UNIVERSITY OF NAIROBI

DEPARTMENT OF CIVIL ENGINEERING AND CONSTRUCTION

An Assessment of Water Resources, and IWRM Strategy

In Bahari Sub Basin, Kilifi District

BY
Marete J.M.
F56/7676/2004

UNIVERSITY OF NAIROBI
EAST AFRICANA COLLECTION

This Thesis is submitted to the Department of Civil Engineering and Construction in the Faculty of Engineering for partial fulfillment of the requirement for the award of Masters of Science in Water Resources Engineering.

Supervisor

Dr. Z.N.I. Oonge

Nairobi, July 2006

University of NAIROBI Library
0442004 8

ABSTRACT

The main purpose of this study was to identify water sources in Bahari Sub basin, and determine how they were managed so that they benefit the whole community while preserving the environment for the future generation. It also aimed to determine whether integrated Water Resources Management (IWRM) principles offered sustainable development and management of water resources. The study identified the challenges facing the Kenya water sector as:-

- Growing population
- Water scarcity
- Climate variability and water Resources Degradation
- Declining flow volumes
- Natural phenomena
- Catchment Degradation
- Invasive Species
- Storage and infrastructure investment
- Water Demand
- Ground water depletion
- Solid waste management

To handle these challenges, the study assessed the water resources, their utilization, policies, and institutions in Bahari Sub basin. The study focused on the following areas:-

- Indicate the wide range, and ramifications, of water management, and the relationship between the 'water sector 'and other parts of the economy.
- Identify the principal issues involved in managing water resources, for the guidance of policy-makers.
- Preparation of an inventory of existing water resources data, reports and maps covering rainfall, evaporation, groundwater, steam flow, water abstraction permits and water quality. The data collected was evaluated to determine additional data to be collected from the field for an improved assessment of water resources availability in the study area. This was followed by a field inventory of natural and constructed water points on rainwater, surface water and ground water.

The stakeholders involved in the water sector were identified and their roles in the water sector determined. Their knowledge of the ongoing sector reforms was also ascertained. Household survey was conducted to provide data on the water and sanitation situation in the study area, the level of knowledge of water regulations by the communities and the conservation methods applied within the households. The survey involved selection of a representative probability sample of 12 households. The contents of the questionnaire included collection of data on population, water, sanitation, management and water conservation. Enumerators who had been trained earlier did the interviewing of the respondents.

The results of the study showed that;

- The sub basin had water resources that if properly managed, could supply adequate water to the residents. The water sources included wells,srings,and boreholes and tap water

- The development of the water resources was not done in an orderly manner and this lend to abandonment of 77%of the boreholes, and 54% of the wells.
- Pipelines took water from the main Baricho-Mombasa pipeline which passed through the basin. These pipelines were constructed by the government, NGOs or the local community with technical assistance from the MW&I staff.
- The water resources were polluted by agricultural activities, agro based industries and factories, urbanization, and ocean water intrusion.

Based on the results obtained from the research, conclusions were drawn, and recommendations made on the best way of implementing IWRM strategy in Bahari sub basin.

DECLARATION

I confirm that this thesis is my original work and has not been presented for award of a Degree in any other University.

Sign .....

17th October 2006

Jason Mbogo Marete

This thesis has been submitted for examination and was examined with my approval as the university supervisor for award of the Degree of Master of Science in Water Resources Engineering.

Sign ..... 7th August 2007

17th October 2006

Dr Z.N.I. Oonge (supervisor)

ACKNOWLEDGEMENT

I owe my special gratitude to Dr Z. I. Oonge, Senior lecturer, Department of Civil and Construction Engineering, University of Nairobi for all the assistance he gave.

To all the people I interviewed, I thank you for sharing the information with me. Special thanks go to the staff of the Ministry of Water and Irrigation both at the Headquarters and Coast Province. I really appreciate your assistance.

To my family Mary, Cindy and Njoki thank you for your support and patience.

To you all your commitment to excellence will allow us to offer hope and encouragement to meet the millennium goals.

Jason Mbogo Masete
July 2006

TABLE OF CONTENTS

LIST OF TABLES

PAGE

LIST OF FIGURES

LIST OF PLATES

LIST OF ABBREVIATIONS AND ACRONYMS

ADB-African Development Bank

ASAL-Arid and Semi-Arid Lands

BCM-Billion Cubic Metres

CBOs-Community Based Organizations

CDTF-Community Development Trust Fund

Cl-Chlorine

DANIDA-Danish International Development Agency

ECI-Electrical Conductivity

EEC-European Economic Community

EIA-Environmental Impact Assessment

EMCA- Environmental Management and Coordination Act

EU-European Union

FAO-Food and Agriculture Organization

FC-Faecal Coliform Bacteria

GDP-Gross Domestic Product

GIS-Geographical Information Systems

GOK-Government of Kenya

GPS-Geographical Positioning System

GTZ-German Technical Cooperation

GWP-Global Water Partnership

IDA-International Development Agency

IDB-International Development Bank

IDB- Irrigation and Drainage Branch

IDWSSD- International Drinking Water Supply and Sanitation Decade

IWRM-Integrated Water Resources Management

JICA-Japan International Cooperation Agency

KARI-Kenya Agricultural Research Institute

KDDP-Kilifi District Development Programme

KIWASAP-Kififi Water and Sanitation Project

LA-Local Authority

LU-Livestock Units

L/S-Litres per Second

M-Metres

MCM-Million Cubic Metres

Mg/L-Milligrams per Litre

MoLG- Ministry of Local Government

MoWD-Ministry of Water Development

MWR&I-Ministry of Water Resources and Irrigation

Na-Sodium

NGO-Non-Governmental Organization

NIB-. National Irrigation Board

NWMPS-National Water Master Plan

NWPC-National Water and Pipeline Corporation

pH-Measure of Acidity or Alkalinity

PWD- Public Works Department

SAP-Structural Adjustment Programmes

SAR-Sodium Adsorption Ratio

SO_4-Sulphate

SIDA-Swedish International Development Agency

SSIDP -Small Scale Irrigation Development Project

TA-Total Alkalinity

TAC-Technical Advisory Committee

TAMS- Tibbetts, Abbetts, McCarthy, and Stratton

TB-Turbidity

TC-Total Coliform Bacteria

TDS-Total Dissolved Solids

TH-Total Hardness

UNDP-United Nations Development Programme

USAID-United States Aid for International Development

WAB-Water Appeals Board

WB-World Bank

WRMA-Water Resources Management Agency

WSRB-Water Services Resources Board

WSB-Water Services Board

WSTF-Water Services Trust Fund

CHAPTER ONE: INTRODUCTION

1.1 Background Information

According to the United Nations, Human Development Report, 2003 (UN, HDR, 2003), during the gathering of heads of state in 2000, the United Nations Millennium Declaration was made and the countries adopted and committed themselves to:

- Eradicate poverty.
- Promote human dignity and equality.
- Achieve peace and democracy.
- Achieve environmental sustainability.

The world leaders present during the gathering, promised to work together to meet concrete targets for advancing development and reducing poverty by 2015 or earlier. The water related targets set out were as follows:

- Goal 1: Eradicate extreme poverty and hunger
    - Target 1:To halve the proportion of people whose income was less than one dollar a day by 2015
    - Target 2: To halve the proportion of people who suffered from hunger by 2015
- Goal 7: Ensure environmental sustainability
    - Target 9: Integrate the principles of sustainable development into country policies and programmes and reverse the loss of environmental resources
    - Target 10: To halve by 2015 the proportion of people without sustainable access to safe drinking water
    - Target 11: To have achieved by 2020 a significant improvement in the lives of at least 100 million slum dwellers

The UN, HD Report, 2003,stated that, in nine countries more than one person in four did not have access to safe water, and in fifteen countries more than one person in four did not have access to adequate sanitation and the situation was either not improving or was getting worse.

1.2 World water situation

According to UN, World Water Development Report, 2003, the world water balance indicated that only 2.53% of the world water was fresh. Only 0.67% of the 2.53% world fresh water resources were available for abstraction in form of rivers, ground water, or fresh water lakes. The remaining potion was either in form of ice, or was located at places from which it was economically not feasible to abstract. Thus the gap was closing between water demand and supply. The main uses of water included:

- Domestic purposes: - This was the water that was required for drinking, cooking, getting rid of waste including human, and other purposes at the homestead.
- Irrigated agriculture is the largest single consumer of water in volume estimated to be responsible for 70% of all water withdrawals in the world.
- Livestock and wildlife, and aquatic farming also required water for drinking and pasture, and living environment respectively.
- Industrial purposes especially for cooling and the paper and pulp industries
- Environmental requirements for sustenance of the ecosystem
- Tourism and recreation purposes requirements were treated separate from domestic.

The earth was the only planet that had water, which could sustain life. Fresh water was a finite and venerable resource essential to sustain life. Growth in population, increased economic activity, and improvement of living standard, led to additional requirements for the

limited resource. During the 20th century, the world population increased three times where as the water withdrawals increased seven times. It was estimated that one third of the world population experienced medium to high water stress and the ratio was expected to grow by two thirds by 2025 (Human Development Report, UN, 2003).

The changing world climate due to global warming was also threatening to alter the world's climatic regime and give the world water balance a new face whose impacts were yet not so clear. However estimates showed that it could be contributing up to 20% of global water scarcity. Extreme weather conditions of droughts, floods, mudslides, typhoons and cyclones tended to increase in intensity and frequency with climate change. This caused human suffering, loss of arable land and affected stream flows and water quality leading to further strain on clean water availability (UN, WWR, 2003).

Land use development and vegetation cover influenced the physical distribution and quality of water. Tree roots held the soil particles tightly so that they were not easily carried by water or wind. The leaves also reduced the velocity of the raindrops and thus had little effect on hitting the ground to cause soil erosion. They also generated humus, which improved the soil structure reducing the soil erodibility. Thus the human activities that reduced the forest cover had serious effect on the water resources availability. With increasing population, more land was cultivated reducing the forest cover and thus lead to degradation of the catchments and reduction in water quality and quantity.

Human activities generated wastes, which sometimes got discharged into the water bodies. These wastes, which could be domestic, industrial, or agricultural fertilizers and pesticides, were major causes of pollution. The deteriorating water quality caused by pollution influenced water usability downstream, threatened human health, and the functioning of the ecosystem. This reduced the water's effective availability and increased competition for good quality water.

The water policies in many developing countries tended to encourage wastage of water. This was so especially in irrigated agriculture where farmers were not charged for the water they used. The crops grown consumed a lot of water, and were sold at subsidized prices increasing the consumptive use of water. These crops were also of low economic value.

The water infrastructure supply systems required capital for maintenance and deteriorated with time. The rehabilitation needed a lot of capital, which was not available. This led to some schemes having high water wastage or being abandoned. This led to increase in water scarcity.

With the increasing scarcity of water and growing environmental concerns over the decline in water resources focus needed to be enlarged to include all water users. Water resources were to be assessed and planned in an integrated fashion, and consideration for changes in policies and institutions in order to; -

- Indicate the wide range, and ramifications, of water management, and the relationship between the 'water sector' and other parts of the economy.
- Identify the principal issues involved in managing water resources, for the guidance of policy-makers.
- Set out principles and criteria by which water resources can be managed.
- Introduce some of the methods and processes entailed in a water policy review.
- Illustrate how different countries had carried out such reviews, and how they had gone about implementing their findings; and, by means of the above.
- Promote national policy and legislative reform, planning, and institutional development in the water sector.

1.3 Kenya's Water Sector

According to Van Zmerenberg and Roger M.A., An Economic History of Kenya and Uganda 1800-1970, 1975 (V. Zmerenberg and Roger M.A., 1975), the management of the water sector in Kenya was started in 1896 through a branch within the greater Public Works Department (PWD), as the Hydraulic Branch headed by the Hydraulic Engineer under the Director of Public Works. Its initial activities were mainly to look for the means of supplying water to the colonial administrators. The activities were at first restricted to Mombasa, but eventually offices were opened in Nairobi (1902), at Kisumu (1903), at Naivasha, Nyeri, and Eldoret in 1910. It operated as such until 1960 when it was recommended that it becomes a department in the ministry of Agriculture, Animal Husbandry and Water Resources. Since then the water sector had undergone many reforms and improvements to make it more efficient in dispatch of its activities as described in the First National Water Management Strategy, MoWRMD, 2003 and outlined below: -

The policy document "Sessional Paper No.10 of 1965 on African Socialism and its Application to Kenya" directed the government's policy towards priority areas for the African population, which were identified as poverty, illiteracy, and diseases.

Accordingly the government was engaged in all productive activities including provision of water and sanitation services. Owing to the growing involvement of the government in the development of water and sanitation services, the water department under the Ministry of Agriculture was elevated to a full Ministry of Water Development (MoWD) in 1974. The MoWD intensified the Governments ambitious water programme, and envisioned achieving the provision of water for all by the year 2000 as part of the International Drinking Water Supply and Sanitation Decade (IDWSSD).

As reported in the (NWMS, MoWRMD, 2003), the government took up the management of 120 urban water supplies and over 600 rural water supplies. The MoWD then took over the functions of the then Water Resources Authority, County Councils, and Community Water Supplies. This proved not sustainable and in the 1980's the Local Authorities (LA's) were given the mandate to manage some water supplies. The water supply systems deteriorated fast in the majority of the LA's leading to halting of the second phase of reforms in January 1986.

The Sessional paper No 1 of 1986 recommended that cost recovery was introduced and water resources management be given prominence. This brought community managed water projects back again. The Ministry of Local Government (MoLG) with the support of German Technical Cooperation (GTZ) started supporting water undertakers to improve management of water supplies especially in operation and maintenance. Under this initiative some water supplies like Malindi, Nairobi, Eldoret, Kisumu, and Nyeri were earmarked for privatisation. By 1987 the government had realized that for sustainability, water supplies had to be run on commercial basis. This led to the formation of the National Water Conservation and Pipeline Company (NWCPC) in 1988 to manage certain water pipelines.

The 1st National Water Master Plan (NWMP) by Tibbetts, Abbetts, McCarthy, and Stratton (TAMS) 1980 laid the foundation for the subsequent water development projects implemented within 1980-1990 decade. In 1990-1992 the government together with Japan International Cooperation Agency (JICA) undertook the 2nd National water Master plan 1992 whose objective was to promote orderly planning and development of water resources in the country. This study recommended the formulation of a new water policy, which culminated in the publication of the Sessional paper No 1 of 1999, the "National Policy on Water Resources Management and Development". To implement this policy, Water Act (Cap 372) was to be reviewed to have the required legal framework.

This had now been implemented and the legal framework to support it finalized in the Water Act 2002 (WA2002). The main WA2002 institutions are Water Resources Management Authority(WRMA), Catchments Area Advisory Committees(CAACs), Water Services Resources Board (WSRB), Water Services Providers (WSPs), Water Services Board(WSB), Water Services Trust Fund(WSTF), and Water Appeals Board(WAB).
The responsibilities of the WA2002 institutions were as summarized in table 1.1;

Table 1.1 Institutions Responsibility

Institution	Core Responsibility
WRMA	• Implementation of policies and strategies relating to management of water resources. • Development of catchment level management strategies, including appointment of CAACs and their facilitation
WSRB	• Overseeing the implementation of policies and strategies relating to provision of water services. • Regulating the provision of Water Supply and Sanitation (WSS) services • Licensing WSBs and approving their appointed WSPs • Monitoring the performance of WSBs and WSPs
WSB	• Planning for improvement in provision WSS services • Appointment and contracting WSPs • Asset holder of central government facilities
WSTF	• Assisting financing of provision of water supplies in areas that are inadequately provided for
WAB	• Adjudicating disputes within the sector

Source: Draft Plan for the transfer of Management and Operation of Water Services to Water Services Boards, Ministry of Water and Irrigation (2004)

Environmental Management and coordination Act 1999, Government Printers (EMCA 1999) was also a new umbrella legislation that guided and coordinated activities under all other legislation touching on the management of natural resources into which water was categorized.

1.4 Problems Facing Kenya's Water Sector

The water sector was faced with problems that led to formulation of a new water act and policy and the enactment of WA2002. Some of these were outlined in the First National Water and Sanitation Strategy (MWRMD, 2003A) as outlined:

- Lack of comprehensive institutional and legal framework;
- Centralized decision making and ineffective management;
- Inadequate and dwindling financial resources to the sector, for maintenance and augmentation of the existing water supplies and for extension of the water coverage;
- Low efficiency in the management of existing waters supplies;
- Limited natural endowment of freshwater, that made Kenya a water scarce country;
- Lack of inter-linkages with other actors whose activities touched on use of water;
- Poor communication and education hence lack of awareness by the users and general population on their role in the sector; and

- Best practices had not been established, thus hindering performance improvement including financial viability of schemes.

The Water Resources management Strategy (MWRMD, 2003B) recognized other challenges to the management of water resources in Kenya as: -

- Growing Population,
- Water scarcity,
- Climate variability and Water resources degradation,
- Declining flow volumes in rivers
- Catchment Degradation,
- Invasive Species,
- High storage and infrastructure Investment,
- Groundwater depletion,
- Pollution,
- Poor water allocation,
- Inadequate legal and institutional framework,
- Inter/Intra basin water transfer and sharing of her water resources with other countries.

1.5 Problem statement

The taking of an integrated approach to developing and managing water resources advanced goals such as reducing poverty, increasing food security, fostering economic growth, and protecting ecosystems. It also more effectively tackled specific water challenges, such as controlling flooding, mitigating the effects of drought, eliminating water-borne diseases, managing Tran boundary river basins, and addressing increasing competition for water.

1.6 Scope

This research covered the following areas,

- Current situation on water provision in Bahari Sub basin,
- Water resources available in Bahari Sub basin
- Water use practices for selected water users and uses,
- Effect of Tourism on water allocation
- Pollution due to agriculture and industries
- Effects of irrigation on the groundwater
- Legal and institutional aspects of water provision and water accountability.
- Biodiversity in relation to water provision
- Evaluating the necessity, and applicability of IWRM measures.
- Application of water demand management in irrigation

1.7 Objectives

The main objective of the research was to characterize current situation on Integrated Water Resources Management (IWRM), regarding physical measures at domestic, institutional, community, industrial/ commercial levels in Bahari Sub Basin. The policies, legal, economic, and administrative issues were also considered in order to develop strategies for IWRM to optimise water use. The main goals of the research included:

- Evaluation of the existing water resources available in the Sub basin;
- Evaluation of the existing water resources management practices and thus identified the opportunities of applying IWRM strategies;

- Assessing the level of capacity building for IWRM at the Sub basin level
- Assessing the adequacy of the legal framework and institutional arrangements for implementation of IWRM strategies; and
- Assessing the overall level of water accountability within Bahari Sub basin.

1.8 Expected Outputs

The output of the study included:

- The identification and subsequent formulation of relevant IWRM measures applicable to the project area that ensured efficiency, effectiveness, sustainability in the water resources management;
- Identification of proper institutional and administrative arrangement that would ensure the proper implementation of IWRM strategies, sustainability of the accrued benefits and continued growth; and
- The identification of proper channels for data collection, and dissemination on water resources.
- The setting up the institutional framework of IWRM. The framework showed how information on its benefits was disseminated.

1.9 Justification for the Project

Water is vital in the endeavour to achieve food security for the rural majority. There was also a direct relationship between the availability of water and the living standards (hence poverty levels) of community. Efforts at ensuring food security failed if the availability of water was not addressed. Thus a coherent approach was taken to improve on how to develop, manage, and use water resources to further sustainable development goals and meet development challenges. This was possible if stakeholders in water resources management were taken into consideration in an integrated approach.

Water was a key ingredient in generating rural livelihoods, growing food, and producing energy, encouraging industrial, and service sector growth, and ensuring the integrity of ecosystems and the goods and services they provide. Water problems had been hard to address because their solutions often fell outside of the normal purview of the agencies tasked with addressing them, and required cooperation from multiple sectors.

Bahari Sub basin faced the challenges outlined, but it had water resources which if well managed could meet its requirements. The need for new approach to management arose due to the diminishing water supplies, which had led to a new paradigm shift, depletion, and pollution of traditional sources, remoteness of sources and growing costs of provision. An IWRM approach promoted 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.

CHAPTER TWO: LITERATURE REVIEW

2.1 World water resources

The world was estimated to contain about 1 400 million km^3 of water of which 35 million km^3 (2.5 percent) were freshwater (UN, WWDR, 2003). Large amount of freshwater was contained in ice caps, glaciers, and deep in the ground and was not accessible for use. The freshwater that was used stemmed essentially from rainfall over land, generated through the hydrological cycle. The hydrologic cycle was a complex cycle, which was continuously taking place and included the transportation of water, its temporary storage, and change of state. The sources that were conventionally called "water resources" consisted of water available in lakes, reservoirs, streams, and underground aquifers. Not all of the water was economically available for human use. Apart from the annual withdrawals for human use, a certain amount was left to follow its natural course to ensure effluent dilution and safeguard conservation of the aquatic ecosystem. Because both water and population were unevenly distributed, the situation was already critical in various countries and regions. Increasing areas of the world were suffering from freshwater shortages and competition among users was rising.

2.2 Historical Development of Water supply in Kenya (1895 to 1963)

The growth of Kenya's water sector was described in An Economic History of Kenya and Uganda 1800-1970 (E Van Zmerenberg and Roger M.A. 1975) as.

(i) Administration

Water supply in Kenya from 1896 to 1960 was carried out as a branch within the greater Public Works Department (PWD), as the Hydraulic Branch headed by the Hydraulic Engineer under the Director of Public Works. Its activities were at first restricted to Mombasa, but eventually offices were opened in other towns, and Nairobi became the headquarters in 1908.

A commission formed in 1956 recommended that the Hydraulic Branch should form an organization of its own under the ministry of Agriculture, Animal Husbandry and Water Resources during the post 1960 planning period.

(ii) Historical Development

The earliest report on water development in Kenya recorded in (E Van Zmerenberg and Roger M.A., 1975) was by Thompson (1929) who noted the poor water situation in the Northern Frontier and the Rift Valley. The report notes also that Magadi Soda Works had piped water from Ngong Hills at this time. The colonial government had noted that except for relatively small areas, Kenya was a land of poor rainfall and scarce surface water. The provision of water in dry regions and improvement of existing supplies was therefore of major importance and water was fundamental to most schemes of land development. Thus boreholes were dug, dams constructed, bushes cleared of tsetse fly infestations to open up the drier countryside. Some urban centres spread over the country were also supplied with water (V. Zmerenberg and Roger M.A., 1975).

2.3 History of Irrigation development in Kenya

V. Zmerenberg and Roger M.A., 1975 reported that irrigation development in the country started in Marakwet and Taveta in the early 19th century where slave labour was used to construct furrows, even though floods from River Nyando and Tana River were used by local population for irrigation earlier. During the construction of the Kenya-Uganda railway the Indian workers started irrigation schemes in the Kibwezi-Mtito Andei area to grow Asian vegetables.

During World War II the available prison labour was used to start irrigation schemes in Taveta and around Lake Victoria. After the war, the colonial government concentrated on the setting up of large schemes using prisoners and detainees labour in Mwea, Hola, Perkerra, Yatta, and Ishiara. Between the early 1960s and mid 1970 the GOK with assistance of donors initiated smallholder schemes in ASAL areas. National Irrigation Board (NIB) was formed for managing government schemes and planning for other schemes in Kenya. In mid-and late 1970s, the government with assistance from the Netherlands government, established the Small Scale Irrigation Development Project (SSIDP) to oversee the institutional development unit that was capable of dealing with project identification, formulation, design, implementation, organization, and guidance. Irrigation and Drainage Branch (IDB) of the Ministry of Agriculture was formed in 1979 to be responsible for smallholder irrigation activities in the country. Provincial Irrigation Units (PIUs) were created to liaise with the IDB for ease in delivering irrigation services.

The Study on the National Water Master Plan (NWMP), by Kenya-Japan Development Cooperation,1992 estimated total irrigation potential to be 352 400 ha. The total water managed area was 73 025 ha, of which 92% was under full or partial control. Only 650 ha were irrigated from groundwater and the rest was irrigated from surface water, either from pumping, diverted from streams and rivers, or from storage reservoirs. The major irrigated crops were coffee, vegetables, rice, and cut flowers. The government had not been able to achieve the set target of developing irrigated land due to lack of capacity in the implementing ministry, and the approach taken by the funding bodies in development. Lack of water resources had been a major hindrance.

2.4 Kenya's Water Situation

2.4.1 Water Resources

Study on National Water Master Plan 1992 by JICA and reported in Water Resources Management Strategy (MWRMD, 2003B) estimated the average annual water available as 20.2 BCM distributed unevenly. With an estimated population of 31.2 million people in 2002, the endowment of water was 647 m^3 per person per year. Kenya was projected to have an endowment of water of 359 m^3 per person per year assuming a projected population of 56.5 million people by the year 2020.Annual rainfall recharged the ground water storage on infiltration and thus areas with high rainfall had high underground storage. Groundwater possessed large development potential as a source of drinking water in ASAL areas.

2.4.2 Water Resources Management Problems and Challenges

The challenges facing water resources management in Kenya were as a result of factors both within and outside the water sector. Climate variability and increasing demand for water as a result of development and population pressure may not be controlled by the sector, but mitigation measures could be initiated to ensure sustainable water resource development.

The problems and challenges facing the Country in water provision included (MWRMD, 2003):

Growing Population: The growing population increased the demand for water for domestic use, food security and industry, and the increase may reach the point where the requirements outstrip the natural supply.

Water scarcity: Kenya's natural endowment of fresh water was limited by an annual renewable fresh water supply of only 647 cubic metres per capita per year, and hence classified as a water scarce Country. The water scarcity manifested itself in food shortages, fights among communities, power rationing, and damage of our infrastructure as demonstrated in the diminishing available storage.

Climate variability and Water Resources Degradation: Kenya's annual rainfall was also highly variable from year to year and from region-to-region. Droughts and floods were a recurring phenomenon and had devastating impact on water resources.

Declining flow volumes: There was a clear trend that the flow in all the major rivers was decreasing mainly due to human activities.

Natural Phenomena: The recurrence of El-Nino and La-Nina which had devastating effects on water resources called for the pooling of resources together in preparedness and prudent management of water resource for the good of economy and prosperity of nation.

Catchment Degradation: Catchments degradation resulted in increased runoff, flash flooding, reduced infiltration, erosion and siltation, which undermined the limited sustainable water resources

Invasive Species: The proliferation of invasive plants and animal species in the region including fish species and aquatic weeds was of growing concern.

Storage and infrastructure Investment: The storage capacity had been low due to the fact that investment levels in water management infrastructure had been inadequate and on the declining trend for many years.

Water Demand: The Study on National Water Master Plan of 1992 indicated that water demand in the important categories in domestic, industry, agriculture including irrigation, livestock, wild life and hydropower water, increased significantly from 2073 MCM/year in the year 1990 to 5817 MCM/year in the year 2010.

Groundwater depletion: The high demand for water, encroachment on recharge areas, lack of accurate information of groundwater potential and the poor monitoring of groundwater in use led to depletion of groundwater.

Pollution: Agricultural fertilizer and pesticides got leached to waterways during runoff. Most municipal sewerage plants and industries in the country discharged partially treated or untreated wastewater containing high levels of organic, metals and other toxic substance directly into surface watercourses. The increase in water pollution undermined the nation's water resources, escalating public health risks, intensifying poverty and curbing economic development.

Enabling environment: The other factors, which contributed to inadequate water resources management, included inadequacies in legislation, institutional framework, financial mechanisms, and lack of professional and technical capacity in research. There was little private sector engagement or investment and communities, NGOs and other stakeholders

were not given opportunities or incentives to participate in water resources management.

Kenya's shared water resources: According to the Mission report No 7 (World Bank, 2003), about 54% of Kenya's water resources were shared. The report explained that Lake Victoria Basin harbors 50% of the countries surface water resources and was shared by nine Nile river system riparian states (Burundi, DR Congo, Egypt, Eritrea, Ethiopia, Kenya, Rwanda, Sudan, Tanzania and Uganda). Groundwater resources were also shared with neighbors Ethiopia, Sudan, Tanzania, and Uganda.

Inter/Intra Basin Water Transfer: It was clear that water resource both surface and ground water was unevenly distributed spatially in the country. Increasing human activities especially in urban areas had led to a situation where by the demand for water was being met from water abstracted from outside their catchment or drainage basin.

Thus Kenya freshwater resources were under increasing pressure due to growth in population, increased economic activity and poor water resources management that focused on developing new sources rather than managing the existing ones better. The water governance had been sectoral based leading to fragmented and uncoordinated development and management of the resource, inefficient use, and allocation. A process that ensured sustainable development; allocation of water resources use in the context of social economic and environmental objectives was required. Integrated Water Resources Management took into account the overall social and economic goals and was sustainable.

2.5 Water Demand in the Agricultural Sector

2.5.1 Introduction

The largest demand for water came from agriculture, with more than 70 percent by (UN, HDR, 2003) estimates, of the water withdrawn from the earth's rivers, lakes and aquifers was used for irrigation. With the growth of competition, conflicts, shortages, waste, overuse, and degradation of water resources, agriculture was increasingly becoming the system's safety valve. Agriculture was the world's largest water user in terms of volume, relatively low-value, and low-efficiency and highly subsidized water user. In the past, domestic spending for irrigation dominated agricultural budgets in countries throughout the world. However, the economic, social and environmental implications of large publicly funded and operated, irrigation projects now required further consideration. The water resource management was geared towards designing demand-and user-focused approaches that influenced behaviour.

2.5.2 Irrigation Water Requirements

The amount of irrigation water required by crops varies with

- The type of crop grown
- The stage of growth of the crop
- The type of soil on which the crop is growing
- The weather conditions especially the evaporation
- The amount of rainfall and any ground water available to the crop
- Special requirements like leaching, and fertilizer application
- The overall irrigation efficiency

From Practice Manual for Water Supply Services in Kenya, 2005, GOK Printers, Nairobi, the estimated value for irrigation water requirements was 1l/s/ha.

2.5.3 Policy reform in agriculture

Sustainable agricultural development depended on sustainable water use. Sustainable economic growth required, in part, both economy-wide and sector-specific policy reforms. Economy-wide policies attempted to create a favourable macro-economic environment, while water sector policies seeked to encourage resource efficiency among water users. The current emphasis on macro-economic policy reforms and economic liberalization had important implications for irrigation. The cost of turning a water source into a service delivered to a farm made the water sector a prime target for further policy reforms. Irrigation consumed large quantities of capital and foreign exchange and tied up scarce skilled personnel, and thus there was need for a tighter control of finance, more positive active leadership, and better planning of resource allocations, with input from farmers.

2.6 Domestic and Industrial Water Demand

Domestic water supply should be available in the right quantity and quality when required. Industrials water requirements vary with type of industry. Paper and pulp industries are the highest water consumers. Domestic water demand requirements vary with the type of population, whether rural or urban and the number and type of livestock kept in the household. The management of rural and urban water supply required that

- Strategic Partnerships are formed between national, provincial, local agencies and NGOs
- Alternative water sources were developed through reclaimed water, desalinisation, rainwater harvesting, and water reuse
- Implementation of new technologies in water fees/metering, leak detection, and water auditing systems
- Community were engaged in community education, local and regional planning processes, and outreach to cultural and community group
- Research was conducted in aquifer monitoring, coastal marine environment study, supply-demand forecasting, and pollution prevention

Within this perspective, a vision for sustainable water supply was developed based on;

- Development of sustainable local water resources
- Community water usage and its impact on the water supply
- Conducting of a thorough assessment of the existing water supply system
- Having a sustainable long-term water plan
- Involving communities appropriately in decisions that affect their water use
- Using technologies that are available so that sustainable water supply was achieved
- Capacity to effect the changes, and the expertise to operate and continuously improve the water system

The rates of water consumption for the categories of consumers in Bahari sub basin were:

Table 2.1 Water consumption rates in Kenya

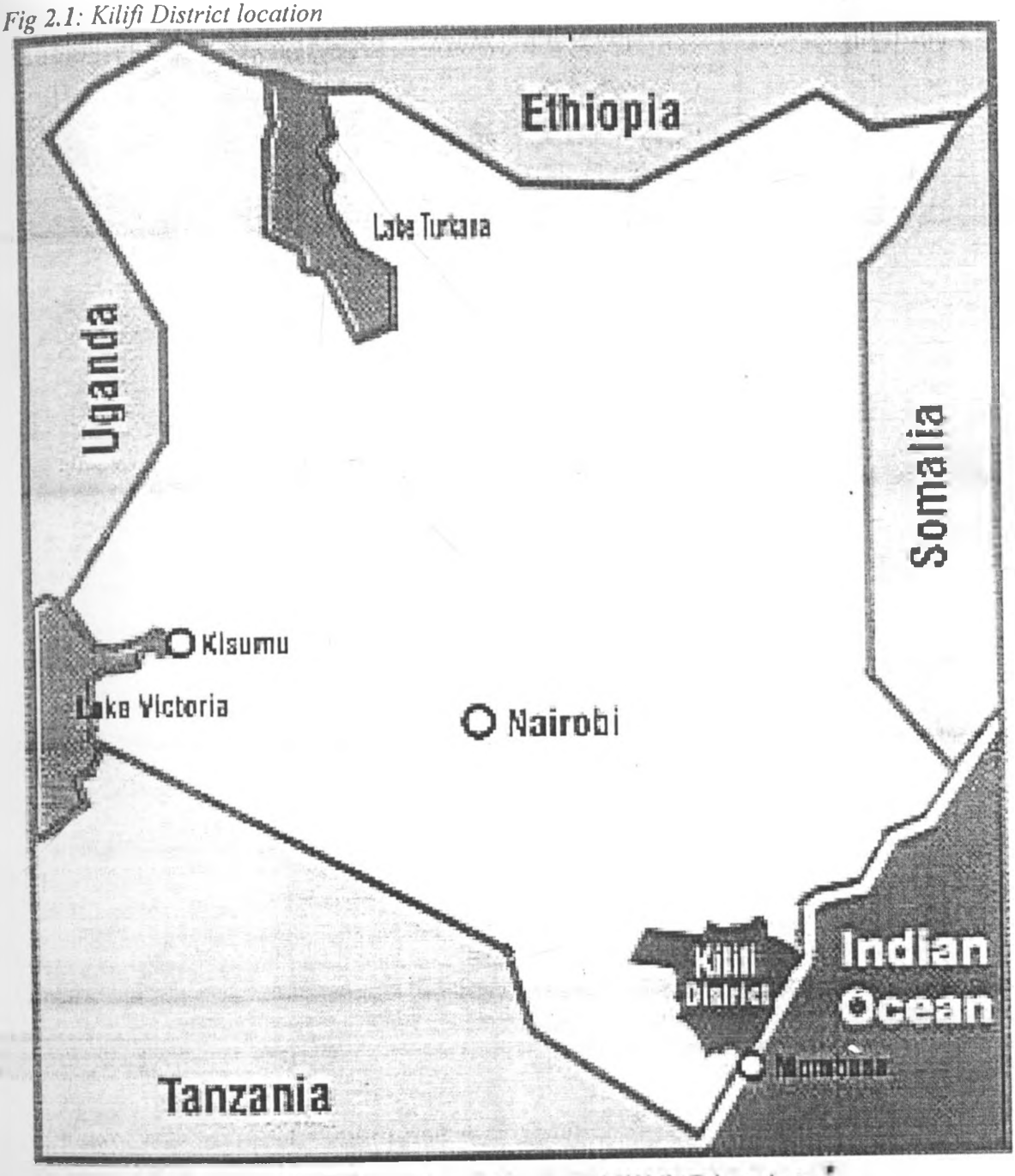
Type of Consumer	Units	Quantity
Households with individual connection	l/head/day	50
Household without connection	l/head/day	20
Boarding Schools	l/head/day	50
Day schools without WC	l/head/day	5
Hospitals	l/day	Minimum 5000
Health centres, Nursing Homes, Dispensaries	l/day	5000
Medium Class Hotels	l/bed/day	300
Bars and Shops	l/day	200
Medium scale Industries	l/day	10,000

Source: Practice Manual for Water Supply Services in Kenya, 2005, GOK Printer, Nairobi

2.7 An Overview of Kilifi District

Kilifi District was one of the seven districts in Coast Province. The other six were Mombasa, Kwale, Taita-Taveta, Tana River, Lamu, and Malindi. It lied between the latitudes 2^0 2'and 4^0 south, and between the longitudes 39^0 and 40^0 14" East. The shoreline was 144 Km from Mtwapa creek to Mida creek. The district bordered Taita Taveta to the west, Malindi to the northwest, Mombasa and Kwale to the south.

Fig 2.1: Kilifi District location

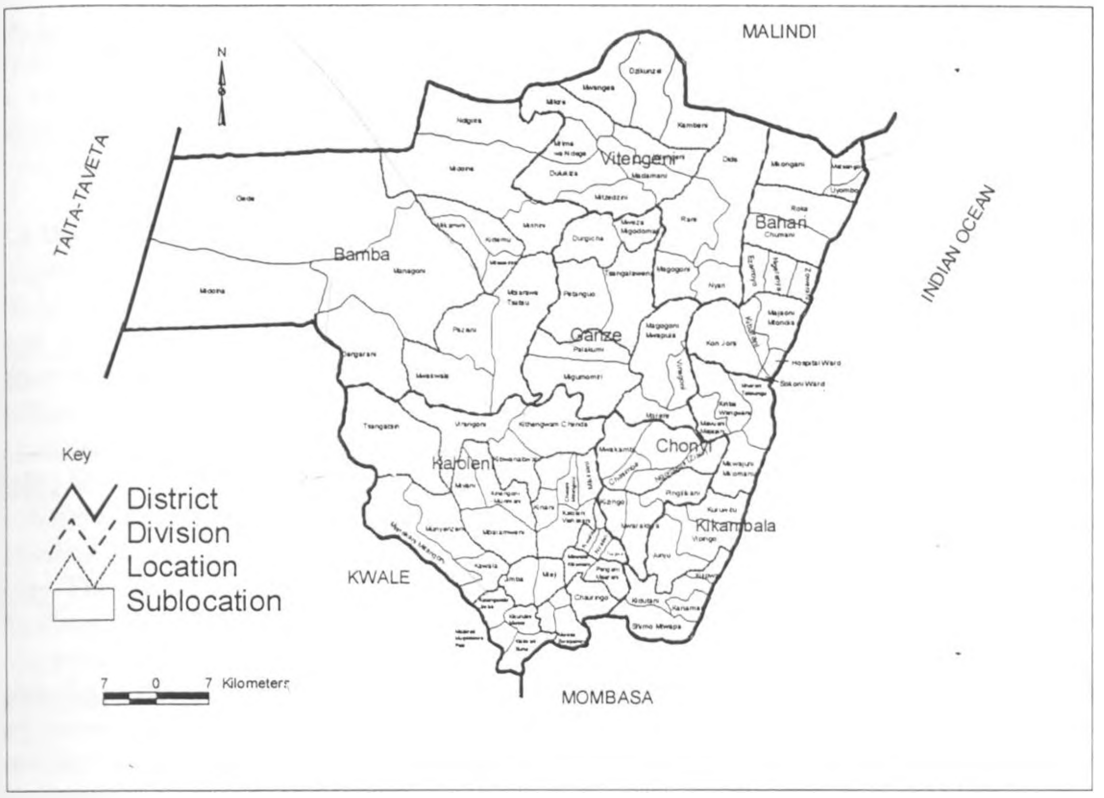


Source: Kilifi District Development Plan 2002-2008, 2003, GOK Printer, Nairobi.

2.7.1 Administration Boundaries

The district had an area of 4779.2km^2. Kilifi district was divided into seven administrative divisions namely Kaloleni, Bahari, Chonyi, Kikambala, Ganze, Vitengeni, and Bamba.

Fig 2.2 Kilifi District Administrative Boundaries



Source: Kilifi District Development Plan 2002-2008, 2003, GOK Printer, Nairobi.

2.7.2 Settlement Structure

High population densities were found in Bahari, Kikambala, and Kaloleni divisions along the tarmac roads from Mombasa-Malindi and Mombasa-Nairobi up to Mariakani town as outlined in Jaetzold and Schmidt, Farm Management Handbook of Kenya, Eastern and Coast Province, 1983(Jaetzold and Schmidt, 1983). High population clusters were also found in Chonyi division and some parts of Kaloleni division. Sparsely populated divisions in the district were Ganze, Vitengeni, Bamba, and some parts of Kaloleni division. The larger towns in the district (Kilifi, Mariakani, Mtwapa, Kaloleni, Majengo, and Bamba)

2.7.3 Water Potential

In terms of water potential, Kilifi District was classified into 3 distinct zones (Jaetzold and Schmidt, 1983), namely:

The Coastal belt: -This encompassed the divisions of Bahari, Kikambala Chonyi, and the wetter locations of Kaloleni division. It occupied approximately 15% of the total district area. Here, the rainfall was usually above 1000 mm per year. The soils were mostly sand overlying a rich sandstone aquifer. Water was thus not a problem in this area as it was easily obtainable from both shallow wells and boreholes

Medium potential: - This zone covered mostly Vitengeni, Ganze as well as parts of Kaloleni division and covered approximately 30% of the total district area. The rainfall was around 500 to 800 mm per year. The soils were either loamy clays or black cotton overlying an unweathered basement rock. The ground water potential was rather poor, though boreholes

in this region yielded reliable amounts of water. The gentle valleys and the loamy-clayey soils made dam construction viable

The Low potential zone: This covered the whole of Bamba Division and Tsangatsini, Mwanamwiga and Kayafungo Locations in Kaloleni Division. The rainfall in this zone was low and erratic. The area was characterized by high evaporation rates (>2000 mm/year). Underground water potential was very poor, required very deep boreholes (80 – 120m) and the water was saline

2.7.4 Water Resources

According to the Water Resources Assessment Study, Kilifi Main Report, by MoWD, 1996 (WRAS Kilifi Main Report), the available water sources in the district were: -

Piped Water: This water source was derived from two pipelines that passed through the District namely Mazeras –Mombasa Pipeline and the Baricho –Mombasa Pipeline. These two pipelines supplied the bulk of their water to Mombasa, and Kilifi District was lucky to lie in the path of the two pipelines (the district did not have its own source of piped water).

Wells: Wells were the traditional source of water in the High and medium potential areas of the district. There were more than 700 documented communal wells. About 60% of the population had access to a well.

Dams: There were 70 documented community dams and 400 pans in the district. The water from dams and pans was used for domestic and livestock. Pans supplied water to about 50% of the population at one time or another.

Boreholes: Private boreholes were concentrated in the Mtwapa area of Kikambala division. They belonged to commercial farms. The water was mainly used for irrigation, livestock, and domestic. There were only a few boreholes in the hinterland owing to the excessive salinity of the groundwater.

Roof Water Catchment: This source was common in institutions which were located along the coastal belt where the rainfall was high.

2.7.5 Challenges Posed in the Provision of Water

The challenges that faced provision of adequate water were as outlined in the Water Resources Assessment Study (WRAS, 1996) for Kilifi included:

(i) Poor Surface Water Potential

The District had no perennial river with potential for development as a water source. The hinterland lied in a rain shadow. The rainfall was scant and erratic. Evaporation rates were also high hence necessitating deep water pans (>4.5 m deep).

(ii) Poor Ground Water Potential

The District was relatively flat. The soils were sandy hence water seeped very fast. The area was underlain by unfractured basement rock hence minimizing ground water potential especially in the interior. The borehole water in the interior was saline, rendering it unfit for human consumption, livestock and irrigation. Along the coast there was seawater intrusion into wells.

(iii) High cost of water "infrastructure"

The cost of constructing 1 km pipeline, or digging a 6000m^3 pan, or sinking a borehole was beyond the reach of the population. In addition there was a steadily diminishing GOK budget and donor support for the development of additional water supplies.

(iv) There was little private sector participation in the construction of Water "infrastructure"

If the onus of providing water was left to the GOK, then the dream of providing all with piped water by the year 2020 would remain a pipe dream.

(v) Poverty
Poverty levels of more than 65% (more than 80% in the water scarce zones) made even roof catchment expensive to implement.
(vi) There was lack of Skilled "Water Infrastructure" Know-how within the population. Water abstraction and conservation would be a lot easier if there existed people within the community who had the necessary skills and know-how. These people would have acted as teachers and propagators of appropriate and improved methods of harnessing water

2.7.6 Opportunities Existing in the Water Sector

Despite the challenges highlighted above, there existed still many opportunities that led towards adequate water provision for the people of Kilifi. These included:

(i) Aiming towards "Zero-Runoff"
Within a short time after downpour, most of the runoff in the district found its way into the Indian Ocean. This meant that ground aquifers were not well replenished. There existed numerous techniques aimed at reducing the amount of surface runoff and at increasing the duration before the runoff found its way into the streams, rivers etc. e.g. terracing, rainwater-soak pits, grassy (green) lanes, accumulation ponds etc. The water that seep into the ground was stored in the natural aquifers for use later in the dry period
(ii) Enhance Roof catchment
The amount of rain that fell on a corrugated iron-sheet roof was substantial and could be harnessed in tanks (Ferro cement, UPVC, Drums) for domestic use. Roofs could be augmented by temporary sheds, erected during rains for harnessing rainwater.
(iii) Improved Food Security through Fish Farming
Fishponds were easy to construct, and the existing pans (especially in areas already served with piped water) could also be served for the purpose of fishponds
(iv) Commercial Water Projects
The revised Water Act recognized the input of the private sector in the provision of adequate water. Avenues existed whereby private entrepreneurs could commercially supply water.

2.8 The Description of Project Area

2.8.1 Location and size

The study area was situated in Kilifi district, Coast province. It lied between latitudes 20'20'S and 4° 14'E.it bordered the Indian Ocean to the east, Mombasa and Kwale district to the south, Taita/Taveta districts to the west and Malindi district to the north and northwest. The district covered an area of 4779.2 square kilometres excluding about 109 square kilometers of water surface comprising of the Indian Ocean. Arabuko Sokoke Forest covered an area of 189.0 square Kilometers. The sub basin was sub divided into three divisions as below:

Table 2.2 Population distributions per division.

Division	Area (sq km)	Population	Population Density
Bahari	277	90009	325
Chonyi	202.2	47128	233
Kikambala	299.7	97898	327

Source: Kenya population and housing census, 1999, CBS

2.8.2 Topography

According to Jaetzold and Schmidt (1983), Farm Management Handbook of Kenya, Eastern and Coast Province, the study area comprised of two main topographical features as shown in Fig. 1.2. The main features were the coastal plain and the coastal plateau. The coastal plain was a narrow belt bordering the Indian Ocean and varied in width between 3 km and 20 km at the widest. The seaward margin of the plain was composed of coral reef, which was backed by a series of variable sands and sandy clays. Most of the coastal plain lied below 30 m above sea level.

The foot plateau unit lied to the west of the coastal plain and was characterized by undulating plain lying between 60 m and 135 m above sea level. The plateau represented a seaward sloping peneplain whose surface had been dissected by numerous dry watercourses.

2.8.3 Drainage and Climate

The Ministry of Water Development (1996), Water Resources Assessment Study, Kilifi Main Report reported that the main seasonal rivers that drained the area as Goshi, Ndzovuni and Mtomkuu. There are also seasonal streams that drain the sub basin. The drainage forms part of the southern part of the Athi River catchment area. As reported in Kilifi District Development Plan 2002-2008, GOK Printers, Nairobi, the rivers and streams flooded during the rainy season resulting in destruction of infrastructure, and pollution of the beaches where they empty.

According to Jaetzold and Schmidt (1983), Farm Management Handbook of Kenya, Eastern and Coast Province, the average annual rainfall ranged from 600 mm in the hinterland to 1200 mm at the coastal belt. The rainfall in the study area occurred in two main seasons: March to July were the long rains, and October to December were the short rains.

The sub basin was generally hot and humid all year round with annual mean minimum temperatures 22°C and 25°C in the months of August to January and maximum temperatures varying between 26°C and 30°C in the coastal belt. Towards the hinterland the maximum temperatures ranged between 30°C and 34°C.

The average relative humidity along the coastal belt was 60% but decreased towards the hinterland. Winds speeds ranged between 4.8 km and 10.9 km per hour.

2.8.4 Soils and Land use

Kilifi District Development Programme (1999), Development Visions, Strategies, and Priorities for Kilifi, GOK Printers, Nairobi, reported that the soils in the sub basin differed widely in depth, texture, physical and chemicals properties. The different soil types had been formed on the coastline mainly due to sedimentation. The soils on the coastline were Jurassic sediments of marine and deltaic origin. These were the coral limestone, marble clay stones and alluvial deposits. The Ministry of Agriculture, Kilifi District Annual Report, 2004 classified these soils were rich and good for agricultural crop development.

The low coastal plains were coarse-grained sands. They were deep well drained of sandy to loamy texture. The soils were suitable for cashew nuts, coconuts, cassava, and cereal crops.

In the coastal uplands of Chonyi, the soils were developed on shales. These soils were fertile and moderately well drained. The land was under food crops and smallholder livestock.

2.8.5 Administration

The present (2004) administrative sub-division of Bahari sub-catchments consisted of three divisions, thirteen locations and thirty four sub locations.

Table 2.2 Administrative locations and sub locations for Bahari Sub basin.

Division	Area (Km^2)	Locations	Sub locations
Bahari	277.0	5	14
Kikambala	299.7	3	11
Chonyi	202.2	4	9
Arabuko Sokoke forest	189.0	-	-
Total		**13**	**34**

Source: Kilifi District Development Plan 2002-2008, Government Printers, Nairobi, 2004.

2.8.6 Infrastructure

The District Public Health Officer reported that the project area had health facilities consisting of two (2) hospitals, six (6) health centres, twenty eight (28) dispensaries, and three (3) nursing homes.

According to the District Development Plan 2002-2008, GOK Printers, Nairobi, the sub basin had a total of ninety (90) primary schools and eleven (11) secondary schools. There were two government training institutes, Kilifi Institute of Agriculture and Kilifi Medical Training Centre that train in Agriculture and Medical Engineering respectively.

Table 2.3 Schools distribution per division in the Sub basin

Division	No of Primary Schools	No of Secondary School
Bahari	37	4
Kikambala	28	4
Chonyi	25	3
Total	**90**	**11**

Source: Kilifi District Development Plan 2002-2008, Government Printers, Nairobi, 2004.

There were no rivers, which could supply water of good quality and sufficient quantity to meet the water needs. The Sabaki River that supplied the Baricho-Mombasa pipeline was the only permanent river (the greater Athi River catchments).

Other water sources were wells, boreholes, dams, pans, springs and roof catchments.

For electricity services the area was connected to the national grid and had a high voltage power line running parallel up to Baricho.

The area had 848 km of road network, with 78 km of it bitumen standard. The earth roads are impassable during the rainy season.

Table 2.4 Total road network per division for the project area

Division	Bitumen	Gravel	Earth	Total
Bahari	55	80	58	193
Kikambala	33	140	270	443
Chonyi	-	120	92	212
Total	**78**	**340**	**420**	**848**

Source: Kilifi District Development Plan 2002-2008, Government Printers, Nairobi, 2004.

2.8.7 Population

The population for the sub basin was estimated to be 235,045 persons during the 1999 Population and Housing Census. The population distribution is related to land productivity, and thus Kikambala and Bahari being the most productive divisions agriculturally, are the most populated.

Table 2.5 Population distributions by location for Bahari Sub basin

Division	Location/Township	Population	Total
Bahari	Kilifi Township	36,412	**90,009**
	Tezo	17,802	
	Ngerenya	11,631	
	Roka	12,376	
	Matsangoni	11,788	
Chonyi	Mwarakaya	12,187	**47,128**
	Banda Ra Salama	8,824	
	Chasimba	14,385	
	Ziani	11,742	
Kikambala	Mtwapa	53,341	**97,898**
	Junju	23,243	
	Mavueni/Takaungu	21,314	
	Total		**235,035**

Source: Population and housing census 1999, CBS

The Demographic and Health Survey 2003, CBS, Nairobi projected that the population of Kenya was expected to grow at a rate of 3.2% per annum. Thus the projected population of the sub basin will be 310,290 by the year 2008 with 1999 used as the base year when the Population and Housing Census was conducted.

Table 2.6 Projected population distribution by division for Bahari sub basin

Division	Population				
	1999	2002	2004	2006	2008
Bahari	90,009	98,650	104,963	111,681	118,829
Chonyi	47,128	51,652	54,958	58,475	62,218
Kikambala	97,898	107,296	114,163	121,470	129,244
Total	**235,035**	**257,598**	**274,085**	**291,626**	**310,290**

Source: Population and housing census 1999, CBS

Urban Population

The main urban centres are Kilifi, Mtwapa and Majengo. Other upcoming urban centres are Vipingo, Tezo and Mtondia. For the study Majengo and Mtwapa were lumped together as the two are in the same location. Vipingo, Tezo and Mtondia were considered as rural areas. Kilifi District Development Plan 2002-2008, GOK Printers, 2001, projects that the increase in levels of urbanization will require investment in urban infrastructure such as: roads, urban water and sewage system, housing, and telephone. The Demographic and Health Survey

2003, CBS, Nairobi projects that the urban population of Kenya is expected to grow at a rate of 3.25% per annum.

Table 2.7 Urban population projections for the selected centres.

Urban Centre	Urban Population				
	1999	2002	2004	2006	2008
Kilifi Township	36,412	39,962	42,560	45,326	48,272
Mtwapa	53,341	58,542	62,347	66,400	70,715
Total	**89,753**	**98,504**	**104,907**	**111,726**	**118,988**

Source: Population and housing census 1999, CBS

2.8.8 Economy

The major economic activities in the sub catchment were agriculture, livestock rearing, fishing, commerce, industry and tourism. Agriculture was the main activity and engaged about 80% of the labour force according to the District Development plan 2002-2008, GOK. The farming was done on small-scale holdings of about 6 ha. The only large-scale farm was Rhea Vipingo sisal plantation. Livestock rearing was carried out in the same farms that were engaged in farming; however it was more predominant in the semi-arid areas of the sub basin. According to the Kilifi District Animal Production Officer's, Annual Report, 2004 the population of livestock was:

Table 2.8 Livestock population in the sub basin

Type of Livestock	Bahari	Kikambala	Chonyi
Beef cattle (Zebu)	1 000	5 100	4 200
Dairy	16 500	7 000	4 500
Poultry (indigenous)	150 000	10 000	60 000
Commercial layers	21 000	26 000	67
Broilers	9 000	5 000	0
Ducks	5 000	5 000	4 000
Geese	1 000	800	5

Source: Kilifi District Animal Production Officer's, Annual Report, 2004

Two slaughter houses were within the sub basin and handled an average of four cows and five goats per week.

- Mwenzang'ombe slaughter house is at Tezo market centre in Bahari Division
- Vipingo slaughter house is at Rhea Vipingo Sisal Plantation in Kikambala Division

Other livestock kept but in small numbers included: turkey, guinea fowl, ostrich, donkeys and pigs.

The main challenges facing the industry included:

1. Poor water distribution
2. Poor infrastructure for marketing
3. Disease outbreaks
4. Fluctuation in market prices of farm products

Fishing was done mainly along the coastline where individuals carried out small-scale fishing. Tourism activities along the coastline region had resulted in establishment of tourist hotels and villas. Other activities were in the informal sector such as Jua Kali, matatu business and quarrying building stones.

According to Kilifi District Agricultural Officer's Annual Report 2004, the main food crops grown were maize, cassava, cowpeas, and green grams. The cash crops grown were coconuts, cashew nuts, citrus fruits and mangoes. Agro based industries had been set up in the area to process the farm products.

Table 2.9 Agro based industries situated in the sub basin

Name	Locality	Commodity	Remarks
Milly Fruit Processors	Mtwapa	Mangoes, oranges, passion, mineral water	• Processing and bottling of juice and soft drinks • Bottling of mineral water
Rhea Vipingo	Junju	Sisal, Mangoes	• Processing of sisal into fibre • Packaging of mangoes for export
Equitea EPZ	Mtwapa	Tea	• Processing and packaging of Tea from upcountry
Mombasa Cashew Nuts	Kibarani	Cashew nuts	• Purchase raw nuts from farmers • Process raw nuts for sale
Kilifi Plantation	Mnarani	Milk and milk products	• Processing of different milk products
Millennium Management	Kibarani	Cashew nuts	• Purchase raw nuts from farmers • Process raw nuts for sale

Source: Kilifi District Agricultural Officer's Annual Report 2004

2.8.9 Poverty

The poverty line was determined based on expenditure required to purchase food that met the minimum nutritional requirements (2,250 calories per adult per day), and the basic non-food needs. The Geographic Dimensions of Well-being in Kenya, CBS, 2005 had estimated the poverty line in Kenya to be about Kshs 1239 and Kshs 2648 for rural and urban households respectively. In Kilifi District, poverty manifests itself, in inability of people to access basics needs as food, shelter, clothing, health, water, education, land and good infrastructure. The district had 65% food poor and 43% hardcore poor. Hardcore poor was a terminology used to classify the poor who cannot meet basic minimum food requirements (2,250 calories per adult per day), even after spending all their income on food alone. According to the Geographic Dimensions of Well-being in Kenya, CBS, 2005, out of 235,035 (1999) people in Bahari sub basin 63% were food poor.

2.8.10 HIV / AIDS

According to the Kilifi District Development Plan 2002-2008, Government Printers, Nairobi, prevalence of HIV and AIDS was estimated to be 10%. It was evenly distributed in all the divisions and had resulted in lower performance in all the sectors.

2.9 Integrated Water Resources Management

2.9.1 Definition

IWRM is a process which promotes the coordinated development and management of water, land and related resources, in order maximise the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital eco system-Global Water Partnership, 2001(GWP, 2001). This means that objectives established for integrated management must be consistent with the nature of both supply and demand and address specific development challenges and optimize water's contribution to achieve social, economic, and environmental goals.

2.9.2 Introduction

Water projects had predominantly been in water supply and sanitation, irrigation and drainage, and hydroelectric projects. Other projects had been in watershed management, flood control, and waterway projects. The development of these projects had tended to regard the use of water resources as production and consumption, other than integrated management involving other users. An integrated approach aimed to:

- Conserve water through a more efficient allocation of the resource
- Solve conflicts among competing uses and users;
- Account for the social, economic and environmental value of water;
- Increase the participation of communities and the private sector in decision-making and financing

2.9.3 Principles of Integrated Water Resources Management

IWRM approach was founded on the Dublin principles, as outlined in the TAC, Integrated Water Resources Management, GWP, 2000. The principles stated that:

1. Fresh water was a finite and vulnerable resource, essential to sustain life, development and the environment. Since water sustained life, effective management of water resources demanded a holistic approach, linking social and economic development with protection of natural ecosystems. Effective management linked land and water uses across the whole of a catchment area or groundwater aquifer.
2. Water development and management should be based on a participatory approach, involving users, planners, and policy-makers at all levels. The participatory approach involved raising awareness of the importance of water among policy-makers and the general public. It meant that decisions were taken at the lowest appropriate level, with full public consultation and involvement of users in the planning and implementation of water projects.
3. Women played a central part in the provision, management and safeguarding of water. This pivotal role of women as providers and users of water and guardians of the living environment would be reflected in institutional arrangements for the development and management of water resources.
4. Water had an economic value in all its competing uses and was recognized as an economic good. Within this principle, was recognized that it was a basic right of all human beings to have access to clean water and sanitation at an affordable price. Past failure to recognize the economic value of water had led to wasteful and environmentally damaging uses of the resource. Managing water as an economic good

was an important way of achieving efficient and equitable use, and of encouraging conservation and protection of water resources.

2.9.4 The Need for Integrated Water Resources Management

Beneficial Uses of Water: This was applied broadly to mean any use that provided a service to society and/or the environment by removing water from its source, using its flow, or leaving it in place. These were such as, potable water, energy, transportation, conservation of bio-diversity and wetlands, waste disposal and dilution, deposition of fertile soils in flood plains, and irrigation. The uses could be complementary to other uses or may enter in conflict with one or more other uses.

Water-use Conflicts: Water use conflicts were in volume and/or in quality. Conflicts were increased where water was scarce and the maximization of benefits from a single use. This meant that surface and ground water resources as well as coastal areas, would suffer from increased pollution, increasing conflicts between the established beneficial uses and between these and the new uses and the environment.

Fragmented Approach: When population and economic development pressures were relatively low and water use conflicts both in quantity and in quality were relatively rare, water resources problems, specially the scarcity problem, were solved by increasing investments in water resources development. This was by developing new sources of fresh water and increasing the supply for the corresponding beneficial uses. Emphasis was on sub-sectoral project-based water resources development, rather than on integrated water resources management.

A Change of Paradigm: Like in other regions in the world, some important characteristics and trends had started to appear (TAC, IWRM, GWP, 2000). The central government's role was being redefined through a series of structural reforms, such as the expansion of market principles and privatization of state run enterprises. The aim was to reduce direct government intervention in the economy.

2.9.5 Implementation of IWRM

Introduction

The implementation of IWRM required cooperation of many stakeholders, legislation to be put in place, and an enabling environment provided for. It also required knowledge of the water resources and consumption trends of the users. The source of funding, methods of monitoring and condition of the implementation process were to be put in place.

The requirements for implementation of are outlined as reported in (TAC, IWRM, GWP, 2000):

Enabling Environment

This ensured the rights and assets of all stakeholders including the public's environmental values were protected. It constituted the rules that should be followed at national, provincial, or local level by all stakeholders in the development and management of water resources. To achieve efficient, equitable, and sustainable water management, participation of stakeholder at all levels was promoted. Companies involved in the water sector, NGOs and other sectors of the civil society were also involved. To achieve efficient, equitable, and sustainable water management both top down and bottom up participation of all stakeholders was promoted.

The government's role was in creating an enabling environment by creating framework which were participatory, planning water allocation, enforcement and final conflict resolution. Its role as a service provider should be limited to public good elements like flood protection, bulk disposal and treatment of waste products. It should also set up water legislations as part of frame of action and have the political will to enforce it.

Financing of IWRM

The responsibility of government was to ensure and facilitate the overall investment needed to develop and maintain an adequate water infrastructure. But because governments in developing countries like Kenya did not have the resources to do it, they provided legislation to provide for investment security for the private sector. This entailed the sharing of risks between the authority and the investor. Cost recovery was done through reasonable pricing and independent regulation.

Certain aspects like floods and water borne diseases were public goods, which could not be individually charged. For such aspects governments should offer the service wholly, or with private sector partnership ensuring transparency and accountability.

The returns from water related investment took along time to realize. To curb setbacks brought about by this, government should provide investment security to private financiers in the water. This would ensure investment security which is needed to develop and maintain adequate water infrastructure. To ensure long term sustainability and viability of a water supply service, the full cost of water should be charged.

Co-operation among States in International River basins.

Since most river basins cover two or more countries, the use of water resources creates political tensions and conflicts at regional levels around the world. Substantial principles in international water laws were applied to solve the national conflicts, and regionally, the available protocols were used. These includes the Helsinki Rules, International Law Commission and the UN Convention on the Use and Protection of Non-navigational Waters. Regional protocols on shared water courses have also been developed to negotiate water use among states. The Nile Basin Initiative is a group of countries that use the waters within the Nile Basin.

Institutional Roles

The Institutions formed took cognisance of the geographic settings, political structure of the community, capacities of the community and the nature of basin or aquifer. There were coordination mechanisms between different agencies, involved in water management.

Local governments/municipalities

These were involved in the provision of water supply and sanitation services. Irrigation schemes were transferred from government to farmers associations or CBO's. These were responsible for operation and maintenance of the water system.

Capacity Building

These were the efforts to nurture, enhance and utilize the skills and capabilities of people and institutions at all levels of IWRM. It involved empowering and equipping people and organization with appropriate tools and sustainable resources to solve their problems. Human resources can be developed through training, education, and provision of information. Incentives and needs for institution and individuals to change practices and approaches, so that broader goals could be achieved.

Management Instruments

The water resources availability and demand should be assessed in order to identify and assess the existing and potential water resources problems and solutions. These are the IWRM tools and methods that would help the making rational and informal choices between alternative actions. The choices should be based on quantities and qualities methods as analyzed through systems analysis, operations research, and management theory. All the relevant water resource problems should be identified. For both present and future assessments, and effective water management water resources knowledge base should be established.

Communication and information systems.

For all stakeholders to participate in water resources, awareness was raised among politicians, decision makers, in the water sector, professionals, interests groups and the public. A good mechanism for communication of quality and relevant information was necessary and addressed all the issues.

Regulatory Instruments

Appropriate management structures and procedures should be set up to ensure effective and low cost regulation.

CHAPTER THREE: METHODOLOGY OF THE STUDY

3.1 Overall Methodology

The methodology followed was first to prepare an inventory of all existing water resources data, reports and maps. This inventory preparation covered gathering of data on rainfall, evaporation, groundwater, stream flow, water abstraction permits and water quality. The data collected was compiled and stored.

All the data collected was evaluated in order to assist in determining additional data to be collected from the field for an improved assessment of water resources availability in the study area. This was followed by a field inventory of natural and constructed water points on rainwater, surface water and ground water. This inventory gave detailed and up to date information on the status of the available water resources in Bahari sub basin.

The inventory survey showed the distribution and status of the various water resources. It facilitated the determination of the required additional field surveys for the assessment of the water resources. The information obtained from the field inventory surveys was used to supplement the already existing water resources data. Based upon these, conclusions have been made with regard to availability, development and management of water resources in the sub basin.

The inventory data was used as an input form in the preparation of various charts for this report. The local administration and the Ministry of Water and Irrigation staff, who are familiar with the area, were used to assist in locating the water resources. A household survey was conducted to collect data on the water sources, sanitation facilities, management, and conservation aspects at the household level. The stakeholders in the water sector were interviewed on their roles in water resources management.

3.2 Water Quantity Investigation Methodology

The quantity of water available in the water sources was determined. The sources whose quantity of water was measured included:

- All the dams in the sub basin
- The roof catchments
- Water pans
- Flow rate from the springs
- Discharge from wells
- Discharge from boreholes
- Quantity of water served to the residents through the pipelines

3.3 Water Quality Investigation Methodology

The quality of water determines the opportunities for development of the water resources as sources of water supply as well as the requirements for management of those resources. The water quality investigations undertaken in this study included:

- Assessment of the chemical characteristics of the water resources
- Bacteriological characteristics of the water resources
- Identification of potential polluters
- Measurement of water pollution levels

Water Quality Surveys

During the inventory survey, water samples were taken from operational boreholes and wells. As the survey was done during the months of January and February all the dams were dry and the seasonal rivers had no water. Data from previous studies was used.

Samples collected were preserved in cool boxes and transported to Kilifi and Mombasa laboratories for testing. The following parameters were analyzed at Mombasa laboratory:

1. pH
2. Colour
3. Turbidity
4. E C
5. Total hardness
6. Total dissolved solids

Bacteriological tests on Total Faecal Coliform bacteria were also done.

Water Pollution Survey

The water resources pollution survey included the following activities:

- Identification of those activities in the sub basin, which could have a negative impact on the quality of available water resources (potential polluters)
- Field survey to confirm whether the identified potential polluters really pollute the water resources in the study area, as well as assessment of the nature, extent and magnitude of that pollution.

3.4 Household Survey

3.4.1 Objectives and Organization of Survey

The survey was designed to provide data on the water and sanitation situation in the study area, the level of knowledge of water regulations by the communities and the conservation methods applied within the households.

The specific objectives were:

- Provide data that will show the water and sanitation facilities availability and their distribution in the sub basin
- Describe the knowledge of aspects related to water use, its management and conservation
- Determine the availability of water and sanitation facilities

The information provided data to evaluate the strategies for implementation of IWRM. The survey also provided data to monitor the achievements in District Development goals.

3.4.2 Survey Organization

The survey was carried out during the month of April 2006. Three enumerators were trained on how to conduct the survey and each was allocated the clusters which I had identified earlier to conduct the interviews in as in table 3.1

Table 3.1 Interviewing areas for enumerators

Enumerator No	Names of Clusters to Interview	No of House holds to Interview
1	● Chonyi Division	23
2	● Kilifi Township	22
	● Bahari Division	21
3	● Mtwapa Township	36
	● Kikambala Division	21
TOTAL		123

Source: Field survey (February 2006)

3.4.3 Sample Design

The sample for the survey covered the population residing in households in the sub catchments. A representative probability sample of 123 households was selected for the sample. A household was defined as a person or group of people, related or unrelated to each other, who lived together in the same dwelling unit and shared a common source of food. Both urban and rural areas were sampled uniformly.

The list of enumeration areas covered in the 1999 population census constituted the framework for the sample selection and the sample for the survey as well. A total of 12 clusters, 2 urban and 10 rural were selected to form the master frame. The two urban clusters were Kilifi and Mtwapa Townships, while the locations constituted the ten rural clusters. Households were selected randomly but care was made to ensure all the villages were sampled.

Table 3.2: Number of households selected from each location/urban centers

Division	Location/urban centre	No. of households		
		Urban	Rural	Total
Bahari	Kilifi Township	22		43
	Tezo		7	
	Ngerenya		4	
	Roka		5	
	Matsangoni		5	
Chonyi	Mwarakaya		6	23
	Bandara Salama		4	
	Chasimba		7	
	Ziani		6	
Kikambala	Mtwapa	36		57
	Junju		12	
	Mavueni /Takaungu		9	
Total		**58**	**65**	**123**

Source: Field survey (February 2006)

3.4.4 Questionnaire

One questionnaire was used in the survey. The contents of the questionnaire were based on model questions developed for the research. They reflected relevant issues in population, water, sanitation, management and water conservation. A copy of the questionnaire was attached at the appendix A.

The questionnaire collected information on;

- Household size and composition
- Characteristics of households dwelling such as roofing material
- Source of drinking water
- Type of toilet facility
- Knowledge of government water policies
- Knowledge/Application of any soil, and water conservation measures
- Method of disposal of solid wastes

3.4.5 Training

The training of enumerators was done between April 10, 2006 and April 13, 2006. The enumerators were all university graduates with experience in conducting similar surveys.

3.4.6 Fieldwork

Data collection took place from April 13, 2006 to April 25, 2006. There were three interviewing teams and I was supervising them. The teams were made up of one interviewer and a local leader to show the interviewer the villages and translate the questions.

3.4.7 Data Processing

The processing of the results began shortly after the fieldwork commenced. Completed questionnaires were returned daily from the field to the supervisor, where they were edited and those with flawed data returned to the interviewer. This ensured good quality data and field teams could be advised of any errors detected.

3.4.8 Response Rates

The households had been pre-selected and sampled earlier to ensure representative samples were got. This also ensured a response rate of 100%.

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1. Rainwater and Evaporation Investigation

4.1.1 Introduction

The rainwater investigations of the sub basin were done to assess the magnitude, occurrence and distribution of rainfall. The results determined the areas that were suitable for development of rainwater harvesting. Evaporation studies were done to determine the potential evaporation losses from open water sources.

4.1.2 Previous Studies

A summary of the findings from other studies done on rainfall and evaporation in the sub basin were:

- The analysis of rainfall data for Kilifi by WRAP in1992 which showed that rainfall occurred in two main seasons with 40-60% of the average annual rainfall occurring between April and June and 20-35% between October and December.
- The analysis also showed that mean annual rainfall ranged between 1000 and 1200 mm along the coastline, decreasing to 400 mm in the hinterland.
- Evaporation generally increased from the coastline ranging between 1700 mm to more than 2000 mm in the hinterland. In the report open water evaporation for the area was estimated at 2030 mm per year. Up to now, rainfall-runoff studies have not yet been done in this area.
- The survey found out that due to high evaporation rates and low rainfall in the area, most water pans were noted to dry up during the dry seasons. The area was noted to have some potential for rainwater harvesting in the form of water pans and roof catchments. The pans should have a maximum depth of 4 m and a small surface area to reduce the effect of evaporation.

4.1.3 Rainfall

Introduction

Data on the occurrence and distribution of rainfall are important as

- Ground water is recharged through rainfall by infiltration. Shallow ground water maintains the base flow of rivers.
- Direct surface runoff of rainfall water leads to increased river flows and the opportunities for storage of surface water.

The rainfall data used were obtained from Kenya meteorological department in Nairobi, and the MW&I, surface water section. The rainfall data were in the form of monthly totals or daily totals. The analysis was done using computer and outputted as

- Mean monthly graphs
- Annual mean graphs
- Summary tables of rainfall data for each rainfall station

Rainfall Stations

The sub basin has 17 rainfall stations out of which 7 have closed down and did not provide data anymore. The operational ones were located in;

- Bahari Division– 4
- Kikambala Division – 3
- Chonyi Division – 3

A total of 5 rainfall stations distributed within the three divisions and with continuous data for a period of more than 20 years of complete record were selected for detailed rainfall data analysis.

***Table 4.1** Representative rainfall stations used for analysis*

Division	Station name	Station Number	Data period
Bahari	Kilifi D.O.	9339004	1918-1997
	Kilifi plantation	9339005	1918-1974
	Sokoke forest	9339045	1964-1997
Chonyi	Chonyi dispensary	9339013	1938-1974
Kikambala	Mtwapa Agro-met	9339036	1959-1997

Source: Field inventory survey (April 2006)

Monthly rainfall distribution

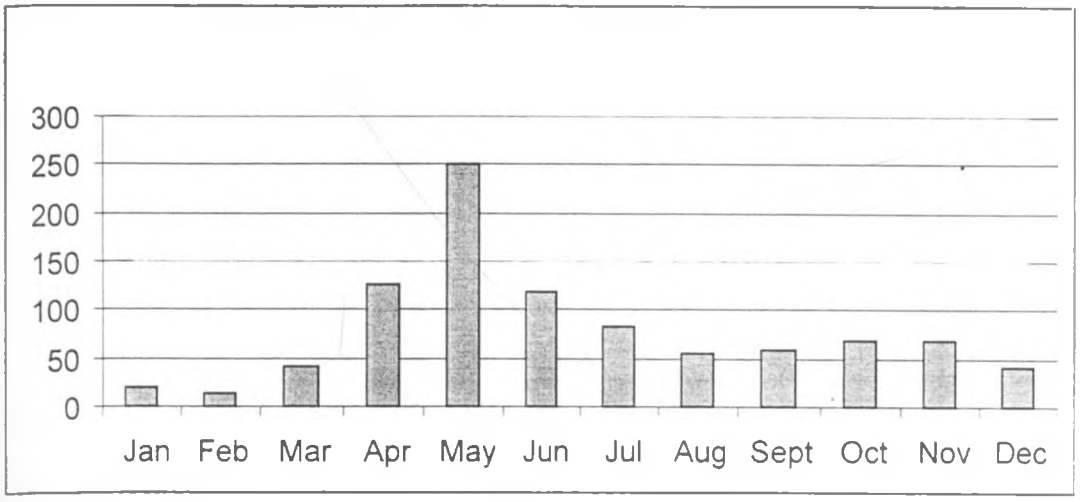
The mean monthly rainfall for the selected rainfall stations are shown in Table 4.2 and the corresponding graphs are shown there after. The monthly rainfall confirms the bimodal rainfall pattern. There are two rainfall seasons characterized by long rains between April and June and the short rains season in October to November. These variations in seasonal distribution pattern of rainfall in the various divisions are depicted in the Table 4.2.

***Table 4.2** Mean monthly rainfall for selected rainfall stations*

Station Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
Kilifi DO	19.1	14.3	40.7	126.1	250.7	118.3	83.0	56.2	59.1	69.6	68.9	42.2	948.2
Sokoke forest	23.4	15.5	55.9	106.5	188.1	106.7	73.7	56.9	56.8	129.5	81.0	76.5	863.8
Kilifi Plantation	40.7	14.5	46.2	121.9	285.6	123.3	92.6	70.9	76.5	83.0	75.1	84.0	1114.3
Chonyi Dispensary	27.5	18.2	52.9	132.8	93.1	89.8	88.1	159.5	84.7	117.0	102.9	75.4	1041.9
Mtwapa Agro-Met	22.8	16.9	58.2	227.5	295.5	169.4	103.1	81.1	70.1	99.1	96.4	52.5	1292.6

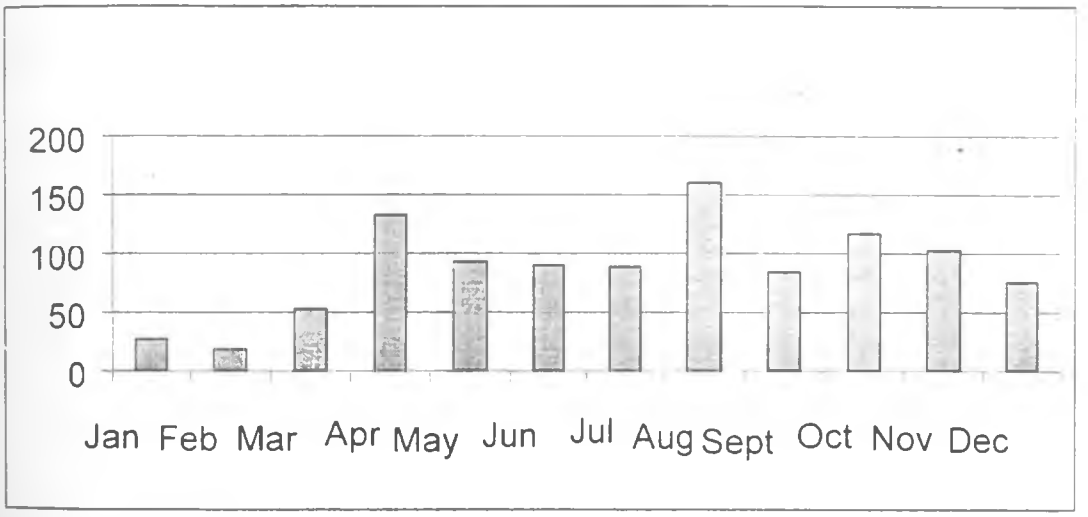
Source: Kilifi water Resources Assessment Report, 1997, MW&I

Fig 4.1 Mean monthly rainfall for Kilifi DO Met Station



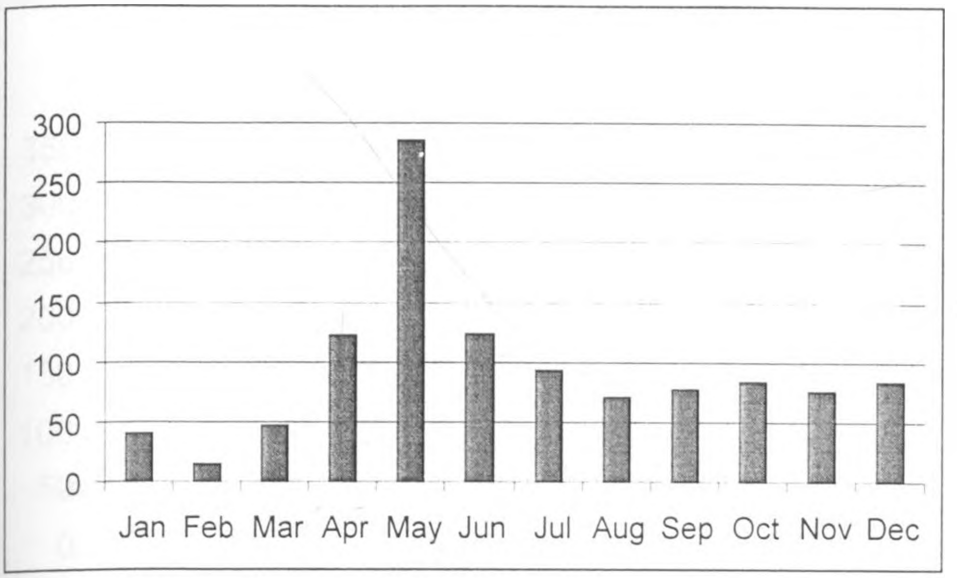
Source: Field inventory survey (April 2006)

Fig 4.2 Mean monthly rainfall for Chonyi Dispensary Met Station



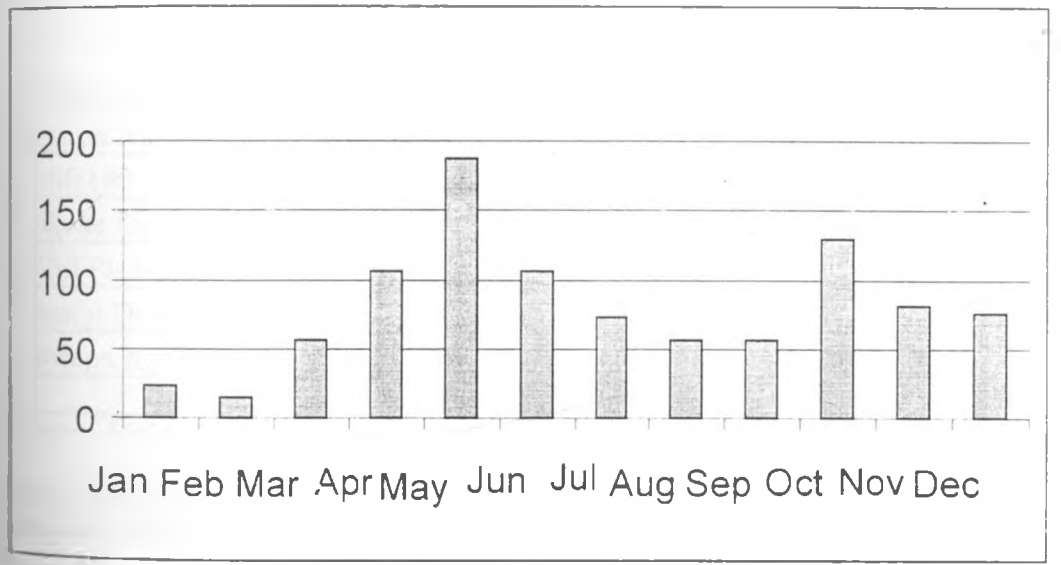
Source: Field inventory survey (April 2006)

Fig 4.3 Mean monthly rainfall for Kilifi Plantation Met Station



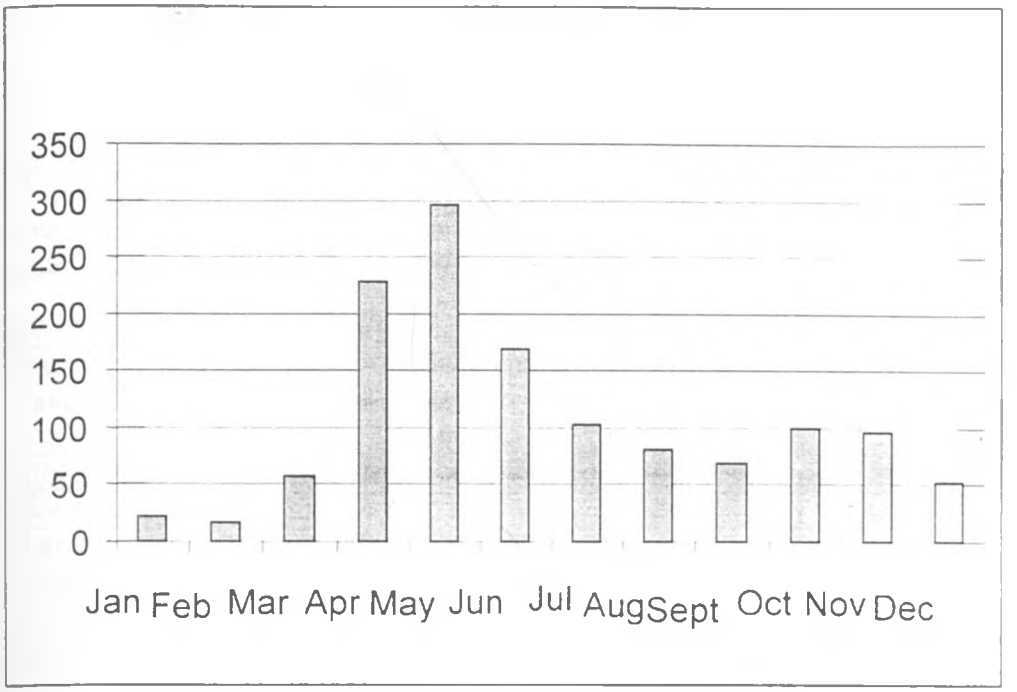
Source: Field inventory survey (April 2006)

Fig 4.4 Mean monthly rainfall for Sokoke Forest Met Station



Source: Field inventory survey (April 2006)

Fig 4.5 Mean monthly rainfall for Mtwapa Agro-Met Station



Source: Kilifi water Resources Assessment Report, 1997, MW&I

***Table 4.3** Mean seasonal rainfall as percentage of the mean annual rainfall*

Station Name	April-June		Oct-Dec		Division
Kilifi DO	54	52	19	21	Bahari
Sokoke forest	55		21		
Kilifi Plantation	48		22		
Chonyi Dispensary	45	45	27	27	Chonyi
Mtwapa Agro-Met	53	53	18	21	Kikambala
	A	B	C	D	

Source: Field inventory survey (April 2006)

The columns A and C show the mean seasonal rainfall expressed as a percentage of the mean annual rainfall for individual rainfall station. Columns B and D are average values for each division.

The seasonal distributions differ among various physiographic zones (divisions). Bahari and Kikambala receive 53% of annual rainfall during April – June period, and 21% between October and December. Chonyi receives 45% of annual rainfall during April –June period and 27% between October and December. The maximum rainfall occurred in the month of May whereas the minimum rainfall was received in the month of February in most parts of the sub basin.

Annual Rainfall Distribution

The annual rainfall for the study area ranges from 900 mm per year in the hinterland to 1200 mm per year along the coastline. About 60% of the study area receives more than 1000 mm per year. There is no particular trend for annual rainfall occurrence.

Annual rainfall reliability

The frequency of occurrence of annual rainfall is useful for long term planning water resources development and management. The probability of exceedence for selected rainfall stations within the sub basin is shown below.

Table 4.4 Mean annual rainfall and 90% annual rainfall reliability

Station Name	Station Number	Mean annual rainfall (mm)	90% rainfall probability	Years of complete records
Kilifi DC	9339004	953.8	638.1	74
Mtwapa Agro-met	9339036	1249.1	800.8	35
Sokoke forest	9339009	1024.8	646.2	58
Chonyi dispensary	9339013	1108.6	705.0	51
Kilifi plantation	9339005	1114.3	706.4	37

Source: Field inventory survey (April 2006)

4.1.4 Evaporation

Introduction

Evaporation is a continuous reduction of available water from open surface water structures. It constitutes a major water loss from impounding reservoirs in arid and semi-arid climates. Data on potential evaporation rates is used for the estimation of the amount of water that can be expected to be lost through evaporation from pans and dams.

Evaporation Stations

The basin had only one evaporation pan at Mtwapa Agro-met. The nine that had been set up in1993 were run down and required rehabilitation. Previous studies were used to obtain the evaporation data.

Monthly evaporation distribution

Evaporation data was only available from Mtwapa Agro-Met station. For comparison and verification of the data, data from another station which was from the same basin, but a different sub basin was considered.

Table 4.5 Mean monthly evaporation

Station Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
Mtwapa Agro-Met	193.8	183.4	198.6	161.6	150.7	137.8	132.5	143.6	158.6	175.0	166.3	179.4	1980
Msabaha Agro-Met	177.7	169.6	182.0	155.6	119.7	115.6	118.2	129.9	122.8	146.9	143.3	148.7	1730

Source: Kilifi water Resources Assessment Report, 1997, MW&I

From the WRA's Kilifi Main report the pan evaporation data showed that the highest mean monthly evaporation in most parts of the basin occurs between January and March.

Annual potential evaporation

From the WRA's report, the potential evaporation the ranged from 1990 to 2000 mm per year. The Penman's method, which considers climatic factors; humidity, solar radiation, wind speed and latitude, gave an evaporation rate of 2048 mm per year for the study area.

4.2.0 Rain water Inventory Survey Results

4.2.1 Introduction

The inventory for rainwater harvesting systems was done as part of fieldwork data collection for the study. The survey covered the following rainwater harvesting systems:

- Roof catchments
- Pans
- Dams

The inventory survey centred on

- The quantity of water that the water source stored and for how long. The data enabled estimation for the number of users the water source can serve.
- The quality of water of the source showed the use for which the water could be used for.
- The reliability of the water source showed the length of time the water source could be used
- The way the water was used
- Who managed the water source and how it was managed
- Who maintained the water source and how was it maintained

4.2.2 Roof Catchments

Introduction

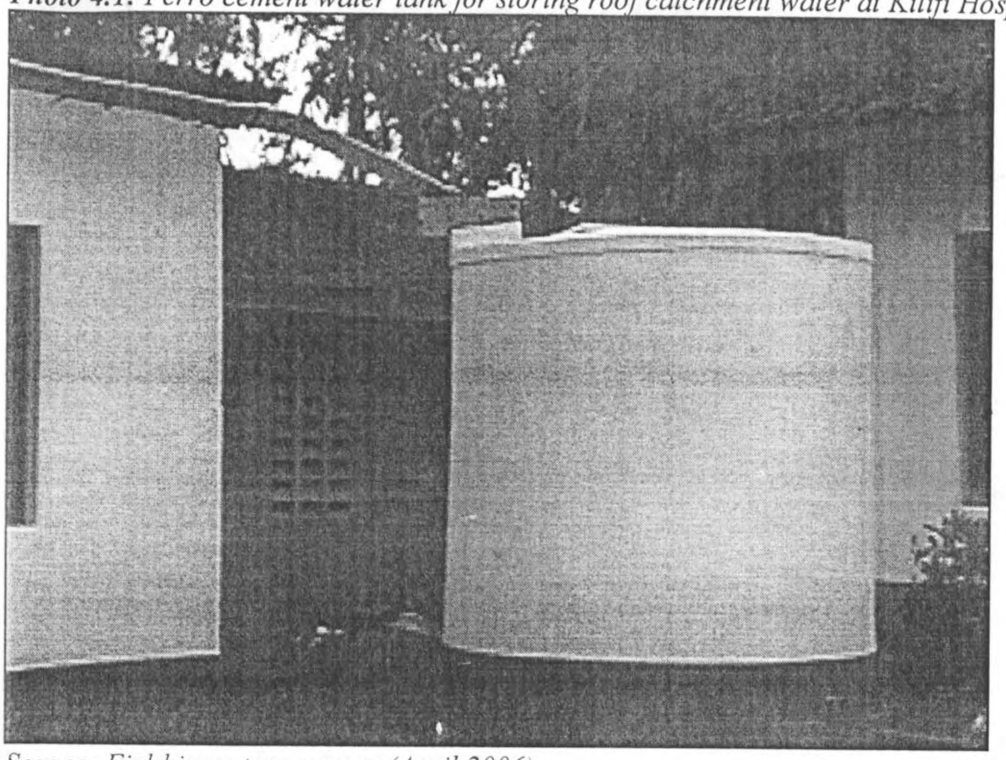
Roof catchments system is where a house roof is used as a water catchment for collecting rainwater and directing it through gutters into storage facilities from where the water is used. A total of 16 roof catchments were identified during the survey. The roof catchments were selected randomly and were distributed evenly in the catchment. For each of the roof catchment selected, data was collected and entered in tables 4.6, 4.7, 4.8, 4.9.

Table 4.6 Roof Catchments inventory results for Bahari sub basin

Roof catchment No	Site Name	Constructed By	Year of Construction	Location	Users	Present Status	Maintenance
RC01	S. Mwachiro	Owner	1978	Pingilikani	50	In use	Owner
RC02	Kidutani P.S.	GOK	1940	Pingilikani	600	In use	Others
RC03	William Tshume	Owner	1997	Mwarakaya	10	Dry	Owner
RC04	B. Mwangombe	Owner	1999	Chasimba	15	Dry	Owner
RC05	Mtepeni Mosque	Community	1989	Kidutani	50	In Use	Others
RC06	John Mumba	Owner	2003	Kidutani	15	In Use	Owner
RC07	Ngerenya Disp.	NGO	1981	Ngerenya	100	In Use	GOK
RC08	Stephen Mzungu	Owner	2001	Roka	10	In Use	Owner
RC09	Amina WG	Community	1992	Matsangoni	2000	In Use	Others
RC10	Naomi Kawe	Owner	2004	Matsangoni	15	In Use	Owner
RC11	James Kazungu	Owner	1992	Matsangoni	10	In Use	Owner
RC12	James Charo	Owner	1990	Mkongani	10	In Use	Owner
RC13	KIWASAP	NGO	1992	Water Off	150	In Use	GOK
RC14	Kilifi Hospital	GOK	1960	Kilifi Town	500	In Use	GOK
RC15	County Council Gar.	GOK	1960	Kilifi Town	50	In Use	GOK
RC16	Kilifi Institute	NGO	1993	Kilifi Town	20	In Use	GOK

Source: Field inventory survey (April 2006)

Photo 4.1: *Ferro cement water tank for storing roof catchment water at Kilifi Hospital*



Source: Field inventory survey (April 2006)

Table 4.7 Roof Catchments Technical data for Bahari sub basin

Roof catchment No	Catchment Material	Roof Catchment Area (M^2)	Gutter Material	Reservoir Capacity (M^3)	Reservoir Material	Water quality	Proposed Improvement
RC01	Corrugated Iron Sheet	100	Steel Metal	13	Ferro-cement	Good	Replace gutters
RC02	Asbestos	280	Steel Metal	5	Masonry	Good	Replace gutters
RC03	Corrugated Iron Sheet	150	Steel Metal	14	Steel	Good	Repair tank & gutters
RC04	Corrugated Iron sheet	120	No Gutters	8	Masonry	Good	Provide gutters, Connect to storage
RC05	Corrugated Iron Sheet	250	Steel Metal	5	Corrugated Iron	Good	Non
RC06	Corrugated Iron Sheet	200	Steel Metal	4	Corrugated Iron	Good	Tank Replacement
RC07	Corrugated Iron Sheet	300	Steel Metal	4	Masonry	Good	Additional Storage
RC08	Corrugated Iron Sheet	74	Steel Metal	53	Masonry	Good	Non
RC09	Corrugated Iron Sheet	100	Steel Metal	20	Masonry	Good	Additional Storage
RC10	Corrugated Iron Sheet	150	Steel Metal	12	Masonry	Good	Additional Storage
RC11	Corrugated Iron Sheet	150	Steel Meta	27	Masonry	Good	Additional Storage
RC12	Makuti	150	Corrugated Iron Sheet	20	Masonry	Good	Replace catchment material
RC13	Corrugated Iron Sheet	280	Steel Metal	20	Ferro-cement	Good	Non
RC14	Tiles	1075	Steel Metal	39	Ferro-cement	Good	Additional Storage, repair gutters
RC15	Corrugated Iron Sheet	425	Steel Metal	11	PVC	Good	Additional Storage, repair gutters
RC16	Corrugated Iron Sheet	180	Steel Metal	7	Ferro-cement	Good	Non

Source: Field inventory survey (April 2006)

***Table 4.8** Roof catchments in Bahari sub basin*

Division	No. of identified Roof catchments	Av. No. of consumers Per catchment
Bahari	10	290
Chonyi	4	170
Kikambala	2	40

Source: Field inventory survey (April 2006)

The average number of consumers per roof catchment was over fifty, because most of the roof catchment users were in institutions which had more than 50 users.

Roof Catchment Ownership

The inventory survey of the roof catchments showed that most of them were constructed by the families that own them.

Table 4.9 *Ownership of Roof catchments*

Ownership	Number	%age of total
Family	8	50
GOK	3	19
Community	2	12
NGO's	3	19
Total	16	100

Source: Field inventory survey (April 2006)

Use and Operational Status

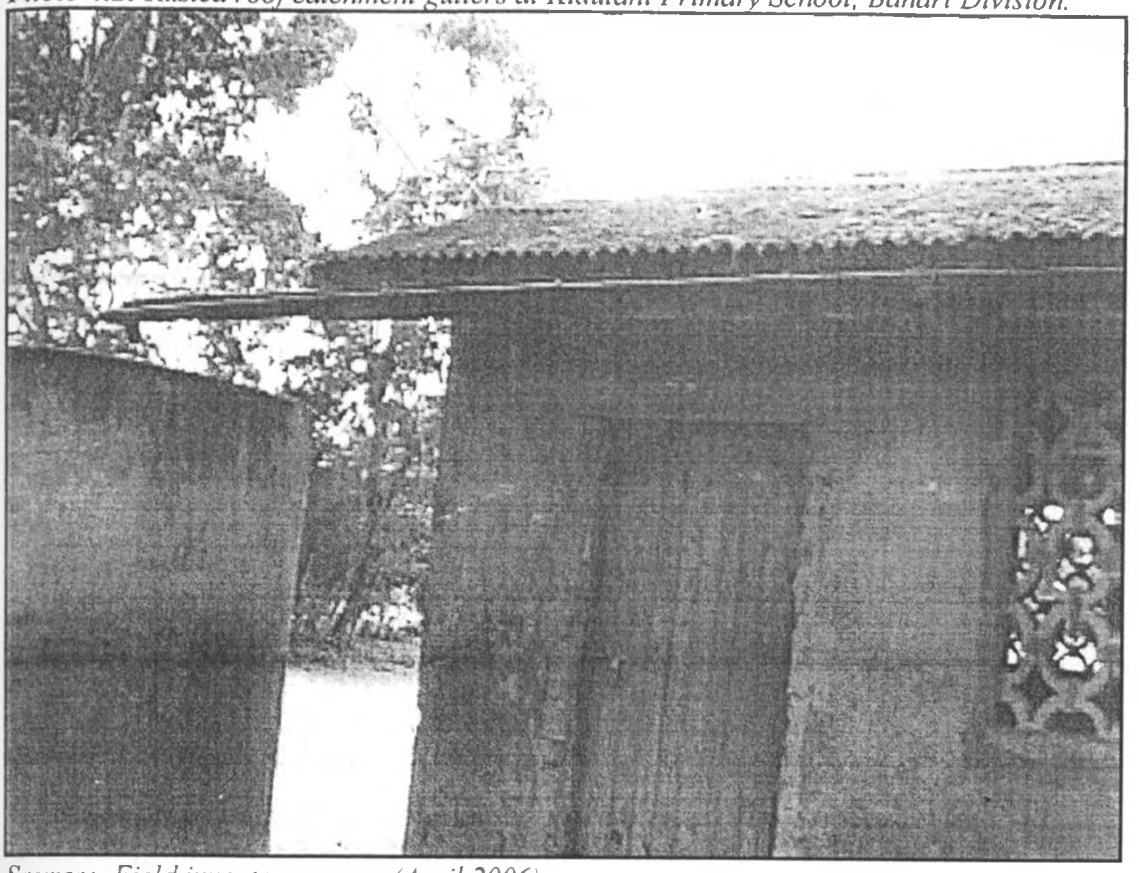
The roof catchments identified were mostly used for domestic livestock water supply and watering of gardens. The storage capacity of the roof catchments reservoirs was less than 10,000 lts for six of the sixteen roof catchments inventoried. Thus the water met only part of the water supply needs. The reservoirs served only the people living in the compound where they were located. The water from all the roof catchments was clean, and chemical tests for five of the inventoried roof catchments showed that the water was suitable for drinking as per Rural Water Supply Guidelines, MW&I,2003 GOK.

Possible Improvements

The following improvements are possible in various places depending on technical conditions:

- Replacement of old rusted gutters
- Repair of leaking tanks
- Increase of roof catchment area and additional storage

Photo 4.2: Rusted roof catchment gutters at Kidutani Primary School, Bahari Division.



Source: Field inventory survey (April 2006)

4.2.3 Water Storage Pans

Introduction

Water pans are excavated surface water storage facilities of capacity not exceeding 20,000 cubic meters, which are constructed where topography does not allow the construction of a small dam. A total of 9 pans were inventoried and their distribution was as in tables 4.10, 4.11, and 4.12:

Table 4.10 General information of inventoried Water storage pans

Pan No	Site Name	Constructed By	Location	Users	Present Status	Maintenance
P01	Mitangoni P. S.	Community	Mavueni	500	In use	Community
P02	Kilifi Plantation	Owner	Mavueni		In use	Owner
P03	Nguya	Community	Chasimba	1000	In use	Community
P04	Mwaeba	GOK	Tsangalaweni	2000	In Use	Community
P05	Mwaeba	GOK	Migomiri	100	In Use	Community
P06	Kindunguni	Natural	Ziani	200	In Use	Community
P07	Bemzoga	Community	Ziani	200	In Use	Community
P08	Kirimo	Community	Ziani	300	In Use	Community
P09	Dito	Community	Ziani	100	In Use	Community

Source: Field inventory survey (April 2006)

Table 4.11 Technical data of the inventoried Water storage pans

Pan No	Catchment area (Km^2)	Present Storage (M^3)	Max. Capacity (M^3)	Water Quality	Dry Months Per year	Proposed Improvement
P01	0.5	1050	1050	Muddy	6	Deepening, Widening, Fencing
P02	0.06	10	15	Muddy	6	Deepening, Widening,
P03	1.0	75	75	Muddy	3	Deepening, Widening, Desilting
P04	0.04	7000	7050	Muddy	2	Desilting, Enlargement
P05	0.02	1000	1500	Muddy	6	Deepening, Enlargement
P06	0.03	0	1000	Dry	6	Widening, Desilting, Fencing
P07	0.05	8400	8400	Clear	0	Widening, Desilting, Deepening
P08	0.08	0	1500	Dry	6	Widening, Desilting, Fencing
P09	0.01	5700	6000	Muddy	0	Widening, Desilting, Fencing

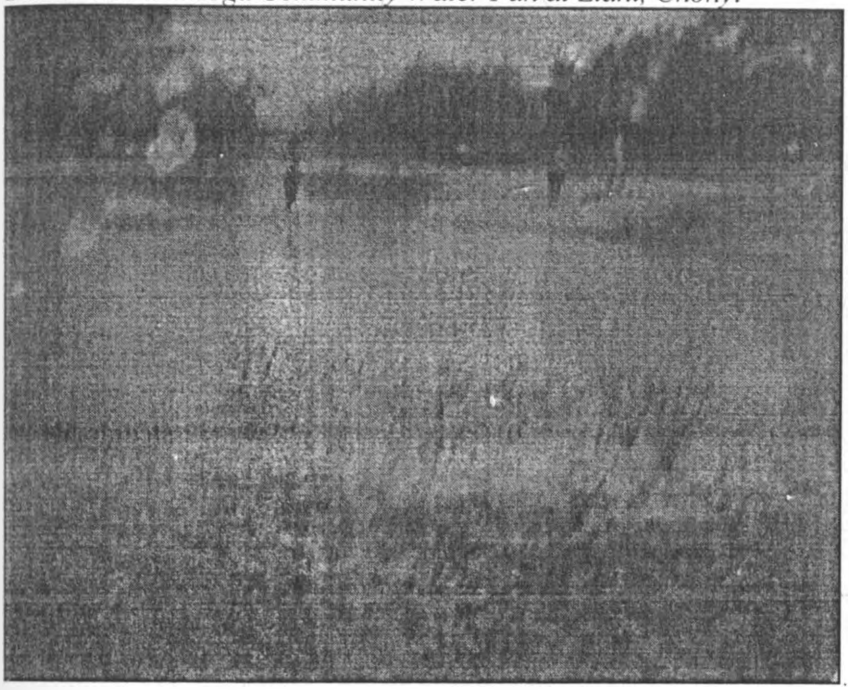
Source: Field inventory survey (April 2006)

Table 4.12 Storage pans and their distribution

Division	No. of pans	Av. No. Consumers Per pan
Bahari	4	460
Chonyi	3	320
Kikambala	2	210
Total	**9**	**358**

Source: Field inventory survey (April 2006)

***Photo 4.3**: Bemzoga Community Water Pan at Ziani, Chonyi*



Source: Field inventory survey (April 2006)

Construction and Ownership

The pans were constructed by GOK, the community or NGO's. All the pans were owned by the communities who use them.

Use and Operational Status

They are mainly used for domestic and livestock water supply needs. During the inventory survey, all the pans were found dry. From the interviews done with the local communities and the MW&I staff the pans remained dry for 6-8 months of the year. The pans served users from a radius of 10 Km during the dry season.

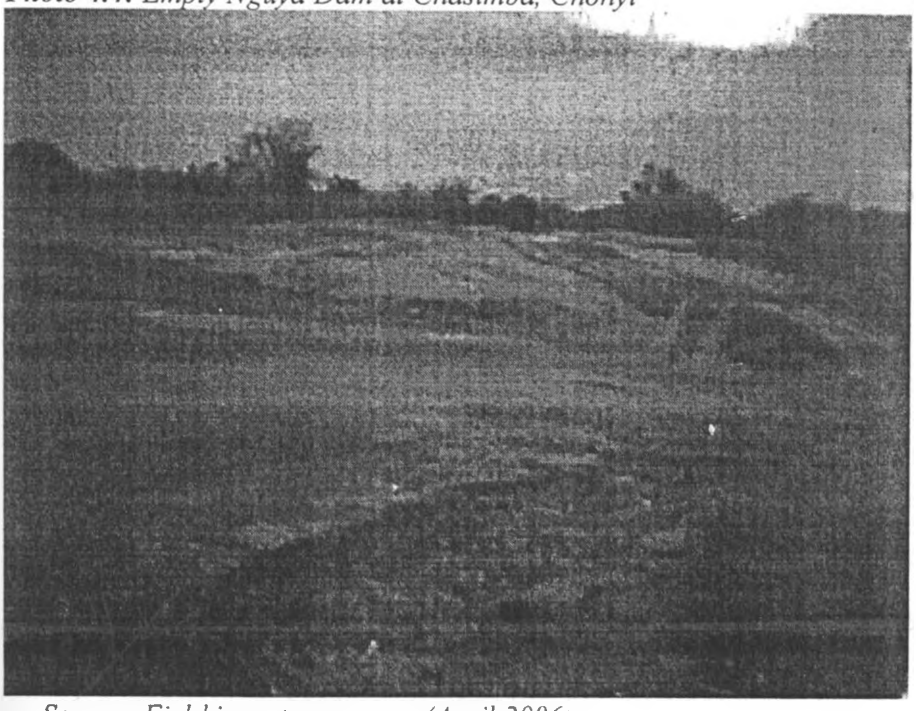
The water pans were maintained by the local community. The pans were silted up which showed a poor maintenance programme.

Required Improvements

The quality and quantity of pan water can be improved by:

- Desilting
- Fencing of the dam area
- Reconstruction of the embankment
- Catchment's management to reduce excessive erosion and siltation
- Provision of cattle troughs

Photo 4.4: *Empty Nguya Dam at Chasimba, Chonyi*



Source: Field inventory survey (April 2006)

4.2.4 Dams

Introduction and Distribution

Dams are open water reservoirs created by a seasonal or perennial river. A spillway through which excess water outflows after the reservoir is full is provided. A total of 10 dams were inventoried in the study area.

The dams were distributed in the sub basin as shown in table 4.13:

Table 4.13 *Dams and their distribution*

Division	No. of dams	Av. No. of consumers
Bahari	2	1300
Chonyi	6	2000
Kikambala	2	1000
Total	**10**	**4300**

Source: Field survey (April 2006)

Most of the dams are in Chonyi division and the least are in Bahari and Kikambala divisions. All the dams did not have any water during the time of the field survey as the survey was done during the long drought. The characteristics and condition of the dam were listed in table 4.23:-

Table 4.14 Conditions of dams in Bahari Sub basin

No	Name	Type	Design Capacity (M^3)	Present Capacity (M^3)	Location	Use	Physical Status
1	Lutsangani	Earth dam	50,000	25,000	Ziani location Chonyi Division	Domestic Livestock	Silted
2	Kasidi A	Earth dam	80,000	45,000	Pingilikani location Chonyi Division	Domestic	Good
3	Kasidi B	Pan	45,000	30,000	Pingilikani location Chonyi Division	Livestock	Silted
4	Mtwana	Mass concrete dam	20,0000	5,000	Bandara location Chonyi Division	Domestic	Silted
5	Kolongoni	Earth dam	50,000	15,000	Chasimba location Chonyi Division	Domestic Livestock	Silted
6	Mwanzara	Earth	20,000	20,000	Chasimba location Chonyi Division	Recently constructed	Good
7	Mrengi	Earth	23,000	10,000	Mavueni Location, Kikambala Division	Domestic/Livestock	Silted
8	Vipingo	Earth	14,000	6,000	Junju Location Kikambala Division	Privately Owned	Silted
9	Kilifi Plantation	Earth	30,000	20,000	Mnarani Location Bahari Division	Privately Owned	Silted
10	Kilifi Institute	Earth	15,000	10,000	Tezo Location Bahari Division	Owned by Government Institution	good

Source: Field survey (April 2006)

Ownership of Dams

Most of these dams were constructed and owned by the Kenya Government for the local communities. Vipingo and the Kilifi Plantation dams are privately owned by Rhea Vipingo and Kilifi Plantation Companies respectively.

Operation and Maintenance

Government owned dams were not maintained hence their condition was poor, as reeds and weeds were not removed from the dam area, and there was no program on how to desilting of dam should proceed. The Committees formed to manage the dams were not in operation.

Water Use

For the GoK dams, the local communities used the water for domestic and livestock purposes. For the privately owned dams, water was used for livestock and irrigation of citrus in the case of Rhea Vipingo. Kilifi plantation dam water was used for livestock and domestic.

Abstraction

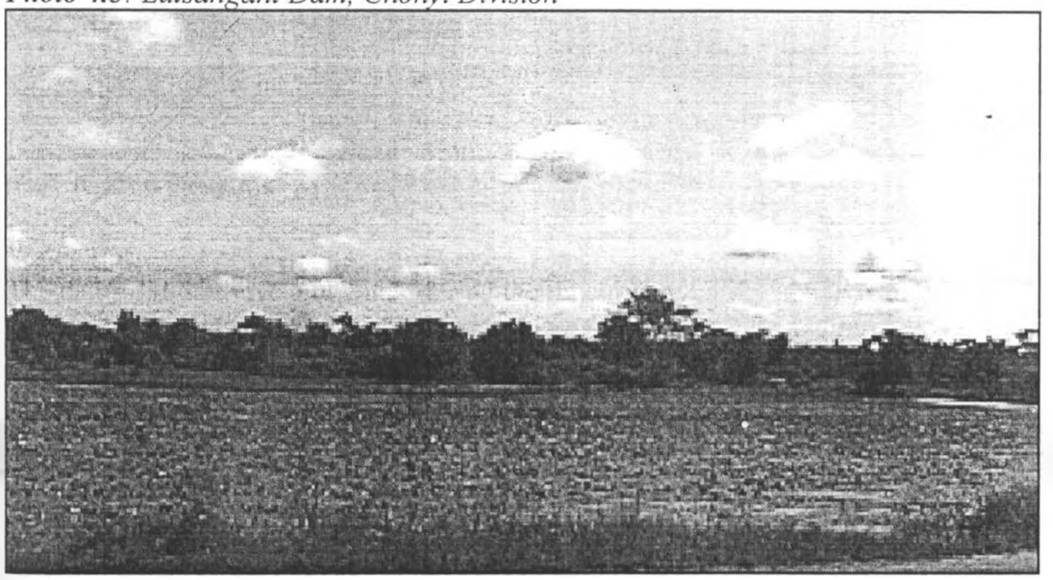
Initially, dams constructed by the GoK had been fitted with hand pumps for drawing water. Cattle water troughs had also been constructed for livestock to take water. However, because of lack of maintenance, the pumps and the water troughs had broken and were no-longer used. Hence, water was drawn directly from the dams by use of containers. Livestock also drunk directly from the dams.

Water Quality

The dams did not have any water during the time the inventory survey was carried out (January-February 2006). However previous studies that had been done and reported in the District Water Officers Annual Report, 2004, indicated that:

- Water abstracted in all the dams complied with the permissible guidelines indicated in Rural Water Supplies Guidelines, MW&I
- Turbidity of water in all the dams was more than 25 NTU
- Total coli form numbers was less than 250 MPN/100 MR

Photo 4.5: Lutsangani Dam, Chonyi Division



Source: Field survey (April 2006)

4.3.0 Ground Water Sources

4.3.1 Introduction

The aim of the survey was to identify the existing ground water points and their characteristics. The ground water sources included the following natural and constructed water points:

- Wells
- Springs

- Boreholes
- Waterholes

The survey included previous studies and reports, and actual field visits.

4.3.2 Wells

Introduction

Wells are hand dug holes excavated into the ground to exploit ground water. They are shallow aquifers found on soft formations. During the field survey 17 wells were inventoried in the study area. The number of wells inventoried per division depended on the total number of wells in that division as reported in District Annual Report, 2004. Kikambala division having reported the highest number of wells had the largest number of wells inventoried for analysis. The results of the survey were presented tables 4.15 and 4.16;

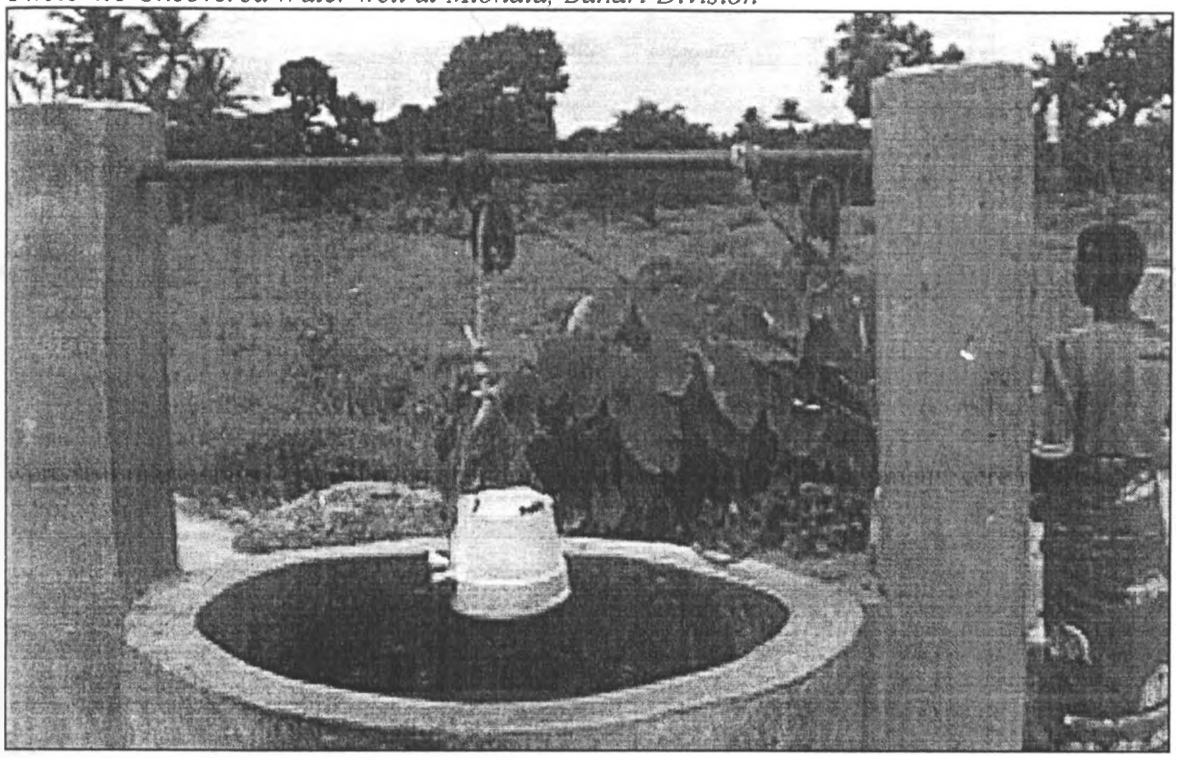
Table 4.15 General information of inventoried wells in Bahari Sub basin

Well No	Site Name	Constructed By	Yr of Constn	Location	Users	Present status	Why Abdoned	Maintained By
W01	KARI	Owner	1957	Mtwapa, Kikambala	Farm, 500	In Use		GoK
W02	Mtwapa Centre	Owner	1981	Mtwapa, Kikambala	Family, 40	In Use		Family
W03	Roka Centre	Owner	1992	Roka, Bahari	Community, 500	In Use		NGO
W04	Wesa	Owner	1991	Ngerenya, Bahari	Family, 50	In Use		Family
W05	Bofa	Owner	1977	Bofa, Bahari	Family, 15	In Use		Family
W06	GK Prison	Owner	1990	Kilifi Town, Bahari	No Body	Abandoned	No funds	GoK
W07	Kuruwetu	Owner	1960	Shariani, Kikambala	No Body	Abandoned	Poor water quality	Family
W08	Amkeni	Owner	1991	Mtwapa, Kikambala	No Body	Abandoned	Poor water quality	Family
W09	Kanamai	Owner	1991	Mtwapa, Kikambala	Family, 15	In Use		Family
W10	Jumba Ruins	Owner	1397	Mtwapa, Kikambala	No Body	Abandoned	Poor water quality	Family
W11	Country Farm	Owner	Unknown	Mtwapa, Kikambala	Farm, 10	In Use		Farm
W12	Barani	Owner	1956	Mtwapa, Kikambala	Community, 500	In Use		Farm
W13	Barani	Owner	1990	Mtwapa, Kikambala	Family, 10	In Use		Family
W14	Barani	Owner	1991	Mtwapa, Kikambala	Family, 5	In Use		Family
W15	Kizingo	Owner	1992	Kizingo, Kikambala	Community, 500	In Use		Family
W16	Chumani	Owner	1992	Chumani, Bahari	Family, 15	In Use		Family
W17	Chasimba	Owner	1992	Chasimba, Chonyi	Community, 300	In Use		Family

Source: Field survey (February 2006)

From the results obtained from the analysis of the inventoried wells, Kikambala had 82% of the wells, Bahari had 12%, and Chonyi had 6 %. Of the 17 wells inventoried wells, 76% were owned by families, 12% by farms, and 6% from both the GoK and NGO. Of these wells 76% were still in use, but 24% had been abandoned. The reasons for abandonment were reported as due to luck of funds, and as due to poor water quality.

Photo 4.6 *Uncovered Water well at Mtondia, Bahari Division*



Source: Field survey (February 2006)

Table 4.16 Technical data of inventoried wells in Bahari Sub basin

Well No	Diameter (M)	Depth (M)	Water level (M)	Lining type	Pump driver	Water production (M^3/h)	Water quality	Proposed improvement
W01	2.5	22.7	22.1	Coral	Diesel Engine	15	Clear	
W02	2.4	18.6	18.4	Concrete	Electric Motor	5	Clear	
W03	3.5	7.1	7.0	Coral	Non		Clear	Cover with concrete slab
W04	1.8	5.5	5.3	Coral	Non		Salty	
W05	1.6	8.0	7.7	Coral	Electric Motor	4	Salty	
W06	2.3	16.6	16.2	Coral	Non		Clear	Cover with concrete slab
W07	1.5	11.1	10.7	Coral	Manually driven		Salty	
W08	4.3	23.3	22.9	Coral	Non		Clear	Cover with concrete slab, pumping unit
W09	2.2	10.7	10.6	Coral	Non		Clear, Salty	Cover with concrete slab, add pumping unit, well deepening
W10	1.1	11.1	12.0	Coral	Non		Clear, Salty	
W11	2.1	17.1	16.1	Coral	Manual	3	Clear	Cover with concrete slab
W12	2.8	21.6	20.5	Coral	Electric Motor	18	Clear	Cover with concrete slab
W13	2.5	17.2	16.7	Coral	Electric Motor	8	Clear	Cover with concrete slab
W14	3.0	19.1	18.5	Coral	Electric Motor	15	Clear, salty	Cover with concrete slab
W15	1.3	5.9	4.0	Coral	Non		Clear	Cover with concrete slab, add pumping unit
W16	1.5	13.0	12.0	Coral	Non		Clear	Cover with concrete slab, add pumping unit
W17	1.9	8.2	8.0	Coral	Non		Clear	Cover with concrete slab, add pumping unit,

Source: Field survey (February 2006)

From analysis of the results in table 4.16, all the 17 wells inventoried were lined. Of these only six wells had water of poor quality and could not be used for drinking. All the others had clear water. Chemical analysis tests were done on the water from the selected wells and the results were as below;

Table 4.17: Water quality analysis for selected wells in Bahari sub basin

Well No	Name	ECL	pH	CLR	TB	TA	TH	Na	SO_4	NaCl	TDS	SAR
W01	KARI	1136	8	<5	0	444	466	45	11	116	738	0.91
W02	Mtwapa Centre	2130	8	<5	0	384	338	231	35	591	1385	5.44
W03	Roka Centre	2980	8.2	<5	1	170	874	84	597	215	1940	1.23
W04	Wesa	7384	7.6	<5	1	234	906	1438	250	3663	4800	20.72
W05	Tezo	7540	7.4	<5	1	224	907	1380	240	3620	4600	20.64
W06	G.K. Prison	2980	7.9	<5	1	380	340	408	50	1040	2300	9.6
W07	Mtondia	2980	8.0	<5	1	180	830	81	580	220	1930	1.32
W08	Hassan Farm	2120	7.8	<5	1	387	338	47	12	118	740	1.11
W09	Chumani Mosque	2550	7.4	<5	1	225	904	1390	235	2040	1180	1.33
W10	JumbaRuins	7952	7.6	<5	1	248	940	1457	238	3713	5169	20.64
W11	Country Farm	738	7.3	<5	1	262	244	50	5	123	473	1.4
W12	Barani	2272	7.2	<5	1	362	270	252	43	644	1477	6.67
W13	Mwangaza Farm	2360	8.0	<5	1	189	750	50	240	120	1450	10.58
W14	Kwa Tom	668	7.5	<5	1	270	210	53	7	129	480	2.51
W15	Issa Juma	2150	7.3	<5	1	338	340	420	42	1920	1210	7.59
W16	TSS Tezo	2130	8.2	<5	1	430	339	224	37	1038	1720	8.53
W17	Kizingo	2414	8	<5	1	100	324	239	125	611	2150	5.79

Source: Field survey (February 2006)

According to Water Resources Management Draft Rules, WRMA, 2006, the recommended drinking water quality guidelines are in table 4.18;

***Table 4.18:** Recommended drinking water Quality*

Parameter	Unit	Guidelines
pH		Lie between 6.5 and 8.5
Sodium	Mg/l	Not greater than 200
Total Dissolved Solids	Mg/l	Not more than 1200
Sulphate	Mg/l	Not greater than 400
Turbidity	NTU	Less than 5
Total Hardness	Mg/l	Less than 500
Taste & Odour		Inoffensive

Source: Water Resources Management Draft Rules, WRMA, 2006

Thus from the chemical analysis of the water, five wells had water that was suitable for drinking. The other wells had water which was not suitable due to;

1. Total dissolved solids being more than 1200 mg/ l (12 Wells)
2. Levels of Sodium content being greater than 200 mg/ l (10 Wells)
3. Level of dissolved Sulphates being greater than 400 mg/ l (2 Wells)
4. Total Hardness being greater than 500Mg/l (8 Wells)

The guidelines recommended for water quality for use in irrigation, and the chemical levels are listed in table 4.19;

Table 4.19: Guidelines for irrigation and drainage water quality

Parameter	Unit	Intensity of problem		
		No Problem	Moderate	Severe
Salinity (TDS)	Mg/l	<480	480-2000	>2000
Sodium Adsorption Ratio	-	<3.0	3-9	>9.0
Chloride	Mg/l	<4.0	4-10	>10
Boron	Mg/l	<0.75	0.75-2.0	>2.0
pH		6.5-8.4	8.5-9.5	9.5^{+}

Source: World Food and Agriculture Organisation, Paper No 3, 2003.

Thus according to guidelines on irrigation water quality, only eight wells out the seventeen wells sampled had water that was not suitable for irrigation. This was because the water;

- Had salinity levels of over 2000mg/l.
- Sodium adsorption ratio of over 9

4.3.3 Boreholes

Boreholes are small diameter, vertical, round holes drilled into the ground to tap water from aquifers. Their construction involves large capital investment and hence they are found where no other cheaper option for safe water exists.

The borehole data were collected from:

- Field inventory survey
- Previous reports and studies done
- From borehole completion records obtained from MW&I reports

One hundred and fifty two (152) boreholes were identified from existing borehole completion forms, the inventory field survey, and previous reports and studies done. From the survey, the boreholes were found only in Bahari and Kikambala divisions. Out of these boreholes, 13 were selected randomly for a more detailed analysis. The result of this analysis was presented in tables 4.20, 4.21, and 4.22:

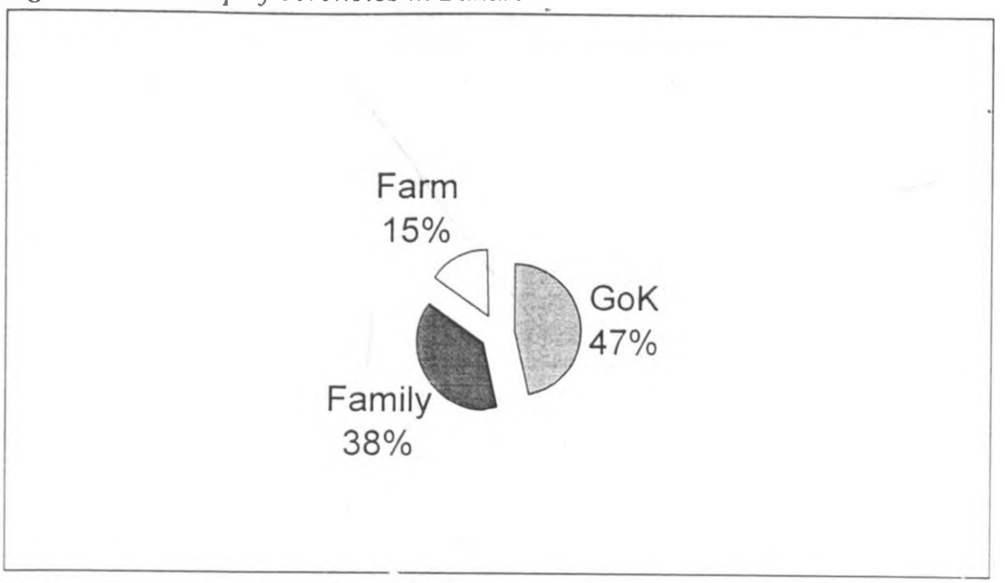
Table 4.20: General information on Boreholes inventoried in Bahari Sub basin

B.H./ No	Site Name	Const. By;	Year of Const.	Location	Users	Status	Reason for Abandn	Owners
BH01	Mwatundo	MOWD	1991	Mtwapa, Kikambala	Family, 10	In Use		Family
BH02	Kikambala	Not Known	1950	Mtwapa, Kikambala	Farm, 30	In Use		Family
BH03	Mtwapa	Pwani Fabr.	1992	Mtwapa, Kikambala	Nobody	Abandoned	Not Known	Family
BH04	K. Cashew nuts		1952	K.C. Factory, Bahari	Nobody	Abandoned	Not Known	Farm
BH05	Chumani	MOWD	1986	Chumani, Bahari	Nobody	Abandoned	Not Known	GoK
BH06	Maweni	Not Known	1961	Tezo Settlement, Bahari	Nobody	Abandoned	Poor water quality	GoK
BH07	Maweni	Dan Bothma	1963	Chumani, Bahari	Nobody	Abandoned	Not Known	GoK
BH08	Bofa	Insta Pump	1981	Bofa, Bahari	Nobody	Abandoned	Poor water quality	Family
BH09	Vipingo Estate	Dan Bothma	1956	Vipingo, Kikambala	Nobody	Abandoned	Low yield	Farm
BH10	Shariani	Mowlem	1971	Shariani, Kikambala	Nobody	Abandoned	Not Known	GoK
BH11	Ndonya	MOWD	1984	Kidutani, Kikambala	Family, 20	Abandoned		Family
BH12	Ngerenya	Dan Bothma	1961	Ngerenya, Kikambala	Nobody	Abandoned	Poor Water Quality	GoK
BH13	Kilifi Institute	MOWD	1994	Kilifi, Kikambala	Farm, 200	In Use		GoK

Source: Field survey (February 2006)

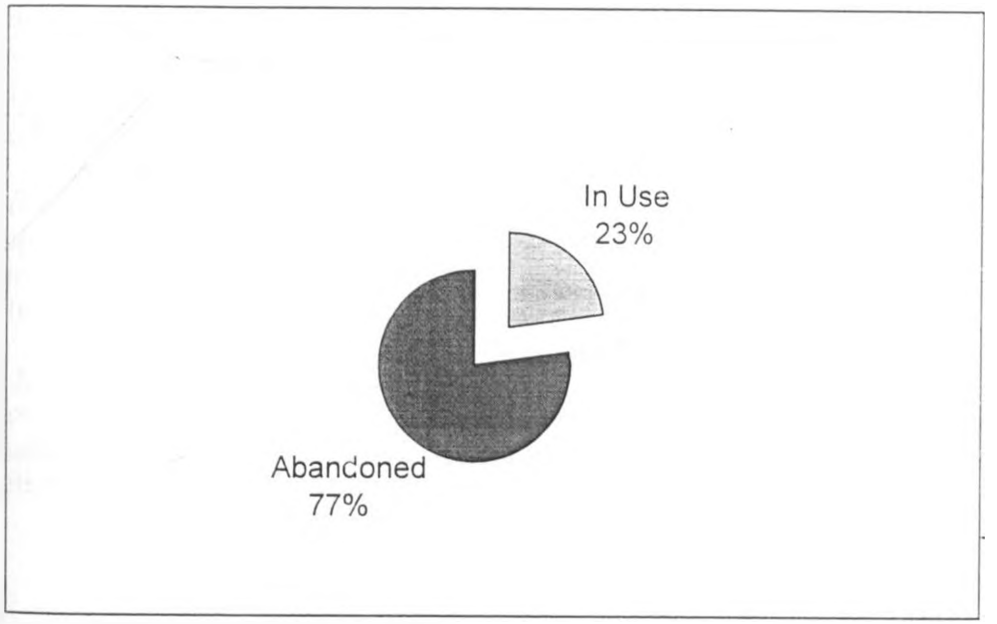
From the data obtained during the field survey it was observed that 62% of the boreholes were in Kikambala, and 38% were in Bahari divisions. No boreholes were inventoried in Chonyi Division. Of the thirteen inventoried boreholes, the ownership was as follows; GoK (47%), Family (38%), and Farm (15%). The survey also showed that only 23% of the boreholes inventoried were in use, the rest (77%) were abandoned. The reasons for abandonment were; poor water quality, low yield, and unknown reasons. The analysis of results is presented in figures 1.5 and 4.6;

Fig 4.6: Ownership of boreholes in Bahari



Source: Field survey (February 2006)

Fig 4.7 Status of boreholes in Bahari



Source: Field survey (February 2006)

Table 4.21: Technical Data of the Boreholes inventoried in Bahari Sub basin

B.H./ No	Energy source for pump	Present water available (M^3)	Water Quality	Proposed Improvement
BH01	Electric motor	10.00	Good	Non
BH02	Electric motor	4.00	Good	Non
BH03	Non		Poor	Non
BH04	Non		Poor	Non
BH05	Non		Poor	Non
BH06	Non		Poor	Non
BH07	Non		Poor	Non
BH08	Non		Poor	Non
BH09	Non		Poor	Non
BH10	Non		Poor	Non
BH11	Electric motor	18	Good	Non
BH12	Non	Poor	Poor	Non
BH13	Electric motor	15	Fair	Non

Source: Field survey (February 2006)

Table 4.22: Water quality analysis for selected boreholes in Bahari sub basin

Name	ECl	pH	TB (ntu)	TA (mg/l)	TH (mg/l)	SO_4 (mg/l)	NaCl (mg/l)	TDS (mg/l)	SAR (mg/l)
Mwatundo	1380	6.8	1	236	310	72	526	690	5.07
Kikambala	1580	7	14	380	212	58	414	790	4.92
Bofa	13600	8.3	0	0	3680	112.5		8200	31.7
Ndonya	900	7.3	14	234	170	21	167	450	2.18
Kilifi Inst.	2900	7.9	0	0	3800	112	220	1856	14.3

Source: Field survey (February 2006)

From the chemical analysis of the borehole water, three had water that was chemically suitable for drinking. The other two had total dissolved solids above 1200mg/l and thus were unsuitable for drinking.
The three boreholes water was also chemically fit for use in irrigation.

4.3.4 Springs

Springs are natural water points where groundwater emerges from the sub soil. They are mainly found in the mountainous hilly areas and at the foot of escarpments. Five springs were selected for analysis and the results were entered in tables 4.23, and 4.24:

Table 4.23: General Data of the springs inventoried in Bahari Sub basin

Spring No	Site Name	Location	Users	Present Status	Owner
S01	Gande	Chasimba, Chonyi	100 Community	In Use	Community
S02	Bwerere	Chasimba, Chonyi	100 Community	In Use	Community
S03	Bembaga	Mwarakaya, Chonyi	2000 Community	In Use	Community
S04	Dzitsoni	Kizingo, Kikambala	2400 Community	In Use	Community
S05	Kambu	Kizingo, Kikambala	2000 Community	In Use	Community

Source: Field survey (February 2006)

Table 4.24: Technical Data of the springs inventoried in Bahari Sub basin

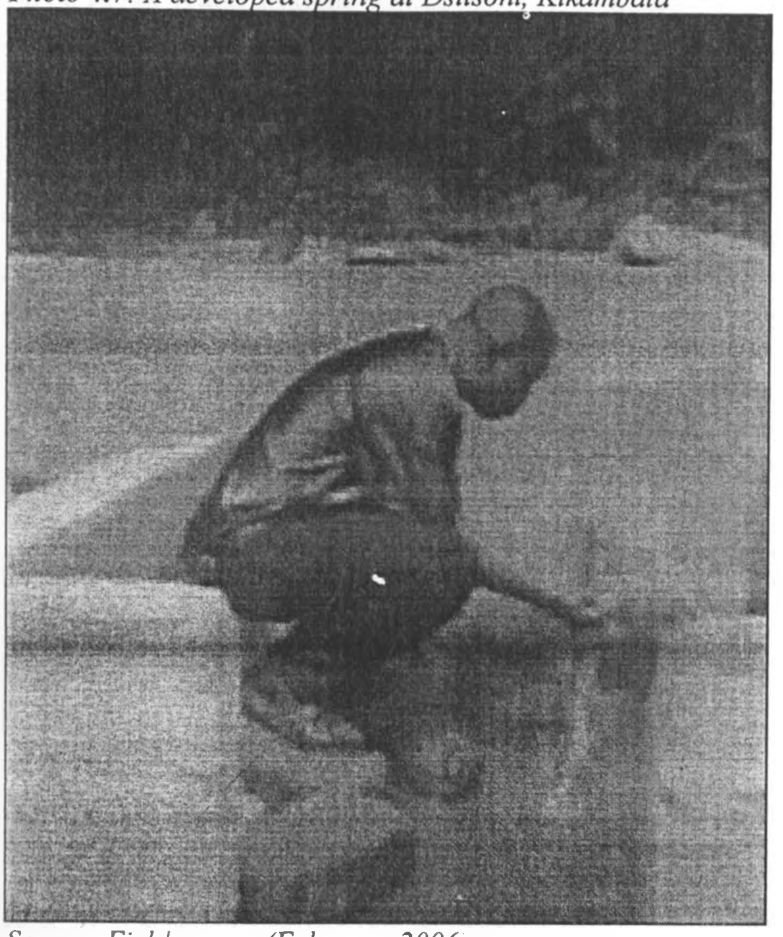
Spring No	Width (M)	Depth (M)	Discharge (l/s)	Water Quality	Proposed improvement
S01	5	2	2	Clear	Spring Box, Fencing
S02	5	2	10	Salty	Drain, Fencing
S03	4.5	0.2	30	Clear	Spring Box, Drain , Fencing
S04	3.6	2	2	Clear	Spring Box, Fencing
S05	4.9	0.9	40	Clear	Spring Box, Fencing, Drain

Source: Field survey (February 2006)

From the field results, all the five springs are owned by the communities. All the springs were also in use and are all used by 100 to 2400 consumers. Only one of the inventoried springs had salty water. All the springs required improvement listed below;

- Construction of spring box
- Provision of down stream drainage of water
- Fencing the area around the spring

Photo 4.7: A developed spring at Dsitsoni, Kikambala



Source: Field survey (February 2006)

Chemical analysis of water from selected springs gave the results below:

Table 4.25: Water quality analysis for selected springs in Bahari Sub Basin

Spring No	Name	ECL	pH	CLR (tcv)	TB (ntu)	TA (mg/l)	TH (mg/l)	Na (mg/l)	SO_4 (mg/l)	NaCl (mg/l)	TDS (mg/l)	SAR (mg/l)
S01	Gande	1180	7.5	5	2	220	40.2	242	88	266	740	4.74
S02	Bwerere	1520	7.2	5	1	120	38.2	72	107	174	450	4.65
S03	Bembaga	1160	7.2	5	1	432	394	68	130	173	580	4.66
S04	Dzitsoni	1610	7.3	10	7	230	580	255	85	652	800	4.68
S05	Kambu	980	7.2	5	22	106	186	143	77	366	490	4.56

Source: Field survey (February 2006)

From the chemical analysis all the springs had water that was chemically suitable for drinking.

4.4.0 Piped Water System

4.4.1 Introduction

Bahari sub basin does not have its own source of piped water, and hence relies on Baricho – Mombasa Pipeline which passes through it. Piped water supply used to be provided through the National Water Conservation and Pipeline Corporation (NWCPC) until July 2005, when Coast Water Services Board took over its operations. The CWB had licensed Kilifi Mariakani Water and Sanitation Company (KIMAWASCO) to offer water and sanitation services in Kilifi District. The functions of KIMAWASCO were;

- Operation and Maintenance of the existing pipe network
- Billing of the consumers
- Provide Water services established Water User Associations (WUAs)
- Collection of solid wastes from Townships

The water pipelines were distributed in the sub basin as in table 4.26;

Table 4.26 Distribution of Water pipelines in the Divisions

Division	Population (1999)	Length of Branch Pipelines (Km)
Bahari	90009	164
Kikambala	97898	66
Chonyi	47128	68
Total	**235035**	**298**

Source: Field survey (February 2006)

4.4.2 Major Pipelines

All the pipelines take off their water from Baricho - Mombasa pipeline which passes through the basin. The pipelines were constructed by the government, NGOs or the local community with technical assistance from the MW&I staff. The main pipelines identified during the survey were presented in table 4.27;

Table 4.27 The main pipelines in the Sub basin

Name of Pipeline	Length (Km)	Locations Served	Division	Area Served (Km^2)	Population Served
Mtwapa / Vipingo	30	Mtwapa, Vipingo, Kanamai	Kikambala	120	40000
Takaungu / Mnarani	20	Mnarani, Mavueni, Takaungu	Bahari, Kikambala	80	10000
Junju Pipeline	38	Junju, Kuruwitu	Chonyi, Kikambala	100	20000
Chonyi South	5	Zowerani	Chonyi	20	8000
Pingilikani	15	Pingilikani	Chonyi	20	4000
Ngerenya	10	Ngerenya	Bahari	20	6000
Mwele / Chasimba	10	Chasimba	Chonyi	20	5000
Ng'ombeni	5	Ngomeni	Chonyi	10	4000
Kistsoeni-Bungu	5	Kitsoeni, Mwakabi	Chonyi	10	5000
Total	**133**			**400**	**102000**

Source: Field survey (February 2006)

The residents applied for water connection from the KIMAWASCO. The design of pipeline from the water supply to the applicant's household was prepared by technicians from KIMAWASCO. On purchase of the required pipes, water metre, and pipe fittings, the applicant was supplied with water. The minimum new connection charge was Kshs.3200. This excluded the cost of pipes, water metre, and pipe fittings. The cost of the water metre was refunded by the KIMAWASCO later. The government, through the MW&I designed and implemented the following water projects to supply water to the residents before the water sector reforms:

- Tezo-Roka Water Supply
- Mnarani-Takaungu Water Supply
- Mtwapa-Vipingo Water Supply
- Kilifi Urban Water Supply

4.4.3 Community based Piped Water Schemes

Introduction

The MW&I in conjunction with NGOs have funded several piped water schemes which had brought water closer to communities. The community identified the need for water project and then the Ministry staff conducted a profile survey for the proposed pipeline. They also prepared the design for the proposed project and forwarded it to the MW&I headquarters for approval. The proposal was then presented to the community who approached donors for possible funding. Once the donor agreed to fund the project, implementation begun under the supervision of the MW&I staff. Main while the community was advised to form a water committee to oversee the implementation of project and running of the scheme. The

committee was also trained in water scheme management. Once the scheme was completed, it was handed over to the community who were to be in charge of its daily operation.

Organization

The water committees were elected annually to manage the water supplies. Their main functions were;

- Operation and Maintenance of the scheme
- Sale of the water from the water kiosks
- Organize training of members in scheme management, water conservation,
- Solve disputes among water users and staff
- Set the cost of water to the members to ensure sustainability
- Manage the funds from water sale properly by having trained honest accounts clerks

To ensure the functions were accomplished the committee employed the following staff;

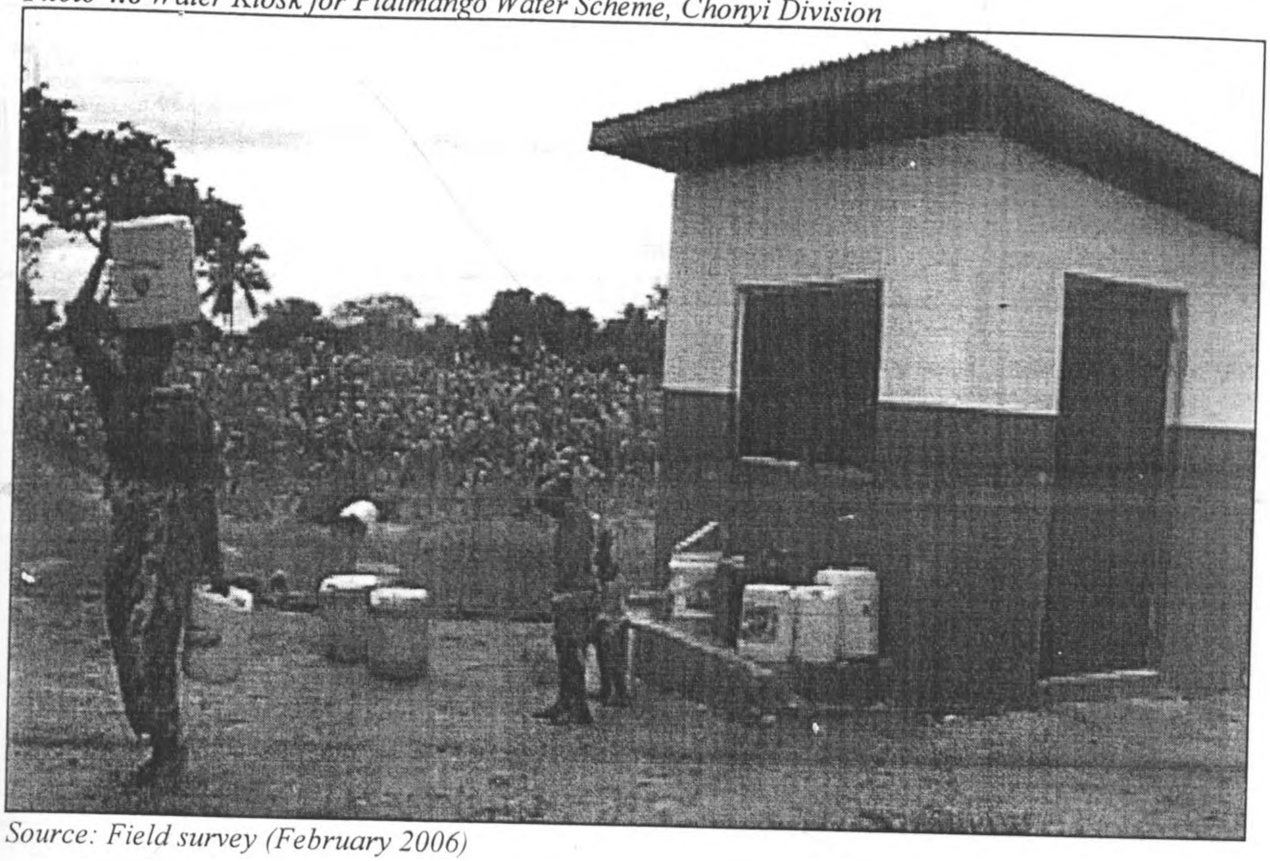
- Water kiosk attendants for selling the water from the water kiosks
- Accounts clerks to collect sales from the attendants and deposit it in a bank
- Auditors to audits the scheme on an annual basis

Problems facing Water based Piped Water Schemes

Out of the seven water schemes surveyed, three were functioning well and offering the services they were designed for. The other four required rehabilitation or had management problems as indicated in table 4.28. The major challenges facing the schemes were;

1. High water bills from the CWSB. This is because their method of billing does not regard the operations cost and the water project cost recovery. The Schemes are charged the same as individual connections
2. Mismanagement of funds by staff, and committee members.
3. Frequent brake down of pumps, pipe network and other connections
4. In some schemes the water pressure is low and hence the water does not reach some areas.
5. Low capacity storage tanks resulting to shortages whenever there is water rationing or breakdown.

Photo 4.8 *Water Kiosk for Pidimango Water Scheme, Chonyi Division*



Source: Field survey (February 2006)

Major Water Schemes in Bahari

Table 4.28 Inventoried water schemes in Bahari,

Name of Scheme	Funding Agency	Division	Villages Served	No of Consumers	Supply Area (Km^2)	Condition of Scheme
Mida / Matsangoni	EU-CDTF	Bahari	Mida, Matsangoni	16,000 people and 100 L.U.	20	Operational and Well managed
Kitsoeni / Bungu	KIWASAP & PLAN Kenya	Chonyi	Kitsoeni, Dsitsoni, Bungu	10,000 people and 10,000 L.U	20	¼ of area served. Not well managed
Mwakuhenga	EU-CDTF	Kikambala	Mwakuhenga	6,000 people and 100 L.U	15	Operational and Well managed
Pidimango	KIWASAP	Kikambala	Pingilikani, Dindiri, Makata, Ngomeni	10,000 people and 100 L.U	20	Operational but has management problems
Mwele	KIWASAP	Chonyi	Chasimba	5000 people and 50 L.U	13	Operational but has management problems
Ngerenya	KDDP	Bahari	Ngerenya	4,000 people and 100 L.U	10	Operational and Well managed
Songea	Nature Kenya	Bahari, Vitengeni	Ngerenya, Sokoke Arabuko forest	4,000 people and 50 L.U	20	Operational and Well managed
Muungano	EU-CDTF	Bahari	Konjora, Mkingilini, Ndera	10,000 people and 100 L.U	26	Operational and Well managed
Bundacho Water Project	KDDP, SIDA	Chonyi	Bundacho, Takai, Bauni, Majewa	6 000 people and 15 L.U	10	Operational and Well managed
Kujemudu	Plan Kenya	Bahari	Kwa Moyo, Eza Moyo, Jezazhom	6,000 people and 15 L.U	18	Operational and Well managed
Tezo Ngala	Plan Kenya	Bahari	Ngala, Maweni	6,000 people	9	Operational and Well managed

Source: Field survey (February 2006).

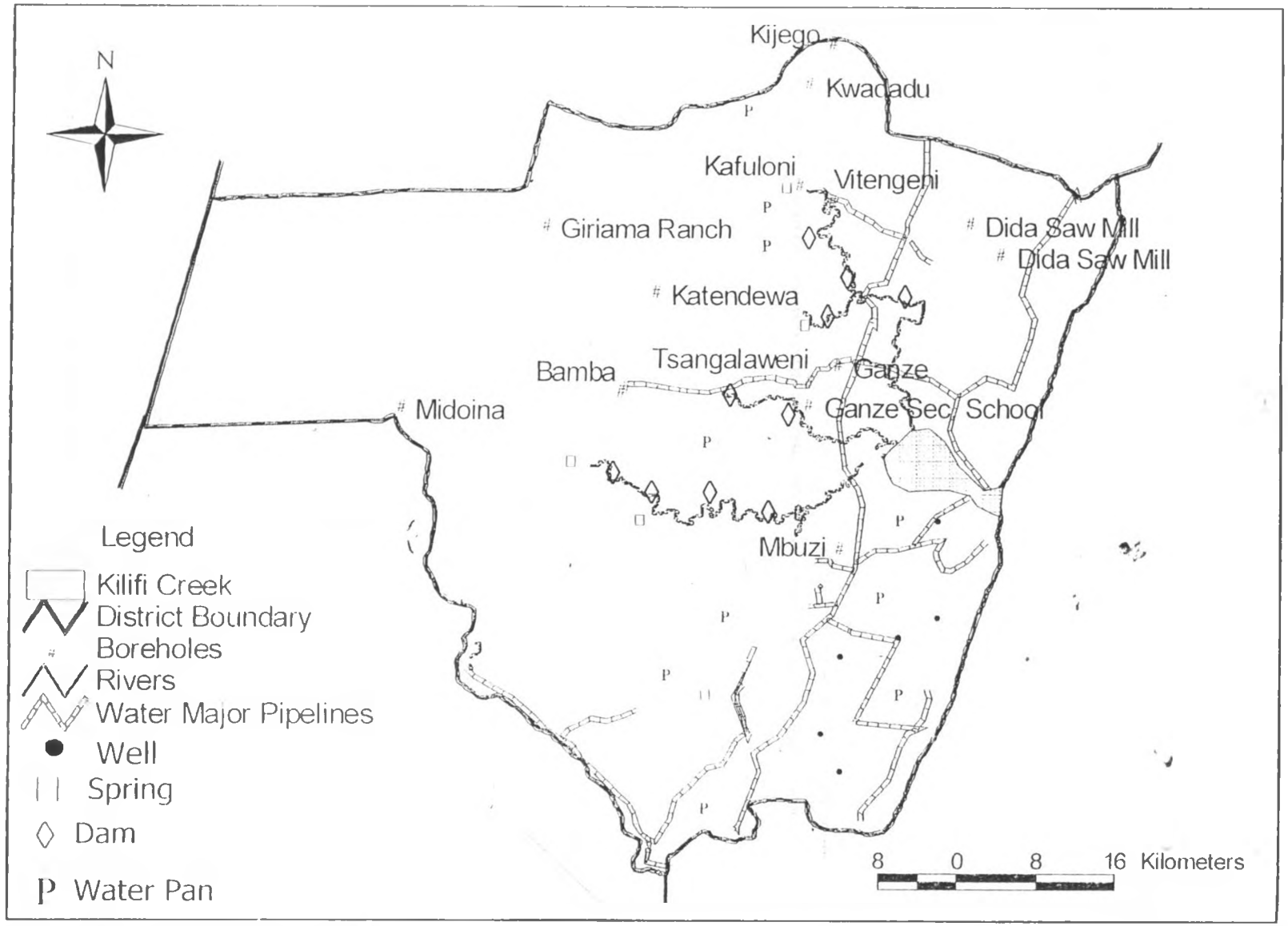


Fig 4.1 Water Resources of Bahari Sub Basin

4.5 Activities that Cause Water Pollution in Bahari Sub basin

4.5.1 Agricultural Activities

Most agricultural activities in the sub basin are confined to subsistence farming by individual farmers. Crops grown are maize, cassava, peas and bananas. Hardly any fertilizers or chemicals are used in subsistence farming. Pollution is restricted to erosion. Runoff from rainfall is deposited into water sources which pollutes them. Cash crops grown in the area were cashew nuts and coconuts.

In commercial farming, as practiced at Kilifi Plantation and Vipingo Estate a large input of

- Fertilizers (inorganic nitrogen and phosphates) to increase crop yields
- Organo-phosphorous pesticides are used to control pests.

The commercial irrigation farmers at Mtwapa/Kikambala area used fertilizers and chemicals. Crop rotation was sparingly practiced to conserve soil fertility.

4.5.2 Agro Based Industries and Factories

The four factories in the sub basin were visited and the following observations made:

- At Kilifi Plantation factory, wastewater was directly released to the sea. It had no retention reservoir. Thus no breakdown of organic waste occurred before the water reached the sea.
- At the Rhea Vipingo Estate, wastewater flowed to a valley located close to the factory. The soils are sandy soils overlaying corals and hence ground pollution was expected to occur.
- The Milly Fruit Factory at Mtwapa processed mangoes and pineapples and canned the juices for export and local sales. The factory has constructed a series of 4 lagoons to biologically breakdown the wastewater. However the solid fruit waste was dumped at a site near the factory which had a bad smell for surrounding residents.
- There were two Slaughterhouses at Tezo/Vipingo and Mtwapa were also visited. The slaughterhouses had constructed holding tanks from which the liquid effluent percolated into the underground, and the solid wastes remained on surface. The solids were later collected to be used as manure.

4.5.3 Block Mining and Sand Harvesting

Mining for building sand and stones was done at Kakuyuni, Tezo, Mto Ndia and Bofa areas of Bahari division. Accelerated erosion and big abandoned holes in the landscape were the direct negative effects of mining activities.

4.5.4 Livestock Rearing

Livestock rearing was found over the water catchment area on an individual peasant farming basis and large scale commercial farms. Kilifi Plantation had a packing factory for its milk products. Commercial farms keeping Dairy animals and poultry were also found at Mtwapa/Kikambala areas. The effluents from livestock caused surface water pollution.

4.5.5 Urbanization

The most important urban centres are Kilifi, Mtwapa and Vipingo. In these urban centers solid waste was indiscriminately dumped. During the rains surface pollution was washed to surface and ground water sources.

Wastewater also reaches the ground water via leaking septic tanks, soak pits and pit latrines. None of the centers had a sewage treatment system. Wastewater of hospitals, slaughterhouses and small-scale industries, was discharged without or with minimal treatment. The wastes got into surface and ground water resources when rains fell.

Hotel solid and liquid wastes were dumped around the Kilifi, Mtwapa and Kikambala town centres. Evacuation of sewage directly to the sea was noted in some hotels in the study area.

4.5.6 Ocean Water Intrusion

In areas where there is extensive extraction groundwater, the possibility of sea water intrusion is likely. This was so especially around Mtwapa where wells and boreholes have been sunk without regard to the problem. Further investigations for the problem are necessary.

Samples of water were taken from selected water sources that are suspected to be polluted and chemical and Bacteriological tests were done. The results of the tests are tabulated in table 4.29;

Table 4.29 Results of water pollution investigation for Bahari Sub basin

Source	ECl Mg/l	pH	TH Mg/l	Na Mg/l	BOD Mg/l	COD Mg/l	TC No/100 ml	FC No/100 ml
Well at KARI farm	620	7.4	216	42	2.2	53.3	2400	2400
Well at Mtwapa	940	7.5	438	82	1.8	44.3	2400	2400
Borehole at Vipingo Estate	1250	7.7	320	250	5.5	63.3	2500	2550
Sea Water, Bofa	46000	7.8	6600	10500	10.5	43.8		
Well at Majengo	1550	7.2	598	51	2.8	45.5	1100	10

Source: Field survey (February 2006)

4.6.0 Responsibility of the Main Stakeholders

4.6.1 Introduction

The main stake holders in the implementation of IWRM were identified and interviewed so that their roles could be known. The identified stakeholders were;

Main Stake Holders

- NGOs-Plan Kenya, Action Aid, Coast Development Authority, EU-CDTF (European Union-Community Development Trust Fund), AMREF, World Vision, DANIDA, USAID
- Private Sector
    1. Milly Fruit Processors and Mineral Water Packaging
    2. Aqua Mineral Water Processing Company
    3. Water Sector Contractors and Equipment Suppliers
- Consumers
    1. Rhea Vipingo Sisal Estates
    2. Tourists Hotels
    3. Kilifi Plantation Milk Processing Plant

4. Irrigation Farmers
5. Bahari Sub basin Community

- Government Parastatals
  1. Athi Drainage, Water Resources Management Authority
  2. Coast Water Services Board
  3. Kilifi Mariakani Water and Sanitation Company (KIMAWASCO)
- Government Departments
  1. Ministry of Water and Irrigation
  2. Ministry of Agriculture
  3. Ministry of Health
  4. Ministry of Livestock, and Fisheries
  5. Kenya Agricultural Research Institute
  6. Forestry Department
  7. Office of the President
- Local Authorities
  1. Kilifi Town Council
  2. Kilifi County Council
  3. Mariakani Town Council

4.6.2 Non-Governmental Organizations (NGO) and Community Based Organisations

The NGOs and CBOs interviewed reported that they were involved in the following water related activities:

- Provision of roof catchment facilities to organized groups and schools
- Building of latrines and sanitation facilities
- Training of communities on water conservation and sanitation aspects
- Water infrastructure development

4.6.3 Private Sector

The private sector was involved in;

- Supplying bottled water to communities within or outside the catchment
- Improving the water infrastructure so that more community members can access water.
- Contracted to supply materials and services required in the water and sanitation sector

4.6.4 Ministry of Water and Irrigation

In the ongoing reforms the MW&I role in water issues has been devolved to regional bodies. However the irrigation and drainage branch is represented at the district by district irrigation and drainage engineer whose responsibilities are;

- Identification of areas with potential for irrigation
- Design of irrigation and drainage systems for the identified groups and individuals
- Assist the farmers in acquisition of equipments required for the designed scheme
- To develop water-related legislation and regulations for the water utilisation for irrigation, drainage and its conservation.

The MW&I in the water supply sector is now limited to the national level on policy formulation such as;

- To establish a national/regional Information System.

- To establish appropriate programmes of rate management, compilation, storage and dissemination of water-related data and information.
- To establish institutional and legal mechanisms for the management of the water resources
- To establish the institutional mechanisms for effective coordination and integration among the water users.
- To design and carry out ongoing public education programmes nationally and regionally.
- To establish interregional communication links for the exchange and dissemination of information.
- To develop water-related legislation and regulations covering surface and ground water uses.
- To develop water-related legislation and regulations for the protection and conservation of water resources
- To finance the devolution for a short time before the institutions stabilize

4.6.5 Athi River Water Resources and Management Authority

The WRMA is represented by Sub Regional officer who covers Malindi, Kilifi, Mombasa and Kwale Districts. In the proposed setup, ground water officers, surface water officers, and hydrologist are to be deployed in each district to assist the sub regional officer in his duties which include;

- Allocation and of issuing permits for development and supply.
- Monitoring of the water resources.
- Rate-setting for water resources.
- Liaise with sector bodies and institutions.
- Hydrological data collection and research.
- Monitoring of pollution
- Catchment management

4.6.6 Coast Water Services Board

The Coast Water Services Board is represented at the district level by the district area manager, whose roles are;

- Develop water resources facilities
- Prepare business plans and performance targets
- Apply for license to provide water and sewerage service
- Apply regulations on water services and tariffs
- Contract water services providers
- Purchase, lease, or acquire water and sewerage infrastructure and land
- Training communities in water management aspects
- Monitor water service providers
- Assisting communities in preparation of project proposals
- Inform public on sector performance

4.6.7 Kilifi Mariakani Water and Sanitation Company

This company was formed to be the main water service provider in the district. The directors of the company are selected by the following organisations;

1. Kilifi Town Council
2. Kilifi County Council
3. Mariakani Urban Council
4. Private Sector
5. Coast Water Services Board

The company's roles are;

- Bid for service provision in the water and sewerage sector.
- Operating and Maintaining water and sewerage facilities.
- Supplying of clean water to consumers at an affordable rate
- Comply with quality standards and service levels
- Billing and revenue collection for services rendered

4.6.8 Government Departments

The other government departments involved in the water sector and there roles are as below;

1. Ministry of Heath;
    - Checking for any water contamination of water sources
    - Disinfecting of contaminated water sources
    - Educating local communities on issues of water cleanliness and sanitation

2. Office of the President
    - Mobilization of communities
    - Conflict resolution among other users

3. Ministry of Agriculture;
    - Irrigation water matters
    - Advice on efficient water use in the agricultural sector

4. Ministry of Livestock and Fisheries
    - Establishing watering points for livestock
    - Advice on water requirements for livestock both in quality and quantity

5. Forestry Department;
    - Educating communities on importance of agro forestry
    - Catchment conservation

4.6.9 Local Authorities

The three councils will elect a specified number of directors to KIMAWASCO. Their roles will be;

- Set up regulations that are.not in conflict with changed roles in the water sector
- Licence companies to offer water services and sanitation services in the rural and urban areas of the councils

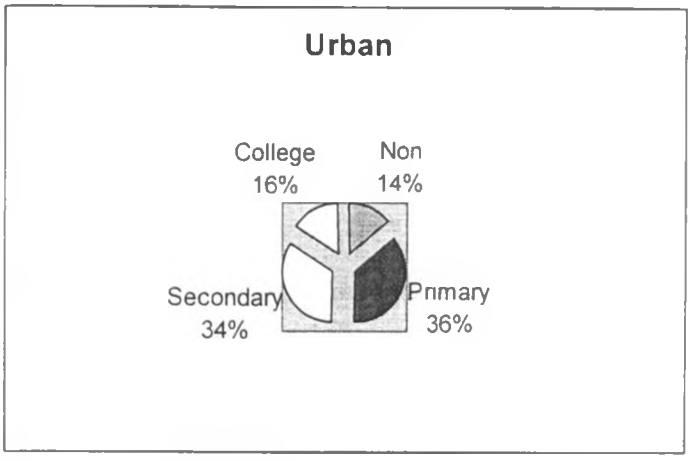
4.7.0 Household Survey Specific Findings

4.7.1 Social Economic Indicators

Level of Education

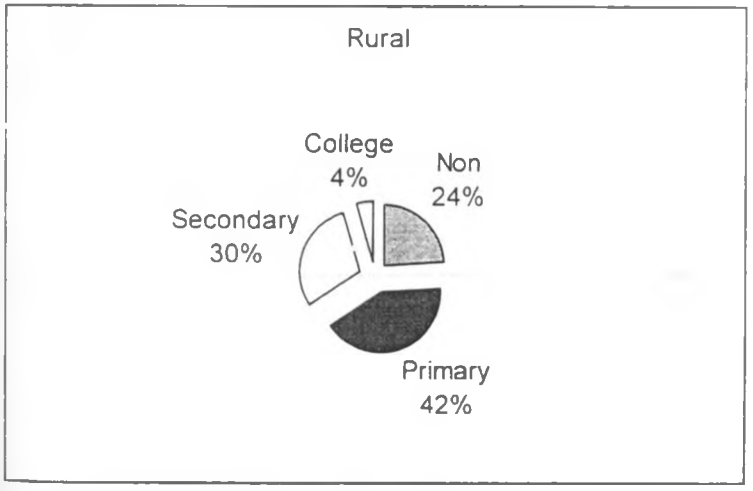
The level of education for most of the respondents in Bahari Sub basin was mainly primary school level. There was only a slight difference in level of education between the respondents from rural areas and those from urban areas. Since 80% of the respondents had at least primary education, they were able to answer the questions put to them.

Fig.4.12 Level of Education for urban respondents



Source: Field Data Survey (April 2006

Fig.4.13 Level of Education for rural respondents



Source: Field Data Survey (April 2006

Household Composition

Table 4.30 shows the distribution of households by household size, according to rural-urban residence and division.

Table 4.30 Household composition

	Residence		Division			
No of Usual Members	**Urban**	**Rural**	**Bahari**	**Chonyi**	**Kikambala**	**Total**
1	5	1	0	3	6	**3**
2	2	0	0	0	2	**1**
3	0	7	0	6	6	**4**
4	11	7	7	6	13	**9**
5	20	10	5	16	23	**15**
6	14	18	14	22	17	**17**
7	23	9	21	13	13	**15**
8+	25	46	53	34	21	**36**
Total	100	100	100	100	100	**100**
No of Households	56	67	43	32	48	**123**
Mean Size	6.4	8.4	9.7	6.9	5.9	7.5

Source: Field Data Survey (April 2006

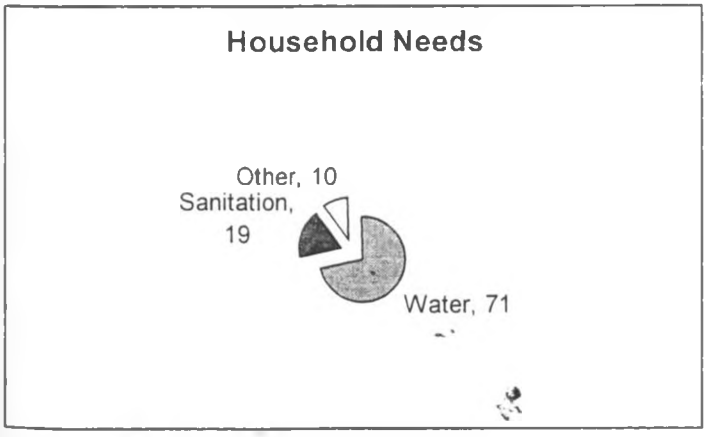
Table 4.39 shows that the mean size of the sub basins household is 7.5 persons, way above the mean household size of 5.3 found in the 1999 population census (Central Bureau of Statistics, 2002, Government Printers). However, the 2003 KDHS reported 6.6 persons per household, which was below the 7.5 reported. The increase could be due to the migration of relatives from drier areas of the district to the sub basin. The drier areas had experienced drought prior and during the time of the survey.

4.7.2 Water and Sanitation

Drinking Water Situation

The community of Bahari was requested to prioritize the needs that they would want to have in their households. Of the 123 respondents requested, 71% preferred water, 19% sanitation, and 10% other requirements. The other requirements were employment, electricity, drainage and market for produce. The people's preference is illustrated in the figure 4.14;

Fig 4.14 Community ranking of preferred household need

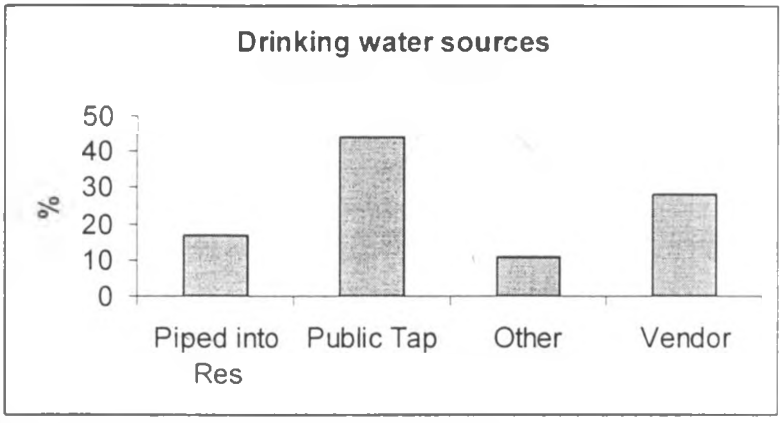


Source: Field Data Survey (April 2006)

Drinking Water Source, Cost, and Quality

According to the respondents, only 17% had water piped into their households, 44% got their drinking water from a public tap, while 28% got their water from vendors. The remaining 11% got their drinking water from other sources that included wells, ponds, and dams. There was little difference in source of drinking water between the rural and urban respondents. The 17% respondents, who had water pumped into the residence, paid a monthly bill of between Kshs 250 and Kshs 600 unless they sold water to other residents. For these respondents, the monthly bill varied from Kshs 1000 to Kshs 6000. All the respondents who got water from public tap paid between Kshs 2 and Kshs 5 for a 20 litres can of drinking water. However, respondents who bought water from vendors in Kikambala Division paid between Kshs 10 and Kshs 30 for the 20 litres water can, which is expensive. There were no respondents who indicated that they bought drinking water from vendors in Bahari and Chonyi Divisions.

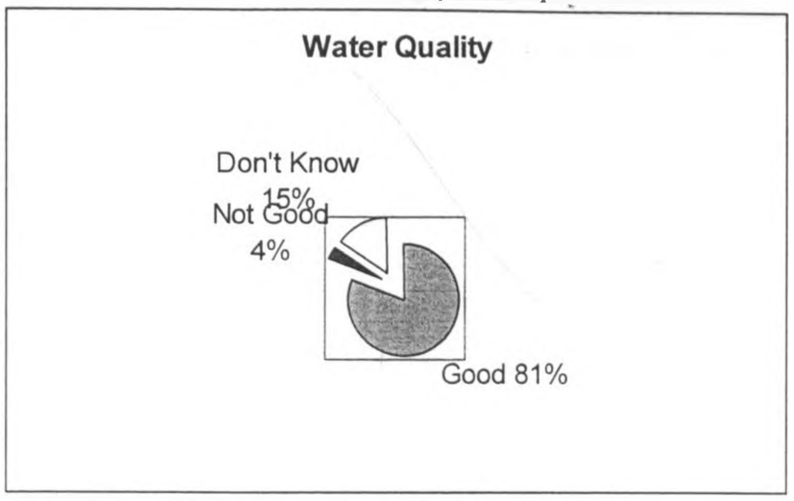
Fig 4.15 Sources of Drinking water for the respondents



Source: Field Data Survey (April 2006)

From the house hold survey, 81% of the respondents thought that the water they were drinking was of good quality, 4% believed it was not good and 15% did not know. In Kikambala, however the respondents who believed the water they were drinking was not of good quality was high at 38%. This could be attributed to the high number of vendors who hawk the commodity in containers that were not clean.

Fig 4.16 Quality of drinking water by the respondents

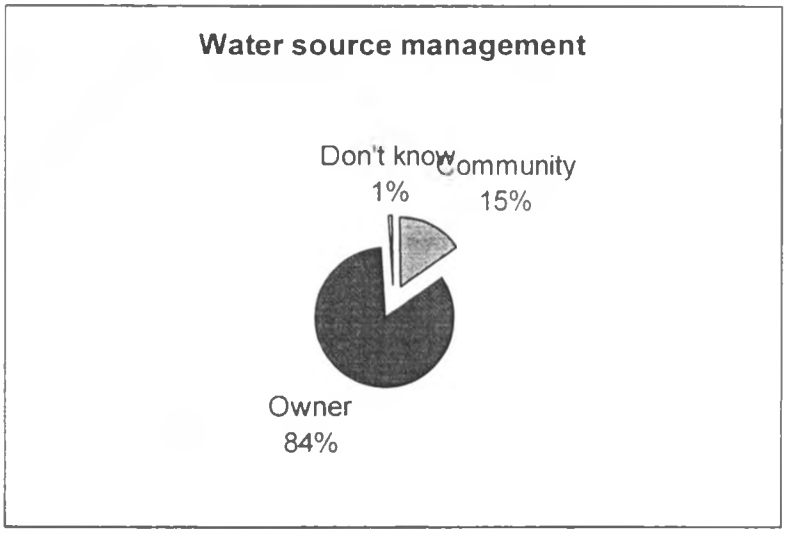


Source: Field Data Survey (April 2006)

Water Source Management and Responsibility to Look for Water

Out of the 123 respondents, 84% said that the water source for their drinking water was managed by the owner, 15% by the community, and only 1% did not know. This shows that most respondents take interest in the source of their drinking water.

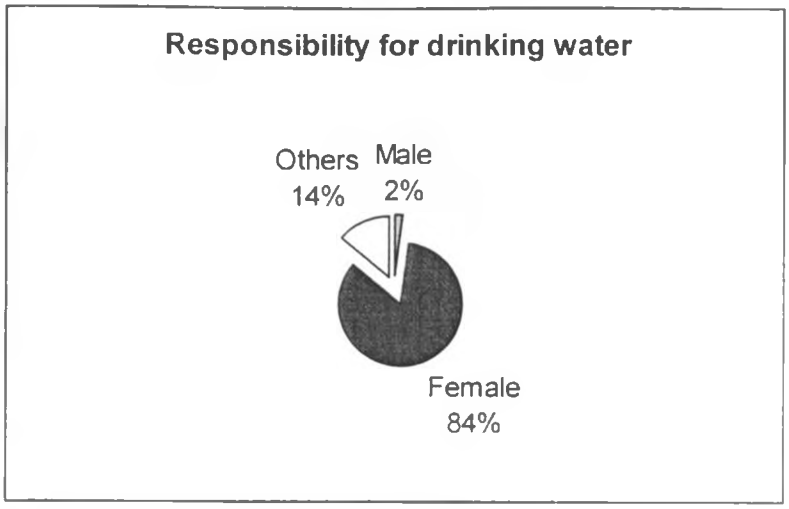
Fig 4.17 Source of drinking water management



Source: Field Data Survey (April 2006)

84% of the respondents reported that it is the responsibility of the female members of the household to look for drinking water, and 2% reported that it was the male members' responsibility. The remaining 16%, either did not know, had water in the residence or bought it from vendors who brought it to the household. This shows the important role women play in the water sector.

Fig 4.18 Responsibility to look for household drinking water

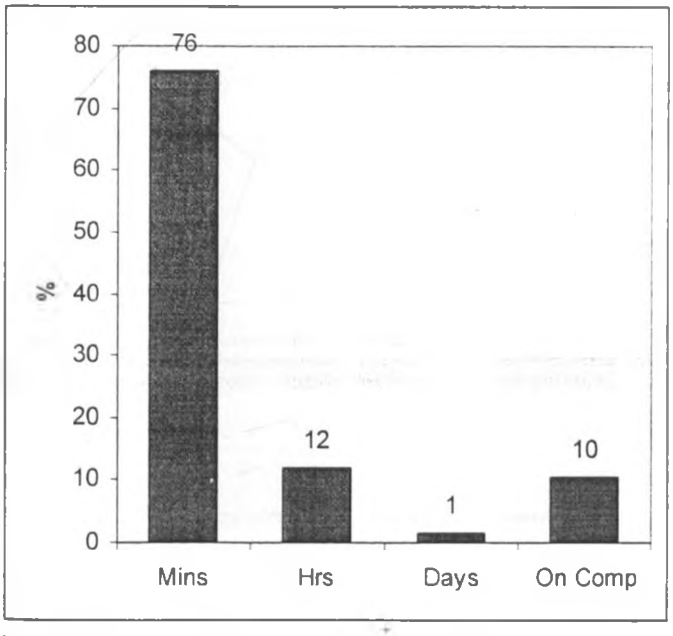


Source: Field Data Survey (April 2006)

Time taken to get Water

The rural respondents reported that 76% took minutes to get to the nearest water point, collect water and back. 12% of the respondents took hours while 10% had water in their compounds. Only 1% of the rural respondents took days to collect water from the nearest water point and be back.

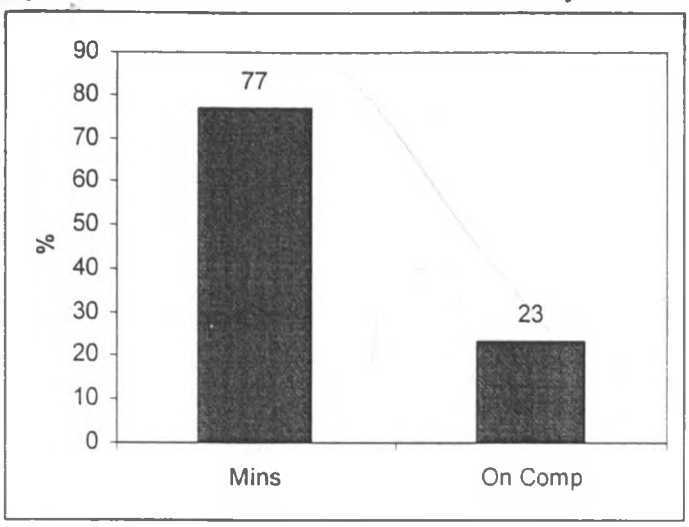
Fig 4.19 Time taken to collect water and back from nearest water point (rural areas)



Source: Field Data Survey (April 2006)

Of the 56 urban respondents 77% took minutes to collect water from the nearest water point and be back, while the remainder (23%) had water within the compound.

Fig. 4.20 Time taken to collect water and back from nearest water point (urban areas)

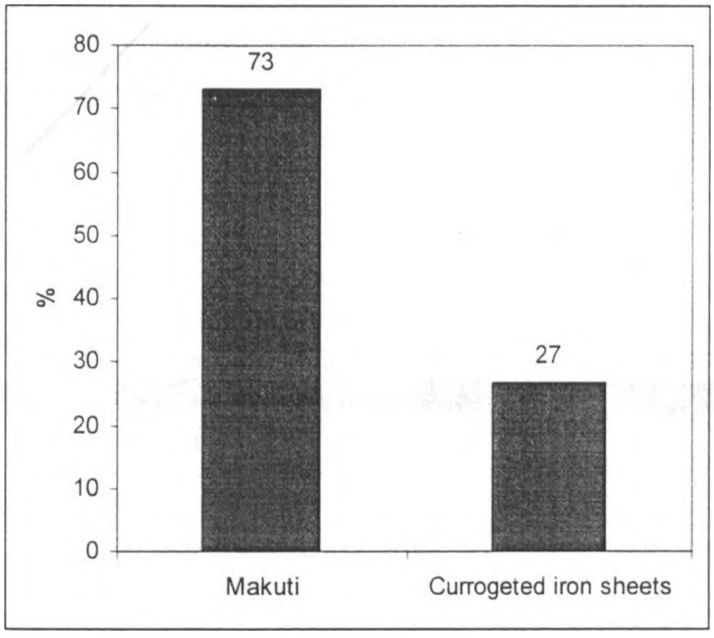


Source: Field Data Survey (April 2006)

Type of Roofing Material for Household

The households in the rural areas which had thatched roofs of makuti were 73%, while the rest of the households reported corrugated iron sheets type of roofing material. Since makuti is not suitable as a roof catchment material, its development will be limited.

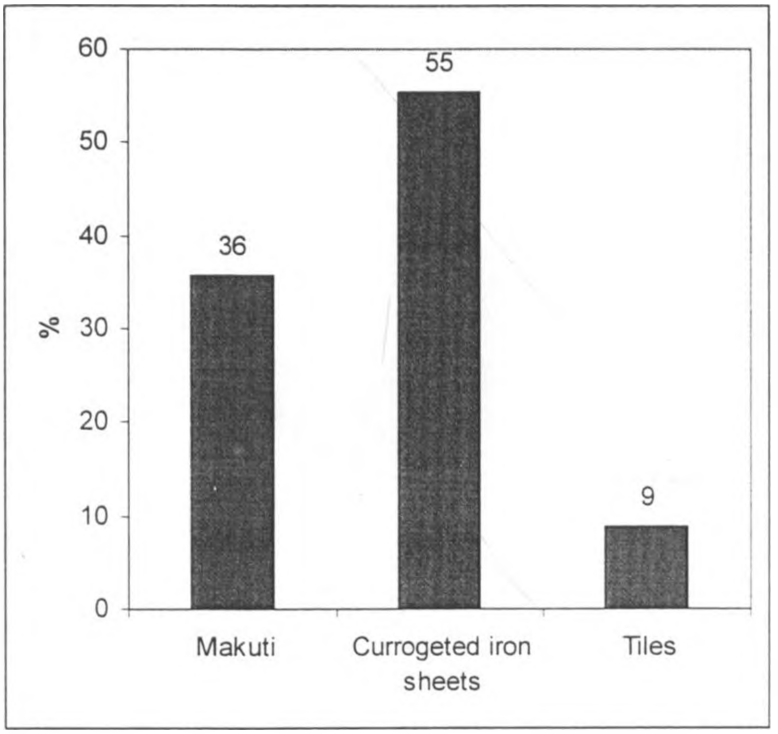
Fig. 4.21 Type of roofing material for rural households



Source: Field Data Survey (April 2006)

Urban areas respondents had 36% of the households having makuti roofing material, 55% corrugated iron sheets, and 9% had tiled roofs. This showed that there was greater potential for roof catchment in the urban areas.

Fig. 4.22Type of roofing material for urban households



Source: Field Data Survey (April 2006)

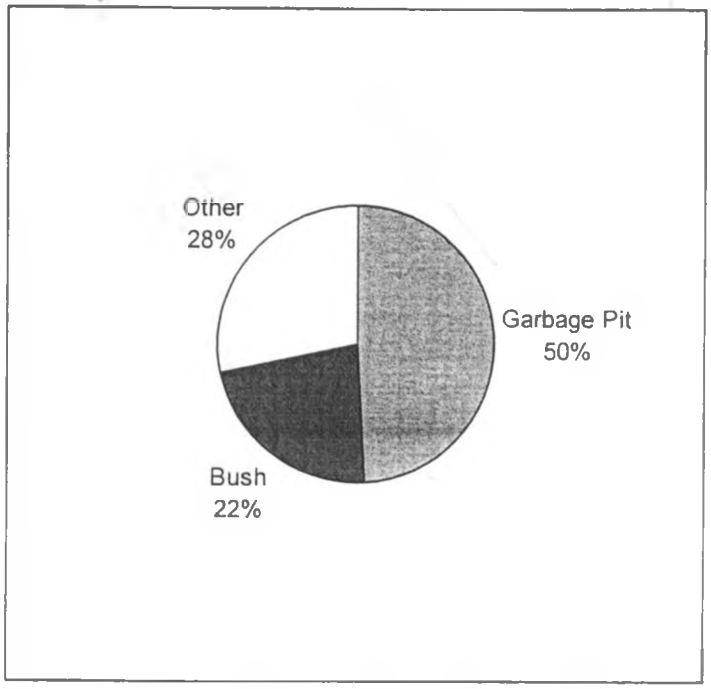
Solid Waste Management

The solid waste that is generated by both the households and businesses is mainly;

- Food leftovers
- Waste papers, plastic containers
- Polythene bags
- Tins, empty boxes
- Coconut shells
- Rotten vegetables
- Livestock manure
- Crop residues

For the rural areas, 50% respondents reported that their solid waste was dumped into a garbage pit, 22% threw it into the bush, and 28% disposed it in other ways. These other methods of disposal used by the rural respondents were mainly dumping it in the farm, or collecting it in a heap and then burning it.

Fig. 4.23 Methods of disposing solid waste for rural households

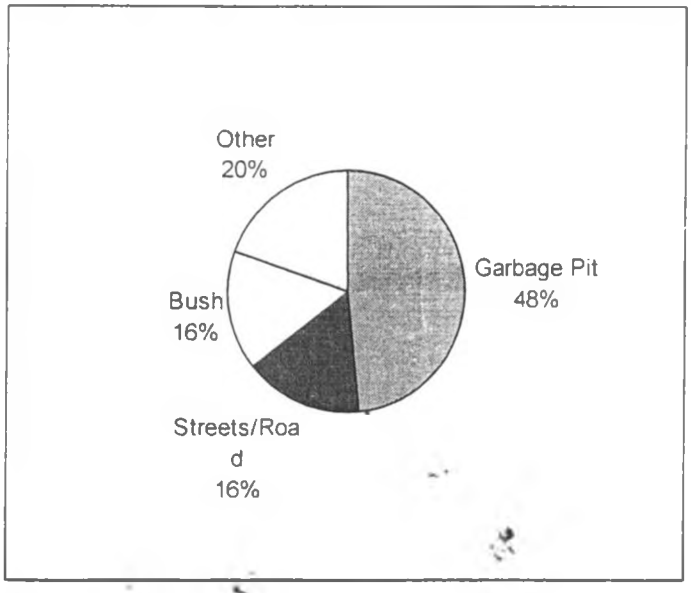


Source: Field Data Survey (April 2006)

In the urban areas solid waste was mainly disposed of through collection by councils. Kilifi Town Council collected solid waste in Kilifi Township, and Kilifi County Council collected garbage in Mtwapa Town.

Kilifi Town Council had two tractor fitted with trailers that collected solid waste at some designated points, and dumped it at an abandoned quarry for burning. Mtwapa was served by two tractors that collected garbage from residents and dumped at an abandoned road. The methods were poor and are led to pollution of environment.

***Fig 4.24** Methods of disposing solid waste for urban households*

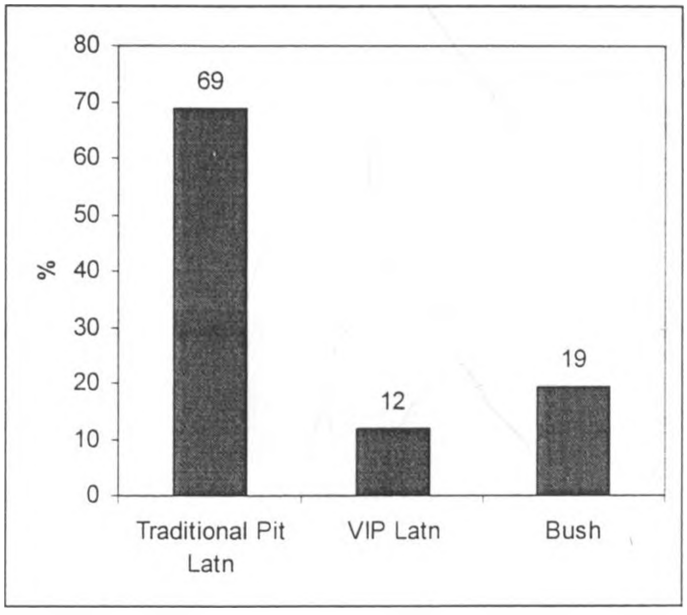


Source: Field Data Survey (April 2006)

Sanitation Facilities in the Household

About 81% of the households reported to have access to some type of sanitary facility. In the rural areas, 69% had access to the traditional pit latrine while 12% had VIP latrine. 19% of the rural respondents used the bush as toilet facility.

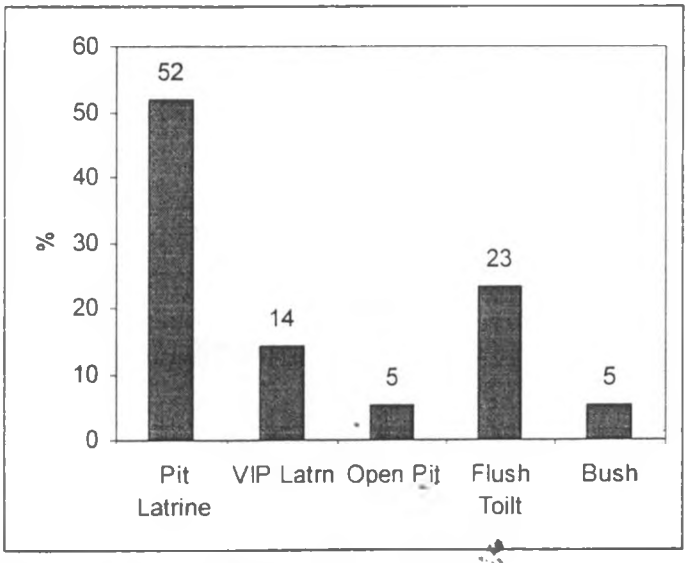
Fig. 4.25 Type of sanitary facilities in the rural households



Source: Field Data Survey (April 2006)

In the urban centres only 5% of the respondents had no toilet facility and used the bush. The urban respondents reported that 52% had traditional pit latrine, 23% had flush-toilets, 14% had VIP pit latrines, and 5% had open pits.

Fig 4.26 Type of sanitary facilities in the urban households

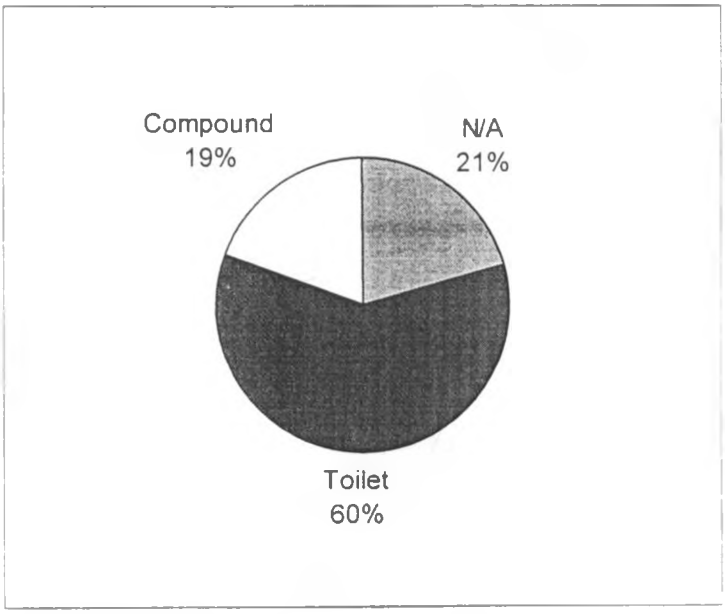


Source: Field Data Survey (April 2006)

Disposal Methods for Stools of Children (0-3 years) in the Household

The rural respondents reported that 60% disposed young children's stool by throwing it into the toilet, 19% respondents buried or threw it into the compound. The remaining 21% did not report anything because these household did not have young children at the time of survey or they could not recall how they used to dispose of the stool when they had young children.

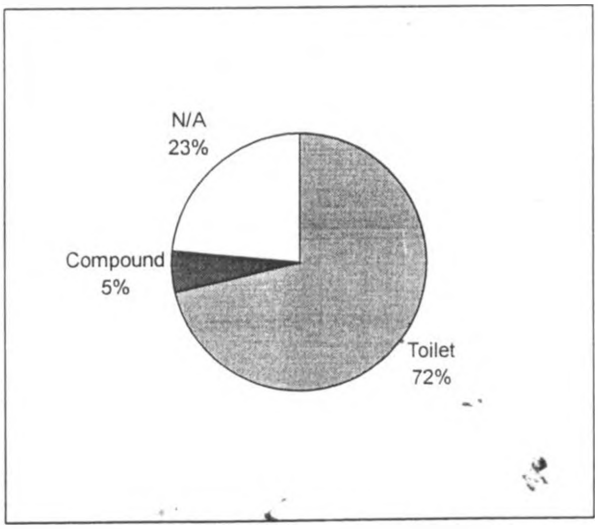
Fig 4.27 *Disposal of young children's stool for rural households*



Source: Field Data Survey (April 2006)

The urban respondents reported that 72% disposed the stool of young children by throwing it into the toilet, 5% buried or threw it in the compound, while 23% of the urban respondents did not report any method. The failure for the 23% not to report was due to their not having small children or not recalling what used to be done when they had.

Fig 4.28 *Disposal of young children's stool for urban households*



Source: Field Data Survey (April 2006)

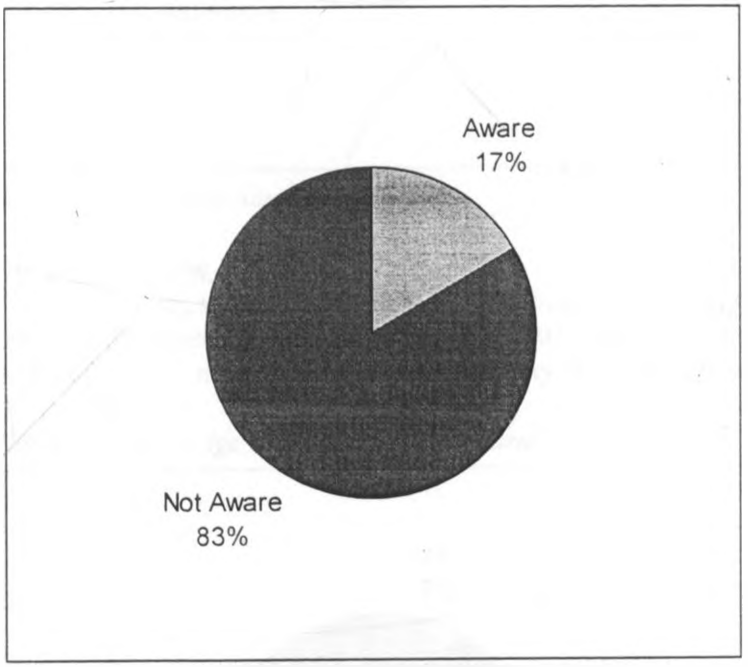
4.7.3 Awareness of Legislative Policies in the Water Sector

The respondents were asked questions to test on their knowledge of the policies and legislations in the water sector. They were also asked to state the areas within the water sector, which they felt that certain organizations should play a part.

Policy Awareness

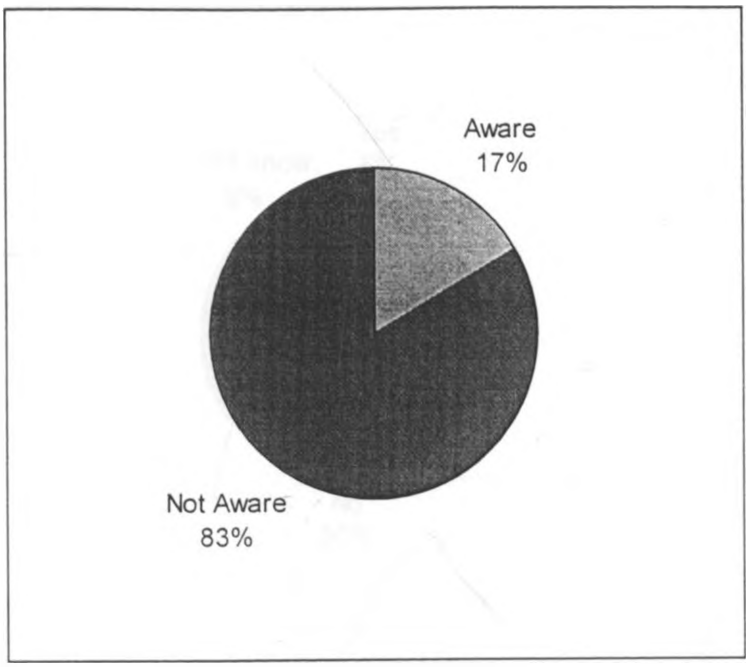
When the respondents were asked whether they were aware of any policies or legislation that affected the water sector, 17% of the rural respondents and 17% of urban respondents reported they were. When the aware respondents were asked to state what they knew about the legislations the ones they stated were getting licenses for bore holes, provision of clean water to the people, paying their water bills, and keeping of water points free of contaminants. Others could not remember any. The results from rural respondents do not vary much from those of urban respondents.

Fig 4.29 Policy awareness for the rural respondents



Source: Field Data Survey (April 2006)

Fig 4.30 Policy awareness for the urban respondents

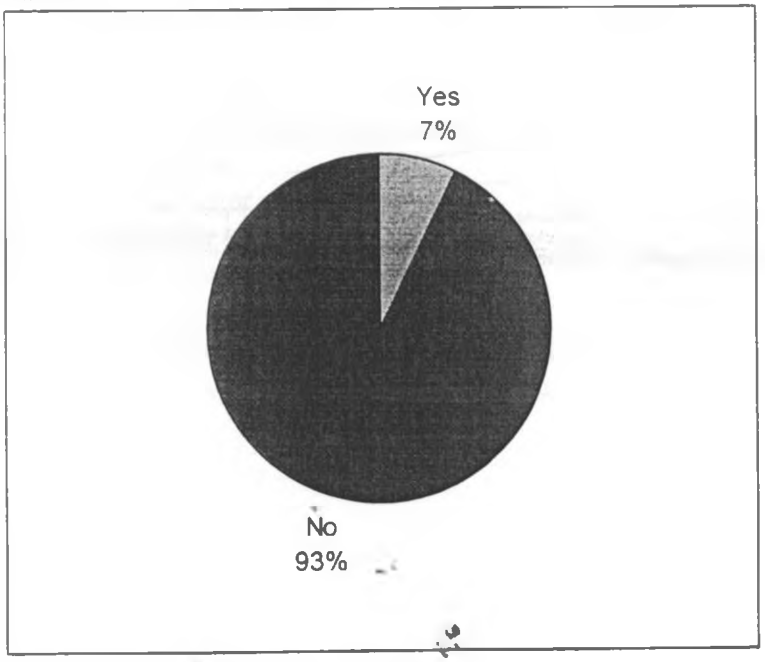


Source: Field Data Survey (April 2006)

Knowledge of the Water Act

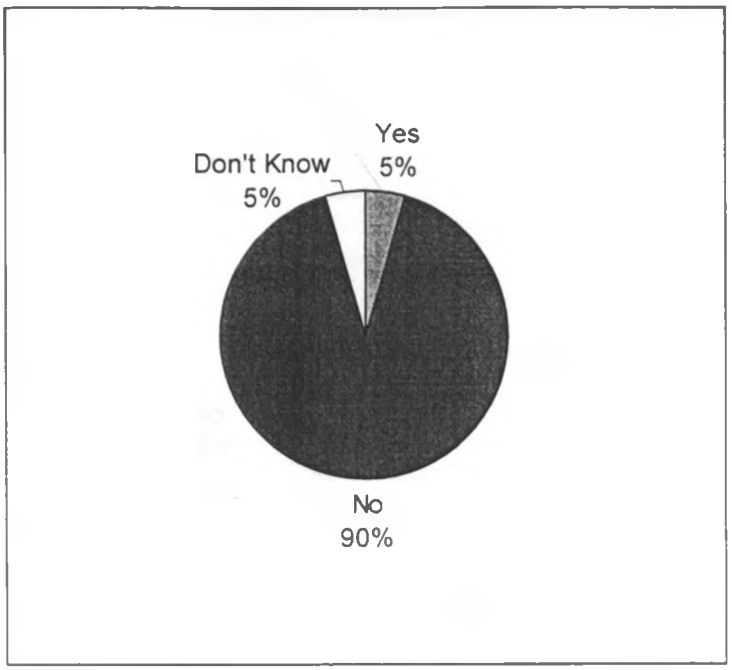
For the 67 rural respondents, only 7% had heard of the Water Act 2002. In the urban areas only 5% of respondents had heard of WA2002. On further probing the respondents who had heard of the act, none of them could recall any of its provisions.

Fig 4.31 Knowledge of the WA2002 for rural respondents



Source: Field Data Survey (April 2006)

Fig 4.32 Knowledge of the WA2002 for urban respondents



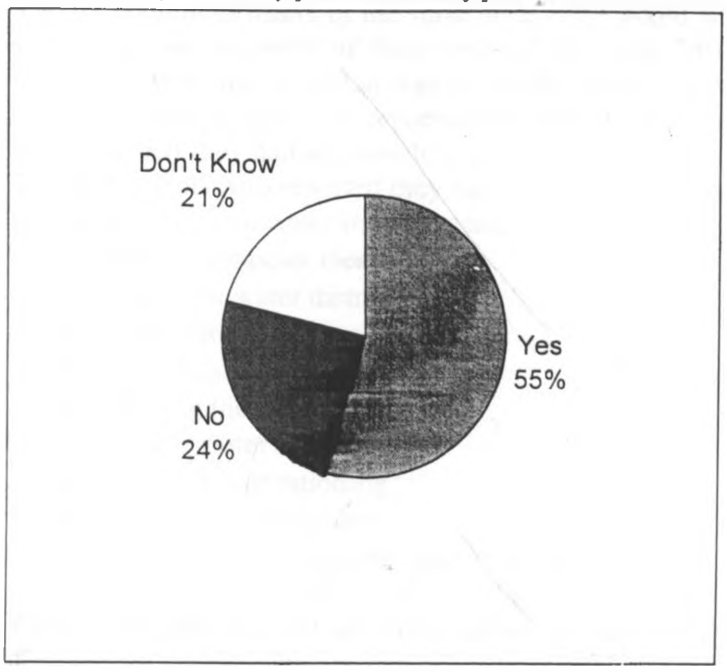
Source: Field Data Survey (April 2006)

Responsibility in Environmental Policies in Water Management

When the respondents were asked as to whether they had any role to play in creation of suitable legislations in water management, 55% of the rural respondents reported yes, 24% did not think so, while 21% did not know. In the urban respondents, 29% reported yes, 18% reported no and 53% did not know. The respondents, who reported that they had a responsibility, had the following as some of the responsibilities;

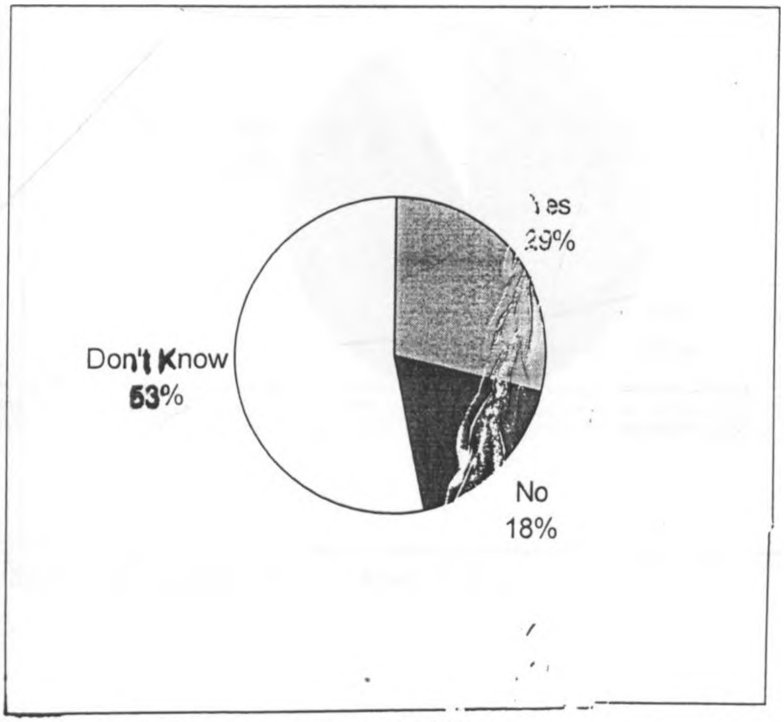
- Availing of clean water
- Offer security at water
- Excavating wells
- Abiding by the water regulations
- Treating water
- Reducing water wastage
- Proper water billing
- Forming water user associations
- Owning the water source
- Making sure that water is not contaminated at water point

Fig. 4.33 Responsibility for creation of policies in water management by rural respondents



Source: Field Data Survey (April 2006)

Fig.4.34 Responsibility for creation of policies in water management for urban respondents



Source: Field Data Survey (April 2006)

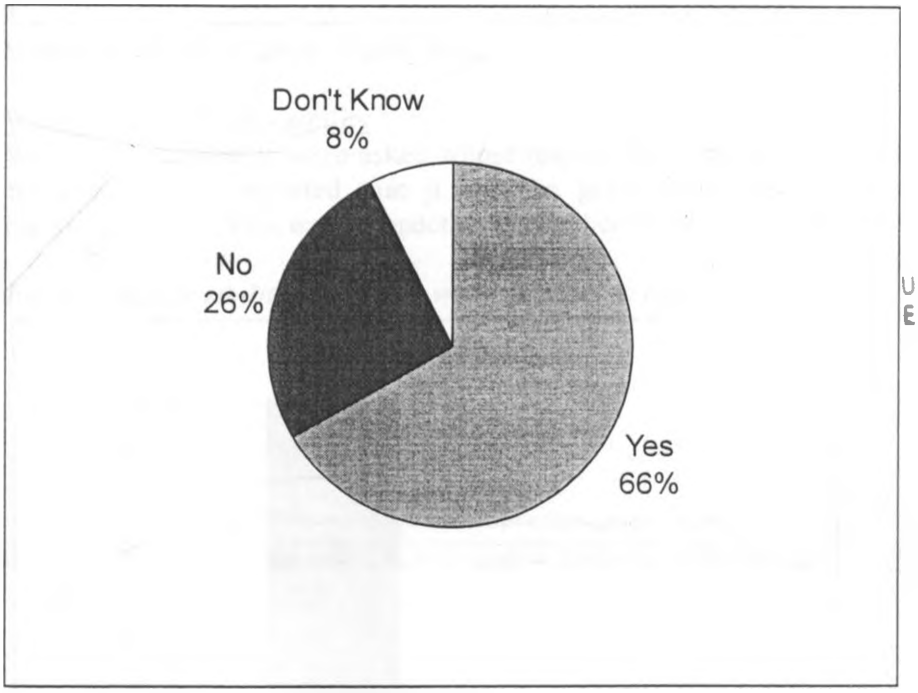
Role of People in Water Management

The 67 household heads in the rural areas were asked whether they had any role to play in water management, 66% of them reported they had, 26% did not and 8% reported they did not know. The same question was put to the urban respondents on which 71% reported that they had a role to play, 6% reported that they did not have a role to play, and 23% did not know whether they had any role to play.

The respondents who reported they had a role to play reported the following as the roles people could play in water management;

- Keep water point clean
- Decide on water distribution
- Form water user associations
- Protect catchment areas
- Keeping the environment clean
- Prevent water misuse
- Control water rationing
- Managing water points
- Training people in water resources management

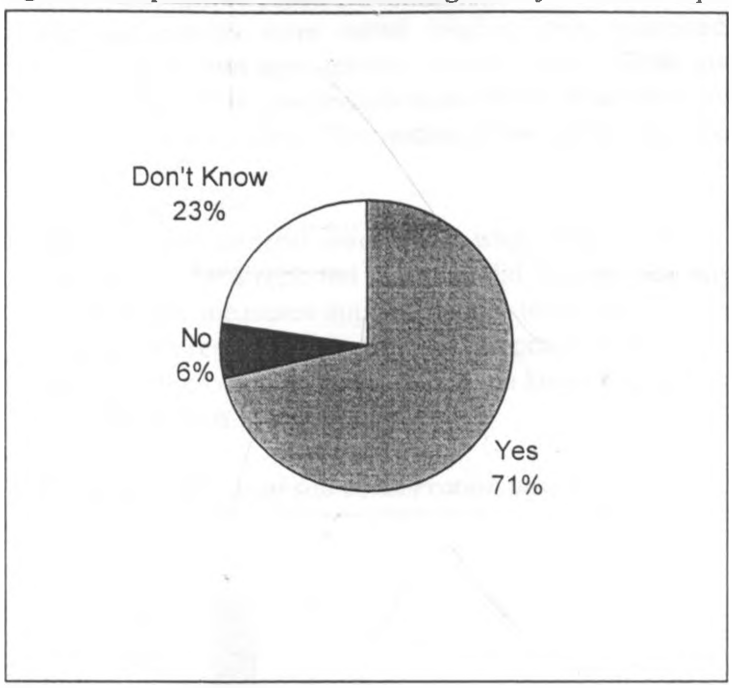
Fig 4.35 Peoples role in water management for rural respondents



UNIVERSITY OF NAIROBI
EAST AFRICANA COLLECTION

Source: Field Data Survey (April 2006)

Fig 4.36 Peoples role in water management for urban respondents

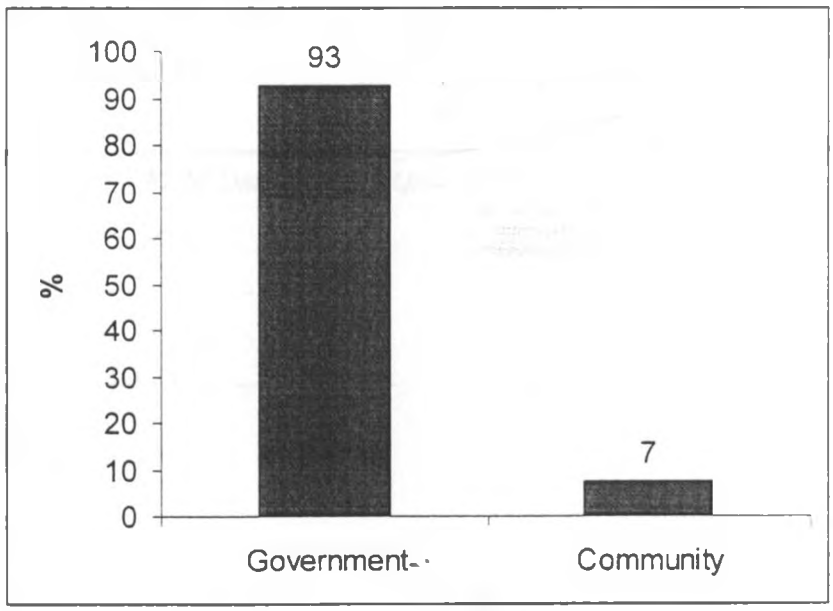


Source: Field Data Survey (April 2006)

Water Services Responsibility

When the respondents were asked whose responsibility it was to offer water services to the community, 93% reported that it was the government, while 7% reported it was the community itself. This was irrespective of whether the respondents were rural or urban.

Fig 4.37 Responsibility of offering water services to communities



Source: Field Data Survey (April 2006)

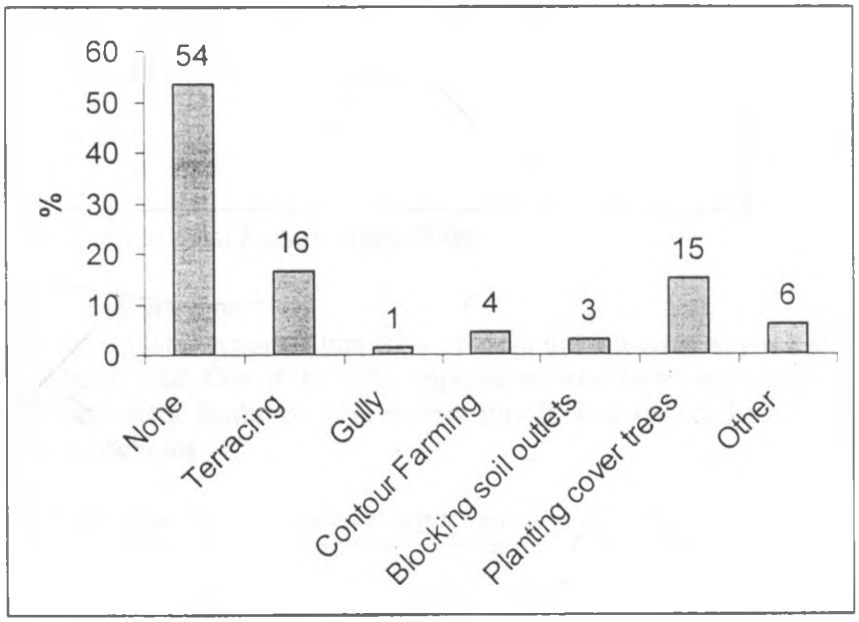
4.7.4 Sustainable Land Development

The respondents were asked whether they practiced soil conservation measure, water conservation, and agro-forestry in their farms. These questions were put only to the 67 rural respondents. This was because most of the urban respondents do not practice the conservation measures in their plots. The results of the survey indicated that;

Soil Conservation

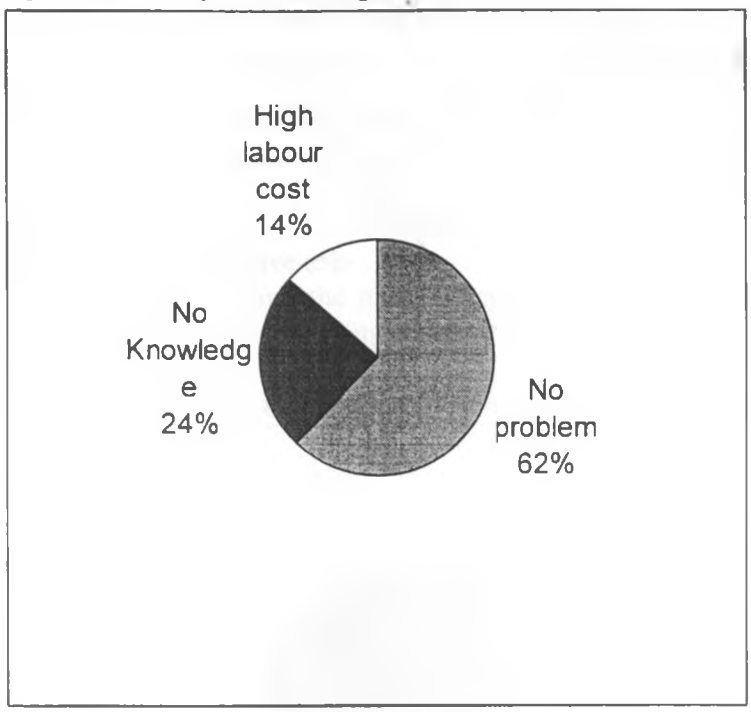
When the respondents were asked what method of soil conservation they practiced in their households, 54% reported that they did not practice any. The ones who practiced some soil conservation measures applied mainly terracing (16%) and planting cover trees (15%). The respondents reported that they did not practice any soil conservation measures because there was no soil erosion problem (62%), no knowledge of soil conservation measures (24%), and high labour cost (14%).

Fig 4.38 Methods of soil conservation measures



Source: Field Data Survey (April 2006)

Fig 4.39 Reason for not taking any soil conservation measures

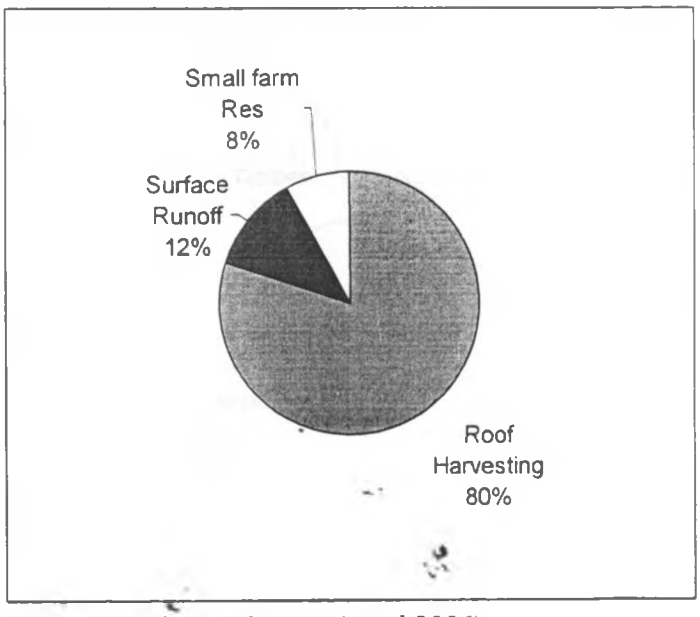


Source: Field Data Survey (April 2006)

Water Conservation

The respondents reported that 63% of them did not have any water conservation facilities in their household. Out of the 37% respondents who had water conservation facilities, 80% had roof catchment facilities, 12% surface runoff, and 8% used small pans to conserve water in their households.

Fig 4.40 Types of water conservation facility in household



Source: Field Data Survey (April 2006)

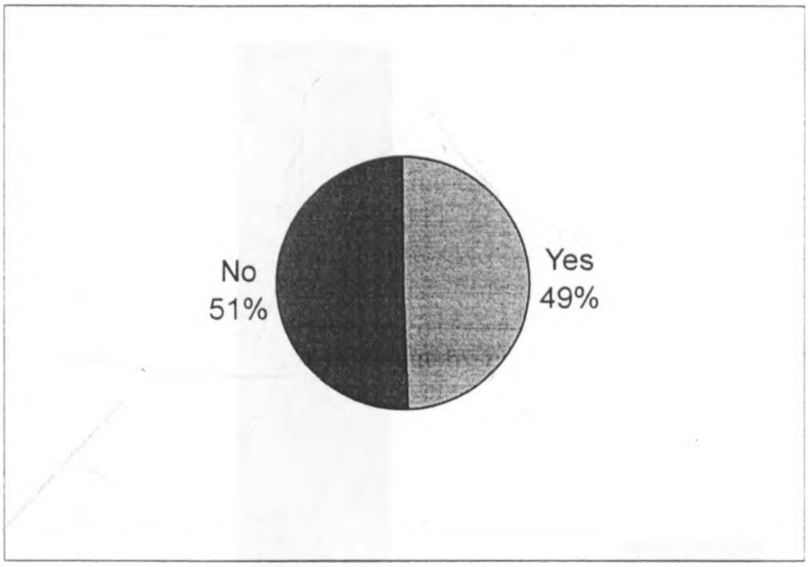
Agro forestry

Out of the 67 respondents, 28 reported that they had planted one or more trees during the last twelve months. This represented about 42% of the respondents. The number of trees planted per household varied from non to two hundred and fifty. The total number of trees planted was 729. Thus the average number of trees planted by each household was 11.

The respondents reported that 51% of them had cut at least one tree in the last twelve months. The number of trees cut by each household ranged from none to sixty. The total number of trees cut by the respondents was 331. Thus the average number of trees cut by each household was five (5).

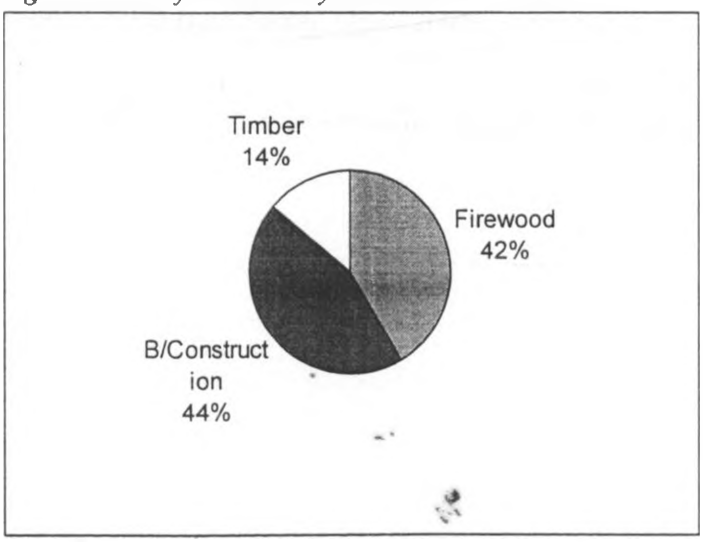
The purpose for cutting the trees as reported by the respondents were either for firewood-42%, timber-14%, and building construction-44%.

Fig 4.41 Households that had cut trees in the last twelve months



Source: Field Data Survey (April 2006)

Fig 4.42 Use of trees cut by households

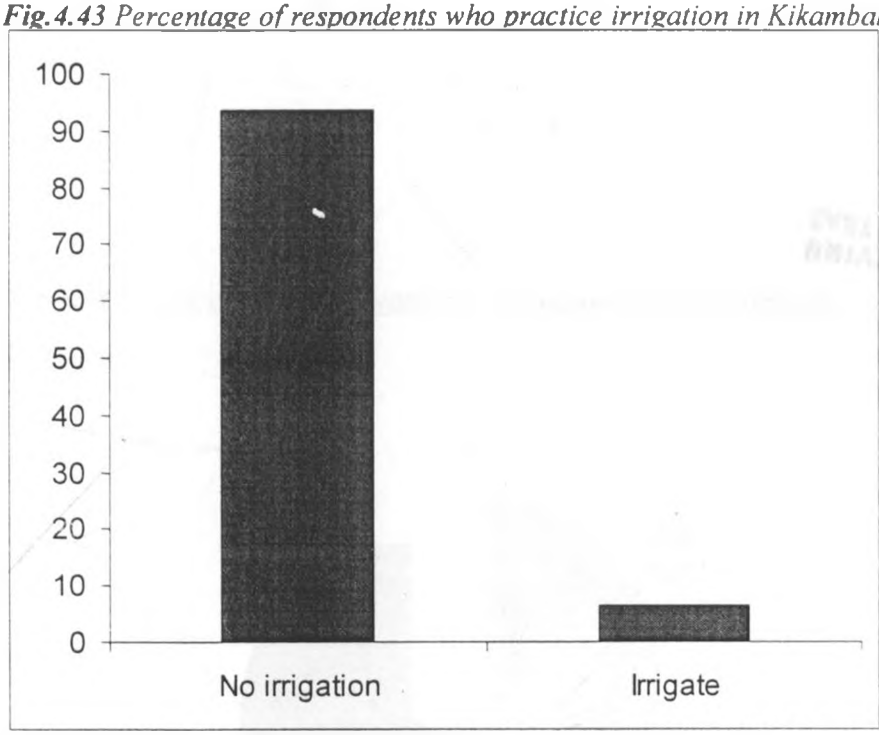


Source: Field Data Survey (April 2006)

4.7.5 Irrigation Water Use

Irrigation was only practiced in Kikambala Division. Out of the 48 respondents, only 3 reported that they practiced irrigation. Of the three respondents who irrigated two used water from a well and one used a nearby seasonal river. The two used an electric motor to pump water from the well. The respondent, who used the river as his water source, used a bucket to fetch it. The two respondents who had the wells as their water source used the basin method of irrigation. All the respondents irrigated every day. The crops grown were maize, bananas, amaranthus and tomatoes. The time of irrigation by all the respondents varied from 4 hours to 6 hours every day. All the respondents who irrigated did not have a water permit and did not intend to get one soon. Of the three respondents, only one kept also some livestock.

Fig.4.43 Percentage of respondents who practice irrigation in Kikambala



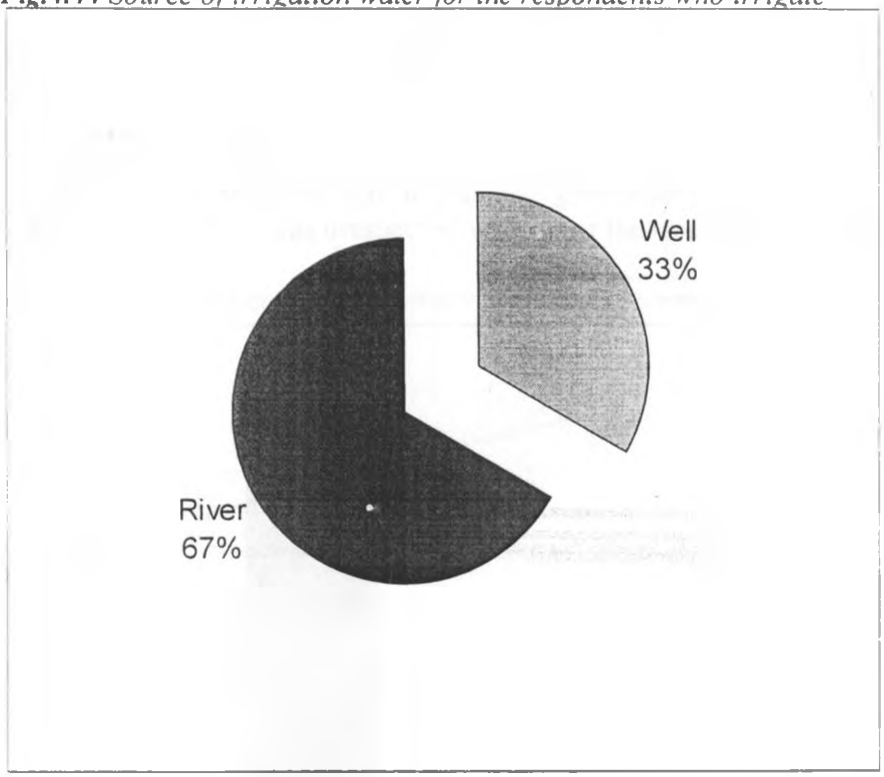
Source: Field Data Survey (April 2006)

4.8 Water Demand

From the results obtained in field data the water demand for the sub basin was estimated and the results presented. Reults

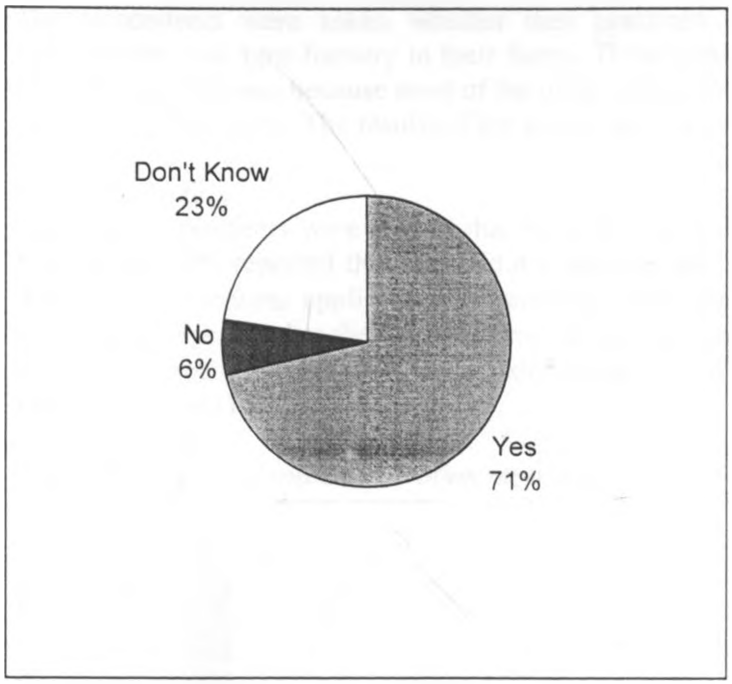
4.8.1 Irrigation Water Requirments

Fig.4.44 Source of irrigation water for the respondents who irrigate



Source: Field Data Survey (April 2006)

Fig 4.36 Peoples role in water management for urban respondents

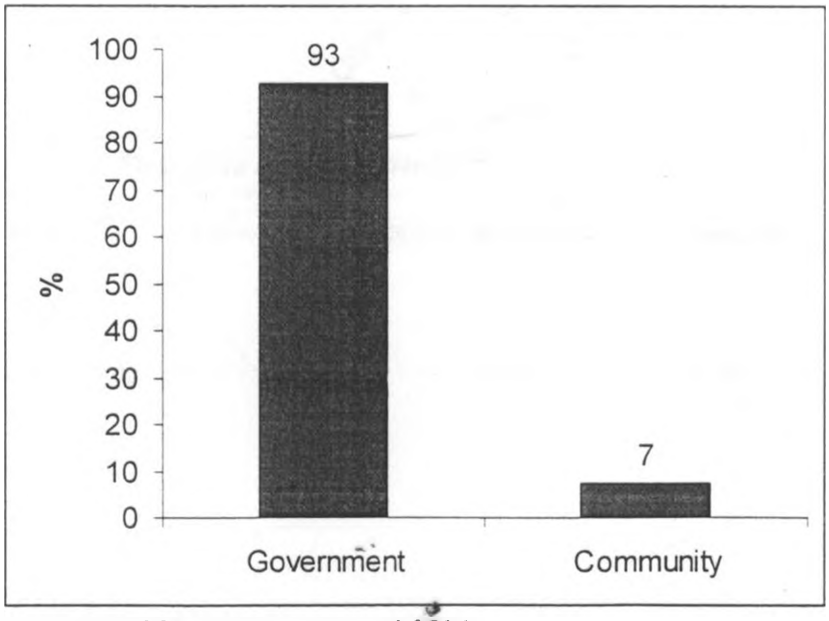


Source: Field Data Survey (April 2006)

Water Services Responsibility

When the respondents were asked whose responsibility it was to offer water services to the community, 93% reported that it was the government, while 7% reported it was the community itself. This was irrespective of whether the respondents were rural or urban.

Fig 4.37 Responsibility of offering water services to communities



Source: Field Data Survey (April 2006)

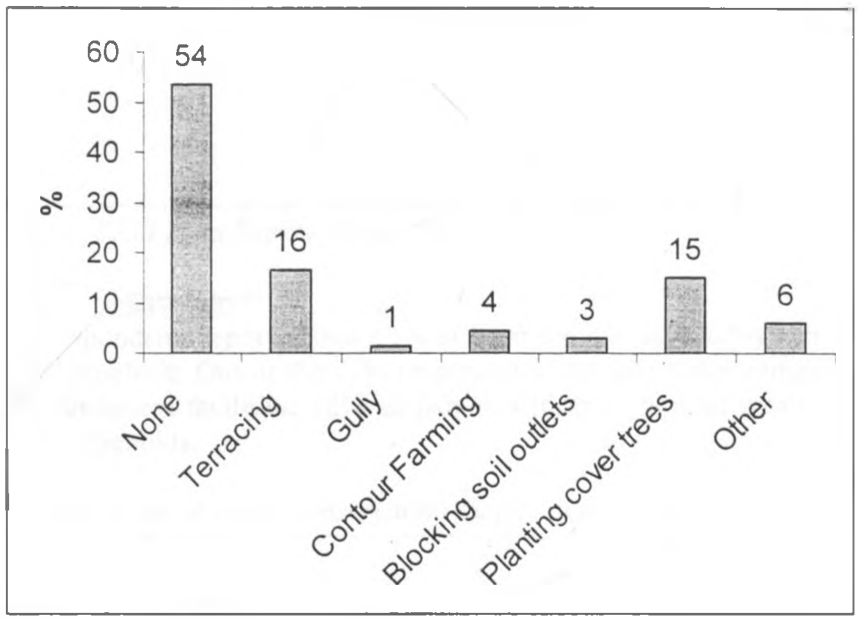
4.7.4 Sustainable Land Development

The respondents were asked whether they practiced soil conservation measure, water conservation, and agro-forestry in their farms. These questions were put only to the 67 rural respondents. This was because most of the urban respondents do not practice the conservation measures in their plots. The results of the survey indicated that;

Soil Conservation

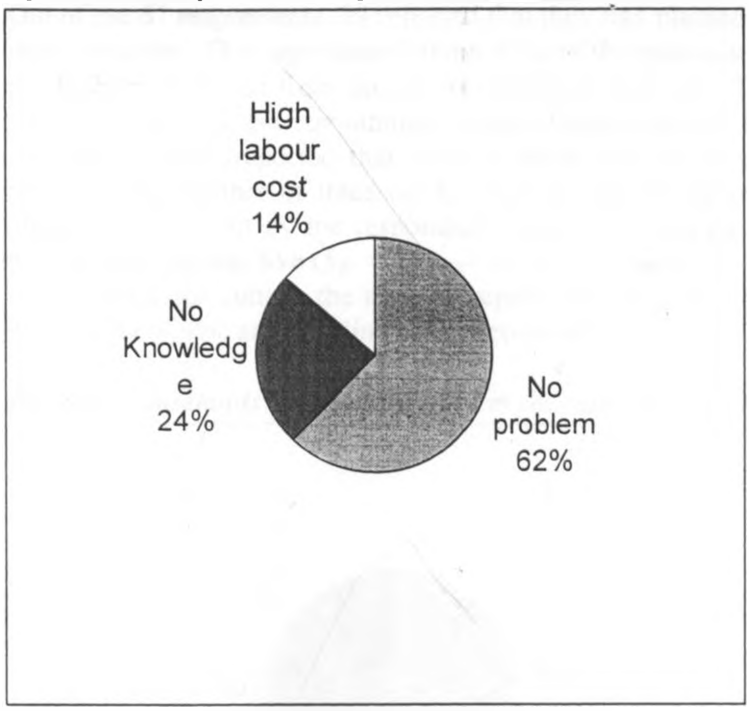
When the respondents were asked what method of soil conservation they practiced in their households, 54% reported that they did not practice any. The ones who practiced some soil conservation measures applied mainly terracing (16%) and planting cover trees (15%). The respondents reported that they did not practice any soil conservation measures because there was no soil erosion problem (62%), no knowledge of soil conservation measures (24%), and high labour cost (14%).

Fig 4.38 Methods of soil conservation measures



Source: Field Data Survey (April 2006)

Fig 4.39 Reason for not taking any soil conservation measures

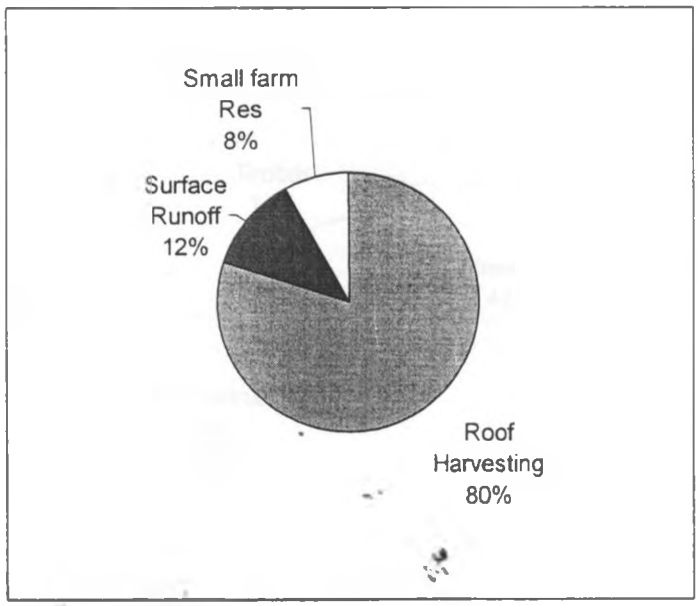


Source: Field Data Survey (April 2006)

Water Conservation

The respondents reported that 63% of them did not have any water conservation facilities in their household. Out of the 37% respondents who had water conservation facilities, 80% had roof catchment facilities, 12% surface runoff, and 8% used small pans to conserve water in their households.

Fig 4.40 Types of water conservation facility in household



Source: Field Data Survey (April 2006)

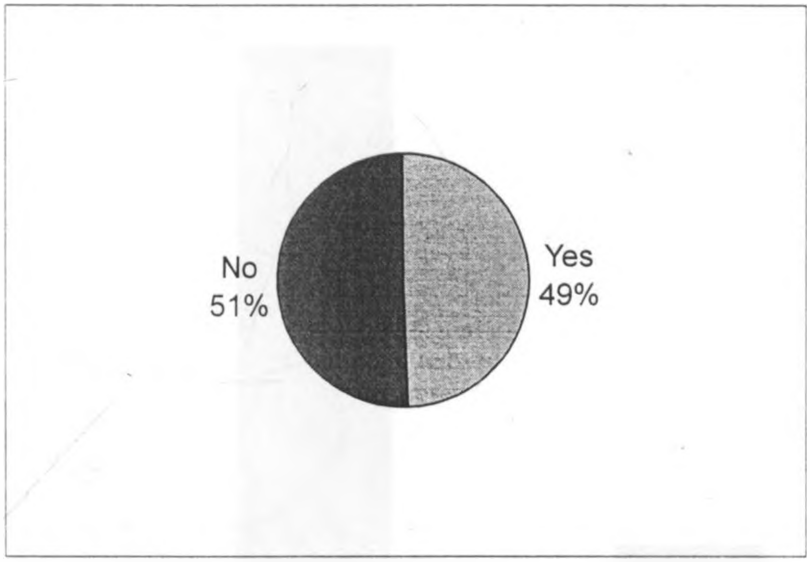
Agro forestry

Out of the 67 respondents, 28 reported that they had planted one or more trees during the last twelve months. This represented about 42% of the respondents. The number of trees planted per household varied from non to two hundred and fifty. The total number of trees planted was 729. Thus the average number of trees planted by each household was 11.

The respondents reported that 51% of them had cut at least one tree in the last twelve months. The number of trees cut by each household ranged from none to sixty. The total number of trees cut by the respondents was 331. Thus the average number of trees cut by each household was five (5).

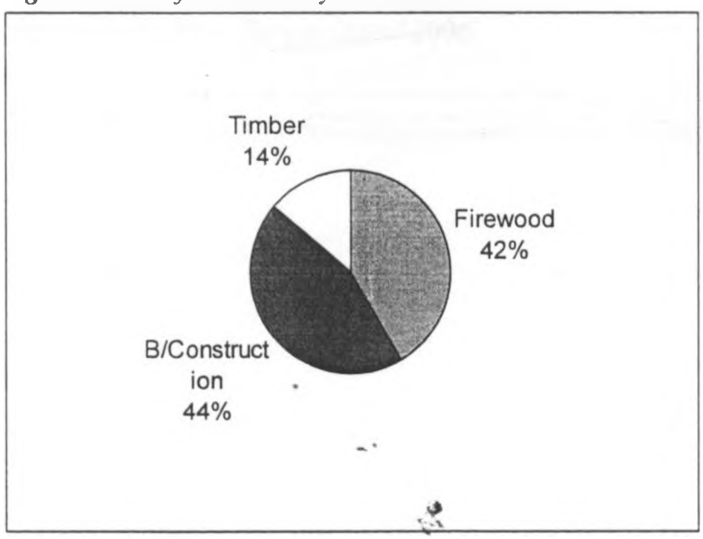
The purpose for cutting the trees as reported by the respondents were either for firewood-42%, timber-14%, and building construction-44%.

Fig 4.41 *Households that had cut trees in the last twelve months*



Source: Field Data Survey (April 2006)

Fig 4.42 *Use of trees cut by households*

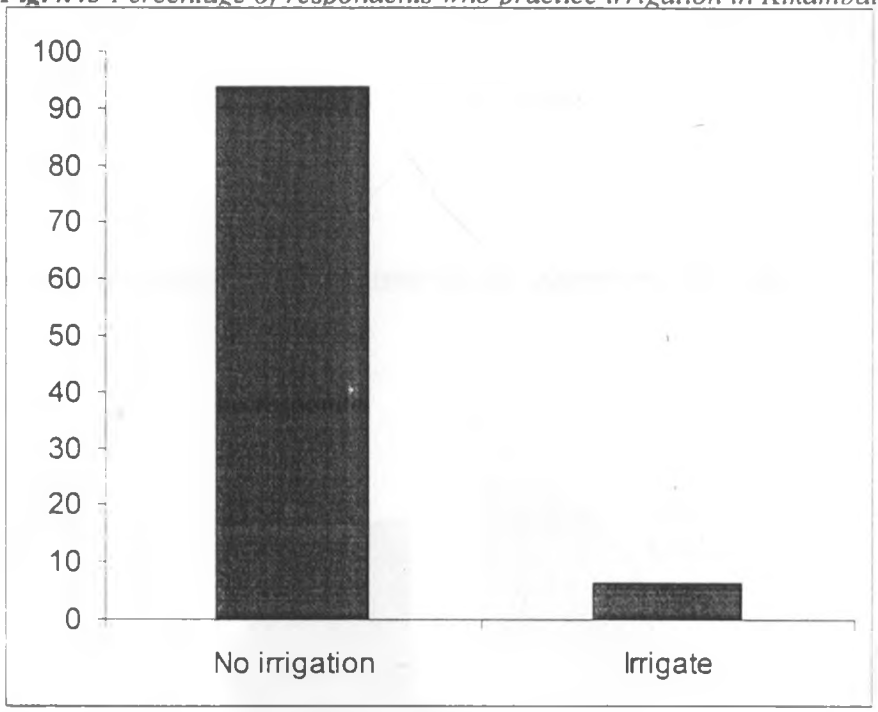


Source: Field Data Survey (April 2006)

4.7.5 Irrigation Water Use

Irrigation was only practiced in Kikambala Division. Out of the 48 respondents, only 3 reported that they practiced irrigation. Of the three respondents who irrigated two used water from a well and one used a nearby seasonal river. The two used an electric motor to pump water from the well. The respondent, who used the river as his water source, used a bucket to fetch it. The two respondents who had the wells as their water source used the basin method of irrigation. All the respondents irrigated every day. The crops grown were maize, bananas, amaranthus and tomatoes. The time of irrigation by all the respondents varied from 4 hours to 6 hours every day. All the respondents who irrigated did not have a water permit and did not intend to get one soon. Of the three respondents, only one kept also some livestock.

Fig.4.43 *Percentage of respondents who practice irrigation in Kikambala*



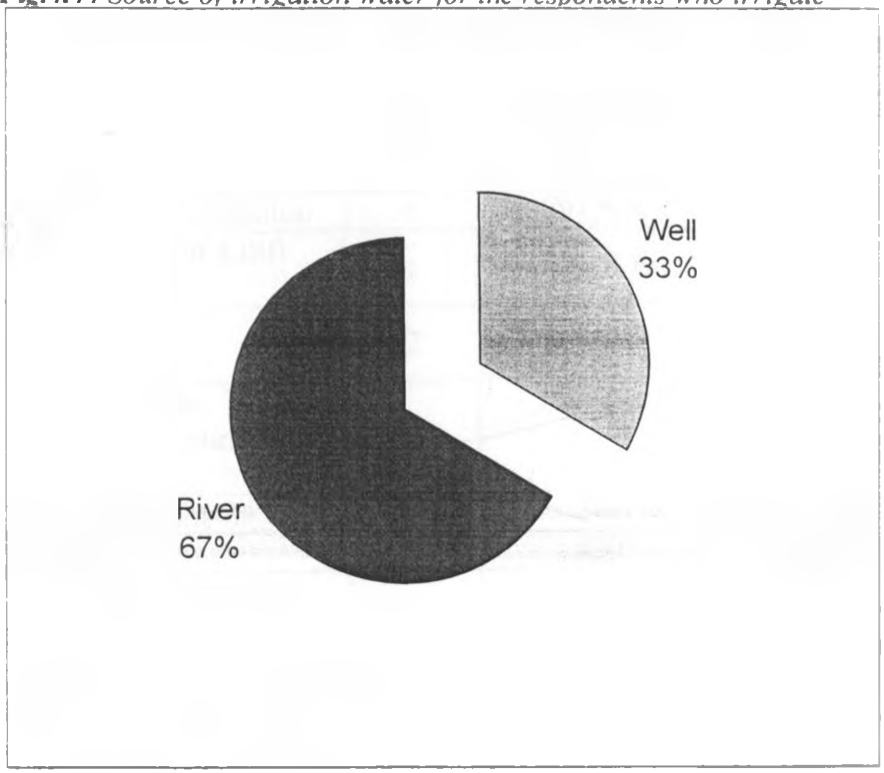
Source: Field Data Survey (April 2006)

4.8 Water Demand

From the results obtained in field data the water demand for the sub basin was estimated and the results presented. Reults

4.8.1 Irrigation Water Requirments

Fig.4.44 Source of irrigation water for the respondents who irrigate



Source: Field Data Survey (April 2006)

4.8 Water Demand

From the results obtained in field data the water demand for the sub basin was estimated and the results presented.

4.8.1 Irrigation Water Requirements

The area under irrigation was estimated to be 200 Ha in Bahari Sub Basin. The individual farms were located in Kikambala Division and relied on water from wells dug within the farm. For Coast Province the Irrigation Water Requirements is estimated at 1l/s/Ha.
Thus:

- The water required for irrigation = 200 Ha x 1 l/s/Ha =200 l/s.
- The monthly irrigation water required = 200 x 60 x 60 x 24 x 30 = 518400 M^3

4.8.2 Domestic Water Demand

Using results of the survey as reported in tables 2.1, 2.3, 2.6, 2.7, and the infrastructure facilities in the sub basin on page reported on page 18, monthly water demand for the consumers during the survey period were;

Table 4.3: Monthly domestic water requirements for Bahari Sub Basin

Item No	Categories of Consumers	No of Units	Estimated Population	Units Required	Monthly Water Required (M^3)
1	Rural Areas Population	1	291,626	20 l/head/day	174975.6
2	Urban Areas of Kilifi and Mtwapa	1	111,726	50 l/head/day	167589
3	Hospitals	2	150	Minimum 5000 l/day	300
4	Health Centres, dispensaries, nursing homes,	37		5000 l/day	5550
5	Secondary schools	11	200	50 l/head/day	3300
6	Primary schools	90	400	5 l/head/day	5500
7	Government training institutes	2	200	50 l/head/day	600
	Total				**357715**

Source: Field Data Survey (April 2006)

4.8.3 Industrial Water Demand

Using results of the survey as reported in tables 2.1, and 2.9 the industries were classified as medium scale and their water consumption rated at 10,000 l/day. Therefore the Industrial water requirements for the sub basin was = 6 x 10000 x 30 / 1000 = 1800 M^3 per month.

4.8.3 Livestock Water Demand

By using field data reports in tables 2.8 the water demand for livestock was estimated. The water requirements for I Livestock Unit (LU) is 50 l/day according to(GOK, MW&I, Practice manual for water Supply Services in Kenya, 2005)

For estimation of water demand for livestock conversion factors used were 1 Grade cow was equivalent to 1 Livestock unit, 3 Indigenous cows were equivalent to 1 Livestock Unit, and 25 Poultry birds equivalent to 1 Livestock Unit. (GOK, MW&I, Practice manual for water Supply Services in Kenya, 2005)

Table 4.4 Livestock water demand in the sub basin

Type of Livestock	Livestock Population	Equivalent Livestock Unit (LU)	Daily Water Required (M^3)	Monthly Water Required (M^3)
Beef cattle (Zebu)	10300	3433	170	5100
Dairy	28000	28000	1400	42000
All Poultry	76872	3075	154	4612
Total			**1724**	**51714**

Source: Field Data Survey (April 2006)

Thus the total water demand for domestic, livestock, industrial and irrigation purposes for the sub basin was = 518400+357715+1800+51714=929635M^3 per month.

4.8.4 Available Water Supply

The water supply from each of the water sources was summed up and the results were tabulated in table 4.5

Table 4.5 Total water supply from major sources in the sub basin

Source No	Source Name	Quantity of Water Available	Length of Time Source has quality water (Months /year)	Comments
1	Water Pans	23,235 M^3	6 Months	Used for domestic and Livestock
2	Earth Dams	186,000 M^3	6 Months	Used for domestic and Livestock
3	Springs	4,320 M^3/ Month	12 Months	Used for domestic and Livestock
4	Bore Holes	Discharge data not available	12 Months	Used for domestic, industrial, and Livestock
5	Wells	Discharge data not available	12 Months	Used for domestic, irrigation, and Livestock
6	Roof Catchments	262 M^3	6 Months	Used for domestic and Livestock
7	Portable water	120,101M^3/ Month	12 Months	Used for domestic, Industrial and Livestock

Source: Field Data Survey (April 2006)

4.8.5 Meeting the Water Demand in Bahari Sub basin

The water demand from the main consumers was estimated for Bahari Sub Basin as;

- Domestic-357715M^3 per month
- Irrigation Water use-518,400 M^3 per month
- Livestock water use-51714M^3 per month
- Industrial water use-1,800 M^3 per month.

The total water demand for the sub basin was thus 929635 M^3 per month. The irrigation water demand (518,400 M^3 per month) was met by use of wells located in Mtwapa and Kikambala. The water supply sources available to meet the remaining water demand of 411,235 M^3 per month were;

- Roof catchment with a capacity 262 M^3
- Water pans with a capacity of 23,235 M^3
- Dams which had a capacity of 186,000 M^3
- Springs which had a combined discharge of 4,320 M^3/ Month
- Potable water with a flow of 120,101M^3/ Month
- Borehole whose discharge had not been determined
- Wells whose discharge had not been determined

If all the potable water and the spring water was used to meet the remaining demand (411,235 M^3) there remained a deficit of 286,814 M^3 per month. The roof catchment, water pans, and dams had a combined capacity of 209,497 M^3. The supply could meet this demand for only 21 days. The estimation assumes there are no other uses and no provisions have been provided for the ecological requirements, and losses.

CHAPTER FIVE: CONCLUSIONS, AND RECOMMENDATIONS

5.1 Conclusions

From the study the following conclusions, which are restricted to the sample size, can be drawn;

1. The main water sources for Bahari Sub Basin were;
   - Roof catchments reservoirs which had capacity varying from 4 to 50 M^3 with the number of water users varying from 10 to 600 per reservoir,.
   - Water storage pans with capacity varying from 0 to 5700 M^3 and users varied from 100 to 2000 people per pan,
   - Ten dams of which 60% were in Chonyi division,
   - Wells for which 75% were in Bahari Division and were used mainly for irrigation at Mtwapa in Kikambala division,
   - Boreholes of which only 23% were still in use
   - Piped water from Baricho-Mombasa pipeline which is managed by Coast Water Services Board.
2. The water resources outlined in 1 were affected by the following activities which caused pollution;
   - Agricultural activities
   - Agro based industries and factories
   - Block mining and sand harvesting
   - Livestock rearing
   - Growth of urban centres
   - Ocean water intrusion due to over extraction of water in the wells
3. The total water demand for the sub basin was 951,725 M^3 per month. The irrigation water requirement was met by use of water from wells located around Mtwapa in Kikambala division where irrigation was done. After using potable and spring water sources there was a deficit of 308,904 M^3 per month. The dams, water pans and roof catchments could only sustain this deficit for 20 days assuming they were full once a year. Thus the sub basin required additional 308,904 M^3 per month to satisfy its water demand. This demand could be satisfied by;
   - Increasing the storage of roof catchment, dams, and water pans
   - Abstraction of more water from ground sources after ascertaining their potential
   - Improvement of the storage structures
4. From the household survey, 86% of the respondents have at least primary education. Thus they are able to answer the questions put to them responsibly. 70% of the respondents listed water as the most important household need, underlining the importance of water to the community as a whole. Only 17 % of the respondents had water piped into their households. The rest got water from either public tap (44%) or vendors (28%). Thus in the water resource management, vendors and water sellers play an important role.
5. For 70% of the respondents it took less than an hour to go to the water point, collect the water and be back. Thus for most of the residents, little time is lost looking for the water. The responsibility of looking for the water is left to the female members of the household for 84% of the households. Thus women play a crucial role in water resources management.

6. Since 73% of the households had makuti or thatched type of roofing material, roof catchment as a method of tapping rain water is limited. Thus for possible increase in harnessing of roof water catchment, the type of roofing material should be addressed.
7. From the survey, only 50% of the residents dispose their solid waste in garbage pits. The rest dispose it by throwing it in the bush or the shamba. Therefore to avoid contamination of the water courses and outbreak of diseases, the residents should be advised on proper methods of waste disposal. There are two tractor drawn trailers for disposing the solid waste generated in Kilifi and Mtwapa towns with a projected total population of 111,726 this year. The disposal sites are near residential areas and hence cause pollution.
8. 81% of the households have some type of toilet facility ranging from traditional pit latrine, VIP latrine and flush toilet. Those who do not have any facility use the bush which is unhygienic.
9. The implementation of IWRM required a legal framework as set out in WA2002. The institutions set up to implement the policies were KIMAWASCO, CWSB, WUAs, and ARBWRMA. For successful IWRM implementation awareness should be created among the stakeholders. From the survey only 17% of the households were aware of the policies that were being implemented by the MW&I, including the WA2002. Thus the stake holders needed to hold meetings to create awareness on the proposed changes.
10. Management committees had been set up to manage dams, springs, water pans, and community based water pipelines. This was reflected in the field survey where 55% of households agreed that it was their responsibility to manage water resources. The management committees were trained in leadership dynamics, operation, and maintenance of water resources. This capacity building is important in implementation of IWRM.
11. Conservation of the catchment is important in IWRM. From the survey only 24% of households practiced any soil and water conservation measure in their farms. The reasons for not practicing were because of high labour costs, no knowledge, and farm not requiring conservation measures. For benefits of IWRM to be felt the importance of Soil and Water conservation measures should be enhanced.
12. Agro forestry in the sub basin enhances soil fertility and conservation. The trees planted acted as sources of fuel, building materials, food, and fodder for animals. Half of the households had cut trees in the last one year for use as firewood, building construction, and timber extraction. Only 42% had planted at least a tree in the last 12 months.

5.2 Recommendations

From the results obtained from the research the following recommendations are made:

1. All the stakeholders should be brought together to chart the way forward. The MW&I should organise the symposium that brings the stake holders together. The role of each stakeholder will need to be stated. Trust building among the stake holders is important in the implementation of IWRM
2. More rainfall monitoring stations should be established and the existing ones rehabilitated. At least a rain gauge in every sub location and a self recording rain gauge in each location are recommended. The rain gauges should be located in schools and at least two staff members trained in taking the records. The staff should be paid an honorarium as incentives for the work. With this data, a data base for

hydrological data should be established. Evaporation pans should also be set up in each location within the sub-basin.

3. Ground water offers an efficient water supply in Kikambala location and more studies are needed to ascertain its potential. Hydro geological and geological data monitoring should be enhanced so that the ground water resources can be obtained. Pumping tests should be done to determine the discharge of the boreholes and wells. Further research should be done to determine the boreholes and well yields, and also monitor the effects of over extraction.
4. The methods of irrigation practised in the sub basin are basin and furrow. These methods are wasteful and may lead to salinity. More area can be irrigated using less water and hence increase food production per unit of water used by use of improved methods of irrigation. Farmers should be encouraged to use trickle and sprinkler irrigation methods which utilises water more efficiently.
5. Poor disposal of solid wastes causes contamination the water sources leading to pollution. The residents should be informed the importance of having toilets in their house holds for disposal waste, and the townships to develop sewerage system.. Collection of garbage should be enhanced by increasing the number of trailer to two per township. The garbage dump should located far from residential areas and water bodies.
6. Management of water resources requires formation of institutions that promote efficient water use, water supply development, resource protection, water reuse, and storm water recharge, and permit streamlining, pollution control strategies. The tariff structures should reflect the true cost of water delivery without inflicting hardship on the poorest. The water users should be encouraged to form WUAs who will articulate their requirements to the service providers. Since women play a crucial role in water resource management, they should be well represented in all the committees set up to manage water resources

REFERENCES

Anne Chohin-Kuper, Thierry Rieu, Marielle Montginoul(2006) Water policy reforms: pricing water, cost recovery, water demand and impact on agriculture. Lessons from the Mediterranean Experience
http://www.edie.net/channel.asp?channel=4

European Economic Community (1999), Towards Sustainable Water Resources Management, a Strategic Approach

Food and Agriculture Organization (1995), Irrigation and Drainage Paper 52, Rome

Government of Kenya (1999), Environmental Management and Coordination Act 1999 Government Printers

Government of Kenya (1999), Population and Housing Census Volume I, Government Printers

Government of Kenya (1987), Scheme design Manual, Government Printers, Nairobi, Kenya

Government of Kenya (1985), Scheme Water Management Irrigation Manual, Part III, Government Printers, Nairobi, Kenya

Government of Kenya (1999), Population and Housing Census Volume II, Government Printers

Government of Kenya (2002), Water Act 2002, Government Printers

Hirji R., Patomi F.M., Rubin D (1996), Integrated Water Resources Management in Kenya, World Bank

International Water Association(2006): Industry Sector Report for WSSD
http://www.environment-agency.gov.uk/commondata/acrobat/bulletin_82_final_1748841.pdf

Jaetzold and Schmidt (1983), Farm Management Handbook of Kenya, Eastern and Coast Province

Japan International Cooperation Agency (1992), National Water Master, Agriculture/Irrigation

K. Subramanya (1996), Engineering Hydrology, McGraw-Hill, New Delhi

Kilifi District Development Plan 2002-2008 (2002), Government Printers, Nairobi

Kilifi District Development Programme (1999), Development visions, strategies and priorities for Kilifi

Michael A.M.(1987), Irrigation Theory and Practice, Vikas Publishing House PVT Ltd, New Delhi, India

Ministry of Water Development (1996), Water Resources Assessment Study, Kilifi Main Report

Ministry of Water Resources Management and Development (2003), First National Water and Sanitation Strategy

Ministry of Water Resources Management and Development (2003), Water Resources Management Strategy

Ministry of Water and Irrigation (2004), Draft Plan for the transfer of Management and Operation of Water Services to Water Services Boards

Operational Guidelines for IWRM Projects
http://www.mottmac.com/newsandpublications/publicationsandbrochures/

Technical Advisory Committee of Global Water Partnership (2003), Sharing knowledge for equitable, efficient and sustainable water resources management, Global Water Partnership

Technical Advisory Committee of Global Water Partnership (2000), Towards Water Security: A framework for Action, Global Water Partnership

Technical Advisory Committee of Global Water Partnership (2002), Unlocking the Door to Social Development and Economic Growth: How a more integrated Approach can Help, Global Water Partnership

Technical Advisory Committee of Global Water Partnership (1997), Regulation and Private Participation in Water and Sanitation Sector, Global Water Partnership

United Nations Department of Economic and Social Affairs (2002), Governing Water Wisely for Sustainable Development, Paper No 15

United Nations (2003), Human Development Report: A Compact among Nations to End Human Poverty
http://www.un.org/Pubs/whatsnew/e03hdr.htm

United Nations (2003), World Water Development Report: Water for People, Water for Life
http://unesdoc.unesco.org/images/0012/001295/129556e.pdf

Van Zmerenberg and Roger M.A. (1975) An Economic History of Kenya and Uganda 1800-1970. Macmillan, London.

World Bank (1993), Water Resources Management.
http://publications.worldbank.org/ecommerce/catalog/product?item_id=195592

Widespread flooding a wake-up call for planners *(26 July 2006)*
http://www.edie.net/channel.asp?channel=4

Appendix A: Questionnaire for selected Households in Bahari Sub Basin

IDENTIFICATION

Area

Q 01 District _____

Q 02 Division _____

Q 03 Location _____

Q 04 Urban centre _____

Q 05 Sub location _____

Q 06 Village _____

Q 07 Name of Household Head _____

Q 08 Level of education of Household Head

(I) Non _____

(II) Primary _____

(III) Secondary _____

(IV) Post Secondary _____

Date _____

Interviewers Name _____

Interviewers Id No. _____

LANGUAGE OF QUESTIONAIRRE: ENGLISH

PEOPLE LIVING IN THE HOUSEHOLD

NAME	NUMBER LIVING IN HOUSEHOLD	AGE*
MEN		1
WOMEN		2
CHILDREN		3

AGE* CODE 1 MEN OVER 15 YEARS

2 WOMEN OVER 15 YEARS

3 CHILDREN UNDER 15 YEARS.

B. Water and sanitation

20) Among the following, which is the most important need in your household? **Circle the one that apply.**	Toilets.....1 Water.....2 Drainage.....4 Waste dumping.....5 Other.....96	
21) What is the main source of drinking water for members of your household	Piped into residence/ compound/ plot.....1 Piped public tap .....2 Well/ borehole on residence /compound/ plot.....3 Public well/ borehole .....4 River /stream .....5 Pond .....6 Lake .....7 Rainwater .....8 Tanker-truck, vendor .....9 Other (*specify*) 96	
22) How long does it take to get to the nearest water point, get and back?	Minutes ..... Hours ..... Days ..... On compound 2	
23) Whose responsibility is it to look for water in your household?	Man/Boy .....1 Woman /Girl .....2 Other (*specify*) 96	
24) How much do you pay for the water you use		
25) In your own opinion is the water in Q24 of good quality	Yes .....1 No .....2 Don't Know 96	
26) Who manages the water point	Community .....1 Owner .....2 Don't Know.....96	

27) Main material of the roof (Record Observation)	Grass /Thatch ....1 Corrugated iron (mabati) ....2 Tiles ....3 Other (*specify*) 96	
28) Where do people in your household dispose of their garbage	Toilet .....1 Garbage pit.....2 Rivers .....3 On the streets/Roads .....4 Bush .....5 Other (*specify*) 96	
29) What kind of toilet facility do members of your household use?	Traditional pit latrine .....1 Improved pit latrine (VIP).....2 Open pit .....3 Bucket .....4 Flush toilet .....5 Bush /Open field 6	
31) Is the facility located within dwelling, or compound?	Yes in dwelling or compound .....1 No outside dwelling /yard/compound .....2 Don't know 97	
32) In your household what happens with the stool of young children (0-3 years) when they do not use the toilet facility.	Children always use toilet .....1 Thrown into toilet .....2 Thrown outside the compound .....3 Buried in the yard .....4 Not disposed of, just left on the ground .....5 Other (specify) 96	

C. Legislative and policy awareness

40) Are you aware of any policies or legislation that affect the water sector	Yes.....1 No..... .....2 Don't Know.....3 N/A..... 96	
41) If yes which ones?	.... N/A	
42) Have you ever heard of the Water Act 2002	Yes .....1 No .....2 Don't Know .....3 N/A 96	
43) If yes what does it say?	.... Don't know..... N/A.....	
44) Do residents of this area have any responsibilities in creation of suitable policy and legislative environment in water management?	Yes .....1 No ....2 Don't Know .....3 N/A 96	
45) If yes what do you feel should be the responsibilities of people in water management	.... N/A	
46) Do you think people have any roles in water management	Yes .....1 No .....2 Don't Know .....3 N/A 96	
47) If yes what are the roles they can play?	.... Don't Know ..... N/A	
48) Whose responsibility should it be to offer water services to the community?	Government .....1 Community .....2 Parents .....3 Teachers .....4 Religious Leaders.....5 NGO's.....6 Other*(specify)* 96	

D. Irrigation Water Use

50) What is the source of the irrigation water that you use?	Dam.....1 Borehole.....2 Well.....3 Roof Catchment.....4 Others (Specify).....96	
51) How is the water abstracted from the source stated above?	Hand pump.....1 Electric Pump.....2 Diesel Pump.....3 Bucket.....4 Others (Specify).....96	
52) What acreage of Land is under each of the following Crops?	1. Maize.....Ha 2. Bananas.....Ha 3. Tomatoes.....Ha 4. Amaranthus.....Ha 5. Others(specify).....Ha	
53) Specify the method used to irrigate the crops above?	Basin.....1 Furrow.....2 Sprinkler.....3 Drip.....4 Others (Specify).....96	
54) How often do you irrigate your crops?	Every day.....1 After Two days.....2 After Three day.....3 After Four days.....4 After Five days.....5 After Six days.....6 After Seven days.....7	
55) For what length of time do you irrigate your crops?	.....Hours	

56) State the type and Number of livestock kept in household?	Grade Cattle..... Local Breed..... Grade Layers..... Grade Broilers..... Others (Specify).....	
57) Do you have a water permit for the water abstraction?	Yes /No	
58) If not do you intend to get one?	Yes / No	

E. Sustainable Land Development

59) What soil conservation method(s) does your household use?	1. None..... 2. Terracing..... 3. Gully Control..... 4. Gabions..... 5. Contour Farming..... 6. Blocking Soil erosion outlets..... 7. Planting cover crops..... 8. Other (specify).....	
60) If none, Why?	1. No problem..... 2. No Knowledge..... 3. High Labour Costs.....	
61) Which Method(s) of rainwater harvesting does your household have?	1. None..... 2. Roof catchment harvesting... 3. Surface runoff..... 4. Small farm reservoirs..... 5. Others (specify).....	
62) Has this household planted any trees in the last 12 months?	1. Yes..... 2. No.....	
63) If Yes, how many were planted?	.....	
64) Has this household cut any tree during the last 12 months?.	1. Yes..... 2. No.....	
65) If yes, how many? (Estimate)	.....	
66) What was the use for the tree that were cut?	1. Charcoal..... 2. Firewood..... 3. Building/Construction..... 4. Timber..... 5. Others (Specify).....	