COMMUNITY PARTICIPATION IN THE PLANNING AND MANAGEMENT OF HARVESTED WATER RUNOFF IN MARIGAT DIVISION, KENYA

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A THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN ENVIRONMENTAL PLANNING AND MANAGEMENT IN THE SCHOOL OF ENVIRONMENTAL STUDIES UNIVERSITY OF ELDORET, KENYA.

October 2015

DECLARATION

DECLARATION OF CANDIDATE

I hereby declare that the work therein unless otherwise cited is my original work and has not been presented for a degree in any other university. No part of this thesis may be reproduced without prior permission of the author and/or School of Environmental Studies of University of Eldoret.

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To my loving dad and mum, for their love, prayers and support, and to my brothers and sisters for their love and support; then to my husband Robert for support and encouragement, and to my son, Reagan for inspiration.

ACKNOWLEDGEMENT

First of all I would like to thank the almighty God for his endless Grace and Blessings on me during the study. I am very grateful to my supervisors, Eng. Prof. E.C. Kipkorir, Dr. D. Fatuma and Dr. J. Ayonga for their untiring and excellent guidance, supervision, invaluable suggestions and critical reviews of my thesis.

I wish to express my sincere gratitude to my beloved parents Mr. and Mrs. Magut for the encouragements, love, financial, spiritual and moral support, my brothers Moses and Silas and sisters Joan Miriam and Gertrude for your love, encouragement and support. I remain indebted to Lawrence Yego, Robert Buttit and Joseph Songok for your encouragement and financial support.

Special thanks to Lawrence Sum and Dennis Ndiema for their support and advice during modelling and GIS. I wish to thank my classmates Sandra, Elvira and Mayaya for their moral support and encouragement during difficult times in the study, as well as the happy moments shared.

Special thanks to many organizations for their support and providing me with the needed data to complete fieldwork, i.e. Marigat Water Office (Eng. Kirui and other staff) for your great support, KARI Marigat (Mr. Chengole) for rainfall data, and Regional Centre for Mapping of Resources for Development, for the images. I also thank all individuals, some of whom I have not been able to mention, who in one way or the other gave inputs that enabled me conduct this study.

May God bless you all abundantly.

ABSTRACT

Water is vital to basic livelihoods and economic growth. Marigat division, Baringo County, Kenya experiences water scarcity during the dry periods, a situation that is further aggravated by droughts and erratic rains. During the rainy seasons, a lot of water is lost as runoff which can be harvested and stored in water reservoirs and used for domestic and livestock throughout the dry seasons. This study seeks to identify the source, the reliability of water sources, investigate the willingness of the community to participate in harnessing water runoff, determine suitable sites of water pans for harvesting runoff water to meet Marigat's water demand and propose a water supply network for the Marigat community. The study adopts a survey research design. The study was based on systems theory of planning, where smaller components interrelate within and at their hierarchical level. The sampling procedure was based on stratified random sampling size of 383 household heads and 10 key informants. Questionnaires were distributed to the household heads using stratified random sampling while interview schedule were used to obtain information from Focus Group Discussions and key informants. Data was cleaned, coded and entered into SPSS and analysis conducted as per the objectives. Weighted overlay suitability analysis within Geographical Information System (GIS) was used to site the potential sites of water reservoirs, weightings were assigned to each criterion depending upon their relative significance. Water Evaluation and Planning System model (WEAP 21) was used to determine whether the water to be harvested was able to meet the Marigat community's water demand thus, a scenario was built from the reference scenario; Creation of new water pans. The results of the reference scenario were validated using observed flows at Marigat Bridge station and WEAP 21 was also used to come up with a water supply network. The research findings indicated that the main source of water in Marigat was surface water from the river. The water sources were not reliable and they are sparse. In addition, the Marigat community has the willingness to harness water runoff and there was significant association between water scarcity and willingness to contribute to the harvesting of water runoff. The results show that with the creation of proposed five new water pans for harvesting runoff in areas facing water scarcity, the unmet domestic and livestock water demand is met up to 2020. There are suitable sites for construction of water pans in the study area. Some of the organizations involved in efforts to avail enough water resources to the Marigat community are: The World Vision, Marigat Child and Care Program (MCPF), Kerio Valley Development Authority (KVDA) and Kenya Rainwater Association. The study will add to the body of knowledge on water resources planning and management ~~skill~~ to alleviate the problem of water shortage especially in dry areas like the study area.

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DEFINITION OF TERMS

Rainwater harvesting is a technology used for collecting and storing rainwater from rooftops, land surface or rock catchments using simple techniques such as jars and pots as well as more complex techniques such as underground check dams for later use.

Surface water runoff is the water that flows over the land from rainfall during or after a storm event.

Community participation is the process by which individuals voluntarily participate by taking initiatives independent of external institutions and develop a capacity to contribute to their communities' development.

ACRONYMS

ASALs	Arid and Semi-Arid Lands
BTC-BWP	Belgium Technical Cooperation – Belgium Water Programme
CBOs	Community-Based Organizations
DEM	Digital Elevation Model
FGDs	Focus Group Discussions
GIS	Geographical Information Systems
GL	Gallons
GOK	Government of Kenya
GPS	Global Positioning System
IWRM	Integrated Water Resource Management
JICA	Japan International Cooperation Agency
KARI	Kenya Agricultural Research Institute
KVDA	Kerio Valley Development Authority
MCFP	Marigat Child and Fund Programme
MDGs	Millennium Development Goals
NDMA	National Drought Management Authority
PVC	Polyvinyl Chloride
RS	Remote Sensing
RWH	Rain Water Harvesting
UNEP	United Nations Environment Programme
UN	United Nations
WEAP 21	Water Evaluation and Planning System

WRUAs	Water Resources Users Associations

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Water is such a vital part of everyday life (Bertone & Stewart, 2011) and human bodies contain around 78% water. It is essential for all socio-economic development and for maintaining healthy ecosystems. Water is a major environmental issue in the 21^{st} century and is emerging as a key issue for future urban environmental management (Harris, 2005).

In as much as water covers 98% of the earth's surface, scarcity of portable water is a major problem in very many parts of the world. The problem is aggravated by the fact that of the remaining 2%, a significant portion of it is locked away in glaciers and the polar ice caps, 0.36% is in underground aquifers and about the same amount makes up our lakes and rivers (Sipes, 2010, Bertone & Stewart 2011).

Globally, 1.4 billion people lack daily access to sufficient amounts of portable water (Huston *et al*, 2012). The demand for water has been increasing for both human and animal needs partly due to the rapid population increase that the world is mainly experiencing presently in the developing countries and also due to the rising affluence of the population (Huston *et al*, 2012). The world's population is expected to grow from 6.2 billion in 2010 to at least 8 billion by the year 2025, with about 90% of the increase being added to the developing world and to over 9.4 billion by 2050 (Sipes, 2010). As population increases and development calls for increased allocations of groundwater and surface water for the domestic, agriculture and industrial sectors, the pressure on water resources intensifies, leading to tensions, conflicts among users, and excessive pressure on the environment (FAO, 2007, Godskesen *et al*, 2013, Cassardo & Jones, 2011).

In developing countries, a large proportion is still lacking portable water. About 64% of Africa's population relies on water supply that is limited and highly variable. Kenya's water shortage also means that a large population of women and children spend up to one-third of their day fetching water in the hot sun from the nearest fresh water source (*www.thewaterproject.org)*. This backbreaking work leaves roughly half of the country's inhabitants vulnerable to serious dangers. In addition to exposure to the elements and risk of attack by predators, the primary water gatherers are also the most susceptible to water-borne diseases (Synder, 2006). Water shortage bring about water related diseases, food insecurity, poverty and according to UN, globally, each day, nearly 1,000 children die due to preventable water and sanitation- related diarrheal diseases (*www.un.org*).

World water resources are facing changes as a result of global climate change, high water demands, population growth, industrialization and urbanization (Cassardo & Jones 2011, NWP, 2007). As climate change leads to more extreme variations, water harvesting solutions must cope with both extreme rainfall and extreme droughts. Extreme rainfall requires good flood protection and diversion structures while extreme drought requires large storage capacity (NWP, 2007). To respond to water scarcity, rainwater harvesting techniques provide a direct solution especially in rural and drought prone areas. A World Bank report revealed that over 64% of Africa's population is rural, most people are heavily dependent upon each year's rainfall pattern and adequate rains are vital for livelihoods and food security (UNEP, 2010).

In wet climates, rainwater harvesting can provide enough water to meet almost all needs, while in arid and semi-arid climates, harvesting usually acts as a supplement to an existing water source. If designed and constructed properly, rainwater harvesting systems can collect and store water in a manner where the benefits quickly exceed the cost and, in many cases, costs can be greatly reduced by using discarded materials that are readily available.

Kenya is a water scarce country (NEMA, 2009) and harvesting of rainwater is capable of meeting the water needs of her population of about 40 million, six to seven times its current population (UN-Water, 2006).Instead of allowing rainwater to flow over the surface of the earth and cause environmental disasters such as the negative impacts of flooding, landslides and soil erosion it is possible to harness it for use in domestic, agriculture, industrial as well as for livestock and environmental improvement.

1.2 Problem Statement

During the dry season that on average lasts six months in a year, there is water scarcity in Marigat division. However, there is plenty of water during rainy season most of which go to waste and frequently causes havoc due to lack of appropriate harvesting technologies (BDVS 2005-2015). The wasted water during rainy season can be salvaged with improved storage and rainwater harvesting methods and such water can be used during periods of water shortages for domestic and livestock use. The common storage methods used include water tanks in individual homes, water pans and sand dams that are silting. Currently, Marigat community is not effectively using such storage because of inappropriate methods and because most people cannot afford the tanks. Individuals who can afford the water tanks soon run out of water because of low reservoir capacity of the tanks. Hence, Marigat community experiences water shortages for both domestic and livestock purposes during the dry seasons. As sources dry out, the community has to walk long distances for water and women and children suffer the most.

Thus Rain Water Harvesting technologies should be adopted to meet water requirements in all seasons, increase water security and also improve livelihoods in all areas of the country especially Marigat division. This shall require participation of all members of the community in the planning and management of harvesting surface water runoff in water pans since individual effort cannot be sustainable and cannot be of help to the whole community. But for these technologies to be effective the water shortage problem must be felt by everybody and the community must volunteer and be willing to participate in the task that aims to improve water supply. The knowledge gap in this study is; the willingness of the communities to participate and the potential sites for water harvesting are not documented and it is not known. In this regard, the following questions and objectives were investigated in this study.

1.3 Broad Objective

The main objective of this study is to assess the willingness of Marigat community to participate in the planning and management of harvesting surface water runoff and to propose suitable sites for water harvesting reservoirs.

1.4 Specific Objectives

1. To identify the sources of water sources in Marigat division.
2. To find out the reliability of water sources in Marigat division.
3. To assess the willingness of the community to participate in harnessing surface water runoff in Marigat division.
4. To determine suitable sites of water pans for harvesting water runoff to meet water demand in Marigat division.
5. Based on objectives 1-4, propose a water supply network for the Marigat community.

1.5 Research Hypothesis

H_1 Marigat community does not have the willingness to harness surface water runoff in water pans which will reduce water shortage in Marigat Division.

H_2 Harvesting of surface water runoff in water pans cannot meet Marigat's community water demand.

1.6 Justification of the Study

Water scarcity affects more than 40% of the global population and is projected to rise (*www.un.org, 2015*). Most rural areas in Kenya, including Marigat experience water shortages and thus Kenya is classified as a water scarce country (NEMA, 2009). The Sustainable Development Goals target of ensuring availability and sustainable management of water and sanitation for all by 2030 has to be met. Water is a major factor for meeting other Sustainable Development Goals including ending poverty in all its forms everywhere, ending hunger, achieving food security and improved nutrition and promote sustainable agriculture, ensuring healthy lives and promote well-being for all at all ages and ensuring environmental sustainability.

According to the Kenya population census of 2009, it was revealed that the main source of water in Rift Valley province is spring, well and borehole and this constitutes 36.3% of the water sources while rain water harvesting was the least, constituting 1.2%. Despite these areas receiving high rainfall, rainwater harvesting technologies have not been fully utilized especially harvesting of surface water runoff yet; rainwater is the best way of conserving water because it is very simple and very cost effective method (KNBS, 2009). Surface runoff harvesting has not been exploited as a source of water for domestic use and livestock. Therefore, this study will help improve the planning and management of surface water runoff for domestic and livestock to meet Marigat sub-catchment water demand throughout the year especially in areas with high potential sites for harvesting surface water runoff.

1.7 Scope of the study

The scope of this study in spatial dimension covered the administrative division of Marigat in Baringo County. Marigat Division comprises of 8 administrative locations and 24 sub-locations. The study covered the rural areas of Marigat division but not the urban areas thus, was based on regional planning approaches. In terms of subject matter, rainwater harvesting can be done using land surface, rock surface and roof catchments and this study was restricted to land surface catchment.

1.8 Study Area

1.8.1 Geographical Location

Marigat division is one of the fourteen divisions in Baringo County. The County lies between latitudes 0° 12 and 1° 36 N and longitudes 35° 36 and 36° 30 E. It borders Turkana County to the North, West Pokot and Marakwet Counties to the West, Koibatek to the South and Samburu and Laikipia Counties to the East (Figure 1.1). The location of the study area is given in Figure 1.1 and the drainage network is given in Figure 1.2

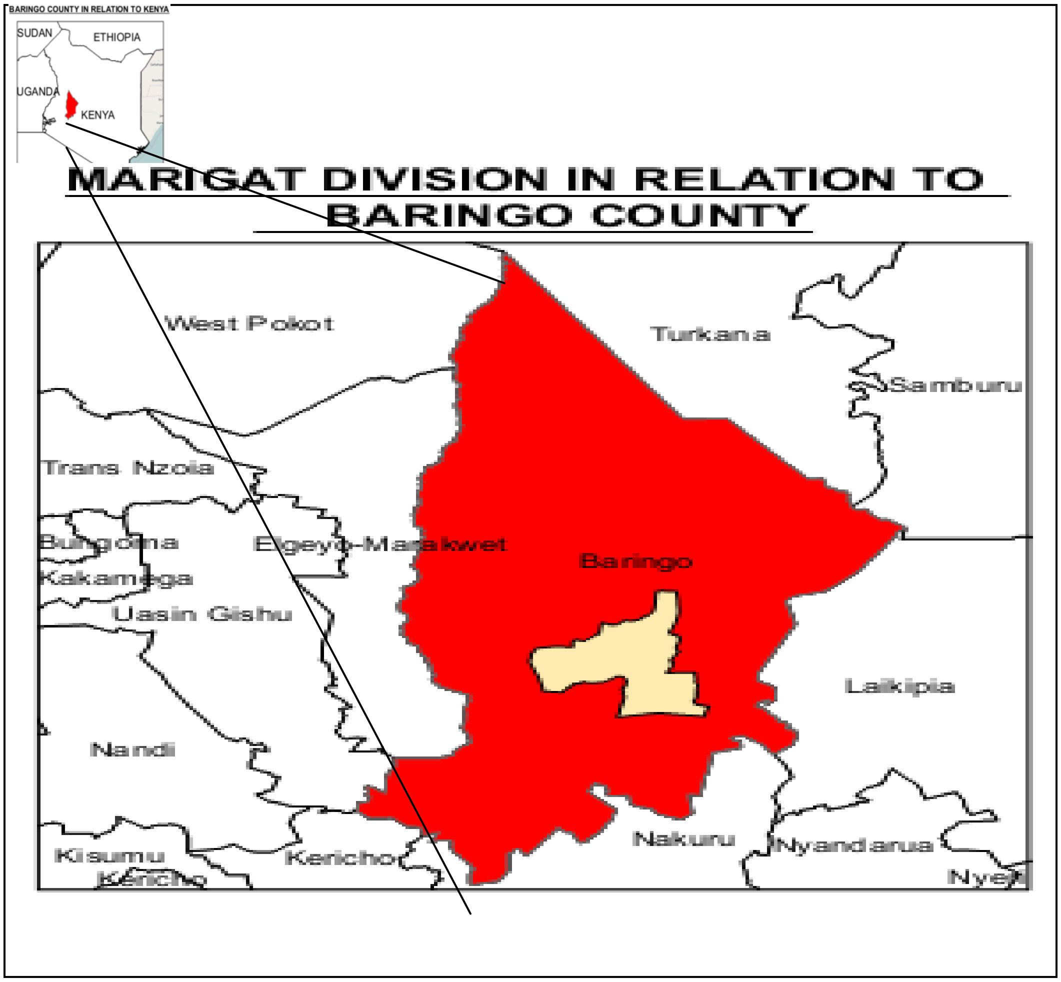

Figure 1. 1: Map of Marigat Division

(Source: Author, 2011)

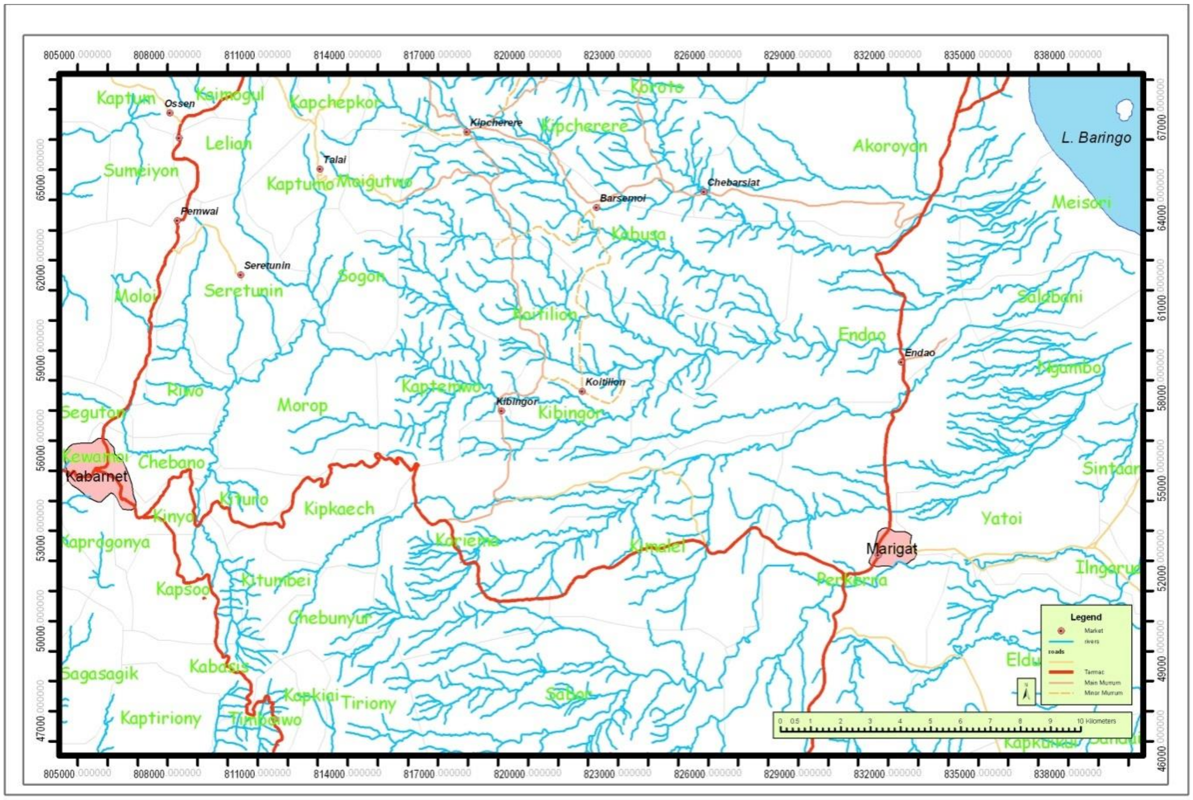

Figure 1. 2: Marigat Division Drainage Network
(Source: Author, 2011)

1.8.2 Climate

The study area is hot and dry almost throughout the year. The average annual rainfall is 650 mm with weak bimodal peaks recorded from March-May and June-August. There is one rainy season from end of March to August and a prolonged drought. The rainfall is about 50% reliable and is strongly influenced by the local topography. The mean annual temperature of the area is about 30° C and occasionally rises to over 35° C. January to March are the hottest months.

1.8.3 Geology

The soils are mainly clay loams with alluvial deposits derived from tertiary/ quaternary volcanic and pyroclastic rock sediments that have been weathered and eroded from the uplands. The soils are fertile but high evapotranspiration rates and low variable rainfall creates water scarcities that limit intensive agricultural use.

1.8.4 Topography

The major topographical features are river valleys, plains and the floor of Rift Valley. The area is on Loboi plain and is characterized by rolling slopes that range from 5% to 25% towards downstream of the rivers.

1.8.5 Land Use

The main land use practices are pastoralism, crop agriculture around homesteads and irrigated agriculture, fishing in Lake Baringo, conservation (L. Baringo), tourism and settlements.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter presents related literature to the study so as to identify the gap that needs further study. It specifically reviews the literature related to the study topic "Community Participation in the planning and management of harvested surface water runoff in Marigat division, Kenya".

2.2 Surface Water Harvesting

Rainwater harvesting is a technology used to collect, convey and store rainwater for later use from relatively clean surfaces such as a roof, land surface or rock catchment. It is a technology used for collecting and storing rainwater from rooftops, the land surface or rock catchments using simple techniques such as jars and pots as well as more complex techniques such as underground check dams (*www.gdrc.org*).

Surface water harvesting includes all systems that collect and store runoff water after a rainstorm in open ponds or reservoirs and usually provides water for livestock, irrigation, and aquaculture, (NWP, 2007). If the collected water is used for domestic, it needs treatment.

Rainwater harvesting (RWH) systems are increasingly becoming an integral part of the sustainable storm water management 'toolkit'. This is not only to reduce capital costs, but also to reduce materials used in manufacturing systems, as well as the costs and resource requirements related to system installation and maintenance (Ward *et al*, 2012).

In the water cycle, there are several methods by which the earth loses water, and is only through rainfall does the water come back to the earth. At this stage the water is relatively clean and can be collected for use with minimal capital investment. Compared to the conventional systems of water supply for domestic consumption, agriculture, industrial and other uses that emphasize abstraction from surface streams, deep wells and even the seas, rainwater is much cheaper, as it requires minimum treatment (KRA, 2006).

Kenya is among the "water–scarce" countries of Africa. The country has seen her water per capita diminish in the face of deteriorating catchment areas, an increasing population, expanding irrigated agricultural activities, and a growing industrial base. Access to water has become a limiting factor in socio economic development of the country. Therefore, the Government has been promoting various ways of harnessing water resources, including rainwater through rainwater harvesting techniques (KRA, 2006).

Due to climate change, many parts of the world including Marigat are receiving erratic rainfall, extreme floods and droughts. NWP (2007) points out that the world water resources are facing dramatic changes as a result of global climate change, high water demands, population growth, industrialization and urbanization. The United Nations

Water Development Report, 2006 (NWP, 2007) also points out that a combination of lower precipitation and higher evaporation in many regions reduces water levels in rivers, lakes and groundwater.

As climate change leads to more extreme variations, water harvesting solutions must cope with both extreme rainfall and extreme droughts. Extreme rainfall requires good flood protection and diversion structures and extreme drought requires large storage capacity. In some cases, droughts last so long that alternative water sources are required, which means that water rationalization schemes must be developed in advance (NWP, 2007).

Rain Water Harvesting, is an age-old system of collection of rainwater for future use. But systematic collection is a recent development and is gaining importance as one of the most feasible and easy to implement remedy to restore the hydrological imbalance and prevent a crisis (Rane & Arjun, 2006).

Rainwater harvesting is not new, as communities in Kenya have practiced it for a long time. Most rainwater harvesting technologies are simple, acceptable and replicable across many cultural and economic settings. Unlike big dams, which collect and store water over large areas, small-scale water harvesting project lose less water to evaporation because the rain or run-off is collected locally and can be stored in a variety of ways (UN-Water, 2006). A report presented by UNEP and World Agro-forestry Centre (UN-Water, 2006) showed that Kenya with a population of about 40 million is capable of meeting the water needs of six to seven times its current population. The rainwater harvesting potential in Kenya is estimated at over 12,300 m^3/person compared with the current annual renewable water availability of just over 600 m^3/person (KRA, 2006 and Futi *et al*, 2011).

2.3 Surface Water Harvesting and Storage Technologies

In most parts of the country, a lot of water is lost as surface runoff which can be harnessed, stored in reservoirs such as dams, water pans and can be used in times of need.

2.3.1 Pans and Ponds

A water pan is an excavated water storage structure that is square, rectangular or round, used to retain surface runoff from uncultivated grounds, roads, home compounds, hillsides, open pasture lands, laggas and may also include runoff from watercourses and gullies (SearNet 2011, ICRAF & UNEP 2005, Mati, 2007, *www.paceproject.net*).

Water pans are simple to construct and hold at least 100 m^3 but less than 5,000 m^3 of water. They have been used for rainwater harvesting for livestock watering were popularized by "food for work" programs in the ASALs of Kenya and Ethiopia and this was to provide employment to people affected by droughts (Mati, 2007, Amha, 2006).

Ponds are more similar to pans; they are small tanks or reservoirs constructed for the purpose of storing surface runoff (Amha, 2006). The pans are 1-3m deep and have a capacity of 100-5,000m^3 of water. However, ponds are constructed in ground recharge areas usually due to high water table. They are excavated in perennial swamps and streambeds to increase the volume of water storage and improve inflows from outlying areas (Mati, 2007).

Livestock farmers with large herds or flocks need access to large amounts of water to keep their animals watered and healthy, particularly during the dry months (RRRP, 2007). Pans and ponds are dug up to capture and store runoff from surfaces such as hillsides, roads, rocky areas and open rangelands. Pans have been used to harvest rainwater in many parts of East Africa, especially for livestock.

2.3.2 Dams

Sand Dams

According to RAIN (2008), a sand dam is a small dam build on and into the riverbed of a seasonal sand river and its function is based on sedimentation of coarse sand upstream of the structure by which the natural storage capacity of the riverbed aquifer is enlarged. During the wet season, surface runoff and groundwater recharge fills the aquifer and the river starts to flow as it does in the absence of the dam. The groundwater flow through the riverbed is obstructed by the sand storage dam creating additional groundwater storage for the community.

Mati (2007) defines sand dam as a reservoir created when a short wall is constructed across the sand river to restrict surface flow, allowing the water and sand carried by the flood to settle and get stored in the dam. It is constructed in stages for various years to avoid silting up. The dam wall is increased by 0.3 m after floods have deposited sand to the level of the spillway. It is constructed in such a way that; the foundation goes down to the impervious layer below the sand to allow sand to be trapped upstream of the dam wall increasing the storage of the riverbed. Water is stored under the sand thus; it is protected from evaporation losses and also less liable to contamination. Water stored in sand dams is used for domestic, livestock and supplementary irrigation of crops.

Charco-dams

Charco-dams are small rectangular, excavated pans or ponds, which are constructed at a relatively flat topography for livestock watering (Mati, 2007). They collect runoff from outlying areas of a rangeland and the contour bunds (ridge terraces) are constructed to divert runoff into the dams.

Earth Dams

Earth dams are constructed to retain flood runoff during the rainy season on a watercourse which may be a perennial or a dry river bed. The wall normally does not exceed 2-5m high and has a clay core, stone apron and spillway to discharge excess runoff. These earth dams can store large volumes of water, (Mati, 2007) notes that the maximum volume of water ranges from hundreds to tens of thousands of cubic meters and can provide adequate water for irrigation and livestock watering. They are common in Mwingi district, Kenya, and Dodoma, Shinyanga and Pwani regions in Tanzania (Mati *et al*, 2006).

Sub-surface Dam

A subsurface dam is a reservoir created when an embankment is constructed across a sand river to restrict surface flow, allowing water and sand carried by the flood to settle and get stored in the dam. Unlike a sand dam, the embankment in a subsurface dam can be constructed with stone masonry or compacted clay.

Underground Tanks

Tanks can also be dug into the ground. They differ from ponds in that the walls of the tank, constructed inside the dug hole, are typically made from bricks and cement, or else are covered with a plastic liner. Tanks are also covered by a roof, made either from iron sheets or from another material, such as grass. Thus the tank is not accessible by animals, and people do not wash in it directly. Water is drawn from the tank, either by a tap, a pump or a bucket.

The roof not only adds security, preventing access, but also reduces loss of water through evaporation. Water stored in tanks may be safe for human consumption, or it may need to be boiled to make it safe (RRRP, 2007).

2.4 Studies Related to Surface Water Runoff Harvesting

In rural areas, especially in arid and semi-arid regions access to a sustainable and adequate supply of portable water is critical and under severe pressure due to the increasing needs of the population, tourism and agriculture (Rochdane *et al* 2012, Keshavarzi *et al* 2006). Therefore, determining the number of people who will be served, their per capita use, and the factors that affect the water consumption is very important in management of water resources appropriate as potable water (Keshavarzi *et al* 2006).

Australia being the driest continent, (UNEP, 2010) they have been relying on rainwater harvesting to meet their water demand, Hunter Valley inhabitants in New South Wales depended so much on rainwater harvesting and refused to connect to the town water supplies. The government had to convince them to connect to the town water supplies and the water authorities discouraged rainwater tanks via storm water drainage standards and informing citizens that they were illegal and dangerous and by 1990s the use of rainwater tank in urban areas was illegal (Chanan *et al*, 2007). Most of the Australian cities are located along the coastline and receive adequate rainfall every year to satisfy their water needs. In Sydney, 420GL of storm water is collected every year and the water demand is about 660GL, thus, rainwater could provide a potential source of water for

Sydney metropolitan area. Kogarah Municipal Council is the first local government in Sydney to promote the use of rainwater tanks in schools. After installation in the schools within the council area, the water was used for flushing toilets and two schools used it for irrigation only and this maximized the reduction of portable water use (Chanan *et al*, 2007).

In rural Beijing, groundwater has been diminishing rapidly caused by frequent droughts, increasing domestic and industrial water demand. Liang & Dijk (2011) did a study on promoting rainwater harvesting for irrigation by increasing the charge of using groundwater to discourage groundwater consumption. Due to the high cost of groundwater, the consumption of rainwater will increase, since rainwater is an appropriate replacement for groundwater for irrigation (Liang & Dijk, 2011).

Tsiko & Haile (2011) did a study on modeling water reservoir site selection in Debub district, Eritrea since water scarcity has been a fundamental problem. The region has been facing erratic rainfall, droughts and unfavorable hydro-geological characteristics which have exacerbated the water supply. The study identified candidate sites for locating water reservoirs using GIS techniques and promoted the building of water reservoirs as a possible solution to meet the future water demand.

Rainwater harvesting has been successful in China. Gansu, Sichuan, Guangxi, Guizhou and Yunnan provinces have adopted rainwater harvesting techniques. Amha (2006), points out that rainwater harvesting projects have been carried out in almost 700 counties of the 15 provinces in semi-arid and humid areas and by the end of 2001, around 12 million water cellars, tanks and small ponds were built with a total storage capacity of 16 billion m^3, supplying water for domestic use for 36 million people and supplemental irrigation for 2.6 million m^2 of dry farming land. Therefore, these have helped the people to access water and engage in agricultural production hence improving food security and reduce poverty (Amha, 2006).

Loess Plateau of China which is a semi-arid region and has erratic rainfall patterns carried out runoff harvesting for large scale agriculture. The study proposed the use of mixture of locally available soils, compacted by simple rollers to increase runoff which would then be collected into other areas using common methods of water diversions (Baker *et al*, 2007).

In Pakistan, sporadic floods from temporary rivers are diverted and spread over a large area of land by earthen bunds about 1km long, several metres high and up to 20m wide at the base. Near the mountains, the bunds divert part of the fast flowing flood. Water is guided through a system of flood channels to the banded fields. The collected water is used for irrigation, filling the water ponds and the recharge of groundwater. This spate irrigation is an ancient form of water management in arid and semi-arid environments and is practiced most widely in Pakistan, Asia, the Horn of Africa and North Africa (NWP, 2007).

In Aroma zone, Southern Ethiopia, which is a water scarce area, rainwater and surface runoff harvesting has been effectively used to provide a substantial quantity of water which is used by rural communities for domestic, livestock and crop growing (NWP, 2007). RAIN (2008) noted that children in the region have the lowest school enrolment rate in the country since they spend most of their time collecting water and other domestic tasks. Surface runoff is harnessed during the rainy seasons and collected in a tank below ground surface, and channeled by bunds and gutters. The runoff capacity is increased by reducing vegetation cover, increasing the land slope with artificial ground cover and reducing soil permeability by compacting the ground. There are series of sedimentation basins to minimize siltation in the tanks (NWP, 2007). In Alaba, domestic and livestock sources of drinking water were scarce and the government had to promote rainwater harvesting at household level and in Woreda there are community managed water ponds which is their source of water (Amha, 2006).

In Kenya surface runoff harvesting for domestic and livestock has been carried out for instance road and compound runoff mainly in Kitui, Machakos and Laikipia is collected and stored in underground/subsurface tanks and water pans. Mutunga (2001) notes that rainwater conservation and harvesting in semi-humid areas is picking up on crop production since the land users are trying to be food self-sufficient and sell the surplus to generate income to meet other basic needs while in arid areas, land users are pastoralists and thus harvest water for domestic and livestock purposes.

Surface runoff in the floodplains of Lake Victoria is being harnessed and stored in finger ponds during the dry seasons. The water is harvested for aquaculture, fish cultivation and small-scale irrigation. The local communities are thus benefiting from additional protein and also a source of income. The finger ponds are excavated at the upstream edge of naturally occurring floodplains or wetlands and are lined with PVC plastic to prevent water from running out. They then fill up during the flood cycle and fish is trapped within them as the flooding recedes (NWP, 2007). In Bolivia, farm ponds that had been dug by farmers were enlarged and during rainy seasons runoff from higher slopes is collected and stored in these ponds and used for irrigation and fish farming.

In Athi river town, surface runoff is collected in storm drains and stored in reservoirs. Harvest Ltd. is able to pump flood waters into reservoirs for storage for use during the dry periods. There are two compacted earthen reservoirs having a maximum capacity of 230,000 cubic meters. The reservoirs can hold the water for a whole season without losing much to percolation. Rainwater harvesting and its storage would be an effective solution for both commercial and subsistence farmers (UNEP and SEI, 2009).

Surface runoff has been harnessed in most parts of the world although it is used mostly for agriculture in ASALs because of food insecurity and poverty in such areas. It has not been used widely for domestic and livestock since it needs some treatment before use. It is evident that rainwater harvesting is a decentralized water source in areas where other means of water supply have little potential. This study therefore, seeks to find out if the

Marigat community can adopt surface runoff harvesting to curb their problem of water scarcity during the dry seasons.

2.5 Land Tenure

According to Olima & Obala (1999), land tenure is a systematic land holding that embodies legal, contractual and communal arrangements under which people gain access to and utilize land. It constitutes various laws, rules, procedures and obligations that govern the rights, interests in land, duties and liabilities of the people in their use and control of the land resources. Thus, land tenure is a relationship between people and land that is embodied in land rights and restrictions or mode by which land is held or owned.

Land tenure systems are those legal, constructional or customary arrangements whereby individuals or organizations gain access to economic or social opportunities through land. Land tenure systems in Kenya are characterized as private/modern, communal/customary, public/state, and open access (Mbote, 2005). In Kenya, land is owned by four different entities, these are the government, county councils, individuals and groups and so different legal instruments govern different categories of land and owners (Mbote, 2005).

Customary land tenure refers to land ownership practices by ethnic communities under unwritten customary law. The tradition rules under such tenure systems are recognized by the legal systems and are upheld to the extent that they are consistent with written land law. The system is mainly practiced by communities in rural areas and sometimes in secondary towns (Olima & Obala, 1999). It is mainly found in most parts of Africa, the Middle East, and once upon a time in North America. Some of the characteristics of customary land tenure common in most communities are; individuals or groups acquire guaranteed communal rights of access and use of community land by virtue of their kinship relations, rights of control (allocation, use) including access to common areas for instance pasture are vested in the traditional authority of the community and property rights are restricted to the benefits and profits resulting from investment of capital and/or labour, and transmission rights through inheritance. The application of customary law is ousted and the land is removed from the ambit of Council control for conservation and development purposes (Mbote, 2005).

Private/modern system is based on individual title to land and permits almost unrestricted use and exchange of land and is intended to ensure its most intense and efficient use. Its limitation is the difficult to access by lower income groups. Tenure to trust land is increasingly changing from trust status to ownership by individuals, legally constituted groups and the state (Mbote, 2005).

Land tenure system is very important in the siting of water reservoirs in a community. This will help the researcher to know the problems expected to be encountered during the siting of the water reservoirs. If the land under study is private, there might be conflicts and some members of the community might not have access to the water source, so there is need to come up with alternative solutions for instance buying land from the individuals and converting it to be communal so that every member of the community to freely access the water resource.

2.6 Policies and International Conventions

Agenda 21 in Article 18.2 notes the need for water in all aspects of life. The general objective is to make certain that adequate supplies of water of good quality are maintained for the entire population of this planet, while preserving the hydrological, biological and chemical functions of ecosystems, adapting human activities within the capacity limits of nature and combating vectors of water-related diseases. Innovative technologies, including the improvement of indigenous technologies, are needed to fully utilize limited water resources and to safeguard these resources against pollution (UNDSD, 2009).

The UN Mar del Plata Water Conference held in 1977, stated that "… all people, whatever their stage of development and social and economic conditions have the right to have access to drinking water in quantities and of quality equal to their basic needs" (*data.iucn.org).* In July 2010, the United Nations declared "the right to safe and clean drinking water and sanitation as a human right that is essential for the full enjoyment of the right to life" (Ongware, 2011). Kenya has adopted in the new constitution, the right to water. Article 43(1) (d) states that "Every person has the right to clean and safe water in adequate quantities" (GoK, 2010).

The International Conference on Water and the Environment, held in Dublin, Ireland in January 1992 issued the Dublin Statement on Water Sustainable Development. This document reflected the freshwater resources found in Chapter 18 in Agenda 21. The Dublin conference identified four guiding principles for action at the local, national and international levels: 1) Fresh water is a finite and vulnerable resource, essential to sustain life, development and the environment; 2) Water development and management should be based on a participatory approach, involving users, planners and policymakers at all levels; 3) Women play a central role in the provision, management and safeguarding of water; and 4) Water has an economic value in all its competing uses and should be recognized as an economic good (UNDSD, 2009).

Global Water Partnership defined Integrated Water Resource Management (IWRM) as "a process which promotes the coordinated development and management of water, land and related resources in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems" (WVLC, 2008, ADB, 2007).

IWRM has also been defined by Grigg (1999) as a framework for planning, organizing and controlling water systems to balance all relevant views and goals of stakeholders (WVLC, 2008). IWRM encourages the examination of all biophysical and socio-economic linkages such as those that exist among natural resource sectors or those that exist between upstream activities and downstream impacts. It is also more of "bottom up" than "top down" and thus emphasizes the building of capacity among water users (it has also been described as the meeting of top down and bottom up, as government certainly can have a major role in settling up frameworks to facilitate engagement) (WVLC, 2008).

Integrated water resources planning and management aims to take appropriate account of important physical, social, economic and cultural linkages within a water resources system (WVLC, 2008).

NWP (2007), points out that water harvesting has not received adequate recognition from policy makers and engineers. The biggest challenge with using rainwater harvesting is that it is not included in water policies in many countries including Kenya (UNEP and SEI, 2009). In fact, in Kenya, the Water Act 2002 recognizes ground and surface water as sources of water. It does not recognize rainwater harvesting as a potential source of water.

2.7 Environmental Benefits of Rainwater harvesting

Rainwater harvesting is environmental friendly and has environmental benefits such as mitigation of floods, groundwater replenishment and thus reducing famine, drought and desertification and reduces erosion. It balances biodiversity, coastal management and other wetland water conservation by managing rainfall and runoff patterns in sustainable development initiatives. RWH also mitigates against negative socio-economic and environmental impacts of waste disposal into important water bodies and trans-boundary waters while runoff harvesting feeding sand and sub-surface dams is critical in dry season emergency storage (Engineer, 2007-2008).

RWH offers new opportunities for income generation activities including small-scale irrigation, zero grazing, light industry, soil and water conservation for higher yielding varieties in agricultural produce, fruit farming and fast growing trees for domestic use and development of tree nurseries. Others include beekeeping and sustainable sand harvesting (Engineer, 2007-2008).

2.8 Rainwater Harvesting and the Millennium Development Goals

During the Millennium Development Summit in 2000, 189 heads of state declared their full commitment to achieve eight Millennium Development Goals (MDGs). Since then, the world has had an unprecedented opportunity to improve the living conditions of billions of people in rural and urban areas. MDG_7 which is to ensure environmental sustainability is fundamental to achieve each of the other MDGs and in particular to improve health and eradicate extreme poverty and hunger (NWP, 2007).

Target 10 of MDG_7 is to halve the number of people without sustainable access to safe drinking water and improved sanitation by 2015 can be met. According to UNEP and SEI (2009), rainwater harvesting consists of a wide range of technologies used to collect, store and provide water with the particular aim of meeting water demand for humans and human activities.

UNEP and SEI (2009) further explains the roles of rainwater harvesting in meeting the MDGs these are;

MDG1 End poverty and hunger; this can act as an entry point to improve agricultural production, regenerate degraded landscapes and supply water for small horticulture and livestock and can also improve incomes and food security.

MDG2 Universal primary education; it can reduce the time devoted to tedious water fetching activities, enabling more time for schooling.MDG3 Gender Equality; interventions have been shown to improve gender equality and income group equity by reducing the time spent by women gathering water for domestic purposes, provides water so that girls can attend school even during their menstrual cycles thus increasing school attendance.

MDG4 Child health; contributes to better domestic water supply and improves sanitation reducing the incidence of water borne diseases which are the major cause of deaths among the under-fives.

MDG5 Maternal health; can supply better quality domestic water, which helps suppress diarrhea etc., and can release time from tedious water fetching activities.

MDG7 Environmental sustainability; interventions provide fresh water for humans and livestock, can regenerate ecosystem productivity and suppress degradation of services by soil erosion and flooding, rainwater harvesting can improve environmental flows by increasing base flow where groundwater is recharged.

The fact that MDGs implementation ends in 2015, the goals remain relevant especially in improving the wellbeing of people whereby one of the component is access to clean and safe water. It is due to such recognition, the country through its Vision 2030 as a long term national planning strategy and the Second Medium Term Plan (MTP) 2013 – 2017 sets 10 Sustainable Development Goals (SDGs) from which the issue of access to safe and clean water is given high priority. The unmet MDGs targets are addressed in the Second MTP (GoK, 2013), therefore, this study charts out ways that contribute to community access to water even post 2015.

2.9 Theoretical Framework

2.9.1 Participatory Planning Theory

Participatory planning is defined as joint actions of local people and project staff with the objective of formulating development plans and selecting the best available alternatives for their implementation. It should be a two-way learning process of dialogue, negotiation and decision-making between insiders (local community) and outsiders (project), concerning activities to be undertaken by the insiders and supported by the outsiders (*www.who.org*).

Kurian and Ramkumar (2003) notes that participatory planning is the initial step in the definition of a common agenda for development by a local community and an external entity(s). Participatory planning approaches aim at strengthening the local capacity for sustainable development in terms of knowledge, skills and organization. One of the important ways to ensure that local capacity is improved is through the recognition of the appropriateness of local knowledge in designing project actions. Mutunga, (2001) also adds that in water harvesting for domestic and livestock purposes, it is important to involve the land users or farmers right from project identification, planning, and implementation, to ensure a strong feeling of ownership and guaranteed operation and maintenance for sustainability.

Women should also be involved in the planning of water resources because they are mostly affected when there is limited access and they have to walk the long distances to collect water. Traditionally, women and young children, especially girls, are instrumental in providing water for their families, particularly in rural Africa. They often fetch and carry water in containers from long distances, spending large amounts of time and energy that could otherwise be used for other productive tasks. Women often perform between 65 and 72 per cent of water collection duties and some African women spend as much as 40 per cent of their daily nutritional intake travelling to collect water (UNEP, 2010).

This theory stresses the importance of involving the community in the planning and management of water resources and that in designing a participatory project, planning process should draw attention to local knowledge, skills, decision-making procedures and communication systems, as well as to existing organizational structures. Development and management of rainwater harvesting system should therefore be based on a participatory approach involving users, planners and policy makers at all levels and recognizing that women play a central role in its provision, management and safe handling. For any project in the community to be successful, community involvement is very important because they will feel part of the project, gives them the sense of ownership, will be able to sustainably manage the resource and ensures that every household in Marigat community has equal access to water resources.

2.9.2 Systems Theory of Planning

Beaulieu *et al* (2004) defines a system as an organized set of components, that in turn is composed of a series of smaller sets or components (or sub-systems), and which itself forms part of a larger set (or super system). There are interactions among their components and among their hierarchic levels.

McLoughlin (1985) also defined a system as ‘a complex whole, a set of inter-connected things or parts, an organized body of material or immaterial things and as a group of objects related or interacting so as to form a whole’.

This theory was first postulated by McLoughlin in 1969 and asserted that in order to identify a specific system, then it should be a set of elements or entities of the system, interactions between the entities and a boundary between the system and the environment of the system McLoughlin (1985). Therefore, for there to be harmony in the planning process, every institution or sector involved in planning must act in a coordinated and harmonious way and planning process itself is a system whose components (all the stakeholders and institutions involved) must work in association with each other in order to achieve the ideal coordinated planning envisaged.

The theory urges that there should be a systematic approach to planning and management of the water resource and needs to run in a harmonious way and involve all the stakeholders including women. Beaulieu *et al* (2004) also notes that while making a decision, it is always better to consult representatives of the interest groups themselves. The components identified are all the stakeholders involved in the planning and management of harvesting surface runoff and include the various Private and Public organizations and the communities.

Systems approach improves the basis for decision making for complex water management problems. In a social system, it describes the way water resources are used by people. The water resources system comprises of four linked subsystems these are; individuals, organization, and society nested within the environment. To achieve sustainable water resources management, interactions between the four subsystems; individuals, organization, society and environment, must be appropriately integrated.
Individuals are actors that drive organizations and society and they are the decision makers and have a role in water resources use and management. Organizations are structured to achieve goals. In water resource management system, every river is part of a

larger system which is a water shed, which is the land drained by a river and its tributaries. They are linked as networks, where 2 or 3 rivers join to make a larger river. Rivers are large natural streams of water flowing in channels and emptying into larger water bodies, a super-system.

The physical environment exerts passive pressure on the subsystems to ensure fit. The environment can limit action by running out of a resource or by changing circumstances to make the resource more precious i.e. climate change (Simonovic, not dated). This theory therefore emphasizes the importance of harmonization and integration of all stakeholders in water resource planning and management and surface runoff harvesting in particular to be successful.

2.10 Conceptual Framework

The interlinking between the systems theory of planning and participatory planning has been used to develop a conceptual framework as shown in Fig. 2.1. This may be used to conceptualize the water scarcity in a community and their involvement in the planning and management of surface water runoff harvesting to curb the community's problem.

The common sources of water in Marigat community are groundwater (boreholes), surface water (streams, rivers, and dams) and rainwater harvesting (rooftop, pans and dams). These sources are unreliable especially during the dry periods when the community members walk long distances to access water. Water scarcity is experienced due to the unreliable access to portable water. For water scarcity to be reduced, the community has to cope by harvesting surface water runoff that goes to waste during the rainy seasons and stored in several water pans. For this to be successful, it needs the community's participation in the harnessing of rainwater in terms of contributions, labour, time and building materials. Community participation ensures sustainable management of the water resources.

Local organizations can provide support to the community. Strong local organizations such as Water Resource Users' Associations (WRUAs), CBOs, Churches water policies are used as guidelines in the planning and management of water resources such as the Water Act 2002 and the need to be incorporated.

Surface runoff harvesting has not been fully exploited as a source of water in Marigat division yet it can provide adequate water for domestic and livestock. Thus, rainwater harvesting will continue to be an adaptation strategy for people living with high rainfall variability, both for domestic supply and livestock. The water to be supplied should be demand driven. Therefore, water that will be harvested will either be equal to the demand or adequate. If it does not meet the community's demand, then the community should adjust its participation and the rainwater technique used until the supply is met throughout the dry period.

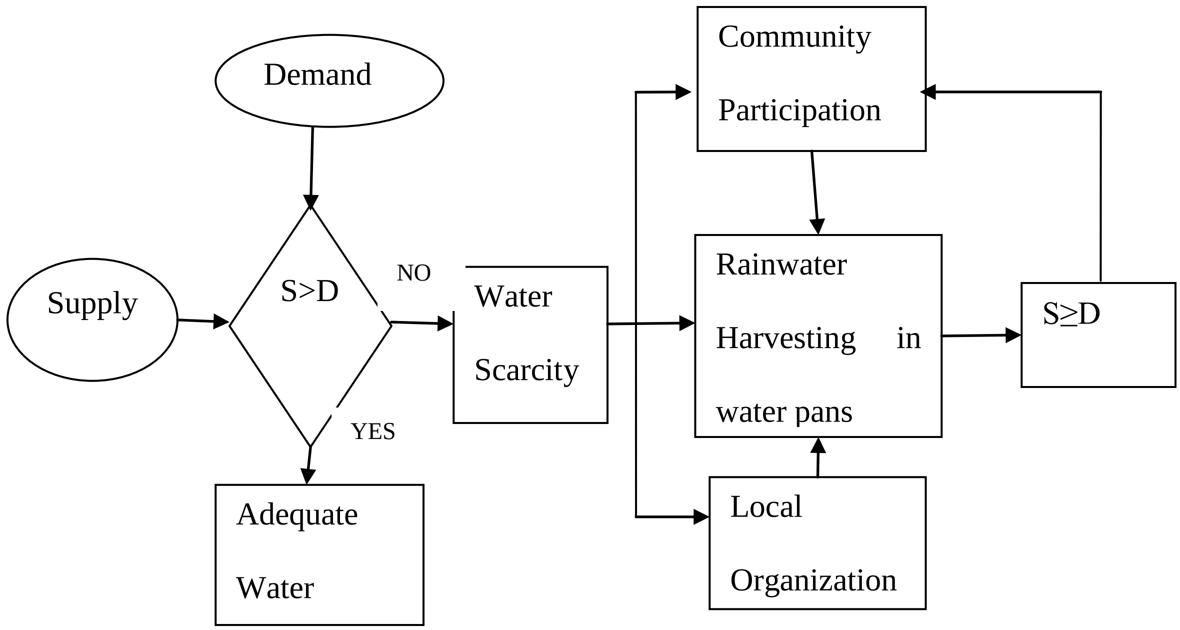

Figure 2. 1:Community participation in planning of water resources

(Source: Author's Construct, 2012.)

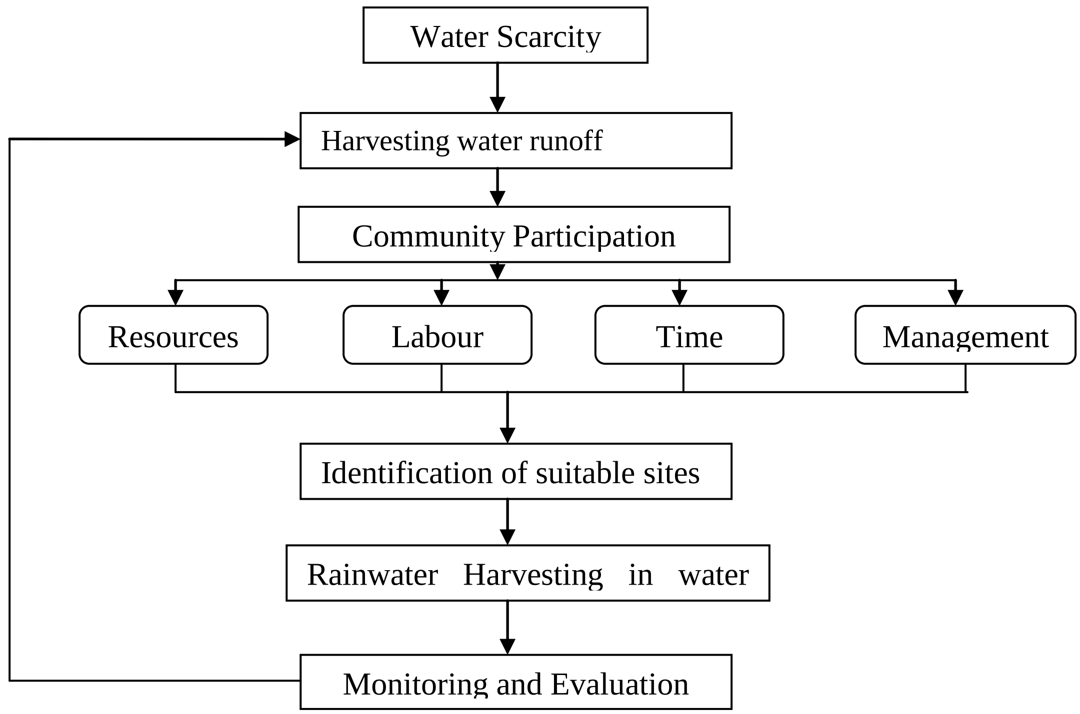

Figure 2. 2:Planning process in a community for sustainable water management (Source: Author's Construct, 2012.)

The main components in this conceptual framework (Figure 2.1) are; water resources, local community and the local organizations. The available water sources are key determinants for the strategies to be taken by the local community and the local organizations (WRUAs, CBOs, and Churches) in order to address the problem of water scarcity in the area. However, such strategies should be guided by relevant policies. Hence, there is need for in depth understanding of the key components. Figure 2.2 shows the planning process of water resource in Marigat community where a problem is first identified where in this case it is water scarcity, then solutions to the problem are identified. From the solutions one suitable solution is then selected and in this case it is rainwater harvesting in water pans where the community mobilize themselves and contribute in terms of resources, labour, time and management. The suitable sites for water pans are then identified and implemented. Finally, they are monitored and evaluated if the solution does not meet the community's problem of water shortage then the solution has to be revisited and adjustments made and the same process is followed again.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Introduction

This chapter presents the methodology of the study. It outlines the materials and methods of the study, giving materials used, and sample selection and, in line with the specific objectives, and methods of data collection.

3.2 Sample Selection

According to 2009 population census (KNBS, 2010), Marigat Division comprises of 40,423 people and 8,828 households. The sampling unit will be households; data will be obtained from household heads. The sample size will be determined from formula proposed by Yamane (1967) cited by Israel (2009) which states that;

$$n = \frac{N}{1 + N(e)^2}$$

Where n is the sample size, N is the population size and e is the level of precision (sampling error).

$$n = \frac{8828}{1 + 8828(0.05)^2}$$

n = 383 households

The study sample comprised of 383 household's heads, key informants drawn using purposive sampling and household's heads drawn using stratified random sampling.

3.3 Materials

The materials used were A GPS for collecting geographic-coordinate values in (UTM, Lat-Long) of the various water sources and taking tracks of the water pans for mapping; a digital camera to capture views that were deemed relevant to the study, Questionnaires and computer model for simulations and analyses.

3.4 Data Collection

The data collected for the study was both primary and secondary. To obtain primary data, the study used GPS's points of boreholes and tracks of water pans, photography and questionnaires (appendix 1) collected from a sample of 383 households and ten key informants. Stratified random distribution of questionnaires, focus group discussions (Appendix 2) and interviews were used to find out how reliable their water sources are by asking the duration of time in a year that water is available from the source, time it takes to fetch water. Percentages were taken to indicate the proportion of the scores having particular attribute.

Purposive sampling was used to collect data from key informants (Appendix 3): the water officer, World Vision, K.V.D.A, MCFP, NDMA, Kenya Rainwater Association and JICA.

Secondary data was obtained from topographical maps and satellite images to obtain data for rivers, streams, and dams. Relevant journals, and researches undertaken in Baringo district, other sources included Governments publication such as the National Development Plan, Water Resource Management Strategy, District Strategic Plan, census data 2009 and Water Resource Management Authority's reports.

Stratified random sampling was used to draw a sample of 383 household heads from the eleven locations who gave the desired information of the study (Table 3.1). These locations are: Kimalel, Marigat, Salabani, Ngambo, Sandai, Kapkuikui, Loboi, and Eldume. Sampling was done proportionately to the population of locations in the division. A total of 383 questionnaires were administered to the household heads.

Table 3. 1: Number of Questionnaires per Location

Locations	No. of Questionnaires
Eldume	32
Kapkuikui	17
Kimalel	47
Loboi	24
Marigat	144
Ng'ambo	43
Salabani	48
Sandai	28
Total	**383**

Focus Group Discussions

Two Focus Group Discussions were carried out; the locations were divided into two and comprised of two members from every location, therefore every FGD had between 10-12 members. The participants were selected using purposive sampling depending on their age, level of education, gender and good knowledge or experience of water resources. The information given by every participant was recorded for analysis purposes.

3.5 Data Analysis

Data analysis was done to facilitate conversion of data from the field into information. The analysis was conducted starting with socio-economic attributes to provide background for discussing the results as well as provide information which could be used in other sections, for example the household size and gender.

3.5.1 Willingness of the community to participate in harnessing water runoff

Stratified random sampling was used in the distribution of questionnaires and FGDs were used to obtain information about the willingness of the community to participate in harvesting of surface water runoff. It is a method that ensures certain subgroups in the population are represented in the population and is represented in the sample in proportion to their number in the population. This was determined by the willingness to participate in terms of costs, time, labour and management. The willingness of the community to participate was measured using Likert scale (Figure 3.1). Rensis Likert came up with a method of attitude measurement and published in 1932 (Boone & Boone 2012, Warachan 2011 and Johns 2010), he argued that attitudes vary along a dimension from negative to positive as illustrated below.

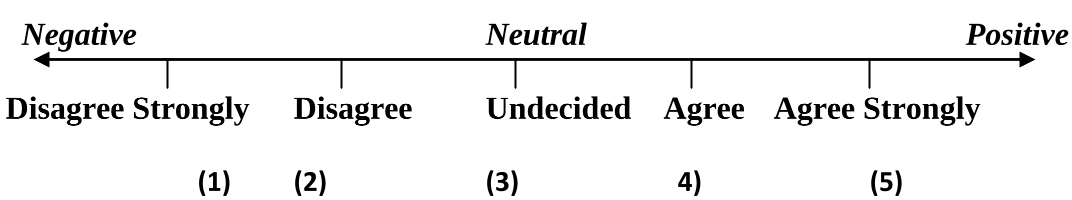

Figure 3. 1: Likert Scale
(Source: Boone & Boone 2012)

He recommended assigning of numerical values one through five for these multiple choices for the purposes of data analysis (Warachan, 2011). Armstrong (2008) used Likert scale to measure the willingness to donate organs among the Citizen Potawatomi membership to help guide the tribe's health programs aimed at profiling potential donors.

3.5.2 Siting of potential sites for water reservoirs

GIS techniques was used to identify potential water reservoir sites which was based on the topography, land use, roads, rivers, slope and soil type and done by creating buffer zones around geographic features (Table 3.2) to be protected and to be excluded in the list of possible sites, Mwasi (2011) notes that buffers are useful methods for analyzing the landscapes, solving environmental problems, water quality studies, road highways studies and pipeline alignment studies etc.

Table 3. 2: Water reservoir site selection criteria and the proposed buffer zones

CRITERIA	SUITABILITY BUFFER (m)
Roads	50
Rivers	30
Pit latrines	100
Agricultural lands	150
Houses	30

(Source: Modified from the Water Act 2002.)

3.5.3 Weighted Overlay Suitability Model

The weighted overlay tool is used for overlay analysis to solve multi-criteria problems such as site selection and suitability models (*http://help.arcgis.com*). Such models are used for applying a common measurement scale of values to diverse and dissimilar inputs in order to create an integrated analysis. Additionally, the factors of the analysis may not be equally important. Each individual raster cell is reclassified into a common preference scale such as 1 to 10, with 10 being the most favorable. An assigned preference on the common scale implies the phenomenon's preference for the criterion and then multiplies them by a weight to assign relative importance to each and finally add them together for the final weight to obtain a suitability value for every location on the map (Riad *et al*, 2011, *http://help.arcgis.com*). The topographical maps were digitized with a resolution of 20 m contour intervals and a scale of 1:50,000 to be used to develop the DEM.

Digital Elevation Model (DEM) was used to determine the slope information including slope angle. DEM data was obtained from digitizing topographical map. From the DEM (Figure 3.2), the slope map was derived (Figure 3.3). The slope map is important in defining the direction of flows within a catchment to potential reservoir sites, a slope of <2% was used. Other factors critical to siting the reservoir was considered from expert sources and key informants.

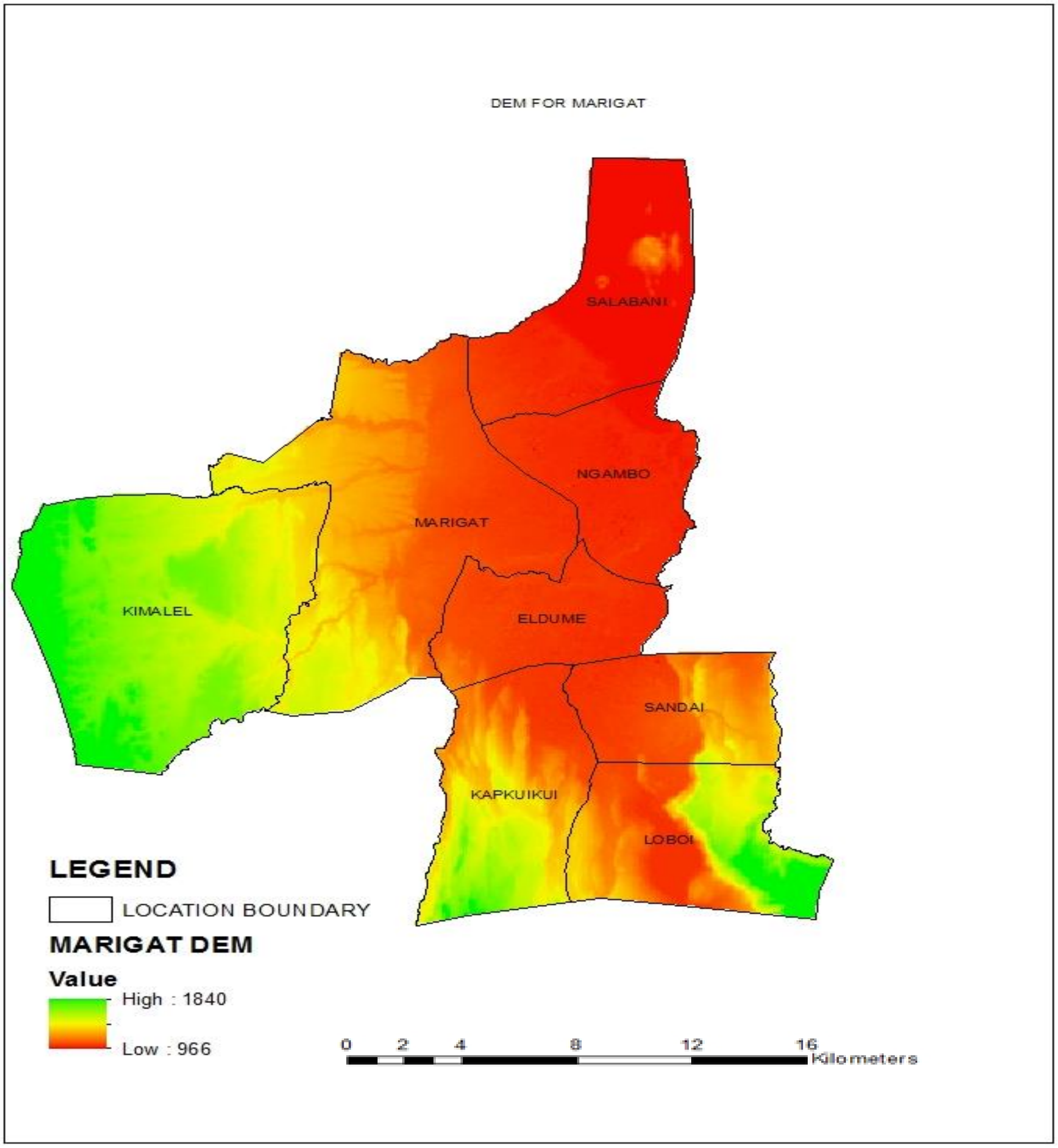

Figure 3. 2: Digital Elevation Map for Marigat

(Source: Author, 2013)

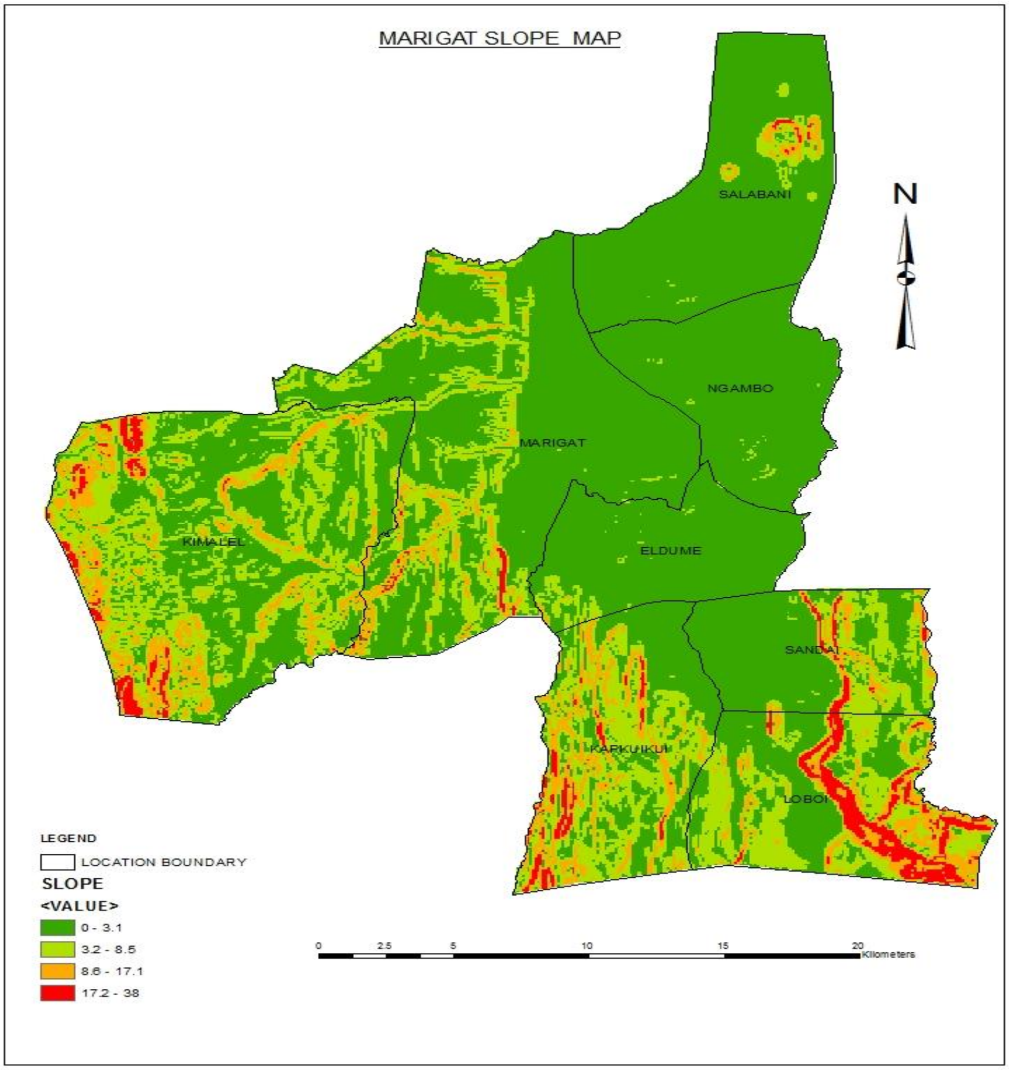

Figure 3. 3: Slope Map derived from the DEM map
(Source: Author, 2013)

Land use maps (Figure 3.4) were used for delineating agricultural lands like Perkerra irrigation scheme, urban areas and houses.

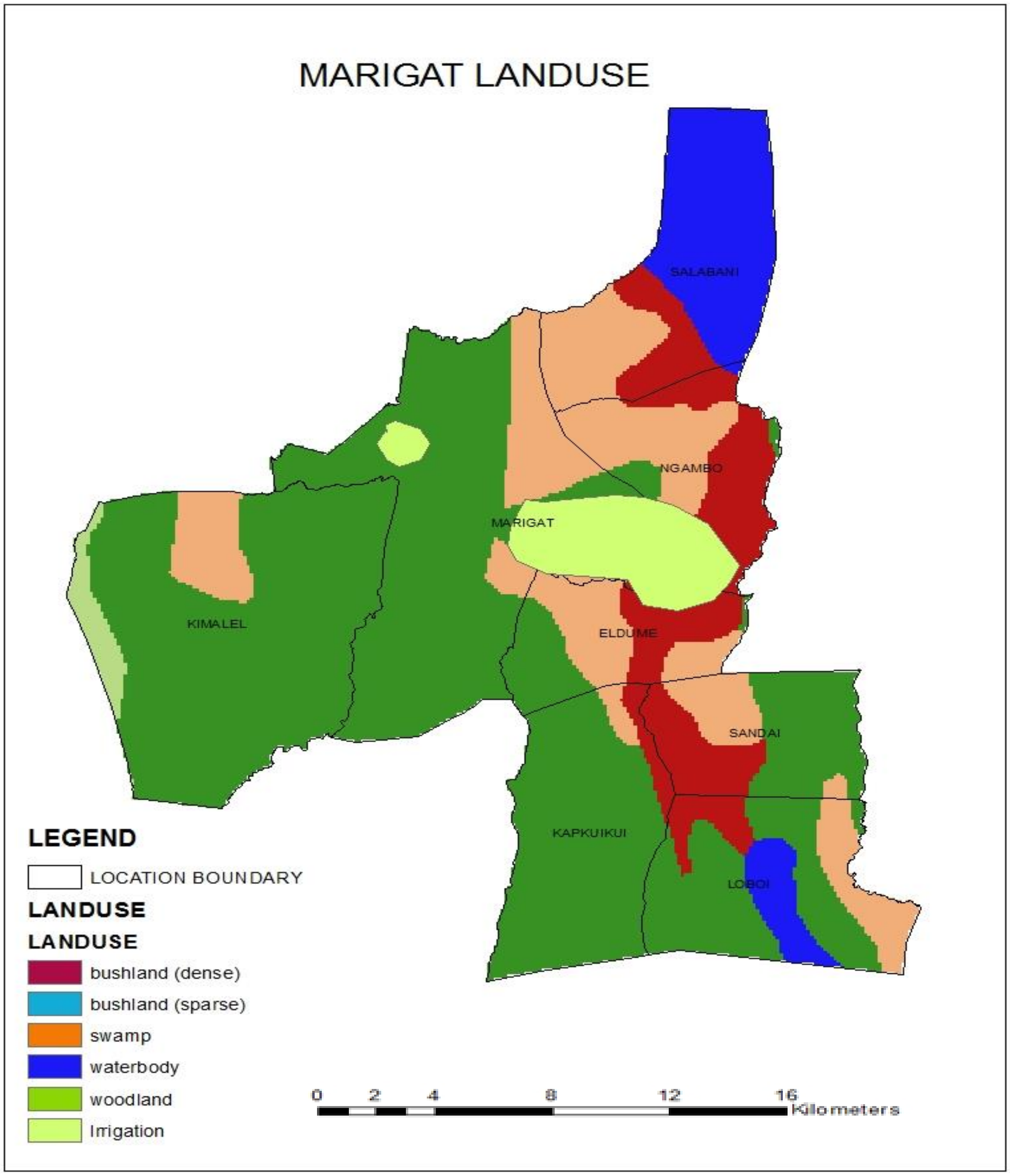

Figure 3. 4: Land use Map for Marigat

(Source: Author, 2013)

Runoff harvesting into water pans depends also on soil type and geology, especially to avoid seepage problems. Soil types have been useful to determine suitability of water pans although seepage can be controlled in water pans/pond through different interventions. Soil was categorized in terms of clay since clay soil determines the seepage rates, if the soil is clayey or not clayey it indicates that the soil is sandy while if the soil is very clayey, then it is very suitable for creation of water pans because it does not allow seepage of water. Figure 3.5 shows the soil map of Marigat Division.

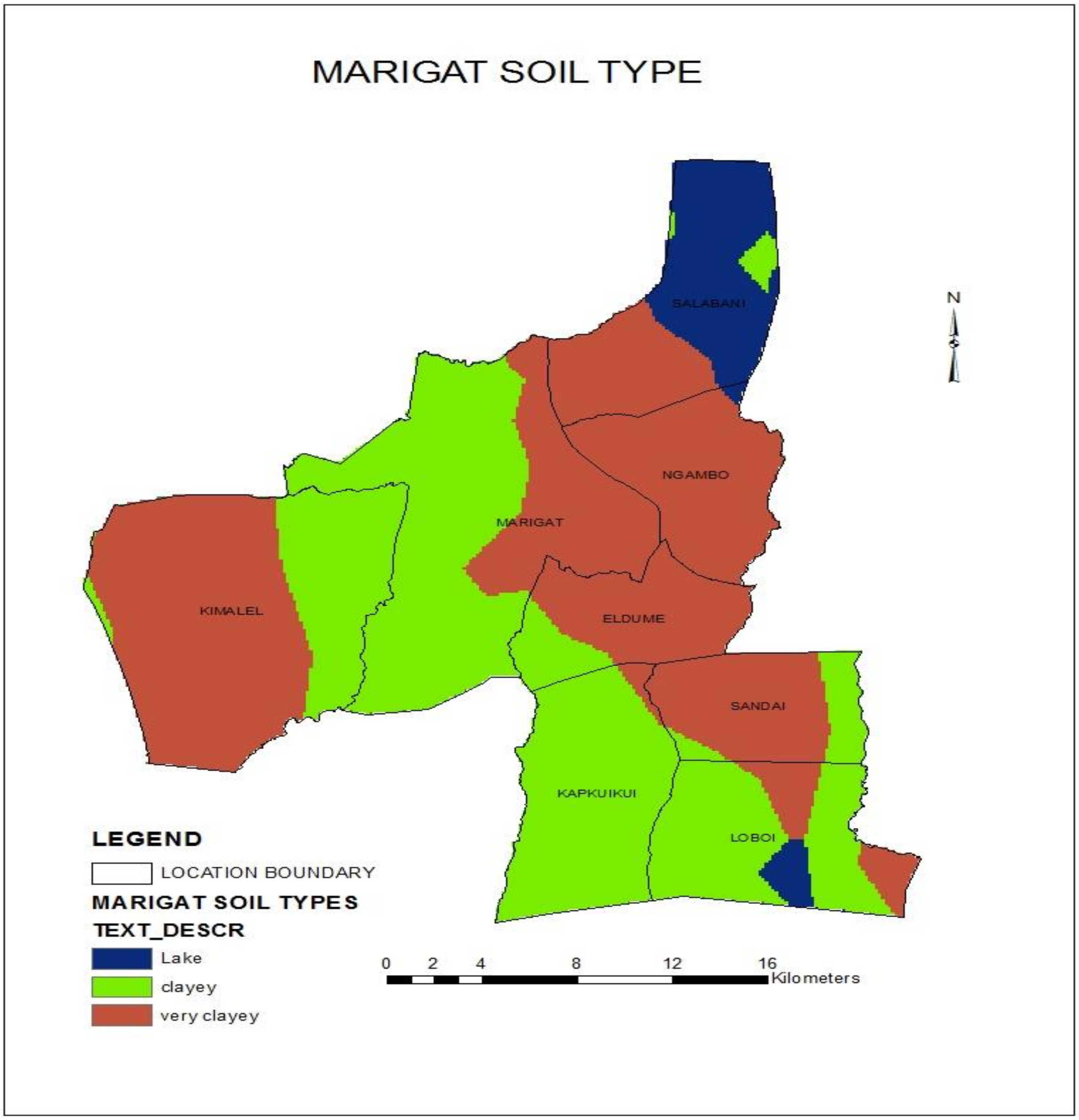

Figure 3. 5: Soil Map for Marigat Division
(Source: Author, 2013)

In the study, all the thematic layers were integrated in ArcGIS platform in order to prepare a map depicting suitable sites for water pans. Suitability analysis steps consisted of the following methods:-

i. The first step in the spatial analysis involved the creation of raster data. All layers had to be converted from vector to rasters before the Spatial Analyst could be used to perform any type of analyses. The conversion of vector data to raster layers was completed using the Spatial Analyst conversion tool.
ii. Distance Buffers: The second step comprised creating multiple ring buffers for some of the layers. Distance buffers were created for the major roads, agricultural lands, houses and rivers as shown in Table 3.2.
iii. Reclassifying Values: Once all the data sets were buffered and converted to raster data, the reclassify tool was used to reclassify the data sets. The suitability values ranged from high to low and a summation of the values for every raster cell was calculated.
iv. Weighing Data: To establish a logical assessment of optimal suitability, there were certain features that were deemed to be more important than others in the suitability model. Each input layer was weighted and assigned a decimal weight based on its importance. To find the suitable sites the data was calculated using the weighted overlay suitability model.

3.6 Determination of capacity of proposed reservoir to meet water demand

Historic monthly rainfall data for the past 39 years from 1970 to 2008 was obtained from Kenya Agricultural Research Institute (KARI) station and used in simulation. Conceptual framework for water planning in the study area was developed and subsequently customized in WEAP21 model. The river system, boreholes and water pans were schematized from an ArcView GIS layer. This information was obtained from different water users within the Marigat sub-catchment through questionnaires, individual interviews and to determine the extent to which the water stored in the proposed reservoirs can meet the water demand for the community. WEAP21 is a surface and ground water tool based on water balance accounting principles, which can test alternative sets of supply and demand conditions. It integrates a range of physical hydrologic processes with the management of demands and installed infrastructure in a seamless and coherent manner. Both the engineered and biophysical components of a water system are represented to facilitate multi-stakeholder water management dialogue on a broad range of topics, including sectorial demand analysis, water conservation, water rights and allocation priorities, reservoir operations, hydropower generation, pollution tracking, ecosystem requirements, and project benefit-cost analysis (Akivaga *et al*, 2010). The demand was classified as domestic, livestock, and agriculture with reducing order of allocation priority respectively.

3.6.1 Land use

The main land use practices are pastoralism, agriculture, fishing, tourism and settlements and the spatial distribution of areas and locations was determined using RS techniques.

3.6.2 Drainage

The drainages consist of rivers Endao, Molo and Perkerra, streams and storm water and the spatial distribution of locations was determined using GIS techniques.

3.6.3 Water supply

River flows from R. Molo, R. Endao, R. Perkerra and other seasonal streams are a source of water for the proposed water reservoirs.

3.6.4 Water demands

i. Domestic

The total consumptive water requirement was obtained from the number and sizes of households in Marigat based on 2009 population census, with a total of 8,828 households. A unit water requirement of 50 litres per person per day (FAO, 2007) was used for WEAP domestic water demand calculations.

ii. Livestock

A unit water requirement of 50 litres per day for each livestock was given as the unit consumption rate to estimate the water demand for all livestock in Marigat sub-catchment. The population of livestock was based on 2009 census data.

iii. Reserve / Environmental flows

The key principles of the Kenya Water Act 2002 are sustainability and equity (Mutiga *et al*, 2010).In using water resources to promote social and economic development, it is essential to protect the environment while ensuring that the water needs of present and future generations can be met. This is partly achieved by leaving enough water in a river, referred to as the “reserve”, to protect aquatic ecosystems in order to secure ecologically sustainable development and use of the water resource (Water Act 2002).

iv. Agriculture

The water demand for agriculture was estimated by multiplying the total area under irrigation with the average water requirement for the main crops that is from Perkerra irrigation. Since there was no data available on the exact amount of water used for irrigation and farmers do not know how much water they use for irrigation, irrigation water demand for the basin was calculated using the reference evapo-transpiration (ETo) and effective precipitation (P) concept as outlined in FAO-56 (Mutiga *et al*, 2010) (Table 3.3). Where Kc is the crop coefficients and ET_o is the reference crop evapo-transpiration.

Table 3. 3: Average crop coefficients for the common crops grown in the basin

Crop	Average Kc for the total growing period	Average Kc
Cabbage	0.75	
Maize	0.88	0.83
Onions	0.85	
Tomatoes	0.82	

Adopted from FAO-33;(Source: Mutiga *et al*, 2010)

A schematic diagram of the WEAP model for the Marigat division in Kenya (Figure 3.6) shows all the demand sites and various water sources (water pans, boreholes and rivers).

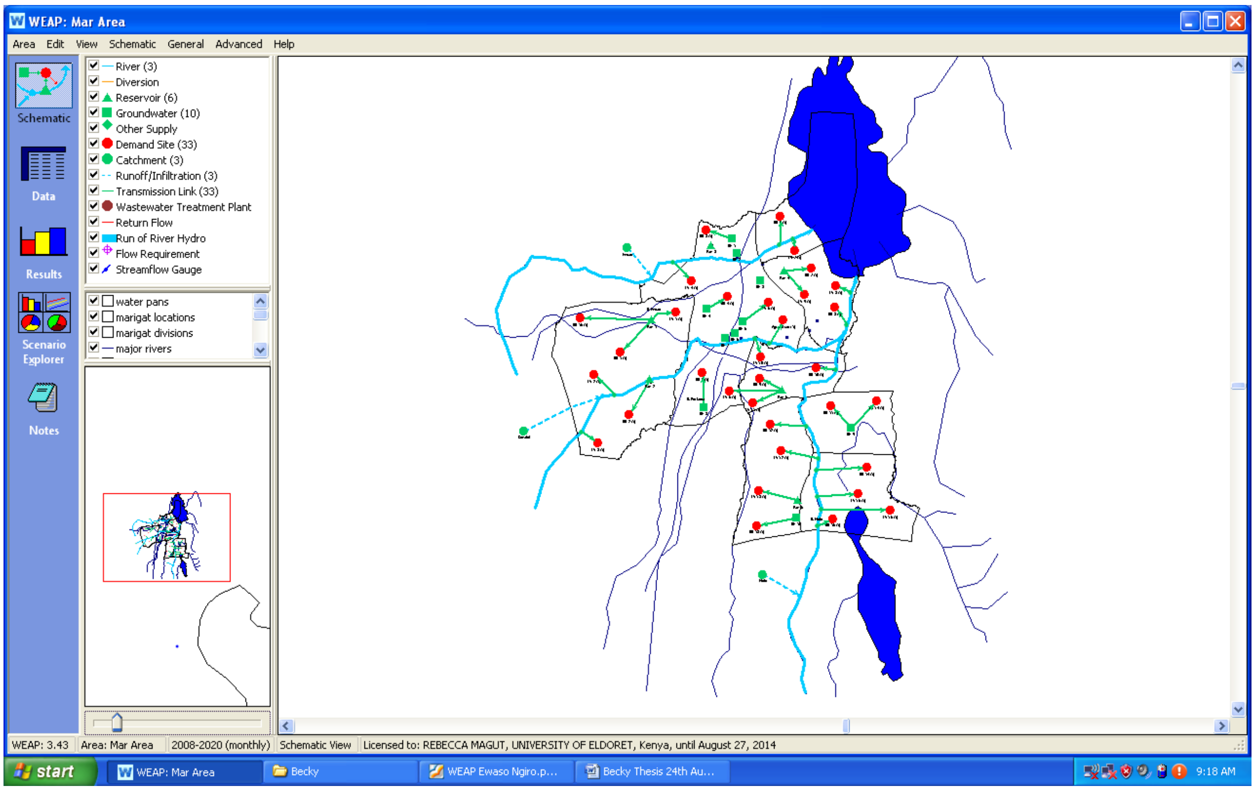

Figure 3. 6: Schematic diagram showing the configuration of the WEAP model for Marigat Division

(Source: Author, 2014)

3.6.5 Water priorities

This process was guided by the priority as described in the Water Act 2002 which ranks the reserve and domestic water requirements above other uses, reserve means quantity and quality of water required to satisfy basic human needs for all people who are or may be supplied from the water resource and to protect aquatic ecosystems in order to secure ecologically sustainable development (Water Act 2002), thus, domestic and environmental flows was assigned the highest priority over all other water uses and must strictly be met before water resources allocated to any other uses. Domestic water use and environmental flows were given priority (1) as shown in Table 3.4. This satisfied water demand downstream according to the water allocation hierarchy in the Water Act 2002.

Table 3. 4: Priorities for different water demands in accordance with The Water Act 2002

Water uses	**Priorities**
Domestic	1
Livestock	3
Agriculture	4
Reserve/ Environmental flows	1
Urban	5

Supply-oriented simulation models are not always adequate for allocation of water resources, environmental and policy issues, therefore an integrated approach for water resources development has emerged, which places water supply projects in the context of demand-side issues, as well as issues of water quality and ecosystem preservation (Mutiga *et al*, 2010).

WEAP model was selected for this study as it incorporates all these values into a practical tool for water resources planning (Mutiga *et al*, 2010). A schematic diagram of the WEAP model for the Marigat Division (Fig.3.6) shows all the demand sites and various water sources (streams, boreholes, and water pans).

3.6.6 Rainbow Model

Rainbow model (Raes *et al,* 2006) was used to come up with the water year method. Water year method is an in-built model in WEAP that allows the predictions of hydrological variables based on the analysis of historical inflow data. It uses the statistical analysis to identify the coefficients, which is used to replace the real data for future projection.

i. Catchment Hydrology

The rainfall runoff method was used to simulate river flows; it was chosen since it best suited the characteristics of the study area. The type of data required to perform rainfall-runoff simulation included:

i. Land use (Area, Kc, effective precipitation)
ii. Climate (Precipitation and ET_o)

Observed river flow data for Marigat Bridge station was available as gauge heights and were converted using the rating curve to get the flows in cubic metres per second (Appendix 4). The observed flows were used to calibrate and validate the model.

3.6.7 Model Calibration and Validation

The complexity of water allocation models and the fact that they are required to simulate human behavior (to reflect changes in demand) in addition to physical processes means that model calibration and validation is extremely difficult and has often been neglected in the past (Akivaga *et al*, 2010). Calibration was necessary in order to evaluate performance of the model. To calibrate the model, observed stream flow data at gauging station at Marigat Bridge of 2008 were used. These flows present an integrated time series of climate, changes in demand, water resource development and land use within the catchment (Akivaga *et al*, 2010).

The WEAP 21 model performance is evaluated using standard statistics; mean error (ME), mean square error (MSE) and model coefficient of efficiency (EF) as described by the equations below.

$E_Q = Q_M - Q_O$ (Model residual)

$$ME = \overline{E}_Q = \sum_{i=1}^{n} \frac{Q_m(i) - Q_o(i)}{n} = \sum_{i=1}^{n} \frac{E_Q(i)}{n}$$

$$MSE = \sum_{i=1}^{n} \frac{(Q_m(i) - Q_o(i))^2}{n} = \sum_{i=1}^{n} \frac{(E_Q(i))^2}{n}$$

$$EF = \left[1 - \frac{\sum_{i=1}^{n} \left(Q_m(i) - Q_o(i) \right)^2}{\sum_{i=1}^{n} \left(Q_o(i) - \overline{Q_o} \right)^2} \right] = \left[1 - \frac{MSE}{S_{Q_o}^2} \right]$$

Where;

Qo - Observed flow

QM - Simulated flow

ME - Mean Error

MSE - Mean Squared Error

EF- Model Efficiency Coefficient

n- The number of data points

s- Variance (squared standard deviation)

The ME and MSE reflects the bias or systematic deviation in the model results and the random error after correction. The model efficiency coefficient EF of Nash and Sutcliffe, which is a dimensionless and scaled version of the MSE for which the values range between 0 and 1 (0 or 1 for a perfect model) gives a much clearer evaluation of the model results and performance (Akivaga *et al*, 2010).

R-Squared is another statistical measure of how well a regression line approximates real data points; an R-squared of 1.0 (100%) indicates a perfect fit. The formula for R-squared is:

$$R^2 = \left[\frac{\sum_{i=1}^{N} \left(o_i - \bar{o} \right) \left(s_i - \bar{s} \right)}{\sqrt{\sum_{i=1}^{N} \left(o_i - \bar{o} \right)^2} \sqrt{\sum_{i=1}^{N} \left(s_i - \bar{s} \right)^2}} \right]^2$$

3.6.8 Creation of Scenarios

Scenario Analysis

A scenario can be defined as a plausible description of how the future may develop, based on a coherent and internally consistent set of assumptions about key relationships and driving forces (Arranz & McCartney, 2007). Scenario analysis enables the answering of ‘what if’ questions in a water system. The objective of a reference scenario is to bring an understanding of the current trend. Other scenarios are built on this reference scenario with variations on the demand or supply side.Scenarios are built and then compared to assess their water requirements, costs and environmental impacts (Akivaga *et al*, 2010). All scenarios inherit data from the Current Accounts year.

The scenarios can address a broad range of "what if" questions, such as: What if Population growth and economic development patterns change? What if reservoir operating rules are altered? What if a water recycling program is implemented? What if climate change alters the hydrology? 'What if' scenario analyses were built and done for 2009 to 2020 (Figure 3.7).

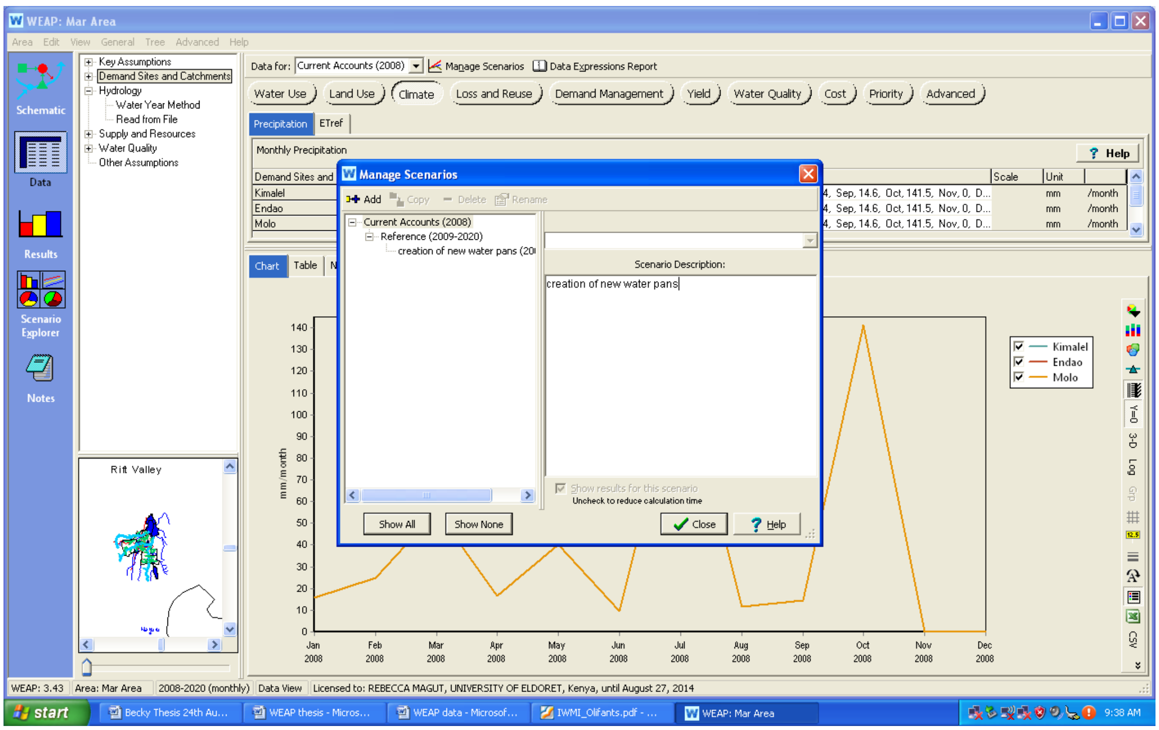

Figure 3. 7: Illustrates a window showing scenarios in WEAP21. The Current Accounts represent the basic definition of the water system as it currently exists. (Source: Author, 2014)

Hydrology

Hydrological events and processes in the study area were defined in order to simulate some aspects of its hydrology, including precipitation, evapo-transpiration, stream flow data and dominant crops within the study area like maize, onions and cabbages. Groundwater analysis was not considered in this study; this is because it was not within the scope of the study.

Stream Flow Data

The data used in this analysis were obtained from Akivaga's (2010) study. The catchment monitoring station at Marigat Bridge was used for stream flow analysis and model calibration and validation.

Catchment

In setting up the WEAP21 model, three catchment sites (Kimalel, Endao and Molo) represent the contribution of the mid catchment streams. Using FAO rainfall runoff method, the land use and climate of a catchment site were defined. The other input options of the catchment sites: 'Loss and reuse', 'Yield', 'Water quality', and 'Costs' were not taken into consideration in this project.

3.6.9 Proposed water supply network in Marigat

The demand and supply sites were identified and using WEAP21 model, link the demand and supply points to come up with a water supply network in the community.

3.7 Data Presentation

The results of data analysis were presented using various methods. Percentages were used to show the proportion of scores having particular attribute to the total number of cases. Frequency tables were also used and supplemented with graphical presentations using pie charts, bar charts, and line graphs.

CHAPTER FOUR

RESULTS

4.1 Introduction

This chapter provides the results of the data collected in the study. This study sought to assess the willingness of Marigat community to participate in the planning and management of rainwater harvesting and propose suitable sites for water harvesting reservoirs. The chapter presents descriptive statistics on demographic characteristics of the respondents and inferential statistics in testing the hypotheses of the study. The above activities were guided by research objectives which are: To identify the sources of water, reliability of water sources in Marigat division, to investigate the willingness of the community to participate in harnessing water runoff in Marigat division, to determine suitable sites of water pans for harvesting water runoff to meet water demand in Marigat division, and based on objectives i-iv, propose a water supply network for the Marigat community.

4.2 Findings

4.2.1 Demographic Characteristics of the Respondents

This is analyzed in terms of gender, age, occupation, education level, location, monthly income, and household size. The study found that 69 % and 31 % of the respondents who participated in this study were male and female respectively, the duty of collecting water was found to be handled solely by women as most of them had gone to fetch water (Plate 4.1). The levels of education attained by the heads were 2.9% had no formal education, 17.8% had primary education, 56.4% had secondary education, certificate and diploma were 11% and 8.1% respectively and undergraduates were 3.1% while those who had attained postgraduate education were the least with 0.8%. This shows that the majority of the population did not have education beyond the secondary education (77.1%). The respondents who participated in the study had diverse ages, ranging from a minimum of 20 to over 50 years. A higher proportion of the respondents were aged between 25-30 years (34.5%). This was followed by those aged between 35-40 years (27.7%). The distribution of the monthly household incomes in Kshs were such that 0.8% earned less than 1,000, 15.1% were in the range 1000-2000, 58% were in the range 2001-3000, while 26.1% earned more than 3000. The results show that the community has low income which they use in the basic needs like food and with the low income, they are unable to buy or construct water tanks for rainwater or connect tap water from the boreholes and so they have no choice but to walk long distances to fetch water.

Plate 4.1: Women, children and men fetching water.

(Source: Author 2013)

0

4.2.2 Main source of water for the respondents

In Marigat, there are many sources of water as shown in Plate 4.2. These sources of water can be categorized into surface water and underground water. Surface water occurs as rivers, streams, pans and lakes. Ground water occurs in the pore spaces within rocks and alluvium, in fractures, and in solution openings or conduits in areas underlain by soluble carbonate rocks (e.g., limestone). Figure 4.1 shows the main sources of water and distribution in the study area. A significant proportion of the respondents obtain water from the river or stream (47.3%) while the least get water from the tap (6.3%). Those who get the water from the borehole and water pan are 23.3% and 16.7% respectively (Table 4.1).

Table 4. 1: Main sources of water

Source of water	Frequency	Percent
River/Stream	181	47.3
Tap water	24	6.3
Borehole	93	24.3

Water pan	64	16.7
Lake	21	5.5
Total	**383**	**100.0**

Plate 4.2: Various sources of water, boreholes (a-b), water pans (c-d), streams (e) and rivers (f)(Source: Author 2013)

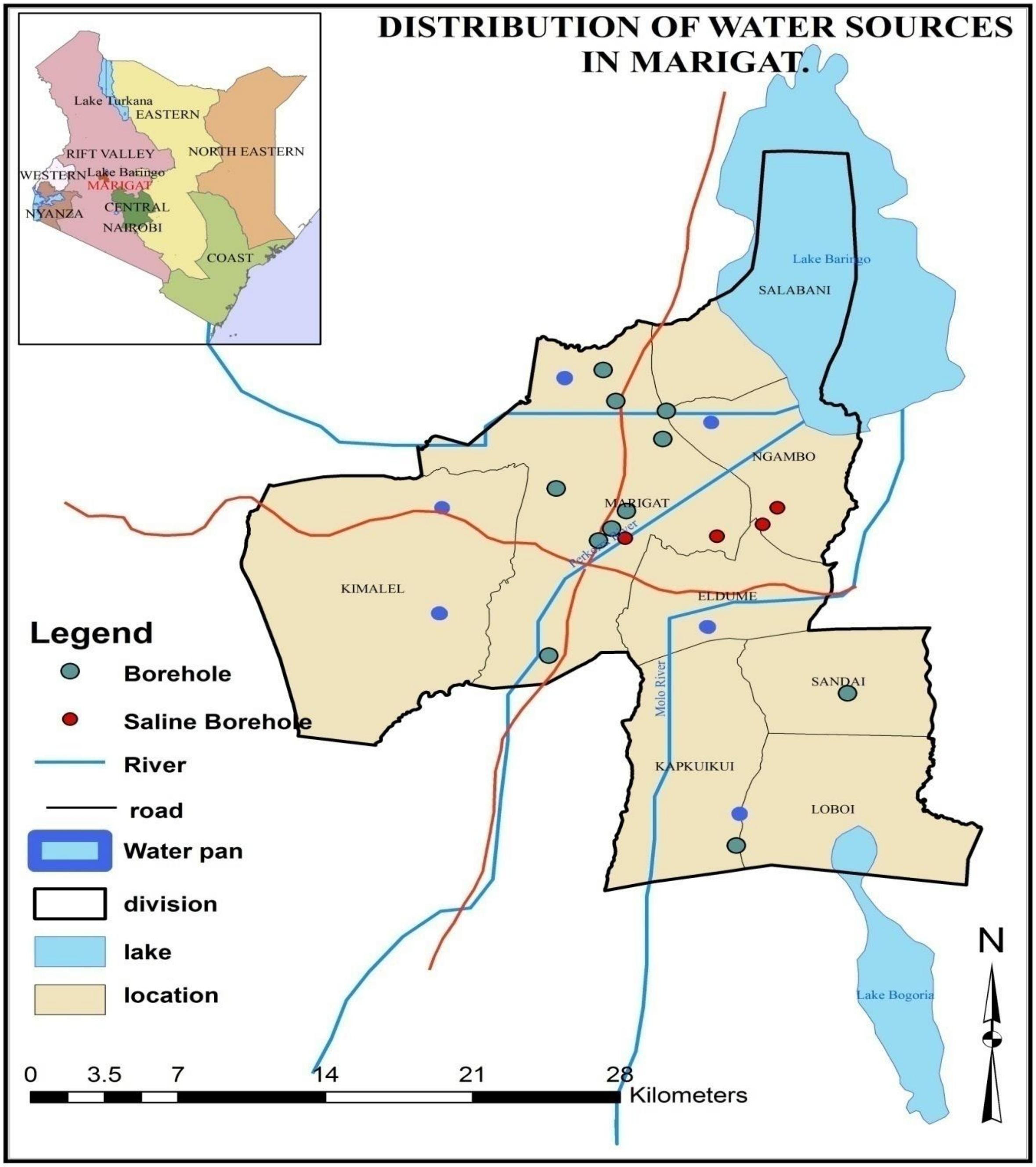

Figure 4. 1: Distribution of various sources of water in Marigat Division

(Source: Author 2013)

Water for animals

The study findings indicated that a significant proportion of the households utilize the source of water together with their animals. The study findings indicate that 80.9% of the household utilize the source with their animals which include cattle, goats and sheep. However, 19.1% indicated that they do not use the same source of the water for both domestic and animals (see table 4.2).

Table 4. 2: Same Source of water for both domestic and livestock

Response	**Frequency**	**Percent**
Yes	310	80.9
No	73	19.1
Total	**383**	**100.0**

The study findings indicated that a significant proportion (77.6%) of the residents take their animals to the river. This was followed by those who use the stream (17.2%). These results are summarized in table (4.3). Streams are seasonal rivers that occasionally dry up and are during such seasons they are forced to take the animals to the river or water pan. Least percentage of the respondents use water pans 5.2%.

Table 4. 3: Source of water for livestock

Source of water for the animals	**Frequency**	**Percent**
River	297	77.6
Water pan	20	5.2
Stream	66	17.2
Total	**383**	**100.0**

4.2.3 Water Sources Reliability

In the study findings, 7.8 % of the respondents indicated that the water is available in their sources for 10 months while 1.6% indicated that the water is available in the river for 11 months and those whose source was available throughout the year was 25.8%, these are the households that get water from the main rivers and lake (L. Baringo) (Table 4.4).

Table 4. 4: Reliability of water in a household's source

No. of months	Frequency	Percent
10	30	7.8
11	6	1.6
12	99	25.8
Not sure	248	64.8
Total	**383**	**100.0**

Asked if they experience any water shortage from the sources, a significant proportion (64%) of the respondents indicated that they experience water shortage. However, 36% indicated that they do not experience water shortage in their water sources (Table 4.5).

Table 4. 5: Water shortage from a household's source

Response	Frequency	Percent
Yes	245	64.0
No	138	36.0
Total	**383**	**100.0**

The study findings indicated that the shortage in the area is serious with 25.1% indicating that the water shortage is very serious and 31.9% saying that it is serious. The proportion of those who indicated the water scarcity is not serious stood at 32.1% (Table 4.6).

Table 4. 6: Extent of water scarcity in the community

Extend of water scarcity	**Frequency**	**Percent**
No water scarcity	123	32.1
Moderate	42	11.0
Serious	122	31.9
Very serious	96	25.0
Total	**383**	**100.0**

A significant proportion (62.1%) use borehole water, 32.1% use river water while 5.7% use water pans (Table 4.7).

Table 4. 7: Alternative sources of water

Alternative source	**Frequency**	**Percent**
River	123	32.1
Borehole	238	62.1
Water pan	22	5.8
Total	**383**	**100.0**

The other factor of water scarcity is the distance covered by respondent to fetch water. Majority of the respondents cover a distance of 0-3 Km (61.9%). Those were followed closely by those who walk a distance of 4-6 Km at 34.2% and the least (3.9%) walk 7-9 Km. Table 4.8 gives a summary of these research findings.

Table 4. 8: Distance to a water source

Distance in Km	Frequency	Percent
0-3	237	61.9
4-6	131	34.2
7-9	15	3.9
Total	**383**	**100.0**

The amount of water fetched in a day varies with the use. From the findings, the respondents indicated that they fetch water using jericans from the water source. The study findings revealed that they use containers that can be able to carry as much water as possible most of the respondents were using a 30 litre jerican, though they were also using a 20 litre and 10 litre jerican. Rarely were the respondents using a 5 litre jerican because it carries little amount of water. The respondents spent on average 121-160 litres of water per day. The findings revealed that there are households that use as low as 80 litres and a maximum of 280 litres. A significant proportion of the households (44.1%) use on average between 121–160 litres of water per day, this was followed by those who consume between 161-200 liters per day. Few (2.4%) households spent between 241-280 litres per day (Table 4.9).

Table 4. 9: The quantity of consumption of water per household per day

Consumption in litres	Frequency	Percent
80-120	70	18.3
121-160	169	44.1
161-200	99	25.9
201-240	33	8.6
241-280	12	3.1
Total	383	100.0

The research findings revealed that a higher proportion of the residents have animals that number between 21-30. This category of the residents comprised 60.3%. This was followed closely by those with between 1-10 animals at 15.7%. Table 4.10 below gives a summary of the number of cattle that the residents have.

Table 4. 10: The number of cattle per household

Size of herd	Frequency	Percent
1-10	60	15.7
11-20	43	11.2
21-30	331	60.3
31-40	49	12.8
Total	**383**	**100.0**

These animals are watered for between 1 to 3 times a day and an average of 42 litres per day. The study findings indicate that on average, the cattle are watered once per day (62.9%), see table 4.11 for a summary of watering the cattle.

Table 4. 11: The number of times animals are watered in a day

No of times of watering in a day	Frequency	Percent
1	241	62.9
2	139	36.3
3	3	0.8
Total	**383**	**100.0**

4.2.4 Willingness of the community to participate in harnessing surface water

In the wake of scarcity of water in the study area, the study investigated the willingness of the community to harness water runoff. The study findings indicate that indeed, there is huge demand for water both for domestic and animals use. First the respondents were asked to respond to whether, they are willing to participate in harvesting rainwater runoff as a solution to water scarcity. The study findings indicated that a significant proportion of the respondents who were willing to participate were 64.5% while those who were not willing were 35.5% (Figure 4.2).

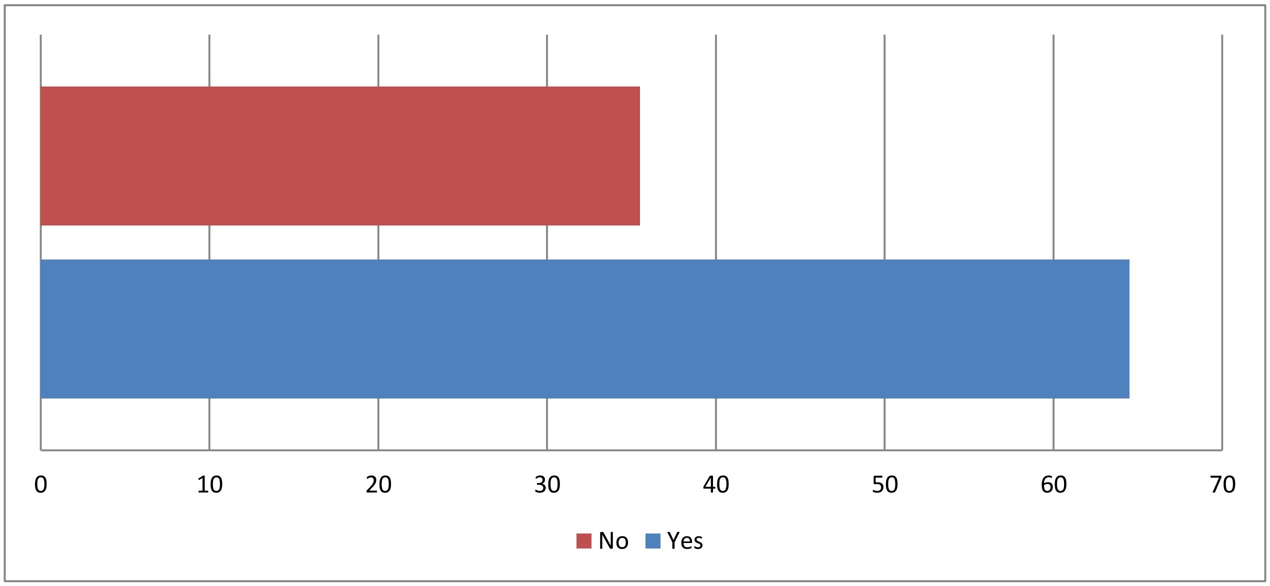

Figure 4. 2: Willingness to participate in harvesting water runoff as a solution to water scarcity

In addition to the willingness, most of the residents prefer to harvest water as a community as opposed to an individual as shown in table 4.12.

Table 4. 12: Opinions on whether to harvest water as a community or individual

Participation	Frequency	Percent
Community	362	94.5
Individual	21	5.5
Total	**383**	**100.0**

In the study 94.5% are willing to participate as a community while 5.5% are willing to contribute as individuals.

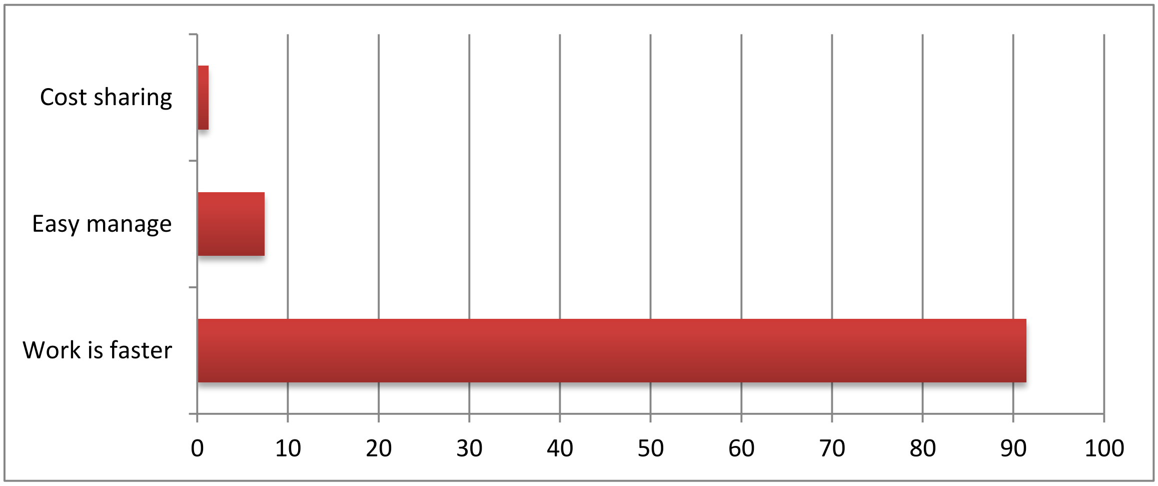

Figure 4. 3: Reasons of harvesting water as a community

This implies that the residents would prefer the community approach because of the work been done faster together with the aspect of cost sharing (Figure 4.3). This is an indication that the respondents are willing to offer themselves in terms of labour and engage in participating in the actual work of harnessing surface runoff water. In the study, 63.1% were willing to give up themselves to do the actual work that is developing of infrastructure of harvesting surface runoff water. In addition, there are other aspects that the respondents were willing to contribute to harvesting the water. They include contributing to the cost of harvesting water, spare time and provide management of the harvested water. Those who preferred to contribute to the cost of the project were at 77.1% while those who would wish to spare time were 50.3%. The least was those willing to participate in management (table 4.13).

Table 4. 13: Willingness to participate in various ways in harvesting of water runoff

Ways of contribution	Strongly disagree	Disagree	Undecided	Agree	Strongly Agree	TOTAL
Willingness to contribute to the cost of harvesting water runoff%	-	-	-	77.1%	22.9%	100%
Frequency				295	88	383
Willingness to provide labour for harvesting water runoff? %	-	-	-	63.1%	36.9%	100%
Frequency				242	141	383
Willingness to spare time for harvesting surface water runoff? %	-	-	-	50.3%	49.7%	100%
Frequency				193	190	383
Willingness to provide management for harvesting surface water runoff? %	-	-	-	36.9%	63.1%	100%
Frequency				141	242	383

Association between water scarcity and willingness

The study wanted to establish the reason behind the enormity of the respondents to willfully participate in harnessing surface runoff water. To do this, chi-square test statistic was conducted to test if there is a relationship between the willingness and water scarcity. The test was conducted at significance level 0.05 and chi-square statistic and p-value obtained and interpretation made. The responses of the willingness were cross tabulated with the responses of water scarcity as shown in tables 4.14 and 4.15.

Table 4. 14: Extent of water scarcity in the community * Overall willingness Crosstabulation

Extent	Overall willingness		Total
	Agree	**Strongly Agree**	
No water scarcity	73	51	**124**
Moderate	18	22	**40**
Serious	62	61	**123**
Very serious	57	39	**96**
Total	**210**	**173**	**383**

Table 4. 15: Chi-Square Tests

Statistics	**Value**	**df**	**P-value. (2-sided)**
Pearson Chi-Square	4.151	3	.0246
Likelihood Ratio	4.148	3	.0246
Linear-by-Linear Association	.022	1	.881
N of Valid Cases	**383**		

The chi-square statistics indicate that there is a significant relationship (0.0246) between water scarcity and the willingness to participate in harnessing water. The p-value is less than 0.05 and the hypothesis that there is no relation between willingness to harness water and water scarcity is rejected and conclusion made that there is a significant relationship between water scarcity and willingness.

Findings from the Key Informants and FGDs

The study sought to solicit information from key informants pertaining to water management and their role in assisting the Marigat community to alleviate or reduce water shortages. The key informants in the study comprised of key respondents from Kerio Valley Development Authority (K.V.D.A), Marigat Child and Care program (MCFP) and National Drought Management Authority (NDMA).

The role of these organizations appeared distinct. However, each supplements the other in providing essential services in the Marigat community. K.V.D.A is charged with the role of planning, co-ordinating and implementing integrated programs and utilizing the available resources for the benefit of the communities in their areas of jurisdiction. MCFP is charged with alleviation of child poverty while NDMA's mandate is to try and mitigate drought emergencies through community resilience creation and climatic change adaptations. Other organizations that supplement include World Vision, KARI, GOK, Kenya Red Cross Society, JICA and Kenya Rainwater Association.

The organizations support the community in mitigating water shortage problems. For instance, K.V.D.A does this by assisting the community construct water pans and dams to store water. NDMA plan and conduct Food for Asset programmes and construction of pans. At the time of study, K.V.D.A was assisting, through sourcing of funds and capacity building to construct dams in Kipkututia. On the other hand, MCFP was engaged in extending water supply from Endao to KampiyaSamaki and in construction of water tanks, pipes and kiosks. They are also engaged in the business of capacity building. JICA have been drilling boreholes in the whole of Baringo County.

The organizations are involved in continuous efforts to educate the community on rain water harvesting. This is because they have helped to boost crop production through irrigation. The study findings indicated that these organizations strategically partner and provide funds where possible to activities that avail water to the residents of Marigat division. Other methods facilitated to harness rain water include facilitating purchase of water pipes and construction of semicircular and zai pits.

With regard to sustainability of already existing projects, the organizations ensure that they are maintained through check dams to reduce siltation and ensuring that governance and community management structures are in place through community initiatives. The government has been handy in as far as such projects is concerned because they provide technical expertise at all times.

From FGDs, the community confirmed that they are facing water shortages and it is always the work of women and children to look for the scarce resource. Women have always spent a lot of time looking for water instead of doing other income generating activities like business and farming. The community is ready to mobilize its resources as a community than individuals in terms of finances, labour, time and management so as to curb their problem of water shortage. The community has tried to engage themselves in activities that help them get water for instance the Word Vision's 'Food For Asset (FFA)' programme where the community provide labour in constructing water pans and then they are given food in return and will also have water once it is harvested in water pans.

4.2.5 Siting of potential sites for water reservoirs

The results of the weighted overlay suitability model indicated that there were several areas that were suitable for siting water pans for rainwater harvesting. Figure 4.4 shows the suitable sites indicating a variation from least suitable to most suitable sites.

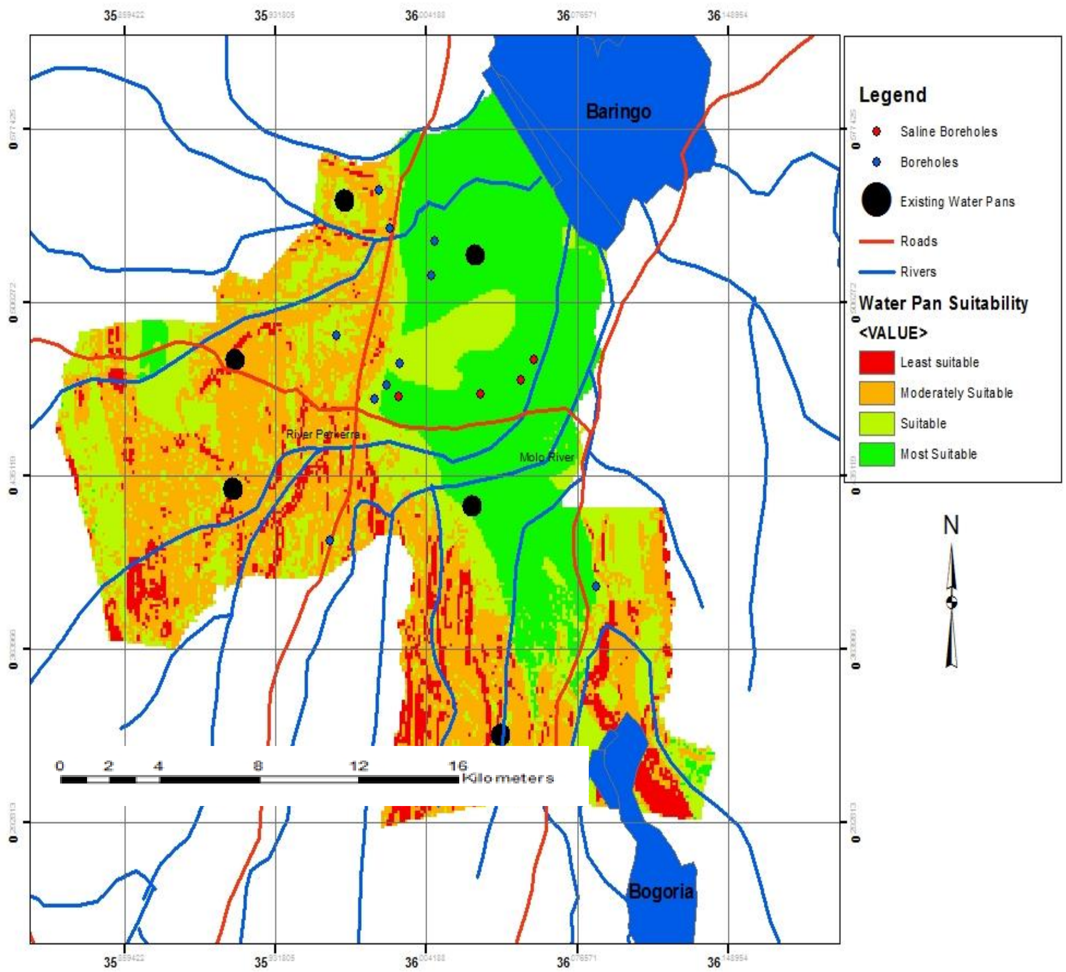

Figure 4. 4: Suitability Map Showing the Potential Sites for Water Pans (Source:Author 2013)

The reasons given by the respondents if worth harvesting surface water runoff in the community include the fact that it is a boost to agriculture in dry areas (51.7%). Other reasons cited include; curbs water shortage during dry season (7.8%), reduce soil erosion (2.1%) and the harvested water may be used in fish ponds (1.6%). On the other hand, the reasons that those who are against water harvesting site reasons such as the area being floody (31.3%), hence no need to harvest water, harvested water contains algae (0.8%) and that it creates breeding ground for mosquitoes (1.6%).

‘Marigat community has no willingness to harness water runoff in water pans which will reduce water shortage in Marigat division’

The study adopted chi-square (χ^2) goodness of testing technique to ascertain if Marigat community has the willingness to harness water. The technique is applicable to Likert scale which was employed in the study. Thus, this section therefore presents inferential data analysis and discussion of the results of the hypothesis tests. The hypothesis was tested at significant level of 0.05. The respondents were instructed through a set of statements to indicate whether they Strongly Agreed, Agreed, Strongly Disagreed, Disagreed or they were Undecided on the statements that pertained to their willingness to contribute to harnessing surface runoff water. The degree of freedom was calculated as (C-l) (R-l), where (C) is the number of columns and (R) is the number of rows, the degree of freedom for this study was thus: (5-1) (4-1) = 4 x 3 = 12.

To reject or accept the null hypothesis, we check if the significant level exceeds or is less than 0.05 in which case, the null hypothesis is accepted or rejected respectively and the alternative hypothesis is adapted if the null has been rejected. Also we can compare the sample chi-square with the critical value, and if the former exceeds the later, then we reject the null hypothesis and pick on the alternative hypothesis.

From the first hypothesis, there are no independent and dependent variables here but rather two categories of the respondents who exhibit or do not exhibit the willingness to harness water. The output of chi-square goodness of fit was conducted and it yielded the following outputs table 4.16 and 4.17.

Table 4. 16: Goodness of fit

Overall response	**Observed N**	**Expected N**	**Residual**
Disagree	6	191.5	-185.5
Agree	377	191.5	185.5
Total	**383**		

Table 4. 17: Goodness of fit

Test Statistics

	Goodness fit
Chi-Square	359.376
Df	1
P-value	.000

The overall computed willingness for those who agreed were 377 (98.4%) and those who disagreed were 6 (1.6%). The chi-square value computed was 359.376 and the p-value = 0.00.

4.2.6 Water Demand

'Harvesting of water runoff in water pans cannot meet Marigat's community water demand'

Reference Scenario

The Reference scenario is the scenario in which the current situation, current account year as 2008 is extended to the 'future' (2008-2020). A population increase was based on the Central Bureau of Statistics reports (Facts and Figures, 2009), the population growth rate was 2.6% while livestock growth rate was 1.2%. The model mimics reality over the period of 2008 to 2020.

Model Calibration and Validation

The observed stream flows for the period 2008 were used due to limited data to calibrate the model. The results presented in figure 4.5 indicate that the flows show the true presentation on the ground. The analysis was done where the ME is 0.18m^3, the MSE is 3.8647758m^3 and the EF was found as 74.8%. Though the magnitudes of the ME and MSE are high, the EF indicates that the model is good.

The model results as shown in Figure 4.5 had an R-squared value of 99.5%.

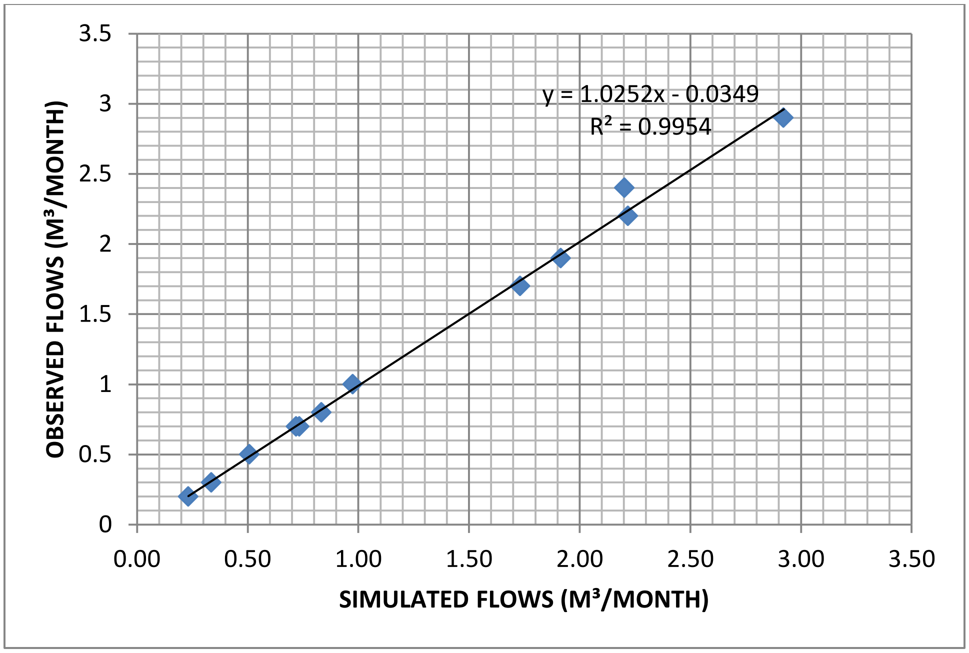

Figure 4. 5: Line of Best fit

In Figure 4.5, the observed stream flows and simulated stream flows of the reference scenario was used to draw the line of best fit.

Unmet Demand and Demand Coverage

Some sub-locations as shown in Figures 4.6 and 4.7 experience the shortage.

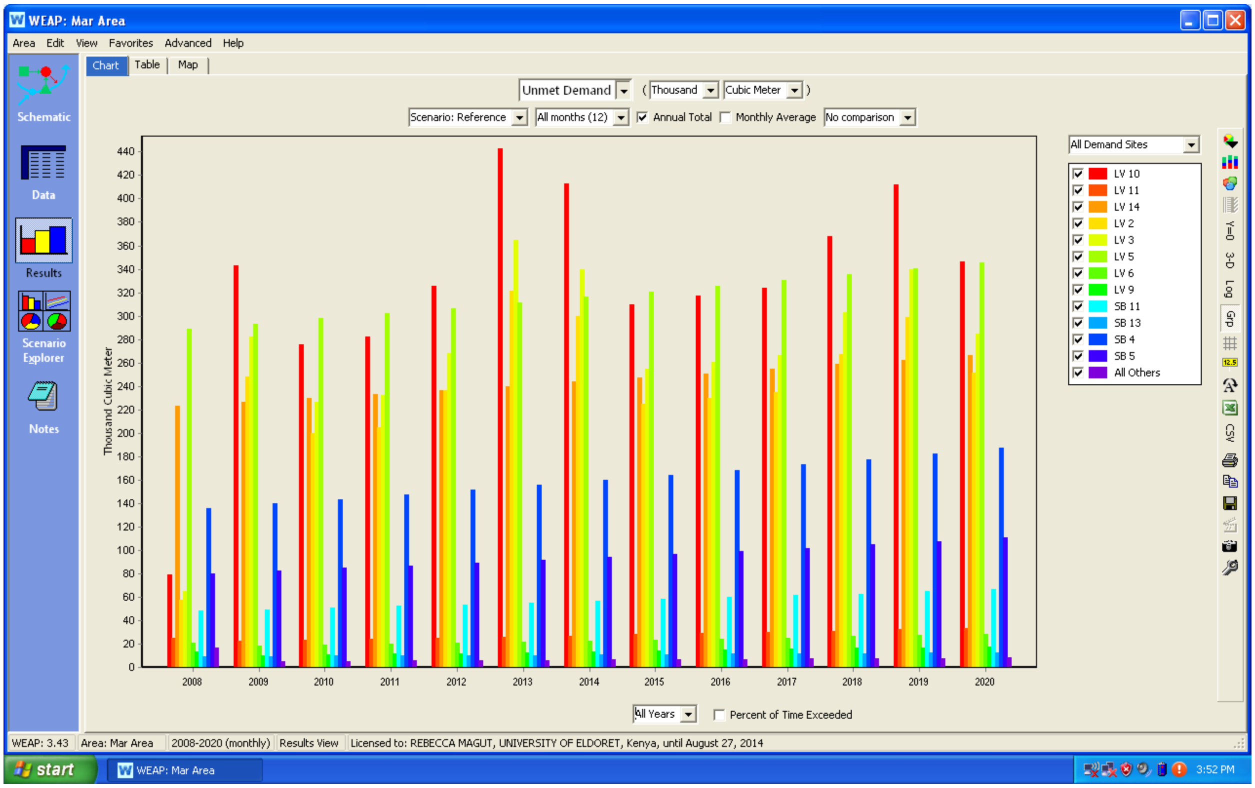

Figure 4. 6: Reference Scenario; Annual Unmet Water Demands

(Source:Author 2013)

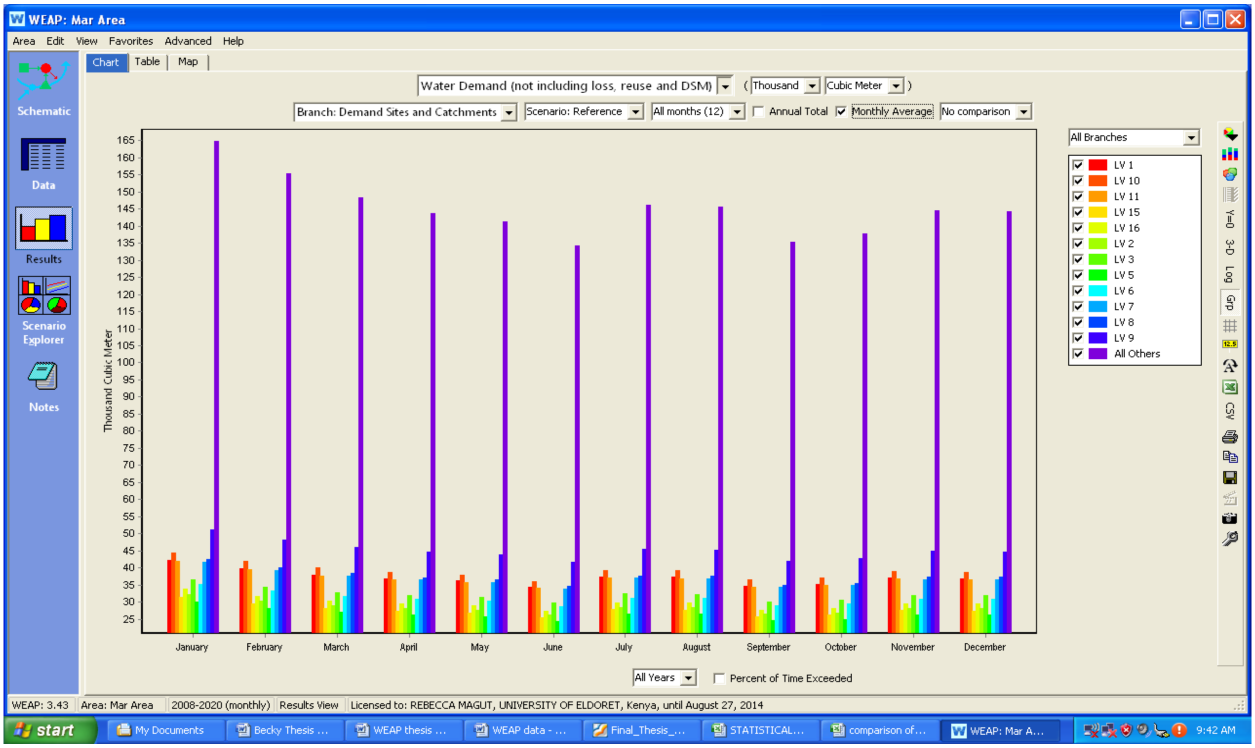

Figure 4. 7: Reference Scenario: Mean Monthly Water Demand Coverage of Marigat Division.(Source:Author 2013)

Scenario: Creation of New Water Pans

Marigat Division has been experiencing water shortage especially during the dry seasons. The study proposes creation of new water pans in sub-locations with unmet demand. Five new water pans of 50,000 m^3 each were proposed in Marigat (2), Sandai (1), Kapkuikui (1), and Kimalel (1) locations. The scenario looks at the effect of having new water pans to meet the unmet demand. The demand sites and hydrology remains as in the reference scenario. The unmet demand in the study area for the simulated period as compared to the results obtained from the reference scenario (Fig. 4.8) is met (Figure 4.9).

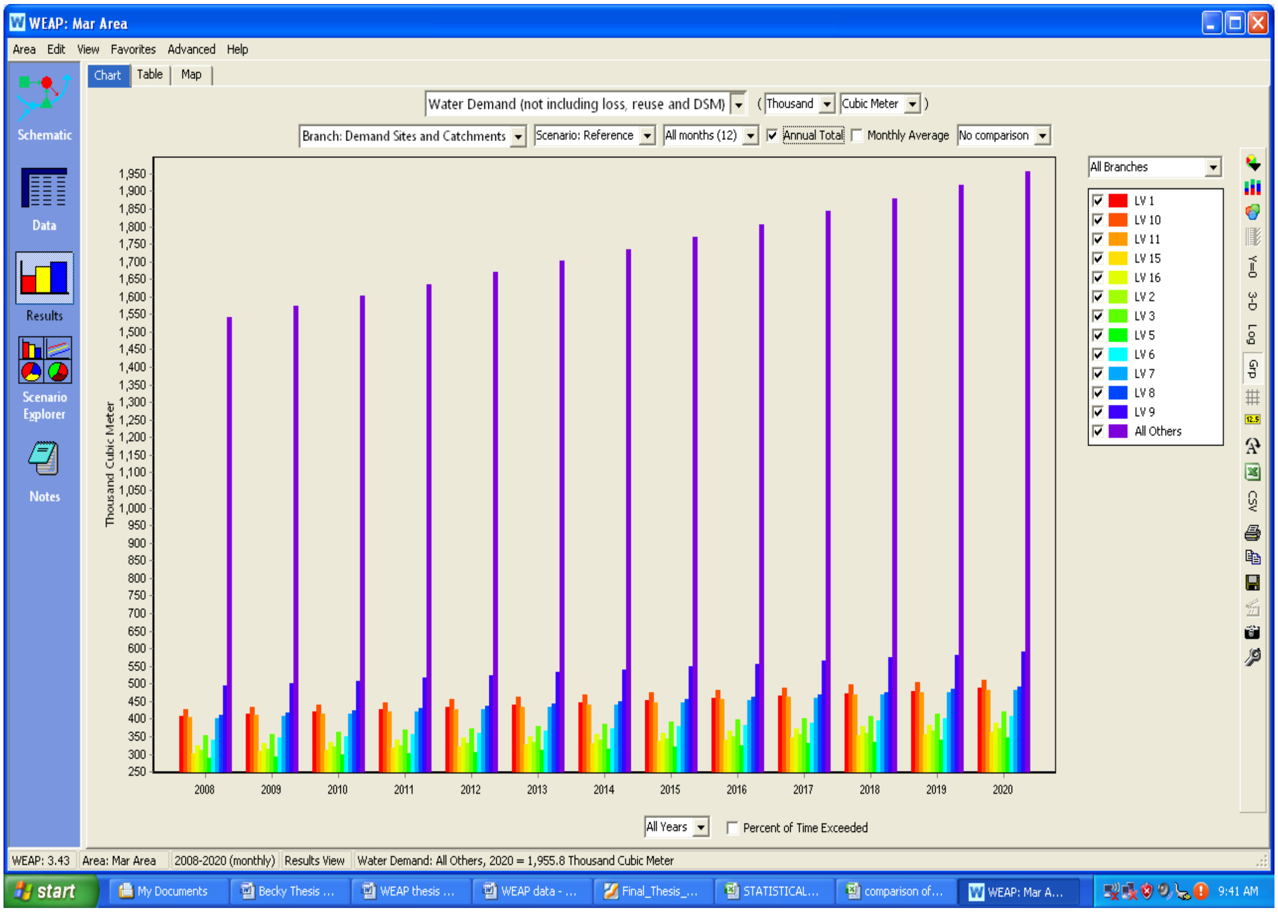

Figure 4. 8: Creation of New Water Pans Scenario: Annual Water Demand (Source: Author 2013)

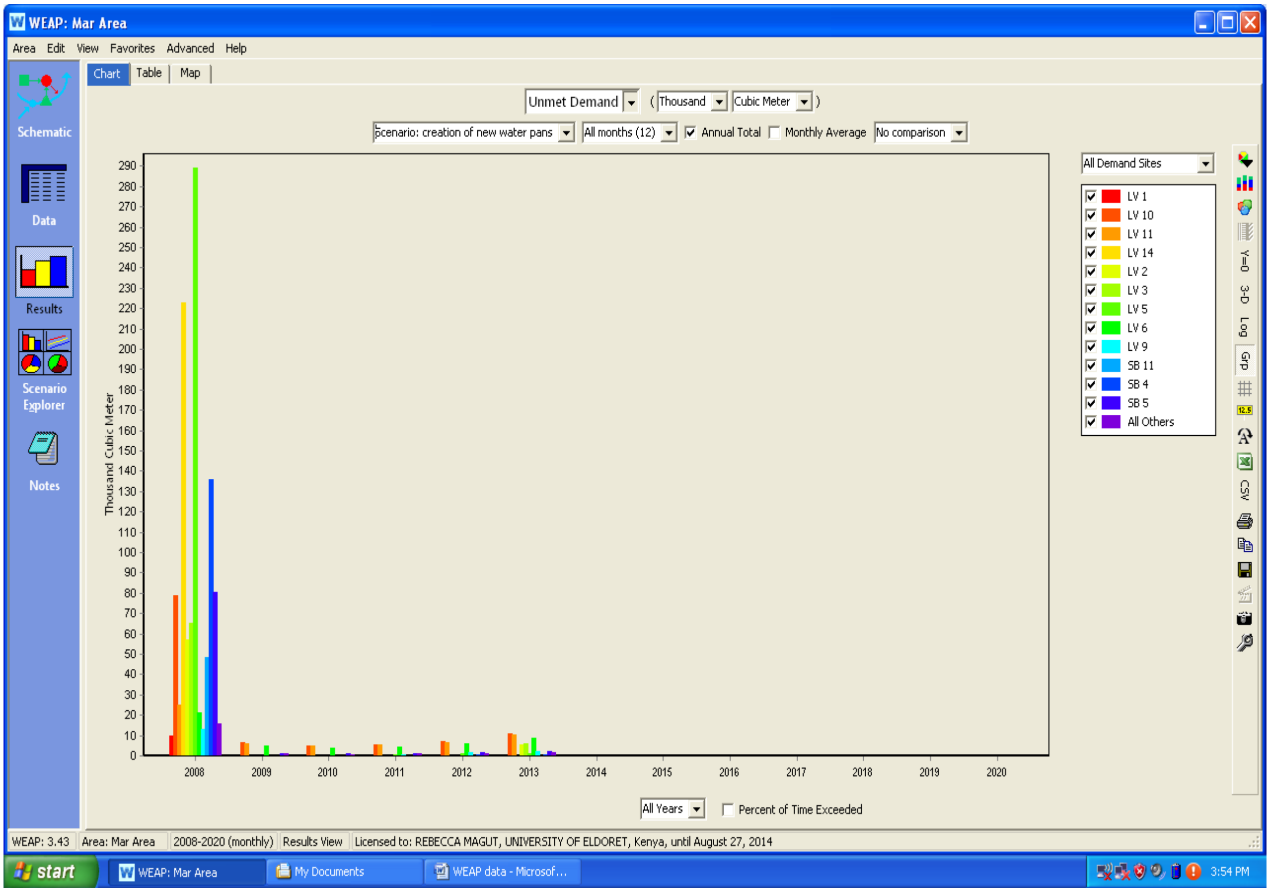

Figure 4. 9: Creation of New Water Pans Scenario: Annual Unmet Water Demand (Source: Author 2013)

4.2.7 Water Supply Network

Based on objectives i-iv, a water supply network was proposed. Figure 4.10 below shows the schematic diagram of proposed water supply network.

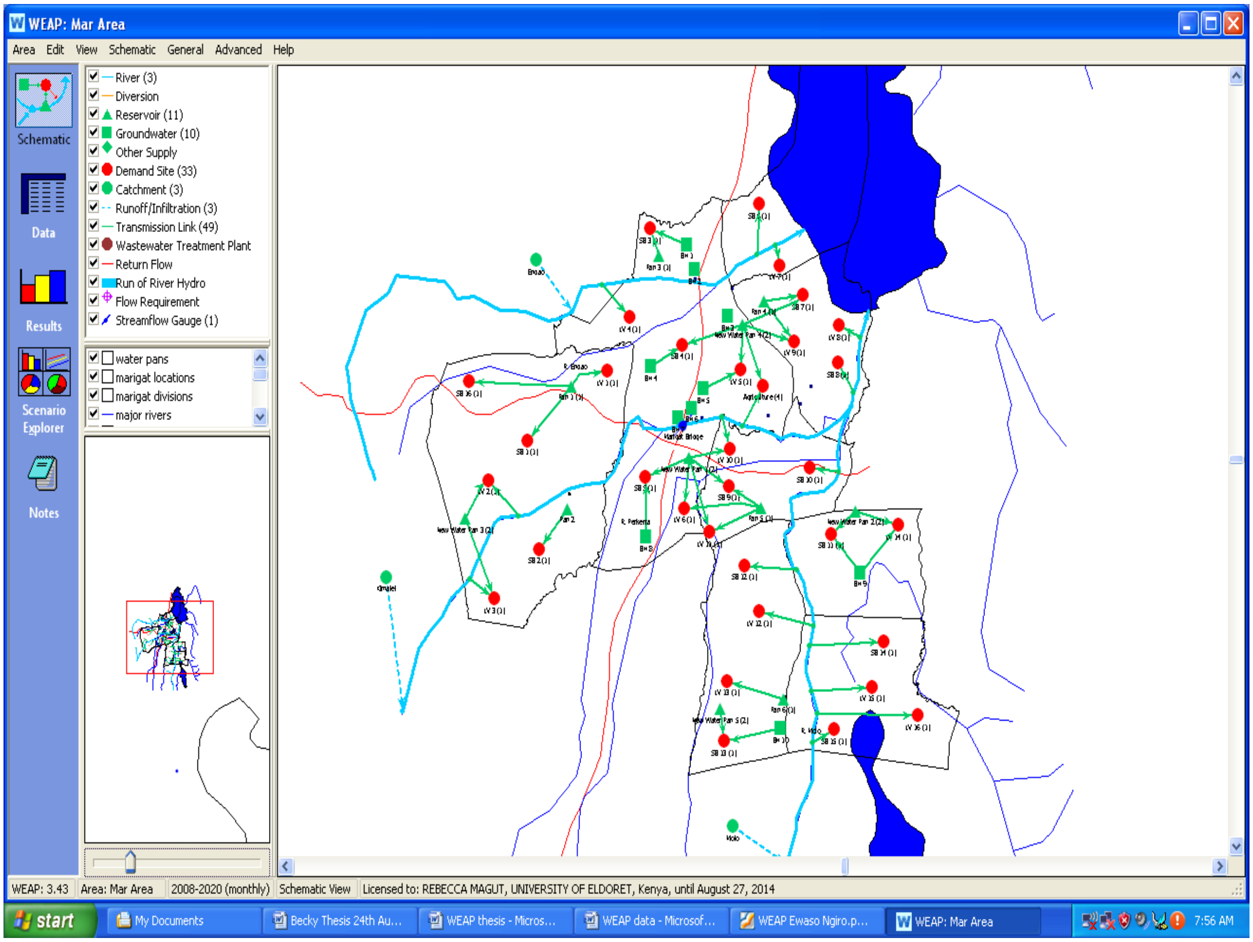

Figure 4. 10: A Schematic View of Water Supply Network

(Source: Author 2013)

CHAPTER FIVE

DISCUSSIONS

5.1 Introduction

This chapter entails the discussion of the findings in line with the specific objectives from the study area which is Marigat Division.

5.2 Demographic Characteristics of the Respondents

From the findings, most of the respondents were males. The men are always in the front when championing the community course and the appearance of the researcher and research assistants in the field was their jurisdiction. The females who participated were either household heads themselves or they represented their families because their spouses are away or because they are working far away from home. Also most women had gone to fetch water as water collection duties are left for women and children, men are also engaged in fetching water for business, they supply water to Marigat town.

5.3 Water Sources

There were several sources of water sparsely distributed in the study area. This implied that water infrastructure is not well established, at least in terms of laying of pipes and drilling of boreholes. Approximately 75 percent of Marigat is underlain by hard rock features. Although we often address of groundwater and surface water as though they were two different things, ground water is the sustaining supply for surface water, and, in karst areas, surface water often enters or returns to the ground-water system through sinkholes and cave openings. Other sources of water include the lake.

Most of the water sources in Marigat Division are donor funded, five boreholes from Belgium government and the Kenyan government through Belgium Technical Cooperation- Belgium Water Project (BTC-BWP); two boreholes in Salabani, Ilng'arua, Kampi ya Turkana and Chepkoimet. Childfund Kenya in partnership with the community had constructed two boreholes; Endao-Loberer and Maoi-Kaptim CBOs. In Ng'ambo and Salabani locations, five boreholes had been drilled and collapsed due to salinity, Sintaan borehole was also saline and dried up. Fluoride in the study area is also a challenge in the study area, Salabani and Kailer water has fluoride but Salabani borehole has a de-flourization unit while Kailer does not. Kimorok water pan in Kimalel was constructed by German Development Services through Kenya Rain Water Association (KRA), while Kapowen water pan was constructed by Kerio Valley Development Authority Eldoret (KVDA). Ng'ambo water pan had flooded after R. Perkerra changed its course.

Water for animals

In dry seasons, water is very scarce and all the time the residents of the entire Marigat division share the only source of the water with the animals. Those respondents that do not share the same source of water with the animals water the animals at the water pans and rivers while they get the water from boreholes. Usually these animals are driven into the river and water pans where they take the water.

5.4 Water Sources Reliability

Reliable portable water supply is crucial for the vitality of Marigat's economy and quality of life of its residents. The study sought to establish the number of months that water is available in the sources. This was necessitated so that reliability of the water sources could be established. The reliability of a water source is the ability of the source to be relied on or depended on at all times of the year, especially during drought. The study findings indicated that river is the single most reliable source of water in Marigat division. Indeed, the research findings indicated that water in the river is available throughout the year, i.e. for 12 months although during the dry periods the water levels go down. Some rivers, however report water shortages at less than 12 months.

Those who were not sure about the availability of water in the source are those whose source are boreholes because they could not tell exact period it is taken for repair when there is a mechanical problem and also male respondents who do not fetch water could not tell how reliable the source is but knew at times there is no water in the source. The reliability of the water in a household's source was to give a confirmation that there is water scarcity in the study area.

The difference between these periods may seem small, but one cannot imagine staying without water for a day or two. Water, being a primary element in the diet and a necessary resource for the agriculture, can be considered a basic need for humans. In addition, also industrial practices need a growing amount of water (Cassardo & Jones, 2011).

Water shortage from a household's source

From the findings, 64% of the respondents indicated that they experience water shortage while 36% indicated that they do not experience water shortage. This generally implies that water shortage is a problem in Marigat. According to UN report, water availability and use is key in the development and sustainable use of the ASALs. The development of surface waters through appropriate structures such as pans and dams need to be emphasized while groundwater will be developed only based on high cost technologies. The drilling of new boreholes and equipping the community with high maintenance pumping equipment such as solar panel sand generators sets will only be undertaken after thorough Environmental Impact Assessment hence emphasis need be laid on rehabilitating and operationalizing existing boreholes as opposed to drilling of new ones (UN, 2006).

Extent of water scarcity in the community

The extent of the shortage of water in the community was also ascertained by asking the respondents to give their view on the seriousness of water shortage in the community.

This implies that, indeed there is water scarcity in Marigat rated at 56.9% that is from those who experienced water scarcity seriously and very seriously, which is indeed acute. According to the UN report, Kenya is classified as a water scarce country with only 647 cubic metres of renewable fresh water per capita. Marigat is one of the ASAL areas in Kenya where there is a high scarcity of water (UN, 2006).

Respondents indicated that, in situations where there is no water in their main source, they resort to alternative sources. In the study, the alternative sources cited by the respondents included stream, borehole and water pan, but the problem is that they have to walk long distances to access water from these alternative sources.

Distance to a water source

The findings indicate that like other areas in Kenya, Marigat has a semi-arid climate associated with limited water resources because the research findings indicate that respondents have to travel for long distances. Majority of the respondents covered a distance of 0-3 Km (61.9%) followed by those who walk a distance of 4-6 Km at 34.2% and then (3.9%) walk 7-9 Km. According to WHO (*www.un.org*), the water source has to be within 1,000 metres of the home and collection time should not exceed 30 minutes. On the other hand, the principal cause of water scarcity in the area is the combination of limited availability and excess demand of water among competing uses; this is illustrated by the fact that more jericans of water are fetched each day only for domestic use.

According to WHO, the recommended consumption of water in litres per person per day is between 50 and *100l* needed to ensure that most basic needs are met and a few health concerns arise (*www.un.org)* while in Marigat, approximately water consumption per person per day is 33.3*l*.This implies that the consumption of water in the study area is low. The water deficit in the study area is 16.7*l* per person per day. Other than water for consumption, the demand for water is not complete until we consider the consumption of water by the animals. The study findings revealed that the households have a sizeable herd of cattle that requires water too. This increases the demand for the scarce water resource.

These animals were watered for between 1 to 3 times a day and an average of 42 litres per day. The study findings indicate that on average, the cattle were watered once per day. This indicates that indeed there is a water problem in the area since *www.ukulimasmart..co.ke* emphasizes that cattle should have adequate clean water and from a reliable source.

5.5 Willingness of the community to participate in harnessing surface water

The study findings indicated that a significant proportion of the respondents were willing to participate. Those who were not willing to participate as a community did not experience water scarcity since they live along L. Baringo and instead the too much water was being a problem to them and some had even been displaced. Others thought that resources that are being shared will at some point bring conflicts within the members of the community.

The overall computed willingness for those who agreed were 377 (98.4%) and those who disagreed were 6 (1.6%). The chi-square value computed was 359.376 and the p-value = 0.00. This implies that, the respondents who have the willingness to harness water are indeed different from those who do not have the willingness. Therefore, it was concluded that Marigat community has have the willingness to harness run off.

This implies that, there is need to give households or farmers incentives to use rainwater or surface run off. As the situation is in Marigat, farmers have few incentives to use rainwater. In other parts of the world for instance Beijing the consumption of rain water is promoted by introducing a charge on underground water (Liang & Dijk, 2011). Higher cost of groundwater will increase the consumption of rainwater, but can have a negative impact on farmers' incomes. This is carefully done to increase rainwater consumption without discouraging farming. The relation between the cost of groundwater and the consumption of rainwater has been studied by analyzing the elasticity of groundwater demand graphically. If the cost of groundwater is lower than the elasticity threshold, farmers lack incentives to use rainwater (Liang & Dijk, 2011).

The reason for this is that more work is done faster as a community since such projects are intended to benefit the very community. This is a clear indication that communities participate and are willing to harvest water as a community. Most sources were donor funded and this shows that there is a dependency syndrome in the study area, and such water projects are not sustainable. It should be community demand driven whereby the community members mobilize themselves and construct the water pans to solve their water problems. Ishaku & Majid (2010) states that No community should sit back and expect others to provide services for them and that they must be ready to organize themselves for community project. Community participation in water projects is a necessary strategy in sustainable water supply. Every member in the community gets to participate in the planning process and decision making and this ensures sense of ownership of the water resource.

5.6 Siting of potential sites for water reservoirs

The spatial pattern of the identified sites in Figure 4.4 strongly reflects the influence of the river network data layer, the sites were located along the perennial and seasonal streams. In addition, the candidate sites also satisfied the criterion used in this study as they are located outside the agricultural schemes and households. This is mainly due to the fact that the Boolean overlay technique used to combine the constraint data layers is considered to be a very extreme form of decision making in which a location must meet every criterion for it to be included in the decision set. Boolean overlay selects locations based on the most cautious strategy possible and hence is considered a risk-averse technique (Tsiko & Haile, 2011). Suitable flat to moderate slopes of between 2% and 8% was used, the soils were mainly clayey to very clayey, making them sticky when wet hence have poor drainage, which makes them more suitable as solid foundations for a water reservoir. The least suitable sites, slopes were moderate to very steep >8% and the soil was mainly course textured and highly permeable sand and newly weathered and weathering soils.

5.7 Water Demand

5.7.1 Unmet Demand and Demand Coverage

Water shortages normally occur between November to March of most years that is during the dry periods. Some sub-locations within the study area experience water shortages due to high population of humans and livestock while the water resources are limited for instance there is one water pan and a borehole supplying water to the whole sub-location.

While other locations have a number of water sources to meet domestic and livestock water demands for instance streams, rivers, water pans, boreholes and during the rainy season they harvest water, this is the reason why there is low demand coverage in such areas.

5.7.2 Scenario: Creation of New Water Pans

The unmet demand in the study area for domestic and livestock for the simulated period as compared to the results obtained from the reference scenario is met. The five new water pans are situated in areas where water shortage is experienced, and the pans are of 50,000 m^3 each. The water demand from 2008-2020 increases annually because of the population increase for both humans and livestock. The unmet demand in the different sub-locations is met after introducing the new water pans as supply priority 2.

The unmet domestic demand for Zarqa city also dropped to zero for the year 2050 due to the implementation of the Disis project, which was expected to start operation in 2013 (Al-Omari et al. 2014). Mutiga et al. (2010) incorporated two dams in the scenario and the result showed that building of dams would reduce the unmet water demand by about 5%.

5.8 Water Supply Network

Demographic and water use information was used to construct a scenario that examine how total consumption of water evolved over time and if creation of new water pans will be able to meet the unmet demand. These demands scenarios were computed in WEAP21. Demand analysis is central to integrated water planning analysis with WEAP21, since all supply and resource calculations are driven by the allocation routine which determines the final delivery to each demand node, based on the priorities specified by the user (Yates *et al,* 2005). A demand scenario comprised of several sectors including households, livestock, ecosystem, and agriculture.

Individual demand sites, and reservoirs requirements were assigned a priority number, which are integers that range from 1 (highest priority) to 99 (lowest priority). Similar to demand priorities, supply preferences applied an integer ranking scheme to define which sources will supply a single demand site.

The WEAP21 IWRM incorporates a demand priority and supply preference approach to describing water resource operating rules, as system demands drive the allocation of water from surface and groundwater supplies to the demand centers. The water allocation problem is solved at each time step using an iterative, linear programming approach that introduces the concept of Equity Groups (Yates *et al,* 2005).

The study took into account criteria representing the views and values of different stakeholders, the process by which the model selected water pans sites is suitable for other case studies, which require multi-stakeholder engagement and community participation. Participatory approaches are complimentary, to decision support tools such as WEAP. It was done by linking the demand and the supply. The areas facing water shortages, the new water pans were created in the scenarios so as to meet the unmet demand for humans and livestock.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

Based on the results of the study of determining the willingness of Marigat community to participate in the planning and management of harvesting surface water runoff in water pans and to propose suitable sites for water harvesting reservoirs, a number of conclusions were made;

1. The water resource is scarce in the study area and there is need to harness water runoff that occurs during the rainy season. In addition, the water resources are sparsely distributed although some of the sources run out of water and others are quite reliable, women and children have to walk long distance to fetch water. 98. 4 percent of the community has the willingness to harness this water for domestic and animal use.

2. Rainwater harvesting in water tanks is a water supply alternative acceptable to the local people but utilization has been hindered by limited financial resources and thus coming together as a community to mobilize themselves and harvest in water pans is the cheapest and best way of curbing their problems of water shortage and instead of waiting for external organizations to fund their water projects.

3. From GIS analysis, assigning of weights to factor characteristics of the study area made it possible to identify suitable sites and thus, there are potential sites for

harvesting surface water runoff. From WEAP21, building of a scenario, that is, creation of new water pans in areas with unmet demand, it shows that all the unmet demands of domestic and livestock is met up to 2020.

6.2 Recommendations

1. This study found that 98.4 percent of the community is willing to harness runoff water, to address the water scarcity issue Marigat community should come together and harvest surface rainwater in water pans to solve their water problems and not wait for donors to so, this will also ensure sustainability of the water projects.

2. The successful implementation of this study calls for the Baringo County to adapt this study and be part of the strategic plan as the suitable sites for constructing water pans have been identified where there is unmet demand.

6.2.1 Possible Areas of Further Research

The study proposes further research in the following area; a study should be done on water quality of surface water runoff and how it can be made portable for domestic use.

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APPENDICES

APPENDIX I: QUESTIONNAIRE FOR HOUSEHOLD HEADS

I am Rebecca Magut, a master of philosophy student at University of Eldoret School of environmental studies, Eldoret. I am conducting research on harvesting of runoff water in Marigat Division. Kindly facilitate the study by participating in the interview as truthfully and honestly as you can. The information will be treated in confidence and is needed solely for academic purposes.

SECTION A: BASIC INFORMATION

Occupation…………………………………………………………...

Village …………………………………………………………………

Sub-location ………………………………………………………….

Location ………………………………………………………………

GENDER: Male ☐

Female ☐

Age: ☐ (Number of years)

1. Level of education (what is the highest level of education you have completed)
   a) Primary ☐ b) Secondary ☐ c) Certificate ☐ d) Diploma ☐
   e) Undergraduate ☐ f) Postgraduate ☐ g) No formal education ☐
2. What is the average monthly household income in KShs?
   a) Less than 1000 ☐ b) 1000-2000 ☐ c) 2001-3000 ☐ d) more than 3000 ☐
3. How many are you in the household?
   a) 1-5 ☐ b) 6-10 ☐ c) 11-15 ☐ d) 16-20 ☐ e) Over 20 ☐

SECTION B: WATER SOURCES AND RELIABILITY

4. What are your main sources of water?

   a) Shallow well ☐ b) River / stream ☐ c) Rainwater ☐

   d) Tap water ☐ e) Borehole ☐ f) Water pan ☐

   g)Others ☐

   Specify…………………………………………………………………………….

5. Do you use water from the same source for both domestic and livestock?

   a) Yes ☐ b) No ☐

   If no, what is the source of water for livestock? ....

6. For how long (number of months in a year) is water available in your sources in a year?

   i. Shallow well …………………………
   ii. Rainwater ……………………………
   iii. River …………………………………
   iv. Stream ……………………………….
   v. Tap …………………………………..
   vi. Borehole …………………………….

7. Do you experience water shortages from the sources?

   a) Yes ☐ b) No ☐

8. If yes, where do you obtain water when the main source is not available? ………………………………………………………………………………………………

9. What distance in km do you walk to fetch water during the dry season? ....

   ……………………………………………………………

10. How many jerry cans of water do you fetch in a day?

    i. 30 litre …………………………….
    ii. 20 litre …………………………….
    iii. 10 litre …………………………….

iv. 5 litre ………………………………

11. How many cattle do you have?

a) 1-10 ☐ b) 11-20 ☐ c) 21-30 ☐ d) 30-40 ☐ e) Over 40 ☐

12. How many times do you water cattle, sheep, goats and donkeys in a day? ……………………………………………..

SECTION C: WILLINGNESS OF THE COMMUNITY TO PARTICIPATE

13. What is the extent of water scarcity in the community?

a) Very serious ☐ b) Serious ☐ c) Moderate ☐ d) No water scarcity ☐

14. Are you willing to participate in harvesting of surface water runoff as a solution to water scarcity in the community? (Proceed if answer in question 14 is that there is water scarcity)

a) Yes ☐ b) No ☐

If no, why?

…………………………………………………………………………..

……………………………………………………………………………………..

15. Do you prefer to harvest surface water runoff as a community or individual?

a) Community ☐ b) Individual ☐

Why?

…………………………………………………………………………….. ……………………………………………………………………………………… ……………………………………………………………………………………….

If answer is community, go to question 17.

16. In what way are you willing to participate in harvesting of surface water runoff?

Cost	○ Strongly agree	○ Agree	○ No opinion/ not sure	○ Disagree	○ Strongly disagree
Labour	○ Strongly agree	○ Agree	○ No opinion/ not sure	○ Disagree	○ Strongly disagree
Time	○ Strongly agree	○ Agree	○ No opinion/ not sure	○ Disagree	○ Strongly disagree
Management	○ Strongly agree	○ Agree	○ No opinion/ not sure	○ Disagree	○ Strongly disagree

17. Is it worth harvesting of surface water runoff for domestic and livestock use in your community?

a) Yes ☐ b) No ☐

Give reasons? ....

APPENDIX II: CHECK LIST FOR FOCUS GROUP DISCUSSION

BASIC INFORMATION

Location of the Focus Group Discussion:

Occupation…………………………………………………………..

Village ……………………………………………………………….

Sub-location ………………………………………………………….

Location ………………………………………………………………

QUESTIONS

1) Is there water scarcity in this area?
2) Community Vs individuals in harvesting of surface water runoff.
3) Should the harvesting of water be self-mobilized or involve the external organizations?
4) Land in which potential sites are to be sited, should it be donated or bought?
5) Who normally fetch domestic water in the household?
6) Does the person in Question 5 spend a lot of time (in hours) fetching water instead of doing other income generating activities?
7) Has the community invented ways to curb their water problems and if so give the main methods?
8) Does the community have the capacity to mobilize themselves without the local organizations?
9) Are there organizations that have worked with the community on water quantity and quality?

APPENDIX III: QUESTIONS FOR KEY INFORMANTS

Name of the organization …………………………………………………………..

What is the role of this organization

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

……………………………………………………..

1) Does your organization help the communities' problems of water shortage?

   How?

2) Are there other organizations that help the community to solve their water shortage problems if so name them?
3) Are there upcoming projects that will address the issues of water shortages if so name them and state what role you will play?
4) Has your organization ever educated the community on rainwater harvesting technologies as methods that will curb their water shortage if yes explain?
5) Are there other methods other than rainwater harvesting that you have promoted? Which ones?
6) In case the community is to harvest water runoff, is your organization ready to fund the project and to what extent?
7) How do you ensure that the community's water projects are sustainable?
8) Do you partner with other organizations in community water projects and if so explain?

APPENDIX IV: STATISTICAL ANALYSIS OF MODEL CALIBRATION AND VALIDATION RESULTS

RGS No	DATE	GHT1	GHT2	DISCH(M3/S) Q FLOWS	AVERAGE FLOWS
2EE7 "B"	01/01/2008	0.40	0.40	0.0825	
2EE7 "B"	02/01/2008	0.40	0.40	0.0825	
2EE7 "B"	03/01/2008	0.40	0.40	0.0825	
2EE7 "B"	04/01/2008	0.40	0.40	0.0825	
2EE7 "B"	05/01/2008	0.39	0.39	0.0733	
2EE7 "B"	06/01/2008	0.39	0.39	0.0733	
2EE7 "B"	07/01/2008	0.39	0.39	0.0733	
2EE7 "B"	08/01/2008	0.38	0.38	0.0650	
2EE7 "B"	09/01/2008	0.38	0.38	0.0650	
2EE7 "B"	10/01/2008	0.38	0.38	0.0650	-0.0886
2EE7 "B"	11/01/2008	0.37	0.37	0.0574	
2EE7 "B"	12/01/2008	0.37	0.37	0.0574	
2EE7 "B"	13/01/2008	0.37	0.37	0.0574	
2EE7 "B"	14/01/2008	0.36	0.36	0.0505	
2EE7 "B"	15/01/2008	0.36	0.36	0.0505	
2EE7 "B"	16/01/2008	0.36	0.36	0.0505	
2EE7 "B"	17/01/2008	0.36	0.36	0.0505	

2EE7 "B"	18/01/2008	0.35	0.35	0.0443
2EE7 "B"	19/01/2008	0.35	0.35	0.0443
2EE7 "B"	20/01/2008	0.35	0.35	0.0443
2EE7 "B"	21/01/2008	0.35	0.35	0.0443
2EE7 "B"	22/01/2008	0.34	0.34	0.0387
2EE7 "B"	23/01/2008	0.34	0.34	0.0387
2EE7 "B"	24/01/2008	0.34	0.34	0.0387
2EE7 "B"	25/01/2008	0.49	0.49	0.2122
2EE7 "B"	26/01/2008	0.48	0.48	0.1928
2EE7 "B"	27/01/2008	0.47	0.47	0.1748
2EE7 "B"	28/01/2008	0.46	0.46	0.1581
2EE7 "B"	29/01/2008	0.50	0.49	0.2122
2EE7 "B"	30/01/2008	0.49	0.48	0.1928
2EE7 "B"	31/01/2008	0.48	0.48	0.1928
				0.0000
2EE7 "B"	01/02/2008	0.53	0.53	0.3057
2EE7 "B"	02/02/2008	0.53	0.53	0.3057
2EE7 "B"	03/02/2008	0.53	0.53	0.3057
2EE7 "B"	04/02/2008	0.53	0.53	0.3057
2EE7 "B"	05/02/2008	0.53	0.53	0.3057
2EE7 "B"	06/02/2008	0.51	0.51	0.2556
2EE7 "B"	07/02/2008	0.51	0.51	0.2556
2EE7 "B"	08/02/2008	0.51	0.51	0.2556
2EE7 "B"	09/02/2008	0.51	0.51	0.2556
2EE7 "B"	10/02/2008	0.58	0.58	0.4652

2EE7 "B"	11/02/2008	0.58	0.58	0.4652	0.3035
2EE7 "B"	12/02/2008	0.58	0.58	0.4652	
2EE7 "B"	13/02/2008	0.56	0.56	0.3951	
2EE7 "B"	14/02/2008	0.56	0.56	0.3951	
2EE7 "B"	15/02/2008	0.56	0.56	0.3951	
2EE7 "B"	16/02/2008	0.56	0.54	0.3335	
2EE7 "B"	17/02/2008	0.54	0.54	0.3335	
2EE7 "B"	18/02/2008	0.54	0.54	0.3335	
2EE7 "B"	19/02/2008	0.54	0.52	0.2798	
2EE7 "B"	20/02/2008	0.52	0.52	0.2798	
2EE7 "B"	21/02/2008	0.52	0.52	0.2798	
2EE7 "B"	22/02/2008	0.52	0.52	0.2798	
2EE7 "B"	23/02/2008	0.50	0.50	0.2331	
2EE7 "B"	24/02/2008	0.50	0.50	0.2331	
2EE7 "B"	25/02/2008	0.50	0.50	0.2331	
2EE7 "B"	26/02/2008	0.50	0.50	0.2331	
2EE7 "B"	27/02/2008	0.50	0.50	0.2331	
2EE7 "B"	28/02/2008	0.48	0.48	0.1928	
2EE7 "B"	29/02/2008	0.48	0.48	0.1928	
				0.0000	
2EE7 "B"	01/03/2008	0.50	0.50	0.2331	
2EE7 "B"	02/03/2008	0.50	0.50	0.2331	
2EE7 "B"	03/03/2008	0.50	0.50	0.2331	
2EE7 "B"	04/03/2008	0.50	0.50	0.2331	
2EE7 "B"	05/03/2008	0.50	0.50	0.2331	

2EE7 "B"	06/03/2008	0.50	0.50	0.2331	
2EE7 "B"	07/03/2008	0.50	0.50	0.2331	
2EE7 "B"	08/03/2008	0.50	0.50	0.2331	
2EE7 "B"	09/03/2008	0.50	0.50	0.2331	
2EE7 "B"	10/03/2008	0.50	0.50	0.2331	
2EE7 "B"	11/03/2008	0.50	0.50	0.2331	
2EE7 "B"	12/03/2008	0.50	0.50	0.2331	
2EE7 "B"	13/03/2008	0.50	0.50	0.2331	0.2687
2EE7 "B"	14/03/2008	0.50	0.50	0.2331	
2EE7 "B"	15/03/2008	0.50	0.50	0.2331	
2EE7 "B"	16/03/2008	0.50	0.50	0.2331	
2EE7 "B"	17/03/2008	0.50	0.50	0.2331	
2EE7 "B"	18/03/2008	0.50	0.50	0.2331	
2EE7 "B"	19/03/2008	0.50	0.50	0.2331	
2EE7 "B"	20/03/2008	0.50	0.50	0.2331	
2EE7 "B"	21/03/2008	0.50	0.50	0.2331	
2EE7 "B"	22/03/2008	0.50	0.50	0.2331	
2EE7 "B"	23/03/2008	0.50	0.50	0.2331	
2EE7 "B"	24/03/2008	0.50	0.50	0.2331	
2EE7 "B"	25/03/2008	0.50	0.55	0.3633	
2EE7 "B"	26/03/2008	0.60	0.55	0.3633	
2EE7 "B"	27/03/2008	0.56	0.57	0.4290	
2EE7 "B"	28/03/2008	0.56	0.56	0.3951	
2EE7 "B"	29/03/2008	0.56	0.56	0.3951	
2EE7 "B"	30/03/2008	0.56	0.56	0.3951	

2EE7 "B"	31/03/2008	0.56	0.56	0.3951	
				0.0000	
2EE7 "B"	01/04/2008	0.54	0.54	0.3335	
2EE7 "B"	02/04/2008	0.54	0.54	0.3335	
2EE7 "B"	03/04/2008	0.54	0.54	0.3335	
2EE7 "B"	04/04/2008	0.54	0.52	0.2798	
2EE7 "B"	05/04/2008	0.52	0.52	0.2798	
2EE7 "B"	06/04/2008	0.52	0.52	0.2798	
2EE7 "B"	07/04/2008	0.52	0.52	0.2798	
2EE7 "B"	08/04/2008	0.52	0.52	0.2798	0.3219
2EE7 "B"	09/04/2008	0.56	0.56	0.3951	
2EE7 "B"	10/04/2008	0.56	0.56	0.3951	
2EE7 "B"	11/04/2008	0.56	0.56	0.3951	
2EE7 "B"	12/04/2008	0.56	0.56	0.3951	
2EE7 "B"	13/04/2008	0.56	0.53	0.3057	
2EE7 "B"	14/04/2008	0.53	0.53	0.3057	
2EE7 "B"	15/04/2008	0.53	0.53	0.3057	
2EE7 "B"	16/04/2008	0.53	0.53	0.3057	
2EE7 "B"	17/04/2008	0.53	0.5	0.2331	
2EE7 "B"	18/04/2008	0.50	0.50	0.2331	
2EE7 "B"	19/04/2008	0.50	0.50	0.2331	
2EE7 "B"	20/04/2008	0.50	0.50	0.2331	
2EE7 "B"	21/04/2008	0.50	0.50	0.2331	
2EE7 "B"	22/04/2008	0.50	0.63	0.6836	
2EE7 "B"	23/04/2008	0.60	0.58	0.4652	

2EE7 "B"	24/04/2008	0.55	0.53	0.3057	
2EE7 "B"	25/04/2008	0.53	0.53	0.3057	
2EE7 "B"	26/04/2008	0.53	0.53	0.3057	
2EE7 "B"	27/04/2008	0.53	0.53	0.3057	
2EE7 "B"	28/04/2008	0.53	0.53	0.3057	
2EE7 "B"	29/04/2008	0.53	0.53	0.3057	
2EE7 "B"	30/04/2008	0.53	0.53	0.3057	
				0.0000	
2EE7 "B"	01/05/2008	0.50	0.50	0.2331	
2EE7 "B"	02/05/2008	0.50	0.50	0.2331	
2EE7 "B"	03/05/2008	0.50	0.52	0.2798	
2EE7 "B"	04/05/2008	0.52	0.52	0.2798	
2EE7 "B"	05/05/2008	0.52	0.52	0.2798	
2EE7 "B"	06/05/2008	0.52	0.52	0.2798	
2EE7 "B"	07/05/2008	0.50	0.50	0.2331	
2EE7 "B"	08/05/2008	0.50	0.50	0.2331	0.1899
2EE7 "B"	09/05/2008	0.50	0.48	0.1928	
2EE7 "B"	10/05/2008	0.48	0.48	0.1928	
2EE7 "B"	11/05/2008	0.46	0.46	0.1581	
2EE7 "B"	12/05/2008	0.46	0.46	0.1581	
2EE7 "B"	13/05/2008	0.51	0.51	0.2556	
2EE7 "B"	14/05/2008	0.50	0.48	0.1928	
2EE7 "B"	15/05/2008	0.48	0.48	0.1928	
2EE7 "B"	16/05/2008	0.46	0.46	0.1581	
2EE7 "B"	17/05/2008	0.46	0.46	0.1581	

2EE7 "B"	18/05/2008	0.45	0.45	0.1427	
2EE7 "B"	19/05/2008	0.45	0.45	0.1427	
2EE7 "B"	20/05/2008	0.45	0.45	0.1427	
2EE7 "B"	21/05/2008	0.45	0.45	0.1427	
2EE7 "B"	22/05/2008	0.45	0.45	0.1427	
2EE7 "B"	23/05/2008	0.45	0.43	0.1155	
2EE7 "B"	24/05/2008	0.55	0.53	0.3057	
2EE7 "B"	25/05/2008	0.49	0.49	0.2122	
2EE7 "B"	26/05/2008	0.49	0.49	0.2122	
2EE7 "B"	27/05/2008	0.49	0.49	0.2122	
2EE7 "B"	28/05/2008	0.49	0.49	0.2122	
2EE7 "B"	29/05/2008		0.48	0.1928	
2EE7 "B"	30/05/2008			0.0000	
2EE7 "B"	31/05/2008			0.0000	
				0.0000	
2EE7 "B"	01/06/2008	0.45	0.45	0.1427	
2EE7 "B"	02/06/2008	0.45	0.45	0.1427	
2EE7 "B"	03/06/2008	0.45	0.45	0.1427	
2EE7 "B"	04/06/2008	0.45	0.45	0.1427	
2EE7 "B"	05/06/2008	0.45	0.45	0.1427	
2EE7 "B"	06/06/2008	0.45	0.45	0.1427	
2EE7 "B"	07/06/2008	0.45	0.45	0.1427	0.1298
2EE7 "B"	08/06/2008	0.45	0.45	0.1427	
2EE7 "B"	09/06/2008	0.45	0.45	0.1427	
2EE7 "B"	10/06/2008	0.45	0.45	0.1427	

2EE7 "B"	11/06/2008	0.45	0.45	0.1427
2EE7 "B"	12/06/2008	0.43	0.43	0.1155
2EE7 "B"	13/06/2008	0.43	0.43	0.1155
2EE7 "B"	14/06/2008	0.43	0.43	0.1155
2EE7 "B"	15/06/2008	0.43	0.43	0.1155
2EE7 "B"	16/06/2008	0.43	0.43	0.1155
2EE7 "B"	17/06/2008	0.43	0.43	0.1155
2EE7 "B"	18/06/2008	0.43	0.43	0.1155
2EE7 "B"	19/06/2008	0.43	0.43	0.1155
2EE7 "B"	20/06/2008	0.46	0.46	0.1581
2EE7 "B"	21/06/2008	0.46	0.46	0.1581
2EE7 "B"	22/06/2008	0.46	0.46	0.1581
2EE7 "B"	23/06/2008	0.43	0.43	0.1155
2EE7 "B"	24/06/2008	0.43	0.43	0.1155
2EE7 "B"	25/06/2008	0.43	0.43	0.1155
2EE7 "B"	26/06/2008	0.43	0.43	0.1155
2EE7 "B"	27/06/2008	0.43	0.43	0.1155
2EE7 "B"	28/06/2008	0.43	0.43	0.1155
2EE7 "B"	29/06/2008	0.43	0.43	0.1155
2EE7 "B"	30/06/2008	0.43	0.43	0.1155
PERKERRA 2EE7 "B"				0.0000
2EE7 "B"	01/07/2008	0.45	0.45	0.1427
2EE7 "B"	02/07/2008	0.45	0.45	0.1427
2EE7 "B"	03/07/2008	0.45	0.45	0.1427
2EE7 "B"	04/07/2008	0.50	0.50	0.2331

2EE7 "B"	05/07/2008	0.50	0.50	0.2331	
2EE7 "B"	06/07/2008	0.50	0.50	0.2331	
2EE7 "B"	07/07/2008	0.48	0.48	0.1928	0.6468
2EE7 "B"	08/07/2008	0.46	0.46	0.1581	
2EE7 "B"	09/07/2008	0.46	0.46	0.1581	
2EE7 "B"	10/07/2008	0.46	0.43	0.1155	
2EE7 "B"	11/07/2008	0.43	0.43	0.1155	
2EE7 "B"	12/07/2008	0.43	0.43	0.1155	
2EE7 "B"	13/07/2008	0.43	0.43	0.1155	
2EE7 "B"	14/07/2008	0.72	0.65	0.7906	
2EE7 "B"	15/07/2008	0.60	0.54	0.3335	
2EE7 "B"	16/07/2008	0.50	0.46	0.1581	
2EE7 "B"	17/07/2008	0.45	0.45	0.1427	
2EE7 "B"	18/07/2008	0.45	0.47	0.1748	
2EE7 "B"	19/07/2008	0.45	0.91	3.7861	
2EE7 "B"	20/07/2008	0.81	0.7	1.1163	
2EE7 "B"	21/07/2008	0.64	0.57	0.4290	
2EE7 "B"	22/07/2008	0.53	0.53	0.3057	
2EE7 "B"	23/07/2008	0.53	0.48	0.1928	
2EE7 "B"	24/07/2008	0.46	0.42	0.1035	
2EE7 "B"	25/07/2008	0.42	0.42	0.1035	
2EE7 "B"	26/07/2008	0.42	0.42	0.1035	
2EE7 "B"	27/07/2008	0.46	0.48	0.1928	
2EE7 "B"	28/07/2008	0.48	0.67	0.9104	
2EE7 "B"	29/07/2008	0.82	0.85	2.7562	

2EE7 "B"	30/07/2008	0.91	0.9	3.5963
2EE7 "B"	31/07/2008	0.85	0.85	2.7562
				0.0000
2EE7 "B"	01/08/2008			0.0000
2EE7 "B"	02/08/2008			0.0000
2EE7 "B"	03/08/2008			0.0000
2EE7 "B"	04/08/2008			0.0000
2EE7 "B"	05/08/2008			0.0000
2EE7 "B"	06/08/2008			0.0000
2EE7 "B"	07/08/2008			0.0000
2EE7 "B"	08/08/2008			0.0000
2EE7 "B"	09/08/2008			0.0000
2EE7 "B"	10/08/2008			0.0000
2EE7 "B"	11/08/2008			0.0000
2EE7 "B"	12/08/2008			0.0000
2EE7 "B"	13/08/2008			0.0000
2EE7 "B"	14/08/2008			0.0000
2EE7 "B"	15/08/2008			0.0000
2EE7 "B"	16/08/2008			0.0000
2EE7 "B"	17/08/2008			0.0000
2EE7 "B"	18/08/2008			0.0000
2EE7 "B"	19/08/2008			0.0000
2EE7 "B"	20/08/2008			0.0000
2EE7 "B"	21/08/2008			0.0000
2EE7 "B"	22/08/2008			0.0000
2EE7 "B"	23/08/2008			0.0000
2EE7 "B"	24/08/2008			0.0000

2EE7 "B"	25/08/2008	0.0000
2EE7 "B"	26/08/2008	0.0000
2EE7 "B"	27/08/2008	0.0000
2EE7 "B"	28/08/2008	0.0000
2EE7 "B"	29/08/2008	0.0000
2EE7 "B"	30/08/2008	0.0000
2EE7 "B"	31/08/2008	0.0000
		0.0000
2EE7 "B"	01/09/2008	0.0000
2EE7 "B"	02/09/2008	0.0000
2EE7 "B"	03/09/2008	0.0000
2EE7 "B"	04/09/2008	0.0000
2EE7 "B"	05/09/2008	0.0000
2EE7 "B"	06/09/2008	0.0000
2EE7 "B"	07/09/2008	0.0000
2EE7 "B"	08/09/2008	0.0000
2EE7 "B"	09/09/2008	0.0000
2EE7 "B"	10/09/2008	0.0000
2EE7 "B"	11/09/2008	0.0000
2EE7 "B"	12/09/2008	0.0000
2EE7 "B"	13/09/2008	0.0000
2EE7 "B"	14/09/2008	0.0000
2EE7 "B"	15/09/2008	0.0000
2EE7 "B"	16/09/2008	0.0000
2EE7 "B"	17/09/2008	0.0000
2EE7 "B"	18/09/2008	0.0000
2EE7 "B"	19/09/2008	0.0000
2EE7 "B"	20/09/2008	0.0000

2EE7 "B"	21/09/2008			0.0000	
2EE7 "B"	22/09/2008			0.0000	
2EE7 "B"	23/09/2008			0.0000	
2EE7 "B"	24/09/2008			0.0000	
2EE7 "B"	25/09/2008			0.0000	
2EE7 "B"	26/09/2008			0.0000	
2EE7 "B"	27/09/2008			0.0000	
2EE7 "B"	28/09/2008			0.0000	
2EE7 "B"	29/09/2008			0.0000	
2EE7 "B"	30/09/2008			0.0000	
				0.0000	
2EE7 "B"	01/10/2008	0.62	0.64	0.7356	
2EE7 "B"	02/10/2008	0.72	0.70	1.1163	
2EE7 "B"	03/10/2008	0.67	0.67	0.9104	
2EE7 "B"	04/10/2008	0.65	0.65	0.7906	
2EE7 "B"	05/10/2008	0.65	0.65	0.7906	1.0911
2EE7 "B"	06/10/2008	0.63	0.63	0.6836	
2EE7 "B"	07/10/2008	0.60	0.60	0.5447	
2EE7 "B"	08/10/2008	0.58	0.58	0.4652	
2EE7 "B"	09/10/2008	0.58	0.58	0.4652	
2EE7 "B"	10/10/2008	0.58	0.58	0.4652	
2EE7 "B"	11/10/2008	0.62	0.60	0.5447	
2EE7 "B"	12/10/2008	0.58	0.51	0.2556	
2EE7 "B"	13/10/2008	0.53	0.51	0.2556	
2EE7 "B"	14/10/2008	0.51	0.51	0.2556	
2EE7 "B"	15/10/2008	0.51	0.51	0.2556	

2EE7 "B"	16/10/2008	0.51	0.51	0.2556	
2EE7 "B"	17/10/2008	0.72	0.70	1.1163	
2EE7 "B"	18/10/2008	0.68	0.65	0.7906	
2EE7 "B"	19/10/2008	0.65	0.65	0.7906	
2EE7 "B"	20/10/2008	0.62	0.62	0.6345	
2EE7 "B"	21/10/2008	0.62	0.65	0.7906	
2EE7 "B"	22/10/2008	0.86	0.86	2.9104	
2EE7 "B"	23/10/2008	0.76	0.66	0.8489	
2EE7 "B"	24/10/2008	0.68	0.68	0.9754	
2EE7 "B"	25/10/2008	0.72	0.76	1.6370	
2EE7 "B"	26/10/2008	0.91	0.88	3.2391	
2EE7 "B"	27/10/2008	0.86	0.84	2.6084	
2EE7 "B"	28/10/2008	0.84	0.82	2.3317	
2EE7 "B"	29/10/2008	0.81	0.81	2.2022	
2EE7 "B"	30/10/2008	0.81	0.80	2.0785	
2EE7 "B"	31/10/2008	0.80	0.80	2.0785	
				0.0000	
2EE7 "B"	01/11/2008	0.78	0.74	1.4459	
2EE7 "B"	02/11/2008	0.74	0.72	1.2727	
2EE7 "B"	03/11/2008	0.72	0.72	1.2727	
2EE7 "B"	04/11/2008	0.70	0.70	1.1163	1.6836
2EE7 "B"	05/11/2008	0.70	0.70	1.1163	
2EE7 "B"	06/11/2008	0.68	0.68	0.9754	
2EE7 "B"	07/11/2008	1.10	1.10	9.1526	
2EE7 "B"	08/11/2008	0.85	0.91	3.7861	

2EE7 "B"	09/11/2008	0.88	0.85	2.7562
2EE7 "B"	10/11/2008	0.81	0.78	1.8474
2EE7 "B"	11/11/2008	0.75	0.76	1.6370
2EE7 "B"	12/11/2008	0.73	0.73	1.3572
2EE7 "B"	13/11/2008	0.75	0.72	1.2727
2EE7 "B"	14/11/2008	0.72	0.72	1.2727
2EE7 "B"	15/11/2008	0.72	0.70	1.1163
2EE7 "B"	16/11/2008	0.70	0.79	1.9603
2EE7 "B"	17/11/2008	0.79	0.79	1.9603
2EE7 "B"	18/11/2008	0.79	0.79	1.9603
2EE7 "B"	19/11/2008	0.76	0.76	1.6370
2EE7 "B"	20/11/2008	0.76	0.76	1.6370
2EE7 "B"	21/11/2008	0.76	0.73	1.3572
2EE7 "B"	22/11/2008	0.73	0.73	1.3572
2EE7 "B"	23/11/2008	0.73	0.73	1.3572
2EE7 "B"	24/11/2008	0.73	0.70	1.1163
2EE7 "B"	25/11/2008	0.70	0.70	1.1163
2EE7 "B"	26/11/2008	0.67	0.67	0.9104
2EE7 "B"	27/11/2008	0.67	0.64	0.7356
2EE7 "B"	28/11/2008	0.64	0.64	0.7356
2EE7 "B"	29/11/2008	0.62	0.62	0.6345
2EE7 "B"	30/11/2008	0.62	0.62	0.6345
				0.0000
2EE7 "B"	01/12/2008	0.62	0.62	0.6345
2EE7 "B"	02/12/2008	0.62	0.62	0.6345

2EE7 "B"	03/12/2008	0.60	0.60	0.5447	
2EE7 "B"	04/12/2008	0.60	0.60	0.5447	
2EE7 "B"	05/12/2008	0.60	0.58	0.4652	0.3641
2EE7 "B"	06/12/2008	0.58	0.58	0.4652	
2EE7 "B"	07/12/2008	0.58	0.58	0.4652	
2EE7 "B"	08/12/2008	0.58	0.57	0.4290	
2EE7 "B"	09/12/2008	0.57	0.57	0.4290	
2EE7 "B"	10/12/2008	0.57	0.57	0.4290	
2EE7 "B"	11/12/2008	0.57	0.56	0.3951	
2EE7 "B"	12/12/2008	0.56	0.56	0.3951	
2EE7 "B"	13/12/2008	0.56	0.56	0.3951	
2EE7 "B"	14/12/2008	0.56	0.56	0.3951	
2EE7 "B"	15/12/2008	0.55	0.55	0.3633	
2EE7 "B"	16/12/2008	0.55	0.55	0.3633	
2EE7 "B"	17/12/2008	0.55	0.55	0.3633	
2EE7 "B"	18/12/2008	0.53	0.53	0.3057	
2EE7 "B"	19/12/2008	0.53	0.53	0.3057	
2EE7 "B"	20/12/2008	0.53	0.53	0.3057	
2EE7 "B"	21/12/2008	0.53	0.52	0.2798	
2EE7 "B"	22/12/2008	0.52	0.52	0.2798	
2EE7 "B"	23/12/2008	0.52	0.50	0.2331	
2EE7 "B"	24/12/2008	0.50	0.50	0.2331	
2EE7 "B"	25/12/2008	0.50	0.50	0.2331	
2EE7 "B"	26/12/2008	0.50	0.50	0.2331	
2EE7 "B"	27/12/2008	0.50	0.50	0.2331	

2EE7 "B"	28/12/2008	0.50	0.50	0.2331
2EE7 "B"	29/12/2008	0.50	0.50	0.2331
2EE7 "B"	30/12/2008	0.50	0.50	0.2331
2EE7 "B"	31/12/2008	0.50	0.50	0.2331