1,401,600
	180	0.9	319	51,678	57,600	51,678	552,200	133,002	19	700,800
	250	0.9	319	71,775	76,800	71,775	780,000	184,725	20	934,400
	386	0.9	319	110,821	72,000	110,821	1,200,560	285,215	32	876,000
	300	0.9	319	86,130	67,200	86,130	930,000	221,670	27	817,600

	360	0.9	319	103,356	96,000	103,356	1,103,000	266,004	22	1,168,000
	300	0.9	319	86,130	144,000	86,130	930,000	221,670	12	1,752,000
	450	0.9	319	129,195	115,200	129,195	1,375,000	332,505	24	1,401,600
	360	0.9	319	103,356	144,000	103,356	1,103,000	266,004	15	1,752,000
	1350	0.9	319	387,585	115,200	272,385	2,950,837	997,515	71	1,401,600
<b>Dagoretti</b>	450	0.9	350	141,750	115,200	141,750	1,535,625	375,840	26	1,401,600
	1060	0.9	350	333,900	288,000	333,900	3,617,250	885,312	27	3,304,000
	288	0.9	350	90,720	96,000	90,720	982,800	240,537	21	1,168,000
	930	0.9	350	292,950	172,800	200,000	2,166,666	776,736	37	2,102,400
	360	0.9	350	113,400	76,800	113,400	1,228,500	300,672	32	934,400
	600	0.9	350	189,000	96,000	189,000	2,047,500	501,120	43	1,168,000
	900	0.9	350	283,500	115,200	283,500	3,071,250	751,688	54	1,401,600
	870	0.9	350	274,050	230,400	274,050	3,071,250	726,624	26	2,803,200
	396	0.9	350	124,740	115,200	124,740	1,351,360	330,739	24	1,401,600
	300	0.9	350	94,500	115,200	94,500	1,023,750	250,560	18	1,401,600
	360	0.9	350	113,400	115,200	113,400	1,228,500	300,672	21	1,401,600
	350	0.9	350	110,250	115,200	110,250	1,194,375	292,320	21	1,401,600
<b>Moi Airbase</b>	420	0.9	300	113,400	168,000	113,400	1,228,500	314,874	15	2,044,000
	450	0.9	300	121,500	96,000	121,500	1,316,250	337,365	29	1,168,000
	450	0.9	300	121,500	163,200	121,500	1,316,250	337,365	17	1,985,600
	1,500	0.9	300	405,000	192,000	213,000	2,307,500	1,124,550	48	2,336,000
	120	0.9	300	32,400	38,400	32,400	323,000	89,964	19	467,200
	900	0.9	300	243,000	172,800	200,000	2,166,666	674,730	32	2,102,400
	1,240	0.9	300	334,800	144,000	190,800	2,067,000	929,628	53	1,752,000
	600	0.9	300	162,000	172,800	162,000	1,755,000	449,820	21	2,102,400
	300	0.9	300	81,000	115,200	81,000	87,750	224,910	16	1,401,600

	248	0.9	300	66,960	76,800	66,960	410,002	185,925	20	934,400
<b>J.K.I.A</b>	214.8	0.9	226	43,528	57,600	43,528	520,000	178,848	25	700,800
	270	0.9	226	54,918	67,200	54,918	564,000	178,848	22	817,600
	576	0.9	226	117,158	134,400	117,158	1,269,211	381,542	33	1,635,200
	350	0.9	226	71,190	96,000	71,190	780,000	381,542	33	1,168,000
	400	0.9	226	81,360	168,000	81,360	855,000	235,520	12	2,044,000
	1500	0.9	226	305,100	192,000	220,000	2,383,333	993,600	42	2,336,000
	600	0.8	226	108,480	168,000	108,480	1,175,200	397,440	19	2,044,000
	360	0.9	226	73,224	72,000	73,224	780,000	211,968	24	876,000
	1000	0.9	226	203,400	115,200	200,000	2,166,666	662,400	47	1,401,600
	275	0.9	226	55,935	134,400	55,935	605,962	182,160	11	1,635,200
	800	0.9	226	162,720	57,600	120,000	1,300,000	471,040	67	700,800

**Appendix 5: Capacities and cost of manufactured plastic tanks**

	<b>CAPACITY (LITRES)</b>	<b>DIMENSIONS</b>		<b>PRICE (KSH)</b>
		Height (cm)	Diameter (cm)	
<b>1.</b>	500	103	86	5,000
<b>2.</b>	750	118	98	6,800
<b>3.</b>	920	81	135	8,150
<b>4.</b>	1000	127	109	8,600
<b>5.</b>	1,350	138	121	9,980
<b>6.</b>	1,500	142	124	11,000
<b>7.</b>	2,000	159	135	13,800
<b>8.</b>	2,300	165	138	15,500
<b>9.</b>	2,500	169	148	16,800
<b>10.</b>	3,000	180	156	21,100
<b>11.</b>	3,500	183	165	28,120
<b>12.</b>	4,000	202	175	32,200
<b>13.</b>	5,000	205	185	34,000
<b>14.</b>	6,000	217	191	44,000
<b>15.</b>	8,000	250	219	63,000
<b>16.</b>	10,000	267	236	75,000
<b>17.</b>	16,000	280	290	150,000
<b>18.</b>	24,000	280	356	260,000

**Appendix 6: Group society housing and space availability for installing rainwater harvesting systems**





Discharge of rainwater from roof catchments